Heat vulnerability in Phoenix, Arizona: Health outcomes, sensitivity, exposure, and coping capacity at the neighborhood scale

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Introduction

Vulnerability to heat hazards is on the rise in cities. Heat hazards appear at the intersection of seasonally hot climates, summer heat waves, and city-specific urban heat islands, and are exacerbated by localized climate change effects. Urban heat waves linked to global and regional climate change have been shown to have increased in frequency and intensity over the 20th century as high temperatures exceed normal ranges of temperature variability (Meehl et al. 2004; IPCC 2007). Among weather-related hazards, extreme heat accounts for the majority of fatalities in the United States (CDC 2006). Extreme heat is a seasonal phenomenon, with prolonged events occurring during summers, and intra-urban exposure varying according to ecological and built environment structure (Harlan et al. 2006; Jenerette et al. 2007).

Research Question

How does heat-related vulnerability at the neighborhood scale vary according to socio-economic and ecological differences in Phoenix?

This paper is focused on evaluating the socio-spatial distribution of sensitivity, exposure, and coping capacity that shape present heat-related vulnerability in urban areas in metro Phoenix, Arizona. To do this, we first construct and map a predictive Heat Vulnerability Index (HVI) from socio-economic and biophysical environment variables identified in the climate change vulnerability and public health literature as influencing sensitivity to heat-related hazards. Second, we examine the relationship between exposure and health outcomes by estimating rates of heat-related hospitalizations as a function of air temperature. Third, we compare the hospitalizations/exposure relationship in neighborhoods according to predicted HVI differences. Finally, we will describe coping capacity among neighborhoods with different HVI profiles by analyzing response data from the Phoenix Area Social Survey (PASS, Harlan et al. 2006). PASS is an ongoing study of 45 neighborhoods whose objective is to explore the relationship between social and biophysical environments in Phoenix.

Table 1. Principal components analysis of cumulative heat vulnerability and concentrated disadvantage variables in Maricopa County census block groups

	Factor Loadings[a]		
	Heat vulnerability		
	Factor 1: Socio-economic vulnerability	Factor 2: Vegetation and Built Environment	Factor 3: Age/Isolation
Ethnic Minority	**0.86**	0.09	-0.33
No AC	**0.78**	0.11	-0.03
No H.S. Diploma	**0.85**	0.14	-0.09
Below Poverty	**0.83**	0.13	0.03
Age 65 or Older	-0.29	-0.07	**0.81**
Living Alone	0.06	0.06	**0.81**
Age 65 x Alone	-0.13	-0.01	**0.92**
Developed Imperviousness	0.36	**0.54**	0.41
Unvegetated Surface - Residential (Mean)	0.39	**0.65**	0.30
Unvegetated Surface - Residential (StdDev)	-0.01	**-0.79**	0.10
Unvegetated Surface - Non-Residential (Mean)	0.42	**0.77**	0.19
Unvegetated Surface - Non-Residential (StdDev)	0.06	**-0.80**	0.25

a: Factor extraction performed using varimax rotation
b: Scores in bold indicate similar factor loadings

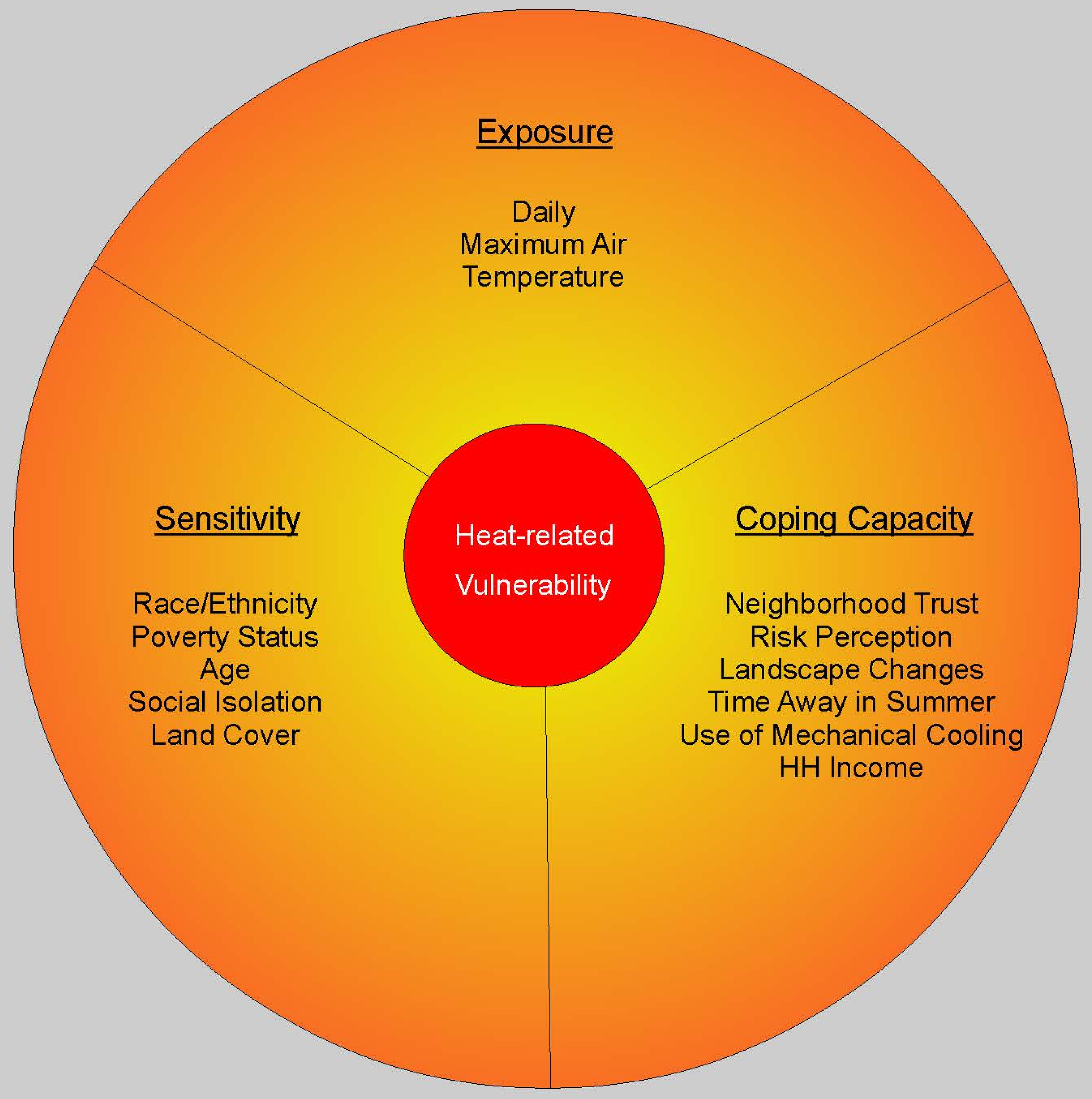
Vulnerability to the effects of climate change occurs within a socio-spatially differentiated spectrum of *exposure*, *sensitivity*, and *coping* (or *adaptive*) *capacity* that can mitigate or exacerbate the impacts of environmental hazards like extreme heat (Romero Lankao et al. 2011; Turner et al. 2003).

Exposure usually refers to the biophysical environment's manifestation of hazards (e.g., extreme temperatures).

Sensitivity describes the degree to which populations are susceptible to the deleterious effects of exposure.

Coping capacity encompasses the mechanisms through which populations cope with environmental hazards (Adger 2006). This tri-partite framework is commonly used throughout climate change vulnerability literature.

A Heat Vulnerability Framework at the Neighborhood Scale (after Adger 2006; Turner et al. 2003; Blaikie et al. 1994)



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Preliminary Results

Sensitivity: Three areas of high vulnerability are apparent in the HVI map: 1) Central Phoenix, encompassing downtown and the Central City South district (i.e., South Phoenix), but also a NW-oriented industrial corridor along the old US Route 66; 2) the elderly residential communities of Sun City, northwest of Phoenix; and 3) an E-W historical transportation corridor extending through the East Valley communities of Tempe and Mesa. The Central Phoenix high vulnerability neighborhoods house a large part of the County's impoverished Black and Hispanic minorities.

Exposure: Census Block Groups in the High HVI category have higher rates of heat-related hospitalizations than those in the Mid and Low categories. The clear gradient of higher hospitalization rates in neighborhoods of higher predicted vulnerability is consistent with previous research that suggests that low-income, minority, and socially-isolated neighborhoods with little vegetation cover are more vulnerable to heat stress than those who are wealthier and have abundant vegetation.

Coping Capacity: Analysis of PASS questions is in preliminary stages and will be reported on later. We are currently selecting questions from the survey that can have an impact in measuring coping capacity in households within neighborhoods.

Future Steps: We will continue refining the vulnerability components results, complete the analysis of coping capacity, and integrate results into a comprehensive discussion of heat-related vulnerability in metro Phoenix.

Health Outcomes & Sensitivity

Health outcomes in this paper are hospitalizations directly due to heat exposure. We account for visits related to summertime temperatures by considering hospitalizations between May and October of each year between 2005 and 2009. These visits are geocoded based on the residential address of the admitted person, and only visits with a geocoding precision of Census Block Group or finer spatial detail, and also within urban areas of Maricopa County were selected (n=1,006).

A Heat Vulnerability Index (HVI) after Harlan et al. (2012) was constructed in order to predict sensitivity to heat-related health outcomes. The HVI incorporates socioeconomic status and biophysical environment variables that are consistently identified in the heat vulnerability literature as determining heat health risks. Scores of three factors yielded from a Principal Component Analysis (PCA) were summed into the HVI. HVI scores were divided into three groups of low, mid, and high sensitivity and mapped below. (See Table 1 for PCA factor loadings).

Exposure

In this paper, exposure is characterized as the rate of heat-related hospitalizations at a maximum daily air temperature (TMAX, °C) by the number of days in the study period that the population was exposed to that TMAX value. We estimate the "Rate of Hospitalizations by Person-Days at TMAX" for each of the three HVI groups in the sensitivity component.

Coping Capacity

PASS responses from survey questions related to social capital, environmental and climate change risk perception, coping mechanisms, and summertime activities, will be analyzed to evaluate potential capacity to cope with extreme heat hazards.

Social Capital:
- Neighborhood trust
- Neighborhood as support network

Summertime Activities:
- Time away from Phoenix
- Seasonal Employment

Cooling capacity:
- Mechanical (air conditioner, evaporative cooler, fan)
- Awnings, shades
- Trees and plants

Environmental Risk Perception:
- Air Pollution
- Drought
- Floods
- Climate Change

Self-reported Health Outcomes:
- Respiratory
- Heat Exposure