UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

ANALYZING HEAT WAVES EXPERIENCED BY UNDERREPRESENTED COMMUNITIES LIVING IN LOW-INCOME NEIGHBORHOODS OF OKLAHOMA CITY, OKLAHOMA

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

Degree of

MASTER OF SCIENCE

By

EBONE SMITH

Norman, Oklahoma

2024

ANALYZING HEAT WAVES EXPERIENCED BY UNDERREPRESENTED COMMUNITIES LIVING IN LOW-INCOME NEIGHBORHOODS OF OKLAHOMA CITY, OKLAHOMA

A THESIS APPROVED FOR THE

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL SUSTAINABILITY

BY THE COMMITTEE CONSISTING OF

Dr. Renee A. McPherson, Chair

Dr. Randy Peppler, Co-Chair

Dr. Mark A. Shafer

Acknowledgments

I would like to express my sincere gratitude to all those who contributed to the completion of this research project.

First and foremost, I am immensely grateful to my research advisors, Dr. Renee McPherosn and Dr. Randy Peppler, for their exceptional involvement in my research project. Their guidance, encouragement, and unwavering support have been invaluable throughout every stage of this endeavor. Their expertise and insightful feedback have not only shaped the direction of my research but have also inspired me to push the boundaries of my academic pursuits. I am truly fortunate to have had the privilege of working under their mentorship, and I am deeply appreciative of their dedication to fostering my growth and development as a researcher.

I extend my heartfelt gratitude to the members of the research committee, including Dr. Mark Shafer and Dr. Lauren Mullenbach, for their invaluable guidance during the data collection and data analysis steps of this study. Their expertise and dedication have been instrumental in helping me navigate the complexities of the research methodological process. Their insightful feedback and constructive criticism have not only enhanced the quality of my research but have also deepened my understanding of research methodologies. I am sincerely appreciative of their commitment to supporting my academic journey and am grateful for the opportunity to learn from their wealth of experience and knowledge.

Furthermore, I wish to thank the Cooperative Institute for Severe and High-Impact Weather Research and Operations (CIWRO) for funding my graduate research assistantship and both the Data Institute for Societal Challenges (DISC) and Department of Geography and Environmental Sustainability for providing the additional financial support necessary to conduct this research. Their funding made it possible for us to acquire the resources and equipment needed to carry out our investigations effectively.

My sincere appreciation also goes to the focus group participants who generously volunteered their time, insights, and experiences to this research study. Their participation was instrumental in shaping my understanding of the challenges posed by extreme heat in the community. The information collected during the process will serve as a critical foundation for developing strategies to mitigate the risks associated with extreme heat in our community. Their willingness to share their perspectives has been invaluable, and the project could not have been completed without their active involvement.

I am deeply grateful to RestoreOKC, more specifically Dr. Ann Miller and Ms. Dee Edwards, for their invaluable support and partnership throughout this research endeavor. Their commitment to our project and their extensive network within the community have been instrumental in connecting us with other non-profit organizations to recruit focus group participants. Their dedication to our cause has not only facilitated the logistics of participant recruitment but has also enriched the diversity and depth of perspectives within our study. Their collaborative spirit and unwavering assistance have significantly contributed to the success of this research project.

Finally, I would like to acknowledge my family and friends for their patience, encouragement, and understanding throughout this academic journey. Their unwavering support has been a constant source of motivation, whether it was through lending an empathetic ear during challenging times, celebrating small victories with genuine enthusiasm, or providing practical assistance when needed. Their belief in my capabilities and their willingness to stand by me through the highs and lows of research has been truly humbling. Their support extends beyond mere words, as they have selflessly accommodated my long hours of study and research, sacrificing their own time and comfort to ensure that I could pursue my academic goals with dedication and focus. Their presence in my life is a constant reminder of the importance of fostering strong relationships and nurturing a supportive community, and I am profoundly grateful for their unwavering love and encouragement.

In conclusion, I recognize and appreciate the collective efforts of everyone involved in this research endeavor. Without their contributions, this work would not have been possible.

Table of Contents

Abstract

According to the United States (U.S.) National Weather Service, extreme heat was the most fatal weather phenomena in 2022. As climates change around the U.S. and, more specifically, across the Southern Great Plains, extreme heat events are projected to increase in intensity, duration, and frequency. Past research demonstrates that heat-related mortality has increased throughout the state of Oklahoma in recent years, and that heat-related deaths are disproportionately represented by Black people, senior citizens, males, and single individuals.

To examine the impacts of extreme heat in a low-income and racially diverse community in the northeastern quadrant of Oklahoma City, Oklahoma, this qualitative research study employed focus groups to address two research questions: 1) how do extreme heat conditions influence the lives of people living in Oklahoma City neighborhoods identified by significant social vulnerability?, and 2) what are the best practices for mitigating heat stress that can be implemented in Oklahoma City without harming the natural and social landscape that already exists? The focus groups were composed of four separate groups of people: 1) seniors, 2) youth, 3) mixed-aged adults, and 4) community leaders. Each group was asked the same set of questions, and the resulting discussions were transcribed to form the research dataset. To analyze the collected data, a thematic analysis was performed using three coding stages (open, axial, and selective). Five themes emerged from the data analysis: 1) adaptation, 2) communication/awareness, 3) health, 4) infrastructure, and 5) resources.

In response to the first research question, participants discussed being burdened by the high cost of utility bills and disadvantaged by the lack of amenities, such as pools, splash pads, shade trees, and bus shelters. In response to the second research question, participants listed many ways they employed self-agency to stay cool, such as staying in cooled buildings, using fans, and preventing outdoor heat from penetrating inside their homes using shading equipment. Findings also showed that community members could benefit from local programs that offer financial assistance for cooling expenses and educational materials to inform the public of heat-health coping strategies and available resources.

Chapter 1: Introduction

Extreme heat, especially with high humidity, is a fatal weather and climate hazard that disproportionally impacts people within specific demographic groups across the world (Mora et al. 2017; Khatana, Werner, and Groeneveld 2022). These groups include people of color, low-income households, people with pre-existing medical conditions, older citizens, people lacking access to central air conditioning, people with limited physical mobility, non-homeowners, and outdoor workers (Semenza et al. 1996; O'Neill, Zanobetti, and Schwartz 2003; Gronlund 2014; Johnson et al. 2016; Hayden et al. 2017; Khatana, Werner, and Groeneveld 2022). The impacts of extreme heat include high surface temperatures, reduced air quality, and extreme indoor temperatures when not properly ventilated (Schnell and Prather 2017; Teyton et al. 2022). In the United States (U.S.), extreme heat results in the greatest number of human fatalities of all hazardous weather and climate events reported by the National Weather Service (National Weather Service (NWS) 2023). Therefore, it is imperative that researchers and decision makers advance their collective understanding of how extreme heat conditions influence different populations living in their region. By studying how extreme heat conditions impact people living in a neighborhood characterized by high social vulnerability, sustainable and equitable practices to adequately adapt to extreme heat events can be established and implemented.

"Extreme heat" refers to air temperatures that generate thermal stress on humans, which can be evaluated using various metrics for magnitude, frequency, and duration. Recent studies have found that there is a correlation between warming of the global mean temperature due to increased greenhouse gases from human activity and the frequency, intensity, and duration of local heat events (Horton et al. 2016). Heat waves are one manifestation of extreme heat. There are a range of definitions of extreme heat used throughout the literature. For example, a case study on heat-related mortality in New York City defined heat wave days as “those days when the maximum temperature or maximum heat index exceeded 95°F for at least 2 consecutive days (Madrigano et al. 2015)” In a different study, Mullens and McPherson (2023) define ‘extreme heat days’ as days with temperatures greater than or equal to 100°F.

Although extreme heat can occur anywhere, areas with more impervious surfaces and less vegetation, such as cities, often experience hotter temperatures and the heat impacts a greater number of people. Recent studies have found that urban areas across the U.S., and in other parts of the world, have experienced significantly hotter temperatures than their rural counterparts (Li et al. 2015; Cui et al. 2019). According to Bodnaruk et al. (2017), most of the global population lives in urban areas due to increasing levels of urban land cover. Urbanization can result in several negative effects on human and natural ecosystems, such as the excessive temperatures of the urban heat island (UHI) (Bodnaruk et al. 2017), and increased populations in urban settings expose a greater number of people to risks associated with extreme heat (McInnes and Ibrahim 2010). As climate change continues to alter the living environment of people in the U.S., it is essential for scientists, researchers, and other professionals to advance their understanding of how climate change impacts, namely extreme heat and heat waves, affect human livelihood.

I next review literature relating to extreme heat. I will first discuss historical heat events as background information on extreme heat events across the globe, then highlight future projections for extreme heat events. Afterward, I will explain how extreme heat can be measured based on physical observations as well as how social vulnerability indicators are helpful to analyze heat risk. The next section will review the negative impacts that extreme heat has on individuals, society, and the surrounding environment. Lastly, I will discuss intervention strategies to mitigate and adapt to extreme heat conditions.

1.1.Historical Heat Events

In the United States, one of the most fatal recorded heat waves occurred in Chicago in 1995. The Chicago 1995 heatwave occurred over a 5-day period from July 12 to July 16, with temperatures exceeding 100°F for two consecutive days (Changnon, Kunkel, and Reinke 1996; Browning et al. 2006; Angel n.d.). This heat wave resulted in hundreds of people losing their lives due to exposure to extreme heat conditions (Semenza et al. 1996; Kaiser et al. 2007). Semenza et al. (1996) indicated that three of the main drivers of fatalities were: 1) pre-existing medical conditions, 2) lack of at-home air conditioning, and 3) social isolation. Some studies have found that an individual's race played a role in heat-related mortality during the 1995 Chicago heat wave. Kaiser et al. (2007) found that the relative risk of heat-related death during this heat wave was higher for Black people than for White people. This result was consistent with a study of seven U.S. cities that found that Black people were more susceptible to heat-related mortality (O'Neill, Zanobetti, and Schwartz 2003).

Other places across the U.S. also face heat-related mortality. On the east coast of the U.S., New York City, New York, experienced higher mortality rates when the heat index reached 90°F or higher. Madrigano et al. (2015) found that non-Hispanic Black residents were more likely to be living with high blood pressure and without home air conditioning. In addition, they found that people receiving public assistance had a greater risk of heat-related mortality (Madrigano et al. 2015). Results from this study demonstrated that Black people and impoverished residents of New York City, especially those with prior medical conditions and without access to at-home air conditioning, had a high level of vulnerability to heat-related mortality.

Research also has examined extreme heat conditions in the U.S. Southern Great Plains. Between 1990 and 2011, Johnson et al. (2016) found that 394 heat-related deaths occurred across Oklahoma, with the highest fatality rates during the years of 1998, 2006, and 2011. Extreme heat conditions in Texas also have been evaluated in Houston (Zhou et al. 2014; Zhang, Chen, and Begley 2015; Conlon et al. 2016; Hayden et al. 2017; Baniassadi, Sailor, and Olenick 2018; Marsha et al. 2018; Mortensen, Heaton, and Wilhelmi 2018; O'Lenick et al. 2020), Dallas (Harries and Stadler 1983, 1988; Gamble and Hess 2012; Winguth and Kelp 2013; C. Zhao et al. 2020), Austin (Quintana 2020; C. Zhao et al. 2020; Bixler et al. 2022; Lanza et al. 2022; Lanza, Alcazar, et al. 2023), San Antonio (Chang 2010; Boice, Garza, and Holmes 2018; Lasme et al. 2019; C. Zhao et al. 2020), and other metropolitan areas (Li et al. 2022).

In Summer 2008, Oklahoma City observed a record high temperature of 106°F for two consecutive days in August (Basara et al. 2010), which exceeded the 'extreme heat days' threshold. In a study of a heat wave in Oklahoma during July and August of 2008, Basara et al. (2010) found that the urban core of Oklahoma City experienced warmer temperatures than its rural surroundings during the day and at night. By observing hotter temperatures than surrounding rural areas, Oklahoma City was characterized by an urban heat island effect which imposed greater risks to populations living in its urban center than in the suburbs.

1.1.1. Projections of Extreme Heat

Over recent decades, the U.S. has endured frequent flooding events, long-lasting drought events, more frequent and intensified hurricanes, more frequent heat waves, and record-breaking extreme temperature patterns that have been attributed, in part, to climate change (Marvel et al. 2023). Although international policy decision-makers, such as the Intergovernmental Panel on Climate Change (IPCC) and the United Nations (UN), have emphasized the importance of reducing climate change induced by human activity (IPCC 2022; UN Environment Programme 2022), global climate models forced by both low and high greenhouse gas emission conditions project that the intensity, duration, and frequency of heat events are likely to increase (Vanos, Kalkstein, and Sanford 2015; Dahl et al. 2019; Martín and Paneque 2022).

As the climate warms, not only are surface temperatures projected to increase (Almazroui et al. 2021), but the number of extreme events and their severity also is expected to increase (McInnes and Ibrahim 2010; Lay et al. 2021). Karl, Knight, and Baker (2000) found that the rate of warming of the globally averaged air temperature has increased during the 21st century, exceeding the average rate of warming from the 19th and 20th centuries. Models have projected that warm conditions are likely to increase in frequency and extreme values. For example, the south-central U.S. is expected to experience an average daily high temperature that is 5°F warmer by 2050 if significant reductions in greenhouse gas emissions are not met (Dixon et al. 2020). As temperatures warm, climate projections also demonstrate that extreme heat events are expected to increase in intensity and frequency. According to Jahn et al. (2019), by 2050, the average number of days exceeding 100°F in the Great Plains will double in comparison to the 1900s.

In addition to the increase of intensity, duration, and frequency of extreme heat events, there are social concerns related to the most vulnerable demographic populations. Population projections estimate that the percentage of residents living in urban areas will increase from 81 percent in 2018 to 88 percent by 2050 (United Nations, Department of Economic and Social Affairs, Population Division 2019). As urban environments deviate from historical climate patterns, cities with expansive amounts of impervious-surface infrastructure may endure uncomfortably hot temperatures exacerbated by the lack of green vegetation (Li et al. 2015; Cui et al. 2019) The increase of heat risk in urban areas is exemplified by various projections of heat-related mortality in over 40 U.S. cities, which demonstrate at least a 70 percent increase by 2050 (3,190–4,748 excess deaths per summer, on average) compared to the 1990s (average of 1,840 excess deaths per summer) (Kalkstein and Greene 1997).

1.1.2. Measuring Extreme Heat and Heat Vulnerability

To measure extreme heat, there are several physical and meteorological indicators. Weber et al. (2015) employed temperature thresholds set by the National Oceanic and Atmospheric Administration (NOAA) as well as land surface temperatures and the normalized vegetation difference index (NDVI) captured by remote sensing to study heat vulnerability. By using data collected by remote sensors, researchers can study heat vulnerability indicators at a high spatial and temporal resolution. While air and land surface temperatures provide an outlook for thermal comfort, other factors such as the NDVI can impact one's thermal comfort due to evaporation cooling and shading; thus, other indicators related to extreme heat are percentages of tree canopy and impervious surface cover (Ziter et al. 2019).

Although extreme heat is quantifiable, there are social issues associated with extreme heat conditions that can be characterized as qualitative and are influential to one's thermal comfort. For example, Cui et al. (2019) state that urban landscape configuration, population, urban size, and other social aspects of urbanization can be used to measure heat vulnerability. Socioeconomic status also plays a role in one's ability to overcome extreme heat conditions and has been used as a proxy for heat vulnerability in many studies. For example, people with lower socioeconomic status may have limited access to air conditioning or may not be able to afford mitigative or adaptive resources to combat urban heat. Families living in apartment complexes within areas with more development than vegetation may not have tree canopy and other landscape amenities available to provide shading or cooling.

1.2.Impacts of Extreme Heat

Extreme heat affects domestic and business infrastructure, including those providing energy. With nearly 90 percent of all buildings in the U.S. using electricity to power their air conditioners, electricity loads increase during extreme heat due to the large demand for cooling. Therefore, generating, distributing, and transmitting electricity becomes a challenge for homes and businesses (Jahn et al. 2019).

More than half of the U.S. transit-user population walks to public transit stops and stations and thus are exposed to the hazardous heat conditions outside while performing physical activity (Clark et al. 2017; Lanza and Durand 2021). According to Lanza and Durand (2021), high temperature extremes have a negative relationship with bus ridership. For example, public transit ridership decreased in Salt Lake City, Utah, when temperatures exceeded 73°F and bus stops were unsheltered; however, when bus stops provided cover from the rain or excessive temperatures, public transit ridership was higher than that of unsheltered bus stops (Miao, Welch, and Sriraj 2019).

Thermal comfort represents the balance of the human response to temperatures in their environment. The level of thermal comfort experienced can be influenced by elements of the human body (e.g., metabolic rate, clothing) and its surrounding environment (e.g., air temperature, radiant temperature, humidity, wind speed). According to Yasmeen and Liu (2019), heat stress can vary based on environmental, physiological, and psychological factors. In addition, a person's geographic location and individuality may cause variations in how different people experience their bodily relationship between thermal comfort and heat stress.

One group of people that is notably vulnerable to extreme heat is senior citizens. The human body's response to temperatures inducing heat stress, heat exhaustion, and heat stroke is to increase blood flow to the skin; however, cardiovascular challenges and lower fitness levels in older adults can negatively impact the body's ability to regulate body temperature. In addition, having chronic medical conditions, such as Parkinson's disease, renal diseases, and cognitive disorders, increases one's risk to heat-related illnesses. Thus, senior citizens with health conditions that reduce their body's ability to regulate its thermal temperature are more vulnerable to heat-related illnesses (Hansen et al. 2011).

1.2.1. Heat Inequity

Research studies have found that historically marginalized people are most vulnerable to extreme heat conditions; these people include the following: 1) seniors, 2) youth, 3) outdoor workers, 4) people of color, 5) people with pre-existing medical condition (particularly those with cardiovascular diseases), 6) people living in lower-income households, 7) people lack air conditioning at their place of residence, and 8) people with physical or mental disabilities (O'Neill, Zanobetti, and Schwartz 2003, 2005; Falk and Dotan 2008; Basara et al. 2010; McInnes and Ibrahim 2010; Hansen et al. 2011, 2013; Sampson et al. 2013; Cui and Sinoway 2014; Mitchell and Chakraborty 2014; Madrigano et al. 2015; Riley et al. 2018; Broadbent et al. 2022). Many of these populations live in areas where the built environment (i.e., building infrastructure, sidewalks, and other man-made cement or impervious surfaces) exacerbates extreme heat conditions by absorbing the heat, instead of having trees and other vegetation (or green infrastructure) around to assist with cooling (Wilson 2020; Broadbent et al. 2022; Kalkstein et al. 2022). Thus, these frontline communities are left to deal with the heat conditions which may result in public health complications, high utility bills, and other social issues that can impede one's quality of life.

In a study evaluating modifiers of temperatures on human mortality, O'Neill et al. (2003) found that 1) death at a location other than a hospital, 2) race, and 3) educational level influenced heat-related mortality rates. Their results demonstrated that Black people and people with a high school education or less were more effected by heat-related mortality. Finding that Black people were among the most heat-vulnerable populations was consistent with previous studies in Texas and Chicago (Greenberg et al. 1983; Kaiser et al. 2007). More recently, Mitchell and Chakraborty (2014) performed analyses that demonstrated that neighborhoods with higher population density of non-Hispanic Black, Hispanic, and Asian races were strongly correlated with warmer mean land-surface temperatures in Pinellas, Florida.

Naughton et al. (2002) found in their study of the 1999 heat wave in Chicago that low-income individuals, seniors, people who lived alone, those who do not leave the house regularly, and lived on the top floor of a building had an increased risk of heat-related mortality. Similarly, Semenza et al. (1996) found in their study of the 1995 heat wave in Chicago that people living alone, seniors, and people living on the top floor of a building experienced a greater risk of heat-related death. Their results also revealed that people with prior medical conditions and those utilizing public assistance programs (e.g., Meal on Wheels) were associated with greater heat-related mortality risk.

Studies have found that minority groups including people without a high school education, low-income residents, adults aged 65 or older, and non-White individuals have a disproportionately greater risk of negative health outcomes from extreme temperature events (Curriero 2002; Medina-Ramón et al. 2006; Johnson et al. 2016; Lee and Brown 2022; Sharpe and Wolkin 2022). In addition to lower socioeconomic status, underrepresented communities living in the center of cities often live in older residences with poor household infrastructure (Medina-Ramón et al. 2006). For example, many homes and apartment complexes in Oklahoma City do not have central air conditioning, exacerbating heat conditions; therefore, these underrepresented groups face higher risks of heat-related illnesses and fatalities (Basara et al. 2010).

According to Lee and Brown (2022), vegetation is a vital component of the urban landscape that reduces heat to offer health benefits. Neighborhoods consisting primarily of low-income households or minority families are disproportionately subjected to unsustainable land use practices, such as lesser urban tree canopy, that set limitations on underrepresented communities' ability to conserve energy, reduce temperatures, and sequester carbon from the surrounding atmosphere (Koo et al. 2019). A restricted capacity for a low-income community to adapt to extreme heat due to disproportionately less green infrastructure, finite financial resources, and lack of access to air conditioning (AC) or transportation, increases their social vulnerability to heat; thus, they tend to be exposed to greater heat-related health risks (Dahl et al. 2019).

Redlining has played a role here as well. Historically, it was initiated by the Home Owners Loan Corporation (HOLC), a government entity created to map mortgage security (Li et al. 2022). The HOLC graded neighborhoods and created maps that served to empower U.S.-born White families with financial assistance for home ownership (Hoffman, Shandas, and Pendleton 2020; Nowak, Ellis, and Greenfield 2022). The HOLC grades were calculated using variables that were biased and prejudiced, resulting in the HOLC maps defining locations of immigrant families, low-income households, and communities of color as "high risk" to prevent access to mortgage financing and homeownership. Today, this disparity is exemplified by how Class D neighborhoods, or neighborhoods that were redlined to indicate high risk, are characterized by dense development and lesser space for vegetation in many cities (e.g., Baltimore, Maryland), whereas the Class A neighborhoods in cities mainly consist of single-family homes and spatial lots more capable of sustaining tree canopy (Li et al. 2022; Nowak, Ellis, and Greenfield 2022).

Inequitable access to various amenities and resources also influences people's ability to cool during extreme heat events. In a study of Phoenix, Arizona, Napieralski et al. (2022) found that the number of pools, amount of green and blue space, and percent of vegetated area decreased as social vulnerability levels increased. Lack of green and blue space was commonly noted by racially marginalized research participants in a research study conducted by Lanza, Jones, et al. (2023). The results from their interviews indicated that thermal comfort was negatively impacted by lack of shade from trees and lack of pools, splash pads, lakes, and rivers.

Another amenity that influences people's ability to cool during extreme heat events is air conditioning. On one hand, some people do not have access to air conditioners in their homes, which increases vulnerability levels to heat-related mortality (O'Neill, Zanobetti, and Schwartz 2005). On the other hand, some people from lower income households may struggle with the cost of running air conditioners in their homes. Many studies have found that research participants note that utility bills increase during extreme heat events (Lane et al. 2014; Lanza, Jones, et al. 2023; Diallo et al. 2024). For example, in their study of New York City (New York), Lane et al. (2014) found that some of their focus group participants discussed limiting their usage of air conditioning because of the cost of electricity.

Lastly, various aspects of the public bus system also have an influence on people during warmer seasons. While waiting for the bus, the thermal comfort of bus riders may be adversely affected (Lee and First 2023). As a result, bus ridership numbers may shift. For example, Lanza and Durand (2021) found that bus ridership decreased as temperatures increased. Similarly, Ngo (2019) found that extreme heat negatively influences bus ridership. In a study of bus riders' perceptions of heat, field surveys revealed that many participants experienced thermal discomfort while at the bus stop (Dzyuban et al. 2022). This study also demonstrated that shade structures, trees, water drinking fountains, grass, and benches help people feel cooler during extremely hot conditions; however, the authors noted that benches expose people to the risk of skin burns if surface temperatures exceed skin burn thresholds. An effective method for lowering surface temperatures below skin burn thresholds was the provision of shade. In a study of Salt Lake City, Miao, Welch, and Sriraj (2019) found that bus shelters are associated with higher levels of bus ridership, which suggested that regular commuters and passengers exposed to extreme temperatures for long periods of time value sheltered bus stops.

While bus shelters and other amenities can benefit bus riders, studies have discovered an inequitable distribution of bus shelters. In San Francisco, Moran (2022) found that bus shelters, seating, and clear curbs were more available in residential areas with mostly white residents than residential areas with more residents of color. In Los Angeles, nearly 67 percent of all bus stops have bus shelters; however, a disparity exists between incorporated and unincorporated areas (Yoon 2023). Another aspect of the public bus system that influences people in general are commutes to bus stops. Zhao et al. (2003) found that transit use decreased as walking distances increased. Hess (2012) also found that longer walks were associated with decisions to not utilize public transit. Some studies have found that transit users commonly misperceive waiting time and walking distance (Hess 2012; Fan, Guthrie, and Levinson 2016). For example, Hess (2012) found that seniors often overestimated their perceived walking distance to bus stops.

1.3.Extreme Heat Mitigation and Adaptation

Extreme heat can be reduced in urban neighborhoods through a variety of heat mitigation methods, and communities or individuals can adapt to extreme heat through different strategies. According to the Environmental Protection Agency (EPA) (U.S. EPA 2008), methods of mitigating extreme heat conditions in urban areas include the following: 1) adding trees and vegetation, 2) constructing green roofs or cool roofs, 3) replacing heat-absorbing pavements for "cool" pavements, 4) establishing or accelerating voluntary community efforts, and 5) being attentive to local and state policy initiatives.

1.3.1. Individual Adaptation Actions

There are many individual-level actions that people take to cope with extreme heat conditions and mitigate the potentially fatal consequences extreme heat can cause. Some studies have found that people alter the type of clothing they are wearing. For example, in California, one interviewee stated that they chose to wear short sleeve shirts and shorts to stay cool (Palinkas et al. 2022). In other cities across the U.S., both Lane et al. (2014) and Sheridan (2007) found that participants of their studies stated that they wear lighter clothing to help them stay cool during extreme heat events. In addition, both studies found that people stay hydrated by drinking water to protect themselves from the risks associated with extreme heat. Similarly, in Phoenix (Arizona), respondents to field surveys revealed that people stay hydrated and carry more water when waiting at or walking to bus stops during summer heat (Dzyuban et al. 2022).

In addition to staying hydrated and modifying clothing, studies have showed that people will choose to stay indoors (Sheridan 2007; Lane et al. 2014; Lanza, Jones, et al. 2023; Diallo et al. 2024). In New York City (New York), focus group participants discussed going to a cooling center or staying at home during extreme heat events (Lane et al. 2014). During extreme heat events in Baltimore (Maryland), people reported altering their daily routines to avoid thermal discomfort (Diallo et al. 2024). More specifically, the authors of the study in Baltimore found that people were less likely to go get groceries or perform outdoor activities. As a result, interviewees shared that they felt less productive and more rushed to complete responsibilities. Similar results were found in a study of Austin (Texas), where interviewees discussed avoiding the hottest times of the day and minimizing their time outside (Lanza, Jones, et al. 2023). Dzyuban et al. (2022) also found that people chose to travel at different times during the day, earlier or later, to avoid the peak temperatures. Lastly, Sheridan (2007) found that many survey respondents reported avoiding outside and direct sunlight. In addition, they found respondents indicated that they remained in an air-conditioned location.

Another common coping strategy involves shielding sunlight from penetrating windows by closing blinds, shutters, or curtains. For example, in Cologne, Germany, researchers found that all of their study participants had access to shading equipment and most of them used the equipment to help them cool (Kemen et al. 2021). In a survey study of primary school teachers in India, researchers found that most of the study participants recommended curtains or blinds be provided in classrooms to block sunlight and assist with cooling (Lala and Hagishima 2023). In California, researchers found that some interviewees reported their behavioral response to extreme heat events was to close windows, curtains, or blinds (Palinkas et al. 2022).

1.3.2. Urban Greening

Increasing the number of trees and other types of green infrastructure in urban areas has been notably addressed in various sources of literature. For example, some cities in the U.S., such as Oklahoma City, Oklahoma, have set goals for mitigating risks associated with extreme heat by publishing city plans with strategies for adapting to climate change and conducting analyses of city tree coverage (City of Oklahoma City Parks and Recreation Department, Oklahoma City Community Foundation, and Oklahoma Forestry Services 2016; City of Oklahoma City Planning Department 2020). Federally, the EPA (2008) has noted that trees offer the following benefits: decreased energy use, reduced temperatures, lessened maintenance costs, and the reduction and filtration of stormwater runoff. Urban forestry can also lower the impacts of noise (Nowak, Ellis, and Greenfield 2022), which benefits peoples' hearing as well as their general quality of life. Additionally, costs of electrical cooling are also reduced by the shade provided by vegetation, cooling temperatures of external surfaces (Akbari et al. 1997). Lastly, the EPA (2008) also indicates that trees improve air quality and human health. Through the transpiration process, trees can lower air temperatures and lessen the effects of air pollutants (Nowak and Heisler 2010).

1.3.2.1. Green and Cooling Infrastructure

Green roofs are building rooftops that are covered with vegetation to assist with mitigating the UHI effect. The vegetation on top of roofs not only absorbs the sun's rays to reduce surrounding temperatures in the environment, but it also serves as a mitigator of stormwater runoff (Piracha and Chaudhary 2022). An alternative to green roofs is green walls, which consist of vegetation on the outer surfaces of buildings. Implementing green walls as a UHI mitigation strategy is especially beneficial for buildings with rooftops that are characterized by steep slopes or composed of equipment that resist the installation of vegetation. Green walls can also serve as a method of improving air quality because vegetation absorbs air pollution (Piracha and Chaudhary 2022).

Another type of cooling infrastructure is cool roofs that use reflective or "cool" materials (e.g., elastomeric, acrylic) that have high values of solar reflectance and high infrared emittance. Many studies have found that using "cool" surfaces reduce temperatures in the lower atmosphere (Roman et al. 2016; Zhang et al. 2018; Mushore, Odindi, and Mutanga 2022). According to Synnefa, Santamouris, and Livada (2006), architects have found that reflective color coatings on buildings can help reduce building thermal loads. Taleghani (2018) indicates the high level of reflectivity from cool rooftops helps to reduce costs of energy for cooling and improves thermal comfort for people within a building. In addition, the thermal stress level of cool roofs is low, thus expanding the longevity of cool roofs. Although surfaces composed of "cool" materials can reduce surrounding air temperatures during the day, temperature reductions at night are less commonly found (Synnefa, Santamouris, and Livada 2006).

1.3.2.2. "Cool" and Permeable Pavements

Similar to "cool" roofs, "cool" pavements use reflective materials to reduce outdoor surface temperatures and decrease heat absorption into surfaces (Ferguson et al. 2008). Because pavements absorb and store solar radiation, as well as release it as infrared radiation, asphalt and black-top concrete can increase surrounding atmospheric temperatures (Asaeda, Ca, and Wake 1996). To learn how “cool” pavements and surfaces influence the surrounding environment, Sen et al. (2019) modeled the relationship between pavement surface temperatures and urban air temperatures in Phoenix, Arizona. Their results demonstrated that replacing asphalt pavements with reflective concrete pavements decreased air temperature. Another study also showed that pavements with higher reflectance rates are associated with lower daytime near-surface air temperatures than pavements with lower reflectance rates (e.g., asphalt) (Li et al. 2013). Other studies have revealed, however, that reflective roofs and walls were more effective at reducing air temperature in an urban heat island than were reflective pavements (Sen et al. 2019). An alternative to using “cool” pavements emerging in some communities is the reduction of paved surfaces by lowering parking space requirements, narrowing street width requirements, and incentivizing multi-level parking lots (Ferguson et al. 2008).

In addition to “cool” or reflective pavements, there are permeable and water-retentive pavements that help to reduce pavement surface temperatures through the evaporation of water (Santamouris 2013). According to Lui, Li, and Peng (2018), evaporation-enhancing permeable pavements can cool surface temperatures of pavements and contribute to the mitigation of the urban heat effect. In addition, Li et al. (2013) found that permeable asphalt pavement lowered near-surface air temperatures.

1.3.3. Voluntary Community Efforts

There are several different methods for establishing and accelerating voluntary community efforts to reduce the impacts of extreme heat. One method involves demonstrating a specific heat island mitigation strategy to reveal its benefits and educate people on how to replicate the strategy. To attract attention to demonstration projects, the project must be highly visible to community members (Cole et al. 2008). For example, in 2004, the American Society of Landscape Architects (ASLA) installed a green roof on top of their headquarters building in Washington, D.C., to demonstrate the environmental benefits of green roofs (ASLA 2011). Their research findings showed that green roofs reduced costs associated with building operations, extended the life of the rooftop, increased property values, and decreased lifelong costs for the roof.

Governments, utility companies, and other organizations can provide incentives for community members to perform heat-island reduction actions. Example incentives include tax breaks, product rebates, grants, below-market loans, and giveaways. Although many incentive programs are offered across the world, the majority of programs exist in North America and Europe (Liberalesso et al. 2020). In Pennsylvania, for example, the Philadelphia Zoning Code offers the Green Roof Density Bonus, which provides exceptions to specific residential density rules for those installing green roofs (Philadelphia Water Department 2024). Also, to reduce the cost of monthly stormwater bills, Philadelphia offers the Stormwater Billing Fee Credits for eligible installed green roofs. In Chicago (Illinois), a suite of incentive programs is offered by the city's Department of Buildings to encourage developers to design buildings with environmental elements, such as green roofs (Kazmierczak and Carter 2010). These programs include the Green Permit Program, the Green Roofs Initiative, the Green Roof Improvement Program, and the Green Homes Program.

Tree planting and urban forestry initiatives are another form of voluntary community efforts that can help to mitigate the heat island effect. For example, in

Sacramento (California), to assist with the reduction of urban temperatures, the Sacramento Municipal Utility District (SMUD) provides free shade trees to customers (SMUD 2024). The Free Shade Tree Program has planted over 600,000 shade trees around the city of Sacramento. Some states offer grants to support urban forests (Cole et al. 2008). In particular, the State of Wisconsin provides opportunities for cities, towns, villages, non-profit organizations, counties, and tribes to receive four different types of grants for urban forestry initiatives (Wisconsin Department of Natural Resources n.d.). Some afforestation projects in urban areas focus on underserved communities, such as low-income populations, where there is limited tree cover available (Cole et al. 2008). The Community Forest Revitalization Program in Virginia encourages collaboration between local governments and residents to execute and maintain community forest projects in underserved communities (Virginia Department of Forestry n.d.).

Another way to support low-income residents and other underserved communities is by coordinating weatherization programs. The U.S. Department of Energy provides states with weatherization funding to assist people with heating bills and lower energy costs by investing in energy efficient actions (Cole et al. 2008). In addition, the funds can be used for the installment of efficient cooling measures, including screens and shading equipment. For example, in Philadelphia, the Energy Coordinating Agency pilot tested their Cool Homes Program to address the heat-related health risks experienced by low-income senior residents (Michael Blasnik 2004). From 2001 to 2004, the Cool Home Program served nearly 400 senior households by coating rooftops white, insulating roofs, and performing other similar weatherization measures to reduce the amount of heat gained within participants' homes.

Vital to comprehensive voluntary community efforts are outreach and education programs (Cole et al. 2008). For example, in Utah, TreeUtah offers Tree Planting Grants that K-12 schools can apply for (TreeUtah n.d.). Recipients of the Tree Planting Grants receive a curriculum to educate students on the importance of trees as well as tools, trees, and mulch to plant trees. Lastly, awards may be given by governments, local organizations, and corporations to reward, spotlight, and promote public and private solutions to the urban heat island effect (Cole et al. 2008). In particular, the Green Roofs for Health Cities non-profit organization based in North America grants the Green Roof & Wall Awards of Excellence to recognize excellence in design and installation of green roofs and green walls (Green Roofs For Healthy Cities n.d.).

1.3.4. Local and State Policy Initiatives

There is a range of local and state policy initiatives that promote the mitigation of urban heat island effects. Some governments' mitigation strategies involve procuring technologies that support cooling in municipal buildings. In Tucson (Arizona), for example, the local government mandates that newly constructed roofs and replacement roofs for city facilities incorporate "cool" roofing materials. Another policy effort is the development of resolutions (or documents) to declare a group's acknowledgement of their awareness of or interest in an issue (Cole et al. 2008). The Annapolis (Maryland) Energy Efficiency Resolution was adopted in 2006 to set goals for building planning, design, and construction that promote sustainable development and support the mitigation of heat island effects (U.S. EPA 2023a).

Similar to resolutions are ordinances which can also be enacted by local governments. To reduce the impacts of a heat island, local governments have passed tree and landscape ordinances that govern how to protect trees, plant and remove street trees, and shade parking lots. In Orlando (Florida), a local ordinance was established to mandate that street trees be planted along public and private streets. Aside from resolutions and ordinances, many localities and states have released comprehensive plans and design guidelines to encourage the reduction of extreme heat. While comprehensive plans include policies, goals, and objectives set by local governments to manage conservation and development efforts, design guidelines support comprehensive plans by implementing regulations (Cole et al. 2008). An example of a design guideline can be demonstrated by the "ecoroof" design requirements set by Portland (Oregon). The City of Portland enforces a number of requirements for vegetated rooftops, such as specific soil-depth rules, to support goals for managing stormwater (City of Portland n.d.). Another example of a design guideline is zoning codes. Zoning codes are connected to comprehensive plans by implementing their goals and objectives (Cole et al. 2008).

Aside from zoning codes, there are building codes that are also adopted by local and state governments to set standards for construction, alteration, and repair of buildings. As a subset of building codes, energy codes also guide the requirements and standards for buildings as pertaining to energy usage and conservation. For example, the states of Georgia and California incorporated cool roofs into their energy codes. Lastly, governments can implement air quality requirements to control emissions and reduce air pollution in hopes of attaining national ambient air quality standards. Each state has a federally approved State Implementation Plan to dictate how the state will achieve and maintain federal standards for air quality (Cole et al. 2008).

1.4. Summary

Extreme heat is a phenomenon that is projected to increase in intensity, duration, and frequency as climate changes. Although the negative consequences of extreme heat affect everyone, certain individuals and communities, such as senior citizens, people of color, people without a high school education, and people living in poverty, disproportionately face the risks associated with extreme heat. Heat mitigation and adaptation actions are available, but their implementation requires knowledge of the community at risk. For this study, I examine how extreme heat impacts historically marginalized communities living in the northeast quadrant of Oklahoma City, Oklahoma. Chapter 2 overviews the data collection and analysis methods for this project. Then, Chapter 3 details the findings from the analyzed data. Chapter 4 discusses how the findings support results from other studies and Chapter 5 summarizes the study.

Chapter 2: Data and Methods

In Oklahoma City, Oklahoma, residents are faced with summer temperatures exceeding 32.2°C (90°F) for multiple days, weeks, or months at a time. Climate projections demonstrate that Oklahoma is expected to see an increase in annual average temperatures, more extremely hot days, and intensified drought conditions (McPherson et al. 2023). Human fatalities and co-morbidities associated with extreme heat may be a concern for residents of Oklahoma City because, according to the Oklahoma City County Health Department (OCCHD), Oklahoma City-County's age-adjusted death rate resulting from chronic lower-respiratory disease was 61.7 per 100,000 people, which is greater than the national rate of 40.4 (OCCHD 2021, 98). Hence, this population is at relatively high risk when extreme heat occurs.

Research from Basara et al. (2010) discusses the risk that vulnerable populations, such as adults aged 65 or older and minority races, living in the urban core experience due to the exacerbation of extreme heat conditions by older or low-income housing structures. Although social vulnerability associated with race, age, home renting, and socioeconomic status is discussed by Basara et al. (2010), the distribution of those socially vulnerable populations across the city was not considered. This gap led to my research questions:

A. How do extreme heat conditions influence the lives of people living in Oklahoma City neighborhoods identified by significant social vulnerability?

B. What are the best practices for mitigating heat stress that can be implemented in Oklahoma City without harming the natural and social landscape that already exists?

In this section, an overview of the methods will be provided. I first created maps to identify socially vulnerable populations in Oklahoma City; thus, the chapter will start with a description of the mapping component of this project. Then I discuss the qualitative data collection process, encompassing information relating to the Institutional Review Board process, the recruitment process for the focus group discussions, and the facilitation process for the focus group discussions. The third section details the three steps in the data analysis process before defining the validation process for this study in the final section.

2.1.Mapping Vulnerability

To identify specific areas within Oklahoma City that are most vulnerable to extreme heat (as described in prior literature), I mapped various socioeconomic variables. Maps were created using the Environmental Protection Agency's (EPA) EJScreen and the Centers for Disease Control and Prevention's (CDC) Social Vulnerability Index (SOVI).

EJScreen is an environmental justice screening and mapping tool that allows users to overlay environmental, demographic, and socioeconomic indicators throughout the U.S. The EPA recommends that users explore EJScreen as an initial step of evaluating environmental injustice. Users of EJScreen can study geographic areas at various units of analysis, including at the block, census block, census tract, county, state, and national levels. While EJScreen provides researchers with the ability to map where environmental justice concerns may exist, it is important to note that the screening tool is not comprehensive in incorporating all aspects of environmental justice and therefore cannot be used to directly identify environmental justice communities. In addition, EJScreen uses estimates based on historical data; thus, there is uncertainty in the data because it does not reflect current or future conditions. More data uncertainty exists for smaller geographic areas, therefore it is recommended that users summarize data for larger geographic areas (U.S. EPA 2023b).

SOVI is a national index that summarizes social vulnerability data for every census tract in the U.S. The CDC defines social vulnerability as possible negative impacts on human health caused by natural and man-made stressor events (CDC 2024a). SOVI uses data from the U.S. census to rank the social vulnerability of each census tract. To rank each census tract, 16 social factors are grouped into four themes. Each theme is ranked for each census tract, then an overall ranking is provided. Some of the social factors considered for the four themes include access to transportation, poverty, and housing composition (CDC 2024b). The four themes are socioeconomic status, household characteristics, race and ethnic minority status, and housing type/transportation. Although data are provided for the years the census is collected, intercensal years can experience rapid rates of change in population, housing development, and relocation. For example, during Hurricane Katrina people were relocated for housing renovations; thus, data from the 2000 census was an inaccurate representation of 2005. An additional limitation involves the lack of consideration of where people perform activities outside of their home, such as work. Since SOVI is calculated using limited data, the calculation of social vulnerability may not fully represent a census tract's vulnerability (Flanagan et al. 2011).

To identify areas to study for this project, maps were created using socioeconomic indicators of environmental justice in EJScreen (Figs. 2.1 and 2.2). I found that the near northeast and near southwest regions of Oklahoma City were most vulnerable to extreme weather events, such as extreme heat. After mapping the national percentiles of low-income and people of color indicators in EJScreen, I found that most census tracts within Oklahoma County characterized by national percentiles between 95 and 100 (colored red) were in the northeast and southwest region. EJScreen defines their people-of-color indicator as the percent of people in a block group who identify as a race other than White including Black, Asian, Native American, Hispanic, and multiracial individuals. The low-income indicator is defined as the percentage of individuals with household income to poverty level ratios less than two during the past 12 months (U.S. EPA 2024).

The national percentile of people of color in Oklahoma County (Fig. 2.2) showed that two census tracts in the northeast area and one census tract in the central area were identified as in the 95^{th} and above percentile. On the other hand, the low-income indicator (Fig. 2.2) showed that more than four census tracts were in the northeast and southeast areas of the county and characterized by the 95^{th} percentile and above.

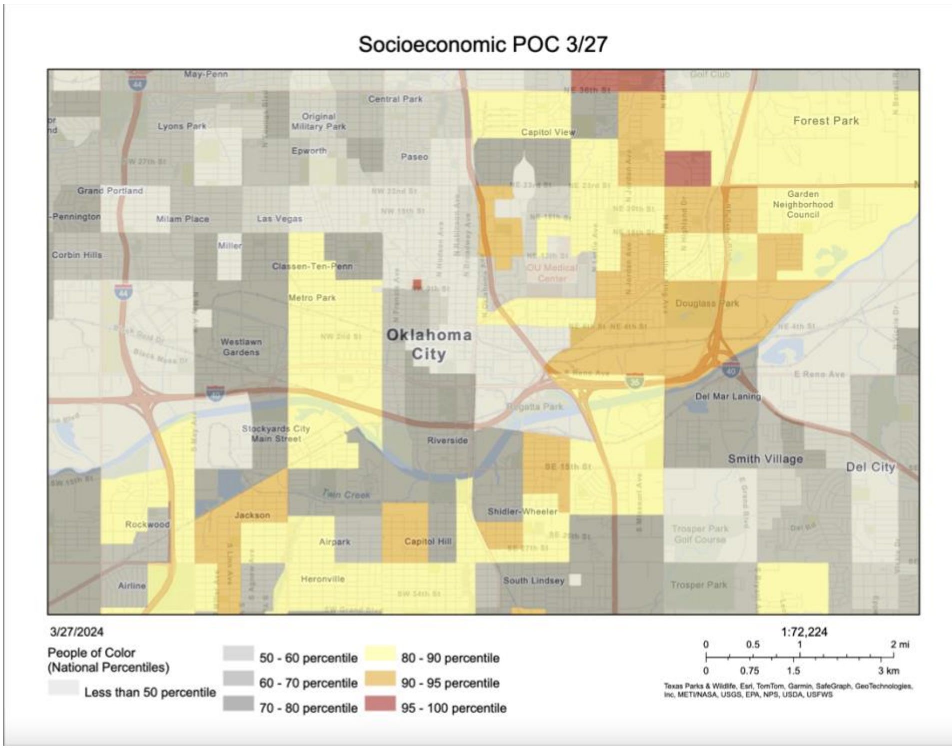

Figure 2.1. Map from the EPA's Environmental Justice Screening and Mapping Tool demonstrating the distribution of people of color, a socioeconomic indicator, throughout Oklahoma City using national percentiles. The various shadings of gray represent national percentiles ranging from less than 50 to 80, whereas yellow represents the 80 to 90 national percentiles. Orange represents the 90 to 95 national percentiles while red represents the 95 to 100 national percentiles.

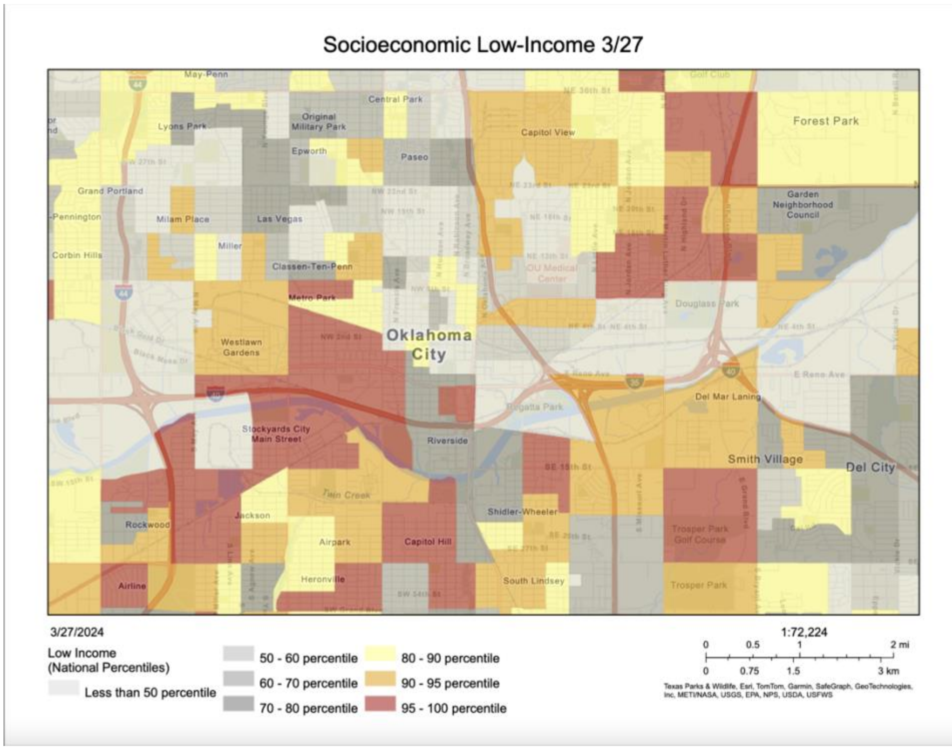

Figure 2.2. Map from the EPA's Environmental Justice Screening and Mapping Tool demonstrating the distribution of low-income, a socioeconomic indicator, throughout Oklahoma City using national percentiles. The various shadings of gray represent national percentiles ranging from less than 50 to 80, whereas yellow represents the 80 to 90 national percentiles. Orange represents the 90 to 95 national percentiles while red represents the 95 to 100 national percentiles.

To ensure that the socioeconomic indicators of environmental justice represented socially vulnerable communities, maps were generated using SOVI data from 2020. When mapping with SOVI, I layered the socioeconomic status (Fig. 2.3) as well as the race and ethnic minority status themes (Fig. 2.4). The socioeconomic status layer demonstrated that there were census tracts in every quadrant of Oklahoma County with high social vulnerability rankings; however, most census tracts were located in the northeastern and southern areas of the county. The race and ethnic minority status layer also demonstrated that census tracts in the southern and northeastern areas of the county were ranked with high (dark purple) social vulnerability.

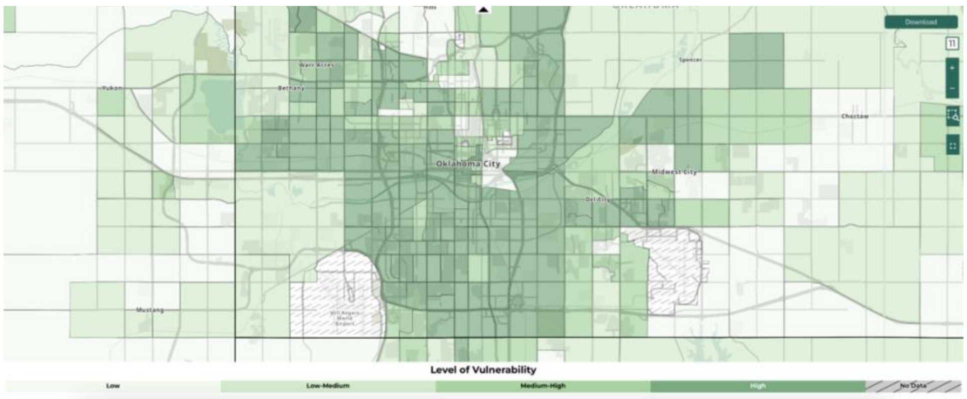

Figure 2.3. Map from the CDC's SOVI demonstrating the distribution of socioeconomic status throughout Oklahoma City using the national comparison. Social vulnerability is ranked as low (off-white), low-medium (light green), medium-high (light-medium green), and high (dark green).

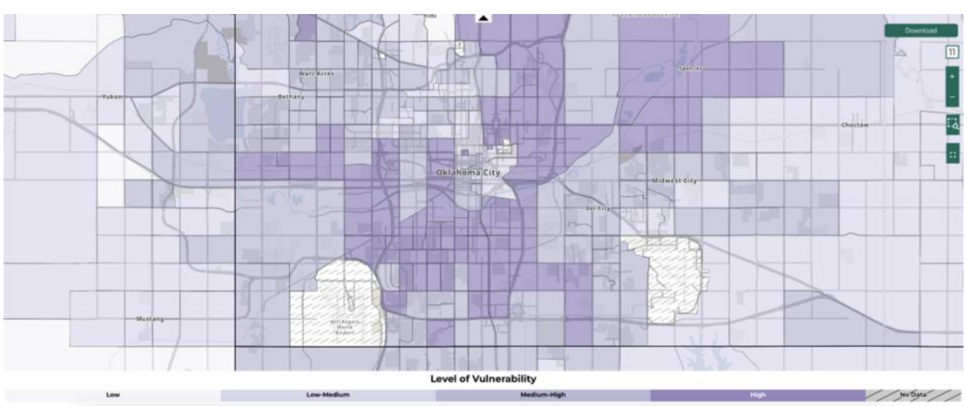

Figure 2.4. Map from the CDC's SOVI demonstrating the distribution of racial and ethnic minorities throughout Oklahoma City using the national comparison. Social vulnerability is ranked as low (off-white), low-medium (lavender), medium-high (light purple), and high (purple).

After identifying socially vulnerable regions of Oklahoma City, I contacted 17 organizations serving those localities to begin stakeholder engagement for focus group recruitment. Many of the organizations either did not respond to the communication or could not contribute to the project due to various reasons, such as not being able to speak about extreme heat issues, not having constituents to suggest speaking with, or having constraints on time availability. Of the 17 organizations contacted, three contributed to recruiting the focus groups: RestoreOKC, the Boys and Girls Club, and the Reach Forward Foundation (Reach Forward).

RestoreOKC is an organization with a mission to achieve restorative justice and equity for the northeastern community of Oklahoma City by assisting community members with employment, housing, environment, and school issues (RestoreOKC n.d.). To help with community development, RestoreOKC has four programs: 1) Restore Farms, 2) Restore Jobs, 3) Restore Schools, and 4) Restore Homes. Leadership at the Restore Schools program at RestoreOKC connected me with the Boys and Girls Club of Oklahoma County (BGCOKC), which is one of their partner organizations. The Boys and Girls Club is a youth-focused organization focusing on academic success, overall health wellness, and character development. To assist families with positive youth development, the BGCOKC has youth centers across Oklahoma County (BGCOKC n.d.); however, for this project, I worked only with the BGCOKC youth center in the northeast community (a direct partner of RestoreOKC).

The last organization I worked with was Reach Forward, a nonprofit organization that provides career and educational support to youth living in the Oklahoma City Metropolitan Area. Through community engagement activities, workshops, and mentorship opportunities, Reach Forward empowers children in middle and high school and assists with their development of life and social skills (Reach Forward Foundation n.d.).

The census tract encompassing the RestoreOKC service area was characterized by high social vulnerability and composed of a large population of people of color. The EPA's EJScreen demonstrated that the population of people of color in that census tract was in the 95^{th} to 100^{th} national percentiles. The CDC's SOVI demonstrated that the census tract was characterized by high social vulnerability with respect to racial and ethnic minority status. Using these metrics, I proceeded to select this census tract and partnered with RestoreOKC to recruit focus groups for data collection to answer my research questions.

2.2.Participant Recruitment and Data Collection

I now describe the steps taken to recruit participants and facilitate focus group discussions. First, to explain why focus groups were selected for this study, I will describe the importance of focus groups. Then, to address how the project met ethical standards and protected the rights of participants, an overview of the research proposal submitted to the Institutional Review Board (IRB) is provided. Third, I detail the participant recruitment process and highlights information about the participant samples for each focus group. Lastly, I explain the steps taken to prepare for the focus groups discussions and moderate the conversations, respectively.

2.2.1. Focus Groups

With the rise of participatory research, focus groups have become a more common approach to qualitative data collection. Focus groups, like one-on-one interviews, allow for discussions to occur; however, focus groups differ from interviews in a number of ways that were helpful for my research. During a focus group, the researcher moderates or facilitates a conversation between participants instead of serving as a participant in the discussion (Nyumba et al. 2018). Focus groups also differ from one-on-one interviews in that focus groups allow for researchers to study interpersonal dynamics among participants in addition to learning participants' perspectives on a given topic (Guest et al. 2020). According to Onwuegbuzie et al. (2009), focus groups offer an open, non-threatening environment for participants to discuss perceptions, ideas, opinions, and thoughts.

Participants in a focus group are usually selected through purposive sampling whereby the researcher recruits potential participants who most likely can provide information that is appropriate and useful for the study (Rabiee 2004; Campbell et al. 2020). Through purposive sampling, the researcher selects people with similar characteristics, such as age, occupation, and socioeconomic status, to ensure participants feel comfortable speaking to the researcher and other participants (Rabiee 2004).

2.2.2. Institutional Review Board

To conduct the focus group method of data collection, I submitted a research proposal to the IRB at the University of Oklahoma to ensure my research was ethically sound. I did not identify any immediate risks or benefits for research participants. To inform adult participants of their risks, rights, and benefits for participating in the study, the project required written and verbal consent from participants older than 18 and written and verbal assent for youth participants between 12 and 18. Media release forms were also collected to authorize the researcher to take pictures and record video of the discussion.

I obtained parental consent and child assent prior to facilitating the youth focus group. To allow children to participate in research projects, guardians must fill out parental consent forms, which are written and signed documents stating a child has permission to be a research participant. Like parental consent forms, child assent forms ensure the child participants are willing to be a part of the study and understand what will be expected of them. All consent forms and media release forms were signed prior to conducting all focus groups to comply with ethical standards set by the IRB. The IRB number for this study is 14938.

For the focus group interactions, I used personal devices, including phones and laptops, to record the conversation. I adhered to the confidentiality guidance from the IRB by securely transferring all recordings to a private cloud drive where only the IRB-approved researchers had access. In addition, recordings were removed from personal devices.

2.2.3. Participant Sample and Recruitment

The sampling method for participation in focus groups was a mix of purposeful and snowball sampling. I worked with personnel at RestoreOKC to recruit focus-group participants. Meetings provided an opportunity for the researchers and RestoreOKC staff to identify strategies to recruit participants. Based on prior research, I identified five different populations that are socially vulnerable to extreme heat. The five groups were presented to RestoreOKC leadership, which agreed, were as follows: 1) youth, 2) seniors, 3) community leaders, 4) outdoor workers, and 5) mixed-aged adults. Although I planned to host all five groups in conversations about extreme heat, only four groups were engaged due to limited time.

To ensure a dynamic dialogue among focus group participants, RestoreOKC staff members suggested we recruit participants from their Community Action Team (CAT) and farm interns, resulting in two focus groups. The farm interns provided a sample of nine youth participants, ages 14 to 18 years old, who worked outdoors during the summer months. The CAT provided a sample of eight mixed-aged adults ages 18 or older. (One of the CAT participants was a mother with a young child who had to leave the conversation shortly after it started.) The CAT focus group consisted of both mixed-aged adults and community leaders, where all but two of participants identified as senior citizens. In addition, one participant from the CAT identified as an outdoor worker while another participant identified as a former worker of a utility company. Hereafter, I will refer to this focus group as the mixed-aged focus group.

Due to the lack of age diversity for the CAT focus group, I conducted a second focus group for mixed-aged adults. For this group, each of the nine consenting participants worked for local non-profits to help with empowering underserved youth in the community. To recruit a diverse pool of participants for the community leaders' focus group, I hosted three three-hour recruitment sessions during March with the BGCOKC local to Northeast OKC to recruit parents and guardians throughout the community. The days/times of the weeks when the recruitment took place were strategically selected after conversing with the BGC staff about when most child pick-ups occur. Hereafter, I will refer to this focus group as the community leaders' focus group.

Lastly, for the senior focus group, we recruited seniors in the community who attended a local senior center. After setting up a table and explaining the research project on three separate occasions, we were able to obtain a list of 33 interested seniors willing to participate in the conversation. To ensure the focus group occurred when many of the interested seniors were available, we coordinated with seniors to schedule the time of the discussion. The senior focus group comprised 13 participants; however, about half had to leave halfway through the discussion due to transportation conflicts and the length of the meeting.

Table 1 lists the four focus groups, the number of participants, where the focus group was held, and the duration of the discussion.

Focus Group	**Number of Participants**	**Location**	**Duration**
Youth	9	RestoreOKC	1 hour and 2 minutes
Mixed-aged Adults	7	RestoreOKC	1 hour and 18 minutes
Seniors	14	Senior Center	1 hour and 40 minutes

Community Leaders	9	Boy and Girls Club	1 hour and 23 minutes

Table 1. The number of participants, location, and the duration of the focus group dialogue for each of the four focus groups conducted for this study.

2.2.4. Focus Group Facilitation

Before conducting the focus groups, questions were drafted by the researchers and reviewed by the IRB. In addition, I prepared a script to help moderate the conversation. The focus group questions were listed under five separate categories: 1) introduction, 2) past experiences, 3) awareness and prevention, 4) housing conditions, and 5) futurity. Appendix A lists the questions and Appendix B provides the facilitation script. In the introduction category, the questions focused on general information about the participants and memories of their experiences with heat during the previous summer. Participants were then asked to share their experiences with extreme heat conditions and how they acted in response to extreme heat. Following their discussion on their past experiences with extreme heat, I asked the participants how they learned of heat conditions and the impacts heat can cause. Next, I asked questions about how equipped everyone's housing was to deal with extreme heat conditions. Lastly, I inquired about potential solutions to improve the community's capacity for recovering from and responding to extreme heat.

The focus groups were facilitated in a semi-structured format to allow for flexibility in how the participants responded to the questions. Key questions were outlined prior to the date of the focus group sessions and potential follow-up questions were listed to collect specific details pertaining to the key questions' theme; however, impromptu questions were also asked during the focus group discussion to clarify participants' points. Although key questions were open-ended, some of the impromptu follow-up questions were closed-ended to ensure clarification.

The mixed-aged adults, youth, and senior focus groups took place in Fall 2022, and the community leaders focus group took place in Spring 2023. To allow participants to meet in a familiar location, focus groups were held where they met regularly for their work, leadership, or social activities in northeastern Oklahoma City. The youth and mixed-aged adults focus groups were held at the RestoreOKC center, while the senior focus group was held at the local senior center where participants were recruited from. The community leaders focus group took place at the local Boys and Girls Club.

The senior focus group required two meetings; one meeting to go over the consent paperwork and a second meeting to conduct the actual discussion. For the youth participants, consent paperwork was completed prior to the scheduled focus group discussion to allow for parents to return the forms back to the researcher. Consent paperwork for community leaders and mixed-aged adults was filled out before the audio and video recordings for the discussion started. Each focus group discussion was recorded with audio and video; however, for the community leaders and senior focus groups, only part of the discussion was recorded with video due to limited resources.

Each focus group discussion was then transcribed. The youth, senior, and mixed-aged adults focus group discussions were transcribed and anonymized by the primary researcher. Due to limited time, the community leaders focus group was transcribed by an external transcription service, Datagain. The transcription for community leaders was reviewed by the primary researcher to confirm accuracy in the dialogue.

2.3.Data Analysis

For this study, I employed an inductive thematic analysis to provide a rich description of the data. Thematic analysis is an analytic method used by qualitative researchers to convey themes or patterns that have been identified and analyzed in data. Inductively conducting thematic analysis allows themes to emerge from the data, rather than configuring data to fit into pre-conceived themes identified by the researcher (Braun and Clarke 2006). According the Braun and Clarke (2006), there are six steps in the thematic analysis process: 1) familiarization with the data, 2) developing initial codes, 3) identifying themes, 4) reviewing themes, 5) defining and naming themes, and 6) reporting how themes answer research questions. For this study, I familiarized myself with the data by transcribing discussions and reviewing transcriptions prior to the initial coding process. When developing initial codes and identifying patterns within the data, I employed the open, axial, and selective coding strategy. Open, axial, and selective coding is an process, where the researcher interacts with the data through practice of comparison, applied data reduction, and consolidation (Williams and Moser 2019). In the sections below, the open, axial, and selective coding processes employed in the study are detailed.

2.3.1. Open coding

The open coding process was done using the NVivo software program to help with organization of data. The first step in the thematic analysis process consists of deriving short annotations to classify excerpts from the transcription (Williams and Moser 2019). During this stage of analysis, quotes from the transcript were identified as relating to a single word or a short sequence of words to assign concepts to specific content discussed during the focus groups. There was a total of 121 initial codes created during the open coding process.

2.3.2. Axial coding

After open coding in NVivo, all codes were transferred to an Excel spreadsheet to continue the second and third steps of the coding process. The second stage in the coding process is known as axial coding. To prepare for the selective coding stage, axial coding consists of refining, aligning, and categorizing initial codes to generate themes (Williams and Moser 2019). During the axial coding process, I identified excerpts from the transcripts that connected to multiple open codes. I employed a constant comparison method (Williams and Moser 2019) when analyzing text from the transcripts to ensure consistency between the axial-coded data for all four focus groups. During the axial coding process, comparing and contrasting between the data was done to allow for major codes to emerge. Comparison was conducted within each separate focus group transcript to allow for nuances to present themselves throughout the data analysis process. For example, if an excerpt was open coded as "air conditioning (AC)" but it also related to "bills," then the codes were combined, and a new code (an axial code) was created to encompass the meaning of both open codes.

2.3.3. Selective coding

After axial coding, I conducted the third and final stage of analysis, selective coding. During the selective coding stage, data are further refined and defined. In addition, main theme categories are selected (Williams and Moser 2019). During the selective coding phase, I solidified themes and respectively assigned them to the data. To ensure that themes were derived from the axial codes, categories were consolidated into themes which were listed before the selective coding process.

2.4. Validation

Validation is a method employed to ensure the research is credible and reliable. Creswell and Miller (2000, 124) define validity as the accuracy and credibility of how participants social realities are represented by the researcher. Although validity is more commonly associated with quantitative research, Hayashi, Abib, and Hoppen (2019) share a processual approach to establish validity in qualitative studies, providing an outline of how researchers can validate their study while conducting various stages of research.

Before collecting data, Hayashi, Abib, and Hoppen (2019) emphasize the importance of pilot testing and gaining exposure to a community or being immersed in the field. For this study, I immersed myself in the field prior to collecting data by volunteering for several RestoreOKC events and networking with organizational volunteers and leaders. A pilot focus group was conducted with the youth participants, as suggested by RestoreOKC directors. The pilot focus group ensured that the interview questions were framed to stimulate conversation about heat experiences and confirmed the need to continue exploring the research questions.

During the data collection process, Hayashi, Abib, and Hoppen (2019) recommend various methods of validation, including extensive exposure in the field and saturation. Saturation in data occurs when no new data or useful information is found because the researcher has collected enough data from interviews or focus groups. After moderating four focus group discussions, saturation was achieved as themes, such as health and resources, emerged from the data collected. Prolonged exposure to the field was attained by recruiting focus group participants in-person and conducting focus groups at locations familiar to the participant and in their community. Creswell and

Miller (2000) list triangulation and reflexivity as validation strategies. Triangulation is a post-positivist process because it requires a systematic approach to analysis, whereas reflexivity is a critical process because it recognizes the situatedness of the researcher to uncover biases during analysis.

I performed a mix of triangulation and research reflexivity to provide validation for my qualitative research analysis. Although I established my positionality in the early stages of the research process to demonstrate reflexivity, I also sought repetition of themes when sifting through the data collected from the four focus groups conducted for this study. Repetition of evidence for themes identified is key for validation through the triangulation process, while reflection of social, cultural, and historical influencing interpretations shaped by the researcher is key to the reflexivity process. For my study, I focused on being reflexive to ensure validity because calling into question my perspective could be critical for employed analyses to address biases reflected in the interpretation of data. Reflexivity also allows the researcher to mitigate inequality by establishing positionality and seeking collaboration.

Lastly, after data collection, Hayashi, Abib, and Hoppen (2019) suggest the need for scientific exposure and peer review. This study was peer reviewed by a committee of three people on the project. In addition, this study will be presented at a conference to obtain feedback and participation from the broader scientific community on how to further refine discussion points for the research.

Chapter 3: Results

Five major themes were derived from the thematic analysis: 1) adaptation, 2) communication/awareness, 3) health, 4) infrastructure, and 5) resources. The adaptation theme reflects excerpts from the transcripts that are related to modifying actions to address the heat. The communication/awareness theme reflects excerpts from the transcripts that centered around general knowledge of the weather and communication sources of weather conditions. The health theme incorporates transcript excerpts pertaining to physical or mental health issues such as medication, pre-existing medical conditions, heat-related injuries, and altered psychological conditions. The infrastructure theme incorporates topics associated with human-made structures or facilities such as cooling centers, bus shelters, green and blue infrastructure, and housing structures. Lastly, the resources theme includes financial or personal assets, including utilities, amenities, and non-profit assistance. Table 2 shows the total number of excerpts categorized by each theme and focus group.

Theme	**Seniors**	**Youth**	**Mixed-aged Adults**	**Community Leaders**
Adaptation	33	31	23	21
Communication/Awareness	20	10	15	38
Health	18	29	5	30
Infrastructure	14	1	22	7
Resources	48	12	19	42

Table 2. Five themes emerged from the focus groups. The table identifies each theme and the associated number of excerpts from each focus group.

3.1.Adaptation

Adaptation was a common theme among all four of the different focus groups. The adaptation theme was primarily represented by excerpts relating to how individuals cope with extreme heat conditions. Many participants shared how they altered their actions during the summer months to ensure safety in the heat. Adaptation was one of the most common topics of discussion for the senior, youth, and mixed-aged adults' focus groups.

3.1.1. Seniors

There were 33 excerpts from the seniors' transcript related to the adaptation theme. Seniors discussed actions they performed to combat the heat, such as staying at home, going to a friend's house who had access to air conditioning, choosing to adjust or not adjust the temperature on the thermostat, turning on fans, modifying their clothing choices, closing the blinds, drinking water, opening the windows, and turning on water sprinklers for children to run through.

One senior highlighted the importance of self-advocacy by emphasizing the need to express issues of unjust expense of utility bills to the State Corporation Commission and other decision-makers. Although some seniors discussed concerns about their utility bills being unfairly high in cost, this senior stated that by not voicing concerns to the appropriate decision-maker able to make a change, their concerns will not be heard. "I did some calling about some trees. OG&E told me they couldn't cut it. My son told me who to call and I called the State Corporation Commission. And do you know, two or three days later they sent somebody out there to cut my trees? So, if we don't ever say anything, they think we're satisfied." Another senior proposed a solution: "a survey or something needs to be done for people who don't have central air conditioning during the hot days in Oklahoma." Another senior proposed that a list of helpful resources, such as cooling centers, funding sources, and affordable companies, would benefit the community by informing them of opportunities for assistance.

3.1.2. Youth

Most of the content coded from the youth transcript was classified in the adaptation theme (31 excerpts). When discussing how they adapt to the heat while inside, the youth mentioned closing the blinds and covering the windows to protect the interior home from outdoor sunlight, using fans, keeping doors shut (to reduce loss of cooler air), minimizing physical interaction with others, taking a cold shower, and going to a friend or family member's house with air conditioning. When discussing how they adapt to the heat outside, the youth mentioned taking work breaks, stretching (to reduce possible cramping), chewing ice, wearing light-colored clothing, drinking water, eating food, and using a cold compress.

One youth focus group participant stated, "so when we were over here, and we were in the heat, and it was so hot that we had to like take breaks and drink water so we wouldn't pass out." In agreement that breaks are important, another youth participant stated, "It's OK if you want to take a water break or a food break or whatever it is. You can go back inside and sit in there." Alternative adaptation methods for cooling were expressed by other participants. One participant stated that their parents "turn the AC off at nighttime," while another youth participant said, "If the AC's broken in my house, I have some friends that live close to me – that live like down the street and stuff – so, I'll just walk over there."

3.1.3. Mixed-aged Adults

Most of the content coded from the mixed-aged adults' transcript was classified into the adaptation theme (23 excerpts). To combat the hot temperatures, participants from the mixed-aged adults' focus group discussed turning up their air conditioning, asking for assistance with home weatherization from local non-profit organizations, using the air conditioning in their vehicles, modifying clothing decisions, hanging black curtains to shield sunlight, putting up plastic or aluminum foil in the windows to reflect sunlight, adjusting what time of the day they go grocery shopping, and staying hydrated. In addition to sharing the heat-adapted actions they take during hot circumstances, the mixed-aged adults proposed ways for the community to adapt to the heat. Some of the suggestions included providing sun visors for seniors and offering funding resource options for adults struggling to pay their utility bills.

One participant in the mixed-aged adult focus group proposed the following ideas for adapting to the heat: "Provide pools or play spaces for children. The only community center that has a pool is in the Northeast community that does not even open at the beginning of summer. They open in the middle of summer and close two weeks before school starts. Lower electric prices during the summer. Provide water fountains at the downtown EMBARK [bus] station, so people can drink and stay hydrated. Then, provide other resources for parents to pay their bill during the summer." The same mixed-aged adult proposed, "They should provide those [sun visors] for seniors because not a lot of the houses around here have garages or car ports. You get in your car to go anywhere – I don't know about you, but I burn my arm off because it was so hot. So, they should provide those to keep their [senior's] cars more cool." Another participant emphasized the struggle residents face when dealing with utility bills, stating “I think the main thing we probably all experience is the high utility bills. That's the most common complaint amongst all of us.”

3.1.4. Community Leaders

Twenty-one excerpts from the community leaders’ focus group were coded as the adaptation theme. To adapt to the heat, community leaders discussed going swimming, chewing ice, modifying clothing decisions, adjusting the time of day to go grocery shopping or to exercise, drinking water or soda, bringing pets indoors, using a wet compress, taking a shower, staying indoors, and applying sunscreen.

A leader from the local Boys and Girls Club stated that “what we’re going to do this summer at the Boys and Girls Club is once it hits a certain temperature, like I said we did a pile of changes, you can only stay outside for about 30 minutes just to avoid any heat injuries, rashes, and all that stuff like that. So, we’re going to limit our outside play time.” Two leaders proposed ideas for adapting to the heat: 1) tinting car windows and 2) renovating apartments. Lastly, one leader said they used a smart thermostat to help them stay cool (e.g., to reduce indoor temperature extremes).

3.2.Communication/Awareness

Many different channels of communication were discussed during the focus group conversations. Participants mentioned learning about the weather via television news and weather apps, while some others indicated that they were aware of the temperature after stepping outside. In addition, some participants shared that they would prefer additional methods of communication when it comes to heat alerts, while others stated that compounding heat alerts with tornado, flood, and AMBER (America's Missing: Broadcast Emergency Response) alerts would be information “overload.”

3.2.1. Seniors

The communication/awareness theme was the third most discussed topic during the focus group conversations for the seniors (20 excerpts). Many seniors agreed that receiving mobile notifications for the heat “would be overload;” however, a couple of seniors thought it could be helpful if there was a way to distinguish the alert from other mobile notifications, such as AMBER alerts and flood warnings. While the idea of mobile alerts about the heat was not favored by most senior focus group participants, most seniors agreed that the news was their source of information about the weather conditions. A few seniors indicated that they are advised on the weather by both listening to the news and checking a software application on their phone.

When asked about their past experiences in the heat, one senior stated their awareness of the difference in heat experiences between urban and rural settings. They stated, “in the country, you know, they have like the dirt roads which the dirt doesn't hold heat like this [the city].” In addition, a few seniors expressed their concern for the changing climate conditions. One senior stated, “because of the climate change, I think it's gotten hotter.” Regarding communication, one senior recommended a list of cooling centers in the city be distributed to local churches, stating “I know it might be a little costly, but if you could send that to some of the churches, where a lot of the seniors are.”

3.2.2. Youth

There were 10 excerpts related to the communication/awareness theme in the youth focus group transcript. The youth participants shared that they learn of the heat conditions by listening to the news, checking weather applications on their phones, and being advised by their family members. One youth participant noted that their parents not only informed them of the heat, but also advised them on how to prepare for the heat: "My parents, they always tell me when it's hot, like make sure you drink water, you eat some food, and you bring a hat."

Some of the youth participants expressed their awareness of climate change. Two youth participants agreed about the changing climate, with one stating, "well, it just seems like it gets hotter every year."

3.2.3. Mixed-aged Adults

There were 15 excerpts related to the communication/awareness theme in the transcript for the mixed-aged adults' focus group. Although many adults shared that they learned of the weather through various news sources, three excerpts expressed a concern for public communication.

One adult stated that seniors could benefit from additional sources of information regarding assistance programs. One adult mentioned that it would be important for agencies to "publicize your [assistance] programs on TV," while another adult recommended that advertisements could be posted on billboards and bulletin boards across the city. One adult participant said that seniors should receive notifications in the mail, not only about assistance programs, but also about utility rate increases.

When asked if they checked on the wellbeing of people during extreme heat conditions, many of the adults indicated that they communicated with their family and friends to ensure community safety. One participant said, “They’ll check on you, but when they do, it’s at night when the sun starts going down, then they'll come and say ‘hey.’”

3.2.4. Community leaders

Among the community leaders, the communication/awareness theme was the second most common topic of discussion, with 38 excerpts. Like the other group discussions, the community leaders mentioned how they became aware of the weather, including using weather applications on their phones, reading email notifications, watching the news, and listening to the radio. The idea that communication could be improved for the community was a shared notion among the community leaders, especially pertaining to cooling center education. For example, the group discussed the importance of knowing where cooling centers are located and proposed that decision-makers publicize where cooling centers are located to ensure more community awareness. One participant stated, “that goes back to again, we don't know. I've been staying in Oklahoma for my whole life, and I've never heard of a cooling center.”

3.3.Health

The health theme most commonly arose during the youth and community leaders’ focus group discussions. Encompassing both physical and mental health, this theme covered topics relating to pre-existing medical conditions, such as asthma, high blood pressure, emphysema, sickle cell disease, and eczema. In addition, the health theme incorporated statements relating to altered moods, attitudes, and behaviors during extreme heat events.

3.3.1. Seniors

Health was one of the least discussed themes during the senior focus group. There were 18 excerpts from the senior focus group transcript that related to the health theme. A few of the pre-existing medical conditions mentioned included eczema, high blood pressure, and emphysema. “And one illness that some of people might have that would be affected in the heat is a person that has eczema,” said one senior. According to participants, sweating during hot conditions exacerbates the skin rash conditions. In addition, one senior said that their grandchild avoided swimming over the summer to ensure their skin rash did not worsen.

Due to some pre-existing medical conditions, some seniors stated that they or their family members had to limit time outside to avoid heat injuries. Although one senior noted that they used fans to cool down during the summer months, they became “panicky” after realizing that they were still hot. They stated, “the summer of 2011, we could not keep the house cool even with air conditioning. We had these big fans we would buy and had them all over the house and still could not [keep cool]. That made me feel kind of panicky. It's like this is the best we can do, and it's still too hot.”

3.3.2. Youth

Among the youth, the health theme was the second most common topic of discussion, with 29 excerpts. The main pre-existing medical condition discussed during the youth focus group was asthma. A few of the youth participants shared their personal experiences of having asthma during the summer heat. One participant expressed how they had to leave their outdoor job to avoid heat injury, stating “I had to go home once because we were doing chickens. And then like you know chicken, it has that much dust in the air. So, my asthma got [irritated].” Another participant said their family member had an asthma attack over the summer due to being in the heat.

Other health topics involved how attitudes, moods, and behaviors shifted during the summer months. The youth focus group participants mentioned sluggishness and exhaustion as effects of being outdoors in the heat. In addition, irritability, anger, and drowsiness were common moods during the summer months. Some youth participants shared that they experienced lightheadedness, dehydration, sunburn, and heat rash due to being outdoors during extreme heat conditions.

3.3.3. Mixed-aged adults

Health was the least common topic of discussion amongst the participants in the mixed-aged adults’ focus group (five excerpts). One parent stated that asthma among children in the community was a concern: “It’s affecting a lot of people’s asthma. We had seven kids coming to see the nurse today saying that they couldn't breathe, especially during the summer when school first started, which is in August.”

3.3.4. Community leaders

Health was among the top three themes discussed during the community leaders’ focus group (30 excerpts). For mental health, community leaders shared how people’s attitudes altered during the summer months. One leader stated that she shifted into a more irritable and impatient attitude when exposed to extreme heat conditions. Another community leader expressed that people may become angrier. For example, a leader from a local non-profit organization stated that “I feel we had an increased number of violent interactions at the day shelter [for unhoused individuals] because everyone was just so hot and angry here in a crowded space.” Lastly, one leader said they had difficulty sleeping due to the heat.

For physical health, community leaders shared stories of the heat injuries they experienced themselves or that their loved ones experienced, including during participation in sports and exercise. One leader said they became lightheaded as a result of traveling outdoors after working out at the gym. Another leader stated that their former teammates lost their lives due to heat exposure: “I have had two teammates that have died from heat strokes because we used to play out there practicing football.” Another leader shared that their athletic son fainted from heat exposure.

Some participants said that rheumatoid arthritis, lupus, and sickle cell disease were pre-existing medical conditions impacted by heat exposure. A staff member of a local non-profit supporting children was reported as having to quit because of her skin flaring up when exposed to extreme heat. One leader said, “Her lupus had flared-up from the heat and she had to quit because of that.” Another leader from the same non-profit organization stated that “I have rheumatoid arthritis. You can't go outside in the heat because it feels like your skin is on fire.” Lastly, one leader from a local non-profit focused on mentorship noted that people carrying the sickle-cell trait are at risk of becoming overheated and suffering from heat exhaustion. This leader shared an anecdote about her son who is a sickle-cell carrier: “He had become completely lethargic. His skin was on fire, it almost burned you to touch his skin.” In response to his reaction to the heat, the leader said that she had to carry her son to her car to ensure his safety.

3.4.Infrastructure

The infrastructure theme was commonly discussed during the focus groups with mixed-aged adults, but the least explored for the other three groups. Common topics under the infrastructure theme included housing structure, cooling centers, blue and green infrastructure (e.g., ponds, creeks, and trees), and bus shelters.

3.4.1. Seniors

Infrastructure was the least talked about theme among the seniors’ focus group. There were 14 excerpts from the seniors’ transcript related to the infrastructure theme. The seniors discussed how the structure of their housing impacts their experiences, mentioned a few different cooling center locations, and shared their experiences with trees in landscape design for providing shade. Some seniors shared that they had their houses weatherized while others noted that they could not have their homes weatherized. One participant said that they asked for a company to weatherize their house, but “they wouldn't do it because I have a basement.” For those who were able to have their homes weatherized, various companies prepared their houses for extreme temperatures by reinstalling insulation, changing windows, adding new weatherstripping to doorways, and replacing light bulbs to increase energy efficiency.

Aside from their housing structure, artificial and natural infrastructure such as cooling centers and shade trees were among the topics of discussion related to the infrastructure theme. The main places listed as cooling centers during the seniors’ focus group were the public library and medical establishments with community areas within them. For example, one participant said, “I go to Arch Well Health out in Midwest City and they actually have a little area. It's called a community area.” Another participant said, “I think Global Health has a community area as well.”

For the discussion on shade trees, one senior said they planted trees to provide shade over their home; however, some seniors said that they were reluctant to keep trees around their homes because of the potential damage they could cause during Oklahoma’s other hazardous weather events. While one senior said, “I'm scared of the trees, I need to cut it down,” another senior said, “I've planted trees throughout the years on my property because I know that having shade helps.” Another senior stated that they used both green (trees) and blue infrastructure (creeks and ponds) to stay cool during the summer heat. Lastly, seniors discussed that there was a lack of shade provided for bus riders at local bus stops.

3.4.2. Youth

Participants in the youth focus group talked about infrastructure the least (one excerpt) among the five themes. When discussing the public transportation system, the youth mentioned the lack of shade provided for bus riders. “Sometimes they don't have trees, so they get no shade,” said one youth participant.

3.4.3. Mixed-aged adults

The infrastructure theme was the second most common topic of conversation for the mixed-aged adults’ focus group, with 22 excerpts. Among the infrastructure theme, trees, insulation, bus stop shelters, cooling centers, and housing structures were discussed. Many adults expressed concern for a lack of trees in the northeast side of Oklahoma City. One adult stated, “There used to be more trees and more abundance of trees, but it's lacking. You know, a lot of the trees you don't see around no more.” In addition, one adult advocated that there is a need for bus stops to have shelter or trees to provide shade for bus riders: “Single mothers with children, you see a lot of them sitting at the bus stop with the stroller and little babies. There’s nothing covering them, and it can be 105 degrees outside and that’s their only transportation to their doctor's appointment.”

For cooling centers and housing structures, adults expressed concern about the number of cooling centers available to the community and for housing infrastructure not being equipped to withstand current climate conditions. Although adults in the discussion were able to list the library, main Embark (public transportation system) bus station, shopping malls, YMCA, movie theatres, recreation centers, gyms, and stores as spaces to cool, some adults thought that more cooling centers should be available to the community. Particularly, some adults expressed a need for public cooling spaces available for free. In addition to cooling centers, adults noted that housing infrastructure was old and in need of repair. Many adults expressed a need for improved insulation and updated window installations. One adult stated, “it is a low-income community. They’re not able to change out the windows.”

3.4.4. Community leaders

The community leaders’ focus group talked about infrastructure the least (seven excerpts) among the themes. A common topic of conversation was about the impact housing structure had on utilities, specifically air conditioning. One person stated that the shade provided by their building's orientation and surrounding trees allowed them to stay cool inside their home; however, many other leaders expressed a need for improved housing structures to allow them to remain cool inside their homes. One community leader said, "One of the problems that I can see that happens to these low-income apartments. The problem is that they're not, hopefully I'm wording it right, they're not insulated right. And so, then what ends up happening is they got all these cracks in the windows and the doors and everything. So even though they're running their AC, and it's running out[side]." Another leader noted, "So, I don't know that things are always built efficiently either for people to have cost savings."

Another concern expressed during the community leaders' discussion was for bus shelters at local bus stops to keep bus riders cool while they are waiting for the bus. One leader shared that her senior mother uses the bus, "so, for someone like her who's older, just walking from your house to the nearest stop is almost unbearable, and then you get there, and the bus stop is in open sun. So, it makes it very difficult for them." One community leader proposed an idea: "I feel like a really easy improvement would be putting shelters over all the bus stops and perhaps putting more bus stops because you would have to walk less." They also recommended that they add more cooling centers to the public transportation routes.

For cooling centers, community leaders shared that many non-profit organizations provide cooling spaces for community members to go to during the summer months. Also, community leaders discussed shade provided by trees. While one leader stated that some people cut down trees to reduce debris and house damage during Oklahoma's severe weather events, other leaders expressed that the community needs more trees. One leader said, “on Earth Day, a lot of donors have came and said they want to come in and put a lot of trees and vegetation out here to help us with shade.”

3.5.Resources

Seniors and community leaders discussed more content relating to the resources theme than did the youth and mixed-aged adults. Major topics under the resources theme were utilities and air conditioning. Some focus group participants discussed various programs available to the public to assist with cooling expenses. In addition, the public transit system was named as a resource to help residents stay cool; however, the bus system was also stated to be ineffective due to lack of shade, long waiting periods, and large distances between bus stops.

3.5.1. Seniors

With 48 excerpts from the seniors’ transcript, the resources theme was the most prevalent theme amongst the senior focus group. The most common topic relating to the resources theme was the cost of utility bills. One senior said, “I experienced the expensive cost of air. My bill ran around $250 a month on senior citizens’ income. So, I never got any relief.”

Another senior stated that resources, such as air conditioners, need to be provided to those who cannot afford central air conditioning. “Well, there are some people in our community that may not have air conditioning, so we need to think about those people that don't have air conditioning. They need something. And sometimes the fans aren't enough.” One senior said they did not have an air conditioner because they could not afford to replace or repair the one installed in their house. Although there was a common sentiment among seniors about the cost of air conditioners, one senior said they purchased appliance insurance to help with the cost of appliance replacement or repair when needed. Another senior said they found an air conditioning repair company that they could afford after calling around to get various quotes.

Aside from air conditioning, some seniors shared that there was a need for more summer activities and facilities, such as splash pads and water parks, for youth. In addition, one senior expressed concern for the unhoused population's accessibility to shelters during hot temperatures. A few seniors discussed the need for more fans to be given away to help people with their cooling needs. While some seniors expressed their appreciation for the bus system, others discussed how the bus transit system was inefficient. According to one senior, the city bus system allows free transit when temperatures exceed 37.8°C (100°F); however, another senior stated, "you don't know very many people riding the bus." In discussion, seniors noted that distance between destinations and bus stops, lack of awareness of how to use the transit system, and long waiting times in the heat were among the reasons for people not riding the bus.

Although one senior felt their concerns were heard by respective decision-makers able to change their circumstances, some seniors complained that they communicated about issues they faced but sometimes were not provided with solutions. One senior called Oklahoma Gas and Electric (OG&E) and the Salvation Army to inquire about installing new insulation in their home, while another senior called OG&E about receiving a free fan to assist with their summer cooling efforts. Although these seniors received assistance from their calling efforts, another senior called OG&E to inquire about their high utility bill cost but did not receive the assistance they needed to lower their bills. Many seniors agreed that the community's needs were not met by decision-makers, stating "Well, we used to have more, maybe, like, community centers where the people could go to or where the kids go to so that they could go play basketball and different things. You know, we just don't have that over here on the east side in lieu of the ones that they have mainly northwest and southwest." Another senior expressed concern for the lack of pools available to community members in the northeast quarter of the city.

3.5.2. Youth

There were 12 excerpts relating to the resources theme from the youth focus group. The youth discussed accessibility to pools and splash pads, family utility bills, air conditioning, and bus stops. The youth participants listed pools and splash pads as resources to help them cool; however, many of the youth mentioned that there were not many pools and splash pads available in the northeast quadrant of the city. One youth participant said, "I only know where one splash pad is." The youth participants mentioned that other youth and adults complained about either the cost of air conditioning or having to ride the bus. One participant said, "You're just sitting there while the heat is beaming on you waiting for the bus that takes forever."

3.5.3. Mixed-aged adults

There were 19 excerpts relating to the resources theme from the focus group of mixed-aged adults. The most common topic under this theme was related to air conditioning and utility bills. Given the community is predominantly low-income, participants expressed concern about how the heat impacts people's ability to pay for high utility bills. One participant said, “There are people that will not turn their air up to be comfortable, all because they feel like they cannot afford to pay that bill which has an effect on their health. So, that to me, is one of the big effects that heat really does have in this community.” Another participant shared that they knew someone whose central air conditioning unit broke, but they could not afford to repair or replace it.

Another aspect of the air conditioning conversation amongst mixed-aged adults focused on homes lacking access to central air-conditioning units. One adult shared that having multiple window units, as opposed to one central air-conditioning unit, in a home could increase utility bills as well, stating “so, with running three or four air-conditioner window units, your bill is going to increase.”

Aside from air conditioning, another common topic relating to the resources theme consisted of naming programs that may help to alleviate challenges that community members faced when dealing with their utility bills. One participant mentioned the Low-Income Home Energy Assistance Program (LIHEAP), which is a federal program that assists low-income families with their summer cooling expenses. In addition, the SmartHours Program offered by OG&E was named as helpful for bills, but ineffective at helping people stay cool because the preset temperatures are uncomfortably hot. One participant stated that people utilizing the SmartHours program will “burn up” in their home.

Participants also named the public bus transit system as a resource for the community. A couple of participants shared that the buses are occupied by numerous people when the riding fee is waived; however, one participant stated that due to high occupancy, the bus may pass by public transit users at bus stops because it is at maximum capacity.

3.5.4. Community leaders

The resources theme was the most discussed theme amongst the community leaders' focus group, with 42 excerpts. Topics included air conditioning, utility bills, non-profit assistance, misting devices, public buses, pools, and splash pads.

There was a shared expression of concern for the cost of air conditioning among the community leaders; however, many leaders shared information about non-profit assistance resources available in the Oklahoma City area, such as those from RestoreOKC, Homeless Alliance, City Center, and Oklahoma City Youth Literacy. One community leader said, "I work with the unhoused population and so there was just a lot of increased foot traffic coming into RestoreOKC and coming into the Homeless Alliance. Just people needing ice and water and just people who had been out in the sun for days and just couldn't catch a freaking break. It got really rough for a while, but I saw a lot of people coming in with super high utility bills because if their AC wasn't broken, it was running crazy." Another community leader said, "it seemed like right before it got hot, OG&E had announced that they were going to go up the prices and I remember my electric bill being $300-$400 a month. And you're talking about struggling to pay it because of the heat and you have to use your AC."

In addition to issues with high utility bills, community leaders expressed their frustration with rolling blackouts in the electric power grid. One leader explained, "it's where there is so much energy being used that they have to cut off the energy in certain places at certain times to bring down the energy levels so that they don't pop the grids."

Although community leaders listed three community swimming pools available to the residents, issues were expressed relating the access and safety. One leader said that a teenager lost their life while at one pool due to overcrowding. They expressed sadness saying, "I think he was a sixth grader, 13 years old. He was an innocent bystander. He lost his life in the middle of interaction with older people." Adding, "I also know the pools get really packed so it's not even enjoyable to even be at the pool when it's hot." Many of the community leaders agreed that the number of people at the pools deters people from wanting to go to the pools to cool. One leader said that the number of pools available to people in the community had decreased: "when I stayed in this area when I was younger, they had these about three or four pools that you could walk to in your neighborhood. Now, they just got one that's just right around the corner and unfortunately, if you don't stay close to that, then you don't get to enjoy it."

Although some apartment complexes have swimming pools, leaders discussed the uneven distribution of pools in the northeast side of the city. One leader said that many people had to travel to the other side of town to go to a pool. In response, another leader lamented, "it's sad though if you stay on the east side community, you have to go find a pool for you to be able to get in. And sometimes it may mean breaking the rules to sneak into an apartment and get into their pool because there's only one in the east side community." There was consensus about the need for more pools and splash pads in the northeast part of Oklahoma City.

Chapter 4: Discussion

In this study, I worked to answer the research questions by moderating four focus groups composed of four different participant cohorts (seniors, youth, mixed-aged adults, and community leaders). Across the focus groups, there were specific topics relevant to each group.

Research Question 1 focused on how extreme heat conditions influenced the lives of people living in neighborhoods characterized by significant social vulnerability. To address this question, I combined mapping several quantitative datasets relating to social vulnerability with direct contact with numerous community-based organizations that work in areas that I identified as most vulnerable. Three organizations were especially responsive and were those chosen to work with directly. All three focused efforts in parts of northeast Oklahoma City that aligned with my mapping efforts. Hence, all community members in my four focus groups were people who lived, worked, or went to school in my study area.

Participants across all focus groups discussed amenities, such as pools and air conditioning, that they used to minimize the effects of extreme heat in their lives. Most comments relating to air conditioning were negative and centered on the cost of utility bills. This finding is consistent with other research studies (Lane et al. 2014; Lanza, Jones, et al. 2023; Diallo et al. 2024). In some cases, the ability to use air conditioning resulted in stress other than that directly attributed to the heat. For example, although youth did not mention utility bills for air conditioning, seniors, mixed-aged adults, and community leaders emphasized that electricity bills during extreme heat events were a cost burden for many people living in the northeast region of Oklahoma City. Youth participants discussed how adults in the community were concerned about wasting air conditioning through actions like opening doors. In fact, many participants stated that they chose to stay indoors until temperatures cooled, which supports the findings from other research studies (Sheridan 2007; Lanza, Jones, et al. 2023; Diallo et al. 2024). In addition to air conditioning, lack of accessibility to water amenities, such as pools and splash pads, was discussed throughout each focus group. Most comments indicated a need for more pools and splash pads by highlighting that only a few were available to residents or suggesting that more pools and splash pads needed to be constructed. Similarly, Lanza, Jones, et al. (2023) found that some of their interviewees argued that there were not enough pools and splash pads in their community of Austin, Texas.

Another common amenity discussed during each of the focus groups was the public bus system, which was highlighted across multiple themes. Most comments were complaints, arguing that bus stops lacked shelter thus causing bus riders to sit under the sun and directly experience the heat. These results resonated with those in a study of public transit during warmer temperatures in Austin, Texas, by Lanza and Durand (2021). They found that bus ridership *decreased* as temperatures increased and noted that bus stops need to be adapted to increase bus ridership during the warm season. In a study of how bus ridership was influenced by extreme weather in Lane County, Oregon, Ngo (2019) found that bus ridership decreased during extremely hot days. In a different study, however, Miao et al. (2019) found that ridership *increased* with access to bus shelters in Salt Lake City, Utah, during extreme heat days. Although I did not analyze whether bus shelters in Oklahoma City could increase bus ridership, there are interventions that have been shown to protect riders from extreme heat temperatures, such as providing artificial shade structures and street trees (Dzyuban et al. 2022; Alcocer et al. 2023). In addition to shade being provided at bus stops, access to water amenities such as water fountains and misting devices could improve thermal comfort for bus riders (Dzyuban et al. 2022).

Some participants also noted that the distance between bus stops was too far for older riders and not easily accessible for walkers. They emphasized that there was limited accessibility to public transportation and bus riders' commutes were lengthened due to long waiting periods. Longer wait periods can result in bus riders experiencing extreme outdoor temperatures for longer periods (Ngo 2019). For example, Hess (2012) found that longer walks to the bus stop were associated with decisions to not ride the bus.

All focus groups discussed learning about extreme heat temperatures from television news and through mobile weather applications. This result is consistent with past research, where studies have found that people are aware of heat events from television news (Sheridan 2007). Although all groups agreed that the news provides information relating to extreme heat, community leaders expressed concern for the "dramatic" tendencies associated with news reports. For instance, one community leader mimicked the news, stating "Call your grandmother, she's going to die."

Research Question 2 highlighted what the community members thought were the best practices for mitigating heat stress that can be implemented in Oklahoma City without harming the natural and social landscape that already exists. Self-advocacy was a common theme among the seniors' and mixed-aged adults' discussions. Participants promoted the action of calling decision-makers and utility companies to voice concerns about electric bills being unjustly high in expense. The youth noted that some people turn off their air conditioning at night likely to prevent high utility bill costs. This result is consistent with a study by Sheridan (2007) that identified that people either did not turn on their air conditioning or limited their usage due the financial burden high usage can incur.

Mixed-aged adults discussed lowering electric utility rates to help low-income families with the cost of their bills. Both seniors and mixed-aged adults suggested additional financial assistance be provided to families struggling to pay them. Programs have been established in other parts of the U.S. to do just that. For example, the Salvation Army in the Phoenix (Arizona) metropolitan area provides utility assistance to individuals and families experiencing economic hardships. Specifically, they provide financial assistance, supplement current energy assistance resources, and share additional sources of support (Q. Zhao et al. 2020).

Each focus group emphasized the desire for more water amenities in the area to allow community members to cool themselves during extreme heat. Mixed-aged adults, seniors, and community leaders also agreed that more pools and play spaces were needed to engage youth. These results also resonate with other studies. Researchers have found the number of pools, water bodies, and percent of greenness decreased as social vulnerability levels increased in Phoenix, Arizona (Napieralski et al. 2022). These authors emphasized the need for equitable urban planning practices to ensure socially vulnerable communities have access to water amenities, such as pools and water bodies, that provide cooling during extreme heat events.

For shade trees, mixed-aged adults, community leaders, and youth agreed to the community needing more trees to help community members cool their body temperature, especially for pedestrians and bus riders. Increasing the urban tree canopy has demonstrated reductions in solar radiation, yet lack of green infrastructure perpetuates social inequity, as researchers have found that predominately low-income and Latinx populations have less shading from overhead tree coverage (Lanza and Durand 2021). This outcome is concerning because vegetation has been found to improve thermal comfort for pedestrians in urban open spaces (Taleghani 2018). Therefore, I emphasize the need for equitable urban planning practices to ensure socially vulnerable populations have access to the cooling effects of shade trees and other vegetation. In addition, Oklahoma has weather that is renowned for its wind and drought seasons (U.S. EPA 2016; Oklahoma Climatological Survey n.d.). Thus, it is imperative for newly planted trees to be adaptive to the Oklahoma climate. While trees generate cooling effects in urban heat islands by both transpiration and shading, the magnitude of cooling is dependent on tree growth which is influenced by the built environment and local management decisions for the maintenance of the trees. Therefore, it is essential to understand the biophysical drivers of urban transpiration rates that vary between different tree species (Nowak and Heisler 2010; Winbourne et al. 2020).

Participants were able to name cooling spaces across parts of northeast Oklahoma City, including the public library, shopping malls, local non-profits, and medical community areas. None of these locations were established solely as cooling centers; rather, they were nearby, cooled buildings where residents already visited and were familiar with. Still, community leaders, mixed-aged adults, and seniors emphasized the need to provide more cooling centers for people to go to cool during extreme heat events. While many participants listed places to cool, consensus was established around the importance of publicizing where cooling centers are located to promote community awareness, making them more accessible to nearby residents of Oklahoma. Similarly, Lane et al. (2014) noted the importance of making cooling centers more accessible to support the development of New York City (New York) heat-health programs. In addition, they indicated that efforts to educate and communicate with heat-vulnerable people needed improvement to be effective in motivating people to take protective actions during extreme heat events.

Some input from the focus groups was uncommon but important content. For example, only the youth outdoor workers emphasized the need for work breaks when experiencing signs of heat-related injuries, such as heat exhaustion. Yet this comment highlighted an important health strategy. The U.S. Centers for Disease Control (CDC) recommends taking frequent breaks in a cooler area to help outdoor workers prevent heat-related illness (Tustin et al. 2018). Participants in my youth focus group also recommended stretching to reduce heat cramps and eating food to address issues with lightheadedness.

Many of the suggested adaptation strategies were relatively low cost and easy to do. For example, youth and community leaders underscored that many people chew ice to stay cool during extreme heat events, while all focus groups emphasized that drinking water and staying hydrated was a way of cooling. All focus groups discussed the modification of clothing to mitigate the absorption of heat. These actions have been used in other communities with high social vulnerability. Wearing lighter-colored clothing and staying hydrated, for example, were common preventative measures taken by people who were not regularly using air conditioning in New York City during extreme heat events

(Lane et al. 2014). Sheridan (2007) also found that people adjust to the heat by modifying the types of clothes that they wore and drinking fluids to stay hydrated. These behaviors, in addition to taking frequent showers, are recommended actions for people to take when heat exposure cannot be avoided (Luber and McGeehin 2008).

All focus groups agreed that some form of changing their daily habits was imperative for adjusting to extreme heat events. Mixed-aged adults and community leaders agreed that changing the time of day to run errands was important, while one senior stated that they stopped mowing their lawn due to the extreme temperatures. One community leader shared that time outdoors would be limited for youth in their program to avoid heat injuries and illnesses. Similarly, limited time outdoors and restructuring or reducing activities outdoors were among the top responses to extreme heat in a survey study of four cities in North America (Sheridan 2007). Studying global warming and the urban heat island effect, Kondo et al. (2021) found in their survey that some respondents adapted to the heat by choosing to avoid going outside on extremely hot days. They also documented that respondents mitigated heat indoors by closing curtains and blinds. Their result aligns with actions that mixed-aged adults and youth participants in my focus groups took to cover their windows with shading equipment, such as blankets, aluminum foil, plastic, and curtains.

Some of the adaptation actions discussed by participants in my research, however, have not been shown to be effective in all cases. For example, in all focus groups, most participants reported using fans to keep cool; however, in a study of heat-related deaths during the 1995 Chicago heat wave, Semenza et al. (1996) found that fans did not reduce heat-related mortality and that they were an ineffective preventative measure for extreme heat. Additionally, electric fans have been found to be associated with lower thermal satisfaction levels as compared to air conditioning (Lee and Shaman 2017). According to the New State Department of Health (2017), fans should not be used when temperatures exceed 95°F because they create challenges for the body to naturally cool by causing sweat to evaporate from the skin at a slower rate (2017). To prevent this maladaptation during extreme heat events, the Oklahoma City-County Health Department could establish an educational campaign for community leaders that follows successful examples elsewhere. For example, the Philadelphia Health Department's Division of Health Promotion organized an educational campaign prior to the summer to inform residents about heat vulnerability, heat-health effects, and proper usage of fans (Sheridan 2007). The educational material was distributed to religious leaders, local civic agencies, and other officials.

While community leaders expressed the need for more publicity of cooling spaces for the community to be more aware of the resources available to them during extreme heat events, mixed-aged adults and seniors emphasized the need for financial assistance programs being more publicized to ensure residents are informed of the resources available to them. Seniors stated that lists of resources available, such as cooling centers and funding sources, would empower people by providing helpful information that can assist them in dealing with the heat as well as other extreme weather phenomena. Similarly, VanderMolen, Kimutis, and Hatchett (2022) found that their study participants preferred heat risk education and warning messaging to be more thorough and specific. To create more effective heat risk education and warning messaging, they recommended that content include information on specific groups vulnerable to heat, potential heat-related health impacts and how to recognize their symptoms, and preventative measures that can be taken to mitigate heat-related health impacts.

One community leader in Oklahoma City recommended that more advisories be shown on TV to help inform watchers of the importance of heat awareness. Although community leaders recommended that marketing be conducted around extreme heat, both seniors and community leaders agreed that receiving mobile notifications regarding extreme heat conditions would not be helpful for the community. While some groups from our study disliked the idea of heat risk messaging on mobile devices, VanderMolen, Kimutis, and Hatchett (2022) emphasized that educational campaigns should engage the public using multiple channels of communication. This idea could be incorporated easily to help residents of northeast Oklahoma City. For example, one community leader recommended that more cooling centers post signs stating they are a public cooling space for people passing by.

Both research questions were addressed by participants in the four focus groups, leading to in-depth local knowledge and experience that can aid the City of Oklahoma City in future planning efforts. Still, there remain limitations to this research. First, due to limited funding, I (the primary researcher) moderated the focus group discussions. While I had prior experience facilitating interview conversations, I did not have professional experience moderating group dialogues. My lack of focus group moderation training may have influenced the responses, as I may not have fully avoided bias in the dataset by balancing the conversation between domineering participants and more reserved participants. In the future, I recommend researchers either be trained in moderating group conversations or hire a professional moderator to facilitate the focus groups to ensure the group dynamics are guided impartially.

Another limitation involves the composition of the focus groups. Hay (2016) recommends that focus groups be comprised of people who are not well-acquainted with each other to reduce peer pressure and increase the opportunity for different or dissenting opinions. For the focus groups used in this study, however, participants mostly engaged with other participants through work, community centers, and volunteer initiatives. Additionally, because participants from all focus groups were from or associated with only the northeastern quadrant of Oklahoma City results and recommendations may not be generalizable to other parts of the city.

To avoid these limitations in the future, I recommend conducting a more thorough study that is inclusive of participants from across various locations and sectors (e.g., business community, faith communities) of the city. In addition, to ensure the focus group samples accurately represent the population demographics of the city, more time should be allotted to form community partnerships between the researchers and local agencies, churches, and non-profits. By collaborating with more partners, researchers can reach out to a broader base of constituents, recruit more potential participants, and diversify the participant sample.

Chapter 5: Conclusions

The state of Oklahoma is projected to experience warmer temperatures in the next 20 to 30 years if greenhouse gas emissions are not significantly curbed (Dixon et al. 2020), with a related increase in the number of extreme heat days (McPherson et al. 2023). Research has found that urban heat islands disproportionately and adversely impact people of color and low-income individuals, which is of concern for Oklahoma City, Oklahoma, because the city observes an urban heat island effect (Basara et al. 2010; Hsu et al. 2021). Our study found that parts of northeastern Oklahoma City are characterized by high percentages of people most vulnerable to extreme heat, including low-income individuals and people of color. To develop an understanding of how extreme heat impacts vulnerable communities living in the northeastern quarter of Oklahoma City, this research engaged four focus groups (seniors, youth, mixed-aged adults, and community leaders) to learn from their lived, place-based experiences and knowledge.

The first research question inquired about how extreme heat conditions influenced the lives of people living in neighborhoods characterized by significant social vulnerability. I found that many participants emphasized that extreme heat events impose a significant economic burden on community members in the northeastern quadrant of Oklahoma City. The increased cost of utility bills during extreme heat events was a common concern voiced by each of the adult focus groups. In addition, all focus groups expressed that lack of available resources, such as bus shelters, shade trees, pools, and splash pads, affected people's experiences in the heat. For example, many participants complained about the lack of bus shelters because bus riders experience direct heat exposure. Given that some of the most heat-vulnerable populations (e.g., low-income and non-White) are more likely to use public transportation (Anderson 2016), it is important that amenities, such as bus shelters, be provided for bus riders to stay cool and mitigate their risk of heat-related mortality. In addition, many participants from all focus groups highlighted that more trees are needed to provide shade. In fact, at the time of this writing, the Boys and Girls Club of Oklahoma County are collaborating with a community partner to get more trees planted around their community center in the northeastern quarter of Oklahoma City.

The second research question asked what the community members thought were the best practices for mitigating heat stress that can be implemented in Oklahoma City without harming the natural and social landscape that already exists. Participants voiced the need for financial assistance programs to be more available to ensure people needing support can access the programs and for more publicity about heat-related impacts and adaptation to increase community awareness. Results from this study provide opportunities for local planning agencies and non-profit leaders to address community needs relating to extreme heat. Based on previous research and the findings from this study, I recommend that an educational campaign be established by city officials, in collaboration with non-profits and churches, to effectively communicate the risks associated with extreme heat and inform the public of preventative strategies to mitigate their risk.

Overall, this study is important to understanding the place-based needs of residents in parts of northeastern Oklahoma City – an area with a population that is highly vulnerable to weather extremes such as extreme heat. The research contributes to the broad literature on extreme heat by building an understanding of how these weather phenomena impact socially vulnerable communities living in the northeastern quadrant of Oklahoma City. In addition, it provides ideas for advancing heat-health programs, such as educational campaigns and financial support services.

Appendices

Appendix A: Focus Group Questions

Theme: Introduction

1. Can we please go around the room one at a time to the name you would like to go by during this discussion (such as a nickname), how long you've lived in the area, and a fun fact (such as a favorite movie, series, superhero, me-time activity, etc.)?

2. To start, can you all please share with me what you remember about the heat from this past summer?

Theme: Past Experiences

3. Thinking about heat waves in this way, can you remember any past experiences you have had with uncomfortably hot temperatures, lasting for days or weeks at a time, in Oklahoma City?

4. How do you generally act in response to the extremely hot temperatures during heat wave events in Oklahoma City? For example, what are some of the ways you get ready for hot temperatures that you take, does your routine change, do you still go to school or work, do you go to public locations where air conditioning is freely available, and how do you get around to where you need to go.

Theme: Awareness and Prevention

5. Can you please explain how you know when there will be extremely hot temperatures and the impacts the heat may have on your life?

6. Do you know how members of your surrounding community deal with extremely hot temperatures? If yes, can you please explain?

Theme: Housing Conditions

7. How does the structure of your house handle extremely hot temperatures?

Theme: Futurity

8. Can you please share any ideas you may have for improving how you and your surrounding community respond to and recover from extremely hot temperatures?

Appendix B: Focus Group Script

Introduction

Scripted Transition: Welcome everyone! Thank you so much for joining us today and agreeing to participate in this focus group discussion. My name is Ebone Smith, a second-year masters at the University of Oklahoma. My research interests focus on learning how justice can be brought to vulnerable neighborhoods that survive hazardous weather conditions. These focus group discussions are a part of my masters research, which focuses on learning how uncomfortably hot temperatures impact underrepresented communities, such as people of color, low-income communities, seniors, youth, and single-parent families, living in Oklahoma City.

These focus groups are designed to create a safe space for community members to share their experiences with heat and discuss ways to improve resources/services to prevent risks from extreme heat in the future. Today we will be sharing our experience with hot temperatures during the past summer months.

1. Before we begin with the experience questions, it would be great if I could get to know a bit about you all so we can become more familiar with each other. Can we please go around the room one at a time to share your name or pseudonym, how long you've lived in the area, and a fun fact (such as a favorite movie, series, superhero, me-time activity, etc.)?

2. To start, can you all please share with me what you remember about the heat from this past summer?

<u>Past Experiences with Heat Waves</u>

Scripted Transition: Thank you sharing that information with me. I will now start asking questions focused on your past experiences with heat waves while living in Oklahoma City. For your reference, this research defines heat waves as a type of severe weather threat that maintains uncomfortably hot temperatures for two days or longer. These high temperatures are above the normal, expected outdoor temperatures for a city or town.

3. Thinking about heat waves in *this* way, can you remember any past experiences you have had with uncomfortably hot temperatures, lasting for days or weeks at a time, in Oklahoma City?

Prompted Follow-up Questions (to be asked only if needed to further conversation):

i. During these past experiences, do you recall how you typically felt emotionally and physically? (e.g., exhausted, thirsty, faint, irritable)
ii. Have heat ways negatively impacted your health, work, methods of transportation, family, or friends?
iii. What actions did you take to overcome these impacts?

4. How do you generally act in response to the extremely hot temperatures during heat wave events in Oklahoma City? For example, what are some of the necessary precautions that you take, does your routine change, do you still go to work, do you go to cooling centers, and how do you get around to where you need to go.

Prompted Follow-up Questions (to be asked only if needed to further conversation):

i. How did you develop your ways of dealing with heat waves? Did you learn them from someone? Are these behaviors you have adapted over time?
ii. How do you typically prepare for heat waves? (e.g., do you have an emergency preparedness plan, do you reschedule your work shifts, do you use fans or A/C, do you learn where the nearest cooling center is)
iii. If you have to prepare for heat waves, how do you typically feel when preparing? (e.g., overwhelmed, worried, uninformed, nonchalant, burdened, etc.)
iv. What resources are available to you that you know about?
v. How do you feel about the resources available to assist you with these impacts?
vi. When there are extreme heat conditions, are the people you communicate with to ensure each other's safety? (e.g., do you check on anyone, does someone check on you)

Awareness of Heat Waves and Preventative Measures

Scripted Transition: Thank you for telling me about your past experiences with heat waves. We are now going to start talking about your awareness of heat waves and how you stay safe during them.

5. Can you please explain the process of which you are informed of extreme heat conditions and the impacts the heat may have on your quality of life?

Prompted Follow-up Questions (to be asked only if needed to further conversation):

i. Can you please explain how you are informed of heat wave conditions?

ii. How much time in advance do you have to prepare?

iii. How do you get warnings about heat conditions? (e.g., on your phone, through the local news, from a friend tell, or from leadership or administration in your community, etc.)

iv. Are there any actions or steps that have been recommended to you to prevent serious health consequences caused by extreme heat? (e.g., cold damp compress, water, A/C, cooling centers, etc.)

   a. Where did you learn these from?

   b. How have these recommendations helped you in the past, if at all?

v. How do you feel about the heat wave information you have been given in the past? (e.g., do you feel like you have the information you need to keep yourself safe, do you feel like you need more information, is there anything you are curious about)

Housing Conditions

Scripted Transition: We are now going to discuss how equipped your house is for dealing with extreme heat.

6. How do you feel the structure of your house and your surrounding community deals with extreme temperatures?

Prompted Follow-up Questions (to be asked only if needed to further conversation):

i. Can you please describe your access to air conditioning within your home when heat waves are taking place?

    a. What influences your use of air conditioning generally or during heat waves? (e.g., cost, outages, etc.)

ii. If you live in an apartment, can you please explain how your apartment complex leadership handles heat wave events? (e.g., do they send out notifications and provide information, do they offer a place for cooling)

    a. Do you think the way your apartment complex deals with heat waves helps you?

iii. Do you know how far away you live from the nearest cooling center to your neighborhood?

iv. Do you have well-insulated windows?

<u>Future Adaptation and Resilience</u>

Scripted Transition: Before we wrap up this interview, I would like to ask you a few questions about how you think your community can respond better and deal with heat waves.

7. Can you please share any ideas you may have for improving how your community responds to and recovers from extremely hot temperatures?

Prompted Follow-up Questions (to be asked only if needed to further conversation):

i. What are some resources you feel are lacking when dealing with the hot temperatures that come from heat waves? (e.g., transportation, proximity to cooling centers, general warning information, etc.)

ii. Can you please share if there are resources you feel you could benefit from, so you can avoid the potentially fatal consequences of the hot temperatures?

iii. How do you feel your needs are responded to by emergency officials, such as medical responders? (e.g., do feel your needs at met in a timely fashion)

References

Akbari, H., D. M. Kurn, S. E. Bretz, and J. W. Hanford. 1997. Peak power and cooling energy savings of shade trees. *Energy and Buildings* 25 (2):139–148. https://linkinghub.elsevier.com/retrieve/pii/S0378778896010031 (last accessed 20 November 2022).

Alcocer, D., M. Estrada, M. Gallarza, A. Gormsen, G. Karam, A. Koshollek, N. Matteson, M. Miguel, J. Negrete, C. Odom, E. Ramirez, S. Reichert, and T. Rivera. 2023. *Identifying and Addressing Heat Inequities in the City of Los Angeles.* UCLA: Luskin Center for Innovation. https://escholarship.org/uc/item/9sf0b27b.

Almazroui, M., M. N. Islam, F. Saeed, S. Saeed, M. Ismail, M. A. Ehsan, I. Diallo, E. O'Brien, M. Ashfaq, D. Martínez-Castro, T. Cavazos, R. Cerezo-Mota, M. K. Tippett, W. J. Gutowski, E. J. Alfaro, H. G. Hidalgo, A. Vichot-Llano, J. D. Campbell, S. Kamil, I. U. Rashid, M. B. Sylla, T. Stephenson, M. Taylor, and M. Barlow. 2021. Projected Changes in Temperature and Precipitation Over the United States, Central America, and the Caribbean in CMIP6 GCMs. *Earth Systems and Environment* 5 (1):1–24. http://link.springer.com/10.1007/s41748-021-00199-5 (last accessed 4 April 2024).

Anderson, M. 2016. Who relies on public transit in the U.S. *Pew Research Center*. https://www.pewresearch.org/short-reads/2016/04/07/who-relies-on-public-transit-in-the-u-s/.

Angel, J. The 1995 Heat Wave in Chicago, Illinois. *State Climatologist Office for Illinois*. https://www.isws.illinois.edu/statecli/general/1995chicago.htm#Records.

Asaeda, T., V. T. Ca, and A. Wake. 1996. Heat storage of pavement and its effect on the lower atmosphere. *Atmospheric Environment* 30 (3):413–427. https://linkinghub.elsevier.com/retrieve/pii/1352231094001405 (last accessed 4 April 2024).

ASLA. 2011. *ASLA Green Roof Demonstration Project Fact Sheet*. 636 Eye Street, NW, Washington, DC 20001. https://www.asla.org/contentdetail.aspx?id=25362.

Baniassadi, A., D. J. Sailor, and C. R. Olenick. 2018. Indoor air quality and thermal comfort for elderly residents in Houston TX—a case study. In *Healthy, Intelligent and Resilient Buildings and Urban Environments*, 787–792. International Association of Building Physics (IABP) https://surface.syr.edu/ibpc/2018/IE2/4 (last accessed 23 April 2023).

Basara, J. B., H. G. Basara, B. G. Illston, and K. C. Crawford. 2010. The Impact of the Urban Heat Island during an Intense Heat Wave in Oklahoma City. *Advances in*

Meteorology 2010:1–10. http://www.hindawi.com/journals/amete/2010/230365/ (last accessed 18 July 2022).

Bell, R., D. Cole, B. DeAngelo, L. Desaultes, E. Dickerhoff, M. Estes, G. Heisler, D. Hitchcock, K. Klunich, C. Kollin, M. Lewis, J. Magee, G. McPherson, D. Nowak, P. Rodbell, J. Rosenthal, M. Sarkovich, K. Wolf, J. Yarbrough, and B. Zalph. 2008. Trees and Vegetation. In *Reducing Urban Heat Islands: Compendium of Strategies*, 32. Environmental Protection Agency https://www.epa.gov/sites/default/files/2014-06/documents/treesandvegcompendium.pdf.

BGCOKC. About Us. *Boys and Girls Club of Oklahoma County*. https://www.bgcokc.org/about-us/.

Bixler, R. P., M. Coudert, S. M. Richter, J. M. Jones, C. Llanes Pulido, N. Akhavan, M. Bartos, P. Passalacqua, and D. Niyogi. 2022. Reflexive co-production for urban resilience: Guiding framework and experiences from Austin, Texas. *Frontiers in Sustainable Cities* 4:1015630. https://www.frontiersin.org/articles/10.3389/frsc.2022.1015630/full (last accessed 23 April 2023).

Bodnaruk, E. W., C. N. Kroll, Y. Yang, S. Hirabayashi, D. J. Nowak, and T. A. Endreny. 2017. Where to plant urban trees? A spatially explicit methodology to explore ecosystem service tradeoffs. *Landscape and Urban Planning* 157:457–467. https://linkinghub.elsevier.com/retrieve/pii/S016920461630175X (last accessed 20 November 2022).

Boice, D. C., M. E. Garza, and S. E. Holmes. 2018. The Urban Heat Island of San Antonio, Texas, from 1991 to 2010. *Journal of Geography, Environment and Earth Science International* 17 (2):1–13. https://journaljgeesi.com/index.php/JGEESI/article/view/11 (last accessed 23 April 2023).

Braun, V., and V. Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3 (2):77–101. http://www.tandfonline.com/doi/abs/10.1191/1478088706qp063oa (last accessed 7 March 2024).

Broadbent, A. M., J. Declet-Barreto, E. S. Krayenhoff, S. L. Harlan, and M. Georgescu. 2022. Targeted implementation of cool roofs for equitable urban adaptation to extreme heat. *Science of The Total Environment* 811:151326. https://linkinghub.elsevier.com/retrieve/pii/S0048969721064044 (last accessed 23 April 2023).

Browning, C. R., D. Wallace, S. L. Feinberg, and K. A. Cagney. 2006. Neighborhood Social Processes, Physical Conditions, and Disaster-Related Mortality: The Case of the 1995 Chicago Heat Wave. *American Sociological Review* 71 (4):661–678.

http://journals.sagepub.com/doi/10.1177/000312240607100407 (last accessed 2 June 2023).

Campbell, S., M. Greenwood, S. Prior, T. Shearer, K. Walkem, S. Young, D. Bywaters, and K. Walker. 2020. Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing* 25 (8):652–661. http://journals.sagepub.com/doi/10.1177/1744987120927206 (last accessed 4 April 2024).

CDC. 2024a. CDC/ATSDR Social Vulnerability Index. *Place and Helath*. https://www.atsdr.cdc.gov/placeandhealth/svi/index.html.

———. 2024b. CDC/ATSDR SVI Fact Sheet. *Place and Helath*. https://www.atsdr.cdc.gov/placeandhealth/svi/fact_sheet/fact_sheet.html.

Chang, N.-B. 2010. Assessing the long-term urban heat island in San Antonio, Texas based on moderate resolution imaging spectroradiometer/Aqua data. *Journal of Applied Remote Sensing* 4 (1):043508. http://remotesensing.spiedigitallibrary.org/article.aspx?doi=10.1117/1.3335611 (last accessed 23 April 2023).

Changnon, S. A., K. E. Kunkel, and B. C. Reinke. 1996. Impacts and Responses to the 1995 Heat Wave: A Call to Action. *Bulletin of the American Meteorological Society* 77 (7):1497–1506. http://journals.ametsoc.org/doi/10.1175/1520-0477(1996)077<1497:IARTTH>2.0.CO;2 (last accessed 4 April 2024).

City of Oklahoma City Parks and Recreation Department, Oklahoma City Community Foundation, and Oklahoma Forestry Services. 2016. *Oklahoma City, Oklahoma Community Forest Assessment*. Oklahoma City, Oklahoma: Davey Research Group. https://www.okc.gov/home/showpublisheddocument/6890/636253614873670000.

City of Oklahoma City Planning Department. 2020. *AdaptOKC*. Oklahoma City, Oklahoma. https://www.okc.gov/home/showpublisheddocument/18882/637299972915330000.

City of Portland. Ecoroofs. https://www.portland.gov/bes/stormwater/managing-rain-your-property/ecoroofs#:~:text=Summary%20of%20Ecoroof%20Design%20Requirements&text=Locate%20ecoroofs%20on%20flat%20or,least%204%20inches%20of%20soil.

Clark, H. M., K. Basinger, K. Maloney, and C. Whiteman. 2017. *Who Rides Public Transportation*. American Public Transportation Association (APTA). https://www.apta.com/wp-content/uploads/Resources/resources/reportsandpublications/Documents/APTA-Who-Rides-Public-Transportation-2017.pdf.

Cole, D., N. Dietsch, G. Gero, D. Hitchcock, M. Lewis, J. Magee, M. Sarkovich, J. Yarbrough, and B. Zalph. 2008. Heat Island Reduction Activities. In *Reducing Urban Heat Islands: Compendium of Strategies*, 32. Environmental Protection Agency https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_6.pdf.

Conlon, K., A. Monaghan, M. Hayden, and O. Wilhelmi. 2016. Potential Impacts of Future Warming and Land Use Changes on Intra-Urban Heat Exposure in Houston, Texas ed. K. L. Ebi. *PLOS ONE* 11 (2):e0148890. https://dx.plos.org/10.1371/journal.pone.0148890 (last accessed 23 April 2023).

Creswell, J. W., and D. L. Miller. 2000. Determining Validity in Qualitative Inquiry. *Theory Into Practice* 39 (3):124–130. http://www.tandfonline.com/doi/abs/10.1207/s15430421tip3903_2 (last accessed 9 March 2024).

Cui, J., and L. I. Sinoway. 2014. Cardiovascular Responses to Heat Stress in Chronic Heart Failure. *Current Heart Failure Reports* 11 (2):139–145. http://link.springer.com/10.1007/s11897-014-0191-y (last accessed 18 July 2022).

Cui, Y., X. Xiao, R. B. Doughty, Y. Qin, S. Liu, N. Li, G. Zhao, and J. Dong. 2019. The relationships between urban-rural temperature difference and vegetation in eight cities of the Great Plains. *Frontiers of Earth Science* 13 (2):290–302. http://link.springer.com/10.1007/s11707-018-0729-5 (last accessed 20 November 2022).

Curriero, F. C. 2002. Temperature and Mortality in 11 Cities of the Eastern United States. *American Journal of Epidemiology* 155 (1):80–87. https://academic.oup.com/aje/article-lookup/doi/10.1093/aje/155.1.80 (last accessed 14 June 2023).

Dahl, K., E. Spanger-Siegfried, R. Licker, A. Caldas, J. Abatzoglou, N. Mailloux, R. Cleetus, S. Udvardy, J. Declet-Barreto, and P. Worth. 2019. *Killer Heat in the United States: Climate Choices and the Future of Dangerously Hot Days*. Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/resources/killer-heat-united-states-0.

Diallo, I., L. He, K. Koehler, A. P. Spira, R. Kale, J. Ou, G. Smith, S. L. Linton, and J. Augustinavicius. 2024. Community perspectives on heat and health in Baltimore City. *Urban Climate* 54:101841. https://linkinghub.elsevier.com/retrieve/pii/S2212095524000373 (last accessed 22 April 2024).

Dixon, K. W., A. Wootten, M. J. Nath, J. Lanzante, D. J. Adams-Smith, C. E. Whitlock, C. F. Gaitán, and R. A. McPherson. 2020. South Central Climate Projections Evaluation Project (C-PrEP). https://www.sciencebase.gov/catalog/item/5ee7b8a882ce3bd58d82ef9f (last accessed 1 April 2024).

Dzyuban, Y., D. M. Hondula, P. J. Coseo, and C. L. Redman. 2022. Public transit infrastructure and heat perceptions in hot and dry climates. *International Journal of Biometeorology* 66 (2):345–356. https://link.springer.com/10.1007/s00484-021-02074-4 (last accessed 2 April 2024).

Falk, B., and R. Dotan. 2008. Children's thermoregulation during exercise in the heat — a revisit. *Applied Physiology, Nutrition, and Metabolism* 33 (2):420–427. http://www.nrcresearchpress.com/doi/10.1139/H07-185 (last accessed 4 August 2022).

Fan, Y., A. Guthrie, and D. Levinson. 2016. *Perception of Waiting Time at Transit Stops and Stations*. Minnesota: Center for Transportation Studies.

Ferguson, B., K. Fisher, J. Golden, L. Hair, L. Haselbach, D. Hitchcock, K. Kaloush, M. Pomerantz, N. Tran, and D. Waye. 2008. Cool Pavements. In *Reducing Urban Heat Islands: Compendium of Strategies*, 32. Environmental Protection Agency https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_5.pdf.

Flanagan, B. E., E. W. Gregory, E. J. Hallisey, J. L. Heitgerd, and B. Lewis. 2011. A Social Vulnerability Index for Disaster Management. *Journal of Homeland Security and Emergency Management* 8 (1). https://www.degruyter.com/document/doi/10.2202/1547-7355.1792/html (last accessed 27 March 2024).

Gamble, J., and J. Hess. 2012. Temperature and Violent Crime in Dallas, Texas: Relationships and Implications of Climate Change. *Western Journal of Emergency Medicine* 13 (3):239–246. http://www.escholarship.org/uc/item/1613p1gt (last accessed 23 April 2023).

Green Roofs For Healthy Cities. Awards of Excellence. *Green Roofs For Healthy Cities*. https://greenroofs.org/awards-of-excellence.

Greenberg, J. H., J. Bromberg, C. M. Reed, T. L. Gustafson, and R. A. Beauchamp. 1983. The epidemiology of heat-related deaths, Texas--1950, 1970-79, and 1980. *American Journal of Public Health* 73 (7):805–807. https://ajph.aphapublications.org/doi/full/10.2105/AJPH.73.7.805 (last accessed 4 April 2024).

Gronlund, C. J. 2014. Racial and Socioeconomic Disparities in Heat-Related Health Effects and Their Mechanisms: a Review. *Current Epidemiology Reports* 1 (3):165–173. http://link.springer.com/10.1007/s40471-014-0014-4 (last accessed 23 April 2023).

Guest, G., E. Namey, A. O'Regan, C. Godwin, and J. Taylor. 2020. *Comparing Interview and Focus Group Data Collected in Person and Online*. Patient-Centered Outcomes Research Institute® (PCORI). https://www.pcori.org/research-results/2014/comparing-interview-and-focus-group-data-collected-person-and-online (last accessed 4 April 2024).

Hansen, A., L. Bi, A. Saniotis, and M. Nitschke. 2013. Vulnerability to extreme heat and climate change: is ethnicity a factor? *Global Health Action* 6 (1):21364. https://www.tandfonline.com/doi/full/10.3402/gha.v6i0.21364 (last accessed 18 July 2022).

Hansen, A., P. Bi, M. Nitschke, D. Pisaniello, J. Newbury, and A. Kitson. 2011. Older persons and heat-susceptibility: the role of health promotion in a changing climate. *Health Promotion Journal of Australia* 22 (4):17–20. http://doi.wiley.com/10.1071/HE11417 (last accessed 18 July 2022).

Harries, K. D., and S. J. Stadler. 1983. Determinism Revisited: Assault and Heat Stress in Dallas, 1980. *Environment and Behavior* 15 (2):235–256. http://journals.sagepub.com/doi/10.1177/0013916583152006 (last accessed 23 April 2023).

———. 1988. Heat and Violence: New Findings from Dallas Field Data, 1980–19811. *Journal of Applied Social Psychology* 18 (2):129–138. https://onlinelibrary.wiley.com/doi/10.1111/j.1559-1816.1988.tb00010.x (last accessed 23 April 2023).

Hay, I. ed. 2016. *Qualitative research methods in human geography* Fourth edition. Don Mills, Ontario: Oxford University Press.

Hayashi, P., G. Abib, and N. Hoppen. 2019. Validity in Qualitative Research: A Processual Approach. *The Qualitative Report*. https://nsuworks.nova.edu/tqr/vol24/iss1/8/ (last accessed 9 March 2024).

Hayden, M. H., O. V. Wilhelmi, D. Banerjee, T. Greasby, J. L. Cavanaugh, V. Nepal, J. Boehnert, S. Sain, C. Burghardt, and S. Gower. 2017. Adaptive Capacity to Extreme Heat: Results from a Household Survey in Houston, Texas. *Weather, Climate, and Society* 9 (4):787–799. https://journals.ametsoc.org/doi/10.1175/WCAS-D-16-0125.1 (last accessed 18 July 2022).

Hess, D. B. 2012. Walking to the bus: perceived versus actual walking distance to bus stops for older adults. *Transportation* 39 (2):247–266. http://link.springer.com/10.1007/s11116-011-9341-1 (last accessed 2 April 2024).

Hoffman, J. S., V. Shandas, and N. Pendleton. 2020. The Effects of Historical Housing Policies on Resident Exposure to Intra-Urban Heat: A Study of 108 US Urban Areas. *Climate* 8 (1):12. https://www.mdpi.com/2225-1154/8/1/12 (last accessed 2 December 2022).

Horton, R. M., J. S. Mankin, C. Lesk, E. Coffel, and C. Raymond. 2016. A Review of Recent Advances in Research on Extreme Heat Events. *Current Climate Change*

Reports 2 (4):242–259. http://link.springer.com/10.1007/s40641-016-0042-x (last accessed 15 March 2023).

Hsu, A., G. Sheriff, T. Chakraborty, and D. Manya. 2021. Disproportionate exposure to urban heat island intensity across major US cities. *Nature Communications* 12 (1):2721. https://www.nature.com/articles/s41467-021-22799-5 (last accessed 5 April 2024).

IPCC. 2022. *Climate Change 2022: Impacts, Adaptation and Vulnerability Technical Report*. Cambridge, UK and New York, NY, USA: Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_TechnicalSummary.pdf.

Jahn, D. E., W. A. Gallus, P. T. T. Nguyen, Q. Pan, K. Cetin, E. Byon, L. Manuel, Y. Zhou, and E. Jahani. 2019. Projecting the Most Likely Annual Urban Heat Extremes in the Central United States. *Atmosphere* 10 (12):727. https://www.mdpi.com/2073-4433/10/12/727 (last accessed 21 March 2023).

Johnson, M. G., S. Brown, P. Archer, A. Wendelboe, S. Magzamen, and K. K. Bradley. 2016. Identifying heat-related deaths by using medical examiner and vital statistics data: Surveillance analysis and descriptive epidemiology — Oklahoma, 1990–2011. *Environmental Research* 150:30–37. https://linkinghub.elsevier.com/retrieve/pii/S0013935116302079 (last accessed 18 July 2022).

Kaiser, R., A. Le Tertre, J. Schwartz, C. A. Gotway, W. R. Daley, and C. H. Rubin. 2007. The Effect of the 1995 Heat Wave in Chicago on All-Cause and Cause-Specific Mortality. *American Journal of Public Health* 97 (Supplement_1):S158–S162. https://ajph.aphapublications.org/doi/full/10.2105/AJPH.2006.100081 (last accessed 18 July 2022).

Kalkstein, L. S., D. P. Eisenman, E. B. De Guzman, and D. J. Sailor. 2022. Increasing trees and high-albedo surfaces decreases heat impacts and mortality in Los Angeles, CA. *International Journal of Biometeorology* 66 (5):911–925. https://link.springer.com/10.1007/s00484-022-02248-8 (last accessed 23 April 2023).

Kalkstein, L. S., and J. S. Greene. 1997. An evaluation of climate/mortality relationships in large U.S. cities and the possible impacts of a climate change. *Environmental Health Perspectives* 105 (1):84–93. https://ehp.niehs.nih.gov/doi/10.1289/ehp.9710584 (last accessed 4 April 2024).

Karl, T. R., R. W. Knight, and B. Baker. 2000. The record breaking global temperatures of 1997 and 1998: Evidence for an increase in the rate of global warming? *Geophysical Research Letters* 27 (5):719–722. http://doi.wiley.com/10.1029/1999GL010877 (last accessed 22 April 2023).

Kazmierczak, A., and J. Carter. 2010. Adaptation to climate change using green and blue infrastructure: a database of case studies.

Kemen, J., S. Schäffer-Gemein, J. Grünewald, and T. Kistemann. 2021. Heat Perception and Coping Strategies: A Structured Interview-Based Study of Elderly People in Cologne, Germany. *International Journal of Environmental Research and Public Health* 18 (14):7495. https://www.mdpi.com/1660-4601/18/14/7495 (last accessed 24 April 2024).

Khatana, S. A. M., R. M. Werner, and P. W. Groeneveld. 2022. Association of Extreme Heat With All-Cause Mortality in the Contiguous US, 2008-2017. *JAMA Network Open* 5 (5):e2212957. https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2792389 (last accessed 3 April 2024).

Kondo, K., L. Mabon, Y. Bi, Y. Chen, and Y. Hayabuchi. 2021. Balancing conflicting mitigation and adaptation behaviours of urban residents under climate change and the urban heat island effect. *Sustainable Cities and Society* 65:102585. https://linkinghub.elsevier.com/retrieve/pii/S2210670720308039 (last accessed 3 April 2024).

Koo, B. W., N. Boyd, N. Botchwey, and S. Guhathakurta. 2019. Environmental Equity and Spatiotemporal Patterns of Urban Tree Canopy in Atlanta. *Journal of Planning Education and Research* :0739456X1986414. http://journals.sagepub.com/doi/10.1177/0739456X19864149 (last accessed 27 November 2022).

Lala, B., and A. Hagishima. 2023. Impact of Escalating Heat Waves on Students' Well-Being and Overall Health: A Survey of Primary School Teachers. *Climate* 11 (6):126. https://www.mdpi.com/2225-1154/11/6/126 (last accessed 25 April 2024).

Lane, K., K. Wheeler, K. Charles-Guzman, M. Ahmed, M. Blum, K. Gregory, N. Graber, N. Clark, and T. Matte. 2014. Extreme Heat Awareness and Protective Behaviors in New York City. *Journal of Urban Health* 91 (3):403–414. http://link.springer.com/10.1007/s11524-013-9850-7 (last accessed 18 July 2022).

Lanza, K., M. Alcazar, C. P. Durand, D. Salvo, U. Villa, and H. W. Kohl. 2023. Heat-Resilient Schoolyards: Relations Between Temperature, Shade, and Physical Activity of Children During Recess. *Journal of Physical Activity and Health* 20 (2):134–141. https://journals.humankinetics.com/view/journals/jpah/20/2/article-p134.xml (last accessed 23 April 2023).

Lanza, K., and C. P. Durand. 2021. Heat-Moderating Effects of Bus Stop Shelters and Tree Shade on Public Transport Ridership. *International Journal of Environmental Research and Public Health* 18 (2):463. https://www.mdpi.com/1660-4601/18/2/463 (last accessed 24 March 2023).

Lanza, K., J. Gohlke, S. Wang, P. E. Sheffield, and O. Wilhelmi. 2022. Climate change and physical activity: ambient temperature and urban trail use in Texas. *International Journal of Biometeorology* 66 (8):1575–1588. https://link.springer.com/10.1007/s00484-022-02302-5 (last accessed 23 April 2023).

Lanza, K., J. Jones, F. Acuña, M. Coudert, R. P. Bixler, H. Kamath, and D. Niyogi. 2023. Heat vulnerability of Latino and Black residents in a low-income community and their recommended adaptation strategies: A qualitative study. *Urban Climate* 51:101656. https://linkinghub.elsevier.com/retrieve/pii/S221209552300250X (last accessed 22 April 2024).

Lasme, O. Z. D., M. Y. Ta, A. S. Koffi, D. Baka, L. K. Adopo, T. Lasm, D. C. Boice, M. E. Garza, S. E. Holmes, M. N. Dammo, B. S. U. I. Abubakar, A. Y. Sangodoyin, V. V. M. Ferreira, A. L. Oliveira, R. L. M. Fonseca, N. M. G. D. Oliveira, R. O. D. Albuquerque, C. A. C. Filho, L. M. A. L. Auler, P. K. Wokoma, N. E. Ekeocha, A. E. Daniel., C. U. Godwill., S. S. A. Lima, S. C. D. Paiva, H. T. Figueiredo, G. M. C. Takaki, A. S. Messias, A. Sagar, P. Malkani, A. Dubey, P. Singh, W. M. Shukry, G. H. S. Al-Hawas, R. M. S. Al-Moaikal, M. A. El-Bendary, B. Patel, A. Adewale Mathew, A. O. Ayanboye, O. B. Adelodun, T. A. Kolawole, Y. A. Twumasi, T. L. Coleman, A. Manu, E. C. Merem, and A. Osei. 2019. *Current Perspectives to Environment and Climate Change Vol. 2* ed. Dr. H. Yu. Book Publisher International (a part of SCIENCEDOMAIN International). http://bp.bookpi.org/index.php/bpi/catalog/book/80 (last accessed 23 April 2023).

Lay, C. R., M. C. Sarofim, A. Vodonos Zilberg, D. M. Mills, R. W. Jones, J. Schwartz, and P. L. Kinney. 2021. City-level vulnerability to temperature-related mortality in the USA and future projections: a geographically clustered meta-regression. *The Lancet Planetary Health* 5 (6):e338–e346. https://linkinghub.elsevier.com/retrieve/pii/S2542519621000589 (last accessed 22 April 2023).

Lee, K., and R. D. Brown. 2022. Effects of Urban Landscape and Sociodemographic Characteristics on Heat-Related Health Using Emergency Medical Service Incidents. *International Journal of Environmental Research and Public Health* 19 (3):1287. https://www.mdpi.com/1660-4601/19/3/1287 (last accessed 2 December 2022).

Lee, S., and J. M. First. 2023. Investigation of the Microenvironment, Land Cover Characteristics, and Social Vulnerability of Heat-Vulnerable Bus Stops in Knoxville, Tennessee. *Sustainability* 15 (14):10866. https://www.mdpi.com/2071-1050/15/14/10866 (last accessed 24 April 2024).

Lee, W. V., and J. Shaman. 2017. Heat-coping strategies and bedroom thermal satisfaction in New York City. *Science of The Total Environment* 574:1217–1231. https://linkinghub.elsevier.com/retrieve/pii/S0048969716314498 (last accessed 3 April 2024).

Li, D., G. D. Newman, B. Wilson, Y. Zhang, and R. D. Brown. 2022. Modeling the relationships between historical redlining, urban heat, and heat-related emergency department visits: An examination of 11 Texas cities. *Environment and Planning B: Urban Analytics and City Science* 49 (3):933–952. http://journals.sagepub.com/doi/10.1177/23998083211039854 (last accessed 2 December 2022).

Li, D., T. Sun, M. Liu, L. Yang, L. Wang, and Z. Gao. 2015. Contrasting responses of urban and rural surface energy budgets to heat waves explain synergies between urban heat islands and heat waves. *Environmental Research Letters* 10 (5):054009. https://iopscience.iop.org/article/10.1088/1748-9326/10/5/054009 (last accessed 1 December 2022).

Li, H., J. T. Harvey, T. J. Holland, and M. Kayhanian. 2013. The use of reflective and permeable pavements as a potential practice for heat island mitigation and stormwater management. *Environmental Research Letters* 8 (1):015023. https://iopscience.iop.org/article/10.1088/1748-9326/8/1/015023 (last accessed 4 April 2024).

Liberalesso, T., C. Oliveira Cruz, C. Matos Silva, and M. Manso. 2020. Green infrastructure and public policies: An international review of green roofs and green walls incentives. *Land Use Policy* 96:104693. https://linkinghub.elsevier.com/retrieve/pii/S0264837719310543 (last accessed 25 April 2024).

Liu, Y., T. Li, and H. Peng. 2018. A new structure of permeable pavement for mitigating urban heat island. *Science of The Total Environment* 634:1119–1125. https://linkinghub.elsevier.com/retrieve/pii/S0048969718311987 (last accessed 4 April 2024).

Luber, G., and M. McGeehin. 2008. Climate Change and Extreme Heat Events. *American Journal of Preventive Medicine* 35 (5):429–435. https://linkinghub.elsevier.com/retrieve/pii/S0749379708006867 (last accessed 3 April 2024).

Madrigano, J., K. Ito, S. Johnson, P. L. Kinney, and T. Matte. 2015. A Case-Only Study of Vulnerability to Heat Wave–Related Mortality in New York City (2000–2011). *Environmental Health Perspectives* 123 (7):672–678. https://ehp.niehs.nih.gov/doi/10.1289/ehp.1408178 (last accessed 23 April 2023).

Marsha, A., S. R. Sain, M. J. Heaton, A. J. Monaghan, and O. V. Wilhelmi. 2018. Influences of climatic and population changes on heat-related mortality in Houston, Texas, USA. *Climatic Change* 146 (3–4):471–485. http://link.springer.com/10.1007/s10584-016-1775-1 (last accessed 23 April 2023).

Martín, Y., and P. Paneque. 2022. Moving from adaptation capacities to implementing adaptation to extreme heat events in urban areas of the European Union:

Introducing the U-ADAPT! research approach. *Journal of Environmental Management* 310:114773. https://linkinghub.elsevier.com/retrieve/pii/S0301479722003462 (last accessed 1 December 2022).

Marvel, K., W. Su, R. Delgado, S. Aarons, A. Chatterjee, M. E. Garcia, Z. Hausfather, K. Hayhoe, D. A. Hence, E. B. Jewett, A. Robel, D. Singh, A. Tripati, and R. S. Vose. 2023. *Chapter 2 : Climate Trends. Fifth National Climate Assessment*. U.S. Global Change Research Program. https://nca2023.globalchange.gov/chapter/2 (last accessed 1 April 2024).

McInnes, J. A., and J. E. Ibrahim. 2010. Minimising harm to older Victorians from heatwaves: A qualitative study of the role of community-based health profession and carer organisations: Minimising harm to older Victorians from heatwaves. *Australasian Journal on Ageing* 29 (3):104–110. https://onlinelibrary.wiley.com/doi/10.1111/j.1741-6612.2010.00393.x (last accessed 22 April 2023).

McPherson, R. A., P. A. Fay, S. G. Alvarez, D. Bertrand, T. L. Broadbent, T. Bruno, A. Fares, B. McCullough, G. W. Moore, B. Moorhead, L. Patiño, A. Petersen, N. G. Smith, J. L. Steiner, A. Taylor, and T. Warziniack. 2023. Chapter 26: Southern Great Plains. In *Fifth National Climate Assessment*, eds. A. R. Crimmins, C. W. Avery, D. R. Easterling, K. E. Kunkel, B. C. Stewart, and T. K. Maycock. U.S. Global Change Research Program https://nca2023.globalchange.gov/chapter/26 (last accessed 4 April 2024).

Medina-Ramón, M., A. Zanobetti, D. P. Cavanagh, and J. Schwartz. 2006. Extreme Temperatures and Mortality: Assessing Effect Modification by Personal Characteristics and Specific Cause of Death in a Multi-City Case-Only Analysis. 114 (9). https://www.proquest.com/docview/222614077/fulltext/B418DA2774F744D5PQ/1?accountid=12964&sourcetype=Scholarly%20Journals.

Miao, Q., E. W. Welch, and P. S. Sriraj. 2019. Extreme weather, public transport ridership and moderating effect of bus stop shelters. *Journal of Transport Geography* 74:125–133. https://linkinghub.elsevier.com/retrieve/pii/S0966692318300681 (last accessed 2 April 2024).

Michael Blasnik. 2004. *Impact Evaluation of the Energy Coordinating Agency of Philadelphia's Cool Homes Pilot Project*. Boston, MA: M. Blasnik & Associates. https://www.coolrooftoolkit.org/wp-content/uploads/2012/04/Blasnik-2004-Eval-coolhomes_Philly-EAC.pdf.

Mitchell, B., and J. Chakraborty. 2014. Urban Heat And Climate Justice: A Landscape Of Thermal Inequity In Pinellas County, Florida. *Geographical Review* 104 (4):459–480. http://www.jstor.org/stable/43916079 (last accessed 18 July 2022).

Mora, C., B. Dousset, I. R. Caldwell, F. E. Powell, R. C. Geronimo, C. R. Bielecki, C. W. W. Counsell, B. S. Dietrich, E. T. Johnston, L. V. Louis, M. P. Lucas, M. M. McKenzie, A. G. Shea, H. Tseng, T. W. Giambelluca, L. R. Leon, E. Hawkins, and C. Trauernicht. 2017. Global risk of deadly heat. *Nature Climate Change* 7 (7):501–506. https://www.nature.com/articles/nclimate3322 (last accessed 3 April 2024).

Moran, M. E. 2022. Are shelters in place? Mapping the distribution of transit amenities via a bus-stop census of San Francisco. *Journal of Public Transportation* 24:100023. https://linkinghub.elsevier.com/retrieve/pii/S1077291X22000236 (last accessed 24 April 2024).

Mortensen, J. W., M. J. Heaton, and O. V. Wilhelmi. 2018. Urban Heat Risk Mapping Using Multiple Point Patterns in Houston, Texas. *Journal of the Royal Statistical Society Series C: Applied Statistics* 67 (1):83–102. https://academic.oup.com/jrsssc/article/67/1/83/7058362 (last accessed 23 April 2023).

Mullens, E., and R. McPherson. 2023. The Changing Nature of Hazardous Weather and Implications for Transportation: Example from Oklahoma, USA. *Climate* 11 (2):32. https://www.mdpi.com/2225-1154/11/2/32 (last accessed 22 May 2023).

Mushore, T., J. Odindi, and O. Mutanga. 2022. “Cool” Roofs as a Heat-Mitigation Measure in Urban Heat Islands: A Comparative Analysis Using Sentinel 2 and Landsat Data. *Remote Sensing* 14 (17):4247. https://www.mdpi.com/2072-4292/14/17/4247 (last accessed 13 April 2023).

Napieralski, J., C. Sulich, A. Taylor, and P. Draus. 2022. Mapping the link between outdoor water footprint and social vulnerability in Metro Phoenix, AZ (USA). *Landscape and Urban Planning* 226:104498. https://linkinghub.elsevier.com/retrieve/pii/S0169204622001475 (last accessed 3 April 2024).

National Weather Service (NWS). 2023. *Summary of Natural Hazard Statistics for 2021 in the United States*. https://www.weather.gov/media/hazstat/sum21.pdf.

Naughton, M. 2002. Heat-related mortality during a 1999 heat wave in Chicago. *American Journal of Preventive Medicine* 22 (4):221–227. https://linkinghub.elsevier.com/retrieve/pii/S074937970200421X (last accessed 4 April 2024).

New York State Department of Health. 2017. When it’s Too Hot for a Fan. https://www.health.ny.gov/publications/6594/.

Ngo, N. S. 2019. Urban bus ridership, income, and extreme weather events. *Transportation Research Part D: Transport and Environment* 77:464–475. https://linkinghub.elsevier.com/retrieve/pii/S1361920918309945 (last accessed 2 April 2024).

Nowak, D., and G. Heisler. 2010. *Air Quality Effects of Urban Trees and Parks*. Syracuse, New York: National Recreation and Park Association. https://www.nrpa.org/globalassets/research/nowak-heisler-research-paper.pdf.

Nowak, D. J., A. Ellis, and E. J. Greenfield. 2022. The disparity in tree cover and ecosystem service values among redlining classes in the United States. *Landscape and Urban Planning* 221:104370. https://linkinghub.elsevier.com/retrieve/pii/S0169204622000196 (last accessed 20 November 2022).

Nyumba, T., K. Wilson, C. J. Derrick, and N. Mukherjee. 2018. The use of focus group discussion methodology: Insights from two decades of application in conservation ed. D. Geneletti. *Methods in Ecology and Evolution* 9 (1):20–32. https://besjournals.onlinelibrary.wiley.com/doi/10.1111/2041-210X.12860 (last accessed 4 April 2024).

OCCHD. 2021. *Wellness Score 2020*. Oklahoma City, Oklahoma: Oklahoma City-County Health Department. https://www.occhdwellnessscore.com/_files/ugd/2d5fe4_1f1d0aeed7f749a2889c393eb6e9f21a.pdf.

Oklahoma Climatological Survey. Climate of Oklahoma. *Oklahoma Climatological Survey*. https://climate.ok.gov/index.php/site/page/climate_of_oklahoma.

O'Lenick, C. R., A. Baniassadi, R. Michael, A. Monaghan, J. Boehnert, X. Yu, M. H. Hayden, C. Wiedinmyer, K. Zhang, P. J. Crank, J. Heusinger, P. Hoel, D. J. Sailor, and O. V. Wilhelmi. 2020. A Case-Crossover Analysis of Indoor Heat Exposure on Mortality and Hospitalizations among the Elderly in Houston, Texas. *Environmental Health Perspectives* 128 (12):127007. https://ehp.niehs.nih.gov/doi/10.1289/EHP6340 (last accessed 23 April 2023).

O'Neill, M. S., A. Zanobetti, and J. Schwartz. 2003. Modifiers of the Temperature and Mortality Association in Seven US Cities. *American Journal of Epidemiology* 157 (12):1074–1082. https://academic.oup.com/aje/article-lookup/doi/10.1093/aje/kwg096 (last accessed 18 July 2022).

———. 2005. Disparities by Race in Heat-Related Mortality in Four US Cities: The Role of Air Conditioning Prevalence. *Journal of Urban Health: Bulletin of the New York Academy of Medicine* 82 (2):191–197. http://link.springer.com/10.1093/jurban/jti043 (last accessed 18 July 2022).

Onwuegbuzie, A. J., W. B. Dickinson, N. L. Leech, and A. G. Zoran. 2009. A Qualitative Framework for Collecting and Analyzing Data in Focus Group Research. *International Journal of Qualitative Methods* 8 (3):1–21. http://journals.sagepub.com/doi/10.1177/160940690900800301 (last accessed 14 April 2023).

Palinkas, L. A., M. S. Hurlburt, C. Fernandez, J. De Leon, K. Yu, E. Salinas, E. Garcia, J. Johnston, Md. M. Rahman, S. J. Silva, and R. S. McConnell. 2022. Vulnerable, Resilient, or Both? A Qualitative Study of Adaptation Resources and Behaviors to Heat Waves and Health Outcomes of Low-Income Residents of Urban Heat Islands. *International Journal of Environmental Research and Public Health* 19 (17):11090. https://www.mdpi.com/1660-4601/19/17/11090 (last accessed 25 April 2024).

Philadelphia Water Department. 2024. Green Roof Density Bonus Review Process. https://water.phila.gov/pool/files/green-roof-density-bonus-review-process.pdf.

Piracha, A., and M. T. Chaudhary. 2022. Urban Air Pollution, Urban Heat Island and Human Health: A Review of the Literature. *Sustainability* 14 (15):9234. https://www.mdpi.com/2071-1050/14/15/9234 (last accessed 2 December 2022).

Quintana, A. 2020. The urban heat island effect in Austin : current trends and opportunities for further mitigation. https://repositories.lib.utexas.edu/handle/2152/83165 (last accessed 23 April 2023).

Rabiee, F. 2004. Focus-group interview and data analysis. *Proceedings of the Nutrition Society* 63 (4):655–660. https://www.cambridge.org/core/product/identifier/S0029665104000874/type/journal_article (last accessed 6 June 2022).

Reach Forward Foundation. About: Mission and History. *Reach Forward Foundation*. https://reachforward.wixsite.com/reachforward/about.

RestoreOKC. RestoreOKC. https://www.restoreokc.org.

Riley, K., H. Wilhalme, L. Delp, and D. Eisenman. 2018. Mortality and Morbidity during Extreme Heat Events and Prevalence of Outdoor Work: An Analysis of Community-Level Data from Los Angeles County, California. *International Journal of Environmental Research and Public Health* 15 (4):580. http://www.mdpi.com/1660-4601/15/4/580 (last accessed 23 April 2023).

Roman, K. K., T. O'Brien, J. B. Alvey, and O. Woo. 2016. Simulating the effects of cool roof and PCM (phase change materials) based roof to mitigate UHI (urban heat island) in prominent US cities. *Energy* 96:103–117. https://linkinghub.elsevier.com/retrieve/pii/S036054421501703X (last accessed 13 April 2023).

Sampson, N. R., C. J. Gronlund, M. A. Buxton, L. Catalano, J. L. White-Newsome, K. C. Conlon, M. S. O'Neill, S. McCormick, and E. A. Parker. 2013. Staying cool in a changing climate: Reaching vulnerable populations during heat events. *Global Environmental Change* 23 (2):475–484. https://linkinghub.elsevier.com/retrieve/pii/S0959378013000022 (last accessed 18 July 2022).

Santamouris, M. 2013. Using cool pavements as a mitigation strategy to fight urban heat island—A review of the actual developments. *Renewable and Sustainable Energy Reviews* 26:224–240. https://linkinghub.elsevier.com/retrieve/pii/S136403211300350X (last accessed 4 April 2024).

Schnell, J. L., and M. J. Prather. 2017. Co-occurrence of extremes in surface ozone, particulate matter, and temperature over eastern North America. *Proceedings of the National Academy of Sciences* 114 (11):2854–2859. https://pnas.org/doi/full/10.1073/pnas.1614453114 (last accessed 1 April 2024).

Semenza, J. C., C. H. Rubin, K. H. Falter, J. D. Selanikio, W. D. Flanders, H. L. Howe, and J. L. Wilhelm. 1996. Heat-Related Deaths during the July 1995 Heat Wave in Chicago. *New England Journal of Medicine* 335 (2):84–90. http://www.nejm.org/doi/abs/10.1056/NEJM199607113350203 (last accessed 2 June 2023).

Sen, S., J. Roesler, B. Ruddell, and A. Middel. 2019. Cool Pavement Strategies for Urban Heat Island Mitigation in Suburban Phoenix, Arizona. *Sustainability* 11 (16):4452. https://www.mdpi.com/2071-1050/11/16/4452 (last accessed 20 November 2022).

Sharpe, J. D., and A. F. Wolkin. 2022. The Epidemiology and Geographic Patterns of Natural Disaster and Extreme Weather Mortality by Race and Ethnicity, United States, 1999-2018. *Public Health Reports* 137 (6):1118–1125. http://journals.sagepub.com/doi/10.1177/00333549211047235 (last accessed 2 April 2024).

Sheridan, S. C. 2007. A survey of public perception and response to heat warnings across four North American cities: an evaluation of municipal effectiveness. *International Journal of Biometeorology* 52 (1):3–15. http://link.springer.com/10.1007/s00484-006-0052-9 (last accessed 3 April 2024).

SMUD. 2024. Shading Sacramento. https://www.smud.org/en/Going-Green/Free-Shade-Trees.

Synnefa, A., M. Santamouris, and I. Livada. 2006. A study of the thermal performance of reflective coatings for the urban environment. *Solar Energy* 80 (8):968–981. https://linkinghub.elsevier.com/retrieve/pii/S0038092X05002975 (last accessed 9 March 2023).

Taleghani, M. 2018. Outdoor thermal comfort by different heat mitigation strategies- A review. *Renewable and Sustainable Energy Reviews* 81:2011–2018. https://linkinghub.elsevier.com/retrieve/pii/S1364032117309474 (last accessed 6 April 2023).

Teyton, A., M. Tremblay, I. Tardif, M.-A. Lemieux, K. Nour, and T. Benmarhnia. 2022. A Longitudinal Study on the Impact of Indoor Temperature on Heat-Related

Symptoms in Older Adults Living in Non–Air-Conditioned Households. *Environmental Health Perspectives* 130 (7):077003. https://ehp.niehs.nih.gov/doi/10.1289/EHP10291 (last accessed 1 April 2024).

TreeUtah. School Tree Planting Grants. *TreeUtah*. https://www.treeutah.org/apply-for-a-grant/school-tree-planting-grants#:~:text=TreeUtah%20will%20bring%20kid%2Dsized,and%20health%20of%20the%20tree.

Tustin, A. W., G. E. Lamson, B. L. Jacklitsch, R. J. Thomas, S. B. Arbury, D. L. Cannon, R. G. Gonzales, and M. J. Hodgson. 2018. *Evaluation of Occupational Exposure Limits for Heat Stress in Outdoor Workers — United States, 2011–2016*. Centers for Disease Control and Prevention.

UN Environment Programme. 2022. *Adaptation Gap Report 2022: Too Little, Too Slow – Climate adaptation failure puts world at risk*. Nairobi. https://www.unep.org/resources/adaptation-gap-report-2022.

United Nations, Department of Economic and Social Affairs, Population Division. 2019. *World Urbanization Prospects: The 2018 Revision*. New York: United Nations.

U.S. EPA. 2008. Urban Heat Island Basics. In *Reducing Urban Heat Islands: Compendium of Strategies*, 32. Environmental Protection Agency https://www.epa.gov/sites/default/files/2017-05/documents/reducing_urban_heat_islands_ch_1.pdf.

———. 2016. *What Climate Change Means for Oklahoma*. https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-ok.pdf.

———. 2023a. Heat Island Community Actions Database. https://www.epa.gov/heatislands/heat-island-community-actions-database#:~:text=Annapolis%20Energy%20Efficiency%20Resolution%20–%20In,range%20of%20energy%20efficiency%20measures.

———. 2023b. What is EJScreen? *Overviews and Factsheets*. https://www.epa.gov/ejscreen/what-ejscreen.

———. 2024. EJScreen Map Descriptions. *Collections and Lists*. https://www.epa.gov/ejscreen/ejscreen-map-descriptions.

VanderMolen, K., N. Kimutis, and B. J. Hatchett. 2022. Recommendations for increasing the reach and effectiveness of heat risk education and warning messaging. *International Journal of Disaster Risk Reduction* 82:103288. https://linkinghub.elsevier.com/retrieve/pii/S2212420922005076 (last accessed 5 April 2024).

Vanos, J. K., L. S. Kalkstein, and T. J. Sanford. 2015. Detecting synoptic warming trends across the US Midwestand implications to human health and heat-related mortality. *International Journal of Climatology* 35 (1):85–96. https://onlinelibrary.wiley.com/doi/10.1002/joc.3964 (last accessed 2 December 2022).

Virginia Department of Forestry. Community Forest Revitalization Program. https://dof.virginia.gov/urban-community-forestry/urban-forestry-community-assistance/community-forest-revitalization-program/.

Weber, S., N. Sadoff, E. Zell, and A. de Sherbinin. 2015. Policy-relevant indicators for mapping the vulnerability of urban populations to extreme heat events: A case study of Philadelphia. *Applied Geography* 63:231–243. https://linkinghub.elsevier.com/retrieve/pii/S014362281500171X (last accessed 17 March 2023).

Williams, M., and T. Moser. 2019. The Art of Coding and Thematic Exploration in Qualitative Research. 15 (1). http://www.imrjournal.org/uploads/1/4/2/8/14286482/imr-v15n1art4.pdf.

Wilson, B. 2020. Urban Heat Management and the Legacy of Redlining. *Journal of the American Planning Association* 86 (4):443–457. https://www.tandfonline.com/doi/full/10.1080/01944363.2020.1759127 (last accessed 23 April 2023).

Winbourne, J. B., T. S. Jones, S. M. Garvey, J. L. Harrison, L. Wang, D. Li, P. H. Templer, and L. R. Hutyra. 2020. Tree Transpiration and Urban Temperatures: Current Understanding, Implications, and Future Research Directions. *BioScience* 70 (7):576–588. https://academic.oup.com/bioscience/article/70/7/576/5857071 (last accessed 20 November 2022).

Winguth, A. M. E., and B. Kelp. 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. https://journals.ametsoc.org/view/journals/apme/52/11/jamc-d-12-0195.1.xml (last accessed 9 March 2023).

Wisconsin Department of Natural Resources. Urban Forestry Grants. *Wisconsin Department of Natural Resources*. https://dnr.wisconsin.gov/topic/urbanforests/grants.

Yasmeen, S., and H. Liu. 2019. Evaluation of thermal comfort and heat stress indices in different countries and regions – A Review. *IOP Conference Series: Materials Science and Engineering* 609 (5):052037. https://iopscience.iop.org/article/10.1088/1757-899X/609/5/052037 (last accessed 22 March 2023).

Yoon, A. 2023. *Bus Shelter Equity: A study of the distribution of bus shelters in Los Angeles County and unincorporated communities*. Los Angeles, California: University of California, Los Angeles. https://escholarship.org/uc/item/0fx2c8pn.

Zhang, J., A. Mohegh, Y. Li, R. Levinson, and G. Ban-Weiss. 2018. Systematic Comparison of the Influence of Cool Wall versus Cool Roof Adoption on Urban Climate in the Los Angeles Basin. *Environmental Science & Technology* 52 (19):11188–11197. https://pubs.acs.org/doi/10.1021/acs.est.8b00732 (last accessed 24 May 2023).

Zhang, K., T.-H. Chen, and C. E. Begley. 2015. Impact of the 2011 heat wave on mortality and emergency department visits in Houston, Texas. *Environmental Health* 14 (1):11. https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-14-11 (last accessed 18 July 2022).

Zhao, C., J. L. R. Jensen, Q. Weng, N. Currit, and R. Weaver. 2020. Use of Local Climate Zones to investigate surface urban heat islands in Texas. *GIScience & Remote Sensing* 57 (8):1083–1101. https://www.tandfonline.com/doi/full/10.1080/15481603.2020.1843869 (last accessed 23 April 2023).

Zhao, F., L.-F. Chow, M.-T. Li, I. Ubaka, and A. Gan. 2003. Forecasting Transit Walk Accessibility: Regression Model Alternative to Buffer Method. *Transportation Research Record: Journal of the Transportation Research Board* 1835 (1):34–41. http://journals.sagepub.com/doi/10.3141/1835-05 (last accessed 24 April 2024).

Zhao, Q., C. Dickson, J. Thornton, P. Solís, and E. A. Wentz. 2020. Articulating strategies to address heat resilience using spatial optimization and temporal analysis of utility assistance data of the Salvation Army Metro Phoenix. *Applied Geography* 122:102241. https://linkinghub.elsevier.com/retrieve/pii/S0143622819308719 (last accessed 3 April 2024).

Zhou, W., S. Ji, T.-H. Chen, Y. Hou, and K. Zhang. 2014. The 2011 heat wave in Greater Houston: Effects of land use on temperature. *Environmental Research* 135:81–87. https://linkinghub.elsevier.com/retrieve/pii/S0013935114002916 (last accessed 23 April 2023).

Ziter, C. D., E. J. Pedersen, C. J. Kucharik, and M. G. Turner. 2019. Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proceedings of the National Academy of Sciences* 116 (15):7575–7580. https://pnas.org/doi/full/10.1073/pnas.1817561116 (last accessed 18 July 2022).