The Howard University Center of Excellence in Housing and Urban Research and Policy (CHURP)

Urban Exposure to Extreme Heat for Individuals Experiencing Homelessness (IEH)

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I. Abstract

Unhoused populations or individuals experiencing homelessness (IEH) face greater risks when exposed to extreme heat. Unhoused populations, or IEH are described as individuals living on the streets, in encampments[1] or shelters, in transitional housing programs, or doubled up with family and friends. Although, individuals experiencing homelessness (IEH) face health risks when exposed to extreme heat, their heat-related experiences are understudied (Bezgrebelna et al 2021; Kidd et al 2021). As heat waves become more common because of climate change, heat-related death and illness rates are expected to rise. Specifically, for unhoused populations, who may be disproportionately affected by high heat or lack resources that enable them to cope with the health risks of rising temperatures (Gabbe et al, 2023; Kid et al, 2023; Karanja et al, 2023; Tol et al, 2024). Data limitations have prevented researchers from studying environmental risks faced by unhoused populations at finer geographic levels. This analysis utilizes 311 service request data that has recently become available, to measure extreme heat exposure, among nearly 5,000 IEH in the city of Dallas, Texas. Then it conducts a spatial analysis to reveal "hotspots", indicating areas where IEH are clustered in the city. This understanding of spatial patterns in homelessness and heat risk can optimize mitigative and preventative care services for extreme heat illness and death in the City of Dallas.

II. Background

Extreme heat, a period of high heat and humidity with temperatures above 90 degrees for at least 2-3 days, is one of the leading causes of weather-related deaths in the U.S. (National Center for Environmental Health, 2023). Heat has caused more deaths annually than hurricanes, floods, and tornadoes combined (U.S. Natural Hazard Statistics Report, 2021). Although there is no absolute temperature at which extreme heat can turn dangerous, research has demonstrated a strong relationship between ambient temperatures and mortality (Basu 2009; Vaidyanathan et al 2020; Khatana et al 2022). In extreme heat our body works extra hard to maintain a normal temperature, which can cause damage to the brain and other vital organs. Heat-related illness ranges from heat exhaustion, which causes heavy sweating and a rapid pulse, to heatstroke, which causes confusion, loss of consciousness, high fever, and in severe cases, death. Heat vulnerability is a major issue of concern in the Southwestern U.S., where extreme heat events are predicted to increase significantly due to climate change (NCEH, 2021). In the summer of 2023, there were unparalleled stretches of triple-digit temperatures throughout the south. In Texas, more than 300 residents died from heat related-illness and Dallas, topped the list of the most heat-related deaths in the state (Douglas and Martinez, 2024; Dallas County Health & Human Services, 2023).

In the city of Dallas there were nearly 40 heat related deaths and over 1,000 residents were treated for heat-related illness in the summer of 2023 (Miles, 2023). In Dallas, a city of 1.3 million

[1] An encampment is an outdoor location on public property where one or more individuals have established temporary living accommodations, typically involving structures like tents (City of Baltimore Homelessness Services, 2023).

residents, buildings and roads are highly concentrated, while greenery is limited, which intensifies the urban heat island (UHI)[2] effect (Houston Advanced Research Center, 2009; Texas Trees Foundation, 2017, Winguth and Kelp, 2013). Climate projections for Dallas predict that the number of days exceeding 100 degrees to increase by 40-60 days by 2050 (Office of Environmental Quality and Sustainability, 2019). Extreme heat and UHI effects are expected to worsen in Dallas, and without effective interventions incidences of heat-related death and illness will continue to rise.

Unhoused populations or individuals experiencing homelessness (IEH) face greater risks when exposed to extreme heat. Unhoused populations, or IEH are described as individuals living on the streets, in encampments[3] or shelters, in transitional housing programs, or doubled up with family and friends. There are 4,570 IEH in the city of Dallas, the highest urban unhoused population in the state of Texas (Annual Homelessness Assessment Report, 2023). IEH are more vulnerable to high temperatures because they spend extended periods outdoors and have less adaptive capacity to respond to extreme heat (Gronlund et al, 2018). Studies have also shown pre-existing conditions play a significant role in the level of vulnerability a person experiences during an extreme heat event (Tol et al, 2024; Brown et al, 2016) and unhoused populations often have poorer health outcomes than the general population, putting them at risk for these comorbidities (Richards & Kuhn, 2023; Schanzer et al, 2007). Furthermore, while the city of Dallas has created programs to mitigate and address the impacts of extreme heat, no programs have prioritized needs of local IEH. Without attention, as heat waves become more common, heat-related death and illness rates will rise amongst unhoused populations.

Although, individuals experiencing homelessness (IEH) face health risks as a result of extreme heat, their heat-related experiences are understudied (Bezgrebelna et al 2021; Kidd et al 2021). Identifying specific locations of unhoused populations within cities has been a challenge for researchers. This study will use 311 service request data, that has become recently available, to locate unhoused individuals in the city IEH of Dallas. Then it will conduct a spatial analysis to reveal "hotspots", indicating areas where are clustered in the city. Visualization and spatial regression techniques are employed in this study to examine associations between IEH and heat risks to show where IEH in the city of Dallas are located and their proximity to areas at high risk for extreme heat events. This understanding of spatial patterns in homelessness and heat risk can optimize mitigative and preventative care services for the City of Dallas.

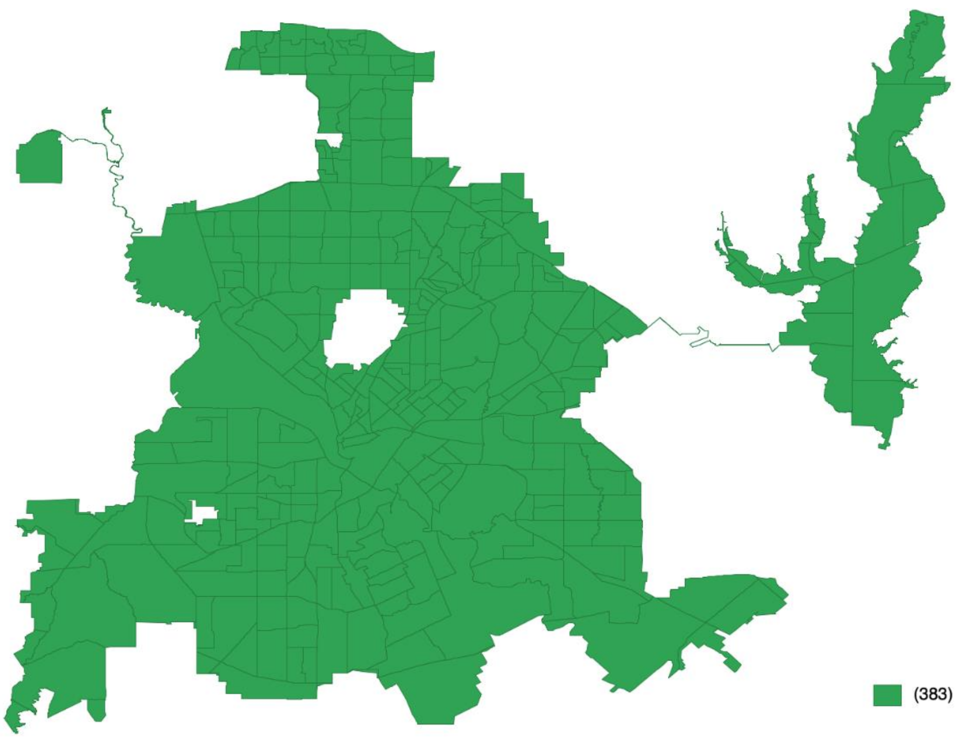
[2] Urban Heat islands are urbanized areas that experience higher temperatures than outlying areas. Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. Daytime temperatures in urban areas are about 1–7°F higher than temperatures in outlying areas and nighttime temperatures are about 2-5°F higher (US EPA, 2023)

[3] An encampment is an outdoor location on public property where one or more individuals have established temporary living accommodations, typically involving structures like tents (City of Baltimore Homelessness Services, 2023).

III. Study Area

This paper examines the city of Dallas, Texas. Dallas city limits were provided by city government GIS open data platform. There are 383 Census tracts in the city of Dallas that are included in Dallas, Collin, Denton, Kaufman, and Rockwall counties.

Exhibit I: Map of census tracts in the city of Dallas



IV. Data

311 Service Request Data

The city of Dallas operates a calling center to manage resident concerns about unhoused individuals. Dallas City residents can call 311 to report sightings of panhandling and encampments, both considered unlawful acts in the city (Kalthoff, 2023). The street address for each 311 report is recorded by a dispatcher and logged in a database "Homeless 311". This dataset is published on the City of Dallas open data platform, updated daily with 311 call information going back to 2013. Location information from the 311 calls are used to locate IEH in Dallas. Although 311 complaint data are not a perfect reflection of where unsheltered residents may be living, aggregate values that summarize the number of calls by census tract can help us understand seasonal and yearly patterns in locations where unhoused populations frequent. Corinth & Finley (2019) provide evidence that the distribution of IEH related 311 calls in New York City reflect the actual locations of people experiencing unsheltered homelessness. They find, IEH related calls are similarly distributed to official Point-in-Time[4] counts. 311 service request data are used in similar analyses to represent the prevalence of other community distress attributes like opioid use, examined in Li et al (2020) and crime, examined in Wheeler (2018) and O'Brien (2018).

There are other datasets that describe unhoused populations, like HUD's Annual Homelessness Assessment Report (AHAR). However, AHAR does not specify locations of unhoused populations beyond the county level. Furthermore, because PIT counts are collected on a single night in January, summer months, where extreme heat is at its worst, are unrepresented in this data. Climate impacts can vary across census tracts as shown in Exhibit II (right), which summarizes current heat risk across the city of Dallas, and 311 calls can serve as an alternative data source to provide more specific geographic and temporal information about unhoused populations for more local analyses.

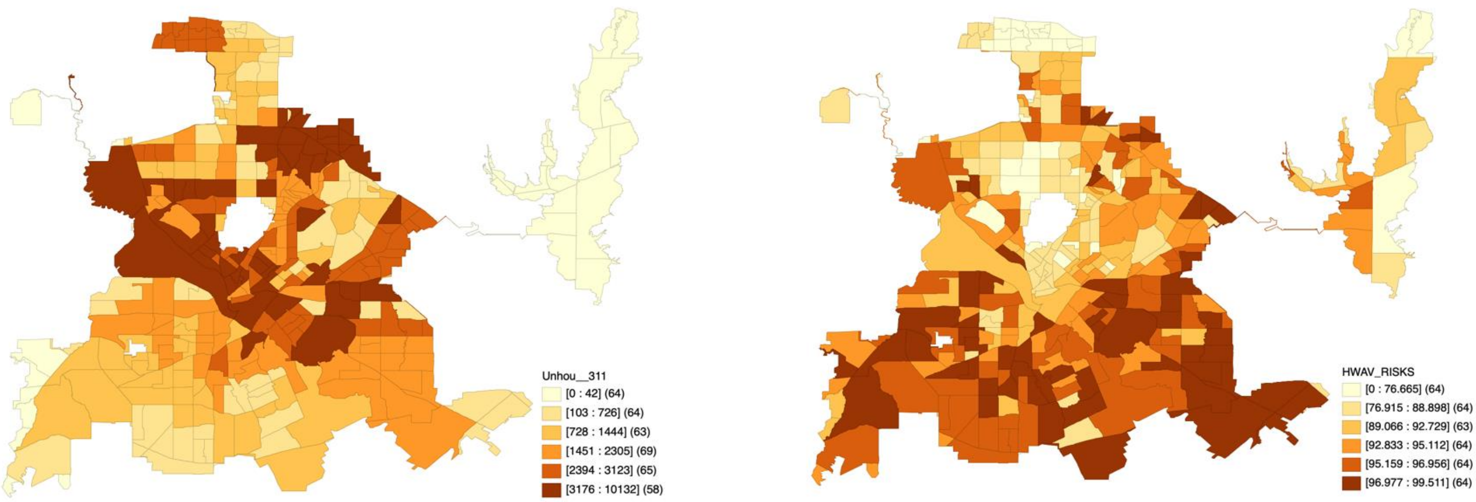
Heat Wave Risk Index

The Federal Emergency Management Agency (FEMA) National Risk Index provides census tract-level data about current local risks to 18 natural hazards[5] that occur in the U.S. This analysis focuses on heat wave risk, and FEMA's index is used to understand risks to extreme heat across the city of Dallas. High temperatures are not the only determinants of heat vulnerability, vulnerability to heatwaves can be dependent on age, existing illnesses, level of education and socioeconomic circumstances (Szugri et al 2023). To account for this, FEMA's heat-risk index is calculated to include measures of expected annual loss, social vulnerability, and community resilience to more accurately determine regional extreme heat vulnerability. This data is used in similar research to understand spatial patterns in risk to environmental hazards (Indaco and Ortega, 2024; Asl,2023; Tedesco et al, 2024).

[4] The Point-in-Time (PIT) Count is a count of sheltered and unsheltered people experiencing homelessness on a single night in January. Data for the PIT count are submitted to HUD Annually by HUD funded homeless service centers.

[5] The list of 18 natural hazards includes, avalanches, coastal flooding, cold waves, droughts, earthquakes, hail, heat waves, hurricanes, ice storms, landslides, lightning, riverine flooding, strong winds, tornado, tsunami, volcanic activity, wildfire, and winter weather.

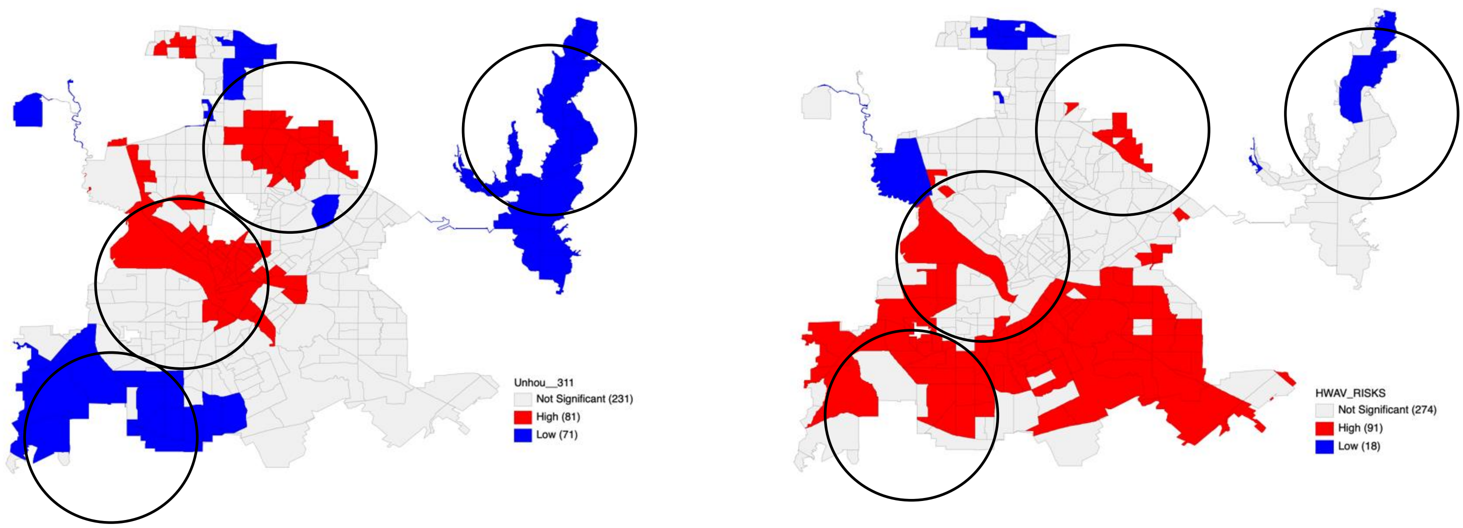
Exhibit II: Total number of IEH related 311 calls by census tract (left) and heat risk by census tract (right). Scales from 1 to 6 with lightest colors representing lowest values and darkest colors representing highest values as compared to other census tracts in the study area.



V. Analysis

A spatial analysis is conducted to identify "hotspots" for homelessness and extreme heat risk in the city of Dallas. Hotspot analyses use spatial clustering and outlier techniques to identify communities that are similar or different from their neighbors and assign significance to neighboring communities with similar features, i.e. where positive spatial autocorrelation is captured. Hotspot analysis is used in research to identify regions with a prevalence of particular features. In Ho et al (2015), Barron et al (2018) and Li et al (2020) hotspot analyses examine urban neighborhoods across the U.S. for features that increase community vulnerability to extreme heat, like high temperatures and sparse tree canopy cover. Conclusions from these studies, aim to help local governments create more effective mitigation for future extreme heat events because they offer a better understanding of localized needs. Similar techniques are used in this analysis, to examine census tracts in the city of Dallas to understand spatial patterns in two local features, homelessness and risk to extreme heat. Conclusion from this analysis aim to optimize mitigative and preventative care services, specifically for IEH and their extreme heat needs. Getis-Ord Gi* spatial statistics will identify hotspots, for each feature using techniques outlined in similar studies. Each census tract is evaluated with its neighbors in three categories: high-high, low-low, and not significant. Where, a census tract evaluated as high-high indicates (1) the tract has significantly higher risk to extreme heat than other tracts, and neighboring tracts also have significantly higher risk to extreme heat or (2) the tract has a significantly higher volume of IEH related 311 calls than other tracts, and neighboring tracts have a similarly large volume. These locations are considered heat risk and IEH hotspots, respectively. A census tract evaluated as low-low indicates (1) the tract has significantly lower heat risk than other tracts, and neighboring tracts also have significantly lower in heat risk than other tracts or (2) the tract has a significantly lower risk to extreme heat than other tracts, and neighboring tracts have a similarly low risk. These locations are considered heat risk and IEH coldspots, respectively. Statistically insignificant locations have dissimilar features to their neighbors and are excluded from hot and cold clusters. Hot and cold spots are identified in Exhibit III, the map on the right highlights, heat risk hot and cold spots, indicated by red and blue, respectively. while the map on the left, highlights IEH hot and cold spots, tracts with pronounced volumes of homeless service related 311 calls.

Exhibit III: Hotspot Analysis ad determined by Getis-Ord Gi* statistic for IEH related 311 calls (left) and heat risk (right). These tracts have significantly higher (red) and lower (blue) volumes of IEH related 311 calls or heat risk than other tracts, along with their neighboring tracts. Note: the light gray area represents areas of no data



VI. Results

A spatial analysis is conducted to identify "hotspots" for homelessness and extreme heat in the city of Dallas. A Getis-Ord Gi* statistic is used to partition spatial data into meaningful clusters, such that spatial objects in the same cluster are similar to each other, and indicate hot and cold spots. There is significant spatial clustering in both the number of IEH related 311 calls (Exhibit III, left) and heat risk (Exhibit III, right), red and blue colors on each map shown in Exhibit III indicate hot and cold spots, respectively.

Out of 383 census tracts in the city of Dallas, there are 81 census tracts that are hotspots for IEH related 311 calls. IEH hotspots are defined as clustered census tracts with significantly high volumes of IEH related 311 calls. On average, IEH hotspots received more than double the number of daily IEH related 311 calls compared to non-IEH hotspots. Maps of the city of Dallas show a majority of IEH hotspots are located in central and west Dallas surrounding downtown and its major tourist attractions including, the Dallas Museum of Art and the Dallas World Aquarium. Hotspots are also concentrated in northeast Dallas, proximate to interstate 75, the setting of several media reports discussing rising tensions between growing encampments and local homeowners.

Out of 383 census tracts in the city of Dallas, 91 are "hotspots" for extreme heat risk. We define heat risk hotspots as clustered census tracts with significantly high heat risk index scores, which rate a community's relative risk for heat waves. As previously mentioned, the heat risk index considers daily temperatures as well as many social, economic, and ecological factors to accurately calculate vulnerability to extreme heat. A majority of heat risk hotspots are located in southern and central parts of the city, where on average, ambient temperatures are 0.10 degrees higher. Although temperatures are minimally variable, heat risks are significantly higher in heat risk hotspots because of other temperature vulnerability factors like income and race. On average, median income is 50% lower for residents in heat risk hotspots and over 90% of residents in these areas are non-white which both contribute to heightened heat vulnerability (Szugri et al 2023). Many IEH hotspots coincide with heat risk hotspots in Dallas, specifically, in central and western regions of the city. Meaning, many IEH in Dallas are located in and around areas at significantly high risk for extreme heat events.

Furthermore, out of 383 census tracts in the city of Dallas, there are 71 census tracts that are "coldspots" for IEH related 311 calls and 18 census tracts that are coldspots for extreme heat risk. We define coldspots as clustered census tracts with significantly low volumes of IEH related 311 calls and extreme heat risk respectively. IEH coldspots indicate there is little or no presence of IEH. These areas are located in southern and far west, east and northern regions of the city and for the most part, coincide with regions in Dallas with significantly low heat risk index score. Heat risk coldspots are located in far west, north and east part of the city, most of which surround local waterbodies. Although there is some overlap between census tract features, the southern region of Dallas is characterized as an IEH coldspot as well as a heat risk hotspot. Census tracts clustered in this region have little to no IEH but have high vulnerability to extreme heat. Despite this mismatch, there are several coincidences between heat risk and homelessness that indicate there is heightened risk to extreme heat amongst IEH.

Although there are strong visual association between IEH and heat risk hotspots, it is unclear whether this relationship is statistically significant. Using statistical methods, similar to those used by Harlan et al (2012) and Voelkel et al (2018), this analysis attempts to reveal whether the likelihood of heat risk is significantly higher amongst IEH hotspots in Dallas, to indicate a whether IEH are at heightened risk to extreme heat. A logistic regression is used to estimate the likelihood of a binary outcome, based on a given set of independent variables. In this analysis, IEH hotspot classification acts as the binary dependent variable, where the observation is equal to 1 if it is located in an IEH hotspot and equal to 0 otherwise. Neighborhood characteristics including heat risk and average daily summer temperatures are independent variables in the model. Local measures of median rents, poverty and share of renters are included from the American Community Survey 5-year summary (2018-2023) to identify other characteristics of IEH hotspot neighborhoods. Results from the logistic regression are provided in Exhibit IV.

Coefficients of interest, highlighted in yellow, describe the probability of a census tract being located in an IEH hotspot given its surrounding areas are at high risk for extreme heat, shown in model 1 and, given its surrounding areas have heightened average temperatures, shown in model 2. The logit (or "log odds") for being located in an IEH hotspot is estimated to rise by 0.003 with an increase in heat risk. Since bigger logit regression coefficients correspond to bigger probabilities, this means that higher heat risk census tracts are more likely to be IEH hotspots. The same positive relationship is true for, annual maximum temperatures. The logit for being located in an IEH hotspot is estimated to rise by 0.42 with an increase in annual maximum temperature.

Meaning the likelihood of a census tract being located in an IEH hotspot increases with average maximum temperatures. The logit regression coefficient for being located in an IEH hotspot is estimated to drop with an increase in the share of renters, and median rent prices, similar to conclusions found in literature investigating the determinants of homelessness. Homelessness rates correlate to median rents and the share of households in rental housing, and in some cases to poverty rates (National Low-Income Housing Coalition, 2017). These relationships signal social and environmental distresses in IEH hotspot communities in Dallas.

Exhibit IV. Logistic Regression

Model 1: Dependent Variable = Located in an IEH Hotspot	**Odds Ratio (Standard Error)**	**Significance**
Heat Risk Index Score	0.0025 (0.0002)	***
Total Number of 311 Calls	0.3382 (0.0019)	***
Intercept	-1.7631 (0.0226)	***
Model 2 Dependent Variable = Located in an IEH Hotspot	**Odds Ratio (Standard Error)**	**Significance**
Average Maximum Temperature	0.4299 (0.0140)	***
Total Number of 311 Calls	0.2712 (0.0023)	***
Share of Renters	2.9260 (0.0132)	***
Median Rent Prices	0.0001(0.0000)	***
Share of Poverty	-2.8960 (0.0378)	***
Intercept	-17.960 (0.4974)	***
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1		

VII. Conclusion/Discussion

There is significant spatial clustering in both the number of IEH related 311 calls and heat risk. Many IEH hotspots coincide with heat risk hotspots in Dallas, specifically, in central and western regions of the city. Meaning, many IEH in Dallas are located in and around areas at significantly high risk for extreme heat events. Then, a logistic regression is used to calculate the likelihood of heat risk among IEH hotspots in Dallas to establish a probable relationship between heat risk and homelessness. The model finds the likelihood of a census tract being located in an IEH hotspot increases with heat risks and average maximum temperatures. Further supporting conclusions that IEH in Dallas are at heightened risk for extreme heat. To abate further heat-related morbidity and mortality, Dallas should tailor extreme heat interventions and services to target IEH, with recently available 311 data that provides a better understanding of where they are located. Cooling centers can be a valuable resource for heat-vulnerable populations without access to A/C (Widerynski et al, 2017), but limited or lack of accessibility of these facilities is often a barrier to their utilization. An assessment of the accessibility of cooling centers for IEH, using address-level 311 service request data, could provide local agencies with important information to help guide heat adaptation planning in their jurisdictions. Previously, studies have assessed the accessibility cooling centers to heat-vulnerable populations and this analysis will use similar methods (Nayak et al, 2019; Fraser et al, 2016; Sehgal and Sehgal 2023; Elton, 2021)

Cooling Center Proximity for IEH

Although the city of Dallas has prioritized local programs and policies to combat extreme heat and its related impacts (Office of Environmental Quality & Sustainability, 2019), they have not prioritized needs of unhoused populations, although they are likely at heightened risk for extreme heat and associated impacts. Locations of cooling centers can be essential in providing relief from extreme heat (Bedi et al, 2022). Currently, the city of Dallas offers air-conditioned public facilities such as libraries and community centers as places where people can get out of the sun. As well, recently Dallas Area Rapid Transit (DART) began providing select transit centers as cooling stations for customers looking for ways to stay safe from the excessive heat. However, many of these public cooling centers close in the late afternoon, often when temperatures are their peak, and shutter over the weekend, and for many they are too far away to access. We examine access to cooling centers among IEH in the city of Dallas. Locations of cooling centers are pinpointed using public information from the city's Office of Emergency Management. Average minimum distances from IEH related 311 calls to cooling centers are calculated. Accessibility is defined for general populations as 0.5 miles (walking distance) suggesting that ideally one should not have to walk more than 0.5 miles (15 min) to get to a cooling center (Nayak et al, 2019).The median distance between IEH and cooling centers is almost a mile (0.943 miles) and 75% of IEH are further than 0.5 miles from the nearest cooling center. For a majority of IEH in Dallas, cooling centers are inaccessible. Optimizing cooling center locations in the city may be necessary to better serve IEH and reduce their risk to extreme heat.

Local service request data from the city of Dallas can be used to optimize cooling center locations and other extreme heat mitigation plans for vulnerable populations, like IEH, in Dallas. Using methods and data outlined in this study, Dallas, can understand local heat and other climate risks for IEH. This can help the city improve already aggressive efforts like, The Comprehensive Environment & Climate Action Plan (CECAP), to meet heat reduction and other climate goals.

VIII. References

1. Basu, R. (2009). High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. *Environmental health*, *8*, 1-13.
2. Bedi, N. S., Adams, Q. H., Hess, J. J., & Wellenius, G. A. (2022). The role of cooling centers in protecting vulnerable individuals from extreme heat. *Epidemiology*, *33*(5), 611-615.
3. Bezgrebelna, M., McKenzie, K., Wells, S., Ravindran, A., Kral, M., Christensen, J., ... & Kidd, S. A. (2021). Climate change, weather, housing precarity, and homelessness: A systematic review of reviews. *International Journal of Environmental Research and Public Health*, *18*(11), 5812.
4. Corinth, K., & Finley, G. (2020). The geography of unsheltered homelessness in the city: Evidence from "311" calls in New York. *Journal of Regional Science*, *60*(4), 628-652.
5. Dallas County Health & Human Services. (2023) Heat-Related Illness Surveillance Report. Dallascounty.org. https://www.dallascounty.org/departments/dchhs/data-reports/heat-related-surveillance.php
6. Douglas, E. & Martinez, A. (2024). "*I don't wish this on anyone": Two families mourn their losses after a record year for Texas heat deaths.* Texas Tribune, https://www.texastribune.org/2024/01/12/texas-heat-deaths-2023-record-climate-change/
7. Gabbe, C. J., & Pierce, G. (2020). Extreme heat vulnerability of subsidized housing residents in California. *Housing Policy Debate*, *30*(5), 843-860.
8. Gabbe, C. J., Chang, J. S., Kamson, M., & Seo, E. (2023). Reducing heat risk for people experiencing unsheltered homelessness. *International journal of disaster risk reduction*, *96*, 103904.
9. Houston Advanced Research Center. (2009), Dallas Urban Heat Island: Dallas Sustainable Skylines Initiative. https://uccrnna.org/wp-content/uploads/2017/06/19_2009_Dallas-Urban-Heat-Island.pdf
10. Indaco, A., & Ortega, F. (2024). Adapting to Climate Risk? Local Population Dynamics in the United States. *Economics of Disasters and Climate Change*, 1-46
11. Jay, O., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., ... & Ebi, K. L. (2021). Reducing the health effects of hot weather and heat extremes: from personal cooling strategies to green cities. *The Lancet*, *398*(10301), 709-724.
12. Karanja, J., Vieira, J., & Vanos, J. (2023). Sheltered from the heat? How tents and shade covers may unintentionally increase air temperature exposures to unsheltered communities. *Public Health in Practice*, *6*, 100450.
13. Khatana, S. A. M., Werner, R. M., & Groeneveld, P. W. (2022). Association of extreme heat with all-cause mortality in the contiguous US, 2008-2017. *JAMA Network Open*, *5*(5), e2212957-e2212957.
14. Kidd, S. A., Bezgrebelna, M., Hajat, S., Keevers, L., Ravindran, A., Stergiopoulos, V., ... & McKenzie, K. (2023). A response framework for addressing the risks of climate change for homeless populations. *Climate Policy*, *23*(5), 623-636.
15. Kidd, S. A., Greco, S., & McKenzie, K. (2021). Global climate implications for homelessness: a scoping review. *Journal of Urban Health*, *98*(3), 385-393.
16. Li, Y., Hyder, A., Southerland, L. T., Hammond, G., Porr, A., & Miller, H. J. (2020). 311 service requests as indicators of neighborhood distress and opioid use disorder. *Scientific reports*, *10*(1), 19579.

17. Miles, J.D (2023). Nearly 40 deaths being investigated as heat-related in Dallas County, ME says. CBS NEWs. https://www.cbsnews.com/texas/news/nearly-40-deaths-investigated-heat-related-dallas-county/
18. National Center for Environmental Health. (2021, January 7). *Regional Health Effects*. cdc.gov. https://www.cdc.gov/climateandhealth/effects/southwest.htm
19. National Center for Environmental Health. (2023, May 30). *Extreme Heat and Your Health*. cdc.gov. https://www.cdc.gov/nceh/features/trackingheat/index.html#:~:text=Extreme%20heat%20events%2C%20or%20heat,deaths%20in%20the%20United%20States.
20. National Integrated Heat Health Information System (2023). *Current Conditions & Future Outlooks*. Heat.gov. https://www.heat.gov/search?q=dallas%20texas%20risk
21. National Weather Service. (2021). *Weather Related Fatality & Injury Statistics.*weather.gov. https://www.weather.gov/hazstat/
22. Nicolay, M., Brown, L. M., Johns, R., & Ialynytchev, A. (2016). A study of heat related illness preparedness in homeless veterans. *International Journal of Disaster Risk Reduction*, *18*, 72-74
23. Razzaghi Asl, S. (2023). To What Extent Have Nature-Based Solutions Mitigated Flood Loss at a Regional Scale in the Philadelphia Metropolitan Area?. *Urban Science*, *7*(4), 122
24. Richards, J., & Kuhn, R. (2023). Unsheltered homelessness and health: a literature review. *AJPM focus*, *2*(1), 100043.
25. Schanzer, B., Dominguez, B., Shrout, P. E., & Caton, C. L. (2007). Homelessness, health status, and health care use. *American journal of public health*, *97*(3), 464-469.
26. Tedesco, M., Foster, S., Baptista, A., & Zuzak, C. (2023). A multi-hazard climate, displacement and socio-vulnerability score for New York City. *Sustainability*, *16*(1), 42.
27. Texas Trees Foundation. (2017). Urban Heat Island Management Study. https://www.texastrees.org/wp-content/uploads/2019/06/Urban-Heat-Island-Study-August-2017.pdf
28. Vaidyanathan, A. (2020). Heat-related deaths—united states, 2004–2018. *MMWR. Morbidity and mortality weekly report*, *69*.
29. Van Tol, Z., Vanos, J. K., Middel, A., & Ferguson, K. M. (2024). Concurrent Heat and Air Pollution Exposures among People Experiencing Homelessness. *Environmental health perspectives*, *132*(1), 015003.
30. Van Tol, Z., Vanos, J. K., Middel, A., & Ferguson, K. M. (2024). Concurrent Heat and Air Pollution Exposures among People Experiencing Homelessness. *Environmental health perspectives*, *132*(1), 015003.
31. Wheeler, A. P. (2018). The effect of 311 calls for service on crime in DC at micro places. *Crime & delinquency*, *64*(14), 1882-1903.
32. Winguth, A. M. E., & Kelp, B. (2013). The urban heat island of the north-central Texas region and its relation to the 2011 severe Texas drought. *Journal of applied meteorology and climatology*, *52*(11), 2418-2433.
33. Bedi, N. S., Adams, Q. H., Hess, J. J., & Wellenius, G. A. (2022). The role of cooling centers in protecting vulnerable individuals from extreme heat. *Epidemiology*, *33*(5), 611-615.
34. Elton, N. (2021). *Extreme Heat Vulnerability and Spatial Accessibility to Cooling Centers in Connecticut* (Doctoral dissertation, Yale University).

35. Fraser, A. M., Chester, M. V., Eisenman, D., Hondula, D. M., Pincetl, S. S., English, P., & Bondank, E. (2017). Household accessibility to heat refuges: Residential air conditioning, public cooled space, and walkability. *Environment and Planning B: Urban Analytics and City Science, 44*(6), 1036-1055.
36. Nayak, S. G., Shrestha, S., Sheridan, S. C., Hsu, W. H., Muscatiello, N. A., Pantea, C. I., ... & Lin, S. (2019). Accessibility of cooling centers to heat-vulnerable populations in New York State. *Journal of Transport & Health*, *14*, 100563.
37. National Low-Income Housing Coalition. (2017). Homelessness Higher in Areas with Higher Share of Renters, Median Rents, and Poverty Rates. Nlihc.org. https://nlihc.org/resource/homelessness-higher-areas-higher-share-renters-median-rents-and-poverty-rates
38. Szagri, D., Nagy, B., & Szalay, Z. (2023). How can we predict where heatwaves will have an impact?–A literature review on heat vulnerability indexes. *Urban Climate*, *52*, 101711.
39. Sims, V. (2023). Some residents in North Dallas want the city to do more to address nearby homeless encampments. https://www.nbcdfw.com/news/local/some-residents-in-north-dallas-want-the-city-to-do-more-to-address-nearby-homeless-encampments/3418295/
40. Voelkel, J., Hellman, D., Sakuma, R., & Shandas, V. (2018). Assessing vulnerability to urban heat: A study of disproportionate heat exposure and access to refuge by socio-demographic status in Portland, Oregon. *International journal of environmental research and public health*, *15*(4), 640.
41. Harlan, S. L., Declet-Barreto, J. H., Stefanov, W. L., & Petitti, D. B. (2013). Neighborhood effects on heat deaths: social and environmental predictors of vulnerability in Maricopa County, Arizona. *Environmental health perspectives*, *121*(2), 197-204.
42. Dallas Area Rapid Transit (DART). (2023). DART Providing Transit Centers as Cooling Stations. Dart Daily. https://dartdaily.dart.org/home/dart-providing-transit-centers-as-cooling-stations-June-2023
43. City of Baltimore Homelessness Services. (2023). UNDERSTANDING ENCAMPMENTS IN BALTIMORE. Baltimore City. *https://homeless.baltimorecity.gov/sites/default/files/Understanding%20Encampments%20in%20Baltimore.pdf#:~:text=•,the%20individuals%20are%20not%20present*.
44. Vaidyanathan A, Malilay J, Schramm P, Saha S. Heat-Related Deaths — United States, 2004–2018. MMWR Morb Mortal Wkly Rep 2020;69:729–734.
45. Oka, M. (2011). The influence of urban street characteristics on pedestrian heat comfort levels in Philadelphia. *Transactions in GIS*, *15*(1), 109-123.
46. Barron, L., Ruggieri, D., & Branas, C. (2018). Assessing vulnerability to heat: a geospatial analysis for the City of Philadelphia. *Urban Science*, *2*(2), 38.
47. Ho, H. C., Knudby, A., & Huang, W. (2015). A spatial framework to map heat health risks at multiple scales. *International journal of environmental research and public health*, *12*(12), 16110-16123.
48. Widerynski, S., Schramm, P. J., Conlon, K. C., Noe, R. S., Grossman, E., Hawkins, M., ... & Hilts, A. S. (1917). Use of cooling centers to prevent heat-related illness: summary of evidence and strategies for implementation.
49. Sehgal, N. K., & Sehgal, A. R. (2023). Spatial access to cooling centers in the city of Boston. *The Journal of Climate Change and Health*, *11*, 100231.

50. Kalthoff, K. (2023). What's next for the panhandling ordinance in Dallas?Federal Judge declines to block enforcement. https://www.nbcdfw.com/news/local/whats-next-for-the-panhandling-ordinance-in-dallas/3326296/#:~:text=NBC%20Universal%2C%20Inc.,the%20green%20light%20to%20enforcement.

IX. Appendix

FEMA's Heat Wave Index Details

In the National Risk Index, risk is defined as the potential for negative impacts as a result of a natural hazard. The risk equation behind the National Risk Index includes three components: a natural hazards risk component, a consequence enhancing component, and a consequence reduction component. EAL is the natural hazards risk component, measuring the expected loss of building value, population, and/or agriculture value each year due to natural hazards. Social Vulnerability is the consequence enhancing component and analyzes demographic characteristics including, income, age, illnesses, to measure the susceptibility of social groups to the adverse impacts of natural hazards. Community Resilience is the consequence reduction component and uses demographic characteristics to measure a community's ability to prepare for, adapt to, withstand, and recover from the effects of natural hazards. The Social Vulnerability and Community Resilience components are combined into one Community Risk Factor (CRF) which is multiplied by the EAL component to calculate risk using Equation 2. The Risk Index values

Equation 2: Generalized National Risk Index Risk Equation

$$Risk = Expected\ Annual\ Loss \times Community\ Risk\ Factor$$

$$where\ Community\ Risk\ Factor = f\left(\frac{Social\ Vulnerability}{Community\ Resilience}\right)$$

form an absolute basis for measuring risk within the National Risk Index. They are used to generate all Risk Index scores and ratings.