YALE CENTER on
CLIMATE CHANGE
and HEALTH

Climate Change and Health in Connecticut 2020 Report

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AUTHORS

Laura Bozzi, PhD

Robert Dubrow, MD, PhD

CONTRIBUTORS

Mauro Diaz-Hernandez

Melpomene Vasiliou, MPH

Kai Chen, PhD

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More information about the Yale Center on Climate Change and Health can be found at: https://publichealth.yale.edu/climate.

Table of Contents

EXECUTIVE SUMMARY

This report tracks 19 indicators related to climate change and health in Connecticut. Its purpose is to inform policymakers, health professionals, advocates, and residents about the impact of climate change, now and in the future, on human health in Connecticut. The indicators have been developed using publicly available data from state and federal agencies, peer-reviewed literature, and medical associations. Where possible, we directly track trends in health impacts (e.g., West Nile virus infections; emergency department visits and hospitalizations for heat stress). However, because of the relative paucity of Connecticut-specific data on health impacts associated with climate change, we also track environmental and climate conditions (e.g., drought; outdoor allergens) that can lead to adverse health outcomes.

We note trends when they are statistically significant, and wherever possible we report indicator results for each county. Some of our indicators demonstrate a trend over time consistent with what is expected under climate change, such as increasing average temperatures and heavy rainfall events. Other indicators do not yet show a trend, but scientific studies project changes as the planet continues to warm (see PANEL). The number of heat waves, for example, is projected to increase, in turn causing more heat-related illness.

There is overwhelming evidence that the dominant cause of warming temperatures is human activities, particularly from the emissions of greenhouse gases through the burning of fossil fuels (i.e., coal, oil, and natural gas), as well as from other activities including livestock production and deforestation.[1] Greenhouse gases warm the planet by acting like a blanket that traps heat from the Earth that would otherwise escape into space; the more greenhouse gases in the atmosphere, the more heat is trapped. In this report, we track indicators related not only to the impacts of climate change, but also to impacts caused by the drivers of climate change (specifically, air quality impacts largely driven by fossil fuel combustion).

While climate change affects everyone, it does not affect everyone equally. Climate change is sometimes called a "risk amplifier," meaning that many existing

PROJECTED CLIMATE CHANGE PHYSICAL IMPACTS

University of Connecticut researchers projected climate change impacts in Connecticut employing a high greenhouse gas emissions scenario (RCP 8.5, or "business as usual," in which no efforts are made to reduce emissions). Under this scenario, the following impacts are projected for mid-century (2040–69), compared with 1970–99:

- 5 ºF increase in annual mean temperature
- 8.5% increase in annual precipitation, due primarily to increases in winter and spring
- Greater flood risk due to the increase in heavy rainfall events
- Extreme summer droughts that occur three times as often[4]

The Connecticut Institute for Resilience and Climate Adaptation recommends planning for 20 inches (0.5 meters) of sea level rise by 2050, with continued sea level rise to occur after 2050.[5, 6] Higher sea levels lead to more severe storm surges associated with coastal storms. In addition, as climate change progresses, Atlantic hurricanes are expected to become more intense (higher sustained wind speeds), with greater amounts of precipitation.[7]

risks to health—derived from environmental, economic, demographic, social, or genetic factors—are intensified by climate change impacts.[2, 3] Populations disproportionately vulnerable to the effects of climate change include those with low income, communities of color, immigrant groups (including those with limited English proficiency), Indigenous people, children and pregnant women, older adults, vulnerable occupational groups, people with disabilities, and people with preexisting or chronic medical conditions.[3]

KEY FINDINGS

The following section presents the report's key findings for each of the 19 indicators, along with a brief explanation about the indicator's relationship to climate change and health. A complete description of each indicator, including data figures, is found in the full report.

TEMPERATURE

INDICATOR 1: AVERAGE ANNUAL TEMPERATURE. Average annual temperature increased by 3.0–3.5 ºF in each county from 1895 to 2019. The increase in average temperature has wide-ranging effects, including for human health. For instance, warmer nighttime temperatures can be especially dangerous, particularly for people living in urban areas and for those without access to air conditioning. This is because cool nights are typically an opportunity for the body to cool down; without this cooling-off time, heat waves can be even more perilous.

INDICATOR 2: EXTREME HEAT DAYS. From 1950 to 2018, the number of extreme heat days (days with maximum temperature over 90 ºF) did not change significantly in any county. However, under climate change, such extreme heat days can be expected to increase, which is a significant concern for human health. Extreme heat days can be especially dangerous in cities because of the urban heat island effect, a phenomenon in which urban areas are hotter than surrounding areas because of the density of buildings and roads and the lack of trees, other greenery, and streams, rivers, ponds, and lakes.

INDICATOR 3: FROST DAYS. The number of frost days (days with minimum temperature at or below 32 ºF) decreased from 1950 to 2018 in four of the eight counties: Middlesex, New London, Tolland, and Windham. Fewer frost days, an earlier winter-spring transition, and a later fall-winter transition transform the natural environment in ways that can negatively affect human health, including by creating conditions for larger tick and mosquito populations that are active over a greater proportion of the year; a longer season for ragweed pollen,[8] which causes hay fever and exacerbates asthma; and a greater abundance of and longer seasons for plant pests, adversely affecting both forests and agriculture.[9]

INDICATOR 4: EMERGENCY DEPARTMENT VISITS AND HOSPITALIZATIONS FOR HEAT STRESS. From 2007 to 2016, there were on average 422 emergency department visits and 45 hospitalizations per year for heat stress in Connecticut. It is important to note, however, that the numbers of emergency department visits and hospitalizations are likely underreported; medical personnel often mistakenly fail to attribute the cause of illness to extreme heat, especially in a state like Connecticut where heat-related illness may not be as common as in some other parts of the country. Heat-related illnesses, such as heat exhaustion or heat stroke, happen when the body is not able to properly cool itself. Heat stroke can cause damage to the brain and other vital organs, or even death.

INDICATOR 5: POPULATIONS VULNERABLE TO HEAT-RELATED ILLNESS. This indicator tracked the following groups that are especially vulnerable to heat-related illness: outdoor workers (farm laborers; workers in the landscape and construction industries), people experiencing homelessness, and people age 65 and older. **The number and proportion of people over 65 in Connecticut is increasing, while the number of**

people experiencing homelessness is decreasing. The number of people in the other groups shows no trend over time. Together, these populations represent a substantial number of people at risk for heat-related illness.

EXTREME EVENTS

INDICATOR 6: HEAVY RAINFALL EVENTS. From 1960 to 2019, the annual number of heavy rainfall events (three consecutive days with cumulative precipitation of 3 inches or more) increased in New Haven, Hartford, Litchfield, Tolland, and Windham counties. Heavy rainfall can overwhelm the natural and human-made systems that normally process rainwater, leading to flooding along river systems and in urban areas. Flooding can cause injury and death due to drowning; can lead to indirect health impacts from disruption to medical care and critical infrastructure; and can result in human exposure to pathogens or toxic chemicals through their release into floodwaters or drinking water sources.[10] Heavy rain and flooding also can adversely affect indoor air quality by causing mold growth, chemical off-gassing from damaged building materials, and formation of other air contaminants.[11, 12] Exposure to extreme events, including flooding, is associated with a range of mental health impacts, such as post-traumatic stress disorder.[12]

INDICATOR 7: HIGH TIDE FLOODING. The annual number of days with high tide flooding has increased at the New London and the Bridgeport tide gauges, a trend consistent with the 8–9 inches of global sea level rise since 1880. High tide flooding occurs when seawater temporarily inundates low-lying areas until the tide recedes. As the flooding becomes more common or greater in magnitude or both, it can have an adverse effect on health. Flooding can transmit pathogens such as *Vibrio* bacteria, which can cause wound infections among people walking through the water. Saltwater can contaminate drinking water sources near the coast, as well as coastal agricultural fields. With a highly developed coastline, Connecticut also is at risk for high tide flooding affecting a large number of roads, homes, businesses, and other infrastructure.[13]

INDICATOR 8: DROUGHT. While there is no significant trend toward increased drought in any county, Connecticut has recently experienced disturbing droughts, including a 46-week statewide drought in 2016–2017. Expected impacts of moderate drought include increased wildfires, stressed trees and landscaping, and lake and reservoir levels below normal capacity. As a drought worsens, impacts expand, with particular concerns about agriculture, wildlife, and wildfires. Drought strains drinking water systems by lowering surface water reserves and contributing to saltwater intrusion into freshwater aquifers along the coast. The prolonged 2016–2017 drought raised awareness in Connecticut that river basins can become depleted, even though water scarcity has not typically been a problem for the state in the past.[14]

INDICATOR 9: DRINKING WATER RESERVOIR CAPACITY. We found no indication of a trend toward lower reservoir levels. Climate change may affect drinking water availability by increasing the intensity or frequency of droughts, storms, and other system shocks. Droughts, especially if prolonged, lower water levels in reservoirs (and wells), an impact we investigated through this indicator. Hurricanes may damage drinking water system infrastructure, as occurred during Hurricane Irene in 2011.[15, 16] Wells near the coast may be at risk for contamination from saltwater intrusion due to sea level rise and drought. Blue-green algae blooms—and more dangerously, harmful algal blooms—are more likely as surface water sources warm with rising temperatures.[17]

INDICATOR 10: WEATHER DISASTERS. From 2010 to 2019, nine federal disaster declarations for weather events were issued for Connecticut, compared with only 13 in the previous 56 years. Following those nine disaster declarations, the Federal Emergency Management Agency provided a total of $304.6 million in combined individual and public assistance grants to support recovery efforts. Nationally, weather disaster events are rising, with significant economic and social cost: 2019 was the fifth consecutive year in which the country endured 10 or more billion-dollar weather disaster events.[18] Over the past five years, the total cost of these disaster events nationally was approximately $500 billion.[18]

INDICATOR 11: SUPERFUND SITES. Seven of Connecticut's 16 Superfund sites are vulnerable to climate change impacts, including flooding and hurricane storm surge. Under the U.S. Environmental Protection Agency's Superfund program, the federal government identifies and cleans up contaminated sites to protect human health and the environment. In Connecticut, these sites range from old industrial sites to waste lagoons, quarries, and landfills. Climate change is making coastal storms more intense and extreme precipitation events and coastal and inland flooding more frequent, which may further damage Superfund sites and potentially release contaminants into ground or surface water, the air, or the soil.[19]

INFECTIOUS DISEASES

INDICATOR 12: MOSQUITOS. During 2001–2019, of 28 mosquito species found in Connecticut to carry viruses that cause human disease, 10 show trends of increasing abundance and three show trends of decreasing abundance. Mosquito abundance is a key factor that influences the capacity of a mosquito to transmit a virus and the rate at which infections spread. A high abundance is often a prelude to an epidemic.[20] Each of the mosquito species we tracked has been found in Connecticut to carry one or more of the following viruses: Cache Valley, Eastern equine encephalitis, Jamestown Canyon, Trivittatus, or West Nile.[21] Mosquitos, which are ectothermic (i.e., cold-blooded), can thrive in a warmer world.[22] As Connecticut becomes warmer, disease-carrying mosquitos may become even more abundant.

INDICATOR 13: WEST NILE VIRUS INFECTIONS. During 2000–2018, the number of reported symptomatic cases per year of West Nile virus infection, the leading mosquito-borne disease in the United States,[23] varied from 0 (2004 and 2009) to over 20 (2012 and 2018). Only about one in five people infected with West Nile virus show symptoms, which can include fever, headache, muscle pains, and rash. In very rare cases (1%), the infection can cause serious illness affecting the central nervous system, which can be fatal.[24] West Nile virus is transmitted by *Culex* mosquitos. Under INDICATOR 12, we found that one *Culex* species (*Culex salinarius*) has exhibited an increasing trend, which may be influenced by warmer weather or changes in precipitation patterns caused by climate change.

INDICATOR 14: EASTERN EQUINE ENCEPHALITIS. Connecticut's first reported human case of Eastern equine encephalitis, a rare mosquito-borne disease, occurred in 2013. In 2019, four cases were reported, of which three were fatal. Most people infected with this virus have no symptoms. Only in rare cases does an infected person develop a central nervous system infection; in these cases, Eastern equine encephalitis can be fatal. It is transmitted by *Aedes*, *Coquillettidia*, and *Culex* mosquitos. INDICATOR 12 shows that *Aedes albopictus*, *Culex salinarius*, and *Coquillettidia perturbans* are increasingly abundant in Connecticut, which may be influenced by warmer weather or changes in precipitation patterns caused by climate change.

INDICATOR 15: LYME DISEASE. Reported cases of Lyme disease declined from about 3,700 per year in 2008–2010 to about 1,900 per year in 2016–2018. Lyme disease, a bacterial disease transmitted to humans by the blacklegged tick, is generally cured with treatment; without treatment, symptoms can progress to severe joint pain and swelling, facial palsy, heart palpitations, inflammation of the brain and spinal cord, and nerve pain or numbness.[25] Transmission of Lyme disease occurs seasonally, with the most cases in Connecticut reported in June and July.[26] Cases may have declined because people are taking protective measures such as applying tick repellant and wearing long pants and sleeves when outdoors. Shorter and milder winters and earlier springs projected under climate change may lead to earlier tick activity and larger tick populations.[27] But extreme heat and drought increase tick mortality, so climate change also may lead to a countervailing force on tick abundance.[28]

INDICATOR 16: FOODBORNE *VIBRIO* INFECTIONS. The annual number of confirmed cases of foodborne *Vibrio* infections has increased. *Vibrio* bacteria live naturally in warm coastal waters, especially in lower-salinity estuaries. Humans can become infected by eating contaminated seafood that is raw or under-cooked. Symptoms include abdominal cramps, nausea, headaches, diarrhea, fever, and chills. As sea surface temperature rises, the abundance of *Vibrio* increases.[29] In Connecticut, summer near-surface water temperature is increasing at a significant rate on Long Island Sound,[30] consistent with the increase in *Vibrio* food-borne infections.

AIR QUALITY

INDICATOR 17: GROUND-LEVEL OZONE. Since 1990, the annual number of days on which ground-level ozone exceeded safe levels decreased in all counties, but more improvements are needed to fully protect human health. In fact, the American Lung Association gave all eight Connecticut counties an F grade for ozone pollution in its 2019 *State of the Air Report*.[31] The decreasing ground-level ozone trend in Connecticut (and nationally) is due to national and state environmental regulations, including those that limit emissions of precursor pollutants from the burning of fossil fuels in vehicles, power plants, and industry. Ground-level ozone is a strong lung irritant that can cause respiratory symptoms, asthma exacerbation, and premature death. In the Northeast's urban areas, the hottest days are associated with the highest concentrations of ground-level ozone.[9] This combination of extreme heat and poor urban air quality poses a major health risk to vulnerable groups, especially those with asthma and other preexisting respiratory conditions.[9]

INDICATOR 18: FINE PARTICULATE MATTER ($PM_{2.5}$). Since 1999, the annual number of days on which fine particulate matter exceeded safe levels decreased in Fairfield, Hartford, New Haven, and New London counties. No days meeting $PM_{2.5}$ Air Quality Index categories of unhealthy, very unhealthy, or hazardous have been reported in any of the five monitored counties in at least the past eight years. (There are no $PM_{2.5}$ monitoring stations in Middlesex, Tolland, and Windham counties.) As with ground-level ozone, this improvement in $PM_{2.5}$ pollution can be attributed to national and state environmental regulations that limit $PM_{2.5}$ emissions produced by the burning of fossil fuels in power plants, vehicles, and industrial sources. Exposure to $PM_{2.5}$ causes or aggravates heart and lung conditions and can cause premature death. Communities of color often live near power plants, major roads, and industrial facilities, increasing their exposure to $PM_{2.5}$ (as well as to ground-level ozone and other pollutants).

INDICATOR 19: OUTDOOR ALLERGENS (MOLD AND POLLEN). Since 2007, the percent of measured days with "high" or "very high" outdoor mold concentrations has increased. Concentrations of tree, grass, or weed pollen did not have increasing or decreasing trends. Nevertheless, increased carbon dioxide emissions and higher temperatures are expected to worsen allergies by lengthening the pollen season, raising the amount of pollen produced by plants, and possibly increasing the allergenic potency of the produced pollen, which would cause more intense allergic reactions.[32–34] Higher temperature and humidity have been found to promote the growth of mold outdoors.[35–37]

CONCLUSION

To protect human health now and in the future, Connecticut decision makers and residents alike must undertake strong action to confront the challenges identified in this report. First, this means swift action to mitigate climate change by reducing greenhouse gas emissions. Under its *2008 Global Warming Solutions*

Act and *2018 Act Concerning Climate Change Planning and Resiliency*, Connecticut has committed to reducing greenhouse gas emissions below 2001 levels by 45% by 2030 and 80% by 2050. Other states have committed to even more significant cuts, suggesting that Connecticut has further to go: New York, for instance, set a target of net-zero greenhouse gas emissions by 2050. Second, Connecticut must expand its work to prepare for and adapt to the climate change impacts that have begun and will worsen in the future. The Governor's Council on Climate Change now guides both efforts, with policy recommendations anticipated in early 2021 as part of the updated *Adaptation and Resilience Plan* for Connecticut and the council's annual report on the state's climate mitigation progress.

With this in mind, we offer seven crosscutting recommendations to support equitable, science-based, and holistic mitigation and adaptation actions to protect human health.

1 Monitor current conditions and project trends for Connecticut

To make rapid and effective responses based on data, decision makers need systems in place that monitor environmental and climatic changes and that track climate-sensitive health outcomes. Also needed is more research that projects Connecticut-specific impacts of climate change on human health in the future and identifies vulnerable populations. The state should pursue funding opportunities and partnerships to support the collection, monitoring, analysis, and dissemination of these critical data.

2 Invest in the social determinants of health

Social factors, including housing, education, employment, income, and access to medical care, are major drivers of population health. Climate change makes the imperative of addressing these social determinants to improve health and reduce health disparities even more urgent.[38] Actions to address climate change mitigation or adaptation that also invest in the social determinants of health produce synergistic benefits and should be prioritized.

3 Tackle the upstream drivers of climate change and health disparities

It has been aptly stated that "the root causes and upstream drivers of climate change and health inequities are often the same: Our energy, transportation, land use, housing, planning, food and agriculture, and socioeconomic systems are at once key contributors to climate pollution and key shapers of community living conditions."[39] Furthermore, these systems are "shaped by current and historical forces that include structural racism and the persistent lack of social, political, and economic power of low-income communities and communities of color."[39] Addressing climate change and health inequities requires confronting these upstream drivers by challenging historic and systemic burdens, including environmental pollution, income inequality, racism, and inequitable access to power and resources.

4 Pursue actions that integrate mitigation, adaptation, and immediate health benefits

Measures that combine climate change mitigation and adaptation with immediate health benefits should be prioritized. For example, increasing forested green space in coastal urban areas accomplishes mitigation because trees absorb carbon dioxide from the atmosphere; accomplishes adaptation because trees reduce the urban heat island effect through evapotranspiration and shade provision and because green space reduces flood risk; and provides immediate health benefits of space for physical activity, improved mental health, and healthier shellfish in Long Island Sound.

5 Build the capacity of health professionals and decision makers in other sectors to address climate and health

Most health professionals did not learn about climate change and its health effects in their formal training, and many other decision makers lack specific knowledge about how their issue area relates to climate change and health. Incorporating this material into health and other higher education curricula, as well as continuing education courses, would help close this key knowledge gap and prepare the workforce to make informed decisions under a changing climate.

This challenge should be addressed through combined efforts of colleges and universities, public health agencies, and professional associations.

6 Incorporate climate change into decision making across sectors

For both adaptation and mitigation efforts to be effective, climate change needs to be considered and incorporated into planning and investment at all levels of government. To do so requires that climate change not be treated as a siloed issue that can be addressed in isolation by personnel and policies focused only on climate change. Rather, inter-sectoral collaboration is essential.

7 Incorporate public health into climate change decision making

A "health in all policies approach" calls for public health representatives to be at the table when making policy decisions ranging from urban planning to transportation to voter registration.[40] Public health considerations should be incorporated into all climate change policymaking. An encouraging sign in Connecticut is that the Department of Public Health now has a seat on the Governor's Council on Climate Change. Its role on the council should fully cover both adaptation and mitigation workstreams, particularly given the opportunities for immediate health benefits from mitigation.

INTRODUCTION

Climate change is no longer a distant threat, and its impacts on public health are growing. This report tracks 19 indicators related to climate change and health in Connecticut. Its purpose is to inform policymakers, health professionals, advocates, and residents about the impact of climate change, now and in the future, on human health in Connecticut. The indicators have been developed using publicly available data from state and federal agencies, peer-reviewed literature, and medical associations. Where possible, we directly track trends in health impacts (e.g., West Nile virus infections; emergency department visits and hospitalizations for heat stress). However, because of the relative paucity of Connecticut-specific data on health impacts associated with climate change, we also track environmental and climate conditions (e.g., drought; outdoor allergens) that can lead to adverse health outcomes. Finally, we track indicators related to the impacts caused by the drivers of climate change (specifically, air quality impacts largely driven by fossil fuel combustion).

Wherever possible we report indicator results for each county, and we note linear trends when they are statistically significant (i.e., $p<0.05$). Some of our indicators demonstrate a trend over time consistent with what is expected under climate change, such as increasing average temperatures and heavy rainfall events. Other indicators do not yet show a trend, but scientific studies project changes as the planet continues to warm. The number of heat waves, for example, is projected to increase, in turn causing more heat-related illness.

Throughout the report we emphasize an important theme of vulnerability: while climate change affects everyone, it does not affect everyone equally. Climate change is sometimes called a “risk amplifier,” meaning that many existing risks to health—derived from environmental, economic, demographic, social, or genetic factors—are intensified by climate change impacts.[2, 3] For instance, those with chronic diseases are more likely to become sicker or die during an extreme weather event—a hurricane may disrupt electrical and transportation infrastructure, preventing chronic kidney failure patients from obtaining dialysis; wildfire smoke may precipitate asthma attacks among people with asthma; or heat stress during a heat wave may cause a worsening of symptoms among congestive heart failure patients. Similarly, residents in underinvested communities are more exposed to climate hazards like extreme heat because of fewer trees, poor building quality, or lack of access to air-conditioned spaces.[41] This means that developing policies and programs to address the health impacts of climate change must be done equitably and by prioritizing the most vulnerable.

This report has a second important theme: although we are seeing certain climate impacts now, and some future effects are already unavoidable, preventing catastrophic future impacts will require urgent and comprehensive action from local to global to reduce emissions of greenhouse gases, which cause climate change. Importantly, doing so also brings about major public health benefits—or "co-benefits"—in the short term. For example, generation of electricity using solar or wind energy instead of by burning fossil fuels not only reduces emission of carbon dioxide, the major greenhouse gas produced by humans, but also reduces emission of toxic air pollutants that cause illness and death.

The State of Connecticut, through Public Act Nos. 08-98 and 18-82, has committed to reduce greenhouse gas emissions below 2001 levels by 45% by 2030 and 80% by 2050. The Connecticut Governor's Council on Climate Change recognizes that "a 45% reduction by 2030 is an ambitious goal that will require significant changes to all sectors of the State's economy, and participation by all parts of society." [42] We hope that this report informs that process to assure that it is equitable, comprehensive, and swift.

19
INDICATORS

Average Annual Temperature

Extreme Heat Days

Frost Days

Emergency Department Visits and Hospitalizations for Heat-Related Illness

Populations Vulnerable to Heat-Related Illness

Heavy Rainfall Events

High Tide Flooding

Drought

Drinking Water Reservoir Capacity

Weather Disasters

Superfund Sites

Mosquitos

West Nile Virus Infections

Eastern Equine Encephalitis

Lyme Disease

Foodborne *Vibrio* Infections

Ground-Level Ozone

Fine Particulate Matter ($PM_{2.5}$)

Outdoor Allergens (Mold and Pollen)

TEMPERATURE

INDICATOR

1

Annual Average Temperature*

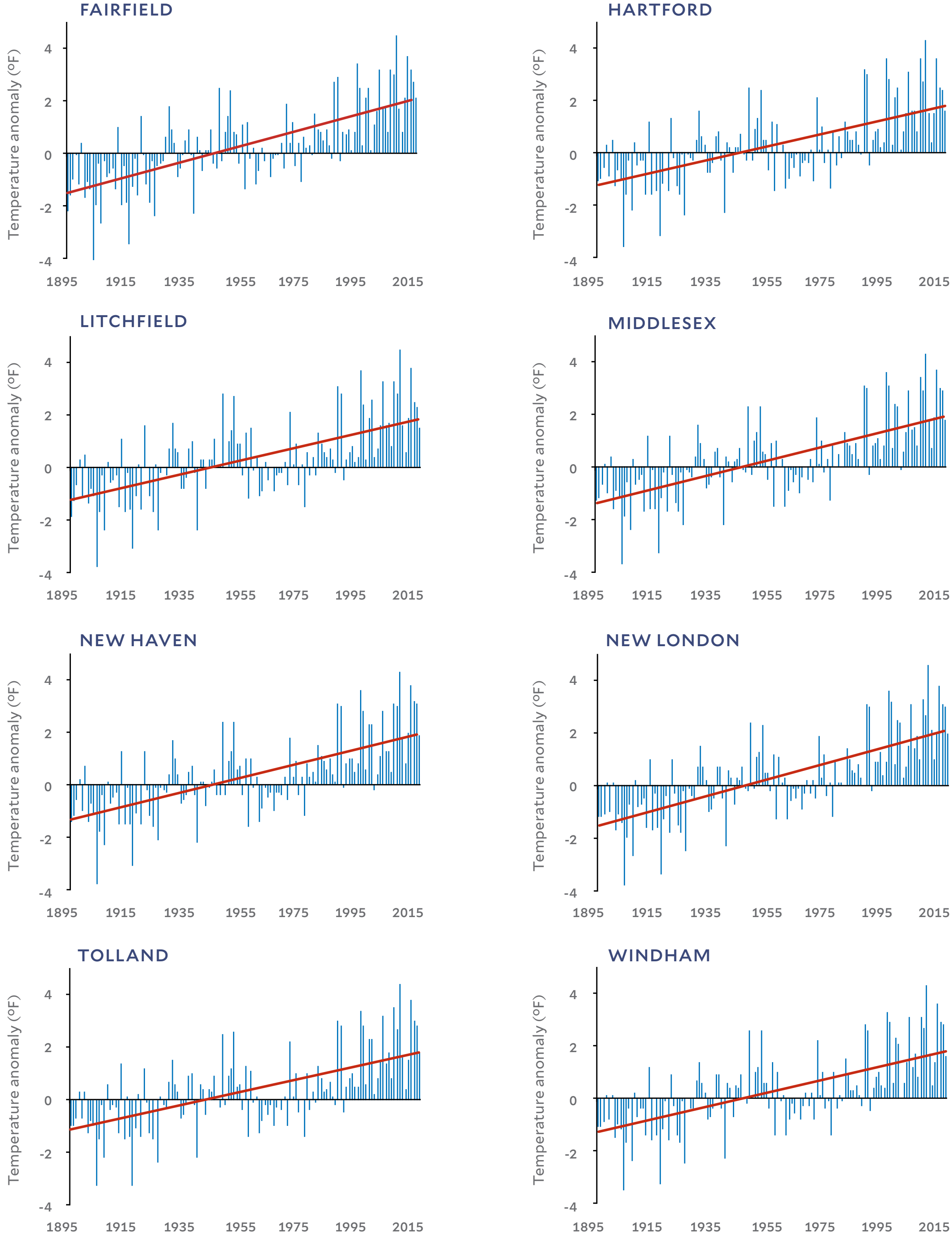


FIGURE 1: *Annual average temperature, 1895–2019, compared to 1901–2000 average, by Connecticut county.* The bars show the annual temperature anomaly (Y-axis), which is the deviation from the 1901–2000 average (set at 0) during a given year. Red solid trendline indicates statistical significance. Data source: (43).

* AVERAGE ANNUAL TEMPERATURE INCREASED BY 3.0–3.5 ºF IN EACH COUNTY FROM 1895 TO 2019.

What this indicator shows

Globally, temperatures are increasing due to climate change; global average temperature increased by about 1.7 ºF from 1901 to 2016.[7] We show in this indicator that in Connecticut the average temperature has increased even more—by approximately 3.0–3.5 ºF in each county since 1895 (**FIGURE 1**). Six of the ten hottest years (i.e., highest average temperature) since 1895 in Connecticut have taken place since the year 2005; in order, they are: 2012, 2016, 2010, 2006, 2011, and 2017.

There is overwhelming evidence that the dominant cause of warming temperatures is human activities, particularly from the emissions of greenhouse gases (primarily carbon dioxide and methane) through the burning of fossil fuels—coal, oil, and natural gas—as well as from other activities including livestock production and deforestation.[1] Greenhouse gases warm the planet by acting like a blanket that traps heat from the Earth that would otherwise escape into space; the more greenhouse gases in the atmosphere, the more heat is trapped.

How this relates to health

The increase in average temperature has wide-ranging effects, including for human health. Warmer nighttime temperatures can be especially dangerous, particularly for people living in urban areas and for those without access to air conditioning. This is because cool nights are typically an opportunity for the body to cool down; without this cooling-off time, heat waves can be even more perilous.

Importantly, it is not only high temperature that affects health, but also the amount of *temperature variation*. Areas of New England with more variable temperature in the summer have been found to have higher mortality from heat-related illness.[44] Similarly, a large change in temperature from one day to the next can increase heat-related deaths.[45, 46] One explanation for these findings is that when the temperature fluctuates significantly day-to-day, there is not sufficient time for our bodies to acclimate to the new temperature.

What can we expect in the future?

University of Connecticut researchers have made projections of future temperature increases for the state using a high greenhouse gas emissions scenario (RCP 8.5, or “business as usual,” in which no efforts are made to reduce emissions). Under this scenario, it is projected that Connecticut will experience an approximately 5 ºF increase in annual mean temperature by mid-century, compared to the reference period of 1970–1999.[4] Especially from a health perspective, it is important to keep in mind that an increase in average temperature will result in a substantial increase in dangerous extreme heat events. We can avoid this undesirable scenario through rapid local and global action to sharply reduce greenhouse gas emissions. We also can institute adaptation measures to limit the exposure of vulnerable people to extreme heat and to make our communities cooler through actions such as planting trees.

INDICATOR

2

Extreme Heat Days*

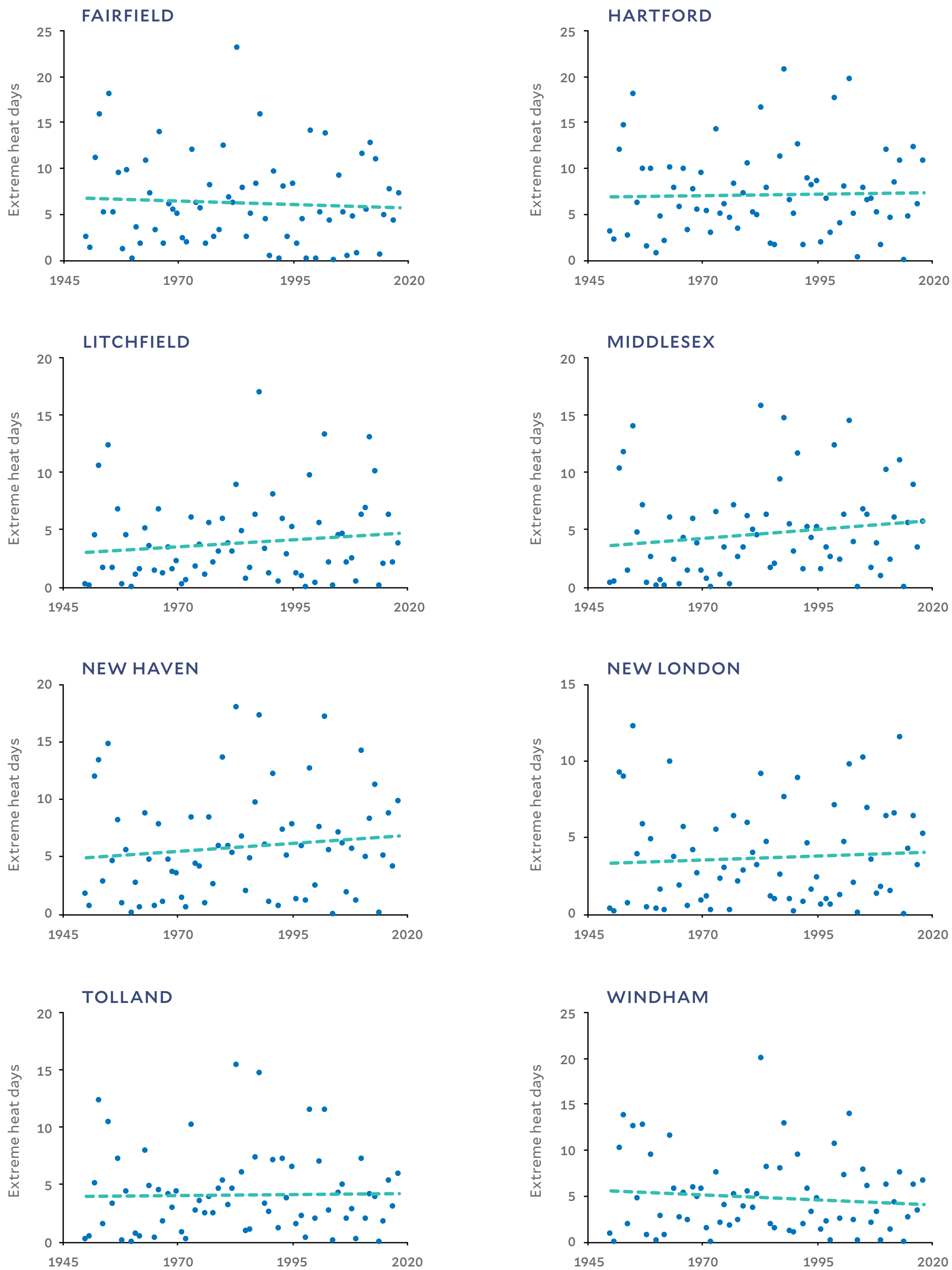


FIGURE 2: *Number of days per year with maximum temperature over 90 ºF, 1950–2018, by Connecticut county.* Data source: (47).

*** FROM 1950 TO 2018, THE NUMBER OF EXTREME HEAT DAYS DID NOT CHANGE SIGNIFICANTLY IN ANY COUNTY.**

What this indicator shows

This indicator tracks a measure of extreme heat days: the number of days per year with maximum temperature over 90 ºF. We found no statistically significant trend in the number of extreme heat days in any county (FIGURE 2). This finding is similar to that of Seth et al., who found no statistically significant increase since 1950 in warm spell days (similar to a measure of the number of heat wave days per year) throughout Connecticut.[4] However, as climate change progresses, the number of extreme heat days can be expected to increase, which is a significant concern for human health. Extreme heat days can be especially dangerous in cities because of the urban heat island effect (see PANEL).

“Extreme heat” does not have a uniform definition; it depends on the location, time of year, and other weather factors like humidity. Residents of Connecticut are generally less adapted to extreme heat than are residents of warmer parts of the country.[48] It is reasonable to expect that this acclimatization also varies within the state, as some regions are on average hotter than others (e.g., the central inland region versus the southeastern coast). While this indicator uses a commonly applied metric—days above 90 ºF—research indicates that in nearby New England states, adverse human health effects begin to occur at less extreme temperatures.[49, 50]

How this relates to health

Extreme heat stresses the body’s ability to maintain its normal temperature. The resulting heat-related illness may require emergency medical treatment or hospitalization, and in severe cases, can lead to death (see INDICATOR 4). Elderly people with pre-existing chronic diseases are particularly vulnerable to heat-related

THE URBAN HEAT ISLAND EFFECT

Cities can be much warmer than the surrounding areas. A city’s infrastructure—largely made up of dark-colored asphalt, concrete, and metal—traps and absorbs the sun’s energy and re-emits it as heat, increasing the air temperature. Vehicles and buildings generate heat, as well. This is known as the “urban heat island effect.” Greenspace (trees, parks, and gardens) and blue space (ponds, lakes, rivers, and streams), on the other hand, help cool the air. Connecticut’s urban heat islands coincide with low-income communities and communities of color where housing more frequently lacks insulation, good ventilation, and air conditioning. Therefore, the urban heat island effect is a factor that contributes to the inequitable burden of climate change impacts borne by low-income and marginalized communities.

illness. High temperatures also interact with air pollution, resulting in amplified health impacts, particularly related to ozone pollution (see INDICATOR 17).

Extreme heat can affect mental health and overall well-being. Several studies suggest that extreme heat events may be accompanied by a general increase in aggression and violence.[51, 52] Further, heat waves can limit outdoor physical activity, reducing not only exercise, but also opportunity for social connectedness.

What can we expect in the future?

Generally, we can expect extreme heat events to become more common and severe, and to last longer. Researchers projected into the future the number of warm spell days in Connecticut under a high greenhouse gas emissions scenario (RCP 8.5).[4] They found that the number of warm spell days would increase from less than three per year in the 1950s to approximately 44 per year by 2050 and more than 120 per year by 2100. The Union of Concerned Scientists published a similar study in which they estimated the number of future extreme heat days under scenarios of “no action” (RCP 8.5) or “slow action” (RCP 4.5) on climate change.[53] Hartford, for example, experienced about 11 days per year during 1971–2000 with a heat index above 90 ºF. By mid-century, this is projected to increase to 44 days per year under a “no action” scenario and 34 days per year under a “slow action” scenario.[53]

Frost Days*

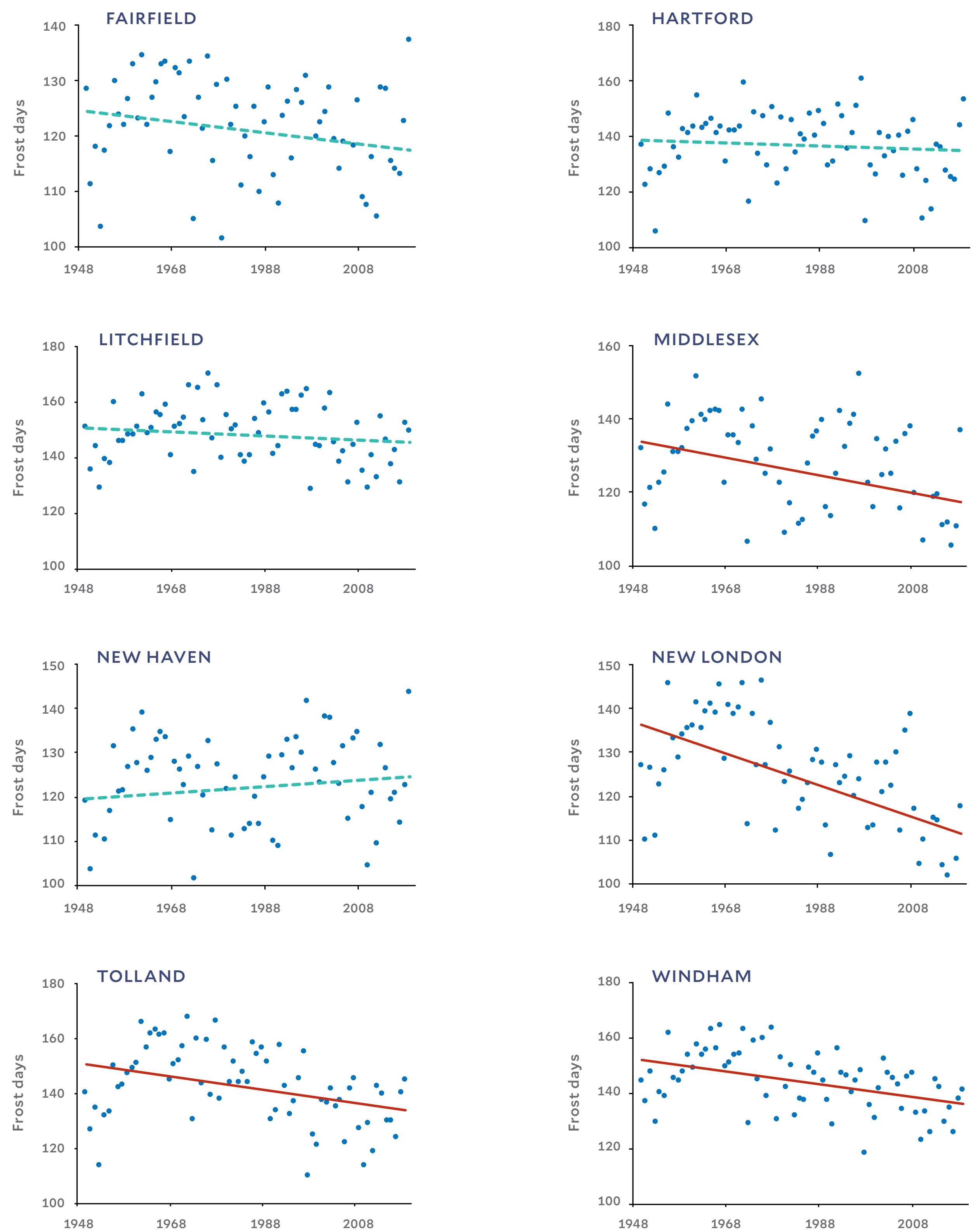


FIGURE 3: *Number of days per year with minimum temperature at or below 32 ºF, 1950–2018, by Connecticut county.* Red solid trendline indicates statistical significance. Data source: (47).

*** THE NUMBER OF FROST DAYS DECREASED FROM 1950 TO 2018 IN FOUR COUNTIES: MIDDLESEX, NEW LONDON, TOLLAND, AND WINDHAM.**

What this indicator shows

This indicator measures the number of days with a minimum temperature at or below 32 ºF (“frost days”). We found that from 1950 to 2018, the number of frost days decreased in four counties: Middlesex, New London, Tolland, and Windham (FIGURE 3). This is consistent with climate change in two ways. First, climate change results in greater increases in nighttime temperatures compared to daytime temperatures because differing atmospheric conditions at night versus during the day amplify the nighttime greenhouse effect. Second, so far the greatest increase in average temperature in Connecticut has occurred during the winter.[4] This is consistent with regional trends: across the Northeast, winters have warmed three time faster than summers.[9]

How this relates to health

There are positive and negative health effects resulting from fewer days below freezing. On the positive side, the number of injuries and deaths from extremely cold temperatures may decrease. This is important in a state like Connecticut, where the vast majority of weather-related deaths are due to extreme cold.[54] However as the climate warms, the decrease in deaths due to warmer winters is expected to be less than the increase in deaths due to hotter summers in the United States;[55] more research is required to understand the projected impact in Connecticut.

Furthermore, fewer frost days, an earlier winter-spring transition, and a later fall-winter transition transform the natural environment in ways that can negatively affect human health. Earlier springs, later falls, and milder winters can lead to larger disease-carrying tick or mosquito populations that are active over a greater proportion of the year (see INDICATOR 12).[28, 56] A longer frost-free period is also associated with a lengthening of the season for ragweed pollen,[8] which causes hay fever and exacerbates asthma (see INDICATOR 19). Warmer winters, earlier springs, and later falls can lead to greater abundance of and longer seasons for plant pests, adversely affecting both forests and agriculture .[9] Finally, fewer frost days lead to indirect impacts for Connecticut, including on regional identity and livelihoods. The 2018 National Climate Assessment explains:

The seasonality of the Northeast is central to the region's sense of place and is an important driver of rural economies. Less distinct seasons with milder winter and earlier spring conditions are already altering ecosystems and environments in ways that adversely impact tourism, farming, and forestry. The region's rural industries and livelihoods are at risk from further changes to forests, wildlife, snowpack, and streamflow.[9]

What can we expect in the future?

In the future, we can expect shorter, milder winters and less pronounced seasons.[9] Specifically, under a high greenhouse gas emissions scenario (RCP 8.5), the number of frost days in Connecticut is projected to decrease from the current average of 124 days to approximately 85 days by mid-century and only 60 days by late century.[4]

INDICATOR

4

Emergency Department Visits and Hospitalizations for Heat Stress*

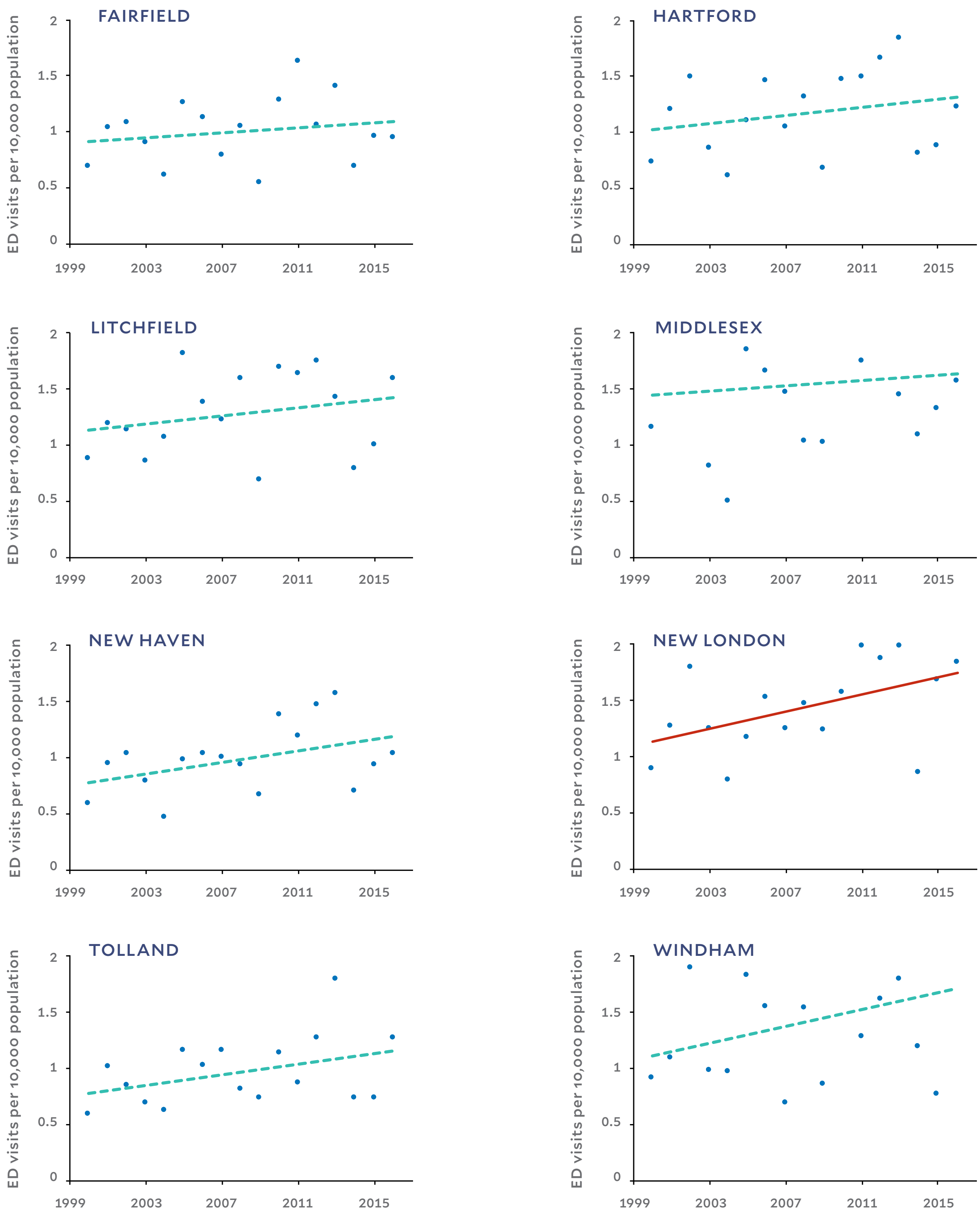


FIGURE 4: *Emergency department visits for heat stress, crude rate per 10,000 population, 2000–2016, by Connecticut county.* Red solid trendline indicates statistical significance. Data source: (57).

* FROM 2007 TO 2016, THERE WERE ON AVERAGE 422 EMERGENCY DEPARTMENT VISITS AND 45 HOSPITALIZATIONS PER YEAR FOR HEAT STRESS IN CONNECTICUT.

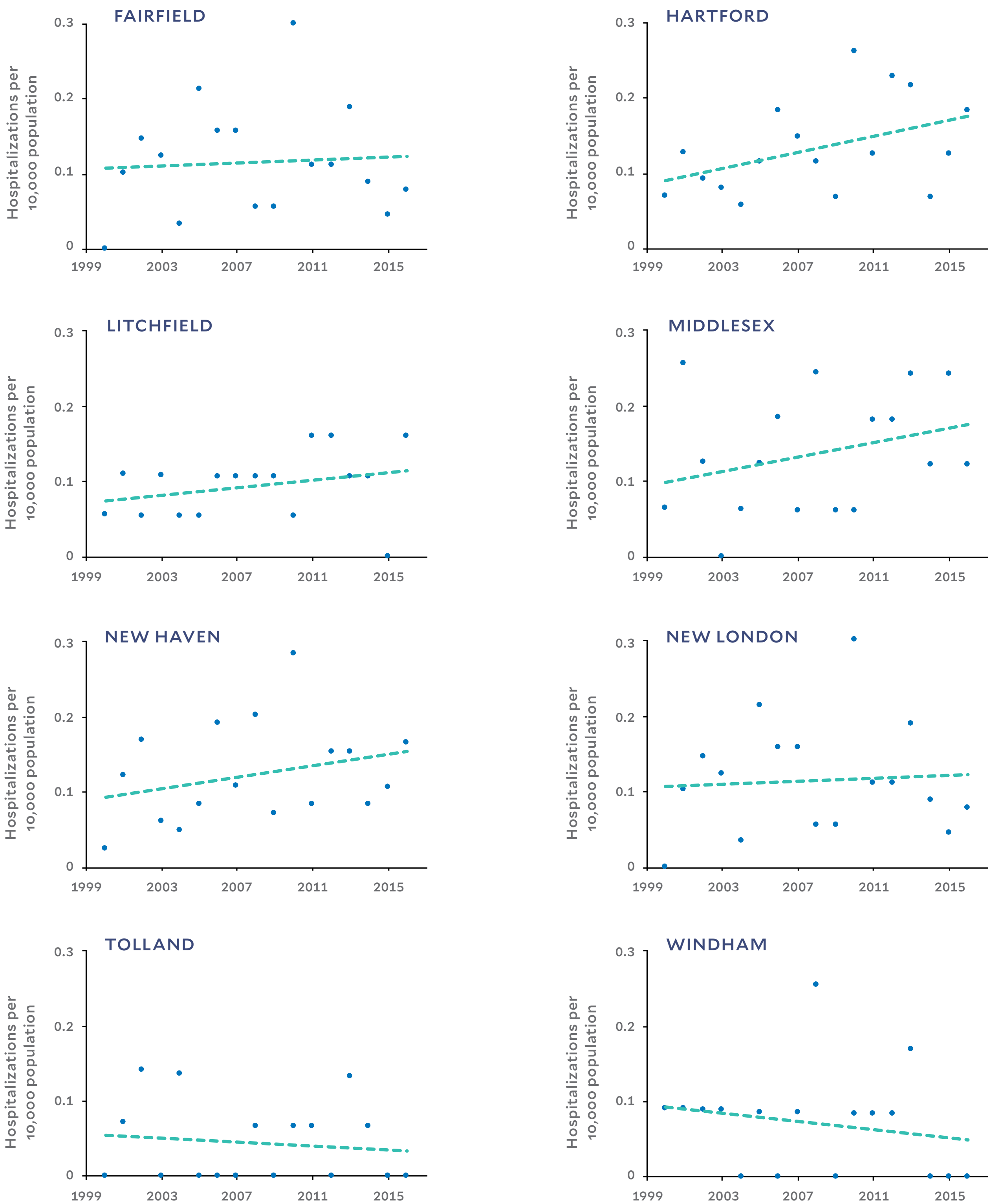


FIGURE 5: *Hospitalizations for heat stress, crude rate per 10,000 population, 2000–2016, by Connecticut county.* Data source: (57).

What this indicator shows

High temperatures cause heat stress, heat exhaustion, heat stroke, the worsening of some existing medical conditions, and even death. This indicator measures the rates per 10,000 population of emergency department visits and hospitalizations for heat stress. We found a significant increasing trend in emergency department visits for New London county; there was no significant trend for the other counties (FIGURE 4). Across the state, there was an average of 422 heat-related emergency department visits per year for heat stress from 2007 to 2016.[57] Reported hospitalizations for heat stress are relatively uncommon in Connecticut, with an average of 45 hospitalizations per year statewide from 2007 to 2016. Our indicator for the rate of hospitalizations shows no significant trend over time for any county (FIGURE 5). It is important to note, however, that the numbers of hospitalizations and emergency department visits are likely under-reported; medical personnel often mistakenly fail to attribute the cause of illness to extreme heat, especially in a state like Connecticut where heat-related illness may not be as common as in some other parts of the country.

How this relates to health

Heat-related illnesses, such as heat exhaustion or heat stroke, happen when the body is not able to properly cool itself. While the body normally cools itself by increasing blood flow to the skin (which then transfers heat from the skin to the surrounding air) and by sweating, during extreme heat, this might not be enough, especially during physical exertion. In these cases, a person's body temperature rises faster than the body can cool itself down. In heat stroke, this can cause damage to the brain and other vital organs, or even death.

Some people are more vulnerable to heat-related illness than others. Vulnerability to heat increases when either physiological or behavioral responses are compromised. Vulnerable groups include: the elderly; young children; people with pre-existing medical conditions (especially heart disease, lung disease, kidney disease, diabetes, and mental illness); people with limited social or financial resources; people who are socially isolated (particularly those experiencing homelessness); outdoor workers; and athletes (see INDICATOR 5).

In a study on public perceptions of the health risks of extreme heat, researchers found that Connecticut residents perceived their risk to be lower than the national average.[58] At the county level, residents in New Haven, Fairfield, and Hartford counties felt the highest perceived risk. While the actual heat exposure in Connecticut is indeed lower than in many other parts of the country, the danger of a low risk perception is that Connecticut residents may not prepare for hot weather when it does occur. In fact, a study in the neighboring state of Rhode Island found that an increase in maximum daily temperature from 75 ºF to 85 ºF was associated with a 24% increase in the rate of heat-related emergency department visits and a 1.3% increase in all-cause emergency department visits.[59] This finding is important because it indicates how health impacts occur at moderate temperatures, below when the National Weather Service issues heat advisories.[49]

What can we expect in the future?

We can expect the number of premature deaths from extreme heat to increase in the future, particularly if climate action is weak. For the Northeast overall, researchers projected 2,300 additional premature deaths per year by late century under a high greenhouse gas emissions scenario (RCP 8.5), but only 960 additional premature deaths per year under a moderate emissions scenario (RCP 4.5).[60] This result underscores the need to rapidly reduce emissions.

Taking action at multiple scales to adapt to higher temperatures also is required to protect human health. These actions can range from individual behavioral adaptation (e.g., wearing cool clothing; reducing physical activity during hot weather) to policy changes (e.g., government regulations requiring frequent water breaks in the shade for outdoor workers during hot weather; programs to check on socially-isolated people during heat waves) to community design enhancements (e.g., increasing tree canopy cover; pavement and roofs that reflect heat). Policies like heat wave early warning systems and provision of cooling centers must incorporate the needs of vulnerable populations in order to be effective.

Populations Vulnerable to Heat-Related Illness*

FIGURES 6 & 8

- Fairfield
- Hartford
- Litchfield
- Middlesex
- New Haven
- New London
- Tolland
- Windham

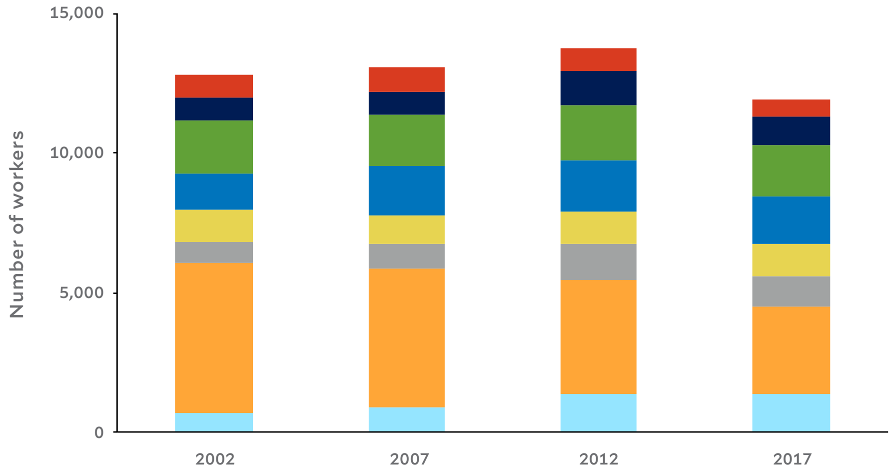


FIGURE 6: *Hired farm labor employment, 2002–2017, by Connecticut county*. Data source: (61).

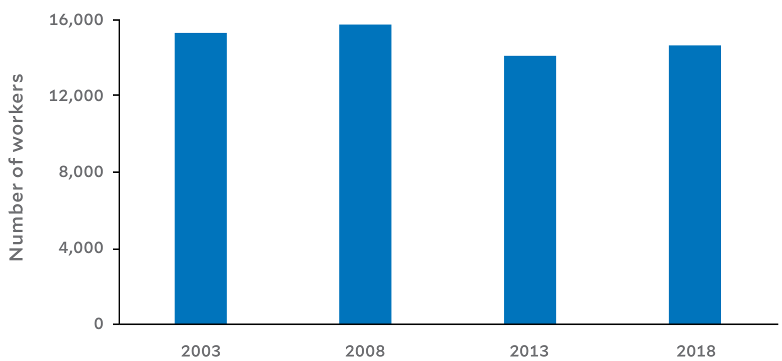


FIGURE 7: *Landscaping industry employment in Connecticut, 2003–2018*. Data source: (62).

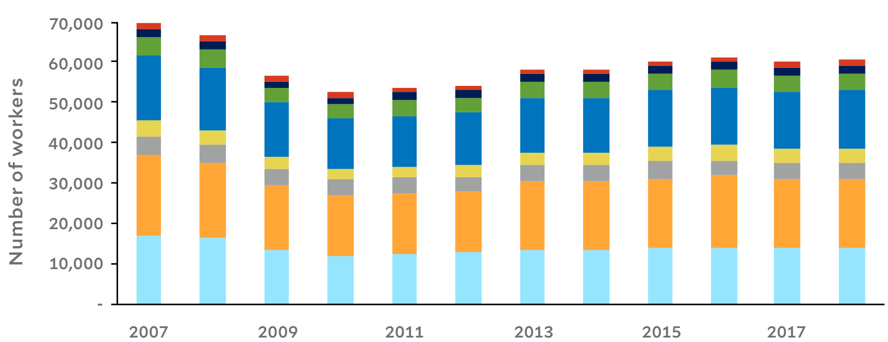


FIGURE 8: *Private and local government construction sector employment, 2007–2018, by Connecticut county*. Data source: (63).

*THE NUMBER AND PROPORTION OF PEOPLE AGE 65 AND OLDER IN CONNECTICUT IS INCREASING, WHILE THE NUMBER OF PEOPLE EXPERIENCING HOMELESSNESS IS DECREASING. THE NUMBER OF PEOPLE IN THE OTHER GROUPS SHOWS NO TREND OVER TIME. TOGETHER, THESE POPULATIONS REPRESENT A SUBSTANTIAL NUMBER OF PEOPLE AT RISK FOR HEAT-RELATED ILLNESS.

FIGURE 9

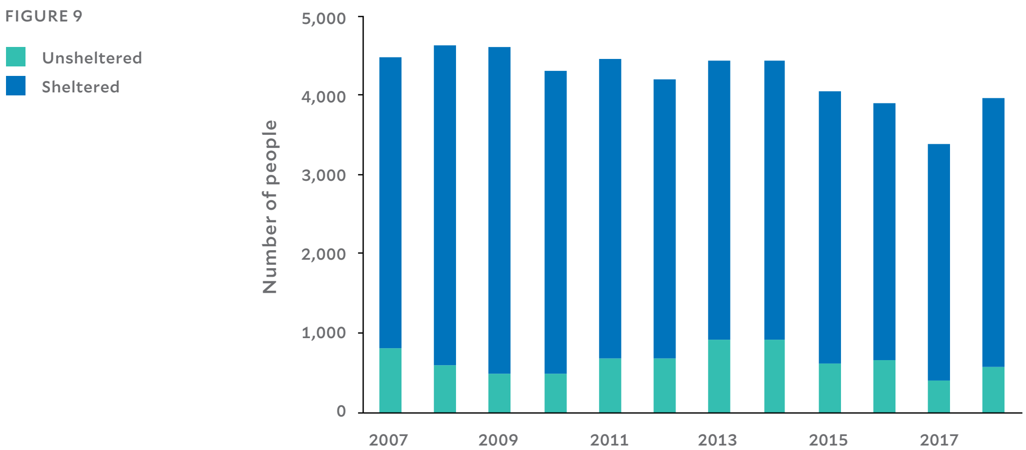


FIGURE 9: *Number of people experiencing homelessness in Connecticut, sheltered and unsheltered, 2007–2018*. "Sheltered" category includes individuals in emergency shelters, transitional housing, and Safe Haven. Data source: (64).

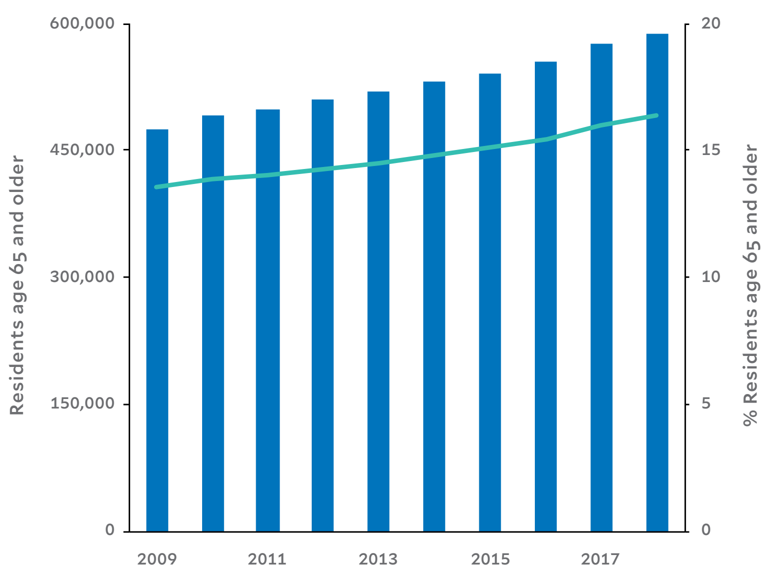


FIGURE 10: *Connecticut residents age 65 and older, 2009–2018*. Bars show the total number of residents age 65 and older; solid line shows residents age 65 and older as a percent of total state population. Data source: (65).

What this indicator shows

This indicator identifies three population groups vulnerable to extreme heat: outdoor workers, people experiencing homelessness, and residents age 65 and older (FIGURES 6–10). For outdoor workers, the indicator tracks the number of workers in three important outdoor sectors in Connecticut: hired farm laborers, landscaping workers, and construction workers.

We observed an increase over time in the population age 65 and older and a decrease in the number of people experiencing homelessness, but no significant changes in the sizes of the populations of outdoor workers. However, together, these populations represent a substantial number of people at risk for heat-related illness (about 12,000 hired farm laborers, 14,000 landscaping workers, 60,000 construction workers, and 4,000 people experiencing homelessness, in addition to the nearly 600,000 people age 65 and older).

Outdoor workers are at higher risk for heat-related illness due to the requirements of work (i.e., they are required to work outdoors and physically exert themselves even in hot weather). In addition, they often lack control over their work environment and important behavioral adaptation decisions like taking breaks or seeking shade.[66] Workers in hot indoor environments that lack air conditioning, such as dry cleaners/laundries, manufacturing facilities, warehouses, and kitchens/bakeries, also are at risk.[3]

People experiencing homelessness are especially vulnerable to extreme heat for a number of reasons related to exposure, sensitivity, and adaptive capacity (see SIDEBAR). They are likely to be exposed to outdoor temperatures and to live in urban areas, where their exposure is amplified through the urban heat island effect. They are likely to have high sensitivity to extreme heat effects due to risk factors such as psychiatric illness, heart or lung disease, substance use, and social isolation.[67] Finally, people experiencing homelessness have less access to important adaptive capacity measures, including shade from trees, air conditioning, and medical services.

Older adults are not only physiologically at greater risk, but they also are less likely to perceive being overheated and to respond accordingly.[68, 69] In addition, older adults are more likely to have a chronic medical condition that can be exacerbated by heat stress, and the medicine they take may affect their body's ability to regulate its temperature. Their vulnerability also can be compounded by other risk factors. For instance, a study using data from 109 U.S. cities found that the association between extreme heat and hospitalization for heat, kidney, and respiratory illnesses among individuals over age 65 was stronger among Blacks, the very old, in ZIP codes with lower educational attainment or older housing, and in cities with lower prevalence of air conditioning.[70] Social isolation is another factor that can greatly increase vulnerability among the elderly.[71, 72]

EXPOSURE, SENSITIVITY, & ADAPTIVE CAPACITY

How climate change impacts a person's health is shaped by three factors: exposure, sensitivity, and adaptive capacity.

EXPOSURE

Exposure indicates how much a person is in contact with a climate hazard, such as extreme heat. This is influenced by circumstances including occupation, socioeconomic status, community infrastructure condition, and level of mobility or cognitive function.

SENSITIVITY

Sensitivity measures how much the climate hazard affects the person. This differs from person to person based on biological traits—like health status and age—and socioeconomic status.

ADAPTIVE CAPACITY

An individual or community's adaptive capacity is defined as its ability to adapt to or cope with the climate hazard.

Overall, a person's vulnerability is greatly influenced by the social determinants of health: social, economic, and environmental factors that limit or enable resources and opportunities for well-being.

How this relates to health

Most heat-related illness and death occurs among the elderly. For instance, 72% of heat-related deaths in the 1995 Chicago heat wave, [73] and 91% of excess deaths in the 2003 French heat wave,[74] occurred among individuals aged 65 years or older. With regard to homelessness, a study found that people experiencing homelessness accounted for 11% of 455 heat-related deaths in Maricopa County, Arizona during 2000–2008 .[75]

A study of heat-related illness and death among U.S. workers found that most of the affected workers had worked outdoors, and all had performed heavy or moderate physical labor.[76] Importantly, the study also found that nine of the 13 deaths occurred during the first three days on the job, and four occurred on the first day. In all of these cases, the employer's heat prevention plan was missing or insufficient, and in no case was the worker brought through an acclimatization period. Acclimatization is an important process in which the body gradually adapts to work in the heat. To achieve acclimatization, it generally takes two weeks or longer of regular work for at least two hours per day in the heat. Best practices set by the U.S. Occupational Safety and Health Administration (OSHA) call for employers to assure that over a period of days, the workers slowly increase the time and intensity of outdoor work, while also consuming adequate fluids and learning to identify heat illness symptoms.[77]

It is likely that the number of outdoor workers and people experiencing homelessness who are injured, become sick, or die from heat is under-reported. Workers, especially those who are undocumented, may underreport their injuries and illnesses as being work-related due to fear of losing their jobs,[78, 79] and they may not seek medical treatment at all if they lack health insurance.

What can we expect in the future?

With both average temperatures and extreme heat projected to increase under climate change, vulnerable populations—including outdoor workers, people experiencing homelessness, and the elderly—will be at higher risk in Connecticut.

Currently, there is no federal heat stress standard to protect workers against hazardous heat. Only Washington, Minnesota, and California have state-specific laws governing occupational heat exposure.[80] In 2011 and again in 2018, a coalition of worker safety organizations led by Public Justice petitioned OSHA unsuccessfully to develop a federal standard.[81] Adopting such a standard at the federal or state level would be one step toward better protecting workers from extreme heat health risks.

EXTREME EVENTS

INDICATOR

6

Heavy Rainfall Events*

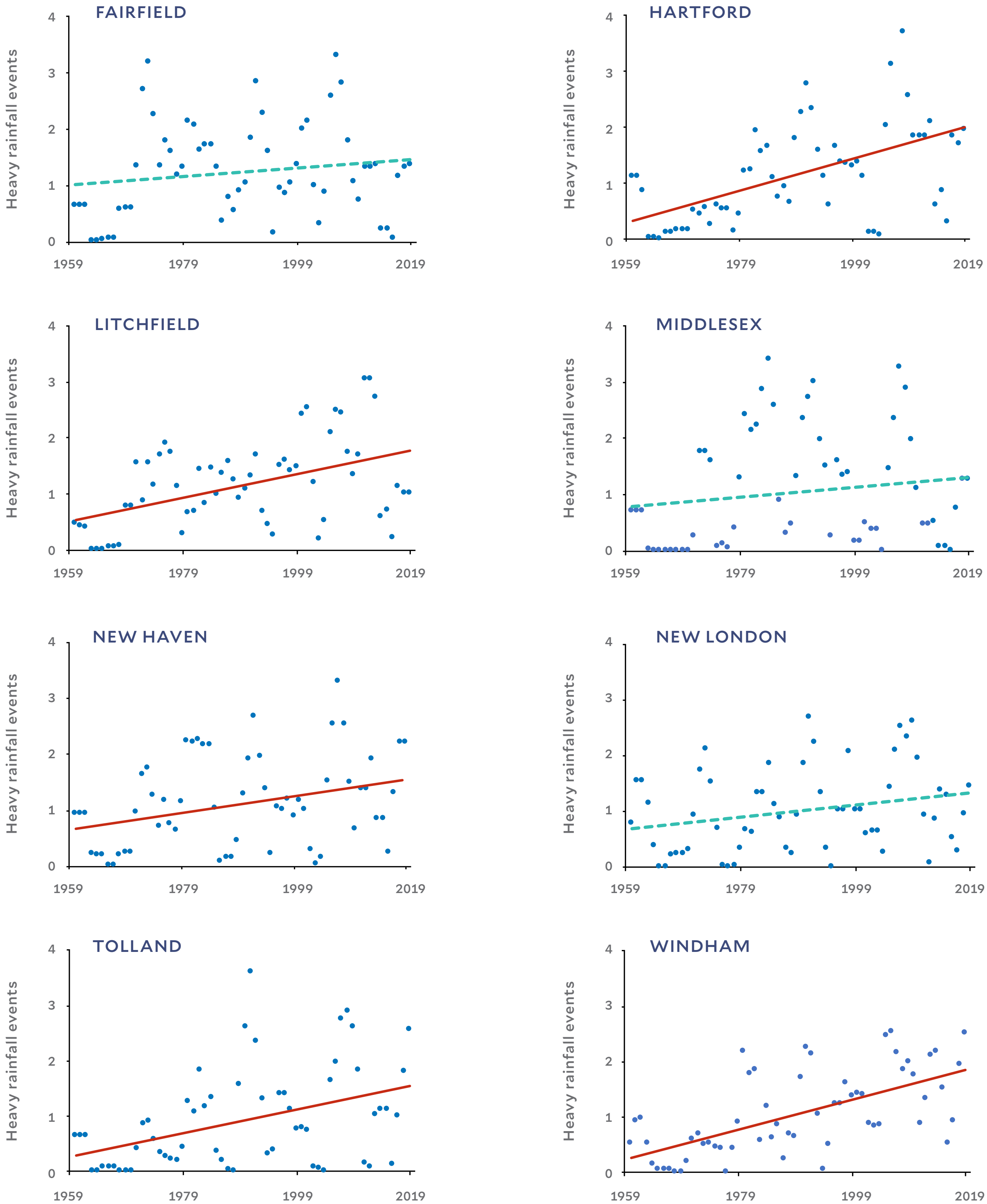


FIGURE 11: *Number of heavy rainfall events per year, 1960–2019, by Connecticut county.* Heavy rainfall events are defined as three consecutive days with cumulative precipitation of three inches or more. Red solid trendline indicates statistical significance. Data source: (47).

*** FROM 1960 TO 2019, THE ANNUAL NUMBER OF HEAVY RAINFALL EVENTS INCREASED IN HARTFORD, LITCHFIELD, NEW HAVEN, TOLLAND, AND WINDHAM COUNTIES.**

What this indicator shows

This indicator measures the number per year of heavy rainfall events, defined as three consecutive days with cumulative precipitation of three inches or more. From 1960 to 2019, the number of heavy rainfall events increased in Hartford, Litchfield, New Haven, Tolland, and Windham counties (FIGURE 11). For the state as a whole, total precipitation in 2018 was 37% more than last century's average,[43] and summer precipitation increased by 10 to 20% across the state from 1950 to 2013.[4] However, year-to-year precipitation in Connecticut is variable, with average precipitation in six of the last 10 years lower than the 20th century average of 46.9 inches.[43]

How this relates to health

Heavy rainfall can overwhelm the natural and human-made systems that normally process rainwater, leading to flooding. This occurs in river systems, and it also occurs in urban environments. Such "urban flooding" takes place when rainfall overwhelms storm sewers and other drainage infrastructure, particularly in heavily developed areas with little permeable surface. When these storm sewers are connected to sanitary sewers, this can lead to the release of raw sewage into streams, rivers, Long Island Sound, and the ocean (see PANEL).

Flooding can cause injury and death due to drowning; it also leads to indirect health impacts from disruption to medical care and critical infrastructure. In addition, people can experience direct exposure to floodwaters that contain pathogens from

COMBINED SEWER OVERFLOWS

Combined sewers carry both wastewater from homes and businesses (sewage and other waste-water from toilets, laundry, and kitchens) and stormwater runoff. This can become an issue during heavy rainstorms when combined sewer systems get overloaded, and the water overflows into streams, rivers, Long Island Sound, or the ocean without first getting treated to remove bacteria and other contaminants that affect human health. These events are called combined sewer overflows.

Six Connecticut municipalities still have combined sew-er systems: Bridgeport, Hartford, New Haven, Norwalk, Norwich, and Waterbury. Plans are underway to sep-arate the remaining combined sewers in Connecticut, as required by the Clean Water Act, but the process is expected to cost $3 billion and take at least another twenty years.[84]

raw sewage that can cause waterborne infections, or to toxic chemicals released from industrial or brownfield sites during flooding.[10] Heavy precipitation can result in increased levels of pathogens or toxic chemicals in sources of drinking water.[82]

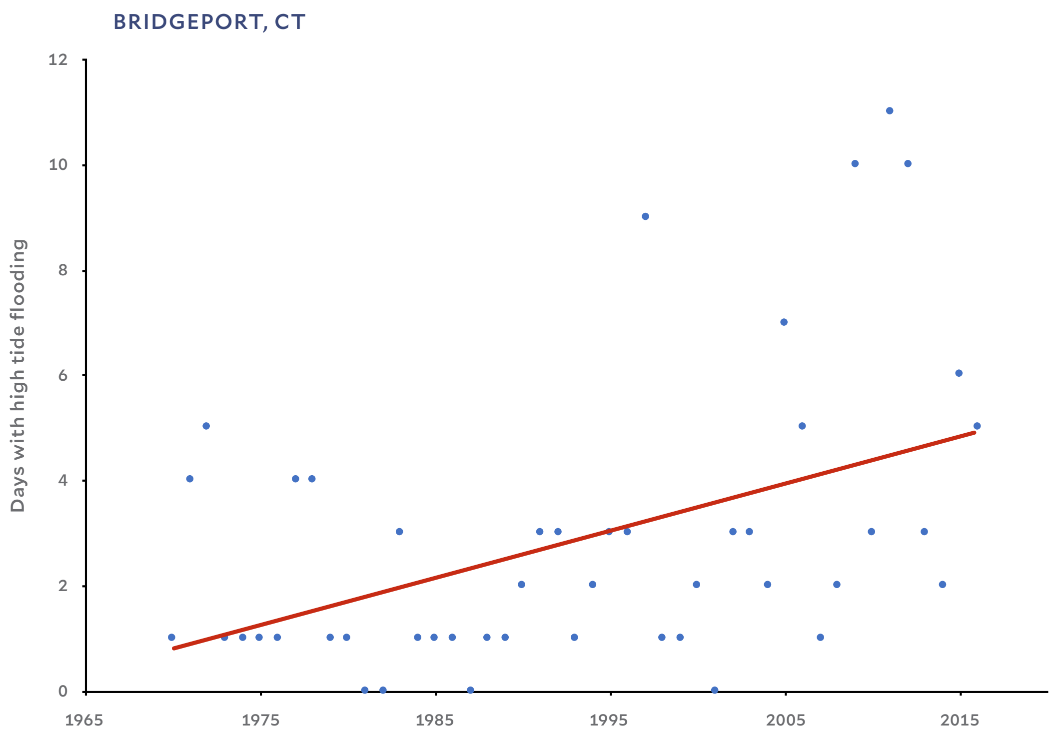
Heavy rain and flooding also can adversely affect indoor air quality. This occurs when floodwaters damage building walls and foundations and enter basements or the ground floors of homes. This can lead to indoor mold, dust mites, chemical off-gassing from damaged building material, and other air contaminants.[10, 11] These contaminants can cause upper respiratory symptoms, allergic reactions, and exacerbation of asthma or chronic obstructive lung disease.[83]

What we can expect in the future

In Connecticut, increases in precipitation are expected primarily during the winter and spring.[4] Under the high greenhouse gas emissions (RCP 8.5) scenario, it is projected that total annual precipitation will increase across the state by 8.5% mid-century and 9.5% by late century.[4]

In addition to an increased total precipitation, heavy rainfall events are projected to continue to increase in Connecticut as climate change progresses. Under the RCP 8.5 scenario, by mid-century key indicators of flood risk are expected to increase substantially: the number of days with more than one-inch precipitation, the number of heavy precipitation days (days with precipitation >99th percentile), and maximum one-day and five-day precipitation amounts.[4] More events of these sort will increase the risk for flooding.

High Tide Flooding*



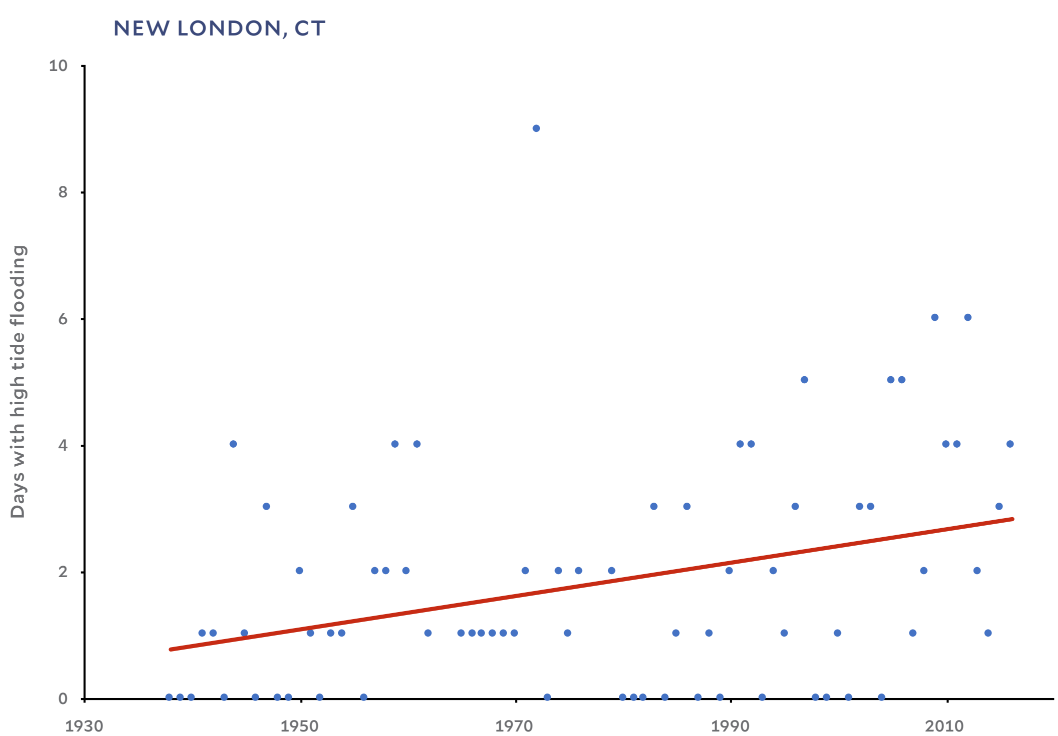


FIGURE 12: *Annual days with high tide flooding, New London, CT (1938–2016) and Bridgeport, CT (1970–2016) tide gauges*. Red solid trendline indicates statistical significance. Data source: (85).

*THE ANNUAL NUMBER OF DAYS WITH HIGH TIDE FLOODING HAS INCREASED AT THE NEW LONDON AND THE BRIDGEPORT TIDE GAUGES, A TREND CONSISTENT WITH THE 8–9 INCHES OF GLOBAL SEA LEVEL RISE THAT HAS OCCURRED SINCE 1880.

What this indicator shows

Global mean sea level has risen eight to nine inches since 1880, with approximately three inches occurring since 1993.[5] In Connecticut and elsewhere, this has resulted in erosion and coastal flooding events at increased frequency during high tides and coastal storms. This indicator measures the frequency of high-tide flooding at two tide gauges in Connecticut: Bridgeport and New London (FIGURE 12). High tide flooding, also called nuisance or sunny day flooding, occurs when sea water temporarily inundates low-lying areas until the tide recedes.[85] The flooding causes road closures, overwhelmed storm drains, and other infrastructure issues, as well as water quality concerns.

The New London tide gauge has a longer period of record with readings that began in 1938, while readings at the Bridgeport tide gauge began in 1970. The number of days with high tide flooding is increasing at both locations. The three highest years in Bridgeport occurred in 2009, 2011, and 2012 (10 days, 11 days, and 10 days, respectively). In New London, the highest years occurred in 1972 (9 days) followed by 2009 and 2012 (both years, 6 days).

How this relates to health

Minor high tide flooding is disruptive but not typically damaging. However, as the flooding becomes more common or greater in magnitude, it may lead to direct and indirect health effects of concern. Saltwater flooding can transmit pathogens like *Vibrio* bacteria, which can cause wound infections among people walking through the water (see INDICATOR 16). Saltwater also can contaminate drinking water sources near the coast, as well as coastal agricultural fields.

What can we expect in the future?

High tide flooding is projected to happen more frequently and for longer durations of time. That is, "today's flood will become tomorrow's high tide."[85] In a recent study, NOAA researchers projected the number of high tide flooding days annually under different climate change scenarios: For an "intermediate-low" global sea level scenario (0.5 m global rise by 2100), they projected that by 2050, New London will experience 35 high tide flood days annually, and Bridgeport will experience 43 days; by 2100, the number of days rises to 234 and 170, respectively. Under an "intermediate" scenario (1 m global rise by 2100), however, the number of high tide flood days is much higher: by 2050, 167 days in New London and 129 days in Bridgeport; by 2100, high tide flooding would occur nearly every day of the year in both locations (TABLE 1).[85]

HIGH TIDE FLOOD DAYS

Sea level scenario	**Year**	**New London**	**Bridgeport**
Intermediate- low	2050	35	43
	2100	234	170
Intermediate	2050	167	129
	2100	365	363

TABLE 1: *Projected number of high tide flood days at New London and Bridgeport, Connecticut tide gauges, under intermediate-low and intermediate global sea level scenarios, 2050 and 2100.* Data source: (85).

The Connecticut Institute for Resilience and Climate Adaptation recommends planning for 20 inches (0.5 meters) of sea level rise by 2050,[6] with continued sea level rise to occur after 2050.[5] Higher sea levels lead to more severe storm surges associated with coastal storms, including hurricanes.

Connecticut and other northeastern states have substantially developed coastlines, which means that a large number of roads, homes, businesses, and other infrastructure are at risk from high tide flooding.[13] As sea level continues to rise, this can lead to costly repairs or even the need to relocate these assets before the temporary inundation becomes permanent. Such "retreat" from the coastline, whether planned or unplanned, will be hugely expensive, producing negative economic impacts and straining municipal budgets, which can drain resources away from health. Furthermore, homeowners and small business owners who are forced to retreat are likely to endure considerable mental stress. Although painful and politically difficult, in situations where retreat is inevitable, planned retreat is highly preferable to unplanned retreat. These discussions need to begin to take place.


CAUTION
Debris from hurricane
may still be present
WEAR
PROTECTIVE
FOOTWEAR

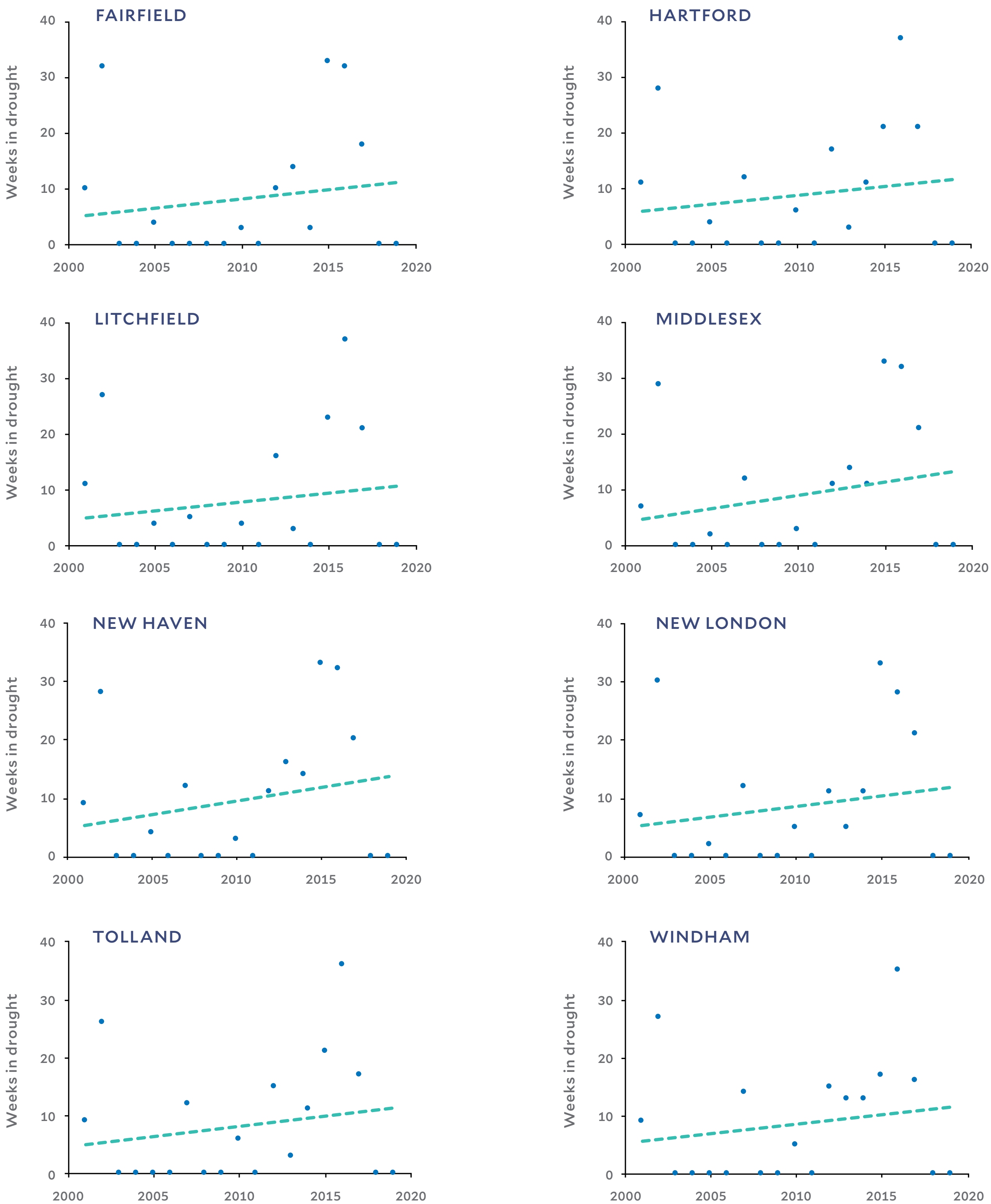


FIGURE 13: *Number of total weeks in moderate drought or higher, 2001–2019, by Connecticut county.* Figure is inclusive of weeks reaching moderate drought (D1), severe drought (D2), and extreme drought (D3). No exceptional drought (D4) was recorded during this period. Data source: (86).

WHILE THERE IS NO SIGNIFICANT TREND TOWARD INCREASED DROUGHT IN ANY COUNTY, CONNECTICUT HAS RECENTLY EXPERIENCED DISTURBING DROUGHTS, INCLUDING A 46-WEEK LONG STATEWIDE DROUGHT IN 2016–2017.

What this indicator shows

This indicator tracks the number of weeks per year that have reached at least the moderate drought threshold, based on the *U.S. Drought Monitor*'s drought classification system (FIGURE 13). Since 2000, the *U.S. Drought Monitor* has tracked conditions nationwide to assess and categorize drought levels. Classification into the stages of drought are based on factors including precipitation totals compared to long-term averages, soil moisture, and water levels.[87] There are five categories: Abnormally Dry or D0, (a precursor to drought, not actually drought), Moderate (D1), Severe (D2), Extreme (D3) and Exceptional (D4) Drought (TABLE 2).

Over the period 2001 to 2019 there was considerable year-to-year variability, and no statistically significant trend. However, there were concerning droughts during this period, including a statewide drought that lasted 46 weeks, from June 21, 2016 to May 2, 2017. The most intense period of drought occurred the week of November 15, 2016, when extreme drought (D3) affected nearly 50% of Connecticut land.[88]

How this relates to health

Expected impacts under moderate drought (D1) include the following: wildfires increase, trees and landscaping are stressed, voluntary water conservation is requested, and lake and reservoir levels are below normal capacity. As a drought worsens, impacts expand, with particular concern for agriculture viability, wildlife impacts, and wildfire risk (TABLE 2).

Drought also strains drinking water systems (see INDICATOR 9) by lowering surface water reserves and contributing to saltwater intrusion into freshwater along the coast. *The Connecticut State Water Plan* acknowledged that the prolonged 2016–2017 drought raised awareness in Connecticut that river basins can become depleted, even though water scarcity has not typically been a problem for the state.[14]

CATEGORY	DESCRIPTION	IMPACT
D0	Abnormally dry	Crop growth is stunted; planting is delayed Fire danger is elevated; spring fire season starts early Lawns brown early; gardens begin to wilt Surface water levels decline
D1	Moderate drought	Irrigation use increases; hay and grain yields are lower than normal Honey production declines Wildfires and ground fires increase Trees and landscaping are stressed; fish are stressed Voluntary water conservation is requested; reservoir and lake levels are below normal capacity
D2	Severe drought	Specialty crops are impacted in both yield and fruit size Producers begin feeding cattle; hay prices are high Warnings are issued on outdoor burns; air quality is poor Golf courses conserve water Trees are brittle and susceptible to insects Fish kills occur; wildlife move to farms for food Water quality is poor; groundwater is declining; irrigation ponds are dry; outdoor water restrictions are implemented
D3	Extreme drought	Crop loss is widespread; Christmas tree farms are stressed; dairy farmers are struggling financially Well drillers and bulk water haulers see increased business Water recreation and hunting are modified; wildlife disease outbreak is observed Extremely reduced flow to ceased flow of water is observed; river temperatures are warm; wells are running dry; people are digging more and deeper wells
D4	Exceptional drought	Connecticut has had little or no experience in D4, so no impacts have been recorded at that level in the *Drought Impact Reporter*

TABLE 2: *Drought impacts in Connecticut by drought category, DO–D4.* Table adapted from source: (86).

What can we expect in the future?

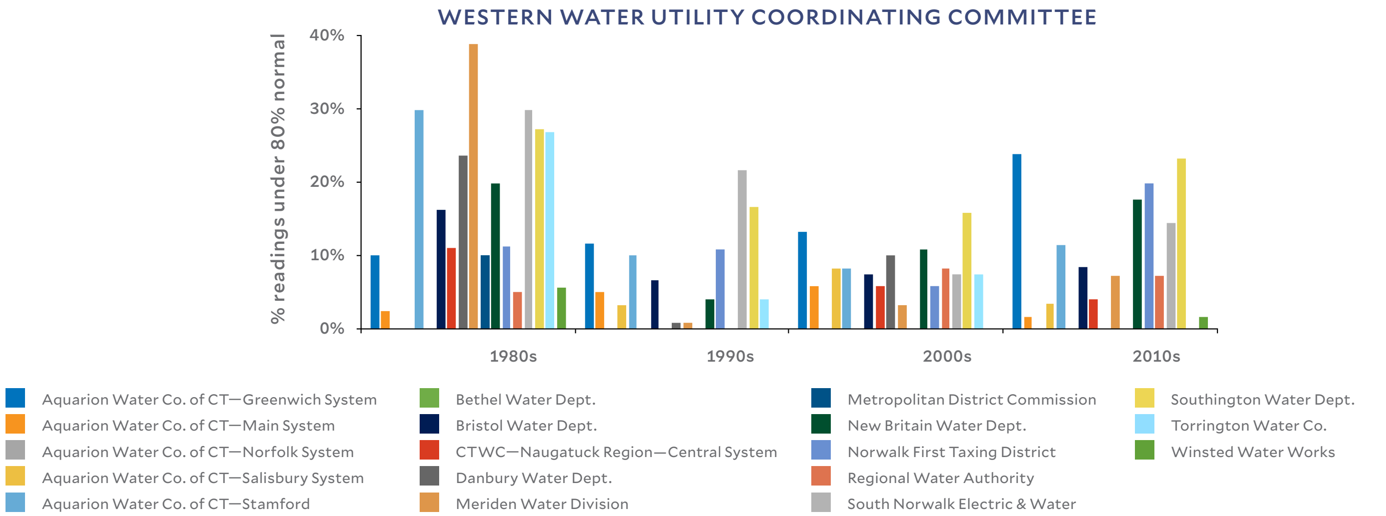
Summer droughts are projected to be more frequent and severe by late century.[4] For example, University of Connecticut researchers found that extreme summer droughts—which historically have occurred every 20 years—would occur about every six years by 2050 and every three to four years by 2100 under the high greenhouse gas emissions (RCP 8.5) scenario. This would occur due to the increase in evapotranspiration from warming temperatures, which would be especially pronounced in the summer.

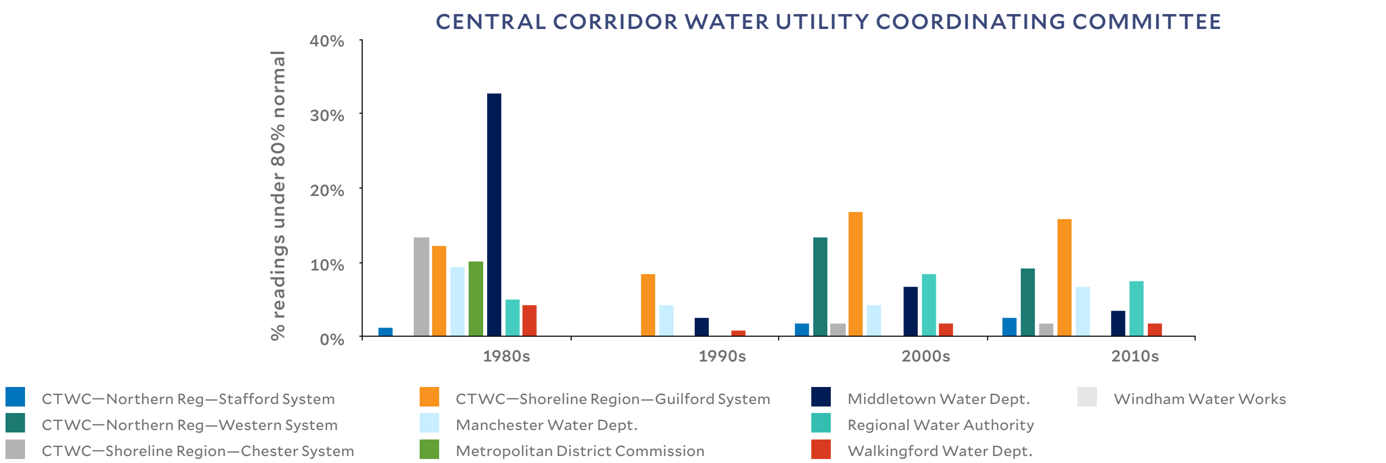
We can plan for the increased frequency of drought by instituting water conservation measures for homes, businesses, and agriculture, and preparing contingency plans in the case of extreme drought's impact on drinking water. *The Connecticut Drought Preparedness and Response Plan*, for instance, lays out a number of long-term planning and preparedness actions for state and local agencies, including encouraging low-impact design for new development and existing infrastructure; working collaboratively with water utilities and heavy water users to implement drought mitigation strategies; and identifying temporary water supply sources that can be made available during a water emergency.[89]

INDICATOR

9

Drinking Water Reservoir Capacity*





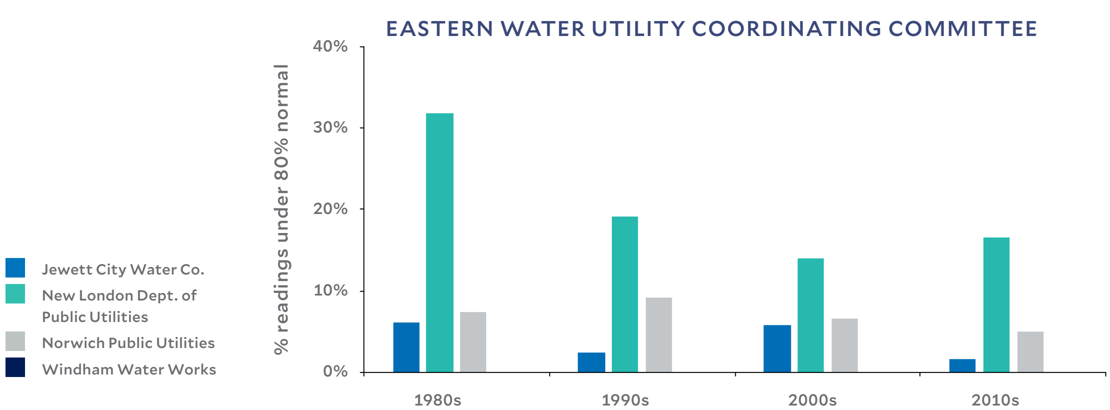


FIGURE 14: *Percent of monthly readings per decade with reservoir levels below 80% historic average in each drinking water system, during each system's period of record from 1980–2019, by Connecticut Water Utility Coordinating Committee (WUCC).* WUCCs are regional planning entities based on Public Water Supply Management Areas, which are areas determined by the Commissioner of the CT Department of Public Health to have similar water supply problems and characteristics. Data source: (90).

* WE FOUND NO TREND TOWARD LOWER RESERVOIR LEVELS.

What this indicator shows

This indicator tracks an important component of drinking water security for Connecticut residents: reservoir levels compared to their historic average. According to the *Connecticut Drought Preparedness and Response Plan*, one criterion considered when issuing a drought declaration is a reservoir system level falling below a threshold; for Stage 2 Drought, this occurs at 80% of the historic monthly average.[89] Therefore, this indicator evaluates the proportion of monthly readings per decade in which reservoir capacity levels fall below 80% historic monthly average in each drinking water system. In our analysis of data from the 1980s to the present, we found no trend toward lower reservoir levels (FIGURE 14).

How this relates to climate change

Climate change may affect drinking water availability by increasing the intensity or frequency of droughts, storms, and other system shocks. Droughts, especially if prolonged, lower water levels in reservoirs (and wells), an impact we investigated through this indicator. Climate change may affect drinking water quality and quantity in other ways, too. Hurricanes and other storms can damage drinking water infrastructure. During Hurricane Irene, for instance, some drinking water utilities across the Northeast region lost electricity, sustained damage to the well house or treatment plant, or had difficulty reaching the water system due to road damage, among other issues.[15] In Connecticut, 14 public water systems were inundated during Hurricane Irene and/or Hurricane Sandy.[16] Following those two hurricanes, the State of Connecticut assessed storm-related vulnerabilities to drinking water and other infrastructure and took numerous steps to address the identified issues.[16]

Increasing temperatures and sea level rise also threaten drinking water quality. Wells near the coast may be at risk for contamination from saltwater intrusion, driven by sea level rise, drought, and changes to water use demands. Blue-green algae blooms—and more dangerously, harmful algal blooms—are more likely as surface water sources warm with rising temperatures.[17]

What can we expect in the future?

While we found no trend toward lower capacity levels at reservoirs, we can expect more drought conditions in the future as climate change progresses (see INDICATOR 8). This is likely to strain drinking water resources. However, the degree to which drinking water security is actually affected depends on adaptation measures adopted, including those already identified in the *Connecticut State Water Plan* and the *Connecticut Drought Preparedness and Response Plan*.[14, 89]

Weather Disasters*

INCIDENT PERIOD	DISASTER TYPES	DESIGNATED COUNTIES							
		FAIRFIELD	HARTFORD	LITCHFIELD	MIDDLESEX	NEW HAVEN	NEW LONDON	TOLLAND	WINDHAM
October 14–15, 2005	Severe Storms and Flooding		■	■			■	■	■
April 15– April 27, 2007	Severe Storms and Flooding	■	■	■	■	■	■		■
March 12– May 17, 2010	Severe Storms and Flooding	■			■	■	■		■
October 29–30, 2011	Severe Storm	■	■	■	■	■		■	■
August 27– September 1, 2011	Tropical Storm/ Hurricane (Tropical Storm Irene)	■	■	■	■	■	■	■	■
January 11–12, 2011	Snowstorm	■	■	■		■	■	■	
October 27– November 8, 2012	Hurricane (Hurricane Sandy)	■		■	■	■	■	■	■
February 8–11, 2013	Severe Winter Storm and Snowstorm	■	■	■	■	■	■	■	■
January 26–28, 2015	Severe Winter Storm and Snowstorm					■	■	■	■
September 25–26, 2018	Severe Storms and Flooding				■		■		
May 15, 2018	Severe Storms, Tornado, and Straight-line Winds	■				■			

TABLE 3: *Federal disaster declarations for weather events issued for Connecticut, 2000–2019, by type and county.* Green cell indicates county was included in the disaster declaration. Data source: (92).

* FROM 2010 TO 2019, NINE FEDERAL DISASTER DECLARATIONS FOR WEATHER EVENTS WERE ISSUED FOR CONNECTICUT, COMPARED TO ONLY 13 IN THE PREVIOUS 56 YEARS (1954–2009).

What this indicator shows

This indicator shows the federal disaster declarations for weather events experienced by Connecticut from 2000 to 2019. In accordance with the Stafford Act, disaster declarations are made by the U.S. President at the request of the affected state's Governor. From 2010 to 2019, nine federal disaster declarations for weather events were issued for Connecticut (TABLE 3). By comparison, there were only two disaster declarations for weather events in the prior decade and 11 in the 46 years before that (1954–1999).[91, 92] Once a disaster declaration is issued, the Federal Emergency Management Agency (FEMA) is authorized to provide assistance; in Connecticut, FEMA provided a total of $304.6 million in combined individual and public assistance grants to support recovery efforts following those nine disasters (FIGURE 15).

The nine declared disasters in 2010–2019 include two named storms: Tropical Storm Irene in 2011 and Hurricane Sandy in 2012. Among its effects, Tropical Storm Irene downed about 1–2% of the state's trees and left 800,000 customers without power for up to 12 days. Hurricane Sandy caused significant destruction in Connecticut, particularly along the southwestern coastline: 5,000 people were evacuated from their homes, patients were evacuated from hospitals and nursing homes, and five individuals died, among many other impacts. Another storm, nicknamed the "Halloween Nor'easter," in October 2011 brought a combination of snow and tropical storm force winds, causing significant infrastructure damage and leaving more than 750,000 residents without power.[93] This storm resulted in $90 million in FEMA public assistance, the largest amount for a single storm in Connecticut's history. Of the remaining six declared disasters, three were caused by winter snowstorms, two by severe storms and flooding, and one from a severe storm that caused tornadoes and straight-line winds.

Nationally, weather disaster events are rising, with significant economic and social cost: 2019 is the fifth consecutive year in which the country endured 10 or more billion-dollar weather disaster events.[18] Over the past five years, the total cost of disaster events nationally was approximately $500 billion.[18]

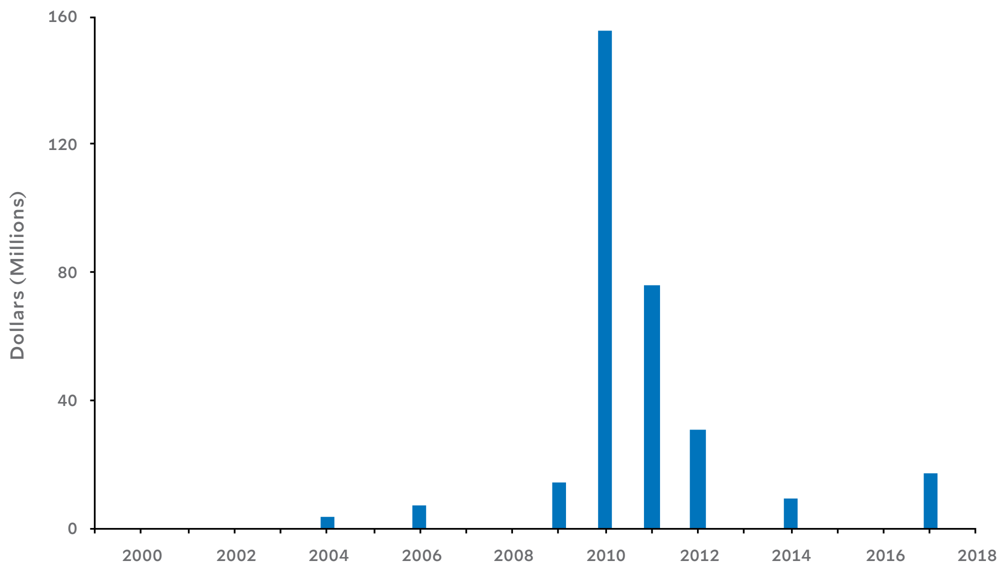


FIGURE 15: *FEMA assistance for federally designated weather disasters, Connecticut total, 2000–2019*. Data source: (92).

How this relates to health

Immediate dangers from severe storms and flooding include drowning or injuries due to high water (see INDICATOR 6). Road flooding also can cut people off from safely evacuating. Disruptions can occur to critical infrastructure, including electricity, sanitation, water treatment and water supplies, food refrigeration, communications systems, and transportation.[10] This interferes with medical care and access to medication, particularly for those with chronic illness.[94, 95] Loss of electric power can affect people who need life-supporting equipment, such as home dialysis, in their homes. People who need to evacuate may leave medications behind. Doctor's offices, hospitals, and pharmacies may be closed for indefinite periods of time. Ambulances may be slowed due to roads blocked by flooding or downed trees.

There also are important, though less visible, downstream impacts to health from severe storms. Individuals whose households experienced a flood or risk of flood report higher levels of depression and anxiety, and these impacts can persist several years after the event. Those particularly vulnerable include the elderly, pregnant women, people with preexisting mental illness, the economically disadvantaged, tribal and Indigenous communities, and first responders.[2] Children have been found to experience high rates of posttraumatic stress disorder (PTSD) symptoms after certain natural disasters.[2] Recovery from this trauma can be prolonged if the children also experience, as a long-term consequence of the disaster, displacement from their homes or community disruption.[96]

The building stock in lower-income communities is often at increased risk for damage by natural disasters like floods and hurricanes. This is in part because of historic patterns of development in areas vulnerable to natural hazards, as well as underinvestment in public infrastructure in these neighborhoods.[97, 98]

Disaster planning experts recommend that households prepare to be self-sufficient (able to live without running water, electricity and/or gas, and telephones) for three to seven days following a disaster.[99] This includes having enough nonperishable food stored to last for that period. However, food insecure households may not be able to maintain this amount of stored food.

What can we expect in the future?

Due to climate change, Atlantic hurricanes are expected to become more intense (higher sustained wind speeds) in the future, with greater amounts of precipitation.[7] Sea level rise will amplify storm impacts in the Northeast region, contributing to higher surges that extend further inland.[9] As discussed under INDICATOR 6, extreme precipitation events also are expected to increase under climate change, which will increase the risk for flooding.

Low-income communities are disproportionately underinsured for protection against damage from storms and floods and often lack access to emergency credit to recuperate from property loss.[100] Renters, in particular, are vulnerable to displacement after a disaster, for reasons including that they lack control over whether or when the property will be rebuilt.[101] Municipal, state, and federal policies to make housing more affordable, safe, and climate resilient is one important way to address this issue.[102–104]

Superfund Sites*

SUPERFUND SITE NAME	CITY	CLIMATE CHANGE HAZARDS				
		SLR 8 FT.	SLOSH CATEGORY 1	SLOSH CATEGORY 4 OR 5	FLOODING 1 PERCENT	FLOODING OTHER
FAIRFIELD						
Kellogg-Deering Well Field	Norwalk				■	■
Raymark Industries, Inc.	Stratford	■	■	■	■	
HARTFORD						
Solvents Recovery Service of New England	Southington				■	■
NEW HAVEN						
Beacon Heights Landfill	Beacon Falls					■
Cheshire Ground Water Contamination	Cheshire				■	■
Nutmeg Valley Road	Wolcott				■	■
Scovill Industrial Landfill	Waterbury				■	■

TABLE 4: *Vulnerability of Superfund sites in Connecticut to specific climate change hazards.* Green cell indicates site is in an area potentially impacted by the climate change hazard. Climate change hazards identified for Connecticut sites as follows: "SLR 8 ft" (inundation by 8 feet of sea level rise), "SLOSH Category 1" (impact by storm surge from Category 1 hurricane), "SLOSH Category 4 or 5" (impact by storm surge from Category 4 or 5 hurricane), "Flooding 1 Percent" (1% or higher annual chance of flooding), "Flooding Other" (other flood hazards). Data source: (19).

*** SEVEN OF CONNECTICUT'S 16 SUPERFUND SITES ARE VULNERABLE TO CLIMATE CHANGE IMPACTS, INCLUDING FLOODING, HURRICANE STORM SURGE, AND SEA LEVEL RISE.**

What this indicator shows & how it relates to health and climate change

Under the U.S. Environmental Protection Agency's Superfund program, the federal government identifies and cleans up contaminated sites to protect human health and the environment. In Connecticut, these sites range from old industrial sites to waste lagoons, quarries, and landfills. This indicator evaluates the risk from climate change to Superfund sites in Connecticut. Its results are sourced from an analysis by the Government Accountability Office (GAO), which conducted a mapping analysis to identify Superfund sites nationwide that could be impacted by flooding, storm surge, wildfire, or sea level rise.[19]

Climate change is making coastal storms more intense and extreme precipitation events and coastal and inland flooding more frequent, which may further damage Superfund sites and potentially release contaminants. This is a concern for human health because people can be exposed to contaminants that enter ground or surface water, become released to the air, or leach into the soil.

According to the GAO report, seven of Connecticut's 16 designated Superfund sites are vulnerable to climate change impacts (TABLE 4). Eight feet of sea level rise, which could occur by 2100 under the intermediate global mean sea level scenario,[85] or flooding from the storm surge of a Category 1 or greater hurricane, would place one site, Raymark Industries in Stratford, at risk. That site also is located in the 1% or higher annual chance of flooding flood hazard category. Five other sites—all inland—also are located in the 1% annual chance of flood hazard area; in addition, they are vulnerable to other flood hazards. The final site, Beacon Heights Landfill in Beacon Falls, is at risk from other flood hazards, including being located in the 0.2% or higher annual chance of flooding flood hazard category.

Importantly, the FEMA flood hazard areas are static and do not incorporate climate change impacts, and therefore can be viewed as an underestimate of likely future flooding, in terms of both area affected and likelihood of occurrence.[105] The best protection against a climate disaster causing spreading of contaminants from Superfund sites would be to place a high priority on cleaning up the sites.

INFECTIOUS DISEASES

Mosquitos*

SPECIES	TIME TREND, 2001–2019[A]	MOSQUITOS/TRAP-DAY, 2015–2019[B]	VIRUSES CARRIED[C]
Aedes albopictus	**0.020**	0.28	CV, WNV
Aedes cinereus	-0.052	7.51	CV, EEE, JC, WNV
Aedes vexans	-0.050	9.88	CV, EEE, JC, WNV
Anopheles punctipennis	**0.083**	2.79	CV, EEE, JC, TVT, WNV
Anopheles quadrimaculatus	**0.025**	0.60	CV, EEE, WNV
Anopheles walkeri	**0.163**	2.80	CV, EEE, JC, WNV
Coquillettidia perturbans	**1.314**	33.34	CV, EEE, JC, TVT, WNV
Culex pipiens	-0.054	1.65	EEE, WNV
Culex restuans	-0.008	2.33	EEE, JC, WNV
Culex salinarius	**0.849**	17.61	EEE, WNV
Culex territans	**0.005**	0.13	EEE
Culiseta melanura	0.247	8.49	CV, EEE, WNV
Culiseta morsitans	-0.0004	0.11	EEE
Ochlerotatus abserratus	0.045	2.22	JC
Ochlerotatus aurifer	**0.119**	3.02	JC
Ochlerotatus canadensis	0.511	19.74	CV, EEE, JC, WNV
Ochlerotatus cantator	-0.021	1.90	CV, EEE, JC, WNV
Ochlerotatus communis	-0.002	0.01	JC
Ochlerotatus excrucians	0.005	0.66	JC
Ochlerotatus provocans	**0.009**	0.15	JC
Ochlerotatus sollicitans	**-0.067**	0.51	CV, EEE, JC
Ochlerotatus sticticus	**-0.314**	0.62	CV, EEE, JC, TVT, WNV
Ochlerotatus stimulans	-0.021	0.82	JC
Ochlerotatus taeniorhynchus	**0.279**	7.53	CV, EEE, JC, WNV
Ochlerotatus triseriatus	**-0.072**	0.93	CV, EEE, JC, WNV
Ochlerotatus trivittatus	-0.447	1.66	CV, EEE, JC, TVT, WNV
Psorophora ferox	0.242	5.30	CV, EEE, JC, TVT, WNV
Uranotaenia sapphirina	0.012	2.45	EEE, WNV

TABLE 5: *Mosquito species that carry human viruses found at 87 trapping stations across Connecticut: time trends in abundance (2001–2019); recent abundance (2015–2019); and viruses carried.* Red/bold indicates statistically significant trend. Data source: (106)

A The trend in abundance of each mosquito species, as measured by the total number trapped each year in light traps (which trap a broad range of mosquito species), normalized for the total number of trap-days each year. A trap day represents one trap set for one day. For example, the number of *Culex salinarius* mosquitos trapped per trap-day had an increasing trend of 0.849 per year. There was a total of 25,481 trap-days during 2001-2019. Species with statistically significant trends are highlighted in red.

B Total number of mosquitos trapped divided by the number of trap-days in the state in 2015-2019. This gives an indication of the recent relative abundance of each species. There was a total of 6,647 trap-days during 2015–2019.

C Viruses causing human disease that have been isolated from the species in Connecticut: Cache Valley (CV), Eastern equine encephalitis (EEE), Jamestown Canyon (JC), Trivittatus (TVT), and West Nile virus (WNV).

*** DURING 2001–2019, OF 28 MOSQUITO SPECIES FOUND IN CONNECTICUT TO CARRY VIRUSES THAT CAUSE HUMAN DISEASE, 10 SHOW TRENDS OF INCREASING ABUNDANCE AND THREE SHOW TRENDS OF DECREASING ABUNDANCE.**

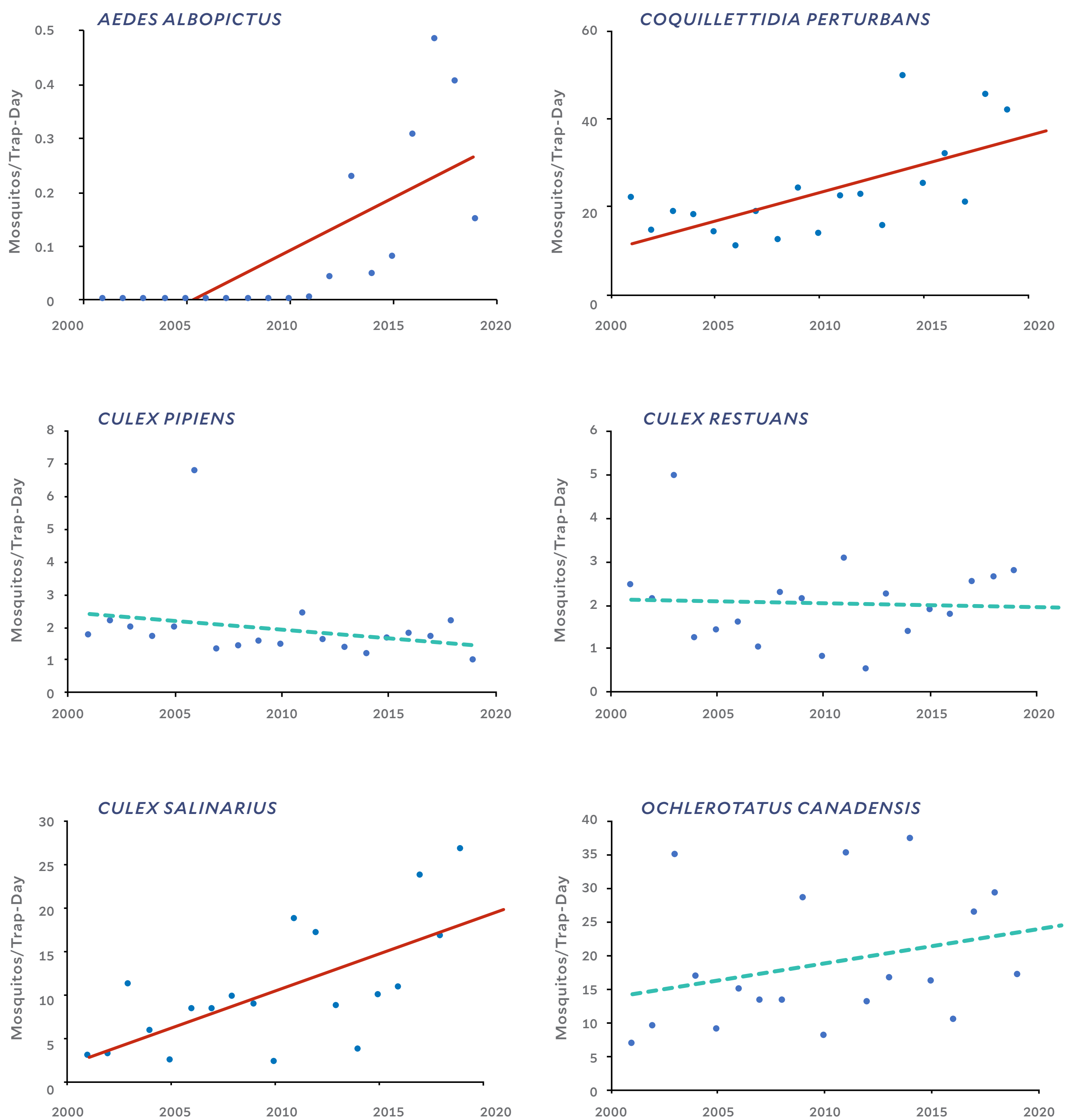


FIGURE 16: *Time trends in abundance of six mosquito species of special interest in Connecticut, 2001–2019*. The Y-axis shows the total number of mosquitos trapped each year, normalized for the total number of trap-days each year. Red solid trendline indicates statistical significance. Data source: (106).

What this indicator shows

This indicator tracks the abundance over time of 28 mosquito species that serve as vectors for viruses that cause disease in humans. To generate the indicator, we plotted annual statewide counts of each species trapped at 87 locations operated by the Connecticut Agricultural Experiment Station mosquito surveillance program.[107] To take into account differences from year to year in the number of traps set, we normalized for number of trap-days each year. (A trap-day represents one trap set for one day.) Ten of the 28 species show increasing trends (*Aedes albopictus, Anopheles punctipennis, Anopheles quadrimaculatus, Anopheles walkeri, Coquillettidia perturbans, Culex salinarius, Culex territans, Ochlerotatus aurifer, Ochlerotatus provocans*, and *Ochlerotatus taeniorhynchus*) and three species show decreasing trends (*Ochlerotatus sollicitans, Ochlerotatus strictus,* and *Ochlerotatus triseriatus*) (TABLE 5). For each species, we also calculated the total number of mosquitos trapped per trap-day during 2015–2019, as a marker of recent relative abundance. The most abundant species in order of abundance are *Coq. perturbans, O. canadensis,* and *Cul. salinarius* (TABLE 5).

FIGURE 16 shows the time trends for six species of special interest: *Cul. pipiens, Cul. restuans,* and *Cul. salinarius* (the main West Nile virus vectors, one of which is among the most abundant mosquitos in Connecticut), *Aedes albopictus* (a major vector worldwide for dengue virus, chikungunya virus, Zika virus, and yellow fever virus, none of which have been isolated from *Aedes albopictus* mosquitos in Connecticut), *Coq. perturbans* (the most abundant mosquito in Connecticut and an important vector for Eastern equine encephalitis), and *O. canadensis* (the second most abundant mosquito in Connecticut). As mentioned above, three of these species (*Aedes. albopictus, Coq. perturbans*, and *Cul. salinarius*) exhibited increasing trends.

We also examined recent relative abundance and time trends for these six species by county. *Aedes albopictus* was first identified in Connecticut in 2006. Since then, almost all *Aedes albopictus* mosquitos have been trapped in Fairfield and New Haven, with increasing trends in abundance observed in both counties. During 2015–2019, about three-quarters of *Aedes albopictus* mosquitos were trapped in Fairfield on a per-trap basis. *Cul. pipiens* exhibited a decreasing trend in Windham, with no other county trends. During 2015–2019, *Cul. pipiens* abundance was highest in Fairfield (2.33 mosquitos/trap-day), New Haven (2.08), and Hartford (1.63), compared with 0.40 mosquitos/trap-day in the remainder of the state. *Cul. restuans* exhibited no county trends. During 2015–2019, *Cul. restuans* abundance was highest in Middlesex (3.83 mosquitos/trap-day), New Haven (2.71), Fairfield (2.49), Hartford (1.98), and New London (1.77), compared with 0.86 mosquitos/trap-day in the remainder of the state.

Cul. salinarius exhibited increasing trends in Fairfield, Hartford, Middlesex, New Haven, and New London. During 2015–2019, *Cul. salinarius* abundance was highest in Middlesex (33.5 mosquitos/trap-day), New Haven (32.7), Fairfield (14.6), and New London (14.1), compared with 4.60 mosquitos/trap-day in the remainder of the state. *O. canadensis* exhibited an increasing trend in Litchfield, with no other county trends. During 2015–2019, *O. canadensis* abundance was highest in Litchfield (60.2 mosquitos/trap-day) and Windham (30.6), compared with 18.0 mosquitos/trap-day in the remainder of the state. Finally, *Coq. perturbans* exhibited increasing trends in Fairfield, Middlesex, Tolland, and Windham. During 2015–2019, *Coq. perturbans* abundance was highest in Windham (141.8 mosquitos/trap-day), Litchfield (121.6), Tolland (66.9), and Middlesex (61.8), compared with 23.6 mosquitos/trap-day in the remainder of the state. *Coq. perturbans* represented 65.3% of all mosquitos trapped in Windham and 48.2% of all mosquitos trapped in Tolland. During 2015-2019 for all 28 species combined, abundance was highest in Litchfield (304.7 mosquitos/trap-day) and Windham (217.2), compared with 126.7 mosquitos/trap-day in the remainder of the state.

How this relates to health

Mosquito abundance is a key factor that influences the capacity of a mosquito to transmit a virus and the rate at which infections spread. A high abundance is often a prelude to an epidemic.[20] Each of the mosquito species we tracked has been found in Connecticut to carry one or more of the following viruses that infect humans: Cache Valley (CV), Eastern equine encephalitis (EEE), Jamestown Canyon (JC), Trivittatus (TVT), or West Nile virus (WNV) (TABLE 5).[21] Increases in the abundance of mosquito species that are vectors for these viruses could portend increases in the incidence of viral infections.

Aedes albopictus is one of the two main vectors for dengue virus, chikungunya virus, Zika virus, and yellow fever virus. *Aedes aegypti*, the other main vector for these viruses, currently is only found in tropical and subtropical locations. As mentioned, *Aedes albopictus* was first detected in 2006 in Connecticut, which is near the northern boundary of its current range,[108] and its abundance in Fairfield and New Haven counties has been increasing since then, probably due to mild winters. Although there has been no known spread of dengue, chikungunya, Zika, or yellow fever in Connecticut, as the climate warms, further increased abundance and range expansion of *Aedes albopictus* in Connecticut can be anticipated, making the introduction of these infections into the state an increasing concern.

What can we expect in the future?

Mosquitos, which are ectothermic (i.e., cold-blooded), can thrive in a warmer world.[22] As Connecticut continues to warm, disease-carrying mosquitos may continue to become more abundant, and as warm seasons lengthen, so might the transmission seasons for the diseases these mosquitos carry. Furthermore, changes in precipitation, which are expected to occur in Connecticut due to climate change (see INDICATOR 6), could influence mosquito abundance in complex ways.

Climate change has already been shown to affect vector-borne disease incidence or spread in many localities around the world,[22] pointing to the need for vigilance. First, we need to address the root cause of the problem by steeply reducing greenhouse gas emissions, locally and globally. But we also need to adapt to the climate change that is occurring by working to reduce the size of populations of mosquitos that cause disease, preferably using integrated pest management approaches that limit the use of toxic insecticides, and by working to limit human exposure to mosquitos by eliminating breeding sites in populated areas and ensuring high-quality housing with mosquito-tight screens on doors and windows and without spaces in walls, doors and windows through which mosquitos could otherwise enter.[109] Continued mosquito surveillance, public education about personal protection against mosquitos, and selective insecticide spraying when epidemic conditions occur would also help to protect against increased incidence of mosquito-borne diseases in Connecticut in the face of climate change.


LKERS
ON TRAILS

West Nile Virus Infections*

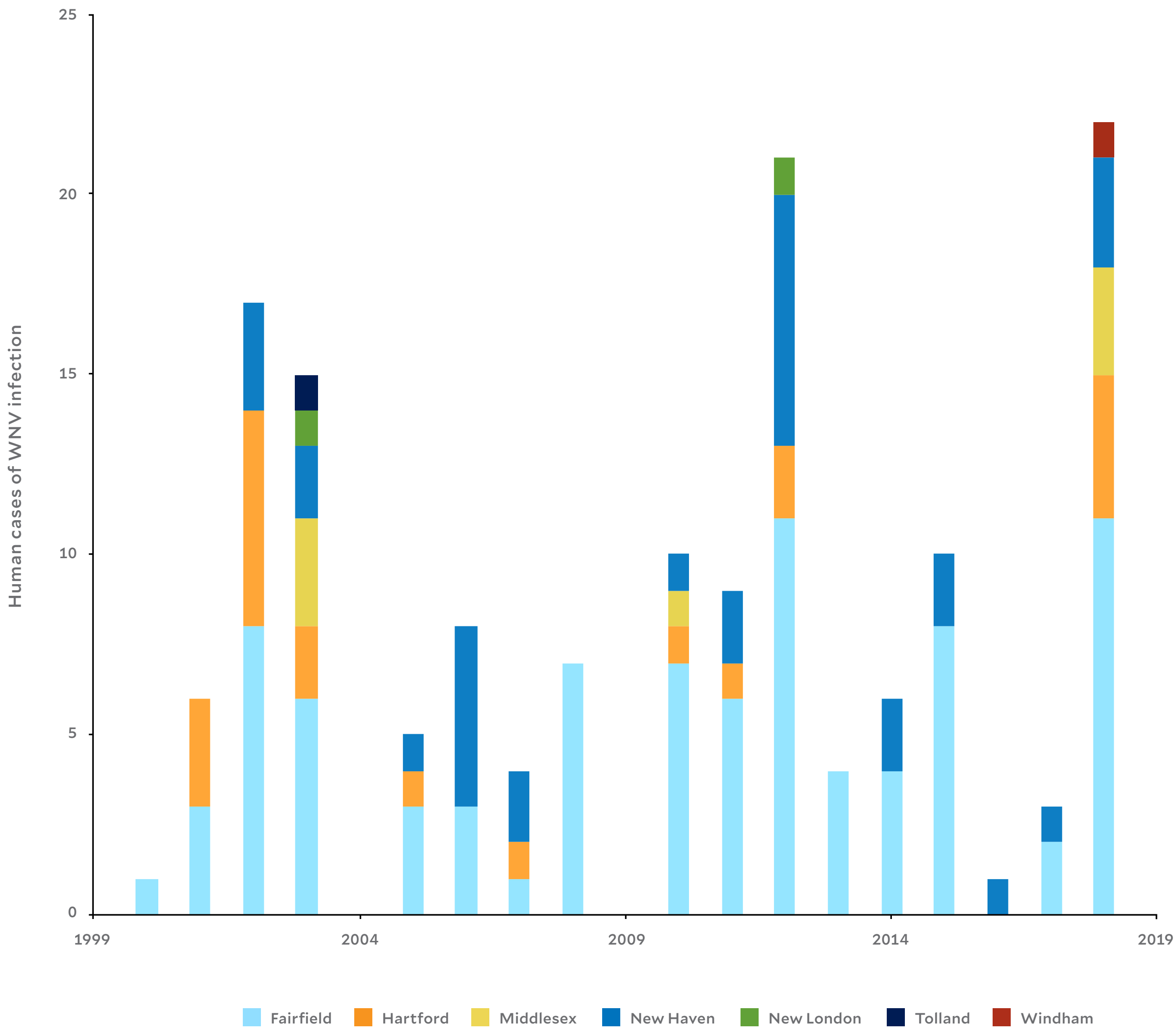


FIGURE 17: *Human cases of West Nile virus (WNV) infection acquired in Connecticut, 2000–2018, by county.* No cases were reported for Litchfield county. Data source: (110).

*DURING 2000–2018, THE NUMBER OF REPORTED SYMPTOMATIC CASES PER YEAR OF WEST NILE VIRUS INFECTION VARIED FROM 0 (2004 AND 2009) TO OVER 20 (2012 AND 2018).

What this indicator shows

West Nile virus (WNV) is the leading cause of mosquito-borne disease in the United States.[23] The first case in North America was recorded in New York in 1999, and infections have since expanded throughout most of the United States. This indicator tracks the number of cases reported in each county from 2000 to 2018. As FIGURE 17 shows, the number of reported symptomatic cases per year in Connecticut varies from zero (2004 and 2009) to over twenty (2012 and 2018). The majority of these cases (85 of 149 cases, or 57%) has been located in Fairfield County. Most have occurred during August and September.[111]

Only about one in five people infected with WNV show symptoms, which can include fever, headache, muscle pains, and rash. For this reason, the number of WNV infections is underreported, since those who do not experience symptoms (or those who experience very mild symptoms) will not go to the doctor and be diagnosed.[23] Fewer than 1% of infected people experience a serious illness that affects the central nervous system, such as meningitis or encephalitis.[24] In rare cases, the infection can lead to death.

How this relates to climate change

The number of people infected by WNV per year is influenced by many factors, including the abundance of the *Culex* mosquitos that transmit the virus, the proportion of these mosquitos that become infected from biting a variety of bird species that are infected with the virus, and the abundance of these bird species. INDICATOR 12 tracks the abundance of the main mosquito species that transmit WNV: the abundance of *Culex pipiens* (the main WNV vector) and *Culex restuans* has been constant, whereas the abundance of *Culex salinarius*, the third most common mosquito species in Connecticut, has exhibited an increasing trend, which may be influenced by warmer weather or changes in precipitation patterns caused by climate change. WNV human infection rates could also be influenced by changes in the mix and abundance of bird species that reside in Connecticut, which could be affected by climate change.

A study in Suffolk County (Long Island, New York) found that wet winters, warm and wet springs, and dry summers were associated with more *Culex* mosquitos carrying WNV during that summer and fall.[112] A plausible explanation is that the winter and spring conditions facilitate early mosquito activity and an early increase in numbers of mosquitos, while the dry summer weather brings birds and mosquitos into close contact around the remaining water sources, increasing their interaction and infection rates.[112, 113] These results are consistent with another study that found summertime drought to be strongly associated with higher numbers of WNV cases.[114] Summertime heavy rainfall, however, also has been found to result in higher infection rates, though too much rainfall can lead to a flushing of larvae.[113, 115]

What can we expect in the future?

As discussed in INDICATOR 12, in the absence of mosquito control measures, the abundance of *Culex* mosquitos that transmit WNV may increase in the future as Connecticut becomes warmer. Changes in precipitation, which are expected to occur in Connecticut due to climate change (see INDICATOR 6), could influence mosquito abundance in complex ways. Under the high greenhouse gas emissions scenario (RCP 8.5), an additional 490 serious cases of WNV infection affecting the central nervous system per year are projected in the Northeast in 2080–2099 compared with 1986–2005. Under a lower emissions scenario (RCP 4.5), an additional 210 cases per year is projected.[60] However, measures to reduce the abundance of the *Culex* mosquito population and to separate mosquitos from humans by eliminating breeding sites in populated areas and through high-quality housing can help counter these projections (see INDICATOR 12). Development of a safe, effective vaccine should also be pursued.

INDICATOR

14

Eastern Equine Encephalitis *

What this indicator shows

Eastern equine encephalitis (EEE) is a rare mosquito-borne disease. Nationally, on average only seven cases are reported per year.[116] The first human case of EEE was reported in Connecticut in 2013.[117] In 2019, four human cases were reported, three of which were fatal. All four cases were clustered in southern Connecticut.[117] Concern over EEE during Fall 2019 led officials in some Connecticut towns to change the time of high school sporting events, among other precautionary actions.

EEE virus is maintained by a cycle between songbirds and the *Culiseta melanura* mosquito species, which lives in forested, freshwater swamps. It is transmitted to humans by “bridging” mosquitos that feeds on both birds and mammals; infected mosquitos from the *Aedes, Coquillettidia*, and *Culex* genera transmit to humans. Infections typically occur in warm weather months. In 2019, the majority of infected mosquitos were found in August and September; the onset of symptoms in the four human cases also occurred during this period.[118]

Most people infected with EEE virus have no symptoms. In only rare cases (estimated less than 5%) does the infected person develop an infection of the central nervous system (i.e., meningitis or encephalitis); [119] in these cases, EEE can be fatal. Based on a national surveillance dataset, the fatality rate for those officially diagnosed with EEE was found to be 41%.[119] However, the real fatality rate is much lower when considering the cases in which people have mild or no symptoms and do not seek medical attention.

How this relates to climate change

The EEE virus was discovered in the 1930s, and since then there have been sporadic, geographically clustered outbreaks in the U.S. Since the early 2000s, infections have become more frequent and have extended northward into central and northern New England.[120] This reemergence is likely due to a suite of factors, including changes in land use and changes in climate. In terms of land use, suburban development has brought human populations in closer proximity to the swampy habitats where the mosquito vectors and bird hosts live.

Like WNV, the incidence of EEE is influenced by the abundance of mosquito vectors (i.e., *Culiseta melanura, Aedes, Coquillettidia,* and *Culex* mosquitos) that transmit the virus, the proportion of these mosquitos that become infected from biting a variety of bird species that are infected with the virus, and the abundance of

CONNECTICUT'S FIRST REPORTED HUMAN CASE OF EASTERN EQUINE ENCEPHALITIS OCCURRED IN 2013. IN 2019, FOUR CASES WERE REPORTED, THREE OF WHICH WERE FATAL.

these bird species. INDICATOR 12 shows that *Aedes albopictus, Culex salinarius,* and *Coquillettidia perturbans* mosquitos have exhibited an increasing trend in Connecticut, which may be influenced by warmer weather or changes in precipitation patterns caused by climate change. *Coquillettidia perturbans* is the most common mosquito in the state, and *Culex salinarius* is the third most common. EEE human infection rates in Connecticut also could be influenced by changes in the amount of forested, freshwater swamp habitat (where *Culiseta melanura* mosquitos and birds mix), as well as changes in the mix and abundance of bird species, both of which could be affected by climate change. In particular, increased rainfall and accumulated groundwater can create more swamp habitats.[120]

What can we expect in the future?

As discussed in INDICATOR 12, in the absence of mosquito control measures, the abundance of EEE mosquito vectors may continue to increase as Connecticut becomes warmer. Changes in precipitation, which are expected to occur in Connecticut due to climate change (see INDICATOR 6), could influence mosquito abundance in complex ways. It is difficult to predict how the amount of swamp habitat will change because this will be affected by land use decisions regarding whether to drain or preserve these habitats. The future mix and abundance of bird species is also difficult to predict. Regardless, as with WNV, measures to reduce the abundance of mosquito vectors and to separate mosquitos from humans by eliminating breeding sites in populated areas and by improving the quality of housing can help prevent EEE (see INDICATOR 12). Development of a safe, effective vaccine should also be pursued.

INDICATOR

15 Lyme Disease *

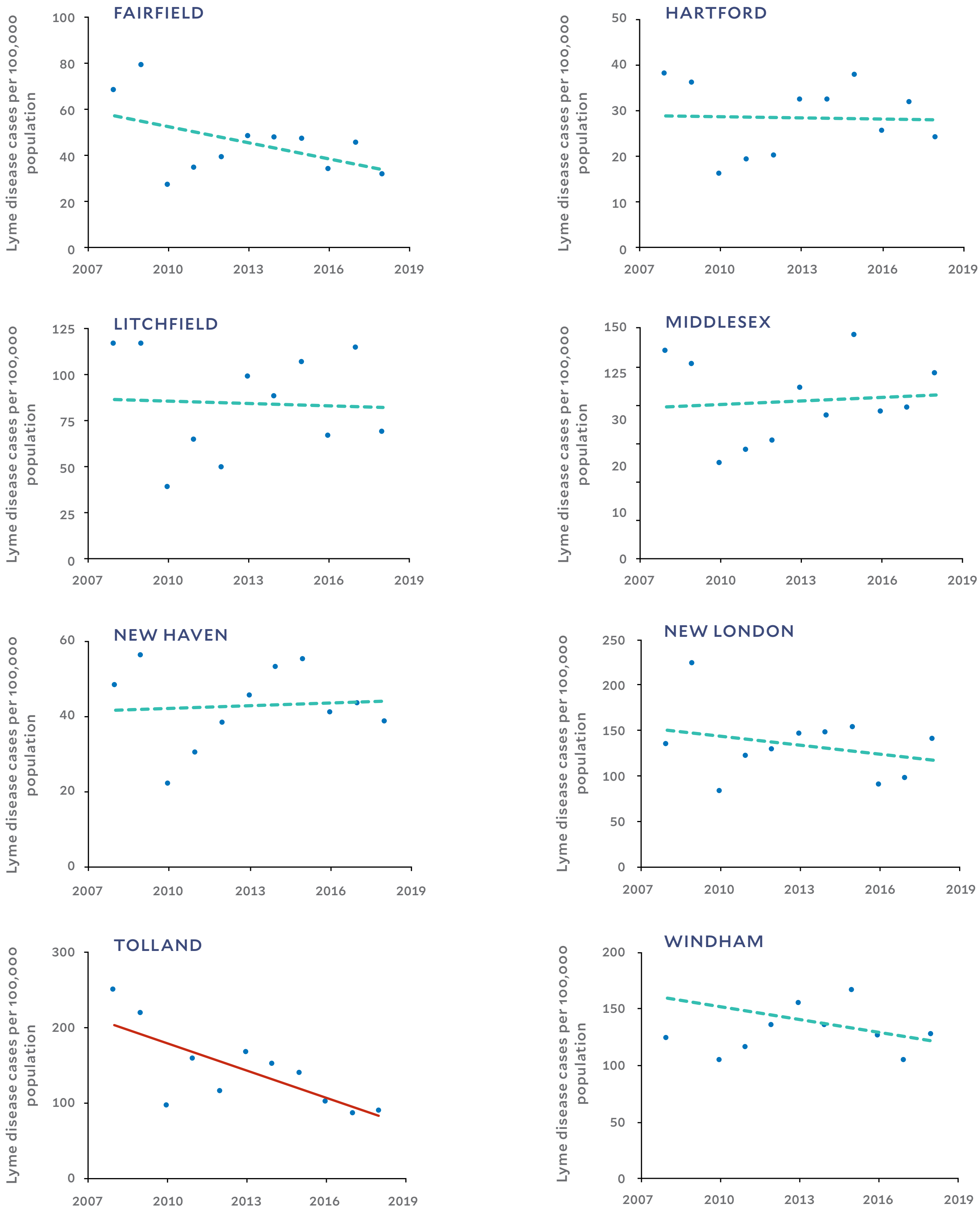


FIGURE 18: *Confirmed and probable Lyme disease cases (per 100,000 population), 2008–2018, by Connecticut county.* Red solid trendline indicates statistical significance. Data source: (26).

*** REPORTED CASES OF LYME DISEASE DECLINED FROM ABOUT 3,700 PER YEAR IN 2008-2010 TO ABOUT 1,900 PER YEAR IN 2016–2018.**

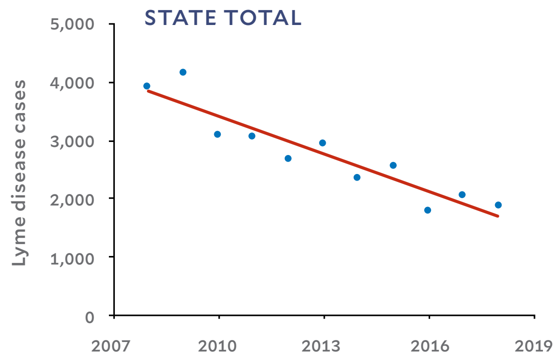


FIGURE 19: *Total confirmed and probable Lyme disease cases in Connecticut, 2008–2018*. Yearly totals include the sum of county totals plus cases of unknown county. Red solid trendline indicates statistical significance. Data source: (26).

What this indicator shows

This indicator tracks the number of Lyme disease cases in Connecticut overall and the number of cases per 100,000 population in each Connecticut county. Lyme disease is a bacterial disease transmitted to humans in the United States by the blacklegged tick, commonly known as the deer tick. Blacklegged ticks, in fact, are vectors for other diseases as well: anaplasmosis, babesiosis, and Powassan encephalitis virus. Lyme disease is the most commonly reported vector-borne disease in the United States, as well as in Connecticut. It is generally cured with treatment, but particularly without treatment, symptoms can progress to severe joint pain and swelling, facial palsy, heart palpitations, inflammation of the brain and spinal cord, and nerve pain or numbness.[25] Transmission occurs seasonally, with the most cases reported in June and July in Connecticut.[26] This coincides with when ticks are most active and when humans spend time outdoors in areas where tick bites are more likely to happen.

For this indicator, we tracked only from 2008 to 2018, a time period with consistent data when the Connecticut Department of Public Health tracked both confirmed and probable cases. During this period, there is only one county—Tolland—with a trend (decreasing) (FIGURE 18). However, once aggregated together, the downward trend in number of total cases statewide is clear (FIGURE 19). (This decreasing trend in number of cases cannot be explained by a decrease in the Connecticut population, which was basically stable during this period.) Cases may have declined because people are taking protective measures when in high risk areas such as applying tick repellant, wearing long pants and long sleeves, and doing tick checks and taking showers after leaving these areas.

We found differences in the rate of infection across the counties (FIGURE 18); for instance, while Fairfield has the most annual cases on average (426 per year), the average annual incidence rate is approximately three times higher in New London, Tolland, and Windham counties (134, 143, and 141 cases per 100,000 people, respectively) than in Fairfield (46 cases per 100,000 people). The average annual incidence rates were 29 cases per 100,000 people in Hartford, 85 in Litchfield, 103 in Middlesex, and 43 in New Haven.

How this relates to climate change

Climate conditions—temperature, rainfall, and humidity—are important for determining the geographic area in which the deer tick can survive. When Lyme disease first emerged in North America in the late 1970s, Connecticut's climate was already conducive to serve as deer tick habitat, so climate change was not a factor in Lyme disease's emergence. Rather, Lyme disease emerged due to, first, conversion of agricultural land to forests, which resulted in overabundance of white-tailed deer (a keystone host for deer ticks) and burgeoning tick populations; and second, suburban encroachment on forested areas, which resulted in increased human-deer tick encounters.[23, 121] In this context, the main factors that determine deer tick abundance in local areas within Connecticut (which is a key element in determining the number of human infections) are the presence of suitable habitat (especially conditions on the ground, mainly soil type and the presence of leaf litter) and the abundance of deer tick hosts (which include white-footed mice, other small rodents, and birds, in addition to white-tailed deer).[122, 123]

What can we expect in the future?

Climate change may affect the risk of being infected with Lyme disease in a few ways. First, the warmer winters and earlier springs projected under climate change may cause the Lyme disease season to begin earlier as a result of earlier tick activity, extending the period of Lyme disease transmission (see INDICATOR 3). Under the high greenhouse gas emissions scenario (RCP 8.5), it is projected that by 2065 to 2080, the Lyme disease season would begin approximately 1.5 weeks earlier in Connecticut compared to the base period of 1992 to 2007; under a low greenhouse gas emissions scenario (RCP 2.6), the Lyme disease season would begin 0.4 weeks earlier.[124] Second, shorter and milder winters and earlier springs make it more likely that deer ticks will survive the winter, leading to larger tick populations.[27] But extreme heat and drought increase tick mortality, so climate change also may lead to a countervailing force on tick abundance.[28]

Climate change also is likely a factor in the northward expansion and emergence in Connecticut of another tick species, the lone star tick (see PANEL). Lone star ticks are aggressive biters that can transmit several diseases and medical conditions, though they do not transmit Lyme disease.

Tick surveillance and public education about personal protection against ticks help to prevent Lyme disease and other tick-borne diseases. Development of a safe, effective Lyme disease vaccine should also be pursued.

LONE STAR TICKS

The lone star tick, which is the most common human biting tick in the southeastern United States, is expanding into Connecticut, likely due to abundant hosts such as white-tailed deer, and climatic and environmental factors including warming temperatures, and especially, warmer winters.[125, 126] While lone star ticks do not transmit Lyme disease,[127] they transmit other diseases and medical conditions, including tularemia, ehrlichiosis, Heartland virus disease, southern tick-associated rash illness, red meat allergy, and likely, Bourbon virus disease. The Connecticut Agricultural Experiment Station reports that the number of lone star ticks submitted to its Tick Testing Laboratory and acquired in Connecticut increased by 75% from the period of 1996–2006 (n = 396) to 2007–2017 (n = 693), with most originating in Fairfield County.[126] Importantly, established breeding populations were discovered in Fairfield and New Haven counties in 2018 and 2019, respectively.[125]

INDICATOR

16

Foodborne *Vibrio* Infections *

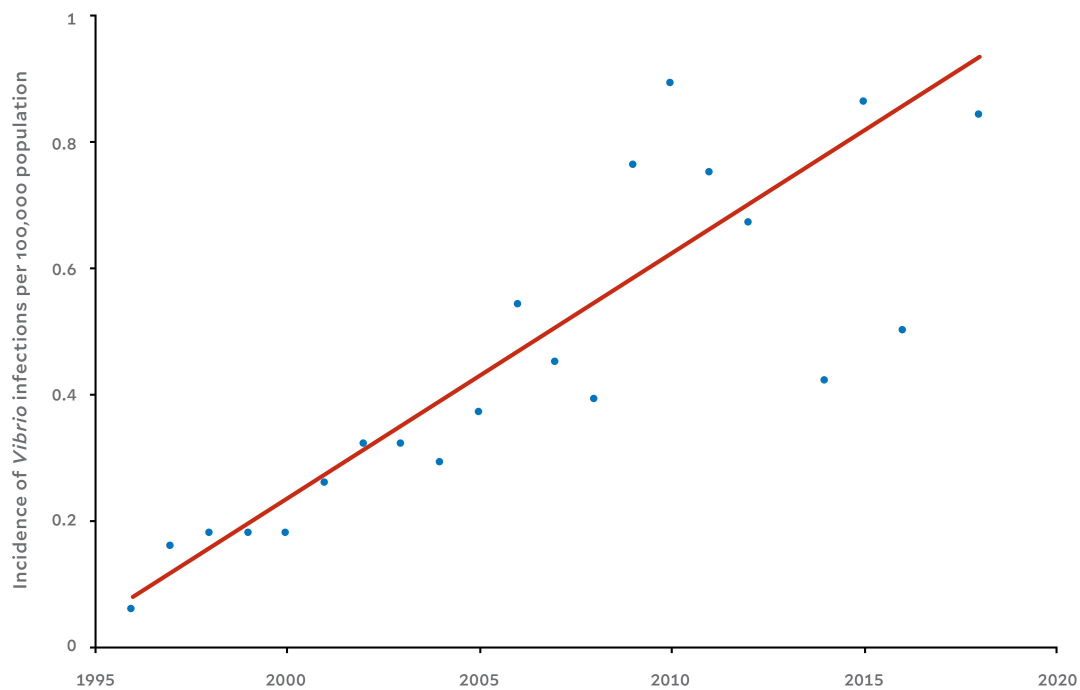


FIGURE 20: *Confirmed foodborne Vibrio infections per 100,000 population in Connecticut, 1996–2018.* Red solid trendline indicates statistical significance. Data source: (128).

What this indicator shows

Vibrio bacteria live naturally in warm coastal waters, especially in lower-salinity estuaries. Humans become infected through two routes: by eating contaminated seafood (especially shellfish) that is raw or undercooked or by direct exposure to water carrying the *Vibrio* bacteria, especially when a wound is exposed. The majority of cases are diagnosed during the summer months when water is warmer. Between 2006 and 2014, among major bacterial foodborne infections, *Vibrio* infections exhibited the greatest increase in incidence in the United States.[129]

This indicator tracks infections reported in Connecticut that were acquired from ingesting food contaminated with the *Vibrio* bacteria. We found that like for the United States as a whole, the annual incidence of confirmed cases of foodborne *Vibrio* infections increased in Connecticut from 1996 to 2018 (FIGURE 20).

* THE ANNUAL INCIDENCE OF CONFIRMED CASES OF FOOD-BORNE *VIBRIO* INFECTIONS HAS INCREASED.

There are a number of *Vibrio* species that cause human infections. The most well-known species is *Vibrio cholerae*, which causes cholera. Fortunately, due to well-developed water treatment and sanitary infrastructure, cholera does not occur in Connecticut or anywhere else in the United States. The most common species to cause foodborne infections in Connecticut is *V. parahaemolyticus*, accounting for at least 53% of reported cases from 1996 to 2018, followed by *V. alginolyticus* (18%) and *V. fluvialis* (6%), other species (9%), and not speciated (15%).[128]

Foodborne infections from *Vibrio* typically result in symptoms including abdominal cramps, nausea, headaches, diarrhea, fever, and chills. Since the symptoms generally resolve in a few days, people often do not seek medical attention, so there is under-reporting of the number of infections. However, foodborne *Vibrio* infections can be serious, especially when caused by *V. vulnificus*, which causes 95% of all seafood-related mortality in the United States.[130] Fortunately, foodborne *V. vulnificus* infections in Connecticut are rare. (During 2000–2012, there was one likely case in the state due to Connecticut-harvested shellfish.[131]) *Vibrio* wound infections, for which reporting is not required and which are not included in FIGURE 20, are often life-threatening, especially when caused by *V. vulnificus*.

How this relates to climate change

Increasing temperature, extreme precipitation events, storms, and floods all may contribute to increased *Vibrio* infections. First, the bacteria grow best in warm water—there is a strong association between higher sea surface temperature and greater *Vibrio* abundance.[29] Already, it has been observed that infections increase during heat waves.[130]

Second, heavy precipitation, storms, and floods also can lead to increased *Vibrio* infections. *Vibrio* can spread in floodwaters or be transferred to new areas through storm surge.[132] At least 25 cases of *Vibrio* infection occurred after Hurricane Katrina, including 18 wound infections that likely resulted from exposure to floodwaters.[133] Heavy rainfall also lowers the salinity of ocean and coastal waters, making them a more conducive environment for the bacteria.[130]

In fact, some researchers suggest that *Vibrio* species serve well as indirect measures—or “bellwethers”—of climate change.[130] They point out that the bacteria are very sensitive to temperature changes: the warmer the water, the faster they reproduce. They also note that *Vibrio* replicate rapidly in response to changes in their environment that promote their growth, so that there is little lag time between

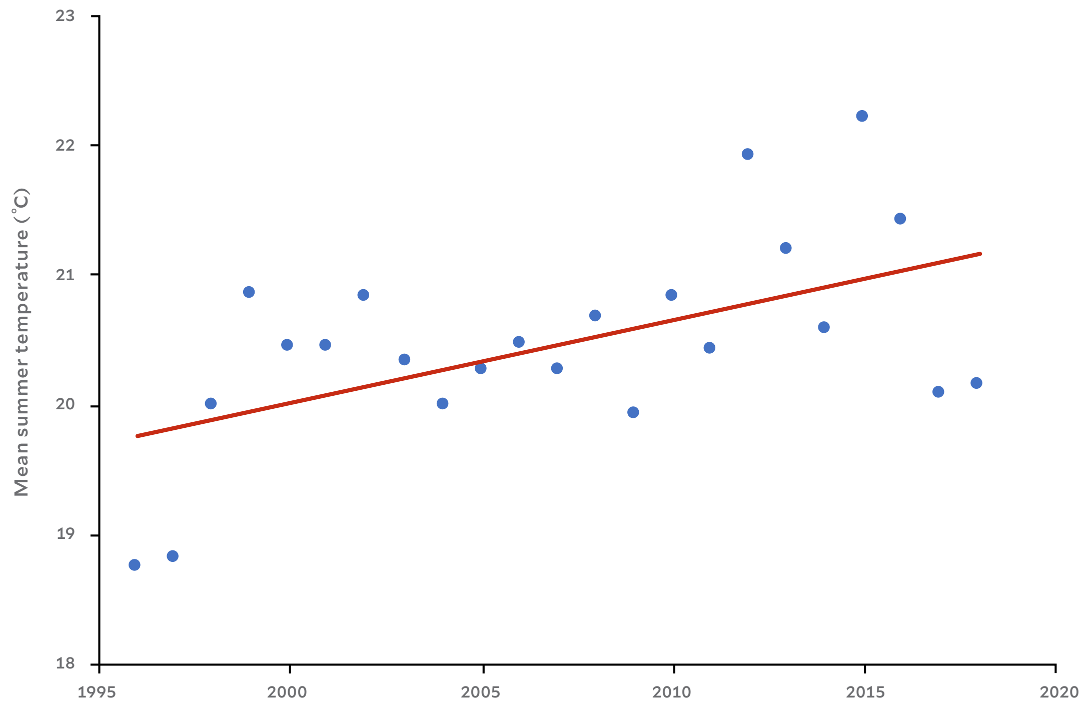


FIGURE 21: *Near-surface water temperature in Niantic Bay, CT, summer (July–September), 1996–2018*. Red solid trendline indicates statistical significance. Data source: (30).

changes in the environment and changes in their abundance. FIGURE 21 shows that summer near-surface water temperatures are increasing in Niantic Bay on Long Island Sound, consistent with the increase in *Vibrio* foodborne infections.

What can we expect in the future?

We can generally expect greater risk of *Vibrio* infections in the future. As sea temperatures rise, the abundance of *Vibrio* will likely increase, and its geographic and seasonal ranges may expand into regions and months that had previously been too cold.[82, 132] One study found that under either a high (RCP 8.5) or moderate (RCP 4.5) greenhouse gas emissions scenario, between 2015 and 2050, warming sea surface temperatures in the Baltic Sea would cause the area suitable for *Vibrio* growth during summer months to double, the *Vibrio* transmission season to become longer, and the number of *Vibrio* infections to increase along the Swedish Baltic Sea coast.[134] The primary approach to prevent this anticipated increase in *Vibrio* infections is to sharply reduce greenhouse gas emissions, locally and globally. We also can work to improve surveillance for foodborne *Vibrio* infections, to initiate surveillance for *Vibrio* wound infections, and to continue to closely monitor Long Island Sound, especially shellfish beds, for *Vibrio* contamination.

AIR QUALITY

INDICATOR
17

Ground-Level Ozone

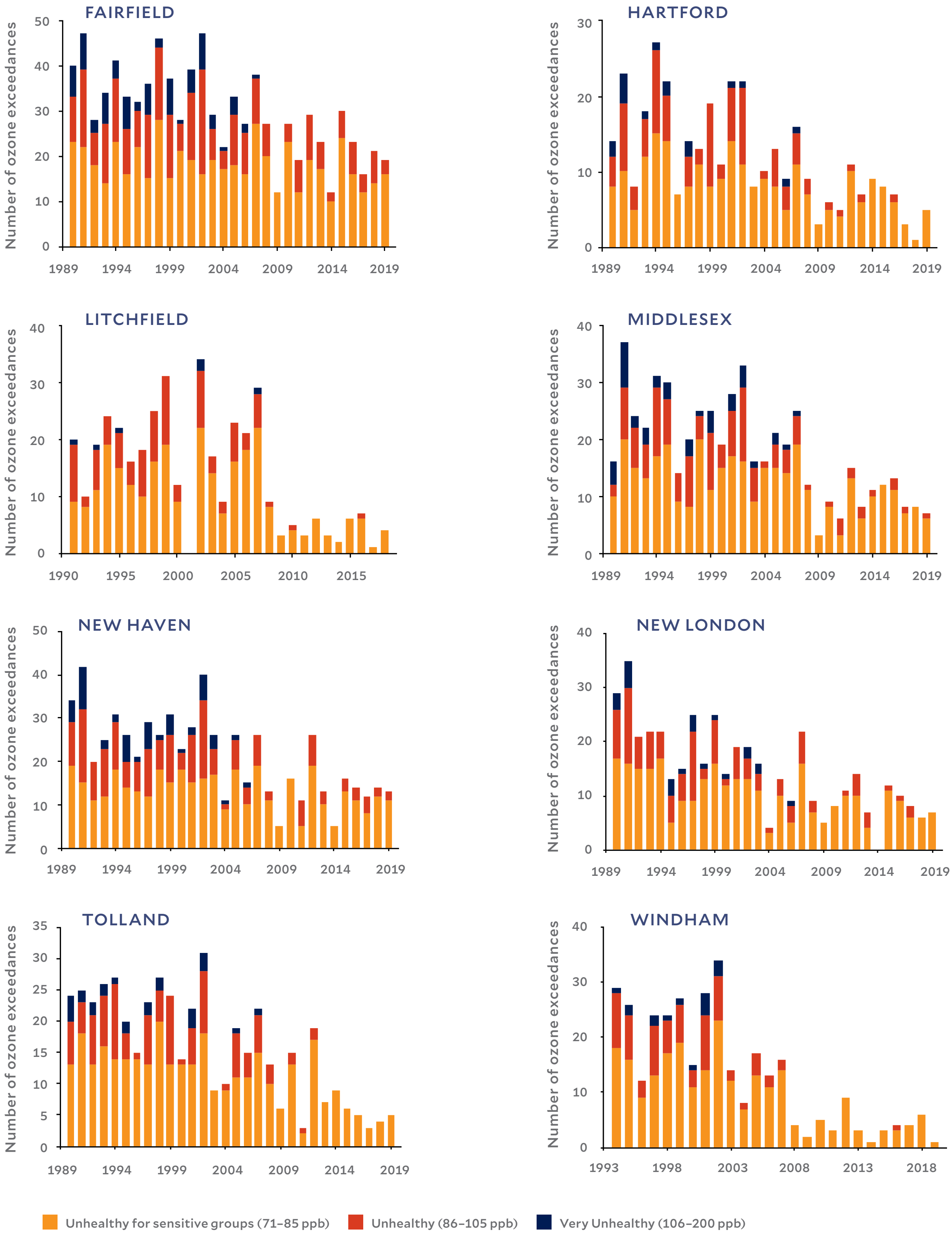


FIGURE 22: *Number of ground-level ozone exceedance days per year by EPA Air Quality Index (AQI) alert levels, 2000–2019, by Connecticut county*. An exceedance day occurs when the daily maximum 8-hour ozone average is 71 parts per billion or higher. AQI alert levels displayed are as follows: unhealthy for sensitive groups (71–85 ppb) (orange), unhealthy (86–105 ppb) (red), very unhealthy (106–200 ppb) (purple). Due to no data/ insufficient data, Litchfield County figure excludes 1990 and 2001, and Windham County figure excludes 1990–1993. Data source: (135).

* SINCE 1990, THE ANNUAL NUMBER OF DAYS ON WHICH GROUND-LEVEL OZONE EXCEEDED SAFE LEVELS DECREASED IN ALL COUNTIES, BUT MORE IMPROVEMENTS ARE NEEDED TO FULLY PROTECT HUMAN HEALTH.

What this indicator shows

This indicator tracks the number of ground-level ozone exceedance days, stratified by EPA Air Quality Index (AQI) alert level (FIGURE 22). An ozone exceedance day occurs when the daily maximum 8-hour ozone average is 71 parts per billion (ppb) or higher. According to EPA methodology, a day is considered to be an exceedance day for a given county if any monitor in the county registers an exceedance for that day.

Importantly, ground-level ozone, or "smog," a toxic pollutant that forms in the lower atmosphere (troposphere), is different than the "good" ozone layer that is located higher in the atmosphere (stratosphere) and blocks ultraviolet light that is dangerous to human health. Ground-level ozone is formed in the lower atmosphere by chemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of heat and sunlight. NOx and VOCs are largely produced from the burning of fossil fuels in vehicles, power plants, industrial boilers and other industrial sources. VOCs also are emitted into the atmosphere from gasoline, industrial solvents, and paints, and some are emitted by natural vegetation.

We found that the number of ozone exceedance days is decreasing in all counties in Connecticut. However, air quality alert days still occur throughout the state: over the last five years (2015–2019), all counties had days recorded with ozone at levels unhealthy for sensitive groups (71–85 ppb), and all but Tolland County had at least one day reaching "unhealthy" levels (86–105 ppb). (See TABLE 6 for a listing of all ozone Air Quality Index levels.) In fact, the American Lung Association gave all eight Connecticut counties "F" grades for ozone pollution in its 2019 *State of the Air Report*, which analyzed monitoring data for years 2015–2017.[31] More air quality improvements are needed to be fully protective of human health.

The overall decreasing trend in Connecticut coincides with a long-term national trend in dramatic ozone air quality improvements, thanks to national and state environmental regulations that limit NOx and VOC emissions. However, Connecticut-based actions alone can only improve our ozone air quality to a certain point. Since ground-level ozone and its precursor pollutants can travel long distances along wind currents, Connecticut's ozone concentrations are substantially influenced by pollution originating outside the state borders.

0 to 54 ppb	Good (green)
55 to 70 ppb	Moderate (yellow)
71 to 85 ppb	Unhealthy for Sensitive Groups (orange)
86 to 105 ppb	Unhealthy (red)
106 to 200 ppb	Very Unhealthy (purple)
> 200 ppb	Hazardous (maroon)

TABLE 6: *EPA Air Quality Index levels for ground-level ozone.*

How this relates to health

Ozone is a strong lung irritant that can cause lung damage. Exposure to ground-level ozone can cause respiratory symptoms such as coughing, wheezing, and shortness of breath; exacerbation of chronic obstructive pulmonary disease and asthma; increased susceptibility to lung infections; and increased risk of death.[136] Since their lungs are still developing and they are likely to be active outdoors when ozone levels are high, children are at higher risk from ozone exposure, especially for asthma exacerbations. In addition, ground-level ozone exposure may contribute to the initial development of asthma in children. Nationally, asthma is a leading cause of student school absenteeism.[137] Correspondingly in Connecticut, a 2015 analysis found that approximately one in 10 middle and high school students statewide reported an episode of asthma or an asthma attack in the past year; prevalence was highest among non-Hispanic black students (12.4%), followed by non-Hispanic white students (10.6%), Hispanic students (10.2%), and non-Hispanic Asian students (5.4%).[138] Poor children and children of color bear the highest asthma burden.

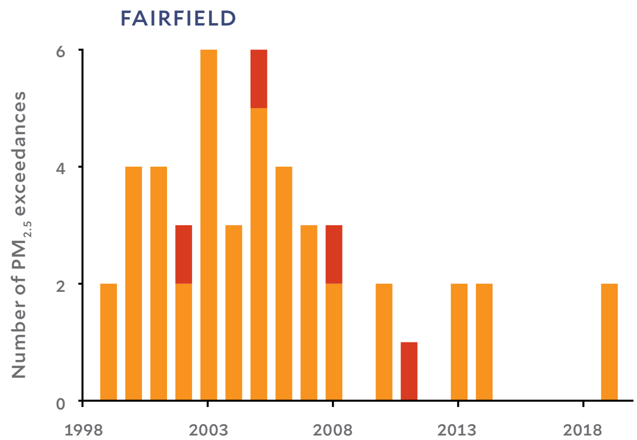
In the Northeast's urban areas, the hottest days often are associated with the highest concentrations of air pollutants, including ground-level ozone.[9] Heat catalyzes the chemical reactions between NOx and VOCs that form ground-level ozone, and hot days are associated with increased use of vehicles and air conditioning (and therefore electricity) that generate NOx and VOC pollution. This combination of extreme heat and poor urban air quality poses a major health risk to vulnerable groups: young children, elderly, socially or linguistically isolated, communities of color, and economically disadvantaged, especially those with asthma and other preexisting respiratory conditions.[9]

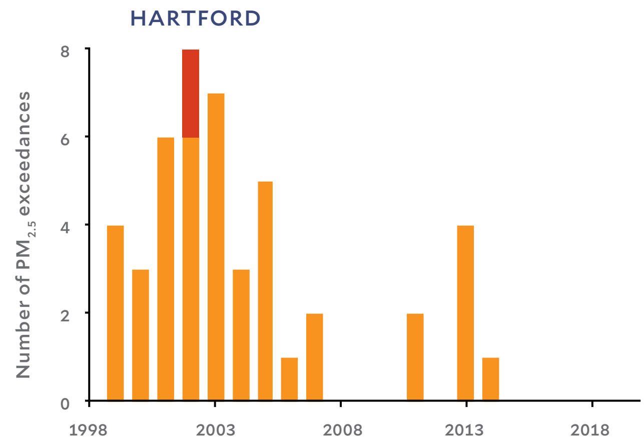
What can we expect in the future?

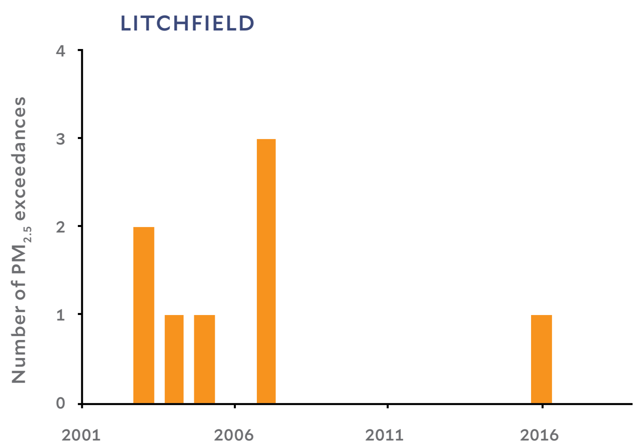
Past progress on reducing ground-level ozone pollution is likely to be counteracted in the future by a "climate penalty:" everything else being equal, higher temperatures, as well as changes to atmospheric circulation patterns caused by climate change, are expected to bring about higher ground-level ozone concentrations, especially in already polluted areas.[139] One analysis estimates 200 to 300 excess deaths (under RCP greenhouse gas emissions pathway 4.5 or 8.5, respectively) to occur in the Northeast in 2050 compared to 2000, due to this climate penalty.[140] Indeed, even with strong climate mitigation action, increased ozone-related deaths are expected because of warming that is now already unavoidable. However, the size of the climate penalty will depend on our collective action to reduce greenhouse gas emissions. Following a moderate emissions path (RCP 4.5) rather than the high emissions path (RCP 8.5) could prevent approximately 360 deaths per year by 2090 in the Northeast, saving an estimated $5.3 billion per year.[60]

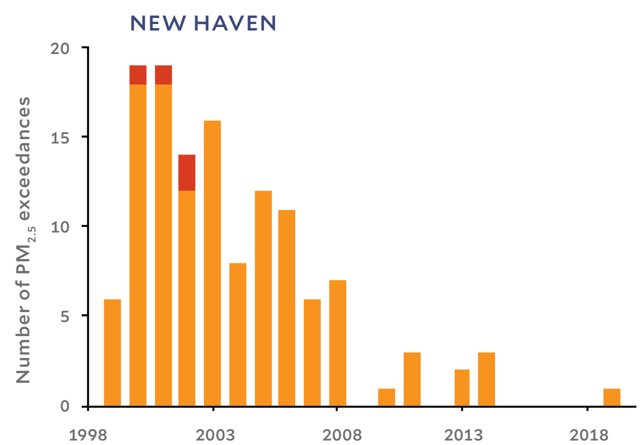
Additionally, many actions to mitigate climate change also will reduce the emission of other air pollutants, including the ozone precursors, NOx and VOCs. This is a key health co-benefit of climate action; by reducing the vehicle, electricity, and industrial emissions that produce both local toxic air pollution and greenhouse gas emissions, we can improve health today and in the future.

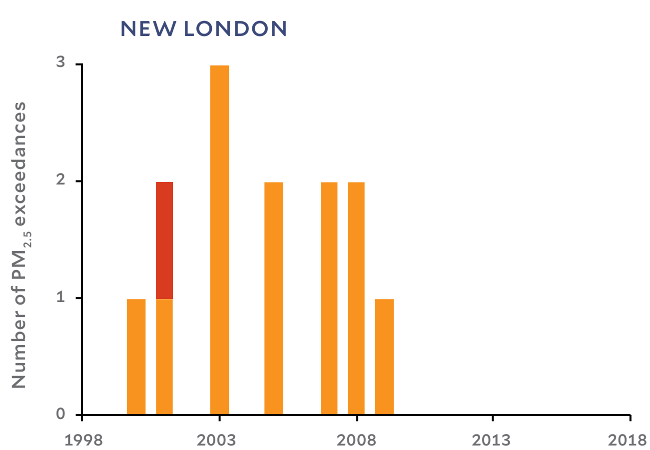
Fine Particulate Matter ($PM_{2.5}$)*











Unhealthy for sensitive groups (35.5–55.4 ug/m3)
Unhealthy (55.5–150.4 ug/m3)

FIGURE 23: *Number of $PM_{2.5}$ exceedance days per year by EPA Air Quality Index (AQI) alert levels, 1999–2019, by Connecticut county.* AQI alert levels recorded are as follows: unhealthy for sensitive groups (35.5–55.4 ug/m^3) (orange) and unhealthy (55.5–150.4 ug/m^3) (red). Due to no data/insufficient data, Litchfield County figure excludes 1999–2001. No monitoring data are collected for Middlesex, Tolland, and Windham counties. Data source: (135)

* SINCE 1999, THE ANNUAL NUMBER OF DAYS ON WHICH FINE PARTICULATE MATTER ($PM_{2.5}$) EXCEEDED SAFE LEVELS DECREASED IN FAIRFIELD, HARTFORD, NEW HAVEN, AND NEW LONDON COUNTIES.

What this indicator shows

This indicator tracks the number of ground-level fine particulate matter ($PM_{2.5}$) exceedance days, stratified by EPA Air Quality Index (AQI) alert level (FIGURE 23). A $PM_{2.5}$ exceedance day occurs when the 24-hour average concentration is above the National Ambient Air Quality Standard (NAAQS) level of 35 ug/m^3. As with the ozone indicator, a day is considered to be an exceedance day for a given county if any monitor in the county registers an exceedance for that day. The Connecticut Department of Energy and Environmental Protection does not monitor $PM_{2.5}$ in Middlesex, Tolland, or Windham counties.

$PM_{2.5}$ is an air pollutant made up of solid or liquid particles no more than 2.5 micrometers in diameter, or approximately 30 times smaller than the diameter of a strand of hair. $PM_{2.5}$ is especially dangerous to human health because its small size enables it to enter deep into the lungs and into the bloodstream. The primary source of particulate matter is the burning of fossil fuels. It can either be emitted directly or formed in the atmosphere. Power plants, vehicles, and industrial sources release precursor pollutants—sulfur dioxide, nitrogen oxides and ammonium, which react in the atmosphere to form $PM_{2.5}$.[141] Additionally, some particles are produced directly from sources including fires, construction sites, and vehicle tire and break wear.

Because of $PM_{2.5}$'s varied sources and how it is formed, its concentration at a particular location is the result of both local and regional pollution. $PM_{2.5}$ pollution is often higher along major roadways and in urban and industrial areas due to localized sources like vehicles and industrial facilities. Additionally, $PM_{2.5}$ precursor pollutants emitted from power plants can travel long distances and affect regional air quality. In fact, one study found that 90% of Connecticut deaths from $PM_{2.5}$ pollution from electric power plants were due to sources outside the state border; the states whose pollution was most responsible for Connecticut deaths were Pennsylvania, Ohio, Michigan, and New York.[142]

In our analysis for this indicator, we found that the number of $PM_{2.5}$ exceedance days has decreased in Fairfield, Hartford, New Haven, and New London counties (FIGURE 23). No unhealthy, very unhealthy, or hazardous days (average $PM_{2.5}$ concentration over 55.5 ug/m^3) have been reported in any of the five monitored counties in at least the past eight years (2012–2019). (See TABLE 7 for a listing of all $PM_{2.5}$ Air Quality Index levels.) This improvement can be attributed to environmental regulations enacted at the state and federal level to limit air pollution. The NAAQS limits the emission of air pollutants, including $PM_{2.5}$, from stationary sources like power plants.

0.0 ug/m^3 to 12.0 ug/m^3	**Good (green)**
12.1 ug/m^3 to 35.4 ug/m^3	**Moderate (yellow)**
35.5 ug/m^3 to 55.4 ug/m^3	**Unhealthy for Sensitive Groups (orange)**
55.5 ug/m^3 to 150.4 ug/m^3	**Unhealthy (red)**
150.5 ug/m^3 to 250.4 ug/m^3	**Very Unhealthy (purple)**
250.5 ug/m^3 and above	**Hazardous (maroon)**

TABLE 7: *EPA Air Quality Index levels for $PM_{2.5}$.*

The standard for $PM_{2.5}$ has been reduced a number of times since the Clean Air Act began to be implemented in 1971; the current standard for annual mean $PM_{2.5}$ concentration is 12.0 ug/m^3 and the standard for daily mean $PM_{2.5}$ concentration is 35 ug/m^3.[143] Connecticut has developed additional policy strategies to decrease particulate pollution. For instance, the Connecticut Department of Energy and Environmental Protection introduced the Connecticut Clean Diesel Plan in 2006 to reduce diesel applications in vehicles and machinery, as well as stationary sources; diesel exhaust not only is a significant contributor to $PM_{2.5}$ pollution but also has been classified by the EPA as a probable human carcinogen.[144]

How this relates to health

In 2017 in Connecticut, there were 783 deaths attributed to $PM_{2.5}$; for the entire nation, this number was over 88,000 deaths in 2015.[145] The pollutant causes or aggravates heart and lung conditions including heart attacks, heart rhythm disorders, heart failure, respiratory symptoms, chronic obstructive pulmonary disease, asthma, and lung cancer.[146] Worsening the pollutant's health effects, toxic "hitchhiker" elements and compounds (including lead, cadmium, arsenic, and polycyclic aromatic hydrocarbons) can attach to $PM_{2.5}$ and thereby be brought deep into the lungs.[147] Chronic exposure during fetal growth or early childhood development has been linked to impaired brain development, pre-term birth, low-birth weight, and impaired lung growth; children also are at increased risk for later development of asthma, pneumonia, and chronic obstructive pulmonary disease.[148, 149]

Communities of color often live in close proximity to power plants, industrial facilities, and highways, increasing their daily exposure to $PM_{2.5}$ and other pollutants, like ground-level ozone. These communities are affected by respiratory illnesses at rates higher than comparable communities located away from these pollution sources. One recent study found that, on average, communities of color in the Northeast and Mid-Atlantic regions breathed 66% more air pollution from vehicles than white residents.[150] In another study, the mortality rate associated with $PM_{2.5}$ pollution from electricity generation nationwide was found to be highest among Blacks.[142]

What can we expect in the future?

Action to mitigate climate change by reducing the burning of fossil fuels will have the immediate health "co-benefit" of also reducing $PM_{2.5}$ emissions. Researchers estimated that an aggressive greenhouse gas emissions reduction scenario for the United States aimed at limiting warming to no more than 2 ºC over pre-industrial levels would avoid about 19,000 premature deaths nationwide in 2030 from decreased $PM_{2.5}$ pollution due to decreased burning of fossil fuels, compared to the "business-as-usual" RCP 8.5 scenario.[151]

INDICATOR

19

Outdoor Allergens (Mold and Pollen)*

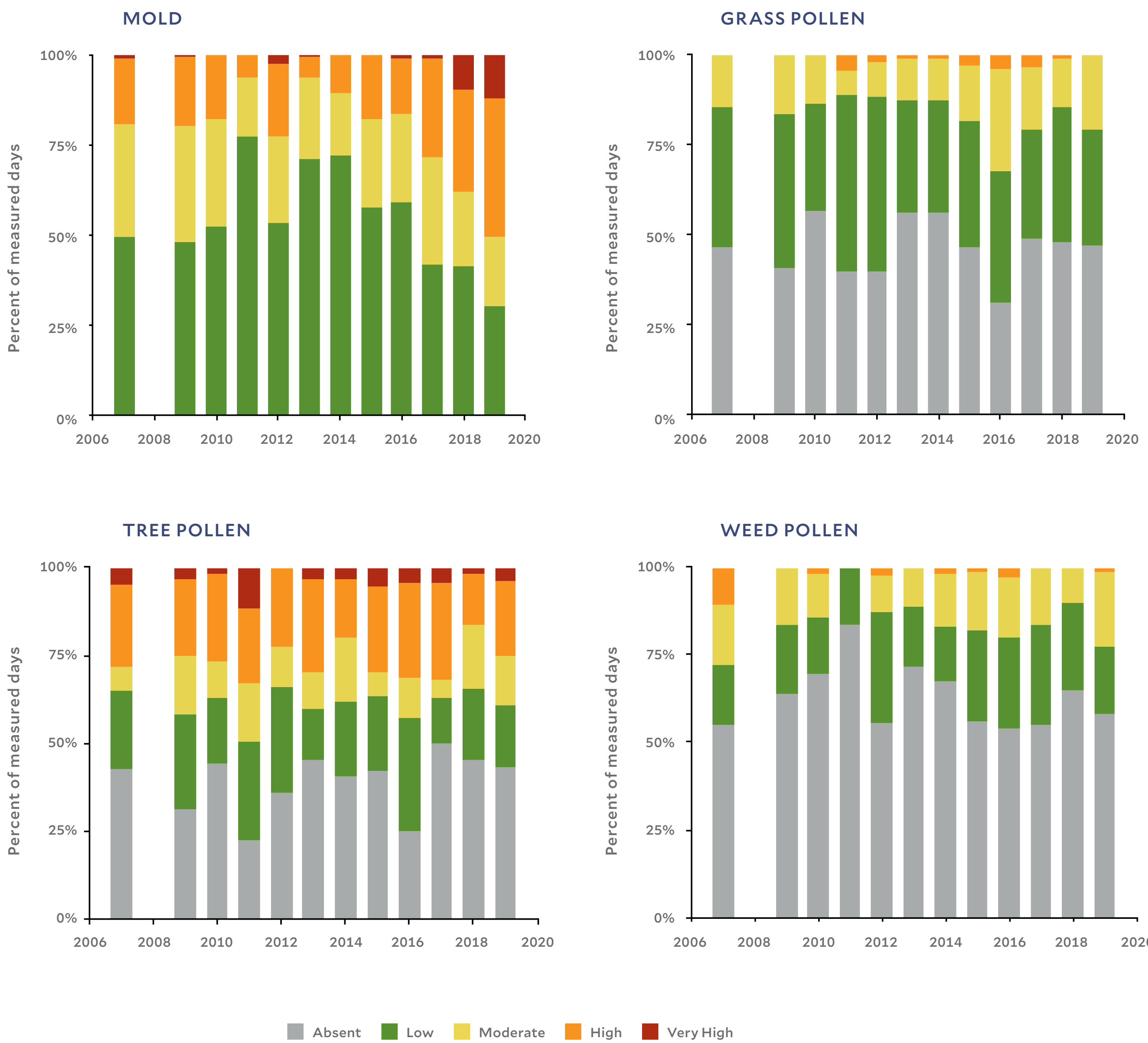


FIGURE 24: *Allergen concentration levels, percent of measured days by National Allergy Bureau (NAB) Scale category, Waterbury, CT monitoring station, 2007–2019, April–September.* No data available for 2008. NAB Scale categories are as following: grey = absent; green = low; yellow = moderate; orange = high, red = very high. See TABLE 8. Data source: (152).

✻ SINCE 2007, THE PERCENT OF MEASURED DAYS WITH "HIGH" OR "VERY HIGH" OUTDOOR MOLD CONCENTRATIONS HAS INCREASED.

What this indicator shows

This indicator looks specifically at outdoor aeroallergens: mold, grass pollen, tree pollen, and weed pollen. We tracked the percent of measured days corresponding to each level on the National Allergy Bureau (NAB) Scale (TABLE 8), from "absent" to "very high," from 2007 to 2019. Data used in this indicator were collected at a monitoring site in Waterbury, Connecticut, the only NAB pollen counting site in New England.[152] We found an increasing trend for the percent of measured days with "high" or "very high" mold concentration; no other trends were found to be statistically significant (FIGURE 24).

Although we did not observe significant increases in high pollen days, there are some national indications of changes in pollen and outdoor mold exposure that might be associated with climate change. Increased atmospheric carbon dioxide concentrations (which stimulate plant growth), in concert with warmer temperatures, already appear to be resulting in changes in the geographic distribution of allergen-producing plant species, longer pollen seasons, increased pollen production, and possibly increased allergenic potency of the produced pollen, which would cause more intense allergic reactions.[32–34] For instance, researchers found that between 1995 and 2015 the ragweed pollen season increased by 15 days in parts of the United States that lie on the same latitude as Connecticut, probably due to later first frosts in the fall.[153] Other studies have found that counts of certain outdoor mold species increase with higher temperature and humidity.[35–37]

NAB SCALE				
	MOLD	GRASS	TREE	WEED
Absent	0	0	0	0
Low	1–6,499	1–4	1–14	1–9
Moderate	6,500–12,999	5–19	15–89	10–49
High	13,000–49,999	20–199	90–1,499	50–499
Very High	50,000 and above	200 and above	1,500 and above	500 and above

TABLE 8: *National Allergy Bureau (NAB) Scale by allergen concentration (pollen or spores per cubic meter).*

How this relates to health

Pollen—especially, grass pollen and ragweed—is a common trigger for seasonal allergies. Many people are affected by seasonal allergies, with typical mild symptoms including sneezing, watery eyes, itchy throat and eyes, and runny nose.[154] More severe health effects also occur. Exposure to pollen can lead to increased emergency department visits and hospitalizations for asthma in children.[155, 156] Exposure to high levels of outdoor mold concentrations also have been linked to higher asthma hospitalizations and higher rates of asthma mortality.[157–159]

What can we expect in the future?

Outdoor aeroallergen exposure will likely increase in the future, though the degree to which this happens depends on how quickly we collectively reduce greenhouse gas emissions. One study found that by 2090, asthma emergency department visits triggered by grass and tree pollen in the United States would increase 14% under a high emissions (RCP 8.5) scenario, but only 8% for a moderate (RCP 4.5) emissions scenario.[160]

A particular area of concern is the vulnerability of urban areas, where both carbon dioxide concentrations and temperatures are higher than in rural areas. In one study, researchers found that ragweed grew faster and larger, flowered earlier, and produced more pollen in an urban area compared with a rural area, where atmospheric carbon dioxide concentrations and temperatures were lower.[161]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CONCLUSION

To protect human health now and in the future, Connecticut decision makers and residents alike must undertake strong action to confront the challenges identified in this report. First, this means swift action to mitigate climate change by reducing greenhouse gas emissions. Under its 2008 *Global Warming Solutions Act* and the 2018 *Act Concerning Climate Change Planning and Resiliency*, Connecticut has committed to reducing greenhouse gases to 45% below 2001 levels by 2030 and to 80% below 2001 levels by 2050. Other states have committed to even more significant cuts, suggesting that Connecticut has further to go: New York, for instance, set a target of net-zero greenhouse gas emissions by 2050. Second, Connecticut must expand its work to prepare for and adapt to the climate change impacts that are already occurring and will worsen in the future. The Governor's Council on Climate Change now guides both efforts, with policy recommendations anticipated in early 2021 as part of the updated *Adaptation and Resilience Plan* for Connecticut and the council's annual report on the state's climate mitigation progress.

With this in mind, we offer seven crosscutting recommendations to support equitable, science-based, and holistic mitigation and adaptation actions to protect human health.

1 Monitor current conditions and project trends for Connecticut

Climate change introduces new and expanded threats to the health of Connecticut residents, such as higher risk of heat-related illness, emergent vector-borne diseases like those spread by the lone star tick, and expanded risks to drinking water quality and quantity. To make rapid and effective responses based on data, decision makers need systems in place that monitor environmental and climatic changes and that track climate-sensitive health outcomes. Since climate change effects will change over time, more research that projects Connecticut-specific impacts to human health in the future and identifies vulnerable populations also is needed. The Centers for Disease Control and Prevention's Building Resilience Against Climate Effects (BRACE) Framework sets out a systematic approach to accomplish these activities; however, these activities require resources beyond what the Connecticut Department of Public Health could reasonably deploy without additional funding. The state should pursue funding opportunities and partnerships to support the collection, monitoring, analysis, and dissemination of these critical data.

2 Invest in the social determinants of health

Social factors, including housing, education, employment, income, and access to medical care, are major drivers of population health. Addressing the social determinants of health is fundamental to improving health and reducing health disparities,[38] and climate change makes this imperative even more urgent. An example from a key social determinant of health—housing—makes this clear: Substandard housing is generally poorly insulated, making inhabitants more exposed to temperature extremes, humidity, and outdoor air pollutants, including particulate matter, pollen, and mold. Renters are especially vulnerable because they have less power to make home improvements and are often not eligible for government funding programs designed to address these issues. In addition, after a natural disaster, renters or those who cannot afford to repair their homes are more likely to become displaced.[101] Therefore, programs to make housing more stable, affordable, and healthy also help make those homes more climate resilient. Local and state actions to invest in the social determinants of health and to cultivate community resilience will make Connecticut healthier and better prepared for climate change. Actions to address climate change mitigation or adaptation that also invest in the social determinants of health produce synergistic benefits and should be prioritized, given limited funding.

3 Tackle the upstream drivers of climate change and health disparities

It has been aptly stated that "the root causes and upstream drivers of climate change and health inequities are often the same: Our energy, transportation, land use, housing, planning, food and agriculture, and socioeconomic systems are at once key contributors to climate pollution and key shapers of community living conditions."[39] Furthermore, these systems are "shaped by current and historical forces that include structural racism and the persistent lack of social, political, and economic power of low-income communities and communities of color."[39] Addressing climate change and health inequities requires confronting these upstream drivers by challenging historic and systemic burdens, including environmental pollution, income inequality, racism, and inequitable access to power, resources, and opportunities.

4 Pursue actions that integrate mitigation, adaptation, and immediate health benefits

To efficiently address climate change and its health impacts, measures that combine mitigation, adaptation, and immediate health benefits should be prioritized. For example, improved energy efficiency standards for refrigerators accomplish mitigation by reducing greenhouse gas emissions through less electricity consumption (assuming the electricity is generated by burning fossil fuels); accomplishes adaptation by reducing the urban heat island effect through less heat expelled by refrigerators; and provides immediate health benefits by reducing emission of toxic air pollutants such as $PM_{2.5}$ and NOx, again through less electricity consumption. Increasing forested green space in coastal urban areas accomplishes mitigation because trees absorb carbon dioxide from the atmosphere; accomplishes adaptation because trees reduce the urban heat island effect through evapotranspiration and shade provision and because green space reduces flood risk; and provides immediate health benefits of space for physical activity, improved mental health, and healthier shellfish in Long Island Sound (due to less flooding, which can result in bacterial contamination of shellfish). There are many other opportunities for achieving the triple benefits of climate change mitigation, adaptation, and immediate health benefits.

5 Build the capacity of health professionals and decision makers in other sectors to address climate and health

Most health professionals—including physicians, physician assistants, nurses, psychologists, community health workers, and public health professionals—did not learn about climate change and its health effects in their formal training. Although the situation is improving, climate change currently is covered in only a small proportion of health professional schools in the United States.[162, 163] In addition, many other decision makers, including municipal staff, planners, and community leaders—while experts in their fields—lack specific knowledge about how their issue area relates to climate change and health. Incorporating lessons about climate change and its health impacts into health and other higher education curricula, as well as continuing education courses, would help close this key knowledge gap and prepare the workforce to make informed decisions under a changing climate. This challenge should be addressed through combined efforts of colleges and universities, public health agencies, and professional associations.

6 Incorporate climate change into decision making across sectors

Climate change touches nearly all sectors of government in some way, including planning, transportation, energy, environmental protection, housing, economic development, engineering, public works, parks and recreation, buildings, emergency management, food and agriculture, and health. For both adaptation and mitigation efforts to be effective, climate change needs to be considered and incorporated into planning and investment in all these sectors and all levels of government. To do so requires that climate change not be treated as a siloed issue that can be addressed in isolation by personnel and policies expressly focused only on climate change. Rather, inter-sectoral collaboration is essential. This can be a challenge especially when enabling legislation or other policies mandate an agency's scope and activities. Connecticut's Lead by Example program to increase clean energy and energy efficiency at state facilities and Public Act No. 18-82, which requires municipalities and the state to plan for sea level rise, are the kind of comprehensive and systems-level policies we need, and more of these should be pursued.

7 Incorporate public health into climate change decision making

"Health in all policies" is a collaborative approach to improving population health by embedding health considerations into decision making across sectors and policy areas.[40] Building on the concept of the social determinants of health, this approach calls for public health representatives to be at the table when making policy decisions ranging from urban planning to transportation to voter registration. Correspondingly, public health considerations should be incorporated into all climate change mitigation and adaptation policymaking. An encouraging sign in Connecticut is that the Department of Public Health now has a seat on the Governor's Council on Climate Change. Its role on the council should fully cover both adaptation and mitigation workstreams, particularly given the opportunities for immediate health benefits from mitigation.

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