Planning for Disaster by Pinpointing Populations Vulnerable to Hazards

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Abstract

In a recent publication (Cutter et al., 2003), the authors constructed a county-level Social Vulnerability Index consisting of 11 variables thought to affect human vulnerability to environmental hazards. I plan to construct a similar weighted index using variables specific to hurricane vulnerability at the census block group level in Louisiana and Mississippi, and compare the outcome with the distribution of fatalities in Hurricane Katrina both visually and statistically to test the predictive capabilities of the resultant index. Indices of this type can pinpoint specifically where special needs planning and extra attention should be focused prior to onset by emergency managers.

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It is an understatement to note that Hurricane Katrina thrust into high relief the vulnerability of certain classes of people in one of the world's richest countries, the United States. Susan Cutter decries this disastrous "confluence of natural and social vulnerabilities" as a failure not only of the government's emergency response at all levels, but of the social support systems for America's impoverished (2005:1). Neil Smith concurs, stating that there is no such thing as a natural disaster, but "who lives and who dies is…a social calculus" (2005:1).

When evaluating personal risk of experiencing a natural hazard, and then assessing what action should be taken should one be threatened by such an event, myriad pieces of information likely come into play, many of which would be difficult to measure. Past experience, exposure to both damaging and non-damaging events, education about the event, from both the formal education system and elsewhere; media exposure, number and location of family members, and type of structure inhabited at the time all likely play a role in assessment of one's own risk and reaction in a disaster situation. Social status can considerably affect each of these factors.

Often the general public's information source about hazards is the national media; aside from television and print news, outlets such as *The Weather Channel, USA Today,* news magazines such as *Time* and *Newsweek*, and other sources such as *National Geographic* offer stories—sometimes informative, sometimes sensational—related to hazards and risk. How, or even if, different social groups view and use this information is at question. Socioeconomic differences between regions and even neighborhoods in the

United States could contribute to fatality rates in several ways, such as the type of structure in which one lives and its ability to withstand an assault by wind, water, or both. Access to media sources—which not only give us maps and stories that influence ideas of our personal risk, but warn us in the face of disasters—may differ among demographic groups, or regionally.

Cutter *et al.* (2003) note several ways in which these socioeconomic differences might affect human vulnerability to natural hazards such as hurricanes, floods, and even tornadoes. Specifically, they note building age; access to resources (such as information, knowledge, and technology); access to health care and physical handicap/frailty (both during and following a storm). Extremes of age affect physical ability to shelter; race/ethnicity can raise language or cultural issues in understanding warnings, as well as maps and stories that influence ideas of personal risk. Many others have covered how socioeconomic factors might relate to not only recovery from disaster, but evacuation and other pre-onset behavior. These factors could thus result in decisions which could even result in death or serious injury.

This paper endeavors to use the ability of geographic information systems (GIS) to pull large quantities and types of data into manageable layers which can be compared and contrasted across space, in an attempt to not only reconstruct a vulnerability index like that of Cutter *et al* but 1) at the block-group level rather than the broad sweep of an entire county, and 2) including education as a variable, and 3) test it to understand if 'vulnerability' includes an increase in fatalities using information from Hurricane Katrina. The goal is to discern whether this index can predict fatality rates and thus would be useful for disaster managers across the country for use in focusing on small areas for evacuation, rescue, or other efforts pre- and post-disaster. Census Summary File 3 for the year 2000, which extrapolates from sample data across each block group, will be used, along with fatality count by census block from the Louisiana Department of Health and Human Services and a very rough collection of address data from Mississippi gleaned from lists of fatality names, obituaries, tax records, as the author was unable to obtain a complete list of fatalities from a central source in time for this effort. This data includes only addresses of victims that are fairly certain. These addresses were geocoded and counted using the spatial join function. Census data was obtained directly from the American Fact Finder at the Census Bureau at block group level for the coastal counties and parishes most affected by Katrina: Harrison and Hancock in Mississippi, and Orleans, Jefferson, St. Bernard, Plaquemines, and St. Charles in Louisiana.

Methodology

Cutter *et al.*'s 2003 variables include the following: personal wealth (measured by per-capita income, median home value, and median rent); age (number of children and number of elderly); density of built environment (housing units); housing stock (items such as mobile homes, location rural/urban); race (African American, especially female-headed African American households); ethnicity (Hispanic and/or Native American, depending on region); occupation (service, especially personal services); and two others difficult to measure at the block group level, infrastructure dependence and single-sector economic dependence. Because of the lack of data for block groups, these last two items were not considered in this study.

My measure will use the following variables in an attempt to replicate those used in the Cutter study, but also include education for reasons noted above. Like Cutter's study, my index will not at first be weighted, and will simply rate block groups in the counties most affected by Hurricane Katrina, noted above, using an SQL statement which finds those with above and below the mean number of the important variables, based on a preliminary statistical study using correlation: percent urban (above, density), percent African American (above), percent over 65 years of age (above), percent schoolaged (under 18) children (above), per-capita income (below), percent below poverty level (above); median home value (below), percent employed in service sector (above), percent unemployed (above), percent not in workforce (an excellent proxy measure for number of dependents–above); percent with less than a high-school education (above), and percentage female heads of household who are African American (above). I first rasterized and then reclassified the data into 12 layers to construct the final additive model, and then calculated the mean value for each block group using Zonal Statistics. The results are presented in Figure 1. The New Orleans area and portions of the Gulfport-Biloxi area (far right) stand out as having several areas well above the mean index value. The areas in blue do not *necessarily* show areas of high socioeconomic status, but just higher relative to the other areas. A countrywide study would probably show much of the South as lower in SES overall relative to the rest of the nation, as does the Cutter *et al.* map. What is shown in Figure 2, however, shows a marked split between the Louisiana and Mississippi block groups. The lower SES areas of Mississippi are, at least at first glance, not areas of high fatalities; this likely reflects the fact that the wealthy are more likely to have beachfront homes. Louisiana, on the other hand, looks more like the predicted map. I will now statistically measure these differences.

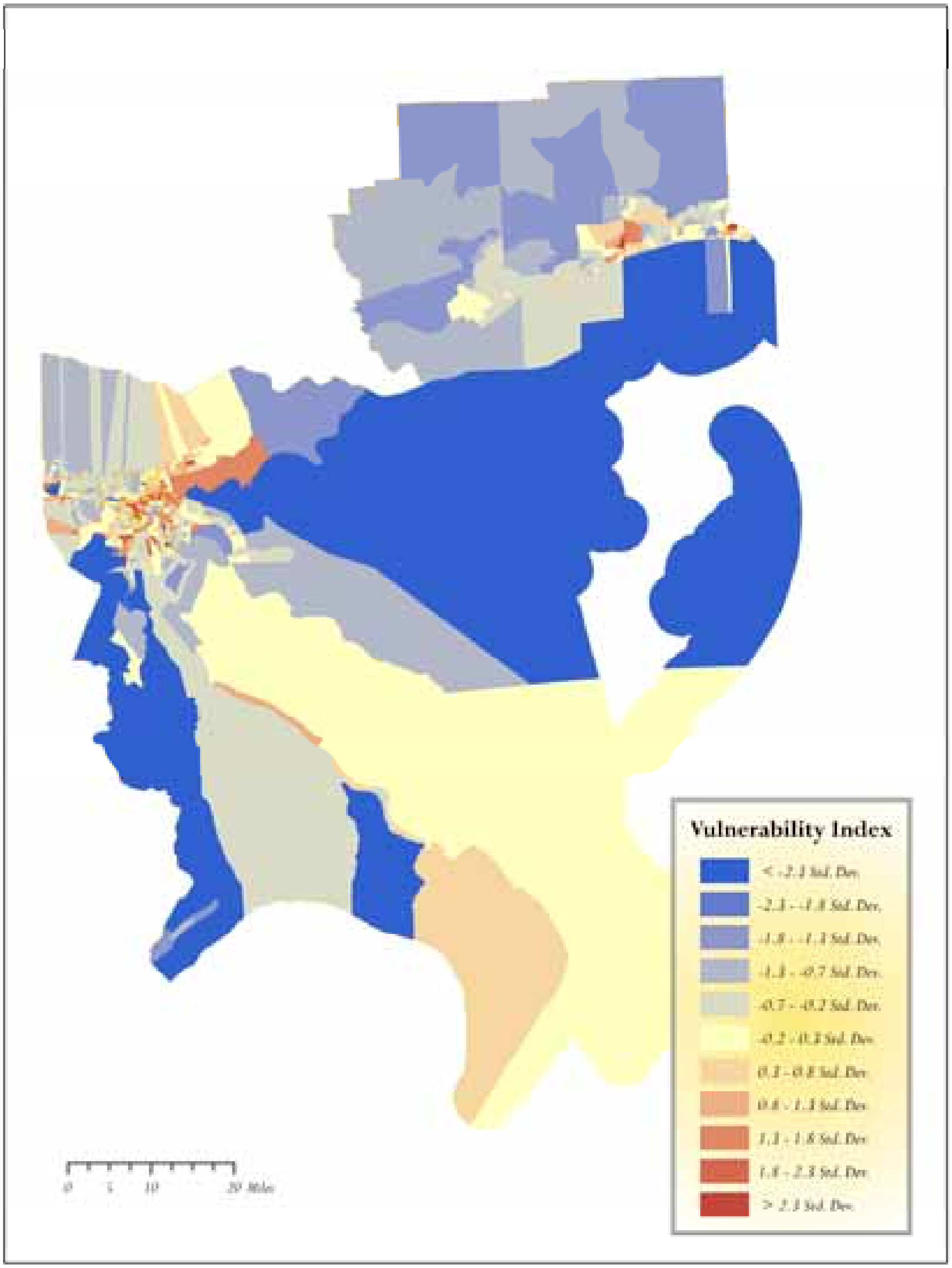

Figure 2: Vulnerability index for Louisiana and Mississippi census block groups, 2006 (2000 data).

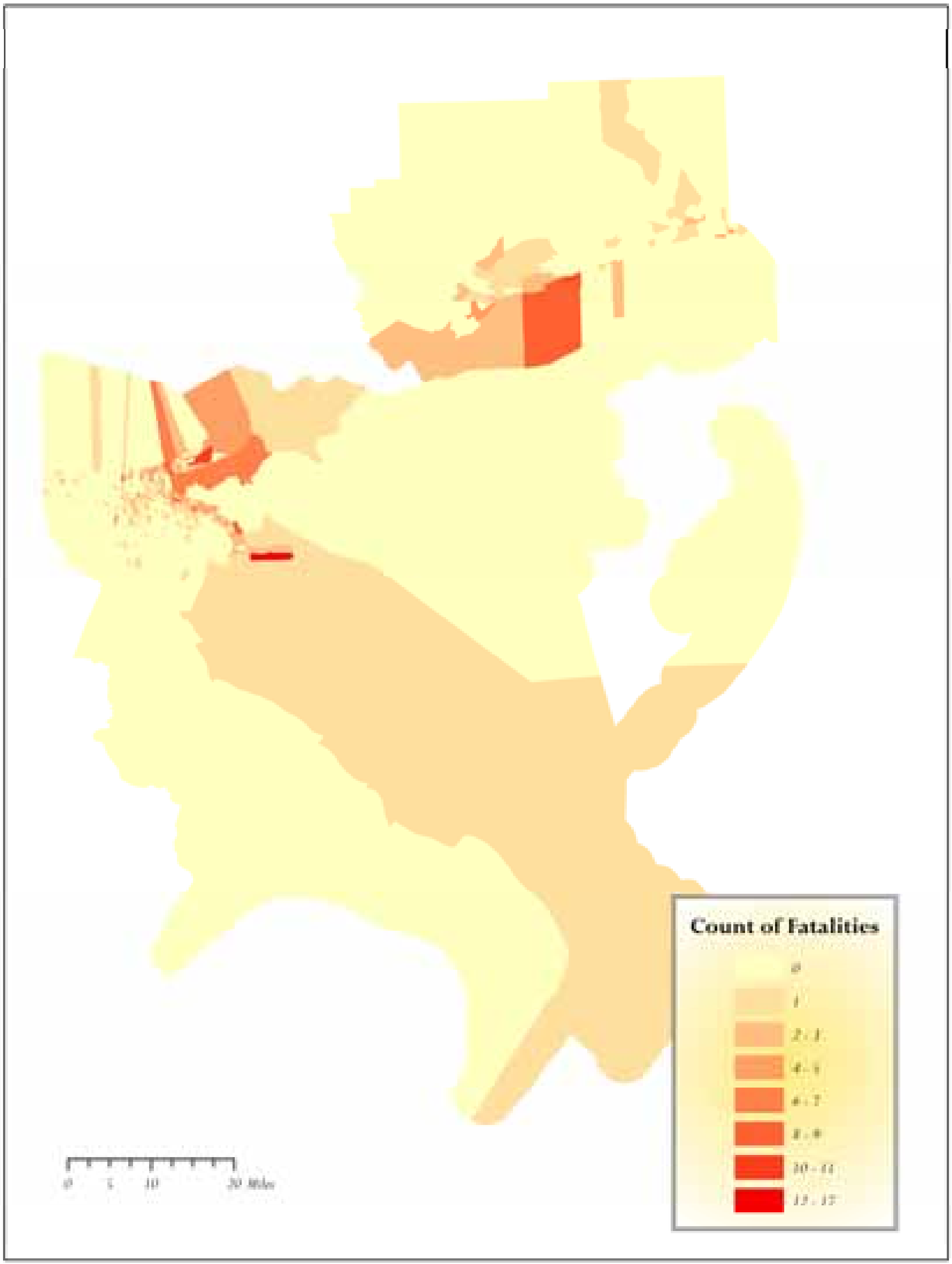

Figure 2: Hurricane Katrina fatalities by block group.

Results

The attribute table was saved to dBase to test just the Vulnerability Index mean compiled by Zonal Statistics in Spatial Analyst with the fatality count to test its viability as a measure of potential loss of life. The findings were weak at best; the two correlate weakly, but significantly (Pearson correlation .072, significant at the .019 level). However, a t-test to test if there is a significant difference in the index between those census block groups having no fatalities and those having one or more shows absolutely no significance. This could be a result of the canceling out of the Louisiana findings with the Mississippi findings, or indeed, that those fatalities missing from the Mississippi data are those very persons who may be in the lower SES groups. All findings must, of course,be viewed with caution in light of the lack of confirmed fatality data from Mississippi.

Looking at each state's data individually, the results for Louisiana are similar, showing that its data is likely skewing the results due to the preponderance of fatalities in that state. Fatalities and the vulnerability index correlate weakly, but significantly (Pearson correlation .081, significant at the .015 level), and there is again no significant difference between the groups with fatalities and without in the t-test. As suspected, there is no correlation whatsoever in Mississippi.

However, when the entire data set is tested in SPSS, several of the variables correlated strongly with fatalities, as noted above. A stepwise regression was run to find those variables with the least multicollienarity and best predictive power, with the following results: five variables explained about 9.3 percent of variance in fatalities:

% African American
% Over 65
% Under 6
Total population (density)
Percentage of structures over 9 units (another density measure)

The results for Louisiana were slightly better, with an R^2 of .106 using these six variables:
% African American
Total population
% Over 65
% African American female head of household
% Structures over 9 units

A t-test of each independent variable against fatality counts showed the only strongly significant ($p < .01$) variables to be percent African American, percent over 65, per capita income, percent below poverty, possibly median year built (only if unequal variances assumed, which is probably the case), median rent, percentage African American female head of household, percentage of those with less than a high-school education, all three employment measures (employed, unemployed, not in workforce), median home value, and percent in service employment. Almost all of these are strongly intercorrelated and measure poverty in one way or another, most directly outside of race and age. It must also be understood that most spatial data is not considered independent data; some of these parametric test results could be considered illegitimate. However, in this case only trends are being looked at for the possibility of future use as a predictive device.

The weighted equation for the final model was based on the stepwise regression model, but simplified. The importance of the 5 variables chosen was weighted in the following manner: Percent African American, .5; total population, .2; Percent over 65 .15; Percent Under 6 .08; and Percent Structures over 9 units, .07. This was based on the t-statistic indicating strength of the prediction rendered by each variable. A Boolean raster was made of each previously constructed raster consisting of all those cells that were over the mean for each variable (0 = under mean, 1 = over mean) and the resulting rasters went into the final model. The resulting map is shown in Figure 4. I again exported the table with attached Zonal Statistics for each block group, and tested it in SPSS for strength in predicting the number of fatalities. This model tested stronger than the unweighted model (Pearson correlation .167, significant at 0.000). These variables point to a good fit of several of Cutter *et al.*'s variables for predicting fatalities–race, density of built environment, and age. These variables should be looked at farther as predictors of evacuation or action behavior, and be the foundation, or at least part of, a nationwide set for future use, as described below.

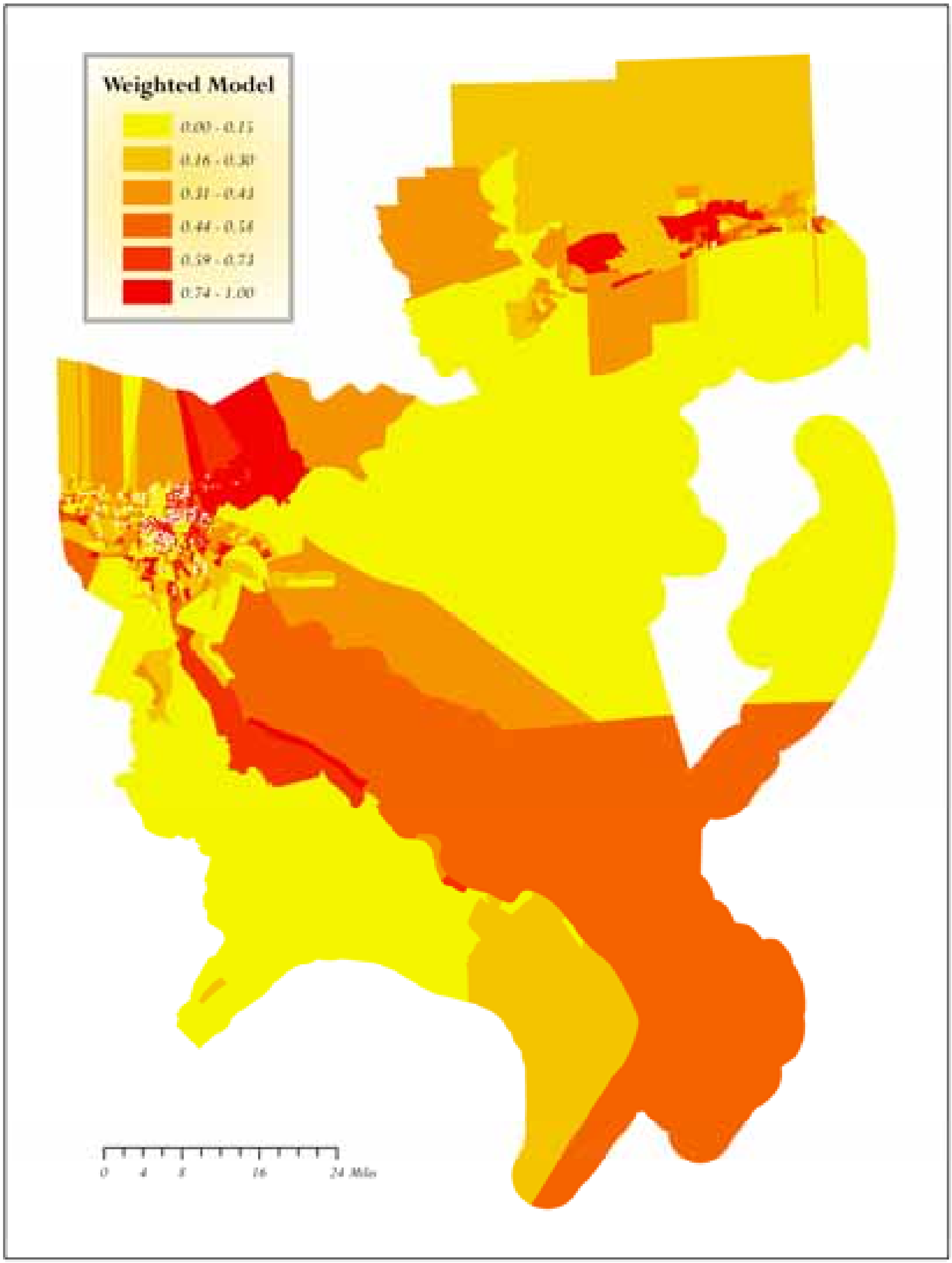

Figure 3: Weighted model of vulnerability in Katrina-affected census block groups.

Future Themes

The most enlightening piece of information that could be used to build a model is the exact demographics of everyone who has died in a natural hazard. This is not possible. I would like to extend this study to not only a far larger area using what I have learned, but test it with a variety of hazard agents, such as floods, tornadoes, heat/cold waves. I also would like to tailor it to the hazard at hand; as noted earlier, behavior in the face of a slow-onset event like a hurricane or river flooding, with ample warning, may vary wildly from that before a tornado. Again, those socially vulnerable people across the country may take completely different actions from those more able to evacuate, more educated, those more trusting of authority, etc. etc.

Clearly, there are an enormous number of factors coming between a human being and an oncoming event which may result in making a good or bad choice—and sheer luck may be one of them. These variables predict only *one-tenth* of the variance in fatality rates. There are, however, factors that vary across regions that did seem to account, at least to some extent, for higher death counts in some census blocks affected by Katrina than in others that could enable a model to be built to pinpoint locations requiring special efforts by emergency managers to aid in evacuation, search and rescue, warning, and other life-saving actions.

REFERENCES

Cutter, S. 2005. The geography of social vulnerability: Race, class, and catastrophe. *Understanding Katrina: Perspectives from the Social Sciences.* Online, Social Science Research Council, at http://understandingkatrina.ssrc.org/Cutter/pf. (last accessed 11 May 2007).

Cutter, S., B. Boruff, and W.L. Shirley. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly* 84, 2 (June): 242-61.

Smith, N. 2005. There's no such thing as a natural disaster. *Understanding Katrina: Perspectives from the Social Sciences.* Online at the Social Science Research Council site at http://understandingkatrina.ssrc.org/Smith/pf. (last accessed 11 May 2007).

Data Sources

American Fact Finder, U.S. Census Bureau for all demographic data from Summary File 3 online at http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=DEC&_submenuId=datasets_1&_lang=en

Many thanks to Mr. Henry Yennie of the Louisiana Department of Health and Human Services for sharing the compiled number of home addresses of Katrina victims.

TIGER road data for geocoding obtained from ESRI's ArcData site at http://arcdata.esri.com/data/tiger2000/tiger_download.cfm

Fatalities in Mississippi gleaned from:

http://co.harrison.ms.us/assistance/confirmed
http://co.harrison.ms.us/landroll/landroll.asp?year=2005&status=Official
http://www.nola.com/katrina/pages/
http://www.earthinstitute.columbia.edu/%7Emutterj/katrina_statistics_10-04-06.xls
http://www.findagrave.com/cgi-bin/fg.cgi?page=gs&

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