Differential Adaptive Capacity to Extreme Heat: A Phoenix, Arizona, Case Study

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ABSTRACT

Climate change is projected to increase the number of days producing excessive heat across the southwestern United States, increasing population exposure to extreme heat events. Extreme heat is currently the main cause of weather-related mortality in the United States, where the negative health effects of extreme heat are disproportionately distributed among geographic regions and demographic groups. To more effectively identify vulnerability to extreme heat, complementary local-level studies of adaptive capacity within a population are needed to augment census-based demographic data and downscaled weather and climate models. This pilot study, conducted in August 2009 in Phoenix, Arizona, reports responses from 359 households in three U.S. Census block groups identified as heat-vulnerable based on heat distress calls, decedent records, and demographic characteristics. This study sought to understand social vulnerability to extreme heat at the local level as a complex phenomenon with explicit characterization of coping and adaptive capacity among urban residents.

1. Introduction

Climate change is projected to increase the number of days with excessive heat across the southwestern United States, increasing population exposure to extreme heat (Solomon et al. 2007; Diffenbaugh and Ashfaq 2010). Extreme heat is currently the main cause of weather-related mortality in the United States [(Centers for Disease Control) CDC 2006; NOAA 2010], and the negative health effects of extreme heat are disproportionately distributed among geographic regions and demographic groups (Kilbourne 1997; Harlan et al. 2006; Buyantuyev and Wu 2009; Johnson et al. 2009; Ruddell et al. 2010; Anderson and Bell 2011). Performing research to better characterize regions and populations at risk and modify responses to heat according to local ecologies and cultural settings is critical to reducing heat-related morbidity and mortality. Although extreme heat and related morbidity and mortality are on the rise in urban settings (Kovats and Hajat 2008; UN-Habitat 2009), the actual number of extreme heat events fluctuates in response to variability in the geographic location and the extent and number of heat waves that occur annually. To date, few studies have considered the complexity of vulnerability and its relationship with the capacity to cope with, or adapt to, extreme heat, particularly as it pertains to social capital (Wolf et al. 2010; Abrahamson et al. 2009; Kalkstein and Sheridan 2007; Sheridan 2007; Harlan et al. 2006). Coping is the ability of a system (or actors within a system) to manage external stress, such as excessive heat. In a social setting, coping involves taking steps to reduce exposure and impacts while not fundamentally altering the social or physical system. In contrast, adaptive capacity is a measure of the resources (e.g., social, financial, physical) required to undertake or bring about change to the social or biophysical system to systematically reduce potential harm—including improving coping capacity (Yohe and Tol 2002; Adger 2003; Smit and Wandel 2006). In keeping with Few (2007) and Wilhelmi and Hayden (2010), we propose that examining social vulnerability from an aggregate perspective (i.e., census demographic data) presents only a partial view of extreme heat health risks and responses and does not allow for an understanding of existing coping or potential adaptive capacity. In addition, identifying differential characteristics of adaptive capacity among the...
most vulnerable residents could lead to more targeted health interventions and effective extreme-heat preparedness programs. This concept of differential ability to cope with present and future heat stress is important, as there may be profound increases in morbidity and mortality in response to direct and indirect mechanisms associated with future climate change. Therefore, public health measures need to focus not only on reactive or short-term responses to heat stress, but also on long-term adaptation measures. To do so, adaptive capacity research needs to converge on developing collaborative efforts that engage the community to bring about assessments of existing coping capacity and explicit resource needs, as well as practical initiatives to reduce vulnerability. This can only effectively be undertaken when a multilevel, multidirectional approach is considered (Smit and Wandel 2006; Lopez-Marrero 2010; Yardley et al. 2010); specifically, an approach that engages both from the top down and the bottom up (Wilhelmi and Hayden 2010), employing strategies that connect participants from the state, county, and city level down to the neighborhood level.

As such, to better understand current coping and adaptive capacity within a given population, we conducted a pilot study whereby we identified neighborhoods at the scale of the U.S. Census block group level that might be vulnerable to extreme heat exposure based on 911 heat distress calls, decedent records, and demographic characteristics within the Phoenix, Arizona, metropolitan area. (Fig. 1) This study was designed to examine how members of three U.S. Census block groups (referred to in this study as neighborhoods A, B, and C) with variable degrees of vulnerability indicators (e.g., income levels and racial composition) understood symptoms of heat stress and how they modified their behavior in response to extreme heat. Survey questions also sought to reveal what types of resources respondents had available to them, both physical and social, to cope with extreme heat in a region of the United States known for excessive heat during the summer season. Previous studies have advocated for the need to understand both physical and social responses to hazards, and research by Klinenberg (2002) supported the importance of determining existing social capital as a mechanism to understand differential adaptive capacity to survive extreme heat. To this end, we queried participants from 359 households across three U.S. Census block groups regarding their

![Fig. 1. Phoenix, AZ; U.S. Census block groups 2000; general areas in which study neighborhoods are located are denoted by solid red circles.](image-url)
knowledge, attitudes, and practices during extreme heat events, including steps taken to cope with extreme heat, and factors that facilitated or served as barriers to reducing overall vulnerability to extreme heat.

This paper describes results from a pilot study that sought to undertake a more nuanced exploration of the differential adaptive capacity among selected census block groups that were potentially at risk from extreme heat and to inform public health officials and other stakeholders of possible adaptation strategies to address differential vulnerability. The following sections in the paper provide a brief background of heat-related health effects in general, and of Phoenix, Arizona, in particular. The study site and methods are then described to set the stage for the Phoenix case study. Then we present the results related to awareness of heat risks, information about heat, experience with heat-related health problems, steps for coping, awareness of programs and resources to bolster coping, and social isolation/crime that may influence coping strategies. We then examine community variation among the neighborhoods and discuss differential adaptive capacity and overall vulnerability. We briefly address limitations of the study and finally the conclusions provide some short and long-term recommendations targeted at the specific neighborhoods within the study area.

2. Background

Heat-related mortality occurs across a range of geographic settings and in countries with all levels of income (Hajat and Kosatsky 2010). Decedent records from extreme-heat events indicate that certain demographic characteristics are associated with increased vulnerability (Wilhelmi et al. 2004), and conditions that lead to exposure to extreme heat may be related to socioeconomic differences (Wilhelmi et al. 2012). Those older than 75 yr or younger than 5 yr are less physiologically capable of adjusting to extreme heat, and they may not perspire adequately to cool their bodies (Luber and McGeehin 2008). Low-income and minority populations who are exposed to higher temperatures and related health risks associated with higher housing density and less green environments are at highest risk from heat-related morbidity and mortality in the United States (CDC 2006; Harlan et al. 2006; Golden et al. 2007; Uejio et al. 2011). Furthermore, those living in heat-stressed neighborhoods have fewer coping resources to deal with extreme heat (Davis et al. 2004; Naughton et al. 2002; O’Neill et al. 2003; Harlan et al. 2008). Certain preexisting medical conditions and disabilities also contribute to heat-related morbidity and mortality (McGeehin and Mirabelli 2001). Additionally, indications are that social isolation—living alone without regular contact with others—plays a role in increased vulnerability to extreme-heat events (e.g., Klinenberg 2002; Le Tertre et al. 2006). Recent data and studies in the greater Phoenix, Arizona, area, a metropolitan region in which the residents are assumed to be “acclimated” to the heat, show an average of 26 heat-related deaths every summer season (1992–2009) from exposure to excessive heat (ADHS 2010). In the poorest neighborhoods—those with highest rate of minority status, lowest education and income levels, and highest percentages of Spanish-only speakers—vulnerability to heat-related weather events was high, particularly among the elderly and the young (Harlan et al. 2006).

Negative heat health outcomes in Phoenix, Arizona, may not result from lack of awareness among the residents about extreme heat. Survey-based research targeting elderly residents (> 65 yr) in four North American cities (including Phoenix) sought to examine the effectiveness of heat-watch warning systems (Sheridan 2007). Despite widespread awareness of heat warnings in the Phoenix area (90% of elderly residents surveyed were aware of heat warnings), on average, only 35% of Phoenix respondents reported modifying behaviors to reduce exposure during extreme heat events (Sheridan 2007). Furthermore, a 2001 convenience study in the metropolitan Phoenix area suggested that despite an overall concern about the dangers associated with heat and a high level of awareness regarding issued warnings, less than half (47.3%) of the respondents reported taking different action in response to heat warnings and advisories (Kalkstein and Sheridan 2007).

Despite the fact that decedent records and recent survey work reveal specific indicators of vulnerability to extreme heat, behavioral aspects of vulnerability to extreme heat are not well understood. To address this gap, this study used the framework developed by Wilhelmi and Hayden (2010) to contribute toward understanding and addressing heat-related vulnerability by expanding the knowledge of a population’s adaptive capacity at the household level in three socioeconomically and ethnically diverse census block groups in Phoenix, Arizona (Table 1). The Extreme Heat Vulnerability Framework (Fig. 2) outlines the conceptual elements of adaptive capacity and other internal and external factors of extreme-heat vulnerability.

3. Study site and methods

a. Study site

Phoenix, a major metropolitan area in central Arizona in the southwestern United States (population 1.5 million), is located in the Sonoran Desert (Fig. 1). Summer temperatures regularly climb above 100°F (37.8°C) with minimum temperatures often sustained at 90°F (32°C) or above for long periods (NOAA 2010). Although
heat-wave warnings are only issued when temperatures are projected to be above 110°F (43°C) for three consecutive days (A. Haefer 2008, personal communication), high nighttime temperatures may be a factor in reduced ability to cope with extreme heat. Recent work in the Phoenix metropolitan area indicates statistically significant differences in exposure to heat as well as the population’s capacity to cope (Harlan et al. 2006). Despite the extreme heat and demonstrated population vulnerability within Phoenix, the city’s official municipal heat-mitigation plan is still under development. However, the Phoenix NWS office does issue heat warnings based on “oppressive” air masses linked with mortality (Kalkstein and Sheridan 2007) and engages with the local National Weather Service (NWS) office in the event of heat watches and warnings by activating its Heat Emergency Response plan so that surveillance for vulnerable populations increases. These plans are in the process of being more fully developed and will focus on those deemed vulnerable by the city: “the elderly, individuals with a serious mental illness, homeless, medically frail, and/or shut-ins.” Currently, heat-related information posted on the Arizona Department of Health Services (ADHS) hotline is available in both English and Spanish (ADHS 2011).

Vulnerability to extreme heat is not a new phenomenon in Arizona (Yip et al. 2008). Between 1993 and 2003, 253 deaths in Arizona were heat-related, according to a report published by the CDC (CDC 2005). The age-adjusted death rate, based on U.S. death certificate data, was 3 to 7 times higher in Arizona for those 25 years old and older as compared to the U.S. overall. In 2009, when our pilot study was conducted, Maricopa County reported 71 heat-related deaths (V. Berisha 2010, personal communication).

b. Methods

Door-to-door household surveys were conducted in Phoenix during the first two weeks of August 2009, during which time maximum daytime temperatures averaged 107.2°F (41.8°C) and minimum temperatures averaged 83.2°F (28.4°C). On 2 and 3 August maximum temperatures were reached of 113°F (45°C) and 114°F (45.5°C), respectively, both of which tied a record for the dates (NOAA 2009). This seasonal time frame was selected to reduce potential recall bias among survey participants. To sample populations specifically in heat-vulnerable neighborhoods, U.S. Census block groups were stratified by race/ethnicity, decedent records of heat

Table 1. Sample description by neighborhood. Footnotes indicate statistically significant differences among neighborhoods.

<table>
<thead>
<tr>
<th></th>
<th>Neighborhood A</th>
<th>Neighborhood B</th>
<th>Neighborhood C</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (% female)</td>
<td>66.7%</td>
<td>56.8%</td>
<td>45.8%</td>
<td>54.1%*</td>
</tr>
<tr>
<td>Age (mean)</td>
<td>38.7 yr</td>
<td>39.1 yr</td>
<td>43.7 yr</td>
<td>40.9 yr</td>
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<tr>
<td>Tenure (mean)</td>
<td>20 yr</td>
<td>17.8 yr</td>
<td>27 yr</td>
<td>21.9 yr</td>
</tr>
<tr>
<td>Owner occupied (%)</td>
<td>40.7%</td>
<td>61.5%</td>
<td>82.5%</td>
<td>66.5%*</td>
</tr>
<tr>
<td>Number of occupants (3+)</td>
<td>88.1%</td>
<td>84%</td>
<td>73.1%</td>
<td>80.3%</td>
</tr>
<tr>
<td>Language</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>15%</td>
<td>26.9%</td>
<td>48.6%</td>
<td>33.7%</td>
</tr>
<tr>
<td>Spanish</td>
<td>31.7%</td>
<td>12.8%</td>
<td>7.5%</td>
<td>13.8%</td>
</tr>
<tr>
<td>Both</td>
<td>50%</td>
<td>58.3%</td>
<td>41.4%</td>
<td>50%</td>
</tr>
<tr>
<td>Other</td>
<td>3.4%</td>
<td>1.9%</td>
<td>2.7%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>1.7%</td>
<td>7.7%</td>
<td>33.6%</td>
<td>17.1%*</td>
</tr>
<tr>
<td>Caucasian</td>
<td>3.3%</td>
<td>18.6%</td>
<td>7.5%</td>
<td>11.6%*</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>88.3%</td>
<td>71.2%</td>
<td>55.5%</td>
<td>67.7%*</td>
</tr>
<tr>
<td>American Indian</td>
<td>8.3%</td>
<td>4.5%</td>
<td>2.1%</td>
<td>3.9%</td>
</tr>
<tr>
<td>Other</td>
<td>5.1%</td>
<td>1.9%</td>
<td>0.7%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>55%</td>
<td>35.3%</td>
<td>20.8%</td>
<td>32.8%*</td>
</tr>
<tr>
<td>High school</td>
<td>30%</td>
<td>30.8%</td>
<td>34.7%</td>
<td>32.2%*</td>
</tr>
<tr>
<td>Some college</td>
<td>11.7%</td>
<td>22.4%</td>
<td>29.9%</td>
<td>23.6%*</td>
</tr>
<tr>
<td>College graduate</td>
<td>3.3%</td>
<td>11.5%</td>
<td>14.6%</td>
<td>11.4%*</td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>38.3%</td>
<td>43.9%</td>
<td>33.8%</td>
<td>38.9%</td>
</tr>
<tr>
<td>Outdoor</td>
<td>15%</td>
<td>14.2%</td>
<td>8.6%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Indoor service</td>
<td>31.7%</td>
<td>25.7%</td>
<td>41%</td>
<td>32.9%</td>
</tr>
<tr>
<td>Indoor office</td>
<td>15%</td>
<td>16.2%</td>
<td>16.5%</td>
<td>16.1%</td>
</tr>
</tbody>
</table>

* p ≤ 0.05.

b p ≤ 0.01.

* p ≤ 0.001.
mortality (S. Harlan 2009, personal communication), and heat-related 911 calls (Uejio et al. 2011). Three block groups were then randomly selected to represent varying levels of poverty (14%, 22%, and 44%) as reported in the U.S. Census 2000. Expert opinion was subsequently solicited from local, county, and state public health officials to ensure research team safety. The number of houses sampled in each neighborhood was determined proportional to population based on an estimated frequency of 50% (unknown) air conditioning use at the 95% confidence level (using version 2 of OpenEpi, available online at www.openepi.com). Three hundred eighty-four households were randomly selected among the three neighborhoods using residential parcels GIS data (D. Ruddell 2009, personal communication) and spatial analysis tools (Hawth’s Analysis Tools, Spatial Ecology Version 3.27), resulting in 362 completed surveys, of which 359 surveys were analyzed after 100% quality control.

Data were collected using semistructured surveys conducted at the randomly selected households noted previously (National Center for Atmospheric Research Human Subjects Committee approval 2008–014). Five bilingual teams conducted the interviews with the first person 18 yr or older encountered in each household. Interviews were conducted in either Spanish or English based on participant preference. The survey questionnaire included questions about participants’ knowledge, attitudes, and practices around extreme heat, sources of information for heat warnings, experience with and response to heat, coping mechanisms and barriers to their use, social capital (such as how well they knew their neighbors and if they would call their neighbor in an emergency), and extent of knowledge of existing neighborhood, community, and city-wide resources to mitigate extreme heat. Some questions were closed-ended to generate quantitative data; others were open-ended to contextualize closed-ended responses and allow respondents to describe their experiences and views in greater depth in their own words. The survey questionnaire was pretested with several residents of the Phoenix area and revised prior to implementation based on the pretests.

4. Results

Analyses were performed using SPSS software (version 18; SPSS, Inc., Chicago, IL). Frequency analyses were conducted to provide descriptions of the three neighborhoods, including demographic characteristics of respondents, and Pearson’s chi-square test was conducted to assess differences among neighborhoods. Results indicated that among the 359 respondents, just over half were female with a median age of 40.9 yr. Average tenure in the Phoenix area was just over 20 yr and over half of respondents were homeowners in households. While

FIG. 2. The Extreme Heat Vulnerability Framework explicitly represents population’s adaptive capacity through qualitative and quantitative interview data (from Wilhelmi and Hayden 2010).
respondents from the three neighborhoods were relatively similar in terms of age, sex, and tenure, there were significant differences in the rates of owner versus renter, ethnicity, and education (Table 1). Occupation, often a proxy for socioeconomic status, was not significantly different among study communities.

a. Awareness of heat risks

To gauge familiarity with physiological responses to heat, participants were asked to list as many symptoms as possible that they felt were associated with exposure to extreme heat. Overall, study participants were able to list multiple symptoms associated with heat stress. The most commonly reported symptoms were intense thirst/dehydration (47.5%), dizziness (39.6%), headaches (28.7%), nausea (27.9%), and fatigue (24.8%). Interestingly, participants also reported heatstroke (7.24%), skin problems (e.g., heat rash, cancer; 4%), respiration problems (2.5%), and diarrhea (1.6%) as symptoms associated with exposure to too much heat. Qualitative data collected through open-ended questions suggest that there may be some confusion about the role sun exposure plays in heat stress. Almost 10% of respondents reported using sunscreen [9.6% (n = 35)] as a way of protecting oneself from heat. This may indicate that while a broad understanding of heat stress exists, there is still room for education regarding how to protect oneself from excess heat exposure.

b. Information

Overall, respondents reported having a high degree of awareness about heat warnings from passive sources of information. Slightly more than 80% of respondents (80.2%) reported having heard warnings about excessive heat in the summer of 2009. The primary source of heat-related information was from local television (72.1%), suggesting that the local meteorologist may be an important conduit for dissemination of heat-related information. This is corroborated by previous research suggesting that people tend to develop relationships with specific individuals in the media, and many find television a trustworthy and expert source of hazard information and recommendations (Driscoll and Salwen 1996; Sherman-Morris 2005; Phillips and Morrow 2007; Morss and Hayden 2010). Other sources of heat-warning information cited by the participants included cable/satellite television (7.2%) and radio (7.8%).

Among respondents who actively sought information about heat-related illness, 48.9% of respondents reported that they would use the Internet to look for information about heat-related illness (only 13.4% would look for such information on the television and only 2.2% would rely on the radio). Only 18.6% of respondents reported ever having spoken with a doctor about steps to prevent heat-related illness, a similar rate to those who had spoken with family members (17.7%). Importantly, a large percentage, 46.3% (n = 152), reported never having spoken with anyone about how to prevent heat-related illness, despite the fact that nearly one-third of participants reported CDC-cited symptoms (CDC 2005) related to exposure to heat.

c. Experience

Among the respondents, 36.2% (n = 129) reported symptoms related to heat or high temperatures such as leg cramps, dry mouth, dizziness, fatigue, fainting, rapid heartbeat, or hallucinations during the summer of 2009.

Among those reporting heat-related symptoms, 30.9% (n = 38) were unemployed, 16.3% (n = 20) worked outdoors, 35.8% (n = 44) worked indoor service jobs, and 17.1% (n = 21) worked indoor office jobs. Twenty-six percent of respondents (n = 95) reported that a family member had experienced heat-related symptoms in the summer of 2009. Among all respondents reporting heat-related symptoms, 89.9% (n = 116) used air conditioning and 20.9% (n = 27) used evaporative coolers to cool their home at rates identical to air conditioning (89%) and evaporative cooler (20.7%) use for the total sample.

Thirty-six percent (35.8%) of respondents worked at indoor service jobs, which might seem protective because most commercial buildings are air conditioned. However, qualitative data reveal that some of those interviewed worked in buildings after normal business hours in janitorial positions where the air conditioning was turned off at 6 p.m. to reduce electricity costs, potentially increasing their vulnerability, particularly as most of the respondents in this category were performing physical labor.

Not surprisingly, 95.3% of respondents indicated that they felt most at risk to heat-related illness outdoors.

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1 Can you tell me any symptoms you think you can get from too much heat?
2 Can you tell me where you heard weather warnings about excessive heat this summer?
3 Where have you found or would you look for information about heat-related illness?
4 Have you had symptoms this summer related to heat or high temperatures such as leg cramps, dry mouth, dizziness, fatigue, fainting, rapid heartbeat, or hallucinations?
5 Has anyone in your family had symptoms this summer related to heat or high temperatures such as leg cramps, dry mouth, dizziness, fatigue, fainting, rapid heartbeat, or hallucinations?
6 Which of the following are you using to cool your house this summer? (Options: air conditioning, swamp or evaporative cooler, fans, awnings, shades and/or shutters, misters, trees and plants, none, or other).
many commenting on the fact that even staying in the
shade while outdoors in Phoenix is not protective. Lack
of transportation places people at risk either because they
are exposed outdoors while walking to the bus stop and/or
waiting for the bus, or because they are unable to mitigate
the heat in their cars with air conditioning, having to drive
with the windows lowered. Fully 30% (n = 109) of re-
spondents reported using the bus for transportation, likely
placing them at risk when having to walk to the bus stop
and/or wait outdoors for the bus. Of those who did own a
car, 13.2% (n = 42) did not have a working air condi-
tioner in the car, and some mentioned feeling at risk to
extreme heat in the car without air conditioning.
Participants in the study were asked if they ever felt
too hot inside their homes. While there were no signifi-
cant differences among neighborhoods, those who rented
their homes and those who listed their race/ethnicity as
Hispanic were significantly more likely to report feeling
too hot inside their homes. However, not speaking En-
glish at home and being unemployed were not signifi-
cantly associated with feeling hot inside one’s home.
Furthermore, although one might suspect that residents
who were new to the Phoenix area might be more vul-
erable or less “acclimated” to extreme heat, length of
time or tenure in the city of Phoenix was not significantly
related to having felt heat-related symptoms that summer
either among the respondents or their families (Table 2).

d. Coping

The two most commonly reported strategies to pro-
tect oneself from heat were staying indoors (62.1%) and
drinking plenty of water (66.9%). Most respondents
(82.3%) reported altering daily outdoor activities in order
to cope with very hot weather by limiting outdoor activities,
engaging in outdoor activities early in the morning or late in
the evening, and staying inside. Others suggested not al-
lowing children to play outdoors, go to the park, or par-
ticipate in summer sports. This suggests that the majority
of respondents believed themselves to be enough at risk
to heat-related illness that a change in behavior was
warranted.
While staying inside was a predominant strategy re-
spondents reported using as protection from heat, 38%
reported feeling too hot inside their homes during the hot
season. This was true despite the fact that 89% of re-
spondents reported having air conditioning in their homes.
While this may seem to be a high percentage, 36.4% of respondents reported that the cost of electricity prevented
them from using their air conditioner and 6% reported
having a nonfunctional air conditioner (Table 3). Among
those reporting that cost of electricity prevented them
from using the air conditioner, 89.7% (n = 113) have
central air and 16.8% (n = 21) have evaporative coolers
(rates consistent with the overall sample of air conditioner
users with 88.3% reporting central air conditioning and
12.4% reporting using window units).
Prohibitive costs not only led households to limit air
conditioner use, but participant observation and quali-
tative data reveal that even in houses with running air
conditioners, use was often limited to simply reducing
the extreme heat but not necessarily providing relief.

e. Awareness of programs/resources for coping

Despite the fact that in 2009 Phoenix had 51 hydration
stations and 42 refuge stations11 across the city, only
31.7% of respondents indicated that they knew what a
heat refuge station was. Furthermore, only 15.1% of
those who were familiar with heat refuge stations knew
where one was located. Not surprisingly, only 9 respon-
dents from the sample of 359 had ever used a heat refuge
station. Additionally, respondents were unaware of the
resources available to them through city programs to repair
air conditioners and assist with payment of electric bills
during the hot summer months and/or extreme heat events.

f. Social isolation/crime

As a research team, we had been advised to collect data
only during daylight hours because of general concerns
about crime and gang activity in our selected neighbor-
hoods. As such, we expected that issues of social isolation,
fear, and lack of community interaction would make
residents in the three target neighborhoods more vul-
erable to heat hazards. Indeed, the literature suggests
that residents who do not feel safe in their neighbor-
hoods may leave doors and windows closed and locked
in the relative cool of the evenings (Klinenberg 2002).
Despite relatively high rates of crime (violent, prop-
erty, and drug-related) based on crime statistics reported
by the Phoenix police (City of Phoenix Crime Statistics
2009) indicating that the targeted neighborhoods might
not be “safe,” 91.1% of those surveyed reported feeling
safe. All of the study neighborhoods reported violent,

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7 Where do you feel most at risk to heat-related illness?
8 What steps do you take to protect yourself from the heat during
very hot weather?
9 Do you change your daily outdoor activities when the weather
is very hot? How?
10 Does anything prevent you from using your air conditioning?
11 Hydration station: A place where people can get water or
other donations. Refuge station: A location that provides a safe,
cool place indoors during the day for homeless people.
12 Do you know what a heat refuge station/cooling center is?
property, and drug-related crime during the time period from 1 June to 31 August 2009 (Table 4). The highest numbers of violent, property, and drug-related crime were found in neighborhood B, which was also the census block group with the lowest number of inhabitants below the poverty level. Qualitative responses from participants indicate that nighttime gunshots and drug-related activity were apparent in all neighborhoods.

Further, 53.6% reported knowing most or all of their neighbors. Almost 44% (43.6%) reported talking often or daily, and 83.8% reported feeling comfortable asking for assistance from a neighbor, suggesting that they knew a neighbor well enough to ask for help. Three-quarters of respondents (74.5%) reported that the nearest person they would call in an emergency was either their next-door neighbor or someone in the neighborhood. Interestingly, there were no significant differences among the communities in response to questions about social networks or social capital.

Despite indications of regular and positive interactions with neighbors, most participants reported that they were not active members of organizations within their neighborhoods. Only 34.3% of participants were members of religious organizations in their neighborhood and only 8% reported being a member of a community group in the neighborhood. Furthermore, less than 10% (9.4%) of respondents were aware of community programs related to heat. Similarly, there were no significant differences among communities.

g. Community variation

Previous research demonstrated high levels of variability of exposure and coping capacity among neighborhoods in the Phoenix metropolitan area but examined a diverse cadre of neighborhoods across the socioeconomic spectrum (Harlan et al. 2006). In this study, we specifically targeted socioeconomically vulnerable neighborhoods to understand them, not in comparison to wealthier neighborhoods, but to identify the ways in which vulnerability and adaptive capacity function within similar neighborhoods. Despite the fact that the target neighborhoods were selected because of their economic and social vulnerability, variation within this categorization is apparent.

Furthermore, while 89% of the overall sample reported having central or window unit air conditioning to cool their homes, the distribution of this resource is not even among the neighborhoods. In neighborhoods B and C, 6.4% and 7.5% (respectively) of the homes do not have air conditioning. In neighborhood A, however, a full 31.7% of the homes do not have air conditioning available to reduce indoor temperatures. The differences among neighborhoods are statistically significant ($p \leq .001$).

Neighborhood A participants reported having more evaporative coolers (35%) compared to 23.1% in

<table>
<thead>
<tr>
<th>Variable</th>
<th>Amount of time spent in Phoenix (yr)</th>
<th>Own home (vs. rent)</th>
<th>Hispanic (vs. non-Hispanic)</th>
<th>English spoken in home</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are you ever too hot inside your own home?</td>
<td>$&lt;3 \quad p &amp; X^2 \quad NS$</td>
<td>$0.007^*$</td>
<td>$0.009^{**}; 0.016^* X^2$</td>
<td>$0.068; 0.108,$</td>
</tr>
<tr>
<td>Have you had symptoms this summer related to heat?</td>
<td>$&lt;3 \quad p &amp; X^2 \quad NS$</td>
<td>$p &amp; X^2 \quad NS$</td>
<td>$p &amp; X^2 \quad NS$</td>
<td>$p &amp; X^2 \quad NS$</td>
</tr>
<tr>
<td>Has anyone in your family had symptoms this summer related to heat?</td>
<td>$&lt;3 \quad p &amp; X^2 \quad NS$</td>
<td>$p &amp; X^2 \quad NS$</td>
<td>$p &amp; X^2 \quad NS$</td>
<td>$p &amp; X^2 \quad NS$</td>
</tr>
</tbody>
</table>

Table 3. Factors that prevent air conditioning use by neighborhood. Participants were asked “Does anything prevent you from using your air conditioning?”.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Neighborhood A</th>
<th>Neighborhood B</th>
<th>Neighborhood C</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of electricity</td>
<td>50%</td>
<td>34.2%</td>
<td>33.3%</td>
<td>36.4%</td>
</tr>
<tr>
<td>Does not work</td>
<td>5.4%</td>
<td>7.9%</td>
<td>4.3%</td>
<td>6%</td>
</tr>
<tr>
<td>Cost of repairs</td>
<td>3.6%</td>
<td>3.9%</td>
<td>2.1%</td>
<td>3.2%</td>
</tr>
</tbody>
</table>
neighborhood B and 12.3% in neighborhood C. Evaporative coolers are generally useful cooling mechanisms during the drier months of the year, but they lose their effectiveness in the summer monsoon months because of the high ambient relative humidity (Kalkstein and Kalkstein 2010).

5. Discussion and recommendations

Societal vulnerability is a major factor in the determination of who experiences the most severe impacts of extreme heat. Although we can forecast the physical extent of a heat wave, it is far more difficult to forecast vulnerability at a scale that will allow for targeted interventions. As this study indicates, access to cooling may be one of the most important factors in determining household-level adaptive capacity. This is, however, a nuanced indicator, as simply noting whether a household has air conditioning is not enough to understand the degree of vulnerability. Many of those in our study neighborhoods had access to cooling devices but still reported feeling too hot inside their homes because they could not afford to cool their homes to the extent necessary for comfort. Our study further notes that many of the most vulnerable were unaware of citywide programs that assist with repairs to broken air conditioners and/or options for city assistance with electric bills during the hot summer months. This indicates the importance of evaluating the dissemination mechanism for critical information. As our study points out, most of our participants were aware of heat warnings and gleaned this information from local television, in particular from the local television broadcast meteorologist. This suggests potential partnerships with public health departments to use this forum to provide information to the population, a mechanism which may enhance population survivability as knowledge of and access to resources will help reduce vulnerability during future extreme heat events.

Previous studies of U.S. and European heat waves underscore other indicators of vulnerability such as social isolation (O’Neill and Ebi 2009; Le Tertre et al. 2006; Vandentorren et al. 2006; Fouillet et al. 2006; Klinenberg 2002). During the August 2003 heat wave in Europe, mortality from extreme heat in France and Italy was associated with social isolation (Fouillet et al. 2006; Michelozzi et al. 2005) as well as environmental factors such as building materials and, in urban heat island settings, bedrooms located on the top floor of a home near the roof (Vandentorren et al. 2006). Interestingly enough, our research shows that the study neighborhoods are places where social cohesion is strong despite negative indicators such as presence of criminal activity. This connectivity may, in fact, be protective against heat-related mortality as more than half of our participants (53.6%) reported knowing most or all of their neighbors and, perhaps more importantly, most participants (83.8%) would feel comfortable asking a neighbor for help. As we move forward with a focus on short-term adaptation strategies, one way to augment the existing strong neighborhood ties as a more effective heat response may be to advocate for neighborhood watch groups to regularly disseminate heat risk-related information in addition to crime-reduction tips, as well as promote checking on the elderly or infirm during heat events akin to the “buddy system” in Philadelphia (Sheridan and Kalkstein 2004). Further strengthening neighborhood ties, a long-term adaptation strategy could be undertaken through budgeting for multiservice centers that would provide a cooling shelter coupled with community outreach programs such as exercise programs and senior-centered activities. This may encourage the use of community cooling centers, as there may be stigma attached to using the existing heat refuge centers in Phoenix because they are specifically targeted to the homeless. However, these proposed multiuse centers do not negate the importance of community-wide efforts to ensure that neighbors, social workers, and home-healthcare providers check on those who are socially isolated during extreme heat events.

One of the surprising results of our study was the uniformity of unemployment rates across our neighborhoods, particularly in light of the variance in poverty levels based on census data. This emphasizes the importance of gathering local-level data because census data, and particularly those statistics that are 9–10 years old, may not be reflective of current circumstances in a neighborhood. It also stresses the lack of adaptive capacity in our neighborhoods as many of the unemployed remain at home during periods without work with diminished economic ability to cool their homes effectively.

### Table 4. Crime statistics for neighborhoods A, B, and C [Source: City of Phoenix Crime Statistics (2009), June–August].

<table>
<thead>
<tr>
<th>Census block group</th>
<th>Population</th>
<th>Violent crime Tot</th>
<th>Property crime Tot</th>
<th>Drug crime Tot</th>
<th>Tot crimes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3777(^a,b)</td>
<td>9</td>
<td>18</td>
<td>7</td>
<td>34</td>
</tr>
<tr>
<td>B</td>
<td>3709(^c)</td>
<td>4</td>
<td>10</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>B</td>
<td>3709(^c)</td>
<td>4</td>
<td>45</td>
<td>7</td>
<td>56</td>
</tr>
<tr>
<td>C</td>
<td>2587(^a)</td>
<td>1</td>
<td>14</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Totals</td>
<td>18</td>
<td>87</td>
<td>21</td>
<td>126</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Population information taken from The American Community Housing Survey estimates for 2005.

\(^b\) One crime grid covered two census block groups, so 3777 reflects the combination of the neighborhood A population (2265) plus the population of the adjacent census block group (1512).

\(^c\) Two crime grids covered one census block group.
Differential adaptive capacity leads to differential vulnerability, which requires interventions targeted to meet the specific needs of those at risk, particularly in times of economic downturn when resources are particularly limited. Neighborhood A is an at-risk community where almost a third of the population is without access to air-conditioning, half of the population with air conditioning cannot cool their homes as needed because of high electricity costs, and adaptive capacity in terms of neighborhood resources is limited, based on 44% of the population living below the poverty level. Long-term adaptation measures such as provision of a multiuse/multiage community center would likely reduce existing vulnerability while lowering crime rates and strengthening neighborhood ties and community involvement (Los Angeles Mayor’s Office 2010). In neighborhoods B and C, approximately one-third of respondents noted that the cost of electricity prevents them from using their air conditioners to the extent needed. These neighborhoods would likely benefit from short-term adaptation measures such as targeted interventions ensuring that residents are provided help with electric bills during the summer heat. All of the neighborhoods could benefit from improved access to information in both English and Spanish about available citywide resources to ameliorate risk from extreme heat, which should be an integral component of a long-term government adaptation strategy.

6. Limitations

This study is limited by the inability to generalize the results of the study to the greater Phoenix area in that only three neighborhoods were sampled in a large urban area, and no ecologic studies were conducted at the time of the interviews, thereby limiting our understanding of potential microlevel environmental differences that could account for individual and household responses to extreme heat. Earlier measurements of the environmental factors, such as mean and maximum surface temperature, vegetation health, and percent of impervious surfaces (Uejio et al. 2011) revealed small variation among three census block groups. Areal mean nighttime surface temperature, measured by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) in 2005 (Uejio et al. 2011) ranged between 30.5°C and 31.6°C (neighborhoods B and A, respectively). Because our 2009 pilot project did not include explicit measurements of environmental parameters in the selected neighborhoods, this study could not evaluate potential impacts of geographic and environmental characteristics on the results. The study does, however, provide a metric for conduct of qualitative studies that address local-level differential adaptive capacity, a first step toward improving our ability to adapt to extreme heat events.

7. Conclusions

This study provides a unique perspective by filling a void in the literature through the provision of local-level qualitative work that is designed to complement quantitatively driven regional-scale weather and climate models. While these models provide robust information about current weather and projected future climate, regional models are not sensitive to local adaptive capacity and do little to further our understanding of how best to adapt in the face of climate variability and change. This study highlights the importance of scale in addressing issues related to adaptation and mitigation; local-level responses to environmental impacts are needed to ensure that the proposed solutions address the problems at a workable scale.

Heat-related deaths and illnesses are preventable. In Arizona, although people may become “acclimated” to the heat over the course of the summer, heat-related deaths still peak during July and August (V. Berisha 2010, personal communication). Short-term coping measures can be undertaken to reduce vulnerability to heat, such as ensuring that information about heat refuge centers or state government utility assistance programs reaches the population most at risk during the course of the summer or in the event of a brownout or blackout. Additionally, providing information on coping measures to prevent heat-related illness such as increasing consumption of water and reduction and rescheduling of activities for cooler mornings or late evenings could be disseminated through broadcast media, in particular through the local broadcast meteorologist. This study focuses on the differences in vulnerability among three block groups that could be considered “at risk” based on initial assessment. The results indicate that vulnerability is nuanced and may be offset by information that is not readily captured through demographic data such as important social ties (i.e., whether a participant would call a neighbor in an emergency). These connections at a neighborhood level likely provide a degree of protection in the event of an extreme heat event or other hazard. However, as previous studies have indicated, over the long term, structural resources need to be allocated to ensure household- as well as neighborhood-level adaptation in the face of extreme heat events. Connections at the neighborhood level are complex people- and place-based interactions; this research highlights the need for more local-level studies to better understand the factors contributing to vulnerability to extreme heat.

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REFERENCES


