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Examining the Relationship Between Physical Vulnerability and Public Perceptions of Global Climate Change in the United States

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Although there is a growing body of research examining public perceptions of global climate change, little work has focused on the role of place and proximity in shaping these perceptions. This study extends previous conceptual models explaining risk perception associated with global climate change by adding a spatial dimension. Specifically, Geographic Information Systems and spatial analytical techniques are used to map and measure survey respondents' physical risk associated with expected climate change. Using existing spatial data, multiple measures of climate change vulnerability are analyzed along with demographic, attitudinal, and social contextual variables derived from a representative national survey to predict variation in risk perception. Bivariate correlation and multivariate regression analyses are used to identify and explain the most important indicators shaping individual risk perception. Analysis of the data suggests that the relationship between actual and perceived risk is driven by specific types of physical conditions and experiences.

Keywords: *climate change; vulnerability; public perceptions*

The potential adverse impacts associated with global climate change are of increasing concern to scientists, elected officials, and the general public. Scientific agreement on the anthropogenic causes (i.e., burning of fossil fuels) of climate change, mounting evidence that human activities are partially responsible for a temperature increase over the past century (Oreskes, 2004), and pervasive media coverage of extreme weather events have contributed to heightened awareness of climate change risks (Bell, 1994a, 1994b; Wilson, 2000). At the same time, public risk perception plays an increasingly important role in shaping environmental policy and management response systems. The level to which individuals understand the causes and consequences of climate change, and the extent to which they regard climate change as harmful to their well-being, may correspond to their personal lifestyle decisions, voting behavior, and willingness to support climate change policy initiatives (Bostrom, Morgan, Fischhoff, & Read, 1994).

Although a large amount of research has examined public perceptions related to global climate change using national surveys or targeting large geographic regions, little work has focused on the role of place and proximity in shaping these perceptions. Previous studies have highlighted attitudinal, psychometric, and standard socioeconomic characteristics as predictors of climate change risk perception (Bord & O'Connor, 1997; McDaniels, Axelrod, & Slovic, 1996; O'Connor, Bord, & Fisher, 1999). These studies rarely or only superficially include data measuring the degree to which individuals are physically at risk from the negative impacts of climate change and whether such physical vulnerabilities influence risk perceptions (see Brechin, 1999; Inglehart, 1995).

This study expands on previous conceptual models explaining risk perception associated with global climate change by adding characteristics associated with the local environment. Specifically, we test the degree to which a person's level of physical vulnerability to climate change influences his or her perception of this risk. Climate scientists anticipate that the negative effects of climate change will vary regionally and across demographic groups (Scheraga & Grambsch, 1998). For example, climate change impact assessments forecast regional variations in agricultural yield (Watson, Zinyowera, & Moss, 1997), loss of native habitat and key species,

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changes in water supply and weather-related mortality, and even costly disruptions to recreational activities (Scheraga & Grambsch, 1998).

In response to a general lack of inquiry into the effects of local place and proximity, we use Geographic Information Systems (GIS) analytic techniques to map and measure survey respondents' degree of physical risk associated with climate change at the local level of spatial resolution and precision. Using existing spatial data, we analyze multiple measures of climate change vulnerability along with socioeconomic, demographic, and attitudinal variables derived from a representative national survey that examines variation in risk perception. This research approach allows us to (a) empirically test theoretical propositions by environmental social scientists on the determinants of risk perception, (b) statistically unpack the physical and geographic factors triggering public risk perception, (c) develop and analyze a more fully specified model predicting risk perception of climate change, and (d) provide direction to planners and policy makers on how to garner public support for government initiatives meant to reduce the adverse changes associated with climate change.

The following section examines past literature on risk perceptions related to climate change. We also review work on the role of location, proximity, and other physical characteristics influencing environmental perceptions in general. Next, sample selection, variable measurement, and data analysis procedures are described. Results are then presented in three phases. First, we conduct bivariate correlation analysis using a range of physical vulnerability variables possibly affecting risk perceptions grouped into four categories: proximity, weather, natural hazards, and anthropogenic hazards. Second, we analyze these variables using multiple regression analysis to test their overall statistical significance and more effectively isolate the effect of specific physical vulnerability variables on climate change risk perception. Third, we analyze a more fully specified model by introducing socioeconomic and attitudinal control variables to the original model. In the final section, we discuss the implications of the results and provide guidance for future research to further enhance understanding of how physical risk influences public risk perceptions on global climate change.

Public Risk Perception: Demographics, Attitudes, and Social Context

Public risk perception plays a key role in shaping natural hazards policy and management response systems (Slovic, 2000). Because the regulation and management of risks such as extreme weather events are subject to public debate and input, perceptions of these risks are of considerable interest to local planners and policy makers (Fischhoff, Lichtenstein, Slovic, Derby, & Keeney, 1981; Johnson & Tversky, 1983). The growing importance of public participation in environmental hazards planning is well documented (Brody, 2003; Brody, Godschalk, & Burby, 2003; Burby, 2003; Wood, Gooch, Pronovost, & Noonan 1985). In fact, researchers argue that public perceptions of risk are driving policy as much as technological and scientific risk assessments (Correia, Fordham, Saraiva, & Bernardo, 1998; Slaymaker, 1999; Tierney, Lindell & Perry, 2001).

Public perceptions of risk are different from scientific risk assessments with regard to the methods of reasoning and valuation (Garvin, 2001; Lichtenstein, Slovic, Fischhoff, Layman, & Combs, 1978; Margolis, 1996; Powell & Leiss, 1997; Shrader-Frechette, 1991; Slovic, 1999). Expert assessments of risk rely on probabilistic and mathematical description. Public valuations of risk are often more intuitive and experiential (Garvin, 2001; Jasanoff & Wynne, 1998; Kempton, 1991; Kraus, Malmfors, & Slovic, 1992; Krimsky & Plough, 1988; Margolis, 1996). When experts subjectively valuate a risk, their judgments correlate strongly with technical estimations of injury and fatality probabilities. The public relies less on metrics of injury and death, evaluating risks more qualitatively: They consider whether a risk is voluntary or involuntary, chronic or catastrophic, common or novel, and known or unknown to science (Slovic, 1987; Slovic, Finucane, Peters, & MacGregor, 2004). Public risk valuations also vary predictably by demographic and psychological attributes, individual personal and historical experiences, and social context (Garvin; Jasanoff & Wynne, 1998; Kempton; Krimsky & Plough; Margolis; Savage, 1993).

On the risk of climate change, researchers find that public literacy on the properties, causes, and likely effects of global climate change is relatively low (Henry 2000). Mass publics conflate stratospheric ozone depletion, greenhouse effects, and climate variability (Bell, 1994a; Bostrom et al., 1994; Dunlap, 1998), and seem to misunderstand the relationship between carbon dioxide concentrations in the atmosphere and temperature change (Sterman & Sweeny, 2002). Instead of knowledge of expert-defined risks, public risk perceptions of climate change appear to correlate more strongly with demographic, attitudinal, and social contextual variables (O'Connor, Bord, Yarnal, & Wiefek, 2002).

With regard to demographic variables, research consistently shows that White women consider the risks of climate change as more harmful than do men (Bord, Fisher, & O'Connor, 1998; O'Connor et al., 1999). This dichotomy is described in risk perception literature as the "White male effect" (Finucane, Slovic, Mertz & Flynn, 2000; Flynn, Slovic & Mertz, 1994; Marshall, 2004). Research on educational attainment and income indicates that persons of higher socioeconomic status are less likely to perceive climate change as threatening (O'Connor et al., 1999). Similarly, persons knowledgeable about the causes, properties, and effects of climate change have lower levels of risk perception. Empirical investigations of how people perceive both technological and ecological risks show that lower (not higher) levels of education, income, and knowledge predict heightened risk perception (see Savage, 1993). Consistent with previous literature, we expect education and income to be negatively associated with climate change risk perceptions (O'Connor et al., 1999; Savage, 1993). Thus, people with higher levels of education and household income will perceive a lower risk associated with global climate change. Because environmental behavior studies typically indicate that women are more aware of environmental risks and more readily support environmental and climate initiatives (see Barkan, 2004; Diekmann & Preisendorfer, 1998; Dietz, Stern & Guagnano, 1998; Zelezny, Chua, & Aldrich, 2000), we also expect gender to behave negatively in our prediction model. We thus hypothesize that females will perceive a greater risk associated with global climate change.

Regarding attitudinal variables, studies find that worldviews are highly predictive of risk perceptions on a range of technological and ecological dangers (Kempton, 1993; Peters & Slovic, 1996). For example, O'Connor et al. (2002) found that persons with pro-environmental attitudes were significantly more willing to support risk reduction efforts related to greenhouse gas emissions. Similarly, Bord et al. (1998) found that persons regarding the biophysical world as "fragile" were more likely to adopt behaviors and support policies that mitigate the risks of climate change. Thus, respondents with a stronger set of ecological values will perceive a greater risk associated with global climate change.

With regard to social contextual variables, scholars find that individuals who regard themselves as capable of positively affecting climate change, as well as influencing others in their social network to behave in ways that mitigate the problem, are significantly more likely to regard the risk seriously and take corrective actions. Thus, we expect that persons with higher perceived personal efficacy are more likely to define climate change as risky (Bord et al., 1998; O'Connor et al., 1999; Savage, 1993). Additionally, persons attached to social networks that manifest high concern about climate change are more likely to regard the risks of climate change as harmful (Jaeger, Durrenberger, Kastenholz & Truffer, 1993). Based on previous literature, we hypothesize that people will perceive a greater risk associated with global climate change if they (a) have a greater sense of efficacy and (b) have a greater affiliation with a climate-concerned social network.

Overall, existing research shows that climate change risk perceptions, as with perceptions of other ecological risks like air pollution, ozone depletion, and contamination of water supplies, are strongly influenced by demographic, attitudinal and social contextual variables (Bord et al., 1998; Kempton, 1993; Peters & Slovic, 1996). However, these studies rarely include local geographic and physical variables in their models that may reduce the level of unexplained variance for risk perception. In the next section, we examine emerging literature on the spatial dimension of risk perception.

Public Risk Perception: Proximity and Place

Traditionally, natural hazards risk perception has been explained by factors such as prior experience, knowledge, socioeconomic and demographic characteristics, and household composition. Comparatively little research has been conducted on the influence of respondents' location and proximity on perception of risk. Although little or no empirical research has been conducted on location-based risk perceptions related to climate change, some informative work has been done on natural and environmental hazards. For example, Farley, Barlow, Finkelstein, and Riley (1993) discovered that the adoption of risk-sensitive behaviors is correlated with proximity to the New Madrid fault. Lindell (1994) finds that proximity is an important factor in hazard risk assessment in relation to volcanic, toxic gas, and/or radioactive materials releases. More recently, Peacock, Brody, and Highfield (2005) reported a significant positive correlation between residence in locations identified by experts as being high hurricane wind risk areas and homeowner risk perceptions in Florida.

Evaluations of the importance of place and proximity also include research into attitudes toward and decisions about environmental risk. For example, Elliot, Cole, Krueger, Voorberg, and Wakefield (1999) showed that closer proximity to adverse air quality locations affects community cohesiveness over air pollution issues. Drori and Yuchtman-Yar's (2002) study of three municipalities in Israel/Palestine—Jerusalem, Tel Aviv, and Haifa—found that environmental perceptions correspond predictably with environmental risks. Persons residing in higher-risk areas express higher levels of environmental concern, even when adjusting for subjective values and demographic characteristics. In a quantitative study, Brody, Highfield, and Alston (2004) test the degree to which driving distance from household residence to two creeks in San Antonio, Texas, affects respondents' knowledge and perceptions of the water bodies. The authors show that when controlling for socioeconomic and geographic contextual variables, proximity is a significant factor in explaining perceptions of the creeks' water quality. Brody, Peck, and Highfield (2004) also examined the spatial pattern of risk perception associated with air quality within the metropolitan regions of Dallas and Houston, Texas. Results indicated no significant correlation between perceptions of air quality risk and air quality as measured by monitoring stations.

Although the studies described above are not specific to climate change, which has its own unique set of risk characteristics, they provide justification for examining the effects of local environmental conditions on perceptions of climate change. First, it appears that members of the public are, in some circumstances, aware of their physical vulnerabilities to hazards as identified by scientific experts. Based on this rationale, we expect people will perceive a greater risk associated with climate change if they are located in areas that (a) experience statistically significant temperature change over time, (b) are prone to natural hazards, and (c) have high carbon dioxide emissions.

Second, proximity to high-risk areas and repetitive hazard events may be an important factor influencing risk perceptions. Insofar as respondents reason rationally in terms of risk signals from physical place, we expect people will perceive a greater risk associated with climate change if they live (a) closer to the coastline, (b) at lower elevations relative to the coast, (c) in areas at high risk of sea level rise/inundation, and (d) within the 100-year floodplain where the negative effects of increased precipitation and associated storms will be more strongly felt.

Research Methods

Sample Selection

Survey data were derived from a national telephone survey of randomly selected adults in the United States conducted from July 13 to August 10 of 2004. The survey instrument was designed by research scientists at the Institute for Science, Technology and Public Policy in the George Bush School of Government and Public Service at Texas A & M University. The survey probed a wide array of citizen attitudes and behaviors on global warming and climate change. Telephone interviews were performed in English, averaging 37 min to complete. Based on the American Association for Public Opinion Research outcome calculator IV, the response rate was 37% and the cooperation rate was 48%. Overall, 1,093 interviews were completed, constituting ± 3% sampling error.

We geo-coded respondents (placed in their true location on earth using *X* and *Y* coordinates) by tying their addresses to a 2000 U.S. Census Bureau TIGER (Topologically Integrated Geographic Encoding and Referencing) line file. Of 1,093 persons interviewed, a sample of 512 respondents (for whom address records were available) was analyzed representing a broad range of physical and geographical settings. The majority of respondents were drawn from coastal and urban areas where the population of the United States is most densely concentrated. With each respondent located in geographic space, we could effectively employ geographic factors and spatial analytical techniques to examine vulnerability to climate change within the study area. Spatial data were derived from numerous public and private sources, including the Hazard Research Lab at University of South Carolina, the Energy Information Administration, the National Climatic Data Center, and Applied Geographics Solutions Inc.

Concept Measurement

Dependent variable. We constructed the dependent variable for the study, climate change risk perception, by combining three survey questions on the risks of climate change to dimensions of individual well-being. Respondents were asked to indicate their level of agreement on whether global warming and climate change will have a negative impact on their health, financial situation, and local environment in the next 25 years. Respondents indicated their level of agreement for each statement on a 4-point scale, where 1 is *strongly agree* and 4 is *strongly disagree*. We then reversed the scale of each item, combined them into a single measure (Cronbach's alpha = .843), and divided by 3 to maintain the original scale. This procedure produced a robust variable measuring individual perceptions of climate change on a scale from 1 to 4, where 1 = *strongly disagree* and 4 = *strongly agree* (see Table 1 for all variables measured).

Physical variables. Based on climate change impact literature, we measured and analyzed physical context variables associated with three types of risk: proximity, weather, and natural hazards. Proximity risk variables refer

Table 1
Concept Measurement

Variable	Description	Source	*M*	*SD*
Dependent variable				
Risk perception	Threat of climate change to individual	Survey	2.71	0.645
Physical variables				
Distance to coast	Distance (in meters) from respondent address to nearest point on coast	Survey	252947.60	296421.20
Relative elevation	Difference between respondents' elevation and the elevation of the nearest point location on the coast	Survey; U.S. Ground Elevation Retriever	1290.68 444.30	
Sea level rise	Respondents within 1 mile of nearest coastline with negative elevation (0,1)	Survey; U.S. Ground Elevation Retriever	0.07	0.26
Floodplain	In or out of 100-year floodplain	Q3 FEMA Digital data[a]	0.04	0.21
Temperature trend	Correlation between year and the number of days exceeding average temperature from 1948 to 2005	U.S. Heat Stress Index Data, National Climatic Data Center, Asheville, North Carolina	0.49	0.33
Economic damage	Weather-related disasters between 1980 and 2004 for which overall damages reached or exceeded $1 billion at time of the event	Ross and Lott (2003)	3.49	1.64

Injuries	Number of injuries from natural hazards	Spatial Hazard Events and Losses Database for the United States, Version 1.	143.73	190.97
Fatalities	Number of fatalities from natural hazards		33.85	124.78
Property damage	Amount of damage from natural hazards		9.88e+07	1.74e+08
Fires	Number of fires 2001-2004	USDA[b] Forest Service, Remote Sensing Application Center	79.83	361.85
State CO_2 emission	Carbon dioxide emissions from fossil fuel combustion (million metric tons CO_2)	State Energy Data tables 2001, Energy Information Administration	Total: 1229.64	1039.25
			Commercial: 52.37	58.20
			Industrial: 226.45	335.83
			Transport: 370.18	90.99
			Electric: 497.13	319.52
			Residential:83.51	406.96
Per capita CO_2	Volume of CO_2 emitted per capita.	U.S. Federal Highway Administration	1.57	0.28
Control variables				
Ecological values		Survey	2.89	0.42
Knowledge		Survey	1.14	0.74
Perceived efficacy		Survey	2.71	0.52
Network Interest		Survey	0.95	0.41
Education		Survey	3.92	1.18
Income		Survey	6.34	2.88
Gender		Survey	0.45	0.50

a. Taken from <http://www.fema.gov/hazard/map/q3.shtm >. Q3 Flood Data is a digital representation of certain features of FEMA's Flood Insurance Rate Maps, intended for use with desktop mapping and Geographic Information Systems technology.
b. USDA = U.S. Department of Agriculture.

to the respondent's physical vulnerability associated with his or her location. Vulnerability to sea level rise, the predominant proximity-based risk associated with climate change, was captured using the following four variables:

1. We used GIS analytical techniques to measure distance from a respondent to the nearest point on the coastline.
2. We computed relative elevation as the difference between the respondents' elevation and the elevation of the nearest point location on the coast.
3. We also calculated a dichotomous sea level rise/inundation risk variable by identifying respondents living within 1 mile of the nearest coastline—a cautiously conservative radius—that also have a negative relative elevation to the coast. Respondents at risk were assigned a 1; all others were assigned a 0.
4. Finally, we measured vulnerability associated with inland flooding by calculating whether a respondent is located in the 100-year floodplain as designated by the most current Federal Emergency Management Agency (FEMA) maps. Respondents in the floodplain were assigned a 1; all others were assigned a 0.

Weather vulnerability variables were measured using existing climate-based data and associated models. We calculated a temperature trend variable based on a correlation between time (year) and the number of days exceeding average temperature from 1948 to 2005. Temperature exceedance was measured based on data collected from the U.S. Heat Stress Index Data, National Climatic Data Center in Asheville, North Carolina. Time series 85th percentile exceedances of average apparent temperature for a 1-day period were mapped and intersected with the location of survey respondents. Respondents were assigned the attributes of their respective climatic division. Respondents residing in a climatic division with a statistically significant correlation ($p = <.05$) between time and the number of days exceeding average temperature were assigned the corresponding coefficient. All others were assigned a score of zero.

According to climate scientists, a key signature of climate change is the pattern of extreme weather and natural hazard events (Scheraga & Grambsch, 1998). We estimated a natural hazards vulnerability variable from three sources of data. First, we calculated overall economic damage at the state level using data collected by Ross and Lott (2003) on weather-related disasters between 1980 and 2004 for which overall damages and costs reached or exceeded $1 billion at the time of the event. Second, we used the Spatial Hazard Events and Losses Database for the United States from January 1, 1960, to July 31, 2004, to calculate the following variables: injuries, fatalities, and property damage. Third, we calculated the number of forest fires from January 1, 2001 to July 31, 2004 using the TERRA MODIS data from the U.S. Department of Agriculture. Using GIS analytical techniques, the data were intersected with the location of survey respondents, and respondents were assigned the damage attributes of their respective counties.

Finally, we introduced an economic impact variable based on carbon dioxide emissions, the principal greenhouse gas explaining variation in temperature change in the last century. Because the policy costs of climate change mitigation and adaptation fall unevenly by place, with some areas having to use greater effort to reverse greenhouse gas trends, we expect persons residing in high emission areas to be either (a) less supportive of climate change policies because of higher expected economic burdens associated with policy implementation or (b) more supportive of climate change policies because they are sensitive to the adverse impacts associated with heavy emissions of greenhouse gases. At the state level, we calculated total carbon dioxide emissions from fossil fuels, as well as for industrial, commercial, residential, electric, and transportation sectors. Data were obtained using the 2001 State Energy Data tables reported by the Energy Information Administration (http://www.eia.doe.gov/emeu/states/_use_multistate.html). Each respondent was assigned the respective state emission attributes. We also calculated a per capita level carbon dioxide emissions variable using data from the U.S. Federal Highway Administration. Respondent locations were tied to county-level estimates of average carbon dioxide emissions per person within each county in the United States. Carbon dioxide estimates were based on vehicle miles traveled and the number of people in each county.

Control variables. We measured and included in the regression model several attitudinal, demographic, and social contextual control variables to better isolate the influence of physical vulnerability characteristics. We employed an abbreviated version of the New Ecological Paradigm (NEP) scale developed by Dunlap, Van Liere, Mertig, and Jones (2000) to estimate general environmental concern. Our abbreviated measure excluded human exemptionalist items appearing in the original index. The new ecological values scale (alpha = .727) averages responses on seven items derived from the NEP Scale. Respondents were asked to indicate agreement (4 = strongly agree; 1 = strongly disagree) with statements on resource scarcity, human impacts on nature, and ethical responsibility toward nonhuman life.

Our climate risk perception model also included a measure on perceived efficacy related to the issue of climate change. This variable (alpha = .667) was a three-item measure estimating the perceived ability of a respondent to influence climate change outcomes, the perceived ability to induce others to behave in ways that mitigate human sources of climate change, and whether a respondent accepts climate change as a human responsibility. Finally, we included a contextual measure called network interest. This variable is composed of four items (alpha = .732). Two questions measured the frequency of communication between respondents and their families and friends on global warming and climate change, and two questions measured whether anyone has ever asked for or influenced a respondent's opinion on global warming and climate change.

In addition to attitudinal, personal efficacy, and social contextual control variables, we also modeled socioeconomic and demographic measures. Education was measured on a 6-point scale, ranging from *elementary school* (1) to *post-graduate degree* (6). Household income was measured on an 11-point scale with $10,000 intervals (1 = *less than $10,000*; 10 = *more than $100,000*). Lastly, we included gender in the model as a dichotomous variable where *female* = 0 and *male* = 1.

Data Analysis

We analyzed the data in three related phases. First, we computed bivariate correlations between risk perception and all physical vulnerability variables collected. This step allowed us to examine the effect of a wide range of vulnerability indicators on the dependent variable. Second, we analyzed these variables in a multiple regression equation (omitting those causing significant multicollinearity) to test their overall effects. Finally, we introduced socioeconomic and attitudinal control variables to evaluate a more fully specified model. Controlling for attitudinal and socioeconomic factors enabled us to more effectively isolate the statistical effect of the most powerful vulnerability predictors. Tests for estimate reliability including specification, multicollinearity, and spatial autocorrelation exhibited no significant violation of ordinary least squares regression assumptions. We did, however, detect heteroskedasticity in the model, leading us to estimate the regression equation with robust standard errors.

Results

As shown in Table 2, bivariate correlations indicate proximity-based physical vulnerability variables are significantly correlated with risk perceptions of climate change. Respondents located on relatively higher ground and farther

Table 2
Correlations Between Physical Variables and Climate Change Risk Perception

Variable	Correlation Coefficient	*p* value
Proximity		
Distance to coast	–0.098	.026
Relative elevation	–0.096	.029
Sea level rise/inundation risk	0.087	.048
100-year floodplain	–0.063	.105
Weather		
Temperature trend	0.016	.720
Natural hazards		
Economic damage	0.012	.780
Injuries	0.049	.265
Fatalities	0.103	.018
Property damage	0.012	.771
Fires	0.047	.282
Emissions		
Total state CO_2 emissions	–0.032	.465
Commercial state CO_2 emissions	–0.045	.307
Industrial state CO_2 emissions	0.025	.569
Transportation state CO_2 emissions	–0.029	.509
Residential state CO_2 emissions	–0.037	.403
Electricity state CO_2 emissions	–0.018	.677
Per capita CO_2 emissions	–0.076	.085

away from the coastline perceive a significantly lower level of risk from climate change ($p < .05$). Furthermore, those surveyed who are most vulnerable to inundation from sea level rise perceive global climate change as a greater personal-level risk ($p < .05$). It is interesting to note that although the effect is not statistically significant at the .05 level ($p = .10$) respondents living in 100-year floodplains have a lower level of personal risk associated with climate change.

Compared to proximity, the weather-related variable has less of an impact on individual risk perceptions of climate change. In general, past local temperature changes do not significantly influence risk perceptions. These results indicate a possible disconnect between long-term changes in weather patterns and perception of these changes as associated with adverse effects on individual well-being because of global climate change.

As with weather, most natural hazards vulnerability variables are weakly correlated with climate change risk perception. Survey respondents living in areas that have incurred both overall and sector-specific economic damage (i.e., property, crops) do not seem to relate these events to increased risks from climate change. Similarly, an increasing number of reported fires do not seem to correspond with significantly increased risk perception. In contrast, the number of human fatalities associated with natural hazard events does correlate significantly with increased perception of climate change risk ($p < .05$). Of all the natural hazard vulnerability measures, actual deaths from natural hazards seem to trigger a perception that climate change may threaten individual well-being.

Total state-level and sector-specific emissions data are not statistically related to risk perception of climate change. On the other hand, per capita-level carbon dioxide emissions are significantly (albeit weakly) correlated with our dependent variable. It is important to note that this variable is negatively associated with perceived risk associated with climate change. That is, our results show that respondents living among heavy greenhouse gas emissions believe their relative risk from global warming is significantly lower.

Next, we analyzed all physical vulnerability variables together in a multiple regression model (using robust standard errors) to test whether they have an overall statistically significant impact on perceptions of climate change and to isolate the effects of individual predictors. We excluded the following variables that were statistically repetitive and introduced significant multicollinearity into the regression equation: relative elevation, injuries from natural hazards events, the number of fires within a respondent's county, and all state-level carbon dioxide emissions data. This procedure left nine physical vulnerability variables for analysis. As shown in Table 3, although all of the physical vulnerability predictors together have a significant impact on the dependent variable, they explain just more than 4% of its variation. Three of the nine variables have a significant impact on risk perceptions of climate change where $p < .05$. The number of fatalities resulting from natural hazards is the most significant predictor of heightened risk perception ($p < .01$). Survey respondents residing in low-lying areas within immediate proximity of the coast, thus making them most vulnerable to sea level rise and storm surge, also demonstrate a significantly greater perceived risk ($p < .05$) from climate change. Finally, respondents living in the 100-year floodplain (indicating increased vulnerability to flooding from an increasing number of storm events and precipitation) perceive significantly less risk ($p < .05$).

As shown in Table 4, the robust regression model explains approximately 40% of the variance in the dependent variable, which is consistent with other studies predicting environmental and natural hazards perceptions. With the

Table 3
Explaining Risk Perceptions Using Physical Vulnerability Variables

Variable	Unstandardized Coefficient	Standardized Coefficient	Robust Standard Error	*t* Value	Significance
Sea level rise	0.211	0.086	0.099	2.13	.034
Floodplain	–0.285	–0.091	0.124	–2.29	.022
Distance to coast	–1.66e–07	–0.076	1.04e–07	–1.60	.111
Fatalities	0.000	0.110	0.000	2.75	.006
Fires	0.000	0.044	0.000	1.48	.140
Property damage	1.19e–10	0.047	1.02e–10	1.17	.243
Economic damage	0.016	0.040	0.018	0.90	.366
Temperature trend	–0.037	–0.019	0.084	–0.44	.660
Per capita CO_2 emissions	–0.125	–0.053	.112	–1.11	.266
Constant	2.873		0.187	15.40	.000

Note: $n = 511$. $F(9, 501) = 2.50$. $p>F = 0.012$. Adjusted $R^2 = .041$.

addition of attitudinal and socioeconomic controls, fatalities from natural hazards, vulnerability to sea level rise, and living within the 100-year floodplain remain statistically significant where $p < .05$. Additionally, a respondent's proximity to the nearest point on the coastline also becomes statistically significant ($p < .01$) where residents closer to the coast feel more vulnerable to climate change. In fact, our distance to the coast (β = –.093) and fatality (β = .087) variables rival more traditional sociodemographic variables in explanatory power. Finally, total economic damage resulting from weather-related disasters has a significant effect on increasing risk perceptions associated with climate change ($p < .05$).

Several attitudinal and socioeconomic control variables also significantly predict climate change risk perceptions. For example, perceived efficacy is one of the most significant independent variables in our model associated with increasing risk perception (β = .361, $p = .000$). As expected, respondents who believe they have the responsibility and ability to mitigate the potential adverse impacts of climate change appear to be more concerned about the potential risks. The new ecological values measure also has a strong positive effect on climate change risk perception (β = .298, $p = .000$), second among predictors in explanatory power. Survey respondents who are more concerned for the state of the natural environment appear to be significantly ($p = .000$) more sensitive to the negative consequences of climate

Table 4
Explaining Risk Perceptions Using a Fully Specified Model

Variable	Unstandardized Coefficient	Standardized Coefficient	Robust Standard Error	*t* Value	Significance
Physical vulnerability variables					
Sea level rise	0.159	0.065	0.076	2.09	.037
Floodplain	–0.157	–0.050	0.077	–2.04	.042
Distance to coast	–2.03e-07	–0.093	7.57e-08	–2.68	.008
Fatalities	0.000	0.087	0.000	3.05	.002
Fires	0.000	0.010	0.000	0.44	.661
Property damage	5.70e-11	0.023	8.48e-11	0.67	.520
Economic damage	0.030	0.075	0.014	2.07	.039
Temperature trend	–0.051	–0.026	0.065	–0.79	.432
Per capita CO_2 emissions	0.012	0.005	0.085	0.14	.885
Control variables					
Education	–0.022	–0.041	0.022	–1.05	.296
Gender	–0.110	–0.076	1.046	–2.14	.033
New ecological values	0.454	0.298	0.067	6.73	.000
Network interest	0.144	0.093	0.062	2.34	.020
Perceived efficacy	0.445	0.361	0.061	7.24	.000
Income	–0.002	–0.011	0.009	–0.29	.769
Knowledge	–0.044	–0.012	0.032	–1.37	.170
Constant	0.238		0.237	1.00	.316

Note: $n = 511$. $F(16, 494) = 21.95$. $p>F = 0.000$. Adjusted $R^2 = .415$.

change. The social contextual measure of network interest is positively correlated with the dependent variable ($p < .05$). This result indicates the more connected a person is to social networks interested in climate change, the more likely he or she is to regard climate change as personally risky. This finding corroborates Huckfeldt and Sprague's (1987, 1991) argument that political discussion networks engender attitudinal change and activism. Finally, women are more likely than men to be cognizant of the adverse impacts of global climate change. This result is consistent with past research on female environmental perception and concern (Foster & McBeth, 1994; Jones & Dunlap, 1992; Raudsepp, 2001).

Discussion

Analysis of the data suggests that out of a range of physical vulnerability indicators, several correlate with a heightened sense of personal risk from potential global climate change. That is, the relationship between scientifically measured and perceived risk appears driven in part by specific types of physical conditions and experiences.

First, respondents appear to register climate change risk when the threat or sense of vulnerability is most overt. For example, living adjacent to the coastline and/or in areas of low elevation presents an obvious threat from sea level rise. Thus, physical position and proximity characteristics lend themselves to increased public perceptions of the potential negative impacts of climate change. If risk perception is correlated with a person's physical location, then decision makers can spatially target policies toward areas most vulnerable to the adverse effects of climate change. Once a constituency of support is established, policy makers can more effectively spread their initiatives to less vulnerable locations. Another indicator, cumulative fatalities, also focuses public attention on the potential danger of climate change and possibly increases the motivation to support mitigation efforts (see Zahran, Brody, Vedlitz, & Grover, 2005). In contrast, less blatant risk signals such as long-term temperature change appear more difficult for the public to see and understand clearly.

A second factor explaining why only select physical vulnerability variables significantly influence risk perception is that the members of the public tend to calculate their risk level based on a limited understanding of the impacts of climate change. The majority of Americans associate climate change with sea level rise (Bell, 1994a; Kempton, 1991), which may help explain why those closest to the coast and most vulnerable to inundation perceive the greatest personal risk. Equally legitimate risks such as increased property damage from climatic events, increasing temperature trends, and residing in the 100-year floodplain do not appear to affect levels of risk perception in this study. In fact, respondents located within the 100-year floodplain where flood damage and loss of life is more likely, where increased precipitation and coastal storms are expected, perceive a significantly lower risk associated with climate change. Increased education programs and communication to the public of the precise causes and consequences of climate change at geographically precise levels may help the public become more sensitive to a broader range of physical vulnerability characteristics. For example, recent advances in data collection and modeling climate change have increased the spatial precision with which we can predict temperature trends into the future. The results of these models can be disseminated to the public as easily interpreted maps that indicate where, on a regional basis, and to what degree climate change is expected to occur. By better understanding the scope and severity of impacts associated with climate change, the public's perception of the risk may be more congruent with the conditions of the local environment.

It is important to note that physical vulnerability variables are weak in their explanatory power compared to socioeconomic and attitudinal control variables. These more traditional factors used to explain risk perceptions remain important signals for policy makers. For example, personal efficacy is one of the strongest predictors in our model of risk perception associated with climate change, where a unit increase on the efficacy scale corresponds to almost half of a point increase in risk perception. If an individual's perception of risk depends on the belief that he or she can influence climate change outcomes, then public officials may benefit by more effectively engaging the public in the policy-making process. Public participation fosters increased ownership over environmental problems and leads to a greater sense of responsibility for mitigating adverse impacts. At present, climate change policy is more concentrated in the hands of international negotiators, and the average local citizen is disengaged from the policy-making process. However, involving the public in addressing climate change policy issues may boost the perception of its associated risk and lead to more responsive and proactive local communities.

Public involvement related to climate change may also strengthen the social network attached to this issue, thereby broadening risk perceptions. Public participation usually involves information sharing, education, communication, and discussion about a problem. This process can facilitate network interest which, based on our results, may increase public recognition of the severity and geographic impacts of potential climate change.

Conclusion

This study offers an in-depth analysis of several physical and geographic factors impacting risk perception associated with climate change. Using bivariate correlation and multivariate regression analyses, we identify and explain several important indicators shaping individual risk perception. Our results not only shed light on the dichotomy between scientifically measured and perceived risk, but also provide important information to policy makers interested in mitigating the adverse impacts of climate change on local communities.

Although this study provides information on the factors influencing perceptions of climate change risk, it should be considered only a starting point for examining the topic. Additional research is needed before any conclusions can be made about the degree to which physical vulnerability plays a role in influencing public perceptions. First, our study focuses on perceptions of risk. More concrete measures such as actual policy response to climate change are needed. Second, we were limited to using existing datasets compiled at different levels of spatial aggregation. For example, fatality data were compiled at the county level, but some carbon dioxide emissions data were only available at the state level. Although we relied on the best available data at the time, future studies should use more spatially precise and consistent data to reduce the chances of statistical bias in results. Third, our study is limited to a random sample of individuals, making it difficult to extend the findings to larger geographic areas. Additional research should be conducted that characterizes and maps the relative physical vulnerability of the entire United States. Only through this approach will we be able to accurately identify hotspots of climate change vulnerability where policy initiatives are more urgently needed. Finally, our study uses a telephone survey to understand risk perceptions. Given the complex physical and sociological nature of the topic, future research is needed involving in-depth case studies. Case study analysis of specific jurisdictions would provide a clearer contextual picture of why communities may be willing to adopt costly measures to reduce the threat of climate change.

Note

1. The majority of survey participants were female (55.6% vs. 44.4% male). The average age was 47.31 (SD =16.40), and the range was 18-90. About 37% of respondents held a college or postgraduate degree, and 2.5% had no high school diploma. The racial distribution of the sample was predominately White non-Hispanic (84.1%), followed by African American (8.1%), Hispanic (5.4%), Native American (1.2%), and Asian American (0.2%). On self-reported political ideology, 42.0% of respondents regarded themselves as conservative, compared to 32.7% who regarded themselves as leaning liberal. Compared to the national U.S. Census figures, our sample was older in average age (47.31 vs. 32.3) and better educated (one fifth of Americans are without a high school diploma). It undercounted males (44.4% vs. 49.1%), African Americans (8.1% vs. 12.3%), Hispanics (5.4% vs. 12.5%), and Asian Americans (0.2% vs. 3.6%).

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