Addressing the Adverse Health Effects of Climate Change in New York State

Recommendations for Protecting New Yorkers' Health and Safety from Global Warming and Climate Instability

By the Medical Society of the State of New York
Preventive Medicine and Family Health Committee

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This original "white paper" was developed by the Preventive Medicine and Family Health Issues Committee in response to a directive from the 2018 House of Delegates. This document was primarily drafted by Emily Senay, MD, Moshe Y. Bressler, and Geoffrey E. Moore, MD, Chair. Much thanks to Sheila M. Cherry, PhD, Catherine Brown, and Leore Lavin for editorial assistance.

Special thanks to Pat Clancy, MSSNY Sr. Vice President for Public Health and Education/Managing Director.

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Overview of Sources

This analysis of the health effects of global warming and climate instability in New York State draws from the 4th National Climate Assessment; ClimAID: the integrated Assessment for Effective Climate Change Adaptation in New York State (2011 and updated 2015); the New York City Panel on Climate Change 2015 Report (NPCC); the New York State Department of Health Building Resilience Against Climate Effects (BRACE) in New York State; and the scientific and medical literature.

Executive Summary

Humanity faces an unprecedented existential threat from climate instability and global temperature rise caused by human activities, most notably the emission of greenhouse gases from combustion of fossil fuels. The threat to human health from climate instability has been called the greatest of the 21st century.[4] New York State does not escape this threat. The Medical Society of the State of New York acknowledges that immediate action is needed to prevent catastrophic health effects related to climate instability.[4] Physicians must warn society and advocate for protecting the health of our patients and communities. The pandemic of SARS CoV2 has revealed many weaknesses in our ability to meet large scale disasters that must be rapidly addressed if New York is to meet the challenges posed by climate change.

The Medical Society of the State of New York (MSSNY) presents this white paper to guide stakeholders including physicians, MSSNY members, healthcare organizations, community members, policy makers and legislators on actions needed to protect the health of New Yorkers. This paper focuses on direct (e.g., injuries/deaths) and indirect (e.g., reduced nutrients in crops) health effects driven by fossil fuel combustion and climate instability. We address: 1) the evidence for global warming and climate instability; 2) the observed and projected environmental changes in New York State; 3) the observed and projected health and safety consequences of these changes; and 4) recommendations to mitigate, adapt and protect New Yorkers from climate change.

The path ahead will stress the health sector in unprecedented ways, yet solutions bring profound opportunities to provide immediate benefits—if New York State converted to 100% renewables, reductions in air pollution would save 4000 lives and $33 billion annually in health care costs.[7] Therefore, we also highlight the specific and immediate health benefits from reducing greenhouse gas emissions.

MSSNY aligns with climate science experts who have sounded the alarm—the threats to New York are profound and time is limited. Climate instability is already hurting New Yorkers and will continue to do so for decades to come even with aggressive reductions in emissions. We therefore make specific calls to action by key stakeholders to protect all New Yorkers, especially the most vulnerable. The silver lining is that—if everyone acts—we will see immediate health benefits. The challenges ahead cannot be met by the medical community alone. Every sector of society must come together to create a unified and sustained response to the looming threats. MSSNY therefore recommends that governmental and non-governmental leaders join with the medical and scientific communities to combat global warming and to create a healthier, safer environment for all New Yorkers.

Section 1: Overview of Global Warming and Climate Instability in New York State

> ***Scientific evidence for warming of the climate system is unequivocal.*** - Intergovernmental Panel on Climate Change[8]

1.1 Scientific Consensus on Global Warming and Climate Instability

The scientific community concurs that global warming caused by greenhouse gas emissions is leading to worldwide climatic instability.

The *National Climate Assessment* (NCA) is a federal mandatory interagency summary of climate change science that is extensively reviewed by experts, agencies and a panel from the National Academy of Sciences. The 4th NCA is the most authoritative assessment on the current and future impacts of climate change on society in the U.S.A.[1] The *Intergovernmental Panel on Climate Change* (IPCC) is the United Nations' body that provides policymakers with regular assessments of climate change, evaluates the implications and potential risks, and suggests adaptation and mitigation options.[3] The *NASA Global Climate Program* (NASA) conducts space-based research encompassing solar activity, the state of the ozone layer, air pollution, and changes in sea ice and land ice.[5] , enhancing understanding of global integrated Earth science. The *United Nations Framework Convention on Climate Change* (UNFCCC) is an international treaty that sets non-binding greenhouse gas emission limits for individual countries, which would prevent dangerous anthropogenic interference with the climate.[6]

These four leading agencies, the U.S. National Academy of Sciences, the American Association for the Advancement of Science, the American Medical Association and many other scientific bodies cite the wealth of evidence that demonstrates that global warming is occurring and that greenhouse gases emitted by human activities are the primary driver. At least 97% of actively-publishing climate scientists agree that climate warming is due to human activities.[9]

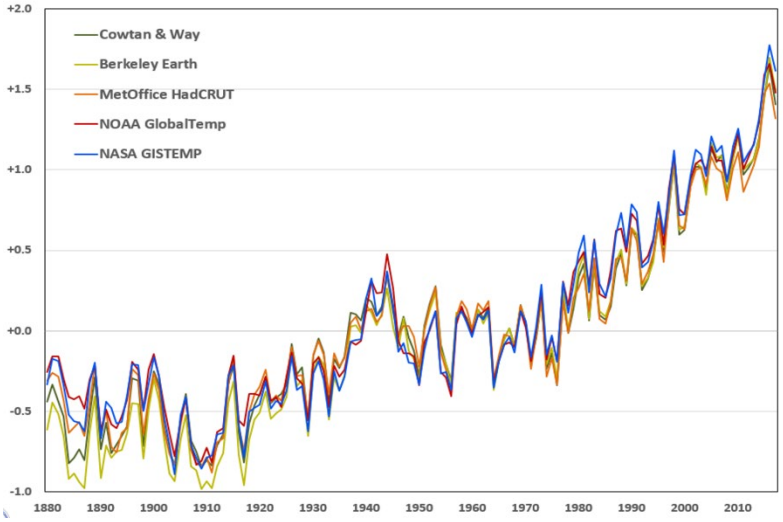


Figure 1: Global temperature rise documented by multiple sources shows rapid increases in the past several decades. Adapted from [10].

Earth's climate is changing faster than at any point in the history of modern society. Researchers worldwide have documented increases in temperature at the Earth's surface, as well as in the atmosphere and oceans (Figure 1). Rapid increase in temperature in the last several decades has resulted in a range of impacts across every region of the U.S. and the world. Human activities of fossil-fuel combustion, deforestation and land-use changes are primarily driving this large-scale warming.[10,11]

1.2 Greenhouse Gas Emissions Link to Global Warming Effects and Air Pollution

Greenhouse gases (GHG) include carbon dioxide (CO_2), methane and other gases that trap heat in the atmosphere. GHG emissions from fossil-fuel combustion have risen more than 50% since the beginning of the industrial revolution (Figure 2), which has been linked to the observed increases in atmospheric heat[12]. According to NASA, the effects of heat-trapping gases include[9]:

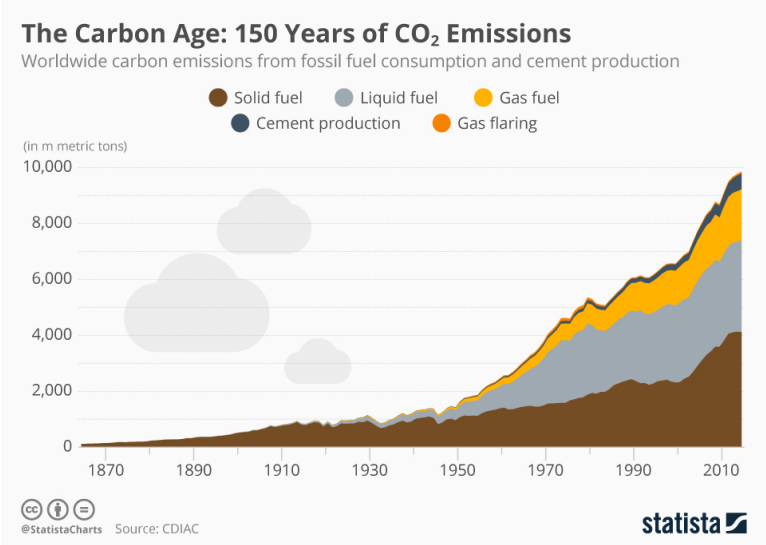


Figure 2: Global greenhouse gas emissions have increased significantly since the 1900s.

- Global Temperature Rise: The planet's average surface temperature has risen 1.62 degrees Fahrenheit (ºF) [0.9 degrees Celsius (ºC)] since the late 19th century, driven largely by increased carbon dioxide and other human-made emissions into the atmosphere. Most of this warming has occurred in the past 35 years.
- Warming Oceans: The oceans have absorbed much of the trapped heat, with the top 700 meters (about 2,300 feet) of ocean showing warming of more than 0.4ºF since 1969.
- Shrinking Ice Sheets: The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost an average of 281 billion tons of ice per year between 1993 and 2016, while Antarctica lost about 119 billion tons during the same time period. The rate of Antarctic ice mass loss has tripled in the last decade.
- Glacial Retreat: Glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes and Rocky Mountains, and Alaskan and African regions.
- Decreased Snow Cover: The amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades, and the snow melts earlier.

- Sea Level Rise: Global sea level rose about 8 inches in the last century. Much of this rise occurred in the last two decades, and the rate is accelerating slightly each year.
- Declining Artic Sea Ice: Both the extent and thickness of Arctic sea ice has declined rapidly over the last several decades.
- Extreme Events: The number of record high temperature events in the U.S. has been increasing, while the number of record low temperature events has been decreasing, since 1950. The U.S. has also witnessed increasing numbers of intense rainfall events.
- Ocean Acidification: Since the beginning of the Industrial Revolution, the acidity of ocean surface waters has increased by 30 percent because of atmospheric carbon dioxide being absorbed into the upper layer of the oceans, which is increasing by about 2 billion tons per year.

In addition, the sources of GHGs are often also sources of air pollutants. Air pollution is primarily driven by combustion of fossil fuels from vehicles, furnaces and power plants, but is also caused by road traffic dust, the manufacturing and building sectors, wood burning, farming and industries, as well as food preparation and heating.

A major component of air pollution is particulate matter (PM), a complex mixture of solids and liquids that can contain hundreds of types of chemicals, organic compounds and metals. PM can remain airborne for long periods of time and travel great distances from its original source. Particulate matter in the smaller size range, called $PM_{2.5}$, is a major threat to heart, lung, and brain health because this size of these particles allow travel deep into the lungs and circulation when inhaled.

Further, "secondary pollutants" are produced in the atmosphere through chemical reactions between toxic substances and heat or other atmospheric factors. The most important secondary pollutant is ozone (O_3), which is predicted to increase until 2040 (Figure 3).[14]

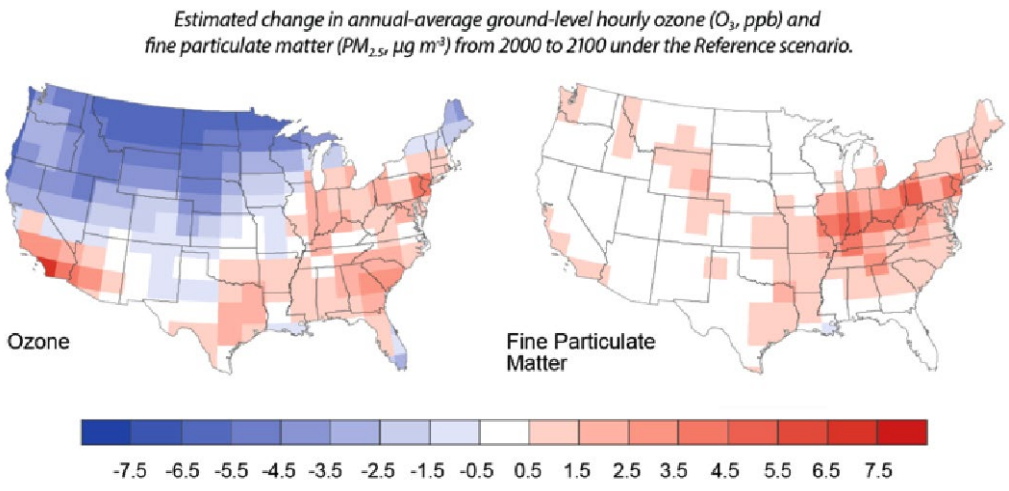


Figure 3: Projected changes in ozone and $PM_{2.5}$.[13]

Particulate Matter Air Pollution

Particulate matter (PM) is an airborne mixture of tiny particles and droplets (aerosols), often referred to as dust, haze or smoke. PM is both a primary and a secondary pollutant: it can be directly emitted by sources, or it can form in the atmosphere through physical or chemical processes. The U.S. Environmental Protection Agency (EPA) characterizes PM levels as the mass of particles found in a specific volume of air, commonly as micrograms of particles per cubic meter of air ($\mu g/m^3$). Unlike ozone, PM lacks a unique chemical identity and is commonly described in terms of particle size, usually by the particle's aerodynamic diameter. Like ozone, fine PM (particles with aerodynamic diameters <2.5 micrometers, $PM_{2.5}$) can be carried long distances from a source. Coarse PM (particles with aerodynamic diameters of 2.5 to 10 micrometers, PM_{10}), generally remain closer to the source. The ability of fine PM to travel great distances from its source is demonstrated by smoke from wildfires. In 2002, a wildfire in northern Quebec raised PM concentrations and dramatically impaired visibility in New York State and the eastern United States as far south as Maryland.

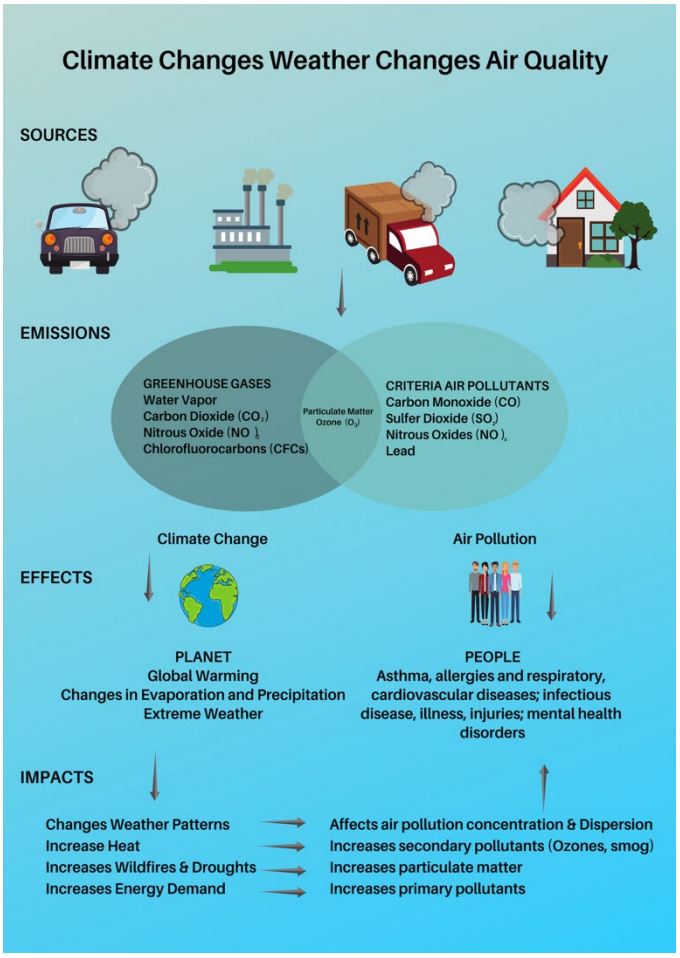


Figure 4: Effects of climate instability, air pollution, and ozone.

GHG emissions alter weather patterns by influencing the movement and dispersion of atmospheric pollutants through the action of winds, vertical mixing and rainfall (Figure 4).[1] For example, calm winds and cool air limits dispersion of traffic emissions during morning rush hour in winter, which worsens air quality and concomitant health risks. But as temperatures rise, demand for electricity for air conditioning increases, so GHG and PM emissions from power plants increase substantially during heat waves. Rising temperatures also lead to more droughts and, consequently, wildfires, which again increase air pollution. Also, warmer, drier areas have greater air stagnation and produce more ozone (Figure 5).[15] In short, climate instability leads to worsening air quality.

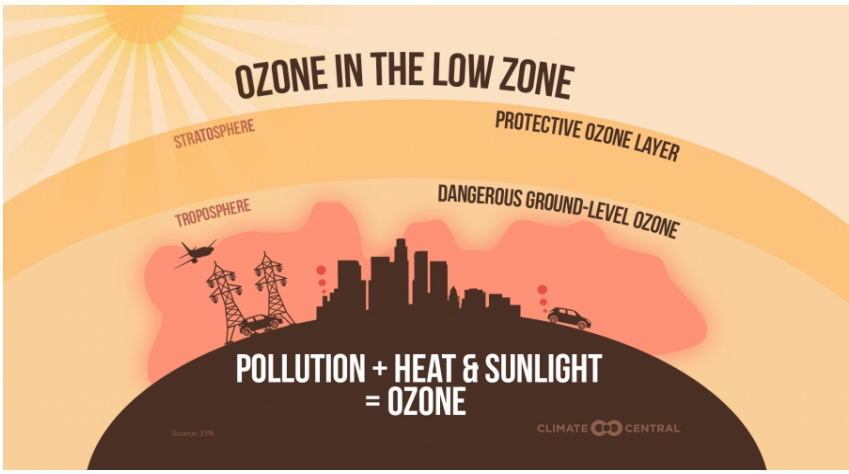
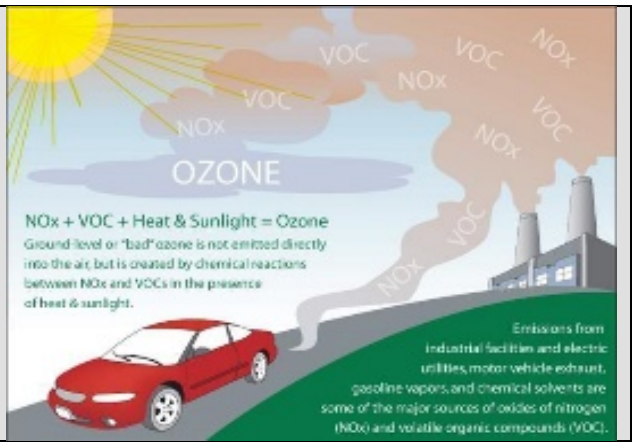


Figure 5: Unlike stratospheric ozone which forms naturally in the upper atmosphere and protects us from the sun's harmful ultraviolet rays, ground-level (or tropospheric) ozone is created through the interactions of man-made (and natural) emissions of volatile organic compounds and nitrogen oxides in the presence of heat.[15]

What's wrong with Ozone?

Pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in sunlight, producing ground-level ozone. Ozone is most likely to reach unhealthy levels on hot sunny days in urban environments but can still reach high levels during colder months. Ozone can also be transported long distances by wind, so even rural areas can experience high ozone levels.[16]



1.3 Warming and Climate Instability Already Observed in New York State

Observations in New York State (NYS) reveal trends of changing temperature, precipitation, as well as frequency and intensity of extreme weather events. The NYS Department of Environmental Conservation has observed:[17]

1. Warming Trends (Figure 6):
   - The annual average temperature statewide has risen about 0.25°F per decade since 1900, and about 2.4°F since 1970 with winter warming exceeding 4.4°F.
   - Annual average temperatures have increased in all regions of the state.
   - Nighttime temperatures have increased and annual number of days below freezing has decreased (figure 6).

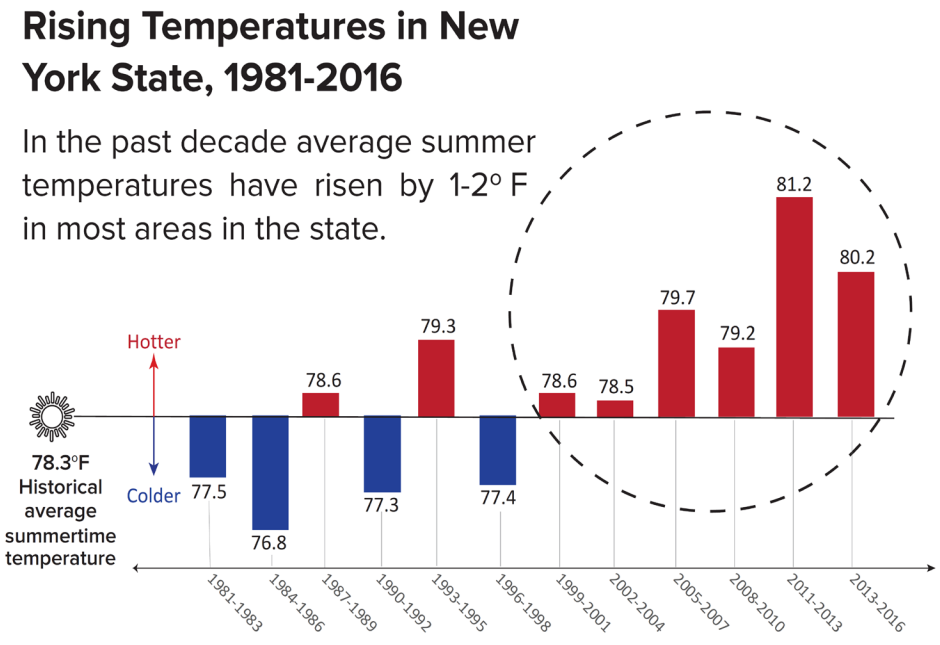


Figure 6: Rising temperatures observed in New York State since 1981.[87]

2. Increased Precipitation (Figures 7 & 8):

- Average annual precipitation has increased across NYS since 1900, with year-to-year variability becoming more pronounced.
- New York is getting more precipitation in the winter and less precipitation in the summer.
- Between 1958 and 2010, the amount of precipitation falling in very heavy downpours increased more than 70% across the northeastern U.S.

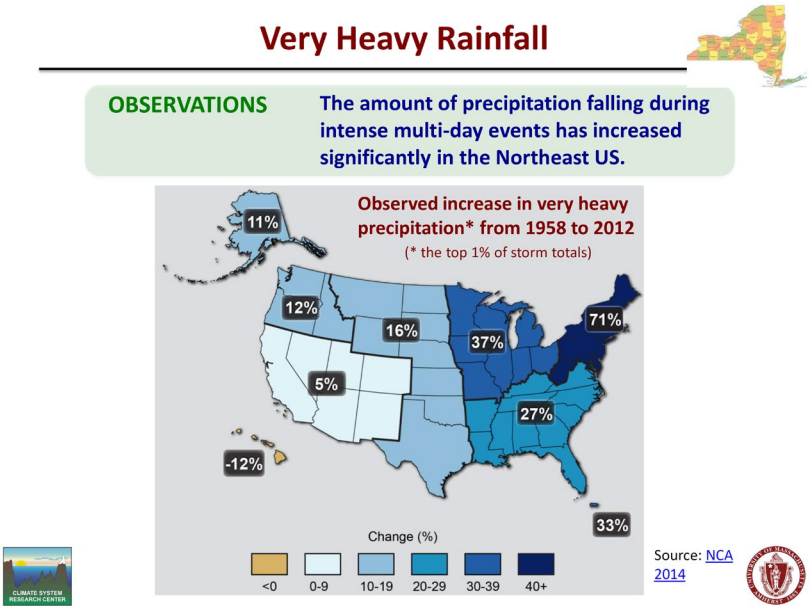


Figure 7: Increase in intense precipitation events in New York since 1958.[1]

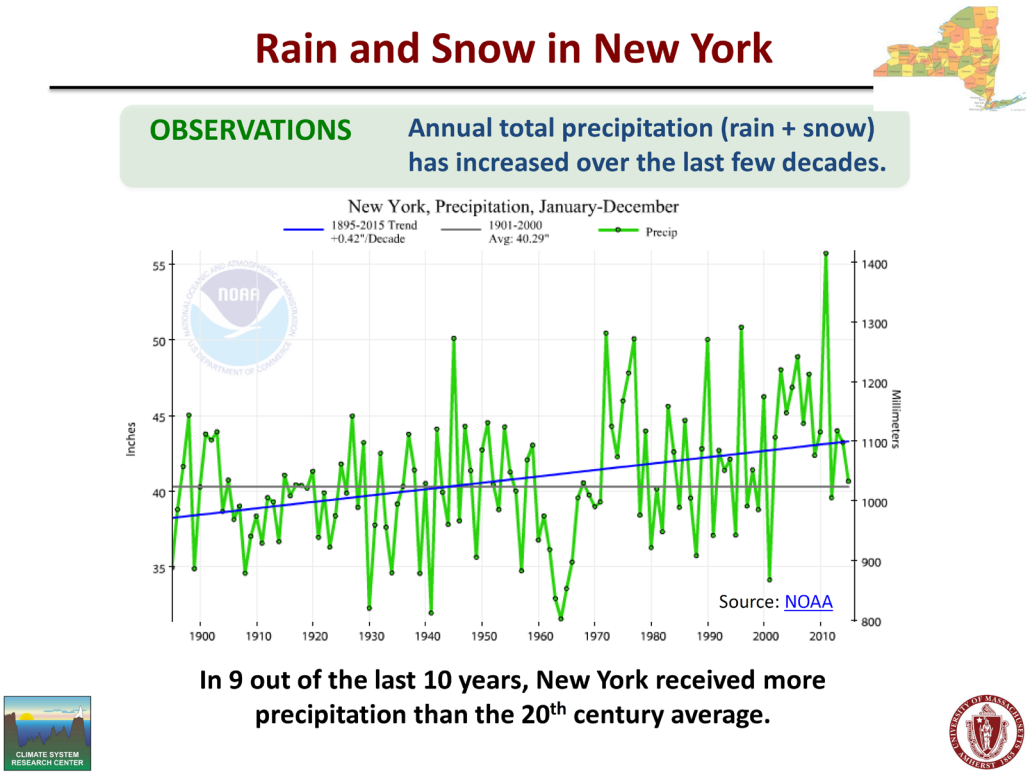


Figure 8: Increase in precipitation in New York since 1900.[98]

3. Sea Level Rise (Figure 9):
   - Sea levels along New York's coast, home to more than half of New Yorkers, have already risen more than a foot since 1900 (1.2 inches/decade).

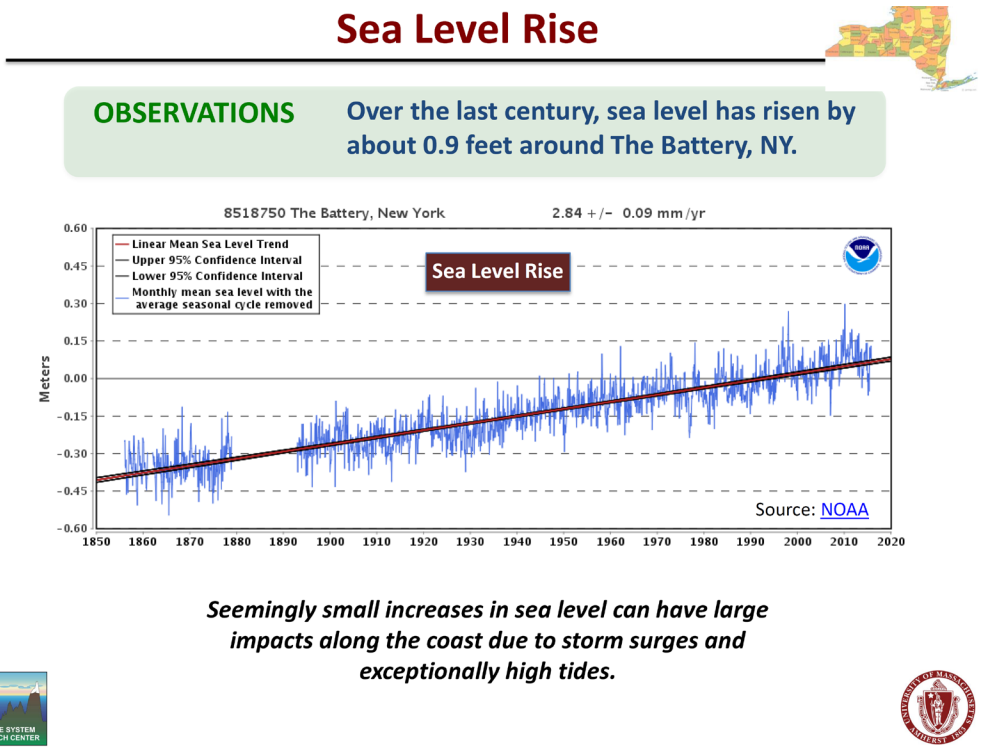


Figure 9: Sea level rise along New York's coast line between 1890 and 2015.[20]

Further, all of these effects–warming temperatures, increased precipitation and sea level rise–threaten crops, dairy farms and fisheries[26]. Between 1851 and 2014, 12 hurricanes struck NYS. The frequency, intensity and duration of these coastal storms are increasing, as exemplified by the pattern of extreme weather in 2011 (Hurricane Irene and Tropical Storm Lee), 2012 (Hurricane Sandy), 2013 (Niagara County and Mohawk Valley flooding) and 2014 (Long Island Flooding).[34]

1.4 Projected Warming and Climate Impacts in New York State

GHGs remain in the atmosphere for decades or even centuries, guaranteeing ongoing change even with reductions in GHG emissions. Some degree of climate change is already "locked in", but its severity will depend on efforts to rapidly reduce GHG emissions (Figure 10).

Primary concerns resulting from these projections include the continuation of observed trends, including increased precipitation, greater extremes of temperature, wider variability and the spread of vectors that carry disease. In addition, infrastructure, agriculture, fisheries and ecosystems will be increasingly compromised.[17,27]

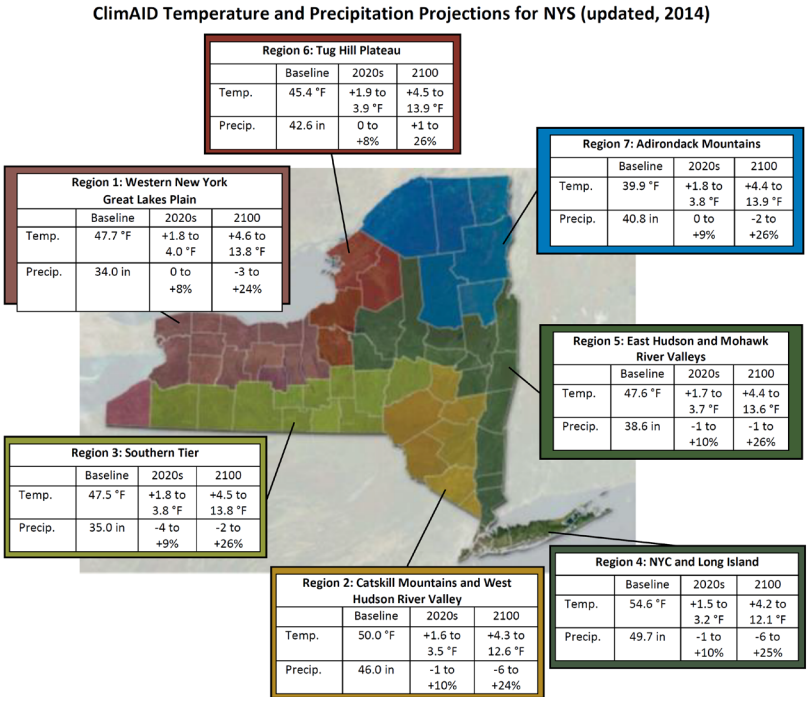


Figure 10: Projected increases in temperature and precipitation for New York State.[28]

1. <u>Rising Temperatures</u>

- Modeling shows that New York should anticipate more warming. Compared to the 1971-2000 period, average temperature will be:
  - up to 3°F warmer by the 2020s.
  - up to 6°F warmer by the 2050s.
  - up to 10°F warmer by the 2080s.

- The most warming is expected to occur in northern NYS.

- The number of days over 85, 90 and 95 degrees will increase, as will the length and frequency of heat waves (Figure 11).[29]

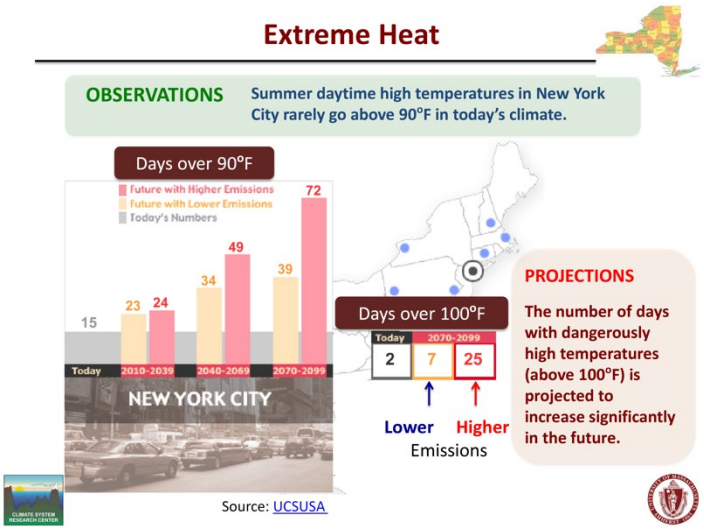


Figure 11: The warming planet means New York will experience a greater number of days with dangerous heat.[30]

2. Longer Frost-free Season and Growing Season

- By 2100, our growing season could be about a month longer, with intense summers and milder winters.[31]

3. Changes in Precipitation Patterns (Figure 12)[29]

- New York is likely to experience more precipitation and more variability in precipitation. Compared to the 1971-2000 period, average precipitation in New York will increase:
  - up to 8% by the 2020s.
  - up to 12% by the 2050s.
  - up to 15% by the 2080s.
- By 2100, the biggest precipitation increases are projected for northern NYS and in the winter months.

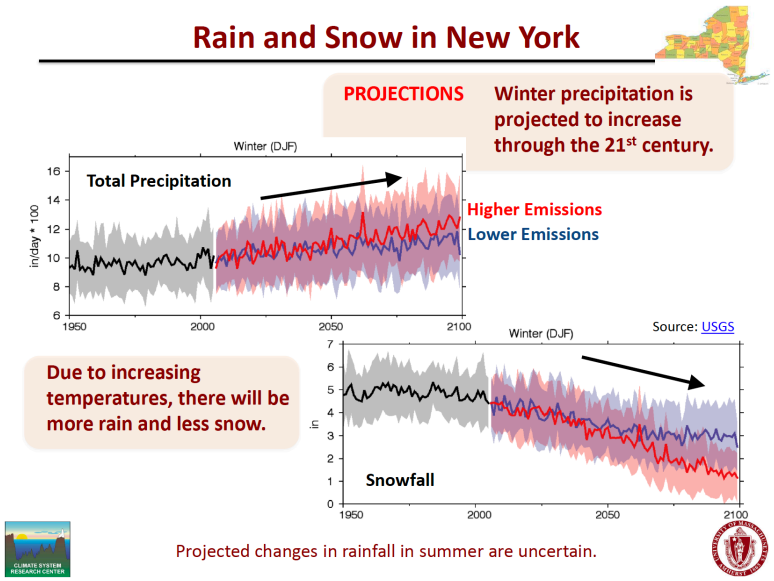


Figure 12: Projected increases in precipitation for New York State.[29]

4. Rising Seas (Figure 13)

- Sea-level rise is locked in for centuries, or even millennia, by GHGs already in the atmosphere. Continuing or increasing emissions will speed up the rise to higher levels.[17] Projections for sea level rise along New York's coastlines are:
  - up to 30 inches (2.5 feet) higher by 2050s.
  - up to 50 inches (~4 feet) higher by 2100 Threats of rising seas include:
- Increased frequency/ intensity of severe flooding and storm surge damage;
- Increased erosion of beaches and bluffs;
- Inundation of low-lying areas;
- Saltwater infiltration of surface waters and aquifers;

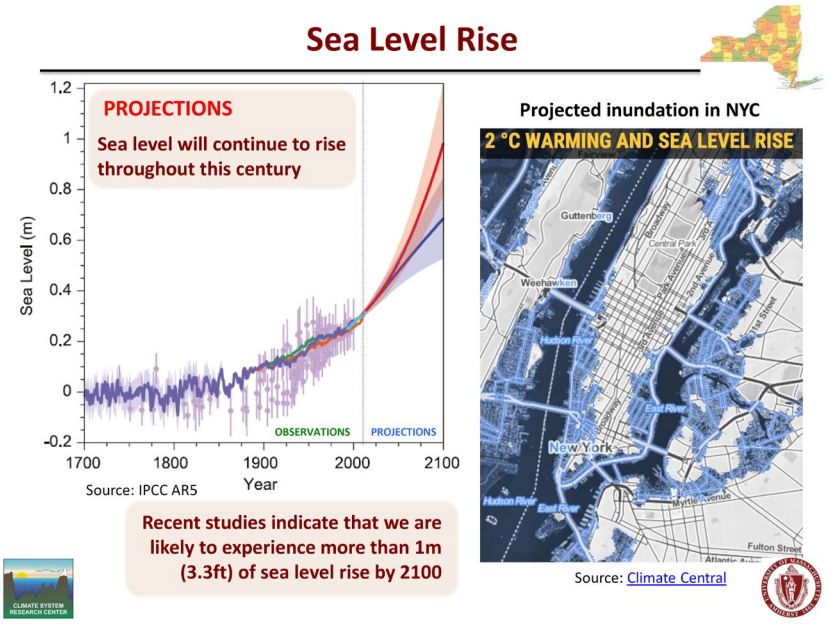


Figure 13: Projected sea level rise for New York City.[29]

- Possible compromise of low-lying sewage, wastewater, transportation, communication, and energy infrastructure and systems.[17]

5. Stronger and More Intense Hurricanes and Resulting Storm Surge
   - Warming temperatures and rising seas will increase the likelihood of damaging floods in New York through tropical cyclones. The previously rare event of 7.5-foot floods is now projected to happen every 25 years. By 2030, these floods will occur every five years.[32]

6. Changes to Ecosystems, Infrastructures, Agriculture and Fisheries[33]
   - Declining fish populations will likely continue. The greatest danger to freshwater trout in rivers throughout New York is the formation of oxygen-poor conditions through increased temperature and drought conditions.
   - Water levels in lakes and rivers are anticipated to decline due to increased evaporation, lower recharge rates, and increased demand for freshwater in cities.
   - Warmer weather may negatively affect production of dairy farms.
   - Risks of forest fires are likely to increase, while sugar maple and paper birch trees are expected to decline.
   - Due to the longer frost-free season, plant hardiness zones assessed by the U.S. Department of Agriculture are anticipated to continue to change (Figure 14).

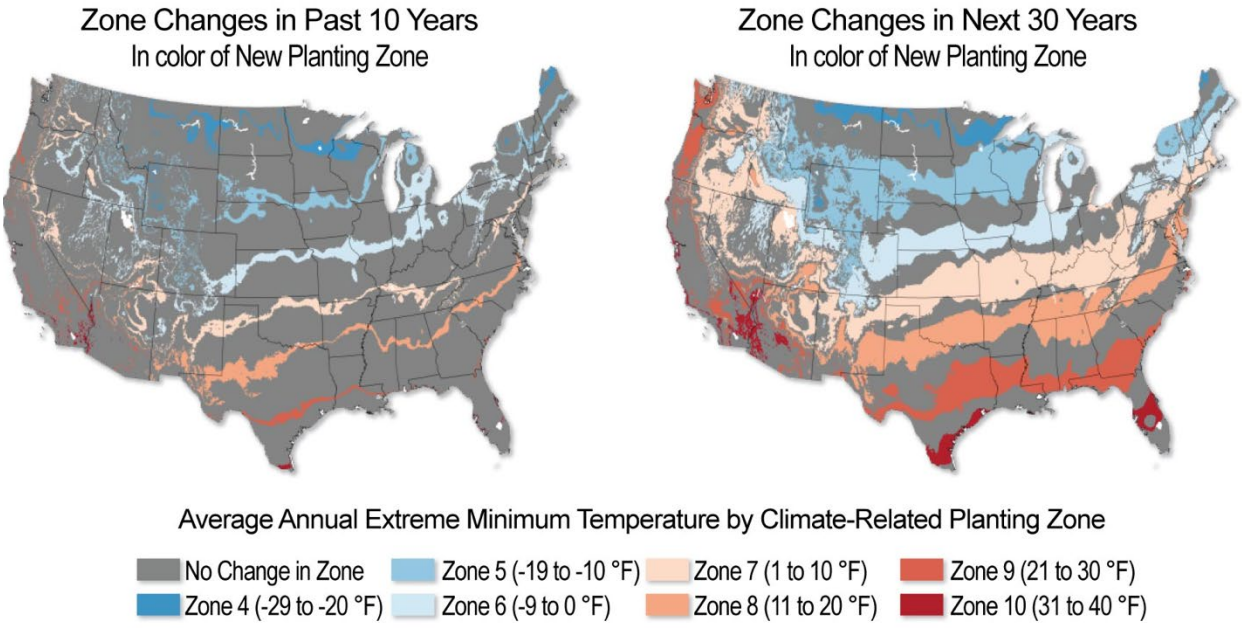


Figure 14: Changes in USDA plant hardiness zones, observed (left), and projected (right).[1]

One major challenge NY faces is the effect on our agricultural system because of the complex role agriculture plays in rural, national, social and economic systems.[21]

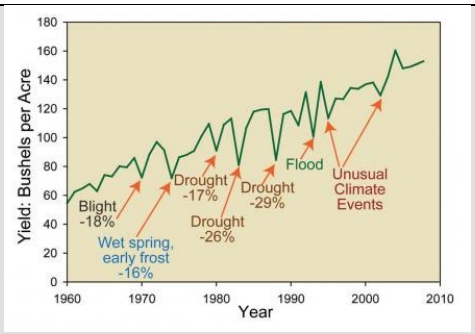
Climate-related vulnerabilities, particularly with respect to those facing New York State's own agricultural and fisheries communities, include[22]:

- Temperature Change
  - Apple trees may not receive enough winter chilling hours required to bear fruit.
  - Maple sap flow may shift to earlier in the year, even back to December.
  - Greater pest pressure from insects, diseases and weeds may harm crops and cause farms to increase pesticide and herbicide use.
  - New crops could become viable, but crop transitions are costly.

- Precipitation Changes
  - Wetter springs may delay planting for crops and reduce yields.
  - Drier summers and intermittent droughts may strain irrigation water supplies, stress crops, and delay harvest.
  - Increased river flooding is likely to cause soil erosion, soil loss, and crop damage.

Weather Impacts on Crops

Despite technological improvements that increase corn yields, extreme weather events have caused significant yield reductions in some years.[1,23]



- Extreme Weather
  - Extreme storms may cause catastrophic damage to crops and fields, farm buildings, equipment and drainage systems.
  - Floodwaters are likely to spread invasive plants.
  - Heavy rainfall is likely to wash away fertile soil and damage water supply.

- Sea Level Rise
  - Increasing tidal range and tidal inundation is likely to cause more saltwater intrusion into aquifers in agricultural areas.
  - Rising sea levels and extreme storms may accelerate erosion of coastal agricultural land.

- Elevated Carbon Dioxide Levels
  - Increasing CO_2 levels stimulate plant growth but decrease the nutritional value of major crops.[24]
  - Increasing CO_2 reduces the protein and nitrogen content in alfalfa and soybeans.
  - Reduced nutritional grain quality can impact the health of grazing livestock.

- Pollinator Reduction
  - Loss of natural pollinator habitat could worsen the health of the managed and wild pollinator colonies, which have already declined by 50% in New York State.
  - Loss of pollinators would impact availability of the state's leading crops including apples, cabbage, berries, pumpkins and several other fruits.[1,25]

- Livestock
  - Dairy cows have low thresholds for temperature stress, moderately warm temperatures (e.g., greater than 80ºF) when combined with moderate humidity (e.g., greater than 50% relative humidity) can lower feed intake, lower milk production, decrease calving, and increase the risk for other bovine disorders.
  - Climate instability is likely to increase the prevalence of parasites and diseases that affect livestock, necessitating increased use of pesticides and parasiticides, which could increase vector resistance.[2]
  - The quality of some of the forage found in pasturelands decreases with higher CO_2, requiring cattle to eat more to get the same nutritional benefits.

Economic Impact of Heat Stress on Dairy Production

An additional factor regarding heat stress on cows is that if stressful conditions occur for even a few days during critical periods, the impacts may persist for many months. Early-lactation cows are most susceptible to the effects of heat stress, and the impact could persist for the complete lactation. If peak milk production is decreased by only 2 pounds per day, as might be seen under mild heat stress, 400 to 500 pounds of milk could be lost for the lactation period. This would amount to a $48 to $60 loss per cow at the current milk price of $12 per 100 pounds of milk. However, if more severely stressed, early-lactation cows may experience decreases of 5 to 15 pounds of peak milk production per day. The New York dairy industry will be more affected by heat stress in the future than in the past, not only because of the warming trend, but also because today's high milk-producing cows are more sensitive to heat stress in terms of milk productivity.[2]

- Fisheries
  - Warmer waters are more hospitable to invasive species and shift the ranges or lifecycle timing of many fish species. These shifts disrupt ecosystems and put species into competition for food and resources.[23]
  - Higher temperature and increased estuarine salinities may increase risks of disease outbreaks.
  - Climate instability will increase the stresses of overfishing and water pollution.[23]

Ocean Acidification Reduces Harvests

In addition to warming, the world's oceans are gradually becoming more acidic due to increases in atmospheric carbon dioxide. CO_2 is absorbed by oceans, resulting in ocean acidification. Acidification reduces the size and abundance of shellfish, which in turn leads to decreased harvest and eventually to changes in prices for consumers. Acidification also threatens the structures of sensitive ecosystems upon which some fish and shellfish rely.[26]

1.5 Implications of Warming and Climate Impacts in New York State

The latest report from the IPCC details the reasoning for action aimed at preventing global temperatures from rising above 1.5°C at any time.[6,9] The highlights of that

reasoning are aimed at limiting significant impacts—exposure of humans to extreme heat, species extinction, sea level rise, crop losses and more—which are non-linearly magnified by warming to 2.0°C. Nonetheless, most models project that even with rapid and large-scale action, Earth's climate will exceed warming of 1.5°C for some period of time before returning to lower temperatures. The direct and indirect impacts on human health and well-being are not to be underestimated and will be addressed in the next sections.

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Section 2: Health Effects Related to Global Warming and Climate Instability

Climate instability combines with other natural and human-made health stressors to affect human health. These effects are mediated by disruptions of physical, biological, and ecological systems both local and distant. Resultant health effects include increased allergies and asthma, respiratory and cardiovascular disease, injuries and premature deaths related to extreme weather events, changes in the prevalence and geographical distribution of food- and water-borne illnesses and other infectious diseases, and threats to mental health.[1]

As the climate continues to change, some existing health threats will intensify, and new health threats will emerge. The public health consequences for New York State are likely to be dramatic, particularly for people who are more vulnerable because of age, pre-existing illness or economic disadvantage.[2] In addition, the demand for health services and the need for public health surveillance and monitoring will increase as climate instability worsens. Specific climate-related health challenges that New York State is currently facing and will likely face in the future are detailed here, with a focus on populations most vulnerable to poor climate-related health outcomes. Finally, any health co-benefits achieved by addressing the sources of global warming and climate instability are highlighted at the end of each section.

Air Conditioning

In New York City, despite rising temperatures over the past 100 years, heat-related deaths have declined. Excess mortality with high temperatures observed between 1900 and 1948 was substantially reduced between 1973 and 2006.[3] This change is due to greater penetrance of air conditioning, and factors such as the implementation of a heat warning system, increased awareness and better housing stock. Most deaths and serious illnesses from extreme heat occur from exposure in homes without air conditioning. About 11% of New Yorkers do not have a functioning air conditioner, and another 14% do not use their air conditioner regularly.[4]

2.1 Temperature-related Health Effects

Section at a Glance:

- *Certain populations are most vulnerable to temperature-related health problems, including children, the elderly, individuals with risk factors for cardiovascular disease and those living in poverty.*
- *Heat-related deaths are expected to increase dramatically in New York and the northeastern U.S. in the coming decades, especially among vulnerable populations.*

Exposure to extreme heat or cold is linked to higher morbidity and mortality rates[5]. In New York State, more people, on average, die in winter than in summer, which is believed to be heavily influenced by influenza and other viral infections, which are more prevalent during the winter season.[2] Extreme heat events cause more deaths than hurricanes, floods and tornadoes combined. Yet, temperature increases do not need to be extreme to cause poor health outcomes. A change of just 5 degrees Fahrenheit can lead to an increase in heat-related illnesses.[6]

Mortality related to modest temperature change is strongly linked to the climate of a particular location. Residents of colder cities such as Buffalo experience higher mortality with modest temperature rise compared to warm cities such as Baton Rouge, where lower temperatures, as opposed to higher temperatures, are linked to mortality increases. Large sudden swings in temperature such as 50-degree changes within a 24-hour period, which may become more common in a changing climate, are linked to increases in heart attacks.[7,8]

Some individuals are at higher risk for heat-related health effects; these include the elderly, children, the chronically ill and the economically disadvantaged. Urban residents who are elderly, with limited mobility and social contact, or belong to nonwhite racial/ethnic groups or lack access to public facilities and public transportation or air conditioning are particularly vulnerable. Children, urban residents and communities in the northern parts of the state that are not adapted to heat may also be vulnerable subgroups for temperature-related mortality and morbidity.[10]

In 2013, New York State (NYS) ranked second in the U.S. in number of deaths occurring as a result of extreme heat, with ten heat-stroke deaths directly attributed to heat.[10] The NYS Department of Health developed Heat Vulnerability Index Maps (Figure 15) to identify areas where people are likely to be injured during periods of hot weather. Heat vulnerability is linked to health status, socio-demographics, environment and community demographics, all of which play an important role in the ability to adapt to heat. More than one-third of the NYS population resides in areas identified as moderately to highly vulnerable to heat. Overall, metropolitan areas and inner cities of NYS are most heat vulnerable.

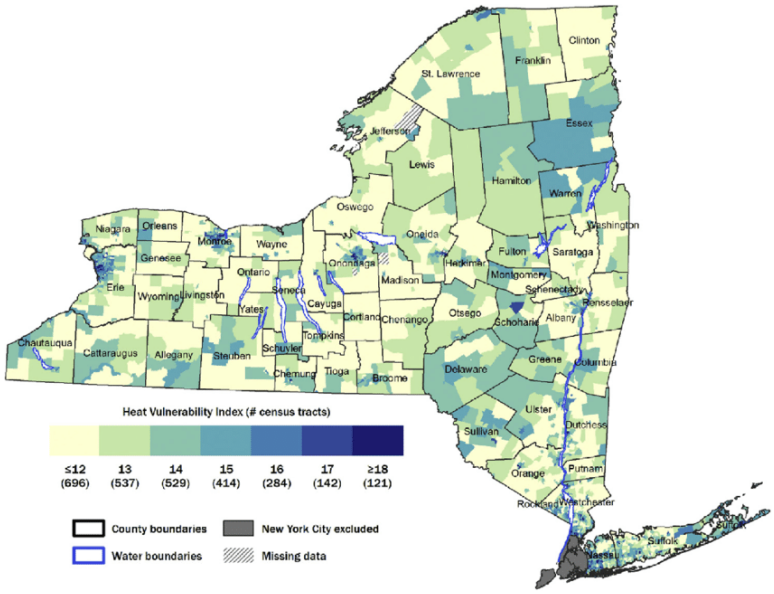

Figure 15: Heat vulnerability index map for New York.[12]

<u>New York City</u>

Urban areas generally are at higher risk than rural areas because of urban "heat islands". Heat islands are built/urban areas where heat is retained compared to nearby less developed areas. In heat islands, temperatures are generally several degrees higher compared to surrounding regions during the night—particularly during extreme heat events—leading to increased heat-related deaths among those less able to recover from the heat of the day (Figure 16).[13]

Even within cities, the "micro-urban heat island effect" results in temperature variation between areas in close proximity. This variation correlates to neighborhood factors including rates of poverty, air conditioning access, educational attainment, housing quality, rates of home ownership, land cover and land surface temperatures. Additionally, living in neighborhoods with less vegetation, or more concrete, metal or asphalt, all of which trap heat, also increases risks of morbidity and mortality for residents.[14]

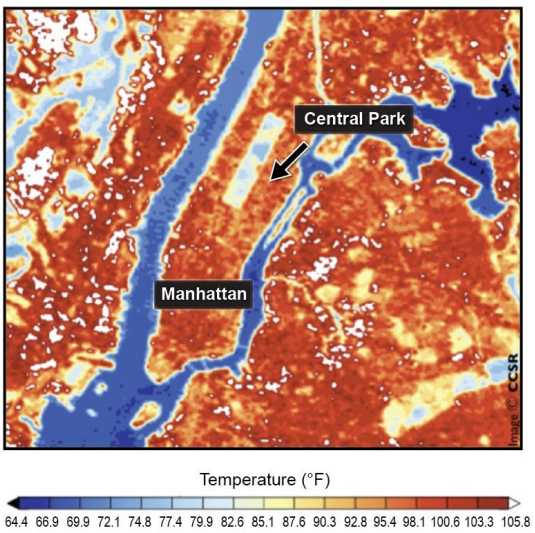

Figure 16: Urban heat island in New York City area.[13]

1. <u>Heat-related Illness and Mortality</u>

Excessive heat can provoke illnesses such as heat edema, heat stroke, heat cramps, heat stress, and dehydration. Heat can also exacerbate existing health conditions such as renal, lung, and cardiovascular disease, especially among children and the elderly.[3] Heat-related morbidity (disease events such as emergency room visits or hospital admissions) and mortality (deaths) are the most well understood, measurable and *preventable* impacts of climate change on human health.[15] In addition to directly causing death, heat can produce an excess of natural-cause deaths. This occurs when chronic conditions are exacerbated by heat and result in death, but heat is not recognized as a contributing cause on the death certificate. NYS county-level data show increases in ER visits and hospitalizations for heat-related health outcomes such as heat illnesses, cardiovascular diseases and renal disease when temperatures rise between May and September (Figure 17).[6] The risk of hospitalization with increased temperature can vary both by state region and by health outcome, suggesting that other factors may contribute to an individual's sensitivity and health risk to extreme heat.[12] For example, obesity is a key risk factor for heat-related mortality; of heat-related deaths in NYC between 2000 and 2011, 48% were among obese individuals and 29% were overweight.[16] The high prevalence of obesity today thus has important implications as global temperatures rise.

Extreme heat events rapidly cause an increase in fatalities, as seen in numerous heat waves domestically and abroad (Chicago 1995, European 2003) and the 2013 New York City heat wave (see Case Study). Deaths resulting from heat waves occur quickly—within 1-4 days of spiking temperatures.

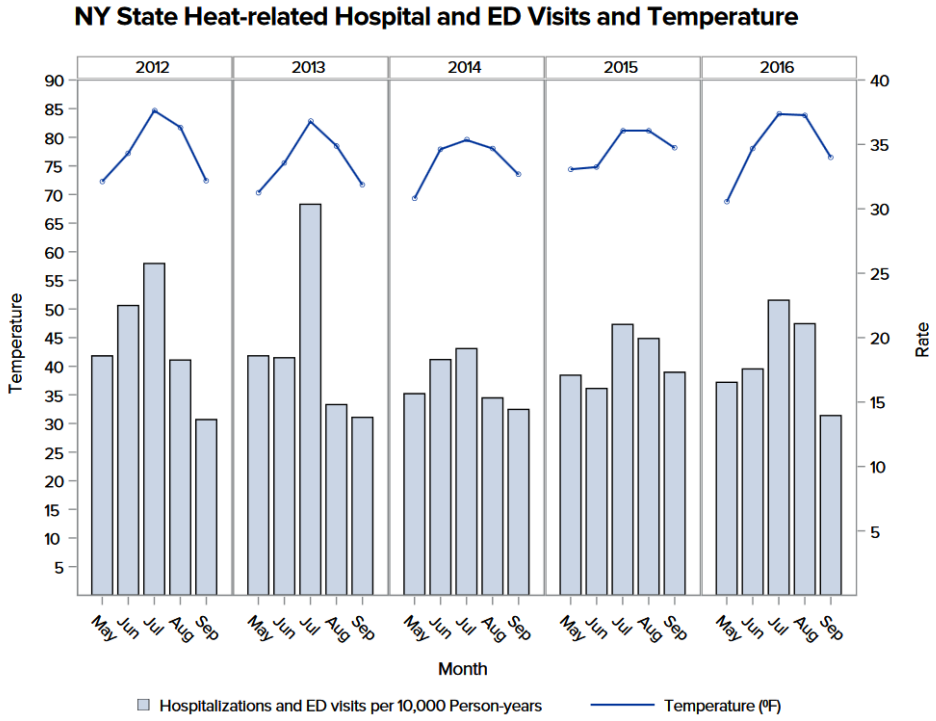

Figure 17: Hospital visits related to heat in New York State.[6]

Health Effects of Blackouts: Morbidity and mortality effects of heat may be especially severe if a blackout occurs during an extreme heat event. Blackouts are more likely during heat waves due to the increased demand for electric power for air conditioning, stressing the systems that supply and

deliver electricity. Blackouts can also increase risk of carbon monoxide poisoning from improper use of generators and cooking equipment.

During August 2003, the largest blackout in U.S. history occurred in the Northeast. Although this blackout did not coincide with a heat wave, it occurred during warm weather and resulted in approximately 90 excess deaths and an increase in respiratory hospitalizations.[17] The most striking increases were among elderly, female and chronic bronchitis admissions. Symptoms appeared to be more severe during the blackout than on comparably hot days.[17]

CASE STUDY: New York City Heat Wave, 2013

An extreme heat event in New York City during July 2013 saw heat indices reaching at least 95°F for seven consecutive days and peaking at 109°F. Nineteen of the 26 (73%) heat-related deaths identified by the New York State Department of Health were associated with the extreme heat event.[5] Of the 24 deaths among adults, nearly all had a pre-existing health condition or risk factors, such as cardiovascular disease, diabetes, substance abuse or cognitive impairment.

2. Heat and Cardiovascular Disease

Cardiovascular disease can impair a body's ability to regulate temperature in response to heat stress, and thus increase vulnerability to heat illnesses.[10] Up to 70% of heat-related deaths occur in individuals who have high risk for or who have established cardiovascular disease. The elderly, obese or chronically ill are more likely to have impaired renal function, heart failure, reduced capacity to lose heat via sweating, or to be on medication that affects salt/water balance, all of which can blunt an effective response to heat stress and increase risk of illness and mortality.[18,19]

3. Heat and Respiratory Disease

Increases in hospital admissions for respiratory illness are associated with temperature variations during the summer. On days with larger differences between the highest and lowest temperatures, there is an increased risk of hospitalization for respiratory diseases 2-4 days later. Temperature variation over multiple days is associated with a proportionally higher increase in respiratory admissions when compared to single-day variations. Thus, while extreme heat can impact health, temperature variations can also influence the risk of hospitalization.[20]

4. Heat and Renal Disease

Exposure to extreme or prolonged heat can worsen kidney disorders. For every 5°F increase in daily average temperature, there is a 9% increased risk of hospitalization for acute renal failure on the following day. Risk of hospitalization for acute renal failure is higher among Blacks and Hispanics, people aged 25-44 years, those in the lowest income range, and those living in urban regions.[21]

5. Heat and Birth Defects

When pregnant women experience high fevers over long time periods, birth defects may result. A study using the New York State Congenital Malformations Registry found that a single-day 5°F increase in outdoor temperature during the critical

period of fetal organ development can increase the risk of being born with cataracts, a clouding of the lens of the eye. This risk nearly doubles if pregnant women experience a heat wave with prolonged exposure to high temperatures during that critical period.[22] Exposure to elevated temperatures may also increase the risk of pre-term birth.[23] While rates of pre-terms births have decreased overall in NYS, in 2016 rates increased in Brooklyn, Manhattan, Nassau and Suffolk .[24] In addition, increased exposure of women to multi-day extreme heat, particularly during spring, is associated with a higher risk heart defects; the risk of such exposures is expected to increase with advancing climate instability.[25,26]

6. Heat, School-age Athletics, and Outdoor Workers

Exertional heat stroke (EHS) is the leading cause of preventable death in high school athletics. EHS can occur in otherwise healthy individuals and is different from classic heat stroke, which usually affects those who are very young or elderly or have pre-existing medical conditions. High-school and college athletes whose uniforms require heavy gear are especially vulnerable.[27,28]

Approximately 680,000 non-governmental employees in NYS spend all or a significant portion of their working hours in outdoor settings. Building and maintenance workers, construction and extraction workers, farming, forestry and fishing workers, and installation and repair workers are at increased risk for heat-related illness and mortality while on the job. Law enforcement officers, firefighters, EMS workers and members of the military may also be exposed to high-heat conditions that can affect job function and increase health risks.[29]

7. Heat, Humidity and Ozone Multiply Health Effects

The effects of extreme heat are worsened by high levels of humidity, which impairs the body's ability to cool itself. Another effect of extreme heat during summer months is poor air quality, which can occur when stagnant atmospheric conditions trap humid air and pollutants, such as ozone, near the ground (see Section 1.2).

Projections for Heat-related Health Effects in New York State

Climate instability will provoke increased temperatures in New York State that could have significant health consequences (see Section 1.4 for projected warming trends). Heat-related mortality could increase, particularly for persons with heat-sensitive conditions.[1] As noted above, obesity and diabetes increase risk of heat illness, and 25.7% of New York's adults are obese, while 10.5% New Yorkers have diabetes and are increasing in prevalence. Additionally, one out of five (20.9%) New Yorkers aged 65 and older report having cardiovascular disease.[31] Thus, a substantial portion of New York's population is at risk for heat-related illness.

A nationwide study projected that some of the largest increases in heat-related mortality would occur in the Northeast region, with an additional 50–100 heat-related deaths per year per million people by 2050 and 120–180 additional deaths per million people by 2100 under the mid-high emissions scenario.

Heat health risks are highest at the start of the warm weather each year, before people acclimate to the warmer conditions.[13] Humans acclimate to higher temperatures over time, which may mitigate heat-related illnesses as our climate gets warmer. Recent studies examining heat acclimatization found that, while there is considerable uncertainty, by mid-century a person's ability to acclimatize may not completely compensate for warmer weather in the New York metropolitan region. It also appears unlikely that climate warming will significantly reduce winter mortality, and future increases in mortality will probably be in the spring and fall seasons.[2]

In addition, as temperature and the frequency of stagnant air events increase, conditions are likely to favor high ozone days. Daily maximum 8-hour ozone concentrations and the number of days with 8-hour ozone concentrations above 60–70 parts per billion (ppb) are useful measures of ozone-related risks for respiratory irritation and damage. These risks are particularly relevant for people working or exercising outdoors, including children and those with respiratory disease. Studies estimating hospitalizations in NYS project respiratory admissions due to excessive heat will be 2 to 6 times higher in 2080–2099 than in 1991–2004. When combined with other heat-associated conditions, the health burden due to global warming could be substantial.[2]

Finally, because of higher summertime temperatures (with a corresponding increase in electricity usage) and an already-stressed electricity grid, climate instability may bring more frequent blackouts. Other indirect health impacts of heat may be associated with increased violence and crime; this will be detailed in Section 2.5.

Projections for New York City

Societal trends toward urbanization means that more people will migrate to cities, where they are more likely to be exposed to extreme heat. Projections for increased length and frequency of heat waves (see Section 1.4) have prompted estimations that by 2080 as many as 3,331 people/year could die from the heat during New York City summers. That compares to 638 heat-related deaths on average between 2000 and 2006.[32]

Summary

The observed warming across New York State has already resulted in increases in heat-related illness and death. Continued warming over the next decades will worsen these adverse outcomes. Vulnerable populations such as children, the elderly and those living in poverty will be most affected, and New York City could face particularly harsh consequences.

Health Co-benefits

Increasing green spaces, particularly in urban areas, reduces heat-related illness and chronic disease.

Climate Action: Plant low-pollen trees and other vegetation.

- Provides shade and reduces humidity, which reduces urban-heat islands.[9]
- Shaded areas may reduce peak reduce peak temperatures by 20–45°F compared to unshaded materials.
- Trees reduce building energy use and GHG emissions.
- Trees remove air pollutants and store carbon dioxide.
- Trees reduce noise.

Immediate Heath Co-Benefit: Urban green space results in a number of direct health benefits.

- Reduces heat-related health risks.
- Increases physical activity which reduces the risk of many chronic diseases such as obesity, diabetes and heart disease.
- Provides psychological benefits and improved self-perceived health status through reduced noise and enhanced safety.
- Reduces risk of cardiovascular disease and mortality through reduced pollution.[11]

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2.2 Allergies, Asthma and Respiratory Disease

Section at a Glance:

- *A longer growing season and air pollution means more New Yorkers are already experiencing allergies, asthma and respiratory diseases.*
- *Continued warming will lengthen allergy season and increase allergen counts, and poor air quality will make asthma and other respiratory disease more severe.*

Allergic conditions and respiratory diseases related to climate instability are on the rise and are projected to increase further as the climate continues to warm. These diseases include chronic rhinitis, asthma, skin allergies, and other respiratory illnesses driven by increases in allergens such as pollen and mold and by increases in ozone and other air pollutants.

Conditions Related to Allergens

The extending length of the growing season in New York State (Figure 18) is driving a longer allergy season with higher allergen concentrations. Pollen levels in NYS are frequently at “high” levels, as determined by national standards. For 2003 to 2010, 49% to 84% of days in late March to mid-June had tree pollen counts at or above the threshold for a “high” pollen count. Similar trends were observed for grass and weed pollen.[1,2] These factors can severely impact health and be a major driver for increased healthcare costs.[3,4] In addition, increased temperatures, coastal flooding and heavy precipitation events can present ideal conditions for the growth of mold and other fungi indoors, and increases in plant growth associated with higher carbon dioxide levels can also accelerate fungal activity.[5]

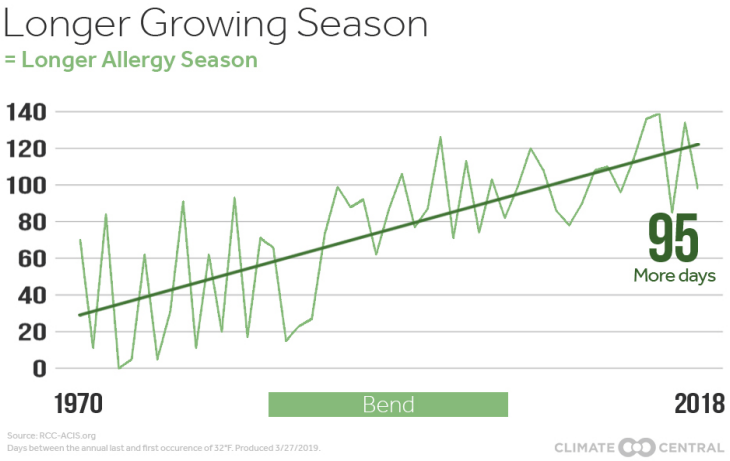

Figure 18: Warmer weather means more days with severe allergies

This increase in allergens is translating to increases in allergic rhinitis, allergic conjunctivitis, and allergic dermatitis. Allergic rhinitis is the most common manifestation of atopic disease and leads to significant morbidity as well as complications including sinusitis and allergic conjunctivitis. Over the past 30 years, allergic rhinitis prevalence in the U.S. population increased from 10% in 1970 to 30% in 2000, and warmer

temperatures are associated with allergic rhinitis.[6] Moreover, allergic conjunctivitis and sinusitis are more common in individuals with chronic rhinitis.

Allergens responsible for dermatitis include those produced by plants such as poison ivy. Poison ivy plants respond to increased CO_2 by growing more rapidly and producing more urushiol, the substance that causes itching. Poison ivy already ranks among the top ten "medically problematic" plants in the U.S., with more than 350,000 cases of contact dermatitis reported each year.[5]

Climate Instability and Allergens: Key Effectors of Respiratory Health

Allergen levels are aggravated by three key features of climate instability[2]:

- CO_2 in the atmosphere increases the growth rate of plants as well as the amount and potency of pollen.
- Warming temperatures extend the growing season and duration of allergy season.
- An extended spring season alters the amounts of blooms and fungal spores.

Conditions Related to Air Pollution and Ozone

Chronic respiratory conditions are particularly sensitive to $PM_{2.5}$ air pollution and ozone. (see 1.2) Asthma and chronic obstructive pulmonary disease (COPD) are particularly susceptible to these environmental factors. Asthma is also exacerbated by the interaction of air pollutants with allergens. For example, when ground-level ozone pollution levels are high, it takes much less ragweed pollen to trigger an asthmatic or allergic response. In effect, the ozone primes the bronchial airways to be more sensitive to the allergen.[7] The risk of asthma attacks is likely to go up as global warming and climate instability increase these risk factors.

The hottest days in the Northeast are often associated with high concentrations of ground-level ozone and other pollutants. The combination of heat stress and poor air quality can pose a major health risk to vulnerable groups: young children, the elderly and those with pre-existing health conditions including asthma.[8] Exposure to ground-level ozone causes adverse effects including:

- Increased pulmonary inflammation
- Increased emergency department visits and hospitalizations for asthma
- New onset of asthma
- Death due to respiratory disorders
- Reduced survivorship among older people with COPD

- Increased bronchial responsiveness among people with atopic asthma to pollen and other aeroallergens.[9]

Asthma in New York[1]

- One in every 10 adults and one in every 10 children in New York State currently have asthma.
- Compared to the nation, New York has higher asthma prevalence, emergency department and hospital discharge rates for all age groups. New York State's rates are roughly twice the levels targeted in Healthy People 2020.
- When compared to residents in upstate New York and Long Island, adults who live in New York City had higher current asthma prevalence in 2011, and higher age-adjusted asthma emergency department visits, hospital discharges, and mortality rates for 2009-2011.
- At the county level, asthma emergency department visits and hospital discharge rates varied across New York State for 2009-2011, with the highest rates in the Bronx. Disparities persist among racial and ethnic groups, with non-Hispanic black adults and children experiencing some of the highest asthma prevalence rates in New York State.

Asthma is a major public health problem in NYS (Figure 19). In 2011, an estimated 9.7% of adults and 10.4% of children ages 0-17 years had current asthma. There were more than 160,000 emergency department visits and over 38,000 hospitalizations per year due to asthma during 2009-2011.[1] The rate of asthma deaths was higher in New York City, at 20.9 per million residents, as compared to 13.1 deaths per million statewide.[9]

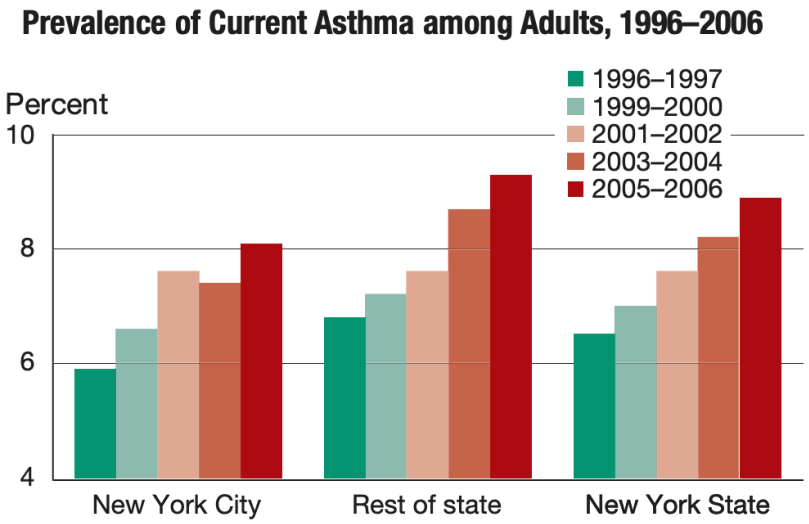

Figure 19: Increasing rates of asthma in New Yorkers[9]

An estimated 900,000 adults (5.8%) in NYS have been diagnosed with COPD, emphysema, or chronic bronchitis. The proportion of adults reporting having COPD increases with age and is significantly higher for adults aged 65 or older (13.1%). Rates

of COPD among adults are highest among those living in Central NY (8.6%) and Western NY (8.2%) and lowest among those living in New York City (5.0%) and Long Island (5.0%) (Figure 20.[10]

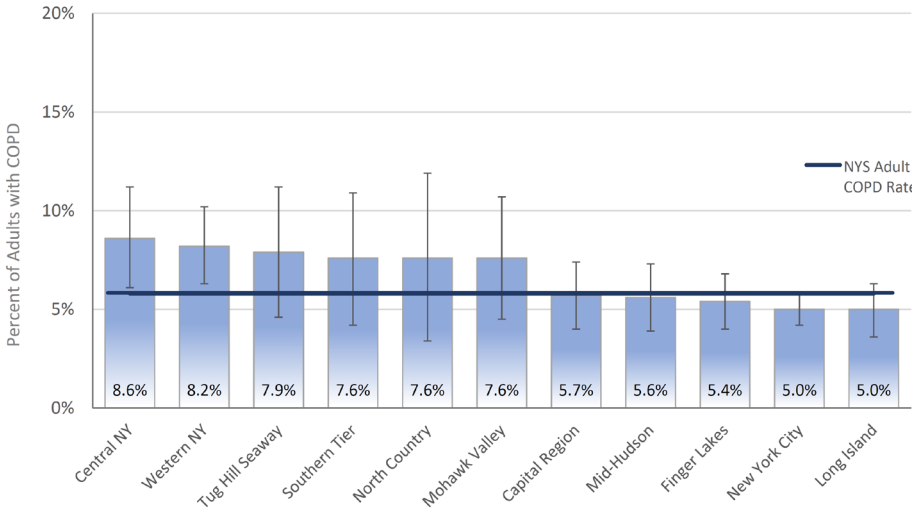

Figure 20: Prevalence of COPD in New York by region.[10]

<u>Chronic Respiratory Conditions in New York City</u>

The prevalence as well as morbidity and mortality of asthma are higher in New York City compared to the rest of the state. More than 2,400 emergency department visits annually for asthma among New York City children are attributable to levels of $PM_{2.5}$. These rates vary greatly, from approximately 15 per 100,000 people younger than 18 years of age, to more than 175 visits per 100,000 in areas with the higher poverty rates (Northern Manhattan, large areas of the Bronx, Central Brooklyn, parts of Eastern Queens and the Rockaways), reflecting the variation in overall asthma emergency department visit rates in children (Figure 21, left).[11]

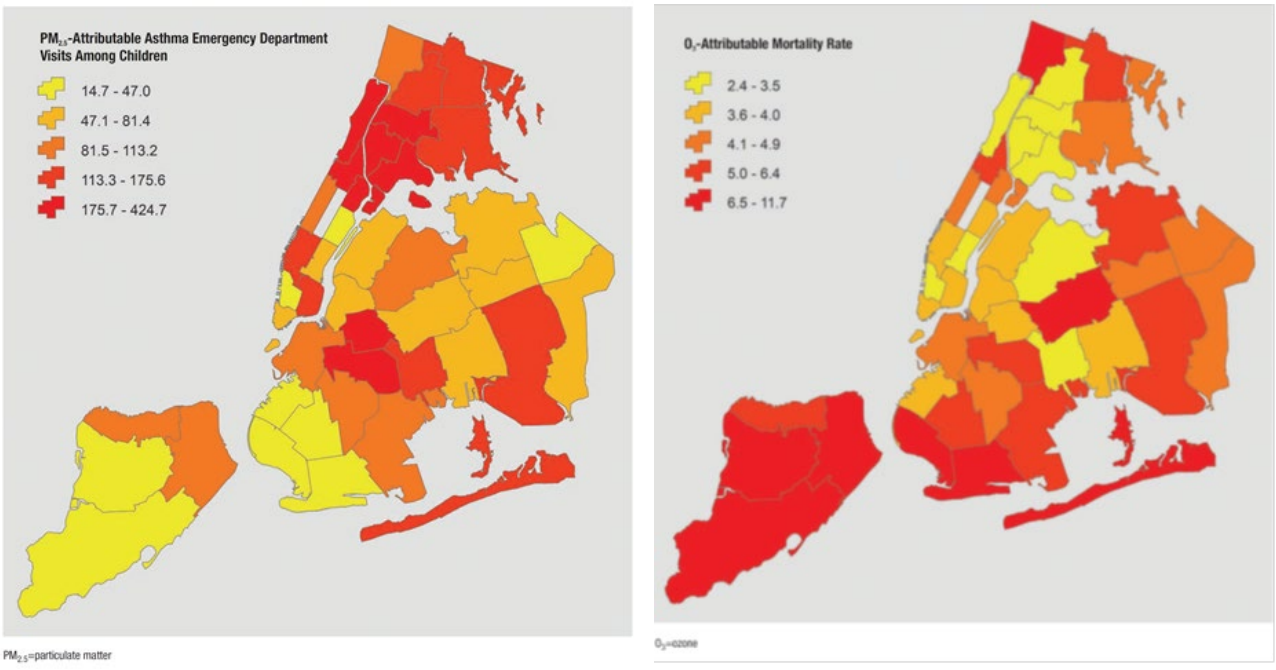

Figure 21: Emergency department visits among children attributed to $PM_{2.5}$ air pollution (left) and mortality attributed to ozone (right) in New York City.[11]

An estimated 400 ozone-attributable deaths occur in New York City annually. By neighborhood, rates of ozone-attributed mortality vary from 2.4 to 11.7 per 100,000 persons. Areas with the highest burden are located outside the city center, in Southern Brooklyn and Staten Island, Central Queens and Northwestern Bronx (Figure 21, right). Nearly 85% of ozone-attributed mortality is among adults older than age 65 years of age. A feasible, modest reduction of just 10% in ozone concentrations in New York City could prevent more than 80 premature deaths, 180 hospital admissions and 950 emergency department visits annually.

Higher concentrations of pollution, mostly caused by vehicular traffic and particularly in poorer neighborhoods, have been linked to worse health outcomes. Traffic-related pollution contributed to an estimated 320 deaths and 870 hospitalizations and emergency department visits annually within NYC due to $PM_{2.5}$ exposures. Trucks and buses within NYC released the largest share of on-road mobile-attributable ambient $PM_{2.5}$. These contributions were not evenly distributed, with high poverty neighborhoods experiencing a larger share of the exposure and health burden than low poverty neighborhoods (Figure 22).[12]

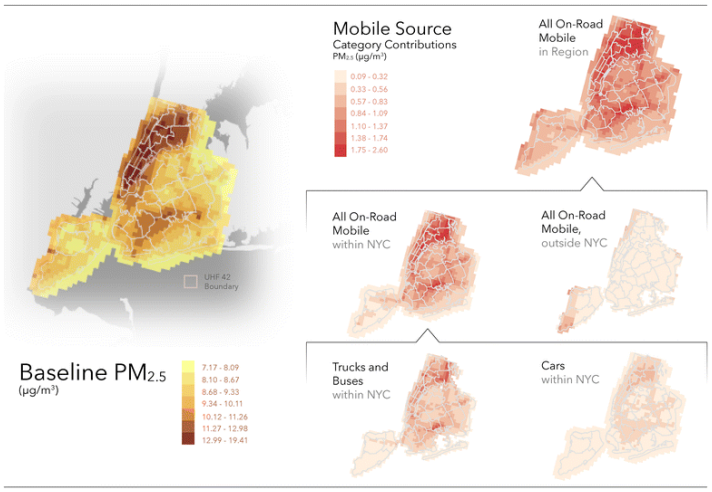

Figure 22: Motor vehicle $PM_{2.5}$ emissions by New York City neighborhood[12]

Projections for Climate-related Asthma, Allergy and Respiratory Health Effects in New York

Estimating future disease burden related to climate change requires modeling of different emissions pathways, and thus will be associated with different temperature rises. Choices made now about emissions will change the potential for allergenic tree pollen, if it curbs the expansion of trees such as oaks and hickories, which produce highly allergic pollen (Figure 23).[5] Urban areas such as New York City may experience further influences on the length and severity of the pollen season from the urban heat island effect and locally higher CO_2 concentrations. And, as noted above, exposure to air pollutants such as diesel exhaust particles enhances allergic response to pollens. As a result, future changes in temperature and CO_2 could lead to changes in the dynamics of the pollen season and potentially increase the morbidity of allergic diseases such as asthma.[7]

Global warming will likely make it even harder to reduce ozone in cities that already have problems with air pollution. Warmer temperatures increase emissions of ozone precursors and accelerate the chemical reactions in the atmosphere that create unhealthy ozone. Higher temperatures, increased air stagnation and higher ground-level ozone can in turn lead to adverse respiratory outcomes. In New York City, ozone-related emergency room visits for asthma among children under the age of 18 have been projected to rise by 7.3% by the 2020s versus the 1980s as the result of climate change-induced increases in ozone concentrations. The New York Climate and Health Project, a multidisciplinary study of climate change and human health in the New York metropolitan area, reported potential increases in ozone-related deaths in New York City ranging from 4% to 6% across the five boroughs by 2050.[13] In a study that projected climate-related increases in hospitalizations for respiratory diseases in 50 eastern U.S. cities, consistent increases were found, by the 2050s, in ozone-related hospitalizations for COPD, asthma, and all respiratory conditions.[5,7]

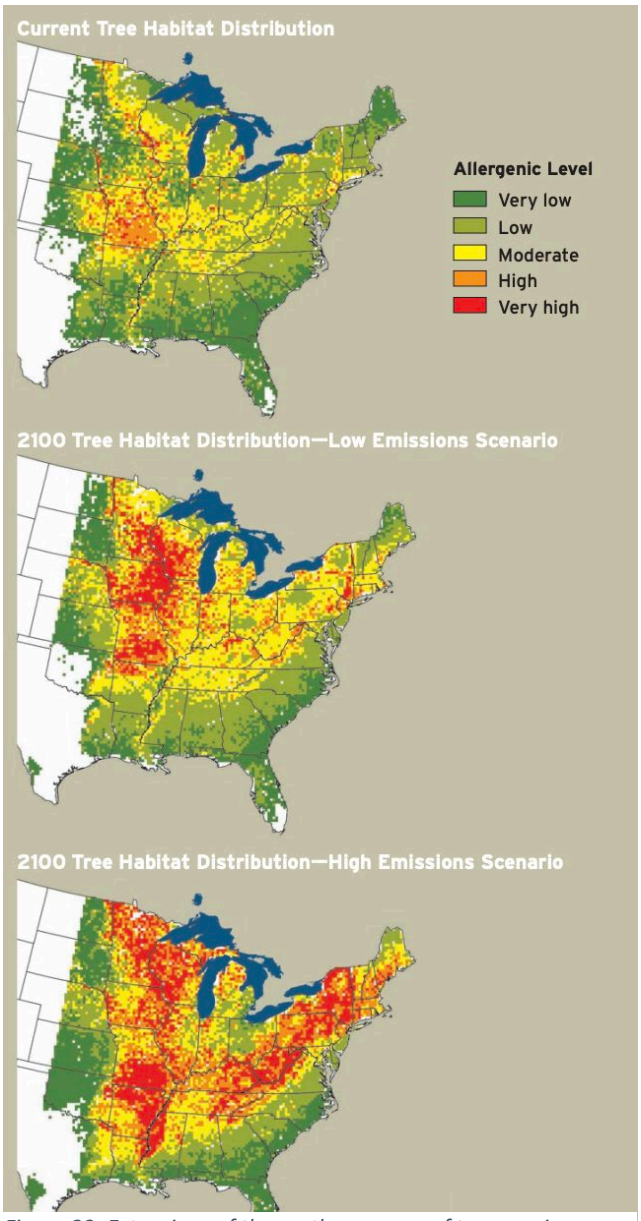

Figure 23: Extensions of the northern range of tree species combined with a longer growing season will adversely affect allergy symptoms[5]

The Costs of Current and Future Climate Change on Respiratory Health in New York State

Current evidence shows a strong relationship between extreme heat days and increases in respiratory diseases. However, few studies have described the economic costs associated with climate change and health. State health researchers studied the impacts of increased respiratory disease hospitalizations resulting from extreme heat in summer in New York State by region and demographic population.

This study attributed approximately 100 excess hospital admissions and nearly 616 days of hospitalization per year to extreme heat, resulting in an estimated $644,069 in direct hospitalization costs. Future projections for the years 2080-2099 project a 2- to 6-fold increase in hospital admissions and an estimated US $26-76 million dollars in hospital costs. When combined with other heat-associated diseases and mortality, the health burden associated with global warming could be substantial.[4]

Summary

Allergies and asthma are already common in New York, with asthma particularly affecting children. These conditions will worsen in severity and affect greater numbers of residents as the climate continues to warm. Warming temperatures also interact with air pollution and ozone levels to lower air quality and exacerbate breathing trouble for those with respiratory conditions.

Health Co-benefits

Reducing transport-related pollution reduces respiratory disease and increases physical activity.

Climate Action: Transition to zero-emission vehicles and hybrid low-carbon vehicles, and increase walking, biking and public transportation options.

- Reduces GHG emissions.
- Reduces $PM_{2.5}$ air pollution and ground level ozone.
- Increases active transport options such as urban walking and cycling.[3]

Immediate Heath Co-benefit: Reduces respiratory disease, promotes active commuting and increases physical activity.

- Reduces acute exacerbation and deaths from respiratory diseases such as asthma and COPD.
- Increases physical activity, reducing the risk of chronic diseases such as obesity.

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2.3 Cardiopulmonary and Neurocognitive Diseases

Section at a Glance:

- *Particular matter (PM) air pollution causes cardiopulmonary disease and premature death.*
- *New Yorkers, especially those residing near roadways, will experience adverse health effects of the interaction between pollution and warming temperatures in coming decades. In particular, premature deaths are projected to increase.*

The interrelationship of climate change, air pollution and ozone (see Section 1.2 and Figure 4 for overview of science, and Section 2.2 for relationship of pollution and ozone with chronic respiratory disease) creates a recipe for adverse cardiopulmonary and neurocognitive health effects.

Relative to many other states, New York air is cleaner, and recent legislation has further improved air quality. New York ranks 11th in clean air. (Figure 24)[1]

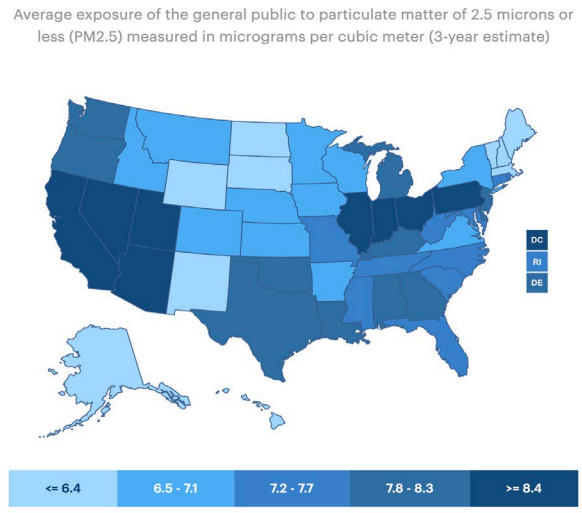

Figure 24: $PM_{2.5}$ air pollution in the U.S., 2019[1]

New York City's air is becoming progressively cleaner. Over the past several decades, actions taken at the federal, state, and local levels have dramatically improved air quality.[2]

New York City's particulate matter ($PM_{2.5}$) concentrate on has decreased more rapidly than in most other big U.S. cities, declining by about 25% between 2008 and 2013. As a result, the city's air-quality ranking among major U.S. cities improved from seventh place in 2008-2010 to fourth place in 2011-2013.[3]

Air Quality Improvements in New York City

In New York City, legislation phased out heavy heating oil used by 5,300 buildings has significantly improved air quality. The 2017 New York City Community Air Survey found:

- Annual average levels $PM_{2.5}$, nitrogen dioxide, nitric oxide and black carbon have declined 28%, 27%, 35% and 24%, respectively.
- Wintertime sulfur dioxide levels have declined by 95%.
- Summertime ozone levels have remained stable.
- High levels of $PM_{2.5}$, nitrogen dioxide and nitric oxide continue to be observed in areas of high traffic density, building density and industrial areas.
- Higher sulfur dioxide levels are observed in areas with remaining heating oil boilers.
- Ozone levels are higher in the outer boroughs that are downwind of high emissions density.

Despite this progress, air pollution remains a leading environmental threat to the health of New Yorkers, and continues to cause serious health problems. In New York City, it is estimated that $PM_{2.5}$ contributes to more than 2,000 deaths and over 6,000 emergency visits and hospitalizations for cardiovascular and respiratory disease each year.[3]

Despite recent reductions in emissions as a result of the Pandemic (figure 25),[4] New York city air quality has varied significantly by neighborhood. The New York City Community Air Survey, which monitors $PM_{2.5}$ levels across the city, indicates that at least two city neighborhoods exceed the current federal "safe limit" of 12 micrograms/m^3, while several others are near that limit. The World Health Organization sets the safe limit at 10 micrograms/m^3. Thus, the health implications from air pollution remain significant for New York City, even if levels are relatively better than in other major cities of the U.S. It is important to note that even pollution levels below federal air quality standards cause adverse health effects.[5]

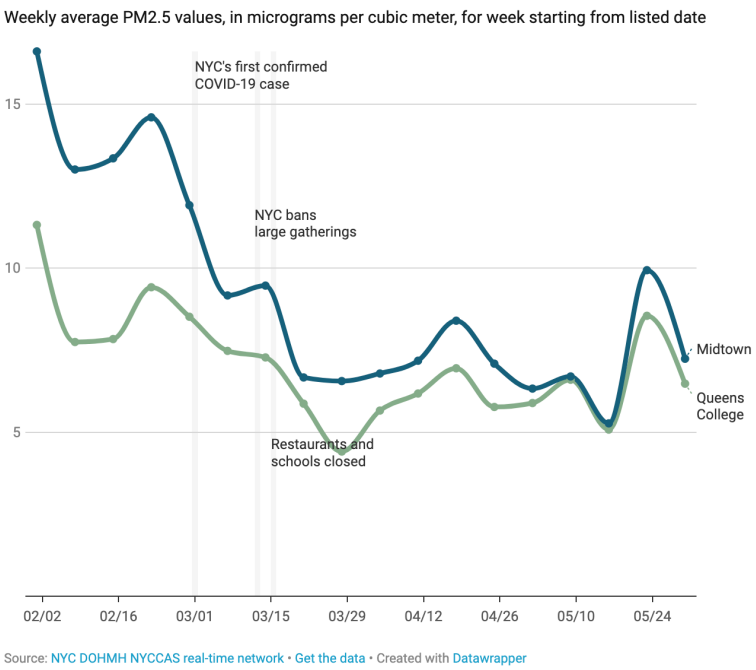

Figure 25: Air quality improved while New Yorkers stayed home.[4]

Lung Cancer

The International Agency for Research on Cancer (IARC) has classified outdoor air pollution as a cancer-causing agent (carcinogen) leading to lung cancer (as well as bladder cancer). The risk of lung cancer associated with air pollution in the U.S. is thought to be lower than in many other countries because of policies that have helped to lower air pollution exposure here in the U.S.[6]

Mechanisms of Air Pollution as a Cause of Cardiometabolic Disease

$PM_{2.5}$ air pollution is linked to 80-100,000 premature deaths annually in the U.S., 70% of which are related to the cardiovascular system.[7]

Long-term exposure to $PM_{2.5}$ increases all-cause mortality by 10% for every 10-mg/m^3 increase in $PM_{2.5}$. Because the dose-response relationship between $PM_{2.5}$ and mortality shows no safe threshold, the American Heart Association recognizes $PM_{2.5}$ as a modifiable risk factor for heart disease.[8]

Medicare and lower socio-economic populations experience increased mortality, even when $PM_{2.5}$ are always below current air standards.[7]

Another consistent finding that there is a stronger association between $PM_{2.5}$ and cardiovascular disease in Eastern states compared to Western states, but this finding

may be confounded variables such as cold weather, time spent outdoors and the source of the air pollution.[1]
Emerging evidence suggests that hypertension, diabetes, non-fatal myocardial infarction, non-fatal stroke and heart failure are increased by high levels of $PM_{2.5}$. The mechanism is thought to be related to increased pro-inflammatory factors which can activate clotting mechanisms.[8]

Such processes would explain findings from recent studies linking $PM_{2.5}$ levels at or below national air quality standards to rising rates of diabetes,[9] coronary artery calcium scores (an early marker for heart disease),[10] and to the development of obesity.[11]

Neurocognitive Conditions Related to Air Pollution
Air pollution is also thought to be related to the development of cognitive decline, dementias and Alzheimer's disease.[12]

As noted above, fine particulate matter in air pollution triggers the traditional cardiovascular risk factors – high blood pressure and lipids, insulin resistance, endothelial dysfunction in arteries, and increased coagulation. These factors also increase the risk of cognitive decline and dementia.

Air Pollution Affecting Child Development and Health
Children are typically outside longer and are more active than adults, and therefore can be disproportionately affected as compared to adults. Particulate matter air pollution, even at low levels, is associated an increased risk for preterm birth, low birth weight and sudden infant death syndrome. [13]

Emerging evidence also links $PM_{2.5}$ air pollution as a possible cause of attention-deficient hyperactivity disorder and autism in children. [14]

Studies on adolescents found that those who grew up in more polluted areas have reduced lung growth and may never achieve the vital capacity of those who grew up in cleaner air. The average drop in lung function was similar to the impact of growing up in a home with parents who smoked. There is also evidence that children growing up in cleaner air have better pulmonary function: when air quality improves in a particular area, children suffer fewer bronchial symptoms whether or not they have asthma.[15]

Being Near Roadways Increases Risk
The health effects of air pollution are magnified in areas close to roadways. Pollution levels along busy highways are typically higher than in the community as a whole. The area most affected is the band within 0.2 to 0.3 miles (300 to 500 meters) of a highway. Unfortunately, 30 to 45 percent of the urban population in North America live next to a busy road. Urban women in a Boston study experienced decreased lung function associated with traffic-related pollution. Similarly, adults living within 300 meters of a road may be at risk for dementia. The strongest association between roadways and dementia is among those who lived closest to the road (less than 50 meters), who had

never moved and who lived in major cities. A 2011 study found that long-term exposure to traffic pollution increased risk of having poor cognition among older men.[16]

Exposure to roadways increases the likelihood of negative health outcomes in children. Traffic pollution causes asthma attacks in children and may cause the onset of childhood asthma [15] (for discussion of asthma, see section 2.2). Notably, areas of New York City with high traffic density have higher levels of $PM_{2.5}$.[17]

Projections

$PM_{2.5}$ accounts for most of the health impacts attributable to air pollution in the U.S., and small changes in average concentrations have large implications for public health. Without consideration of climate effects, concentrations of $PM_{2.5}$ in the U.S. are projected to decline through 2040 due to ongoing emissions control efforts. Yet, $PM_{2.5}$ is highly sensitive to weather conditions, including temperature, humidity, wind speed and rainfall. Some studies have indicated that even without considering increased wildfire frequency, climate change will cause a small but important increase in $PM_{2.5}$ over North America. [18–20]

The interrelationship between PM2.5 air pollution and morbidity and mortality related to Covid-19 is an area of active research. [21]

Summary

Particulate matter air pollution is strongly associated with lung cancer, cardiovascular and neurocognitive disease. Climate instability affects weather patterns and air quality and can increase exposure to $PM_{2.5}$. Without substantial reductions in particulate matter source pollution, related health-effects will continue to grow, particularly in New York's urban communities.

Health Co-benefits of Climate Action

Climate Action: Transition to zero-emission vehicles and hybrid low-carbon vehicles, and increase walking, biking and public transportation options.

- Reduces GHG emissions.
- Reduces $PM_{2.5}$ air pollution and ground level ozone.
- Increases active transport options such as urban walking and cycling.

Immediate Heath Co-benefit: Reduce cardiovascular and neurocognitive disease and increase physical activity.

- Reduces air pollution-related acute cardiovascular diseases and mortality.
- Reduces risk of neurocognitive disease.
- Increases physical activity, which reduces cardiovascular and neurocognitive risk factors of obesity and diabetes.[8-11]

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2.4 Vector- and Water-borne Diseases

Section at a Glance:

- *New York is particularly hard-hit by Lyme disease, which is projected to worsen; emerging tick-borne illnesses are also expected to spread throughout the state.*
- *Infectious diseases transmitted by mosquitos are on the rise and affecting more areas of New York State.*
- *Contaminated and warming waters are posing a greater risk of harmful algae and a number of water-borne pathogens which can make New Yorkers ill.*

Climate instability is increasing the risk of infectious diseases through multiple pathways. Changes in temperature, rainfall, humidity and frequency and intensity of severe weather can affect the geographic distribution and physiological factors that regulate habitat, survivorship, reproduction and transmission of insect vectors. Increases in water-borne diseases can result from contamination due to severe weather events such as hurricanes and floods, and to changes in water temperature and other contaminants that foster growth and transmission. New York State is already experiencing increases in several climate-sensitive vector- and water-borne infectious diseases, and this trend will most certainly continue as temperatures rise.

Vector-borne Diseases

New York State is experiencing changing climate conditions that favor the survival of vectors that carry disease such as mosquitos and ticks, and making West Nile virus, Lyme disease and other infections more prevalent.[1,2] Climate change is also opening the door to new pests and diseases.[3]

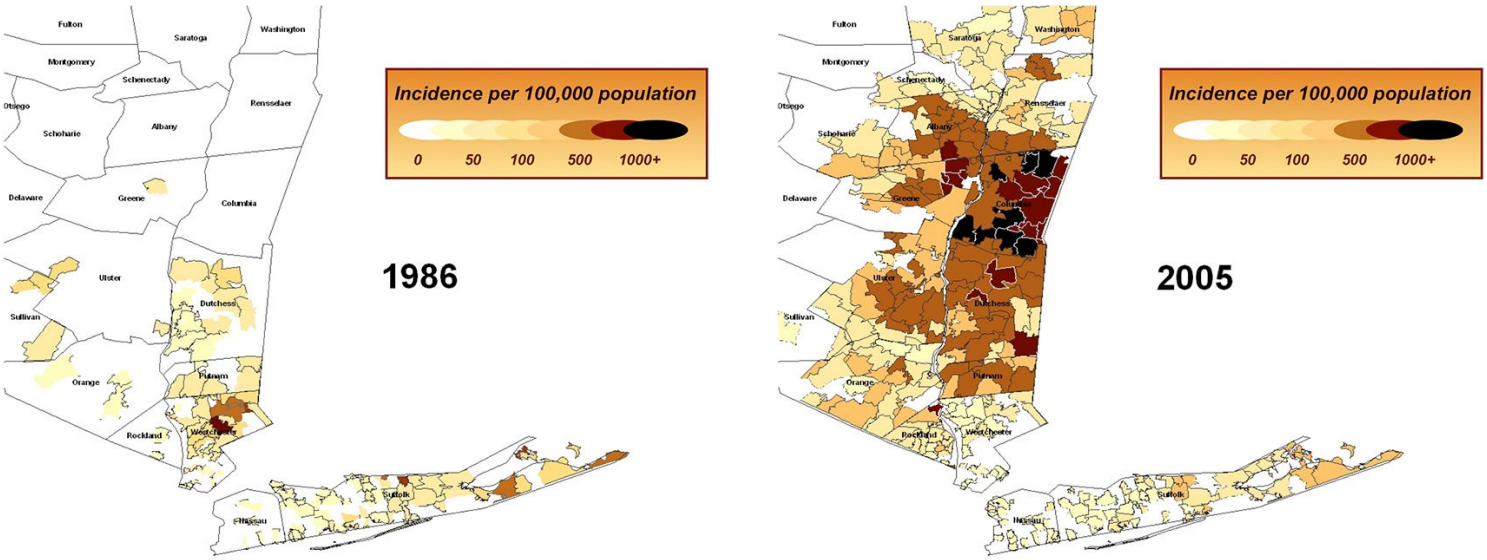

Figure 26: Northward expansion of tick-borne Lyme disease in New York since 1986.[4]

Climate and environmental changes continues to drive expansion of animal reservoirs and insect vector populations into new geographic regions. Coupled with the exponential rise in international travel and commerce,[4] emerging zoonotic diseases are on the rise and are expected to continue rising. The number of cases of vector-borne diseases has tripled over the past 13 years according to the CDC (Figure 26).[5]

Lyme and Other Tick-borne Diseases

New York State ranks number 2 for the most tick-borne illnesses in the country every year since 2004. A total of 69,313 tick-borne diseases were reported in NYS over 13 years. Only Pennsylvania had more, with 73,610. Most of these cases were of Lyme disease, but the CDC identified several tick-borne diseases—spotted fever rickettsiosis, babesiosis, anaplasmosis and ehrlichiosis—that have all seen a rise during the same period.[5]

The aggressive north and westward expansion of tick-borne diseases is clear (Figure 27). Lyme Disease can now be found as far as Georgia and Wisconsin. Other tick borne diseases like anaplasmosis and babesiosis are following similar suit although their expansion lags behind that of Lyme disease by about 10 to 15 years.[5] This growing threat prompted New York Governor Andrew Cuomo to declare tick-borne disease a significant risk to the health of all New Yorkers. In 2017, he announced an aggressive Lyme and tick-borne disease plan to control tick populations on public lands, increase public awareness, provide access to available data, and create a Lyme disease working group.

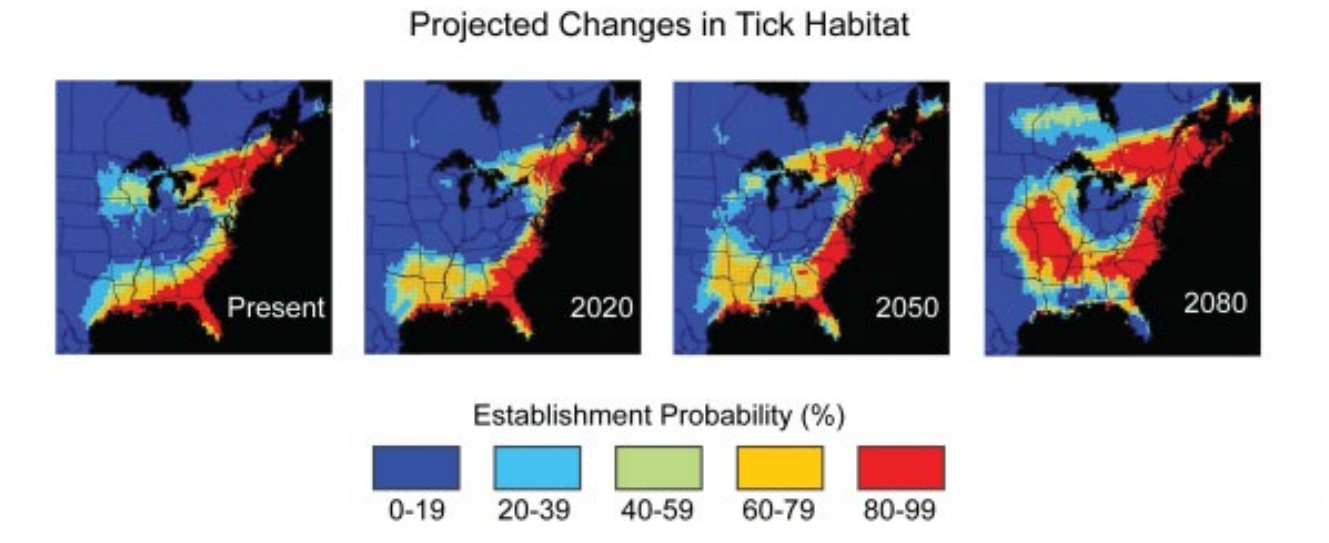

Figure 27: Projected changes in deer tick habitat.[6]

The prevalence of Lyme Disease is considered to be grossly underreported and is a major cost to our economy. Medical costs alone for Lyme Disease cost the US Healthcare system an estimated $712M to $1.3B annually.[7] Efforts to introduce a

vaccine for humans are underway, however the only current method of prevention is avoidance of tick exposure.[8]

Projections for Tick-borne Diseases in New York State

Climate change favors increased survival and reproductivity of ticks. The blacklegged tick (carrier of Lyme) is therefore projected to expand its geographic distribution to higher latitudes and elevations. This will lead to an earlier annual onset of Lyme disease cases. This prediction is consistent with recent observations of the spread of *I. scapularis* in Canada.

The range of other ticks are expanding, and will introduce new risks to New York State. The lone star tick, native to the southeastern US, has been slowly moving northward since becoming established on eastern Long Island, NY in the 1990s. Lone Star ticks do not transmit Lyme but are associated with a number of other human and animal diseases such as ehrlichiosis, Southern tick-associated rash illness (STARI), spotted fever rickettsiosis, tularemia, Heartland virus and, more recently, and permanent red meat allergy.[9]

Emerging Threat: Meat Allergies Caused by Tick Bites

Alpha-gal allergy is a reaction to red meat. Although this allergy remains rare, approximately 80% of cases are caused by the bite of the Lone Star tick. In the U.S., the Lone Star tick is most common in Southeast Texas, Iowa, and New England.

The alpha-gal allergy was identified in 2006, and doctors are still learning about the condition. When alpha-gal enters the body, via a tick bite or otherwise, the immune system produces antibodies to fight the molecule. An alpha-gal allergy can cause a person to have anaphylactic and hypersensitivity reactions when they eat meat.

The term alpha-gal is short for galactose-alpha-1, 3-galactose, a carbohydrate molecule that can cause an allergic reaction in people with an alpha-gal allergy. The molecule is found in the meat of mammals, including cows, sheep, venison, bison, and pigs.[2]

Mosquito-borne Diseases

New York is hit harder than almost any other state by diseases spread by mosquitos (Figure 28), with 7,167 illnesses reported in the state between 2004 and 2016. Only California and Puerto Rico report more cases.[5] Since 2004, nine insect-borne diseases, including Chikungunya and Zika virus, have been discovered or introduced for the first time in the U.S. and its territories.[10] However, more than 90 percent of these people were infected with Chikungunya, Zika or

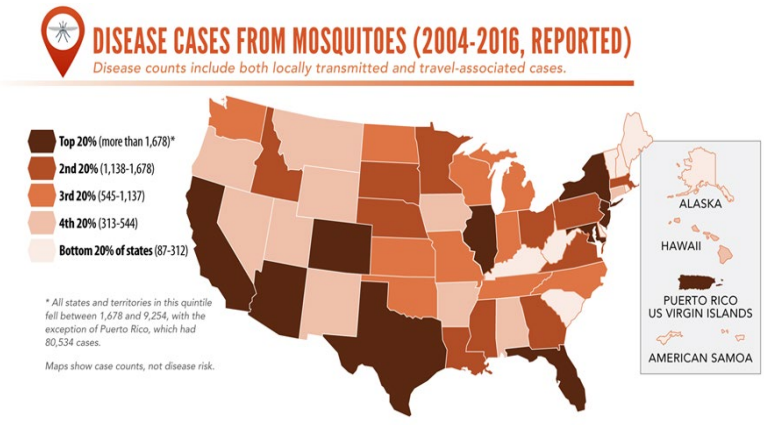

Figure 28: Mosquito-borne disease cases in the U.S.[5]

another mosquito-borne virus, dengue, became infected in Latin America and the U.S. territories and then traveled to the U.S. mainland.[5]

West Nile virus (WNV): is the leading cause of mosquito-borne disease in the nation. Since the late summer of 1999, when an outbreak of WNV first occurred in New York City, human WNV cases have occurred every year in the U.S. Annual WNV incidence remained stable through 2007, decreased substantially through 2011, and increased again in 2012, raising questions about the factors driving year-to-year variation in disease transmission.[3]

Between 1999 and 2017, 858 cases of WNV were reported in NYS.[11] Infection with WNV can cause encephalitis or meningitis. Cases of WNV occur during mosquito season, which starts in the summer and continues through fall. There are no vaccines to prevent or medications to treat WNV, and about 1 out of 150 infected people develops a serious, sometimes fatal, illness.[5]

Emerging mosquito-borne infections of concern to New York State [5] include those recently found in the US but without confirmed NYS transmission such as Chikungunya and Dengue; those seen in NYS but related to travel such as Zika[13] which causes severe birth defects; and those with transmission in NYS that are infrequent but of high concern such as Eastern Equine Encephalitis (a.k.a. EEE) which can cause lasting neurological damage and fatality in one-third of patients—11 cases have been confirmed in NYS of EEE most recently in 2015 [12]

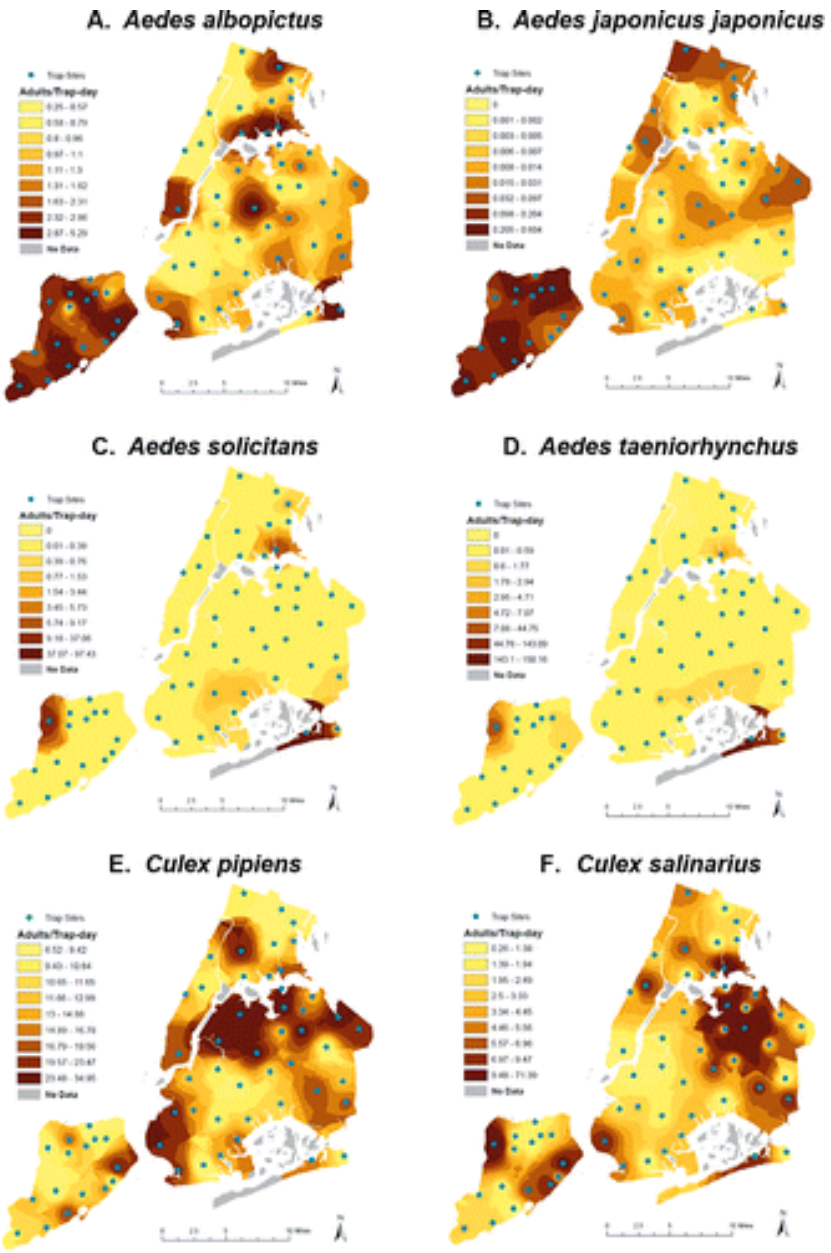

Figure 29: Distribution of several mosquito species within New York City. These include the species that transmit West Nile virus, among other diseases.[15]

Projections for Mosquito-borne Diseases in New York State

As the northeastern U.S. continues warming and experiences increases in precipitation, more mosquito habitat will be created. The season when mosquitos are most abundant will begin earlier and end later.[3] Warmer temperatures also facilitate disease transmission from mosquitos, and the number of warmer days is projected to increase. Asian tiger mosquitos are expected to dramatically increase their range into the Northeastern U.S. (Figures 29 & 30).[15-17] Asian Tiger mosquitos can transmit dengue, Zika, Chikungunya and West Nile. Cases of WNV are projected to increase in regions of the U.S., including NYS.

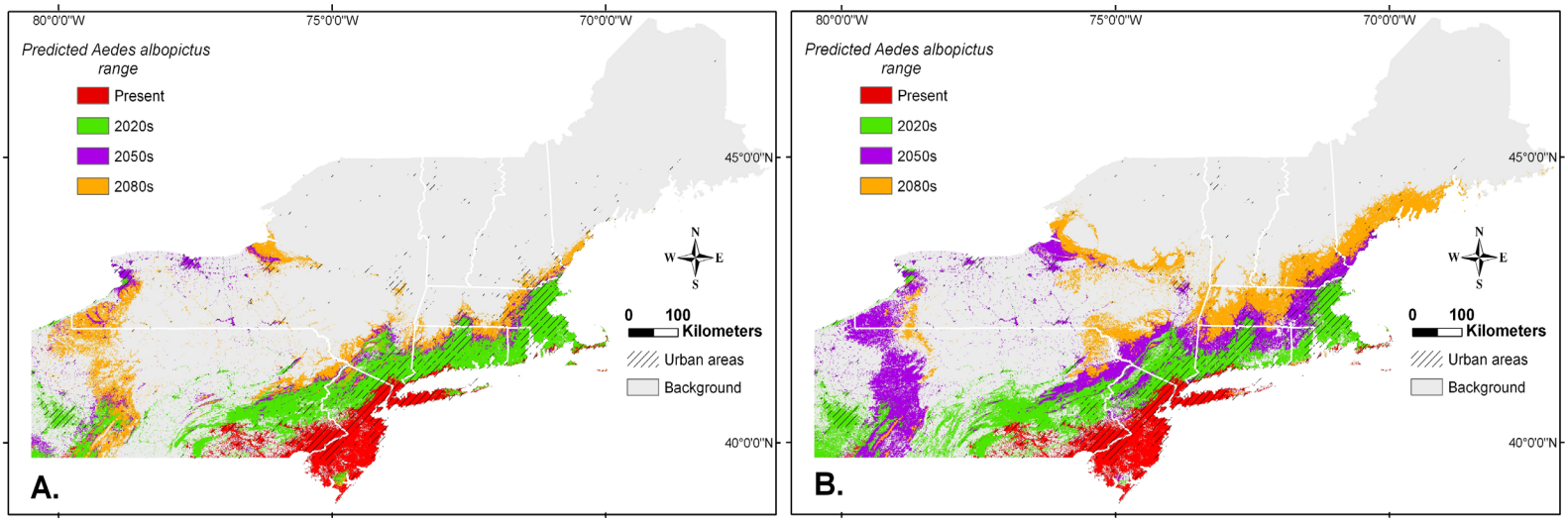

Figure 30: Projected changes in mosquito range as the climate warms and precipitation increases in the Northeastern U.S.; A, moderate emissions scenario; B, high emissions scenario.[16]

Climate-sensitive Water-borne Diseases

Climate instability is expected to increase exposure to water-borne diseases caused by pathogens such as bacteria, viruses and protozoa. Climate instability will also increase exposure to man-made chemicals released into the environment, and to harmful toxin-producing algae and cyanobacteria (blue-green algae).[3,18]

Water contamination primarily originates from human and animal wastes and agricultural use of fertilizers. These materials spread pathogens and nutrients, such as nitrogen and phosphorus, into surface water, groundwater and coastal water (Figure

31). When such runoff adds high concentrations of nutrients to water sources, it promotes growth of naturally occurring pathogens and algae. This process is known as eutrophication. Humans are subsequently exposed by drinking, playing, or consuming seafood from contaminated waters.[18]

Water-borne pathogens cause an estimated 8.5% to 12% of acute gastrointestinal illness cases in the U.S., affecting between 12 million and 19 million people annually. These illnesses are primarily provoked by bacterial and viral pathogens with illnesses ranging from transient diarrhea to malnutrition and hemorrhagic shock.[18]

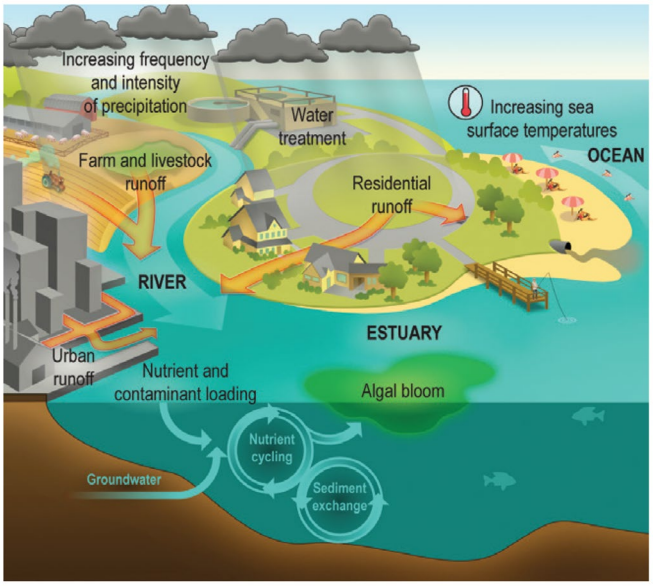

Figure 31: Contamination of water leads to human illness, and this process is boosted by climate instability.[18]

Despite advances in water management and sanitation, water-borne disease outbreaks continue to occur in NYS and across the U.S. (Table 1). The majority of water-borne disease outbreaks in the U.S. are preceded by heavy rainfall and flooding. Such extreme events have seen an increase the incidence of gastrointestinal illness in children[18] which can threaten their lives if fresh water is scarce.

Pathogen or Toxin Producer	Exposure Pathway	Selected Health Outcomes & Symptoms	Major Climate Correlation or Driver (strongest driver(s) listed first)
Algae: Toxigenic marine species of *Alexandrium, Pseudo-nitzschia, Dinophysis, Gambierdiscus; Karenia brevis*	**Shellfish Fish Recreational waters (aerosolized toxins)**	Gastrointestinal and neurologic illness caused by shellfish poisoning (paralytic, amnesic, diarrhetic, neurotoxic) or fish poisoning (ciguatera). Asthma exacerbations, eye irritations caused by contact with aerosolized toxins (*K. brevis*).	Temperature (increased water temperature), ocean surface currents, ocean acidification, hurricanes (*Gambierdiscus* spp. and *K. brevis*)
Cyanobacteria (multiple freshwater species producing toxins including microcystin)	**Drinking water Recreational waters**	Liver and kidney damage, gastroenteritis (diarrhea and vomiting), neurological disorders, and respiratory arrest.	Temperature, precipitation patterns
Enteric bacteria & protozoan parasites: *Salmonella enterica; Campylobacter* species; Toxigenic *Escherichia coli; Cryptosporidium; Giardia*	**Drinking water Recreational waters Shellfish**	Enteric pathogens generally cause gastroenteritis. Some cases may be severe and may be associated with long-term and recurring effects.	Temperature (air and water; both increase and decrease), heavy precipitation, and flooding
Enteric viruses: enteroviruses; rotaviruses; noroviruses; hepatitis A and E	**Drinking water Recreational waters Shellfish**	Most cases result in gastrointestinal illness. Severe outcomes may include paralysis and infection of the heart or other organs.	Heavy precipitation, flooding, and temperature (air and water; both increase and decrease)
Leptospira and *Leptonema* bacteria	**Recreational waters**	Mild to severe flu-like illness (with or without fever) to severe cases of meningitis, kidney, and liver failure.	Flooding, temperature (increased water temperature), heavy precipitation
Vibrio bacteria species	**Recreational waters Shellfish**	Varies by species but include gastroenteritis (*V. parahaemolyticus, V. cholerae*), septicemia (bloodstream infection) through ingestion or wounds (*V. vulnificus*), skin, eye, and ear infections (*V. alginolyticus*).	Temperature (increased water temperature), sea level rise, precipitation patterns (as it affects coastal salinity)

Table 1: Primary climate-sensitive agents of water-borne illness in the U.S.[18]

Toxic algal blooms: Most algae are harmless; however, some species can produce toxins harmful to people and animals. Harmful algal blooms (HABs) usually occur in nutrient-rich waters, particularly during hot, calm weather. Climate-related impacts such as warming water temperatures, increased salinity of freshwaters, higher carbon dioxide levels, and increased rainfall and runoff all increase the risk of algal blooms.[21]
HABs also contribute to fish die-offs because they deplete the amount of oxygen dissolved in the water and therefore "suffocate" the fish from their oxygen supply. Aquatic life can also store these algal toxins which bio-accumulate as animals move up the food web.

The frequency and severity of HABs have increased throughout NYS in recent years (Figure 32).

Year	Suspicious	Confirmed	High Toxins	Total
2012	20	29	9	58
2013	17	37	22	76
2014	19	51	23	93
2015	40	62	35	137
2016	41	95	38	174
2017	45	84	36	165
12-17	**75**	**133**	**77**	**340**

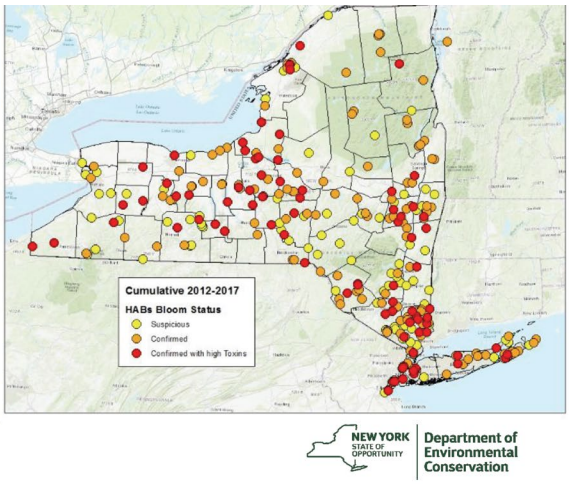

Figure 32: Harmful algal blooms in New York State, 2012-2017.[22]

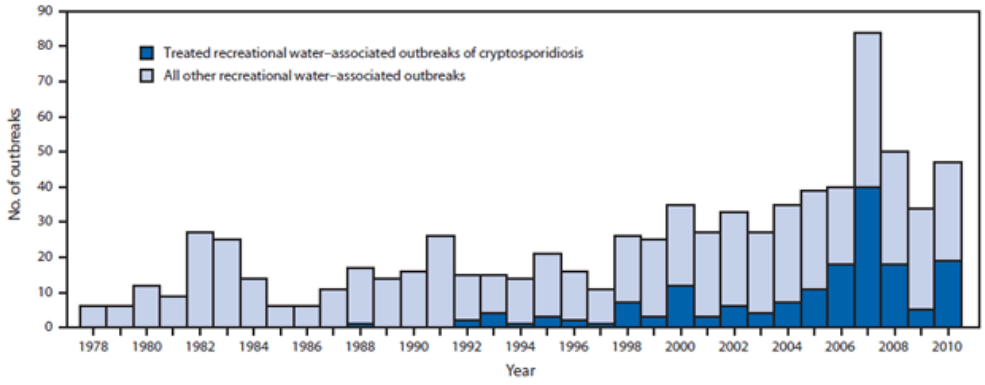

Figure 33: Number of water-borne illnesses associated with recreational water use in the U.S. through 2010.[23]

Projections for Water-borne Disease in New York State

No specific water-borne disease outbreak has been definitively linked to climate instability, but increasing trends of climate-sensitive water-borne diseases have been noted in NYS and beyond. CDC data reveal an upward trend in such outbreaks

between 1978 and 2010, the most recent year for which complete data are available (Figure 33). In 2009-2010, nearly half of the 24 outbreaks associated with untreated recreational water were attributed to HABs, which occurred between June and August in just three states: New York, Ohio and Washington. All occurred between June and August.[24]

Summary

The increased range of tick-borne illnesses in recent decades portends that New York should expect increases in other vector-borne diseases in the coming decades. The warming climate and earlier spring, along with a milder winter, will produce favorable conditions for ticks and mosquitos. Warmer temperatures will also enable the growth of harmful algae in New York's waterways. All New Yorkers are susceptible to illness from vector- and water-borne pathogens, and these illnesses are anticipated to become more common.

Health Co-benefits

Climate Action: Encourage tracking and reporting emerging vector-borne-pathogens, and reduce the amount and frequency of application of agricultural pesticides and fertilizers.

- Increase awareness and reporting of emerging environmental pathogens.
- Reduces runoff into waterways to prevent harmful algal blooms.

Immediate Heath Co-benefit: Reduces the number of people exposed to harmful chemicals in the air and in the water, and vector-borne-pathogens

- Reduces water and air pollution.
- Reduces risk of water-borne pathogens and harmful algal blooms.
- Reduces disease burden of vector-borne-illnesses.

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2.5 Mental Health Effects

Section at a Glance:

- *Both extreme weather events and gradual climate changes result in a spectrum of mental health reactions including stress related symptoms, substance use, depression, anxiety and post-traumatic stress disorder.*
- *Climate change, particularly increased temperatures is associated with increased crime and violence.*
- *Farmers, indigenous people, children and other disadvantaged groups may be most impacted by mental health effects of climate change*

Climate instability is a significant source of stress and can cause mental health concerns for individuals and communities. Natural disasters cause loss of homes, neighborhoods and belongings and result in the deaths of family and friends. Such events will broaden as global warming and climate instability bring continued sea level rise, floods, droughts, heat waves, wildfires, economic stress, forced migrations, displacement and threats to food and water security.[1]

The social and mental health consequences of extreme and slow-moving weather events are well documented, ranging from minimal stress and distress symptoms to clinical disorders such as post-traumatic stress disorder (PTSD), depression, anxiety and suicide. Domestic, interpersonal and collective violence, as well as high-risk coping behaviors such as alcohol use, breakdown of community infrastructure, loss of employment, interrupted and broken social support systems are linked to disasters and climate instability.[2] For example, surveys of survivors of natural and man-made disasters indicate PTSD prevalence among direct victims of disasters of 30% to 40%, as compared to a prevalence of 5% to 19% in the general population. First responders, emergency workers and others involved with responding to extreme weather-related disasters are also at increased risk for mental health consequences both in the short and long term. [3]

Disaster-related Mental Health Impacts

Phases of Psychological Reaction to Disasters

The American Psychiatric Association has studied and modeled the effects of disasters on surviving individuals. Survivors' emotions generally become more difficult to manage around the time of disaster warning, and their negative feelings increase through disaster threat and impact. Most people experience stress symptoms following a trauma, but they generally subside over the following days or weeks after conditions of security has been restored. Finding it difficult to sleep, being more irritable, experiencing shock, confusion and anxiety are all common symptoms following a trauma.[3]

Three months after a trauma occurs is when PTSD tends to be diagnosed in those unable to recover on their own. Emotions improve in a heroic phase, in which they are inclined to try to contribute to the disaster response, followed by a honeymoon phase, when community cohesion peaks. Following the honeymoon, however, is disillusionment, sometimes spurred by disappointment in the slower-than-expected pace of disaster recovery. Disillusionment typically occurs in the second half of the year after the disaster, and after the disaster's first anniversary, it is generally followed by reconstruction, as survivors come to terms with their "new normal" after the disaster.[6,7]

Since 2010, New York State has experienced 11 weather disasters, including severe storms, tornadoes, floods, tropical storms, snow and ice storms and droughts. Indeed, every county in New York has been affected by at least one federally-declared weather disaster since 2010.[8] Hurricane Sandy, the 4th-costliest storm in U.S. history, hit the eastern coast in October 2012, taking 43 lives, damaging or destroying 650,000 homes, causing $71 billion dollars in damage, leaving 2 million without power and causing acute physical and mental health problems for many New Yorkers.[10] Following Hurricane Sandy, a brief telephone screening six months after the disaster identified 14.5% of adults as suffering from PTSD, which was more prevalent among those who experienced a combination of personal and property damage.[11] Emergency department visits for anxiety and mood disorders increased in the Rockaways immediately after the storm. A majority of mental health-related emergency visits involved substance abuse; such incidences increased by a factor of 4 during the blackout caused by Sandy. Power outage was one of the most important environmental factors affecting mental health. With every 1% increase in blackout, emergency departments in The Bronx had almost an 8-fold increased incidence of mental health visits and emergency departments in Queens had a 1.5-fold increased incidence [13] Three years after Sandy, the hard-hit Rockaways had a rate of adult psychiatric hospitalizations that was nearly double that of New York City as a whole.[14] These findings underscore the potential for increasing mental health concerns as climate instability worsens.

New York State Farmers and Indigenous People

Changes to ecosystems caused by climate instability adversely affect the livelihood of those who depend on water and fertile land such as fisherman, farmers and Native Americans.

Droughts, floods and erratic weather leading to economic downturns are well-documented causes of mental stress and suicides in farmers. When temperatures rise, agricultural yields are reduced.[15] Among New York State's dairy farmers, there are well-documented cases of dairy farmers committing suicide as a result of falling milk prices.[16] According to the CDC, in 2012 and 2014, there were 44.9 and 32.2 suicides per 100,000 farmers when the general suicide rate in the U.S. was 13.4 per 100,000.[17] While these suicides have not been directly linked to climate instability, they illustrate the fragility of the American farmer to stresses that threaten their livelihood.

For Native Americans, eco-systems that support subsistence living are often an essential part of their culture and sense of well-being.[15] The NYS Department of Health analyzed populations in the state most vulnerable to climate instability, and Native Americans were identified as being among the most vulnerable.[1] Anyone who subsists

Tribal Populations in New York

There are eight federally recognized tribes in NYS. The Department of Health administers health clinic services and is preparing for a potential increase in demand due to climate instability.[1]

- Native communities are at increased risk due to adverse socioeconomic factors such as high poverty and high unemployment.
- Tribes have cultural and economic ties to the land and environment that shape traditions and indigenous ways of life that includes unique cultural practices tied to water, hunting and fishing that are potentially vulnerable to climate instability.

off the land, who uses well water or who is a migrant and seasonal farmworker may experience a greater severity of impact, be less able to engage in adaptive behaviors to minimize exposure, or have less ability to recover from climate-related adversities.

Heat and Mental Illness

Exposure to extreme heat has been associated with increased use of alcohol to cope with stress, increases in hospital and emergency department admissions for people with psychiatric conditions, and increases in suicidal ideation and suicide.[3] Suicides tend to be more violent as the weather gets warmer. Additionally, heat tends to exacerbate previously existing mental illness, such as worsening the symptoms experienced by persons with schizophrenia and causing more agitation in dementia patients. An increase in mortality due to alcohol and drug misuse has also been documented.[18] Recent projections indicate that, by 2050, climate change could be linked to a total of 14,020 excess suicides in the U.S.[19]

People with mental health conditions are more likely to be affected by extreme weather. Several studies of heat wave-related deaths found that people with mental illness had a three times greater risk of death from a heat wave than those without mental illness. In part, this may be due to psychiatric medications which can interfere with thermo-regulation and awareness that body temperature is rising. In addition, people living with mental illness are more likely to face other adversities such as living in poverty or to have co-occurring substance use disorders, which make it harder for them to cope or adapt to stress.[3]

Heat, Climate Instability and Violence

The destabilizing effects of climate on national and international security are unknown but cause for concern. Climatic events have led to social conflict when local governments failed to adequately protect communities against natural disasters.[15] Such events have the potential to affect how people interact in and between communities, resulting in disruptions to community cohesion and social stability. Threats to natural or limited resources can force migrations that create direct competition within and between communities, increasing the propensity to individual or collective violence. When funding has been diverted from traditional community agencies that mitigate crimes, such as criminal justice systems or mental health agencies, to organizations that need to respond to natural disasters, higher crime rates have been observed.[15]

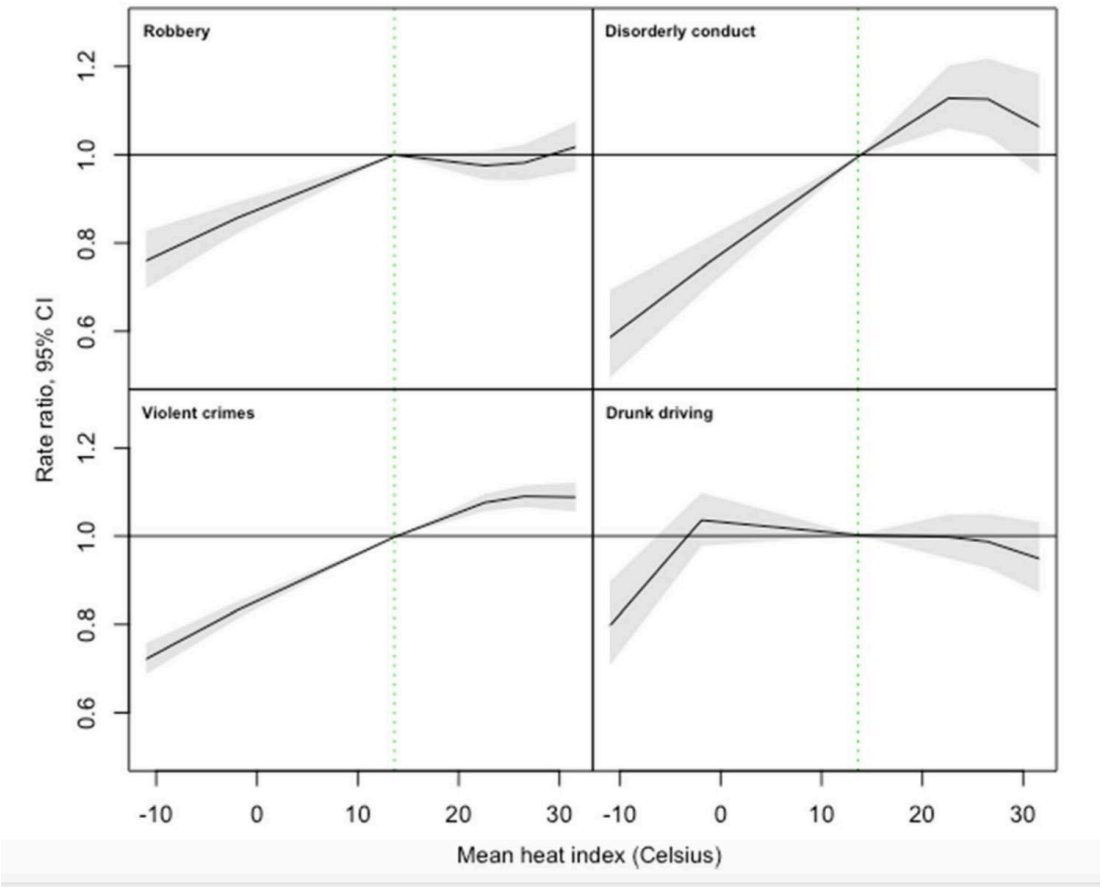

Figure 34: Relative rate and 95% confidence intervals for the relationship between mean daily heat index and select categories of crime, Philadelphia, PA, January 1, 2006–December 31, 2015[20]

The association between heat and interpersonal as well as collective violence has been well-documented (figure 34).[20] Aggression, violence and crimes including domestic violence, assault, rape and murder all rise with the temperature.[21] Moreover, increased crime is linked to warm weather whenever it occurs throughout the year. Heat is believed to impact specific areas of brain function to result in decreased attention and self-regulation, increased hostile or negative thoughts, and reduced ability to resolve conflicts.[21] Increasing evidence suggests that climate instability causes an increase in collective violence.[22]

With projections for continued warming of Earth's climate and the observed links between heat and violence, studies project that violent crimes will increase. Between 2010 and 2099, climate instability is projected to cause an additional 22,000 murders, 180,000 cases of rape, 1.2 million aggravated assaults, 2.3 million simple assaults, 260,000 robberies, 1.3 million burglaries, 2.2 million cases of larceny, and 580,000 cases of vehicle theft in the U.S.[23] For every increase of 2°F in average annual

temperature, an additional 24,000 assaults or murders are projected to occur each year in the U.S.[24]

Eco-anxieties: Emerging Climate-related Mental Health Threats

The slower-moving, more gradual aspects of climate instability are believed to be contributing to the increasing incidence of mental health disorders. Climate change can provoke a number of different emotions, including fear, anger, feelings of powerlessness, helplessness, exhaustion, fatalism and resignation, even in people not yet living directly in the path of climate change. Existential anxieties, also called psychoterratic states or conditions—stemming from earth-related (terra) mental health (psyche)—are beginning to be recognized by the mental health community as: eco-anxieties, climate-anxiety, climate-depression, climate-grief, eco-paralysis, pre-traumatic stress, solastalgia (ones feeling of losing a place that is important to one) and nature deficit.[3]

The majority of New Yorkers believe that global warming is happening, which is consistent with 70% of all Americans. In the majority of New York counties, at least 50% of residents are worried about global warming and at least 60% think global warming will harm future generations. These worries can induce chronic stress, loss of physical health and well-being, and prolonged despair.[25]

Children's Mental Health

After a natural disaster, children often experience anxiety, fear, sadness, sleep disruption, distressing dreams, irritability, difficulty concentrating and anger outbursts. Young children, under 8 years of age, are at particular risk for these issues. Some children develop disorders like anxiety, depression and PTSD after a disaster, and may be at a higher risk than adults of having long-term symptoms. Significantly more children than adults have continued PTSD symptoms more than two years post-disaster, and, in general, children are more likely to be impaired by a disaster. Children with low socioeconomic status, prior traumas, poor education, and the lack of a support network have increased risk of developing PTSD.[3,26] Children's mental health can also be affected by the mental health of their caregivers. It has been theorized that chronic stress from the acute and ongoing impacts of climate instability may alter biological stress response systems and make growing children more at risk for developing mental health conditions later in life, such as anxiety, depression, and other clinically diagnosable disorders.[3,26]

New York has seen these risks first-hand. Three years after Hurricane Sandy, many children were still experiencing psychological effects, particularly those children whose homes were damaged in the storm. The Sandy Child and Family Health Study conducted by a coalition of university centers and funded by the New Jersey Department of Health found the following:

- Children in hurricane-damaged homes are at higher risk for mental health problems than children whose homes suffered no damage.
- The health effects associated with catastrophic damage to one's home are similar to those felt by people living in deep poverty.
- Mold was significantly associated with both asthma and mental health distress.

Hurricane Sandy and the Developing Brain

Approximately eight months before Hurricane Sandy, a study measured children's brain activity in response to negative and positive emotional images using electroencephalogram (EEG). In a follow-up study, nine months after Hurricane Sandy, 77 children experiencing the highest and lowest levels of hurricane-related stress exposure were re-examined. From pre- to post-Hurricane Sandy, and children with low-stress exposure had decreased their brain reactivity to negative emotional images, but children with high-stress exposure failed to decrease their reactivity to negative images.

The results suggest that Hurricane Sandy-related stress disrupted neurodevelopment in a manner that maintains relatively heightened levels of vigilance to threat. Alterations in the development of neural reactivity to negative information may be one way through which disasters lead to higher rates of psychiatric problems that continue into adulthood.[6]

Children are also at risk from disruptions to the educational system.[21] Natural disasters can damage or destroy schools or make them inaccessible to teachers and students. More than 1.1 million children in NYS were unable to attend school for one week after Hurricane Sandy, due to disruption or direct damage to school facilities.

Health Benefits of Urban Green Spaces

A recent systematic review[27] examined the health impact of urban green spaces and found that lack of access to such green spaces are negatively associated with mortality, heartrate, and violence. Further, they found that exposure to green spaces is associated with better attention, mood, and physical activity. While more research is needed, it has been found that exposure to green spaces may positively impact cognitive development in children[9] and may normalize circadian rhythms and improve sleep[12].

Summary

New York State has seen first-hand, most recently through Superstorm Sandy, that climate change and extreme weather events can negatively affect mental health and well-being. The projected increases in frequency and severity of extreme weather events will put more New Yorkers at risk for depression, anxiety, post-traumatic stress disorder, substance abuse, and even suicide.

Health Co-benefits of Urban Green Spaces

Climate Action: Increase green space and natural space in urban areas.

- Produces shade and reduces noise.[4]
- Provides access to natural light.
- Can include community gardens.
- Reduces exposure to traffic and overcrowding.

Immediate Health Co-benefits:

- Buffers stress.[5]
- Builds sense of community by bringing people into contact with other members.[9]
- Provide contact with nature, an opportunity to be active outdoors.[9]
- Gardens give an opportunity to have better access to produce.
- Enhance attention[9] and potentially improves cognitive development in children.
- Normalizes circadian rhythms and improves sleep.[12]

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2.6 Extreme Weather and Natural Disasters

Section at a Glance:

- *The frequency, intensity and severity of extreme weather and natural disasters affecting New York have increased, leading to high economic burdens and negative consequences for residents and businesses.*

- *These events can result in injury or death, from heat illness, drowning, trauma, disruptions in healthcare services and contamination of water sources.*

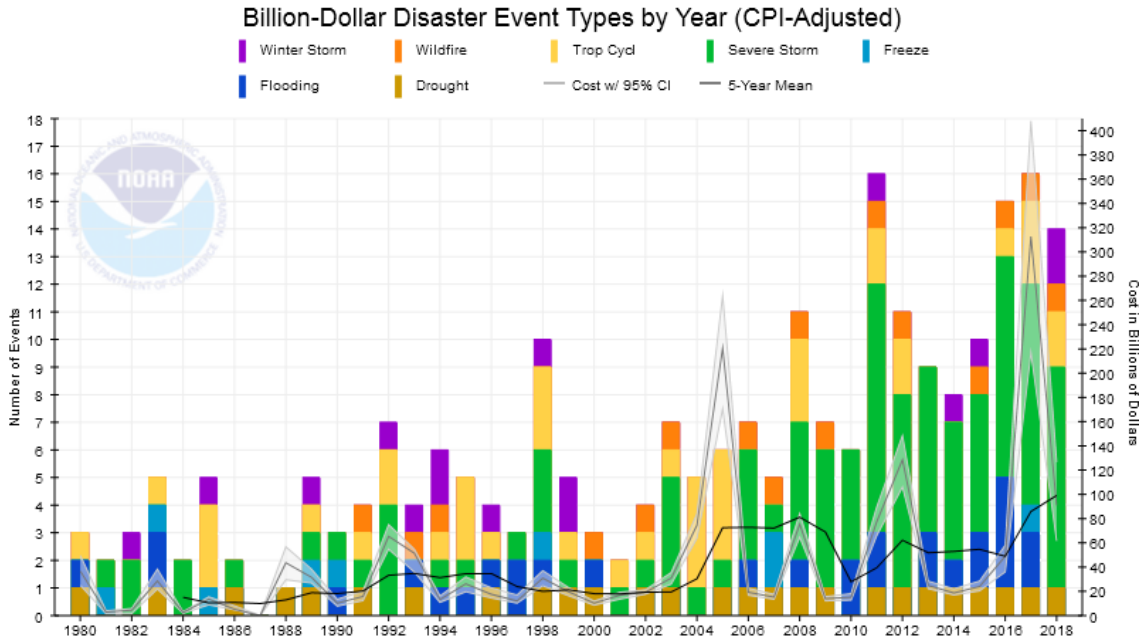

Figure 35: Yearly number of billion-dollar disasters in the U.S. since 1980, adjusted for inflation.[1]

Heat waves, droughts, wildfires, heavy downpours, hurricanes, floods and other extreme weather events have dramatically increased throughout the U.S. over the past two decades. The years 2016-2018 were all historic in the number of billion-dollar disasters that impacted the U.S., totaling 45 separate events for a 3-year average of 15 disaster events/year (Figure 35). The annual average since 1980 is 6.2 events per year. The four most costly years are all in the present decade, with 14 separate Billion-dollar events in 2018 (Figure 36).[2]

Severe Weather Events in New York State

New York has also seen its share of federally declared weather-related disasters, affecting every county in the state with at least one weather disaster. Since September 2010, New York has had 11 weather disasters, including severe storms, tornadoes, floods, tropical storms, snow and ice storms and droughts.[3,4] The most common types of severe weather events in NYS are hurricanes, winter storms, and tornadoes (10/year, on average). According to the Federal Emergency Management Administration (FEMA) disaster records, 84 of the 96 disasters to hit the state since 1954 have been heavy precipitation events[5] The frequency of 2-inch rainfall events has increased since the 1950s, and "100-year storm events" have also nearly doubled in frequency, to almost 1-in-50-year events (Figures 37).[6]

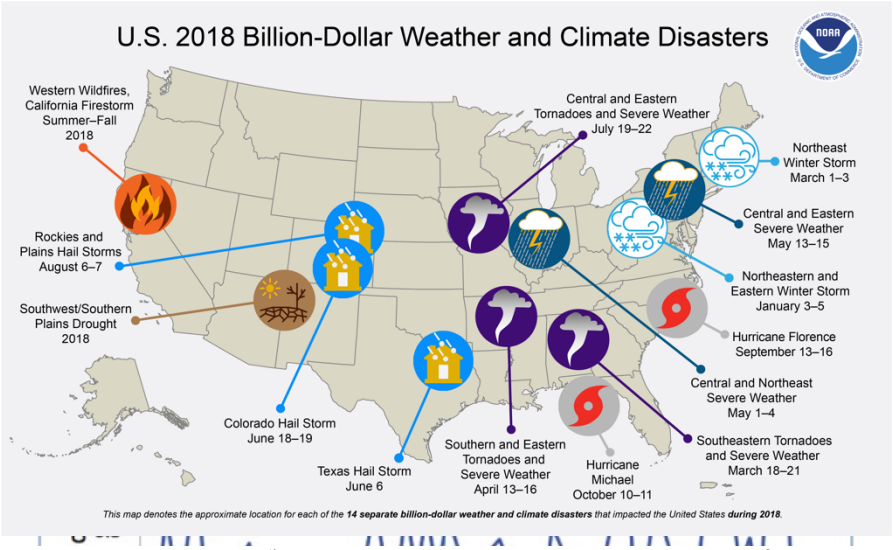

Figure 36: 2018 was the 4th costliest year for natural disasters in the U.S.[2]

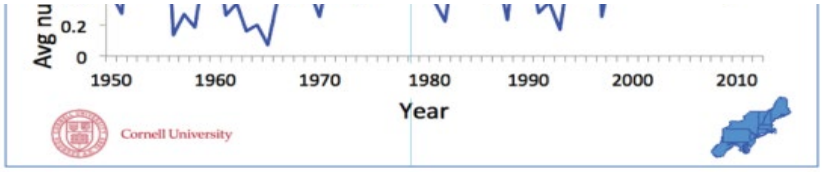

Figure 37: Increase in 2-inch rain events from 1950–2010 across New York State.[6,7]

Between 1851 and 2014, NYS experienced 12 hurricanes, Niagara County and Mohawk Valley flooding in 2013, Long Island Flooding in 2014, and a series of nor'easters which, in 2018, included the biggest windstorm in the mid-Atlantic since Hurricane Sandy. Since 2010, these extreme weather events have caused at least 23 power outages across NYS, some lasting over two weeks in duration. Between 2012 and 2016, 102 deaths and 469 injuries resulted from these hazardous weather events in NYS.

Climate projections predict an even greater burden of extreme precipitation events in New York. These translate to increased public health risks related to flooding, storm surge and severe winter storms, especially in the coastal areas of Long Island and the New York City metropolitan area, impacting access to electricity, transportation and healthcare facilities. In addition to direct deaths and injury from storms, extreme climatic events may be detrimental to population health via trauma-induced mental health impacts (see Section 2.5), impaired ability to manage chronic health conditions, water-borne diseases (see Section 2.4) and disease transmission in shelters.

CASE STUDY: Impact of 2018 Nor'easters The March 2018 series of nor'easters across the Atlantic coast exemplify the damage brought by frequent, intense weather events. The March 1-3rd nor'easter, Winter Storm Riley, produced almost 40 inches of wet, heavy snow in parts of upstate New York, and caused at least 9 deaths, 5 from falling trees. In addition, up to 1.9 million people across the Atlantic lost power, more than 2,900 flights from LaGuardia and JFK airports were cancelled, and Amtrak suspended its Northeast Corridor service. During the two subsequent storms, Putnam County issued a state of emergency, 10 people in North White Plains were taken to the hospital due to carbon monoxide poisoning from a home generator, at least two people were killed in New England, and many school districts across the state were closed. The fourth nor'easter, Winter Storm Toby, produced the heaviest spring snowstorm on record in New York City at rates of over 5 in/hour in New York metropolitan area, and dropping two feet of snowfall in upstate. The storm killed three people and caused power outages for 100,000 people across the North Atlantic coast. Blackouts were prolonged due to utility damage from the heaviness of the snow in Western New York during the fourth storm, which affected health care facilities, at-home treatment, and produced an array of indirect health effects. The series of severe events, hitting consistently week after week in March 2018, hampered recovery across New York.[1]

Injury and Death

Storms and temperature extremes can create physical hazards due to flooding, infrastructure collapse, snow/ice accumulation and flying debris. These hazards increase the risks of drowning, electrocution and physical trauma in impacted areas. Drowning causes a majority of deaths during floods. During Hurricane Sandy, 80% of deaths were due to drowning in storm surge. Urban areas are particularly prone to flooding due to large areas of impermeable paved surfaces.[8]

Certain populations are more vulnerable to risks of injury and death from these extreme events. While such characteristics vary across individuals, households and communities, higher-risk characteristics include, very young or very old age, being homebound, living in poverty, having incomplete plumbing and living in a rural or suburban area without their own vehicle.[9]

Indirect injury may also be caused during the recovery from structural damage. Clean-up and reconstruction efforts, especially amidst unstable infrastructure and new environments can cause additional injuries. Fume inhalation from back-up generators, exposure to newly mobilized pathogens or mold, and physical injury due to demolitions and construction work are common.[8]

Disruption to Healthcare Systems

Disruptions to power and water supplies impact hospital operability. Healthcare systems rely heavily on public transportation infrastructure, which can be disrupted by a disaster. In best-case scenarios, extreme weather makes daily operations more difficult, requiring more staff for protective preparation and handling backup equipment; in worst-case scenarios, patients must be evacuated and facilities closed.

During Superstorm Sandy, despite preparation by discharging patients before the storm hit, hiring of extra staffers and placement of flood barriers, hospitals experienced significant disruption. In New York City, the Manhattan campus of the Veterans Affairs New York Harbor Health System, Coney Island Hospital and New York Downtown

Hospital had to close, as did 26 additional residential care facilities, resulting in the evacuation of more than 6,400 patients.[10] Further, 215 patients, including critical care infants, were evacuated when New York City's East River flooded electrical generators and fuel tanks in the basement of NYU Langone Hospital. NYU Langone remained closed for two months and sustained $1 billion in damages.[11] Evacuation of 725 patients occurred at Bellevue Hospital when basement fuel pumps flooded and failed to provide fuel to the back-up power generator. While no patient died during Hurricane Sandy, patients requiring emergency transfer are at high risk during an evacuation.

During an extreme climatic event, healthcare-related facility closure may exacerbate chronic conditions that require frequent and timely treatment, including diabetes, asthma, renal and cardiovascular diseases. Medical centers, primary and mental healthcare clinics, hospitals, and pharmacies on which such patients rely may have to be closed. Even brief lack of access to medication, treatment delay and care interruptions represent health risks to these vulnerable populations.[9] During disasters and in their aftermath, the number of patients requiring assistance can strain emergency medical services and delay care.

Utility Outages, Water Sanitation and Sheltering in Place

Utility Outages: Utility outages often occur due to damage of infrastructure during extreme weather events. Extended power outages are linked with increased mortality rates (see Section 2.1).[12] Without electricity, it becomes difficult to refrigerate food and medication, control the interior climate and pump water to top floors of high-rise buildings. Medical support equipment, such as medication nebulizers and home ventilators, also require electricity to function.[13]

Improper refrigeration increases the risk of food poisoning. During the 2003 blackout in New York City, an outbreak of diarrheal illnesses was linked to meat and seafood consumption after the blackout.[14] The inability to control interior climate can impact respiratory conditions or cause dangerous behaviors in attempts to heat a home. In the three days after Hurricane Sandy, 10 people were killed and at least 188 were admitted to emergency departments across NYS as a result of carbon monoxide poisoning.[15]

Water Sanitation: During an extreme precipitation event, local water quality and the septic system can be compromised. Heavy rainfall can alter runoff patterns and mobilize pathogens in both surface and groundwater water sources used for drinking and recreation, leading to outbreaks associated with pathogens such as *Giardia*, *Cryptosporidium* and *E. coli*. In the continental U.S., more than half of water-borne disease outbreaks occur after extreme precipitation events, and emergency room visits for acute gastrointestinal illness increase after a heavy rainfall (see Section 2.4).[16]

Chemical toxins from industrial or contaminated sites, including asbestos, pesticides and heavy metals, may also be mobilized during an extreme precipitation event. Storm waters can contain a variety of chemicals, depending on the area. Runoff from highways and roads may contain typical pollutants from traffic such as PAHs, hydrocarbons and heavy metals, while runoff from rural areas may include pesticides.

Industrial areas may contain pharmaceutical residues, asbestos, heavy metals, or other chemical compounds depending on land use.[17]

Each type of water contamination has a variety of impacts on health. In most of NYS's urban areas, cross-contamination between septic and water systems are not a threat to water quality. However, septic systems can be overwhelmed with storm waters, causing outflow to street-level drains and building basements, especially in low-lying areas. Exposure to sewage water can increase health risks of bacterial infection. Large levels of precipitation may also remobilize chemical sludge accumulated in sewers and rivers.[17]

After floodwaters recede, environments may favor growth of molds and fungi. Outdoor mold spores irritate the respiratory system and can cause allergic reaction. Indoor mold as a result of flooding is associated with coughing, sneezing and childhood asthma.[18] Notably, due to the large amount of resources in NYS and the U.S. as a whole, spread of communicable diseases following a flood has not been an issue.

Shelters and Sheltering in Place: In anticipation of an adverse weather event, populations are often ordered to evacuate from zones that will be severely affected. Failure to comply may lead to direct death or injury from storm, yet an alarming number of people do not evacuate despite orders**.** Only 49% of residents in South Brooklyn, the Rockaways, and Staten Island evacuated at any time during Hurricane Sandy. Evacuation was higher among those that who witnessed trauma related to World Trade Center attacks (66% vs. 40%). Evacuation was higher after the storm by those with substantial household damage. Evacuation before the storm was lower among residents living on higher floors (56% vs. 22%) and those with disabilities (figure 38). Such low rates of evacuation are critically important in estimating health risks and assessing health impacts from climatic events.[19]

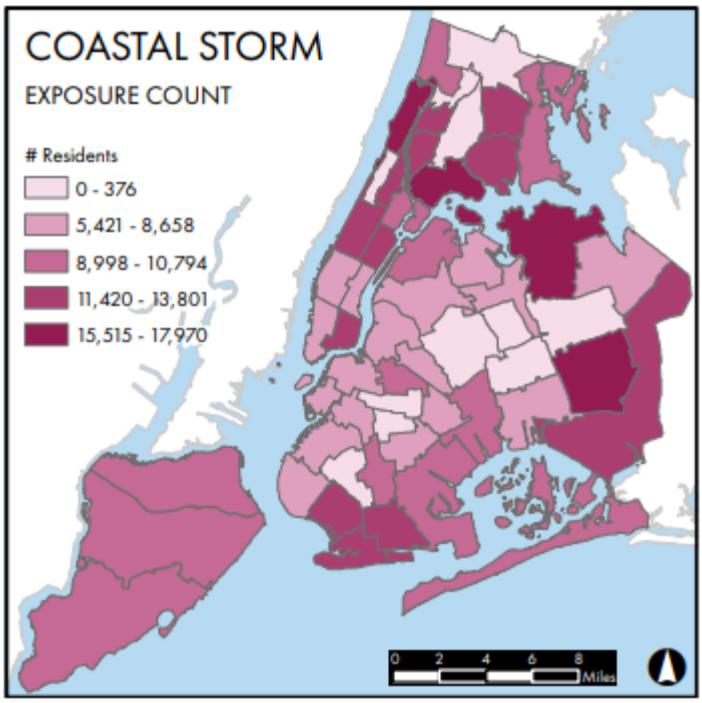

Figure 38: Number of residents living in a coastal storm evacuation zone and having a disability by neighborhood. People may be ordered to evacuate, yet having a disability makes it difficult.[9]

While residents sheltering in place are a source of injury and mortality concern, populations evacuated to shelters are also exposed to numerous health risks.[20] Sanitary conditions in a shelter after disaster may affect transmission of infectious disease within the shelter. Non-residential facilities, such as stadiums and churches, are not designed for sanitary conditions in such a

situation, and often have limited bathing, toilet, bed space and food preparation facilities. Evacuees and shelter workers may have open wounds, infections or incubating infectious disease. During Hurricane Katrina, a random sample of 4,000 sheltered evacuees showed 50% arriving with some symptoms of an acute illness.[21] Risks of transmission are increased by the potential for limited physical space and suboptimal sanitary infrastructure. Respiratory illnesses, diarrheal illnesses and skin infections are all at high transmission risk in shelters.[22]

People displaced to shelters, especially for extended periods of time, may have special health needs. Elderly individuals evacuated from nursing home facilities, patients evacuated from hospitals, and those with chronic health conditions all pose unique challenges to ongoing treatment once they arrive in a shelter. Chronic disease management is disrupted due to inadequate medication supplies, lack/loss of medical records containing names and dosages, poor patient knowledge of medications, and lack of regular care.[23] Access to electronic medical records through regional health informatic organizations (RHIO) in NYS may mitigate care barriers related to insufficient patient knowledge and lost records.

After an extreme weather event, mental health concerns like depression and PTSD, which are common after natural disasters (see Section 2.5), can be exacerbated by closures of mental health facilities or interruptions in a patient's general mental health care routine. An analysis of 1,165 displaced individuals after Hurricane Sandy showed that displacement caused higher risks of depression, anxiety and PTSD symptoms, as opposed to those who were not displaced. Staying in an emergency shelter, as opposed to staying with family or friends when displaced, significantly increases the odds of having PTSD symptoms.[24]

Summary

Severe weather events and natural disasters impose significant health, property, and financial losses across New York. Such events will increase in frequency and severity, bringing substantial physical and mental health consequences for New Yorkers, especially those along New York's coastline. Chronic disease management during loss of infrastructure as well as mitigating health risks in public shelters will be an important part of climate-related planning. As the severity and frequency of extreme events increase, public health concerns will broaden for conditions associated with loss of infrastructure and with sheltering.

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2.7 Food Security and Nutritional Impacts

Section at a Glance:

- *The warming climate, extreme weather events and natural disasters are negatively affecting New York's crop yields and fishing production.*
- *Climate change can make foods less nutritious.*
- *Many New Yorkers already face food insecurity; this status is expected to worsen as increasing climate instability disrupts food supply[1].*

Consumption of a wide variety of nutritious foods, particularly from plants, forms a foundation for good health. Climate change will affect New York's own abundant food sources, in addition to America's domestic and international food supply.[2]

NYS is one of the top five states for agricultural products and the dominant agricultural state in the Northeast, including dairy, cattle, produce, beer, wine, and others (Figure 39).[3] Agriculture in NYS has a significant economic impact, farming alone led to $5.4 billion in sales in 2016.[4] Including contributions from support and processing industries, the total estimated economic impact of agriculture on the state's economy was $37.6 billion in 2011.[4] Additionally, New York's fresh and marine water fisheries are important sources of fish and shellfish. Fisheries are already experiencing stressors which will be worsened by climate instability[5].

	Sales (Millions)	Share of Total	U.S. Rank
Milk from Cows	$2,528	47.1%	3
Grains, Oilseeds, Dry Beans, Dry Peas	$572	10.6%	28
Cattle and Calves	$426	7.9%	31
Fruits, Tree Nuts, and Berries	$400	7.4%	7
Nursery, Greenhouse, Floriculture and Sod	$386	7.2%	10
Vegetables, Melons, and Potatoes	$379	7.1%	12
Other Crops and Hay	$363	6.8%	12
Poultry and Eggs	$195	3.6%	29
Horses, Ponies, Mules, and Donkeys	$34	0.6%	9
Hogs and Pigs	$25	0.5%	30
Other Animals and Other Animal Products	$23	0.4%	20
Sheep, Goats, Wool, Mohair and Milk	$18	0.3%	15
Aquaculture	$13	0.2%	24
Christmas Trees and Woody Crops	$9	0.2%	8
TOTAL	**$5,369**	**100.0%**	**27**

Source: U.S. Department of Agriculture
Note: Totals may not add due to rounding.

Figure 39: New York agriculture commodities by sales, 2017

Climate-related Effects on Food Quantity, Nutritional Content and Contamination

It is uncertain how much global warming and climate instability will affect the foods available to New Yorkers, whether the foods are sourced locally, domestically or internationally. Some estimates project that for every degree Celsius increase in global temperature, there will be a 5 to 15 percent decrease in overall crop production.[6] Under heat stress, livestock are less fertile and more vulnerable to disease, and dairy cows produce less milk (see Section 1.3).

Further, although rising CO_2 can stimulate plant growth, it also reduces the nutritional value of most food crops. Rising levels of atmospheric carbon dioxide reduce

the concentrations of protein and essential minerals in most plant species, including wheat, soybeans and rice. This effect of rising CO_2 on the nutritional value of food is a potential threat to human health.

Pesticides and other contaminants also create a threat to human health. We are experiencing increased exposure to pesticides due to both increased pest pressures and reductions in the efficacy of pesticides.[7] Many fish are contaminated with mercury, which can lead to birth defects, impaired vision and memory in adults. Mercury levels in the Adirondacks and Catskills are high and is understood to result from emissions into the air primarily from coal-fired power plants that falls with rain or snow into waterways, and then bio-accumulates in fish. Even a small amount of mercury in a 25-acre lake is enough to make the fish unsafe to eat.[8]

Climate-related Interruptions to Food Distribution & Food Insecurity

Any climate-related disturbance to food distribution and transport may reduce the safety and quality of food, but also can reduce access to food. Increasing temperatures can cause spoilage and contamination.[7] Interruptions in food supply leading to spikes in food prices after extreme weather events are expected to be more frequent in the future. Similarly, climate instability will likely alter the quantity of produce available for export and import, thereby affecting prices and the global balance of agricultural commerce.[9]

Food insecurity, or lack of access to enough nutritious food for an active, healthy lifestyle, is already a significant health concern in the state, particularly among youth.[10] Currently 12% of New York households face food insecurity.[11] It is expected that climate instability will contribute to further food insecurity. Food insufficiency among children leads to worse academic performance and malnutrition.[12]

Food Systems' Impact on Climate

Food systems have substantial impact on the health of the environment. Food production is a significant emitter of greenhouse gases (GHG) and contributes to environmental degradation. Agriculture (inclusive of meat and dairy) is responsible for about 25% of all GHG emissions, occupies about 40% of the Earth's surface and uses 70% of all freshwater resources. (See figure 40) In particular, livestock production accounts for an estimated 14.5% of global GHG emissions that result from human activities.[13] Food production itself will need to become more sustainable and low-carbon.

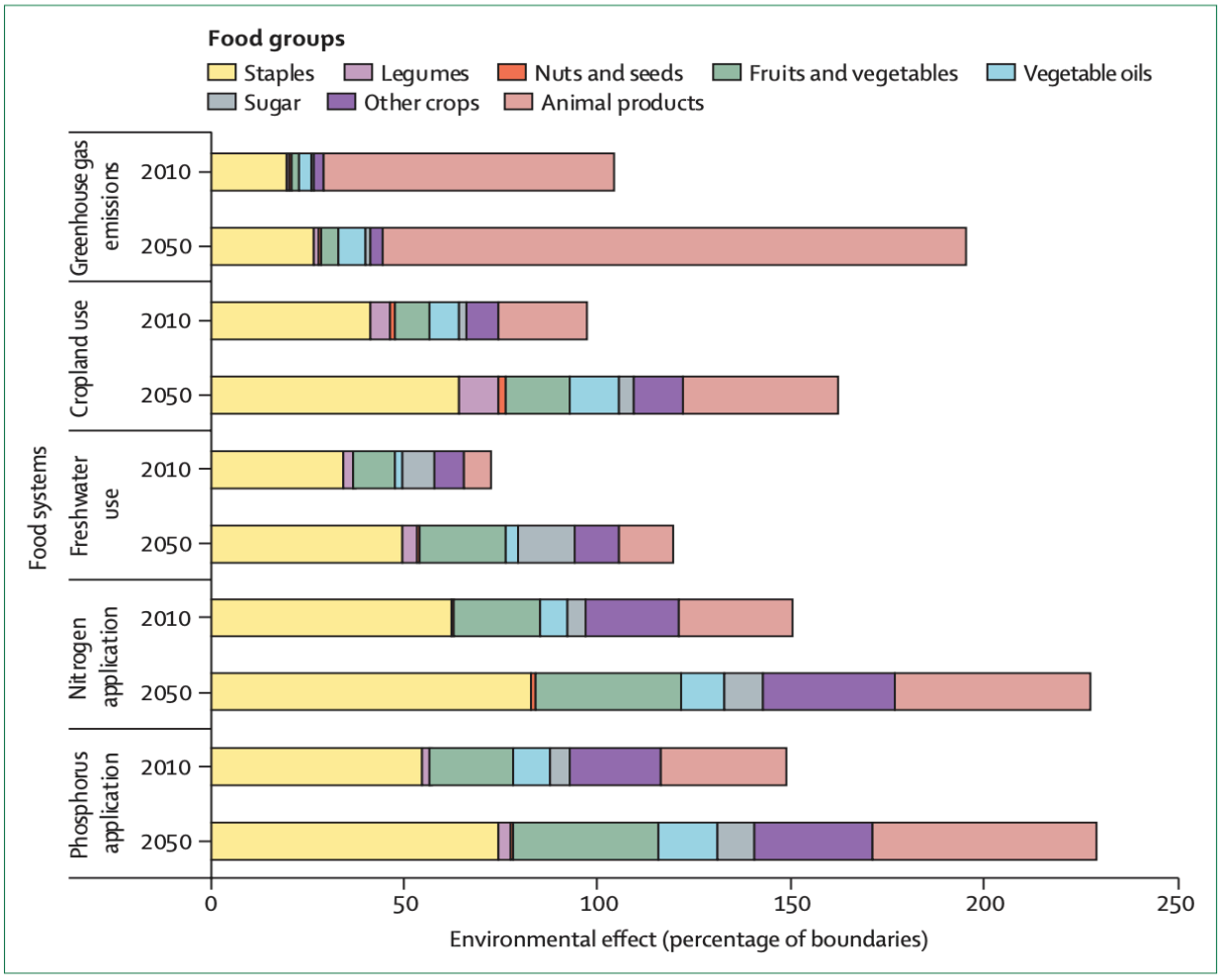

Figure 40: Environmental impact of each food group.[14]

In the U.S., red meat (beef, pork, lamb) and dairy production together account for nearly half of the GHG emissions associated with the food supply chain.[13-16] The single largest share of livestock-related GHG emissions (39%) is from enteric fermentation, which releases methane as a byproduct and most of which is released via eructation (burping). Other major sources include manure (26%), which emits methane and nitrous oxide, feed production (24%) and clearing forests for feed crops and pastures (9%).[13]

These statistics have prompted calls for Americans to reduce their reliance on meat and dairy production, in order to limit the amount of GHG generated in livestock farming. If global meat and dairy consumption increase in parallel with the global population as it increases to 9.6 billion, emissions from food production alone would lead to severe consequences for people, public health, economies and ecosystems.

<u>Plant-based diets with less meat consumption</u>

Diets that are high in plant-based foods and low in animal-based foods not only provide significant health benefits, but also have environmental benefits including more efficient use of land, water, nitrogen and other resources.

- Grass-fed or pastured-grazed livestock offer health, ecological and animal welfare benefits compared to conventional animal products, but do not offer significant climate benefits.
- Eating local or regional foods produced in-season can lower carbon footprints because they are typically produced and transported with a lower climate impact.

Benefits of a Whole Food, Plant-based Diet

Worldwide adoption of a plant-based diet could reduce food-related GHG emissions by up to 70% by 2050. Shifting towards a more plant-based cuisine is a simple and effective measure to reduce climate instability. Shifting to lower livestock production could also free up valuable arable land that could be made available for crops grown for direct human consumption.

Whole-food, plant-based (WFPB) diets are also beneficial for human health. Benefits include[17]:

- Reduced coronary artery disease (CAD) – evidence indicates that CAD can be stopped or even reversed when adopting a WFPB diet.
- Protein- and nutrient-rich foods – daily protein needs can be met from plant sources without any adverse effects.
- "Good" carbohydrates – healthy sources of carbohydrates, including include fruits, vegetables and whole grains, can be consumed without spikes in blood glucose levels.
- Fiber-rich foods – consuming greater amounts of fibers found in plant-based foods aids digestion and promotes feelings of fullness.

A number of national organizations now promote WFPB diets as part of a healthy lifestyles, including the USDA, American Cancer Society, the American Institute for Cancer Research, the Academy of Nutrition and Dietetics, the American College of Preventive Medicine, and the American College of Lifestyle Medicine.

<u>New York Food Waste</u>

Food waste composes roughly 18% of the waste stream in New York State[18], and roughly 20% of the waste stream in New York City.[19] Approximately 3.9 million tons wasted food from New York makes its way into landfills each year[20], where it decays and contributes substantially to GHG production.[21] The U.S. EPA and U.S. Department of Agriculture have called to reduce food waste by half by 2030. Interventions to reduce wasted food in higher-income countries should focus on the consumer, including expiration date labeling and quality standards, improving shopping/eating practices and controlling market supply.[22,23]

<u>Summary</u>

New York already experiences negative consequences on its agriculture and fisheries from a warming climate. As climate instability worsens, our farmers and fishers will increasingly be impacted, as will our food supply. These changes are expected to worsen conditions for New Yorkers, who will face increasing challenges in food security. Lastly, an over-reliance on animal-based and processed foods contributes both to poor health among New Yorkers and to GHG emissions.

Health Co-benefits

Climate Action: Promote transition to whole and plant-based foods and reduce consumption of animal-based agriculture.

- Reduces GHG emissions, particularly methane.
- Reduces antibiotic resistance, water contamination and pesticide use.

Immediate Heath Co-benefit: Decreased consumption of animal products and increased consumption of plant-based foods prevents disease.

- Reduces risk of obesity, cardiovacular disease, stroke, diabetes and some forms of cancer.

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2.8 NYS Healthcare Systems and Climate Instability

Section at a Glance

- *Healthcare systems in New York have experienced severe consequences from climate-related disasters, including infrastructure damage, closures, and mandatory patient evacuations, creating a high economic burden for New York's economy.*
- *Projections for sea-level rise and increased precipitation necessitate climate-based preparedness planning for health system infrastructure.*
- *Health systems are major contributors to GHG.*

New York State has the third-largest economy in the U.S., trailing only Texas and California, and would rank as the 15th or 16th largest economy in the world if it were a country. After the financial services sector, the healthcare sector is the biggest contributor to New York's gross domestic product.[2] In 2017, there were 172 hospitals in the state,[3] 59 of which are located in the New York City metro area.[4] As of 2017, six of the top ten private employers in New York State were healthcare organizations.[1]

Top 20 Private Employers in New York State as of 2017[1]

Full-time equivalent employees located in the state

Rank	Company Name	NYS Employment
1	Northwell Health	54,000
2	Montefiore Health System	32,000
3	Mount Sinai Health System*	29,000
4	Walmart*	28,000
5	NYU/NYU Langone Medical Center	27,000
5	University of Rochester & Affiliates	27,000
5	Verizon NY Inc.**	27,000
8	JP Morgan Chase**	25,000
8	Citigroup Inc.**	25,000
10	New York Presbyterian	20,000

The healthcare sector's role in addressing climate instability is three-fold: 1) meeting increased demands for climate-related health and medical services; and 2) as businesses and employers who must manage climate-related risks to protect their infrastructure, patients, workforces, supply chains and bottom lines; and 3) as significant and unchecked contributors to global warming and climate instability through greenhouse and non-greenhouse gas pollution.

Healthcare Delivery Sector and Preparedness

The vulnerability of healthcare infrastructure to extreme events such as hurricanes, floods and blackouts has been demonstrated repeatedly in NYS (see Section 2.6).[5] Many communities are proactively planning for more storms and floods by creating climate-resilient infrastructure capable of functioning in disaster conditions (see Case Studies). Adaptation planning to buffer against future disasters will be an essential task for healthcare facilities throughout the state. Yet, aging buildings (the average age of an acute care hospital in the U.S. is 31 years) and location of many healthcare facilities near coastal water and rivers represent significant risks.[6] In 2014, the U.S. Department of Health and Human Services published guidance to help hospitals understand how to best prepare to protect buildings and other infrastructure during weather disasters but there are no mandatory requirements that health systems incorporate the totality of climate risks when planning development of infrastructure or healthcare delivery operations.[7]

CASE STUDIES: Hospital Infrastructure in a Changing Climate

1. Hospital Flood Protection: Flood mitigation measures keep critical facilities operational during major storm events.

   Our Lady of Lourdes Hospital in Binghamton suffered over $20 million in losses when the Susquehanna River flooded in the summer of 2006. With funding from FEMA, the hospital constructed a flood wall around the hospital. In September 2011, following Tropical Storm Lee, the flood wall was tested when the Susquehanna River flooded once again and devastated many parts of Binghamton. The hospital was able to remain fully operational. The flood wall cost approximately $7 million and was built over a period of five years.[3]

2. Planning appropriate locations for critical mechanical and power systems.

   New York City's Bellevue Hospital, which serves more than 500,000 patients annually, was forced to close temporarily and move patients when Hurricane Sandy struck in 2012. When it rebuilt, many of the replacements for flooded electrical and mechanical systems were positioned on higher floors, and the hospital's emergency power system added a generator to reduce dependence on the city's grid.

Improving infrastructure alone will not be adequate to meet the health needs related to growing climate instability.[8] Planning must also incorporate the following: 1) educating a healthcare work force capable of addressing climate-related health impacts; 2) creating disaster-resilient communication between hospitals and emergency responders; 3) innovation of climate-resilient and sustainable healthcare products and technologies; 4) anticipating and mitigating disruptions to health services (e.g. supply chains) in extreme weather events and other emergencies, potentially including civil unrest; 5) improving integration between health care systems, city, state, and public health planners aimed at addressing climate-specific concerns; and 6) increased research aimed at understanding climate-related health, workforce, and infrastructure vulnerabilities to inform planning.[8]

Currently there are no healthcare industry best practices or standards that address climate-related planning across the broadest spectrum of needs. There is wide variation in academic medical centers and medical educators in efforts to integrate climate-related research, curriculum, and training of allied health professionals. While no leadership has emerged amongst U.S.-based healthcare systems, numerous countries around the world are developing whole-country "climate-smart health systems" aimed at addressing the climate-related stresses that can undermine the provision of health care.[9]

Many healthcare providers experienced difficulties in commuting to hospitals in the aftermath of Hurricane Sandy.[10] Healthcare systems have already seen how climate instability can threaten their supply chain: in 2017, when Hurricane Maria struck Puerto Rico, power was lost to Baxter International's three saline and nutrient IV bag-manufacturing plants resulting in shortages that created difficult clinical situations throughout the country requiring healthcare providers to cut back on use and improvise new ways to treat patients. Disruptions from Maria also resulted in shortages of approximately 40 other critically important medicines.[11] Many large corporations are

now using climate-risk modeling to plan for infrastructure damage and supply chain and work force disruptions. New York State health systems should do the same (e.g., [12]).

Healthcare Delivery Organizations among Top Polluters

The U.S. health care delivery industry consumes vast resources, the majority of which becomes waste—nearly 7,000 tons of hospital waste is created daily. The health care delivery sector is responsible for 10% of all GHG emissions, 12% of acid rain, 10% of smog formation and 9% of criteria air pollutants such as carbon monoxide as well other pollutants with direct harm to human health (Figure 41)[13]. Collectively, these lead to indirect health burdens commensurate with the 44,000 to 98,000 hospital deaths each year from preventable medical errors[14].

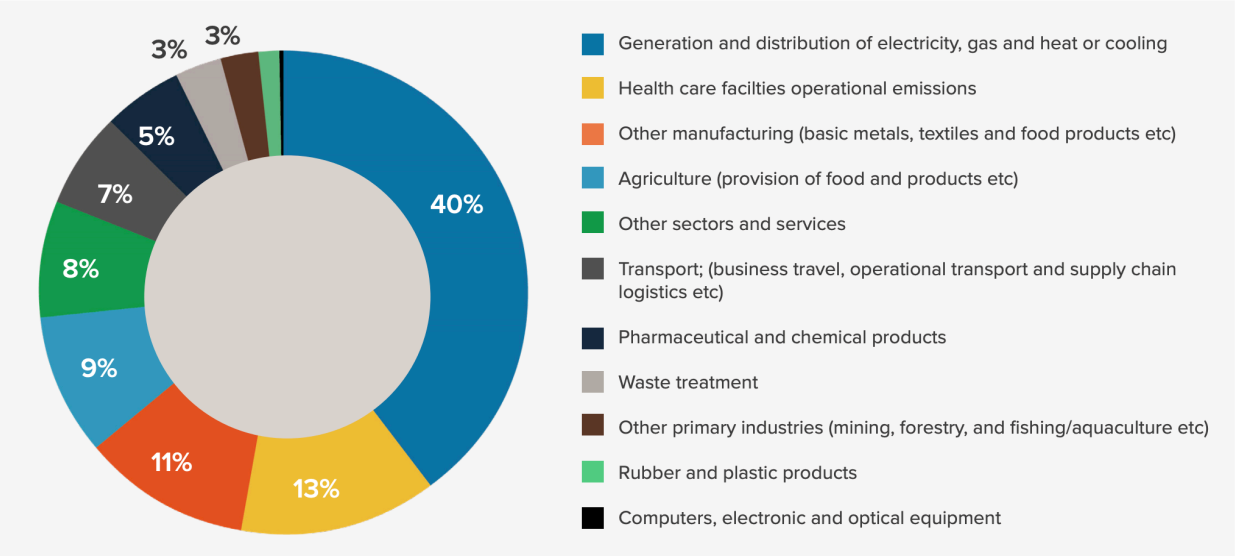

Figure 41: Global health care emissions split by production sector[13].

Health care facilities are among the country's most energy-intensive buildings. Hospitals use 836 trillion British thermal units (BTUs) of energy every year, have more than twice the energy intensity and carbon dioxide emissions of commercial office buildings, and produce more than 30 pounds of carbon dioxide emissions per square foot.[6]

Reducing GHG and non-GHG pollution should be a key objective for healthcare organizations for a few key reasons[15]:

1) Energy efficiency saves money, which can bolster thin operating margins;

2) Reducing emissions helps mitigate climate instability and global warming; and

3) Reduced emissions would improve human health which the central mission of all healthcare activities.

In New York City, the Mayor's Carbon Challenge was launched in 2009 as a voluntary initiative aimed at reducing GHG emissions from private, non-profit and institutional sectors, with a goal of reducing citywide emissions 80% by 2050. The city's 9 largest hospitals signed the initiative, but not all have committed to the 2050 goal. At the start of the Challenge, hospitals' aggregate energy use intensity (EUI) was nearly twice that of the colleges and universities, because of more sophisticated heating ventilation and air conditioning systems, more energy-intensive medical equipment and longer operating hours. By 2016, the participating hospitals increased in size by 19 percent, adding over 9.6 million square feet and growing their total square footage. Simultaneously, absolute source energy from the hospitals remained close to constant, reducing their source energy use per square foot by 16.3%. This resulted in a reduction of GHG emissions by more than 5% and a reduction in GHG emissions per square foot by more than 20%. Based on utility consumption, it is estimated that the participating hospitals are now saving over $60 million per year in reduced energy costs.[12]

Despite these achievements, the healthcare sector lags far behind many other economic sectors in reducing GHG emissions and waste, or in creating plans to address climate-related needs. Corporate sustainability reporting of large healthcare corporations lags all other economic sectors in transparency about the environmental footprint of their business operations. Most large corporations, both private and public, publish sustainability reports detailing their current carbon emissions, goals for reductions and corporate plans to mitigate and manage climate change. To date, no large New York State healthcare organization or hospital has published a corporate sustainability report or reported annual emissions to a third party aggregator such as the Carbon Disclosure Project.[14]

Summary

Systems of healthcare delivery have been severely impacted by climate-related events in New York State. Resilience to future events will depend on a re-examination of planning and preparedness using climate-risk modelling. Healthcare facilities are major contributors to GHG and non-GHG gas pollution and sector wide reductions should be

Health Co-benefits

Climate Action:

- Reduce GHG and non-GHG pollution stemming from healthcare delivery activities.
- Enhance climate-risk informed healthcare delivery through research, education and planning.

Immediate Heath Co-benefit:

- Reduces negative impacts on human health
- Reduces risk of disruption during extreme events.
- Reduces numerous acute and chronic health conditions.
- Maximizes the mission of all healthcare delivery activities—the improvement of human health.

mandated to reduce health impacts and reduce costs. Effective strategies for addressing climate change should become an essential attribute of high-performing health systems in NYS and the U.S.[14]

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Summary and Conclusion

The Medical Society of the State of New York concurs with the scientific community that the Earth is experiencing global warming and climate instability brought on by the emission of greenhouse gases from the burning of fossil fuels and other human activities. Global warming is causing sea level rise and New York State has become warmer, wetter and experiences more extreme weather events. New York's healthcare delivery systems and infrastructure have been repeatedly stressed by severe weather events, Hurricane Sandy. These changes have adverse effects on society, the economy and eco-systems on which New Yorkers rely for food and water. Health effects of climate change include an increase in tick-borne illnesses, allergies, heat-related illness including exacerbations of respiratory and cardiovascular disease. Increases in extreme weather events are also associated with increases in injuries, fatalities, and worsened mental health. New York's most vulnerable are suffering disproportionately including the elderly, children, farmers, low income communities, racial and ethnic minority groups.

Additional increases in temperatures and climate instability are inevitable and are serious threats to the health and well-being of all New Yorkers. If current emission trends continue, New York State may warm by 1.5ºC by 2050 and 3ºC by 2100. The health consequences of such warming would be substantial and potentially catastrophic even with adaptive measures. Even if emissions are curbed and warming is kept at 1.5ºC, New York State will still face more heat waves, extreme weather and potential disruption of agriculture and food production that will adversely impact the economy as well as the health and safety of our citizens.

Events that might overwhelm the capacity to provide healthcare cause the deepest concerns. Warming beyond 1.5ºC would greatly increase the likelihood of catastrophic events, so precautions must be taken to prevent worst-case scenarios. The medical community must assume a leadership role, educating society about the need to act on the drivers of global warming to prevent the escalating threats to health and well-being. Therefore, the Medical Society endorses the principle that GHG emissions from all sources must rapidly and dramatically be reduced.

Action by every sector of society will be necessary to meet the challenges ahead. Pessimism, fear, doubt and denial are all understandable reactions to a challenge of this magnitude. Indeed, the task is daunting, but it is not unachievable. Moving away from fossil fuels will bring many advantages, particularly for human health and well-being. MSSNY seeks to increase awareness of the co-benefits associated with sustainable energy sources including decreased cost of maintenance and increased resilience of operations. It should be widely known that incremental reductions in air pollution from fossil fuels has an equally significant improvement in human health and savings in healthcare costs. MSSNY provides the following recommendations for key stakeholders on taking concrete actions in a unified and effective response to climate change.

Recommendations for Everyone

There are actions that each and every person and organization can do to improve their own health and well-being, and to prevent climate change. These include:

- Reducing consumption of animal products and increase consumption of whole food plant-based meals, for both heart-health and reducing carbon footprint.
- Increase one's own use of green spaces and active transportation (walking, cycling, etc).
- Increase use of renewable electricity generation and reduce use of carbon-powered machines and vehicles.
- Reduce the use of carbon-based energy to power home heating/cooling; and

Recommendations for Physicians

Physicians can assist by helping to inform patient populations on how to protect themselves from climate-related health risks, such as:

- Provide at-risk patients with information about heat-related illnesses, the protective effect of air conditioning, how to receive heat-event alerts, and how to locate cooling centers.
- Provide education for at-risk patients (e.g. COPD, cardiovascular disease, asthma) on health risks related to air pollution and ozone, advise them on how to find and use the Air Quality Index, and what to do when air quality is poor;
- Provide at-risk patients (e.g. allergic rhinitis, asthma) with information on aeroallergens, how to access and act on pollen count and air quality measures, and strategies to control indoor air quality (e.g. HEPA filters); and
- Provide encouragement to all patient populations to undertake preparation and contingency planning (e.g., evacuation routes, safe shelters) for extreme weather events.

Recommendations for Healthcare Organizations

Healthcare organizations can lead the healthcare sector in reducing our carbon footprint, and in protecting healthcare infrastructure from climate-related risks. Actions healthcare organizations can take include:

- Determining baselines and developing goals aimed at reductions of carbon emissions through sustainability metrics (e.g., GHG emissions, waste generation, recycling, environmentally preferable purchasing);
- Incorporating climate-related risks specific to each organization's location (e.g., heavy precipitation, floods, surge capacity during heat events), to guide resilient planning for buildings, facilities, and personnel.

- Implementing climate instability preparedness training for personnel (e.g., under-graduate, post-graduate, and allied health workforce training programs);
- Provide financial and other incentives that encourage climate-friendly actions by employees (e.g., showers for bicycle commuters, communication platforms for encouraging or ride-share, and enabling parking benefit cash-out); and
- Encourage hospitals and health networks to include sustainability and climate change mitigation in their Community Health Needs Assessment (CHNA) initiatives.

Recommendations for MSSNY Actions

- MSSNY should join with the American Medical Association to support the Clean Air Act to reduce GHG emissions.
- Encourage healthcare facility initiatives to reduce carbon footprint through energy conservations, waste reduction, recycling and sustainable procurement.
- Advocate for climate mitigation and adaptation policies that incorporate health equity and environmental justice that protects vulnerable populations (e.g. urban and rural poor. Native American communities.
- Call for research funding to better understand climate change related health outcomes, including epidemiological, translational, clinical and basic science.
- Advocate for medical education to include climate change impact on health.
- Support green spaces, green building design, safe active transportation, whole food plant-based diets and renewable electricity generation.

Recommendations for Legislature

The New York State Legislature should take the lead in acting to prevent climate change. New York can:

- Accelerate efforts to implement the Climate Leadership and Community Protection Act (CLCPA) ensuring a rapid and just transition to a 100% renewable economy in New York State.
- Provide funding to assist hospitals and healthcare institutions to reduce GHG.
- Adopt occupational safety standards to protect outdoor workers from heat and climate related impacts.
- Facilitate plant-based menus and reduce subsidies for livestock.
- Fund the creation of more green spaces (e.g. planting trees) reducing urban heat-islands (e.g. green roofs), and building design standards that reduce heat load (e.g. passive ventilation).

Recommendations for Non-governmental Organizations

Non-governmental organizations should continue to lead New York in acting to prevent climate change. Such support can include:

- Collaborating across multiple sectors and interest groups (e.g. architecture, energy, philanthropies, children's environmental health, environmental justice and transportation to mitigate and adapt to climate change.
- Incorporating climate-related risks specific to each organization's location (e.g. heavy precipitations, floods, surge capacity during heat events), to guide planning for buildings, facilities and personnel.
- Implementing climate instability preparedness training for personnel (e.g. undergraduate, post-graduate and allied health workforce training programs.
- Provide financial and other incentives that encourage climate-friendly actions by employees (e.g. showers for bicycle commuters, communication platforms for encouraging ride-share or enabling parking benefit cash-out).
- Encourage hospitals and health networks to include sustainability and climate change mitigation in their Community Health Needs Assessment (CHNA).
- Promoting consumer/business programs, advocating for and facilitating active transportation (walking, cycling, etc.) encouraging the modification of fleet vehicles, advocating for green building design and reducing carbon intensive consumption (e.g. less meat, less waste, supporting local produce and eliminate bottled water.