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Development of a heat vulnerability index for New York State

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ABSTRACT

Objectives: The frequency and intensity of extreme heat events are increasing in New York State (NYS) and have been linked with increased heat-related morbidity and mortality. But these effects are not uniform across the state and can vary across large regions due to regional sociodemographic and environmental factors which impact an individual's response or adaptive capacity to heat and in turn contribute to vulnerability among certain populations. We developed a heat vulnerability index (HVI) to identify heat-vulnerable populations and regions in NYS.

Study design: Census tract level environmental and sociodemographic heat-vulnerability variables were used to develop the HVI to identify heat-vulnerable populations and areas.

Methods: Variables were identified from a comprehensive literature review and climate-health research in NYS. We obtained data from 2010 US Census Bureau and 2011 National Land Cover Database. We used principal component analysis to reduce correlated variables to fewer uncorrelated components, and then calculated the cumulative HVI for each census tract by summing up the scores across the components. The HVI was then mapped across NYS (excluding New York City) to display spatial vulnerability. The prevalence rates of heat stress were compared across HVI score categories.

Results: Thirteen variables were reduced to four meaningful components representing 1) social/language vulnerability; 2) socioeconomic vulnerability; 3) environmental/urban vulnerability; and 4) elderly/ social isolation. Vulnerability to heat varied spatially in NYS with the HVI showing that metropolitan areas were most vulnerable, with language barriers and socioeconomic disadvantage contributing to the most vulnerability. Reliability of the HVI was supported by preliminary results where higher rates of heat stress were collocated in the regions with the highest HVI.

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Conclusions: The NYS HVI showed spatial variability in heat vulnerability across the state. Mapping the HVI allows quick identification of regions in NYS that could benefit from targeted interventions. The HVI will be used as a planning tool to help allocate appropriate adaptation measures like cooling centers and issue heat alerts to mitigate effects of heat in vulnerable areas.

Introduction

According to the Intergovernmental Panel on Climate Change, vulnerability to climate change results from the imbalance between susceptibility to geophysical, biological, and socioeconomic systems and the ability to adapt or cope with the impacts of climate change.[1,2] Similarly, vulnerability to extreme heat (EH) can be influenced by relationships between such systems. Identifying heat-vulnerability resulting from these relationships can facilitate the allocation of adaptation resources for the community. Heat-related morbidity and mortality among vulnerable populations in New York State (NYS) could rise with the projected increase in frequency, intensity, and the duration of EH events.[1] But how is a region or community determined to be vulnerable to heat? While variations observed in heat-health associations can result from individual attributes, community-level environmental, sociodemographic, and behavioral characteristics can also influence an individual's response and community's adaptive capacity. These factors can contribute to the observed variability in vulnerability among different populations.[3–10]

The elderly are at greater risk of adverse heat-related health outcomes[11–20] with elevated hospitalization and mortality rates especially during EH events in the summer, probably due to excess strain exerted on pre-existing morbidities. The elderly (≥65 years of age) are usually the first to be affected,[11] with the highest risk of heat-related illness during early EH events. Social isolation, possibly due to reduced mobility, is another factor that increases elderly vulnerability to heat.[17–19]

There have been contradictory findings among heat-vulnerability studies with regard to gender. But most studies[21–25] found women at a higher risk of heat-related mortality and morbidity than men regardless of age group.

Race and ethnicity were often identified as key factors in vulnerability to heat. While being of a non-white race was a risk factor for heat-related morbidities and mortality,[26] specifically being Black[14,26–29] or Hispanic[20,27,30] increased that risk significantly. Although some studies have shown Hispanics to be at a lower risk of heat-related morbidity than blacks and Caucasians,[31,32] others observed higher hospitalization rates among Hispanics[16,20,27] and a higher volume of heat distress calls from neighborhoods with larger proportions of African-Americans and Hispanics.[30]

Language can also impact vulnerability to heat. Most emergency alerts in the United States are issued in English, placing limited English proficient populations at an increased vulnerability[29,33–36] as they may miss warnings and alerts in weather reports, and on social media.[37,38] Over the past two decades, 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.[38] This suggests that populations whose primary language is not English, or are foreign born may be vulnerable populations in NYS.

Socioeconomic status indicators including low education,[8,21,39] unemployment[37,40] poverty,[24,39] and age of home[12,14,40,41] have been shown to correlate with availability of heat-adaptation amenities in a community such as shaded recreation areas and air-conditioned cooling centers.[29,41]

Land cover and land use are key factors that play a role in adaptation to EH events. Concrete and asphalt used in urban settings and buildings retain heat and take longer to cool down, creating urban heat islands (UHIs) that are substantially warmer than surrounding suburban and rural areas. Urban populations can therefore experience higher daytime temperatures, less nighttime cooling, and an increased frequency and duration of EH events during the summer.[13,28,30] Within urban areas themselves, the UHI effect has been found to be correlated with sparse vegetation, high population and building density, and less open space.[3,4,9] As urban populations increase, more vulnerable people will be exposed to the UHI effect. Indicators of urbanicity identified as heat vulnerability factors include housing and population density, open green space[8,28] and high-intensity land use.

Air-conditioning (A/C) can also play a role in an individual's adaptation to EH[5,8,28,42] but data on A/C access and usage is available only in selected cities and metropolitan census tracts. Among households in New York City (NYC), those living in poverty, in older homes and low-income neighborhoods were less likely to have A/C, thereby increasing their vulnerability to heat.[43] Older homes can also increase vulnerability if they are poorly maintained or insulated,[41] preventing a home from staying at cooler temperatures. Since statewide data on A/C in NYS is unavailable,[44] age of home and socioeconomic status could be considered as proxies of A/C availability and usage.

All the above indicate that it would be beneficial to identify where vulnerable populations are located and why they are vulnerable. This knowledge will help implement targeted mitigation strategies and provide appropriate adaptation resources. The objectives of this study were therefore to identify characteristics that impact community vulnerability or adaptive capability to heat in NYS and develop a heat vulnerability index (HVI) based on these factors. While other indices have been developed for individual cities[22,34,45–48] and metropolitan areas[8] or more broadly for social vulnerability at national level,[29] this index specifically focuses on heat vulnerability in NYS. The HVI was developed as a tool for local public health and emergency planning officials in NYS. It can assist new or existing heat mitigation efforts[49] by informing the allocation of local resources like cooling centers and issuance of heat alerts in heat-vulnerable areas.

Methods

Literature review

Peer-reviewed articles identifying factors that influenced the impact of heat on health and were published between 1995 and 2015 were reviewed on online databases (PubMed, Science Direct and Google Scholar). Key words and phrases used to identify relevant articles included: 'heat vulnerability', 'vulnerability', 'extreme heat', 'regional/spatial heat vulnerability', 'social vulnerability to heat', 'environmental vulnerability to heat', and 'heat vulnerability index'. Thirteen environmental and sociodemographic variables (Table 1) that were observed to modify the heat-health relationship in NYS[20,25,27,50] and in regions with similar climate, and were also available for census tracts in NYS, were selected as final heat vulnerability variables to create the HVI.

Data sources

We obtained census tract level information on the identified vulnerability variables to develop the HVI for NYS. A vulnerability assessment has been previously performed for NYC,[13] so we focused on the heat-vulnerability assessment for NYS excluding NYC. Census tracts are subdivisions of counties with populations ranging from 1200 to 8000 people and are defined by the U.S. Census Bureau to collect, provide, and present statistical data.[51] Census tract boundaries stay relatively consistent over time allowing for more flexible small-area analyses and comparison across different time periods. Geographical boundaries and data on socioeconomic and demographic vulnerability variables were obtained from the 2006–2010 U.S. Census Bureau American Community Survey (Table 1). Land cover classification data on building intensity, and open land (includes green space developed and undeveloped) were obtained at the spatial resolution of 30-m raster cells from the 2011 National Land Cover Database (NLCD) and then aggregated to census tract. For each census tract, we calculated 1) percentage of population with characteristic; 2) percentage of total tract area in each land cover category; or 3) density per square mile. Measures for variables were calculated for each tract so that an increase in value indicated an increase in vulnerability, except for 'open land' where an increase in value was an indication of lower vulnerability.

Heat stress emergency department (ED) visits and admissions among NYS residents from May to September, for years 2008 through 2012, were used to perform a preliminary validation of the HVI. Heat stress data (International Classification of Diseases, 9th revision Codes of 992.0–992.9 including heat stroke and sunstroke, heat syncope, heat cramps, heat exhaustion-anhydrotic, transient heat fatigue, heat edema, and 'External Causes of Injury Code' E-900.0), were obtained from NYS Department of Health's legislatively mandated database, Statewide Planning and Research Cooperative System (SPARCS).

Study design and methods

We performed univariate analysis and assessed correlation among the variables using Spearman's correlation coefficients. We used principal component analysis (PCA) with varimax rotation to reduce the variables to fewer principal components. Meaningful components were retained based on four criteria:[8,52,53] 1) Eigenvalue-one or Kaiser criterion[54] retaining components with eigenvalue greater than one; 2) the Scree test[55] where eigenvalues are plotted and components appearing before large breaks are retained as meaningful; 3) proportion of variance[56] where any component accounting for approximately 10% of variance is retained or cumulative percent of variance of retained components is at least 70%; and 4) interpretability criterion[52] which affirms that variables loading on a component shared the same concept. In addition, any variable exhibiting complex structure by loading on multiple variables were removed from the analysis[41,52,53] so that resulting components would be more meaningful and easier to interpret. The scores of retained components were

Table 1 – Data sources and distribution of final heat vulnerability variables ($n = 2723$).

Data Source	Variable Definition	Mean (SD)	Minimum, Maximum	Median
US Census American Community Survey (2006–2010)	Percentage population that is Hispanic	8.55 (11.68)	0.00, 79.28	4.10
	Percentage population that is foreign born	10.14 (10.18)	0.00, 63.71	6.65
	Percentage population who speak English less than 'very well'	5.63 (7.72)	0.00, 60.33	2.88
	Percentage population with income below poverty level	11.93 (12.17)	0.00, 100.00	8.01
	Percentage population that is Black	10.44 (6.37)	0.00, 100.00	2.28
	Percentage population over 65 years of age	14.35 (4.80)	0.00, 69.71	13.88
	Percentage population over 65 years of age and living alone	10.32 (17.88)	0.00, 53.09	9.71
	Percentage population (18–64 years) that has a disability	9.88 (18.31)	0.00, 100.00	8.51
	Percentage population (18–64 years) that are unemployed	7.98 (9.47)	0.00, 53.85	7.02
	Percentage houses built before 1980	77.60 (37.78)	0.00, 100.00	80.99
	Density of housing units per square mile	1528 (2118.00)	0.00, 22063.00	817.02
National Land Cover Database (2011)	Percentage land with high building intensity areas	5.82 (5.97)	0.00, 84.12	1.98
	Percentage land that consists of open undeveloped areas	42.12 (5.56)	0.00, 99.80	32.85

normalized (mean of 0 and a standard deviation 1) and were categorized into six groups based on the mean and standard deviations of the scores.[8] Each category was assigned a score from 1 to 6 with a score of 1 indicating least vulnerable and 6 indicating the highest. The HVI was then created by summing the scores[8,29] across the components for each census tract and then mapping the cumulative score across NYS.

To validate the HVI, geocoded addresses of heat stress patients were linked to census tracts to assign HVI scores. We used a negative binomial model to estimate age-adjusted prevalence rates (per 100,000) for the four HVI groups, averaged over age, and calculated rate ratio estimates using the lowest HVI group ($\leq$12) as the referent group for comparisons.

We used SAS version 9.2 (SAS Institute, Cary, NC) to perform statistical analysis and MapInfo Version 15.2 (MapInfo Corp, Troy, NY) for mapping.

Results

There were 2751 census tracts in NYS excluding NYC. Census tracts with missing data or zero population were excluded from the analysis, resulting in 2723 census tracts. About 89% of NYS population live in 2250 census tracts categorized as metropolitan[49] (core, low, and high commuting) with the rest being micropolitan, small town, and rural tracts (data not shown).

Table 1 displays the description and statistical distribution and Table 2 presents correlations among the final 13 vulnerability variables selected for this analysis. Although most variables were positively correlated with each other, percentage of open undeveloped land was negatively correlated with almost all the variables.

Three variables including percent females, percent low education, and population density were dropped during the process of PCA as they loaded on multiple components. Using the four PCA selection criteria, the final 13 sociodemographic and environmental vulnerability indicator variables were reduced to four meaningful components (Table 3) which had eigenvalues ranging from 1.14 to 4.35. The first component accounted for the largest amount of variance (33.4%) and the four components together contributed to over 74% of the total variance. Statistical distribution of each component and the 13 variables loading on them are displayed in Table 3. The components represent four aspects of heat vulnerability and include: 1) ***social/language component***: comprised of variables representing minority populations with language barriers; 2) ***socioeconomic component***: includes variables representing economic disadvantage; 3) ***environmental/urbanicity component***: comprised of variables representing urban and metropolitan areas with older homes; and 4) ***elderly/social isolation component***: includes the elderly and elderly living alone (one-person household).

Fig. 1a–d display the spatial distribution of factor scores across NYS for each of the four components. With the social/language component (Fig. 1a), language vulnerability is mostly seen in the downstate area in census tracts closest to the NYC metro areas. Approximately 12% of census tracts fell in the top two highest vulnerability categories. The socioeconomic component shows spatial diversity across NYS (Fig. 1b) with several rural areas and few metropolitan areas showing

Table 2 – Spearman's correlation coefficients for heat-vulnerability variables in New York State (n = 2723).

	Hispanic	Foreign born	Non-English speaking	Poverty	Black	Disability	Unemployed	Older homes	Building intensity	Open land	Housing density	Elderly	Elderly living alone
Hispanic	1												
Foreign born	0.65	1											
Non-English speaking	0.68	0.82	1										
Poverty	**0.03**	−0.15	**0.02**	1									
Black	0.51	0.43	0.44	0.33	1								
Disability	−0.05	−0.34	−0.17	0.6	0.21	1							
Unemployed	0.17	**−0.02**	0.1	0.48	0.27	0.44	1						
Older homes	0.24	0.17	0.21	0.17	0.24	0.1	0.17	1					
Building intensity	0.45	0.45	0.48	0.15	0.43	**0.01**	0.16	0.53	1				
Open land	−0.44	−0.5	−0.49	**−0.03**	−0.43	0.11	−0.1	−0.63	−0.79	1			
Housing density	0.43	0.47	0.47	0.17	0.45	**−0.01**	0.16	0.67	0.76	−0.91	1		
Elderly	−0.29	−0.13	−0.18	−0.17	−0.3	−0.04	−0.18	**0.01**	−0.09	0.13	−0.11	1	
Elderly living alone	−0.15	−0.1	−0.08	0.12	−0.07	0.17	**0.03**	0.11	0.11	**0**	0.09	0.63	1

Bold-faced values show non-significant correlation with P-values >0.05.

Table 3 – Eigenvalues, proportion of variance and output from principal component analysis.

	Social/language component	Socio-economic component	Environmental/urbanicity component	Social isolation/elderly component
Eigenvalue	4.35	2.18	1.84	1.14
Proportion variance	0.33	0.17	0.14	0.09
Mean (range)	0.00 (−1.44, 6.43)	0.00 (−1.60, 7.56)	0. 00 (−3.84, 4.15)	0.00 (−2.98, 9.03)
Variables	Rotated factor pattern: varimax rotation method			
Hispanic	**0.86**	0.15	0.15	−0.12
Foreign born	**0.89**	−0.11	0.26	−0.04
Non-English speaking	**0.92**	0.08	0.14	−0.07
Below poverty line	0.06	**0.81**	0.17	−0.09
Black	0.27	**0.59**	0.34	−0.20
With a disability	−0.14	**0.82**	−0.02	0.09
Unemployed	0.09	**0.78**	0.10	−0.04
Older homes	−0.08	0.06	**0.79**	0.08
Building intensity	0.32	0.27	**0.59**	0.03
Open land	−0.26	−0.02	**−0.83**	0.04
Housing density	0.33	0.23	**0.73**	0.01
≥65 years old	−0.14	−0.21	−0.03	**0.89**
≥65 years old & living alone	−0.03	0.08	0.10	**0.92**

Values greater than 0.4 are boldfaced.

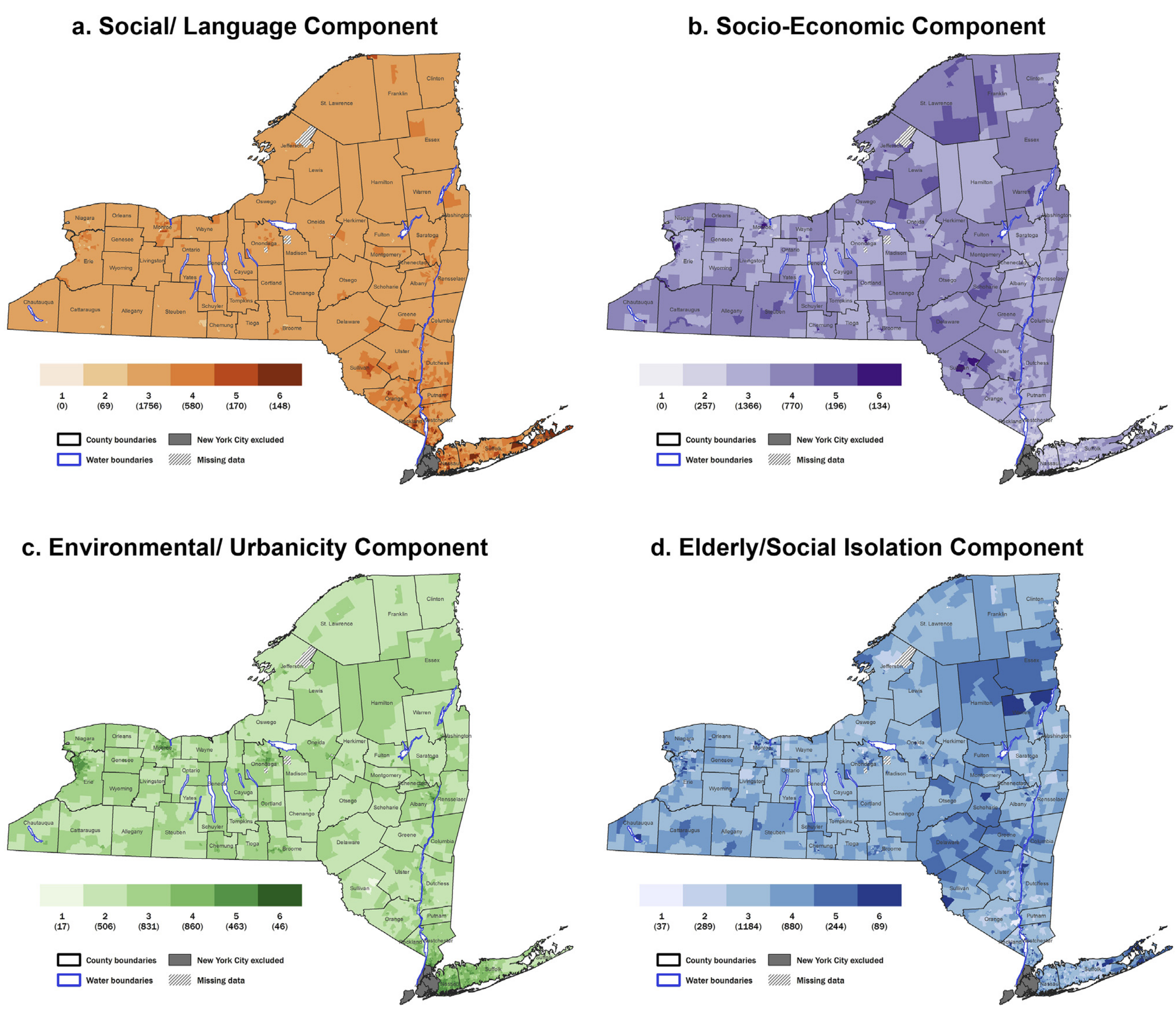

Fig. 1 – a–d: Distribution of principal component scores across New York State (excluding New York City).

moderate to high vulnerability. In Fig. 1c, the most vulnerable areas with the environmental/urbanicity component were observed in the urban tracts with about 20% of the NYS census tracts falling in the highest two categories of vulnerability. Fig. 1d 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.

The cumulative HVI is displayed in Figs. 2 and 3a–f, the latter images display the HVI in six selected metropolitan areas of NYS. The HVI scores for 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 more are concentrated in the more urban and metropolitan census tracts of NYS 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.

Age-adjusted prevalence rates of heat stress increased with HVI scores, with highest rates in HVI scores category ≥17 (Table 4). While comparison of rates between HVI categories showed differences across all groups, statistically significant difference was only observed with category ≥17. When comparing age-specific rates (data not shown), all age groups showed highest prevalence in the ≥17 HVI category except for '10–19 years' age group (highest rates in 13–14 HVI category). Within each HVI category, the age group '≥85 years' consistently showed the highest rates.

Discussion

Early identification of vulnerability to EH events can help guide public health efforts ahead of, during, or in the aftermath of the event. In this study, we created a fine-scale cumulative HVI for NYS using census tract level information to identify communities that are most likely to be impacted during EH events. Consistent with prior studies in other geographic regions,[8,57] we found that highest vulnerability was observed in the more urban and metropolitan census tracts of NYS although most of NYS falls in the lower categories of vulnerability. We also observed heterogeneity in spatial variability across the major vulnerability components. While the cumulative HVI helps to quickly identify communities with highest overall susceptibility to EH, our findings also indicate that understanding underlying basis of vulnerability is equally important for strategic and targeted public health efforts. Interventions can then be tailored for and disseminated to the appropriate target population.

In this HVI, the language component accounted for the most variance, with distribution showing that areas of southern NYS, counties around NYC, showed higher vulnerability than upstate NYS. This observation reflects the higher proportion of immigrants in these regions. Among immigrants and limited English proficient populations, language is commonly cited as a barrier to accessing resources and understanding alert messages issued during disasters.[37,58,59] Risk communication through heat awareness messages should therefore be disseminated in commonly spoken languages other than English through outlets that are more accessible to these communities. Effective risk communications can be likely achieved via radio and television rather than new technologies including text messages, social media, and

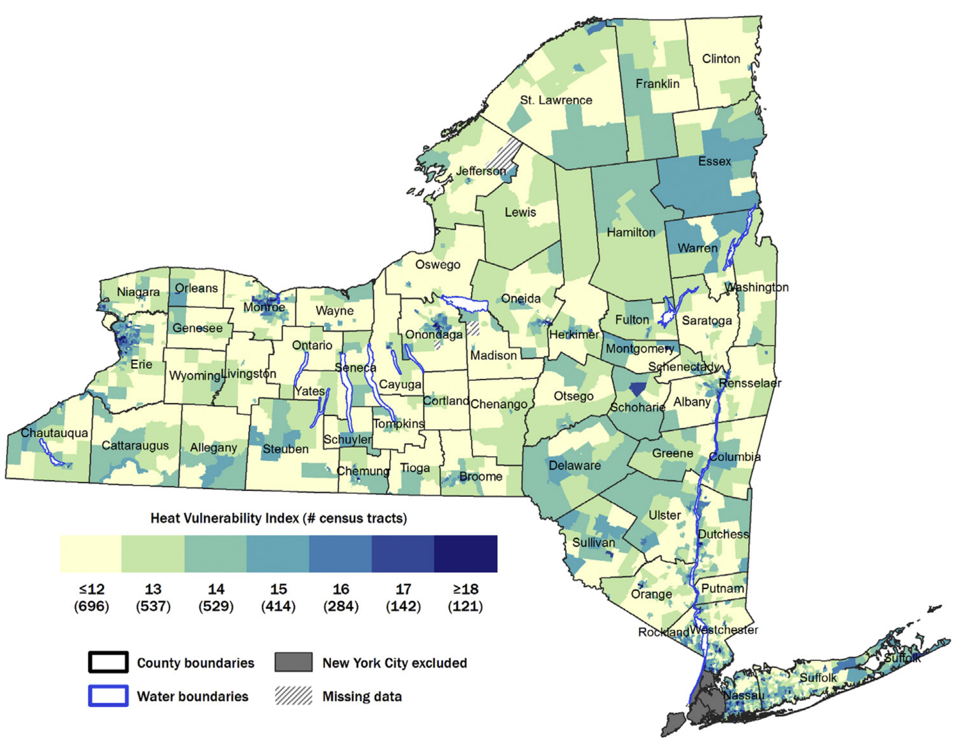

Fig. 2 – Cumulative heat vulnerability index for New York State.

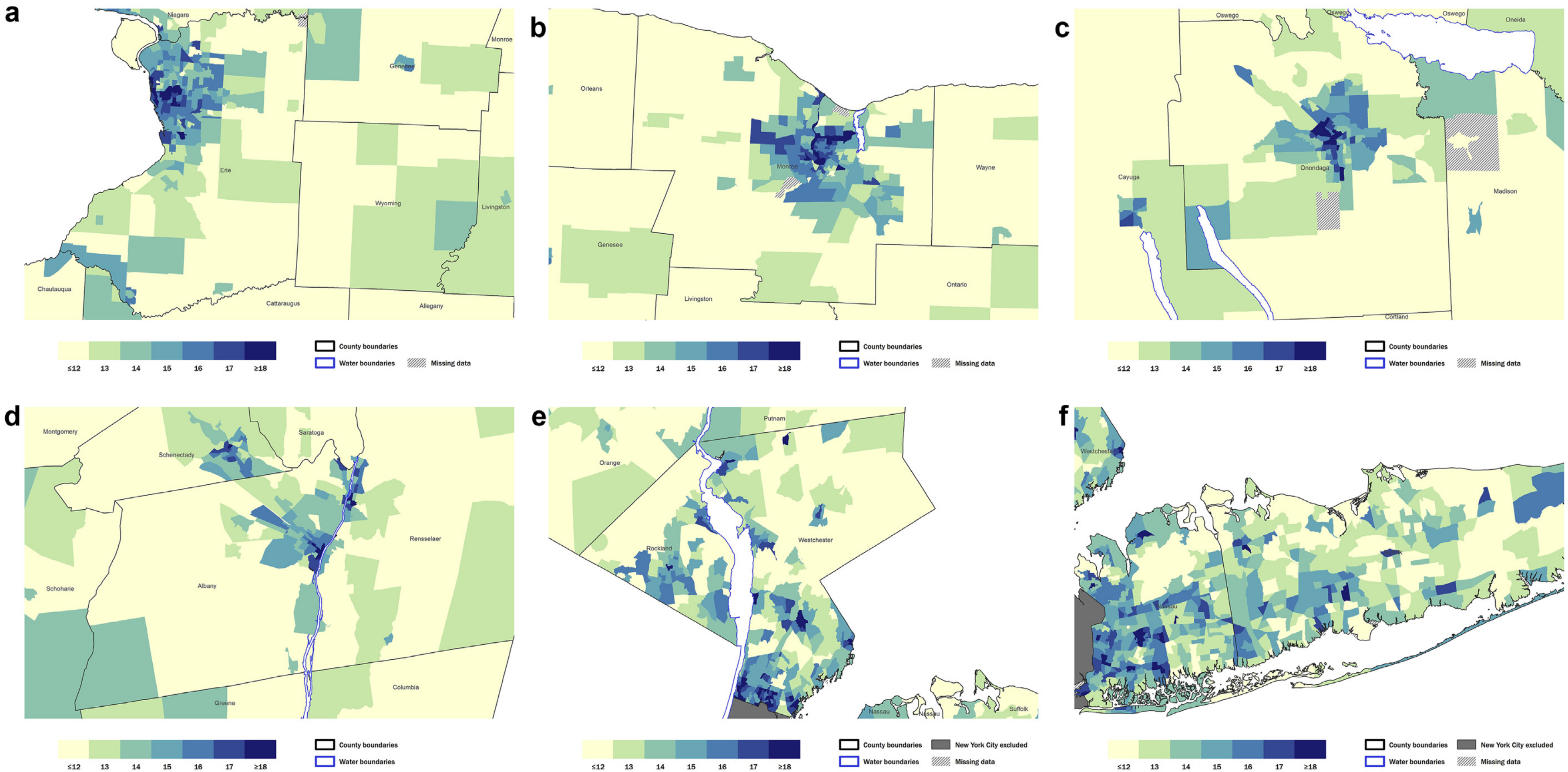

Fig. 3 – a–f: Cumulative heat vulnerability index in selected major metropolitan areas of New York State.

Table 4 – Heat stress prevalence rates by heat vulnerability index score.

Heat vulnerability index score	Heat stress cases[a]	Census tracts	Age-adjusted prevalence rate[b]	Age-adjusted prevalence ratio
≤12	1462	543	9.88	Ref
13–14	2191	835	9.95	0.99 (0.86, 1.14)
15–16	1499	566	10.85	1.06 (0.91, 1.22)
≥17	627	209	12.94	**1.29 (1.10, 1.51)**

[a] Heat Stress Emergency Department visits and hospitalizations, May–September 2008–2012.
[b] Per 100,000 population/year. Denominator = census population obtained from 2006 to 2010 American Community Survey estimates bold faced-statistically significant.

websites which may be less accessible due to the language barrier.

The socioeconomic component, an aggregate of prevalence of poverty, unemployment, disability, and black population, showed greater variability across the state with some clusters in rural and few inner-city areas. Consistent with our findings, the NYC HVI[33] found that black individuals and residents in census tracts with high proportions of households on public assistance had a higher risk of death during a heat wave. Economic status of both an individual and their community affect how one copes with EH. While recommendations to use A/C during periods of EH are commonly a part of cool-down messaging, this may not be an affordable option (cost of A/C unit and utilization bills) for individuals and families with low income. Community resources like cooling centers can help provide the public with a few hours of relief from hot weather. Again, the economic status of the community can influence the accessibility and number of cooling centers available. For instance, the lower-income neighborhoods may not have air-conditioned facilities with capacity for large volumes of visitors during hot days or in the absence of public transportation, accessing these facilities can be an obstacle among families and individuals who may not have their own vehicle. Our recent survey[49] among NYS county offices highlighted that populations in rural or less urban areas have limited access to most cooling centers as most are located metropolitan areas, and there is no public transportation. Heat adaptation planning would have to take these points into consideration.

Environmental heat vulnerability was observed in the more urban areas. It could be influenced by the UHI effect resulting from large areas of hardened impervious surfaces like pavements and rooftops.[60] In comparison to surfaces covered in vegetation, the temperatures in areas covered by impervious surfaces can be considerably higher as constructed structures tend to retain heat in their dense mass.[61,62] Urban areas have also been observed to have more frequent and intense heat events and require longer time to cool during the night.[63] The infrastructure in urban areas is constantly being modified to support the needs of an increasing population size thereby resulting in reduced vegetation and open space, overcrowding, and increased risk of stress and disease.[28,64] Results from the NYC HVI support our findings observing less heat vulnerability in areas with more green space. 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 cold pavements that help with cooling in urban areas.[65]

The elderly/social isolation component showed vulnerability in several non-metropolitan areas of NYS. Distribution of elderly populations in NYS is consistent with the rest of the United States where rural populations are older than urban and sub-urban populations.[66] The contribution to social isolation of the elderly in rural areas is further heightened when the elderly live on their own possibly away from family and majority of the community in comparison to their urban counterparts.[67] 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.[66] Higher proportions of elderly and reduced accessibility to healthcare in non-urban areas suggests that heat mitigation plans or interventions should specifically target elderly in these areas.

Our preliminary results with heat related illnesses showed increasing trends of prevalence with increase in HVI scores which is consistent with other studies where higher rates of heat-related morbidities were observed in areas of high heat vulnerability.[7,28,34,68] Age-specific rates within each HVI category were highest among those ≥85 years, which is also consistent with other studies where highest rates of heat stress were seen among older age groups.[7,28,69] This suggests the reliability of the HVI as a predictive tool for heat stress in New York State. These findings further support conclusions of a validation study[7] of a nationwide HVI of urban areas—and other HVIs created using similar approach as ours[8,70]—that have shown consistent associations with adverse health outcomes during abnormally hot days.

Our method of vulnerability analysis and mapping has some limitations. PCA can sometimes result in components that do not properly represent the impact of a certain characteristic or may not capture the complexity of interaction between the components. However, PCA is a standard procedure often used in vulnerability assessments[8,29,68] for variable reduction and redundancy elimination allowing for easier interpretability. Another limitation is sparsity of data on air-conditioner prevalence and usage in NYS (excluding NYC). A/Cs play an important role in heat adaptation and vulnerability, but heat-health studies have observed that, age of home and socio-economic status[28,43] are good indicators of A/C availability and usage in homes and were therefore were used as proxies for A/C in this study.

The HVI for NYS was constructed to provide local public health and emergency management leaders with a tool that allows quick identification of areas of greatest necessity and plan interventions accordingly. Our next steps include working with these agencies to determine how to best help vulnerable areas in their jurisdiction during EH events. We also plan to conduct adequacy and accessibility assessments of community resources for heat adaptation, like cooling centers in these heat-vulnerable areas. The HVI, as a composite of multiple indicators, is useful in rapid response and effective resource allocation including dissemination of heat-health messages, home visits of at-risk groups, opening of cooling centers, and so forth during EH events. There is no other existing HVI specifically developed for NYS, and this index is different from previously constructed indices as it was developed at a local scale instead of nationally[29] and does not just focus on metropolitan areas.[8,13]

Conclusion

The heat vulnerability index developed in this study observed geographical variability with heat vulnerability due to differences in regional sociodemographic and land cover characteristics. The most vulnerable areas were primarily urban areas with high housing density, less open space, and high proportions of elderly, minority populations, and lower income households. In the event of an EH event, identification of these vulnerable areas in NYS can help streamline efforts toward mitigation of the effect of heat on health.

Author statements

Ethical approval

IRB approval was obtained through NYSDOH protocol for this study.

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Competing interests

None declared.

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