Fifth National Climate Assessment: Chapter 15

# Human Health

# Chapter 15. Human Health

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# Introduction

Climate change has profound negative effects on human health. Climate-related extreme events that impact the US population include floods, droughts, wildfires, extreme temperatures, and storms. All are expected to increase in frequency, intensity, and extent (KM 2.2). Health risks from a changing climate include higher rates of heat-related morbidity and mortality; increases in the geographic range of some infectious diseases; greater exposure to poor air quality; increases in some adverse pregnancy outcomes; higher rates of pulmonary, neurological, and cardiovascular diseases; and worsening mental health.[1,2,3,4,5,6,7] These risks affect all US residents but have disproportionate repercussions for under-resourced and overburdened communities and individuals, such as pregnant people, communities of color, children, people with disabilities, people experiencing homelessness, people with chronic diseases, and older adults. Structural racism and discrimination against groups that have been marginalized play a direct role in health inequities and are public health crises.[8] Existing and projected human health impacts of climate change affect populations that are already experiencing an unprecedented decline in life expectancy due to environmental, social, political, and economic conditions that determine community health and well-being.[9,10,11] Creating climate-resilient health systems, implementing adaptation measures, and mitigating greenhouse gas (GHG) emissions can protect human health.

## Key Message 15.1

## Climate Change Is Harming Human Health

It is an established fact that climate change is harming physical, mental, spiritual, and community health and well-being through the increasing frequency and intensity of extreme events, increasing cases of infectious and vector-borne diseases, and declines in food and water quality and security. Climate-related hazards will continue to grow, increasing morbidity and mortality across all regions of the US (*very likely*, *very high confidence*).

### *Extreme Heat*

In recent decades, rising temperatures have increased heat-related health impacts in the US (Figures 21.8, 22.9, 25.3, 26.2, 27.8, 28.7; KM 2.2).[12] Higher temperatures are associated with adverse pregnancy and birth outcomes, mental health impacts, and increased emergency room visits and hospitalizations related to cardiovascular disease, diabetes, electrolyte imbalance, renal failure, and respiratory outcomes.[13,14,15] Heat-related health impacts are greatest among children, adults over age 65, those with disabilities, people with mental health or substance-use disorders; and those who are pregnant, lack access to cooling, or engage in outdoor labor and activities (Figure 15.1).[13,16,17,18,19] Black, Latinx, Asian, historically redlined, and urban communities are disproportionately exposed to heat, as are those with low wealth and people experiencing homelessness (Figures 12.4, 12.6; KM 22.2);[20,21,22] these groups also report being more worried about heat risks.[23,24,25] Certain medications for management of cardiovascular conditions and mental health disorders may accentuate heat-health risk.[26,27] Heat-related death and illness will continue to increase unless climate change adaptation and mitigation policies are implemented (KM 15.3).[28,29]

**Heat and Health Equity**


**Heat does not impact all communities equally.**

**Figure 15.1.** While anyone can be impacted by heat, location, economics, compound risks, and social and racial factors influence who is most at risk. These impacts disproportionately affect BIPOC (Black, Indigenous, and People of Color) communities as well as communities with low wealth. Figure credit: CDC, University of Colorado, NOAA NCEI, and CISESS NC. Image credits (clockwise from top left): NIEHS/Kelly Government Solutions and USGS/ASRC Federal Data Solutions; FG Trade/E+ via Getty Images; YinYang/E+ via Getty Images; Marc Dufresne/iStock via Getty Images.

## *Drought*

Among weather and climate disasters in the US over the last 40 years that have caused more than a billion dollars of economic loss, drought is responsible for the second-highest number of climate-related deaths—approximately 99 per year (Figure A4.9).[30] However, these statistics probably underreport the total number of deaths, as these estimates account only for heat-related mortality that accompanies droughts.[31] There is growing evidence of an association between drought and increased mortality in adults ages 25–64 in both rural and urban populations.[32,33] Drought can worsen air quality, resulting in adverse health outcomes such as increased cardiovascular and pulmonary disease and premature death (KM 4.2).[34,35] It can also decrease water quantity and quality, which can cause increased exposure to heavy metals, bacteria, and other harmful contaminants (KMs 30.2, 30.2).[36,37,38] Because farmers rely on the land for their livelihood, drought during the growing season is associated with worsening mental health among rural US farmers (KMs 11.2, 22.4).[39]

## *Wildfires*

Wildfire activity has significantly increased over the last few decades, especially in the western US (KM 14.2; Figure 28.9; Focus on Western Wildfires). Roughly half of the increase in burned areas in the US can be attributed to a warming climate.[40] Wildfires and resulting poor air quality can cause disruptions to a person's life, including loss of livelihood and displacement, and can lead to multiple adverse health effects, including death, illnesses, injuries, adverse reproductive outcomes, poor mental health consequences, and declines in psychosocial well-being.[41,42,43,44] Exposure to smoke from wildfires is associated with emergency department visits, hospitalizations, and deaths.[45,46,47,48,49]

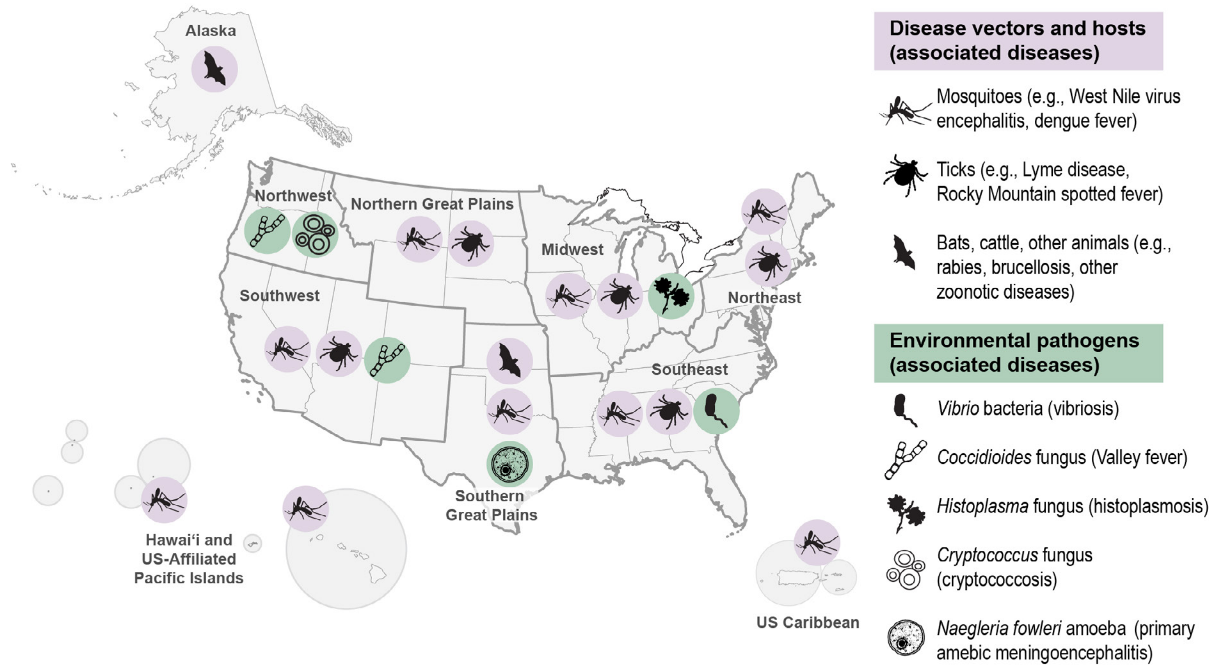
## *Infectious Diseases*

Climate change is expected to alter the distribution, abundance, and seasonality of pathogens and their associated infections (Figure 15.2; Focus on COVID-19 and Climate Change).[50,51,52,53] The range of vampire bats in Texas and Florida is expected to increase due to rising temperatures, which can lead to increased human rabies exposure.[54,55] Exposure to rabies and other zoonoses like brucellosis and toxoplasmosis is also of increasing concern in Alaska, especially for residents who practice subsistence hunting and gathering (KM 29.1).[56] In the eastern US, exposure to the amoeba (*Naegleria fowleri*) that causes primary amebic meningoencephalitis has been documented farther north.[57] Environmental fungal diseases like blastomycosis, coccidioidomycosis (Valley fever), cryptococcosis, and histoplasmosis are expected to be impacted by climate change.[58,59,60] Valley fever is expected to spread northward as drought and temperatures increase (KM 28.4). Case numbers are projected to increase by 220% by the end of the century under a very high scenario (RCP8.5).[61] Valley fever tends to afflict construction and agricultural workers,[62,63,64] and the disease disproportionately impacts Black and Latinx populations, possibly due to occupational exposure.[65,66,67,68]

Lyme disease and other tick-borne diseases account for approximately 80% of all reported cases of vector-borne diseases in the US[69,70] and have steadily increased over the last 20 years due to multiple factors, including climate change (Figure 24.8).[71,72,73] Increased distribution and abundance of ticks are projected to increase human disease cases.[74,75,76,77,78,79] Climate change has contributed to the expansion over the last 20–30 years of the Lone Star tick[80,81,82,83,84] and the Gulf Coast tick, which transmit multiple pathogens.[85] Climate change extends ticks' seasonal activity, prolonging human exposure.[76,86,87,88,89]

Mosquito-borne pathogen spread is influenced by weather, climate, and social factors.[90,91,92] Climate change alters the diversity and distribution of mosquito vectors of dengue, Zika, and chikungunya viruses.[93,94,95,96,97] Dengue is currently a risk in the contiguous US, the US Caribbean, Hawai'i, and US-affiliated Pacific Islands (KMs 23.1, 30.2).[98,99] Increasing weather variability (KM 4.1) may increase West Nile virus transmission. Regional West Nile virus projections indicate geographic expansion in the Northeast over the next 50 years due to climate-related changes in mosquito population distribution (KMs 22.2, 24.3).[100,101,102] Mosquito-borne transmission of other encephalitis viruses has been sporadic in the last decade and may increase as climate change extends seasonality and expands habitat suitability for mosquito species.[103,104,105,106,107,108,109,110,111]

## Regional Examples of Climate-Sensitive Infectious Diseases




**Some climate-sensitive infectious diseases are expected to see expanded geographic range and extended seasonality.**

**Figure 15.2.** The map shows select examples of regional climate-sensitive infectious diseases, based on recent changes in geographic range or incidence. Some regions will experience increases in tick- and mosquito-borne diseases, zoonotic diseases, and pathogens, both in geographic area and extended seasonality. Figure credit: Los Alamos National Laboratory, CDC, Columbia University, University of Arizona, and University of Colorado.

## *Food and Water*

Climate change negatively impacts water quality, water security, food security, and nutrition, which harms health, particularly for communities that rely on agriculture, fishing, and subsistence lifestyles (KMs 4.1, 11.2, 22.2, 23.1, 25.3). For example, the 2021 Pacific Northwest heatwave affected the livelihoods of farmers and Tribes by damaging crops and causing a die-off of mussels, clams, and oysters.[112]

The incidence of certain diseases caused by foodborne and waterborne pathogens is expected to increase due to climate conditions that promote bacterial growth and geographic spread. For instance, vibriosis is a disease caused by ingesting *Vibrio* bacteria in contaminated shellfish or water sources. Symptoms range from food poisoning–like illness to death. Climate change–related vibriosis cases are projected to increase by 51% by 2090 under an intermediate scenario (RCP4.5)[113] due to increasing *Vibrio* populations in warming waters, changing salinity, sea level rise–related coastal changes, and flooding (KM 9.1).[113,114,115,116,117]

## *Mental and Spiritual Health*

Extreme weather events, wildfires, and slow-onset disasters (e.g., drought, sea level rise) can contribute to adverse mental and spiritual health outcomes. These harms may arise from forced displacement and migration (KM 20.3), trauma, loss of sense of place and belonging, and disruption of livelihoods, lifeways, and social support systems.[118] Under-resourced communities bear greater mental and spiritual health burdens (KMs 22.2, 25.2, 27.5).

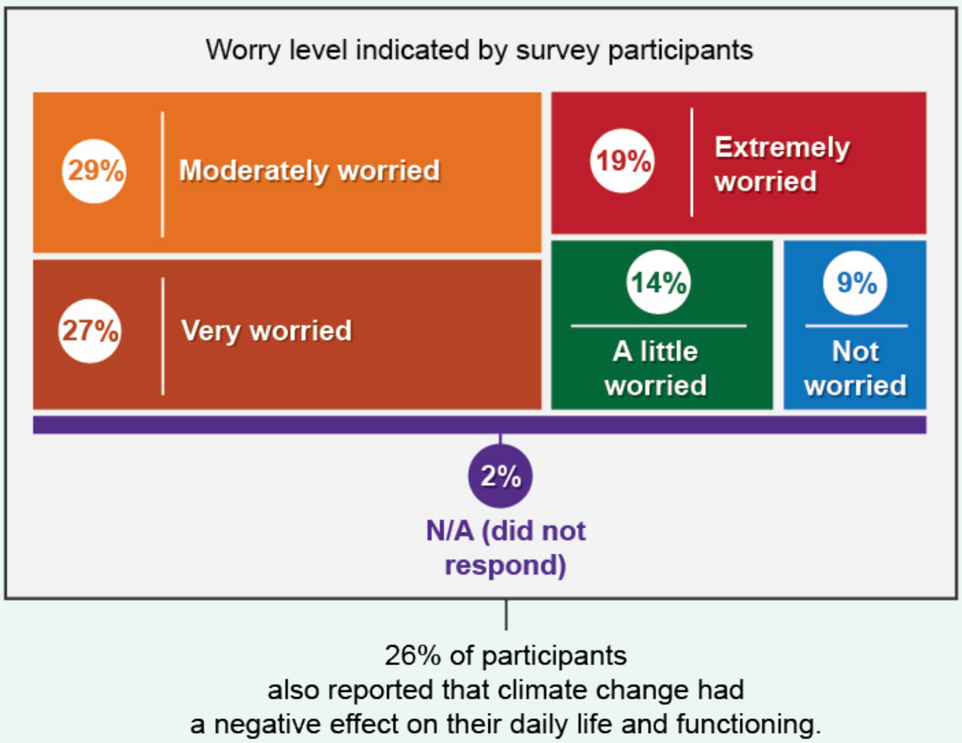
Mental health conditions including anxiety, depression, and suicide have become more prevalent in the US in the past decade, especially among adolescents.[119,120] Climate change may increase these mental health burdens.[55] Greater need for mental health services and psychiatric medications, as well as higher rates of anxiety, have been reported following major hurricanes (KM 23.1). For example, one in six mothers with low income experienced continued post-traumatic stress symptoms 12 years after Hurricane Katrina.[121,122,123,124] Many survivors of California's deadliest wildfire, the 2018 Camp Fire, experienced post-traumatic stress, depression, and anxiety[42] related to home loss and community disruption. Extreme heat exposure has been linked to worsening mental health, including suicide and interpersonal violence.[7,125]

Degradation or destruction of culturally significant places and flora and fauna relatives (KM 24.2),[126,127] shifts in timing of ceremonial practices, disruption of intergenerational teachings and sharing of knowledge and wisdom, and loss of place-based spirituality and traditional livelihoods and lifeways put spiritual health at risk, especially for Indigenous communities.[128,129]

## Box 15.1. Child and Adolescent Mental Health

Compared to previous generations, US children born in 2020 are more likely to experience climate-related adverse childhood events (ACEs) from damage to their homes, schools, and communities.[130] Children with four or more ACEs have 3- to 6-fold greater odds of having anxiety, depression, and substance use disorders and 30-fold greater odds of attempting suicide, in addition to greater physical health risks.[131] Concerns about a potentially uninhabitable world due to climate change can result in "eco-anxiety." Nearly 60% of 1,000 surveyed US adolescents reported anxiety about climate change, and nearly half believe that "humanity is doomed" (Figure 15.3),[132] despite evidence to the contrary (Chs. 1, 2, 31, 32). Psychological resilience training along with mental health care may lessen anxiety and promote engagement on climate change.[5,7,133,134] Youth climate education programs have focused on empowerment with the intent to reframe threats from climate change as opportunities to pursue solutions.[135,136]

### Children's Mental Health




**Out of 1,000 children and young people surveyed in the US, a majority expressed worry about climate change impacts to people and the planet.**

**Figure 15.3.** The figure shows the level of worry about climate change among young people ages 16–25. In the US, 46% of respondents said they were "very" or "extremely" worried about climate change, and 26% of respondents indicated that their feelings about climate change negatively affected their daily life and functioning, including at least one of the following: eating, concentrating, work, school, sleeping, spending time in nature, playing, having fun, and relationships.[132] Figure credit: Boston Children's Hospital, NOAA NCEI, and CISESS NC.

### *Compounding and Cascading Hazards*

Multiple climate-related extreme events that occur concurrently or in rapid succession (KM 2.3; Focus on Compound Events) can result in greater health impacts than singular events and limit the ability of individuals and communities to effectively prepare for, manage, and recover from these events. A singular event that cascades across multiple sectors or regions can result in compounded adverse health consequences. Examples include back-to-back heatwaves, heatwaves during wildfires, drinking-water contamination after flooding, and vector-control program breakdowns during and after flooding.[137] During 2005–2013, windstorms combined with power outages increased emergency department visits, hospital stays, and injury costs in New York, particularly for older individuals and Medicaid recipients.[138]

### *Occupational Safety and Health Impacts*

Climate-related increases in temperature are associated with increases in occupational injuries and occupational exposure to heat, potentially resulting in illness or death (KM 11.2).[139,140,141] Between 2011 and 2019, an average of 3,500 heat-related injuries, resulting in 38 fatalities per year, were reported to OSHA.[139] Between 2001 and 2018, higher-temperature days in California were associated with greatest increased risk of occupational injuries to men, lower-income workers, and young workers. Repeated heat stress coupled with dehydration in occupational environments is a risk factor for the development of kidney disease.[142] Extreme heat is expected to lead to lost labor hours, particularly for workers of color, individuals with low income, and those without a high school diploma. Additionally, these groups are more likely to live in areas where labor is most impacted by extreme heat.[143] Projected estimates of annual lost wages due to unsafe heat range from $19.2 billion to $46 billion (in 2022 dollars) by midcentury (under an intermediate scenario, RCP4.5).[144,145] Industries where workers experience increased risk of heat-related mortality include agriculture (KM 11.2), construction, transportation and warehousing, and waste management.[139] Workers can also face unsafe heat in indoor environments not equipped with adequate climate control.[139] Worker safety is also affected by climate change impacts on economic opportunity and wealth (KM 19.3), exposure to infectious diseases (Focus on COVID-19 and Climate Change), extreme events (Focus on Western Wildfires), and increased mental health risks.[146]

## Key Message 15.2

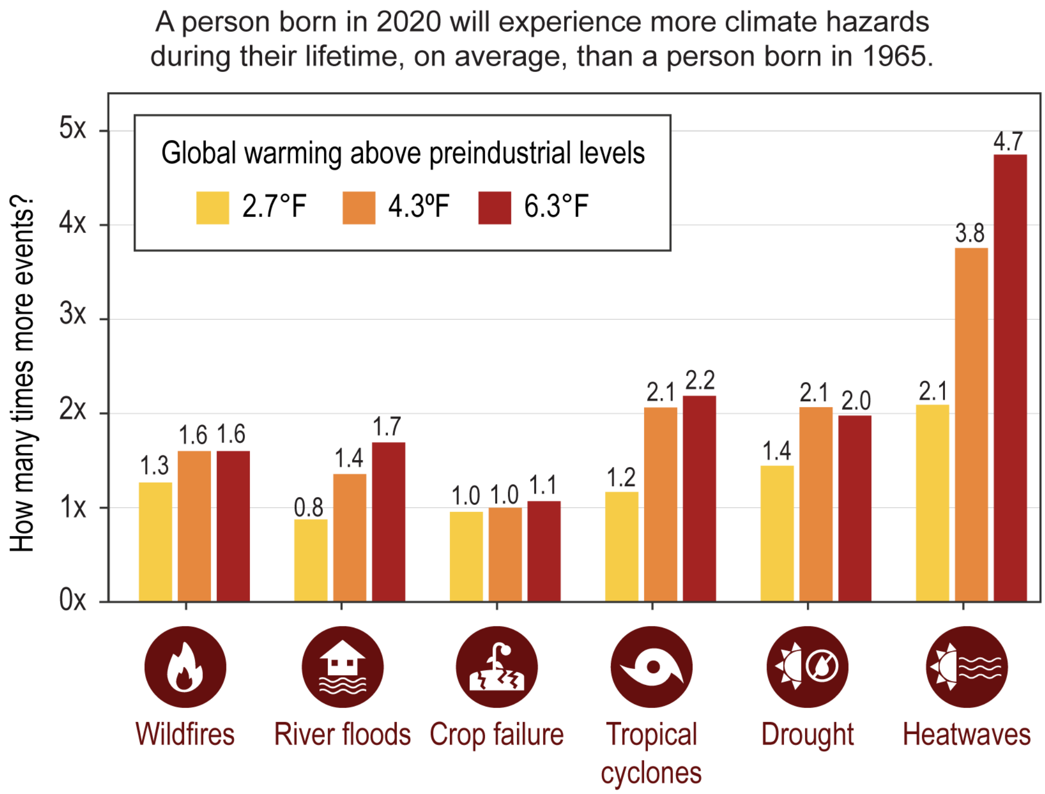
## Systemic Racism and Discrimination Exacerbate Climate Impacts on Human Health

Climate change unequivocally worsens physical, mental, spiritual, and community health and well-being, as well as social inequities. It is an established fact that climate-related impacts disproportionately harm communities and people who have been marginalized. These include BIPOC (Black, Indigenous, and People of Color), individuals and communities with low wealth, women, people with disabilities or chronic diseases, sexual and gender minorities, and children.

### *Community Health and Health Equity*

Climate hazards negatively impact physical, mental, and community health.[147] Although extreme weather threatens all communities (Figure 15.3), health-related burdens are experienced more acutely by BIPOC and low-wealth communities that have been under-resourced and overburdened (KM 19.1; Figure 19.2).[143,148,149] Climate change creates intergenerational inequities as younger generations must endure more extreme weather events than older ones (Figure 15.4). Valuation of intergenerational inequity can inform resilience and mitigation investments. Climate change is a threat multiplier, interacting with and magnifying other life-threatening stressors (Figure 15.5).[150] Fenceline communities—those located adjacent to hazardous industrial facilities, which are disproportionately BIPOC and low-wealth—face higher risks from chemical and industrial disasters following extreme weather.[151,152,153,154,155,156,157,158,159,160,161,162] Hazardous sites, threatened by flooding and sea level rise, exacerbate climate-related health inequities to BIPOC and communities with low wealth (KM 9.2).[163] Additionally, about 70% of Superfund sites—locations contaminated by hazardous materials designated for clean-up—are located within one mile of federally assisted housing, which disproportionately houses people of color, individuals with low wealth, and those with disabilities.[164]

### Intergenerational Inequity




**The number of climate hazards a person born in North America will experience during their lifetime depends on how much Earth warms above preindustrial levels.**

**Figure 15.4.** People born in North America in 2020, on average, will be exposed to more climate-related hazards compared to people born in 1965, an indication of intergenerational inequity. Figure credit: Boston Children's Hospital, NOAA NCEI, and CISESS NC.

## *Food and Water Systems*

Disruptions to food and water quality pose challenges to human health and disproportionately affect BIPOC communities, households with low wealth, single-parent households, and children (KM 11.2; Box 23.1).[165,166] In 2020, 10.5% of US households were food insecure, with higher rates reported among populations that have been marginalized.[165] There are growing concerns about aging or inadequate water infrastructure,[167] especially among households, including many in the Navajo Nation, who experience unequal access to piped and treated drinking water and who are dependent on hauling large quantities of water from nearby facilities.[168] Chemical, physical, and microbial contaminants (e.g., algal blooms and the toxins that cause paralytic shellfish poisoning) threaten water supplies under drought conditions and high temperatures (KM 22.2), which is of particular concern among Indigenous populations who rely on subsistence fishing (KMs 10.1, 28.1, 29.1).

### Healthcare Access and Delivery

Climate-related extreme events have resulted in reductions in healthcare access and an increase in illness and death that can extend for months after the acute event, especially for communities with low wealth (KM 23.1).[169,170] Extreme events can disrupt care for chronic physical and mental health conditions. After hurricanes, risk of death among patients with lung cancer rises in proportion to the length of disaster declarations,[171] and delays in access to dialysis after Hurricane Sandy were associated with more emergency department visits and mortality among patients with chronic kidney disease.[172] Infrastructure and transportation failures contribute to poor health outcomes due to closures, lack of electricity or clean water sources, and/or road failures that prevent access to healthcare providers.[173]

### Tribal and Indigenous Peoples' Health

Tribal and Indigenous Peoples are disproportionately impacted by climate change, and they often equate the health of their people, culture, and traditional practices to the health of the environment (KMs 16.1, 29.1, 27.5, 30.2).[127,174,175] In addition to enduring the historical injustices of colonization, forced relocation, and land dispossession,[176] Indigenous Peoples are among the first to face the spiritual, physical, and mental health threats and impacts of climate change. This undermines their ability to maintain and access their cultural and economic lifeways and worsens community-wide vulnerabilities, such as limited water availability for use by humans, animals, and plants (KM 16.1).[129] Climate-related hazards such as flooding, erosion, sea level rise, and melting ice may lead to impassable roads in remote parts of Tribal territories, thereby widening gaps in the ability to access adequate healthcare (KM 29.2; Focus on Risks to Supply Chains).[177]

### Persons with Disabilities' Health

Climate change disproportionately and differentially harms the health of persons with disabilities, magnifies existing health and socioeconomic inequalities, creates unique challenges, and compounds disparities due to multiple discrimination.[178] During climate disasters, persons with disabilities are at heightened risk of mortality and injury, and they experience disruptions accessing assistive devices, medication, dialysis, other health services, and social support.[178,179] During periods of higher ambient temperatures and heatwaves, persons with physical and mental disabilities experience adverse health impacts, increased emergency room visits, and higher rates of mortality; cooling measures may be physically or financially inaccessible.[178,180] Persons with disabilities are also at elevated risk of exposure to chronic air pollution, as they disproportionately live in neighborhoods with heightened exposure to fine particulate matter due to lower wealth, higher unemployment, and undereducation relative to nondisabled peers.[181]

### African American and Latinx Peoples' Health

Climate change has had and will continue to have disproportionate adverse health impacts on communities with low wealth and BIPOC communities, worsening already-existing health disparities. Discriminatory policies and practices in housing, education, and siting of polluting facilities, including disinvestment in infrastructure and healthcare, amplify adverse climate-related health impacts (KM 22.2; Focus on Risks to Supply Chains).[150] Latinx populations, compared to other demographic groups, are 43% more likely to live in areas that will experience the highest labor reduction hours due to extreme high temperatures (with 2°C (3.6°F) of global warming by 2085–2095 compared to the 1986–2005 reference period).[143,145] African Americans are also expected to face disproportionately greater risks from climate change. African Americans and individuals with low income face higher risks of death from climate-driven floods and air pollution compared to White people (Box 4.2).[143] People of color are disproportionately exposed to greenhouse gas co-pollutants like small particulate matter and face adverse health impacts as a result.[182,183] Due to housing discrimination and redlining, African Americans are more likely to live in neighborhoods with fewer trees and more pavement, suffer disproportionately from heat-related deaths, be exposed to worse air quality, and experience higher rates of asthma-related emergency room visits (KM 22.2; Figures 12.4, 12.6),[184,185,186,187] all of which are compounded by climate change. Latinx and other BIPOC communities face similar challenges (KM 14.3).[188,189]

## *Women's Health*

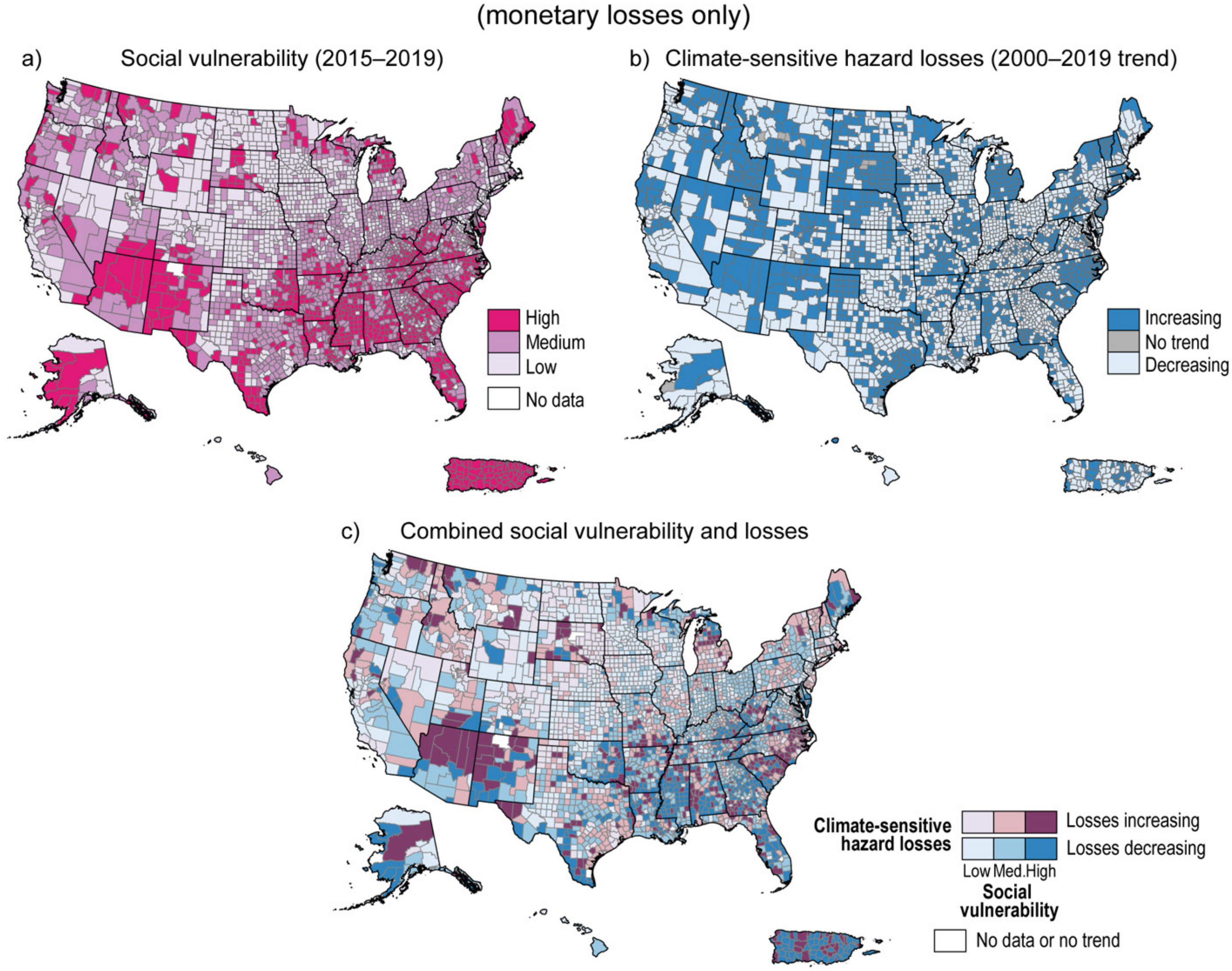
Women disproportionately experience the burden of climate change because of unique mental, sexual, and reproductive health needs that intersect with existing social, racial, and economic disparities. Women, and particularly women of color, are more likely to live in communities with low wealth,[190,191] which is associated with food insecurity[192] and exposure to particulate matter, extreme heat,[2] and climate-related disasters.[193,194] Pregnant cisgender women are particularly vulnerable because exposure to heat, particulate matter, and disaster-associated stressors leads to poor pregnancy outcomes, including miscarriages and low birth weight.[1,195] These factors contribute to maternal mortality, which is more prevalent in the US than in any other developed nation.[196] These outcomes are more likely in groups that have been marginalized, particularly Black pregnant people,[197,198] exacerbating existing social inequities.

In utero exposure to maternal stress during climate-related disasters is linked to subsequent psychiatric disorders in early childhood.[199] Additionally, women have higher caregiving burdens and decreased healthcare access, which makes recovering from climate-driven exposures more difficult. Transgender women may be required to stay in male-only shelters during climate-related disasters, negatively impacting their mental and physical health.[200,201]

## *Sexual and Gender Minorities' Health*

Sexual and gender minorities (SGMs) face social, economic, and health disparities and, as a result, experience greater risk of harm from climate change. SGMs are found in all populations, including frontline communities, and can experience compounding disparities and impacts on the basis of sexual orientation and gender identity. In 2015, Black and Latinx transgender individuals were more than three times as likely as the overall US population to be living below the poverty line (KMs 19.1, 23.1).[190] Indigenous SGMs face heightened health disparities as climate change continues to impact lifeways and economies.[202] SGMs may lack access to critical services during extreme events and are often not included in disaster preparedness and response plans due to discrimination and institutional structures that prioritize the needs of cisgender, heterosexual individuals;[200] may not recognize "chosen families"; and increasingly rely on faith-based organizations as first responders during disasters, which in some cases have blamed SGMs for devastating hurricanes and wildfires as a punishment from God.[193] These discriminatory beliefs have led some SGMs to not seek services at faith-based organizations for fear of being turned away or their SGM status being outed.[203] Because of religious bias, healthcare workers may also refuse to provide health services to or discriminate against SGMs during disasters.[204]

## Social Vulnerability and Climate Hazards




**Some highly vulnerable areas also have high economic losses from climate hazards.**

**Figure 15.5.** Panel (**a**) maps counties based on their Social Vulnerability Index (SoVI) scores for the period 2015–2019. SoVI uses 29 different inputs that characterize underlying socioeconomic and demographic factors, and the index is classified (high, medium, low) using standard deviations. Panel (**b**) shows counties with an increasing trend in climate-sensitive hazard losses (2000–2019) based on data from the Arizona State University/ASU Spatial Hazard Events and Losses Database for the US (SHELDUS). The data is based on property losses and excludes injuries and fatalities from climate-sensitive hazard losses. Exclusion of fatality (especially from heat) explains why some areas of the Southwest appear to have a seemingly decreasing loss trend. The composite map (**c**) identifies counties with high social vulnerability that have less capacity to prepare for, respond to, and rebound from increasing climate-related losses. SoVI does not fully capture the disproportionate impacts of climate hazards in specific neighborhoods, populations, and cultural groups within a county, nor does it account for risk created by historic marginalization. Figure credit: University of Central Florida, Arizona State University, NOAA NCEI, and CISESS NC.

## Key Message 15.3

## Timely, Effective, and Culturally Appropriate Adaptation and Mitigation Actions Protect Human Health

In every sector of society, implementing timely, effective, and culturally appropriate adaptation measures (*high confidence*), creating climate-resilient health systems (*high confidence*), and preventing the release of greenhouse gases can protect human health and improve health equity (*high confidence*).

### *Risk Management and Integrated Approaches*

Proactive and continuous risk management to protect at-risk groups and healthcare facilities is critical to human health and well-being (KM 31.3). This includes integrated approaches that mainstream health into food systems (KM 11.1), infrastructure, water, and sanitation policies. Mitigation options with significant health benefits include reducing point-source (e.g., coal-fired power plants) and mobile-source emissions, increasing active transport (e.g., walking), and increasing consumption of vegetables, legumes, fruits, and nuts (KMs 13.3, 32.4).[205] The economic value of avoided hospitalizations and premature deaths from mitigation activities is larger than the cost of implementation.[29]

### *Climate-Resilient and Sustainable Health Systems*

A climate-resilient health system can "anticipate, respond to, cope with, recover from, and adapt to" climate change to improve the health of communities (KMs 18.2, 19.2).[206,207] Focusing on equity, proactively addressing mental health needs, and linking to community health resources such as community health workers and long-term support and services can create a climate-resilient health system. Climate-related hazards routinely stress and disrupt healthcare systems and threaten access to healthcare for many. For example, a flooding event in 2019 damaged hospitals and disrupted access to healthcare across the central US.[208] Many hospitals (9.3%), nursing homes (10.2%), and pharmacies (12.1%) are at risk of flooding.[209] The COVID-19 pandemic exposed the lack of resilience of the healthcare system when confronted with a large, prolonged increase in healthcare needs (Focus on COVID-19 and Climate Change). Climate-sensitive health problems are linked to a significant economic burden on the healthcare system. There are numerous tools to identify threats and vulnerabilities to healthcare systems—such as the US Department of Health and Human Services' Sustainable and Climate Resilient Health Care Facilities Initiative—with frameworks to guide planning and implementation.[210]

Healthcare systems can play an important role in GHG reduction. The healthcare sector is responsible for 8.5% of US GHG emissions (Figure 19.5).[211,212] Transitioning to clean energy sources and introducing sustainable technologies into healthcare systems would reduce these emissions and associated health harms (KM 32.4).

### *Benefits of Reducing Air Pollution*

Air pollution is a leading cause of premature death worldwide (KM 14.1).[213] It has substantial impacts on lung, heart, and brain health; cancer; and mental health.[214] Reducing GHG emissions and human-caused air pollution would save lives and decrease the burden on the healthcare system (KMs 14.5, 32.4; Figure 32.15).

### *Disease Surveillance*

Implementing surveillance programs for climate-sensitive infectious diseases and non-infectious health outcomes (e.g., heat stroke, respiratory disease, mental and behavior health indicators) is an important adaptation measure. The COVID-19 pandemic illustrated the need for modernization of the US surveillance system and the role of innovative surveillance strategies such as wastewater testing and community-based participatory surveillance (Focus on COVID-19 and Climate Change). Monitoring disease case counts, corresponding indicators (animal health and vector populations), and health outcomes facilitates identifying seasonal trends, responses to climate and environmental variability, geographic hotspots for diseases, and new or reemerging threats.[65,215,216] Enhanced disease surveillance identifies populations most at risk for contracting a disease and improves health by raising disease awareness and reducing time to diagnosis and treatment.[217] This increases capacity to plan for and prevent disease spread or outbreaks, such as by creating predictive models of disease transmission, implementing vector abatement programs, and developing and stockpiling vaccines and pharmaceuticals.[101,218,219,220]

## *Extreme Heat*

Increasing temperatures, urbanization, and an aging population (KM 2.2)[221,222] can result in increased heat-related deaths (KM 2.2).[221,222] Limiting warming to 1.5°C (2.7°F) above preindustrial levels (compared to 3°C, or 5.4°F) and timely adaptations could substantially decrease heat-related deaths, especially in cities.[223,224,225,226] Adaptations range from ensuring equitable access to cool spaces and reducing social isolation to augmenting heat warning systems and improving green infrastructure (KMs 12.3, 12.4).[224]

Air-conditioning access is limited for unhoused populations and households with low wealth. High electricity costs prevent effective use of air-conditioning.[227] Poor self-reported health and reduced life expectancy are more prevalent where families spend a large proportion of household income on residential energy.[228] Government programs can help families reduce their energy costs.[229] Home weatherization can improve health conditions and reduce healthcare costs while reducing GHG emissions, providing societal benefits greater than the implementation cost (KM 5.3).[230,231] There are self-reported health benefits from energy retrofits in households with low wealth.[232]

Increased air-conditioning use can exacerbate the urban heat island effect by transferring hot air from buildings to the outdoor environment (Ch. 12; Figure 12.4) and can increase electricity-related emissions of GHGs and other air pollutants.[233] Buildings that rely on air-conditioning may become dangerously hot during prolonged power outages.[234,235,236,237,238] Sustainable cooling strategies are in development, such as energy-efficient systems (e.g., heat pumps and fans) and affordable passive cooling (e.g., night-flush ventilation).[239,240,241,242]

## *Wildfires*

Under a range of future climate scenarios, wildfire pollutant emissions are expected to increase and result in significant health burdens.[243] Integrated wildfire management and adaptation strategies are critical to reducing deaths and illnesses, as wildfire risk cannot be eliminated. Proactive and effective management of fuel loads (e.g., through prescribed and cultural burning) can reduce wildfire size and intensity, but there may be unintended health consequences.[244] Strategies to reduce wildland fire smoke exposure include personal actions and community-level interventions (KM 14.2).[245] Early warning systems identify areas and populations experiencing higher smoke exposure on a near-real-time basis.[246,247]

## *Vector-Borne Diseases*

Climate change is a significant contributing factor to the increase in vector-borne disease cases reported over the last 20 years.[71,72,73] To adapt to these changing risks, new technologies to prevent transmission of vector-borne diseases are urgently needed, as traditional control measures, including insecticides, are rapidly becoming ineffective.[71,248,249,250] Recent advances include vaccines, spatial repellents, genetically modified mosquitoes, and *Wolbachia* (a naturally occurring bacteria that reduces transmission of viruses such as dengue).

However, these novel adaptations are not yet operational due to funding, regulatory status, and infrastructure needs. Buy-in from communities and decision-makers is critical to ensure that emerging strategies can be utilized to protect health.[92,218,251,252,253,254] Coupling novel strategies with well-established community engagement practices, such as remediating vector habitat and increasing personal protective measures, can effectively reduce risk and empower communities.[255,256]

### Mental and Spiritual Health

Actions to support community social cohesion and cultural continuance, establish trusted and effective communication systems, and ensure that community members and/or officials can effectively manage disasters may buffer against adverse mental health outcomes.[147] A personal sense of agency to take climate action can reduce adverse mental health outcomes during extreme events. It can provide hope for survival and contribute to greater participation in community responses to climate change, which may also improve mental health resilience.[257]

### Community-Level Resilience and Adaptation Strategies to Build Capacity

Communities, connected through relationships and practices,[258] have unique priorities, traditions, and histories relevant to adaptation.[259] Many communities are already making proactive intergenerational adaptation decisions to reduce exposure to climate impacts, build capacity, and enhance healing and self-determination in the face of historical traumas (Figure 15.6).[260] Many Indigenous Peoples in the US practice cultural burning, a fire management approach that promotes ecosystem resilience and growth of culturally important medicinal plants[129,261] while also serving as an eco-centric adaptation strategy for improved planetary health.[262,263] The Swinomish Indian Tribal Community used values-driven data and community input in developing Indigenous health indicators and a climate change health assessment for adaptation decision-making; the indicators included community connection, self-determination, education, resilience, cultural use, and resource security.[174,264,265]

External adaptation strategies can exacerbate inequities through, for example, institutional racism, uneven distribution of adaptive capacity, and resource allocation that ignores distributive and historical injustices (KM 31.1). Adaptations (e.g., tree planting) that make an area more appealing for people with higher income could push existing residents out, resulting in eco-gentrification.[266,267] There are policies and institutional barriers to implementing whole-community adaptation actions.[129,268]

## Indigenous-Led Disaster Recovery Actions and Improved Health Outcomes

**Louisiana Tribal leaders are upholding sovereignty and self-determination in their climate adaptation actions following hurricane damage.**

**Figure 15.6.** Tribal leaders from coastal Louisiana shared Indigenous and local knowledge, wisdom, and experiences of the health impacts and resilience-building recovery actions following Hurricane Ida, which made landfall in coastal Louisiana in August 2021. Interviews were recorded during a convening where the Tribal leaders came together to share how Louisiana Tribes are adapting to climate change while upholding sovereignty and working to improve health outcomes. Link to videos. Image credit: ©Craig Richard and Unitarian Universalist Service Committee, in collaboration with the First People's Conservation Council of Louisiana, Lowlander Center, Livelihoods Knowledge Exchange Network, and Disaster Justice Network, July 2022.

Addressing immediate needs and developing healthier long-term outcomes that reduce inequities[269] and strengthen community resilience[147] involves collaboration and cooperation across multiple scales. Persons with disabilities, for example, are often excluded from adaptation and mitigation efforts,[270] and there is a strong need for disability-inclusive climate planning and response.[271] The most impacted communities must be included in decision-making, from visioning and planning through implementation.[258,272,273]

Community adaptation capacity is enhanced by building and sharing flexibility, humanity, spirituality, and resilience. To be effective, adaptation strategies must integrate workforce development into co-governance and promote institutional support systems for community-defined, -driven, and -led adaptation efforts that include a diversity of cultures, histories, lifeways, and knowledge systems.[129,260,274]

# Traceable Accounts

## *Process Description*

Chapter authors were selected over a three-week period in August 2021. The initial discussion centered around authors who had been nominated or who had self-nominated. The chapter lead author and federal coordinating lead author then expanded the list and focused on balancing career stage, topic expertise, geographic location, and type of institution (academic, federal government, nonprofit). Once the chapter lead author had narrowed down the search, the authors were contacted. All contacted authors agreed to participate and were invited to complete the survey to be officially enrolled. The 18 authors for the Human Health chapter are subject experts in the topics selected for inclusion. Technical contributors were added as needed during the response to comments from the public and the National Academies to bring in additional data and subject-matter expertise.

Authors reviewed and evaluated scientific literature on the human health impacts of climate change, with a focus on new and emerging evidence since the Fourth National Climate Assessment (NCA4). Authors also reviewed technical inputs (submitted as part of the NCA5 process) for relevant information. The entire author team regularly met virtually to create and review chapter content; all authors participated in determining Key Messages and chapter topics and content. A public engagement workshop was held to solicit public input. The chapter was informed by workshop participants' concerns and comments. Authors also met in person in April 2023 to continue writing and incorporating additional information in response to review comments.

## Key Message 15.1

## Climate Change Is Harming Human Health

### Description of Evidence Base

Multiple lines of evidence demonstrate that climate change is already harming human health.[69,269,275,276] Evidence indicates that extreme events and climate-related environmental changes will continue to place stress on food, water, and energy supplies (KM 2.2). This, in turn, will negatively impact the health of the US population in many ways, including reduced access to healthcare. Based on recent peer-reviewed research, this Key Message outlined the existing health impacts in the areas of extreme heat, drought, wildfires, infectious diseases, food and water quality and security, mental and spiritual health, compounding hazards, and occupational safety. Studies demonstrate that these trends will continue to increase.[269,277]

Evolving attribution science allows researchers to study how extreme events, and resultant health impacts, were influenced by climate change. This growing evidence line contributes to our understanding of the role of climate change in the health impacts of heatwaves, floods, droughts, and other disasters.[278,279,280,281]

### Major Uncertainties and Research Gaps

While ample evidence demonstrates the health impacts of climate change, uncertainties remain on specific aspects of these impacts. For example, uncertainties in projections of human health outcomes in response to climate change can partially stem from the underlying human case data involved in the research, which is subject to underreporting or underdiagnosing the human case counts. Quantifying the impacts of climate change on human health is challenging due to lack of long-term surveillance and datasets; differential exposures based on location; and underlying health inequities.[282] In addition, health surveillance related to extreme weather is being improved through utilization of syndromic ("real-time") surveillance, data modernization initiatives, and integration of existing surveillance systems. Decades of research on the impacts of climate change on infectious disease illustrate the complexity of the pathways by which climate change may alter disease transmission dynamics. Uncertainties arise from geographic differences in social–behavioral–environmental interactions, vector and non-human reservoir species involved in the disease system, and difficulties in isolating the impact of climate change from other significant environmental and human-driven changes (App. 4.6).

Evidence is growing that there are emerging mosquito-borne diseases and species that are able to transmit pathogens in the US. However, not all of these are linked entirely to climate change but also to land-use change, global trade, and importation of pathogens related to travel.

There is also a growing body of evidence exploring the bionomics of mosquitoes and ticks and the pathogens they carry to better understand the underlying mechanisms by which changes in thermal conditions could increase or decrease disease risk.[283]

Most projection models of range do not use disease but rather vector range as the endpoint. Arizona, for example, has an abundance of the dengue virus vector *Aedes aegypti*, but there has been little documentation of local transmission of dengue.[284,285] There is also uncertainty around how the mosquitoes and ticks themselves, as well as the pathogens they are carrying, will adapt to climate change.[76]

Uncertainty also stems from challenges with surveillance systems and data collection relating to heat injury and illness, especially in the occupational setting. As is the case with occupational data generally, data on and estimates of heat-related morbidity and mortality differ based on the source of the data.[286,287] Some heat-related impacts may not be properly categorized as heat-related[288] and may not accurately capture the location of exposure, as it may be reported either by the person's residence or by the location where medical treatment was sought.[289] Further, the Bureau of Labor Statistics estimates that its accounting of occupational injuries and illness are undercounted.[290,291] It is therefore challenging to estimate the true number of injuries and illnesses due to extreme heat, and heat morbidity and mortality are underreported.[139] Occupational health impacts from other climate hazards may also be underreported.

Recent cold spells in Texas (e.g., February 2021) and other regions have highlighted the impacts of cold weather on communities, including fatalities that resulted from cold weather exposure and power failures.[292,293] Whether such trends in cold spells will continue is uncertain,[294] but colder temperatures are associated with adverse health outcomes and increase the risks of death and illness.[295,296,297] Positive and negative health impacts arising from climate-related shifts in ice storms, blizzards, and cold spells are an area for future research.

There is little research on the long-term health impacts of wildfire smoke exposure in communities that face repeated wildfires or on human health harms, and associated costs, from exposure to compounding and cascading hazards. There is a lack of research exploring the pathways associated with drought and human health in the United States. The full range of mental health impacts of climate change and climate-related events is not yet fully understood.[298] Additional research is needed in all of these areas, including compounding events such as drought and flooding, to better describe the pathways that affect human health.

There are important administrative, logistical, and methodological challenges in assessing mortality and morbidity common to large-scale disasters and public health emergencies of any provenance. These challenges undercut the ability of practitioners to gather, report, and use mortality and morbidity data to save lives and protect health in the wake of a public health event, from the initial devastation through the long tail of recovery. Accurate and timely information about mortality and significant morbidity related to the disaster is the cornerstone of the efforts of the disaster management enterprise and will require holistic data systems and new approaches in order to be more effective.[299] Specifically, there is not a standardized methodology for counting excess deaths during and after hurricanes, which can result in an underestimation of number of deaths (Figure 23.5).[300] Similarly, vector-borne, food-borne, and water-borne diseases are not fully captured in case numbers.[71,301] For example, cases of the rare, and typically fatal, primary amebic meningoencephalitis from exposure to the amoeba *Naegleria fowleri* have been documented farther north, although this conclusion is based on limited case numbers.[57] Thus, the true burden of climate-attributable health effects may not be known; more research is needed to quantify health impacts in relation to physical, mental, and spiritual health.

### Description of Confidence and Likelihood

Based on multiple lines of peer-reviewed evidence, including field studies, laboratory studies, model projections, and systematic reviews, it is an established fact that climate change is negatively impacting the health of the US population. Based on the amount and quality of peer-reviewed research, it is *very likely*, with *very high confidence*, that climate-related hazards will continue to grow, increasing human health impacts across all regions of the United States. Adaptation and mitigation activities could reduce this impact and protect health; the scope and scale of these efforts will determine future confidence levels around health impacts.

## Key Message 15.2

## Systemic Racism and Discrimination Exacerbate Climate Impacts on Human Health

### Description of Evidence Base

While all people in the US face health risks linked to climate change, some populations are affected sooner and more intensely.[269,302] This is because of differences in the number of and severity of exposures to climate hazards (Figure 15.5), sensitivity to these hazards, and ability to adapt (KM 20.3).[99] This Key Message outlines how ample peer-reviewed literature and data indicate that some populations disproportionately face environmental injustices, including impacts from climate-related extreme events. Systemic racism, discriminatory policies, and longstanding marginalization and disenfranchisement all contribute to increased climate vulnerability and to determining who bears the most climate risk.[99,303] Specifically, this Key Message outlines the peer-reviewed evidence behind climate change's disproportionate impact in the areas of community health, food and water systems, healthcare access and delivery, Tribal and Indigenous Peoples' health, persons with disabilities' health, African American and Latinx peoples' health, women's health, and sexual and gender minorities' health.

### Major Uncertainties and Research Gaps

There is relatively little community-driven participatory research on the health impacts of climate change, which leads to a lack of full understanding of impacts on disproportionately at-risk populations. There may also be underreporting of health outcomes due to a lack of healthcare access in some communities. For example, the mechanisms causing certain demographics, such as Black and Latinx populations, to have an increased risk of contracting Valley fever are unknown. More research is needed to determine links among higher rates of occupational exposure, societal factors such as access to healthcare or health insurance, or genetics.[68]

There is limited data on well-water usage and quality in some states, and limited funding and capacity for water quality testing in disproportionately impacted communities.[304] Similarly, there is a research gap on aspects of climate change impacts on food quality, security, and nutrition in the US, as much of the research focuses on developing countries.[305,306]

There is also limited research on system-wide health impacts, in which communities, ecosystems, and all living relatives depend on the holistic, intact system to survive and thrive.[307] Such understanding is important to ensure that adaptation does not happen in silos or isolation but rather includes the entire living system and that the proposed actions can actually achieve the intended results; this can determine the ability not only to survive but also thrive for generations to come. This is of particular importance to Indigenous communities.

More research could increase understanding of gender disparities for women and for sexual and gender minorities.[193] More research on risk factors and contextualized vulnerabilities could also provide better insights into acceptable prevention and control strategies that can be implemented to protect the health of disproportionately impacted populations. There is limited research exploring the unique vulnerabilities of women and gender minorities in pregnancy, as well as the impact on fetal outcomes.[1,308,309] Some studies demonstrate that women experience more significant health consequences, but very few directly relate them to climate change specifically.[197]

Research gaps at the intersection of disability, climate change, and health are impeding the development of effectual climate adaptation and mitigation policies and initiatives.[271,310] Participatory research is required to understand the climate impacts and health disparities experienced by the heterogeneous disability community.[271] Future climate-related health research can consider compounding multiple discrimination, including persons with disabilities, African Americans, Latinx, women, children, Indigenous People, older persons, and sexual and gender minorities.[178,271,310] A bottom-up approach to the development of public health responses with and by organizations of persons with disabilities may advance innovative public health approaches.[271] Additional research on the health effect of heat could demonstrate effectiveness of interventions for the diverse disability community.[271] Moreover, further environmental justice research inclusive of persons with physical and mental disabilities would assist climate adaptation and mitigation planning and initiatives.[311] A greater proportion of persons with ambulatory and cognitive disabilities were found to reside in neighborhoods with Hurricane Harvey–induced flooding in Harris County, Texas, many in public housing in non-White neighborhoods with low wealth; such research is vital to future disaster risk-reduction strategies.[312] Accurate health surveillance of morbidity and mortality among disability populations that have been marginalized, including persons with intellectual disabilities, is critical to ensuring disability-inclusive climate responses.[271] Additional research would improve knowledge of climate and health impacts on the Latinx population. The use of the term Latinx in the chapter is used to reflect gender diversity and is inclusive of nonbinary, gender nonconforming, and transgender individuals. The term Latinx is primarily used by younger generations and sexual and gender minorities.[313] Some literature suggests that the term should not be used because *x* is not common in the Spanish language, upholds a Western idea that gender neutrality is grammatically superior, and, when used to refer to all Latinx individuals, can erase Latinas similar to the way that "Latinos" does.[313,314,315] Other literature suggests that use of the term allows for individuals, who are often erased and discriminated against, to self-identify as a gender outside of or between the binary or who may not have a gender at all.[313] Use in this chapter is consistent with the inclusion of the sexual and gender minorities section and the CDC's adoption of the term "Latinx" when referring to health equity.[99] Additional community-based research to inform specific impacts on Latinx communities is needed.

There is limited data at the census tract level or similar geographic scale on social vulnerability and climate hazards. Figure 15.5 identifies specific counties with increasing trends in climate hazard–related economic loss that also are designated as vulnerable using the SoVI (Social Vulnerability Index), which synthesizes information across multiple variables at the county scale. It does not, however, fully capture the disproportionate impacts of climate hazards in specific neighborhoods or on specific population or cultural groups within a county, nor does it account for risk created by historic marginalization.

Furthermore, data suppression due to health privacy concerns can limit the availability of data for research on specific racial or gender groups. In addition, political sensitivities around the topic of climate change impacts on specific populations can hinder research and response.

### Description of Confidence and Likelihood

It is unequivocal that some populations are already disproportionately impacted by climate change, as evidenced by multiple lines of data and peer-reviewed research that included longitudinal field studies. Research and data indicate that disproportionately affected populations include persons with disabilities, older adults, pregnant people, children, sexual and gender minorities, some communities of color, and those living in communities that have been under-resourced and over-burdened. Populations at higher risk will continue to be negatively impacted by climate change unless disparities are addressed and adaptation and mitigation strategies are targeted to benefit all communities and, in particular, those that have been marginalized.

## Key Message 15.3

## Timely, Effective, and Culturally Appropriate Adaptation and Mitigation Actions Protect Human Health

### Description of Evidence Base

Multiple lines of research indicate that the health of the US population benefits from adaptation and mitigation activities, including integrated approaches to mainstream health into policies such as improvements in food, infrastructure, water, and sanitation. There is growing evidence that various adaptive strategies (e.g., cooling centers, building resilient healthcare infrastructure, communication campaigns, etc.) have an impact on knowledge, attitudes, and behaviors that can improve health.[269,316] For example, federal programs from the US Department of Health and Human Services (Low Income Home Energy Assistance Program) and the Department of Energy (Weatherization Assistance Program), as well as state governments, are implementing a suite of additional energy efficiency programs to help families reduce their energy costs and protect their health.[229] Recent research and limited literature reviews describe and classify the level of effectiveness of various adaptations and interventions to protect health.[316,317,318] This evidence informed the Key Message content related to adaptation. Additional research and evidence showing direct impact on human health outcomes would be needed to increase the confidence level to *very high*.

Peer-reviewed evidence indicates that strategies to reduce greenhouse gas emissions (mitigation) can protect health by reducing future climate hazards.[205] They also can increase resilience by providing co-benefits that immediately improve health.[319] The economic value of avoided hospitalizations and premature deaths are of the same order of magnitude as or larger than the cost of implementing the mitigation polices.[29]

### Major Uncertainties and Research Gaps

There are still uncertainties and research gaps around timely, effective, and culturally appropriate adaptation and mitigation actions, including in the areas of risk management and integrated approaches, community-level resilience and adaptation strategies to build capacity, climate resilient and sustainable health systems, benefits of reducing air pollution, disease surveillance, and actions to protect populations from extreme heat, wildfires, and vector-borne diseases.

Further research could help document the effectiveness of adaptation and mitigation options in both the short term and long term. This could include examining the specifics affecting the success of interventions, including enabling conditions, constraints, and barriers, as well as effective approaches to overcome challenges and to scale up effective measures. Some mitigation and adaptation activities can have unintended negative health consequences; for example, trees planted to provide shade and reduce exposure to unsafe temperatures may inadvertently increase pollen levels and pose a hazard to those with respiratory health issues such as asthma.[320,321] Providing timely pollen information to clinicians, public health practitioners, and the public could increase awareness and allow at-risk individuals to take preventive measures (KM 14.4). Because pollen monitoring stations are sparsely distributed, using nontraditional data sources such as information from web searches[322] and near-real-time data on symptoms of emergency department patients[323] can offer alternative ways of gathering and communicating potential risks of pollen exposure.

There is also a lack of research on the effectiveness of some health-protective actions in different regions and among varying population demographics; for example, tree planting may not be a feasible strategy to provide shade in a water-scarce ecosystems such as the desert Southwest. More research would improve understanding on how individual and community-level social capital impacts the effectiveness of adaptation and mitigation strategies.[324] More research would also help tailor health communication messages to specific populations, an effective strategy to protect health.[325]

Continuous improvements in research and modeling can help drive evidence-based public health responses to minimize illness and death.[224,225,226] Climate-sensitive disease or health-outcome surveillance systems could be integrated with weather event tracking and economic cost estimates to assess the overall impact of such events.[31,326]

There is limited curriculum on the health impacts of climate change. Greater integration into medical school, nursing school, and public health curricula can increase awareness of the established links between climate change and health and effective adaptation and mitigation strategies to reduce these health impacts.[327,328]

Health departments are chronically underfunded, and most do not have the resources to prepare for and respond to the health impacts of climate change.[329] Increased capacity is needed to track hazards, build community resilience, and address cascading hazards. Improved data and capacity would allow for more effective adaptation and mitigation actions to protect health. Healthcare and public health worker shortages and unstable funding limit the ability of practitioners to engage in climate change–related health protection activities.

More research is also needed on community acceptability of adaptation and mitigation interventions to ensure effectiveness and sustainability. In addition, there are still gaps in implementation science ("the scientific study of methods and strategies that facilitate the uptake of evidence-based practice and research into regular use by practitioners and policymakers"[330]), a practice that helps ensure interventions benefit the communities that are most impacted by climate change.[99]

## Description of Confidence and Likelihood

In the first statement of Key Message 15.3, the author team determined that there is *high confidence* that human health can be protected if adaptation measures are implemented. This statement is based on multiple lines of peer-reviewed evidence and real-world examples of successful adaptation strategies. Measures such as building energy retrofits, the establishment of education and outreach programs, installation of white roofs, and improvement of equitable access to cooling centers and green spaces can help protect human health if the necessary resources to implement these strategies exist or are made available. Based on peer-reviewed literature, there is also *high confidence* that creating climate-resilient health systems will protect health and *high confidence* that mitigation efforts to reduce greenhouse gas emissions can protect health and improve health equity.

There is some uncertainty because it is difficult to determine future human behavioral response to the proposed adoption of adaptation and mitigation strategies. In order to improve health equity, it remains important to contextualize these strategies to specific communities, determine acceptability of strategies to specific communities prior to introduction, and investigate potential unintended consequences prior to adoption of mitigation strategies.

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