Population Vulnerability to Climate Change in New York State

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Population Vulnerability to Climate Change in New York State

Final Report

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Abstract

According to the ClimAID assessment,[1] climate change will lead to increased precipitation, warmer temperatures and more frequent and intense extreme heat events (EHEs) in New York State (NYS). Extreme heat and EHEs have been found to be associated with increased incidence of mortality and morbidity especially among vulnerable populations.

Considering the predicted change in climate, this study identified vulnerability to extreme heat across NYS and assessed the future impact of heat on health by 1) identifying factors that impact population vulnerability to extreme heat, including individual sensitivity (health risk) and community characteristics to help construct a heat-vulnerability index for NYS; 2) conducting a heat-health impact assessment using ClimAID climate projections[1] (observed temperature trends and future temperature projections developed by Columbia University for seven regions across NYS); and 3) assessing the adequacy and accessibility of cooling centers and the public's awareness of cooling centers and heat warning systems in NYS. The NYS Department of Health (DOH) will incorporate study findings into the NYS Environment Public Health Tracking (EPHT)[2] program website and disseminate results to local public health and county emergency management agencies to develop new or supplement existing heat adaptation planning.

Keywords

Heat vulnerability, climate projection, health impact, vulnerability index, extreme heat, climate change, and cooling centers

Acknowledgments

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We would also like to thank the following agencies for their expertise and assistance in various aspects of the project: State of New York's Local and Regional Health Departments, the State and County Offices of Emergency Management, New York State Association of County Health Officials (NYSACHO), NYS Office of Health Emergency Preparedness, NYS Environmental Public Health Tracking (EPHT) program,[2] NYS Outreach and Education, and the four Metropolitan Planning Organizations (MPOs) including the Greater Buffalo-Niagara Regional Transportation Council (GBNRT); Genesee Transportation Council (GTC); Syracuse Metropolitan Transportation Council (SMTC); and the Capital District Transportation Committee (CDTC).

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Acronyms and Abbreviations

AC	Air conditioning
ACS	American Community Survey (U.S. Census Bureau)
AT	Apparent Temperature
CDC	Center for Disease Control and Prevention
CVD	Cardiovascular Disease
DOH	New York State Department of Health
EHE	Extreme Heat Events
EHARA	Extreme Heat Adaptation Resource Awareness survey
GHG	Green House Gases
HIA	Heat Impact Assessment
HVI	Heat Vulnerability Index
IPCC	Intergovernmental Panel on Climate Change
LGA	LaGuardia Airport
MPO	Metropolitan Planning Organization
NCAR	National Center for Atmospheric Research
NWS	National Weather Service
PCA	Principal Component Analysis
PRAMS	Pregnancy Risk Assessment Monitoring System
RCP	Representative Concentration Pathways

Summary

Although NYS currently has mild to moderate temperatures (ranging from 70 to 85°F) during the summer, according to the ClimAID Report,[1] trends in climate change predict more frequent and intense extreme weather events such as heat waves. With these changes in climate, we can expect an increased incidence of heat-related hospitalizations and mortality in the future as well. In the past decade, heat-related mortalities ranked the highest among weather-related fatalities in the United States, with many of the deaths occurring from exposure to outdoor extreme heat or exposure indoors among persons having little or no access to air conditioning.[3-5] Studies in NYS have shown exposure to extreme heat can exacerbate other pre-existing morbidities like respiratory, cardiovascular, and renal diseases.[6-9] The effects of summertime extreme heat on health can be seen especially among vulnerable populations including the elderly, socioeconomically disadvantaged, and those without access to air conditioning (AC).

The main goals of this project were to identify vulnerability to heat, estimate future heat-health impacts, and assess currently available heat adaptation resources. Findings from this study will be disseminated to better inform public health and emergency preparedness planning leaders' efforts toward developing new or supplementing existing heat-impact mitigation activities and interventions, especially focusing on protecting health during extreme heat events (EHEs) in New York State (NYS).

Of the three focus areas of this project, the first identified individual and community characteristics that influence the impact of heat on health in NYS. The impacts of extreme heat on health are largely avoidable when simple measures are taken to reduce long periods of exposure, especially among heat-vulnerable populations. Once vulnerable populations are identified, targeted heat coping and adaptation interventions like cooling centers or AC distribution programs can be provided in a timely manner. In this project, vulnerable populations and regions were identified in NYS in terms of individual heat-health risk and sensitivity, and community's sociodemographic and environmental factors that studies have shown to contribute to vulnerability to heat. The heat-vulnerability characteristics/factors identified in this study included populations who belonged to minority races and ethnicities, did not speak English well, were elderly, unemployed, with low household income, or lived in older homes and/or urban neighborhoods. Using a statistical method called principal component analysis (PCA), these factors were combined to construct a summary metric called the "heat-vulnerability index" (HVI) allowing for quick identification of heat-vulnerable census tracts in NYS. The HVI was constructed separately for NYC and the rest of NYS and was comprised of four major components representing four aspects of vulnerability to heat in

those regions. While the HVI helps with spatial identification of heat-vulnerable regions, the four components give a more nuanced representation of the population and land-cover factors that contribute to vulnerability in a given area. The HVI can, therefore, help counties allocate heat-adaptation resources and interventions in vulnerable areas and in a timely manner, and the four components will help ensure the proper intervention or outreach method targets the appropriate vulnerable population. While the HVI showed that metropolitan and inner cities are the most vulnerable, variability in heat vulnerability among population subgroups can inform actions to mitigate heat effects.

The second focus area of this study was a heat-health impact assessment (heat-HIA) to estimate the impact of heat on health in future decades. The HIA was performed using health risk estimates for cardio-vascular and respiratory illnesses[7,8] along with the ClimAID temperature projections for the 2020s, 2050s, and 2080s. The climate projections are based on historical regional temperature measurements and climate simulations that can provide a projection of how temperature and/or precipitation might change under various greenhouse gas (GHG) emissions scenarios in the future. In this study, the ClimAID climate projections[10] (developed by Columbia University) were used to conduct the heat-HIA for seven ClimAID defined regions in NYS. The projections consist of downscaled temperature projections developed from 35 global climate models and two GHG emission scenarios. Although NYS mostly experiences mild to moderately high temperatures during the summer, the ClimAID projections predict the total number of hot days during the summer will increase, along with an increase in frequency of EHEs like heat waves in the future. This will especially be true in the NYC area, where an 8- to 10-fold increase (depending on the emission scenario) in the number of hot days was predicted when compared to the baseline. These projected temperature changes were used to estimate future changes in heat-impacted health risk estimates. A potential for substantial increases in annual heat-related hospitalizations was observed in all seven ClimAID regions for both health outcomes, with greater numbers where population numbers are larger, and for decades and scenarios with more warming. This predicted increase in excess hospitalization incidence and the difference in rates across the seven regions implies heat-HIA findings should be taken into consideration when planning regional heat impact mitigation.

The final focus area of this project was to assess cooling centers as a resource for heat adaptation in NYS. The purpose of the assessment was to determine the availability, accessibility, and public awareness and utilization of these resources. Cooling centers are a valuable community resource for cooling down during EHEs, especially among populations that do not have access to air conditioning. This study identified 377 cooling centers during the summers of 2012 and 2013 in NYS (excluding NYC) from a survey among county health and emergency management offices as well as from official county website searches. NYC was excluded from this analysis since cooling center data was unavailable for this region. The cooling centers were geocoded, mapped and assessed for adequacy and accessibility in each of the 57 counties of NYS. Spatial analysis of the cooling centers showed that they were primarily located in the more urban areas of NYS and that rural areas were relatively underprovided with cooling centers. But despite their urban distribution, a large proportion of the general (65%) and vulnerable (50%) populations appear to be more than walking distance from a cooling center. Accessibility was significantly improved with availability of public transportation, especially in the upstate regions, with 100% of cooling centers in heat-vulnerable tracts accessible by public transportation. Improving accessibility of cooling centers and broadcasting their locations with heat-health risk communication will improve utilization of the facilities and potentially reduce the impact of heat on health. Another component of the resource assessment was to determine public awareness of cooling centers and National Weather Service (NWS) heat warnings and assess changes in behavior during EHEs (for example: the use of AC), seeking cooler locations, etc.). This evaluation was done via a survey among post-partum women and was conducted as a supplement to the NYS Pregnancy Risk Assessment Monitoring System (PRAMS) questionnaire. Results showed that although majority of the participants had access to AC, most were discouraged from using it primarily because of utility costs. Among those without AC at home, about a fourth preferred to stay home rather than find a cooler location. Less than half of the participants were aware of NWS heat alerts during the summer, but among those who heard them, television and radio were the most common platforms.

The study addresses important public health issues including the future health impacts and population vulnerabilities related to extreme heat. The results of this project could help better inform local and state public health and emergency management leaders and agencies to supplement existing resources, risk communication, and heat impact mitigation efforts, and help communities be better prepared for predicted temperature changes in the summertime. Toward these efforts, the DOH has disseminated findings among local and state agencies via presentations, publications, and the DOH website. Findings from this research will also be incorporated into the NYS Environment Public Health Tracking (EPHT) program website.[2]

1 Identifying and Mapping Vulnerability to Extreme Heat in NYS

1.1 Individual and Community Vulnerability to Extreme Heat

1.1.1 Background

As indicated by the ClimAID report,[1] extreme heat events like heat waves are bound to increase in intensity and frequency in response to global climate change. Along with these changes in exposure to heat, we can expect increases in heat-related morbidities and mortality, especially among heat-vulnerable populations. Vulnerability to heat in this project is defined as the degree to which one is susceptible to injury or harm to health resulting from exposure to extreme heat and heat events. Vulnerability can result from individual biological conditions and personal attributes, as well as other aspects like community-level environmental and sociodemographic characteristics. Studies have shown that the effect of heat on health can vary geographically,[11-20] but there is insufficient knowledge about how this association varies across NYS. It is possible that regional factors either directly modify the heat-health relationship or affect individual response or adaptive capacity to extreme heat, thereby contributing to vulnerability to heat. To identify heat-vulnerability indicators or factors, we selected various individual and community indicators identified from NYS-specific heat-health research[6-9,21] as well as previously conducted studies across the nation. We then examined the spatial distribution of these vulnerability factors, distribution of temperature metrics, and risk of heat-impacted hospitalization (respiratory, cardiovascular, and renal diseases) to identify vulnerable areas with high exposure and incidence of heat-impacted illnesses.

Community vulnerability to heat can play a role in how an individual copes with and adapts to heat. Therefore, identifying *where* the vulnerable populations are, as well as *who* they are, is imperative to effectively implement targeted interventions and provide sufficient adaptation resources. The first objective of this vulnerability assessment was to identify individual and community heat-vulnerability factors and map the distribution of these factors to better understand the spatial variation in **exposure**, **health risk,** and **vulnerability** to extreme heat in NYS. The second objective was to develop a tool, the heat-vulnerability index, to enable quick identification of vulnerable areas, and understand how these individual and community factors together can affect vulnerability to heat.

1.1.2 Materials and Methods

This section will discuss methods, data sources, and resources used to assess extreme heat exposure, heat-health risk/sensitivity, and vulnerability.

1.1.2.1 Data Sources

Hospitalization data was used to determine prevalence of respiratory, cardio-vascular, and renal disease within each NYS county during the months of June through August, in the years 1991 to 2004. Hospitalization data was obtained from the DOH Statewide Planning and Research Cooperative System (SPARCS). Patients' street addresses were geocoded to assist with prevalence rate calculations as well as with heat exposure assignment for the heat-health risk assessment. Details on the SPARCS database, outcomes included, and methodology used in the risk assessment can be found in Appendix A1 and the DOH studies.[6-9,21]

Data for meteorological components was obtained from the National Center for Atmospheric Research (NCAR) data and the National Climatic Data Center (NCDC) and assigned to 14 weather regions across NYS. Meteorological data obtained included daily and hourly observations of daily average, maximum and minimum temperatures, dew point, and wind speed. Details on weather region boundaries and weather exposure assignment can be found in Appendix A.2 and previously published DOH heat-health studies.[6-9,21]

Once vulnerability variables were identified (see Methods), data for individual and community vulnerability factors were obtained from the 2010 US Census Data and the 2011 National Land Cover Database (NLCD) at the county and census tract level.

Statistical analysis for this project was conducted using SAS Version 9.4. Geocoding and mapping was conducted using MapMarker Ver22 and MapInfo Version 12.5. mapping for this project was conducted using MapInfo version 12.5.

1.1.2.2 Methods

In the past decade, NYS-specific heat-health studies have been conducted at the DOH[6-9,21] to identify individual risk factors (sensitivity) for respiratory, cardiovascular, and renal diseases hospitalizations (see Appendix A1) impacted by extreme heat exposure during the summer months of the 14-year period from 1991 to 2004. Findings from these studies were used to determine risk factors, temperature exposure, and vulnerability to heat. Details on these studies are available in the literature published,[6-9,21] but relevant findings across these studies have been assembled and summarized to 1) display regional summertime temperatures and heat exposure; 2) identify and map regions in NYS that showed statistically higher risk of hospitalization for heat-impacted health outcomes; 3) identify individual factors that were observed in the DOH studies to increase risk of hospitalization; and 4) identify community heat vulnerability factors that could influence impact of heat on health in that region. Findings from previous studies were used as groundwork to conduct the vulnerability assessment.

Exposure: Regional Summertime Temperatures

Meteorological data was compiled and summarized to display regional distribution across the state. Table 1 below displays the distribution of various temperature indicators during summer months for the years 1991–2004, across the 14 weather regions. Meteorological data for LaGuardia (LGA) and Staten Island are presented together in Table 1, as the same weather station covered both regions. However, due to the differences in population demographics (socioeconomic status and population density), they were considered two distinct weather regions for the heat-health association analysis.

Mean daily average temperature in NYS (June–August 1991–2004) ranged from 67.7°F to 76.9°F. The lowest average minimum temperature was observed to be 57.7°F in the Western Plateau region, and the highest average maximum temperature of 83.8°F in LGA and Staten Island. The largest variation in temperature (difference between highest and lowest temperatures for that region) of 22.9°F was seen on the Western Plateau, and the least variation of 13°F was seen in the LGA and Staten Island regions. Universal apparent temperature (UAT) [Calculated using Steadman's formulae incorporating daily temperature, vapor pressure, and wind speed: *UAT = -2.7 + 1.04 × temperature (in °C) + 2.0 × vapor pressure (in kPa) – 0.65 × wind speed (in ms-1)*] ranged from 57.6°F in the Adirondack and North region to 83°F in LGA and Staten Island. Frequency of heat waves varied across the regions, indicating that while NYS has mild to moderate temperatures during the summer months, heat waves do occur and can be frequent in some regions.

Table 1. Indicators and Metrics of Daily Temperatures (°F) June–August 1991–2004

Region	Average Temperature	Minimum Temperature	Maximum Temperature	Temperature Variation	Average UAT*	Minimum UAT*	Maximum UAT*	Heatwave HW90 [b]	Heat Wave HW97 [c]
LGA & Staten Island	76.9	70.8	83.8	13.0	75.6	69.1	83.0	23	8
Long Island	73.5	66.4	81.1	14.7	73.5	67.5	80.9	7	8
JFK	74.8	68.6	81.8	13.1	73.8	66.4	81.3	6	9
Buffalo	70.5	61.9	79.0	17.1	69.0	64.6	81.8	0	6
Westchester	72.5	64.5	81.2	16.7	73.0	62.3	82.8	12	12
Rochester	69.0	59.6	78.3	18.7	67.7	60.0	80.0	2	5
Hudson Valley North	69.9	60.0	80.0	20.1	70.0	58.4	78.3	9	8
Central Lakes	70.7	61.5	80.1	18.6	70.0	58.7	78.4	9	8
Hudson Valley South	72.2	62.3	82.5	20.2	72.4	57.7	75.0	23	10
Binghamton	67.7	59.7	76.4	16.8	66.3	58.1	77.1	0	9
Mohawk Valley	69.0	59.9	78.8	18.9	68.5	60.6	79.5	2	11
Adirondack & North	68.7	58.7	78.8	20.0	68.3	57.6	80.3	2	8
Western Plateau	68.8	57.7	80.6	22.9	69.0	60.5	77.4	9	7

* UAT= Universal Apparent temperature

a. HW90= Heat wave: Daily maximum temperature was >=90°F on 3 or more consecutive days.

b. HW97= Heat wave: Daily maximum temperature was >=97th percentile of seasonal daily maximum temperature on 2 or more consecutive days

Figure 1 displays the distribution of daily average temperatures across the 14 weather regions for June to August, from 1991 to 2004. Daily average temperatures ranged from about 67.7°F to 76.9°F, with the highest temperatures in Downstate metro areas (LGA, Staten Island, and JFK) followed by the Long Island and Westchester regions. The rest of the State was observed to have lower temperatures, in the range of 67.7°F to 72.3°F.

Figure 1. Daily Average Temperature Across NYS Weather Regions, June–August 1991–2004

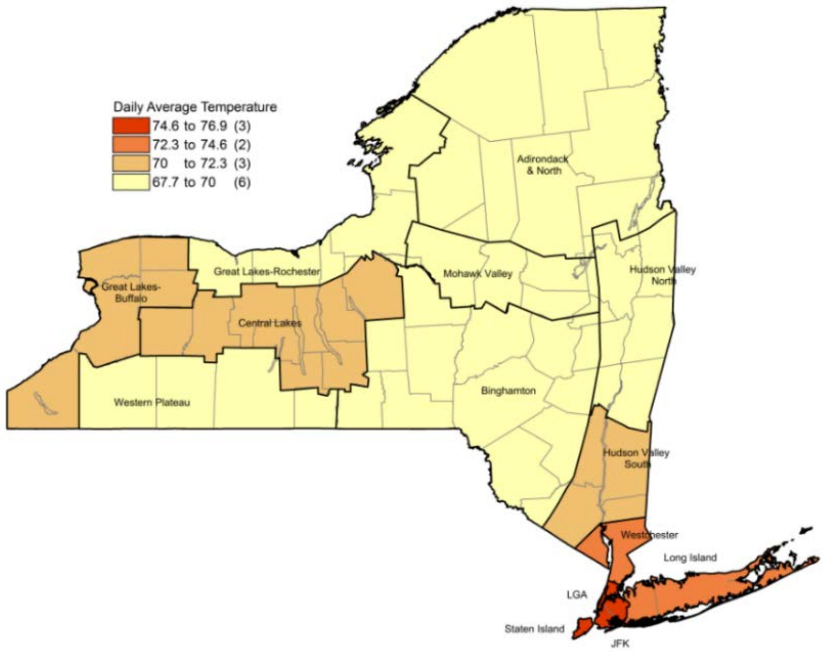
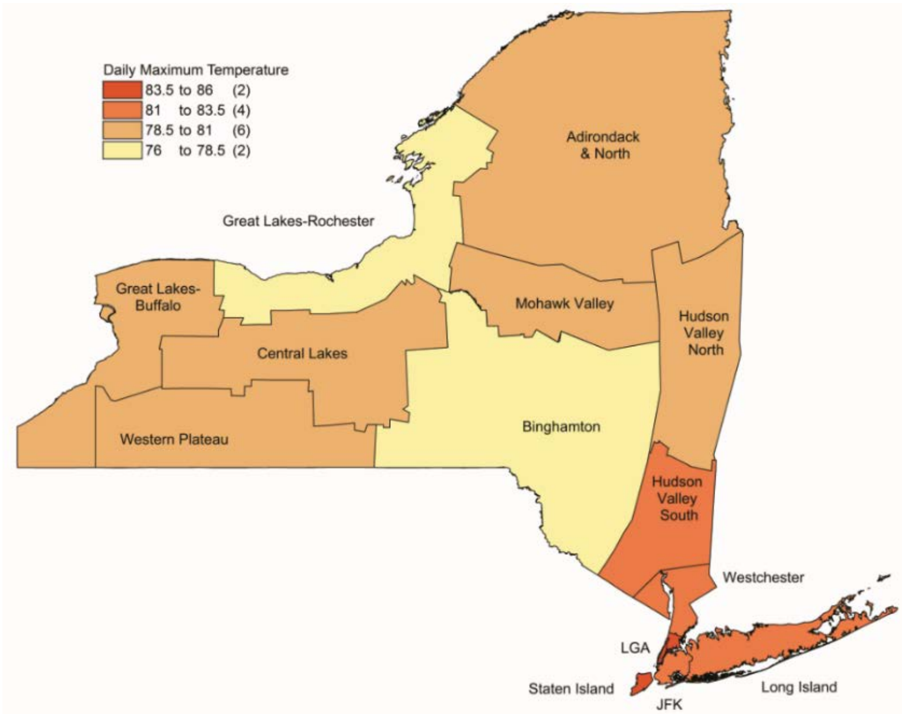


Figure 2 displays the distribution of daily maximum temperatures across the 14 weather regions for June to August, from 1991 to 2004. Daily maximum temperatures ranged from about 76.4°F to 83.8°F with highest temperatures again seen in New York City metro areas (LGA and Staten Island) followed by Long Island, Westchester, and Hudson Valley South weather regions.

Figure 2. Daily Maximum Temperature Across NYS Weather Regions for June–August 1991–2004

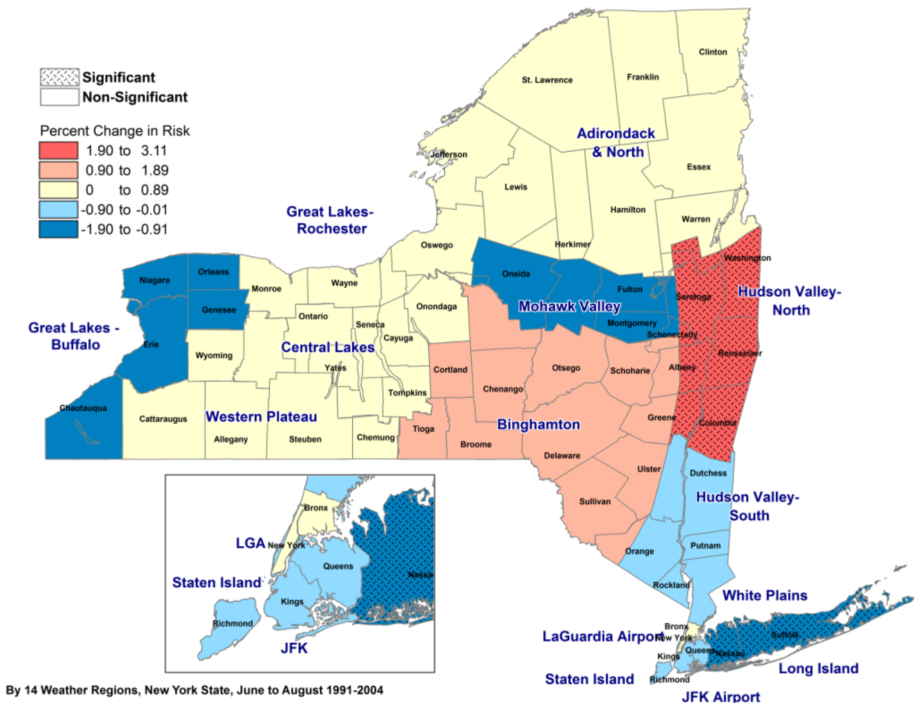


Regional Heat-Health Association

To examine the heat-health association across the 14 weather regions, we reviewed findings from the DOH heat-health studies[6-8] to identify and map regions that showed a high risk of hospitalization for heat-impacted health outcomes. Figures 3-5 display the regional change in risk of hospitalization for cardio-vascular (CVD), respiratory, and acute renal failure with an increase in temperature during the months of June, July, and August from 1991 to 2004.[6-8] In these maps, we used diverging color themes to display percent change in risk of hospitalization with an increase in temperature, and cross-patterned areas to indicate statistically significant changes in hospitalization. Statistical significance in these studies can be explained as the "likelihood that the relationship seen between increase in temperature and the increased risk of hospitalization is more than by random chance." Percent change in risk in positive ranges (i.e., values above 0) indicate an increase in risk of hospitalization with increase in temperature while risk in negative numbers (i.e., values below 0) indicate a decrease in hospitalization with increase in temperature. The purpose of mapping these findings was to display regional differences in the impact of heat on these outcomes; additional details can be found in the DOH publications.[6-8] The maps show that change in risk of hospitalization with increase in temperature can vary both by region and by health outcome, indicating that apart from extreme heat exposure, there may be other factors that come into play when determining sensitivity and health risk to extreme heat.

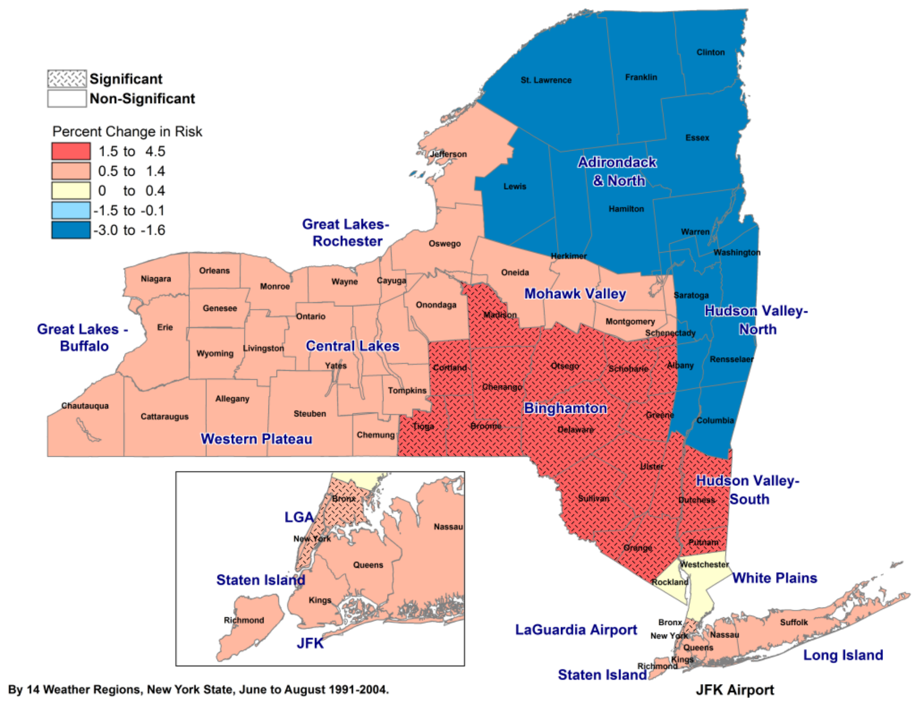
Of the 14 weather regions, seven showed an increase in risk of CVD hospitalization with an increase in temperature. But, a statistically significant increase in risk of hospitalization was only observed in the Hudson Valley North region. A statistically significant decrease in risk was observed in the Long Island region.

Figure 3. Percent Change in Risk of CVD Hospitalizations per Unit Increase in Temperature Between 1991–2004



Increased risk of hospitalization for respiratory illnesses with a unit increase in temperature was seen in all but two weather regions. Statistically significant increases in risk of hospitalization were observed in the Hudson Valley South, Binghamton, and LaGuardia weather regions.

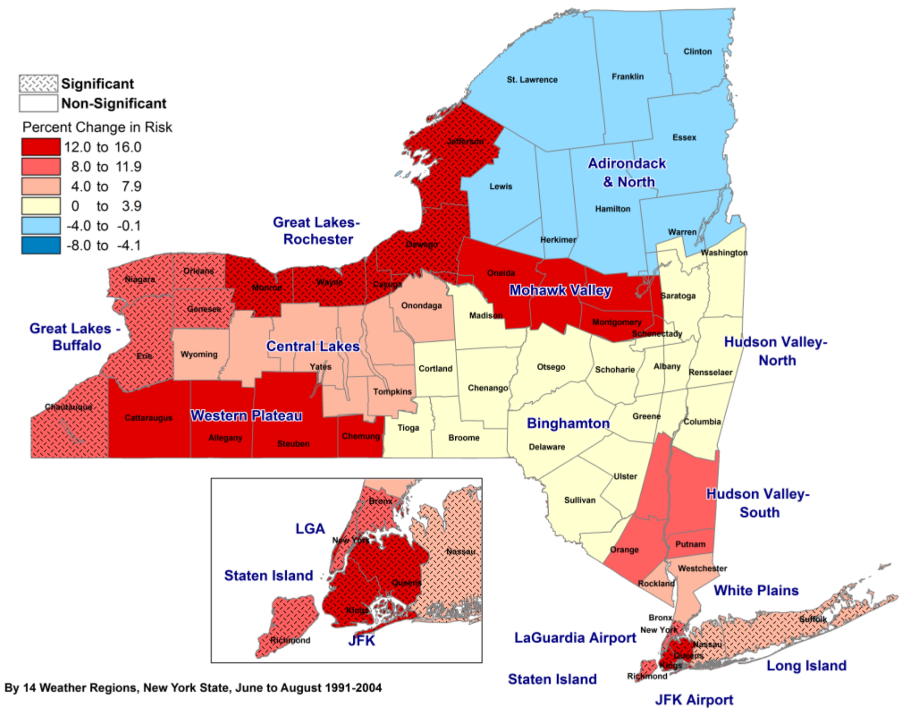
Figure 4. Percent Change in Risk of Respiratory Illness Hospitalizations per Unit Increase in Temperature Between 1991–2004



By 14 Weather Regions, New York State, June to August 1991-2004.

All weather regions except the Adirondack and North region showed an increased risk of hospitalization for ARF with an increase in temperature. The two Great Lakes regions, NYC metro area, and Long Island showed significantly higher risks of hospitalization.

Figure 5. Percent Change in Risk of Acute Renal Failure Hospitalizations per Five-Unit Increase in Temperature Between 1991–2004



Individual factors associated with high risk of heat-impacted hospitalizations

Table 2 summarizes factors from previous studies identified as individual risk factors or sensitivity factors for heat-impacted hospitalizations during the summer months in NYS. The studies showed female, African American, Hispanic, elderly (65 years and older), or residents with incomes below the poverty line were at the most risk for heat-impacted hospitalizations.

Table 2. Individual Risk Factors (Sensitivity) for Heat-Related/Exacerbated Hospitalizations

Risk Factor	Literature review findings
Gender	There are contradictory findings regarding gender vulnerability to heat, but most studies found women at a higher risk of heat-related mortality and morbidity than men, regardless of age.[22-25] We included women as a vulnerable population in our study, since, consistent with most studies, a NYS study showed significantly higher risk of heat-attributable hospitalization among women.[7] Indicators of gender vulnerability included percent of population that were female.
Age	The elderly ($\geq$ 65 years of age) are at greater risk of heat-impacted hospitalization and mortality[26-34] than other age groups, especially during early EH events.[26] Social isolation of the elderly is also a significant indicator of increased susceptibility to heat.[32-34] Elderly NYS residents also showed an increased summertime all-cause mortality, and renal and respiratory hospitalizations.[7,8,28,35] Indicators of age vulnerability used in this study included percent population that was elderly and percent population that was elderly and living alone.
Race and Ethnicity	While being of a non-white race was a risk factor for heat-related morbidities and mortality,[36] specifically being African American [29,36-39] or Hispanic[35,37,40] increased that risk significantly. Some studies have also observed a higher volume of heat distress calls from neighborhoods with larger proportions of African Americans and Hispanics[40]. Similarly climate-health research in NYS showed that African Americans[38] and Hispanics[35,37] had higher rates of mortality and heat-related hospitalizations and were, therefore, included as indicators of race and ethnicity vulnerability.
Income	Poverty[6,25,41] and income-related variables (See Table 3) have been found to modify the effects of heat in some studies. Climate research in NYS observed higher risk of renal hospitalizations among those in the lowest quartile of income. Indicators of heat vulnerability resulting from income status included percent population below the poverty line.

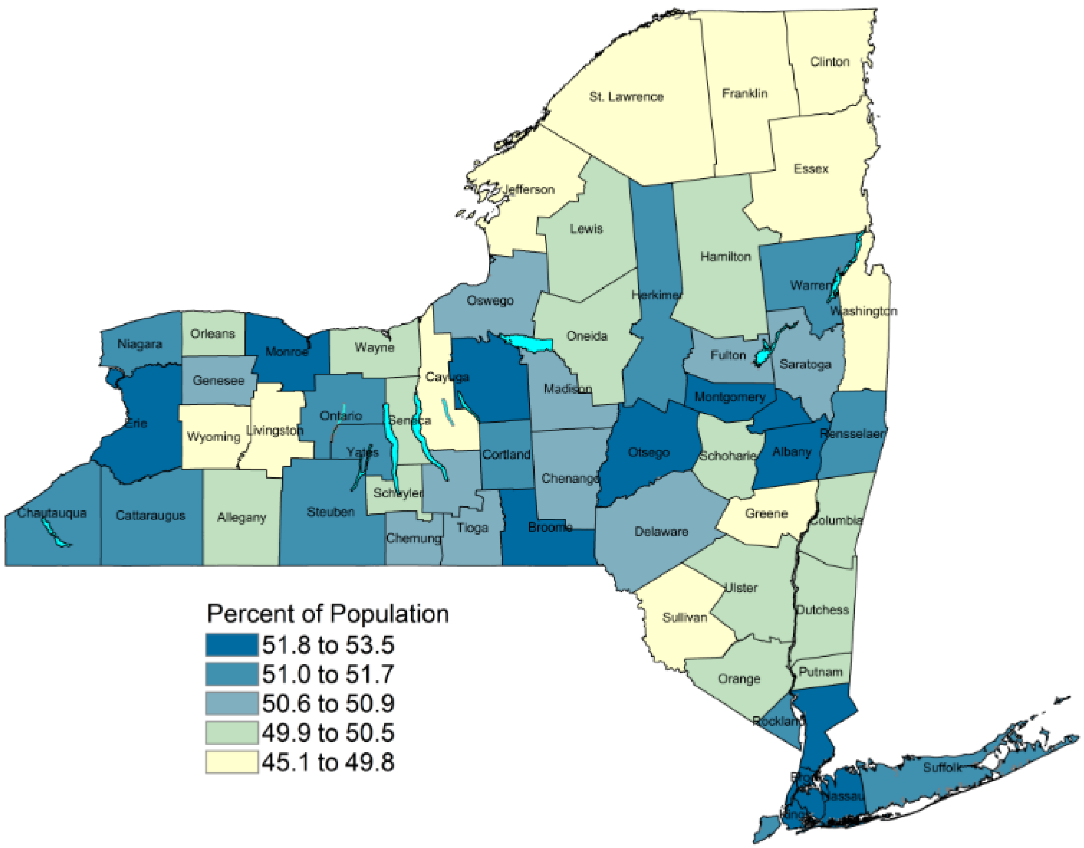
1.1.3 Results and Discussion

The above individual risk factors were mapped across the state for each NYS county to get a better understanding of their spatial distribution (Figures 6-11). Mapping these variables will help identify counties that have a higher proportion of these populations than others. Data were obtained from the 2010 U.S. Census Bureau and 2006–2010 US Census Bureau American Community Survey (ACS).

The distribution of female population across the State was relatively even and ranged from about 45% to 53.5% of total county population. The highest proportion of females was seen in Bronx County followed by Kings (53.1%) and New York (52.5%) Counties. Among the Upstate NY counties, Erie, Montgomery, Onondaga, Westchester, and Albany counties had the highest female populations (about 52.2% in each of the five counties).

Figure 6. Percent of Female Population in NYS Counties

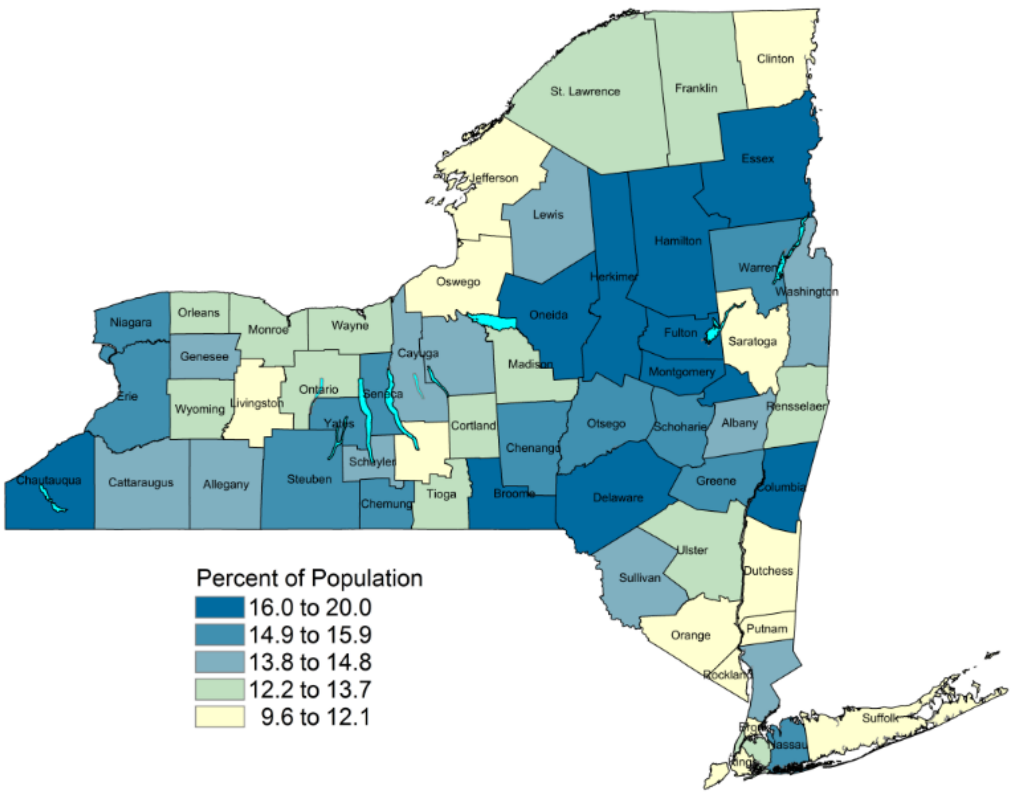
Source: 2010 US Census Bureau and 2006-2010 US Census Bureau American Community Survey (ACS).



Percent of elderly population ranges from 9.6-20%. Most of the counties in NYS had about 15-17% of the total population in the elderly age group. Highest proportions of elderly populations were seen in Hamilton and Delaware (16.8%) counties.

Figure 7. Percent of Elderly Population (Age 65 years and older)

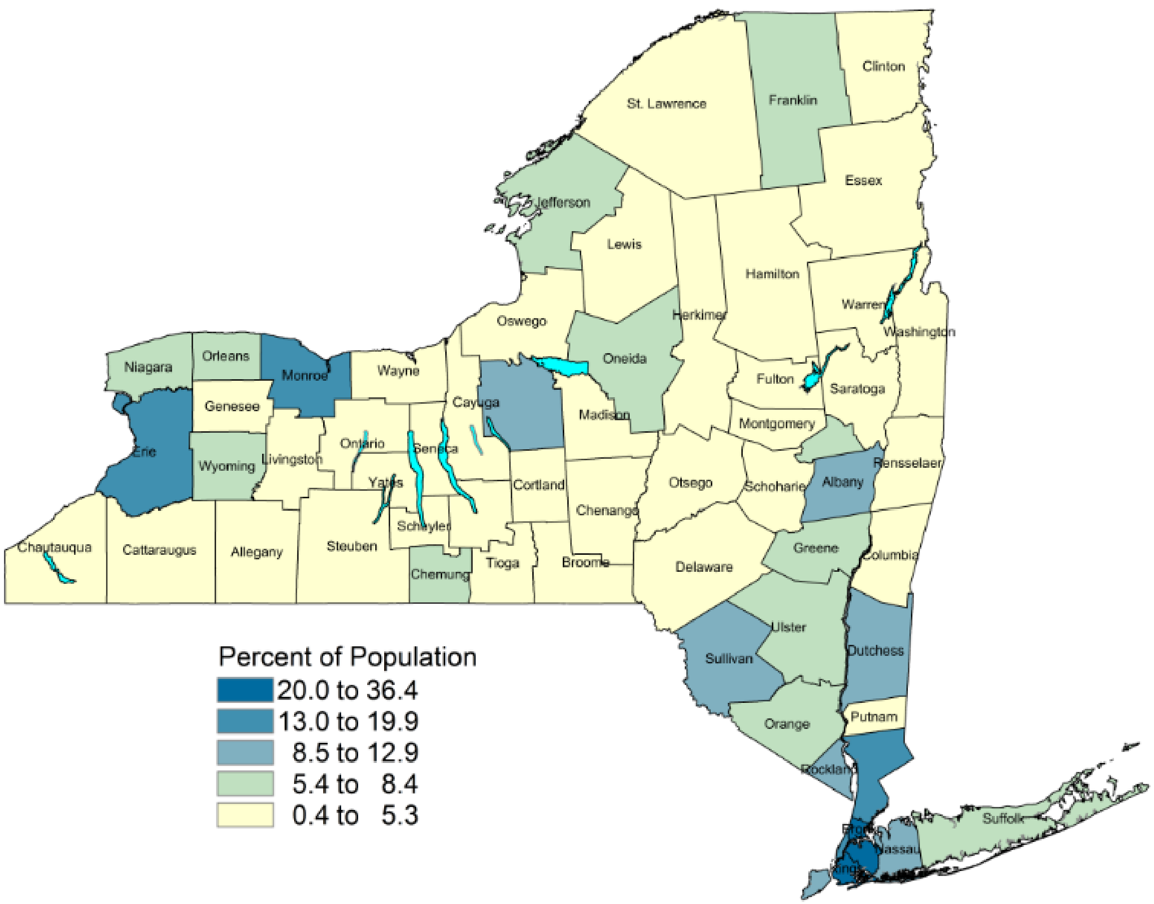
Source: 2010 US Census Bureau and 2006-2010 US Census Bureau American Community Survey (ACS).



The proportion of the African American population ranged from 0.4% to 36.4%. Several counties have 0.4% to 5.3% of total population belonging to the African American race. The highest proportion of the African American population is in four of the NYC counties (Kings, Bronx 35.6%, Queens 20%, New York 17.4%). Among the Upstate counties, Westchester (14.2%), Monroe (13.7%) and Erie (13%) showed the highest proportion of African Americans.

Figure 8. Percent of the African American Population

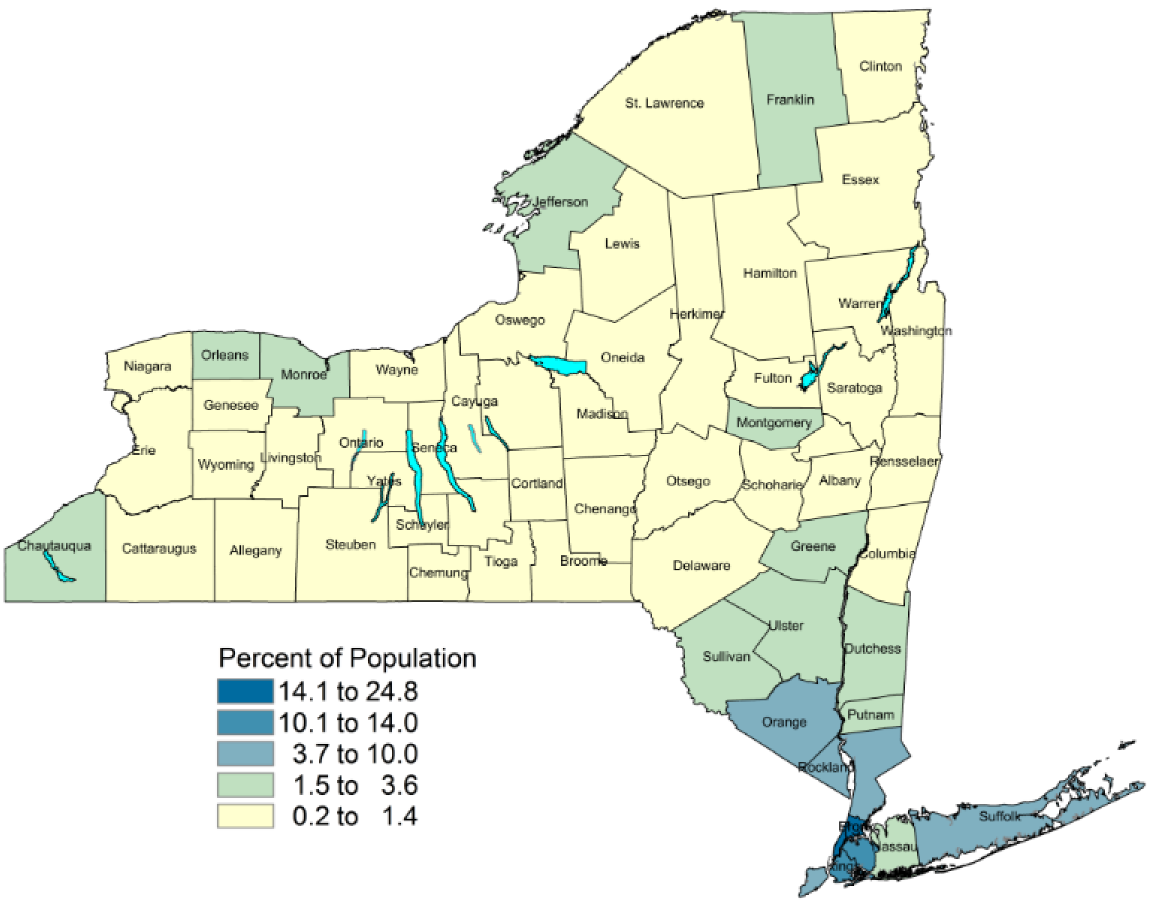
Source: 2010 US Census Bureau and 2006-2010 US Census Bureau American Community Survey (ACS).



Of the 57 Upstate counties, 43 had less than 2% of total population and 10 counties had 2.1 to 4.1% of their total population belonging to "Other" races. The highest proportion in non-NYC counties was seen in Westchester County (6.6%). Among the five NYC counties, populations of "Other" races constituted 4.1% to 24.8% of the total population, highest proportion seen in Bronx (24.7%) and lowest in Richmond (4.1%).

Figure 9. Percent of Population Considered "Other Race"

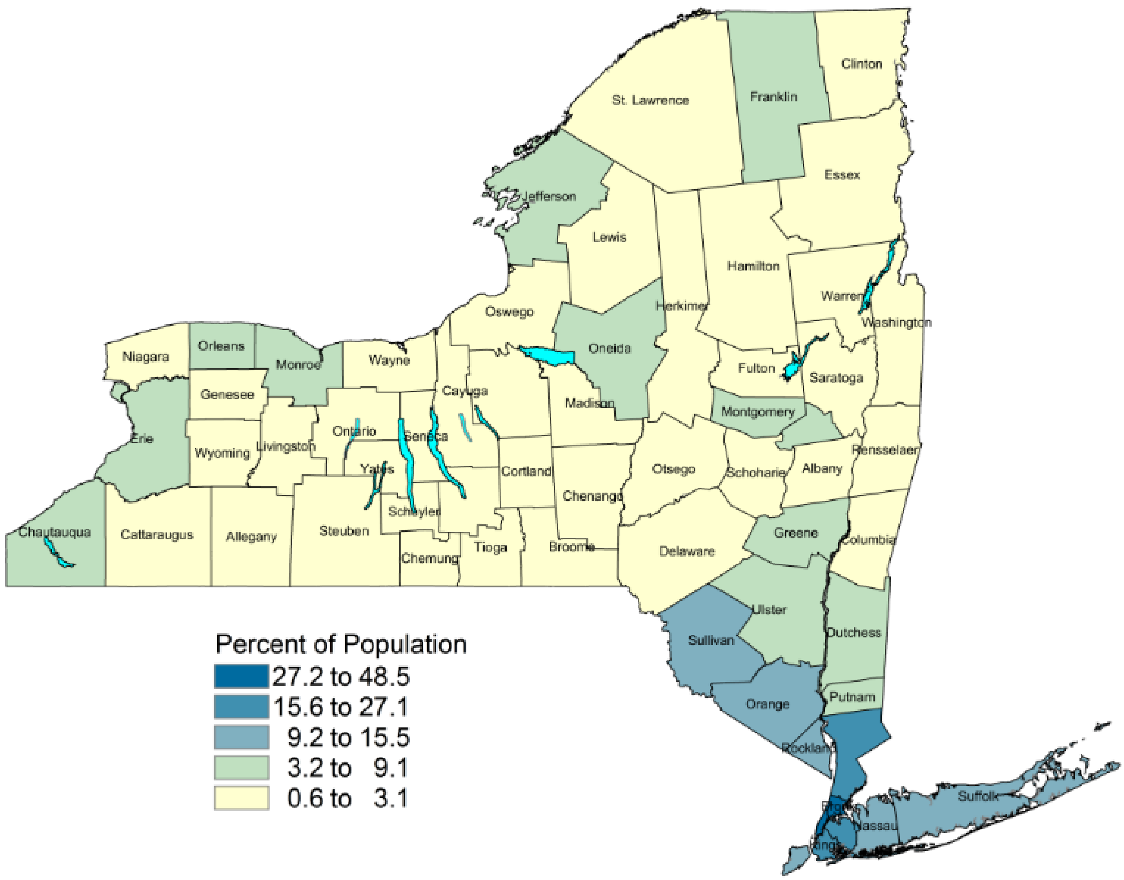
Source: 2010 US Census Bureau and 2006-2010 US Census Bureau American Community Survey (ACS).



The proportion of the Hispanic population across the State ranges from 0.6% to 48.5%, with the highest proportion in Bronx. NYC counties have a Hispanic population ranging from 12.1% to 48.5%, while the rest of the counties total 0.6% to 15.6% of the population. About 75% of NYS counties have a Hispanic population of less than 5%.

Figure 10. Percent of Hispanic Population in NYS Counties

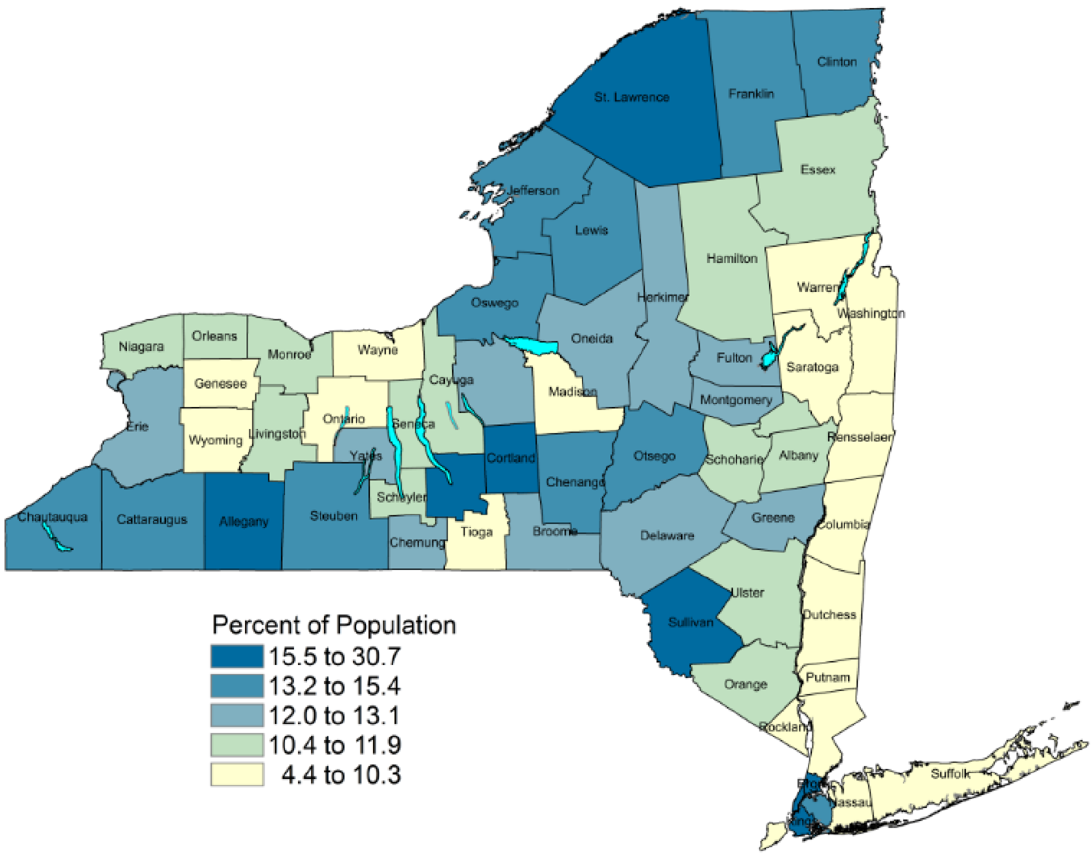
Source: 2010 US Census Bureau and 2006-2010 US Census Bureau American Community Survey (ACS).



The percent of total county population living in low-income households ranges from about 5 to 31%. Highest proportions of populations living in poverty were seen in the NYC counties of Bronx (30.7%), Kings (25.1%) and New York (20%) About 60% had 10 to 15% of the county population with incomes below the poverty line.

Figure 11. Percent of Population with Household Income Below the Poverty Line

Source: 2010 US Census Bureau and 2006-2010 US Census Bureau American Community Survey (ACS).



Community vulnerability factors

Regional socioeconomic and environmental factors have been shown by multiple studies to influence how heat impacts health and affects an individual's response or adaptive capacity to extreme heat. In order to develop appropriate mitigation strategies and interventions to facilitate heat adaptation in a community, it is prudent to understand what makes a community vulnerable. To identify community factors that play a role in a regional and population vulnerability to heat, a comprehensive literature review was conducted of heat-related vulnerability studies in NYS and other regions with climates similar to NYS. Based on the review, numerous individual level and community-level environmental and social factors that impact a community's vulnerability to heat were identified (Table 3).

Table 3. Community socioeconomic and environmental factors that affect vulnerability to heat

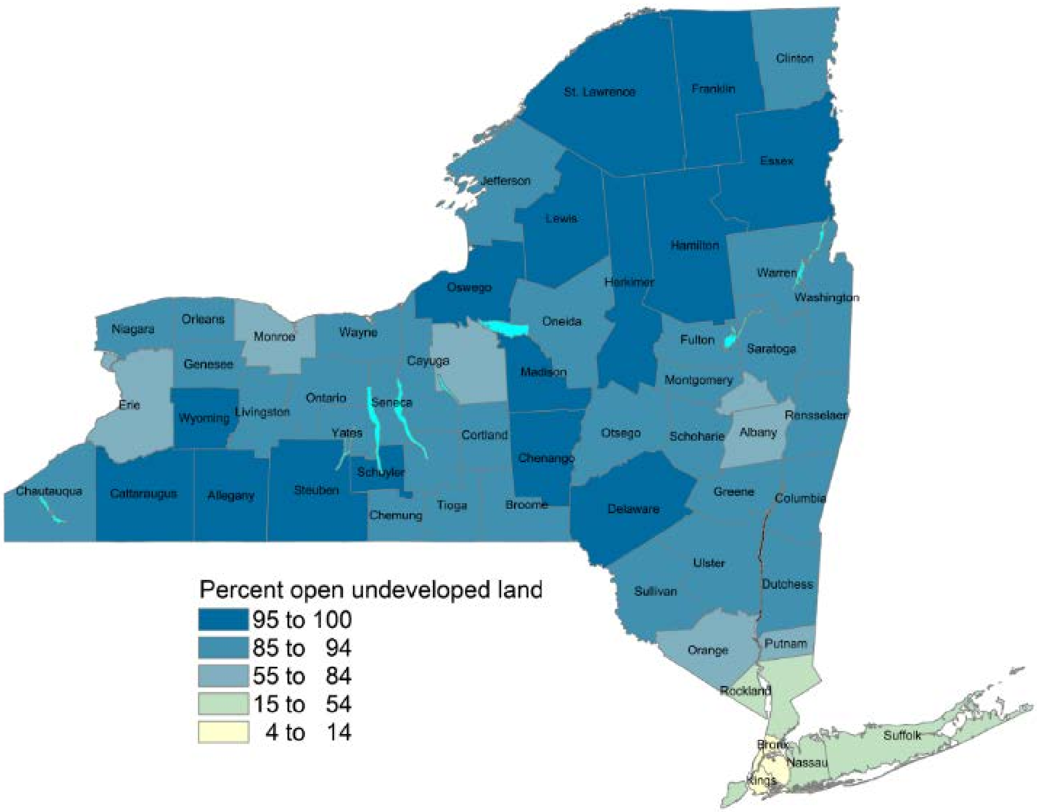
Factor	Literature review findings
Land cover/ use	Building materials used in urban settings and buildings retain heat and take longer to cool down, making urban areas substantially warmer than surrounding sub-urban and rural areas resulting in the urban heat island (UHI) effect. Heat retention due to the UHI effect can raise regional temperatures and urban populations can experience higher daytime temperatures and less cooling during nighttime during the summer.[28,38,40] Within urban areas, effects of UHI can be correlated with sparse vegetation, high population and building density, and less open space.[11,12,20] Open land, especially if covered with vegetation, can reduce the impact of heat on health in a community during hot days and heat events by providing shade and by significantly cooling night-time regional temperatures. All these effects of urbanicity on regional temperature can increase urban populations' risk of heat impact on their health. Indicators of land use and cover used in this study include **housing density, population density, percent of open undeveloped land, and percent of land that has high building intensity**.
Socioeconomic status	Community levels of low education,[17,22,41] disability and unemployment,[42,43] poverty,[25,41] and age of home[27,29,42,44] were identified in several studies as indicators of socioeconomic status factors as they can influence vulnerability to heat by impacting the community's ability to cope with heat. Lower levels of education are associated with a lesser household income and could therefore be linked to less access to cool-down resources (like air conditioning at home/work or owning a vehicle to get to a cooler place) during hot weather, making these populations vulnerable to the impacts of heat. These economic indicators at community-level can also correlate with availability of heat-adaptation amenities in a community such as shaded recreation areas and air-conditioned cooling centers.[39,44] Age of home is an indicator of housing conditions and was included as a heat-vulnerability factor in this study. Older homes, if not well maintained, can fail to keep occupants cool during the summer, making residents of older homes a vulnerable population because they may be less able to adapt to heat. Age of home can also be used a proxy estimate for the availability of air conditioning, since older homes are less likely than newer homes to have built-in central air or multiple AC units especially in low-income neighborhoods. Older homes in cities are less insulated[44] and less likely to have AC, thereby increasing the residents' vulnerability to heat.[45] Communities with larger proportions of older homes can be considered as a heat-vulnerable community. In this study, we identified **less education** (less than high school diploma) **disability, unemployment, households with incomes below the poverty line,** and **age of home** as factors that affect community-level heat vulnerability.
Language barriers	Emergency alerts are usually issued in English, placing populations with limited English proficiency (LEP) at an increased vulnerability[43,46,47] as they are less likely to understand warnings and alerts issued during EH events. The number of Hispanic and migrant workers in NYS has been rapidly increasing, and language barriers were cited as one of the top three obstacles in their work place[46]. Therefore, in this study, due to cultural and socioeconomic barriers they may face during an extreme heat event, populations who "**spoke English less than very well**" or were "**foreign-born**" were identified as heat-vulnerable in NYS.

To observe spatial distribution of the above identified community-level vulnerability factors across NYS, we mapped them by county using MapInfo version 15.2 (Figures 12-17). Spatial distribution of some of these factors have been displayed previously as individual-level vulnerability factors (Figures 6-11) Color theme used for all maps range from dark blue, representing higher percentage, to yellow, representing lower percentage. In all factors except percent open land (Figure 12), higher percentage indicates higher vulnerability. Higher percentage of open land in a county is an indicator of lesser vulnerability and better ability to adapt.

Forty-six counties had 80% or more of their total county land designated as open and undeveloped land. Hamilton and Lewis counties had the highest percentages of open land (99%) while NYC counties being primarily urban counties displayed the least proportion of open undeveloped land (New York 4.3%, Kings 6.6%, and Queens 5.9%).

Figure 12. Percent of Open Undeveloped Land

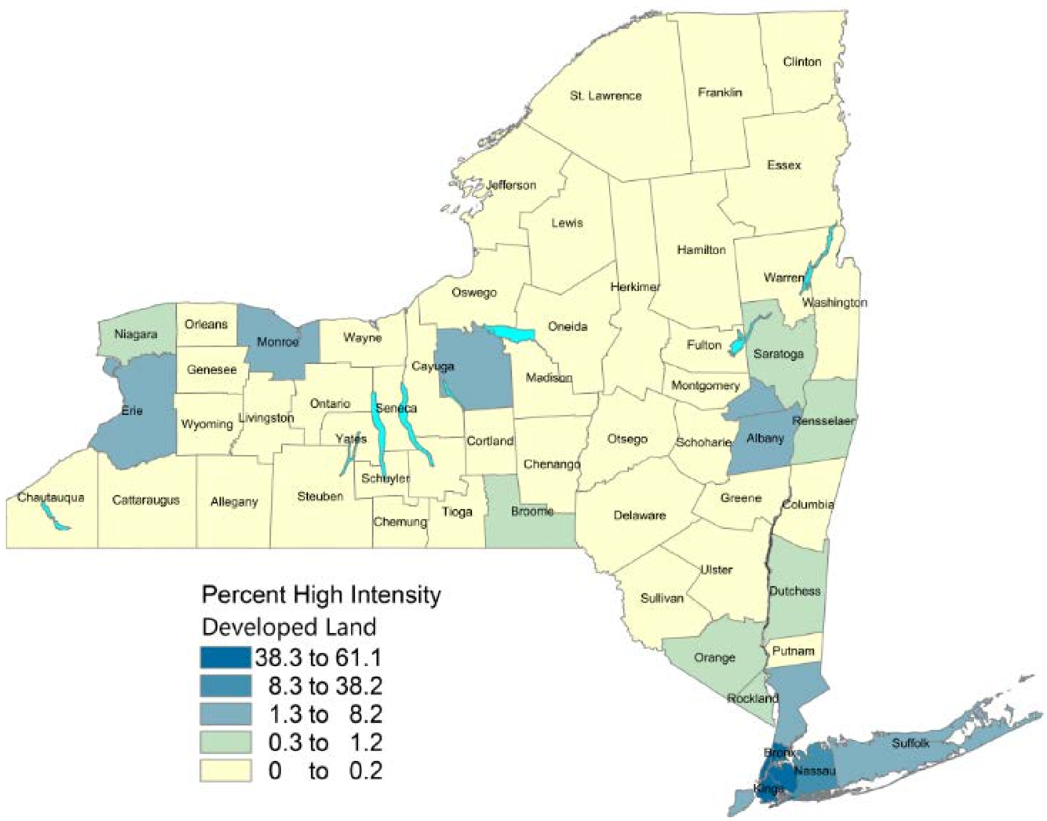
Source: 2011 National Land Cover Database (NLCD)



The proportion of high-intensity developed land ranged from zero to about 61%. Forty-eight counties had high intensity land proportions of 1% or less, eight counties ranged from 1-3%. Four counties (Kings, New York, Queens, and Bronx) had the largest proportions ranging from 38.4 to 61.1%, followed by Nassau (9%) and Richmond (8.2%).

Figure 13. Percentage of High-Intensity Developed Land

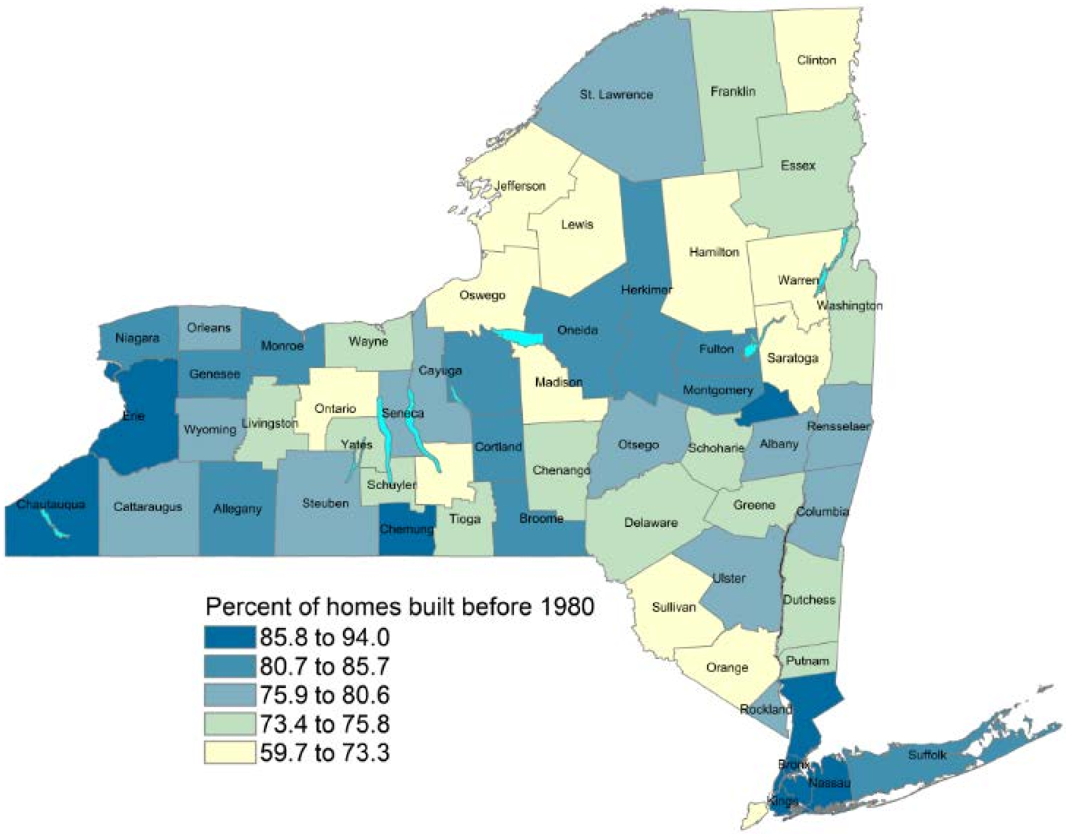
Source: 2011 National Land Cover Database (NLCD)



Statewide, approximately 78% of NYS homes are built before 1980. Percentage of older homes ranged from 60% to 94% with largest proportion of older homes (93-94%) in Queens, Kings, and Nassau Counties. Several counties (75%) had a percentage of older homes ranging from 70% to 85%.

Figure 14. Percentage of Homes Built Before 1980

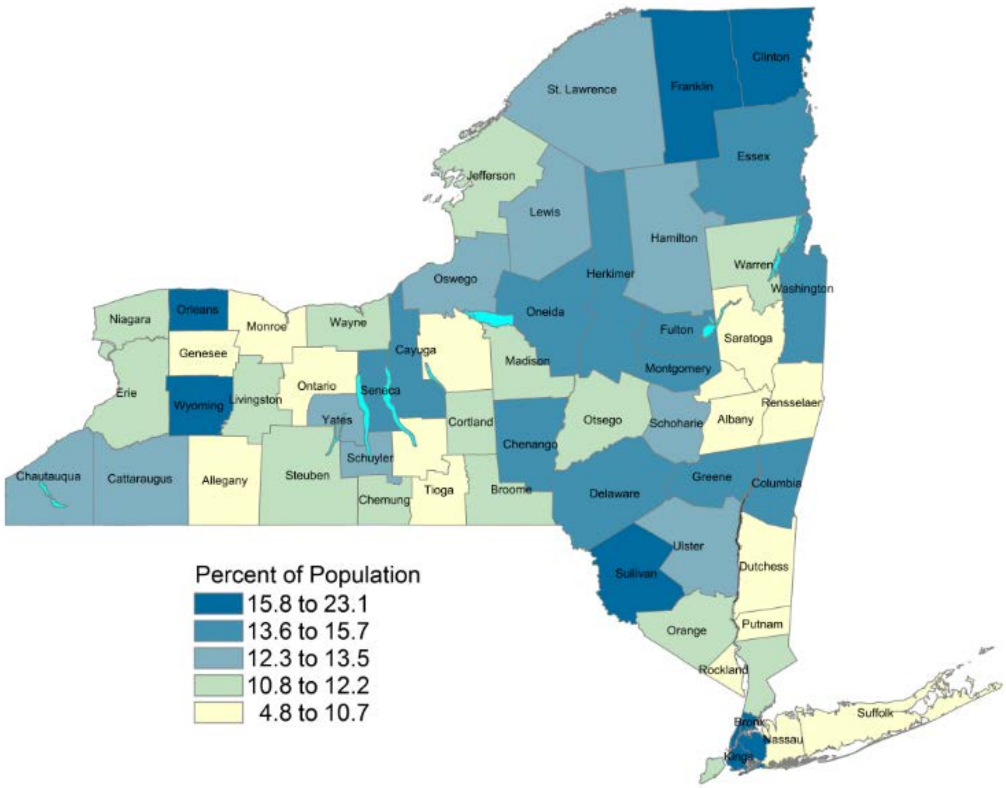
Source: 2010 US Census Bureau and 2006-2010 US Census Bureau American Community Survey (ACS).



Nearly 66% counties had proportions ranging from 10–15%. The highest proportions of population (20-23%) without a high school diploma in Bronx and Kings counties in NYC and Franklin County in the northern part of the State. Tompkins (4.9%) and Putnam (6.7%) counties had the lowest proportions. The distribution of this population across the State indicates 76–95% of county residents have at least a high school diploma.

Figure 15. Percentage of Population with Less Than a High School Diploma

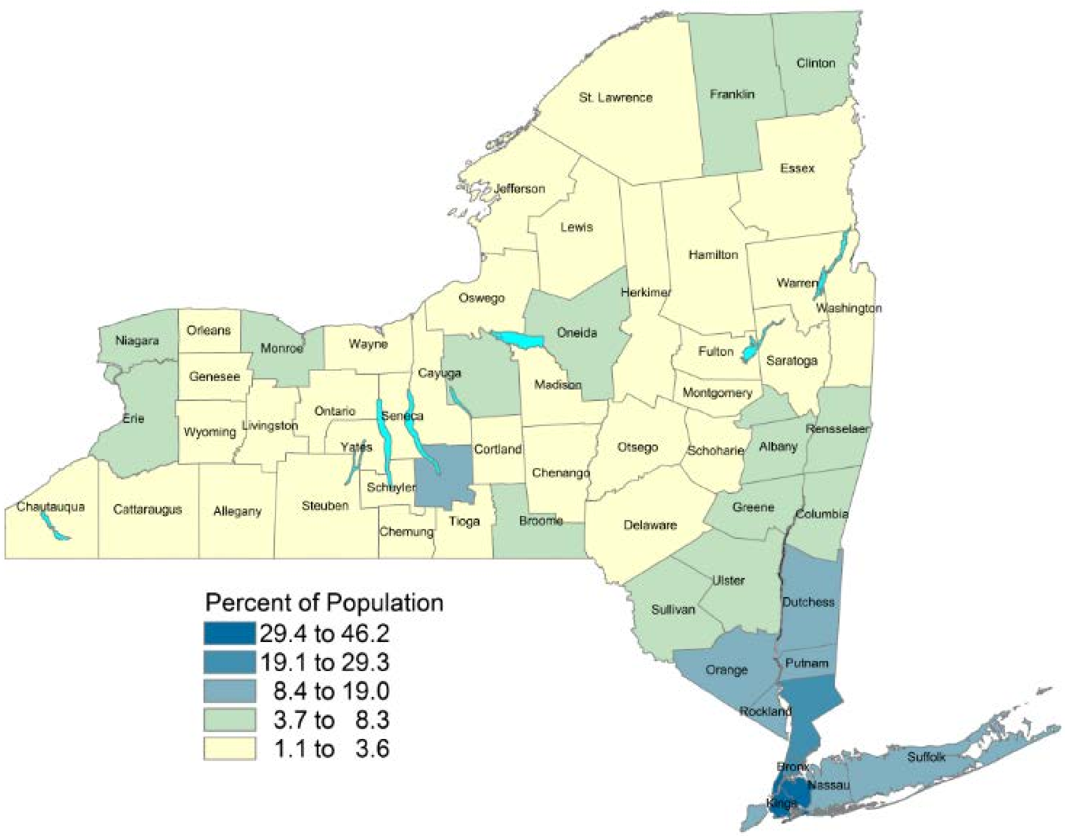
Source: 2010 US Census Bureau and 2006-2010 US Census Bureau American Community Survey (ACS).



In 40 counties (65%), foreign-born or non-native residents represented less than 5% of the population. Higher proportions of non-native residents lived in counties Downstate. Four of five NYC counties, Queens (46.1%), Kings (37.8%), New York (29.4%) and Bronx (28.9%), had the highest percentages of this population.

Figure 16. Percentage of Population That are Foreign Born

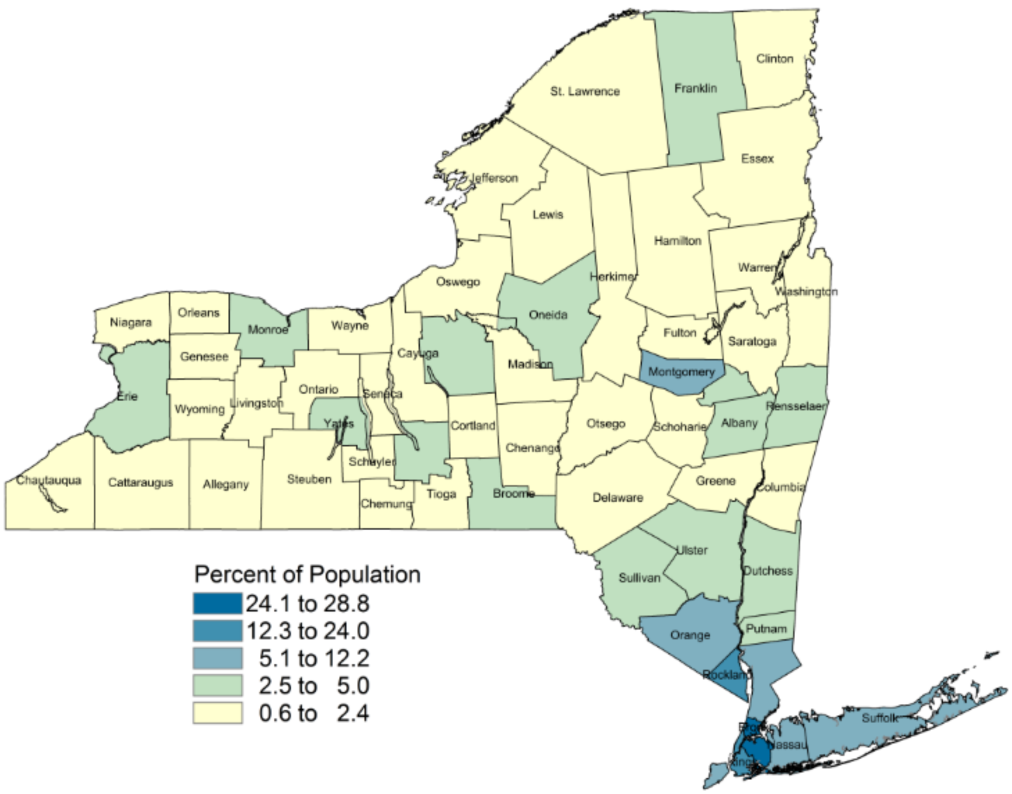
2010 US Census Bureau and 2006–2010 US Census Bureau American Community Survey (ACS).



Four of five NYC counties, Queens (28.8%), Bronx (25.1%), Kings (24.1%) and New York (17.2%), show the highest percentages of the population over the age of five who speak English less than "very well." Nearly 80% of NYS counties had less than 5% of this population.

Figure 17. Percentage of Population Who Speak English Less Than "Very Well"

Source: 2010 US Census Bureau and 2006–2010 US Census Bureau American Community Survey (ACS).



Sixteen heat-vulnerability factors (Table 4) were identified from literature as described above. Based on observations from these studies, a community can also be identified as heat-vulnerable when it consists of a high proportion of populations with individual-level vulnerability factors, for example, a community with a large population of elderly residents (more susceptible to health effects of heat and less access to adaption resources in the community). Data on these factors were obtained from the 2010 U.S. Census Bureau Data, 2006–2010 American Community Survey Data, and 2011 National Land Cover Database (NLCD) for each NYS county. Percentage of land or population with that characteristic or factor was calculated within each NYS county. Prevalence of AC in homes was also found to be a factor that plays a role in vulnerability, but there is no data available for NYS on prevalence or usage of AC in counties in NYS. As described below, this study used socioeconomic status and age of home as a proxy for this measure of AC prevalence.

Table 4. Heat-Vulnerability Factors

Vulnerability Factor	Definition
≥ 65 years	Percent population over 65 years of age
≥ 65 years living alone	Percent population over 65 years of age and living alone
Female	Percent population that is Female
African American	Percent population that is African American
Hispanic	Percent population that is Hispanic
Foreign born	Percent population that is Foreign born
Less English proficient	Percent population (+5 years) who speak English less than 'very well'
Poverty	Percent population with income below poverty level
Disability	Percent population (18-64 years) that has a disability
Unemployed	Percent population (18-64 years) that are unemployed
Education	Percent population with less than high school diploma
Older homes	Percent houses built before 1980
Building intensity	Percent land that is high-intensity developed land
Open land	Percent land that consists of open undeveloped areas
Population density	Density of population per square mile
Housing density	Density of housing units per square mile

1.1.4 Conclusion

This study identified 16 sociodemographic and environmental factors that can impact community heat-vulnerability in NYS. The spatial distribution of each vulnerability factor was observed to vary by county. To effectively summarize and use these findings by combining information on these multiple factors, we developed the HVI. The HVI was constructed at census tract level for higher resolution and allows for the quick identification of heat-vulnerable areas in NYS resulting in better planning and allocation of heat-adaptation resources and interventions. The next section describes the methodology used to develop the HVI and the results obtained once the index was scored and geographically mapped across the State.

1.2 Developing a Heat-Vulnerability Index for NYS

1.2.1 Introduction

Although the effects of extreme heat on health are largely preventable, heat-related deaths and illness are common occurrences during the summer, especially in vulnerable populations. As described previously, 16 community-level environmental and sociodemographic indicators were identified as heat-vulnerability factors in NYS. In this section, we will describe the development of the heat-vulnerability index (HVI) constructed based on these 16 heat-vulnerability factors. The tool was developed using statistical methods and a scoring system and will serve as an informative tool for local and State public health and emergency planning officials to enable quick identification of heat-vulnerable areas in NYS. To maximize its potential for use by local agencies, the tool was developed at the census-tract level, encouraging more targeted adaptation plans and interventions.

The HVI helps with the quick identification of heat-vulnerable areas, while the resulting vulnerability components (explained below) help understand why these regions are vulnerable. This way public health officials can plan intervention strategies and provide heat-adaptation resources like cooling centers to vulnerable communities in a timely manner during heat waves. The HVI can be used to 1) identify vulnerable communities and areas that may need immediate support during heat waves; 2) estimate the amount and type of heat adaptation resources that will be needed, based on characteristics of vulnerable populations in that community; 3) help officials plan community heat-mitigation measures such as developing parks and increasing green space or use of building materials, green roofs, and cold pavements that help with cooling; and 4) assess accessibility and adequacy of existing cool-down and adaptation resources like cooling centers and heat alerts in vulnerable areas.

1.2.2 Methods

The HVI uses data from the 2010 U.S. Census Bureau, 2006–2010 American Community Survey, and 2011 National Land Cover Database to estimate vulnerability to heat in each census tract. To be more useful to local health and preparedness agencies, data on the heat-vulnerability factors was obtained at census-tract level in order to develop the index at a higher resolution than county level. Census tracts with missing data or zero population were excluded from the analysis.

NYC land area is about 1/180th of the total land area of New York, but has a 12-fold higher population and housing density than of the rest of the State. NYC also has higher percentages (two- to four-fold) of populations that are Hispanic, African American, non-English speaking, and foreign born in comparison to the rest of the State. Based on the observed differences in sociodemographic and environmental characteristics between the two regions, the vulnerability assessment was performed separately for NYC and rest of state (ROS). Since the NYC Department of Health and Mental Hygiene has already developed a heat vulnerability index for NYC,[38] to avoid redundancy and confusion we will only display results of the HVI developed for the rest of the State (excluding NYC).

A correlation analysis was performed to assess if any of the 16 community vulnerability factors shared similar characteristics with others. Observing correlation between multiple variables, we used a statistical method and commonly used reductionist technique, namely Principal Component Analysis (PCA),[48] to group multiple related variables so that each group represented similar concepts of vulnerability. In other words, PCA summarizes factors measuring related characteristics into a new group called a "component," and each component resulting from this technique would represent an aspect of vulnerability that is common among the variables loading on (i.e., included in) it.

In addition, any variable exhibiting complex structure was excluded from the analysis.[44,48,49] In other words, if a variable loaded on more than one component, it was removed, and the analysis was rerun. The process was repeated until the components demonstrated a simple structure and each vulnerability variable loaded on just one component. After the process of elimination, the remaining vulnerability variables were used to develop the HVI.

1.2.2.1 Statistical Methods:

Component Selection Criteria:

Although in PCA the number of resulting components is equal to the number of variables being analyzed, only components deemed as meaningful will be retained for inclusion in the index. To identify these meaningful components, four selection criteria were used including 1) Eigenvalue-one criterion; 2) Scree test; 3) Proportion of variance; and 4) Interpretability criterion. The *Eigenvalue-one criterion* recommends retaining components that display an eigenvalue of greater than 1.00 since it indicates that the component accounts for more variance than a single variable (each variable contributes to one unit of variance). The Scree test involves plotting the eigenvalues associated with each component and looking for large breaks between the components. This criterion recommends retaining all components occurring before the last large break. With the proportion of variance criterion, each component that accounts for at least 10% of the total variance in the data would be retained and components that together account for at least 70% of the total variance should be retained as meaningful components. The interpretability criterion is the most important of the selection criteria and states that all variables loading on the component should have a similar concept as well as an inherent substantive meaning in the context of heat vulnerability.

Development of the Heat-Vulnerability Index:

Using the above criteria, four relevant and meaningful components were retained to develop the HVI. As a result of the PCA, each census tract is assigned a "factor score" for each component. The factor scores are standardized in the process of analysis and have a mean of zero and standard deviation of one. To ease interpretability of the components and map the spatial distribution of factor scores, each factor was divided into six categories (Table 5), based on the mean and the standard deviation. A scoring system was created ranging from one to six, with a score of one representing least and six representing highest vulnerability. Final scores for the HVI were calculated by summing scores for each component within each census tract. The cumulative scores for each tract were mapped and displayed spatially across the state (excluding NYC). Diverging color patterns were used to display scores and the final HVI, with blue indicating low and red indicating high vulnerability.

Table 5 Score Assignment

Category	Assigned score
>/=2 SD below mean	1
1-2 SD below mean	2
<1 SD below mean	3
>1 SD above mean	4
1-2SD above mean	5
>/=2 SD above mean	6

1.2.3 Results

Three variables including percent females, percent low education, and population density were dropped because they exhibited complex structure, as described in the "Methods" section above. Using the four PCA selection criteria, the thirteen sociodemographic and environmental vulnerability indicator variables were reduced to four meaningful components. The components represent four different aspects of heat-vulnerability: 1) Language component comprised of variables representing minority populations with language barriers including percent population that is Hispanic, foreign born, or those who speak English less than very well; 2) Socioeconomic component represented variables of economic disadvantage including percent population with household income below poverty line, those who are African American, unemployed, or with a disability; 3) Environmental/Urbanicity component comprised of variables representing urban and metropolitan areas including percent land with highly developed areas, high housing density, less open space, and percent older homes; and 4) Elderly/Isolation component includes percent population that is elderly or elderly and living alone (one-person household). Table 6 displays the number of census tracts in each heat-vulnerability component.

Table 6. Number of NYS Census tracts in each category of the four vulnerability components

Assigned score	Number of census tracts			
	Language Component	Socioeconomic Component	Environmental/ Urbanicity Component	Elderly/ Isolation Component
1	0	0	17	37
2	69	257	506	289
3	1756	1366	831	1184
4	580	770	860	880
5	170	196	463	244
6	148	134	46	89

Table 7 displays the vulnerability variables that load on each component and their statistical distribution. The vulnerability components during the process of PCA are created to have a mean of zero and standard deviation of one.

Table 7. Heat Vulnerability Variables and Components for NYS HVI

	Definition	Mean (Min, Max)	SD
Component 1: Language Component		0 (-1.44, 6.4)	1
Hispanic	Percent population that is Hispanic	8.55 (0, 79.3)	11.7
Foreign born	Percent population that is foreign born	10.14 (0, 63.7)	10.2
Non-English speaking	Percent population who speak English less than well	5.63 (0, 60.3)	7.7
Component 2: Socioeconomic Component		0 (-1.6, 7.6)	1
Poverty	Percent population with income below poverty level	11.9 (0, 100)	12.2
Disability	Percent population (18-64 years) with a disability	9.9 (0, 100)	6.4
Unemployed	Percent population (18-64 years) unemployed	7.9 (0, 53.85)	4.8
African American	Percent population that is African American	10.4 (0, 100)	17.9
Component 3: Environmental/Urbanicity Component		0 (-3.84, 4.15)	1
Older homes	Percent houses built before 1980	77. 6 (0, 100)	18.3
Building intensity	Percent land that consists of highly developed areas	5.8 (0, 84.12)	9.5
Open land	Percent land that consists of open undeveloped areas	42.1 (0, 99.80)	37.8
Housing density	Density of housing units per square mile	1528 (0, 22063)	2118
Component 4: Elderly/Isolation Component		0 (-2.98, 9.0)	1
≥ 65 years	Percent population over 65 years of age	14.4 (0, 69.7)	5.9
≥ 65 years living alone	Percent population over 65 years of age& living alone	10.3 (0, 53.1)	5.6

Abbreviation: SD, Standard Deviation

Figures 18-21 show the distribution of the four heat vulnerability components for NYS. Downstate areas closer to the NYC metro area showed higher language vulnerability than Upstate, with about 12% of the census tracts in the two highest vulnerability categories.

Figure 18. Language Component

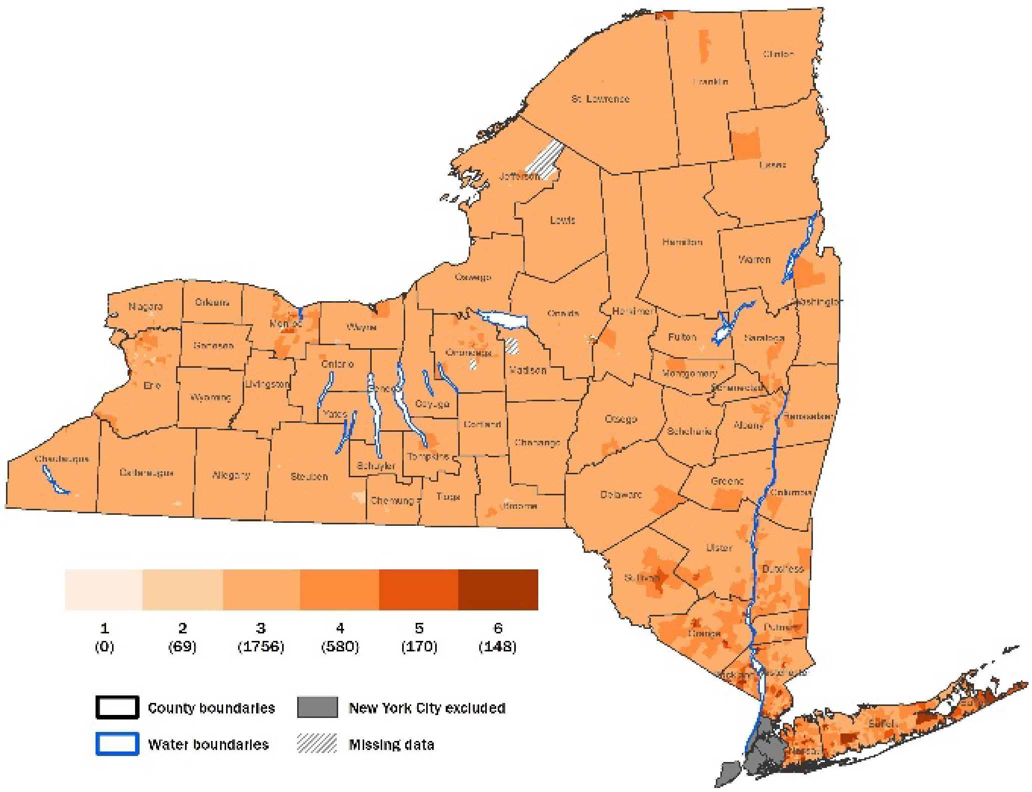
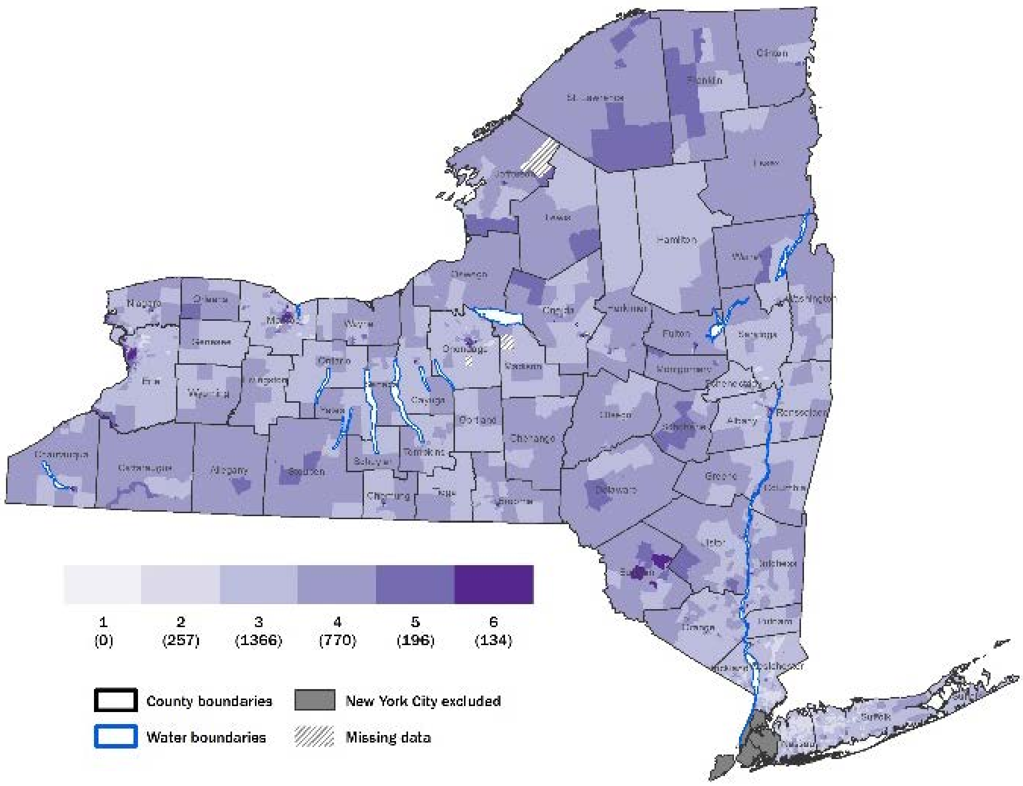


Figure 19. Socioeconomic Component

Greater spatial variability was seen with **socio-economic vulnerability** across the state with some clusters of vulnerable tracts in rural and few inner-city areas.



In Figure 20, the most vulnerable areas with the environmental/ urbanicity component was observed in the urban tracts with about 20% of the NYS census tracts falling in the highest two categories of vulnerability.

Figure 20. Environmental/ Urbanicity Component

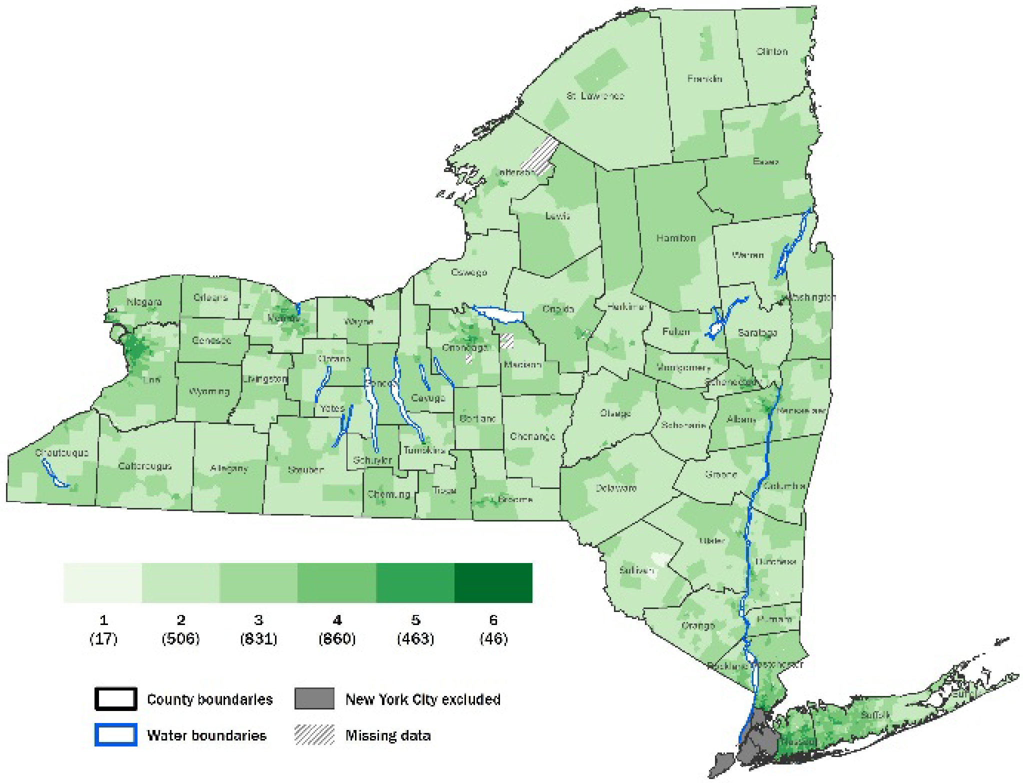
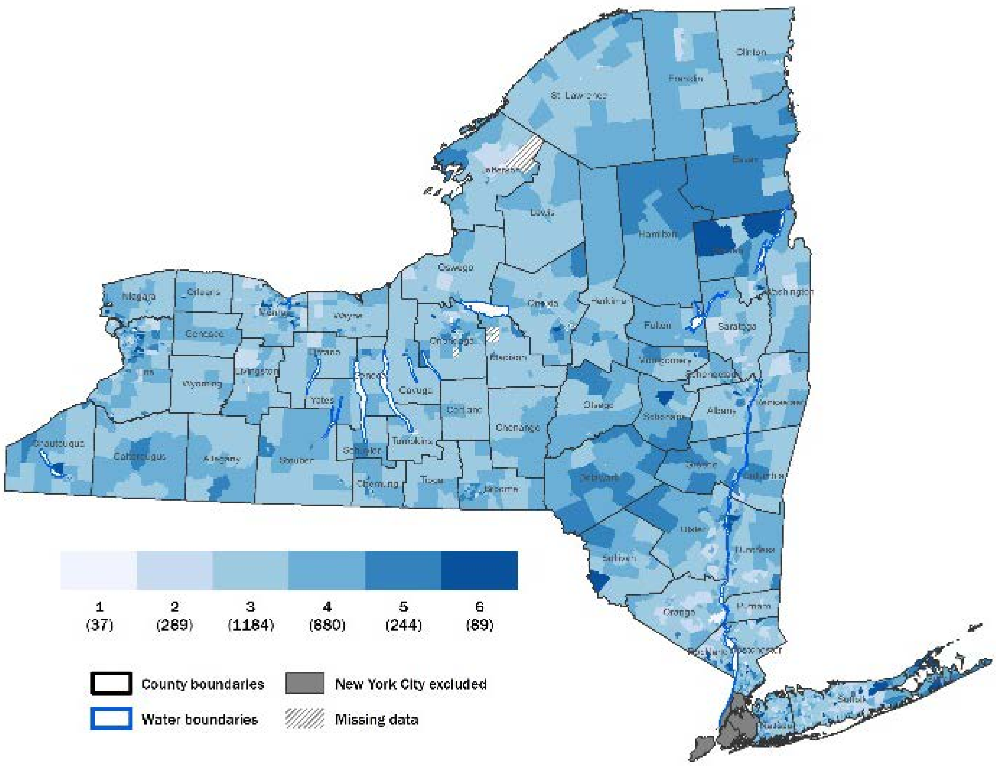


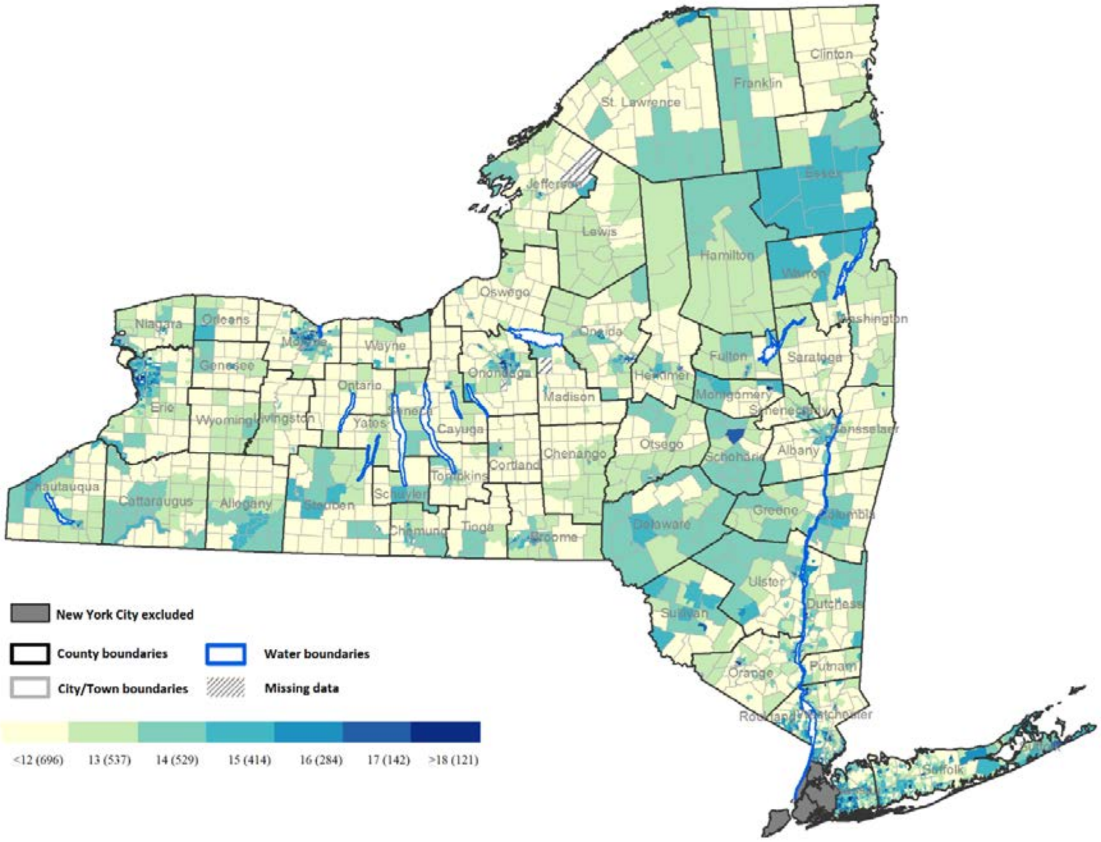
Figure 21 shows spatial variability in the distribution of elderly/social isolation component across the State with areas of higher vulnerability observed in more rural and suburban tracts across several counties in comparison to urban areas.

Figure 21. Elderly/Isolation Component



As displayed in Figure 22, the overall HVI scores (combining all four vulnerability components) for the 2,723 census tracts in NYS ranged from 9 to 24 with a mean of 13.93 and standard deviation of 1.92. Spatially most of NYS appears to be in the low to moderate vulnerability ranges, with about 80% of the NYS tracts falling in these categories (HVI score of 15 and under). One-third of NYS counties do not have any census tracts in the higher vulnerability categories (HVI scores 16 and higher). The most vulnerable areas with HVI scores 18 and above are concentrated in the more urban and metropolitan census tracts of NYS[50] in and around Erie, Monroe, Onondaga, Oneida, Albany counties and Downstate NYS. About 37% of the tracts in the highest vulnerability category are located in Westchester County and, along with those in Erie, Monroe, and Nassau Counties, comprise about 70% of the most vulnerable tracts.

Figure 22. Heat-Vulnerability Index for NYS by Census Tract



The cumulative HVI shows that while the majority of NYS lies in the "low vulnerability" categories, about a third of the census tracts are in the medium to high vulnerability ranges. A statewide vulnerability assessment shows that metropolitan and inner cities are the most vulnerable, but it is important to also be cognizant of the variability in heat vulnerability among population subgroups and take appropriate actions to mitigate heat effects.

1.3 Discussion and Recommendations

We created a fine-scale HVI for NYS using census tract level information to identify communities that are most likely to be impacted during extreme heat (EH), providing local public health and emergency management leaders with information that allows quick identification of areas of greatest necessity to plan interventions accordingly. Consistent with prior studies in other geographic regions,[17,51] we found that the highest vulnerability was observed in the more urban and metropolitan census tracts of NYS, although spatially most of NYS falls in the lower categories of vulnerability. We observed spatial variability across the four major vulnerability components. While the HVI helps to quickly identify communities with the highest overall susceptibility to EH, our findings also indicate that understanding the underlying basis of vulnerability is equally important for public health efforts that tailor appropriate interventions and disseminate them to target populations.

The language component showed downstate areas with higher vulnerability than upstate NYS, probably reflecting the higher proportion of immigrants in these regions. Among immigrants and populations with limited English proficiency (LEP), language is a common barrier to accessing resources and understanding alert messages issued during disasters.[43,52,53] Risk communication should, therefore, be disseminated in commonly spoken languages and through outlets like radio and television that are more accessible to these communities than social media and websites.

The socioeconomic component showed variability across the state with groups of high-vulnerability areas, including rural and inner-city areas. Economic status of both an individual and their community affect how one copes with EH. Using AC during periods of EH are commonly a part of cool-down messaging, but this may not be an affordable option for low-income households. Community resources like cooling centers can provide the public relief from hot weather. The economic status of a community can influence the accessibility and number of cooling centers available. For instance, in the absence of public transportation, accessing these facilities can be an obstacle among those who may not have their own vehicle. New York county offices[50] have stated that populations in rural or less urban areas have limited access to cooling centers as majority of these facilities are in metropolitan areas. Heat adaptation planning would have to take these points into consideration.

Environmental heat vulnerability in urban areas is most likely due to the urban heat island effect resulting from large areas of hardened impervious surfaces (asphalt, brick, concrete, and stone) in pavements and rooftops.[54] In comparison to surfaces covered in vegetation, impervious surfaces retain heat in their dense mass[55,56] and temperatures in these areas can be considerably higher. In addition to the anthropogenic heat generated by industry, traffic, and buildings.[55] urban areas have been observed to have more frequent and intense heat events and require longer time to cool during the night.[57] While heat mitigation programs should focus on residents of inner cities, local officials should also adopt mitigation measures such as parks and green spaces, use of high-albedo materials, green roofs, and cool pavements that help with cooling.[58]

The elderly/elderly isolation component showed vulnerability in several non-metropolitan areas of NYS, consistent across the U.S. where rural populations are older than urban and suburban populations.[59] Social isolation of the elderly is further heightened when the elderly live on their own in rural areas, possibly away from family and the majority of the community in comparison to their urban counterparts.[60] In addition to their health concerns accompanying aging, the elderly in rural areas now face the same challenges as other rural residents in terms of healthcare access and transportation and thus are less likely to receive assistance when needed.[59] Higher proportions of elderly and reduced accessibility to healthcare in non-urban areas suggests that heat mitigation plans, or interventions should also target the elderly in these areas.

1.4 Conclusion

This HVI is a resourceful tool that allows quick identification of heat-vulnerable areas and enables local and State agencies to plan interventions accordingly. The HVI can be useful in rapid response and effective resource allocation during EH events (dissemination of heat-health messages, home visits of at-risk groups, opening of cooling centers, etc.). Our findings also indicate that understanding the underlying basis of vulnerability is equally important for strategic and targeted public health efforts.

The HVI maps for each county will be disseminated among local health departments and emergency preparedness. Further details on the index development are available in an open access article titled “Development of a heat vulnerability index for New York State” and HVI maps for counties are located on the DOH website.

2 Project Future Vulnerabilities to Climate-Related Health Effects

2.1 Introduction

The DOH has done extensive work documenting the epidemiologic associations between climate variables and a variety of climate-sensitive morbidity and mortality outcomes. This section explores the potential future impacts that rising temperatures may have on health in the State under the influence of a changing climate in the 2020s, the 2050s, and the 2080s. Future climate impacts within the seven State climate regions as defined by the ClimAID project[10] were estimated using temperature projections from 35 global climate models and two emission scenarios. ClimAID is a study sponsored by NYSERDA that assesses potential vulnerabilities across NYS that may result from climate change. For information on the ClimAID projections, see "2014 Supplement – Updated Climate Projections Report".[10] In this section, we focus on hospitalizations for two health outcomes—cardiovascular and respiratory illnesses—because sufficient information was available from previous epidemiologic studies in NYS[7,8] to quantify the effects of temperature on these outcomes.

2.2 Methods

2.2.1 Climate Projections:

Climate model projections were obtained from the ClimAID team[10] (PI: Dr. Radley Horton, Columbia University) for each of the seven ClimAID regions (Figure 23). We used 35 different projections produced by the Global Climate Models (GCMs) used in the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5).[1,61] Each model was run using two different Representative Concentration Pathways (RCP) assumptions about the future trajectory of GHG emissions, one relatively high assumption (RCP 8.5) and one intermediate (RCP 4.5). The RCP 4.5 scenario assumes relatively ambitious GHG reduction strategies and stabilization shortly after 2100; the RCP 8.5 scenario is consistent with high GHG concentrations with no implementation of GHG-mitigation strategies and policies. RCP 8.5 assumes almost double the warming influence (or "radiative forcing") compared to RCP4.5.[62]

Figure 23. Seven ClimAID Climate Regions

Using 35 climate models and the two RCP scenarios, ClimAID provides future temperature projections for daily maximum and minimum temperatures in seven regions of the state from 2010 to 2099 based on three 30-year time slices, defined as the 2020s (2010 to 2039), 2050s (2040 to 2069), the 2080s (2070 to 2099), and for a baseline period of 1971 to 2000.

Table 8 and Figures 24 and 25 summarize projected temperatures in the 2020s, 2050s, and 2080s for each of the seven ClimAID regions. The table displays the mean, minimum and maximum number of days above 84°F (28.9°C) for each decade for each region, across the 35 climate models, and separately for the RCP 4.5 and RCP 8.5 emission scenarios. These data make it clear that the NYC region has far more hot days than the other regions in the baseline period (more than six per year vs. less than one on average for other regions), and the future impacts are projected to be the greatest in NYC as well, with up to 48 and 68 hot days by the 2080s under the RCP 4.5 and 8.5 scenarios, respectively, in the NYC region. Extreme temperature days in mid and late century are projected to increase for all regions, most markedly for the RCP 8.5 scenario which assumes almost twice the pace of warming as compared to the RCP 4.5 scenario. For example, some models projecting more than 65 hot days each year by the 2080s in NYC, as compared to the six per year in the baseline period, a tenfold increase. Increases in hot days are predicted for all regions under the RCP 4.5 and 8.5 scenarios, but more markedly for the latter.

Table 8. Numbers of Days Above 84°F in Each 30-Year Period Under Two Scenarios

Average # of days above 84°F per year					
Region	**Baseline**	**Scenario**	**Time period**		
	1970-99		2020s_84°F Mean (min, max)*	2050s_84°F Mean (min, max)	2080s_84°F Mean (min, max)
NYC	6.23	RCP 4.5	13.5(7.77:17.5)	22.9(9.53:38.3)	25.5(9.27:48.0)
		RCP 8.5	14.4(8.97:22.2)	29.5(14.8:47.1)	52.9(24.9:67.7)
Elmira	0.167	RCP 4.5	1.10(0.47:3.33)	3.60(0.63:11.2)	4.87(0.90:17.0)
		RCP 8.5	1.50(0.47:3.33)	6.37(1.53:17.0)	21.0(3.93:47.9)
Port Jervis	0.433	RCP 4.5	2.03(0.60:5.80)	6.17(0.97:16.1)	7.90(0.97:25.3)
		RCP 8.5	2.40(0.70:5.43)	10.8(2.40:22.3)	32.3(6.53:60.1)
Saratoga	0.433	RCP 4.5	1.93(0.70:4.33)	4.37(1.20:15.3)	5.87(1.50:24.9)
		RCP 8.5	2.33(0.70:4.87)	7.83(2.53:23.4)	24.0(5.07:54.3)
Indian Lake	0	RCP 4.5	0.00(0.00:0.10)	0.13(0.00:0.93)	0.23(0.00:2.63)
		RCP 8.5	0.03(0.00:0.13)	0.30(0.03:2.63)	2.97(0.13:16.9)
Rochester	0.533	RCP 4.5	2.57(0.93:7.70)	6.20(1.47:16.4)	7.93(1.93:24.2)
		RCP 8.5	2.87(0.93:6.90)	9.53(2.87:22.8)	23.6(6.93:58.1)
Watertown	0.2	RCP 4.5	1.83(0.33:4.60)	4.20(0.80:13.8)	5.80(1.20:19.7)
		RCP 8.5	2.10(0.47:4.57)	7.50(2.13:19.7)	22.9(4.90:51.0)

* The mean/max/min of model-specific estimated days per year among 35 models.

Figures 24 and 25 display the trend in the number of hot days (temperature predicted for each 30-year period. An increase in number of days above threshold temperature are predicted for all regions, but the NYC region shows consistently higher number of days above 84°F under both scenarios.

Figure 24. Days per Year Above 84°F in Each 30-Year Period Under RCP 4.5

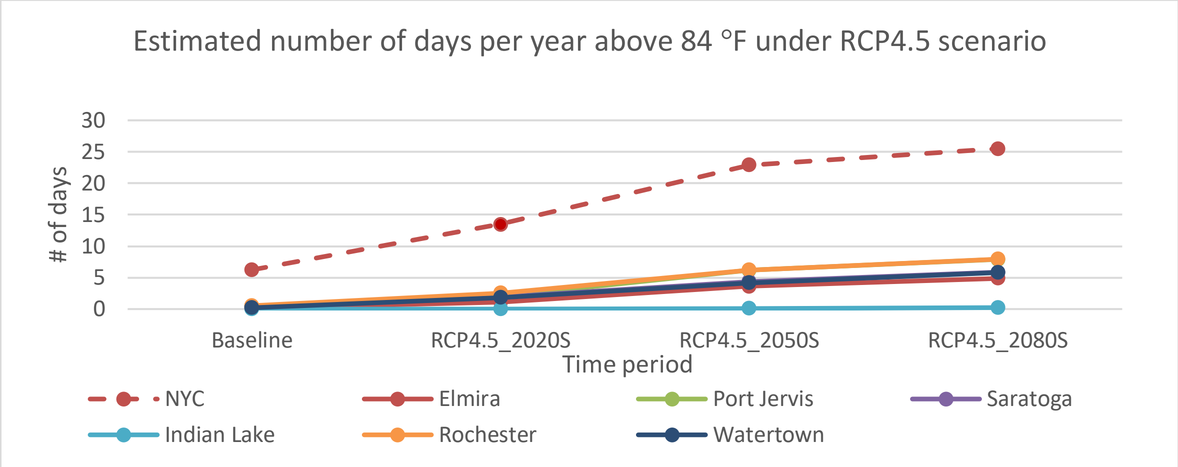
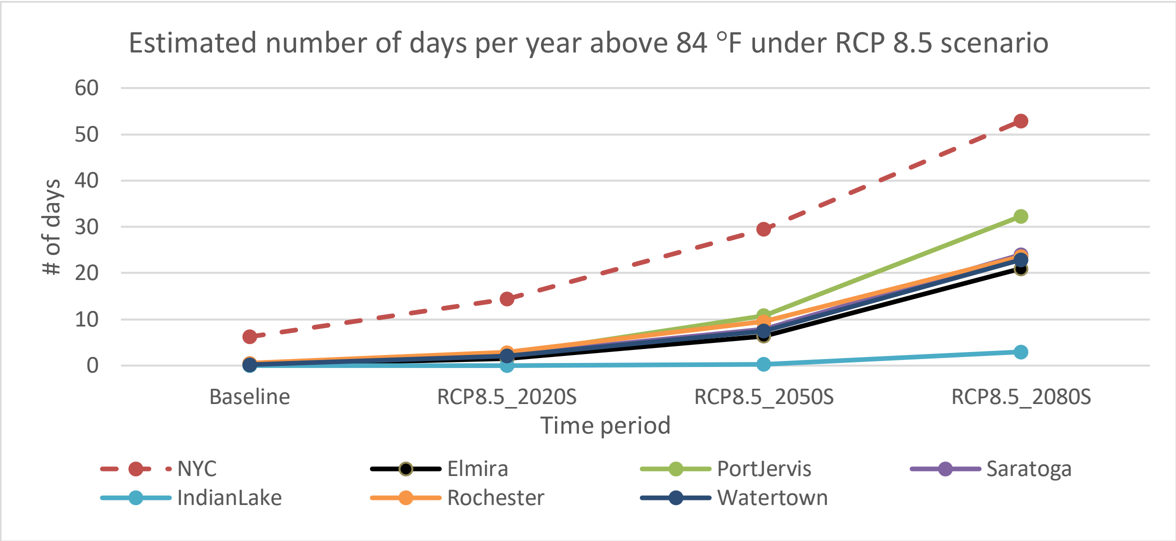


Figure 25. Days per Year Above 84°F in Each 30-Year Period Under RCP 8.5



2.2.2 Threshold Temperatures ($Temp_t$) and Relative Risks

According to the study by Lin et al.,[19] the threshold temperature ($Temp_t$) that no adverse effect would occur is 85°F (29.4°C) and 84°F (28.9°C) for CVD and respiratory disease, respectively. Percent change in risk associated with a one degree increase in temperature above the threshold is 3.60 for CVD at lag 3, and 2.70 for respiratory disease at lag 0. The lag is the number of days after exposure occurs when the increase in health risk is most evident. 'Lag 0' means that respiratory hospitalizations are associated with temperature exposure on the same day as admission, while 'lag 3' means that CVD hospitalization is associated with temperature exposure that occurred three days prior to admission. Other lag days were not considered for these outcomes since the percent change in risk was not statistically significant.

Therefore, for CVD

$$\boldsymbol{RR} = \begin{cases} \mathbf{1} & (\boldsymbol{Temp_{lag3}} < \boldsymbol{Temp_t}) \\ \mathbf{1 + 0.036} \times (\boldsymbol{Temp_{lag3}} - \boldsymbol{Temp_t}) & (\boldsymbol{Temp_{lag3}} \geq \boldsymbol{Temp_t}) \end{cases}$$

For respiratory disease

$$\boldsymbol{RR} = \begin{cases} \mathbf{1} & (\boldsymbol{Temp_{lag0}} < \boldsymbol{Temp_t}) \\ \mathbf{1 + 0.027} \times (\boldsymbol{Temp_{lag0}} - \boldsymbol{Temp_t}) & (\boldsymbol{Temp_{lag0}} \geq \boldsymbol{Temp_t}) \end{cases}$$

Note that the relative risk (i.e., the fractional increase per degree of temperature above the threshold) is 33% higher for CVD as compared with respiratory diseases (0.036 vs. 0.027). This means that high temperatures have a bigger impact on CVD admissions.

2.2.3 Temperature-related morbidity calculations

We estimated the temperature-related hospitalizations for both cardiovascular diseases (CVD) and respiratory diseases in the baseline period (1971–2000) and in 2020s, 2050s, as well as 2080s for the seven regions in NYS.

Excess summertime (June–August) admission or incidence (ΔMorb) attributable to temperature change in relation to the "threshold temperature" was calculated by multiplying baseline incidence rate (y_0), size of the exposed population and the attributable fraction:

$$\Delta\mathbf{Mort} = \boldsymbol{y_0} \times \boldsymbol{AF} \times \boldsymbol{Pop}$$

The attributable fraction, which characterizes the fraction of the disease burden attributable to temperature, was defined using relative risk or risk ratio (RR). In this study RR is a measure comparing the risk of hospitalization among cases exposed to threshold temperature to those not exposed. The attributable fraction is calculated as:

$$\mathbf{AF} = \frac{\boldsymbol{RR} - \mathbf{1}}{\boldsymbol{RR}}.$$

2.2.4 Population and Baseline Incidence Rate (y_0)

Population data from 2000 U.S. Census Bureau was used in all calculations. Summertime (June–August) admissions data from 1991–2004 were used to compute baseline incidence rate.[8] Details on health outcomes included can be found in Appendix A1.

2.3 Results

Baseline (1970–1999) and projected future excess incidence of heat-impacted cardiovascular disease are shown in Table 9 and Figures 26 and 27 in a similar format to those shown above for temperature. We see that there is the potential for substantial increases in annual heat-related CVD hospitalizations in all regions, with greater numbers where population numbers are larger, and for decades and scenarios with more warming. Note in Figures 26 and 27 the vertical scale for NYC is shown separately on the right side.

Table 9. Average Annual Excess CVD Incidence in Each 30-Year Period Under Two Climate Scenarios

Average annual excess CVD incidence					
Region	**baseline**	**Scenario**	**Time period**		
	1970-99		2020S Mean (10th, 90th)	2050S Mean (10th, 90th)	2080S Mean (10th, 90th)
NYC	91.8	RCP 4.5	254.4(160.5:331.8)	548.9(281.9:775.9)	640.1(344.9:1021.6)
		RCP 8.5	277.6(193.8:365.5)	815.5(470.8:1219.4)	2132.2(1062.0:3154.3)
Elmira	0.0394	RCP 4.5	0.52(0.16:1.13)	2.79(0.456:6.06)	4.90(1.08:19.3)
		RCP 8.5	0.71(0.29:1.38)	7.39(1.72:18.9)	42.2(10.0:142.5)
Port Jervis	0.232	RCP 4.5	1.48(0.54:2.48)	6.33(1.48:13.0)	8.56(2.15:42.3)
		RCP 8.5	2.05(0.94:3.32)	14.4(4.29:33.6)	82.2(14.0:176.9)
Saratoga	0.142	RCP 4.5	2.88(0.865:6.03)	13.3(2.80:31.4)	20.7(4.82:63.9)
		RCP 8.5	3.91(1.23:7.77)	29.8(7.75:63.4)	143.4(35.1:437.8)
Indian Lake	0	RCP 4.5	0.00(0.00:0.00)	0.013(0.00:0.037)	0.026(0.00:0.257)
		RCP 8.5	0.00(0.00:0.000924)	0.059(0.00:0.27)	0.87(0.0612:7.44)
Rochester	0.491	RCP 4.5	5.11(2.02:8.33)	18.9(5.16:39.5)	31.4(6.36:154.2)
		RCP 8.5	6.07(2.51:11.6)	40.5(11.9:119.2)	166.7(52.6:558.9)
Watertown	0.031	RCP 4.5	0.53(0.09:1.01)	2.78(0.56:5.94)	5.02(1.05:20.0)
		RCP 8.5	0.59(0.24:1.56)	6.76(1.64:17.3)	35.0(7.76:123.1)

* values in the parentheses show the 10th percentile and the 90th percentile estimates in each of the 30-yr future period

Figure 26. Average Annual Excess CVD Incidence in Each 30-Year Period Under RCP 4.5

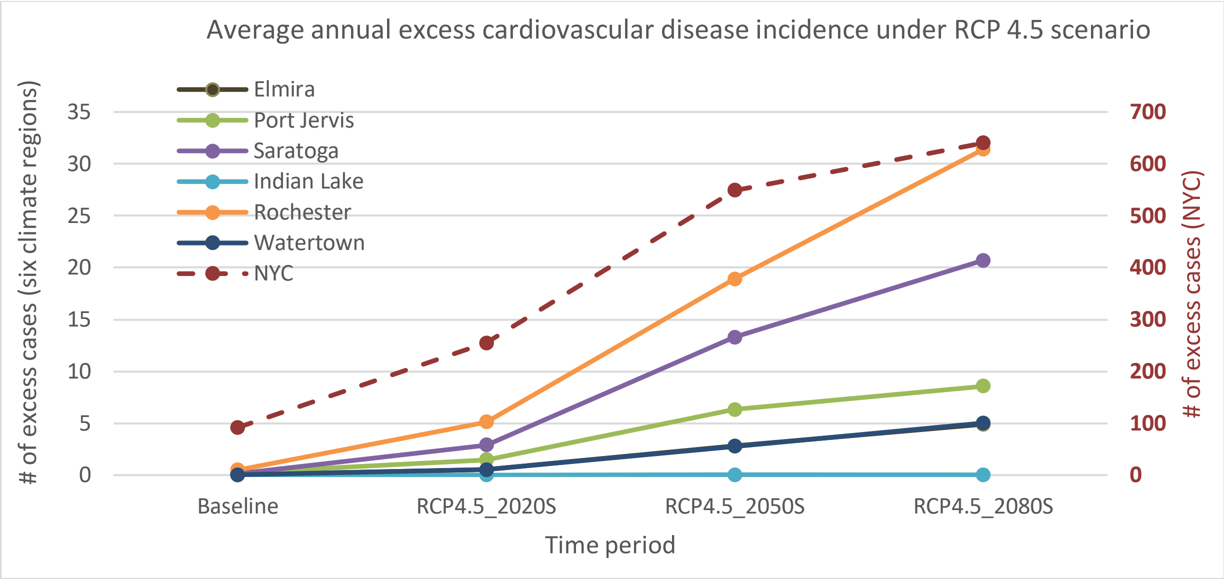
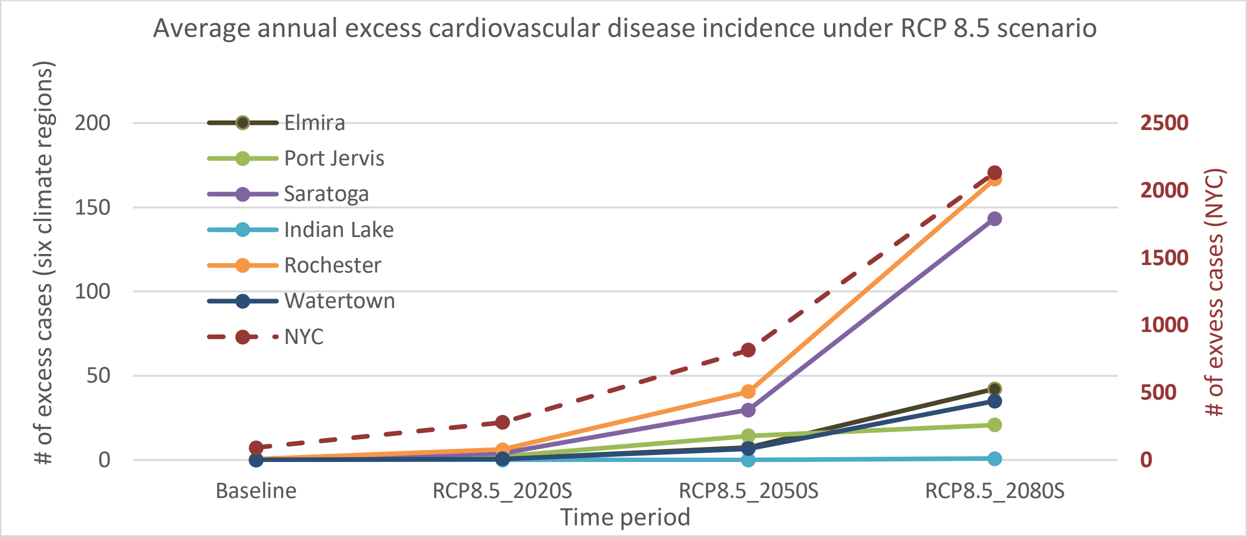


Figure 27. Average Annual Excess CVD Incidence in Each 30-year Period Under RCP 8.5



Corresponding results for projected changes in annual heat-impacted respiratory hospitalizations are shown below in Table 10 and Figures 28 and 29. While the numbers of cases are much lower for respiratory than for CVD, reflecting the lower baseline incidences of respiratory hospitalizations, the patterns over time and scenarios are similar. Climate change has a bigger impact on CVD in our analysis mainly because there are more CVD cases to begin with, but also because the relative risk for temperature-related CVD cases is somewhat higher than for respiratory cases, as previously noted.

Table 10. Average Annual Excess Respiratory Disease in Each 30-Year Period Under Two Climate Scenarios

Annual excess respiratory disease incidence					
Region	**Baseline**	**Scenario**	**Time period**		
	1970-99		2020S Mean (10th, 90th)	2050S Mean (10th, 90th)	2080S Mean (10th, 90th)
NYC	24.3	RCP 4.5	63.1(41.0:81.7)	129.1(69.5:178.4)	149.5(84.9:229.9)
		RCP 8.5	68.8(49.5:89.3)	188.2(111.3:271.4)	461.9(239.2:663.6)
Elmira	0.00888	RCP 4.5	0.14(0.0485:0.269)	0.64(0.137:1.24)	1.05(0.242:3.71)
		RCP 8.5	0.18(0.0841:0.321)	1.48(0.414:3.57)	7.45(1.93:23.0)
Port Jervis	0.0695	RCP 4.5	0.39(0.139:0.633)	1.52(0.398:2.95)	2.05(0.56:8.85)
		RCP 8.5	0.53(0.242:0.852)	3.26(1.04:7.18)	16.0(3.20:32.2)
Saratoga	0.064	RCP 4.5	0.69(0.268:1.40)	2.75(0.698:5.75)	3.90(1.17:11.8)
		RCP 8.5	0.94(0.370:1.71)	5.56(1.73:11.6)	24.5(6.48:68.5)
Indian Lake	0	RCP 4.5	0.00(0.00:0.00)	0.0043(0.00:0.00997)	0.00859(0.00:0.055)
		RCP 8.5	0.00(0.00:0.0014)	0.014(0.00:0.0575)	0.19(0.02:1.40)
Rochester	0.114	RCP 4.5	0.93(0.409:1.54)	3.21(0.997:6.47)	5.04(1.27:22.1)
		RCP 8.5	1.14(0.522:2.11)	6.61(2.22:18.0)	23.6(8.09:73.4)
Watertown	0.00976	RCP 4.5	0.15(0.0390:0.262)	0.63(0.152:1.17)	1.01(0.27:3.67)
		RCP 8.5	0.16(0.0712:0.386)	1.36(0.400:3.17)	6.03(1.51:19.3)

*values in the parentheses show the 10th percentile and the 90th percentile estimates in each of the 30-yr future period

Figure 28. Average Annual Excess Respiratory Incidence in Each 30-year Period Under RCP 4.5

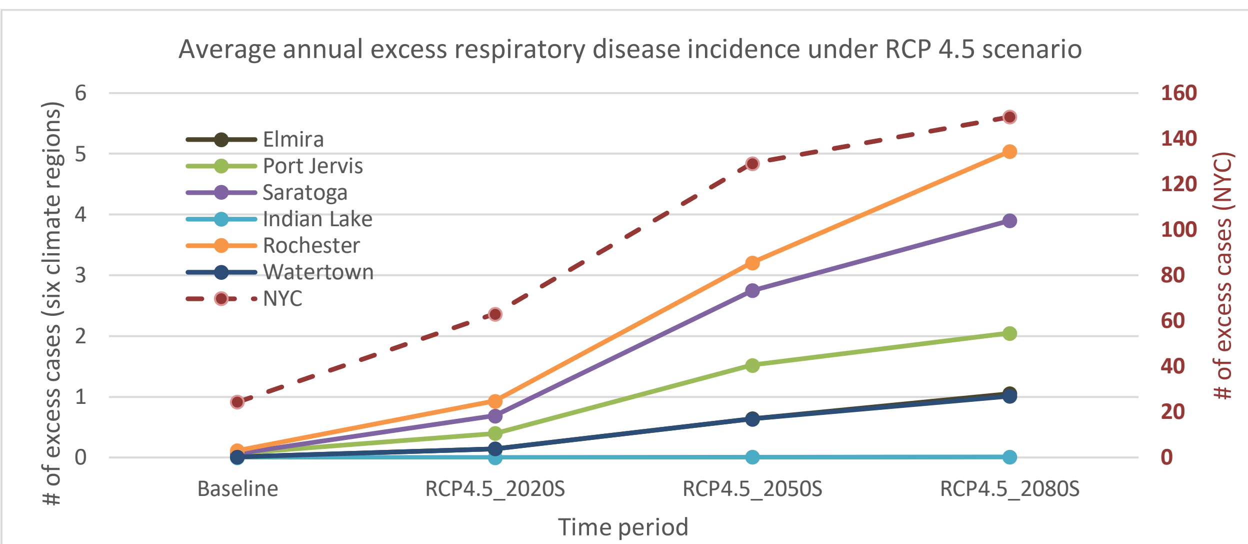
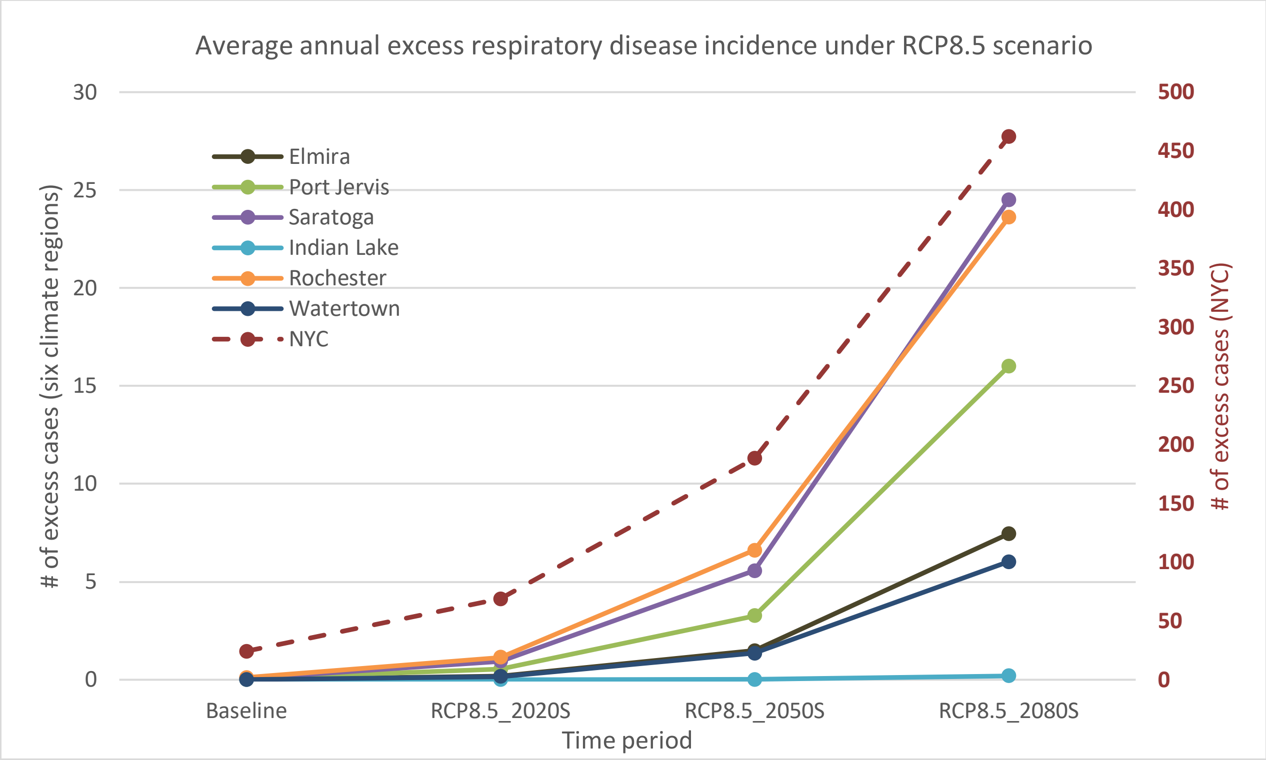


Figure 29. Average Annual Excess Respiratory Incidence in Each 30-year Period Under RCP 8.5



Figures 30 to 36 display the distribution of heat-impacted CVD and respiratory disease hospitalizations across the seven regions for the RCP 4.5 and RCP 8.5 scenarios. Since there are 35 climate projections involved in each climate model, they are unique and provide slightly different future projections of temperature, and as a result, hospitalizations for each region. The box plots below convey these model-to-model variations, with the median value across all models represented by the solid horizontal line in the middle, the 25th and 75th percentiles represented by the lower and upper limits of the box, and the min and max by the extended bars. These plots demonstrate that there is substantial variability across scenarios and models in the projected health impacts, especially for mid to late century. To some extent, this represents the uncertainty in estimates of future health impacts of a changing climate.

Figure 30. Elmira Heat-Impacted Cardiovascular and Respiratory Cases for RCP 4.5 and 8.5

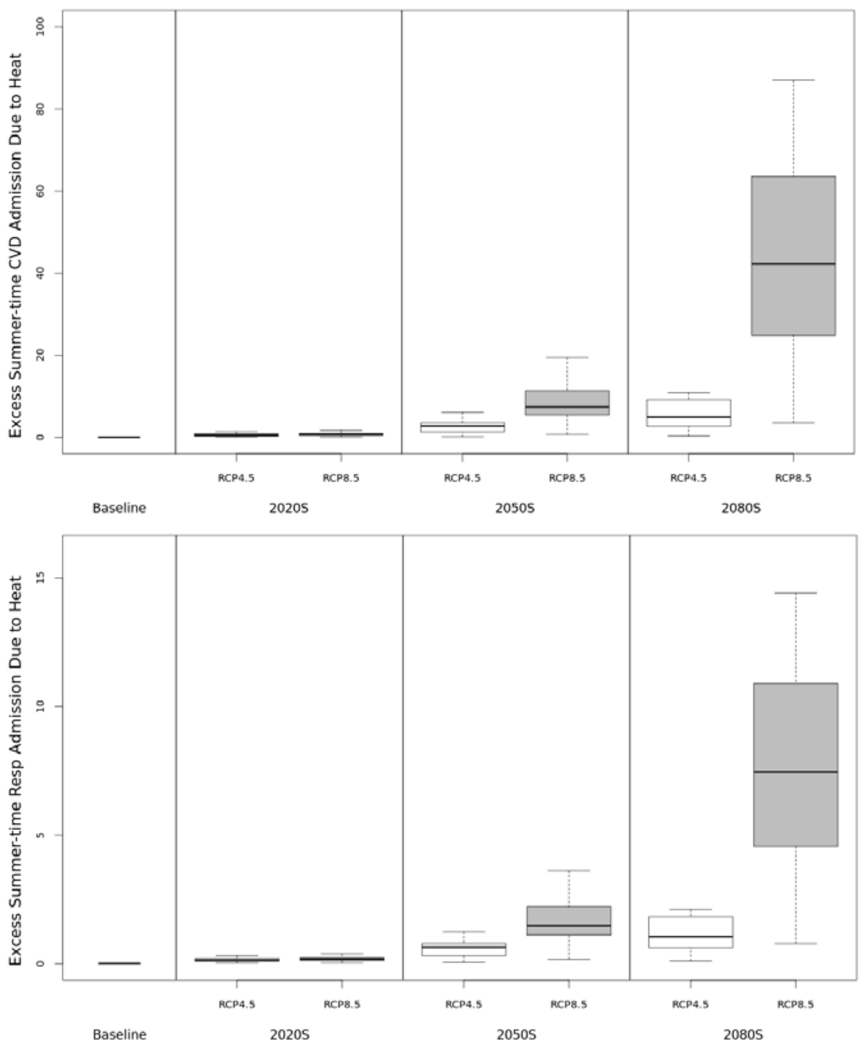


Figure 31. Indian Lake Heat-Impacted Cardiovascular and Respiratory Cases for RCP 4.5 and 8.5

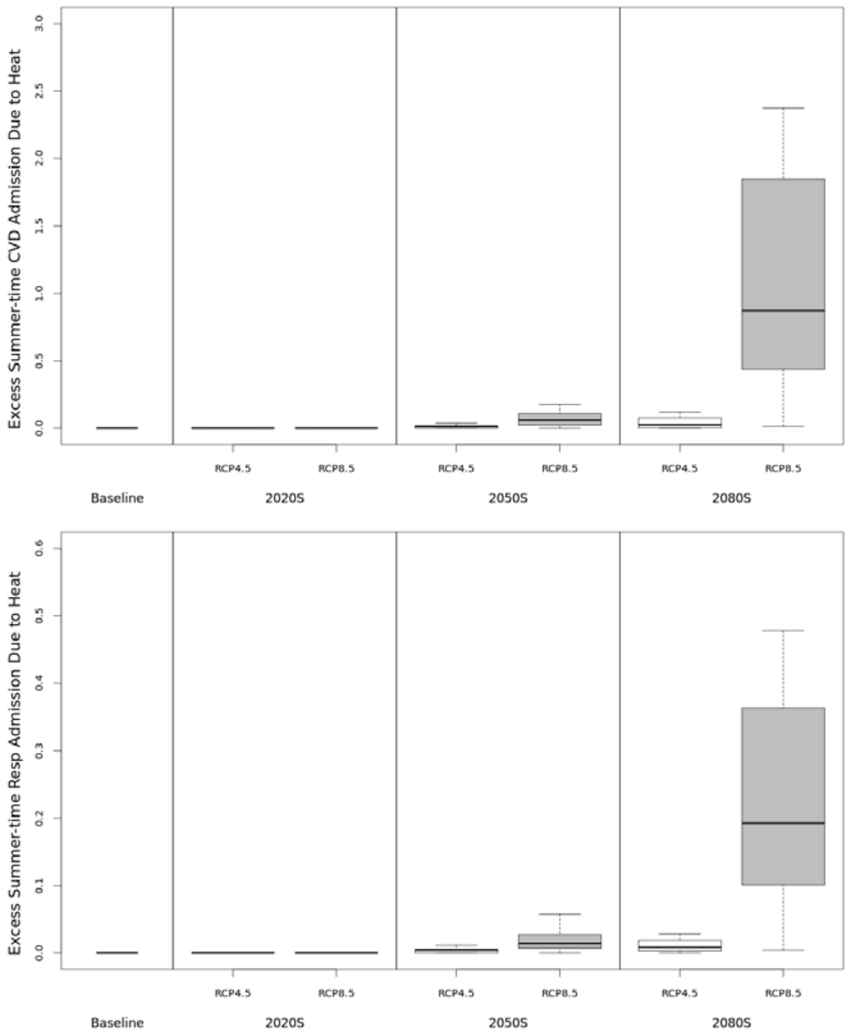


Figure 32. NYC Heat-Impacted Cardiovascular and Respiratory Cases for RCP 4.5 and 8.5

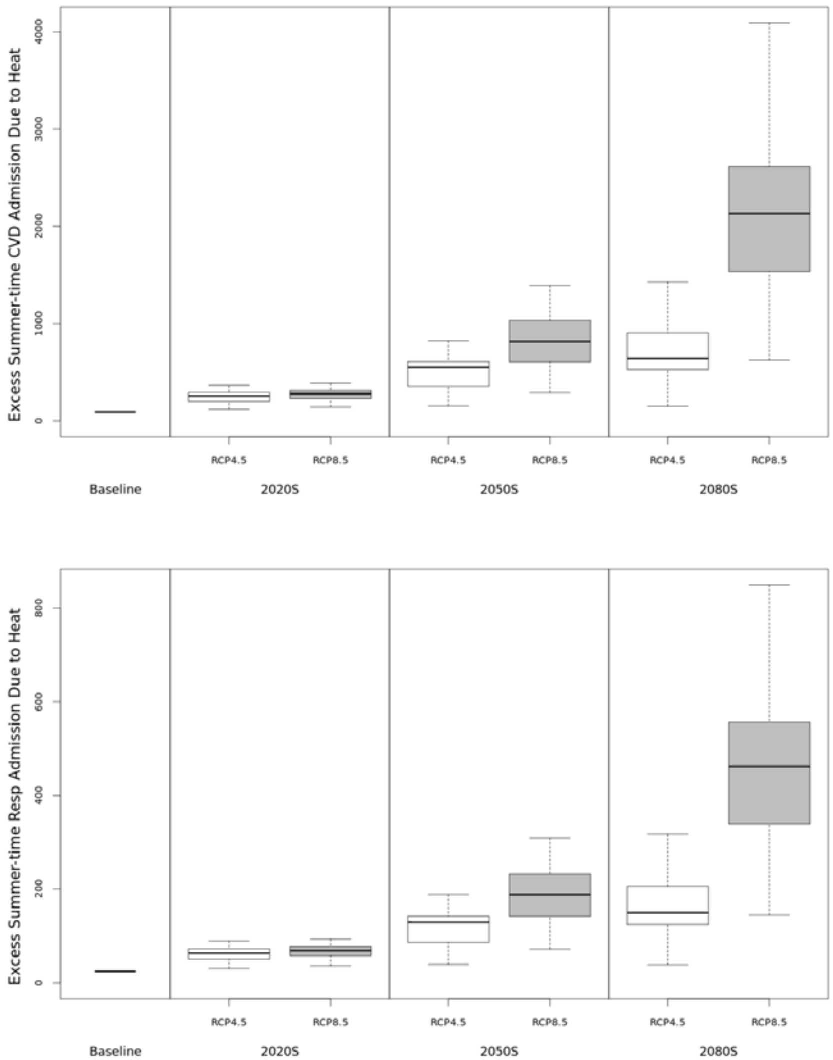


Figure 33. Port Jervis Heat-Impacted Cardiovascular and Respiratory Cases for RCP 4.5 and 8.5

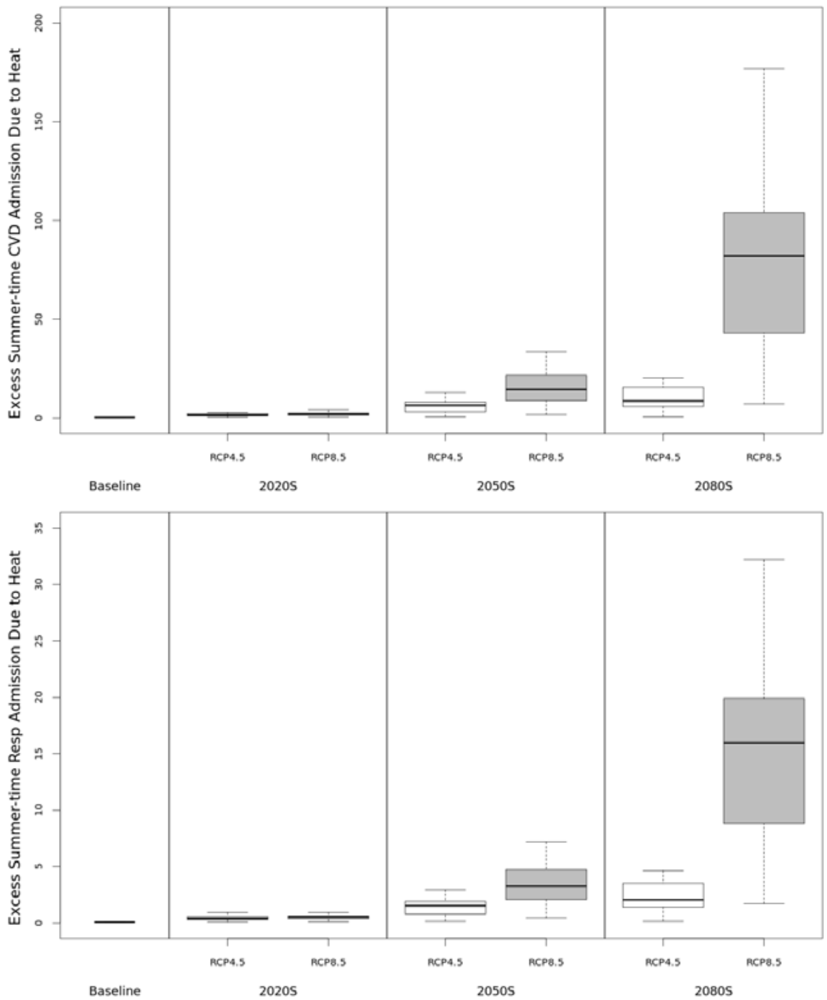


Figure 34. Rochester Heat-Impacted Cardiovascular and Respiratory Cases for RCP 4.5 and 8.5

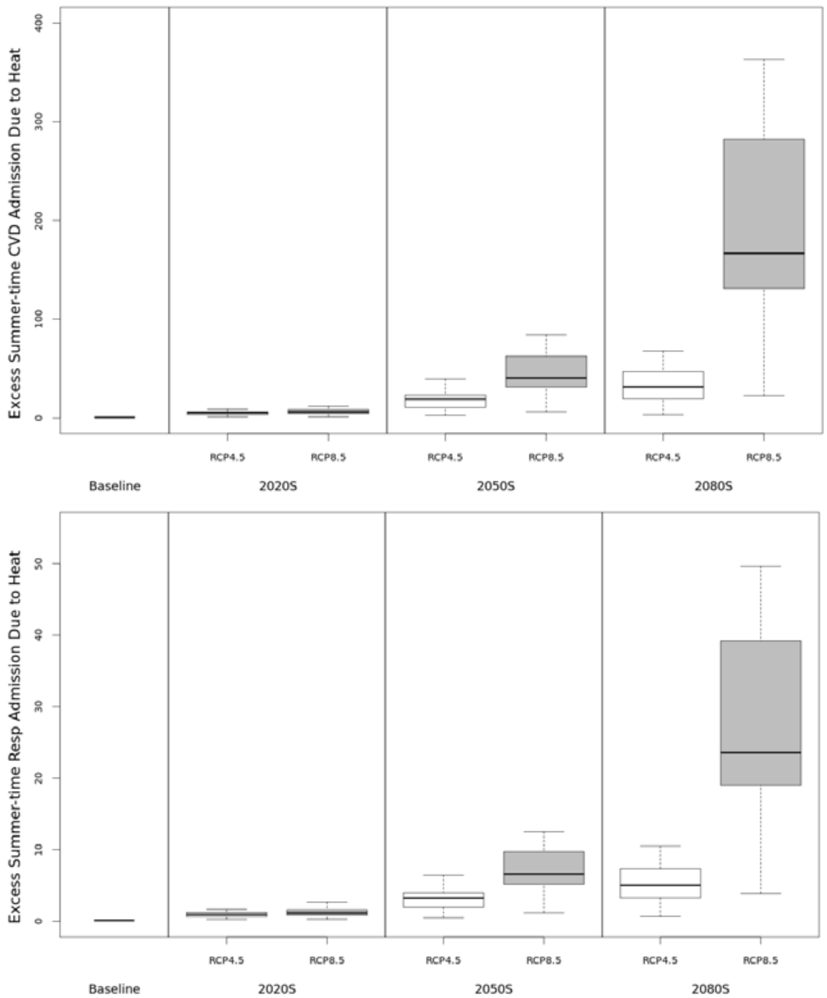


Figure 35. Saratoga Heat-Impacted Cardiovascular and Respiratory Cases RCP 4.5 and 8.5

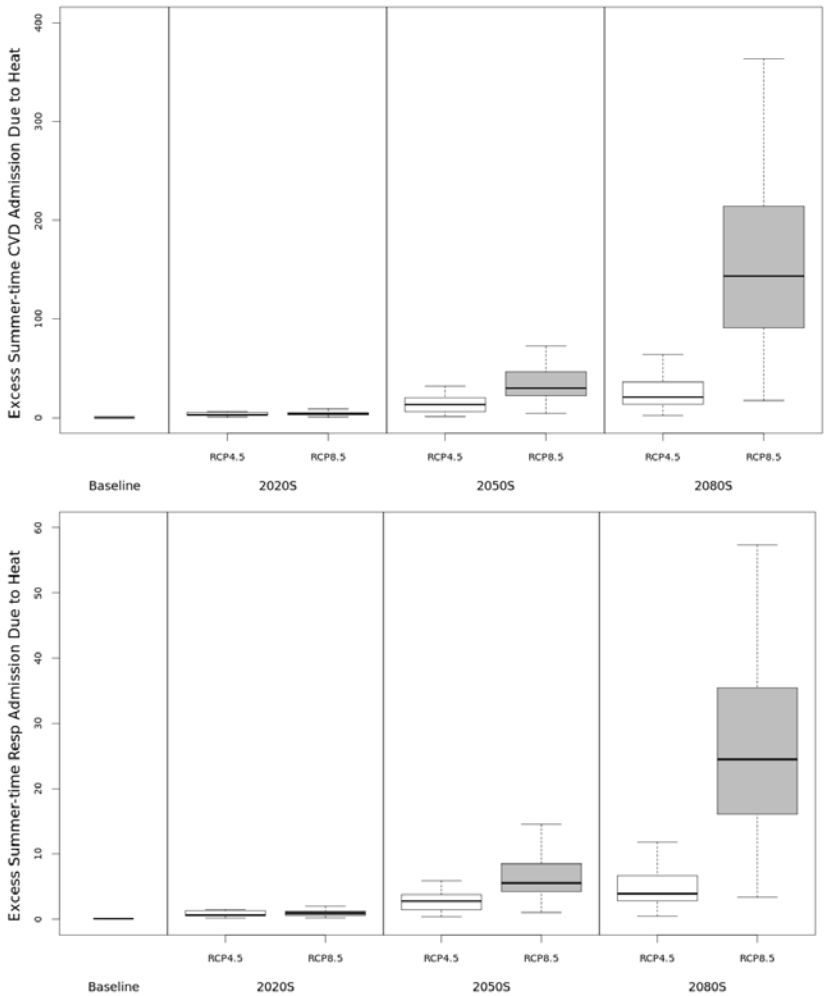
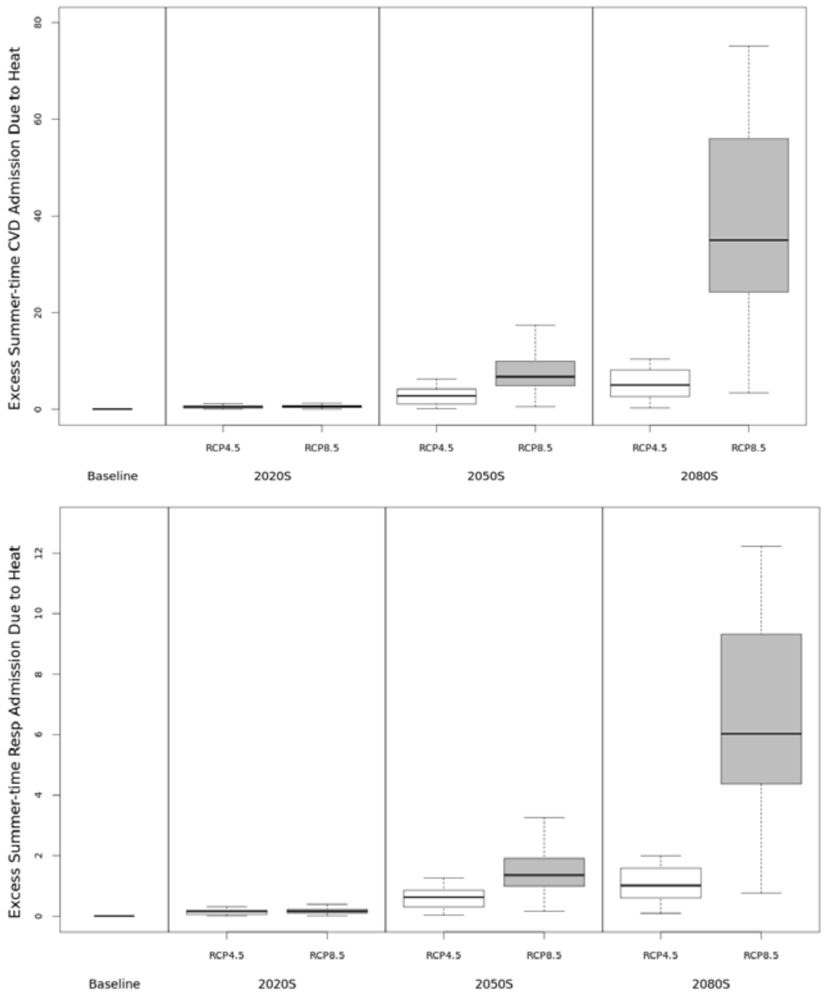


Figure 36. Watertown Heat-Impacted Cardiovascular and Respiratory Cases for RCP 4.5 and 8.5



2.4 Discussion

These projections of potential future health impacts of climate change in NYS take into account the most up-to-date projections of future temperatures from the ClimAID project. As such, they represent our current best understanding of potential future climate change in these regions. The other key inputs to the analysis were exposure response relationships for CVD and respiratory hospitalizations, derived from the epidemiologic work carried out as part of this project. The results imply that climate change, particularly warming temperatures, could result in substantial increases in temperature-related morbidity in the future in NYS. It is important to note that by holding all else constant, including exposure-response functions, populations, and baseline hospitalization rates, we isolate the potential impacts of climate change. However, in reality, all of these inputs most likely will change, with potentially profound impacts on actual future temperature-related health effects observed in the 2020s, 2050s, and 2080s. Our analysis did not attempt to project how these non-climate factors might change in the future. This is consistent with standard practice in the field by incorporating changes in climate, but not changes in health status, age, and population demographics in the future projections.

3 Assess Current Cooling Centers and Public Awareness of Heat Adaptation Resources in NYS

According to the EPA, heat-related mortalities have ranked the highest among weather-related fatalities[63] in the United States. Several of the deaths were attributed to long exposure to outdoor heat or having little or no AC.[4,5] As described in the previous section, the predicted increase in extreme heat events and number of hot days could result in a substantial increase in temperature-related morbidity. But many of the negative health impacts of extreme heat can be reduced or even prevented by avoiding being outdoors for extended periods or staying in cooler places during extreme heat days.[7,16,21-24] Studies show that spending at least two hours a day in an air conditioned place during extreme heat events can greatly prevent or reduce negative health impacts.[7,16,21-23] Following this recommendation, many organizations and local government agencies conduct mitigation efforts like issuing heat advisories and warnings, identifying vulnerable populations, and providing the public with cooling centers in their communities where they can seek relief during extreme heat events. This section describes our assessment of 1) local agency involvement with setting up cooling centers; 2) cooling centers in terms of adequacy and accessibility; and 3) public awareness of cooling centers and heat adaptation strategies.

3.1 Determining the role of county health and emergency management offices in setting up cooling centers

3.1.1 Introduction

Cooling centers are usually located in local government-run locations like libraries, senior or community centers, fairgrounds, and recreation parks, but can also be at privately owned facilities like local shopping malls, sports stadiums, museums, and grocery stores. While cooling centers have become more common in recent years, there has been very little research to assess the availability of cooling centers, and how involved local authorities are in terms of planning and running these centers. Considering that knowledge of this valuable heat adaptation resource can inform county leaders and help plan and implement mitigation activities, the main objectives of this study were to 1) survey local health and emergency preparedness leaders on their involvement in setting up cooling centers and their perception of cooling centers as resources of heat adaptation; 2) determine cooling center locations and create a centralized database available to the public; and 3) disseminate findings to local and State public health and emergency preparedness leaders to help create or supplement regional response plans to extreme heat conditions.

3.1.2 Study Design and Methods

Since a cooling center resource already exists for NYC residents, efforts in this project focused on the rest of the State. Statewide cooling center locations were determined from two main sources: a survey conducted among local health departments and county emergency offices; and online resources including official websites of State County Agencies and American Red Cross Chapters.

The DOH developed and conducted a survey (Appendix B) among local health department (LHDs) and county emergency management offices (EMOs) among 57 NYS counties with the goal of obtaining locations of cooling centers as well as determining the county officials' involvement in setting them up during periods of extreme heat. The American Red Cross (ARC) chapters in NYS were also contacted to obtain locations of cooling centers that were set up by ARC chapters during times of need in NYS. ARC chapters themselves rarely serve as cooling centers, rather they assist with setting up cooling centers or suggest air-conditioned facilities in the community when requested by county offices.

In addition, during the summer months of 2012–2013, searches of cooling center locations were conducted on official websites of 57 counties. Physical address and other details of cooling centers locations were noted.

Survey responses and online search results were recorded using Microsoft Access 2013 and cooling center locations were geocoded and mapped using SAS Version 9.4. MapMarker Ver22 and MapInfo 12.5. Geographical county level analysis was also performed with key demographic and regional characteristics.

3.1.3 Results

A total of 377 cooling center locations were obtained or identified from multiple sources including the survey, online resources and ARC Chapters.

3.1.3.1 Survey findings

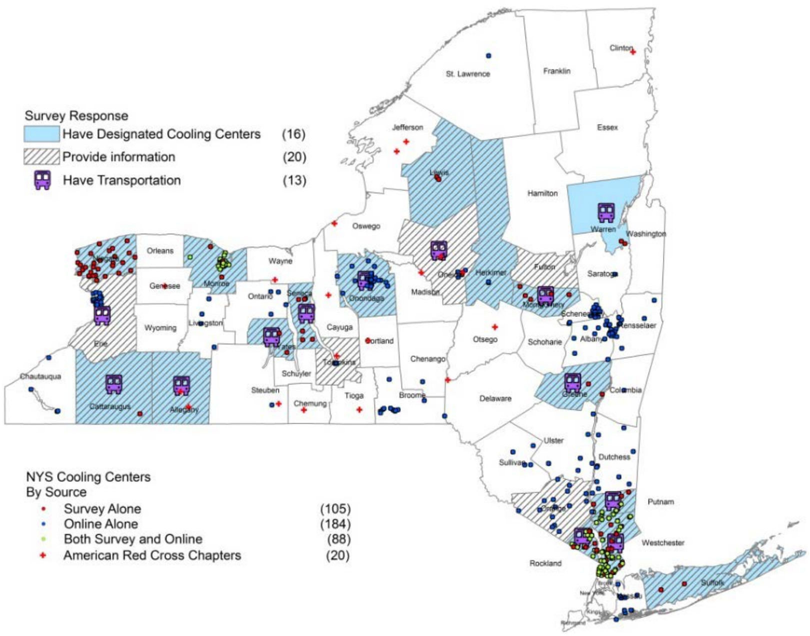
The DOH received 62 responses from LHDs and EMOs covering 56 counties. With the assistance of the directors of the NYS Regional Environmental Health Offices, the local health departments that had not responded were contacted again and the DOH was ultimately able to obtain 98% response rate.

Table 11 and Figure 37 display the 193 cooling center locations across the State and survey responses obtained from the county agencies. Less than a third of the counties reported having cooling centers. Approximately 36% provide information on cool-down locations, with most (90%) providing information to the public when heat advisories were issued for the region. Among the various media and methods agencies use to disseminate cooling center information to the public, radio (90%) was the most frequently used platform, followed by internet (official county websites, social media, and town-wide emails). AC and cold water were provided at almost all facilities. About 65% of the agencies either provided educational materials on vulnerability to heat and/or protection from extreme heat via website or handouts. The majority of agencies reported that cooling centers were accessible via public transportation, and approximately 13% also provided additional transportation to and from the centers especially for seniors.

Table 11. County Offices Responses to 2013 Cooling Center Survey

Survey question	Counties %
Have designated cooling centers	29%
Provide information on cooling centers	36%
When cooling center information is provided	
When there is a heat advisory	90%
Throughout summer	11%
Methods of providing cooling center information	
Radio	90%
Internet (county website/social media/messaging via email)	84%
Newspaper	68%
Television	58%
Other	16%
In-Facility Services at Cooling Center	
Air conditioning (indoor cooling centers)	100%
Cold Drinking Water	81%
Provide information on protection against heat	63%
Provide information on protection on vulnerable populations	50%
Food/Snacks	38%
First Aid or Medical services	31%
Transportation to and from Cooling Centers	
Have public transportation	76%
Provide transportation	13%
County perception and plans for cooling centers	
Promote informal CC	63%
Think CCs are important	63%
Plan to have CCs in future	25%

Figure 37. Cooling Centers (2012–2013) and Survey Responses



We also surveyed agencies on their perception of cooling centers and planning for these facilities as resources for heat adaptation. Responses showed more than 63% of counties without reported cooling centers promote local resources as informal cool-down places during hot weather and consider cooling centers as an important resource of heat adaptation. On the other hand, more than a third said they do not currently have plans for cooling centers in their county nor do they intend to plan for them in the future. Lack of need and low attendance in the past were the most common reasons why county officials did not view cooling centers as an important component of local government’s response and why there were no future plans for centers. Sparse populations, cooler regional temperatures, and the availability of natural cool-down resources in the community were reasons cited for the lack of need. Some counties could not set up cooling centers on their own because of limited resources in terms of facilities, funds, and staff.

3.1.3.2 Online resources

Of the 57 official county websites visited, 16 posted cooling center location information to their websites and 14 counties provided information via media articles, T.V., and radio stations. Overall, 27 counties shared information on 272 cooling centers including addresses and hours of operation (Figure 37). All counties that provided information on their websites also addressed the public on how to protect themselves from heat either directly on the web or via a link to Center for Disease Control and Prevention’s facts about heat stress.[33]

3.1.4 Discussion

We identified 377 cooling centers statewide in this study, with most cooling centers located in metropolitan areas. Almost a third of the counties do not view extreme heat as a threat for their counties and, therefore, do not think heat adaptation resources in the community are necessary. This could be because of the mild to moderate temperatures with the climate usually observed in these parts of the State.

There was a high survey response rate (98%) with responses indicating that county EMOs were more likely to be involved than LHDs in setting up cooling centers as part of their emergency preparedness efforts. The response rate was high in this study because of interagency communication between State offices, LHDs, and EMOs as well as with other organizations including municipalities and fire departments. Regional Environmental Health Directors played a key role in maximizing response rate among counties within their regions by contacting them directly to follow-up on their survey responses.

Radio and internet were the most common methods of communicating information to the public. Although county officials did not report using television as a major platform, it is possible that local networks obtained information from resources used by county agencies and rebroadcast it to the public. But vulnerable populations, such as the elderly and homeless, may not have access to television, radio, or the internet during heat waves, so extra outreach efforts must be made.

Cooling center information was generally available between May and September, but triggers for this provision varied by county. Some counties provided information throughout summer, and some on an "as needed" basis, which usually meant they followed NWS alerts and advisories issued in that the region. NWS heat advisories in NYS are issued when the heat index is expected to exceed 105–110°F (depending on local climate) for at least two consecutive days. However, since studies show that heat can affect health at much lower temperatures and can vary regionally,[6-9] it may be beneficial for counties to have cooling centers available at lower temperatures than current NWS heat warning thresholds.

Although all indoor cooling centers reported in this study had AC, these were not the only cool-down places open to the public. Some municipalities set up outdoor cooling sites like spray parks and State or local parks, which were sometimes used more frequently than indoor cooling centers. With this in consideration, counties should promote the use of outdoor cooling sites as a better alternative to staying indoors without AC. Accessibility can also influence attendance, but not many facilities provided additional transportation unless they cater to a specific population like seniors. Most cooling centers were accessible via public transportation especially when housed in locations like public libraries and senior centers.

Although extreme heat is not perceived as a threat in counties with mild summers, homes in that region may not be equipped with AC. Therefore, when a heat event occurs, the effects of heat on health could be severe as people are neither acclimatized to extreme heat nor do they have resources at home to adapt to hot weather. This may become even more important under future climate change. This emphasizes why cooling centers should be available and accessible to the public and why risk and health protection communication to the public is important, even if the region does not usually experience extreme heat events.

Cooling centers appear to be concentrated in metropolitan areas of the State with few in small towns and rural areas. The distribution of cooling centers seems reasonable in view of population density, although most rural areas have numerous natural cool down resources like wooded areas and lakes, most homes may not have AC. Therefore, cooling centers should be set up in publicly accessible facilities even in rural areas so people without access to AC at home can have community access.

Although this study attempted to capture all the cooling centers, there could be some degree of underreported cooling center locations—locations can change frequently depending on availability, capacity, or the occurrence of an extreme heat event. In addition, people usually go to places in their community like pools, malls, and recreation centers even though those places are not official cooling centers, so usage of these informal locations are not included in this study.

Results from survey and online resources were shared with Regional Directors of Environmental Health. This study has greatly improved our knowledge on cooling center locations across the State helping create a centralized database, which is now available to the public on the DOH website. Through continued collaborative efforts between the DOH, LHDs, and county EMOs, the database will be updated annually. This information is disseminated to the public in a timely manner via multiple platforms including county websites, NWS messaging, and social media outlets.

3.1.5 Conclusions

While many county agencies are proactive about addressing the impact of extreme heat on health, some are yet to accept cooling centers as a resource of heat adaptation for people, especially among those without access to AC. In 2013, less than a third of State counties had designated cooling centers every summer, and those available were mostly located in metropolitan and urban areas. These counties provide information via different venues, but most commonly by internet and radio. Although younger populations obtain their information from the internet, the elderly are more likely to rely on television, radio, or newspapers, highlighting the importance of using multiple media outlets to reach all sectors of the community. Since most cooling centers were located in public buildings, additional transportation was often unavailable. Accessibility and effective communication to the public and between agencies are necessary to maximize attendance at cooling centers.

More information on this assessment can be found in the article titled “Surveying Local Health Departments and County Emergency Management Offices on Cooling Centers as a Heat Adaptation Resource in New York State.”

3.2 Assessing Cooling Centers in NYS as Resources of Adaptation to Heat

Although some Upstate counties already have plans in place to set up cooling centers, it is not uniform across the State. This could be due to numerous reasons pertinent to that region including absence of extreme heat over the past several years, low population density, understaffed or underfunded programs, and adequate open land cover. In lieu of the projected increase in frequency and intensity of extreme heat events and trends of rising temperatures,[1,10,21] it would help to determine if existing cool-down resources are accessible and adequate enough to handle the predicted climate change. This section describes a statewide assessment to determine if cooling centers are adequately distributed and accessible across the State (excluding NYC), especially in vulnerable areas. A survey was conducted to assess public awareness of cooling centers and possible barriers to their utilization.

3.3 Cooling Center Adequacy

3.3.1 Introduction and Methods

The adequacy of cooling centers in a county can be assessed by the presence or absence of cooling centers or the general and vulnerable populations. Currently, several counties in the State have mild to moderate temperatures during the summer with rare heat events and may not need cooling centers. But with the ongoing change in climate and the projected increase in temperature, counties will need to modify their heat adaptation plans and include cooling centers for the public to find relief during hot days.

Data sources for this assessment include 1) 2010 U.S. Census Bureau to obtain data on census tract boundaries and tract data on land area and population counts (to calculate population density); 2) 2013–2014 cooling center database as developed from the survey and online resources described in the previous section; 3) Heat Vulnerability Index (HVI) and vulnerability components described previously used to identify heat-vulnerable tracts with moderate- to high-vulnerability (Component score of four or more and HVI score of 15 or more); and 4) U.S. Department of Agriculture (USDA) to obtain data on the rural-urban classification of census tracts. Cooling center adequacy was assessed in terms of the general population as well as vulnerable populations. Adequacy was determined by the 1) distribution of cooling centers with regards to population density and rural-urban classification of tracts; 2) presence of centers in State counties; 3) presence of cooling centers in vulnerable census tracts; and 4) number of center locations within vulnerable census tract boundaries.

3.3.2 Results and Discussion

As shown in Figure 38, in the summer of 2013 there were 377 cooling centers; 36 of 57 counties (60%) had cooling centers. For 10 of the 21 counties without centers, American Red Cross Chapters were willing to set up centers if requested by county agencies.

Figure 38 shows centers are in 60% of counties and appear to be mostly distributed in areas with high population density. Northern parts of the State are particularly deficient, but they also have a sparse population count, ranging from 0 to 50 per square mile. These areas are also known to have several naturals resources like wooded areas for shade, and lakes or smaller water bodies for swimming etc. Cooling centers seem to be appropriately placed in terms of population distribution.

Figure 38. Census Tract Population Density Overlaid by Cooling Centers

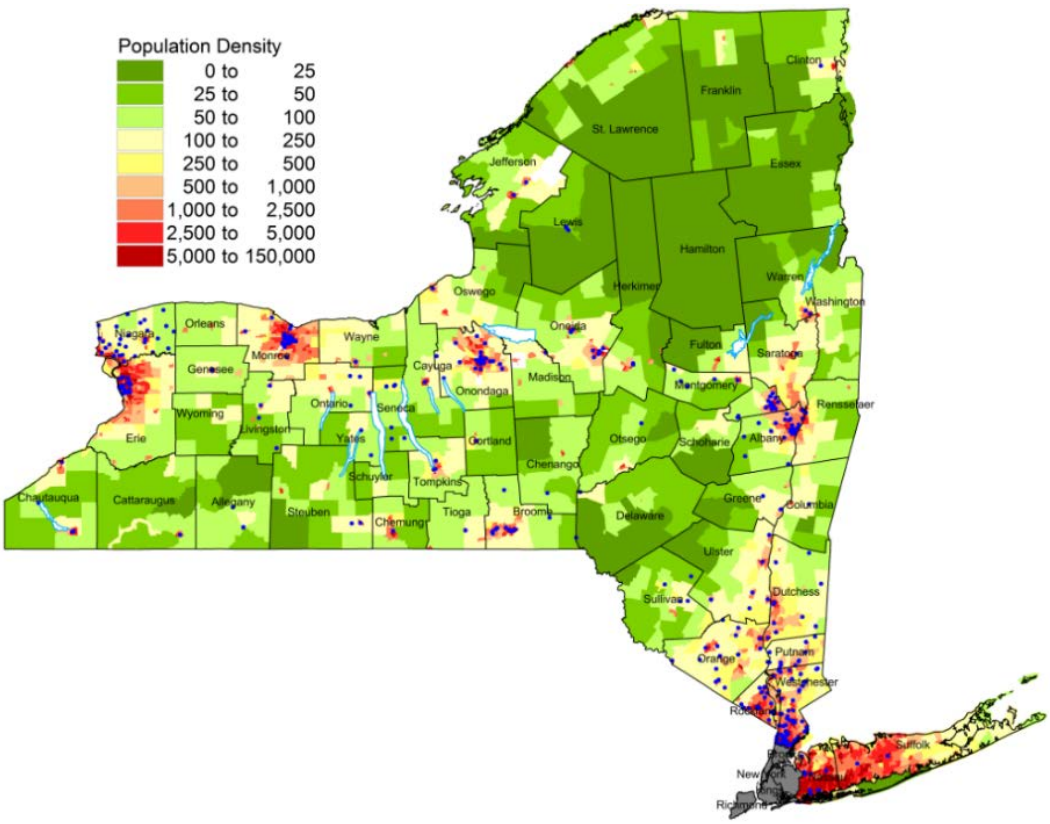
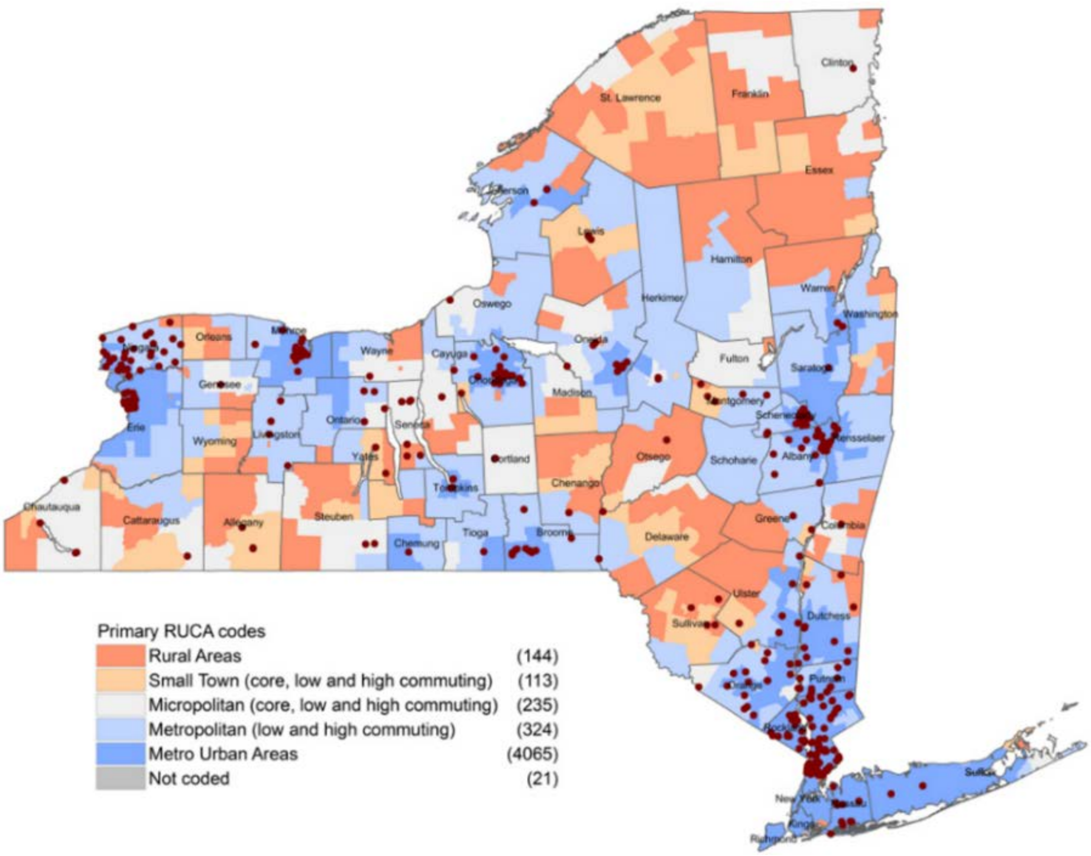


Figure 39 shows cooling center distribution overlaying USDA’s Rural-Urban Commuting Area (RUCA) Coded tracts. The RUCA codes classify tracts into metropolitan, micropolitan, small town, and rural commuting areas based on population density, urbanization, and daily commuting.

Spatial distribution of the cooling centers largely corresponds with the urban (metro, micro) areas in the State. This indicates that locations may be adequate in terms of population distribution.

Figure 39. Census Tracts by Rural-Urban Status with Cooling Centers

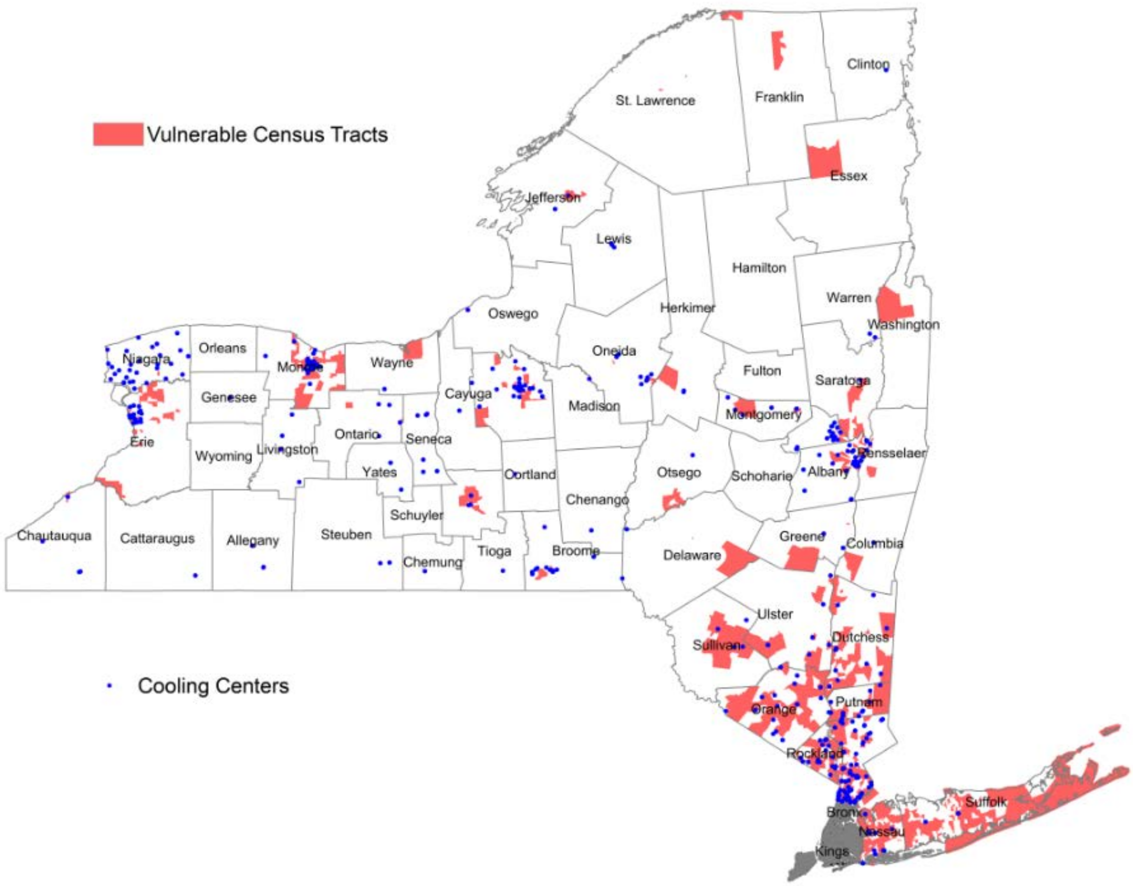


The next step was to explore the distribution in terms of adequacy in vulnerable areas. Vulnerable areas were identified as census tracts with a score of four or more for each of the four vulnerability components (Figures 19-21) or an overall HVI score of 15 or more (Figure 22).

Figures 40-42 demonstrate the cooling center location distribution with each of the four vulnerability components. The cooling centers overlay vulnerable census tracts identified by a component score of four or more.

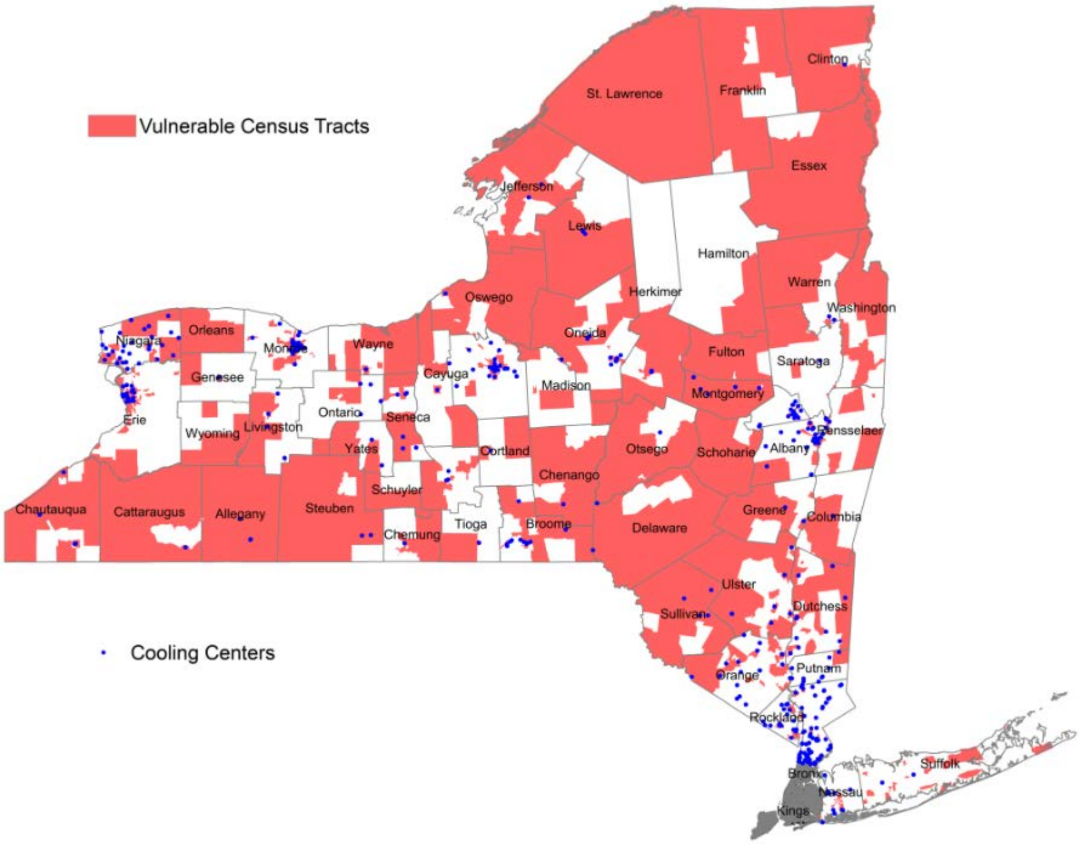
A total of 898 census tracts (34 counties) were defined as vulnerable due to language barriers. There are 149 cooling centers located within these vulnerable census tracts. Although 13 counties with vulnerable tracts did not have cooling centers and only about 14% of vulnerable census tracts had a cooling center located within its boundaries, the map shows that distribution of cooling centers overall appears to be similar to the language vulnerable census tracts. Several cooling centers are located in areas around vulnerable tracts and may still be accessible to these populations.

Figure 40. Cooling Center Locations Overlaying Language Vulnerability



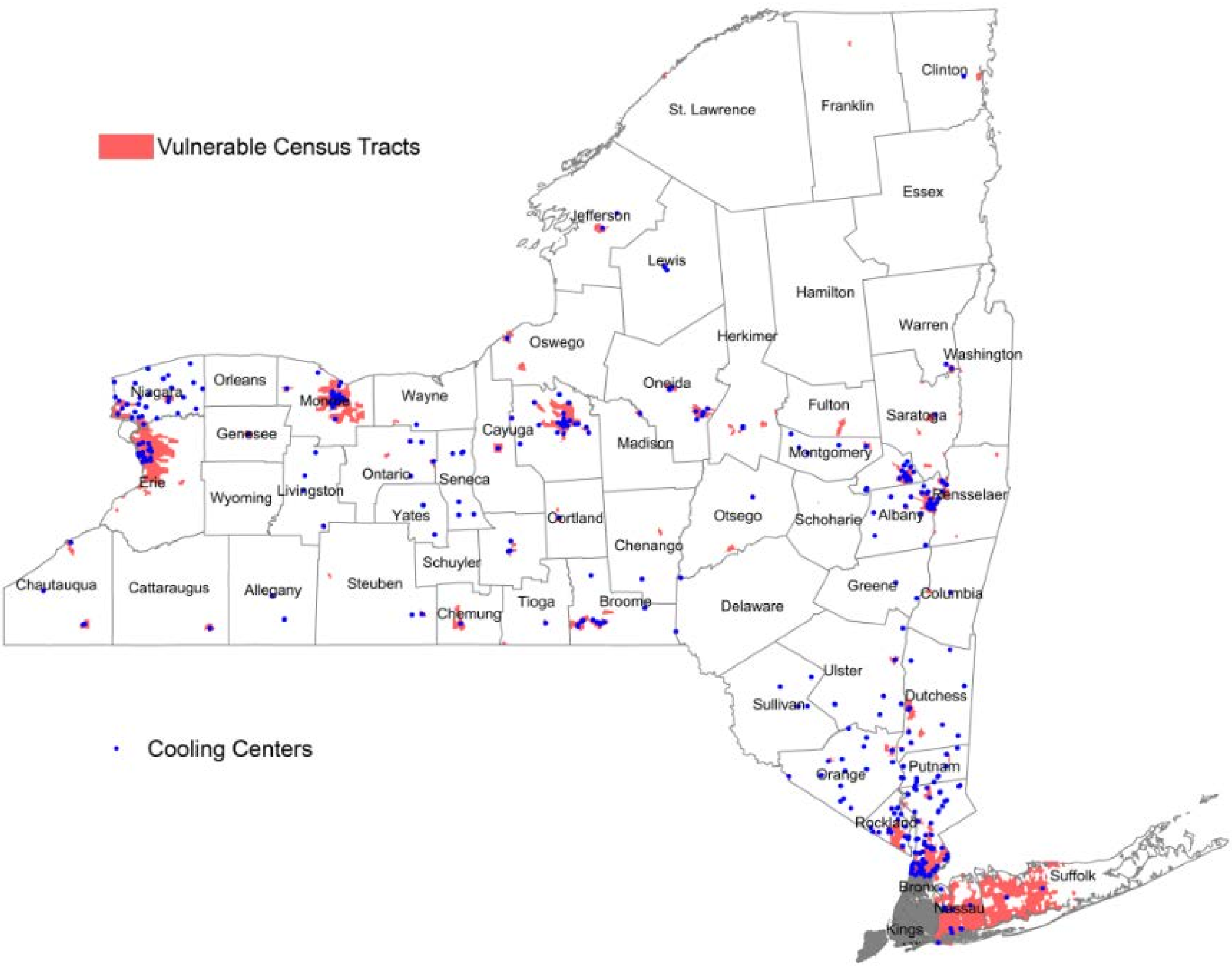
Socioeconomic vulnerability to heat was identified in 1,100 census tracts across the State. While all 57 counties had some degree of socioeconomic vulnerability, only 36 counties had cooling centers. About 15.4% of the vulnerable tracts had at least one cooling center within its boundaries. Several of the larger vulnerable census tracts (surface areawise) have few or no cooling centers. These census tracts tend to be more rural and have higher proportions of populations that are unemployed or have a disability. Spatial distribution of the cooling centers does not appear to correspond adequtely with socioeconomic vulnerability.

Figure 41. Cooling Center Locations Overlaying Socioeconomic Vulnerability



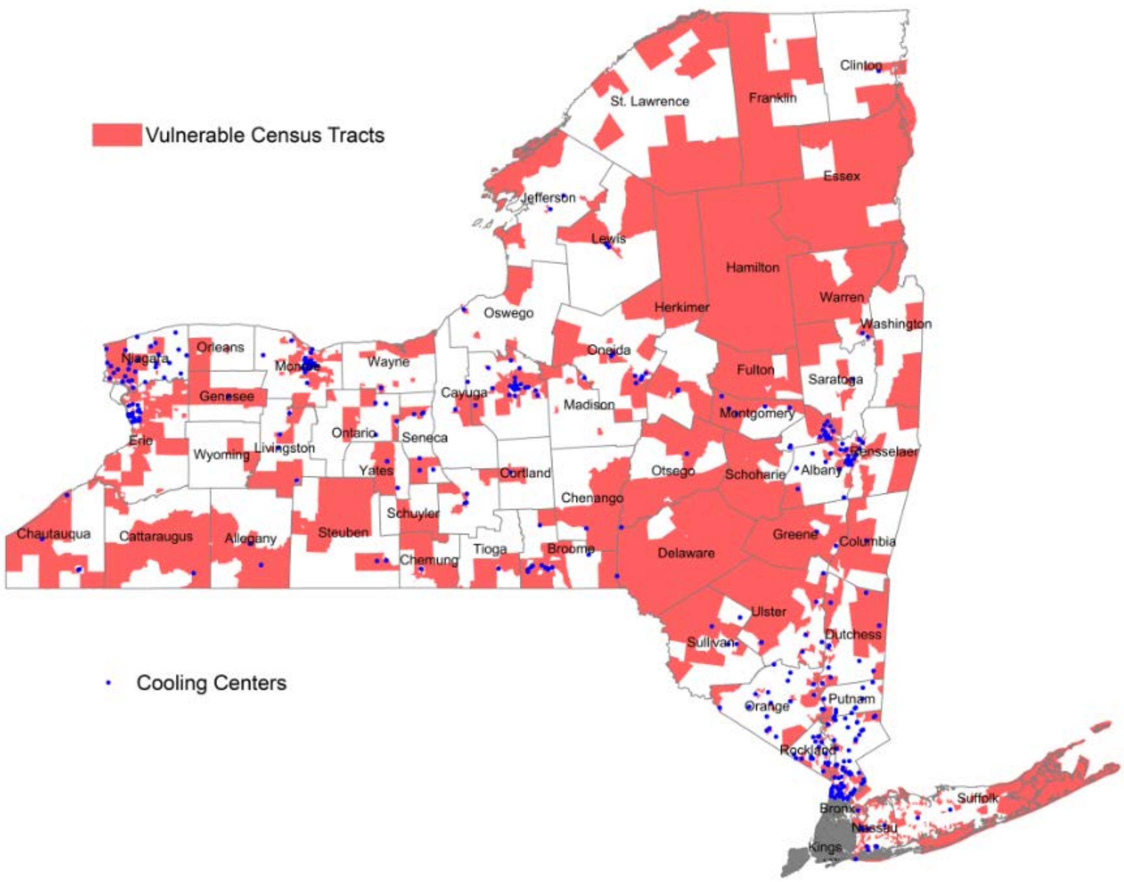
Spatially, the distribution of cooling centers appears to be consistent with urban vulnerability. Of the 1,369 census tracts identified as vulnerable due to environmental and urban characteristics, 13.5% had at least one cooling center; at the county level, 72% of the counties with vulnerable census tracts had at least one cooling center. Almost 60% (217) of cooling centers across the sState were located within the boundaries of these vulnerable tracts. These tracts are primarily urban and have high population densities.

Figure 42. Cooling Center Locations Overlaying Urban Vulnerability



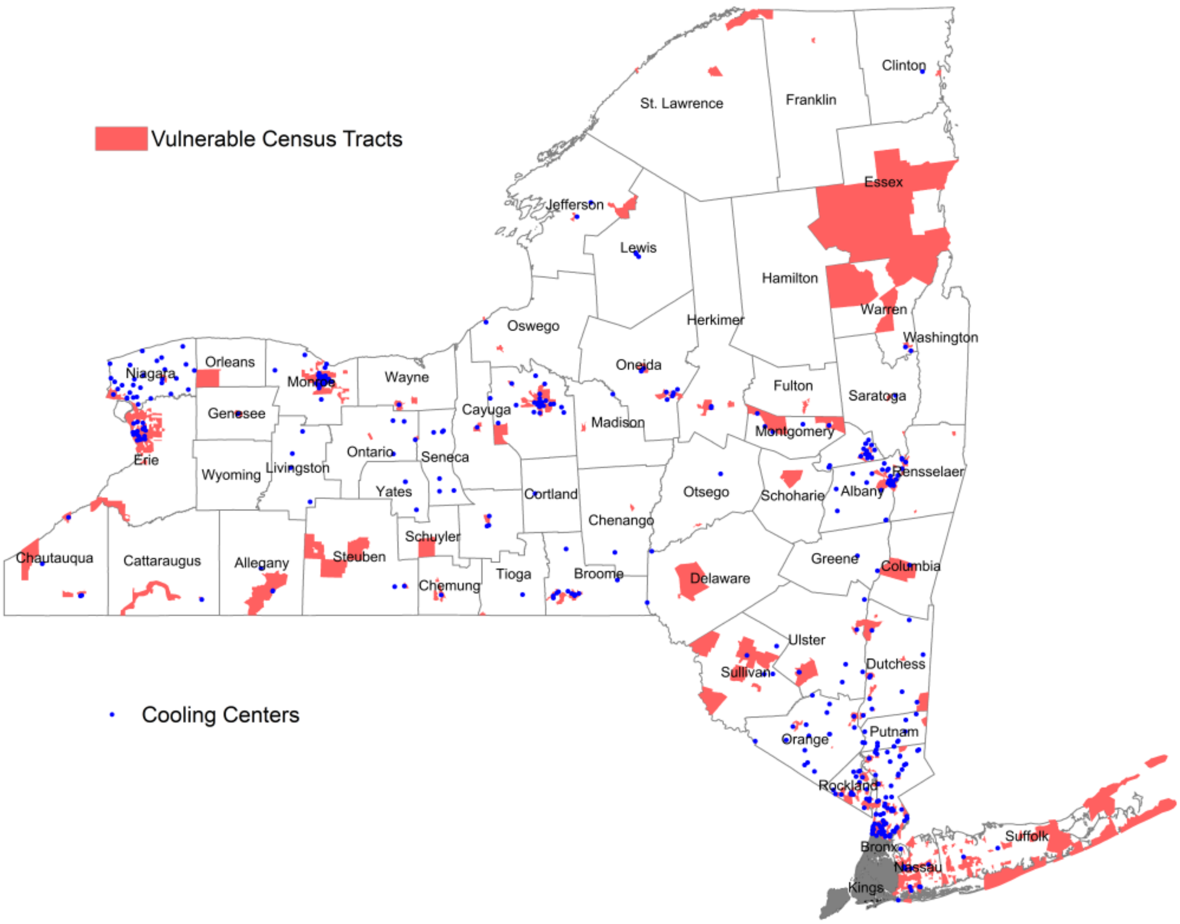
Of the 1,213 census tracts identified as vulnerable due to high proportions of elderly populations, approximately 14% had at least one cooling center for a total of 210. It appears that spatial distribution of cooling centers corresponds to elderly vulnerability except in the larger, more rural census tracts.

Figure 43. Cooling Center Locations Overlaying Elderly Vulnerability



Spatial distribution of cooling centers appears to correspond with language and urban vulnerability across the State, but seems inadequate in areas with socioeconomic vulnerability and in rural areas with high proportions of elderly populations. Cooling center locations overlaying the overall HVI are displayed in Figure 44. Of the 961 tracts identified as heat vulnerable (HVI score of 15 or more), about 41% had at least one cooling center for a total of 190.

Figure 44. Cooling Center Locations Overlaying Overall Heat Vulnerability



Forty-three counties had at least one identified moderate to high heat-vulnerable census tract within its boundaries, but only 31 of these counties had a cooling center. The number of centers available in vulnerable areas does not seem adequate, but during the assessment it became clear that along with adequacy within a geographical region, it is also necessary to determine public accessibility. Populations in a census tract without a cooling center would be able to visit a publicly accessible facility in an adjacent census tract. The following accessibility assessment is a good complement to this adequacy assessment.

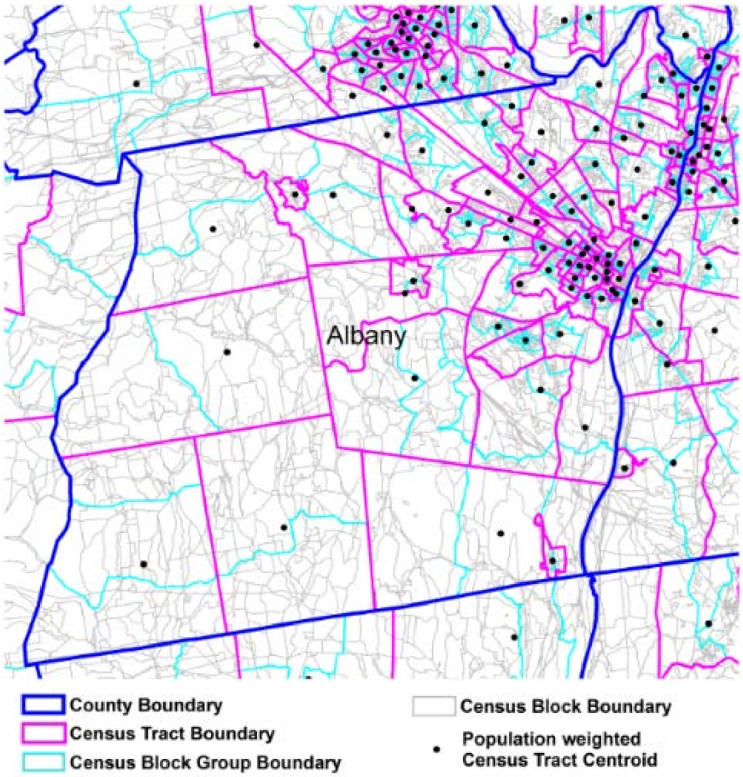
3.4 Cooling Center Accessibility

3.4.1 Introduction and Methods

In the previous section, distribution and adequacy of cooling centers in the State was assessed, and although having sufficient facilities in highly populated areas is important, it is equally important that they be accessible to the public. Accessibility of these cooling centers can play a significant role in their utilization during hot weather. In this project, accessibility in terms of proximity of the cooling centers to the general population and to vulnerable populations was assessed—specifically, whether they are within walking distance or accessible via public transportation. Several cooling centers in the State are in urban areas and may easily accessible. However, in smaller towns and rural areas, access to these facilities may be limited, and people would most likely need to drive to the nearest cooling center. Here, the description of cooling center accessibility is in terms of 1) proximity to the general population; 2) proximity to vulnerable populations; 3) percent of general and vulnerable population living within walking distance of the cooling center; and 4) accessibility via mass transit, including trains and buses.

New York City was excluded from this assessment as data on cooling centers could not be obtained. Data sources for this assessment included 1) 2013–2014 Cooling Center Database created as described previously; 2) 2010 U.S. Census Bureau and 2006–2010 ACS data for population demographics and census geography boundaries; 3) Public transportation data obtained from five Metropolitan Planning Organizations (MPOs) including Niagara-Erie, Rochester, Central NY, Capital District, and Downstate NY (Westchester and Long Island). Public transportation data included geographic coordinates of bus stops, subway stations, and ferry stops in five metropolitan regions. Distance calculations were computed using MapInfo© and PostGIS. As described previously, census tracts with an overall HVI score of 15 or more were identified as vulnerable tracts. Population weighted census tract centroids (a point in space that was nearest to most residents) were created by the DOH using population data in census blocks (Figure 45) within each census tract. The census tract centroid in this assessment represents the point within that census tract where a majority of the population resided.

Figure 45. 2010 U.S. Census Boundary Hierarchy for Albany County



General population proximity was measured by distance between census tract centroid and the nearest cooling center, while proximity to vulnerable populations was measured by distance between vulnerable tract centroid (as identified from HVI) and the nearest cooling center. Accessibility by walking was determined by cooling centers being within 0.5 mile of the census tracts. For accessibility via public transportation, we calculated the distance between cooling centers and the nearest stop in the five MPO regions. A center was considered accessible if it was within 0.5 miles of a census tract or a stop.

3.4.2 Results and Discussion

3.4.2.1 General population proximity to cooling centers

Proximity to the general population was determined by the distance between census tract centroid and nearest cooling centers and percentage of census tract population within walking distance of a center.

Table 12 and Figure 46 display the distance between the general population (census tract centroid) and nearest cooling center. As shown in Figure 46, cooling centers are mostly distributed in the major metropolitan areas, so the population distance to nearest cooling center was less in these areas than rural areas. Areas in the Adirondacks are furthest away from cooling centers, but as discussed previously, these are also areas that have natural cool-down resources and do not experience many heat events. However, with changing climate and the predicted increase in summertime hot days and heat events, it would be practical to set up more cooling centers in these areas. As seen in Table 12, about a third of the total NYS population was within a walking distance of 0.5 miles and about 45% of the population was farther than two miles from a cooling center.

Figure 46. Proximity of Cooling Centers to The Population in NYS by Census Tract

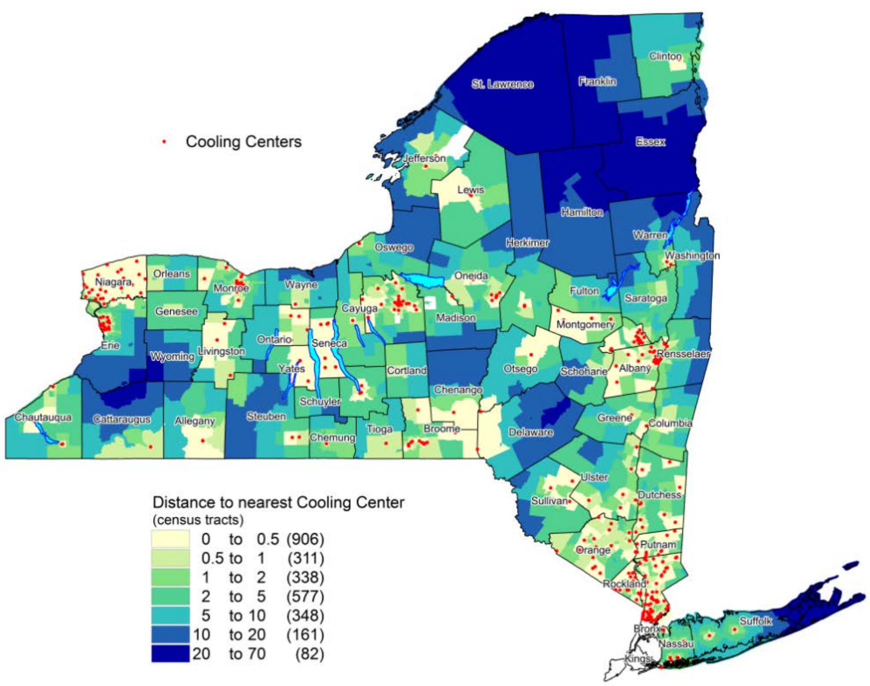


Table 12. Distance between general population tracts and nearest cooling center

Distance to nearest cooling center	General population Tracts (N=2723)	Percent NYS population (Population=11,148,037)
<0.1 miles	475	17.16%
0.1-<0.5 miles	431	14.47%
0.5-1 miles	311	11.17%
1-2 miles	338	12.57%
More than 2 miles	1168	44.62%

3.4.2.2 Vulnerable population proximity to cooling centers

Our next step was to determine if vulnerable populations were within walking distance of a cooling center. As previously mentions, 961 vulnerable tracts were identified from the HVI and distance between the centroids of these census tracts and the nearest cooling center was determined. (See Figure 44 for cooling center location and vulnerable tract distribution.)

More than half of the vulnerable tracts were within walking distance of a cooling center, and about 75% of the tracts were within two miles of a cooling center. Based on these results, it appears that cooling centers are more accessible to the vulnerable populations than to the general population.

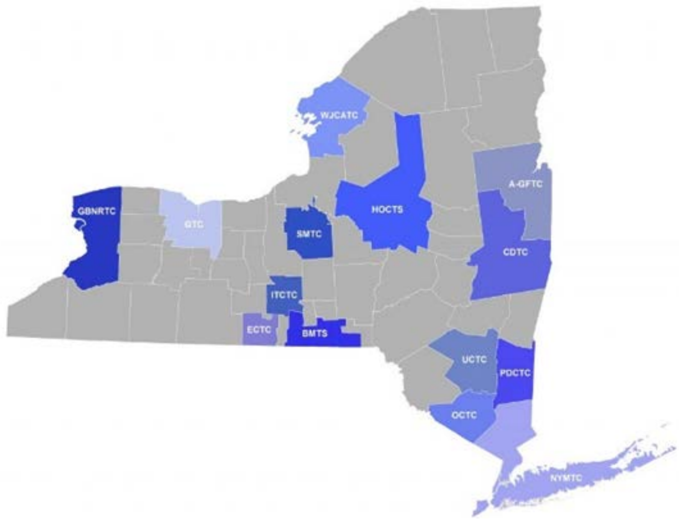
Table 13. Distance from Vulnerable Population Tracts to Nearest Cooling Center

Distance to nearest cooling center	# Vulnerable Tracts (%)
<0.1 miles	244 (25.40%)
0.1-<0.5 miles	250 (26.01%)
0.5-1 miles	119 (12.39%)
1-2 miles	99 (10.30%)
> 2 miles	249 (25.91%)

3.4.2.3 Accessibility of cooling centers via public transportation

To estimate accessibility of cooling centers via public transportation, we computed the distance between cooling centers and the nearest stop (bus, subway, train, and ferry stops). We contacted 14 Metropolitan Planning Organization (MPO) in NYS (Figure 47) and received data from five of them: the Greater Buffalo-Niagara Regional Transportation Council (GBNRT) including Niagara and Erie Counties; Genesee Transportation Council (GTC) covering the Rochester Metro area; Syracuse Metropolitan Transportation Council (SMTC) including Onondaga County; Capital District Transportation Committee (CDTC) including Albany, Schenectady, Saratoga, and Rensselaer counties; and New York Metropolitan Transportation Council (NYMTC) including NYC, Long Island, Westchester, Putnam, and Rockland counties. However, note that NYC counties were excluded from this analysis, as we did not have data on cooling centers in those five counties.

Figure 47. NYS Association of Metropolitan Planning Organizations (NYSAMPO)



Stops in the five MPOs were geocoded and mapped (Appendix C) to overlay cooling center locations and the 961 previously heat-vulnerable tracts identified in the HVI (Figure 48). Distance was computed between each cooling center and the nearest stop to determine if the cooling centers were accessible by public transportation (i.e., the stop was within walking distance of 0.5 miles or less of the cooling center). About 60% of all cooling centers across the State were within walking distance of a stop. While 81% of cooling centers in the four Upstate MPOs (MPO regions excluding NYMTC) were within walking distance of a stop, only 28% of the NYMTC region's (again, excluding NYC) cooling centers were within 0.5 miles of a stop.

Figure 48. Vulnerable Tracts, Cooling Centers, and Public Transportation Stops in Five MPOs

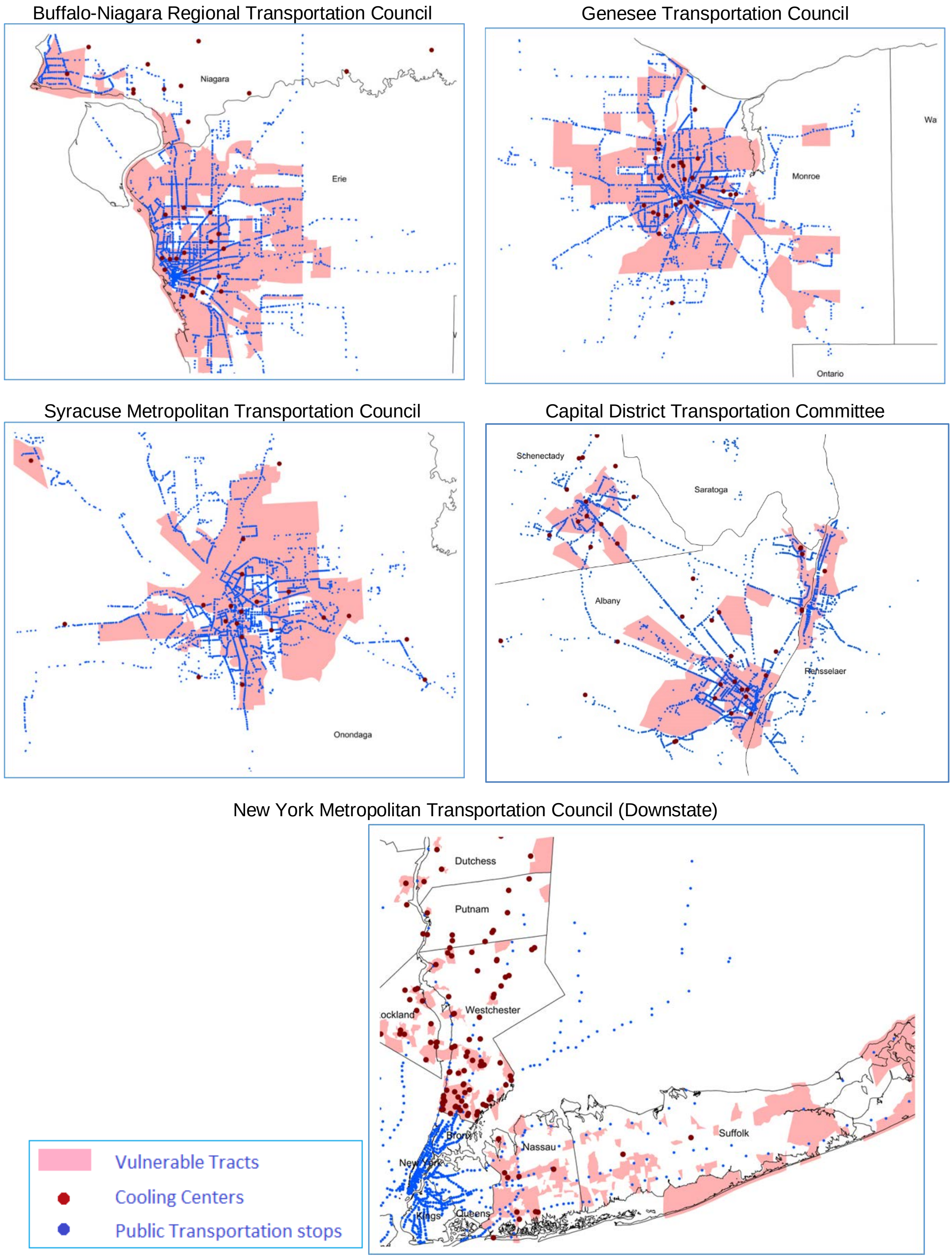


Table 14 shows the distance between cooling centers and the nearest bus stop. About 81% of cooling centers in Upstate metro areas have bus stops located within half mile distance in comparison to downstate regions where less than 30% have public transportation within a half-mile.

Table 14. Number of Cooling Centers and Distance to Nearest Bus Stop in Five MPO Regions

MPO/TC Region*	Total no. of Cooling Centers	Distance (miles)				Farthest cooling center
		0-0.5	0.5-1	1-2	>2	
Greater Buffalo-Niagara Regional TC	52	26	4	3	19	13.1 miles
Genesee TC	38	36	1	0	1	2.8 miles
Syracuse Metropolitan TC	34	31	6	0	2	11.8 miles
Capital District TC	46	42	1	0	3	5.0 miles
New York Metropolitan TC	131	37	24	21	49	15 miles

*TC = Transportation Council

To determine if vulnerable populations had access to cooling centers, the distance between vulnerable census tracts and stops was calculated to determine access to public transportation (Table 15). About 78% (761) of vulnerable census tracts in the State (excluding NYC) were in the five MPO regions. Downstate NY tracts were furthest from public transportation with about 71% located more than 0.5 miles away. In the other four MPO regions, 98% were within walking distance of a stop.

Table 15. Vulnerable Census Tracts and Distance to Nearest Bus Stop in Five MPO Regions

MPO Region*	No. of Vulnerable tracts in MPO region	Distance (miles)			
		0-0.5	0.5-1	1-2	>2
Greater Buffalo-Niagara Regional TC	153	142	9	1	1
Genesee TC	95	91	4	0	0
Syracuse Metropolitan TC	96	94	1	0	1
Capital District TC	61	59	2	0	0
New York Metropolitan TC	356	102	115	122	37

*TC = Transportation Council

In conclusion, despite cooling centers being more concentrated in urban areas, a large proportion of the general and vulnerable populations appear to be more than walking distance from a cooling center. A vehicle (personal or public) may be required for the majority of the population to access these centers.

However, this study shows that while most cooling centers are not within walking distance, public transportation helps improve accessibility, especially among vulnerable populations. For the cooling centers to be best utilized, they should either be within walking distance or be accessible via public transportation. Rural areas especially identified as vulnerable should be targeted during heat impact mitigation planning.

Adequacy and accessibility of cooling centers play important roles in their utilization as does public awareness of these facilities. The next section discusses public awareness of cooling centers among vulnerable populations in NYS.

4 Assessing Public Awareness of Heat Adaptation Resources

4.1 Background

This section describes the assessment of public awareness and use of heat adaptation resources such as heat warning systems and cooling centers and determine public behavior during periods of extreme heat. We developed a survey called the "Extreme Heat Adaptation Resource Awareness" (EHARA) to understand the public's awareness and use of heat adaptation resources (Appendix D). The survey queried the participants' use of and accessibility to AC, their individual responses to heat (change in behavior during hot weather), and awareness of available resources to cool down in their community. The survey solicited the following information: if and where participants routinely seek a cooler location on hot days; if and how they traveled to a cooling center; the reasons for nonuse/obstacles to use; awareness of a heat warning system and how they learned about it; recommendations from any warnings; and if hot weather influenced their behavior (including AC use, drinking water, and/or seeking cooler locations). Since previous studies identified women[22-25] as one of the vulnerable groups to heat-impacted mortality and morbidity, and the DOH conducts an annual survey among post-partum and pregnant women as part of CDC-funded NYS Pregnancy Risk Assessment Monitoring System (PRAMS) program, this heat-vulnerable population was the focus of this section. We attached the EHARA survey as a supplement to the existing PRAMS survey to gather information on and assess awareness of heat adaptation resources among pregnant and postpartum women and the behavioral changes participants made during periods of extreme heat.

4.1.1 Methods

4.1.1.1 Sampling

Sampling for the survey was conducted by the PRAMS workgroup. PRAMS is a surveillance project of the CDC and State health departments that collects State-specific, population-based data on maternal attitudes and experiences before, during, and shortly after pregnancy via surveys among post-partum women. The PRAMS survey is designed to collect details regarding the participants' socioeconomic status and preexisting medical conditions during their most recent pregnancy, which provides further information on the sociodemographic characteristics of the participants. Birth certificate data was used to provide a sampling frame from which births are stratified and then randomly selected for PRAMS surveillance. This data is also used to weight PRAMS survey data so that it is representative of the NYS population in that county and to serve as a source of demographic and clinical information about the sampled mothers.

4.1.1.2 Data collection and analysis

The EHARA survey (Appendix D**)** was developed based on review of previous literature and distributed as a supplement to the PRAMS survey questionnaire. The EHARA surveys were mailed along with the PRAMS survey and followed the same schedule as PRAMS. The first survey was mailed between April and October in 2014, and unless responses were received, they were sent to participants two more times. Telephone calls were initiated 7-14 days after the third questionnaire was sent out. The survey was administered in both English and Spanish, and queries focused on the participant's most recent summer. Return of a filled survey was considered as informed consent. Participants received a $5 pharmacy gift card for completing the survey. Maternal age, race and ethnicity, education level, residential county, and certain medical conditions (fever, hypertension, gestational diabetes, and premature rupture of membrane) were obtained from birth certificates.

Responses were entered twice into a Microsoft Access database by two different staff to ensure data quality and accuracy. Descriptive analysis and Chi square or Fisher's exact tests (when expected cell frequencies were ≤ 5) were performed using SAS 9.4 to assess the difference between distribution of variables among different demographic groups.

4.1.2 Results

A total of 588 responses were received with an overall response rate of nearly 60%. About 92% of the surveys were returned via mail; the remainder were conducted over the phone. Surveys were requested in Spanish for 38 participants (about 6% of total responses).

Table 16 displays the demographic characteristics of the respondents. More than half the participants were non-Hispanic white and in the 25 to 34 year age range. About 40% of respondents were also well educated, citing an education of four years of college or more; only about 11% had an education less than high school. The majority of the participants (75%) did not report any preexisting morbidity.

Table 16. Demographic Characteristics of Respondents (n=588)

Variable	Frequency (%)	Variable	Frequency (%)
Age group (n =583)		**Ethnicity (n=588)**	
14-19 years	22 (3.8)	Hispanic	84 (14.29)
20-24 years	99 (17.0)	Non-Hispanic	504 (85.71)
25-34 years	333 (57.1)	**Education Level (n =575)**	
35-49 years	129 (22.1)	Less than High School	66 (11.48)
Race (n =588)		High School Graduate	122 (21.22)
White	449 (76.4)	Some College	156 (27.13)
African American	61 (10.4)	4+ Years of College	231 (40.17)
Asian/Pacific Islander	55 (9.34)	**Health Conditions* (n =583)**	
Other	1 (0.17)	Any outcome	128 (21.96)
Unknown	22 (3.74)	No outcomes	438 (75.13)

* Health conditions includes fever, hypertension, gestational diabetes, and premature rupture of membrane during pregnancy.

4.1.2.1 Coverage and usage of AC

Approximately 86% of the respondents had at least one type of AC at home, with about two-thirds having central AC or multiple units (Figure 49). Among those who own at least one AC unit, about 65% use it all or most of the time. Preference to use a fan instead of AC was noted in 30% of respondents.

Among those who responded they don't have AC, 25% indicated they can't afford it, followed by 13% people who don't need one, and 8% people who don't like AC. The most common reason cited for not using AC is that they didn't feel hot (45%) followed by a concern of electricity bill (25%) and the desire to conserve energy (18%). Among other reasons for not using AC were concerns for their baby feeling cold, increased seasonal allergies, or the preference for open windows.

Figure 49. During your most recent summer, did you have air conditioners in your home? (n=580)

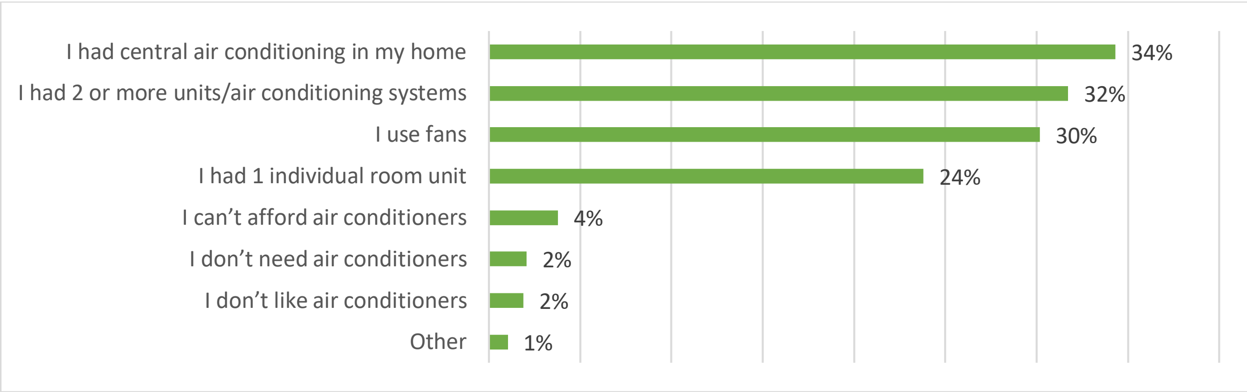


Figure 50. If you have air conditioning, how often did you use it during the most recent summer? (n=559)

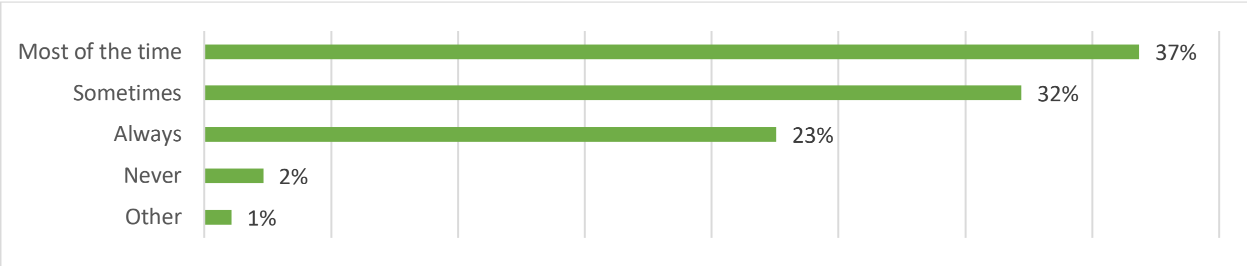
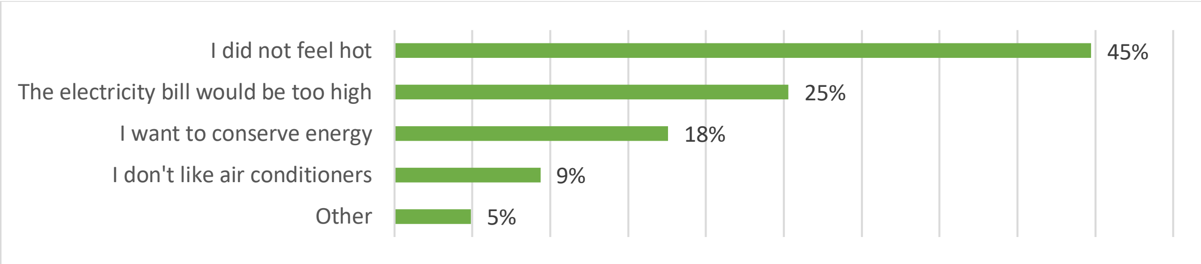


Figure 51. During the most recent summer, if you did not use air conditioning all or most of the time, what were your most important reasons for not using it? (n=427)



4.1.2.2 Accessibility and utility of cooling places/centers

Nearly half of the respondents chose to stay home during the extreme hot weather. Among those who went to a cooler place, most people decided to go to an outdoor recreation facility (27%), someone else's air conditioned home (15%), or a business center (14%). Less than 10% of people went to a public place such as a library or community center. While most respondents used their own vehicle, some got a ride (15%) or walked (14%), but few chose to use public transportation.

Figure 52. During the most recent summer, where did you go if you couldn't cool down at home? (n=514)

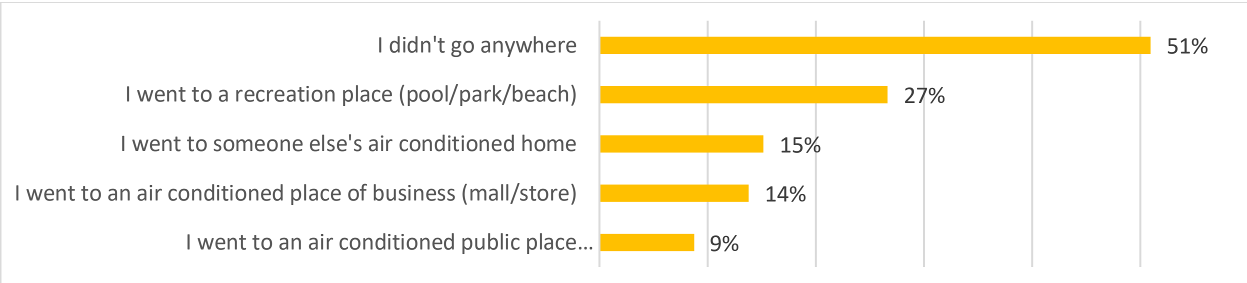
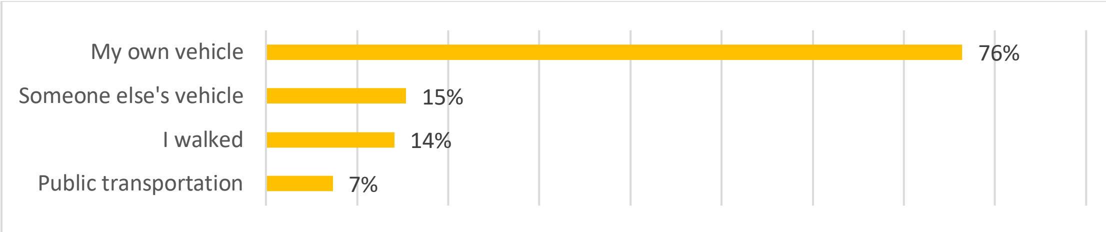
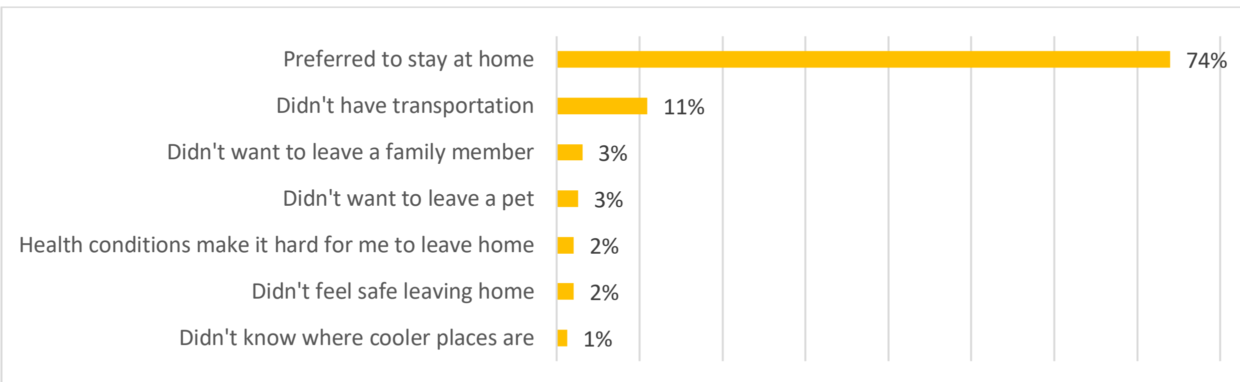


Figure 53. During very hot weather, if you went somewhere cooler, how did you get there? (n=462)



Among those who did not go elsewhere, the most common reason was they preferred to stay home (74%). The most common barrier cited for leaving home was lack of transportation (11%), followed by concerns about leaving family members (3%) or pets (2.6%) alone. Some respondents indicated they did not feel it was safe to leave home (2.08%), did not know where else they could go (1.3%), or could not leave due to medical conditions (0.02%).

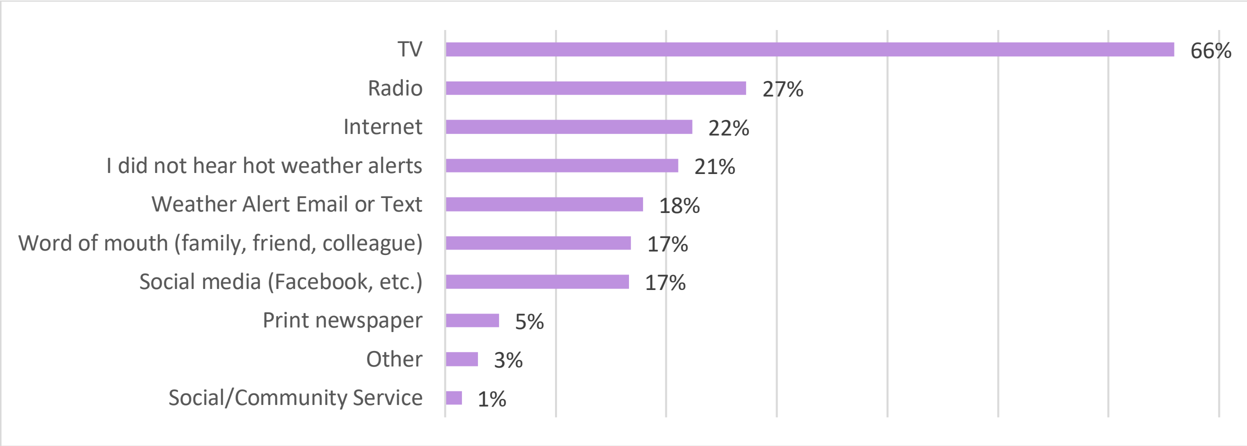
Figure 54. During very hot weather, if you did not go to a cooler place, what were your reasons? (n=384)



4.1.2.3 Awareness of heat alerts/warnings

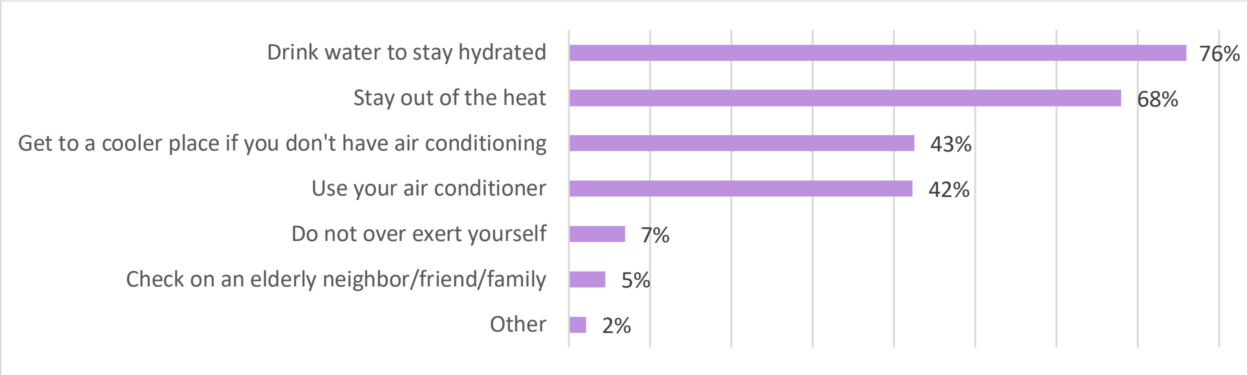
Approximately half of the respondents (51%) reported they heard about a heat warning or alert in the most recent summer. Mass media such as TV and radio were the most frequent source of information on alerts, but online sources such as the internet, social media, and messaging systems also played an important role.

Figure 55. If you heard hot weather alerts or warnings, where did you hear them most often? (n=470)



The most commonly heard heat alerts messages advised respondents to stay hydrated by drinking water, staying out of the heat, and using AC to cool down either at home or elsewhere.

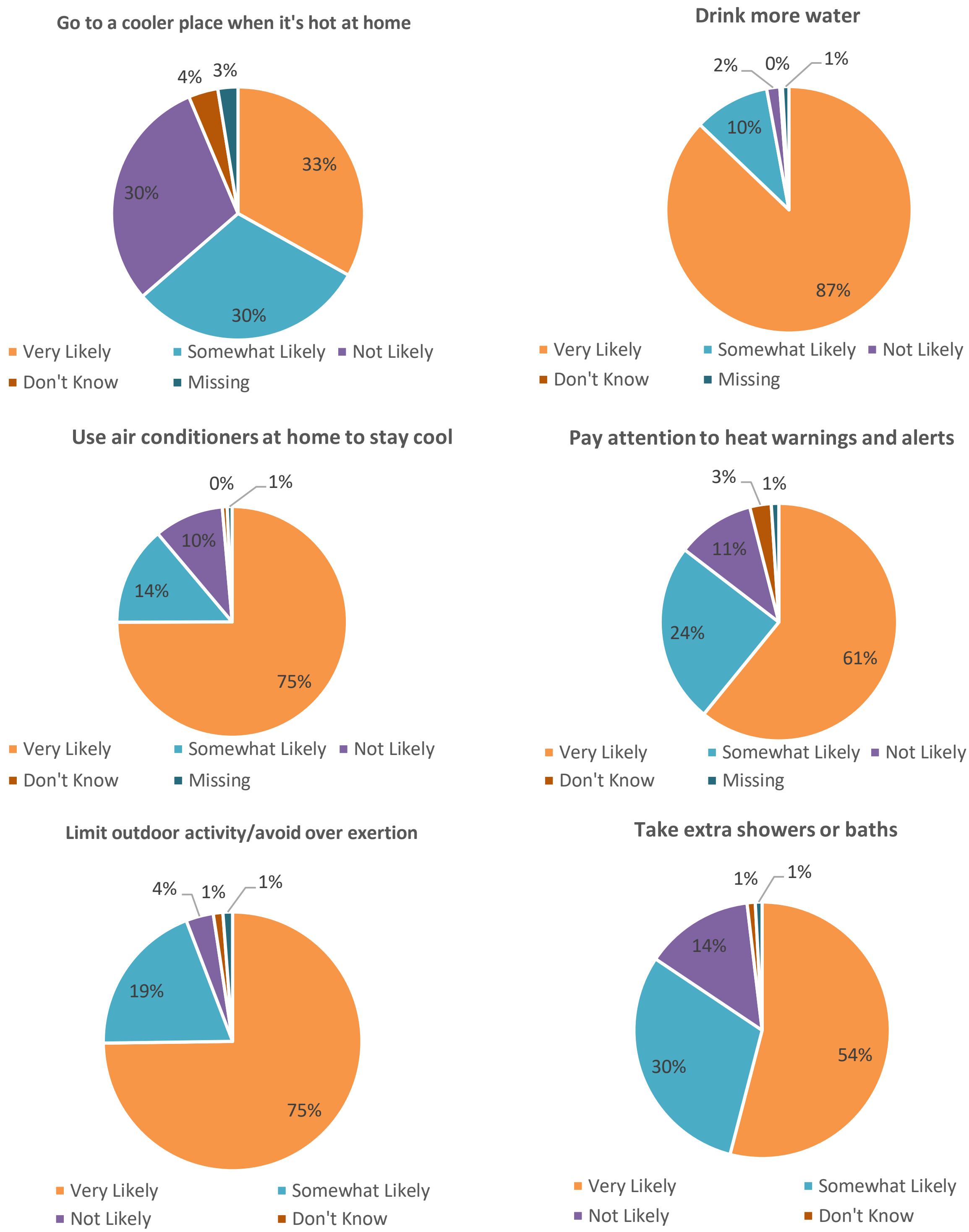
Figure 56. Did the warnings you heard about hot weather include any of the following tips? (n=421)



4.1.2.4 Compliance to the heat warning or alerts

Among all the tips heard by public, highest compliance rates were seen for staying hydrated (87%), using AC (75%), and limiting outdoor activity (75%). Also, more than half of the respondents indicated that they paid attention to the heat warning/alerts (61%) and were likely to take an extra shower (54%) to cool down. However, fewer respondents would choose to go to a cooler place when it’s hot at home (33%). Responses indicate participants are more likely to take measures to cool down within their own homes rather than go elsewhere.

Figure 57. During hot days how likely are you to do the following? (n=568 to 579)



4.1.3 Discussion

4.1.3.1 Air conditioning coverage and use

In this survey, it was found that about one-third of respondents have access to AC at home or at work. Among those without AC, the most common reason was affordability. About 25% of respondents cited high electric bill costs as the reason they don't use AC often. These findings are similar to a study conducted among elderly people in South Australia and the U.S. where authors note that high costs played a role in limiting AC usage.[64]

4.1.3.2 Awareness of heat events

Although more than 50% of respondents heard some type of heat warning or alerts during the last summer, this percentage is lower compared to other studies. The lower percentage in the EHARA survey could be explained by the relatively cooler summers in the last two years accompanied by fewer issuances of heat warnings or alerts. However, it could also be attributed to "recall bias" because of the time since the most recent summer and receiving the survey, which ranged from a few weeks to six months based on date of live birth.

The most common sources of heat alerts were TV, radio, and internet. The EHARA survey also showed that participants are more likely to obtain information from their close friends/family members than the community or weather apps on smart phones. Newspapers were the least common source, which may be explained by the younger mean age of survey respondents compared to the general population. Based on these observations, recommendations include issuing alerts through multiple platforms to capture the maximum audience and improve the dissemination of the information across various age groups.

4.1.3.3 Behavior and response during heat events

Respondents were aware of cooling strategies available during heat events including staying out of the sun, avoiding dehydration, and visiting an air conditioned place. They were more likely to comply with these recommendations in comparison to a study across four U.S. cities[65] where people were aware of heat events, but less likely to take adaptive actions. However, citing lack of transportation, fewer mothers opted to go to a cooler place if they didn't have access to AC at home. While transportation is more available in cities, another barrier could be that the cooling center is located outside the city center with no transportation available.[67] Even if public transportation was available, many mothers prefer to drive or get a ride. Although senior centers were often available as cooling centers, it was observed that low attendance resulted from the elderly not considering themselves vulnerable or younger residents wanting to avoid a senior citizen facility.[66]

With behavior modifications during hot days, it was observed that participants are very likely to drink water to stay hydrated, use AC, heed alerts, restrict outdoor activity, and take an extra shower to cool down, but less likely to find a cool place outside of their own home. This emphasizes the efforts local and State agencies should make to encourage the use of cooling strategies at home or cooling centers in communities. These can be valuable resources to encourage the public to use them as way to reduce the impact of heat on their health.

5 Resources

5.1 NYS Cooling Centers

The DOH contacts local health departments and county emergency management offices every spring to determine locations of cooling centers in their jurisdictions. The locations of cooling centers are mapped and provided to the public through a cooling center mapping application. This information is disseminated to the public and local agencies via DOH social media (Facebook, Twitter) and Press Releases, and the NWS.

5.2 Heat Vulnerability Index for NYS

The heat vulnerability index was developed to supplement local efforts towards heat mitigation. The HVI allows quick identification of heat-vulnerable areas and can be useful in rapid response and effective resource allocation during EH events. State and County HVI maps are available for download on the Heat Vulnerability Index webpage.

5.3 Publications and Presentations

Nayak SG., Shrestha S., Kinney PL., Ross Z., Sheridan SC., Pantea CI., Hsu WH., Muscatiello N., Hwang SA. Development of a heat vulnerability index for New York State. Journal Article. Public Health. Dec 2017. https://doi.org/10.1016/j.puhe.2017.09.006

Widerynski S, Schramm P, Conlon K, Noe R, Grossman E, Hawkins M, Nayak S, Roach M, Shipp Hilts A. The Use of Cooling Centers to Prevent Heat-Related Illness: Summary of Evidence and Strategies for Implementation. Climate and Health Program, Centers for Disease Control and Prevention. Climate and Health Technical Report Series. Aug 2017.

Muscatiello N., Shipp-Hilts A. Preparing for Extreme Heat in NYS. Public Health Live webinar series. June 2017

Muscatiello N., Shipp-Hilts A. ‘Climate Change and Public Heath: What Can Municipalities Do?’ Climate Smart Webinar Presentations. Dec 2016. Climate Change and Public Health - Slides [PDF, 3.9 MB]

Nayak SG., Lin S., Sheridan S, et al. Surveying Local Health Departments and County Emergency Management Offices on Cooling Centers as a Heat Adaptation Resource in New York State. Journal Article. J Community Health. Feb 2017. 42: 43-50. doi:10.1007/s10900-016-0224-4

Nayak SG, Shrestha S, Pantea CI, Kinney P, Ross Z, Sheridan SC, Hsu WH, Hwang SA, Lin S. Developing a Heat-Vulnerability Index to Identify Vulnerable Regions and Populations in New York State. Oral Presentation. 2016 Annual North-East Epidemiology Conference, Burlington, VT. Oct 2016

Nayak SG., Ross Z, Saiyed N, Hwang SA, Lin S. Assessing Accessibility of Cooling Centers to Vulnerable Populations in New York State. Poster. 2016 Annual CSTE Conference, Anchorage, AK June 2016. https://cste.confex.com/cste/2016/webprogram/Paper6461.html

Nayak SG, Ross Z, Hwang SA, Lin S. Assessing Cooling Center Adequacy in Heat Vulnerable Counties in New York State. Poster. 2015 Annual SER meeting, Denver, Colorado June 2015. http://epiresearch.org/poster/view_abstract.php?id=27220

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Nayak SG, Kinney P, Pantea C, Lin S. Identifying Vulnerability Factors for Multiple Health Outcomes in New York State. Oral Presentation. 2013 Annual North-East Epidemiology Conference, Burlington, VT. Oct 2013

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Lu Y, Lin S, Sheridan S, Radigan A, Nguyen T, Nayak SG. Extreme heat adaptation resource awareness among pregnant women in New York State. Poster. SER Annual Meeting, Seattle, WA. June 2017.

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Appendix A: Heat-Impacted health outcomes in health studies at DOH

Health outcomes included in heat-health studies[6-9,21] at the DOH are listed in Table A-1. The data was extracted from the DOH Statewide Planning and Research Cooperative System, which is a legislatively mandated database covering 95% of all State hospitals (excluding federal and psychiatric facilities). Data includes patient information on principal and other diagnoses, date of birth, gender, race, ethnicity, street address, admission date, source of payment, length of stay, and total charges. Data on health outcomes were obtained from respiratory, cardiovascular, and renal disease related hospitalizations among residents in the summer (June to August) from 1991 to 2004. Table A1 displays the heat-impacted health outcomes, and number of admission cases among residents that were used in the climate-health studies assessing vulnerability to heat.

Table A1. Heat-Impacted Health Outcomes

Category	Health Outcome Sub-categories	# Cases
Respiratory diseases	Acute Bronchitis and Bronchiolitis, Chronic Bronchitis, Emphysema, Asthma, Chronic Airway Obstruction, Unspecified Bronchitis	1,216,768
Cardiovascular diseases	Hypertensive disease, Ischemic Heart Disease, Cardiac Arrhythmias, Heart Failure, Cerebrovascular disease	4,129,355
Reno-urinary diseases	Glomerular/Renal Tubulo-Interstitial Disease, Acute Renal Failure, Chronic Renal Failure, Other disorders of Urinary System	880,206

Appendix B: Map displaying the 14 weather region boundaries

Climate/meteorological data for heat-health studies previously conducted at the DOH was obtained from NCAR data and National Climatic Data Center (NCDC) and assigned to 14 weather regions (Figure B-1) across NYS. Meteorological data including hourly observations of temperature, atmospheric pressure, dew point and wind speed for NYS were obtained from the NCAR weather stations. The daily mean, minimum and maximum values for each of these variables were derived from NCAR data. In addition, mean, minimum, and maximum values for Steadman's Apparent Temperature (AT) were also calculated from the hourly data using the following formula: AT = -2.7 + 1.04 × temperature (in °C) + 2.0 × vapor pressure (in kPa) – 0.65 × wind speed (in ms-1).

The heat indicators in the DOH heat-health studies included continuous metrics of daily actual and AT as well as categorical indicators of temperatures namely the 90th percentile indicator (where daily mean temperatures are greater than the 90th percentile of seasonal daily mean temperature and two heat wave indicators including heat wave indicator, HW90, where daily maximum temperature on three or more consecutive days is 90°F or more; and a second heat wave indicator, HW97, where daily maximum temperatures is at or more than the 97th percentile of daily maximum temperature for two or more consecutive days. All weather exposure variables (metrics and indicators) were linked to geocoded hospital admission. In order to assign meteorological exposure data to our study population, 14 geographically defined weather regions were used (Figure B-1). These same weather regions were also used for all DOH heat studies to allow for geographical comparability with various outcomes. Meteorological data was linked to the corresponding weather region based on date. The geocoded patient residential address was then linked to meteorological exposure data (mean, minimum, and maximum values of daily temperature and AT; categorical heat wave indicators) by date and weather region. Further details on weather data assignment can be found in literature published on these studies.[6-9,21]

Figure B-1. Weather Regions Used to Define Exposure in Heat-Impact Health Studies at DOH

In the heat-health studies conducted at the DOH, exposure data were linked with cases by geocoding each case and assigning it to 1 of the 14 weather regions. These regions were based on the National Climatic Data Center's 10 New York State climate divisions. Because there is often a need to address the influence of ozone when studying hospital admissions related to other diseases such as respiratory or cardiovascular disease, the climate divisions were modified by overlaying and merging them with the 11 ozone regions developed for the State by Chinery and Walker. This resulted in 14 regions of relatively homogeneous weather and ozone exposures. We retained the use of our temperature-ozone regions to maintain comparability with our studies of hospital admissions.

Appendix C. Cooling center survey

Upstate New York Local Health Departments Cooling Center Feedback
NYSDOH-CEH-BEOE

Section A: Information on person responding to questions:

A1.Name: ______________________________ A2.Title: ____________________________________

A3.Organization: ___________________ A4.City: ___________ A5.County:____________________

Section B: Questions pertaining to Cooling Centers

B1. In the event of a heat wave/ extreme heat days, does your county have designated cooling centers?

Yes [ ] No [ ] ***Skip to B9***

B2. Do you provide information on the cooling centers to the public?

Yes [ ] No [ ] ***Skip to B5***

If yes:

B3. When do you provide this information? (Check all that apply)

i. When a heat advisory has been issued [ ]
ii. Throughout the summer [ ]
iii. Other_______________________________

B4. How to do you provide this information? (Check all that apply)

i. Internet (County Website: Please provide county website URL___________________) [ ]
ii. Internet (Social Media like Facebook, Twitter) [ ]
iii. Radio [ ]
iv. Television [ ]
v. Newspaper [ ]
vi. Messaging system (email alerts, text alerts) [ ]
vii. Other_______________________________

B5. Are any of the following in-facility services provided at the cooling centers? (Check all that apply)

i. Air-conditioning at the center [ ]
ii. Cold water [ ]
iii. First aid/ Medical services [ ]
iv. Food/Snacks [ ]
v. Information on protection against extreme heat and heat waves [ ]
vi. Information on vulnerable populations [ ]
vii. Other________________________________

B6. Do you provide transportation to and from the cooling centers?

Yes [ ] No [ ]

B7. Is public transportation available to and from the cooling centers?

Yes [ ] No [ ]

B8. Please provide the addresses of designated cooling centers in your county (Building number, Street Address, City and ZIP Code) during the summers of 2011 to 2013. *Please use the space below or add additional lines if needed.*

1.____
2.____
3.____

Skip to End (Section C)

If you answered "No" to B1, please answer the following:

B9. Does your organization promote local resources such as malls, stadiums etc., as possible or 'informal' cooling centers? Yes [ ] No [ ]

If "No", please list reason/s why your county does not have designated or informal cooling centers:

1.____
2.____

B10. Please indicate if you think cooling centers are important components of a local government's response to extreme heat.

Yes [ ] No [ ]

B11. Please indicate if there are plans to have cooling centers, in your county, in the future?

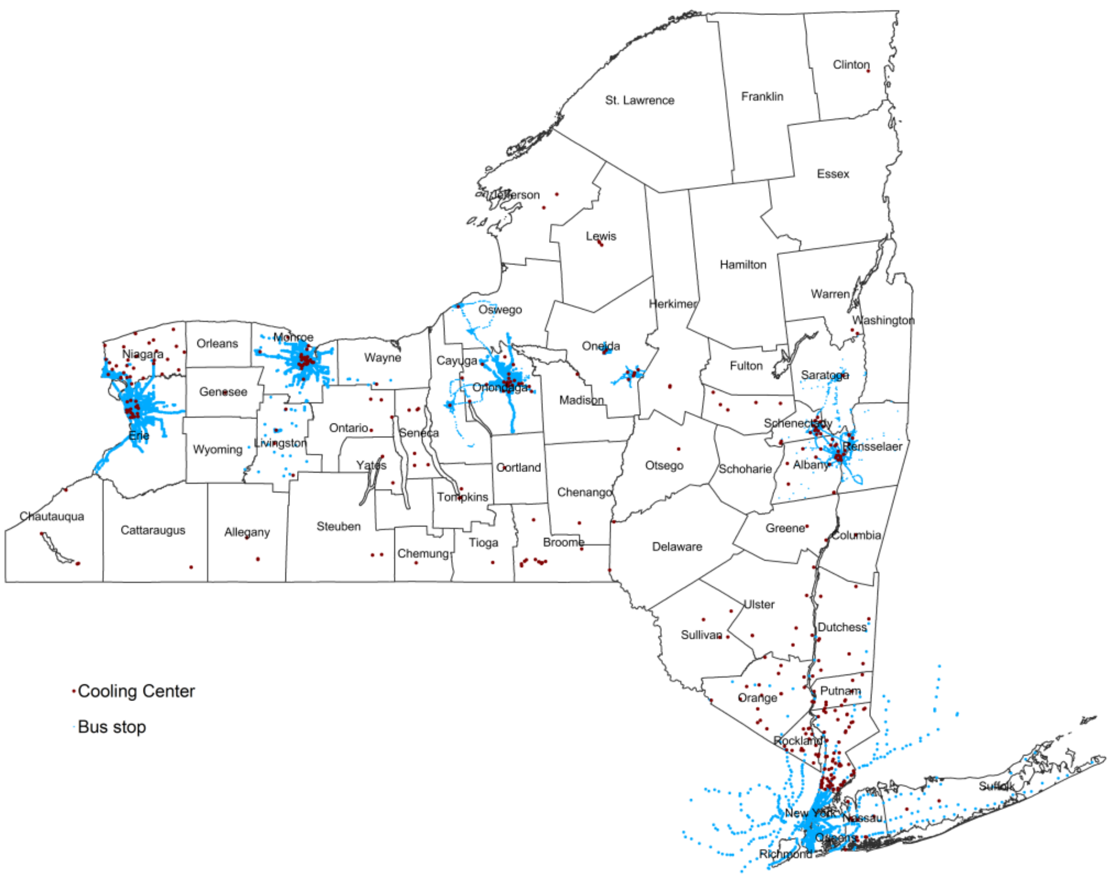
Yes [ ] No [ ]

Section C: Thank you for your time and efforts in responding to this brief survey. Please send your reply to the NYSDOH within 7 days of receipt. If you have any questions regarding this survey, please contact Dr. Seema Nayak at sxn09@health.state.ny.us or at Ph. No: 518-402-7950

C.1 Public Transportation in 5 MPOs

Figure C-1 displays distribution of public transportation stops including bus stops and train stations across the five regions with Metropolitan Planning Organizations. Accessibility to cooling centers via mass transit, including trains and buses, was measured by computing distance between cooling centers in the metro region to the nearest stop.

Figure C-1. Cooling Centers with Public Transportation Stops in Five MPO Regions



Appendix D. Extreme Heat Adaptation Resource Awareness survey

NYSDOH 2014-2015 Extreme Heat Adaptation Resource Awareness Survey

The next few questions are about your experiences and choices during the most recent summer.

Q1. Do you have air conditioners in your home?

1 Yes, a central air conditioning system
2 Yes, 1 individual room unit
3 Yes, 2 or more units/air conditioning systems
4 No, I use fan/s
5 No, I don't need air conditioners
6 No, I don't like air conditioners
7 No, can't afford air conditioners
9 Don't know
99 Other ___________________

Q2. If you have air-conditioning, how often did you use it during the most recent summer?

1 Always
2 Most of the time
3 Sometimes
4 Never
5 Don't have air conditioners
9 Don't know
99 Other___________________

Q3. (Circle all that apply) During the most recent summer, if you did not use air-conditioning all or most of the time, what were your most important reasons?

1 I did not feel hot
2 The electricity bill would be too high
3 I want to conserve energy
4 I don't like air conditioning
5 I used air conditioning all or most of the time
9 Don't know
99 Other___________________

Q4. (Circle all that apply) During the most recent summer, where did you go if you couldn't cool down at home?

1 I didn't go anywhere
2 I went to someone else's air conditioned home
3 I went to an air conditioned public place (library/senior center)
4 I went to an air conditioned place of business (mall/store/restaurant)
5 I went to a recreation place (pool/park/beach)
9 Don't know
99 Other ___________________

Q5. (Circle all that apply) During very hot weather, if you went somewhere cooler, how did you get there?

1 Own vehicle
2 Someone else's vehicle
3 Public transportation
4 Walked
9 Don't know
99 Other ___________________

Q6. (Circle all that apply) During very hot weather, if you did not go to a cooler place, what were your reasons?

1 Didn't have transportation
2 Didn't want to leave a family member
3 Didn't want to leave a pet
4 Didn't know where cooler places are
5 Health conditions make it hard for me to leave home
6 Preferred to stay at home
7 Didn't feel safe leaving home
9 Don't know
99 Other ___________________

Q7. During the most recent summer, did you hear hot weather alerts or warnings?

1 Yes 2 No 3 Don't know

Q8. (Circle all that apply) If you heard hot weather alerts or warnings where did you hear them most often?

1 TV
2 Radio
3 Weather Alert Email or Text
4 Internet
5 Social Media (Facebook etc)
6 Social/Community Service
7 Print Newspaper
8 Word of Mouth (Family, Friend, Colleague)
9 Don't know
10 I did not hear hot weather alerts
99 Other ____________

Q9. (Circle all that apply) Did the warnings you heard about hot weather include any the following tips?

1 Stay out of the heat
2 Use your air conditioner
3 Get to a cooler place if you don't have air conditioning
4 Drink water to stay hydrated
5 Check on an elderly neighbor/friend/family
9 Don't know
99 Other ___________________

Q10. (Circle all that apply) During hot days how likely are you to do the following

1 Go to a cooler place when it's hot at home	a. Very Likely	b. Somewhat Likely	c. Not Likely	d. Don't know
2 Drink more water	a. Very Likely	b. Somewhat Likely	c. Not Likely	d. Don't know
3 Use air conditioners at home to stay cool	a. Very Likely	b. Somewhat Likely	c. Not Likely	d. Don't know
4 Pay attention to heat warnings and alerts	a. Very Likely	b. Somewhat Likely	c. Not Likely	d. Don't know
5 Limit outdoor activity/Avoid over exertion	a. Very Likely	b. Somewhat Likely	c. Not Likely	d. Don't know
6 Take extra showers or baths	a. Very Likely	b. Somewhat Likely	c. Not Likely	d. Don't know

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