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Abstract:

This chapter of the New York City Panel on Climate Change 4 (NPCC4) report considers climate health risks, vulnerabilities, and resilience strategies in New York City's unique urban context. It updates evidence since the last health assessment in 2015 as part of NPCC2 and addresses climate health risks and vulnerabilities that have emerged as especially salient to NYC since 2015. Climate health risks from heat and flooding are emphasized. In addition, other climate-sensitive exposures harmful to human health are considered, including outdoor and indoor air pollution, including aero-allergens; insect vectors of human illness; waterborne infectious and chemical contaminants; and compounding of climate health risks with other public health emergencies, such as the COVID-19 pandemic. Evidence-informed strategies for reducing future climate risks to health are considered.

Keywords:

public health, climate change, exposure pathways, health outcomes, heat-related health outcomes, flood-related health outcomes, climate-sensitive exposures, NPCC4

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Table of Contents

1 Chapter Summary

This chapter considers climate health risks, vulnerabilities, and resilience strategies in New York City's unique urban context. It updates evidence since the last NPCC health assessment in 2015 as part of NPCC2 (Kinney et al., 2015) and addresses climate health risks and vulnerabilities that have emerged as especially salient to NYC since 2015. Climate health risks from heat and flooding are emphasized. In addition, other climate-sensitive exposures harmful to human health are considered: 1) outdoor and indoor air pollution, including aero-allergens, 2) insect vectors of human illness, 3) waterborne infectious and chemical contaminants, and 4) compounding of climate health risks with other public health emergencies, such as the COVID-19 pandemic. At the end of this chapter, evidence-informed strategies for reducing future climate risks to health are considered.

1.1 Key Messages

Key Message 1: *Climate change-related health risks are a threat to all New Yorkers, but especially those most vulnerable because of age, poor health, racial and social inequities, and social isolation. Inequities in household and neighborhood physical environments also mediate vulnerability to climate-health impacts. Addressing key environmental and social drivers of vulnerability is an essential adaptation strategy. Many current NYC policies and strategies, (e.g., improving access to residential air conditioning, tree planting), aim to accomplish this. These efforts can be informed and evaluated using data on climate-health vulnerabilities, such as components of the heat vulnerability index (HVI) and a flooding vulnerability index (FVI) under development (VIA Interim Report).*

Key Message 2: *Heat waves are, on average, the deadliest type of extreme weather in NYC and in much of the US. Even hot, but not extreme, summer weather causes serious illness, death, and other harms to wellbeing. Because of climate change, NYC will experience more dangerous hot weather. Most heat-related deaths are due to exacerbation of chronic health conditions, such as cardiovascular disease. Indoor exposures can be especially deadly for people without air conditioning who have one or more physical or mental health conditions, are energy insecure, or are older adults. Also vulnerable are those with jobs exposing them to unsafe temperatures. These risk factors can be consequences of structural racial, social, and economic inequities. Adaptive measures are needed that protect vulnerable populations from season-long heat-health risks, including from non-extreme but hot weather. Evidence-informed strategies include enhanced access to air conditioning, reducing energy insecurity, engaging community and health provider networks to reach vulnerable populations, and augmenting tree canopy cover.*

Key Message 3: *Public health can be impacted before, during, and after flooding, which exposes New Yorkers to risks of drowning and other injuries, stressful evacuation, short- or long-term displacement from home, and exposures from clean up, repair, water contaminants, and mold from water damage. Climate projections for NYC anticipate an increase in extreme precipitation days and sea level rise contributing to more frequent flooding over wider areas. Socioeconomic disadvantage, racial inequities, pre-existing health conditions, and flood-vulnerable housing and infrastructure amplify health impacts of flooding. Adaptation strategies that modify these factors can reduce future flooding impacts on health.*

Key Message 4: *Hotter weather can increase concentrations of harmful air pollutants, including fine particles and ground-level ozone, by increasing emissions of precursor pollutants and the formation of ozone on warm, sunny days. These pollutants are harmful to health for all New Yorkers, but especially for the very young and old, people with certain chronic health conditions, those without residential air conditioning, and those living where emissions from buildings and traffic are concentrated. Most of these vulnerability factors are more common among Black, Latino, and low-income households. Despite a warming climate, air quality has improved in New York City because of reduced local and regional emissions. Recent wildfire smoke plumes affecting much of the eastern US indicate the potential to reverse a trend of improving air quality. Efforts to further reduce emissions and exposures of vulnerable populations can prevent or mitigate climate-related air quality impacts.*

***Key Message 5**: Nationally, pollen monitoring data shows that climate change is causing an earlier, longer, and possibly more intense plant pollen production season, but this trend is less evident in the northeast. Within New York City, pollen from several common tree species, ragweed, and grasses contribute to seasonal allergic rhinitis and asthma exacerbations. The burden of asthma exacerbations from any cause is greatest in communities with less access to health care and more household asthma triggers leading to less well-managed asthma. Ambient pollen levels are influenced by local weather, allergenic plant density, and species composition. Air conditioning and filtration can reduce indoor pollen exposure. Attention to local tree cover density and species composition along with improved access to care, evidence-based asthma management, and patient education can reduce pollen exposure, vulnerability, and future allergic illness.*

***Key Message 6**: In the northeast, changes in climate, landcover, habitat, and host animal ranges continue to shift the spatial and seasonal distribution of mosquitos and ticks that are current or potential vectors of human illness. Within New York City, the spatial distribution of these vectors and potential for human infection and serious illness varies with differences in the built environment, natural habitat and host animal abundance, human behaviors, and population vulnerability. Seniors, those with chronic illnesses, and people who are homeless are more susceptible to complications from West Nile virus (WNV) infection. Lyme disease risk among New Yorkers is increased among those engaged in outdoor activities mostly outside the city, but also in Staten Island and a limited area in the Bronx. Vector-borne disease (VBD) risk is also increased by international travel to and immigration from disease-endemic areas. Disease surveillance, vector monitoring and control, and public and clinician awareness can reduce future risks in a changing climate.*

***Key Message 7**: Climate change may increase risk of exposure to water-borne pathogens in surface waters and wastewater in and around New York City and could threaten its drinking water sources and distribution system. Increased flooding can cause exposure to contaminants from household sewage backups and in surface waters from combined sewer overflows (CSOs). Rising temperatures facilitate the growth and spread of pathogens such as bacteria that cause gastrointestinal illness, Legionnaire's disease, and a range of illnesses from harmful algal blooms. Extreme weather and climate change impacts on New York City's source and distribution infrastructure could compromise water quality and quantity. Continued maintenance and adaptation of infrastructure along with coordinated surveillance of water quality, human, and animal health can help prevent adverse impacts on health.*

***Key Message 8**: Climate risks can be compounded when they disrupt lifeline infrastructure systems or overlap with non-climate public health emergencies. Examples include power outages during recent extreme heat events and the COVID-19 pandemic creating potential disease transmission risks in cooling centers and other publicly accessible indoor spaces. The health risks from compound hazards can be reduced through investing in lifeline and other critical infrastructure and building mechanical systems that are adapted to extreme weather, redundant, and flexible. Rapid, flexible, collaborative, multi-sectoral responses are needed to respond to pandemics and other unanticipated compound hazards.*

2 Introduction

2.1 Chapter Scope: New York City's Human Habitat, Weather, and Health

A premise of this chapter is that "Cities are for people and therefore human health, wellbeing, safety, security, and opportunity should be central considerations in sustainable urban development (Capon, 2017)."

Protection from the direct harm of climate extremes is just one of many basic biophysical and psychosocial needs that New Yorkers share with all people (Capon, 2017). In a changing climate, New York City shares with all cities the imperative of continually adapting its social and physical infrastructures to provide healthy human habitat, especially for its most vulnerable people and communities. As a coastal, densely developed city, New York has both inherent challenges and advantages for protecting people from climate change health risks, while enabling sustainable, low-carbon living. These health risks and per capita carbon emissions vary considerably within the city and between the city and other parts of the region.

Variation in human vulnerability to climate risks and in contributions to carbon emissions are shaped by New York City's unique and varied built and natural environments, its racial and ethnic diversity, and the enduring legacy of racial and economic injustice and inequality shared with the region, state, and nation. Racial injustice, historical land disposition, and more contemporary land use policies and practices are among the social and economic forces that have shaped an inequitable distribution of access to healthy, climate-adapted human habitat. The topic of climate equity is addressed more fully and in-depth in *NPCC4: Advancing Climate Justice in Climate Adaptation Strategies for New York City* (Foster et al., 2024).

Climate-adapted human habitat includes but is not limited to shelter, especially housing, that protects people from unsafe temperatures and flooding, energy services that affordably and reliably meet essential needs, and outdoor environments with natural and built features that enable healthy activity and mobility while also reducing exposure to heat, flooding, and other climate-sensitive weather hazards. Thus, vulnerability and resilience to climate risks are mediated and modified by the social and population context, by characteristics of the physical environment, and by causal interactions among these factors and characteristics (See Figure 1). This framework is the organizing structure for this assessment of health risks, vulnerabilities, and adaptation/resilience strategies for New York City.

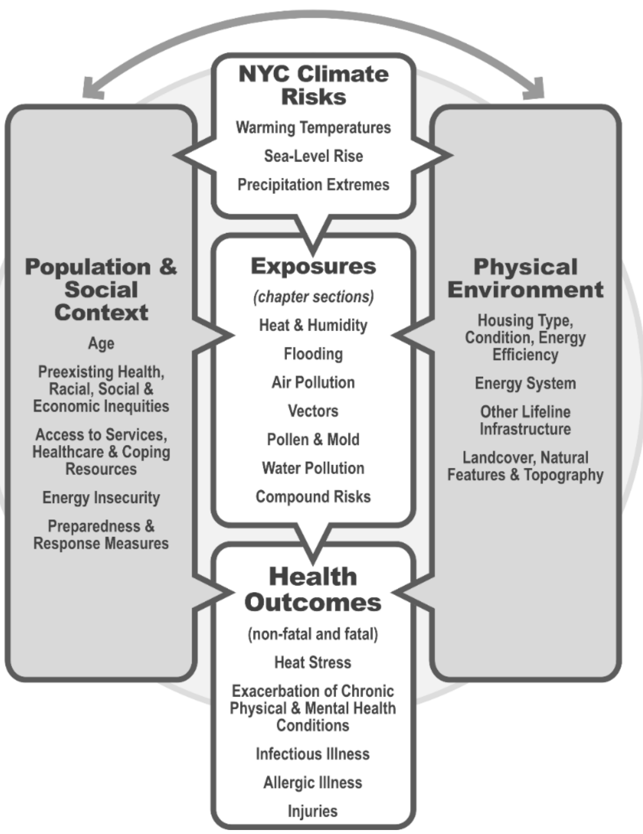

Figure 1: Urban Climate Change Health Impact Framework. Sections of this assessment correspond to exposures. Separate assessment reports cover the topics of racial, social, and economic inequities (Foster et al., 2024) and energy (insecurity, system, and housing energy efficiency) (Yoon et al., 2024). Framework adapted from Chapter 1, Figure 14.1 in Introduction: Climate change and human health. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (Balbus et al., 2016).

2.2 Chapter Organization and Scope

This assessment will consider climate health risks, vulnerabilities, and resilience strategies in New York City's unique context. It will also provide an update on evidence since the last NPCC health assessment in 2015 as part of NPCC2 (Kinney et al., 2015) and address climate health risks and vulnerabilities that have emerged as especially salient to NYC since 2015.

Climate health risks from heat and flooding will again be emphasized, as these represent the largest present threats and because – absent continued adaptation – anticipated climate change (Braneon et al., 2024) will increase health risks from hotter summers, and the increasing frequency and severity of flooding. An assessment of life-safety and health risks from pluvial (cloudburst or extreme rain) flooding will complement a synthesis of coastal storm and flooding health impact evidence, including new studies since NPCC2.

In addition to the two climate risks that are the focus of this chapter — heat and flooding— other climate-sensitive exposures harmful to human health are considered: 1) outdoor and indoor air pollution, including aero-allergens, 2) insect vectors of human illness, 3) waterborne infectious and chemical contaminants. This assessment also considers compound health risks from co-occurrence of extreme weather events and of extreme weather with other public health emergencies, such as the COVID-19 pandemic. At the end of this chapter, evidence-informed strategies for reducing future climate risks to health are considered.

In addition to topics covered in this chapter, a large and growing body of evidence demonstrates how energy insecurity can amplify both overall climate impacts on health and their inequitable distribution among communities and populations, including in New York City. Energy insecurity's role in vulnerability to climate risks is noted in this chapter and addressed more fully in a separate chapter, *NPCC4: Climate Change, Energy, and Energy Insecurity in New York City*, (Yoon et al., 2024). That chapter also notes how protecting public health requires that local, state, and national energy transition policies and investments reduce energy insecurity and preserve and enhance reliability and resilience of NYC's energy system.

Other topics related to climate change and health that are amenable to adaptation at the local level will be addressed in other chapters of this NPCC4 assessment, including health impact assessment to estimate benefits of climate action, adaptive and maladaptive uses of air conditioning in NYC in *NPCC4: Concepts and Tools for Envisioning New York City's Futures* (Balk et al., 2024), and potential for health co-benefits of modifying the public right of way (streets and sidewalks); also in Balk et al., (2024).

Climate impacts on some domains relevant to the health of New Yorkers, such as agriculture, oceans, larger scale ecosystems, and global health, conflict, and international migration, require adaptations and responses primarily at the state and national levels. These domains are considered in other assessments, including the Fourth and upcoming Fifth National Climate Assessments (USGCRP, 2018, 2023), and the Sixth Intergovernmental Panel on Climate Change Impacts Adaptation and Vulnerability Report (Pörtner, H.O. et al., 2022). Finally, while this assessment does consider mental health impacts of, and vulnerabilities to, local climate risks and exposures, the topics of climate anxiety and other mental health effects of awareness about global climate and ecological change and how to best respond – areas of active and evolving research (Clayton, 2020; Crandon, Dey, et al., 2022; Kurth & Pihkala, 2022; Lawrance et al., 2022; Wortzel et al., 2022) – are beyond the scope of this assessment.

3 Climate-health exposures, impacts, and vulnerabilities in New York City

3.1 Heat: Extreme Heat Events and Higher Warm Season Temperatures

3.1.1 Current and projected future climate and local health risks

The NPCC3 noted that observed summer temperatures from 2010 to 2017 largely fell within the range of NPCC2 projections, continuing warming trends observed at Central Park since 1900 and somewhat steeper increases at LaGuardia and JFK airports. Using updated models, the NPCC3 projected that on average heat waves will be more numerous, intense, and longer in the coming decades (González et al., 2019). The NPCC4 climate projections update and refine these but are qualitatively similar in forecasting a future with warming temperatures, more hot days, and more frequent extreme heat events for New York City (see Braneon et al., 2024).

Climate and emissions projections generally align in pointing to anthropogenically driven climate change causing a continued increase in global warming. This is due in part to the inertia inherent in the global climate system and a significant "emissions gap" between commitments and actions (UNEP, 2018). Unavoidable, anticipated increases in multiple climate hazards, including hotter weather, are creating and will increase multiple risks to humans, health infrastructure, and ecosystems (Pörtner, H.O. et al., 2022). In addition, in New York and other large cities, heat exposure is amplified by the urban heat island (UHI) effect, (National Oceanic and Atmospheric Administration, 2023b) which is discussed in more detail later in this chapter and will be addressed more fully in *NPCC4: Tail Risk, Climate Drivers of Extreme Heat, and New Methods for Extreme Event Projections* (Ortiz et al., 2024).

3.1.2 Health impacts and pathways

Hot and humid weather is dangerous and can cause a range of serious health impacts (Figure 2). In a typical summer, heat-related deaths and illnesses are not highly visible because they often happen behind closed doors in homes and without much news coverage. This can make it hard for the public to recognize the dangers of heat. In recent years, however, news coverage of the devastating and historically unprecedented heat waves in India and Pakistan in 2015 and 2022, Canada and the US Pacific Northwest in 2021, and many extreme heat events globally has underscored the increasing dangers of heat and warming climate for the general public and some policymakers (Fears & Eger, 2022; Webber & Sanders, 2023).

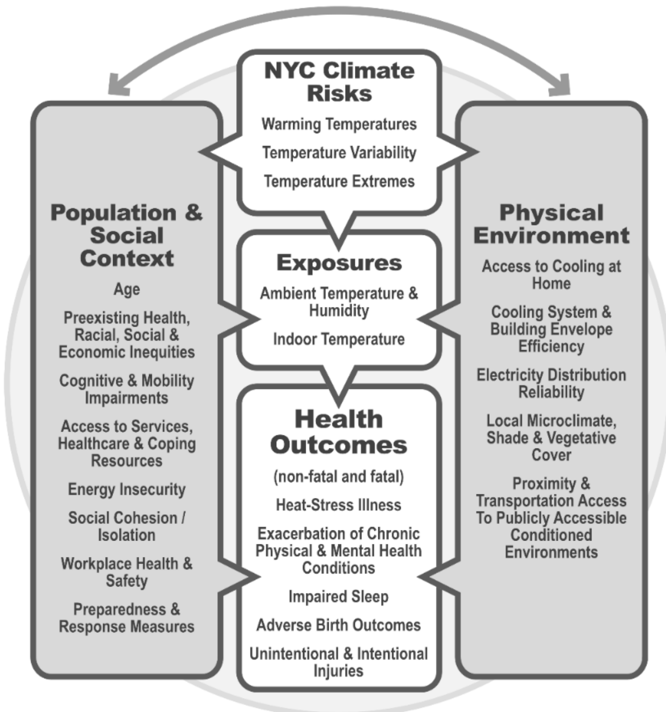

Figure 2: Heat Health Impact Pathways and Vulnerabilities. Framework adapted from Chapter 1, Figure 14.1 in Introduction: Climate change and human health. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (Balbus et al., 2016).

Heat exposure can directly cause heat-related illnesses such as heat cramps, heat exhaustion, and heat stroke (life threatening high body temperature caused by heat exposure) (Mora et al., 2017; National Oceanic and Atmospheric Administration, 2023b). It can also exacerbate existing chronic conditions such as cardiovascular, pulmonary, or renal diseases as discussed further below. Both heat-related illnesses and heat-related exacerbations of chronic conditions can lead to emergency department visits, hospital admissions and, in the most severe cases, death.

Surveillance of deaths identified on death certificates as caused or accompanied by heat-related illnesses – often referred to as heat stroke deaths and hereafter referred to as heat-stress deaths – has the advantage of timeliness and can give insights into circumstances for individuals succumbing to heat. However, heat-stress deaths are likely under ascertained and underreported, and certainly underestimate the true mortality burden from hot weather (Weinberger et al., 2020). Most epidemiologic studies use a comprehensive approach of statistically estimating excess mortality from natural causes (i.e. chronic conditions), all causes, or broad causal categories (Petkova, Morita, et al., 2014). Consistent with this practice, the NYC Department of Health and Mental Hygiene (NYC Health Department) conducts surveillance for both heat-stress deaths and excess mortality from natural causes, referred to as heat-exacerbated deaths. In its 2023 report (City of New York Department of Health and Mental Hygiene, 2023b), the NYC Health Department estimates that hot weather, defined as days with a maximum temperature reaching 82°F or hotter, kills an estimated 352 New York City (NYC) residents each year, on average. This includes an annual average of 7 heat-stress deaths from 2012-2021. By contrast an annual average of 345 heat-exacerbated deaths occurred from 2016-2020; 115 of those deaths occurred during extreme heat events, defined by the National Weather

Service heat advisory threshold for NYC (National Weather Service, 2023): "at least two consecutive days with a maximum heat index (HI) of 95°F or higher or any day with a maximum HI of 100°F or higher".

National counts of heat-stress also greatly underestimate the lethality of hot weather. The annual average of 153 heat deaths in the US according to data compiled by the National Weather Service (National Oceanic and Atmospheric Administration, 2023c) and 702 heat-related deaths according to the US CDC (Centers for Disease Control and Prevention, 2023a) do not include heat-exacerbated deaths. A recent study using data from 297 counties representing 62% of the US population estimated that more than 5,500 deaths were attributable to heat (i.e. were heat-exacerbated deaths) annually from 1997-2006 (Weinberger et al., 2020).

In addition to mortality from exacerbation of chronic health conditions, higher-than-normal warm season temperatures are associated with an increased risk of deaths from external causes in the US. These include deaths from drowning and transport injuries, as well as homicides and suicides (Parks et al., 2020). Higher ambient temperature is associated with homicide and interpersonal violence in cities, including New York, especially during the warm season (R. Xu et al., 2020). Two studies have found that the risk of cocaine overdose deaths in NYC increased with ambient temperature, a relationship also seen in other jurisdictions (Auger et al., 2017; Bohnert et al., 2010; Marzuk et al., 1998).

Nationally, emergency department (ED) visits for all causes increase somewhat on extreme heat days. ED visits for heat-related illness increase much more during heat waves (S. Sun et al., 2021), and are a better indicator for assessing heat-health severity during an extreme heat event than increases in all-cause ED visits. Heat-associated mortality in NYC has been shown to correlate with heat-related illness ED visits by a roughly one-day lag (Mathes et al., 2017). For timely heat related health surveillance, NYC monitors EMS calls for heat and ED visits for heat-related illness using syndromic surveillance data (City of New York Department of Health and Mental Hygiene, 2022j).

A wide variety of chronic health conditions can be exacerbated by heat exposure. In NYC, hospital admissions for renal, cardiovascular, respiratory conditions and mental health conditions increase during hot weather (Fletcher et al., 2012; S. Lin et al., 2009). For this reason, and others discussed below, people with one or more of several chronic health conditions are more susceptible to heat-related illness (see Section 3.1.4.2). In addition, a recent review and meta-analysis of US studies found an increased risk of both pre-term birth and low birthweight associated with higher temperatures and extreme heat, especially during the third trimester; a smaller number of studies have found associations between high temperature and still birth (Bekkar et al., 2020).

Heat-related health problems can also have adverse financial repercussions for individuals, especially for those without health insurance or adequate insurance (Limaye et al., 2019; Y. Liu et al., 2019). Prior work documents some of the heat-mortality impacts that have occurred in NYC (City of New York Department of Health and Mental Hygiene, 2023k). When assessed by applying a Value of Statistical Life approach, these total at least $20.1 billion (in 2023 dollars), from heat-related excess mortality in 2016-2020, and heat stress deaths 2012-2021 (City of New York Department of Health and Mental Hygiene, 2023c; United States Environmental Protection Agency, 2014a). A wider range of societal cost estimates to NYC for care of climate-sensitive illnesses and premature loss of life are being developed for the city and will be reported separately in the Climate Vulnerability, Impact, and Adaptation Analysis (VIA) (McPhearson et al., 2024), a multi-disciplinary research effort, led by faculty at the New School in NYC, focused on future potential climate conditions and associated socio-economic impacts.

Hot weather can strain the power grid, resulting in power outages. While NYC already experiences substantial heat-related mortality each summer, in recent years the city has not had to contend with prolonged and unprecedented temperatures seen in other parts of the world, such as the weeks-long extreme heat that affected Pakistan and India in 2022 with temperatures in some cases exceeding 120°F (E&E News & Harvey, 2022). Such extended heat waves could be catastrophic in NYC if accompanied by a power outage. Lack of mechanical cooling for New Yorkers is a critical concern during a heat wave, especially because indoor temperatures can be higher than outdoor temperatures in the absence of air conditioning due to building thermal inertia (Vant-Hull et al., 2018). In 2003, in NYC, there was a 2-day power outage during hot but not extreme weather. Even so, there was a 122% increase among accidental deaths and a 25% increase among non-external cause deaths attributable to the outage, resulting in 90 excess deaths over the period (G. B. Anderson & Bell, 2012). A 2003 heat wave in Europe resulted in more than 70,000 deaths (Robine et al., 2008). Of those, about 15,000 occurred from August 1 to August 20 in France (Fouillet et al., 2006), where home air conditioning prevalence is also low. Record, extreme heat in the Pacific Northwest in 2021 over about a week resulted in more than 600 deaths directly attributed to the heat in British Columbia (White et al., 2023), many of them in Vancouver where only about a third of the population has home air conditioning (Henderson et al., 2022). Nearly all – 98% – of these deaths occurred in homes without cooling (British Columbia Coroners Service, 2021). In addition to loss of air conditioning, other threats during a heat event complicated by a power outage include lack of subway service, elevators and pumped potable and other water to upper floors of NYC's many high rises, and strain on emergency responders. Outages can also strain the healthcare system as more people require medical care when they lose home cooling, the ability to charge electrically powered medical devices, such as oxygen concentrators, and access to other essential services that require electricity. A heat wave accompanied by a major flooding event that damages energy infrastructure or impedes emergency responders could also be particularly deadly. The public health impacts of power outages are discussed further in Yoon et al., (2024)

The reliability of the energy grid is key to maintaining population health and supporting emergency response efforts (see NPCC4, Yoon et al., 2024). Building-level back up energy systems, for example solar panels with battery storage, or microgrids can help buildings maintain essential services during power outages.

Backup systems can also help the health care sector respond during hot weather with power outages. Nationally, hospitals certified by the U.S. Centers for Medicare & Medicaid Services are required to have generators capable of running air conditioning, but there is no similar explicit federal requirement for nursing homes (Patel et al., 2022). In New York State, nursing homes and long-term care facilities are required to maintain safe temperatures but are not required to have generators capable of running air conditioning (New York State, 2004).

Heat impacts may be felt in other areas, such as schools, that could eventually affect educational attainment, economic opportunity, lifetime income and health. Higher temperatures are associated with lower scores on high stakes academic exams in the US (Graff Zivin et al., 2018) and China (Graff Zivin et al., 2020). An analysis of NYC Regents high school exit exams found that higher temperatures on exam days were associated with substantially lower test scores (J. Park, 2017). Data on air conditioning was incomplete and only available at the school (not classroom) level but indicated that 38% of schools lacked air conditioning and that the temperature effect on test scores was larger in such schools. Cumulative hot days during the school year were also associated with a reduction in student performance. In 2017, NYC announced plans to air-condition all classrooms to provide a safe and comfortable learning environment for students (City of New York, 2017). NYC school buses are required to provide air conditioning on buses transporting children with special needs. There have been reports of dangerously hot conditions on school buses, however, including those transporting kids with special needs (Coleman, 2019; Edelmen & Bamberger, 2022).

Increasing temperatures may also impact food safety. Warm temperatures have been associated with more food safety violations for insufficient refrigeration equipment and cold food holding in the summer in NYC restaurant inspection data, indicating that even during current summer temperatures some restaurant infrastructure is strained (Dominianni et al., 2018).

3.1.3 Temperature, other heat-stress metrics, and health outcomes

Environmental heat stress is influenced by several factors, including air temperature, humidity, velocity, and radiant heat such as from sunlight or hot pavement. A variety of heat exposure metrics have been developed to consider both ways in which humans respond to heat stress and environmental conditions in different settings: indoors and outdoors, in sun and shade, and by populations that engage in physical activity during hot weather and those who are able to avoid strenuous activity.

In hot conditions, body heat is shed to maintain a safe body temperature. This happens in several ways, including evaporation of sweat, contact with cooler air and radiation of heat from skin warmed by increased blood flow (Hosokawa et al., 2019). Heat-related illness results when a person's ability to maintain a safe body temperature or stay hydrated is overwhelmed by environmental conditions. As noted earlier, heat exposure can also exacerbate chronic health conditions, such as through stress on compromised respiratory and cardiovascular systems, and dehydration that decreases kidney function (City of New York Department of Health and Mental Hygiene, 2022b). Physical activity generates more body heat and increases heat stress. People living or working in a locality can acclimatize, generally within a few weeks, to hotter weather to a certain extent, as their bodies become more able to shed heat, such as through sweating (National Institute for Occupational Safety and Health (NIOSH), 2020).

Heat-stress metrics commonly used include the air temperature, heat index (which includes humidity), Humidex, and the Wet Bulb Globe Temperature (WBGT) (Hosokawa et al., 2019). Humidity can impact sweat evaporation, a key cooling mechanism. The WBGT is based on temperature, humidity, sun angle, cloud cover, and wind speed. It was designed to assess heat stress risk in people who are outdoors in unshaded locations and to guide activity limitations and cooling breaks for populations such as workers, soldiers, and athletes (Budd, 2008; Hosokawa et al., 2019).

Temperature and the heat index have been widely shown to predict population risk of increased deaths and serious illness during hot weather in different countries, in US cities, and in NYC in particular (Curriero, 2002; Metzger et al., 2010a; Tobías et al., 2021). An NYC study showed that the maximum heat index predicted excess mortality as well or better than many other metrics and that the risk of heat associated death rose in a non-linear way (Metzger et al., 2010a), though this study did not include the WBGT, which is appropriate for use in outdoor occupational and athletic settings. Despite the influence of humidity on individual heat stress, a recent multi-country study suggests humidity measures may not improve prediction of mortality risk at the population level (Armstrong et al., 2019). This does not mean that humidity does not contribute to heat stress, however. Because temperature and heat index are highly correlated, population-level studies may be unable to disentangle the relative contributions of heat and humidity to associations with health impacts.

The relationship between unseasonably warm and extremely hot daily temperatures and health is both non-linear and cumulative (Gasparrini et al., 2015; Z. Xu et al., 2016). As temperatures rise, the risk of heat-related death begins to increase more steeply and grows with more consecutive days of hot weather. Taking the non-linear and cumulative effect of higher temperatures into account, there may be little if any additional "heat wave effect" on mortality risk (Hajat et al., 2006). It is nonetheless useful to set criteria for extreme heat events, calibrated to health risks in a particular locale, so that heat advisories can be issued to the public and heat emergency plans can be activated on days when the health risk from heat is highest. Even during periods of extreme heat, risk can vary; heat waves that are long and/or those with higher peak temperatures are particularly dangerous (G. B. Anderson & Bell, 2011; Hajat et al., 2006).

In NYC, heat-health advisory levels have been set according to analyses of the local relationship between heat and mortality. An NYC study found that when the heat index reaches 95°F or higher for two or more days, or 100°F or greater for any period, the risk of death from chronic conditions increases more steeply (Metzger et al., 2010a). On the basis of this study, the National Weather Service (NWS) and the NYC Office of Emergency Management in 2008 agreed to lower the threshold for issuing NWS heat advisories and activating NYC's heat emergency plan to these levels (Benmarhnia et al., 2019; Ito et al., 2018) (see Section 4).

While the hottest days of summer are the most dangerous to health, even moderately hot days can be harmful. About two-thirds of NYC's annual heat mortality are associated with moderately hot days when the temperature is between 82°F and 95°F (City of New York Department of Health and Mental Hygiene, 2022b). One reason why these moderately hot days have a greater cumulative impact is that they occur much more frequently than extreme heat days (Figure 3) (City of New York Department of Health and Mental Hygiene, 2022b). For example, from 2011-2020, more than 20% of late June through mid-August days reached 90°F or higher (City of New York Department of Health and Mental Hygiene, 2022b). While the proportion of days above 90°F is highest in July, hot days historically can happen in May through September. In NYC, from 2016-2020, heat-exacerbated deaths occurred most frequently in July (37%), followed by August (28%), June (18%), September (10%), and May (7%). Interventions to address the season-long risk on moderately hot days, as well as the heightened risk during extreme heat events, will protect public health (City of New York Department of Health and Mental Hygiene, 2023b). Ongoing health surveillance can help elucidate risks as the NYC warm season lengthens.

In an analysis of trends in heat-exacerbated mortality, the Health Department found that deaths declined substantially between 1971 and 2000 but leveled off after 2000 and began increasing in the past decade as NYC's climate has warmed and the increase in residential air conditioning plateaued (City of New York Department of Health and Mental Hygiene, 2023b). The increases in heat-exacerbated deaths are attributable to a corresponding increase in moderately hot, but not extreme heat days (Figure 3), indicating that heat adaptation measures such as residential cooling, need to be available to people during entire the warm season.

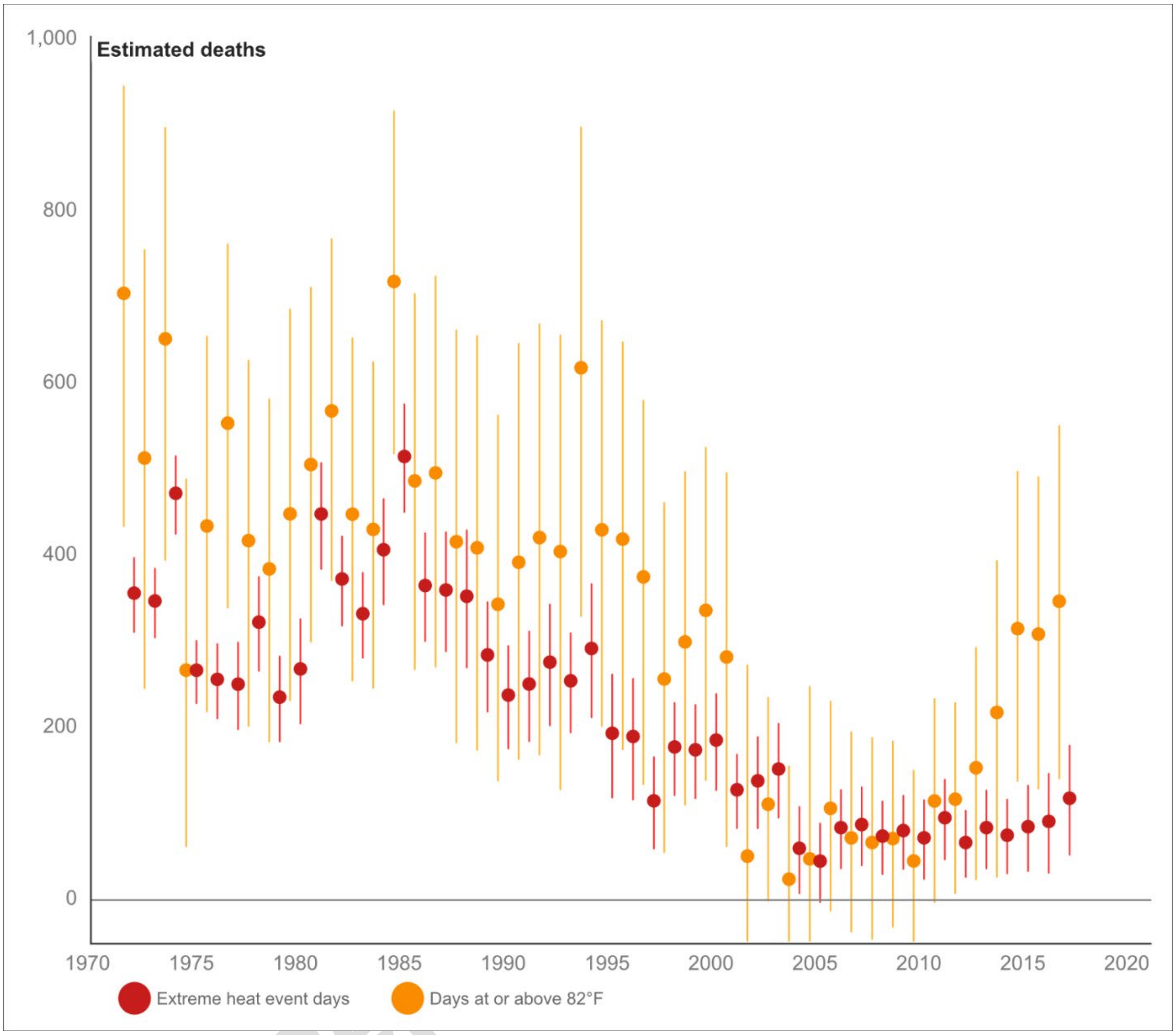

Figure 3: Annual average heat-exacerbated deaths for Extreme Heat Event (EHE) days, and days reaching a maximum temperature of 82°F or higher, including EHE days, in 5-year moving time windows, 1971-2020, New York City. EHE days were defined as at least 2 consecutive days with 95°F or higher daily maximum heat index (HI) or any day with a maximum HI of 100°F or higher. The EHE and Days at or above 82°F estimates come from separate regression models. Source: 2023 New York City Heat-Related Mortality Report.(City of New York Department of Health and Mental Hygiene, 2023b)

The relationship between temperature and mortality varies geographically (USGCRP, 2018) even to the building level. Research at the global scale suggests that the minimum mortality temperature (MMT) collected from 658 communities in 43 countries was between 14.2°C (58°F) and 31.1°C (88°F) decreasing by latitude (Tobías et al., 2021). Research at the national scale indicates that heat-mortality rates are higher in the northeast and midwest compared to the south (B. G. Anderson & Bell, 2009). Another study in 11 large US cities suggests that MMT for heat varies between 65.2°F (18.4°C) and 90.4°F (32.4°C) with higher temperatures at lower latitudes, (Curriero, 2002) reflecting in part less adapted physical environments (e.g. less air conditioning) in northern cities like NYC. Differences in building types and in the prevalence of indoor cooling account for some of the geographic variation (see Section 3.1.5). Less population acclimatization may also play a role, especially when temperatures rise faster than physiologic acclimatization in normally cooler locations and seasons (Guo et al., 2016), such as during an early spring heat wave.

3.1.4 Who is most vulnerable and why? Health, demographic, and social factors

3.1.4.1 Race and Income

Heat risks to health are greater for people with lower household incomes, and other limited financial resources, and higher energy cost burdens, which reduce their ability to avoid heat exposure. The energy cost of air conditioning, for example, must be weighed against other pressing priorities, such as purchasing food or medicine (Bhattacharya et al., 2003; Hernández, 2016). Racist and socially unjust policies have also created differences in economic opportunities, neighborhood environments, housing, energy access, and have led to overlapping health and environmental burdens (Bailey et al., 2017) among communities of color and low-income residents. Black New Yorkers in particular are more likely to be exposed to heat and, as a consequence, have higher rates of heat-health impacts – inequities that are caused by past and current racism (City of New York Department of Health and Mental Hygiene, 2023b; Foster et al., 2024).

The historical roots and current pathways linking structural racism and other unjust policies to present climate risk disparities are complex and the social context itself is also continually changing. The historic and future linkages of inequity to climate vulnerability are considered more fully in Foster et al.,(2024). Some of these pathways most relevant to heat-health risks are briefly considered here. For example, beginning in the 1930s, the practice of "redlining" at the federal level designated over 80% of the Black population in NYC at that time as living in "hazardous" mortgage risk zones. Climate researchers have shown that surface temperatures in formerly redlined areas across the country are on average 2.6°C (4.7°F) warmer than in non-redlined areas, due in part to less tree canopy and more impervious surface (Hoffman et al., 2020a). Redlining, zoning, and land-use planning and patterns over time, and how they interact to create and maintain climate inequities, are discussed in depth in Foster et al.,(2024).These factors, as well as displacement (i.e. gentrification), have shaped heat-health risk in the city. While some formerly redlined neighborhoods have relatively low heat vulnerability indices (Benz & Burney, 2021; City of New York Department of Health and Mental Hygiene, 2022g; Zipp, 2009), inequities in heat vulnerability persist. Neighborhoods that are home to more people living below the poverty line and Black residents tend to have less vegetative and tree cover and less access to air conditioning at home (City of New York Department of Health and Mental Hygiene, 2022b, 2022g; Madrigano et al., 2018). These pathways for increased heat exposure are some of the reasons why Black New Yorkers are disproportionately affected by heat-exacerbated mortality (Madrigano et al., 2015) and experience rates of heat stress mortality that are twice as high as White New Yorkers (City of New York Department of Health and Mental Hygiene, 2022k).

Racism and economic disadvantage create health vulnerabilities through multiple, interacting pathways including, but not limited to, access to affordable and healthy food, access to safe places for physical activity, and health care systems that do not provide care to all who need it. For example, there are large inequities in access to health insurance by race, income, and documentation status. People without health insurance are less likely to have access to primary care, receive preventative health screenings, and have fewer resources to manage chronic conditions (Fiscella & Sanders, 2016; Gaffney & McCormick, 2017; Karliner et al., 2010; Starfield et al., 2005; Timmins, 2002; Vernice et al., 2020). Sub-optimal management of health conditions because of these barriers may, in turn, predispose individuals to heat-related illness or exacerbation of their health conditions. Even when care is accessible, people of color may receive substandard treatment due to racial bias (Bailey et al., 2017).

Households experiencing energy insecurity are much less able to afford air conditioning purchases, maintenance and repair, efficiency upgrades, weatherization, or utility costs of using air conditioning during hot weather (See NPCC4, Yoon et al. (Yoon et al., 2024)). Hotter summers caused by climate change will raise these already high cooling energy cost burdens for low-income households (Ortiz et al., 2022) and will further strain the electric grid, which tends to be more prone to outages and brownouts in marginalized communities (Berkman et al., 2022; Marcotullio et al., 2023).

During the deadly 1995 Chicago heat wave, a comparison of the social conditions in two low-income neighborhoods found that the neighborhood with high levels of social connectedness and vibrant public spaces fared much better. By contrast the community with declining population levels, high levels of empty housing stock and abandoned buildings, reduced levels of business and other street activities, higher crime rates, socially isolated seniors, and neglected public spaces like parks and sidewalks, fared much worse. People living in this neighborhood, which was also home to more Black residents and comparatively more people living below the poverty line, may have felt discouraged from interacting with their surrounding community, making it harder to maintain social connections to call upon during times of emergency. Klinenberg (2001, 2015) posits Black Chicago residents were more likely to live in communities with high levels of disinvestment, and that is one reason why that population suffered higher death rates during the heat wave. There were also some neighborhoods in Chicago with more Black residents that stayed safe during the heat wave, but those areas were not experiencing population decline and other forms of neighborhood depletion.

3.1.4.2 Chronic and mental health conditions

Chronic physical health conditions, including diabetes, obesity, high blood pressure, respiratory conditions like chronic obstructive pulmonary disease (COPD), congestive heart failure, and kidney disease also increase vulnerability to and risk of illness and death from heat stress exposure (Cui & Sinoway, 2014; Ebi et al., 2021; S. Lin et al., 2009; Meade et al., 2020; Sasai et al., 2021). People with these conditions may be less able to maintain a safe body temperature or be more prone to dehydration because of their condition or medications they must take (Meade et al., 2020). People of color and people with lower incomes bear an inequitable burden of chronic conditions, as discussed above, and this is evident in NYC for diabetes and other chronic health conditions (Figure 4).

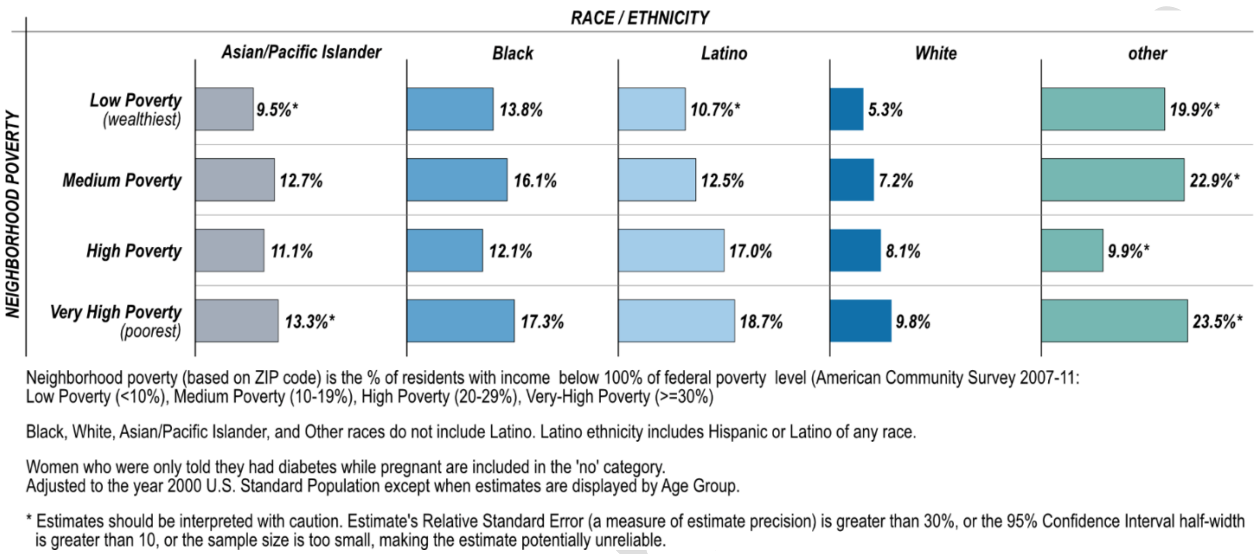

Figure 4. Prevalence of people who have ever been told they had diabetes by neighborhood poverty and race/ethnicity, 2017. Source: (City of New York Department of Health and Mental Hygiene, 2023i)

People with mental health and cognitive conditions are more vulnerable to heat-related illness and to exacerbation of their pre-existing conditions by heat exposure. In a national multi-city study of Medicare participants, those with chronic cardiovascular, respiratory, or neurologic conditions, including dementia, were associated with an increased risk of hospitalization during extremely hot weather (Zanobetti et al., 2013). Recent studies in NYC have shown an increase in ED visits for mental health and cognitive conditions (Yoo et al., 2021) associated with increases in daily outdoor ambient temperatures above 27°C (~81°F), including schizophrenia, mood disorders, anxiety, self-harm, substance use, Alzheimer's disease, and dementia (Yoo et al., 2021). Nationwide studies among US adults also demonstrate these relationships (Nori-Sarma et al., 2022; S. Sun et al., 2021). In addition, several studies have documented increases in suicide attempts associated with increases in temperature and/or humidity (Burke et al., 2018; Hu et al., 2020; Kim et al., 2019; Page et al., 2007; Parks et al., 2020).

There are multiple drivers of risk for people experiencing mental health conditions that likely play a role in increased susceptibility during hot weather. Mental health drivers include medication interference with body temperature regulation, coexisting physical health conditions, and reduced ability to recognize the heat risks and engage in self-care (Health Canada, 2011; R. Thompson et al., 2018). Heat can impact sleep quantity and quality, which may exacerbate mental health conditions (Minor et al., 2022). Limited evidence suggests that schizophrenia patients may be physiologically sensitive to environmental heat stress independent of medication (Bark, 1998). These factors, combined with social and environmental factors, such as social isolation, worse housing quality, or inability to pay for or run air conditioning, can compound risk. Men are more likely than women to be socially isolated through their 50s, in general, and at older ages, when they are never married or experienced relationship disruption (Umberson et al., 2022).

3.1.4.3 Age

Aging is associated with changes in physiology, adaptive capacity, and greater likelihood of social isolation that can increase risk to heat (Gamble et al., 2013). Thirst and thermoregulatory mechanisms, including evaporative heat loss, and adaptive behaviors may decline with age. Older adults are more likely to have chronic health conditions and take medications that predispose to heat-related illness (Gamble et al., 2013; Hooper et al., 2014; Larose et al., 2013;

Millyard et al., 2020). While NYC has a younger age structure than other parts of the state or country, it too is aging and in the coming decades will see sizable increases in the proportion of population over age 65 (City of New York Department of City Planning, 2013). Women are more likely to live longer than men, and by themselves in those older ages, increasing their chances of becoming socially isolated, which may increase risk for mortality associated with heat or other causes (Ausubel, 2020; Holt-Lunstad et al., 2015; Medina et al., 2020). Older adults are more vulnerable to a range of climate risks to health, as discussed further in

BOX 1. Importantly, age increases the likelihood of social isolation (Umberson et al., 2022) which itself increases the likely impact of climate-related stresses and may be associated with living alone. For example, most of the heat-related deaths in British Columbia, Canada in 2021, discussed more in section 3.1.2, occurred among older adults who lived alone and had multiple chronic conditions (British Columbia Coroners Service, 2021). Notably, 67% of the deaths were among adults over age 70 and 56% were of those who lived alone.

Heat creates health risks across the life course. Although children and adolescents do not suffer the highest burden of heat-related disease compared to other age groups in epidemiologic studies, they are sensitive to heat exposure. Infants and children (particularly young children) must rely on adult caregivers to help them stay safe, cool, and hydrated (Centers for Disease Control and Prevention, 2019; National Oceanic and Atmospheric Administration, 2023d). Children and adolescents may also spend more time outside during play and sports, and may take longer to acclimatize to warmer temperatures (Mangus & Canares, 2019; National Oceanic and Atmospheric Administration, 2023d). Few studies have been able to investigate to what extent children's physiological differences influence heat risk, however,(Health Canada, 2011; Mangus & Canares, 2019), and there are also few studies that assess heat impacts among children. In NYC, one study found that higher temperatures were associated with increased rates of ED visits for children aged 0-18, with the greatest risk for children 0-4. Increased rates of hospital admissions for children aged 0-4 and 13-18 were also associated with warmer temperatures. ED visit risks were elevated for heat-specific, general symptoms, and injury diagnostic codes (Niu et al., 2022). In addition, the prevalence of any mental illness and serious mental illness is higher among younger adults, compared to those aged 50 and older in the US, contributing to potential heat risk among this age group (National Institute of Mental Health (NIH), 2023).

BOX 1. Aging and climate vulnerability in New York City

About 15% the population of New York City is above age 65 and this proportion is expected to increase (United States Census Bureau, 2021). This is a lower proportion than state- or nation-wide (17.3% of the U.S. population is over age 65), but like elsewhere, the proportion of the city's population over age 65 is expected to increase substantially in coming decades (City of New York Department of City Planning, 2013; United States Census Bureau, 2021). Between 2010 and 2021 New York City's median age rose considerably, increasing from 35.6 up to 38.2 years and the proportion of NYC's population over age 65 is expected to increase by about 15% between 2020-2030 alone, and with disproportionately greater increases in the Bronx and Staten Island (City of New York Department of City Planning, 2013; NYC Department of City Planning, 2022). In big diverse cities like New York, older urban residents are more likely to come from historically disadvantaged or immigrant communities and have lower levels of education, income and insurance (Garcia et al., 2022; Gusmano et al., 2010).

As New York City's population ages and climate impacts unfold, the vulnerability of older adults to hazards such as temperature extremes (heat and cold), storms and flooding is a growing concern in part due to physical and neurological aspects of aging. Chronic conditions (e.g. dementia, diabetes, and kidney disease) and acute conditions (e.g. heart attacks, falls, and pedestrian accidents) are more common in older adults, with disparities in many conditions by race with higher rates among Black than white adults (Boersma et al., 2020; CDCMMWR, 2022; Younan et al., 2022). Aging may also bring a decreased ability to complete activities of daily living (ADLs) and yield changes in physiology, including mechanisms associated with thermoregulation (Hooper et al., 2014; Kenny et al., 2017; Millyard et al., 2020). Older adults, and those with chronic conditions, may be more likely to experience adverse health outcomes during periods of extreme cold and heat (Gamble et al., 2013; Lane et al., 2018; Millyard et al., 2020). Dehydration is also a concern in older adults (Hooper et al., 2014) and drugs taken for chronic conditions may contribute to dehydration risk (Puga et al., 2019). People with dementia may have a reduced capacity for adaptive behaviors in response to temperature or extreme weather events. Evacuation is a concern, especially for those with mobility or sensory impairments, and since when evacuating, medication may be lost or forgotten (Ochi et al., 2014).

Socioeconomic and demographic characteristics compound these vulnerabilities. These include living arrangements, kin networks, social networks, and housing characteristics as well as ideas and perceptions about risk and planning in old age. Though living alone, loneliness and social isolation are risk factors for mortality at all ages, these increase with age, with risk modified by gender and relationship history (Holt-Lunstad et al., 2015; Umberson et al., 2022). Nearly one out of three older adults living in NYC live alone and one out of three older adults live in a multigenerational household with differences by race and ethnicity (Greer et al., 2019). Older immigrants may be more likely to experience loneliness and social isolation (Zemba & Wilmoth, 2022). One-third of older adults in New York report that they have limited or no English proficiency (Greer et al., 2019). City dwellers live in a wider range of housing types from high-rise apartments to single-family homes, and a wider range of housing tenure arrangements (Molinsky & Forsyth, 2022), which place them at different vulnerabilities in the aging-health-climate interface. Approximately 6% of New Yorkers are New York City Housing Authority (NYCHA) residents (including public housing, PACT, and Section 8 housing), representing 11.2% of the rental housing stock of the city (New York City Housing Authority, 2023). Ten percent of older New

Yorkers do not have working air conditioning (and 21% of older public housing residents) and 13% use supplemental heating (28% of older public housing residents) (Greer et al., 2019). Energy insecurity highlights how poverty, housing, and aging interact to place more vulnerability on people at risk of morbidity and mortality in a warming climate (See NPCC4, Yoon et al. (Yoon et al., 2024)).

3.1.4.4 Pregnant people

Pregnant people are more susceptible to heat-related illness because of pregnancy-induced changes to thermoregulation, including increased weight gain, which may make it harder to release heat, and heat production by the developing fetus (S. Sun et al., 2019). Heat exposure may also lead to pre-term birth, reduced birth weight, and still birth (Bekkar et al., 2020), as noted in Section 3.1.2. Pregnant people who work outdoors, work in un-air-conditioned environments or lack access to home cooling are likely most at risk (Qu et al., 2021). A recent study in New York State found associations between extreme heat and increased ED visits for a number pregnancy complications, including threatened/spontaneous abortion, renal diseases, infectious diseases, diabetes, and hypertension, with effects strongest among Black and low-income residents (Qu et al., 2021).

3.1.4.5 People experiencing homelessness

People experiencing homelessness may be at a high risk for exposure to extreme heat, especially in urban areas due to increased heat exposure from the urban heat island effect. It is unclear how well heat alert messages reach unhoused populations and how they are perceived (Bezgrebelna et al., 2021). Unhoused populations have fewer financial resources, resulting in reduced ability to address health conditions that can contribute to heat susceptibility (Bezgrebelna et al., 2021). A limitation of heat-related illness and death data for this population is that denominators and standard, consistent definitions for people experiencing homelessness are not available to compute absolute rates or relative risks. In NYC, between 2000 and 2011, people experiencing homelessness accounted for an estimated 5%, 3%, and <1% of heat stress deaths and heat-related illness hospital admissions and ED visits, respectively (Wheeler et al., 2013). NYC's most recent annual report on deaths among people experiencing homelessness showed a more than threefold rise in deaths from fiscal years 2018 to 2022, with drug-related deaths increasing most rapidly (NYC Department of Health and Mental Hygiene, 2023). While this report does not examine excess mortality associated with hot weather in this population, it may have risen substantially given the increase in people experiencing homelessness in the city (Brand, 2022; Newman, 2023), and the lack of access to cooling among unsheltered homeless people. Other studies show an association between heat and natural cause and drug overdose deaths in NYC (Bohnert et al., 2010; City of New York Department of Health and Mental Hygiene, 2022b) and with injury deaths nationally (Parks et al., 2020). Exposure to cold temperatures, however, still presents a larger risk in NYC for people experiencing homelessness. Cold exposure was the second most common external cause of death (19 deaths, 4 % of the total) among New Yorkers experiencing homelessness in FY 2022 (NYC Department of Health and Mental Hygiene, 2023).

3.1.4.6 Incarcerated people

In NYC, incarcerated people are exposed to unhealthy hot and cold indoor conditions due to a lack of federal, state, and local protections against dangerous indoor temperatures (Correal, 2019; Donavan, 2021, 2022; Holt, 2015; The Intercept, 2022). Thermal conditions inside these facilities are also a racial justice issue - incarcerated people in NYC and across the US are disproportionately Black or Brown due to a long and ongoing legacy of racist criminal justice practices (Bailey et al., 2017). The US prison population is also aging and has high rates of mental and physical health conditions, putting individuals at increased risk during extreme weather conditions (Holt, 2015). A recent national study found that 3-day heat waves were associated with a 7.4% increase in total mortality in US state and private prisons, with the largest regional effects in the Northeast (Skarha et al., 2023).

3.1.4.7 Occupation

Journalistic investigations of 2010-2020 Occupational Safety and Health Administration (OSHA) records reported that over 380 workers across 37 states in the U.S. died from occupational heat exposure (Shipley et al., 2021). Risk varies by occupation. The construction industry, an important employer in NYC (Jain, 2021), ranks second nationally behind agriculture in the rate of heat-related death (Gubernot et al., 2015). Deaths directly attributed to occupational heat stress are relatively infrequent among NYC construction workers (Toprani et al., 2017), though heat stress may indirectly contribute to other more common fatal construction injuries, such as falls (Gubernot et al., 2014), which accounted for 58% of the 144 construction worker deaths in NYC from 2007-2014 (Toprani et al., 2017).

A meta-analysis of international studies of occupational injury due to heat exposure from 2004 to 2020 found that there was sufficient evidence for a 1% increased risk of occupational injury for every 1°C (1.8°F) temperature increase compared to a regional reference temperature and limited evidence of a 17% higher risk during heatwaves, with the highest occupational injury risk in humid subtropical climates like that of NYC (Fatima et al., 2021). Research suggests that people are comfortable and productive at stable temperatures between 20°C and 25°C (68°F and 77°F) (de Dear & Schiller Brager, 1998; Halawa & van Hoof, 2012). For every 1°C exceeding this range, between 25°C and 32°C (77°F and 89.6°F), work productivity decreases by 2% (Seppanen et al., 2006).

Outdoor workers and those who work in un-air-conditioned indoor spaces are at increased risk of heat exposure and illness during hot weather. Heat-related illness and death have been documented in mail and package delivery workers in the United States (Tannis, 2020). Recent media reports highlighted worker concerns about heat exposure and a lack of air conditioning in trucks and warehouses in the NYC area and across the country during the summer 2022 heatwave (Irizarry Aponte & Maldonado, 2022; Rosenberg, 2022). One source estimates that more than 2.2 million workers in New York State are in high-risk occupations for heat exposure (Constible, 2023). Professions at heightened risk of indoor heat exposure include kitchen, warehouse, and manufacturing workers (Lerardi & Pavilonis, 2020; OSHA, 2022). Workers exposed to high temperatures who wear personal protective equipment such as healthcare workers and firefighters may also be at increased risk of heat stress due to reduced ability shed excess body heat (Bose-O'Reilly et al., 2021; Coca et al., 2017; Davey et al., 2021; McLellan et al., 2013).

3.1.5 Influence of buildings and the built environment

3.1.5.1 Outdoor urban environment

NYC is experiencing higher summer temperatures because of climate change and the Urban Heat Island (UHI) effect. The UHI occurs when cities are hotter than surrounding suburban and rural areas – sometimes up to 15 to 20°F hotter.(National Oceanic and Atmospheric Administration, 2023a) The annual average magnitude of NYC's urban heat island (comparing Central Park to surrounding suburban and rural locations) has been rising gradually and has been observed to be between about 2.5 degrees centigrade (Gaffin et al., 2008). The UHI is caused by more dark paved surfaces that absorb heat, less vegetation and cooling from evaporation, more waste heat from buildings and vehicles, and less ventilation in urban canyons created by tall buildings (National Oceanic and Atmospheric Administration, 2023b). The increasing UHI may explain a third of the warming trend in NYC during last century (Gaffin et al., 2008). In NYC overnight minimum temperatures are increasing the most compared to mean and maximum daytime temperatures (City of New York Department of Health and Mental Hygiene, 2022b), as expected with UHI amplification. The physical processes influencing NYC's UHI are considered in more detail in Ortiz et al., (2024). The rest of this section addresses how the UHI and outdoor landcover influence vulnerability to heat exposure.

Higher overnight temperatures can impair sleep quality (Obradovich et al., 2017) and reduce the respite vulnerable people need to recover from heat exposure. In addition to the regional temperature gradient caused by the UHI, neighborhood environments within cities also cause variations in surface and ambient temperatures and modify the health risks of hot weather. The UHI can worsen human health risks and discomfort by locally increasing ambient temperatures during extreme heat episodes, increasing energy demand for cooling (which can lead to blackouts), and generating higher emissions of air pollutants from associated cooling energy production (United States Environmental Protection Agency, 2023d) and modify the health risks of hot weather. Greenery can decrease ambient and surface temperatures through shade and evapotranspiration. Local temperature reductions depend on the amount of space greened, however. For example, a study of overnight temperature and green space in NYC found that an association between local ambient temperature and vegetative cover was only observed where vegetative cover was 32% or greater in a 200m buffer zone around temperature monitoring sites (Johnson, Ross, et al., 2020). Forested natural areas within cities are significantly cooler than other locations, including landscaped areas under trees (Crown et al., 2023). Thus, NYCs several large urban forests in parks can provide a respite for those able to visit them because they live nearby, can reach those that are accessible by transit, or are able to drive or bike to them. Trees and other nature in locations closer to where most residences and human activity occurs in the city can provide health benefits. In addition to reducing air temperature and providing shade from radiant heat exposure, neighborhood greenspace, such as tree canopy, parks and forests, has been associated with better physical health, reduction in morbidity in some disease categories, lower levels of depression, and lower levels of stress and helps mitigate poor air quality (van Dillen et al., 2012; Yitshak-Sade et al., 2019). A greater proportion of tree and vegetative cover in a community has been associated with a reduced risk of heat-exacerbated deaths (Conlon et al., 2020; Reid et al., 2009). The intersection of the physical environment factors (i.e., lower levels of green space) with neighborhood racial composition and other social factors has been used to construct compound heat vulnerability indices, including one for NYC (Madrigano et al., 2015; Nayak et al., 2018) (Figure 5).

3.1.5.2 Indoor environments and health risks

The home is often a setting for dangerous heat exposure among vulnerable people. Those who die of heat stress in NYC are most often overcome by heat in dangerously hot homes (City of New York Department of Health and Mental Hygiene, 2022b). In addition, heat-exacerbated deaths occur more often at home than in hospitals or other institutions (Madrigano et al., 2015). Although place of exposure is not consistently recorded, exposure at home is also the most reported setting for NYC heat-related illness hospital admissions (Wheeler et al., 2013). Vulnerable

New Yorkers most often stay home during hot weather, even if they are unable to stay cool because of a lack of air conditioning (Lane et al., 2014).

In NYC homes without air conditioning, it can be up to 10°F hotter indoors than outdoors (Vant-Hull et al., 2018). Warm indoor conditions in homes without AC can persist for up to 3 days after the temperatures have cooled off outside following extreme heat (Vant-Hull et al., 2018) due to thermal inertia of the buildings and lack of cross ventilation. This may play a role in the delayed effects of up to 3 days documented in studies of NYC heat-exacerbated deaths (Matte et al., 2016; Metzger et al., 2010a). Elevated indoor temperatures also play a role in deaths and illnesses that occur when the outdoor temperature is moderately hot but not extreme. Higher indoor temperatures during the summer season can also interfere with sleep quantity and quality (Minor et al., 2022; Quinn & Shaman, 2017), which could exacerbate mental health conditions associated with hot weather (Lõhmus, 2018).

National studies have documented declines in excess mortality that occurred as residential air conditioning increased from 10% in 1960 to nearly 90% nationally by 2004 (Barreca et al., 2013). In NYC during the latter part of the 20th century, there was a substantial decline in excess mortality associated with higher temperature during the warm season (Petkova, Gasparrini, et al., 2014). Analyses of data from 1971 to 2020 showed that heat-exacerbated mortality in NYC decreased until 2000, and then plateaued until 2010. Heat-related mortality rates have begun to increase in the recent decade as NYC warm season temperatures have risen and residential air conditioning rates citywide have remained flat (City of New York Department of Health and Mental Hygiene, 2022b). While more than 90% of NYC Households now have air conditioning, the proportions without access vary more than four-fold across neighborhoods (City of New York Department of Health and Mental Hygiene, 2022g). People with lower incomes and Black New Yorkers are less likely to have access to home air conditioning (Madrigano et al., 2018). Racial disparities in central air conditioning prevalence across four other northern US cities explain some of the racial differences in heat-related mortality (O'Neill et al., 2005). Adaptive and maladaptive uses of mechanical cooling in New York City are addressed in NPCC4, Balk et al. (2024).

Increased heat directly impacts thermal conditions in indoor environments, particularly in the absence of air conditioning (Climate Central, 2021; National Oceanic and Atmospheric Administration, 2023b). In a study in NYC, apartments without AC on upper floors receiving direct sunlight with southern exposures were warmer (Vant-Hull et al., 2018). The facades of the building and building albedo affect the heat absorption in a building (Bulkeley et al., 2011; Latha et al., 2015), as does insulation. Some building types and materials require more energy to cool interiors and heat up more rapidly without air conditioning. For example, all-glass high rises and pre-2000 high-rise buildings tend to heat more rapidly during power outages (Porritt et al., 2012; White-Newsome et al., 2012).

3.1.5.3 Neighborhood-level vulnerability

Heat risk is not distributed uniformly across NYC neighborhoods. The city's Heat Vulnerability Index (Figure 5) is a composite measure of social and environmental factors used to identify neighborhoods that are at increased risk of heat-exacerbated mortality during hot weather (City of New York Department of Health and Mental Hygiene, 2022f, 2023f). Components are derived from an epidemiologic study of heat mortality in NYC (Madrigano et al., 2015) and has been validated to show that higher HVI levels are associated with greater heat-exacerbated excess mortality. Components include measures of surface temperature, green space, residential air conditioning prevalence, median income, and the percent of Black New Yorkers, the population most impacted by heat mortality in NYC due to persistent structural racism, described in section 3.1.4.1 above.

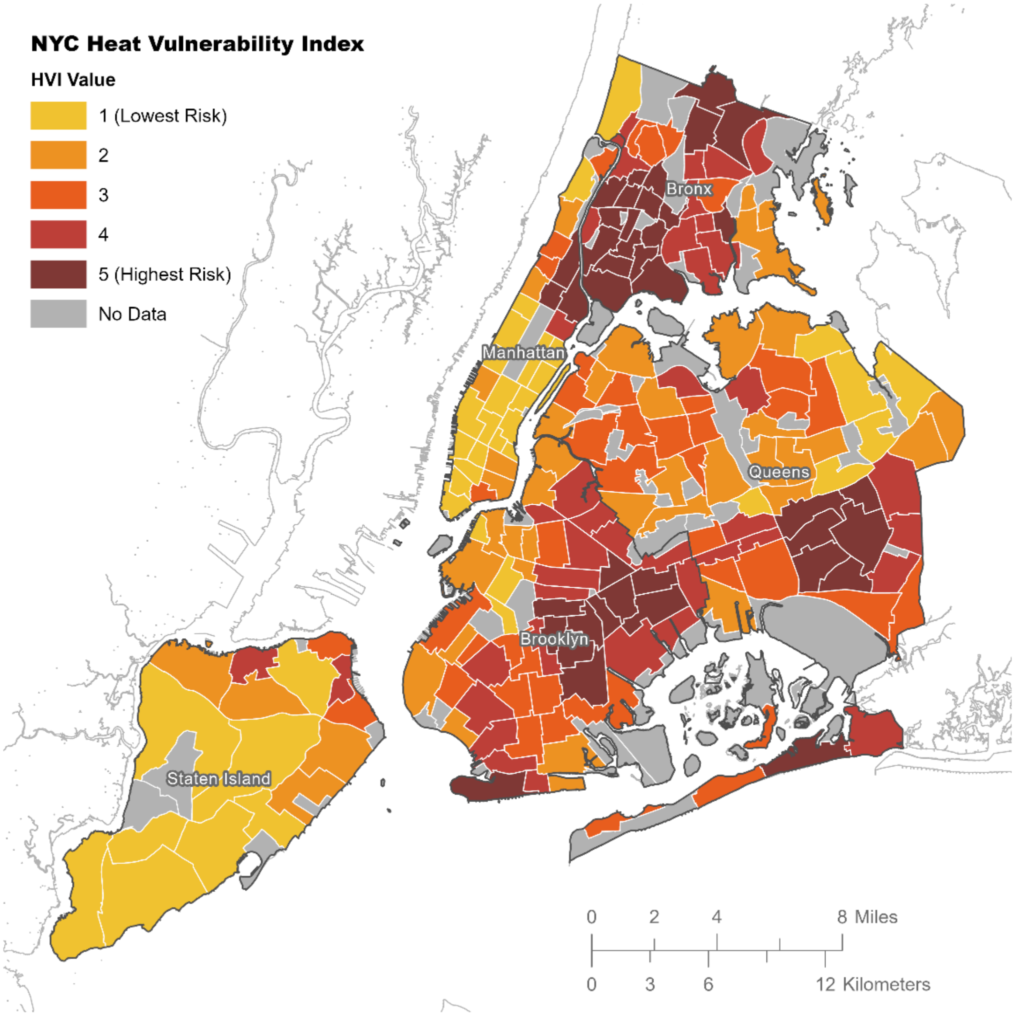

Figure 5: The Heat Vulnerability Index (HVI) for New York City identifies neighborhoods where the risk of death associated with extreme heat episodes is higher. It uses a statistical model based on surface temperature, green space, access to home air conditioning, a measure of home income, and racial-ethnic composition – all at the Neighborhood Tabulation Area (NTA) level. It was adapted and updated from an earlier epidemiologic study (Madrigano et al., 2015). Data Source: (City of New York Department of Health and Mental Hygiene, 2023f)

3.2 Flooding

3.2.1 Synopsis of NPCC2 health assessment

The NPCC2 2015 report was the last detailed assessment of public health risks of flooding in New York City (Kinney et al., 2015). Coastal storms and flooding were identified as principal climate-health hazards, along with extreme heat. Following the devastating impact of Post-Tropical Cyclone Sandy (also sometimes referred to as "Hurricane Sandy," "Superstorm Sandy," or "Sandy"), NPCC2 focused on health impacts of storm surge flooding as well as other coastal storm risks related to wind and evacuation. The Post-Tropical Cyclone Sandy experience showed how health vulnerabilities from floods are "magnified when critical infrastructure is compromised" and storm surge-related health risks are compounded by sea level rise and more intense storms.

Drawing on then-available studies of impacts of Sandy and other coastal storms, such as Hurricane Katrina, the NPCC2 identified seven causal pathways for health impacts from flooding: 1) direct impact phase injuries and deaths such as from immersion, moving debris, or electrocution, 2) evacuation risks, 3) secondary hazards from utility outages, 4) exposure to contaminants or mold from floodwater or water damage, 5) displacement and disruption of services and access to care, 6) stress, trauma, and other mental health impacts, and 7) cleanup and recovery health and safety risks. These same health impact pathways apply to all types of flooding, though their relative importance will vary by type. See Figure 6.

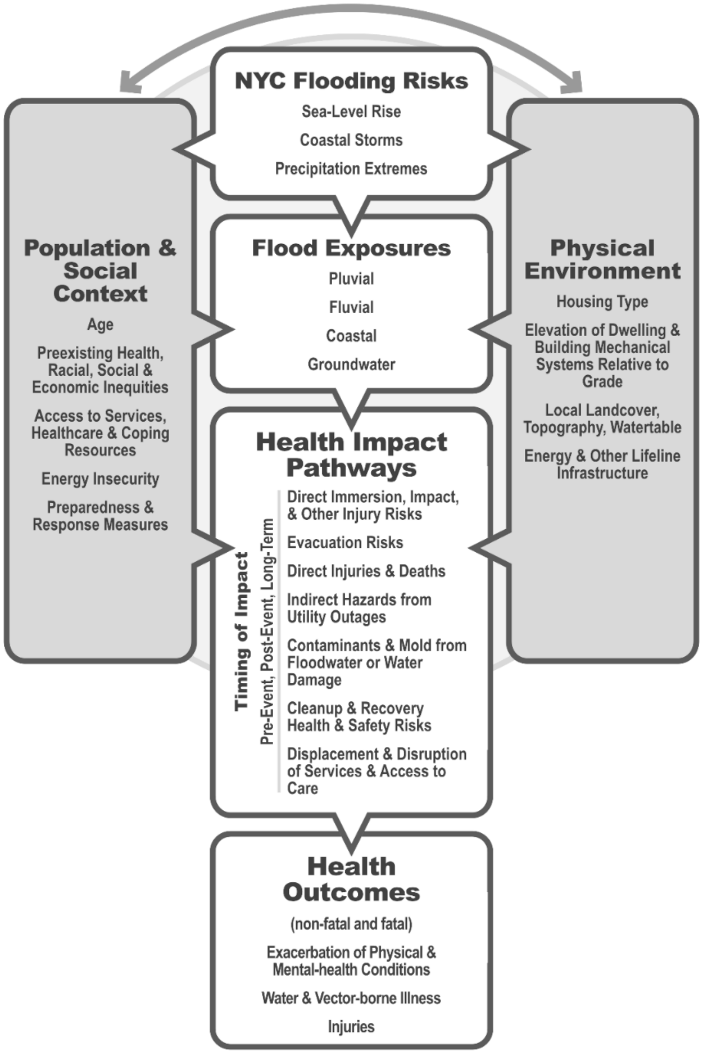

Figure 6: Flooding health impact pathways and vulnerabilities. Framework adapted from Chapter 1, Figure 14.1 in Introduction: Climate change and human health. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment (Balbus et al., 2016).

3.2.2 Recent and projected NYC flood risks

3.2.2.1 Pluvial and fluvial flooding and health

Despite predictions of increasing extreme precipitation events, the 2015 NPCC2 public health report stated, based on experience at that time, that in contrast to Post-Tropical Cyclone Sandy's deadly surge, extreme rain flash flooding was "not a major threat to life safety" in NYC. Hindsight has shown this to be incorrect. Cloudburst events that can cause pluvial (rainfall) flooding continue to grow in magnitude (Huang et al., 2017), and the NPCC3 noted increasing observed precipitation trends that tracked NPCC2 projections while recommending research and NYC-commissioned studies of heavy rainfall levels that could cause severe flooding in NYC (New York City Panel on Climate Change, 2019). Following those recommendations, the NYC Stormwater Resiliency Plan (SRP) and an associated study identified areas of inland flooding from heavy rain (City of New York Department of Environmental Protection, 2022a). NYC had long been under an EPA Clean Water Act mandate to reduce combined sewer overflows (CSOs) that occur during heavy precipitation. The SRP understandably focused on bolstering green and built infrastructure measures for CSO prevention as well as property protection – noting an 80% reduction in CSOs since the 1960s. Thus, efforts to understand and plan for extreme precipitation (pluvial) flooding in NYC came before the lethal risk of cloudburst events was made clear (City of New York Office of the Deputy Mayor for Administration, 2021). As recently as September 29, 2023, unexpected widespread flooding associated with a stalled Tropical Storm dropped over 8 inches of rainfall on JFK Airport, exposing the city's risk of inundation from even indirect storm hits. This emphasizes the benefits of addressing basement apartment vulnerability as part of the city's overall affordable housing efforts and expanding efforts to flood-harden subways beyond coastal surge areas. A detailed discussion of flooding relevant to NYC is presented in NPCC4, Rosenzweig et al. (Rosenzweig et al., 2024) and general flooding-related definitions and terms are included in this assessment's companion glossary. The topics of changes in the public right of way and the importance of acknowledging flood risks to drivers are also mentioned in NPCC4, Balk et al., (2024).

Events since 2015 and the climate and flooding assessments covered in NPCC4, Braneon et al., (2024) and NPCC4, Rosenzweig et al., (2024) have made it clear that life safety and other public health risks for New Yorkers are not limited to flooding from coastal storms. Pluvial (rain-related), fluvial (from rivers and streams), and groundwater flooding hazards also threaten NYC. However, FEMA's Special Flood Hazard Area maps are based only on fluvial and coastal surface water body flooding, and do not consider pluvial or groundwater flooding, both important in NYC (See NPCC4, Rosenzweig et al. (Rosenzweig et al., 2024), Key Message 2).

The potential for cloudburst events to cause deadly pluvial flooding was made clear by Tropical Storm Elsa, in July 2021, and the Ida Remnants Cloudburst (also sometimes referred to as "Hurricane Ida," or "Ida") in September 2021. Heavy rain from Elsa flooded NYC subways and streets, requiring rescue workers to intervene to assist people trapped in below grade dwellings and other low-lying areas that were inundated in that event. Ida's unprecedented 3 or more inches of rainfall in one hour in some neighborhoods warranted NYC's first flash flood emergency in the city's history. Storm sewers were quickly overwhelmed in parts of the city. The rapid onset, extensive flooding of roads and below-grade spaces of inland areas outside established flood plains caused numerous drowning deaths among residents trapped in basement apartments in NYC and in their cars in New Jersey (Rosenzweig et al., 2024, tbl. 2).

Fluvial flooding occurs when a river, creek, or stream stage exceeds the elevation of its banks. Streams across most]of NYC's inland areas have been filled over time, with most surface water flow now redirected to subsurface stormwater sewers. Only a few freshwater stream channels and small inland creeks remain in NYC (Rosenzweig et al., 2024). There are relatively limited areas in NYC with high fluvial flood vulnerability (Rosenzweig et al., 2024, fig. 12). Current understanding of fluvial flood risks and projected future changes are limited by the shortage of stream gauges in the city, but FEMA does include fluvial flood hazard, along with coastal flooding, in the modeling to develop its Special Flood Hazard Area maps.(City of New York Department of Environmental Protection, 2023a)

3.2.2.2 Coastal flooding and health

While future risks are difficult to quantify, coastal flooding is very likely to increase in frequency, extent, and height because of climate change and other factors covered in depth elsewhere in this assessment (see Braneon et al., 2024; Ortiz et al., 2024; Rosenzweig et al., 2024).

Sea level rise increases the range of coastal flooding and introduces lingering effects as areas of New York become increasingly uninhabitable due to chronic flooding, potentially decreasing the available housing stock and increasing the mental stress of unplanned as well as planned relocation. There are interactions between coastal sea level rise and groundwater flooding, and these complex saline-freshwater systems can be further affected by increases in annual precipitation, or subterranean drainage and sewer infrastructure (Rosenzweig et al., 2024). In addition to these interacting coastal flooding risks, recurrent tidal flooding is now a regular occurrence in low lying coastal areas such as Edgemere in Queens. Nationally, the National Oceanic and Atmospheric Administration (NOAA) identified a 200% increase in high tide flood days from 2000 through 2021 and projected average high tide flooding by 2050 to occur on 45-70 days per year (National Oceanic and Atmospheric Administration, 2022). Social and economic risks include loss of neighborhood functions such as shared beaches or piers that support community cohesion and recreation, and loss of housing, businesses, and associated revenues. Notably, flood insurance claims are paid for damages to communities impacted by recurrent overland tidal flooding that affects two or more acres, or two or more properties, but the National Flood Insurance Program (NFIP) doesn't cover flooding due to groundwater entering a basement, or for backups of sewer systems (Federal Emergency Management Agency, 2023a). These flood events can be insured against through purchase of a rider often referred to as a basement backup or sewer backup rider on homeowners' insurance policies.

Prior to coastal storm landfall, evacuation can disrupt health care, increase stress, and create other health risks, especially for the most vulnerable people, such as those dependent on dialysis or other types of frequent health services. While long-range weather forecasting improves awareness of incoming storms and increases the lead time available to prepare, resident preparedness does not necessarily increase, particularly for those with fewer resources or fewer alternatives (Rao et al., 2023). Immediate event-phase health effects include fatal injuries, especially from immersion (drowning) and blunt trauma (from flood debris). During the post-storm phase, health risks persist as residents deal with flooded properties and struggle with access to basic services such as power and transportation. Additional post-storm health risks can arise from exposures to insect disease vectors, water-borne pathogens in floodwaters and from sewage backups and overflows, construction-related hazards, as well as exposure to various hazardous materials and toxic chemicals. Long-term health effects can include chronic physical and mental stress from property and monetary loss, displacement from neighborhoods, social networks and services, and interruption of health care.

3.2.2.3 Groundwater and health

Rising groundwater threatens to flood structures in a number of areas in NYC, particularly in eastern Brooklyn and southern Queens (Rosenzweig et al., 2024), and especially below-grade spaces. Groundwater was pumped for drinking water in parts of southeastern Queens until 2007, but has not been used since then (City of New York Department of Environmental Protection, 2023a). Intrusion from rising or fluctuating underground water levels during especially wet seasons can cause flooding that damages sanitary infrastructure and mobilizes subsurface sources of waterborne pathogens or chemical contaminants. Groundwater flooding can also compromise building and underground infrastructure stability, and can threaten ecosystems (Semenza, 2020). While globally the greatest health-related threat from groundwater relates to arsenic contamination of drinking water systems, NYC's drinking water comes from upstate surface reservoirs, and as a result, arsenic is not detected in NYC drinking water (City of New York Department of Health and Mental Hygiene, 2023e).

3.2.2.4 Compound flooding

Climate change will likely increase risks and health impacts from all four types of flooding under consideration, and from their co-occurrence. Compound flooding (the co-occurrence of coastal, fluvial, pluvial, and/or groundwater) is not well understood due to limitations in modeling and less available research on household or individual health impacts of compound flooding as compared to singular types of flooding. A 2021 study compared various types of flooding to household outcomes, noting significant differences in financial, psychological and physical impacts and resulting coping and preparatory measures (Thieken et al., 2021). While the NYC VIA Team is currently analyzing compound flooding (Rosenzweig et al., 2024, sec. 8), compound flood-related health impacts are not part of the VIA analysis, leaving questions as to impacts of various combinations of flooding types to New Yorkers. Compound flooding impacts are also not included in current FEMA flood maps, which do not consider pluvial or groundwater flood risks.

3.2.3 Updated flooding-health epidemiology evidence

3.2.3.1 Flood event phases and health-relevant exposure pathways

There are multiple possible pathways that can result in flood-related adverse health impacts. The various phases of flooding events – pre-event, event phase, and post-event – are each associated with different pathways of potential disruptions and harms (Parks et al., 2021, 2022), depending in part on the cause of flooding and associated hazards, such as high winds. Because of this complexity, as with heat waves, the complete health toll from flooding cannot be fully ascertained by immediately-available reports of injuries or deaths. Recent excess mortality studies have revealed a much greater toll (Parks et al., 2023) and still more health impacts can be experienced months later by those relocated to far off communities. As with all climate-health risks, pre-existing factors increase vulnerability, including health, socio-demographic, and environmental factors. The following sections describe these overlapping flood phase-related pathways and pre-existing vulnerability factors.

3.2.3.2 Pre-event phase pathways

Emergency Preparation and Evacuation: Pre-event health risks relate to the extent to which New Yorkers have awareness of impending events and readiness to prepare themselves or have the ability and means to evacuate to a safe shelter. Emergency preparation could occur through multiple methods, including cell phone alerts, e-mail notifications, signage, and increasingly, clinical settings (Angelini, 2017; Madrigano et al., 2018; Patz et al., 2014; Trombley et al., 2017). Social media posts also have value, particularly when they permit two-way communication between authority and respondent and provide information on who evacuated or is in the process of doing so (Jaeger et al., 2008; Y. J. Liu & Fraustino, 2012; Wang & Zhuang, 2017). However, the decision to evacuate is a complex one, even under an evacuation order (S. Brown & Parton, 2014). While awareness of evacuation zones may positively correlate with evacuation behavior, exposure to prior alerts that over- or under-estimated the severity of a storm may also impact the decision to evacuate (Rao et al., 2023). The issue of language equity can exacerbate preparedness challenges faced by low English proficiency communities (Venkatraman, 2022).

Insurance and Housing: Many people living in flood prone areas remain uninsured from flood losses. After Post-Tropical Cyclone Sandy, it was estimated that infrastructure damages cost at least $19 billion (City of New York

Office of the Mayor, 2013). Just over half of the 1-4 family homes in the high-risk zone were insured when Sandy hit NYC (Dixon et al., 2013; Limaye et al., 2019). Moreover, even with recent changes to more risk-based pricing of insurance coverage under the National Flood Insurance Program (NFIP), some residents are unable to afford premiums (Dixon et al., 2013; Federal Emergency Management Agency (FEMA), 2022; Natural Resources Defense Council, 2023). Also, residents outside of FEMA designated floodplains may not recognize their flood risks and may not choose to insure for flooding. Most tools show coastal flooding risk but are not clear enough about the types of flooding not shown, leading to a false sense of security about flood risks (Pasternack, 2023). Even when risks are known, residents may have few choices given housing availability and affordability (Limaye et al., 2019; Madajewicz, 2020). Moreover, while NFIP is available to owners and renters, the risks they face may be different. Flood risk disclosure legislation and planned voluntary housing mobility programs may help alleviate this challenge (City of New York Office of the Mayor, 2023a; State of New York, 2021). In 2022, statewide legislation was enacted that requires landlords to disclose past flood damages and risks to renters (Scata, 2022)); in 2023, similar legislation was passed for home buyers. See NPCC4, Rosenzweig et al.,(2024) for more details on flood vulnerability.

3.2.3.3 Event phase pathways

Event phase pathways include direct exposure to fatal and non-fatal immersion, wind-blown debris, and electrocution from downed and submerged power lines. Emergency communications, system failure, access to care, and short-term displacement, and affordable housing shortages contribute to this pathway.

Direct injury risks: Paterson et al. (2018) note that drowning is the most immediate cause of death from flooding particularly among men who may have greater risk-taking behaviors. Among direct injury deaths in NYC due to Sandy, about 70% were drownings; among those who drowned at home, at least 30% (9 people) were found in basements or lived in basement apartments (Seil et al., 2016). Paterson et al.(Paterson et al., 2018) also identify expected acute events such as orthopedic injuries and lacerations, and unexpected ones such as burns from flammable liquids spreading on the surface of floodwaters. Chronic health conditions may also worsen with flooding due to noncompliance with medication from interruption to availability, challenges accessing care, and the physical workload of recovery. For example, mortality rates in those with cardiovascular disease and diabetes may increase. Paterson et al. (Paterson et al., 2018) also identify increases in acute events in those with chronic respiratory diseases due to disrupted maintenance therapy, loss of power to life-saving medical devices, reduced glycemic control, reduced physical activity, poorer nutrition and disrupted treatment leading to increased risks of ketoacidosis and death. Among older adults in nearby New Jersey, ED visits during Sandy increased for the injuries already mentioned as well as a range of other ailments (McQuade et al., 2018).

The majority of the Ida Remnants Cloudburst deaths in NYC resulted from drowning in basement apartments (City of New York Office of Management and Budget, 2023; City of New York Office of the Deputy Mayor for Administration, 2021; Yuan et al., 2024). These tragic deaths revealed the need to evaluate risk based on locations within buildings, with heightened risks to those on lower floors with greater exposure to floodwaters. This is further explored in Rosenzweig et al., (2024) and in the NYC *Flood Vulnerability Index* (FVI) developed in the NYC *Climate Vulnerability, Impact, and Adaptation Analysis* (VIA) (McPhearson et al., 2024). Additionally, the loss of life from Ida brought into sharp relief how NYC's climate vulnerability is increased by its scarcity of affordable housing, which has long caused households to live in illegal basement dwellings that don't meet building codes for safety (Regional Plan Association, 2022). While any lower level could be suddenly inundated by pluvial flooding, those that lack emergency exits or fail to meet other life safety measures increase occupant risks (Afridi & Morris, 2021; FEMA, 2023; Hornbach et al., 2022; Negret, 2021; Pratt Center for Community Development, 2008).

Emergency Communications: Surveys conducted by Yong (2017) and Kreslake (2019) provide insight into opportunities for improving emergency communication by surveying some of the most vulnerable populations on their risk perception and disaster preparedness. Black, Hispanic, and lower-income households placed a strong importance on receiving high-quality information and assistance from the government during a flood disaster as well as on policies to both reduce emissions and pollution and offer rebates and loans to add cooling roofs and other interventions (Kreslake, 2019). Importantly, given the diversity of NYC, providing information in multiple languages and via trusted community-based organizations, particularly for immigrant populations, is key. In Yong's survey, risk perceptions and "societal trust" were found to differ between Canadian-born and immigrant populations in Canada, affecting emergency preparedness positively and negatively, respectively (Yong, 2017).

Systems Failure: The Ida Remnants Cloudburst resulted in MTA and roadway flooding, impacting resident access to home or work. Interruptions to transportation systems in turn introduces challenges to those dependent on others to provide daily support, such as home health workers or home food and pharmacy delivery. In 2012, Sandy led to widespread and lengthy power outages. Health effects of power outages are discussed in NPCC4, Yoon et al. (2024).

Access to Care: Access to emergency care is limited during flood events. Some emergency responders may not be able to travel to emergency rooms or to access New Yorkers in need, for example, when flooded streets cannot be traversed by ambulances. People dependent on buses or subways to access care are similarly challenged. Pharmacies may not be open and healthcare facilities may be unable to serve patients with standing appointments for dialysis and other procedures or types of visits. Healthcare workers may be unable to get to their designated facilities, resulting in staffing shortages. Simultaneously, hospital admissions may increase, particularly for geriatric patients, as evidenced following Post-Tropical Cyclone Sandy (Gotanda et al., 2015; Tarbochia-Gast et al., 2022).

3.2.3.4 Post-event and recovery phase pathways and health impacts

Post-event and recovery phase pathways and health impacts include greater potential exposure to (a) water- and vector-borne illness, (b) aeroallergens as well as (c) other harmful exposures (d) adverse birth outcomes, I stress, fatigue, and mental health burdens due to flood-related destruction of homes and interruptions to workplaces (Alleyne et al., 2021; Bloom et al., 2016). NYC health risks from aeroallergens and water- or vector-borne illnesses are considered later in this chapter. After tropical cyclones, increased hospitalizations from respiratory diseases, infectious and parasitic diseases, and injuries have been observed, along with higher death rates from these as well as neuropsychiatric conditions (Parks et al., 2021, 2022). In addition, the flood recovery phase introduces (f) access to care challenges, (g) building repair risks, and (h) long-term displacement risks. A recent systematic assessment identified the need for "research on disability, chronic disease, relocation populations, and social interventions (NYC Department of Environmental Protection, 2022; Trombley et al., 2017). Workers involved in clean up and recovery are also at greater risk (A. Brown, 2022).

Water-Borne Illness: Increasing temperatures can contribute to the types of more intense rainfall-flooding events described earlier, with associated potential for contact with enteric pathogens (Semenza, 2020) in floodwater or surface water contamination from combined sewer overflows. Nationally, tropical cyclones are associated with an increased risk of several waterborne infectious diseases, lasting days to weeks (Lynch & Shaman, 2023). A fuller consideration of climate change related exposure to pathogens, other contaminants in water and human illness is in section 3.6.

Vector-Borne Illness: While vector-borne illnesses can increase alongside increased mosquito breeding areas following flood events, for some mosquito vector species, flooding can also wash away preferred habitat and breeding sites, helping to reduce vector populations. The relation of flooding to these illnesses is complex, geographically varied, and depends on vector species (see Vector-Borne Pathogens section 3.4 of this chapter). As New York experiences more flood events and as temperatures continue to rise, mosquito breeding is expected to increase and in turn generate increases in West Nile virus (City of New York Department of Health and Mental Hygiene, 2022l).

Other Harmful Exposures: Cleanup of flooded properties can expose residents and workers to mold from water damage (see section 3.4.2) and to hazardous materials including asbestos or toxic chemicals (Smalling et al., 2016) as well as increase risks of electrocution (Yari et al., 2020). Tree removal workers without training in flood cleanup are at greater risk of injury (Ochsner et al., 2018). Construction may pose hazards including exposure to sharp or heavy objects as well as dust. Moreover, when power outages require residents to use alternative power supplies, carbon monoxide poisoning increases (Schnall et al., 2017).

Birth Outcomes: A systematic review of research on flood impacts on pregnancy outcomes found increases in the prevalence of low birth weight and gestational hypertension, but no significant differences in preterm birth rates (Partash et al., 2022). Power outages associated with Sandy in eight NY state counties increased the number of ED visits for several pregnancy complications, especially among young, Black, Hispanic, and uninsured individuals (Xiao et al., 2021). A focused study of pregnancy outcomes following Hurricane Harvey in Texas showed significantly higher likelihood for adverse outcomes (Mendez-Figueroa et al., 2019). Another analysis of birth records in Texas showed coastal storms during pregnancy were associated with an increased risk of labor complications. The authors hypothesize, however, that associations with low birth weight and gestation found in other studies may be an artifact of the method used to define pregnancy interval (Currie & Rossin-Slater, 2013).

Stress, Fatigue, and Mental Health: Chronic flooding and the challenges of being in continuous recovery mode increase stress. Causes range from the stress of displacement (such as from flooded basement apartments to emergency or temporary housing), from the loss of property/assets, to increased financial burdens for recovery costs or wage losses, which in turn exacerbate mental health challenges for some, and introduce new challenges for others. Stressful conditions have been linked to increased cognitive risks (Zuelsdorff & Limaye, 2023). Increasing frequency of flood events fatigues already overworked health service providers and EMS teams. The loss of sense of home as a safe haven is an emerging area of pediatric research (Mort et al., 2018). Following Hurricane Harvey impacting Houston, mental health symptoms consistent with post-traumatic stress disorder (PTSD) were associated with those experiencing impacts to their properties, including displacement and exposure to contaminated floodwater (Li et al., 2021). A more recent analysis of crisis help-seeking in Louisiana before and after Hurricane Ida showed an increase in crisis texts as documented by crisis counseling services including "thoughts of suicide, stress/anxiety, and bereavement, in the four-week, three-month, and four-month post impact period (Wertis et al., 2023)."

Short- and Long-term Damage and Displacement Risks: Short- and long-term loss of housing such as those immediately homeless following Post-Tropical Cyclone Sandy and the Ida Remnants Cloudburst amplifies the ongoing shortage of affordable housing in NYC. With many affordable units being at or below grade, flooding frequently destroys the unit with recovery requiring full remediation before occupants return home. Short-term displacement also impacts the ability to access transit to jobs, resulting in less earnings, or loss of jobs due to absences. More broadly, children who were evacuated are susceptible to a range of mental health symptoms related to their unique relationship to place and time and the disruption of friend networks (Mort et al., 2018). How inequities shape displacement risk is considered more fully in NPCC4, Foster et al. (2024).

Those displaced may face extended recovery timeframes, furthering the financial burden. Damage to neighborhood health care facilities, schools, and other services can further threaten physical and mental health among people remaining in their homes and/or faced with displacement and contemplating relocation. Relocation may impact access to jobs, schools, or childcare or may require greater portions of income for better quality housing, such units on higher floors. Continuity of health care services can be compromised when people needing ongoing care must relocate or neighborhood facilities close. Following Post-Tropical Cyclone Sandy, increases in emergency department, inpatient, and outpatient mental health visits, especially for Medicaid patients, were redistributed to facilities outside the catchment area of two hospitals which closed because of storm damage (Hall et al., 2016). Emergency planning that includes pets and companion animals during disasters is important to limit occurrences of trauma among people forced to abandon their pets, or who refuse to evacuate rather than leave their animals (Chadwin, 2017).

Following Ida, the city identified the need for evacuation measures and communications to those living in basement and ground level apartments (City of New York Office of the Deputy Mayor for Administration, 2021). However, the city has few resources to support evacuations during cloudburst events (such as consistent neighborhood-based shelters prepared to mobilize in advance) (New York City Housing Authority, 2022). Given estimates of over 100,000 basement apartments across NYC (City of New York Housing Preservation and Development, 2022b, 2022a), the scale of need extends well beyond available resources. In 2022, the NYC Comptroller released a new report, *Bringing Basement Apartments into the Light*, which called for establishing a Basement Board to provide basic rights, responsibilities, and protections for basement apartment residents and owners. Moreover, the NYC Department of Environmental Protection (DEP) is attempting to better understand cloudburst flooding and its impacts in different boroughs, but does not have detailed basement apartment locations (Hornbach et al., 2022).

3.2.4 Pre-existing factors that impact flood vulnerability (health, socio-demographic, and physical environment factors)

A range of pre-existing factors can increase people's vulnerability to flood risks. Factors include health (for example, chronic physical and mental illnesses), socio-demographics (age, poverty, and race, among others), and physical environment (such as the type of residential dwelling structure). These factors can increase vulnerability across all or multiple flood event phases; and people are often affected by more than one pre-existing flood vulnerability.

3.2.4.1 Pre-existing factors that impact vulnerability - mental and physical health

Preexisting mental health conditions, including depression, PTSD, and substance dependence, have been identified as potentially increasing susceptibility to harm from flooding. Similarly, multiple indicators of chronic physical illness, such as cardiovascular disease, cancer, end-stage renal disease, and being immunocompromised may make people more sensitive to the consequences of flooding, such as prolonged power outage, water contamination, living in congregate shelters and displacement (Lane et al., 2013; Lempert & Kopp, 2013).

3.2.4.2 Pre-existing factors that impact vulnerability – socio-demographic and physical environment

Household Location: Household location is a significant determinant of flood exposure. Households with proximity to the coastal areas, to riverine areas, or to low-lying areas of NYC, have more direct exposure to floodwaters. One of NYC's biggest challenges is its sizable building stock of structures built prior to 1983 when Flood Insurance Rate Maps (FIRMs) were first enacted (City of New York, 2022). Older buildings are frequently challenging to retrofit to accommodate today's changing, climate change-fueled environmental conditions. However, there are few resources available to help residents understand these inherent risks (see Rosenzweig et al., 2024 for flood vulnerabilities in NYC). As noted earlier and discussed in detail in the Rosenzweig et al., (2024), FEMA Flood Insurance Maps do not currently identify places at risk of pluvial or groundwater flooding. Also, as recent cloudburst events and recent flooding from high groundwater have shown, additional areas throughout the boroughs have flood exposures. The Ida Remnants Cloudburst showed that location in a designated flood hazard area is not the only indicator of actual flooding risk: below-grade areas not yet mapped as such proved to be at heightened risk of flooding. Moreover, with long-term sea level rise, some households are in places that will be subject to permanent inundation, such as in Edgemere, Broad Channel, and Old Howard Beach, Queens. RISE Rockaway and The Nature Conservancy are currently working with residents of Edgemere to develop more community awareness of long-term sea level rise and a shared community vision for Edgemere's future (City of New York Department of Housing Preservation and Development, 2017; Seip, 2022). Particular flooding risks and vulnerabilities occur among mobile homes, which tend to be located in flood plains (Smith, 2022). While only one mobile home park is currently in NYC on Staten Island, mobile homes could come under consideration as a future strategy to expand affordable housing stock, making their over-representation in National Flood Insurance Policy claims more locally relevant (Porpora, 2021).

Socio-Demographic: Demographics also correlate with certain evacuation behaviors: older adults may be less likely to evacuate, while higher-income, white, and female populations may be more likely to evacuate (R. R. Thompson et al., 2017). Many public housing participants in a survey about evacuation behavior did not leave their residences for reasons related to health, responsibility for the care of another family member or neighbor, and distrust of government services and support (Hernández et al., 2018). Post-Tropical Cyclone Sandy revealed more about those populations who are more sensitive to the consequences of flooding, particularly for recent immigrants lacking documentation and dependent on landlords to restore their homes even as they personally lost their possessions. Similarly a disproportionate number of deaths from the Ida Remnants Cloudburst flooding occurred among recent immigrants (Lai & Fisher, 2021). People who are incarcerated, institutionalized or otherwise under government responsibility and living in congregate settings may face unique risks connected to restricted autonomy and movement, and associated vulnerability, especially if living in flood zones (A. Brown, 2022). A fuller assessment of how socio-demographic factors influence vulnerability to flooding is in NPCC4, Foster et al. (2024).

Allostatic Load: [Please refer to this assessment's companion glossary for a descriptive definition of "allostatic load" and other terms.] Multiple social vulnerabilities and chronic hardship among residents of public housing impacted by Sandy were characterized in a qualitative study as depleting the collective "resilience reserve", limiting the capacity of people to take protective measures before and after the storm impact (Guidi et al., 2021; Hernández et al., 2018). Following Post-Tropical Cyclone Sandy, the intersection of race, ethnicity, age, and economic disadvantage contributed to greater flooding exposure and post-storm persistent distress in marginalized communities (Faber, 2015).

Mobility-related Conditions: Following Post-Tropical Cyclone Sandy, people with mobility access needs, such as elderly or disabled people, were vulnerable to immediate flooding impacts, such as escaping flood waters, or longer term, such as isolation in high elevation apartments due to lasting flood-related elevator outages (Weichselbaum, 2012).

Physical Environment: Injury risks and health effects are mediated through infrastructure and building impacts, especially at home. Building typologies and household location amplify loss of life, physical harms, and chronic mental stress. Beyond the immediate health impacts stemming from compromised shelter, other conditions, such as energy insecurity, sustain exposures longer than the lifespan of the event. While energy insecurity is addressed in NPCC4, Yoon et al. (2024), the public realm, water supply, and transportation also warrant attention.

Building Typologies: The risk New Yorkers face during a flooding event, whether from storm surge like Post-Tropical Cyclone Sandy, or flash flooding, like the Ida Remnants Cloudburst, differs depending upon several factors, including the location and type of residence. Whether a resident lives in a high- or low-rise building, the risks of sheltering in place depend on the type of construction and its resilience. Multiple studies on building impact show that 1-2 story bungalows are much more likely to take the bulk of structural damage during storm and flooding events, while high-rise buildings are more structurally stable, but may lose lifeline utilities which can reduce access to life-saving medications, potable water, the ability to get and maintain food at safe temperatures, and increase exposure to heat/cold-related illness and stress (Casey-Lockyer et al., 2013; City of New York Office of the Mayor, 2013). For example, among NYC injury deaths from Post-Tropical Cyclone Sandy, drowning accounted for 70% of all deaths. In addition, 60% of NYC deaths occurred at home, and disproportionately in Staten Island where mostly low-rise, single family home neighborhoods were impacted by the storm surge (City of New York Office of the Mayor, 2013; Seil et al., 2016). Post-Sandy analysis of impacts to building stock recognized that buildings in shoreline areas receiving the brunt of the storm surge had more damage than those that did not have direct storm surge. However, building height, construction type, and age were also predictors of damage, with older and single-story light frame buildings suffering more severe damage (18% of all buildings damaged, yet 73% of structurally damaged or destroyed). High rise buildings in these same areas experienced less structural damage but lost function due to systems (mechanical and electrical) failure (City of New York Office of the Mayor, 2013, Chapter 1). Residents of both types of buildings are at risk and may be asked to evacuate or shelter-in-place, move to higher or lower ground, or a variety of other directives. A recent FEMA report series relates building characteristics, such as un-reinforced weak walls in older NYC buildings, to increased mortality risks from the Ida Remnants Cloudburst, and considers risks to life safety when cellars or basements are occupied (Federal Emergency Management Agency, 2023c).

Moreover, risk can change depending upon the type of material used in a dwelling's walls, roof, and structure. Citywide, a substantial proportion of low-rise (1-2 floors) buildings with wood frame construction were completely destroyed or rendered structurally unsound and uninhabitable by severe storm surge damage, while very few multi-story (7 or more floors) "non-combustible" steel and masonry structures sustained such damage (City of New York Office of the Mayor, 2013). On the other hand, many residents who sheltered in place or returned to mid- and high-rise residential buildings, including many public housing residents (Hernández et al., 2018), experienced other health impacts as building systems were disabled (City of New York Office of the Mayor, 2013; Lane et al., 2013). If mechanical, electrical, or plumbing (MEP) systems are damaged by flood water, elevators, power supply, heat, or water supply/toilets may be compromised. In turn exit routes may be unavailable, particularly for those who require assistance navigating stairs. Moreover, power outages may compromise residents with electrical medical devices or disable air conditioning during a combined flood/heat event, which can lead to heat stroke or other illness. The elderly and medically compromised are particularly vulnerable (Manuel, 2013). Health risks from utility outages are discussed in Yoon et al., (2024).

During cloudburst events and coastal storms, health risks are higher for those living in basement apartments and those with mobility limitations or other disabilities. A substantial number of basement apartments are often without adequate emergency exits or windows, leaving residents unable to exit during flood events (City of New York, 2022; City of New York Housing Preservation and Development, 2022a). This phenomenon is not unique to New York City; flooding in Seoul, South Korea due to record rainfall in the summer of 2022 also resulted in drowning fatalities in semi-underground apartments (Mackenzie, 2022).

Power Supply: Given that the loss of lifeline utilities is one of the largest contributing factors to ill health effects after a major storm, NYC has made efforts to improve the power resiliency of buildings. These measures include cogeneration to provide emergency power and retrofitting initiatives to increase energy-efficiency to slow down heat/cooling loss (City of New York Office of the Mayor, 2013). Similarly, NYCHA and other property owners are elevating electrical and boiler equipment above areas vulnerable to flooding (e.g. basements) (Barnes & Temko, 2022). Power supply may also impact function of elevators, which are critical to accessing high-rise apartments.

Public Realm: In parks, beaches, and surface waters around New York City contaminants from urban runoff caused by flooding can expose people using these for respite, play, and recreation (Lapointe et al., 2022), though better tools and data are needed to characterize the contaminants and human exposure.

Water Supply: There are multiple potential pathways for flooding and SLR to impact NYC drinking water supply, distribution, and quality. Sea level rise could cause salt front movement in the lower Delaware River, adding pressure to release more water from reservoirs and impairing supply (Zimmerman et al., 2019). Downpours in the watershed could increase turbidity and potentially runoff of other pollutants. Flood damage could potentially impair the integrity and function of parts of the distribution system (Zimmerman et al., 2019). Increased turbidity is often used as an indicator of increased microbial contamination, which can increase the risk of gastrointestinal illness (Graydon et al., 2022; J. Schwartz, 2000).

Transportation: NYC transportation systems, including roadways which serve as conveyances and buses and subway cars that move people, continue to be overwhelmed during cloudburst events (Short et al., 2021). Sidewalks, underpasses, subway access stairs, and tunnels continue to flood (Negret & McNulty, 2021), compromising transit and introducing toxins to riders trying to leave subways or navigate city streets. These transportation challenges further compromise New Yorkers' ability to safely move about the city and may disrupt health care services.

3.3 Air Pollution

3.3.1 Synopsis of NPCC2 assessment

The NPCC2 (Kinney et al., 2015) projected increases across the New York metropolitan region in morbidity and mortality attributable to climate change through effects on air pollution, especially increases in ground-level ozone but also from increased emissions from electric power generation for cooling during hot weather. The magnitude of projected ozone changes depended on future emissions scenarios, and the greatest increases were projected in more suburban counties outside the city (Knowlton et al., 2004). Health impacts of air pollution will continue to depend on demographic and neighborhood variation in vulnerability to air pollution, long evident within NYC, especially disparities in asthma prevalence. Also highlighted was the potential for combined health effects of heat waves and associated high ozone levels. Building-level resilience and vulnerability factors include the potential for air conditioning to reduce indoor ozone and pollen exposure and for tighter building envelopes for energy efficiency to increase exposure to some indoor allergens. Finally, black carbon in PM2.5 deposited on surfaces has the potential to accelerate both atmospheric warming by absorbing solar visible and infrared radiation in the atmosphere and snow and ice melt by darkening the surface (Kang et al., 2020; Valenzuela et al., 2017).

3.3.2 Projected climate change and influence on future air pollution exposure

Air quality is affected by local and regional emissions and by weather. For ozone, higher warm season temperatures and more long, sunny days increase its formation in the atmosphere from chemical reactions involving precursor emissions including nitrogen oxides (NOx) and volatile organic compounds (VOCs). Braneon et al., (2024) project that rising temperatures observed from 1991-2020 will continue for the next several decades. Increases in average precipitation levels are projected, but in larger amounts and with greater confidence during the winter season. Smaller increases or possibly decreases during the summer and fall may occur. Thus, weather conditions favoring ozone formation during the summer will occur more frequently in the region, with the net effect depending on trends in regional ozone precursor emissions. However, the climate change penalty to ozone air quality is an area of active research, and knowledge gaps and uncertainties remain due to complex dynamics of ozone chemistry and feedback mechanisms not accounted for in models (Fu & Tian, 2019). For example, NOx is both an important precursor and when present in high concentrations can "quench" of ozone (react chemically with it) and reduce its concentration, especially at night and during the winter. Falling NOx emissions have contributed to higher ozone concentrations during the winter and in the warm season at night (Jhun et al., 2015). Nonetheless, heat waves in NYC, which are projected by NPCC4 to increase in frequency and intensity, cause metro area increase ozone levels to exceed health advisory levels, driven in part by short term increases in local emissions of ozone precursor pollutants (K. Zhao et al., 2019).

Local and regional $PM_{2.5}$ concentrations are also influenced by weather, albeit less directly than ozone. Higher electric power demand for summer cooling can increase emissions from fossil fuel power plants – including more polluting peaker plants located within the city– -- of both primary $PM_{2.5}$ and precursors that form secondary $PM_{2.5}$. A national modeling study predicted increases in average population-weighted $PM_{2.5}$ and ozone exposures in the coming decades, but the projections varied between two climate models used and were substantially reduced when reduced emissions anticipated by 2040 were assumed rather than stable 2011 emissions (Fann et al., 2021).

Higher temperatures and drought can cause wildfires that emit large quantities of smoke $PM_{2.5}$ and other pollutants. Modeling and monitoring show a modest fraction of $PM_{2.5}$ in the region from 2005-2018 was caused by wildfire smoke, enough to cause roughly 0.3% of asthma ED visits in the Northeast. From 2005-2020, marked increases in smoke $PM_{2.5}$ levels from 2005-2020 in the Western US caused little if any increase in smoke $PM_{2.5}$ pollution in the Eastern US and New York State (Childs et al., 2022). As noted below, $PM_{2.5}$ levels in NYC continued to decline during this period, thanks to reductions in local and regional emissions (City of New York Department of Health and Mental Hygiene, 2022i).

The potential for local air quality progress to be reversed by wildfire smoke was made clear in June 2023, when smoke from wildfires in Canada caused a dramatic increase in $PM_{2.5}$ pollution levels at real-time monitors in southern Ontario, New York, and other northeast states (United States Environmental Protection Agency, 2023c). Concentrations of $PM_{2.5}$ in the NYC metro area exceeded any measured at regulatory monitors since regular measurements began in 1999 (United States Environmental Protection Agency, 2014b). State and city officials issued air quality health advisories (New York State Department of Environmental Conservation, 2023b; Notify NYC, 2023), advising that outdoor activity be limited, that masks be worn outdoors and will be distributed, and that people close windows and use air conditioning if possible. Several school districts in New York State canceled outdoor activities. The potential effectiveness and limitations of advisories and public health measures to reduce risks of acute air pollution episodes is discussed in Section 4.

3.3.2.1 Recent observed local and regional trends of key pollutants (NOx, ozone, $PM_{2.5}$)

Even as NYC temperatures have risen in recent decades (see Ortiz et al., 2024), regional emissions contributing to climate-sensitive pollutants have fallen. Across the NYC metro area, annual average $PM_{2.5}$ and nitrogen dioxide (NO_2) concentrations were more than 40% lower in 2015-2019 than in 2000-2004; the average of the fourth highest daily maximum ozone concentration (used by the EPA for regulatory purposes) fell by about 20% (United States Environmental Protection Agency, 2022b). Air quality has improved within the city as well (City of New York Department of Health and Mental Hygiene, 2022i). Because of both regulations and economic influences on fuel usage, a reduction in emissions of upwind, regional and local sources of $PM_{2.5}$ contributed to NYC $PM_{2.5}$ concentrations falling by close to 50 percent from 2002 to 2018 (Pitiranggon et al., 2021). The air quality improvement was attributable to reduced emissions from multiple sources, conversion to cleaner heating fuels in large NYC buildings, natural gas replacing coal in regional electric power generation, and reduced tailpipe emissions in trucks, buses, and passenger vehicles (Kheirbek, Haney, et al., 2014; Pitiranggon et al., 2021; Zhang et al., 2021). See also

BOX 2.

3.3.2.2 Updated health effects epidemiology

Research continues to expand the recognized health effects of air pollution beyond those long-established: exacerbation of cardiovascular disease and respiratory diseases, including asthma, and respiratory tract cancers. Because common air pollutants from fuel combustion are ubiquitous worldwide and statistical power is more limited in local studies, pooled evidence from multi-city studies and global research is increasingly used to estimate health burden and determine policy. The most recent review of global evidence on air pollution and health found sufficient evidence to quantify health impacts of $PM_{2.5}$ on birthweight, gestational age, lung cancer, COPD, lower respiratory infections, type 2 diabetes, ischemic heart disease, and stroke; and of ambient ozone pollution on COPD (Global Burden of Disease Collaborative Network, 2020). Health effects of wildfire smoke are usually studied via contributions to total ambient $PM_{2.5}$ concentrations and include exacerbation of asthma and other respiratory diseases. Other effects may include exacerbation of cardiovascular conditions, all-cause mortality, and mental health outcomes. Children, seniors, and other groups may be more vulnerable. Exposure assessment challenges and method differences are limitations in current evidence (Heaney et al., 2022; Reid et al., 2016).

Ozone has long been known to cause lung inflammation and decreased lung function, as well has exacerbating asthma and COPD, leading to hospital and emergency department visits; emerging evidence suggests ozone exposure may exacerbate diabetes and contribute to complications (United States Environmental Protection Agency, 2020). Traffic-related air pollution as indicated by exposure to NO_2 is linked not only to exacerbation of asthma, but to its onset and to impaired lung development. Growing evidence also links air pollution exposure to functional impairments and diseases affecting nearly all organ systems, neurologic and behavior disorders and cognitive function in young children and older adults (Perera & Nadeau, 2022; Shi et al., 2020). Lower birthweight and preterm delivery effects can produce lasting harm on child health and development (Global Burden of Disease Collaborative Network, 2020). A number of local studies have observed health effects in NYC, consistent with national and global evidence (e.g. Ito et al., 2011; Johnson et al., 2016; Margolis et al., 2016; Savitz et al., 2015). Health harm from air pollution occurs at levels well below US National Ambient Air Quality Standards (NAAQS) (Weichenthal et al., 2022). Thus, measures to reduce ambient pollution can have large health benefits, even where NAAQS are already met.

BOX 2. Gas stoves, indoor air pollution, and health

Gas stoves are used in more than 75% of NYC metro area dwellings (*American Housing Survey (AHS) - AHS Table Creator*, 2021). While climate change is not expected to directly affect gas stove emissions or health impacts and the contribution of gas cooking (including methane leaks) to NYC greenhouse gas emissions is likely small compared to emissions related to heating, (nationally, cooking accounts for less than 5% of residential natural gas use (U.S. Energy Information Administration, 2023)), replacing gas stoves with electric induction stoves could have important health benefits.

Modeling and measurement studies show that: 1) emissions form natural gas burners in unvented kitchens can rapidly increase concentrations of nitrogen dioxide (NO_2) and carbon monoxide (CO), potentially to levels that exceed health-based standards and guidelines for short-term exposure to NO_2; 2) replacing gas with electric stoves effectively reduces indoor NO_2 concentrations while exhaust hoods effectiveness varies.(Lebel et al., 2022; Logue et al., 2014; Mullen et al., 2016; Paulin et al., 2014).

A pilot study in NYCHA apartments demonstrated that increases in indoor NO_2 concentrations caused by use of gas stoves was prevented by replacement with electric induction stoves, which were preferred by households receiving them (WE ACT for Environmental Justice, 2023).

An extensive body of evidence, mostly focused on ambient air pollution, links higher NO2 concentrations to exacerbation of asthma, lung inflammation, and impaired lung growth (Raju et al., 2020; United States Environmental Protection Agency, 2020). Because outdoor NO_2 concentrations are an indicator of a mixture of other pollutants from fuel combustion, including diesel exhaust particles, NO_2 concentration-response relationships may not apply to other settings and emission sources, (Raju et al., 2020) such as household exposure to gas stove emissions. Nonetheless, studies focused on indoor exposure to gas cooking and NO_2 exposure have shown associations with respiratory symptoms, including asthma and wheezing (Hansel et al., 2008; W. Lin et al., 2013). Gas cooking could account for an estimated 18% of asthma cases in New York State (Gruenwald et al., 2023).

At present, direct evidence of the effectiveness of replacing gas stoves with electric ones on occupant health is limited. A randomized study of an air cleaner intervention showed a benefit of particle filtration but not NO_2 removal on symptoms of children with asthma (Gent et al., 2023).

Another health benefit of replacing gas stoves would be eliminating a source of interior gas leaks that can contribute to deadly explosions and fires.

3.3.3 Vulnerable populations

3.3.3.1 Health, social, and demographic factors

Children are more susceptible to air pollution because rapid development of their lungs and other organ systems, greater respiration rates relative to body size, and the potential for air pollution harm to have lifelong consequences (Perera & Nadeau, 2022). Older adults are at higher risk of death and serious illness caused by air pollution, in part because they are more likely to have chronic cardiovascular, respiratory, and metabolic conditions that air pollution exacerbates (United States Environmental Protection Agency, 2022a). Nationally and in NYC, Black, Latino, Indigenous, and low-income populations also have higher burdens of chronic diseases that are exacerbated by air pollution (City of New York Department of Health and Mental Hygiene, 2023i). Improved management of conditions exacerbated by air pollution can help reduce impacts (Hadley et al., 2022); disparities health care access and quality may contribute to vulnerability. Research suggests that chronic psychosocial stress, associated with social disadvantage, shares biologic pathways with air pollution, effects, increasing susceptibility to health effects (Bandoli et al., 2016; Clougherty et al., 2007; Thomson, 2019).

3.3.3.2 Geography and physical environment

Nationally, communities with higher proportions of Black, Latino, Asian and low-income residents have higher than average exposures to $PM_{2.5}$ (Jbaily et al., 2022), and are more likely to be located near busy highways, refineries, and other industrial facilities (American Lung Association, 2023; Y. M. Park & Kwan, 2020). In NYC, air pollution concentrations are associated with the density of emissions from buildings, including heating and commercial cooking, and from motor vehicles. Large buildings and their emissions are most abundant in parts of Manhattan, while traffic is more widely distributed, with the greatest contributions to emissions from diesel trucks and buses. As a result, in NYC, disparities in community ambient air pollution concentrations differ from the national pattern, with more affluent neighborhoods in Manhattan having concentrations of $PM_{2.5}$ and NO_2 that are among the highest in the city; when sensitivity to air pollution harm because of population health is accounted for, communities with more Black, Latino, and low-income populations are by far the most impacted (City of New York Department of Health and Mental Hygiene, 2022d). Traffic-related air pollution exposures, especially from heavy-duty diesel vehicles, is more concentrated in low-income NYC neighborhoods, where populations are most vulnerable and traffic pollution impacts are greatest (Kheirbek et al., 2016). Household exposures and health effects of some outdoor air pollutants, including ozone, $PM_{2.5}$, and pollen, are greater among occupants of dwellings lacking air conditioning or high efficiency particle filters (Bell et al., 2014; Jhun et al., 2014; D. Zhao et al., 2015; Zuraimi et al., 2011). Disproportionate exposure to industrial land use and hazardous pollutants among low-income people of color is addressed further in NPCC4, Foster et al. (2024).

Despite steady citywide improvements (City of New York Department of Health and Mental Hygiene, 2022i) (Figure 7a-d), higher $PM_{2.5}$ and NO_2 pollution levels within the city are observed in locations with more nearby boilers using heating oil or natural gas, traffic density, industrial structures, commercial cooking, and ship traffic (Ito et al., 2016). Reductions in emissions during the spring 2020 COVID-19 shutdown were associated with $PM_{2.5}$ and NO_2 levels in NYC decreasing by roughly 25%, with the greatest improvements in the central business district due to reduced commercial cooking and traffic (Perera et al., 2021; Pitiranggon et al., 2022).

Citywide, annual average levels of four key pollutants have gone down between the first year of monitoring, 2009, and the most recent year of data, 2021: Fine particles ($PM_{2.5}$) -40%, Nitrogen Dioxide (NO_2) -38%, Nitric Oxide (NO) -58%, Sulfur Dioxide (SO_2) -97%. Maps for all pollutants monitored are available in a full report on methods, trends, and sources of spatial variation in air quality (Figure 7).

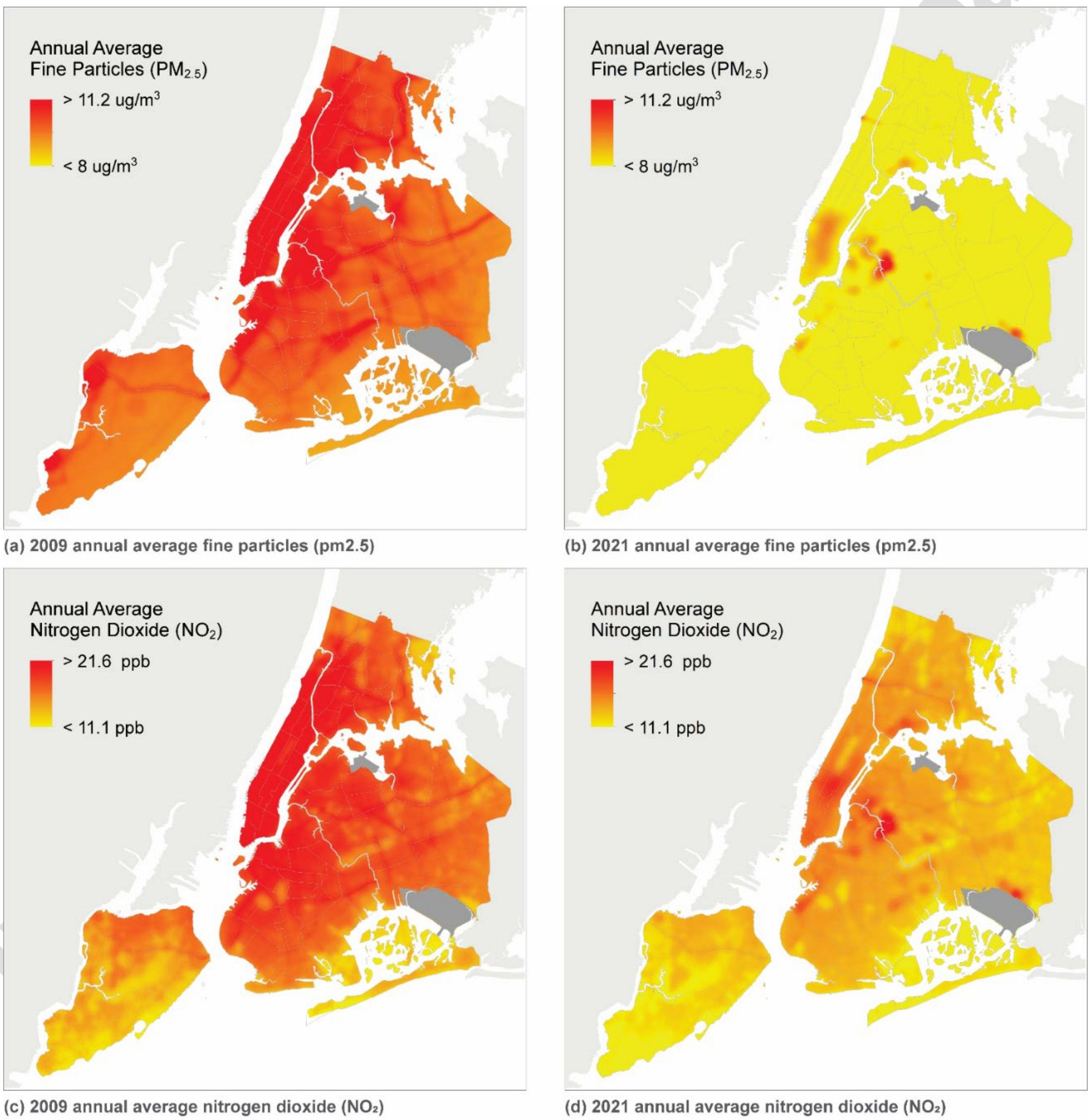

Figure 7: Pollutant distribution throughout New York City in 2009 and 2021. Particulate Matter 2.5 micrometers or smaller (PM2.5) in panels a and b; Nitrogen Dioxide (NO2) in panels c and d. Source: (City of New York Department of Health and Mental Hygiene, 2022i)

3.4 Aeroallergens

3.4.1 Pollen

The NPCC2 health assessment noted the potential for climate change, the urban heat island, and increased CO_2 concentrations to lengthen the seasons for and increase concentrations of allergenic pollen in NYC. Local epidemiologic studies demonstrated that pollen from several tree species common within the city are important contributors to allergic illness, including allergic rhinitis and increases in emergency department visits for asthma, during the spring season. Grass and ragweed pollen also contribute to seasonal allergies in the late summer and early fall (Kinney et al., 2015). Consistent with the NPCC2 assessment, across 60 pollen monitoring locations in North America, warmer weather caused by climate change has led to earlier, longer pollen spring seasons and higher average pollen concentrations during the period 1990 to 2018. However, pollen trends varied geographically; the northeast region showing little or no average trend in pollen concentration or spring onset date (Anderegg et al., 2021). A prior study of New York metro area tree pollen levels from 1990-2007 observed a shift to an earlier spring tree pollen season with a decline in average concentrations, attributed to regional construction and land use change (Kavosh et al., 2009).

NPCC2 also noted that studies of the role different tree species play in seasonal allergy could inform urban tree planting programs (Kinney et al., 2015). Since then, studies have added to local evidence pointing to the importance of local tree species in seasonal allergy. In NYC, pollen counts from trees peaking in the middle of spring pollen season (maple, birch, beech, ash, oak, and sycamore/London plane tree) are associated with over the counter allergy medication sales (an indication of seasonal allergy symptoms) and emergency department visits for asthma syndrome (Ito et al., 2015). In NYC and other locations, nearby tree canopy cover increases average springtime ambient tree pollen levels (Lara et al., 2020; Weinberger et al., 2016). In a birth cohort study of children born to women living in Northern Manhattan and the Bronx, tree canopy coverage near the prenatal address was associated with tree pollen allergic sensitization and asthma at age 7 (Lovasi et al., 2013). As with air pollution and health disparities, differences in the burden of asthma as well as in access to and quality of care could contribute to greater vulnerability to pollen-related asthma exacerbation in low-income communities and among Black and Latino populations.

3.4.2 Mold and fungi

The NPCC2 health assessment briefly summarized the influence of climate change on mold and health, noting that increased temperatures, coastal flooding, and heavy precipitation events can promote growth of mold and other fungi indoors, which in turn may cause respiratory symptoms and exacerbate asthma. Workers and residents could be exposed to unhealthy levels of mold during post-flood mold remediation without proper precautions (Kinney et al., 2015).

Studies and reviews of evidence since NPCC2 have largely been consistent in concluding that climate change and especially flooding events will promote indoor mold growth and increase risks to human health among residents of affected homes and workers involved in mold remediation. Health impacts include respiratory illnesses and exacerbation of asthma in sensitive individuals (Eguiluz-Gracia et al., 2020; Poole et al., 2019; Sampath et al., 2023). Outdoor concentrations of fungal spores involved in allergy and respiratory disease are also influenced by weather and climate change (Anees-Hill et al., 2022; Hanson et al., 2022).

Excess moisture in homes, whether from flooding, leaking roofs or walls, chronically damp basements, or inadequately vented bathrooms can contribute to mold growth in building materials that provide a suitable growth medium. Occupants of these homes, particularly children, are more likely to experience respiratory illness (Thacher et al., 2017). Mold growth on moist building materials in a basement can contaminate other living spaces of a typical single family home through passive air movement (Hegarty et al., 2019). In 2017 in NYC, occupants reported leaks in an estimated 13% of dwellings; those living in low-income communities in northern Manhattan, the Bronx, and central Brooklyn were more likely to report leaks compared with residents of other neighborhoods (City of New York Department of Health and Mental Hygiene, 2023g). These same communities have greater proportions of people with asthma who are more susceptible to mold and other aeroallergens in the home (City of New York Department of Health and Mental Hygiene, 2022c). Compounding these impacts, with COVID-19, those with lung damage from mold are at greater risk (e.g. populations in public housing, elderly populations, young children, people with asthma & other respiratory comorbidities, disabled populations and lower-income populations) (B. Hirsch, 2020).

3.5 Vector-borne pathogens

3.5.1 Synopsis of NPCC2 assessment

NPCC2 noted that some mosquito- and tick-borne illnesses such as West Nile virus (WNV) and Lyme disease are endemic in New York State. Climate change, including warming temperature and changes in precipitation patterns, can shift the seasonal cycle and/or spatial distribution of mosquito and tick vectors of these and other diseases affecting humans. Locally, climate change is expected to produce warmer weather in all seasons of the year as well as more flooding from extreme rain, rising sea levels, and coastal storms. Without adaptation, climate change will increase the risk of vector-borne illnesses among New Yorkers, including the potential introduction of diseases not currently transmitted in the metro area. However, climate change is only one of multiple factors influencing vector habitat and disease risk for humans, (Kinney et al., 2015).

3.5.2 Climate change projections and influence on risk

Life cycles, population, and activities of mosquitos and ticks are sensitive to interactions among climate variables including temperature and rainfall. One national study showed increased temperature, humidity, and heavy precipitation to predict human WNV infection rates in the US (Soverow et al., 2009), but more recent studies show the importance of drought preceding WNV epidemics (Paull et al., 2017; Shaman et al., 2005). Climate change is shifting and will continue to shift the geographic distribution of ticks that transmit Lyme and other human diseases (Alkishe et al., 2021).

While climate is undoubtedly important, complex, dynamic interactions among climate, animals, land use, human settlement and behavior patterns limit the utility of climate-disease modeling for predicting future vector-borne disease risks and informing prevention strategies (Bardosh et al., 2017). Historical trends show how complex, non-climate factors introduced malaria and yellow fever to the Americas, and the role these factors likely played in their elimination in the US. Malaria and yellow fever likely came to the Americas during the slave trade in the 17th century and caused recurrent outbreaks in NYC and as far north as New England (Eastman, 2021; Moreno-Madriñán & Turell, 2018). Because humans are the primary host for amplifying these mosquito borne diseases, improved living conditions that reduced indoor mosquito contact, such as screens, elimination of open cisterns, and air conditioning, likely played a major role in eliminating sustained local transmission of malaria and yellow fever in the US (Eastman, 2021; Moreno-Madriñán & Turell, 2018).

The Fourth National Climate Assessment concluded that climate change will alter the geographic range, seasonal distribution, and abundance of disease vectors, but also the influence on future risks of interactions with "changing ecosystems and land use, demographics, human behavior, and the status of public health infrastructure and management" (USGCRP, 2018). Future risk estimates depend on how these complex interactions are modeled. For example, an increase in WNV, the most common mosquito-borne illness in NYC, is anticipated under a changing climate (City of New York Department of Health and Mental Hygiene, 2022l; Keyel et al., 2021), but in one study, a mosquito biology model contradicted a climate model, predicting decreased WNV-risk in currently high-risk locations leading to an overall decline in population-weighted risk (Keyel et al., 2021). In addition, human acquired immunity after regional outbreaks may also limit WNV transmission (Paull et al., 2017).

Similarly, a warming climate is expanding the northern range of the blacklegged tick (Ixodes scapularis) – the vector for Lyme disease (Alkishe et al., 2021), and Lyme disease cases and exposure to the tick vector in New York State are associated with warmer days and mild winter temperatures (S. Lin et al., 2019), but non-climate factors have also played a role as described in Section 3.5.3.2.

3.5.3 National, regional, and local vector-borne disease (VBD) trends

3.5.3.1 West Nile virus and other mosquito-borne illnesses

The West Nile virus (WNV) in the US was first identified in NYC in 1999, and it has remained a threat to public health ever since. Nationally, more than 55,000 cases and 2600 deaths from WNV have been reported to CDC from 1999 through 2021, with the highest rates of neuroinvasive disease among older adults and residents of West North Central, East South Central, and Mountain regions.(Centers for Disease Control and Prevention, 2022b). Cases have fluctuated substantially from year to year during that period; national rates were fairly stable from 2013-2018 (McDonald et al., 2021).

Within NYC in 2015-2020, reported cases ranged between 6 and 38, with no clear trend (City of New York Department of Health and Mental Hygiene, 2019). 377 cases of neuroinvasive (severe) presentations of West Nile and 47 deaths have been recorded in NYC residents from 1999-2021 (Bajwa W, Slavinski S, Shah Z, Zhou L, 2022). WNV infection is asymptomatic in 70-80% of cases. People with symptomatic infection can experience fever, headache, weakness, muscle, and joint pain. Less than 1% of cases will develop WNV encephalitis and/or myelitis meningitis, which is inflammation of tissues surrounding the brain, brain stem, or spinal cord and can lead to serious morbidities and even death (Centers for Disease Control and Prevention, 2023c). Because most infections are asymptomatic and symptoms are variable, reported cases are much less than the true number of infections.

NYC collects and tests pools of mosquitos for the presence of WNV at 53 permanent locations across the 5 boroughs, with additional collection sites deployed based on surveillance data. In 2022, the number of WNV-positive mosquito pools, 1555, was the highest ever detected (Baisas, 2022; City of New York Department of Health and Mental Hygiene, 2023m). This could be due to increased extreme precipitation events, warmer air temperature, lack of behavioral vigilance, or some combination. Summer of 2022 in NYC was its 6th hottest in recorded history, and rainfall was four inches below average (Davitt, 2022). The combination of hotter temperatures and dry conditions could have contributed to an increase in WNV infected mosquito pools.

Aedes aegypti, the species of mosquito that most commonly transmits chikungunya, dengue and Zika, is not found in NYC, and cases of these diseases among New Yorkers are typically attributed to travel to other places with this vector (Bajwa et al., 2022). Aedes albopictus is present in NYC and is capable of transmitting Zika, dengue, chikungunya, and other viruses, but less efficient at doing so compared to *Aedes aegypti* (Centers for Disease Control and Prevention, 2023d).

3.5.3.2 Lyme disease and other tick-borne diseases (TBDs)

Nationally, between 30,000 and 40,000 Lyme disease cases are reported annually; the number of confirmed and probable cases fluctuated with no clear trend between 2008 and 2019 (Centers for Disease Control and Prevention, 2022c). According to the most recent NYC Health Department surveillance report, (City of New York Department of Health and Mental Hygiene, 2022a) Lyme and other TBD cases among NYC residents have been trending upward for more than 15 years (Figure 8). The abrupt increase in 2022 Lyme diseases cases is an artifact of a changed CDC case definition (City of New York Department of Health and Mental Hygiene, 2023n). Tick-borne diseases (TBD) among New Yorkers are mainly acquired through travel outside of NYC to surrounding areas where the diseases are endemic. Locally acquired Lyme disease cases are most common in Staten Island (City of New York Department of Health and Mental Hygiene, 2023n; Goldstein, 2023). Lyme disease remains the most reported TBD.

People acquire TBDs when bit by a tick carrying the infectious agent, usually during outdoor activity among residents or visitors to regions with a temperate climate and local habitat that supports the lifecycles of the tick vector. For Lyme disease, the blacklegged tick (*Ixodes scapularis)* is the vector, and the causal agent is the spirochete *Borrelia burgdorferi*. Lyme disease cases can occur at any time of the year, but are highest in the spring and summer, both due to the activity of the nymphs and an increase in outdoor activities (Bush & Vazquez-Pertejo, 2018).

New and emerging tick vectors and TBDs are being detected in New York State and in the city. In addition to the blacklegged or deer tick vector for Lyme disease, anaplasmosis, babesiosis, and Powassan virus, the American dog tick, which can transmit Rocky Mountain spotted fever, the lone star tick, a vector of ehrlichiosis, the Asian long horned tick, and Gulf Coast tick have been detected in NYC (City of New York Department of Health and Mental Hygiene, 2022a).

The Asian long-horned tick and lone star ticks are also established in Staten Island and parts of the Bronx. The Asian long-horned tick was first reported in the US in 2017 but has not yet been shown to transmit disease, though internationally they have been shown to spread several animal and human diseases (Pritt, 2020). The American dog tick is found in all five boroughs of NYC (City of New York Department of Health and Mental Hygiene, 2017). The Gulf Coast tick is also in Staten Island. These established ticks, along with the blacklegged tick, have tested positive for multiple pathogens (City of New York Department of Health and Mental Hygiene, 2023n).

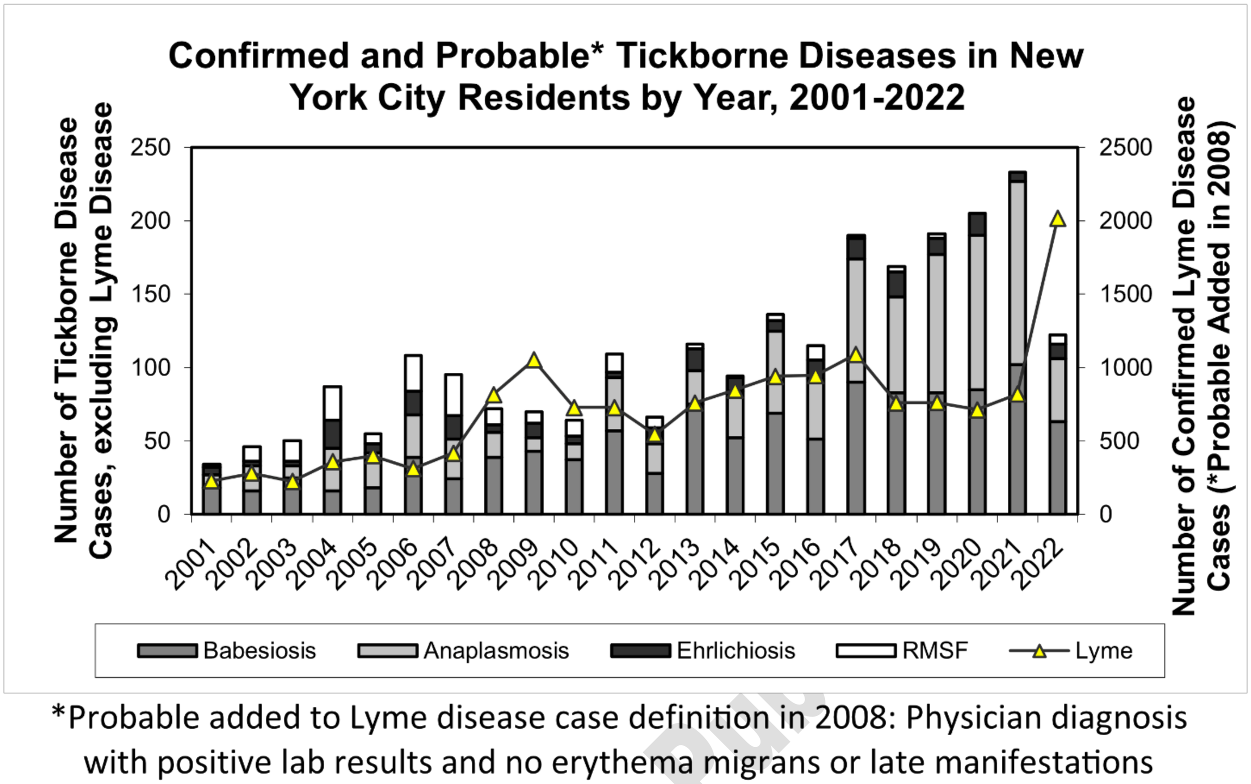

Figure 8: Case counts are by year of diagnosis. The 2022 increase in Lyme Disease cases is attributed to changes in the Centers for Disease Control and Prevention (CDC) case definition. Source: (City of New York Department of Health and Mental Hygiene, 2023n)

3.5.4 Factors influencing population vulnerability

The differences in population vulnerability to a mosquito- or tick-borne illness is influenced by a combination of individual health and behavioral factors, socioeconomic factors and living conditions, and nearby landcover, habitat, and ecosystem factors that influence disease vectors abundance, behavior, and encounters with people.

3.5.4.1 Mosquito-borne illness

Those considered the most susceptible to severe West Nile virus (WNV) infections include the elderly, homeless, and those with underlying conditions or compromised immunity (Ronca et al., 2021). Outdoor workers are at increased risk of exposure to WNV-infected mosquitos (Centers for Disease Control and Prevention, 2022a). Those living in homes with poorly fitting doors and windows or without door and window screens are also at increased risk (Bajwa W, Slavinski S, Shah Z, Zhou L, 2022).

Landcover, including both natural, agricultural, and urban features, can create mosquito breeding habitat. These interact with climate and nearby populations, living conditions, and behaviors to influencing potential exposure to mosquitos carrying WNV and other diseases (DeGroote & Sugumaran, 2012; Keyel et al., 2019). Examples of places where standing water can support mosquito breeding include puddles, pools, catch basins, bird baths, rain gutters, portable swimming pools, and puddles (Bajwa W, Slavinski S, Shah Z, Zhou L, 2022). The NYC Health Department recorded 1,661 complaints of standing water in NYC in 2021 for mosquitoes (Bajwa W, Slavinski S, Shah Z, Zhou L, 2022).

In addition to climate change influencing trends in locally endemic mosquito-borne illness, another concern is the risk of reintroduction and sustained local transmission of once endemic diseases. A recent report documents locally transmitted cases of malaria in 2023 in Florida (7 cases), Texas (1 case), and Maryland (1 case), the first in the US since 2003. While the risk of sustained local transmission of malaria in the US remains extremely low, these cases demonstrate the importance of public health surveillance and prompt treatment of human cases (Centers for Disease Control and Prevention, 2023e).

Human hosts are also important for local transmission of the mosquito borne illnesses dengue, chikungunya, and Zika viruses. Each year, multiple travelers return to NYC with active dengue or malaria infections acquired in places where those diseases are endemic, but *Aedes aegypti*, the insect vector for these diseases, is not currently found in NYC and local transmission has not been sustained. This could change if *Aedes aegypti* or another competent insect vector became established locally (Bajwa W, Slavinski S, Shah Z, Zhou L, 2022; Moreno-Madriñán & Turell, 2018).

Socioeconomic and living conditions are another factor that could influence the risk of these diseases becoming locally endemic. For example, a study comparing the incidence of dengue fever in adjacent towns of Nuevo Laredo, Mexico and Laredo, Texas found a higher risk in Nuevo Laredo despite the greater abundance of dengue-carrying mosquitos in Laredo. Differences were attributed to living conditions, including Laredo's having more residential screens, air conditioning, spacing between homes, and more indoor space per occupant (Reiter et al., 2003).

Land cover change and mosquito control efforts likely also played a role in controlling mosquito borne diseases in the US. These factors will remain important in shaping the future risk for diseases like WNV, which require animal, rather than human hosts to sustain local populations and transmission. The development and urbanization of the mid-Atlantic and northeast states in the 20th century resulted in salt marsh wetlands being modified or lost to alternative uses or for mosquito control efforts. Over time, integrated marsh management (IMM) methods have been developed to support or enhance habitat (Wolfe et al., 2022) and aid in the control mosquito vectors of human disease in combination with integrated pest management (IPM) methods, such as those employed by NYC's mosquito control program (Bajwa W, Slavinski S, Shah Z, Zhou L, 2022).

3.5.4.2 Tick-borne illness

Nationally, reported Lyme disease is more common among men than women; the age distribution of cases is fairly uniform, but the proportion with neurologic, arthritic, or cardiac manifestations is highest among children and middle-aged adults (A. M. Schwartz, 2017). In a survey of people reported with Lyme disease in Pennsylvania, lack of health insurance was a risk factor for delayed treatment, which in turn is a risk for more serious and post-treatment symptoms (A. G. Hirsch et al., 2020). An electronic health record study in Pennsylvania found access to primary or urgent care was protective and that Medicaid-insured patients were at higher risk of more severe illness (Moon et al., 2021). Among occupations, agricultural and forestry workers are at increased risk (Magnavita et al., 2022).

Because Lyme disease is the most common tick-born illness in the US and NYC area, its vector, the blacklegged tick, has been extensively studied. Historically, its range may have spread in the northeastern US as forest habitat and deer populations expanded during the last century (Dennis et al., 1998). Today, blacklegged ticks are established in Staten Island, in Pelham Park in the Bronx but not in Manhattan, Queens, and Brooklyn (City of New York Department of Health and Mental Hygiene, 2022h). A study of NYC parks showed that the density of nymph blacklegged ticks and carrying the spirochete causing Lyme was greatest in parks with high connectivity and vegetated buffers, favorable habitat for the white-tailed deer, which is a host species for adult ticks (VanAcker et al., 2019). Since 2006, the NYC Health Department has conducted tick surveillance annually in a subset of NYC parks, however, the department notes that information on tick populations in the city is limited (City of New York Department of Health and Mental Hygiene, 2023j).

3.6 Water-borne Pathogens and Other Contaminants

Globally, increasing temperatures and flooding related to climate change can increase water borne disease risk such as from enteric pathogens and legionella (BOX 3) (Semenza, 2020). Local waterborne disease risks and their relationship to climate change are highly dependent on infrastructure, including that involved in drinking water supply and treatment, wastewater and stormwater management and treatment, and building systems including potable water supply, cooling towers, and fountains. For NYC's drinking water supply to be impacted, damage to the upstate source watershed and/or water mains typically would have to occur. However, power outages will cause loss of potable water supply in tall buildings when rooftop tanks are exhausted (NYC Department of Environmental Protection, 2022).

Yet, there are multiple potential pathways for flooding and SLR to impact NYC drinking water supply, distribution, and quality. Sea level rise could cause salt front movement in the lower Delaware River, adding pressure to release more water from reservoirs and impairing supply (Zimmerman et al., 2019). Downpours in the watershed could increase turbidity and potentially runoff of other pollutants. Increased turbidity has been associated with an increased risk of gastrointestinal illness (GI), though by itself does not cause GI illness (Graydon et al., 2022; J. Schwartz, 2000).

Pathogen growth and availability increase with warmer temperatures, so flooding in warmer months, such as that with Hurricane Ida, introduces additional risks (Escobar et al., 2015; Trtanj et al., 2016). Vibrio bacteria naturally live in coastal salt and brackish waters and include species that cause human infections, most often gastrointestinal illness caused by ingestion of raw or undercooked shellfish. Less often, vibrio contact with open skin wounds can cause infection. About 110-140 vibrio infections are reported to the NYC Health Department annually. Recently, the US

CDC issued a national health alert concerning potentially life-threatening infections caused by *Vibrio vulnificus* that have been associated with warming coastal waters. In 2023, so far, one *Vibrio vulnificus* case was reported in an NYC resident (compared to about one to three annually), who reported eating shellfish but not exposure to coastal waters (City of New York Department of Health and Mental Hygiene, 2023a).

In general, water-borne illnesses reported after major storms demonstrate increases in cases of gastrointestinal illness due to resident exposures to sewage contaminated floodwaters (Liang & Messenger, 2018). Following extensive flooding caused by Post-Tropical Cyclone Sandy, the overall risk of food and waterborne illness in the NYC area receiving inpatient or outpatient treatment did not increase, but there was a small increase in outpatient food and waterborne illness among those age 65 and older (Greene et al., 2013).

BOX 3. Legionella

Legionella bacteria are present in the environment and can grow in potable water systems and in cooling towers commonly used for air conditioning and commercial refrigeration in large NYC buildings. If released in aerosol form, community outbreaks of legionella pneumonia can occur (Paschke et al., 2019). Warm temperatures and humidity are associated with increased rates of Legionnaire's disease (Simmering et al., 2017), likely related both to favorable conditions for growth of the agent and use of cooling towers. In 2015 an outbreak of Legionnaire's Disease in the Bronx resulted in 138 confirmed cases and 16 deaths. The source was traced to a single cooling tower (Weiss et al., 2017). A local law and health regulations enacted that same year, created requirements for permitting, maintenance, and inspection (City of New York Department of Health and Mental Hygiene, 2023d).Coordinated surveillance connecting human, animal, and environmental health can help with early detection of water-borne disease outbreaks (Semenza, 2020).

Degradation in surface water quality around the city is a risk after any major rain or flooding event, potentially exposing recreational water users. This is because combined mains handle stormwater runoff and sewage in many parts of the city can overwhelm treatment facilities during significant rain events and cause discharge of untreated sewage. The NYC Department of Health and Mental Hygiene (2023h) maintains beach monitoring and surveillance and issues advisories and closures during the summer season.

Harmful algal blooms (HABs) are caused when algae and cyanobacteria grow rapidly in bodies of water. Illness in people and pets is most often from exposures to toxins produced by these organisms via skin contact, inhalation, ingestion of contaminated water, or consumption of contaminated seafood. HABs are more common in warm months and in fresh water. A wide range of symptoms and illnesses can result, including skin and respiratory tract irritation from contact with contaminated water or inhalation of droplets, gastrointestinal and neurologic illness from ingestion of contaminated food or water. Dogs, livestock, and wildlife are also harmed by HABS (Centers for Disease Control and Prevention, 2023b).

A global increase in HABs is being driven by climatic and non-climatic factors. National data also show an increase in the number, types, and geographic range of HABs (Gobler, 2020). The increase in HABs driven by several factors, including climate change and rising water temperatures, improved detection and reporting, nutrient pollution, introduction of species to new areas (D. M. Anderson et al., 2021). In New York State, HAB reports increased in frequency from 2012-2020 (Gorney et al., 2023), and HABs regularly impact some NYC freshwater ponds and lakes (City of New York Department of Parks & Recreation, 2023b). More recent, detailed state level data are available, and show 53 HABs reported for water bodies within the five boroughs from 2019 through 2022 (New York State Department of Environmental Conservation, 2023a).

3.7 Other Compound Impacts

Hot summer weather combined with the risk of COVID-19 transmission for the first time in summer 2020. Indoor gatherings such as at public cooling centers, which can provide a respite for those unable to stay cool at home, were limited. A pilot survey of members of an environmental justice organization during the summer of 2020 suggested people were more likely to stay indoors, avoid crowded green spaces, and rely on home AC units (WE ACT for Environmental Justice, 2021). A racial disparity in access to AC was also shown, consistent with prior surveys. Another evaluation study of the short-term impacts of an NYC program that distributed and installed 73,000 air conditioners in summer 2020 indicated that program participants were more likely to report that they stayed home during hot weather compared to non-participants, with similar levels of staying home among the two groups in 2019. Program participants were also less likely to report that hot weather made them, or household members feel sick at home during summer 2020. Concern about cost of cooling, a hallmark of energy insecurity, was common among both groups and was a barrier to accessing air-conditioning (Lane et al., 2023). Limited access to outdoor green space was noted in another survey (Bock et al., 2021, 2021); power outages during hot weather would amplify these risks (Watkins & Southall, 2019). The co-occurring emergencies of extreme heat and COVID-19 highlighted the need to continue, expand, and evaluate efforts to address disparities in cooling access, energy affordability, and green space in high heat-vulnerable neighborhoods (City of New York Department of Parks & Recreation, 2023a). Similarly, urban flooding preparations, as well as efforts to address basement apartments, were interrupted due to COVID-19 demands for budget reallocations (City of New York, 2016).

Other compound impacts have been considered in earlier sections, including the co-occurrence of hot weather and higher ozone levels, amplification of heat and flooding impacts by power outages, and the potential for hot weather and flooding to cause exposure to pathogens and other contaminants in water. Hurricanes and other storms that cause power outages and occur during hot or cold weather can be dangerous. The 2017 example of Hurricane Irma in Florida is discussed in Yoon et al., (2024). Most recently, when extreme heat combined with wildfire smoke, as prominent in June 2023, potential concurrent exposures introduced greater health risks (Rosenthal et al., 2022) increasing the importance of residential air conditioning for protecting vulnerable people.

4 Reducing Future Impacts

Many cities are implementing measures to provide immediate public health protections from the health impacts of climate change. Several of NYC's measures and plans as well as those of some other cities are discussed below. Structural measures that rely less on behavior change and individual efficacy are generally more effective at the population level. Hence, measures that advance health, equity, and safety by adapting the built and natural environment, while enhancing natural features and ecosystems and supporting greenhouse gas reduction targets where feasible, are the most important.

4.1 Public Health Messaging and Risk Awareness

General principles: Climate risks to health vary greatly among communities and populations, making clear, actionable communication, especially to vulnerable groups, essential for effective emergency preparedness and response. Vulnerable populations are most reliant upon government services when an evacuation order is issued, making the timely deployment of those services and their context-dependent response extremely important to reduce negative health impacts. Evacuation behavior and response may differ throughout the population of NYC for a wide variety of reasons, so a coordinated effort from the city to address this reality will improve outcomes, particularly for those in public housing, those who have health conditions and disabilities, and the elderly. Public health strategies reliant on individual agency and behavior change are inherently less effective than structural interventions that address socioeconomic determinants or the environmental context for health (Frieden, 2010). Thus, to reduce future climate change impacts on health, policies and investments that reduce housing and energy insecurity and ensure the resilience of dwellings and infrastructure are essential complementary approaches to effective public health communication. A population that is informed about climate risks and options for avoidance of risks will be better able to engage in collective advocacy for structural measures and act in the near term to reduce exposures and risks. Specific strategies and approaches are described below.

Heat-health warning systems: NYC activates its heat emergency plan when the National Weather Service (NWS) forecasts extreme heat. The NWS definition of extreme heat – two or more days when the maximum heat index is predicted to reach 95°F or any period when it reaches 100°F – is based on analyses of NYC heat and mortality data (Metzger et al., 2010a). One study estimated that reducing the heat emergency threshold from 105°F to these lower levels in 2008 reduced heat-related illnesses among Medicare beneficiaries in NYC in the two years after 2008 compared to the two years before (Benmarhnia et al., 2019). During emergencies, NYC officials disseminate public messaging about the health dangers of heat to the public, health care and social service providers, and faith- and community-based organizations. People are urged to use air conditioning if they have it or visit an air-conditioned space, such as a Cooling Center. Messaging around setting AC to low-cool or 78°F is also typically included to help with costs of cooling and reducing energy use to protect the power grid. Members of the public are also asked to check in on family, neighbors and friends who may be at risk during hot weather to help them stay cool (See NYC's *"Be a Buddy"* program (City of New York Mayor's Office of Climate & Environmental Justice, 2022)). More outreach workers are deployed to offer shelter to people experiencing homelessness, and shelters are open to anyone who needs them (City of New York Department of Homeless Services, 2023).

It is important to note that warning systems have several limitations. People without air conditioning who have limited mobility may have difficulty accessing public cooling resources, people may be reluctant to leave home during heat waves to visit a cooling center (see section on Cooling Centers below), and emergency warnings are released only on the hottest and most dangerous days to avoid alert fatigue. These limitations highlight the need to couple emergency warning and response systems with other strategies to maintain safety throughout the warm season, including hot but not extreme heat days.

Surveys have also shown that while heat warning awareness is generally high among New Yorkers, awareness is lower among those who may be more at risk, which may be in part due to perceived lack of risk of hot weather, which occurs every summer, and because messages may not effectively reach those most at risk. Trusted messengers for heat-health warnings and information included health professionals, local TV health and medical correspondents, and meteorologists (Lane et al., 2014).

Flood risk awareness: Additional measures to help New Yorkers to understand the health and property risks associated with flooding are needed. FEMA recently published a series of online resources that highlight ways that building owners and tenants can reduce flood risks in urban buildings (Federal Emergency Management Agency, 2023b). Emergency preparedness education, such as *Know Your Zone* and *ReadyNYC*, are ongoing local programs to increase awareness of neighborhood risks. Education on finding safe local shelters as well as sheltering in place are important to limit compound risks from transmissible illnesses. Existing programs could be enhanced by increasing awareness of precipitation-driven flooding. Recent NYS legislation to inform renters and homeowners of flood history (Assembly Bill 2023-A1967, 2023), or to improve community awareness of climate hazards, requires sustained engagement to become part of the New York experience. Assuring translation into multiple languages and offering multiple means of delivering these messages, with assistive technologies for sight, hearing, or mobility impairment is key. Otherwise, those with vision or hearing impairments and without assistive technology may not receive such warnings. NYC Emergency Management translates public materials, outreach materials, and Notify NYC messages and website into the 10 languages designated by Local Law 30 (Local Law 30, 2017) as well as two additional languages, Yiddish and Italian, which are two of the top 10 languages spoken in NYC hurricane evacuation zones. To assess and support Local Law 30 implementation, the Mayor's Office of Immigrant Affairs works with NYC Emergency Management and other agencies and issues regular public reports (NYC Mayor's Office of Immigrant Affairs & NYC Mayor's Office of Operations, 2022). While most of these resources are accessible online, 16% of households in NYC remain without broadband access. Finally, it is important to help New Yorkers to understand how personal choice impacts flooding in NYC. For example, DEP's ongoing WAIT program encourages New Yorkers to monitor and where possible to reduce their potable water use during flooding events, in turn reducing the amount of sewer water combining with stormwater outflows (City of New York Department of Environmental Protection, 2023b).

Air quality health advisories and related public health measures: High levels of $PM_{2.5}$ caused by wildfire smoke and high levels of ozone during hot weather generally cause poor air quality across the NYC metro area. Computer models of weather and pollutant emissions as well as monitor data are used to forecast harmful pollution episodes. The New York State Department of Environmental Conservation (NYSDEC) and the NYS Department of Health issue regional air quality health advisories when "DEC meteorologists predict levels of ozone or $PM_{2.5}$" that are greater than national ambient air quality criteria for short term exposure (New York State Department of Environmental Conservation, 2023b). These advisories use the EPA's Air Quality Index (AQI), a ratio of the forecast or measured pollutant level to a "short-term national ambient air quality standard for protection of public health" (United States Environmental Protection Agency, 2023b). Advisories recommend actions to reduce exposure, such as reducing outdoor exercise during times of high pollution. NYSDEC shares data with the national AirNow program, which makes data and advisories publicly available through smartphone apps and weather forecasts, via a partnership with the National Weather Service (United States Environmental Protection Agency, 2023a). Air quality health advisories are almost always for elevated ozone or $PM_{2.5}$ concentrations. Prior to 2023, $PM_{2.5}$ advisories in the NYC metro area were infrequent in recent years. The AQI (based on a 24-hour average $PM_{2.5}$) was 100 or greater fewer than 3 times per year from 2010 through 2022, and the maximum $PM_{2.5}$ AQI was 154. Smoke from wildfires in Canada caused the $PM_{2.5}$ AQI to exceed100 9 times to date in 2023, reaching a maximum of 254 (United States Environmental Protection Agency, 2023e) (concentrations were much higher over shorter averaging times)

Experts have noted the limitations of an AQI based on a single-pollutant's regulatory threshold, noting that air pollution harm is not limited to concentrations above regulatory standards and much more common days with moderate levels of multiple pollutants do not trigger warnings (Laumbach et al., 2021). Evidence shows some benefits of actions recommended by air quality advisories, but with important limitations. Staying indoors and avoiding physical activity during times or near locations with elevated air pollution and using room or central air filtration may reduce exposures and health risks, but more studies are needed to better quantify effectiveness, safety, and cost (Laumbach et al., 2021).

The use of particle filtering masks outdoors by the public has not been part of standard guidance issued with air quality health advisories but was widely recommended during the recent smoke episodes affecting NYC. Some evidence shows that if properly worn, masks can reduce exposure and provide health benefits in some settings and populations. But important evidence gaps and implementation concerns remain. Patients with pre-existing lung or heart conditions may have difficulty tolerating some masks, improper fit or use may greatly reduce effectiveness, and evidence of improved outcomes is limited to short term use in populations and settings not directly comparable to regional air pollution episodes. It is important to note that particle filter masks do not reduce exposure to ozone, other gaseous pollutants, or ultrafine particles (Carlsten et al., 2020; Laumbach et al., 2021). Indoor central heating, ventilation, air-conditioning (HVAC) and portable air filtration systems can effectively improve indoor air quality during wildfire smoke pollution events, but further study is needed of longevity and maintenance of equipment, pollution mixture effects, and actual health benefits (Davison et al., 2021).

Modeling studies suggest that for most people, the large health benefits of regular physical activity, especially for active transportation, outweigh risks of air pollution (Tainio et al., 2021). Experts note the need for more research to understand these tradeoffs and caution against a too low threshold and frequent advisories to limit outdoor activity, could have little benefit or might even be harmful (Carlsten et al., 2020; Laumbach et al., 2021).

Equity and practical concerns have also been raised about advice given during air pollution episodes. Knowledge and resource limitations make it harder for some populations to understand concepts like the AQI or comply with recommended actions (D'Antoni et al., 2019; Laumbach et al., 2021). During hot weather, households lacking air conditioning can't close windows to reduce ozone or use portable filtration devices without risking harmful heat exposure (Davison et al., 2021).

Preventing tick-borne illness: Strategies for preventing tick borne illness include promoting awareness of where and how encounters with disease-bearing ticks occur, proper use of insect repellents effective against ticks for people and pets (especially dogs), integrated pest management practices to minimize tick habitat, populations, and contact in yards and parks, body checks for ticks at least daily, and awareness of signs and symptoms of tick-borne illness and the importance of seeking care promptly for diagnosis and treatment (Centers for Disease Control and Prevention, 2021; City of New York Department of Health and Mental Hygiene, 2023l). These depend heavily on public education and behavior change and should emphasize risks from outdoor activity in locations where disease-bearing ticks are most likely to be encountered.

4.2 Emergency Response

Cooling and warming centers: Like many other cities, NYC officials encourage people who cannot stay cool at home during periods of extreme heat to visit cooling centers during periods of extreme heat. Cooling centers are senior centers, libraries, community centers, and other public places with air conditioning. Although these spaces are always typically open to the public, during heat events they are advertised as cooling centers and will often open for longer hours. During a heat wave, members of the public can visit an online cooling center finder or call 311 to find their closest center. A NYC Comptroller's report (Office of the New York City Comptroller & Urban Ocean Lab, 2022) recommends the development of Resilience Hubs which broaden cooling center functionality to include complementary community supports, and the city's 2023 sustainability plan includes an initiative to create Resilience Hubs (City of New York Office of the Mayor, 2023a). NYC Speaks (2023) summarizes ongoing Resilience Hub activities.

Population-based NYC surveys indicate that there is a strong preference for staying home during hot weather, even when someone cannot stay cool at home (Lane et al., 2014; Madrigano et al., 2018). About 10-15% of those without AC or those who have it but do not use it often report going to a public place similar to a cooling center (Lane et al., 2014; Madrigano et al., 2018). A 2021 audit of a subset of NYC cooling centers by WE ACT for Environmental Justice found that more signage, information, and consistent standards were needed and recommended, among other measures, more funding and increased community input in center operations (WE ACT for Environmental Justice, 2021). Transport and risk perception may also be barriers to use (Berisha et al., 2017; Lane et al., 2014). A 2022 NYC Comptroller's report noted a need for more centers in under-served, high heat vulnerability areas, more centers on weekends, and more options for younger adults, since many senior centers are for people aged 60 and older (City of New York Bureau of Policy and Research, 2022).

Assessments of cooling center utilization in Phoenix (Maricopa County) found that 22% of respondents used the centers primarily to avoid heat, but most were visiting to access other services offered at the centers. In addition to individuals experiencing homelessness or who did not have home AC, many used cooling centers because they cannot afford the cost of running their home AC (Berisha et al., 2017).

There have been few, if any, studies conducted to examine cooling center effectiveness in reducing heat-health impacts. A Centers for Disease Control and Prevention (CDC) review on the evidence base for use of cooling centers to prevent heat-health impacts did not identify any research linking cooling centers to health outcomes but noted that there is strong evidence that staying in a cool environment generally is beneficial to health. The review concluded that cooling centers can be useful as part of a larger heat-health response strategy, not as a stand-alone measure (Widerynski et al., 2017). Another recent commentary also noted cooling centers have limited potential benefit in the absence of more comprehensive measures and that even with optimistic assumptions about their effectiveness, extremely large numbers of people would need to use them to achieve a meaningful reduction in mortality risk (Bedi et al., 2022). Challenges with cooling centers and Covid-19 in summer 2020 are discussed in Section 3.7.

In NYC, warming centers are not typically opened because of strong heating laws in place during cold weather and right to shelter laws for people experiencing homelessness. However, warming centers and warming buses were used following power outages due to Post-Tropical Cyclone Sandy. FEMA and the National Guard also conducted door-to-door welfare checks on residents affected by the flooding and widespread power outages.

Evacuation shelters: Immediately prior to a hurricane, it is common to provide resources to allow residents to get out of harm's way if safe shelter at home is not possible. This includes community-based evacuation centers. New Yorkers demonstrate a preference for staying home versus evacuating, as demonstrated prior to Post-Tropical Cyclone Sandy (Schmeltz et al., 2013). In fact, mutual aid proved more effective in preparing and providing for communities (Schmeltz et al., 2013). But for residents of basement apartments in flood prone areas, sheltering at home during flood events is not a viable solution. Additional support for evacuation center sustained operations and neighborhood awareness campaigns could help to socialize options available to community members. COVID-19 created a compound risk and additional barrier to using congregate evacuation shelters[1] (Sawano et al., 2021).

For those with chronic health issues or disabilities, flood evacuation requires additional support. However, the NYC Emergency Management website notes that those in wheelchairs or with other disabilities affecting mobility should call NYC 311 for evacuation assistance if they have no other options for evacuating safely (City of New York Office of Emergency Management, 2022; New York City Housing Authority, 2022). With prior planning, those most dependent on others for their evacuation, and for ongoing support while away from home, can gain more control over how their health needs are met. NYCEM guidance in the My Emergency Plan workbook notes that those with disabilities can be taken to an accessible evacuation center, in a hospital outside of the evacuation zone (via ambulance) but will not have the option of giving the evacuation team a specific address.

Household disconnection prevention: Disconnection protections vary by jurisdiction and circumstance but can offer important protections during extreme weather. In NYC, residential electricity disconnections for non-payment are suspended for all residential customers just before, during, and for two days after hot days using criteria based on the heat index. In 2022, Los Angeles prohibited the Department of Water and Power from practicing water or power shutoffs as a debt collection tool for income-qualified residents and seniors (Hayley Smith, 2022). Health risks of utility disconnections and prevention measures are discussed in more detail in NPCC4, Yoon et al. (2024).

Information access: NYC has telephone services such as the 311 call line which in an emergency is regularly updated with information from NYC Emergency Management that can be then conveyed in more than 160 languages (NYC Mayor's Office of Immigrant Affairs & NYC Mayor's Office of Operations, 2022).

4.3 Community & Social Supports

Strengthening community social networks, cohesion, and community-based organization capacity: Social resilience programs that seek to increase community resources, networks, and connections, led by community groups or community members, may also be beneficial. Direct financial and technical assistance approaches with community participation and co-creation are being used. Some examples include:

- In 2017, the NYC Health Department and Mayor's Office of Resiliency launched *Be a Buddy* as an initiative of Cool Neighborhoods NYC, a citywide heat protection strategy (City of New York Mayor's Office of Resiliency, 2017). Through partnerships with Brooklyn Community Services (Brownsville), The Point Community Development Corporation (Hunts Point) and Union Settlement (East Harlem), *Be A Buddy* provided assistance and support to over 1,300 New Yorkers through over 60 volunteers. The partner organizations built and fostered hyperlocal networks to provide heat-health information to neighbors, help them identify community resources, and make and implement emergency plans (City of New York Department of Health and Mental Hygiene, 2022k; Schramm et al., 2020).

- The *Billion Oyster Project* now hosts a Citizens water quality testing site to encourage community awareness of water contamination risks as it aligns with their mission. The project directly addresses community and student engagement while also working to improve harbor water quality and reduce coastal storm damage. Most importantly, the project connects more than 15,000 volunteers, 100 NYC

[1] In September 2020, FEMA issued special guidance on COVID-19 planning considerations for evacuation and shelter-in-place (FEMA, 2020). This guidance provided a structured approach for hospitals and residential care facilities, for mass care and sheltering services, and for tourist populations to review existing protocols in relation to evacuation needs and COVID-19 factors.

schools, over 8,000 students, and 60 restaurants in a community science initiative with substantive adaptation benefits (Billion Oyster Project, 2023)

- Other states such as Virginia and Kansas are garnering attention for their community-focused city-led policy responses such as the *Neighborhood Relief Project* through which various organizations and citizens volunteer to help those vulnerable to extreme heat, such as seniors, people with disabilities or medical conditions (Maricopa Association of Governments, 2023).

Community cloudburst planning: Recognizing that FEMA flood zones, even with updated mapping, do not accurately reflect cloudburst flood areas requires broader approaches to capturing cloudburst impacts to help New Yorkers in those neighborhoods better understand their risks. Flood warnings reach those signed up through *Notify NYC*. However, prior to and during the Ida Remnants cloudburst event, although 29 alerts were dispensed, less than a million of NYC's 8 million+ population received those alerts (A. Walker, 2021). Moreover, the high volume of notifications may result in a dismissal of the threat's severity and delay critical action (Short et al., 2021). Or, conflicting warnings may create confusion (e.g. take shelter from strong winds in basement/find higher ground in case of flooding) (City of New York, 2021). Cities that experienced catastrophic events, such as Hurricane Katrina, turned to social and behavioral programs to build risk readiness in standing community activities. In New Orleans, community groups organized neighborhood events in the places where evacuation buses picked up residents who lacked the means to evacuate on their own. Such habituated events intend to strengthen community cohesion while reinforcing the message of evacuation planning (Kinney et al., 2015). Similar strategies could be considered for NYC in concert with Community Boards or Community-based Organizations. While NYC Emergency Management (NYCEM) preparedness resources identify flash flooding as a risk, community readiness arguably lags. Recent efforts such as the *Rainfall Ready NYC Action Plan* attempt to prepare residents for such events and to help with speed of recovery (City of New York Department of Environmental Protection, 2022b). However, there is significantly more preparation required given the health impacts of local flooding types.

Smart technologies: Smart technologies can be used to connect people with information about flood risk areas, flood monitoring, warnings, MTA routing, and navigation apps, and housing resources like *StreetEasy* to improve awareness. There is also potential in communication tools used during COVID-19, like LINK messaging (nyc covid vaccine appointments [@nycshotslots], 2021), to communicate about climate risks. Resident notification about flooded bus stops/routes and/or subways alongside alternative routing to sustain connections would offer benefits.

4.4 Health Care Provider Roles

Patient interactions and counseling: Through their relationships and interactions with patients, health care providers can play key roles in preventing health impacts from dangerous weather. For example, health professionals can identify patients at risk of heat-related illness, counsel patients and caregivers, and educate other populations and those that interact with them. Studies to evaluate effectiveness are limited, but clinical judgement and an understanding of climate-related illness risk factors and vulnerabilities support several strategies as proposed for preventing heat related illness: 1) target strategies to specific groups, such as general population, occupational risk groups, and athletes, 2) identify vulnerable individuals, 3) provide tailored education and anticipatory guidance to patients, caregivers, coaches, employers and others about illnesses, prevention, and preparedness strategies (Sorensen & Hess, 2022). Several of these strategies are included in health advisories provided by the NYC Department of Health and Mental Hygiene (2022e) to providers at the beginning of the summer season and when heat advisories are issued.

Health professionals could also be encouraged to ask patients about their household energy landscape (e.g., energy use, protective or coping behaviors) and serve as the link between patients and resources to reduce energy insecurity (Cook et al., 2008; Hernández, 2018). Research has demonstrated the efficacy of connections to medical services for protection against energy insecurity, with connections to medical services sometimes leading to referrals to other resources, such as free legal programs to claim settlements for household energy-related damages (e.g., malfunctioning heating systems leading to health consequences) (Cook et al., 2008; Hernández, 2018). Some screening tools of social determinants of health have already incorporated questions about energy insecurity, asking whether one suffers from lack of heat or malfunctioning stove or oven (Hager et al., 2010). Comprehensive screening tools could help systematically identify patients suffering from energy insecurity and refer them to appropriate resources, such as food, financial, legal, tenants' rights services as well as government energy cost and weatherization assistance programs (Hernández, 2018).

Climate-health trainings for providers: The American Public Health Association (APHA) declared climate change a public health emergency in 2022 (American Medical Association, 2022), and some medical schools now host curricula specifically focused on training for climate change risk awareness and response (American Lung

Association, 2019; Columbia University Mailman School of Public Health, 2022a, 2022b). Private health service providers are only beginning to prepare for climate impacts, however. Organizations such as the Medical Society Consortium on Climate and Health (MSCCH) now solicit physicians to support such training and are in the midst of building case studies and curricula to share with physicians (L. Walker, 2023). Health Aid Training and Patient Education need further attention as there are few home-health worker training programs related to climate change and fewer patient resources to offer guidance on climate impacts to health. Trainings for home-health aides were included in the city's *Cool Neighborhoods* heat mitigation and adaptation plan (City of New York Mayor's Office of Resiliency, 2017). Healthcare without Harm also provides applicable guidance (U.S. Health Care Climate Council, 2019). Mental health care providers and emergency responders are also potential partners for patient-level education and intervention (See Community & Social Supports).

4.5 Interventions in the Housing and Energy Sectors

Reducing emissions: Local and regional emission reductions are the best way to reduce local air pollution exposures and health impacts. Air quality health impact assessments described in Balk et al., (2024) estimate the benefits of reduced illness and death already achieved and possible in the future through measures such as *NYC Clean Heat*, achieving NYC's 80x50 greenhouse gas emission reduction targets, and reducing traffic related air pollution (Johnson, Haney, et al., 2020; Kheirbek, Haney, et al., 2014; Kheirbek et al., 2016). NPCC4, Yoon et al. (2024) considers more fully the potential challenges and opportunities for reducing emissions from the energy sector, while ensuring affordable, reliable energy for all New Yorkers.

Residential cooling: Ability to afford home air conditioning and energy to run it is a major driver of indoor temperature. Air conditioning can lower indoor temperatures and increase ventilation. Improving home AC access can also reduce health inequities by race and income (Madrigano et al., 2018). Some types of facilities housing at-risk people are already required to maintain safe indoor temperatures during hot weather. For example, federal legislation requires long-term care facilities that participate in Medicare and Medicaid to provide comfortable and safe temperatures, and facilities certified after 1990 are required to keep temperatures in a range from 71 to 81°F (National Archives, 2023). Some jurisdictions, such as Dallas, Tucson, and Tempe, require that rental properties have cooling equipment (The Times Editorial Board, 2022).

In 2023, NYC announced plans to develop maximum indoor temperature policies to protect all residents by 2030 and require cooling in all new construction by 2025 (City of New York Office of the Mayor, 2023a). Energy efficiency measures, such as higher thermostat settings (Ortiz et al., 2022) can help reduce cooling cost burdens, as can cool roofs that are painted with white reflective paint to reflect rather than absorb heat, which can reduce indoor temperatures (Bock et al., 2021; Y. Sun et al., 2021). Green roofs also have benefits to the indoor environment but are more expensive to install and maintain. Air conditioning, energy use, and equity is discussed further in Balk et al., (2024) and Yoon et al., (2024).

Reduce household flood risk: Recommendations from the NYC Special Initiative for Rebuilding and Resiliency (SIRR) and examples from NYCHA's and Enterprise Community Partners' recent guidance on retrofits offer paths forward to help NYC residents understand what they can do as renters or as owners to reduce their home flood risks. Reducing risk includes addressing basement apartments by making them safer where possible or removing them where flooding is not manageable otherwise. This should occur in concert with increasing safe affordable housing outside of flood prone areas. Supporting home recovery after flooding, to enable re-occupancy as soon as possible, or to offer alternative housing if extended recovery is required (City of New York, 2018; City of New York Housing Preservation and Development, 2022b; City of New York Office of Emergency Management, 2022; Faber, 2015; Hernandez et al., 2019, 2019; Hornbach et al., 2022; Limaye et al., 2019; New York City Housing Authority, 2022; R. R. Thompson et al., 2017; Weichselbaum, 2012; Yong, 2017).

However, as can be seen in places like both New York and Seoul where affordable housing options are extremely limited (Morris, 2022), people will continue to reside in converted cellar or basement apartments and remain at risk. NYC began a basement apartment conversion pilot program in 2019 (Kully, 2020), initially limited to East New York and Cypress Hills, to help middle- and low-income homeowners convert their basement or cellar into safe spaces that could be rented out through low- or no-interest loans, but participation in the program was very low (McDonough, 2023). In November 2023, the city announced the launch of another program to fund 15 homeowners to build or retrofit accessory dwelling units (ADUs), including basement apartments, in an effort to inform plans to increase the availability of affordable housing. These plans, outlined in the *City of Yes* proposal, aim to ease zoning restrictions and legalize more basement and other dwellings to create up to 100,000 new affordable homes (City of New York Department of Housing Preservation and Development, 2023; City of New York Office of the Mayor, 2023b; Hughes & Marroquin, 2023). It will be essential that measures are taken to ensure that location and design of ADUs created through such plans protect the dwellings and occupants from flooding.

For long-term strategies related to homeowner/building-owner options, *FloodHelpNY* (Center for NYC Neighborhoods, 2023) offers retrofitting suggestions that range in expense and disruption to daily life. On the more expensive and disruptive end, one suggestion is to fill in the basement, which is an adaptation measure that blocks off the area that could be flooded. Other suggestions for single-family homes include elevating a residence, moving critical mechanical, electrical, and plumbing services out of the basement, installing flood vents, and installing a backwater valve (or check valve), which prevents flooding from sewage overflow which can occur during heavy rains and is incredibly damaging to property and can cause lingering health risks. The site also offers more budget-friendly options, such as replacing carpeting with non-porous tiles, replacing porous finishes in below-ground areas with non-porous materials and installing a sump pump, which helps remove water during and after flooding.

The *Climate-Driven Rain Response Plan*, released in July 2022, is a citywide action plan specifically meant to address the risks of flash flooding and includes an interactive map to help renters and homeowners determine the risk-levels of their neighborhoods and streets to flooding. The plan also organizes workshops to spread awareness of techniques that can minimize damage and risk to homes, and distributed sandbags and signage at 75 likely-to-be-flooded locations in the summer of 2022. The installation of 1,300 more green infrastructure assets is also an initiative within the plan, which will help divert water away from taxed sewer systems and basements by providing more pervious surfaces during heavy rainfall (City of New York Department of Environmental Protection, 2022b). A network of sensors, starting with 50 and expanding to 500 by 2026, will help populate a publicly available map of flooded areas for monitoring.

In 2023 the city further renewed its green roof tax rebate program, which provides incentives for the addition of pervious surfaces throughout the city. To further research what can be done during cloudburst events like Ida, a Cloudburst Resiliency Planning Study is running two pilot projects in Southeast Queens as well as a check valve study, which could prevent sewage from backing up into homes when the sewage system overflows during a storm. DEP's *Wait* campaign tries to spread messaging about delaying water-intensive activities such as laundry until after a storm passes (City of New York Mayor's Office of Resiliency, 2021).

The topics of relocation from flood prone areas, such as through buyouts of property owners, and the risk of basement apartment flooding is considered in NPCC4, Rosenzweig et al. (2024), NPCC4, Balk et al. (2024), and in the *NYC Climate Vulnerability, Impact, and Adaptation Analysis (VIA)* (McPhearson et al., 2024).

4.6 Occupational Health Protections

While most deaths and admissions for heat-related illness in NYC occur in residential settings, heat-related illnesses can occur in a variety of occupational settings – both indoors and outdoors – as described above. There are no specific federal policies to address worker safety from heat exposure. The Occupational Safety and Health Administration does not require employers to provide air-conditioned (or, in the winter, heated) workplaces, though they recommend that employers implement heat safety plans (Occupational Safety and Health Administration, 2022). In 2021, the agency began a process to create heat safety standards but has not completed the process. In the absence of federal protections, a handful of states, including California, Oregon, Minnesota, Colorado, and Washington have instituted worker protections, including mandating that water, shade, and rest breaks be provided, and that extreme heat response plans be developed and implemented for outdoor workers (Adewumi-Gunn & Constible, 2022). The National Institute for Occupational Safety and Health (NIOSH) has guidelines for working in heat and also recommends that workers be provided with water, shade, rest, and safety training, among other measures (National Institute for Occupational Safety and Health (NIOSH), 2020).

Advocates have noted, however, that enforceable national safety rules are lacking and while these state-level policies are important, most of them still have large gaps, including a need for indoor safety standards, adequate enforcement and penalties, and heat-health safety trainings for workers (Adewumi-Gunn & Constible, 2022). In addition, including clothing absorptivity in the WBGT equation for outdoor workers could improve workplace heat protections by establishing more realistic standards, if WBGT workplace guidelines such as those created by the International Standardization Organization, were enforced (Parsons, 2006). As noted above, though, even those workplace standards that exist are rarely enforced (Constible et al., 2020). Undocumented workers are at increased risk of abusive workplace practices and may not report workplace safety issues for fear of immigration-related retaliation by employers (McConnell, 2019).

4.7 Interventions for the Public Realm and Shared Environments

Controlling mosquito-borne illness: The NYC Department of Health and Mental Hygiene takes numerous measures to prevent West Nile Virus transmission in the city. Standing water sources are removed, larvae are treated with biological agents to prevent them from growing into adult mosquitos, and public education outreach programs are implemented to increase awareness about the risks of standing water and West Nile virus (WNV) (Bajwa W, Slavinski S, Shah Z, Zhou L, 2022). Through surveillance data, the NYC Health Department can identify high transmission risk a few weeks in advance by testing traps for WNV a few weeks before it presents a risk to the public. If more serious measures are needed, such as the use of insecticides to reduce adult mosquito populations (adulticiding) then these can be identified and deployed. Requiring window screens in residential buildings may prevent human infections and appear to prevent sustained local transmission of mosquito-borne illnesses that depend on human hosts, such as dengue, chikungunya, and Zika viruses, and are not currently endemic in the NYC area (Moreno-Madriñán & Turell, 2018; Reiter et al., 2003).

Public realm, flooding, and heat exposure: There are now smartphone applications to provide insights on flooded streets and offer alternative and accessible routes to move about safely before and during a flood (FloodMapp, 2022; Wetlands Watch, 2022). Cloudburst strategies with priorities to provide accessible pathways in critical areas could be a next step. Recognizing that all buildings and open spaces will not offer the same level of adaptive capacity, a complementary retrofit tactic is to develop accessible pathways that enable safe pedestrian movement between locations (City of New York Mayor's Office of Resiliency, 2021). As an example, in Yalding, United Kingdom, a raised walkway provides a mode of egress/access in the event of a flood, which could be a helpful solution in areas with many older buildings or where flooding retrofits are infeasible due to costs or other practical reasons (Barsley, 2020).

Messaging to alert residents to these strategies and how to manage during flood events is a critical health contribution, as is coastal and riverine flood management in parks, at the rivers, and at the beaches to reduce floodwater exposure and associated messaging to keep community members informed of their risks. Continued focus on combined sewer overflow (CSO) prevention is needed as these are amplified with flooding and impact respite areas throughout the coastal and riverine parks of New York. In the Futures and Transitions chapter of this assessment, repurposing space in the public right of way is considered as a strategy for increasing green space to mitigate the urban heat island, prevent flooding, and provide cooler, shaded places for healthy active mobility and outdoor socializing.

Climate adapted street trees: NYC Parks has developed an approved tree species list (City of New York Department of Parks & Recreation, 2023c) for new and replacement street trees that are well adapted to NYC climate and urban conditions and do not add to levels of the most allergenic tree pollen.

5 Opportunities for Future Research

5.1 Summary of Knowledge Gaps

5.1.1 Heat and health

The effects of hot weather on mortality and other health outcomes have been extensively studied in New York and other cities with similar climates. Important knowledge gaps and research opportunities remain, however, and include a need to better understand:

- The projected relationships among higher temperatures, humidity, and other heat metrics under a changing climate.
- Occupational heat exposure and health impacts in NYC, including impacts on food vendors and delivery workers.
- Exposure and health benefits of urban heat island mitigation measures, such as green space.
- Improved data on indoor temperatures and health risks in different types of dwellings and structures.
- The impact of heat exposure on populations experiencing homelessness, both sheltered and unsheltered.

5.1.2 Flooding

5.1.2.1 Economic costs of health impacts from climate sensitive events in NYC

As part of an ongoing Climate Vulnerability, Impact, and Adaptation Analysis (VIA) to study climate change's impacts on decision-making in NYC, a research team is reviewing published reports on the impacts of climate-sensitive events in NY from 2000 to 2020, then evaluating their health-related costs (McPhearson et al., 2024). Health-related costs are not typically estimated and are largely absent from climate change damage estimates (Limaye et al., 2020).The evaluation of health-related costs will inform analyses of associated past, current, and future health costs under plausible climate change scenarios, which will be published in forthcoming work (McPhearson et al., 2024) (also see Section 4.2.1 in NPCC4, Balk et al. (2024)).

5.1.2.2 Location information about compound flooding impacts and areas

As with coastal storm surges, the risk of death from cloudburst flooding during storms like the Ida Remnants Cloudburst and its long-term consequences for survivors were shaped by both geographic location and dwelling characteristics. Most obvious and tragic were drowning deaths in basement apartments. While recent city administrations have undertaken apartment improvement programs, and issued studies relating to basement apartments and subways, the deadly combination of scant affordable housing, illegal basement apartments, and climate change-fueled increases in extreme rainfall events merits further study to inform sustained, effective, and widespread action.

Residents and policymakers could benefit from more information about the vulnerability and resilience of residential buildings at risk of flooding from storm surge, cloudburst events, or sea level rise. Critically important for protecting health is data on the locations of basement dwellings in relation to pluvial and coastal flood hazards. Data on multi-family dwellings that have flood hardened building mechanical systems would be useful for both designing resilience strategies and planning for flood response. For existing renters and owners, having greater flood risk awareness can inform negotiations with landlords and co-op or condo boards and management companies, and help in developing strategies to reduce exposure. This is particularly pertinent for basement and ground floor apartment dwellers who may be unaware of their risks. The *NYC Stormwater Resiliency Plan* includes initiatives to ensure that relevant stakeholders know how to interpret and understand flood maps and preventative measures, as well as targeted messaging for people living in basement apartments prior to a storm. Also recent NYS legislation (Assembly Bill 2023-A1967, 2023) guarantees "right to know" for prospective buyers and complements 2021 legislation which does the same for renters (Assembly Bill A3360A, 2021). However, for those already occupying residential buildings, there is no other mandate to provide information on flood-related health risks and existing residential building capacity to manage those risks.

In addition to improving understanding of risk awareness, an important knowledge gap is the capacity of households living in basement dwellings to receive and respond to timely evacuation warnings, given the relatively limited lead time and spatial uncertainty of cloudburst forecasts, the possibility that warnings will arrive will residents are asleep, that they may have mobility impairments, and may suffer stress, warning fatigue, and other adverse effects from false positive alerts. As the city improves its capacity for understanding the impact of cloudburst events (City of New York Department of Environmental Protection, 2023c) and weather forecasting improves, residents could benefit from receiving such information, helping to raise risk awareness and connect the types of rainfall events and their local weather announcements to household decision-making and, where applicable, the need to shelter elsewhere.

With the latest information in PlaNYC regarding voluntary mobility (City of New York Office of the Mayor, 2023a), New Yorkers could also benefit from additional research on resettlement implications of the latest climate science (see NPCC4, Balk et al. (Balk et al., 2024)).

5.1.3 Vector-borne disease

The influences on human risk of vector-borne disease (VBD) are complex, involving climate, landcover, living conditions, ecosystems, and interactions among these and with humans and animals that can be infected and serve as hosts for further transmission. Further research is needed to understand these factors and better anticipate and control VBD risks in NYC and the metro area. Additionally, improved research and surveillance can help evaluate and improve control measures. For example, mosquito control strategies using integrated pest management (IPM) principles have been widely implemented in response to the spread of WNV in the US. While evidence supports effectiveness in reducing mosquito populations, few studies have used outcomes of reduced human cases or surrogates for WNV risk (Nasci & Mutebi, 2019).

5.1.4 Mental health and social isolation

In addition to the well-established vulnerabilities to climate health risks among people with mental health conditions, climate anxiety is an emerging, but not well studied phenomenon. It disproportionately affects younger people nationally and globally (Crandon, Scott, et al., 2022). While not an NYC-specific phenomenon, studies on its causes, relation to news and messaging about climate change, and vulnerable subgroups are needed to inform effective prevention and care for those affected (Charlson et al., 2022). Recent research describes the effects of climate stressors on dementia risk and those living with cognitive decline (Zuelsdorff & Limaye, 2023). Cities like NYC have an opportunity to shape municipal adaptation responses to better meet the needs of this population.

Social isolation at all ages is associated with worse health outcomes and often associated with mental health conditions. While distinct from living alone (which is fairly easy to measure), social isolation, which increases with age, is much harder to measure. As such, how social isolation influences health outcomes associated with vulnerability to heat, flooding and other climate-stressors presents an important knowledge gap.

5.1.5 Air pollution advisories and public health measures

As this assessment is being written, wildfire smoke has caused several days of poor air quality across much of the eastern US and in NYC. While the issuance of air quality health advisories and guidance based on the Air Quality Index (AQI) is a long established practice in the US, important questions remain about the appropriateness of the AQI and advisory thresholds, the effectiveness of some recommended personal measures to reduce exposure, the ability of different populations to understand and implement recommended actions, and tradeoffs between recommended activity restrictions and health benefits of regular physical activity (Carlsten et al., 2020; Davison et al., 2021; Laumbach et al., 2021).

6 Sustained Assessment

Sustained assessment of NYC climate-health risks, impacts, and vulnerabilities should include monitoring quantitative indicators, city plans and actions to reduce them, and greater public and stakeholder awareness, feedback, and civic engagement to spur ongoing evidence-informed actions with continuity across mayoral and city council terms.

A comprehensive indicator and monitoring system for NYC has been recommended by NPCC in the past (Blake et al., 2019; Solecki et al., 2015) but has not yet been funded or implemented. For climate-health risks, a number of useful climate and health indicators and visualizations are available at the NYC Environment and Health Data Portal (City of New York Department of Health and Mental Hygiene, 2022g). Drawing from these and other previously adopted indicators and coordinating reporting on those indicators alongside the climate change implications could be an early step. Another could be working within the existing Mayor's Management Report and expanding the Health and Human Services component to be inclusive of climate change impacts on health (City of New York Mayor's Office of Operations, 2023a, 2023b). Public web portals provide the possibility of soliciting input and ideas from a much greater range of public stakeholders and organizations than those able to attend scheduled meetings. An example is the interactive Vision Zero Input Map, rolled out at the launch of that initiative, (City of New York Mayor's Office of Operations, 2015). The public, journalists and advocacy groups can now access and visualize safety intervention, crash, injury, and fatality data to assess changes over time (City of New York, 2013).

Future sustained assessment efforts could be enhanced by implementing the roles, communications functions, and regular interactions among the NPCC, the Climate Change Adaptation Task Force (CCATF), and the NYC Mayor's office envisioned in the local law that established the NPCC (Local Law 42, 2012). This, in addition to NPCC engagement with the Environmental Justice Advisory Board (EJAB), the Sustainability Advisory Board, and the Climate Knowledge Exchange (CKE) can enhance the reflection of diverse stakeholders and technical expertise in the NPCC work products. This NPCC has also prioritized sustained assessment through the publication of a public NPCC website, which hosts up-to-date information on NPCC projects, and the production of public- and policymaker-facing, plain-language summaries of their research products.

Specific to the health sector, cultivating a community of health professionals in concert with community members in an ongoing knowledge exchange, deepening, or developing, ongoing relationships within communities to encourage climate and health conversations and to create supportive pathways to ask for help is an important shift. For example, a health ambassador program could offer a possible way forward. The Climate for Health Ambassador Training Program and the NextGen Climate and Health Ambassador Program are examples. To fairly compensate community members for their contributions (Climate for Health, 2023; Physicians for Social Responsibility, 2022), the EPA's Water Ambassador Program offers another example (United States Environmental Protection Agency, 2018).

7 Traceable Accounts

Key Message 1: Climate change-related health risks are a threat to all New Yorkers, but especially those most vulnerable because of age, poor health, and racial and social inequities. Inequities in household and neighborhood physical environments also mediate vulnerability to climate-health impacts. Addressing key environmental and social drivers of vulnerability is an essential adaptation strategy. Many current NYC policies and strategies, (e.g., improving access to residential air conditioning, tree planting), aim to accomplish this. These efforts can be informed and evaluated using data on climate-health vulnerabilities, such as components of the heat vulnerability index (HVI) and a flooding vulnerability index (FVI) under development.

Description of Evidence: Multiple studies in NYC and urban areas with similar climate show that climate change is increasing risks to health from exposure to heat, flooding, and other climate-sensitive exposures (City of New York Department of Health and Mental Hygiene, 2023b; Kinney et al., 2015; Lane et al., 2013; New York City Panel on Climate Change, 2019; Parks et al., 2021, 2022; Weinberger et al., 2020). Evidence of greater vulnerability due to age, pre-existing health conditions, and racial and social inequities is also extensive(City of New York Department of Health and Mental Hygiene, 2022b, 2022g; Cui & Sinoway, 2014; Ebi et al., 2021; Gamble et al., 2013; Hooper et al., 2014; Larose et al., 2013; S. Lin et al., 2009; Madrigano et al., 2018; Meade et al., 2020; Millyard et al., 2020; Sasai et al., 2021). Disparities in home and neighborhood physical environments have been demonstrated to modify health risks (City of New York Department of Health and Mental Hygiene, 2022b, 2022g; Madrigano et al., 2018).

Remaining Uncertainties: Uncertainties and knowledge gaps are summarized for each specific climate exposure below.

Assessment of Confidence Based on Evidence: There is high confidence that NYC climate-related health risks, especially from heat and flooding, will increase, that vulnerable populations have been identified, and that adaptation can reduce risks.

Key Message 2: Heat waves are, on average, the deadliest type of extreme weather in NYC and in much of the US. Even hot, but not extreme, summer weather also causes serious illness, death, and other harms to wellbeing. Because of climate change, NYC will experience more dangerous hot weather. Most heat-related deaths are due to exacerbation of chronic health conditions, such as cardiovascular disease. Indoor exposures can be especially deadly for people without air conditioning who have one or more physical or mental health conditions, are energy insecure, are older adults, or have jobs exposing them to unsafe indoor or outdoor temperatures. These risk factors can be consequences of structural racial, social, and economic inequities. Adaptive measures are needed that protect vulnerable populations from season-long heat-health risks, including from non-extreme but hot weather. Evidence-informed strategies include enhanced access to air conditioning, reducing energy insecurity, engaging community and health provider networks to reach vulnerable populations, and augmenting tree canopy cover.

Description of Evidence: Multiple assessments of the IPCC, US National Climate Assessment, and NPCC state that temperatures will rise, extreme heat events will worsen, and support the conclusion that temperature increases will have a negative impact on health (Intergovernmental Panel on Climate Change, 2023; USGCRP, 2018). Many epidemiologic studies focused on NYC, other parts of the US, and internationally have described the large, negative effect heat currently has on human health, including morbidity and mortality (B. G. Anderson & Bell, 2009; Curriero, 2002; Fletcher et al., 2012; Gasparrini et al., 2015; S. Lin et al., 2009; Metzger et al., 2010b; Nori-Sarma et al., 2022; Parks et al., 2020; S. Sun et al., 2021; Tobías et al., 2021; Weinberger et al., 2020; Z. Xu et al., 2016; Yoo et al., 2021). These studies often identify groups at higher risk; other studies focus specifically on associations and risk factors for heat mortality and morbidity. In addition, several studies and assessments describe multiple pathways through which persistent racism can negatively affect health for people of color through multiple pathways, including through inequitable heat exposure (Bailey et al., 2017; City of New York Department of Health and Mental Hygiene, 2022b; Gamble et al., 2013; Hoffman et al., 2020b; Lewis et al., 2019; Madrigano et al., 2015; O'Neill et al., 2005). Most heat-related deaths are caused by heat exacerbation of chronic conditions (excess mortality) (City of New York Department of Health and Mental Hygiene, 2023b; Kinney et al., 2015; Weinberger et al., 2020). Comparisons of mortality burden across extreme weather types are limited because excess deaths from hurricanes have not been as well-documented, a field that is currently emerging (Parks et al., 2023). Even so, existing and recent evidence continues to support the conclusion that heat is deadliest type of extreme weather in NYC and in the US, on average.

Remaining Uncertainties: There is evidence about the indoor temperature in NYC and US urban areas demonstrating that it can be elevated in the absence of air conditioning during and after hot weather (Vant-Hull et al., 2018; White-Newsome et al., 2012), but there are few studies measuring indoor temperature in relation to health, and less available evidence about indoor temperature thresholds appropriate for vulnerable populations, for example those who are older adults or people with chronic or mental health conditions. However, heat stress and heat-exacerbated deaths are more frequent in NYC residences compared to other settings, underscoring the risk of indoor settings (City of New York Department of Health and Mental Hygiene, 2023b; Madrigano et al., 2015; Wheeler et al., 2013). Some heat adaptation strategies have been assessed or evaluated (Berisha et al., 2017; Lane et al., 2023; WE ACT for Environmental Justice, 2021), but there have been no or limited evaluations of the implementation and effectiveness of many heat interventions. In addition, there are limited studies of long-term or chronic heat exposure effects as well as heat-health effects that do not result in interactions with the healthcare system, with most studies focused on acute and/or severe health effects.

Assessment of Confidence Based on Evidence: There is high confidence that hot weather causes serious illness and death among vulnerable New Yorkers exposed indoors, that the burden is cumulatively greater from hot, but non-extreme weather, and that air conditioning can reduce risk.

Key Message 3: Public health can be impacted before, during, and after flooding, which exposes New Yorkers to risks of drowning and other injuries, stressful evacuation, short- or long-term displacement from home, and exposures from clean up, repair, water contaminants, and mold from water damage. Climate projections for NYC anticipate an increase in extreme precipitation days and sea level rise contributing to more frequent flooding over wider areas. Socioeconomic disadvantage, pre-existing health conditions, and flood-vulnerable housing and infrastructure amplify health impacts of flooding. Adaptation strategies that modify these factors can reduce future flooding impacts on health.

Description of Evidence: National and northeast regional evidence supports the connections between climate change, flooding, and associated health risks (Frankson et al., 2022; Huang et al., 2017; USGCRP, 2018). The wide range of health risks and impacts associated with flooding includes premature mortality from drowning, physical injuries during flooding and from post-event cleanup, asphyxiation from improper use of space heaters, exposures to waterborne pathogens and chemical contaminants, increases in respiratory ailments from mold growth on water-damaged infrastructure, healthcare service disruption caused by flooding, increased risks of adverse pregnancy outcomes, and lasting mental health consequences, such as anxiety, depression, and post-traumatic stress disorder among affected communities (Hegarty et al., 2019; Lane et al., 2013; Limaye et al., 2019; Mendez-Figueroa et al., 2019; Mort et al., 2018; Parks et al., 2021, 2022; Partash et al., 2022; Paterson et al., 2018; Semenza, 2020; Smalling et al., 2016; Thacher et al., 2017; USGCRP, 2018; Wertis et al., 2023). The array of strategies to address these risks now includes efforts to improve the power supply resiliency of buildings, developing ways to increase safe affordable housing outside of flood-prone areas, supporting home re-occupancy or alternative occupancies post-flood, developing more community awareness of long-term sea level rise risks, and use of new technologies like phone applications that can provide insights on safer access routes before and during flooding, among others (Barnes & Temko, 2022; City of New York Department of Housing Preservation and Development, 2017; FloodMapp, 2022; Hornbach et al., 2022; Seip, 2022).

Remaining Uncertainties: Uncertainties exist around the interaction of sea level rise, coastal flooding, pluvial, fluvial, and groundwater flooding to create location-specific compound flooding risks, since these complex systems and events are challenging to simulate with computer modeling. Better predictive capacity regarding the impacts of cloudburst events will help in evaluating localized flooding risks. Furthermore, data on the economic costs associated with flooding-related health impacts are not routinely collected, creating uncertainties as to the full range of flooding-associated societal costs. Uncertainties also exist regarding the factors that can maximize voluntary, timely participation in flood evacuations, New Yorkers could also benefit from additional research on resettlement implications of the latest climate science.

Assessment of Confidence Based on Evidence: Given the evidence and remaining uncertainties, there is high confidence that without significant intervention and reduction of vulnerabilities, New Yorkers' health will be harmed by multiple types of flooding, including pluvial, fluvial, coastal, and groundwater flooding, and their compound flood hazards.

Key Message 4: Hotter weather can increase concentrations of harmful air pollutants, including fine particles and ground-level ozone, by increasing emissions of precursor pollutants and the formation of ozone on warm, sunny days. These pollutants are harmful to health for all New Yorkers, but especially for the very young and old, people with certain chronic health conditions, those without residential air conditioning, and those living where emissions from buildings and traffic are concentrated. Most of these vulnerability factors are more common among Black, Latino, and low-income households. Despite a warming climate, air quality has improved in New York City because of reduced local and regional emissions. Recent wildfire smoke plumes affecting much of the eastern US indicate the potential to reverse a trend of improving air quality. Efforts to further reduce emissions and exposures of vulnerable populations can prevent or mitigate climate-related air quality impacts.

Description of Evidence: The relation of weather to harmful air pollutant concentrations has been thoroughly studied, demonstrating the potential climate change to increase ambient concentrations health risks, especially for ozone. (Kinney et al., 2015; Knowlton et al., 2004; K. Zhao et al., 2019). The national and global body of evidence of health effects from $PM_{2.5}$ and ozone are extensive and robust (Global Burden of Disease Collaborative Network, 2020; United States Environmental Protection Agency, 2020). Physiologic mechanisms and epidemiologic studies have demonstrated the influence of age and chronic health conditions (Perera & Nadeau, 2022; United States Environmental Protection Agency, 2022a). Evidence for physical environment factors influencing vulnerability, including residential air conditioning and proximity to traffic emissions is also substantial (Bell et al., 2014; Jhun et al., 2014; D. Zhao et al., 2015; Zuraimi et al., 2011) as is data showing Black, Latino, and low-income households having a greater burden of health and physical environment vulnerabilities (City of New York Department of Health and Mental Hygiene, 2023i). Robust local data show improving air quality in NYC because of reduced emissions (City of

New York Department of Health and Mental Hygiene, 2022i; Kheirbek, Ito, et al., 2014; Pitiranggon et al., 2021; Zhang et al., 2021).

Remaining Uncertainties: Air pollution epidemiology continues to identify additional health effects at levels well below regulatory standards and current health burdens are likely to be underestimated. Future risks of severe wildfire smoke episodes, like that impacting NYC in the summer of 2023 are yet to be quantified as is the potential for them to reverse decades of progress in reducing $PM_{2.5}$ exposure in NYC. Questions remain about the appropriateness of public health response strategies for acute air pollution episodes, including the AQI and advisory thresholds, the effectiveness of some recommended personal measures to reduce exposure, the ability of different populations to understand and implement recommended actions, and tradeoffs between recommended activity restrictions and health benefits of regular physical activity (Carlsten et al., 2020; Davison et al., 2021; Laumbach et al., 2021). The exposure-response relationship of indoor NO_2 pollution from gas stoves is uncertain and direct evidence of the health benefits of replacing gas stoves with electric ones is limited.

Assessment of Confidence Based on Evidence: Based on high quality local and national studies, there is high confidence that: air pollution will continue to cause substantial public health impacts in New York City, especially among vulnerable populations and that reducing local emissions has and can continue to improve local air quality. There is moderate confidence that climate change will increase the risk of wildfires that can adversely affect NYC air quality. There is substantial uncertainty about the future frequency and severity of wildfire smoke episodes in NYC and the effectiveness of measures to reduce local exposures and health risks.

Key Message 5: Nationally, climate change is causing an earlier, longer, and possibly more intense plant pollen production season, but this trend is less evident in the northeast. Within New York City, pollen from several common tree species contribute to pollen exposure, seasonal allergic rhinitis, and asthma exacerbations. Communities with less access to health care, more household asthma triggers, and less well-managed asthma are more vulnerable. Air conditioning and filtration can reduce indoor pollen exposure. Attention to local tree cover density and species composition along with improved access to care, evidence-based asthma management, and patient education can reduce pollen exposure, vulnerability, and future allergic illness.

Description of Evidence: High quality national and local studies published since NPCC2 (Kinney et al., 2015) add to the weight of evidence available for that assessment that the pollen season timing and intensity are being influenced by climate change and that pollen exposure and allergic illness is influenced by local land cover with plant species producing allergenic pollen (Ito et al., 2015; Lara et al., 2020; Lovasi et al., 2013; Weinberger et al., 2016). Evidence has also grown that climate influences indoor and outdoor mold growth and that mold exposure can cause or exacerbate respiratory illness (Anees-Hill et al., 2022; Eguiluz-Gracia et al., 2020; Hanson et al., 2022; Poole et al., 2019; Sampath et al., 2023).

Remaining Uncertainties: Local data on trends in pollen and mold exposure is limited and there are uncertainties in the relative influence of climate change versus trends in local landcover and housing construction and condition on these exposures. This adds uncertainty to knowledge of recent local trends and future projections of local allergic illness risk from these climate change sensitive aeroallergens.

Assessment of Confidence Based on Evidence: Confidence is high that climate change is influencing and increasing national aeroallergen exposure. Confidence is moderate that climate change will increase local health aeroallergen exposures and health risks, which are also influenced by multiple non-climate factors.

Key Message 6: In the northeast, changes in climate, landcover, and ecosystems continue to shift the spatial and seasonal distribution of mosquitos and ticks that are current or potential vectors of human illness. Within New York City, the spatial distribution of these vectors and potential for human infection and serious illness varies with differences in the built environment, natural habitat and host animal abundance, human behaviors, and population vulnerability. Seniors, those with chronic illnesses, and people who are homeless are more susceptible to complications from West Nile virus (WNV) infection. Lyme disease risk among New Yorkers is increased among those engaged in outdoor activities mostly outside the city, but also in Staten Island and a limited area in the Bronx. Vector-borne disease (VBD) risk is also increased by international travel to and immigration from disease-endemic areas. Disease surveillance, vector monitoring and control, and public and clinician awareness can reduce future risks in a changing climate.

Description of Evidence: High quality local and national studies demonstrate sensitivity of the range and abundance of mosquitos and ticks to climate change and complex interactions among climate variables (Alkishe et al., 2021; Kinney et al., 2015; S. Lin et al., 2019; Paull et al., 2017; Shaman et al., 2005; Soverow et al., 2009). Evidence is also strong that non-climate variables, including human settlement and behavior patterns, and their interactions with climate also influence exposure and health risks from vector-borne pathogens (Bardosh et al., 2017; Keyel et al., 2021; Paull et al., 2017; USGCRP, 2018). Robust local surveillance data shows that tick-borne diseases are most often acquired by New Yorkers during travel outside NYC and that locally acquired infection occurs mostly in Staten Island.

Remaining Uncertainties: The influences of the complex, multiple climate and non-climate factors influencing human risk of VBD make it difficult to project future risks of currently endemic VBD in NYC and the metro area. Even more uncertain are future risks of new or emergent VBD. Additionally, improved research and surveillance can help evaluate and improve control measures. For example, mosquito control strategies using integrated pest management (IPM) principles have been widely implemented in response to the spread of WNV in the US. While evidence supports effectiveness in reducing mosquito populations, few studies have used outcomes of reduced human cases or surrogates for WNV risk (Nasci & Mutebi, 2019).

Assessment of Confidence Based on Evidence: There is high confidence that locally endemic VBDs will continue to cause illness in New Yorkers, that the risk of exposure will vary spatially and with changes in weather, and that robust local surveillance of insect vectors and human infections is essential to early identification and control of outbreaks. There is moderate confidence that changes in climate, international migration, and habitat could cause cases of locally transmitted malaria or other VBD not currently endemic in NYC but high uncertainty concerning the future risk of sustained local transmission.

Key Message 7: Climate change may increase the risk of exposure to water-borne pathogens in surface waters and wastewater in and around New York City and could threaten its drinking water sources and distribution system. Increased flooding can cause exposure to contaminants flood and surface waters from combined sewer overflows (CSOs) and sewer backups. Rising temperatures facilitate the growth and spread of pathogens such as bacteria that cause gastrointestinal illness, Legionnaire's disease, and a range of illnesses from harmful algal blooms. Extreme weather and climate change impacts on New York City's source and distribution infrastructure could compromise water quality and quantity. Continued maintenance and adaptation of infrastructure along with coordinated surveillance of water quality, human, and animal health can help prevent and control quality impacts on health.

Description of Evidence: Global and national studies demonstrate the potential for flooding, higher temperatures and rising humidity caused by climate change to increase risk of waterborne gastrointestinal, respiratory, and other illnesses (D. M. Anderson et al., 2021; Escobar et al., 2015; Liang & Messenger, 2018; Paschke et al., 2019; Semenza, 2020; Simmering et al., 2017; Trtanj et al., 2016). In New York State, HAB reports increased in frequency from 2012-2020 (Gorney et al., 2023). Locally, climate risks to New York City's drinking water supply are more complex because of its protected upstate watershed (Zimmerman et al., 2019). Local data shows the potential for flooding to exposure to water contaminants through sewage backups and combined sewer overflows that affect surface water quality around the city (City of New York Department of Health and Mental Hygiene, 2023h), for legionella outbreaks from cooling towers (Weiss et al., 2017), and for harmful algal blooms to affect local water bodies (New York State Department of Environmental Conservation, 2023a).

Remaining Uncertainties: New York City's unique and complex drinking water infrastructure and behaviors influencing contact with surface water makes it difficult to quantify future waterborne illness risk caused by climate change.

Assessment of Confidence Based on Evidence: There is moderate confidence that, absent adaptation, climate change can increase the local risk of exposure to waterborne contaminants from flooding and to legionella aerosols from cooling towers.

Key Message 8: Climate risks can be compounded when they disrupt lifeline infrastructure systems or overlap with non-climate public health emergencies. Examples include power outages during recent extreme heat events and the COVID-19 pandemic creating potential disease transmission risks in cooling centers and other publicly accessible indoor spaces. The health risks from compound hazards can be reduced through investing in lifeline and other critical infrastructure and building mechanical systems that are adapted to extreme weather, redundant, and flexible. Rapid, flexible, collaborative, multi-sectoral responses are needed to respond to pandemics and other unanticipated compound hazards.

Description of Evidence: In addition to compound risks caused by damage to lifeline infrastructure during extreme weather, covered earlier, local studies demonstrated the compound risks to health created by hot summer weather co-occurring with COVID-19 transmission (Bock et al., 2021; Lane et al., 2023; Watkins & Southall, 2019; WE ACT for Environmental Justice, 2021) or wildfire smoke (Rosenthal et al., 2022).

Remaining Uncertainties: Currently available data does not allow for quantifying the local added burden of human illness caused by the co-occurrence of hot weather with COVID-19 or with wildfire smoke exposure.

Assessment of Confidence Based on Evidence: Confidence is high that compound hazards can amplify climate-health impacts but low concerning the burden of illness caused by the interaction of climate risks and recently emerging hazards of COVID-19 and wildfire smoke.

8 References

Adewumi-Gunn, T., & Constible, J. (2022). *Feeling the Heat: How California's Workplace Heat Standards Can Inform Stronger Protections Nationwide*. NRDC. https://www.nrdc.org/resources/feeling-heat-how-californias-workplace-heat-standards-can-inform-stronger-protections

Afridi, L., & Morris, R. (2021). *New York's Housing Underground: 13 Years Later*. Pratt Center for Community Development. https://prattcenter.net/uploads/1021/1634833975615756/Pratt_Center_New_Yorks_Housing_Undergound_13_Years_Later_102121.pdf

Alkishe, A., Raghavan, R. K., & Peterson, A. T. (2021). Likely Geographic Distributional Shifts among Medically Important Tick Species and Tick-Associated Diseases under Climate Change in North America: A Review. *Insects*, *12*(3), Article 3. https://doi.org/10.3390/insects12030225

Alleyne, L., Thompson, C., Fitzhenry, R., Seeley, A., & Mathes, R. (2021). *Waterborne Disease Risk Assessment Program 2020 Annual Report*. New York City Department of Health & Mental Hygiene Bureau of Communicable Disease & New York City Department of Environmental Protection Bureau of Water Supply. https://www1.nyc.gov/assets/dep/downloads/pdf/about/filtration-avoidance-determination/fad_8.1_wdrap_annual_2020_03-21.pdf

American Housing Survey (AHS)—AHS Table Creator. (2021). https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=35620&s_year=2021&s_tablename=TABLE3&s_bygroup1=3&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1

American Lung Association. (2019). *A Declaration on Climate Change and Health: Climate Change is a Health Emergency*. https://www.apha.org/-/media/files/pdf/topics/climate/190429_declaration_climate_health.ashx

American Lung Association. (2023). *Disparities in the Impact of Air Pollution*. https://www.lung.org/clean-air/outdoors/who-is-at-risk/disparities

American Medical Association. (2022, June 13). *AMA adopts new policy declaring climate change a public health crisis*. https://www.ama-assn.org/press-center/press-releases/ama-adopts-new-policy-declaring-climate-change-public-health-crisis

Anderegg, W. R. L., Abatzoglou, J. T., Anderegg, L. D. L., Bielory, L., Kinney, P. L., & Ziska, L. (2021). Anthropogenic climate change is worsening North American pollen seasons. *Proceedings of the National Academy of Sciences*, *118*(7), e2013284118. https://doi.org/10.1073/pnas.2013284118

Anderson, B. G., & Bell, M. L. (2009). Weather-Related Mortality: How Heat, Cold, and Heat Waves Affect Mortality in the United States. *Epidemiology*, *20*(2), 205–213. https://doi.org/10.1097/EDE.0b013e318190ee08

Anderson, D. M., Fensin, E., Gobler, C. J., Hoeglund, A. E., Hubbard, K. A., Kulis, D. M., Landsberg, J. H., Lefebvre, K. A., Provoost, P., Richlen, M. L., Smith, J. L., Solow, A. R., & Trainer, V. L. (2021). Marine harmful algal blooms (HABs) in the United States: History, current status and future trends. *Harmful Algae*, *102*, 101975. https://doi.org/10.1016/j.hal.2021.101975

Anderson, G. B., & Bell, M. L. (2011). Heat Waves in the United States: Mortality Risk during Heat Waves and Effect Modification by Heat Wave Characteristics in 43 U.S. Communities. *Environmental Health Perspectives*, *119*(2), 210–218. https://doi.org/10.1289/ehp.1002313

Anderson, G. B., & Bell, M. L. (2012). Lights Out: Impact of the August 2003 Power Outage on Mortality in New York, NY. *Epidemiology*, *23*(2), 189–193. https://doi.org/10.1097/EDE.0b013e318245c61c

Anees-Hill, S., Douglas, P., Pashley, C. H., Hansell, A., & Marczylo, E. L. (2022). A systematic review of outdoor airborne fungal spore seasonality across Europe and the implications for health. *The Science of the Total Environment*, *818*, 151716. https://doi.org/10.1016/j.scitotenv.2021.151716

Angelini, K. (2017). Climate Change, Health, and the Role of Nurses. *Nursing for Women's Health*, *21*(2), 79–83. https://doi.org/10.1016/j.nwh.2017.02.003

Armstrong, B., Sera, F., Vicedo, -Cabrera Ana Maria, Abrutzky, R., Åstr, öm D. O., Bell, M. L., Chen, B.-Y., de, S. Z. S. C. M., Correa, P. M., Dang, T. N., Diaz, M. H., Dung, D. V., Forsberg, B., Goodman, P., Guo, Y.-L. L., Guo, Y., Hashizume, M., Honda, Y., Indermitte, E., … Gasparrini, A. (2019). The Role of Humidity in Associations of High Temperature with Mortality: A Multicountry, Multicity Study. *Environmental Health Perspectives*, *127*(9), 097007. https://doi.org/10.1289/EHP5430

Assembly Bill 2023-A1967, Pub. L. No. Amd §§462 & 465, rpld §467, RP L (2023). https://www.nysenate.gov/legislation/bills/2023/A1967

Assembly Bill A3360A, Pub. L. No. Amd §66, add §73, Pub Serv L (2021). https://legislation.nysenate.gov/pdf/bills/2021/A3360A

Auger, N., Bilodeau-Bertrand, M., Labesse, M. E., & Kosatsky, T. (2017). Association of elevated ambient temperature with death from cocaine overdose. *Drug and Alcohol Dependence*, *178*, 101–105. https://doi.org/10.1016/j.drugalcdep.2017.04.019

Ausubel, J. (2020, March 10). Older people are more likely to live alone in the U.S. than elsewhere in the world. *Pew Research Center*. https://www.pewresearch.org/fact-tank/2020/03/10/older-people-are-more-likely-to-live-alone-in-the-u-s-than-elsewhere-in-the-world/

Bailey, Z. D., Krieger, N., Agénor, M., Graves, J., Linos, N., & Bassett, M. T. (2017). Structural racism and health inequities in the USA: Evidence and interventions. *The Lancet*, *389*(10077), 1453–1463. https://doi.org/10.1016/S0140-6736(17)30569-X

Baisas, L. (2022, August 17). *West Nile virus-infected mosquitos break records in NYC | Popular Science*. https://www.popsci.com/health/new-york-city-west-nile-virus/

Bajwa, A., Hussain, S. T., Youness, H., Sawh, R. N., Zhao, L., & Abdo, T. (2022). Endobronchial mucormycosis: A rare clinical entity diagnosed by endobronchial cryobiopsy. *Respiratory Medicine Case Reports*, *37*, 101660. https://doi.org/10.1016/j.rmcr.2022.101660

Bajwa W, Slavinski S, Shah Z, Zhou L. (2022). *COMPREHENSIVE MOSQUITO SURVEILLANCE AND CONTROL PLAN*. https://www.nyc.gov/assets/doh/downloads/pdf/wnv/2022/wnvplan2022.pdf

Balbus, J., Crimmins, A., Gamble, J. L., Easterling, D. R., Kunkel, K. E., Saha, S., & Sarofim, M. C. (2016). *Ch. 1: Introduction: Climate Change and Human Health. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. U.S. Global Change Research Program. https://doi.org/10.7930/J0VX0DFW

Balk, D., McPhearson, T., Cook, E. M., Knowlton, K., Maher, N., Marcotullio, P., Matte, T. D., Moss, R., Ortiz, L. E., Towers, J., Ventrella, J., & Wagner, G. (2024). NPCC4: Concepts and Tools for Envisioning New York City's Futures (pre-publication draft). *Annals of New York Academy of Sciences*.

Bandoli, G., Ehrenstein, O. von, Ghosh, J. K., & Ritz, B. (2016). Synergistic effects of air pollution and psychosocial stressors on adolescent lung function. *Journal of Allergy and Clinical Immunology*, *138*(3), 918-920.e4. https://doi.org/10.1016/j.jaci.2016.04.012

Bardosh, K. L., Ryan, S. J., Ebi, K., Welburn, S., & Singer, B. (2017). Addressing vulnerability, building resilience: Community-based adaptation to vector-borne diseases in the context of global change. *Infectious Diseases of Poverty*, *6*(1), 166. https://doi.org/10.1186/s40249-017-0375-2

Bark, N. (1998). Deaths of Psychiatric Patients During Heat Waves. *Psychiatric Services*, *49*(8), 1088–1090. https://doi.org/10.1176/ps.49.8.1088

Barnes, J., & Temko, L. (2022, February 9). *New York, NY: Cloudburst Infrastructure Workshop for New York City Housing Authority | ULI Knowledge Platform*. Urban Land Institute. https://knowledge.uli.org/en/Reports/TAP/2022/ULI%20New%20York%20NYCHA%20Cloudburst%20Infrastructure%20Workshop

Barreca, A., Clay, K., Deschenes, O., Greenstone, M., & Shapiro, J. (2013). *Adapting to Climate Change: The Remarkable Decline in the U.S. Temperature-Mortality Relationship over the 20th Century* (w18692; p. w18692). National Bureau of Economic Research. https://doi.org/10.3386/w18692

Barsley, E. (Ed.). (2020). *Retrofitting for Flood Resilience: A Guide to Building & Community Design*. RIBA Publishing. https://doi.org/10.4324/9780429347986

Bedi, N. S., Adams, Q. H., Hess, J. J., & Wellenius, G. A. (2022). The Role of Cooling Centers in Protecting Vulnerable Individuals from Extreme Heat. *Epidemiology*, *33*(5), 611. https://doi.org/10.1097/EDE.0000000000001503

Bekkar, B., Pacheco, S., Basu, R., & DeNicola, N. (2020). Association of Air Pollution and Heat Exposure With Preterm Birth, Low Birth Weight, and Stillbirth in the US: A Systematic Review. *JAMA Network Open*, *3*(6), e208243. https://doi.org/10.1001/jamanetworkopen.2020.8243

Bell, M. L., Zanobetti, A., & Dominici, F. (2014). Who is more affected by ozone pollution? A systematic review and meta-analysis. *American Journal of Epidemiology*, *180*(1), 15–28. https://doi.org/10.1093/aje/kwu115

Benmarhnia, T., Schwarz, L., Nori-Sarma, A., & Bell, M. L. (2019). Quantifying the impact of changing the threshold of New York City heat emergency plan in reducing heat-related illnesses. *Environmental Research Letters*, *14*(11), 114006. https://doi.org/10.1088/1748-9326/ab402e

Benz, S. A., & Burney, J. A. (2021). Widespread Race and Class Disparities in Surface Urban Heat Extremes Across the United States. *Earth's Future*, *9*(7), e2021EF002016. https://doi.org/10.1029/2021EF002016

Berisha, V., Hondula, D., Roach, M., White, J. R., McKinney, B., Bentz, D., Mohamed, A., Uebelherr, J., & Goodin, K. (2017). Assessing Adaptation Strategies for Extreme Heat: A Public Health Evaluation of Cooling Centers in Maricopa County, Arizona. *Weather, Climate, and Society*, *9*(1), 71–80. https://doi.org/10.1175/WCAS-D-16-0033.1

Berkman, S., Lane, K., & Fiore, A. J. (2022). *Prepared Exhibits of: New York City Policy Panel in the Matter of Consolidated Edison Company of New York, Inc. Case 22-E-0064 and 22-G-0065*. The City of New York. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={4130F655-7302-4F9A-890D-26FD302A1EF5}

Bezgrebelna, M., McKenzie, K., Wells, S., Ravindran, A., Kral, M., Christensen, J., Stergiopoulos, V., Gaetz, S., & Kidd, S. A. (2021). Climate Change, Weather, Housing Precarity, and Homelessness: A Systematic Review of Reviews. *International Journal of Environmental Research and Public Health*, *18*(11), 5812. https://doi.org/10.3390/ijerph18115812

Bhattacharya, J., DeLeire, T., Haider, S., & Currie, J. (2003). Heat or Eat? Cold-Weather Shocks and Nutrition in Poor American Families. *American Journal of Public Health*, *93*(7), 1149–1154. https://doi.org/10.2105/AJPH.93.7.1149

Billion Oyster Project. (2023). *2022 Community Water Quality Testing Results (Week 20)*. Billion Oyster Project: Water Quality. https://www.billionoysterproject.org/blog/2023-citizens-water-quality-testing-program-weekly-results-

Blake, R., Jacob, K., Yohe, G., Zimmerman, R., Manley, D., Solecki, W., & Rosenzweig, C. (2019). New York City Panel on Climate Change 2019 Report Chapter 8: Indicators and Monitoring. *Annals of the New York Academy of Sciences*, *1439*(1), 230–279. https://doi.org/10.1111/nyas.14014

Bloom, M. S., Palumbo, J., Saiyed, N., Lauper, U., & Lin, S. (2016). Food and Waterborne Disease in the Greater New York City Area Following Hurricane Sandy in 2012. *Disaster Medicine and Public Health Preparedness*, *10*(3), 503–511. https://doi.org/10.1017/dmp.2016.85

Bock, J., Srivastava, P., Jessel, S., Klopp, J. M., & Parks, R. M. (2021). Compounding Risks Caused by Heat Exposure and COVID-19 in New York City: A Review of Policies, Tools, and Pilot Survey Results. *Journal of Extreme Events*, *08*(02), 2150015. https://doi.org/10.1142/S2345737621500159

Boersma, P., Black, L. I., & Ward, B. W. (2020). Prevalence of Multiple Chronic Conditions Among US Adults, 2018. *Preventing Chronic Disease*, *17*. https://doi.org/10.5888/pcd17.200130

Bohnert, A. S. B., Prescott, M. R., Vlahov, D., Tardiff, K. J., & Galea, S. (2010). Ambient temperature and risk of death from accidental drug overdose in New York City, 1990-2006: Temperature and overdose. *Addiction*, *105*(6), 1049–1054. https://doi.org/10.1111/j.1360-0443.2009.02887.x

Bose-O'Reilly, S., Daanen, H., Deering, K., Gerrett, N., Huynen, M. M. T. E., Lee, J., Karrasch, S., Matthies-Wiesler, F., Mertes, H., Schoierer, J., Shumake-Guillemot, J., van den Hazel, P., Frank van Loenhout, J. A., & Nowak, D. (2021). COVID-19 and heat waves: New challenges for healthcare systems. *Environmental Research*, *198*, 111153. https://doi.org/10.1016/j.envres.2021.111153

Brand, D. (2022). *NYC Shelter Count*. https://citylimits.org/nyc-shelter-count-2022/

Braneon, C., Ortiz, L., Bader, D., Devineni, N., Orton, P., Rosenzweig, B., McPhearson, T., Smalls-Mantey, L., Gornitz, V., Mayo, T., Kadam, S., Sheerazi, H., Glenn, E., Yoon, L., Derras-Chouk, A., Towers, J., Leichenko, R., Balk, D., Marcotullio, P., & Horton, R. (2024). NPCC4: NYC Climate Risk Information 2022: Observations and Projections (pre-publication draft). *Annals of the New York Academy of Sciences*.

British Columbia Coroners Service. (2021). *Extreme Heat and Human Mortality: A Review of Heat-Related Deaths in B.C. in Summer 2021*. https://www2.gov.bc.ca/assets/gov/birth-adoption-death-marriage-and-divorce/deaths/coroners-service/death-review-panel/extreme_heat_death_review_panel_report.pdf

Brown, A. (2022). *With Floodwaters Rising, Prisoners Wait for Help in Floating Feces*. The Intercept. https://theintercept.com/2022/02/12/prison-climate-crisis-flood/

Brown, S., & Parton, H. (2014). *Evacuation in New York City During Hurricanes Irene and Sandy*. New York City

Department of Health and Mental Hygiene. https://www1.nyc.gov/assets/doh/downloads/pdf/epi/databrief51.pdf

Budd, G. M. (2008). Wet-bulb globe temperature (WBGT)—Its history and its limitations. *Journal of Science and Medicine in Sport*, *11*(1), 20–32. https://doi.org/10.1016/j.jsams.2007.07.003

Bulkeley, H., Schroeder, H., Janda, K., Zhao, J., Armstrong, A., Chu, S. Y., & Ghosh, S. (2011). The Role of Institutions, Governance, and Urban Planning for Mitigation and Adaptation. In D. Hoornweg, M. Freire, M. J. Lee, P. Bhada-Tata, & B. Yuen, *Cities and Climate Change* (pp. 125–159). The World Bank. https://doi.org/10.1596/9780821384930_CH05

Burke, M., González, F., Baylis, P., Heft-Neal, S., Baysan, C., Basu, S., & Hsiang, S. (2018). Higher temperatures increase suicide rates in the United States and Mexico. *Nature Climate Change*, *8*(8), Article 8. https://doi.org/10.1038/s41558-018-0222-x

Bush, L. M., & Vazquez-Pertejo, M. T. (2018). Tick borne illness—Lyme disease. *Disease-a-Month*, *64*(5), 195–212. https://doi.org/10.1016/j.disamonth.2018.01.007

Capon, A. (2017). Harnessing urbanisation for human wellbeing and planetary health. *The Lancet Planetary Health*, *1*(1), e6–e7. https://doi.org/10.1016/S2542-5196(17)30005-0

Carlsten, C., Salvi, S., Wong, G. W. K., & Chung, K. F. (2020). Personal strategies to minimise effects of air pollution on respiratory health: Advice for providers, patients and the public. *European Respiratory Journal*, *55*(6). https://doi.org/10.1183/13993003.02056-2019

Casey-Lockyer, M., Heick, R. J., Mertzlufft, C. E., Yard, E. E., Wolkin, A. F., Noe, R. S., & Murti, M. (2013). Deaths Associated with Hurricane Sandy—October–November 2012. *Morbidity and Mortality Weekly Report*, *62*(20), 393–397.

CDCMMWR. (2022). QuickStats: Percentage of Adults Aged ≥18 Years with Diagnosed Heart Disease, by Urbanization Level and Age Group — National Health Interview Survey, United States, 2020. *MMWR. Morbidity and Mortality Weekly Report*, *71*. https://doi.org/10.15585/mmwr.mm7123a4

Center for NYC Neighborhoods. (2023). *Learn your flood risk now*. NYC Flood Zones | FloodHelpNY.Org. https://www.floodhelpny.org

Centers for Disease Control and Prevention. (2019). *Heat and Infants and Children*. Heat and Infants and Children | Natural Disasters and Severe Weather | CDC. https://www.cdc.gov/disasters/extremeheat/children.html

Centers for Disease Control and Prevention. (2021, October 21). *Ticks*. Ticks Home | CDC. https://www.cdc.gov/ticks/index.html

Centers for Disease Control and Prevention. (2022a). *Travelers' health: West Nile virus*. West Nile Virus | Disease Directory | Travelers' Health | CDC. https://wwwnc.cdc.gov/travel/diseases/west-nile-virus

Centers for Disease Control and Prevention. (2022b, January 5). *ArboNET: Historic Data (1999-2022)*. Historic Data (1999-2022) | West Nile Virus | CDC. https://www.cdc.gov/westnile/statsmaps/cumMapsData.html

Centers for Disease Control and Prevention. (2022c, October 27). *Surveillance Data: Lyme Disease Data Dashboard*. Surveillance Data | Lyme Disease | CDC. https://www.cdc.gov/lyme/datasurveillance/surveillance-data.html

Centers for Disease Control and Prevention. (2023a). *Heat & Health Tracker*. Heat & Health Tracker | Tracking | NCEH | CDC. https://ephtracking.cdc.gov/Applications/heatTracker

Centers for Disease Control and Prevention. (2023b). *Summary Report – One Health Harmful Algal Bloom System (OHHABS), United States, 2021*. CDC. https://www.cdc.gov/habs/data/2021-ohhabs-data-summary.html

Centers for Disease Control and Prevention. (2023c, May 10). *Clinical Evaluation & Disease*. Clinical Evaluation & Disease | West Nile Virus | CDC. https://www.cdc.gov/westnile/healthcareproviders/healthCareProviders-ClinLabEval.html

Centers for Disease Control and Prevention. (2023d, June 27). *Potential Range of Aedes aegypti and Aedes albopictus in the United States, 2017*. Potential Range of Aedes Mosquitoes in US | CDC. https://www.cdc.gov/mosquitoes/mosquito-control/professionals/range.html

Centers for Disease Control and Prevention. (2023e, August 28). *Important Updates on Locally Acquired Malaria Cases Identified in Florida, Texas, and Maryland*. Health Alert Network (HAN) - 00496 | Important Updates on Locally Acquired Malaria Cases Identified in Florida, Texas, and Maryland. https://emergency.cdc.gov/han/2023/han00496.asp

Chadwin, R. (2017). Evacuation of Pets During Disasters: A Public Health Intervention to Increase Resilience.

American Journal of Public Health, *107*(9), 1413–1417. https://doi.org/10.2105/AJPH.2017.303877

Charlson, F., Ali, S., Augustinavicius, J., Benmarhnia, T., Birch, S., Clayton, S., Fielding, K., Jones, L., Juma, D., Snider, L., Ugo, V., Zeitz, L., Jayawardana, D., La Nauze, A., & Massazza, A. (2022). Global priorities for climate change and mental health research. *Environment International*, *158*, 106984. https://doi.org/10.1016/j.envint.2021.106984

Childs, M. L., Li, J., Wen, J., Heft-Neal, S., Driscoll, A., Wang, S., Gould, C. F., Qiu, M., Burney, J., & Burke, M. (2022). Daily Local-Level Estimates of Ambient Wildfire Smoke PM2.5 for the Contiguous US. *Environmental Science & Technology*, *56*(19), 13607–13621. https://doi.org/10.1021/acs.est.2c02934

City of New York. (2013). *Vision Zero View*. Vision Zero View. https://vzv.nyc/

City of New York. (2016). *New York City's Roadmap to 80 x 50*. City of New York Mayor's Office of Sustainability. https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/New%20York%20City%27s%20Roadmap%20to%2080%20x%2050_Final.pdf

City of New York. (2017, April 25). *Mayor de Blasio Announces Every Classroom Will Have Air Conditioning by 2022*. The Official Website of the City of New York. http://www1.nyc.gov/office-of-the-mayor/news/261-17/mayor-de-blasio-chancellor-fari-a-city-council-every-classroom-will-have-air

City of New York. (2018). *Explore Data: Housing Conditions*. Where We Live NYC: Housing Conditions. https://wherewelive.cityofnewyork.us/explore-data/housing-conditions/

City of New York. (2021, October 28). *New York City to Close Digital Divide for 1.6 Million Residents, Advance Racial Equity*. New York City to Close Digital Divide for 1.6 Million Residents, Advance Racial Equity | City of New York. http://www1.nyc.gov/office-of-the-mayor/news/724-21/new-york-city-close-digital-divide-1-6-million-residents-advance-racial-equity

City of New York. (2022). *NYC Flood Insurance Affordability Study* [Government]. NYC Flood Maps. https://www1.nyc.gov/site/floodmaps/index.page

City of New York Bureau of Policy and Research. (2022). *Overheated, Underserved: Expanding Cooling Center Access*. Office of the New York City Comptroller Brad Lander. https://comptroller.nyc.gov/reports/overheated-underserved/

City of New York Department of City Planning. (2013). *New York City Population Projections by Age/Sex & Borough, 2010–2040* (p. 42). City of New York. https://www1.nyc.gov/assets/planning/download/pdf/planning-level/nyc-population/projections_report_2010_2040.pdf

City of New York Department of Environmental Protection. (2022a). *Climate Resiliency*. Climate Resiliency - DEP. https://www1.nyc.gov/site/dep/environment/climate-resiliency.page

City of New York Department of Environmental Protection. (2022b). *Rainfall Ready NYC Action Plan* [Government]. Rainfall Ready NYC - DEP. https://www1.nyc.gov/site/dep/whats-new/rainfall-ready-nyc.page

City of New York Department of Environmental Protection. (2023a). *Groundwater Supply System*. Groundwater Supply System - DEP. https://www.nyc.gov/site/dep/water/groundwater-supply-system.page

City of New York Department of Environmental Protection. (2023b). *Wait...* [Government]. Wait... - DEP. https://www1.nyc.gov/site/dep/whats-new/wait.page

City of New York Department of Environmental Protection. (2023c, January). *Cloudburst Management—NYC DEP*. https://www.nyc.gov/site/dep/environment/cloudburst.page

City of New York Department of Health and Mental Hygiene. (2017). *Tick-Borne Diseases in the New York City Area: A Reference Manual for Physicians* (DIS1914621 – 5.17). City of New York.

City of New York Department of Health and Mental Hygiene. (2019). *NYC Community Health Survey*. EpiQuery | Search for Data, Surveys and Records on the Health of New Yorkers. https://a816-health.nyc.gov/hdi/epiquery/visualizations?PageType=ps&PopulationSource=CHS&Topic=All&Subtopic=All&DisplayViz=Main&MainDashboard=Explore%20an%20Indicator&MainCustomView=https%3A%2F%2Fa816-healthtableau.nyc.gov%2Ft%2FHDI-EPIQUERY%2Fviews%2FHDISurveyModules_CHS%2FExploreanIndicator%2FHDI_Publicprdsvc%2Fcv1675979130479PS&SAIDashboard=See%20Available%20Indicators&SAICustomView=https%3A%2F%2Fa816-healthtableau.nyc.gov%2Ft%2FHDI-EPIQUERY%2Fviews%2FHDISurveyModules_CHS_SAIOnly%2FSeeAvailableIndicators%2FHDI_Publicprdsvc%2Fcv1675979130479SAIPS

City of New York Department of Health and Mental Hygiene. (2022a). *2022 Health Advisory #10: Tick-borne Disease*

Advisory. City of New York Department of Health and Mental Hygiene.

City of New York Department of Health and Mental Hygiene. (2022b). *2022 NYC Heat-Related Mortality Report*. NYC DOH Environment and Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/beta/key-topics/climatehealth/2022-heat-report/

City of New York Department of Health and Mental Hygiene. (2022c). *Asthma emergency department visits (adults)* [dataset]. GitHub; Environment and Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/data-explorer/asthma/?id=2380#display=summary

City of New York Department of Health and Mental Hygiene. (2022d). *Efforts to reduce air pollution should focus on neighborhoods with the worst health impacts*. Health Impact Assessments | Environment & Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/data-stories/hia/

City of New York Department of Health and Mental Hygiene. (2022e). *Health Alert Network (HAN)—NYC Health*. https://www1.nyc.gov/site/doh/providers/resources/health-alert-network.page

City of New York Department of Health and Mental Hygiene. (2022f). *Interactive Heat Vulnerability Index*. NYC DOH Environment & Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/beta/key-topics/climatehealth/hvi/

City of New York Department of Health and Mental Hygiene. (2022g). *Key Topics: Climate and Health*. Climate and Health | Environment & Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/HeatHub/index.html

City of New York Department of Health and Mental Hygiene. (2022h). *Lyme Disease Report in New York City—2020*.

City of New York Department of Health and Mental Hygiene. (2022i). *NYC Community Air Survey Annual Report: 2008-2021*. NYC Community Air Survey Annual Report | Environment & Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/key-topics/airquality/nyccas/

City of New York Department of Health and Mental Hygiene. (2022j). *Real-time heat-related illness* [dataset]. GitHub; Environment and Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/key-topics/climatehealth/syndromic/

City of New York Department of Health and Mental Hygiene. (2022k, June 16). *Health Department Releases Report on Heat-Related Mortality in New York City*. New York City Department of Health and Mental Hygiene. https://www1.nyc.gov/site/doh/about/press/pr2022/heat-related-mortality-report.page

City of New York Department of Health and Mental Hygiene. (2022l, August 16). *West Nile Virus Detected in Record Number of Mosquitoes Two Human Cases Reported*. https://www1.nyc.gov/site/doh/about/press/pr2022/west-nile-virus-detected-in-record-number--two-human-cases-reported.page

City of New York Department of Health and Mental Hygiene. (2023a). *2023 Health Advisory #19: CDC Advisory Severe Vibrio vulnificus Infections in the United States Associated with Warming Coastal Waters*. City of New York. https://www.nyc.gov/assets/doh/downloads/pdf/han/advisory/2023/han-advisory-19.pdf

City of New York Department of Health and Mental Hygiene. (2023b). *2023 NYC Heat-Related Mortality Report*. NYC DOH Environment and Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/beta/key-topics/climatehealth/heat-report/

City of New York Department of Health and Mental Hygiene. (2023c). *Annual Report on heat mortality in NYC. | Environment & Health Data Portal*. https://a816-dohbesp.nyc.gov/IndicatorPublic/beta/key-topics/climatehealth/heat-report/

City of New York Department of Health and Mental Hygiene. (2023d). *Cooling Tower Registration and Maintenance*. Cooling Tower Registration and Maintenance - NYC Health. https://www.nyc.gov/site/doh/business/permits-and-licenses/cooling-towers.page

City of New York Department of Health and Mental Hygiene. (2023e). *Drinking water quality data. Disinfection by-products (TTHM)* [dataset]. GitHub; Environment and Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/data-explorer/drinking-water-quality/?id=2207#display=summary

City of New York Department of Health and Mental Hygiene. (2023f). *Heat Vulnerability Index (NTA)* [ASCII / CSV]. Environment and Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/beta/data-explorer/climate/

City of New York Department of Health and Mental Hygiene. (2023g). *Housing Maintenance*. Environment & Health Data Portal. https://a816-dohbesp.nyc.gov/IndicatorPublic/beta/data-explorer/housing-maintenance/

City of New York Department of Health and Mental Hygiene. (2023h). *NYC Beaches*. Beaches NYC Area - NYC Health. https://www1.nyc.gov/site/doh/health/health-topics/beach-homepage.page

City of New York Department of Health and Mental Hygiene. (2023i). *NYC Health Data—Diseases and Conditions: Chronic Diseases*. EpiQuery | Search for Data, Surveys and Records on the Health of New Yorkers. https://a816-health.nyc.gov/hdi/epiquery/visualizations?PageType=ts&PopulationSource=CHS&Topic=1&Subtopic=24

City of New York Department of Health and Mental Hygiene. (2023j). *Prevent Tick-borne Diseases*. Prevent Tick-Borne Diseases - NYC Health. https://www.nyc.gov/site/doh/about/press/pr2023/prevent-tick-borne-diseases.page

City of New York Department of Health and Mental Hygiene. (2023k). *The Environment and Health Data Portal: EHDP Data* [dataset]. GitHub. https://github.com/nychealth/EHDP-data

City of New York Department of Health and Mental Hygiene. (2023l). *Ticks—NYC Health*. City of New York Department of Health. https://www.nyc.gov/site/doh/health/health-topics/ticks.page

City of New York Department of Health and Mental Hygiene. (2023m). *West Nile Virus Positive Reports, Results and Summaries: 2022 Positive Results Summary*. West Nile Virus Positive Reports 2022 - NYC Health. https://www.nyc.gov/site/doh/health/health-topics/west-nile-virus-reports-2022.page

City of New York Department of Health and Mental Hygiene. (2023n). *2023 Health Advisory #13: Tick-borne Disease Advisory*. City of New York Department of Health and Mental Hygiene. https://www.nyc.gov/assets/doh/downloads/pdf/han/advisory/2023/han-advisory-13.pdf

City of New York Department of Homeless Services. (2023). *Street Outreach*. Street Outreach - DHS. https://www.nyc.gov/site/dhs/outreach/street-outreach.page

City of New York Department of Housing Preservation and Development. (2017). *Resilient Edgemere Community Plan*. https://www.nyc.gov/assets/hpd/downloads/pdfs/services/resilient-edgemere-report.pdf

City of New York Department of Housing Preservation and Development. (2023, November 21). *New Program Gauges Interest in Adding Small Homes in Line with Goals of the City of Yes for Housing*. The Official Website of the City of New York. http://www.nyc.gov/site/hpd/news/021-39/garage-studios-basement-apartments-backyard-cottages-hpd-pilot-program-helping

City of New York Department of Parks & Recreation. (2023a). *Cool It! NYC*. Cool It! NYC : NYC Parks. https://www.nycgovparks.org/about/health-and-safety-guide/cool-it-nyc

City of New York Department of Parks & Recreation. (2023b). *Harmful Algal Blooms (HABs) in Parks' Lakes and Parks*. Harmful Algal Blooms (HABs) in Parks' Lakes and Parks : NYC Parks. https://www.nycgovparks.org/about/harmful-algal-blooms

City of New York Department of Parks & Recreation. (2023c). *NYC's Urban Forest—Street Tree Planing: Approved Species List*. Street Tree Planting Approved Species List : NYC Parks. https://www.nycgovparks.org/trees/street-tree-planting/species-list

City of New York Housing Preservation and Development. (2022a). *Home Repair and Preservation Financing: Basement Apartment Conversion Pilot Program*. Basement Apartment Conversion Pilot Program - HPD. https://www1.nyc.gov/site/hpd/services-and-information/basement-apartment-conversion-pilot-program.page

City of New York Housing Preservation and Development. (2022b). *Housing Quality / Safety: Basements and Cellars*. Basement and Cellar - HPD. https://www1.nyc.gov/site/hpd/services-and-information/basement-and-cellar.page

City of New York Human Resources Administration. (2023). *Energy Assistance: HEAP Cooling Assistance Component (CAC)*. Energy Assistance - HRA. https://www.nyc.gov/site/hra/help/energy-assistance.page

City of New York Mayor's Office of Climate & Environmental Justice. (2022). *Be a Buddy: A Community-Based Climate Resiliency Model*. City of New York Mayor's Office of Climate and Environmental Justice. https://climate.cityofnewyork.us/initiatives/be-a-buddy/

City of New York Mayor's Office of Operations. (2015). *VISION ZERO: One Year Report*. City of New York. https://www.nyc.gov/assets/visionzero/downloads/pdf/vision-zero-1-year-report.pdf

City of New York Mayor's Office of Operations. (2023a). *Mayor's Management Report: Fiscal 2023*. City of New York. https://www.nyc.gov/site/operations/performance/mmr.page

City of New York Mayor's Office of Operations. (2023b). *Preliminary Mayor's Management Report*. City of New York.

https://donbuqm3ub5fw.cloudfront.net/files/PMMR_2023_f382fe0bd8.pdf

City of New York Mayor's Office of Resiliency. (2017). *Cool Neighborhoods NYC: A Comprehensive Approach to Keep Communities Safe in Extreme Heat* (p. 44). City of New York Mayor's Office of Resiliency. https://www1.nyc.gov/assets/orr/pdf/Cool_Neighborhoods_NYC_Report.pdf

City of New York Mayor's Office of Resiliency. (2021). *New York City Stormwater Resiliency Plan: Helping New Yorkers understand and manage vulnerabilities from extreme rain* (p. 23). City of New York. https://www.nyc.gov/assets/orr/pdf/publications/stormwater-resiliency-plan.pdf

City of New York Office of Emergency Management. (2022). *Ready New York | My Emergency Plan*. NYC Emergency Management | Department for the Aging | Mayor's Office for People with Disabilities. https://www1.nyc.gov/assets/em/downloads/pdf/myemergencyplan_english.pdf

City of New York Office of Management and Budget. (2023). *CDBG-DR Action Plan for The Remnants of Hurricane Ida: Substantial Amendment 1* [HUD Submission Version]. Office of Management and Budget (OMB) of the City of New York. https://www.nyc.gov/assets/cdbgdr/documents/amendments/Ida_Amendments/2_NYC_Hurricane_Ida_Action_Plan_SA1_HUD_Approved_(8.8.23).pdf

City of New York Office of the Deputy Mayor for Administration. (2021). *The New Normal: Combating Storm-Related Extreme Weather In New York City*. NYC Extreme Weather Response Task Force. https://www1.nyc.gov/assets/orr/pdf/publications/WeatherReport.pdf

City of New York Office of the Mayor. (2013). *PlaNYC: A Stronger, More Resilient New York* (PlaNYC). City of New York. https://www1.nyc.gov/site/sirr/report/report.page

City of New York Office of the Mayor. (2023a). *PlaNYC: Getting Sustainability Done* (PlaNYC). City of New York. https://s-media.nyc.gov/agencies/mocej/PlaNYC-2023-Full-Report.pdf

City of New York Office of the Mayor. (2023b, September 21). *Mayor Adams Launches Historic Effort to Build*. The Official Website of the City of New York. http://www.nyc.gov/office-of-the-mayor/news/692-23/mayor-adams-launches-historic-effort-build-a-little-more-housing-every-neighborhood-

Clayton, S. (2020). Climate anxiety: Psychological responses to climate change. *Journal of Anxiety Disorders*, *74*, 102263. https://doi.org/10.1016/j.janxdis.2020.102263

Climate Central. (2021, July 14). *Climate Matters | Urban Heat Islands*. Climate Central. https://www.climatecentral.org/climate-matters/urban-heat-islands

Climate for Health. (2023). *About Us*. About Climate For Health | About Us. https://climateforhealth.org/about-climate-for-health/

Clougherty, J. E., Levy, J. I., Kubzansky, L. D., Ryan, P. B., Suglia, S. F., Canner, M. J., & Wright, R. J. (2007). Synergistic effects of traffic-related air pollution and exposure to violence on urban asthma etiology. *Environmental Health Perspectives*, *115*(8), 1140–1146. https://doi.org/10.1289/ehp.9863

Coca, A., Quinn, T., Kim, J.-H., Wu, T., Powell, J., Roberge, R., & Shaffer, R. (2017). Physiological Evaluation of Personal Protective Ensembles Recommended for Use in West Africa. *Disaster Medicine and Public Health Preparedness*, *11*(5), 580–586. https://doi.org/10.1017/dmp.2017.13

Coleman, A. (2019). *SCI Investigation into the Operation of Dangerously Hot School Buses* (SCI Case #2019-5863). The Special Commissioner of Investigation for the New York City School District. https://nycsci.org/wp-content/uploads/2018/Reports/12-19-Hot-School-Buses-Report.pdf?fbclid=IwAR15_KZmeW7paBnxAbiCOE8Ij7ES5E1ephrHSLZe8qMNqF1dpeIVfAQxn6M

Columbia University Mailman School of Public Health. (2022a). *Climate and Health Program*. Climate and Health Program | Columbia Public Health. https://www.publichealth.columbia.edu/research/climate-and-health-program

Columbia University Mailman School of Public Health. (2022b). *Global Consortium on Climate and Health Education*. Global Consortium on Climate and Health Education | Columbia Public Health. https://www.publichealth.columbia.edu/research/global-consortium-climate-and-health-education

Conlon, K. C., Mallen, E., Gronlund, C. J., Berrocal, V. J., Larsen, L., & O, 'Neill Marie S. (2020). Mapping Human Vulnerability to Extreme Heat: A Critical Assessment of Heat Vulnerability Indices Created Using Principal Components Analysis. *Environmental Health Perspectives*, *128*(9), 097001. https://doi.org/10.1289/EHP4030

Constible, J. (2023, April 17). *Occupational Heat Safety Standards in the United States*.

https://www.nrdc.org/resources/occupational-heat-safety-standards-united-states

Constible, J., Chang, B., Morganelli, C., & Blandon, N. (2020). *On the Front Lines: Climate Change Threatens the Health of Americans's Workers* (R: 20-05-B). The Natural Resources Defense Council.

Cook, J. T., Frank, D. A., Casey, P. H., Rose-Jacobs, R., Black, M. M., Chilton, M., deCuba, S. E., Appugliese, D., Coleman, S., Heeren, T., Berkowitz, C., & Cutts, D. B. (2008). A Brief Indicator of Household Energy Security: Associations With Food Security, Child Health, and Child Development in US Infants and Toddlers. *Pediatrics*, *122*(4), e867–e875. https://doi.org/10.1542/peds.2008-0286

Correal, A. (2019, February 1). No Heat for Days at a Jail in Brooklyn Where Hundreds of Inmates Are Sick and 'Frantic.' *The New York Times*. https://www.nytimes.com/2019/02/01/nyregion/mdc-brooklyn-jail-heat.html

Crandon, T. J., Dey, C., Scott, J. G., Thomas, H. J., Ali, S., & Charlson, F. J. (2022). The clinical implications of climate change for mental health. *Nature Human Behaviour*, *6*(11), 1474–1481. https://doi.org/10.1038/s41562-022-01477-6

Crandon, T. J., Scott, J. G., Charlson, F. J., & Thomas, H. J. (2022). A social–ecological perspective on climate anxiety in children and adolescents. *Nature Climate Change*, *12*(2), 123–131. https://doi.org/10.1038/s41558-021-01251-y

Crown, C. A., Pregitzer, C. C., Clark, J. A., & Plitt, S. (2023). *Cooling Cities: Harnessing Natural Areas to Combat Urban Heat*. Natural Areas Conservancy, New York. https://naturalareasnyc.org/media/pages/in-print/951f086032-1690225094/nac-cooling-cities.pdf

Cui, J., & Sinoway, L. I. (2014). Cardiovascular responses to heat stress in chronic heart failure. *Current Heart Failure Reports*, *11*(2), 139–145. https://doi.org/10.1007/s11897-014-0191-y

Currie, J., & Rossin-Slater, M. (2013). Weathering the storm: Hurricanes and birth outcomes. *Journal of Health Economics*, *32*(3), 487–503. https://doi.org/10.1016/j.jhealeco.2013.01.004

Curriero, F. C. (2002). Temperature and Mortality in 11 Cities of the Eastern United States. *American Journal of Epidemiology*, *155*(1), 80–87. https://doi.org/10.1093/aje/155.1.80

D'Antoni, D., Auyeung, V., Walton, H., Fuller, G. W., Grieve, A., & Weinman, J. (2019). The effect of evidence and theory-based health advice accompanying smartphone air quality alerts on adherence to preventative recommendations during poor air quality days: A randomised controlled trial. *Environment International*, *124*, 216–235. https://doi.org/10.1016/j.envint.2019.01.002

Davey, S. L., Lee, B. J., Robbins, T., Randeva, H., & Thake, C. D. (2021). Heat stress and PPE during COVID-19: Impact on healthcare workers' performance, safety and well-being in NHS settings. *The Journal of Hospital Infection*, *108*, 185–188. https://doi.org/10.1016/j.jhin.2020.11.027

Davison, G., Barkjohn, K. K., Hagler, G. S. W., Holder, A. L., Coefield, S., Noonan, C., & Hassett-Sipple, B. (2021). Creating Clean Air Spaces During Wildland Fire Smoke Episodes: Web Summit Summary. *Frontiers in Public Health*, *9*. https://www.frontiersin.org/articles/10.3389/fpubh.2021.508971

Davitt, J. (2022, August 29). *August brought the most 90-degree days to NYC in over a decade*. https://spectrumlocalnews.com/nc/coastal/weather/2022/08/26/august-brought-the-most-90-degree-days-to-nyc-in-over-a-decade

de Dear, R., & Schiller Brager, G. (1998). Developing an adaptive model of thermal comfort and preference. *ASHRAE Transactions | UC Berkeley: Center for the Built Environment.*, *104*, 145.

DeGroote, J. P., & Sugumaran, R. (2012). National and Regional Associations Between Human West Nile Virus Incidence and Demographic, Landscape, and Land Use Conditions in the Coterminous United States. *Vector-Borne and Zoonotic Diseases*, *12*(8), 657–665. https://doi.org/10.1089/vbz.2011.0786

Dennis, D. T., Nekomoto, T. S., Victor, J. C., Paul, W. S., & Piesman, J. (1998). Forum: Reported Distribution of Ixodes scapularis and Ixodes pacificus (Acari: Ixodidae) in the United States. *Journal of Medical Entomology*, *35*(5), 629–638. https://doi.org/10.1093/jmedent/35.5.629

Dixon, L., Clancy, N., Bender, B., Kofner, A., Manheim, D., & Zakaras, L. (2013). *Flood Insurance in New York City Following Hurricane Sandy*. RAND Corporation. https://www.rand.org/pubs/research_reports/RR328.html

Dominianni, C., Lane, K., Ahmed, M., Johnson, S., McKelvey, W., & Ito, K. (2018). Hot Weather Impacts on New York City Restaurant Food Safety Violations and Operations. *Journal of Food Protection*, *81*(7), 1048–1054. https://doi.org/10.4315/0362-028X.JFP-17-490

Donavan, L. (2021, September 13). *As Conditions at Rikers Reach Crisis Levels, Concerns About Heat Persist*. City

Limits. https://citylimits.org/2021/09/13/as-conditions-at-rikers-reach-crisis-levels-concerns-about-heat-persist/

Donavan, L. (2022, July 27). *Some Rikers Detainees Had No Air Conditioning During Heat Wave, Lawmakers Say*. City Limits. https://citylimits.org/2022/07/27/some-rikers-detainees-had-no-air-conditioning-during-heat-wave-lawmakers-say/

Eastman, C. (2021, March). The Fever That Struck New York. *Smithsonian Magazine*. https://www.smithsonianmag.com/science-nature/fever-struck-new-york-180976997/

Ebi, K. L., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., Honda, Y., Kovats, R. S., Ma, W., Malik, A., Morris, N. B., Nybo, L., Seneviratne, S. I., Vanos, J., & Jay, O. (2021). Hot weather and heat extremes: Health risks. *The Lancet*, *398*(10301), 698–708. https://doi.org/10.1016/S0140-6736(21)01208-3

Edelmen, S., & Bamberger, C. (2022, July 23). NYC students stuck on hot school buses during heat wave. *New York Post*. https://nypost.com/2022/07/23/nyc-students-stuck-on-hot-school-buses-during-heat-wave/

E&E News, & Harvey, C. (2022, May 3). *Astonishing Heat Grips India and Pakistan*. Scientific American. https://www.scientificamerican.com/article/astonishing-heat-grips-india-and-pakistan/

Eguiluz-Gracia, I., Mathioudakis, A. G., Bartel, S., Vijverberg, S. J. H., Fuertes, E., Comberiati, P., Cai, Y. S., Tomazic, P. V., Diamant, Z., Vestbo, J., Galan, C., & Hoffmann, B. (2020). The need for clean air: The way air pollution and climate change affect allergic rhinitis and asthma. *Allergy*, *75*(9), 2170–2184. https://doi.org/10.1111/all.14177

Escobar, L. E., Ryan, S. J., Stewart-Ibarra, A. M., Finkelstein, J. L., King, C. A., Qiao, H., & Polhemus, M. E. (2015). A global map of suitability for coastal Vibrio cholerae under current and future climate conditions. *Acta Tropica*, *149*, 202–211. https://doi.org/10.1016/j.actatropica.2015.05.028

Faber, J. W. (2015). Superstorm Sandy and the Demographics of Flood Risk in New York City. *Human Ecology*, *43*(3), 363–378. https://doi.org/10.1007/s10745-015-9757-x

Fann, N. L., Nolte, C. G., Sarofim, M. C., Martinich, J., & Nassikas, N. J. (2021). Associations Between Simulated Future Changes in Climate, Air Quality, and Human Health. *JAMA Network Open*, *4*(1), e2032064. https://doi.org/10.1001/jamanetworkopen.2020.32064

Fatima, S. H., Rothmore, P., Giles, L. C., Varghese, B. M., & Bi, P. (2021). Extreme heat and occupational injuries in different climate zones: A systematic review and meta-analysis of epidemiological evidence. *Environment International*, *148*, 106384. https://doi.org/10.1016/j.envint.2021.106384

Fears, D., & Eger, A. (2022, July 19). As heat waves hit U.S. and Europe, leaders split on climate change. *Washington Post*. https://www.washingtonpost.com/climate-environment/2022/07/19/heat-wave-europe-climate-change/

Federal Emergency Management Agency. (2023a). *What Flood Insurance Covers*. FEMA | What Does Flood Insurance Cover? https://www.floodsmart.gov/whats-covered

Federal Emergency Management Agency. (2023b). *FEMA Fact Sheet 1: Hurricane Ida NYC MAT - What Building Owners and Tenants Should Know About Urban Flooding*. FEMA. https://www.fema.gov/sites/default/files/documents/fema_p-2333-mat-report-hurricane-ida-nyc_fact-sheet-1_2023.pdf

Federal Emergency Management Agency. (2023c, August 17). *Assessing Disaster Impacts with the Building Science Disaster Support Program*. Assessing Disaster Impacts | FEMA. https://www.fema.gov/emergency-managers/risk-management/building-science/disaster-support

Federal Emergency Management Agency (FEMA). (2022). *Flood Risk Disclosure: Local Best Practices for Disclosing Flood Risk During Real Estate Transactions*. U.S. Department of Homeland Security. https://www.fema.gov/sites/default/files/documents/fema_local-best-practices-disclosing-flood-risk_092022.pdf

FEMA. (2020). *COVID-19 Supplement for Planning Considerations: Evacuation and Shelter-in-Place*. https://www.fema.gov/sites/default/files/2020-09/fema_covid-19_supplement-evacuation-shelter-in-place.pdf

FEMA. (2023). *Building Performance: Egress from Floodprone Basements*. https://www.fema.gov/sites/default/files/documents/fema_p-2333-mat-report-hurricane-ida-nyc_technical-report-2_2023.pdf

Fiscella, K., & Sanders, M. R. (2016). Racial and Ethnic Disparities in the Quality of Health Care. *Annual Review of Public Health*, *37*(1), 375–394. https://doi.org/10.1146/annurev-publhealth-032315-021439

Fletcher, B. A., Lin, S., Fitzgerald, E. F., & Hwang, S.-A. (2012). Association of Summer Temperatures With Hospital Admissions for Renal Diseases in New York State: A Case-Crossover Study. *American Journal of Epidemiology*, *175*(9), 907–916. https://doi.org/10.1093/aje/kwr417

FloodMapp. (2022, January 6). *RISE Update: FloodMapp launches integration with Waze helping reroute drivers in Virginia, USA*. FloodMapp. https://www.floodmapp.com/post/rise-update-floodmapp-launches-integration-with-waze-helping-reroute-drivers-in-virginia-usa

Foster, S., Baptista, A., Nguyen, K. H., Tchen, J., Tedesco, M., & Leichenko, R. (2024). NPCC4: Advancing Climate Justice in Climate Adaptation Strategies for New York City (pre-publication draft). *Annals of the New York Academy of Sciences*.

Fouillet, A., Rey, G., Laurent, F., Pavillon, G., Bellec, S., Guihenneuc-Jouyaux, C., Clavel, J., Jougla, E., & Hémon, D. (2006). Excess mortality related to the August 2003 heat wave in France. *International Archives of Occupational and Environmental Health*, *80*(1), 16–24. https://doi.org/10.1007/s00420-006-0089-4

Frankson, R., Kunkel, K. E., Champion, S. M., Stewart, B. C., Sweet, W., DeGaetano, A. T., & Spaccio, J. (2022). *New York State Climate Summary 2022* (NOAA Technical Report NESDIS 150-NY; p. 5). NOAA/NESDIS. https://statesummaries.ncics.org/downloads/NewYork-StateClimateSummary2022.pdf

Frieden, T. R. (2010). A Framework for Public Health Action: The Health Impact Pyramid. *American Journal of Public Health*, *100*(4), 590–595. https://doi.org/10.2105/AJPH.2009.185652

Fu, T.-M., & Tian, H. (2019). Climate Change Penalty to Ozone Air Quality: Review of Current Understandings and Knowledge Gaps. *Current Pollution Reports*, *5*(3), 159–171. https://doi.org/10.1007/s40726-019-00115-6

Gaffin, S. R., Rosenzweig, C., Khanbilvardi, R., Parshall, L., Mahani, S., Glickman, H., Goldberg, R., Blake, R., Slosberg, R. B., & Hillel, D. (2008). Variations in New York city's urban heat island strength over time and space. *Theoretical and Applied Climatology*, *94*(1–2), 1–11. https://doi.org/10.1007/s00704-007-0368-3

Gaffney, A., & McCormick, D. (2017). The Affordable Care Act: Implications for health-care equity. *The Lancet*, *389*(10077), 1442–1452. https://doi.org/10.1016/S0140-6736(17)30786-9

Gamble, J. L., Hurley, B. J., Schultz, P. A., Jaglom, W. S., Krishnan, N., & Harris, M. (2013). Climate Change and Older Americans: State of the Science. *Environmental Health Perspectives*, *121*(1), 15–22. https://doi.org/10.1289/ehp.1205223

Garcia, M. A., Sheftel, M. G., Reyes, A. M., & Garcia, C. (2022). Sociocultural and Demographic Drivers of Latino Population Health in New York State. *Syracuse University Lerner Center for Public Health Promotion and Population Health*, *Population Health Research Brief Series*. https://www.maxwell.syr.edu/research/lerner-center/population-health-research-brief-series/article/sociocultural-and-demographic-drivers-of-latino-population-health-in-new-york-state

Garrison, V. E. H., Bachand, J., & Ashley, P. J. (2021). Musty Smells, Mold, and Moisture in the U.S. Housing Stock: Results from Two National Surveys. *Cityscape*, *23*(1), 223–236.

Gasparrini, A., Guo, Y., Hashizume, M., Lavigne, E., Zanobetti, A., Schwartz, J., Tobias, A., Tong, S., Rocklöv, J., Forsberg, B., Leone, M., De Sario, M., Bell, M. L., Guo, Y.-L. L., Wu, C., Kan, H., Yi, S.-M., de Sousa Zanotti Stagliorio Coelho, M., Saldiva, P. H. N., … Armstrong, B. (2015). Mortality risk attributable to high and low ambient temperature: A multicountry observational study. *The Lancet*, *386*(9991), 369–375. https://doi.org/10.1016/S0140-6736(14)62114-0

Gent, J. F., Holford, T. R., Bracken, M. B., Plano, J. M., McKay, L. A., Sorrentino, K. M., Koutrakis, P., & Leaderer, B. P. (2023). Childhood asthma and household exposures to nitrogen dioxide and fine particles: A triple-crossover randomized intervention trial. *Journal of Asthma*, *60*(4), 744–753. https://doi.org/10.1080/02770903.2022.2093219

Global Burden of Disease Collaborative Network. (2020). *Global Burden of Disease Study 2019 (GBD 2019) Results.* Institute for Health Metrics and Evaluation (IHME). https://vizhub.healthdata.org/gbd-results

Gobler, C. J. (2020). Climate Change and Harmful Algal Blooms: Insights and perspective. *Harmful Algae*, *91*, 101731. https://doi.org/10.1016/j.hal.2019.101731

Goldstein, J. (2023, June 29). How Bad Will the Ticks Be This Summer? *The New York Times*. https://www.nytimes.com/2023/06/29/nyregion/nyc-tick-diseases-species.html

González, J. E., Ortiz, L., Smith, B. K., Devineni, N., Colle, B., Booth, J. F., Ravindranath, A., Rivera, L., Horton, R., Towey, K., Kushnir, Y., Manley, D., Bader, D., & Rosenzweig, C. (2019). New York City Panel on Climate Change 2019 Report Chapter 2: New Methods for Assessing Extreme Temperatures, Heavy Downpours, and Drought. *Annals of the New York Academy of Sciences*, *1439*(1), 30–70. https://doi.org/10.1111/nyas.14007

Gorney, R. M., June, S. G., Stainbrook, K. M., & Smith, A. J. (2023). Detections of cyanobacteria harmful algal blooms (cyanoHABs) in New York State, United States (2012–2020). *Lake and Reservoir Management*, *39*(1), 21–36. https://doi.org/10.1080/10402381.2022.2161436

Gotanda, H., Fogel, J., Husk, G., Levine, J. M., Peterson, M., Baumlin, K., & Habboushe, J. (2015). Hurricane Sandy: Impact on Emergency Department and Hospital Utilization by Older Adults in Lower Manhattan, New York (USA). *Prehospital and Disaster Medicine*, *30*(5), 496–502. https://doi.org/10.1017/S1049023X15005087

Graff Zivin, J., Hsiang, S. M., & Neidell, M. (2018). Temperature and Human Capital in the Short and Long Run. *Journal of the Association of Environmental and Resource Economists*, *5*(1), 77–105. https://doi.org/10.1086/694177

Graff Zivin, J., Song, Y., Tang, Q., & Zhang, P. (2020). Temperature and high-stakes cognitive performance: Evidence from the national college entrance examination in China. *Journal of Environmental Economics and Management*, *104*, 102365. https://doi.org/10.1016/j.jeem.2020.102365

Graydon, R. C., Mezzacapo, M., Boehme, J., Foldy, S., Edge, T. A., Brubacher, J., Chan, H. M., Dellinger, M., Faustman, E. M., Rose, J. B., & Takaro, T. K. (2022). Associations between extreme precipitation, drinking water, and protozoan acute gastrointestinal illnesses in four North American Great Lakes cities (2009–2014). *Journal of Water and Health*, *20*(5), 849–862. https://doi.org/10.2166/wh.2022.018

Greene, S. K., Wilson, E. L., Konty, K. J., & Fine, A. D. (2013). Assessment of Reportable Disease Incidence After Hurricane Sandy, New York City, 2012. *Disaster Medicine and Public Health Preparedness*, *7*(5), 513–521. https://doi.org/10.1017/dmp.2013.98

Greer, S., Adams, L., Hinterland, K., Dongchung, T., Brahmbhatt, D., Miranda, T., Guan, Q., Kaye, K., & Gould, L. (2019). *Health of Older Adults in New York City* (pp. 1–32). New York City Department of Health and Mental Hygiene. https://www.nyc.gov/assets/doh/downloads/pdf/episrv/2019-older-adult-health.pdf

Gruenwald, T., Seals, B. A., Knibbs, L. D., & Hosgood, H. D. (2023). Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States. *International Journal of Environmental Research and Public Health*, *20*(1), Article 1. https://doi.org/10.3390/ijerph20010075

Gubernot, D. M., Anderson, G. B., & Hunting, K. L. (2014). The Epidemiology of Occupational Heat-Related Morbidity and Mortality in the United States: A Review of the Literature and Assessment of Research Needs in a Changing Climate. *International Journal of Biometeorology*, *58*(8), 1779–1788. https://doi.org/10.1007/s00484-013-0752-x

Gubernot, D. M., Anderson, G. B., & Hunting, K. L. (2015). Characterizing occupational heat-related mortality in the United States, 2000–2010: An analysis using the census of fatal occupational injuries database. *American Journal of Industrial Medicine*, *58*(2), 203–211. https://doi.org/10.1002/ajim.22381

Guidi, J., Lucente, M., Sonino, N., & Fava, G. A. (2021). Allostatic Load and Its Impact on Health: A Systematic Review. *Psychotherapy and Psychosomatics*, *90*(1), 11–27. https://doi.org/10.1159/000510696

Guo, Y., Gasparrini, A., Armstrong, B. G., Tawatsupa, B., Tobias, A., Lavigne, E., Coelho, M. de S. Z. S., Pan, X., Kim, H., Hashizume, M., Honda, Y., Guo, Y. L., Wu, C.-F., Zanobetti, A., Schwartz, J. D., Bell, M. L., Overcenco, A., Punnasiri, K., Li, S., … Tong, S. (2016). Temperature Variability and Mortality: A Multi-Country Study. *Environmental Health Perspectives*, *124*(10), 1554–1559. https://doi.org/10.1289/EHP149

Gusmano, M. K., Rodwin, V., & Weisz, D. (2010). *Health care in world cities: New York, Paris, and London*. Johns Hopkins University Press.

Hadley, M. B., Henderson, S. B., Brauer, M., & Vedanthan, R. (2022). Protecting Cardiovascular Health From Wildfire Smoke. *Circulation*, *146*(10), 788–801. https://doi.org/10.1161/CIRCULATIONAHA.121.058058

Hager, E. R., Quigg, A. M., Black, M. M., Coleman, S. M., Heeren, T., Rose-Jacobs, R., Cook, J. T., de Cuba, S. A. E., Casey, P. H., Chilton, M., Cutts, D. B., Meyers, A. F., & Frank, D. A. (2010). Development and Validity of a 2-Item Screen to Identify Families at Risk for Food Insecurity. *Pediatrics*, *126*(1), e26–e32. https://doi.org/10.1542/peds.2009-3146

Hajat, S., Armstrong, B., Baccini, M., Biggeri, A., Bisanti, L., Russo, A., Paldy, A., Menne, B., & Kosatsky, T. (2006). Impact of High Temperatures on Mortality: Is There an Added Heat Wave Effect? *Epidemiology*, *17*(6), 632–638. JSTOR.

Halawa, E., & van Hoof, J. (2012). The adaptive approach to thermal comfort: A critical overview. *Energy and*

Buildings, *51*, 101–110. https://doi.org/10.1016/j.enbuild.2012.04.011

Hall, G., Jessup, J., Lim, S., Olson, D., Seligson, A. L., He, F. T., De La Cruz, N., & Gwynn, C. (2016). Spatial Shift in the Utilization of Mental Health Services After Hurricane Sandy Among New York City Residents Enrolled in Medicaid. *Disaster Medicine and Public Health Preparedness*, *10*(3), 420–427. https://doi.org/10.1017/dmp.2016.58

Hansel, N. N., Breysse, P. N., McCormack, M. C., Matsui, E. C., Curtin-Brosnan, J., Williams, D. L., Moore, J. L., Cuhran, J. L., & Diette, G. B. (2008). A Longitudinal Study of Indoor Nitrogen Dioxide Levels and Respiratory Symptoms in Inner-City Children with Asthma. *Environmental Health Perspectives*, *116*(10), 1428–1432. https://doi.org/10.1289/ehp.11349

Hanson, M. C., Petch, G. M., Ottosen, T.-B., & Skjøth, C. A. (2022). Climate change impact on fungi in the atmospheric microbiome. *The Science of the Total Environment*, *830*, 154491. https://doi.org/10.1016/j.scitotenv.2022.154491

Hayley Smith. (2022, November 16). *Los Angeles DWP to end water and power shutoffs for low-income customers who can't pay*. Los Angeles Times. https://www.latimes.com/california/story/2022-11-16/l-a-to-end-water-and-power-shutoffs-for-low-income-customers-who-cant-pay

Health Canada. (2011). *Extreme Heat Events Guidelines: Technical Guide for Health Care Workers* (HC Publication 110055). Health Canada. https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/climate-change-health/extreme-heat-events-guidelines-technical-guide-health-care-workers.html

Heaney, A., Stowell, J. D., Liu, J. C., Basu, R., Marlier, M., & Kinney, P. (2022). Impacts of Fine Particulate Matter From Wildfire Smoke on Respiratory and Cardiovascular Health in California. *GeoHealth*, *6*(6), e2021GH000578. https://doi.org/10.1029/2021GH000578

Hegarty, B., Haverinen-Shaughnessy, U., Shaughnessy, R. J., & Peccia, J. (2019). Spatial Gradients of Fungal Abundance and Ecology throughout a Damp Building. *Environmental Science & Technology Letters*, *6*(6), 329–333. https://doi.org/10.1021/acs.estlett.9b00214

Henderson, S. B., McLean, K. E., Lee, M. J., & Kosatsky, T. (2022). Analysis of community deaths during the catastrophic 2021 heat dome. *Environmental Epidemiology*, *6*(1), e189. https://doi.org/10.1097/EE9.0000000000000189

Hernández, D. (2016). Understanding 'energy insecurity' and why it matters to health. *Social Science & Medicine*, *167*, 1–10. https://doi.org/10.1016/j.socscimed.2016.08.029

Hernández, D. (2018). What 'Merle' Taught Me About Energy Insecurity And Health. *Health Affairs*, *37*(3), 504–507. https://doi.org/10.1377/hlthaff.2017.1413

Hernández, D., Chang, D., Hutchinson, C., Hill, E., Almonte, A., Burns, R., Shepard, P., Gonzalez, I., Reissig, N., & Evans, D. (2018). Public Housing on the Periphery: Vulnerable Residents and Depleted Resilience Reserves post-Hurricane Sandy. *Journal of Urban Health*, *95*(5), 703–715. https://doi.org/10.1007/s11524-018-0280-4

Hernandez, E., Torres, R., & Joyce, A. L. (2019). Environmental and Sociological Factors Associated with the Incidence of West Nile Virus Cases in the Northern San Joaquin Valley of California, 2011–2015. *Vector-Borne and Zoonotic Diseases*, *19*(11), 851–858. https://doi.org/10.1089/vbz.2019.2437

Hirsch, A. G., Poulsen, M. N., Nordberg, C., Moon, K. A., Rebman, A. W., Aucott, J. N., Heaney, C. D., & Schwartz, B. S. (2020). Risk Factors and Outcomes of Treatment Delays in Lyme Disease: A Population-Based Retrospective Cohort Study. *Frontiers in Medicine*, *7*. https://www.frontiersin.org/articles/10.3389/fmed.2020.560018

Hirsch, B. (2020, March 31). *Coronavirus puts those living in flood-damaged homes at greater risk*. Kinder Institute for Urban Research | Rice University. https://kinder.rice.edu/urbanedge/coronavirus-puts-those-living-flood-damaged-homes-greater-risk

Hoffman, J. S., Shandas, V., & Pendleton, N. (2020a). The Effects of Historical Housing Policies on Resident Exposure to Intra-Urban Heat: A Study of 108 US Urban Areas. *Climate*, *8*(1), Article 1. https://doi.org/10.3390/cli8010012

Hoffman, J. S., Shandas, V., & Pendleton, N. (2020b). The Effects of Historical Housing Policies on Resident Exposure to Intra-Urban Heat: A Study of 108 US Urban Areas. *Climate*, *8*(1), 1–15.

Holt, D. W. E. (2015). Heat in US Prisons and Jails: Corrections and the Challenge of Climate Change. *SSRN*

Electronic Journal. https://doi.org/10.2139/ssrn.2667260

Holt-Lunstad, J., Smith, T. B., Baker, M., Harris, T., & Stephenson, D. (2015). Loneliness and social isolation as risk factors for mortality: A meta-analytic review. *Perspectives on Psychological Science: A Journal of the Association for Psychological Science*, *10*(2), 227–237. https://doi.org/10.1177/1745691614568352

Hooper, L., Bunn, D., Jimoh, F. O., & Fairweather-Tait, S. J. (2014). Water-loss dehydration and aging. *Mechanisms of Ageing and Development*, *136–137*, 50–58. https://doi.org/10.1016/j.mad.2013.11.009

Hornbach, C., Levers, A., & Yeung, L. (2022). *Bringing Basement Apartments Into the Light*. https://comptroller.nyc.gov/reports/bringing-basement-apartments-into-the-light/

Hosokawa, Y., Casa, D. J., Trtanj, J. M., Belval, L. N., Deuster, P. A., Giltz, S. M., Grundstein, A. J., Hawkins, M. D., Huggins, R. A., Jacklitsch, B., Jardine, J. F., Jones, H., Kazman, J. B., Reynolds, M. E., Stearns, R. L., Vanos, J. K., Williams, A. L., & Williams, W. J. (2019). Activity modification in heat: Critical assessment of guidelines across athletic, occupational, and military settings in the USA. *International Journal of Biometeorology*, *63*(3), 405–427. https://doi.org/10.1007/s00484-019-01673-6

Hu, J., Wen, Y., Duan, Y., Yan, S., Liao, Y., Pan, H., Zhu, J., Yin, P., Cheng, J., & Jiang, H. (2020). The impact of extreme heat and heat waves on emergency ambulance dispatches due to external cause in Shenzhen, China. *Environmental Pollution (Barking, Essex: 1987)*, *261*, 114156. https://doi.org/10.1016/j.envpol.2020.114156

Huang, H., Winter, J. M., Osterberg, E. C., Horton, R. M., & Beckage, B. (2017). Total and Extreme Precipitation Changes over the Northeastern United States. *Journal of Hydrometeorology*, *18*(6), 1783–1798. https://doi.org/10.1175/JHM-D-16-0195.1

Hughes, C. H., & Marroquin, M. (2023, November 16). *The mayor wants to make basement apartments legal*. Crain's New York Business. https://www.crainsnewyork.com/real-estate/eric-adams-hopes-legalizing-basement-apartments-will-boost-nyc-housing-supply

Intergovernmental Panel on Climate Change. (2023). *Fact Sheet-Health*. https://www.ipcc.ch/report/ar6/wg2/downloads/outreach/IPCC_AR6_WGII_FactSheet_Health.pdf

Irizarry Aponte, C., & Maldonado, S. (2022, July 28). UPS Drivers Demand AC in Trucks Following Heat Wave: 'It's Like Walking Into Hell.' *The City*. https://www.thecity.nyc/work/2022/7/27/23281777/ups-drivers-trucks-heat-wave-hell

Ito, K., Johnson, S., Kheirbek, I., Clougherty, J., Pezeshki, G., Ross, Z., Eisl, H., & Matte, T. D. (2016). Intraurban Variation of Fine Particle Elemental Concentrations in New York City. *Environmental Science & Technology*, *50*(14), 7517–7526. https://doi.org/10.1021/acs.est.6b00599

Ito, K., Lane, K., & Olson, C. (2018). Equitable Access to Air Conditioning: A City Health Department's Perspective on Preventing Heat-related Deaths. *Epidemiology*, *29*(6), 749–752. https://doi.org/10.1097/EDE.0000000000000912

Ito, K., Mathes, R., Ross, Z., Nádas, A., Thurston, G., & Matte, T. (2011). Fine particulate matter constituents associated with cardiovascular hospitalizations and mortality in New York City. *Environmental Health Perspectives*, *119*(4), 467.

Ito, K., Weinberger, K. R., Robinson, G. S., Sheffield, P. E., Lall, R., Mathes, R., Ross, Z., Kinney, P. L., & Matte, T. D. (2015). The associations between daily spring pollen counts, over-the-counter allergy medication sales, and asthma syndrome emergency department visits in New York City, 2002-2012. *Environmental Health*, *14*(1), 71.

Jaeger, P., Fleischmann, K., Preece, J., Shneiderman, B., Wu, P., & Qu, Y. (2008). Community Response Grids: Using Information Technology to Help Communities Respond to Bioterror Emergencies. *Biosecurity and Bioterrorism : Biodefense Strategy, Practice, and Science*, *5*, 335–345. https://doi.org/10.1089/bsp.2007.0034

Jain, R. (2021). *The Construction Industry in New York City: Recent Trends and Impact of COVID-19* (3–2021). Office of the State Deputy Comptroller for the City of New York. https://www.osc.state.ny.us/reports/osdc/construction-industry-new-york-city-recent-trends-and-impact-covid-19

Jbaily, A., Zhou, X., Liu, J., Lee, T.-H., Kamareddine, L., Verguet, S., & Dominici, F. (2022). Air pollution exposure disparities across US population and income groups. *Nature*, *601*(7892), 228–233. https://doi.org/10.1038/s41586-021-04190-y

Jhun, I., Coull, B. A., Zanobetti, A., & Koutrakis, P. (2015). The impact of nitrogen oxides concentration decreases on ozone trends in the USA. *Air Quality, Atmosphere, & Health*, *8*(3), 283–292. https://doi.org/10.1007/s11869-014-0279-2

Jhun, I., Fann, N., Zanobetti, A., & Hubbell, B. (2014). Effect modification of ozone-related mortality risks by temperature in 97 US cities. *Environment International*, *73*, 128–134. https://doi.org/10.1016/j.envint.2014.07.009

Johnson, S., Bobb, J. F., Ito, K., Savitz, D. A., Elston, B., Shmool, J. L., Dominici, F., Ross, Z., Clougherty, J. E., & Matte, T. (2016). Ambient fine particulate matter, nitrogen dioxide, and preterm birth in New York City. *Environmental Health Perspectives*, *124*(8), 1283.

Johnson, S., Haney, J., Cairone, L., Huskey, C., & Kheirbek, I. (2020). Assessing Air Quality and Public Health Benefits of New York City's Climate Action Plans. *Environmental Science & Technology*. https://doi.org/10.1021/acs.est.0c00694

Johnson, S., Ross, Z., Kheirbek, I., & Ito, K. (2020). Characterization of intra-urban spatial variation in observed summer ambient temperature from the New York City Community Air Survey. *Urban Climate*, *31*, 100583. https://doi.org/10.1016/j.uclim.2020.100583

Kang, S., Zhang, Y., Qian, Y., & Wang, H. (2020). A review of black carbon in snow and ice and its impact on the cryosphere. *Earth-Science Reviews*, *210*, 103346. https://doi.org/10.1016/j.earscirev.2020.103346

Karliner, L. S., Kim, S. E., Meltzer, D. O., & Auerbach, A. D. (2010). Influence of language barriers on outcomes of hospital care for general medicine inpatients. *Journal of Hospital Medicine*, *5*(5), 276–282. https://doi.org/10.1002/jhm.658

Kavosh, E., Weinstein, M., Kanuga, M., & Bielory, L. (2009). Trends in Tree Pollen in the New York Metropolitan Area. *Journal of Allergy and Clinical Immunology*, *123*(2), S96. https://doi.org/10.1016/j.jaci.2008.12.343

Kenny, G. P., Poirier, M. P., Metsios, G. S., Boulay, P., Dervis, S., Friesen, B. J., Malcolm, J., Sigal, R. J., Seely, A. J. E., & Flouris, A. D. (2017). Hyperthermia and cardiovascular strain during an extreme heat exposure in young versus older adults. *Temperature (Austin, Tex.)*, *4*(1), 79–88. https://doi.org/10.1080/23328940.2016.1230171

Keyel, A. C., Raghavendra, A., Ciota, A. T., & Elison Timm, O. (2021). West Nile virus is predicted to be more geographically widespread in New York State and Connecticut under future climate change. *Global Change Biology*, *27*(21), 5430–5445. https://doi.org/10.1111/gcb.15842

Keyel, A. C., Timm, O. E., Backenson, P. B., Prussing, C., Quinones, S., McDonough, K. A., Vuille, M., Conn, J. E., Armstrong, P. M., Andreadis, T. G., & Kramer, L. D. (2019). Seasonal temperatures and hydrological conditions improve the prediction of West Nile virus infection rates in Culex mosquitoes and human case counts in New York and Connecticut. *PLOS ONE*, *14*(6), e0217854. https://doi.org/10.1371/journal.pone.0217854

Kheirbek, I., Haney, J., Douglas, S., Ito, K., Caputo Jr, S., & Matte, T. (2014). The public health benefits of reducing fine particulate matter through conversion to cleaner heating fuels in New York City. *Environmental Science & Technology*, *48*(23), 13573–13582. http://pubs.acs.org/doi/abs/10.1021/es503587p

Kheirbek, I., Haney, J., Douglas, S., Ito, K., & Matte, T. (2016). The contribution of motor vehicle emissions to ambient fine particulate matter public health impacts in New York City: A health burden assessment. *Environmental Health*, *15*(1), 1–14. https://doi.org/10.1186/s12940-016-0172-6

Kheirbek, I., Ito, K., Neitzel, R., Kim, J., Johnson, S., Ross, Z., Eisl, H., & Matte, T. (2014). Spatial variation in environmental noise and air pollution in New York City. *Journal of Urban Health*, *91*(3), 415–431.

Kim, Y., Kim, H., Gasparrini, A., Armstrong, B., Honda, Y., Chung, Y., Ng, C. F. S., Tobias, A., Íñiguez, C., Lavigne, E., Sera, F., Vicedo-Cabrera, A. M., Ragettli, M. S., Scovronick, N., Acquaotta, F., Chen, B.-Y., Guo, Y.-L. L., Seposo, X., Dang, T. N., … Hashizume, M. (2019). Suicide and Ambient Temperature: A Multi-Country Multi-City Study. *Environmental Health Perspectives*, *127*(11), 117007. https://doi.org/10.1289/EHP4898

Kinney, P. L., Matte, T., Knowlton, K., Madrigano, J., Petkova, E., Weinberger, K., Quinn, A., Arend, M., & Pullen, J. (2015). New York City Panel on Climate Change 2015 Report Chapter 5: Public Health Impacts and Resiliency. *Annals of the New York Academy of Sciences*, *1336*(1), 67–88. https://doi.org/10.1111/nyas.12588

Klinenberg, E. (2001). Dying alone: The social production of urban isolation. *Ethnography*, *2*(4), 501–531. JSTOR.

Klinenberg, E. (2015). *Heat wave: A social autopsy of disaster in Chicago* (Second edition). University of Chicago

Press.

Knowlton, K., Rosenthal, J. E., Hogrefe, C., Lynn, B., Gaffin, S., Goldberg, R., Rosenzweig, C., Civerolo, K., Ku, J.-Y., & Kinney, P. L. (2004). Assessing Ozone-Related Health Impacts under a Changing Climate. *Environmental Health Perspectives*, *112*(15), 1557–1563. https://doi.org/10.1289/ehp.7163

Kreslake, J. M. (2019). Perceived Importance of Climate Change Adaptation and Mitigation According to Social and Medical Factors Among Residents of Impacted Communities in the United States. *Health Equity*, *3*(1), 124–133. https://doi.org/10.1089/heq.2019.0002

Kully, S. K. (2020, May 11). *City's Basement Apartment Program Buried by COVID-19 Budget Cuts*. City Limits. https://citylimits.org/2020/05/11/citys-basement-apartment-program-buried-by-covid-19-budget-cuts/

Kurth, C., & Pihkala, P. (2022). Eco-anxiety: What it is and why it matters. *Frontiers in Psychology*, *13*, 981814. https://doi.org/10.3389/fpsyg.2022.981814

Lai, S., & Fisher, M. (2021, September 5). Life and death underground: N.Y. immigrants perish in flooded basements. *Washington Post*. https://www.washingtonpost.com/politics/hurricane-ida-new-york-floods/2021/09/04/b661e9da-0ce7-11ec-a6dd-296ba7fb2dce_story.html

Lane, K., Charles-Guzman, K., Wheeler, K., Abid, Z., Graber, N., & Matte, T. (2013). Health Effects of Coastal Storms and Flooding in Urban Areas: A Review and Vulnerability Assessment. *Journal of Environmental and Public Health*, *2013*, 913064. https://doi.org/10.1155/2013/913064

Lane, K., Ito, K., Johnson, S., Gibson, E. A., Tang, A., & Matte, T. (2018). Burden and Risk Factors for Cold-Related Illness and Death in New York City. *International Journal of Environmental Research and Public Health*, *15*(4), 632. https://doi.org/10.3390/ijerph15040632

Lane, K., Smalls-Mantey, L., Hernández, D., Watson, S., Jessel, S., Jack, D., Spaulding, L., & Olson, C. (2023). Extreme Heat and COVID-19 in New York City: An Evaluation of a Large Air Conditioner Distribution Program to Address Compounded Public Health Risks in Summer 2020. *Journal of Urban Health*. https://doi.org/10.1007/s11524-022-00704-9

Lane, K., Wheeler, K., Charles-Guzman, K., Ahmed, M., Blum, M., Gregory, K., Graber, N., Clark, N., & Matte, T. (2014). Extreme heat awareness and protective behaviors in New York City. *Journal of Urban Health*, *91*(3), 403–414. https://doi.org/10.1007/s11524-013-9850-7

Lapointe, M., Rochman, C. M., & Tufenkji, N. (2022). Sustainable strategies to treat urban runoff needed. *Nature Sustainability*, *5*(5), Article 5. https://doi.org/10.1038/s41893-022-00853-4

Lara, B., Rojo, J., Fernández-González, F., González-García-Saavedra, A., Serrano-Bravo, M. D., & Pérez-Badia, R. (2020). Impact of Plane Tree Abundance on Temporal and Spatial Variations in Pollen Concentration. *Forests*, *11*(8), Article 8. https://doi.org/10.3390/f11080817

Larose, J., Wright, H. E., Stapleton, J., Sigal, R. J., Boulay, P., Hardcastle, S., & Kenny, G. P. (2013). Whole body heat loss is reduced in older males during short bouts of intermittent exercise. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, *305*(6), R619–R629. https://doi.org/10.1152/ajpregu.00157.2013

Latha, P. K., Darshana, Y., & Venugopal, V. (2015). Role of building material in thermal comfort in tropical climates – A review. *Journal of Building Engineering*, *3*, 104–113. https://doi.org/10.1016/j.jobe.2015.06.003

Laumbach, R. J., Cromar, K. R., Adamkiewicz, G., Carlsten, C., Charpin, D., Chan, W. R., de Nazelle, A., Forastiere, F., Goldstein, J., Gumy, S., Hallman, W. K., Jerrett, M., Kipen, H. M., Pirozzi, C. S., Polivka, B. J., Radbel, J., Shaffer, R. E., Sin, D. D., & Viegi, G. (2021). Personal Interventions for Reducing Exposure and Risk for Outdoor Air Pollution: An Official American Thoracic Society Workshop Report. *Annals of the American Thoracic Society*, *18*(9), 1435–1443. https://doi.org/10.1513/AnnalsATS.202104-421ST

Lawrance, E. L., Thompson, R., Newberry Le Vay, J., Page, L., & Jennings, N. (2022). The Impact of Climate Change on Mental Health and Emotional Wellbeing: A Narrative Review of Current Evidence, and its Implications. *International Review of Psychiatry (Abingdon, England)*, *34*(5), 443–498. https://doi.org/10.1080/09540261.2022.2128725

Lebel, E. D., Finnegan, C. J., Ouyang, Z., & Jackson, R. B. (2022). Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology*, *56*(4), 2529–2539. https://doi.org/10.1021/acs.est.1c04707

Lempert, K. D., & Kopp, J. B. (2013). Hurricane Sandy as a Kidney Failure Disaster. *American Journal of Kidney Diseases : The Official Journal of the National Kidney Foundation*, *61*(6), 865–868.

https://doi.org/10.1053/j.ajkd.2013.03.017

Lerardi, A. M., & Pavilonis, B. (2020). Heat stress risk among New York City public school kitchen workers: A quantitative exposure assessment. *Journal of Occupational and Environmental Hygiene*, *17*(7–8), 353–363. https://doi.org/10.1080/15459624.2020.1776300

Lewis, J., Hernández, D., & Geronimus, A. T. (2019). Energy Efficiency as Energy Justice: Addressing Racial Inequities through Investments in People and Places. *Energy Efficiency*, *13*(3), 419–432. https://doi.org/10.1007/s12053-019-09820-z

Li, D., Newman, G., Zhang, T., Zhu, R., & Horney, J. (2021). Coping with post-hurricane mental distress: The role of neighborhood green space. *Social Science & Medicine (1982)*, *281*, 114084. https://doi.org/10.1016/j.socscimed.2021.114084

Liang, S. Y., & Messenger, N. (2018). Infectious diseases after hydrologic disasters. *Emergency Medicine Clinics of North America*, *36*(4), 835–851. https://doi.org/10.1016/j.emc.2018.07.002

Limaye, V. S., Max, W., Constible, J., & Knowlton, K. (2019). Estimating the Health-Related Costs of 10 Climate-Sensitive U.S. Events During 2012. *GeoHealth*, *3*(9), 245–265. https://doi.org/10.1029/2019GH000202

Limaye, V. S., Max, W., Constible, J., & Knowlton, K. (2020). Estimating The Costs Of Inaction And The Economic Benefits Of Addressing The Health Harms Of Climate Change: Commentary describes illuminates the costs of inaction on the climate crisis and the economic savings of addressing this problem. *Health Affairs*, *39*(12), 2098–2104. https://doi.org/10.1377/hlthaff.2020.01109

Lin, S., Luo, M., Walker, R. J., Liu, X., Hwang, S.-A., & Chinery, R. (2009). Extreme High Temperatures and Hospital Admissions for Respiratory and Cardiovascular Diseases. *Epidemiology*, *20*(5), 738–746. https://doi.org/10.1097/EDE.0b013e3181ad5522

Lin, S., Shrestha, S., Prusinski, M. A., White, J. L., Lukacik, G., Smith, M., Lu, J., & Backenson, B. (2019). The effects of multiyear and seasonal weather factors on incidence of Lyme disease and its vector in New York State. *The Science of the Total Environment*, *665*, 1182–1188. https://doi.org/10.1016/j.scitotenv.2019.02.123

Lin, W., Brunekreef, B., & Gehring, U. (2013). Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children. *International Journal of Epidemiology*, *42*(6), 1724–1737. https://doi.org/10.1093/ije/dyt150

Liu, Y. J., & Fraustino, J. D. (2012). *Social Media Use during Disasters: A Review of the Knowledge Base and Gaps - World | ReliefWeb*. Relief Web. https://reliefweb.int/report/world/social-media-use-during-disasters-review-knowledge-base-and-gaps

Liu, Y., Saha, S., Hoppe, B. O., & Convertino, M. (2019). Degrees and dollars – Health costs associated with suboptimal ambient temperature exposure. *Science of The Total Environment*, *678*, 702–711. https://doi.org/10.1016/j.scitotenv.2019.04.398

Local Law 30, Pub. L. No. 30, Title 23 New York City Administrative Code (2017). https://www.nyc.gov/assets/immigrants/downloads/pdf/Local_Law_30.pdf

Local Law 42, Pub. L. No. 42, Title 3: Elected Officials; Chapter1: Mayor New York City Administrative Code (2012). https://nyc.legistar1.com/nyc/attachments/ade600bb-18ec-46b1-bf06-4a941d838547.pdf

Logue, J. M., Klepeis, N. E., Lobscheid, A. B., & Singer, B. C. (2014). Pollutant Exposures from Natural Gas Cooking Burners: A Simulation-Based Assessment for Southern California. *Environmental Health Perspectives*, *122*(1), 43–50. https://doi.org/10.1289/ehp.1306673

Lõhmus, M. (2018). Possible Biological Mechanisms Linking Mental Health and Heat—A Contemplative Review. *International Journal of Environmental Research and Public Health*, *15*(7), 1515. https://doi.org/10.3390/ijerph15071515

Lovasi, G. S., O'Neil-Dunne, J. P. M., Lu, J. W. T., Sheehan, D., Perzanowski, M. S., MacFaden, S. W., King, K. L., Matte, T., Miller, R. L., Hoepner, L. A., Perera, F. P., & Rundle, A. (2013). Urban Tree Canopy and Asthma, Wheeze, Rhinitis, and Allergic Sensitization to Tree Pollen in a New York City Birth Cohort. *Environmental Health Perspectives*, *121*(4), 494–500. https://doi.org/10.1289/ehp.1205513

Lynch, V. D., & Shaman, J. (2023). Waterborne Infectious Diseases Associated with Exposure to Tropical Cyclonic Storms, United States, 1996–2018. *Emerging Infectious Diseases*, *29*(8), 1548–1558. https://doi.org/10.3201/eid2908.221906

Mackenzie, J. (2022, August 9). Seoul floods: At least eight dead amid heaviest rain in decades. *BBC News*. https://www.bbc.com/news/world-asia-62462275

Madajewicz, M. (2020). Who is vulnerable and who is resilient to coastal flooding? Lessons from Hurricane Sandy in New York City. *Climatic Change*, *163*(4), 2029–2053. https://doi.org/10.1007/s10584-020-02896-y

Madrigano, J., Ito, K., Johnson, S., Kinney, P. L., & Matte, T. (2015). A Case-Only Study of Vulnerability to Heat Wave–Related Mortality in New York City (2000–2011). *Environmental Health Perspectives*, *123*(7), 672–678. https://doi.org/10.1289/ehp.1408178

Madrigano, J., Lane, K., Petrovic, N., Ahmed, M., Blum, M., & Matte, T. (2018). Awareness, Risk Perception, and Protective Behaviors for Extreme Heat and Climate Change in New York City. *International Journal of Environmental Research and Public Health*, *15*(7), 1433. https://doi.org/10.3390/ijerph15071433

Magnavita, N., Capitanelli, I., Ilesanmi, O., & Chirico, F. (2022). Occupational Lyme Disease: A Systematic Review and Meta-Analysis. *Diagnostics*, *12*(2), Article 2. https://doi.org/10.3390/diagnostics12020296

Mangus, C. W., & Canares, T. L. (2019). Heat-Related Illness in Children in an Era of Extreme Temperatures. *Pediatrics In Review*, *40*(3), 97–107. https://doi.org/10.1542/pir.2017-0322

Manuel, J. (2013). The Long Road to Recovery: Environmental Health Impacts of Hurricane Sandy. *Environmental Health Perspectives*, *121*(5), a152–a159. https://doi.org/10.1289/ehp.121-a152

Marcotullio, P., Braçe, O., Lane, K., Olson, C. E., Tipaldo, J., Ventrella, J., Yoon, L., Knowlton, K., Anand, G., & Matte, T. (2023). Local power outages, heat, and community characteristics in New York City. *Sustainable Cities and Society*, *99*, 104932. https://doi.org/10.1016/j.scs.2023.104932

Mares, D. (2013). Climate Change and Levels of Violence in Socially Disadvantaged Neighborhood Groups. *Journal of Urban Health*, *90*(4), 768–783. https://doi.org/10.1007/s11524-013-9791-1

Margolis, A. E., Herbstman, J. B., Davis, K. S., Thomas, V. K., Tang, D., Wang, Y., Wang, S., Perera, F. P., Peterson, B. S., & Rauh, V. A. (2016). Longitudinal effects of prenatal exposure to air pollutants on self-regulatory capacities and social competence. *Journal of Child Psychology and Psychiatry*, *57*(7), 851–860. https://doi.org/10.1111/jcpp.12548

Maricopa Association of Governments. (2023). *Heat Relief Network*. https://azmag.gov/Programs/Heat-Relief-Network

Marzuk, P., Tardiff, K., Leon, A. C., Hirsch, C. S., Portera, L., Iqbal, M. I., Nock, M. K., & Hartwell, N. (1998). Ambient temperature and mortality from unintentional cocaine overdose—PubMed. *Journal of Academic Medicine*, *279*(22), 1795–1800. https://doi.org/10.1001/jama.279.22.1795

Mathes, R. W., Ito, K., Lane, K., & Matte, T. D. (2017). Real-time surveillance of heat-related morbidity: Relation to excess mortality associated with extreme heat. *PLOS ONE*, *12*(9), e0184364. https://doi.org/10.1371/journal.pone.0184364

Matte, T. D., Lane, K., & Ito, K. (2016). Excess Mortality Attributable to Extreme Heat in New York City, 1997-2013. *Health Security*, *14*(2), 64–70. https://doi.org/10.1089/hs.2015.0059

McConnell, M. (2019). *"When We're Dead and Buried, Our Bones Will Keep Hurting": Workers' Rights Under Threat in US Meat and Poultry Plants*. Human Rights Watch. https://www.hrw.org/report/2019/09/04/when-were-dead-and-buried-our-bones-will-keep-hurting/workers-rights-under-threat

McDonald, E., Mathis, S., Martin, S. W., Erin Staples, J., Fischer, M., & Lindsey, N. P. (2021). Surveillance for West Nile virus disease—United States, 2009-2018. *American Journal of Transplantation: Official Journal of the American Society of Transplantation and the American Society of Transplant Surgeons*, *21*(5), 1959–1974. https://doi.org/10.1111/ajt.16595

McDonough, A. (2023, January 24). *NYC's basement apartment pilot draws only 5 participants*. City & State NY. https://www.cityandstateny.com/policy/2023/01/nycs-basement-apartment-pilot-draws-only-5-participants/382166/

McLellan, T. M., Daanen, H. A. M., & Cheung, S. S. (2013). Encapsulated Environment. In *Comprehensive Physiology* (pp. 1363–1391). John Wiley & Sons, Ltd. https://doi.org/10.1002/cphy.c130002

McPhearson, T., Towers, J., Rosenzweig, B. R., & Knowlton, K. (2024). *Climate Vulnerability, Impact, and Adaptation Analysis (VIA) (in preparation)*. NYC Mayor's Office of Climate and Environmental Justice. https://climate.cityofnewyork.us/initiatives/vulnerability-impacts-and-adaptation-analysis/

McQuade, L., Merriman, B., Lyford, M., Nadler, B., Desai, S., Miller, R., & Mallette, S. (2018). Emergency Department and Inpatient Health Care Services Utilization by the Elderly Population: Hurricane Sandy in The State of New Jersey. *Disaster Medicine and Public Health Preparedness*, *12*(6), 730–738. https://doi.org/10.1017/dmp.2018.1

Meade, R. D., Akerman, A. P., Notley, S. R., McGinn, R., Poirier, P., Gosselin, P., & Kenny, G. P. (2020). Physiological factors characterizing heat-vulnerable older adults: A narrative review. *Environment International*, *144*, 105909. https://doi.org/10.1016/j.envint.2020.105909

Medina, L., Sabo, S., & Vespa, J. (2020). *Living Longer: Historical and Projected Life Expectancy in the United States, 1960 to 2060* (P25-1145; p. 27). US Department of Commerce; US Census Bureau.

Mendez-Figueroa, H., Chauhan, S. P., Tolcher, M. C., Shamshirsaz, A. A., Sangi-Haghpeykar, H., Pace, R. M., Chu, D. M., & Aagaard, K. (2019). Peripartum Outcomes Before and After Hurricane Harvey. *Obstetrics and Gynecology*, *134*(5), 1005–1016. https://doi.org/10.1097/AOG.0000000000003522

Metzger, K. B., Ito, K., & Matte, T. D. (2010a). Summer Heat and Mortality in New York City: How Hot Is Too Hot? *Environmental Health Perspectives*, *118*(1), 80–86. https://doi.org/10.1289/ehp.0900906

Metzger, K. B., Ito, K., & Matte, T. D. (2010b). Summer Heat and Mortality in New York City: How Hot Is Too Hot? *Environmental Health Perspectives*, *118*(1), 80–86. https://doi.org/10.1289/ehp.0900906

Millyard, A., Layden, J. D., Pyne, D. B., Edwards, A. M., & Bloxham, S. R. (2020). Impairments to Thermoregulation in the Elderly During Heat Exposure Events. *Gerontology and Geriatric Medicine*, *6*, 2333721420932432. https://doi.org/10.1177/2333721420932432

Minor, K., Bjerre-Nielsen, A., Jonasdottir, S. S., Lehmann, S., & Obradovich, N. (2022). Rising temperatures erode human sleep globally. *One Earth*, *5*(5), 534–549. https://doi.org/10.1016/j.oneear.2022.04.008

Molinsky, J., & Forsyth, A. (2022). Climate Change, Aging, and Well-being: How Residential Setting Matters. *Housing Policy Debate*, *0*(0), 1–25. https://doi.org/10.1080/10511482.2022.2109711

Moon, K. A., Pollak, J. S., Poulsen, M. N., Heaney, C. D., Hirsch, A. G., & Schwartz, B. S. (2021). Risk factors for Lyme disease stage and manifestation using electronic health records. *BMC Infectious Diseases*, *21*(1), 1269. https://doi.org/10.1186/s12879-021-06959-y

Mora, C., Counsell, C. W. W., Bielecki, C. R., & Louis, L. V. (2017). Twenty-Seven Ways a Heat Wave Can Kill You: Deadly Heat in the Era of Climate Change. *Circulation: Cardiovascular Quality and Outcomes*, *10*(11), e004233. https://doi.org/10.1161/CIRCOUTCOMES.117.004233

Moreno-Madriñán, M. J., & Turell, M. (2018). History of Mosquitoborne Diseases in the United States and Implications for New Pathogens. *Emerging Infectious Diseases*, *24*(5), 821–826. https://doi.org/10.3201/eid2405.171609

Morris, C. (2022). N.Y.C. rent prices hit an all-time high, with one borough topping $4,100 [Fortune]. *Finance - Real Estate*. https://fortune.com/2022/08/11/nyc-rent-prices-hit-all-time-high/

Mort, M., Walker, M., Williams, A. L., & Bingley, A. (2018). Displacement: Critical insights from flood-affected children. *Health & Place*, *52*, 148–154. https://doi.org/10.1016/j.healthplace.2018.05.006

Mullen, N. A., Li, J., Russell, M. L., Spears, M., Less, B. D., & Singer, B. C. (2016). Results of the California Healthy Homes Indoor Air Quality Study of 2011–2013: Impact of natural gas appliances on air pollutant concentrations. *Indoor Air*, *26*(2), 231–245. https://doi.org/10.1111/ina.12190

Nasci, R. S., & Mutebi, J.-P. (2019). Reducing West Nile Virus Risk Through Vector Management. *Journal of Medical Entomology*, *56*(6), 1516–1521. https://doi.org/10.1093/jme/tjz083

National Archives. (2023). *42 CFR Part 483—Requirements for States and Long Term Care Facilities*. Code of Federal Regulations. https://www.ecfr.gov/current/title-42/chapter-IV/subchapter-G/part-483

National Institute for Occupational Safety and Health (NIOSH). (2020, February 20). *Heat Stress Acclimatization | NIOSH | CDC*. https://www.cdc.gov/niosh/topics/heatstress/acclima.html

National Institute of Mental Health (NIH). (2023). *Mental Illness*. National Institute of Mental Health (NIMH) | Mental Illness. https://www.nimh.nih.gov/health/statistics/mental-illness

National Oceanic and Atmospheric Administration. (2022). *The State of High Tide Flooding and 2022 Outlook* [Government]. NOAA | Tides & Currents. https://tidesandcurrents.noaa.gov/HighTideFlooding_AnnualOutlook.html

National Oceanic and Atmospheric Administration. (2023a). *About Urban Heat Islands*. Urban Heat Islands | HEAT.Gov - National Integrated Heat Health Information System. https://www.heat.gov/pages/urban-heat-islands

National Oceanic and Atmospheric Administration. (2023b). *Heat.Gov: National Integrated Heat Health Information System (NIHHIS)*. HEAT.Gov - National Integrated Heat Health Information System. https://www.heat.gov/

National Oceanic and Atmospheric Administration. (2023c). *Weather Related Fatality and Injury Statistics: Weather Fatalities 2022*. Weather Related Fatality and Injury Statistics; NOAA's National Weather Service. https://www.weather.gov/hazstat/

National Oceanic and Atmospheric Administration. (2023d). *Who is most at risk to extreme heat?* Who Is at Risk to Extreme Heat | HEAT.Gov - National Integrated Heat Health Information System. https://www.heat.gov/pages/who-is-at-risk-to-extreme-heat

National Weather Service. (2023). *National Weather Service New York, NY Excessive Heat Page*. NOAA's National Weather Service. https://www.weather.gov/okx/excessiveheat

Natural Resources Defense Council. (2023). *How States Stack Up on Flood Disclosure*. How States Stack Up on Flood Disclosure. https://www.nrdc.org/flood-disclosure-map

Nayak, S. G., Shrestha, S., Kinney, P. L., Ross, Z., Sheridan, S. C., Pantea, C. I., Hsu, W. H., Muscatiello, N., & Hwang, S. A. (2018). Development of a heat vulnerability index for New York State. *Public Health*, *161*, 127–137. https://doi.org/10.1016/j.puhe.2017.09.006

Negret, M. (2021, September 15). *Measuring Flood Risk in New York City Housing and Basements*. RPA. https://rpa.org/latest/lab/flood-risk-new-york-city-residential-basement-apartments

Negret, M., & McNulty, M. (2021, July 15). *Improving Stormwater Management in the New York City Subway*. https://rpa.org/latest/lab/flooding-stormwater-in-new-york-city-subway

New York City Housing Authority. (2022). *Emergency Preparedness: Evacuations*. Evacuations - NYCHA. https://www1.nyc.gov/site/nycha/residents/evacuations.page

New York City Housing Authority. (2023). *NYCHA 2023 Fact Sheet*. https://www.nyc.gov/assets/nycha/downloads/pdf/NYCHA-Fact-Sheet-2023.pdf

New York City Panel on Climate Change. (2019). New York City Panel on Climate Change 2019 Report: Conclusions and Recommendations. *Annals of the New York Academy of Sciences*, *1439*(1), 306–311. https://doi.org/10.1111/nyas.14032

New York State. (2004, November 17). *Section 415.29—Physical environment | New York Codes, Rules and Regulations*. https://regs.health.ny.gov/content/section-41529-physical-environment

New York State Department of Environmental Conservation. (2023a, April 4). *Harmful Algal Blooms by Waterbody Summary: Beginning 2019 | State of New York*. https://data.ny.gov/Energy-Environment/Harmful-Algal-Blooms-by-Waterbody-Summary-Beginnin/95my-wijm

New York State Department of Environmental Conservation. (2023b, June 7). *Air Quality Health Advisory Issued for Long Island, New York City Metro, Lower Hudson Valley, Upper Hudson Valley, Eastern Lake Ontario, Central New York and Western New York -*. https://dec.ny.gov/news/press-releases/2023/6/air-quality-health-advisory-issued-for-long-island-new-york-city-metro-lower-hudson-valley-upper-hudson-valley-eastern-lake-ontario-central-new-york-and-western-new-york

New York State Department of Public Service. (2022). *Home Energy Fair Practices Act (HEFPA): About Home Energy Fair Practices Act (HEFPA)* [Government]. Home Energy Fair Practices Act (HEFPA) | Department of Public Service. https://dps.ny.gov/home-energy-fair-practices-act-hefpa

Newman, A. (2023, June 28). A Record 100,000 People in New York Homeless Shelters. *The New York Times*. https://www.nytimes.com/2023/06/28/nyregion/nyc-homeless-shelter-population.html

Niu, L., Herrera, M. T., Girma, B., Liu, B., Schinasi, L., Clougherty, J. E., & Sheffield, P. E. (2022). High ambient temperature and child emergency and hospital visits in New York City. *Paediatric and Perinatal Epidemiology*, *36*(1), 36–44. https://doi.org/10.1111/ppe.12793

Nori-Sarma, A., Sun, S., Sun, Y., Spangler, K. R., Oblath, R., Galea, S., Gradus, J. L., & Wellenius, G. A. (2022). Association Between Ambient Heat and Risk of Emergency Department Visits for Mental Health Among US Adults, 2010 to 2019. *JAMA Psychiatry*, *79*(4), 341–349. https://doi.org/10.1001/jamapsychiatry.2021.4369

Notify NYC. (2023, June 5). *Air Quality Health Advisory: 12:00AM to 11:59 PM on 6/6* [Public Service]. X (Twitter). https://twitter.com/NotifyNYC/status/1665815213868736512

nyc covid vaccine appointments [@nycshotslots]. (2021, June 16). *The LinkNYC vaccine screens are still getting updated weekly. Big thanks to @AnnieMabus for helping us make this happen. This week 1800 kiosks are advertising 184 walk-up sites in English and Spanish.* [Tweet]. X (Twitter). https://twitter.com/nycshotslots/status/1405261562101780481

NYC Department of City Planning. (2022). *2020 Census*. https://www1.nyc.gov/site/planning/planning-level/nyc-population/2020-census.page#ensuring-accurate-account

NYC Department of Environmental Protection. (2022). *Water Supply*. Water Supply - DEP. https://www1.nyc.gov/site/dep/water/water-supply.page

NYC Department of Health and Mental Hygiene. (2023, February 7). *Seventeenth Annual Report on Deaths among Persons Experiencing Homelessness*. https://a860-gpp.nyc.gov/concern/nyc_government_publications/nc580q435?locale=en

NYC Mayor's Office of Immigrant Affairs & NYC Mayor's Office of Operations. (2022). *Local Law 30 Report for Calendar Year 2021*. NYC Mayor's Office. https://www.nyc.gov/assets/immigrants/downloads/pdf/CY2021-local-law-30-report.pdf

NYC Speaks. (2023). *North Star #3: Neighborhood Hubs*. NYC Speaks. https://nycspeaks.org/north-star3/

Obradovich, N., Migliorini, R., Mednick, S. C., & Fowler, J. H. (2017). Nighttime temperature and human sleep loss in a changing climate. *Science Advances*, *3*(5), e1601555. https://doi.org/10.1126/sciadv.1601555

Occupational Safety and Health Administration. (2022). *OSHA Frequently Asked Questions: Temperature and Weather-Related*. OSHA Frequently Asked Questions | Occupational Safety and Health Administration. https://www.osha.gov/faq#v-nav-tempandweather

Ochi, S., Hodgson, S., Landeg, O., Mayner, L., & Murray, V. (2014). Disaster-Driven Evacuation and Medication Loss: A Systematic Literature Review. *PLoS Currents*, *6*, ecurrents.dis.fa417630b566a0c7dfdbf945910edd96. https://doi.org/10.1371/currents.dis.fa417630b566a0c7dfdbf945910edd96

Ochsner, M., Marshall, E. G., & Lefkowitz, D. (2018). Trees down, hazards abound: Observations and lessons from Hurricane Sandy. *American Journal of Industrial Medicine*, *61*(5), 361–371. https://doi.org/10.1002/ajim.22822

Office of the New York City Comptroller & Urban Ocean Lab. (2022). *Social Cohesion as a Climate Strategy: Reflections on Superstorm Sandy*. CIty of New York. https://comptroller.nyc.gov/reports/social-cohesion-as-a-climate-strategy/

O'Neill, M. S., Zanobetti, A., & Schwartz, J. (2005). Disparities by race in heat-related mortality in four US cities: The role of air conditioning prevalence. *Journal of Urban Health : Bulletin of the New York Academy of Medicine*, *82*(2), 191–197. https://doi.org/10.1093/jurban/jti043

Ortiz, L., Braneon, C. V., Horton, R., Bader, D., Orton, P. M., Gornitz, V., Rosenzweig, B. R., McPhearson, T., Smalls-Mantey, L., Sheerazi, H., Montalto, F. A., Goldhandan, M. R., Evans, C., DeGaetano, A. T., Mallen, E., Carter, L., McConnell, K., & Mayo, T. L. (2024). NPCC4: Tail Risk, Climate Drivers of Extreme Heat, and New Methods for Extreme Event Projections (pre-publication draft). *Annals of New York Academy of Sciences*.

Ortiz, L., Gamarro, H., Gonzalez, J. E., & McPhearson, T. (2022). Energy burden and air conditioning adoption in New York City under a warming climate. *Sustainable Cities and Society*, *76*, 103465. https://doi.org/10.1016/j.scs.2021.103465

OSHA. (2022). *Heat—Overview: Working in Outdoor and Indoor Heat Environments*. Occupational Safety and Health Administration. https://www.osha.gov/heat-exposure

Page, L. A., Hajat, S., & Kovats, R. S. (2007). Relationship between daily suicide counts and temperature in England and Wales. *The British Journal of Psychiatry: The Journal of Mental Science*, *191*, 106–112. https://doi.org/10.1192/bjp.bp.106.031948

Park, J. (2017). Hot temperature and high stakes exams: Evidence from new york city public schools. *Unpublished Manuscript, Jisung Park, Job Market Paper, Harvard University*. https://scholar.harvard.edu/files/jisungpark/files/paper_nyc_aej.pdf

Park, Y. M., & Kwan, M.-P. (2020). Understanding Racial Disparities in Exposure to Traffic-Related Air Pollution: Considering the Spatiotemporal Dynamics of Population Distribution. *International Journal of Environmental Research and Public Health*, *17*(3), 908. https://doi.org/10.3390/ijerph17030908

Parks, R. M., Anderson, G. B., Nethery, R. C., Navas-Acien, A., Dominici, F., & Kioumourtzoglou, M.-A. (2021). Tropical cyclone exposure is associated with increased hospitalization rates in older adults. *Nature Communications*, *12*(1), 1545. https://doi.org/10.1038/s41467-021-21777-1

Parks, R. M., Benavides, J., Anderson, G. B., Nethery, R. C., Navas-Acien, A., Dominici, F., Ezzati, M., &

Kioumourtzoglou, M.-A. (2022). Association of Tropical Cyclones With County-Level Mortality in the US. *JAMA*, *327*(10), 946. https://doi.org/10.1001/jama.2022.1682

Parks, R. M., Bennett, J. E., Tamura-Wicks, H., Kontis, V., Toumi, R., Danaei, G., & Ezzati, M. (2020). Anomalously warm temperatures are associated with increased injury deaths | Nature Medicine. *Nature Medicine*, *26*(1), 65–70. https://doi.org/10.1038/s41591-019-0721-y

Parks, R. M., Kontis, V., Anderson, G. B., Baldwin, J. W., Danaei, G., Toumi, R., Dominici, F., Ezzati, M., & Kioumourtzoglou, M.-A. (2023). Short-term excess mortality following tropical cyclones in the United States. *Science Advances*, *9*(33), eadg6633. https://doi.org/10.1126/sciadv.adg6633

Parsons, K. (2006). Heat stress standard ISO 7243 and its global application. *Industrial Health*, *44*(3), 368–379. https://doi.org/10.2486/indhealth.44.368

Partash, N., Naghipour, B., Rahmani, S. H., Pashaei Asl, Y., Arjmand, A., Ashegvatan, A., & Faridaalaee, G. (2022). The impact of flood on pregnancy outcomes: A review article. *Taiwanese Journal of Obstetrics and Gynecology*, *61*(1), 10–14. https://doi.org/10.1016/j.tjog.2021.11.005

Paschke, A., Schaible, U. E., & Hein, W. (2019). Legionella transmission through cooling towers: Towards better control and research of a neglected pathogen. *The Lancet Respiratory Medicine*, *7*(5), 378–380. https://doi.org/10.1016/S2213-2600(19)30041-4

Pasternack, A. (2023, March 28). NYC: Few Cities Are Doing More to Map and Respond to Rising Waters. *Esri Blog*. https://www.esri.com/about/newsroom/blog/new-york-city-flood-mapping/

Patel, L., Conlon, K. C., Sorensen, C., McEachin, S., Nadeau, K., Kakkad, K., & Kizer, K. W. (2022). Climate Change and Extreme Heat Events: How Health Systems Should Prepare. *NEJM Catalyst*, *3*(7). https://doi.org/10.1056/CAT.21.0454

Paterson, D. L., Wright, H., & Harris, P. N. A. (2018). Health Risks of Flood Disasters. *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America*, *67*(9), 1450–1454. https://doi.org/10.1093/cid/ciy227

Patz, J. A., Frumkin, H., Holloway, T., Vimont, D. J., & Haines, A. (2014). Climate change: Challenges and opportunities for global health. *JAMA*, *312*(15), 1565–1580. https://doi.org/10.1001/jama.2014.13186

Paulin, L. M., Diette, G. B., Scott, M., McCormack, M. C., Matsui, E. C., Curtin-Brosnan, J., Williams, D. L., Kidd-Taylor, A., Shea, M., Breysse, P. N., & Hansel, N. N. (2014). Home interventions are effective at decreasing indoor nitrogen dioxide concentrations. *Indoor Air*, *24*(4), 416–424. https://doi.org/10.1111/ina.12085

Paull, S. H., Horton, D. E., Ashfaq, M., Rastogi, D., Kramer, L. D., Diffenbaugh, N. S., & Kilpatrick, A. M. (2017). Drought and immunity determine the intensity of West Nile virus epidemics and climate change impacts. *Proceedings. Biological Sciences*, *284*(1848), 20162078. https://doi.org/10.1098/rspb.2016.2078

Perera, F., Berberian, A., Cooley, D., Shenaut, E., Olmstead, H., Ross, Z., & Matte, T. (2021). Potential health benefits of sustained air quality improvements in New York City: A simulation based on air pollution levels during the COVID-19 shutdown. *Environmental Research*, *193*, 110555. https://doi.org/10.1016/j.envres.2020.110555

Perera, F., & Nadeau, K. (2022). Climate Change, Fossil-Fuel Pollution, and Children's Health. *New England Journal of Medicine*, *386*(24), 2303–2314. https://doi.org/10.1056/NEJMra2117706

Petkova, E. P., Gasparrini, A., & Kinney, P. L. (2014). Heat and Mortality in New York City Since the Beginning of the 20th Century: *Epidemiology*, *25*(4), 554–560. https://doi.org/10.1097/EDE.0000000000000123

Petkova, E. P., Morita, H., & Kinney, P. L. (2014). Health Impacts of Heat in a Changing Climate: How Can Emerging Science Inform Urban Adaptation Planning? *Current Epidemiology Reports*, *1*(2), 67–74. https://doi.org/10.1007/s40471-014-0009-1

Physicians for Social Responsibility. (2022, June 28). *Next Generation Climate & Health Ambassador (NextGen) Program*. Next Generation Climate & Health Ambassador Program | Physicians for Social Responsibility. https://psr.org/get-involved/next-generation-climate-health-ambassadors/

Pitiranggon, M., Johnson, S., Haney, J., Eisl, H., & Ito, K. (2021). Long-term trends in local and transported PM2.5 pollution in New York City. *Atmospheric Environment*, *248*, 118238. https://doi.org/10.1016/j.atmosenv.2021.118238

Pitiranggon, M., Johnson, S., Huskey, C., Eisl, H., & Ito, K. (2022). Effects of the COVID-19 shutdown on spatial and temporal patterns of air pollution in New York City. *Environmental Advances*, 100171. https://doi.org/10.1016/j.envadv.2022.100171

Poole, J. A., Barnes, C. S., Demain, J. G., Bernstein, J. A., Padukudru, M. A., Sheehan, W. J., Fogelbach, G. G., Wedner, J., Codina, R., Levetin, E., Cohn, J. R., Kagen, S., Portnoy, J. M., & Nel, A. E. (2019). Impact of weather and climate change with indoor and outdoor air quality in asthma: A Work Group Report of the AAAAI Environmental Exposure and Respiratory Health Committee. *Journal of Allergy and Clinical Immunology*, *143*(5), 1702–1710. https://doi.org/10.1016/j.jaci.2019.02.018

Porpora, T. (2021, July 31). *Could Staten Island's mobile home park be a blueprint for affordable housing in NYC?* Silive. https://www.silive.com/news/2021/07/could-mobile-homes-help-provide-affordable-housing-in-nyc.html

Porritt, S. M., Cropper, P. C., Shao, L., & Goodier, C. I. (2012). Ranking of interventions to reduce dwelling overheating during heat waves. *Energy and Buildings*, *55*, 16–27. https://doi.org/10.1016/j.enbuild.2012.01.043

Pörtner, H.O., Roberts., D. C., Poloczanska, E. S., Mintenbeck, K., Tignor, M., Alegria, A., Craig, M., Langsdorf, S., Loschke, S., Moller, V., & Okem, A. (2022). *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781009325844

Pratt Center for Community Development. (2008, March). *New York's Housing Underground ← Our Work ← Pratt Center For Community Development*. https://prattcenter.net/our_work/new_yorks_housing_underground

Pritt, B. S. (2020). Haemaphysalis longicornis Is in the United States and Biting Humans: Where Do We Go From Here? *Clinical Infectious Diseases*, *70*(2), 317–318. https://doi.org/10.1093/cid/ciz451

Puga, A. M., Lopez-Oliva, S., Trives, C., Partearroyo, T., & Varela-Moreiras, G. (2019). Effects of Drugs and Excipients on Hydration Status. *Nutrients*, *11*(3), 669. https://doi.org/10.3390/nu11030669

Qu, Y., Zhang, W., Ryan, I., Deng, X., Dong, G., Liu, X., & Lin, S. (2021). Ambient extreme heat exposure in summer and transitional months and emergency department visits and hospital admissions due to pregnancy complications. *Science of The Total Environment*, *777*, 146134. https://doi.org/10.1016/j.scitotenv.2021.146134

Quinn, A., & Shaman, J. (2017). Health symptoms in relation to temperature, humidity, and self-reported perceptions of climate in New York City residential environments. *International Journal of Biometeorology*, *61*(7), 1209–1220. https://doi.org/10.1007/s00484-016-1299-4

Raju, S., Siddharthan, T., & McCormack, M. C. (2020). Indoor Air Pollution and Respiratory Health. *Clinics in Chest Medicine*, *41*(4), 825–843. https://doi.org/10.1016/j.ccm.2020.08.014

Rao, S., Doherty, F. C., Teixeira, S., Takeuchi, D. T., & Pandey, S. (2023). Social and structural vulnerabilities: Associations with disaster readiness. *Global Environmental Change*, *78*, 102638. https://doi.org/10.1016/j.gloenvcha.2023.102638

Regional Plan Association. (2022). *Preventing Another Ida*. https://rpa.org/work/reports/hurricane-ida-stormwater-management-queens

Reid, C. E., Brauer, M., Johnston, F. H., Jerrett, M., Balmes, J. R., & Elliott, C. T. (2016). Critical Review of Health Impacts of Wildfire Smoke Exposure. *Environmental Health Perspectives*, *124*(9), 1334–1343. https://doi.org/10.1289/ehp.1409277

Reid, C. E., O, 'Neill Marie S., Gronlund, C. J., Brines, S. J., Brown, D. G., Diez, -Roux Ana V., & Schwartz, J. (2009). Mapping Community Determinants of Heat Vulnerability. *Environmental Health Perspectives*, *117*(11), 1730–1736. https://doi.org/10.1289/ehp.0900683

Reiter, P., Lathrop, S., Bunning, M., Biggerstaff, B., Singer, D., Tiwari, T., Baber, L., Amador, M., Thirion, J., Hayes, J., & others. (2003). Texas lifestyle limits transmission of dengue virus. *Emerging Infectious Diseases*, *9*(1), 86.

Robine, J.-M., Cheung, S. L. K., Le Roy, S., Van Oyen, H., Griffiths, C., Michel, J.-P., & Herrmann, F. R. (2008). Death toll exceeded 70,000 in Europe during the summer of 2003. *Comptes Rendus Biologies*, *331*(2), 171–178. https://doi.org/10.1016/j.crvi.2007.12.001

Ronca, S. E., Ruff, J. C., & Murray, K. O. (2021). A 20-year historical review of West Nile virus since its initial emergence in North America: Has West Nile virus become a neglected tropical disease? | PLOS Neglected Tropical Diseases. *PLOS Neglected Tropical Diseases*. https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0009190

Rosenberg, E. M. (2022, August 22). Amazon upgraded warehouse AC system after saying worker's death wasn't heat-related. *CNBC*. https://www.cnbc.com/2022/08/22/amazon-upgraded-warehouse-ac-system-after-saying-workers-death-wasnt-heat-related.html

Rosenthal, N., Benmarhnia, T., Ahmadov, R., James, E., & Marlier, M. E. (2022). Population co-exposure to extreme heat and wildfire smoke pollution in California during 2020. *Environmental Research: Climate*, *1*(2), 025004. https://doi.org/10.1088/2752-5295/ac860e

Rosenzweig, B., Montalto, F. A., Orton, P. M., Kaatz, J., Maher, N., Masterson, K., Busciolano, R., Kleyman, J., Chen, Z., Sanderson, E., Adhikari, N., McPhearson, T., & Herreros-Cantis, P. (2024). NPCC4: Climate Change and New York City's Flood Risk (pre-publication draft). *Annals of New York Academy of Sciences*.

Sampath, V., Aguilera, J., Prunicki, M., & Nadeau, K. C. (2023). Mechanisms of climate change and related air pollution on the immune system leading to allergic disease and asthma. *Seminars in Immunology*, *67*, 101765. https://doi.org/10.1016/j.smim.2023.101765

Sasai, F., Roncal-Jimenez, C., Rogers, K., Sato, Y., Brown, J. M., Glaser, J., Garcia, G., Sanchez-Lozada, L. G., Rodriguez-Iturbe, B., Dawson, J. B., Sorensen, C., Hernando, A. A., Gonzalez-Quiroz, M., Lanaspa, M., Newman, L., & Johnson, R. J. (2021). Climate Change and Nephrology. *Nephrology, Dialysis, Transplantation: Official Publication of the European Dialysis and Transplant Association - European Renal Association*, gfab258. https://doi.org/10.1093/ndt/gfab258

Savitz, D. A., Elston, B., Bobb, J. F., Clougherty, J. E., Dominici, F., Ito, K., Johnson, S., McAlexander, T., Ross, Z., Shmool, J. L., & others. (2015). Ambient fine particulate matter, nitrogen dioxide, and hypertensive disorders of pregnancy in New York City. *Epidemiology (Cambridge, Mass.)*, *26*(5), 748.

Sawano, T., Ito, N., Ozaki, A., Nishikawa, Y., Nonaka, S., Kobashi, Y., Higuchi, A., & Tsubokura, M. (2021). Evacuation of residents in a natural disaster during the COVID-19 era. *QJM: Monthly Journal of the Association of Physicians*, *114*(7), 445–446. https://doi.org/10.1093/qjmed/hcab044

Scata, J. (2022, June 7). *New York Renters Will Soon Know Their Flood Risk*. NRDC | New York Renters Will Soon Know Their Flood Risk. https://www.nrdc.org/bio/joel-scata/new-york-renters-will-soon-know-their-flood-risk

Schmeltz, M. T., González, S. K., Fuentes, L., Kwan, A., Ortega-Williams, A., & Cowan, L. P. (2013). Lessons from Hurricane Sandy: A Community Response in Brooklyn, New York. *Journal of Urban Health*, *90*(5), 799–809. https://doi.org/10.1007/s11524-013-9832-9

Schnall, A., Law, R., Heinzerling, A., Sircar, K., Damon, S., Yip, F., Schier, J., Bayleyegn, T., & Wolkin, A. (2017). Characterization of Carbon Monoxide Exposure During Hurricane Sandy and Subsequent Nor'easter. *Disaster Medicine and Public Health Preparedness*, *11*(5), 562–567. https://doi.org/10.1017/dmp.2016.203

Schramm, P. J., Ahmed, M., Siegel, H., Donatuto, J., Campbell, L., Raab, K., & Svendsen, E. (2020). Climate Change and Health: Local Solutions to Local Challenges. *Current Environmental Health Reports*, *7*(4), 363–370. https://doi.org/10.1007/s40572-020-00294-1

Schwartz, A. M. (2017). Surveillance for Lyme Disease—United States, 2008–2015. *MMWR. Surveillance Summaries*, *66*. https://doi.org/10.15585/mmwr.ss6622a1

Schwartz, J. (2000). Drinking water turbidity and gastrointestinal illness in the elderly of Philadelphia. *Journal of Epidemiology & Community Health*, *54*(1), 45–51. https://doi.org/10.1136/jech.54.1.45

Seil, K., Spira-Cohen, A., & Marcum, J. (2016). Injury Deaths Related to Hurricane Sandy, New York City, 2012. *Disaster Medicine and Public Health Preparedness*, *10*(3), 378–385. https://doi.org/10.1017/dmp.2016.36

Seip, M. (2022). *Community Visioning for Vacant Land following Managed Retreat in Edgemere, Queens, N.Y.* Collective for Community, Culture & Environment / Rockaway Initiative for Sustainability & Equity. https://www.riserockaway.org/rise/initiatives/community-visioning-for-vacant-l/community-visioning-edgemere/CVE-final-report-action-plan:en-us.pdf

Semenza, J. C. (2020). Cascading risks of waterborne diseases from climate change. *Nature Immunology*, *21*(5), Article 5. https://doi.org/10.1038/s41590-020-0631-7

Seppanen, O., Fisk, W. J., & Lei, Q. H. (2006, July 1). Effect of temperature on task performance in officeenvironment. *Report Number: LBNL-60946*. https://www.osti.gov/biblio/903490

Shaman, J., Day, J. F., & Stieglitz, M. (2005). Drought-Induced Amplification and Epidemic Transmission of West Nile Virus in Southern Florida. *Journal of Medical Entomology*, *42*(2), 134–141. https://doi.org/10.1093/jmedent/42.2.134

Sherwood, S. C., & Huber, M. (2010). An adaptability limit to climate change due to heat stress. *Proceedings of the National Academy of Sciences*, *107*(21), 9552–9555. https://doi.org/10.1073/pnas.0913352107

Shi, L., Wu, X., Danesh Yazdi, M., Braun, D., Abu Awad, Y., Wei, Y., Liu, P., Di, Q., Wang, Y., Schwartz, J., Dominici, F., Kioumourtzoglou, M.-A., & Zanobetti, A. (2020). Long-term effects of PM2·5 on neurological disorders in the American Medicare population: A longitudinal cohort study. *The Lancet Planetary Health*, *4*(12), e557–e565. https://doi.org/10.1016/S2542-5196(20)30227-8

Shipley, J., Edwards, B., Nickerson, D., Benincasa, R., Chávez, S. M., & Thompson, C. W. (2021, August 17). Heat is killing workers in the U.S. —And there are no federal rules to protect them. *NPR*. https://www.npr.org/2021/08/17/1026154042/hundreds-of-workers-have-died-from-heat-in-the-last-decade-and-its-getting-worse

Short, A., Spivack, C., Moynihan, E., Drinkard, J. S., Rosa-Aquino, P., Pereira, S., Ricciulli, V., & Blackmore, W. (2021, September 2). *Scenes from Ida's Chaotic, Tragic Night in New York City*. Curbed. https://www.curbed.com/2021/09/tropical-storm-ida-new-york-city.html

Simmering, J. E., Polgreen, L. A., Hornick, D. B., Sewell, D. K., & Polgreen, P. M. (2017). Weather-Dependent Risk for Legionnaires' Disease, United States. *Emerging Infectious Diseases*, *23*(11), 1843–1851. https://doi.org/10.3201/eid2311.170137

Skarha, J., Spangler, K., Dosa, D., Rich, J. D., Savitz, D. A., & Zanobetti, A. (2023). Heat-related mortality in U.S. state and private prisons: A case-crossover analysis. *PLOS ONE*, *18*(3), e0281389. https://doi.org/10.1371/journal.pone.0281389

Smalling, K. L., Deshpande, A. D., Galbraith, H. S., Sharack, B. L., Timmons, D., & Baker, R. J. (2016). Regional assessment of persistent organic pollutants in resident mussels from New Jersey and New York estuaries following Hurricane Sandy. *Marine Pollution Bulletin*, *107*(2), 432–441. https://doi.org/10.1016/j.marpolbul.2016.02.077

Smith, K. (2022, February 10). *Mobile home residents face higher flood risk*. Headwaters Economics. https://headwaterseconomics.org/natural-hazards/mobile-home-flood-risk/

Solecki, W., Rosenzweig, C., Blake, R., Sherbinin, A. de, Matte, T., Moshary, F., Rosenzweig, B., Arend, M., Gaffin, S., Bou-Zeid, E., Rule, K., Sweeny, G., & Dessy, W. (2015). New York City Panel on Climate Change 2015 Report Chapter 6: Indicators and Monitoring. *Annals of the New York Academy of Sciences*, *1336*(1), 89–106. https://doi.org/10.1111/nyas.12587

Sorensen, C., & Hess, J. (2022). Treatment and Prevention of Heat-Related Illness. *New England Journal of Medicine*, *0*(0), null. https://doi.org/10.1056/NEJMcp2210623

Soverow, J. E., Wellenius, G. A., Fisman, D. N., & Mittleman, M. A. (2009). Infectious Disease in a Warming World: How Weather Influenced West Nile Virus in the United States (2001–2005). *Environmental Health Perspectives*, *117*(7), 1049–1052. https://doi.org/10.1289/ehp.0800487

Starfield, B., Shi, L., & Macinko, J. (2005). Contribution of Primary Care to Health Systems and Health. *The Milbank Quarterly*, *83*(3), 457–502. https://doi.org/10.1111/j.1468-0009.2005.00409.x

State of New York. (2021). *Bill S5472A-2021*. NYSenate.Gov. https://www.nysenate.gov/legislation/bills/2021/S5472

Sun, S., Weinberger, K. R., Nori-Sarma, A., Spangler, K. R., Sun, Y., Dominici, F., & Wellenius, G. A. (2021). Ambient heat and risks of emergency department visits among adults in the United States: Time stratified case crossover study. *BMJ*, *375*, e065653. https://doi.org/10.1136/bmj-2021-065653

Sun, S., Weinberger, K. R., Spangler, K. R., Eliot, M. N., Braun, J. M., & Wellenius, G. A. (2019). Ambient temperature and preterm birth: A retrospective study of 32 million US singleton births. *Environment International*, *126*, 7–13. https://doi.org/10.1016/j.envint.2019.02.023

Sun, Y., Wilson, R., Liu, H., & Wu, Y. (2021). Numerical investigation of a smart window system with thermotropic Parallel Slat Transparent Insulation Material for building energy conservation and daylight autonomy. *Building and Environment*, *203*, 108048. https://doi.org/10.1016/j.buildenv.2021.108048

Tainio, M., Jovanovic Andersen, Z., Nieuwenhuijsen, M. J., Hu, L., de Nazelle, A., An, R., Garcia, L. M. T., Goenka, S., Zapata-Diomedi, B., Bull, F., & Sá, T. H. de. (2021). Air pollution, physical activity and health: A mapping review of the evidence. *Environment International*, *147*, 105954. https://doi.org/10.1016/j.envint.2020.105954

Tannis, C. (2020). Heat illness and renal injury in mail and package delivery workers. *American Journal of Industrial Medicine*, *63*(11), 1059–1061. https://doi.org/10.1002/ajim.23169

Tarbochia-Gast, A. T., Michanowicz, D. R., & Bernstein, A. S. (2022, September 29). *Flood Risk to Hospitals on the United States Atlantic and Gulf Coasts From Hurricanes and Sea Level Rise—Tarabochia‐Gast—2022—*

GeoHealth—Wiley Online Library. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022GH000651

Thacher, J. D., Gruzieva, O., Pershagen, G., Melén, E., Lorentzen, J. C., Kull, I., & Bergström, A. (2017). Mold and dampness exposure and allergic outcomes from birth to adolescence: Data from the BAMSE cohort. *Allergy*, *72*(6), 967–974. https://doi.org/10.1111/all.13102

The Intercept. (2022). *Interactive map: The Prison Climate Crisis*. The Intercept. https://theintercept.com/fav.icon

The Times Editorial Board. (2022, May 18). Editorial: Heat waves are killing Californians in their homes. Cooling standards could save lives. *Los Angeles Times*. https://www.latimes.com/opinion/story/2022-05-18/extreme-heat-standards

Thieken, A. H., Mohor, G. S., Kreibich, H., & Müller, M. (2021). *Compound flood events: Different pathways–different impacts–different coping options?* [Preprint]. Hydrological Hazards. https://doi.org/10.5194/nhess-2021-27

Thompson, R., Hornigold, R., Page, L., & Waite, T. (2018). Associations between high ambient temperatures and heat waves with mental health outcomes: A systematic review. *Public Health*, *161*(2018), 171–191. https://doi.org/10.1016/j.puhe.2018.06.008

Thompson, R. R., Garfin, D. R., & Silver, R. C. (2017). Evacuation from Natural Disasters: A Systematic Review of the Literature. *Risk Analysis: An Official Publication of the Society for Risk Analysis*, *37*(4), 812–839. https://doi.org/10.1111/risa.12654

Thomson, E. M. (2019). Air Pollution, Stress, and Allostatic Load: Linking Systemic and Central Nervous System Impacts. *Journal of Alzheimer's Disease*, *69*(3), 597–614. https://doi.org/10.3233/JAD-190015

Timmins, C. L. (2002). The Impact of Language Barriers on the Health Care of Latinos in the United States: A Review of the Literature and Guidelines for Practice. *Journal of Midwifery & Women's Health*, *47*(2), 80–96. https://doi.org/10.1016/S1526-9523(02)00218-0

Tobías, A., Hashizume, M., Honda, Y., Sera, F., Ng, C. F. S., Kim, Y., Roye, D., Chung, Y., Dang, T. N., Kim, H., Lee, W., Íñiguez, C., Vicedo-Cabrera, A., Abrutzky, R., Guo, Y., Tong, S., Coelho, M. de S. Z. S., Saldiva, P. H. N., Lavigne, E., … Gasparrini, A. (2021). Geographical Variations of the Minimum Mortality Temperature at a Global Scale: A Multicountry Study. *Environmental Epidemiology*, *5*(5), e169. https://doi.org/10.1097/EE9.0000000000000169

Toprani, A., Rand, M., Conderino, S., Christ, K., & Hamade, A. (2017). *Fatal Injuries among New York City Construction Workers. NYC Vital Signs 2017, 16(3); 1-4.* (16(3); NYC Vital Signs). Department of Health and Mental Hygiene. https://www1.nyc.gov/assets/doh/downloads/pdf/survey/construction-fatalities.pdf

Trombley, J., Chalupka, S., & Anderko, L. (2017). Climate Change and Mental Health. *The American Journal of Nursing*, *117*(4), 44–52. https://doi.org/10.1097/01.NAJ.0000515232.51795.fa

Trtanj, J., Jantarasami, L. C., & Brunkard, J. (2016). Ch. 6: Climate Impacts on Water-Related Illness. *The Impacts of Human Health on Climate Change in the United States*, 32. https://doi.org/DOI:10.7930/J03F4MH4

Umberson, D., Lin, Z., & Cha, H. (2022). Gender and Social Isolation across the Life Course. *Journal of Health and Social Behavior*, *63*(3), 319–335. https://doi.org/10.1177/00221465221109634

UNEP. (2018, November 27). *Emissions Gap Report 2018*. UNEP - UN Environment Programme. http://www.unep.org/resources/emissions-gap-report-2018

United States Census Bureau. (2021). *New York City, New York Population Estimates, July 1, 2021, (V2021)*. U.S. Census Bureau Quick Facts. https://www.census.gov/quickfacts/newyorkcitynewyork

United States Environmental Protection Agency. (2014a, April 20). *Mortality Risk Valuation* [Overviews and Factsheets]. https://www.epa.gov/environmental-economics/mortality-risk-valuation

United States Environmental Protection Agency. (2014b, July 8). *Air Data: Air Quality Data Collected at Outdoor Monitors Across the US* [Collections and Lists]. US EPA. https://www.epa.gov/outdoor-air-quality-data

United States Environmental Protection Agency. (2018, May 8). *Urban Waters Ambassador Toolkit* [Overviews and Factsheets]. https://www.epa.gov/urbanwaterspartners/urban-waters-ambassador-toolkit

United States Environmental Protection Agency. (2020). *Integrated Science Assessment (ISA) for Ozone and Related Photochemical Oxidants (Final Report, Apr 2020)* [Reports & Assessments]. EPA. https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=348522

United States Environmental Protection Agency. (2022a, March 21). *Climate Change and the Health of Older Adults* [Overviews and Factsheets]. Climate Change and the Health of Older Adults | US EPA.

https://www.epa.gov/climateimpacts/climate-change-and-health-older-adults

United States Environmental Protection Agency. (2022b, May 4). *Air Quality—Cities and Counties* [Data and Tools]. https://www.epa.gov/air-trends/air-quality-cities-and-counties

United States Environmental Protection Agency. (2023a). *About AirNow: What is AirNow?* About AirNow | AirNow.Gov; AirNow.gov, U.S. EPA. https://www.airnow.gov/about-airnow

United States Environmental Protection Agency. (2023b). *Air Quality Index (AQI) Basics*. AQI Basics | AirNow.Gov; AirNow.gov, U.S. EPA. https://www.airnow.gov/aqi/aqi-basics

United States Environmental Protection Agency. (2023c). *Get air quality data where you live* (,). AirNow.Gov. https://www.airnow.gov/

United States Environmental Protection Agency. (2023d). *Heat Island Effect*. Heat Island Effect | US EPA. https://www.epa.gov/heatislands

United States Environmental Protection Agency. (2023e). *Outdoor Air Quality Data: Air Data—Multiyear Tile Plot* [Data and Tools]. https://www.epa.gov/outdoor-air-quality-data/air-data-multiyear-tile-plot

U.S. Energy Information Administration. (2023). *Residential Energy Consumption Survey (RECS)*. Residential Energy Consumption Survey (RECS) - Energy Information Administration. https://www.eia.gov/consumption/residential/

U.S. Health Care Climate Council. (2019, July 16). *Climate and health patient education*. Health Care Without Harm. https://noharm-uscanada.org/content/us-canada/climate-and-health-patient-education

USGCRP. (2018). *Fourth National Climate Assessment* (D. R. Redimiler, C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, & B. C. Stewart, Eds.). U.S. Global Change Research Program. https://nca2018.globalchange.gov

USGCRP. (2023). *Fifth National Climate Assessment* (A. R. Crimmins, C. W. Avery, D. R. Easterling, K. E. Kunkel, B. C. Stewart, & T. K. Maycock, Eds.). U.S. Global Change Research Program. https://doi.org/10.7930/NCA5.2023

Valenzuela, A., Arola, A., Anton, M., Quirantes, A., & Alados-Arboledas, L. (2017). Black carbon radiative forcing derived from AERONET measurements and models over an urban location in the southeastern Iberian Peninsula. *Atmospheric Research*, *191*, 44–56. https://doi.org/10.1016/j.atmosres.2017.03.007

van Dillen, S. M. E., de Vries, S., Groenewegen, P. P., & Spreeuwenberg, P. (2012). Greenspace in urban neighbourhoods and residents' health: Adding quality to quantity. *Journal of Epidemiology and Community Health*, *66*(6), e8–e8. https://doi.org/10.1136/jech.2009.104695

VanAcker, M. C., Little, E. A. H., Molaei, G., Bajwa, W. I., & Diuk-Wasser, M. A. (2019). Enhancement of Risk for Lyme Disease by Landscape Connectivity, New York, New York, USA. *Emerging Infectious Diseases*, *25*(6), 1136–1143. https://doi.org/10.3201/eid2506.181741

Vant-Hull, B., Ramamurthy, P., Havlik, B., Jusino, C., Corbin-Mark, C., Schuerman, M., Keefe, J., Drapkin, J. K., & Glenn, A. A. (2018). The Harlem Heat Project: A Unique Media–Community Collaboration to Study Indoor Heat Waves. *Bulletin of the American Meteorological Society*, *99*(12), 2491–2506. https://doi.org/10.1175/BAMS-D-16-0280.1

Vecellio, D. J., Wolf, S. T., Cottle, R. M., & Kenney, W. L. (2022). Evaluating the 35°C wet-bulb temperature adaptability threshold for young, healthy subjects (PSU HEAT Project). *Journal of Applied Physiology*, *132*(2), 340–345. https://doi.org/10.1152/japplphysiol.00738.2021

Venkatraman, S. (2022, March 2). *After Ida, New York AG calls for more language access in severe weather alerts*. NBC News. https://www.nbcnews.com/news/asian-america/ida-new-york-ag-calls-language-access-severe-weather-alerts-rcna18193

Vernice, N. A., Pereira, N. M., Wang, A., Demetres, M., & Adams, L. V. (2020). The adverse health effects of punitive immigrant policies in the United States: A systematic review. *PloS One*, *15*(12), e0244054. https://doi.org/10.1371/journal.pone.0244054

Walker, A. (2021, September 10). *What Went Wrong With NYC's Emergency Alerts, and How Can We Do Better?* Curbed. https://www.curbed.com/2021/09/ida-emergency-alerts-flooding-new-york-city.html

Walker, L. (2023). *Members in Action: Communications Strategies to Improve Engagement With Climate Change*. Communications Strategies to Improve Engagement With Climate Change | The Medical Society Consortium on Climate and Health (MSCCH). https://medsocietiesforclimatehealth.org/members-inaction/communications-strategies-improve-engagement-climate-change/

Wang, B., & Zhuang, J. (2017). Crisis information distribution on Twitter: A content analysis of tweets during Hurricane Sandy. *Natural Hazards*, *89*(1), 161–181. https://doi.org/10.1007/s11069-017-2960-x

Watkins, A., & Southall, A. (2019, July 21). Amid Heat Wave in New York, 50,000 Lose Electricity. *The New York Times*. https://www.nytimes.com/2019/07/21/nyregion/nyc-heat-wave.html

WE ACT for Environmental Justice. (2021). *A Call for NYC Cooling Center Improvements*. WeACT for Environmental Justice. https://www.weact.org/wp-content/uploads/2022/06/WE-ACT-2021-Cooling-Center-Report.pdf

WE ACT for Environmental Justice. (2023). *Out of Gas, In with Justice: Studying the Impacts of Induction Stoves on Indoor Air Quality in Affordable Housing*. WE ACT for Environmental Justice. https://www.weact.org/campaigns/out-of-gas/

Webber, T., & Sanders, L. (2023, September 25). *After summer's extreme weather, more Americans see climate change as a culprit, AP-NORC poll shows*. AP News. https://apnews.com/article/climate-change-poll-opinions-attitudes-extreme-weather-993c392ee57d023ca55600431a39a4be

Weichenthal, S., Pinault, L., Christidis, T., Burnett, R. T., Brook, J. R., Chu, Y., Crouse, D. L., Erickson, A. C., Hystad, P., Li, C., Martin, R. V., Meng, J., Pappin, A. J., Tjepkema, M., van Donkelaar, A., Weagle, C. L., & Brauer, M. (2022). How low can you go? Air pollution affects mortality at very low levels. *Science Advances*, *8*(39), eabo3381. https://doi.org/10.1126/sciadv.abo3381

Weichselbaum, S. (2012). *Lower East Side seniors trapped in the dark for days after Sandy*. New York Daily News. https://www.nydailynews.com/new-york/les-seniors-trapped-dark-days-article-1.1196076

Weinberger, K. R., Harris, D., Spangler, K. R., Zanobetti, A., & Wellenius, G. A. (2020). Estimating the number of excess deaths attributable to heat in 297 United States counties. *Environmental Epidemiology*, *4*(3), e096. https://doi.org/10.1097/EE9.0000000000000096

Weinberger, K. R., Kinney, P. L., Robinson, G. S., Sheehan, D., Kheirbek, I., Matte, T. D., & Lovasi, G. S. (2016). Levels and determinants of tree pollen in New York City. *Journal of Exposure Science and Environmental Epidemiology*. https://doi.org/10.1038/jes.2016.72

Weiss, D., Boyd, C., Rakeman, J. L., Greene, S. K., Fitzhenry, R., McProud, T., Musser, K., Huang, L., Kornblum, J., Nazarian, E. J., Fine, A. D., Braunstein, S. L., Kass, D., Landman, K., Lapierre, P., Hughes, S., Tran, A., Taylor, J., Baker, D., … Varma, J. K. (2017). A Large Community Outbreak of Legionnaires' Disease Associated With a Cooling Tower in New York City, 2015. *Public Health Reports*, *132*(2), 241–250. https://doi.org/10.1177/0033354916689620

Wertis, L., Runkle, J. D., Sugg, M. M., & Singh, D. (2023). Examining Hurricane Ida's Impact on Mental Health: Results From a Quasi-Experimental Analysis. *GeoHealth*, *7*(2), e2022GH000707. https://doi.org/10.1029/2022GH000707

Wetlands Watch. (2022). *Sea Level Rise Phone App*. Wetlands Watch. https://wetlandswatch.org/sea-level-rise-phone-app

Wheeler, K., Lane, K., Walters, S., & Matte, T. (2013). Heat Illness and Deaths—New York City, 2000–2011. *Morbidity and Mortality Weekly Report*, *62*(31), 617–621.

White, R. H., Anderson, S., Booth, J. F., Braich, G., Draeger, C., Fei, C., Harley, C. D. G., Henderson, S. B., Jakob, M., Lau, C.-A., Mareshet Admasu, L., Narinesingh, V., Rodell, C., Roocroft, E., Weinberger, K. R., & West, G. (2023). The unprecedented Pacific Northwest heatwave of June 2021. *Nature Communications*, *14*(1), 727. https://doi.org/10.1038/s41467-023-36289-3

White-Newsome, J. L., Sánchez, B. N., Jolliet, O., Zhang, Z., Parker, E. A., Timothy Dvonch, J., & O'Neill, M. S. (2012). Climate change and health: Indoor heat exposure in vulnerable populations. *Environmental Research*, *112*, 20–27. https://doi.org/10.1016/j.envres.2011.10.008

Widerynski, S., Schramm, P. J., Conlon, K. C., Noe, R. S., Grossman, E., Hawkins, M., Nayak, S. U., Roach, M., & Hilts, A. S. (2017). *The Use of Cooling Centers to Prevent Heat-Related Illness: Summary of Evidence and Strategies for Implementation* (cdc:47657; Climate and Health Technical Report Series). Centers for Disease Control and Prevention. https://stacks.cdc.gov/view/cdc/47657

Wolfe, R., Zarebicki, P., & Meredith, W. (2022). The evolution of saltmarsh mosquito control water management practices relative to coastal resiliency in the Mid-Atlantic and northeastern United States. *Wetlands Ecology and Management*, *30*(5), 1099–1108. https://doi.org/10.1007/s11273-021-09817-5

Wortzel, J. R., Lee, J., Benoit, L., Rubano, A., & Pinsky, E. G. (2022). Perspectives on Climate Change and Pediatric

Mental Health: A Qualitative Analysis of Interviews with Researchers in the Field. *Academic Psychiatry : The Journal of the American Association of Directors of Psychiatric Residency Training and the Association for Academic Psychiatry*, *46*(5), 562–568. https://doi.org/10.1007/s40596-022-01707-z

Xiao, J., Zhang, W., Huang, M., Lu, Y., Lawrence, W. R., Lin, Z., Primeau, M., Dong, G., Liu, T., Tan, W., Ma, W., Meng, X., & Lin, S. (2021). Increased risk of multiple pregnancy complications following large-scale power outages during Hurricane Sandy in New York State. *The Science of the Total Environment*, *770*, 145359. https://doi.org/10.1016/j.scitotenv.2021.145359

Xu, R., Xiong, X., Abramson, M. J., Li, S., & Guo, Y. (2020). Ambient temperature and intentional homicide: A multi-city case-crossover study in the US. *Environment International*, *143*, 105992. https://doi.org/10.1016/j.envint.2020.105992

Xu, Z., FitzGerald, G., Guo, Y., Jalaludin, B., & Tong, S. (2016). Impact of heatwave on mortality under different heatwave definitions: A systematic review and meta-analysis. *Environment International*, *89–90*, 193–203. https://doi.org/10.1016/j.envint.2016.02.007

Yari, A., Ostadtaghizadeh, A., Ardalan, A., Zarezadeh, Y., Rahimiforoushani, A., & Bidarpoor, F. (2020). Risk factors of death from flood: Findings of a systematic review. *Journal of Environmental Health Science and Engineering*, *18*(2), 1643–1653. https://doi.org/10.1007/s40201-020-00511-x

Yitshak-Sade, M., James, P., Kloog, I., Hart, J., Schwartz, J., Laden, F., Lane, K., Fabian, M., Fong, K., & Zanobetti, A. (2019). Neighborhood Greenness Attenuates the Adverse Effect of PM2.5 on Cardiovascular Mortality in Neighborhoods of Lower Socioeconomic Status. *International Journal of Environmental Research and Public Health*, *16*(5), 814. https://doi.org/10.3390/ijerph16050814

Yong, A. G. (2017). *A Social-Ecological Approach to Understanding Natural Disaster Preparedness and Risk Perception amongst Immigrants: A Multi-Method Inquiry* [Thesis, Université d'Ottawa / University of Ottawa]. https://doi.org/10.20381/ruor-21279

Yoo, E., Eum, Y., Roberts, J. E., Gao, Q., & Chen, K. (2021). Association between extreme temperatures and emergency room visits related to mental disorders: A multi-region time-series study in New York, USA. *Science of The Total Environment*, *792*, 148246. https://doi.org/10.1016/j.scitotenv.2021.148246

Yoon, L., Ventrella, J., Marcotullio, P., Matte, T., Lane, K., Tipaldo, J., Jessel, S., Schmid, K., Casagrande, J., & Elszasz, H. (2024). NPCC4: Climate Change, Energy, and Energy Insecurity in New York City (pre-publication draft). *Annals of New York Academy of Sciences*.

Younan, D., Wang, X., Gruenewald, T., Gatz, M., Serre, M. L., Vizuete, W., Braskie, M. N., Woods, N. F., Kahe, K., Garcia, L., Lurmann, F., Manson, J. E., Chui, H. C., Wallace, R. B., Espeland, M. A., & Chen, J.-C. (2022). Racial/Ethnic Disparities in Alzheimer's Disease Risk: Role of Exposure to Ambient Fine Particles. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *77*(5), 977–985. https://doi.org/10.1093/gerona/glab231

Yuan, A., Spira-Cohen, A., Olson, C., & Lane, K. (2024). Immediate Injury Deaths related to the Remnants from Hurricane Ida in New York City, September 1-2, 2021. *Disaster Medicine and Public Health Preparedness, Accepted for Publication*.

Zanobetti, A., O'Neill, M. S., Gronlund, C. J., & Schwartz, J. D. (2013). Susceptibility to Mortality in Weather Extremes: Effect Modification by Personal and Small Area Characteristics In a Multi-City Case-Only Analysis. *Epidemiology (Cambridge, Mass.)*, *24*(6), 809–819. https://doi.org/10.1097/01.ede.0000434432.06765.91

Zemba, S., & Wilmoth, J. (2022). Older Immigrants Are More Likely Than Older Nonimmigrants to Experience Loneliness. *Syracuse University Lerner Center for Public Health Promotion and Population Health*. https://www.maxwell.syr.edu/research/lerner-center/population-health-research-brief-series/article/older-immigrants-are-more-likely-than-older-nonimmigrants-to-experience-loneliness

Zhang, L., He, M. Z., Gibson, E. A., Perera, F., Lovasi, G. S., Clougherty, J. E., Carrión, D., Burke, K., Fry, D., & Kioumourtzoglou, M.-A. (2021). Evaluating the Impact of the Clean Heat Program on Air Pollution Levels in New York City. *Environmental Health Perspectives*, *129*(12), 127701. https://doi.org/10.1289/EHP9976

Zhao, D., Azimi, P., & Stephens, B. (2015). Evaluating the Long-Term Health and Economic Impacts of Central Residential Air Filtration for Reducing Premature Mortality Associated with Indoor Fine Particulate Matter (PM2.5) of Outdoor Origin. *International Journal of Environmental Research and Public Health*, *12*(7), 8448–8479. https://doi.org/10.3390/ijerph120708448

Zhao, K., Bao, Y., Huang, J., Wu, Y., Moshary, F., Arend, M., Wang, Y., & Lee, X. (2019). A high-resolution modeling study of a heat wave-driven ozone exceedance event in New York City and surrounding regions. *Atmospheric Environment*, *199*, 368–379. https://doi.org/10.1016/j.atmosenv.2018.10.059

Zimmerman, R., Foster, S., González, J. E., Jacob, K., Kunreuther, H., Petkova, E. P., & Tollerson, E. (2019). New York City Panel on Climate Change 2019 Report Chapter 7: Resilience Strategies for Critical Infrastructures and Their Interdependencies. *Annals of the New York Academy of Sciences*, *1439*(1), 174–229. https://doi.org/10.1111/nyas.14010

Zinzi, M., Agnoli, S., Burattini, C., & Mattoni, B. (2020). On the thermal response of buildings under the synergic effect of heat waves and urban heat island. *Solar Energy*, *211*, 1270–1282. https://doi.org/10.1016/j.solener.2020.10.050

Zipp, S. (2009). The battle of Lincoln Square: Neighbourhood culture and the rise of resistance to urban renewal. *Planning Perspectives*, *24*(4), 409–433. https://doi.org/10.1080/02665430903145655

Zuelsdorff, M., & Limaye, V. S. (2023). A Framework for Assessing the Effects of Climate Change on Dementia Risk and Burden. *The Gerontologist*, gnad082. https://doi.org/10.1093/geront/gnad082

Zuraimi, M. S., Tham, K.-W., Chew, F.-T., Ooi, P.-L., & Koh, D. (2011). Home air-conditioning, traffic exposure, and asthma and allergic symptoms among preschool children. *Pediatric Allergy and Immunology: Official Publication of the European Society of Pediatric Allergy and Immunology*, *22*(1 Pt 2), e112-118. https://doi.org/10.1111/j.1399-3038.2010.00992.x

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The assessment does not represent the policy position of any agencies whose staff are co-authors.

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Figure List

Box List