Mitigation Planning: Why Hazard Exposure, Structural Vulnerability, and Social Vulnerability Matter

Article *in* Journal of Planning Education and Research · August 2014

DOI: 10.1177/0739456X14531828

3 authors:

Wesley E. Highfield
Texas A&M University - Galveston

Walter Gillis Peacock
Texas A&M University

Shannon Van Zandt
Texas A&M University

Article

Journal of Planning Education and Research
1–14

DOI: 10.1177/0739456X14531828
jpe.sagepub.com

Mitigation Planning: Why Hazard Exposure, Structural Vulnerability, and Social Vulnerability Matter

Wesley E. Highfield[1], Walter Gillis Peacock[2], and Shannon Van Zandt[2]

Abstract

Increasing interest in fostering resilient communities requires a more comprehensive approach to hazard mitigation planning that overcomes the limitations of traditional hazard assessments, notably the failure to explicitly incorporate an analysis of social vulnerability. We statistically analyzed a random sample of 1500 damage assessments of single-family homes collected following Hurricane Ike to assess the contributions of hazard exposure, structural vulnerability, and social vulnerability. The results indicate that hazard exposure, structural characteristics, and socioeconomic characteristics are significant predictors of structural damage. The implications suggest that comprehensive hazard assessments can provide additional insights for mitigation planning and community resiliency.

Keywords

hazard recovery, hazard mitigation, social vulnerability, Hurricane Ike

Introduction

Considering the damage to single-family housing after a hurricane may at first glance appear to be a minor contribution to the planning literature and practice. In many regards, the disaster literature has developed independently of the planning literature and vice versa, often somewhat obtusely and to the detriment of both. However, as the number and severity of disasters increase, along with our awareness of the potential for widespread social and economic consequences of climate change, we would do well to examine the extent to which planning decisions and outcomes may mitigate or exacerbate damage from extreme weather conditions.

The fact basis for both hazard mitigation and comprehensive planning has long been based on hazard exposure and physical or structural vulnerability (Schwab 1998; Burby 1998; Godschalk et al. 1999; Daniels and Daniels 2003). Hazard exposure is a function of the nature of the hazard agent and its potential to impact the geography of urban areas captured in floodplain or risk maps. Physical or structural vulnerability is a function of the location population and the built environment, along with its characteristics relative to the hazard captured in building codes and structural characteristics, such as elevation, roof type, or exterior cladding. Only recently has the notion of social vulnerability been promoted as a dimension of the fact basis (Cutter 1996; Morrow 1999). Social vulnerability considers the socioeconomic characteristics of the households that will impact their ability to prepare for, anticipate, cope with, and recover from hazard events (Blaikie et al. 1994). Mapping the distribution of characteristics, such as poverty, race/ethnicity, age, gender, household composition, and housing tenure, captures the variability in household capacity for both mitigation and recovery (Cutter, Mitchell, and Scott 2000; Cutter, Boruff, and Shirley 2003; Van Zandt et al. 2012; Peacock et al. 2012).

All three aspects can be captured through an examination of impacts to housing resulting from hurricane-induced surge and flooding. Housing is critical infrastructure for a community. The location and characteristics of housing establish the physical and structural vulnerability, while the households within the housing and neighborhoods establish the vulnerability of the population. When a disaster strikes, housing becomes not only a critical element in defining the nature and extent of the impact but also an important indicator of community resiliency. Resilience implies not only the ability to bounce back after being hit but also, equally important, the

Initial submission, December 2012; revised submissions, June and October 2013; final acceptance, January 2014

[1]Texas A&M University at Galveston, Galveston, TX, USA
[2]Texas A&M University, College Station, TX, USA

Corresponding Author:
Wesley E. Highfield, Department of Marine Sciences, Texas A&M University at Galveston, 200 Seawolf Parkway, Galveston, TX 77553-6175, USA.
Email: highfiew@tamug.edu

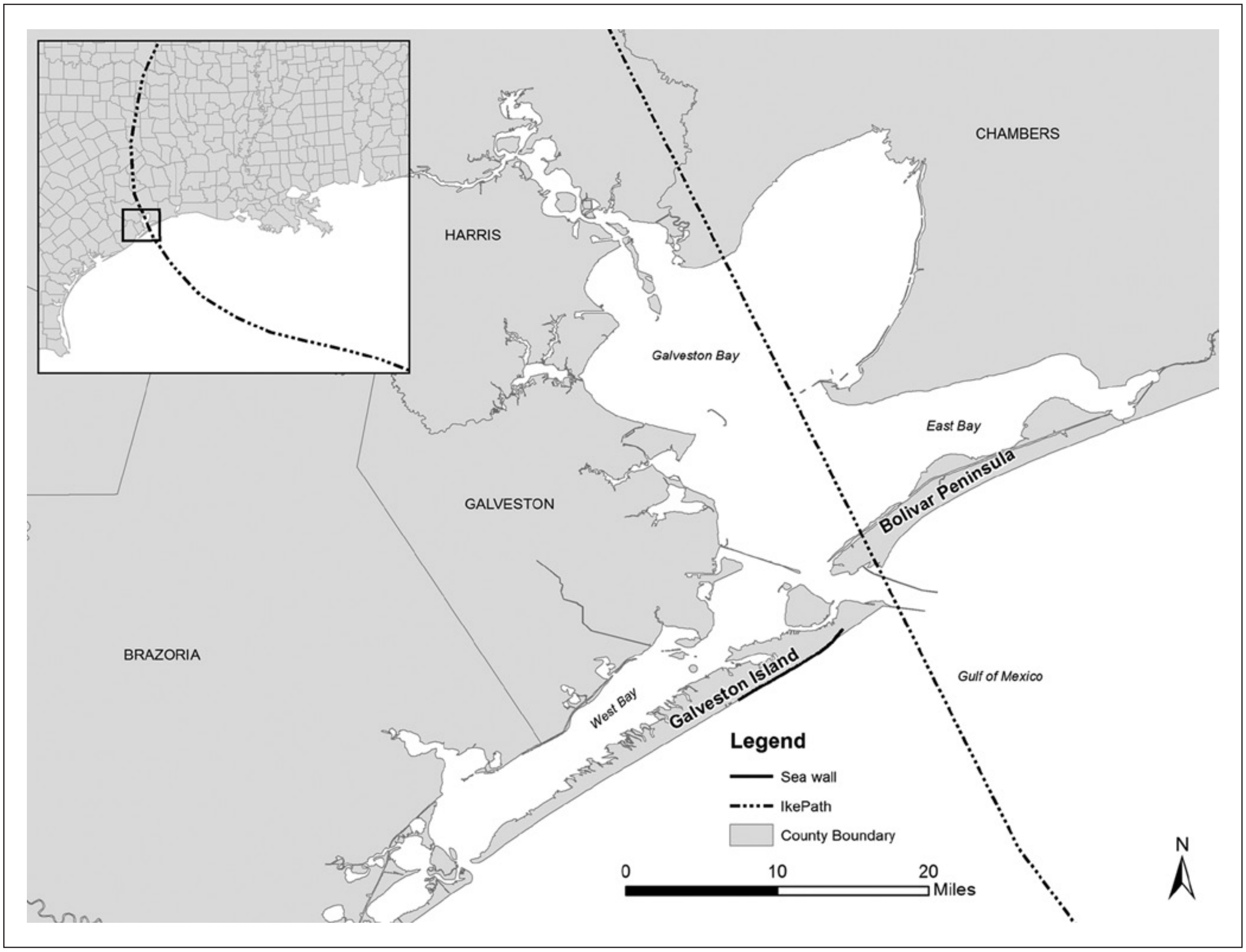

Figure 1. Galveston Island and Bolivar Peninsula study area.

ability to absorb or weather the forces of nature without suffering damage and loss. Furthermore, the extent and nature of damage to housing has consequences on the ability of the community to bounce back from temporary population displacement and more permanent dislocation, which have important consequences for the economic viability of a community. Hence, damage to a community's housing stock can be a key indicator of resilience or a lack thereof.

Since the mid-1990s, members of the broader planning research community have been calling for a systematic analysis of housing issues in a post-disaster context, with respect not only to inequities in recovery but also to differential impacts (Comerio 1997). In this study, an acute event, surge and flooding induced by Hurricane Ike in 2008, allows us for the first time to model the contributions of all three dimensions of hazard assessment—hazard exposure, physical/structural vulnerability, and social vulnerability—to observed impacts to housing.

Hurricane Ike made landfall on the east end of Galveston Island as a category 2 storm in the early morning of September 13, 2008 (see Figure 1). Having decreased in intensity from a category 4 to a category 2 storm along its path over Cuba, many U.S. Gulf Coast residents would not have guessed that Ike would be the third-costliest hurricane in U.S. history. Twelve fatalities in Galveston and Chambers Counties are directly attributable to Ike (Berg 2009). The total financial damage from Ike in Texas, Louisiana, and Arkansas is estimated at $24.9 billion, the third behind Hurricanes Katrina and Andrew, respectively (Berg 2009). Despite its maximum sustained winds of 110 mph in the Galveston area, Ike is known more for its immense storm surge. The maximum high water mark recorded by FEMA was 17.5′, located on Bolivar Peninsula. This surge event caused severe damage to structures and communities on Bolivar Peninsula. Galveston Island did not receive the equivalent surge on the Gulf side, yet its high water mark values still ranged from 10′ to 13′, the result of a surge that pushed into Galveston and West Bay, forcing water back over the island from the north (bay) side.

Following a disaster, damage assessments are a frequently employed and important tool in determining the physical effects of a hazard event on a community's housing stock. However, the results of these assessments tend to be relatively coarse and descriptive in nature, seeking to fulfill specific policy-oriented requirements, such as estimating overall damage and determining substantial loss. Interestingly, while socioeconomic factors are often implicitly employed in these assessments and determinations, such data are often excluded, inhibiting the possibility to improve the equitable distribution of recovery resources. As with most natural hazards, much is known about the characteristics of the hazard agent and the aggregate economic losses, but relatively little is known about the specific pattern and characteristics of damage and those affected by the damage.

In this study, we not only describe but also seek to account for the pattern of damage to housing units resulting from Hurricane Ike. We explored, analyzed, and modeled independently surveyed measures of damage collected post-Ike by using groups of geographic (related to hazard exposure), structural (related to structural vulnerability), and socioeconomic (related to social vulnerability) variables at the household level. First, we examined the location of housing on Galveston Island or Bolivar Peninsula—two barrier islands that bore the brunt of the wind, flooding, and surge. Second, we examined the structural characteristics of the home, specifically elevation and age, with age serving as a proxy for housing quality/building standards. Finally, we examined socioeconomic factors of the home's value and its neighborhood racial characteristics to capture the contribution of social vulnerability to the pattern of damage.

The results indicate that hazard exposure and a home's structural vulnerability based on proximity-derived measures of risk, structural mitigation measures at the household and city levels, estimated inundation, and the age of the residence, assessed both in linear and nonlinear specifications, were all important predictors of a home's damage. In other words, hazard exposure and structural vulnerability factors were important determinants of damage. However, even after controlling for these factors, areas with high proportions of nonwhite residents and lower-valued homes received more damage than their higher-valued counterparts in predominantly white areas despite being farther from or outside high-risk areas. Hence, all three aspects—hazard exposure, structural vulnerability, and social vulnerability—are critical to our understanding of damage patterns.

The following sections discuss the factors that determine hurricane damage, and the roles of hazard exposure and socioeconomics in the distribution and severity of damage. Next, we present the methodological approach, including sample selection and data collection, variable measurement, and analysis procedures. The results are presented first by spatial and descriptive analyses and then through a series of multiple linear regression models. Finally, we discuss how the results can provide insight for planners and policy makers into the effects of a heterogeneous and vulnerable housing stock, the socioeconomic forces that help direct the distribution of hurricane damage, and why a tripartite consideration of hazard exposure, physical vulnerability, and social vulnerably is important in hazard/risk analyses.

Determinants of Hurricane Damage

When seeking to understand the potential for hazard impacts, one of the most important tasks to undertake is a hazard assessment analysis. At the community level, the hazard assessment analysis becomes the fact basis for planning processes, such as the development of a sound hazard mitigation plan or a good comprehensive plan. Hazard assessments are generally undertaken at three levels of sophistication: hazard identification, vulnerability assessment, and risk analysis (Deyle et al. 1998). Hazard identification aims to identify the geographic distribution of hazard threats posed to a community in terms of the magnitude or intensity of hazard forces that might expose an area, such as flood or winds. It may also include some notion of the likelihood for locations within a community to be subject to different intensities. A classic example would be a flood insurance rate map, which identifies different levels and types of flooding, broken down into hundred-year (1 percent annual probability) or five-hundred-year (0.2 percent chance annually) flood zones, as well as likely surge zones in coastal areas.

Vulnerability assessment takes into account property and population characteristics that may increase or decrease the likelihood of impact given exposure to different intensities of hazards. In the past, vulnerability assessments generally focused on the physical vulnerabilities of the property or infrastructure in a community. Hence, the focus was on the quality and nature of construction (i.e., building codes, roof types, elevation, freeboard, etc.) and the location of critical facilities (hospitals, police stations, etc.) in particularly high-hazard areas. Population vulnerability generally focused on simple distributional aspects (i.e., where people are located vis-à-vis hazard exposure). However, since the mid-1980s, there has been a growing literature suggesting that it is just as critical to examine social vulnerabilities that can shape disaster impact as well as response and recovery (Bolin 1986; Bolin and Bolton 1986; Perry and Mushkatel 1986; Cutter 1996; Peacock, Morrow, and Gladwin 1997; Bolin and Stanford 1998; Fothergill, Maestras, and Darlington 1999; Fothergill and Peek 2004; Zahran et al. 2008; Lindell, Prater, and Perry 2007). Consequently, the vulnerability assessments undertaken today generally focus on the physical aspects of vulnerability of property and infrastructure and are beginning to examine not only the distribution of population but social vulnerability as well.

The final and perhaps the most sophisticated level of hazard assessment is risk analysis, which provides a more complete examination of the probabilities of sustaining certain levels of impact given the nature of the hazards in an area. A comprehensive risk analysis will not only include a probabilistic analysis of the hazards, identifying the probabilities of various magnitudes or intensities of events, but will also take into account vulnerabilities. Our purpose in this paper is to undertake a damage assessment on Galveston Island and Bolivar Peninsula, focusing on housing following Hurricane Ike. In that context, the risk has already been played out. However, the general approaches to undertaking a hazard assessment will define our method for modeling damage. Specifically, we will first seek to identify the hazard exposures that the homes in various parts of the community were likely to and did face. Then we will focus on vulnerability and seek to identify not only the physical vulnerabilities of the structure but also more subtle social vulnerabilities that could influence the levels of damage. The following provides a more detailed discussion of the factors considered in each level of analysis: hazard exposure/physical vulnerability, structural vulnerability, and social vulnerability.

Hazard Exposure and Physical Vulnerability

As noted above, hazard exposure is concerned with identifying the geography of an area in terms of hazard intensities and some basic understanding of probable occurrences. The primary forces associated with hurricanes are winds, flooding, and surge. Hurricane Ike was unique in that although it was only a category 2 wind event, its surge levels have been compared to a much more powerful storm. For the purposes of this analysis, therefore, a critical element will be to identify each structure's location relative to various flood zones. Of particular significance will be locations in flood zones A, which represent hundred-year flood zones, and V, which represent hundred-year coastal flood zones likely to experience velocity or wave action. The latter zones are those primarily subject to ocean surges associated with hurricanes, which are not only associated with major damage to structures because of velocity and wave action but are also the major cause of deaths. Indeed, during the 1900 storm, it was the surge with the 1900 storm that killed thousands. The extraordinary loss of life attributed to the 1900 storm was one of the primary reasons that Galveston undertook building its now famous seawall in an attempt to prevent powerful ocean surges from ever entering the city again. The seawall is a classic example of structural mitigation, much like levees and dikes, and should also be an important consideration when seeking to model post-event damage. Finally, while locations in the A and V flooding zones certainly provide important information regarding the likely magnitudes of flooding that a structure might have experienced, these magnitudes are based on various physical hazard models and therefore may not capture completely the actual flooding a structure might experience. Consequently, the actual levels of inundation or wind, to the extent that they can be obtained, should for that matter also be included in attempts to model damage.

Structural Vulnerabilities

Hurricane damage can be a result of high winds, which can penetrate the envelope of a structure; a storm surge, which can flood the interiors and scour the foundations; or, often, a combination of both. Although the pathway may be different, each case may result in various levels of damage, ranging from superficial exterior damage to complete structural failure and destruction. The characteristics of the structure—its roof, foundation, exterior materials, and building standard—act in concert with these forces, either resisting or succumbing to damage. Numerous characteristics have been identified as potential determinants of hurricane damage. For example, gabled roofs are more vulnerable to high winds, while hip roofs are preferred in hurricane-prone areas. Elevated homes on piers are also preferred, if not required, for flood insurance in areas that are prone to storm surges. Such homes generally tend to suffer less damage than low-lying pier and beam structures or structures simply built on at-grade foundations. Unfortunately, Galveston has examples of all forms of housing. While some of its older housing had been built with relatively low-lying pier and beam foundations, much of that housing was actually raised using fill after the 1900 storm to increase its elevation. That general pattern continued until the late 1950s, and especially in the 1960s and 1970s, when homes were built on simple slab-on-grade foundations. Most newer homes (from 1980s onward) built outside the urban core and not protected by the seawall toward the west end of Galveston Island were built and elevated on 6′, 12′, and even higher piers.

The changing nature of building customs, standards, and codes can also be important for understanding physical vulnerabilities. Strong building codes, especially in hazard-prone areas, have been repeatedly shown to reduce damage from a range of hazards and are an important tool available to local communities for hazard mitigation (Mileti 1999). Studies following Hurricane Andrew found problems not only with code enforcement but also with the changing nature of the code itself (Fronstin and Holtmann 1994). The Miami area experienced many powerful storms during the early part of the twentieth century. In response, the homes built during the early part of the century generally took these hazards into consideration, either because of custom and general knowledge of local builders or, later, because of official building standards and codes. However, beginning in the later part of the century, with the housing boom in Miami and national building firms moving into the area, newer building styles and materials were introduced. The result was a weakening of the building code, which, coupled with low enforcement, resulted in tragic consequences. The picture for Galveston is somewhat different and more difficult to discern given the long history and diverse building customs of the island. From interviews with planners and building officials, it appears that building practices were generally good during the early part of the century but became weaker particularly during the middle of the century, when much of the slab-on-grade construction was allowed. More recently, Galveston has had, and continues to have, some of the strongest building standards and codes in Texas. This suggests stronger codes early on, followed by a general weakening of codes as one moved forward, and then stronger codes as one moved toward 2008. Our analysis will address these changes through the elevation of a structure and explore the consequences of changing building codes and standards based on the year the structure was built.

Social Vulnerability

In general, the research on damage and losses due to disasters has often found that factors related to social vulnerability, such as race/ethnicity and income or wealth, are often related to higher relative levels of damage and losses. In large measure, this appears to be due to trickle-down housing processes in the United States, whereby the poor and minorities are often allocated to older and poorer quality housing and often segregated into less desirable and potentially more risky neighborhoods and areas (Foley 1980; Bolin 1986; Bolin and Bolton 1986; Logan and Molotch 1987; Greene 1992; Massey and Denton 1993; Phillips 1993; Phillips and Ephraim 1992; Peacock and Girard 1997; Charles 2003; Peacock, Dash, and Zhang 2006; Van Zandt 2007).

Peacock and Girard (1997), in their study of housing damage due to Hurricane Andrew, which was primarily a wind and not a flooding event in the southern sections of Miami-Dade county, found that factors such as proximity to the eye and housing type (single, multifamily, mobile home, duplex) were critical in shaping damage. In addition, they reported that after controlling for these issues, income was not a significant factor. However, they found that both Black and Hispanic households suffered higher levels of damage when compared to Anglos. Furthermore, neighborhood variations were also important in that housing in highly segregated black neighborhoods reported significantly higher levels of damage, even after other factors were controlled. They speculated that this might be due to the particularly low-quality housing often found in these highly segregated neighborhoods. In subsequent work examining housing damage and recovery using longitudinal data, Zhang and Peacock (2010) found that housing in predominantly Black and Hispanic neighborhoods suffered significantly higher levels of damage due to Hurricane Andrew. This inequitable pattern of damage also set the stage for very different recovery trajectories for minority, and particularly predominantly Black, neighborhoods when compared to Anglo neighborhoods.

Measurement and Data Analysis

The data used in this analysis come from several sources, both primary and secondary. The sample consists of approximately 1,500 detached housing units randomly sampled from parcels on Galveston Island and Bolivar Peninsula (see Figure 1). In the following sections, we describe how the database was assembled.

Hazard Exposure and Physical Vulnerability

Using the coordinates of each sampled single-family home and GIS, a series of seven (7) variables were developed to measure the potential (4) and actual (3) hazard exposure of each residence. The four potential hazard exposure measures are a structure's distance from water and the seawall and its location in either FEMA A or V flood zones. Because of the nature of the storm surge that arose from both the Gulf and bay sides, distance to water should have a negative relationship with damage: the farther the structure was from the water, the lower its assessed damage. Conversely, the seawall on Galveston Island (see Figure 1) is a form of structural mitigation aimed solely at decreasing the impacts of a storm surge. We expected a positive relationship with respect to damage and distance from the seawall: the farther the structure was from the protection of the seawall, the more damage it was likely to receive. The FEMA floodplain designations were also measured as two dichotomous variables: presence in either the A zone (1 percent flood zone) or the V zone (1 percent flood zone with velocity or wave action). Both variables represent an objective measure of flood risk; thus, both variables should have a positive relationship with damage. However, structures in the V zone should experience more damage than structures in the A zone, as the V zone represents not only flood hazards but also storm-induced wave action.

The three hazard exposures related specifically to Hurricane Ike are associated with a home's likely exposure to winds, surge/flood, and the strongest cumulative wind/surge energy. The predicted maximum inundation resulting from the surge was measured for each sampled home by using a flood inundation layer created post-storm by the Harris County Flood Control District. This continuous variable was also expected to show a positive relationship with damage. The maximum sustained winds, as measured by an interpolated surface point data from the NOAA Hurricane Research Division, were also generated and attributed to each surveyed structure. We also expected this variable to be positively related with damage. A third dichotomous variable, which identified a home's location on Galveston Island (1) versus Bolivar Peninsula (0), was also created. Bolivar Peninsula was on the right side of the storm as it moved toward the eastern end of Galveston Island and into Galveston Bay (see Figure 1). Bolivar was subject to the strongest winds and most devastating storm surge, resulting in greater damage compared to Galveston Island. In light of the coding, this variable was expected to be negatively related with damage (Galveston Island = 1) and to serve as a control for geographically induced differences in damage.

Table 1. Descriptive Statistics and Expected Relationships for Independent Variables.

Variable	*n*	Mean	Standard Deviation	Minimum	Maximum	Expected Sign
Damage Index	1,380	7.94	5.52	4	20	
Structure Elevation (feet)	1,181	5.27	4.85	0	25	–
Home Age (years)	1,215	39.18	18.74	3	128	+
Distance to Water (feet)	1,506	1,424.82	1,247.15	0	7,113	–
Distance to Seawall (feet)	1,506	26,683.65	33,222.94	233	154,263	+
Proportion in FEMA A Zone	1,506	0.58	0.49	0	1	+
Proportion in FEMA V Zone	1,506	0.25	0.43	0	1	+
Maximum Sustained Wind (mph)	1,506	85.41	3.69	79.61	98.23	+
Maximum Inundation (feet)	1,506	7.50	2.67	0	12	+
Galveston Island	1,506	0.80	0.40	0	1	–
Improvement Value (2008 dollars)	1,506	109,800	92,201	10060	935,340	–
Proportion Hispanic	1,506	0.19	0.16	0.01	0.58	+
Proportion Black	1,506	0.13	0.20	0	0.98	+

Structural Vulnerability and Damage Assessment

In December 2008, approximately three months after Hurricane Ike, the authors and their students spent approximately two thousand hours on Galveston Island and Bolivar Peninsula (see Figure 1) conducting damage assessments of detached housing units. Approximately fifteen hundred assessments were collected by trained students based on a random sample of parcels identified as single-family residential units by the Galveston County Appraisal District. The damage assessments collected information on the structural characteristics of the housing units and evidence of damage. Two measures collected from these assessments were used in the analysis. First, damage was assessed based on five-point scales, ranging from superficial/no damage to completely destroyed, on four separate home attributes: *Foundation and Structural Damage, Roof Damage, Exterior Damage*, and *Overall Damage*. These four variables were summed to create a highly reliable damage index (Cronbach's $\alpha = 0.96$), ranging from 4, indicating superficial or no damage to all four components, to 20, meaning total damage that left no trace of the home. Second, the assessors determined if the structure was elevated and provided an estimate of the elevation at the lowest part of the first floor. The expectation was that the damage would decrease with increasing home elevation.

Data on the age of the home were collected from the associated Galveston County Appraisal District property value roll (see Table 1). Age may reflect the quality or upkeep of a home; however, it can also capture variations in building standards and codes. As noted above, planners and building officials in Galveston had suggested that building practices were generally good during the early part of the century, due in no small measure to the devastating 1900 hurricane and another destructive storm that followed. However, the standards and codes weakened particularly during the postwar housing boom in the middle of the century, when much of the clearly ill-conceived slab-on-grade construction was allowed. All else being equal, if our sample covered relatively recent decades, age should have a positive relationship with damage, meaning older homes should suffer greater levels of damage because of declining construction standards. However, as will be seen later, the age range in this sample provides the opportunity to determine whether building standards and practices were indeed stronger early in the last century, generally weakened as one moved toward the midcentury, and then evolved into stronger codes as one moved toward 2008.

Social Vulnerability Variables

Social vulnerability has been measured either by using index construction, often at higher levels of aggregation (Cutter, Mitchell, and Scott 2000; Cutter, Boruff, and Shirley 2003); individual social vulnerability attributes, such as race/ethnicity, economic status, etc. (Bolin 1986; Bolin and Bolton 1986; Peacock and Girard 1997; Zahran et al. 2008; Zhang and Peacock 2010); or both approaches (Van Zandt et al. 2012; Peacock et al. 2012). Because our focus is on assessing the relative merits of social vulnerability indicators relative to hazard exposure and structural vulnerability at a highly disaggregated level, we employed three measures of critical dimensions of social vulnerability. The first two are related to race/ethnicity; more specifically, proportions of Hispanic and non-Hispanic Black populations were collected from the U.S. Census Bureau (2000 census) at the block level and spatially transferred to the sampled parcels that they contained. Based on the existing social vulnerability literature, we expected both of these measures to have a positive relationship with damage. Lastly, we used the pre-storm assessed improvement value for each structure as provided by the Galveston County Appraisal District property

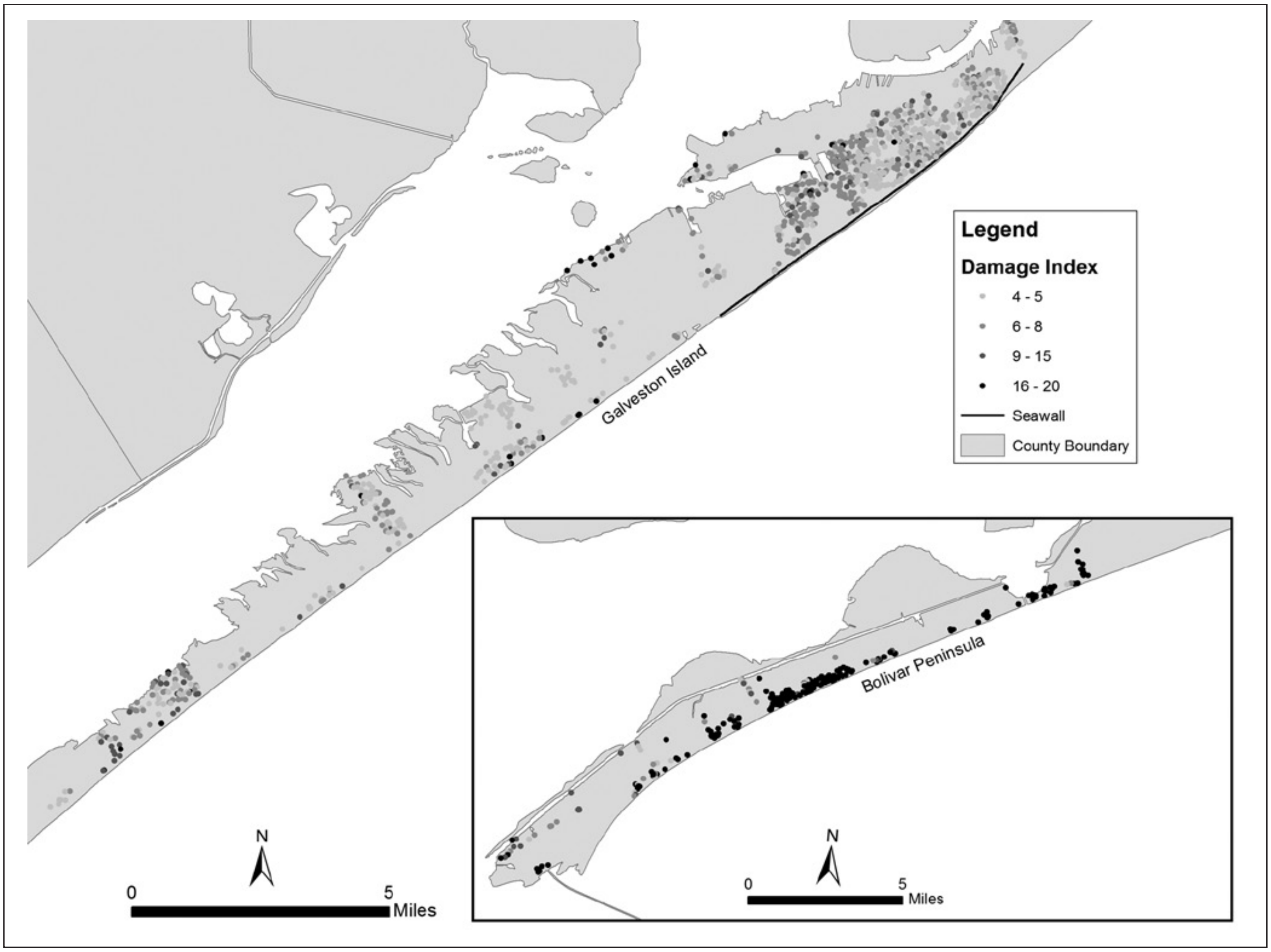

Figure 2. Assessed damage on Galveston Island and Bolivar Peninsula based on Damage Index.

value roll. Property value serves as a proxy for overall household economic status while still retaining an individual level of measurement. We expected the improvement value to have a negative sign, as the value of the residence, and thus financial resources, increases damage should decrease.

Data Analysis

Data were analyzed in three phases. First, two blocks of independent variables representing geographic and structural characteristics were incrementally loaded into ordinary least squares (OLS) regression models to explain the damage as measured by the damage index. Second, we explored and modeled the nonlinear effects of the age of the home by using squared and cubed terms in a third regression block. Finally, we added a fourth regression block consisting of social vulnerability variables. OLS models were run by using robust standard errors to offset heteroskedastic error structures.

Results

Descriptive Results

Our sample of single-family detached housing, reflecting the distribution of housing between Galveston Island and Bolivar Peninsula, included 80 percent of the assessed structures that were on the island. This was nearly representative of the population but slightly skewed toward Galveston.[1] The pattern of damage in many ways reflected this dichotomy, as can be clearly seen in Figure 2, which provides a map of the assessed housing color-coded to reflect damage levels. The majority of structures assessed on Bolivar Peninsula were severely damaged or completely destroyed, especially those adjacent or nearly adjacent to the Gulf of Mexico. Although the mean damage (as measured by the twenty-point damage index) for the study area was 7.94, Bolivar Peninsula had a mean damage index of 16.89 compared to 5.91 for Galveston Island. A much more variable pattern of damage emerged on Galveston Island. Higher levels of damage occurred on the bay side of the island as a result of surge washing back over

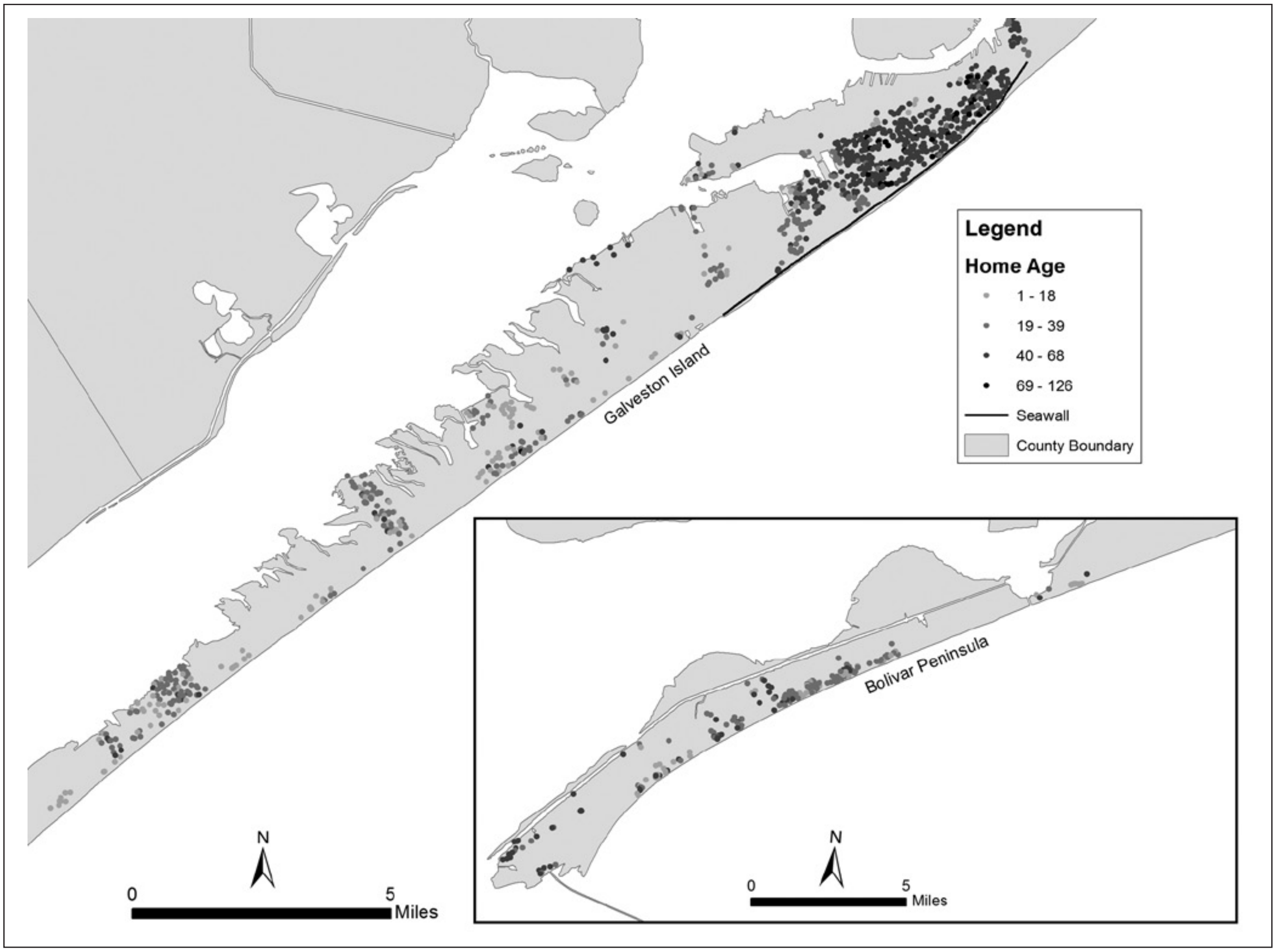

Figure 3. Age of surveyed homes on Galveston Island and Bolivar Peninsula.

from the bay, as reflected by the higher frequency of darker dots in Figure 2. The west end of the island, unprotected from the seawall, also had higher levels of damage, especially those residences that fronted the Gulf of Mexico. Homes that were set back from the Gulf and protected by the seawall, particularly those found in the eastern urban core, had more variable patterns of damage relative to the previous three spatial scenarios. The spatial damage pattern does suggest that the seawall was an effective measure of protection.

The average structure elevation across the study area was 5.27 feet. Nearly 80 percent of structures were elevated in one form or another. However, these elevation figures also included pier and beam foundations that were not elevated to the same extent as those homes elevated on true piers. This characteristic also showed a notable dichotomy. Although the most extreme damage occurred on Bolivar Peninsula, the mean structure elevation in the area was nearly 9 feet, compared to nearly 5 feet for Galveston Island. This differential in elevation was due primarily to FEMA floodplain regulations, which require higher structure elevations in V zones, and a higher proportion of post-FIRM V-zone structures.[2] In other words, newer construction was forced to elevate to meet the requirements on V-zone base flood elevations to comply with the minimum National Flood Insurance Program (NFIP) floodplain regulations. Nearly 95 percent of the surveyed structures were located in the V zone on Bolivar, compared to nearly 40 percent of V-zone structures on Galveston.

The mean age of the surveyed structures was 39 years, corresponding to a build date of 1969. A potentially more illuminating result with respect to home age is its dispersion. The newest home surveyed was a mere three years old, built in 2005. The oldest home surveyed was 128 years old, corresponding to a build date of 1880 and predating the infamous 1900 Galveston hurricane. Simply stated, there was wide variation in the age of the surveyed structures, which reflects the heterogeneous nature of the area's housing stock. This pattern was also evident in the spatial distribution of home age; however, some expected patterns emerged. As shown in Figure 3, the bulk of homes close to and older than the mean structure age were found on the east end of Galveston Island, in the urban core. In a pattern not unlike that found in many developed areas, newer construction was

Table 2. Mean Home Age by V-Zone Designation and Geography.

	Bolivar	Galveston	Total
Out of V Zone	30.54	41.45	40.97
Inside V Zone	28.92	19.92	24.82
Total	29.26	38.70	38.18

spreading outward from this urban core and was found in what many would consider fairly traditional subdivisions.

A second interesting feature of home age is its relationship to hazardous geographies and, ultimately, hazard exposure. Not only did newer construction spread to areas outside the urban core on the eastern end of Galveston; it also expanded into increasingly hazardous areas (see Table 2). The mean home age of a structure inside the V zone on Bolivar was approximately twenty-nine years, compared to a mean home age of 30.5 years outside the V zone, a very small and statistically insignificant difference (t = 0.749, p = 0.46). This was to be expected, as there were less "non-hazardous" areas on Bolivar. Conversely, newer construction on Galveston spread into increasingly hazardous areas despite opportunities to infill and redevelop areas in the urban core behind the seawall. The mean home age of structures inside the V zone on Galveston was nearly twenty years, an approximate build date of 1988. In comparison, the mean home age for structures built outside the V zone was forty-one years, a statistically significant difference of twenty-one years (t = 15.06, p < 0.00).

The consideration of structure elevation and home age raises an interesting development pattern. On the one hand, new homes, while conceivably better constructed as a result of building standards and NFIP elevation requirements, are placed in increasingly hazardous areas. On the other hand, older homes, which should be more vulnerable to damage because of their age, lack of elevation, and higher potential for deterioration, were built in less hazardous areas. This is not a wholly unexpected pattern given development pressures and an "island" geography that caters to second homes, the demand for which is much higher when there is adjacency to or view of water. It does, however, begin to suggest a reliance on engineered structures at the loss of a cultural tradition of building in less hazardous areas; many of these engineered structures were built before there was a "line on a map" suggesting that damage was probable.

Finally, the mean proportion of minorities as determined from block-level census data was 0.13 for blacks and 0.19 for Hispanics. The mean assessed improvement value was \$109,800 (median = \$83,980). Further, given the descriptions of the previous variables, the spatial patterns of socioeconomic variables are generally as expected. Both race variables suggest that each race resides in somewhat segregated areas on the east end of Galveston, in locations that typically have older home ages, lower improvement values, and seemingly variable levels of damage.[3] The race variables also illustrate the extremely low proportions of minorities that reside on both the west end of Galveston Island and Bolivar Peninsula, areas that are characterized by higher improvement values.

Multivariate Results

Our first model, the physical vulnerability and hazard exposure model, includes the potential and actual hazard exposure variables regressed on our damage index (see Table 3). The coefficients all show the expected directions; however, only three of the six variables are statistically significant: distance to water (p < 0.001), maximum modeled inundation (p < 0.05), and the Galveston Island indicator variable (p < 0.001). This model accounts for 26.5 percent of the variance in damage. The second model adds two structural variables to the previous block: the elevation of the structure and the age of the home. Both structural variables show effects in the expected directions and are statistically significant at the p < 0.001 level. The addition of these two variables does not change the direction of any of the physical/exposure variables but raises both the V-zone and the seawall distance to statistical significance at the p <0.01 level. The R^2 value of the second block is 0.313, a statistically significant 0.048 increase in explained variance.

The third block explores the nonlinear effects of home age with respect to damage while controlling for all previous variables, all of which retain their prior directions and significance levels. The addition of a quadratic home age term has a negative result and is statistically significant at p <0.001, opposite the direction of the level age coefficient, which also remains significant at p <0.001. A third cubed home age term is added, which changes the directions to positive and is also significant at p <0.001. The addition of a fourth quartic home age term was insignificant and thus removed, providing evidence to support the inclusion of only the level, quadratic, and cubic terms. The addition of the two transformed variables increases the R^2 from a statistically significant 0.026 to 0.339.

Finally, the fourth model adds variables representative of social vulnerability perspectives. All previous variables retain their prior directions and significance, with the exception of structure elevation, which continues to have a negative relationship while retaining significance in a one-tailed test in the anticipated direction. Both race variables, proportion of blacks and proportion of Hispanics, are positive and statistically significant at p < 0.05 (one-tailed) and p < 0.01, respectively. As expected, home value is negative and statistically significant at p < 0.01.[4] This final model also shows a statistically significant increase in R^2 of 1.2 points, accounting for a total of 35.2 percent of the variance in damage.[5]

Table 3. Incrementally Loaded Regression Models Explaining Structural Damage on Galveston Island and Bolivar Peninsula.

	Hazard Exposure/Physical Vulnerability			Plus Structural Vulnerability			Plus Nonlinear			Plus Social Vulnerability		
	B (SE)	*t*	Beta	*B* (SE)	*t*	Beta	*B* (SE)	*t*	Beta	*B* (SE)	*t*	Beta
Water distance (thousands of feet)	–0.17085 (0.0807)	–2.12*	–0.07098	–0.38718 (0.0870)	–4.45***	–0.16085	–0.35777 (0.0848)	–4.22***	–0.14863	–0.45676 (0.0842)	–5.42***	–0.18976
Seawall distance (thousands of feet)	0.004565 (0.0069)	0.66	0.038862	0.020585 (0.0074)	2.8**	0.175245	0.019482 (0.0073)	2.67**	0.165853	0.023582 (0.0079)	2.99**	0.200763
V zone	0.664187 (0.4819)	1.38	0.082318	1.306155 (0.4750)	2.75**	0.161882	1.358839 (0.4669)	2.91**	0.168412	1.576007 (0.4661)	3.38***	0.195327
A zone	0.298389 (0.2429)	1.23	0.04664	0.492523 (0.2420)	2.04*	0.076984	0.464181 (0.2362)	1.96*	0.072554	0.55171 (0.2419)	2.28*	0.086236
Galveston Island	–4.94952 (0.8189)	–6.04***	–0.41393	–4.79424 (0.8052)	–5.95***	–0.40095	–4.66215 (0.7823)	–5.96***	–0.3899	–4.4749 (0.7927)	–5.65***	–0.37424
Maximum inundation (feet)	0.111324 (0.0536)	2.08*	0.087693	0.151951 (0.0529)	2.87**	0.119696	0.156442 (0.0523)	2.99**	0.123233	0.13756 (0.0514)	2.67**	0.10836
Wind speed (mph)	0.002643 (0.0328)	0.08	0.002722	–0.05037 (0.0338)	–1.49	–0.05187	–0.03977 (0.0332)	–1.2	–0.04096	–0.02939 (0.0339)	–0.87	–0.03027
Structure elevation (feet)				–0.09927 (0.0269)	–3.68***	–0.16184	–0.05667 (0.0280)	–2.02*	–0.09239	–0.04498 (0.0277)	–1.62*†	–0.07333
Home age (years)				0.032947 (0.0060)	5.45***	0.211173	0.143981 (0.0279)	5.16***	0.922837	0.147642 (0.0279)	5.29***	0.946304
Home age^2							–0.00195 (0.0006)	–3.3**	–1.16659	–0.00234 (0.0006)	–4.02***	–1.40005
Home age^3							8.1E–06 (3.35e06)	2.42*	0.507423	0.000011 (0.0000)	3.33***	0.690341
Proportion Hispanic										1.768153 (0.6590)	2.68**	0.09249
Proportion black										0.776848 (0.4618)	1.68*†	0.051114
Improvement value (natural log)										–0.32063 (0.1460)	–2.20**	–0.07926
Constant	9.513458 (3.2071)	2.97**		12.65739 (3.2868)	3.85***		9.881777 (3.2004)	3.09**		12.32225 (3.8098)	3.23	
n	942											
R^2	0.269			0.319			0.344			0.356		

*$p \le 0.05$; **$p \le 0.01$; ***$p \le 0.001$; †one-tailed p value.

Discussion

The results of the hazard exposure and structural vulnerability variables conform to our previous expectations and maintain statistical significance in the final fully loaded regression model. After controlling for other factors, structures located farther from water were found to have suffered less damage, while those located closer to the seawall suffered less damage. Housing located in both the V and A zones suffered significantly higher levels of damage, net of other factors, compared to housing outside these zones. As expected, housing located in V zones suffered significantly higher levels of damage than did housing in A zones, as reflected by the three times higher V-zone coefficient than the A-zone coefficient, a statistically significant difference.[6] This result is no doubt at least partially driven by the higher levels of damage and the presence of a V-zone area on Bolivar Peninsula. The modeled maximum inundation is obviously a significant positive predictor of damage. The maximum sustained wind is statistically insignificant, indicating the lack of wind damage relative to flooding/surge. Not surprisingly, the strongest predictor of among the exposure/physical measures is the dichotomous variable representing Galveston or Bolivar, which captures the concentrated hurricane forces that acted on the peninsula, resulting in significantly higher levels of damage.

The structural characteristics of the home revealed important consequences for damage across these models. While the structure elevation measure showed some movement in terms of significance across the models, the effect was, as anticipated, negative and significant ($p < 0.05$, one-tailed) in the full and final model. This suggests that, holding all other factors constant, the higher the elevation of the home, the less damage the home suffered. It is important to note that this relationship is sustained although proportionately more and higher elevated homes on Bolivar were severely damaged or destroyed.

The age of the home shows perhaps the most interesting relationships in the three models in which it was entered. For the model with the level home age variable alone, the finding simply suggests that as the age of the home increased, the amount of damage increased. However, the entrance of quadratic and cubic terms reveals a relationship that is not simply linear. Damage increased with home age until the first point of inflection at forty-seven years, or approximately 1961. After this point, the effect on damage began to decrease with home age until the second point of inflection at 95 years, or approximately 1913, at which point it began to increase again. This finding suggests that, holding other factors constant, the period between the late 1950s and early 1960s was a low point in building standards and codes with respect to hurricane hazards. After controlling for a host of additional variables, that period was found to be marked by relatively high damage levels compared to the other time periods before and after it. As one moves back in time from 1961, the relative damage levels decrease until around 1913, when they begin to pick up again. Similarly, holding other factors constant, the relative damage levels decrease as one moves forward in time from 1961.

With some caution, we draw the following conclusions.[7] As previously mentioned, the mean home age in highest-risk areas (i.e., V zones) is lower than that in lower-risk areas, likely due to development pressures and increased demand for ocean views. However, it is not simply location that is critical here, because the age of the home maintains this non-linear relationship with damage after controlling for location in high-risk areas. While simple descriptive analysis suggests that the restriction of building in higher-risk areas was lost over time, the modeling results also suggest that building customs and standards, as well as knowledge of structural characteristics suited for building in a coastal environment, also weakened toward the middle of the twentieth century. The decreasing levels of home damage as one moves back in time from 1961 to 1913 suggest that the cultural memory of how—not just where—to build appropriately was gradually lost as development expanded, reaching a low point in 1961. In turn, the decreasing levels of relative damage as one moves forward from 1961 to 2008 suggest a slow reemergence of building standards and more formal codes, promoting more resilient housing that can withstand wind, surge, and flooding. These standards and codes are clearly not perfect, but they are improving. The apparent disregard for previously understood construction practices may well reflect how growth pressures and demand during boom periods can ultimately place more housing and, consequently, households in harm's way. These findings also suggest that construction requirements in the form of building codes may also play an important role in reducing damage, even when building in higher-risk areas. It is probable that the increasing levels of damage in the first period of the home age, moving from 2008 to 1958, corresponds to decreasing effectiveness of and reliance on inappropriate building code standards. More research and additional information on the chronology of the building codes are necessary to confirm this hypothesis.

Lastly, the role of race/ethnicity and income in the context of social vulnerability cannot be ignored. Even after controlling for a host of geographic and structural characteristics, homes located in areas with higher proportions of both Hispanic and Blacks were found to have experienced more damage. Interestingly, the test for significant differences between the minority effects showed negative results, suggesting no differential between areas with higher concentrations of Hispanics and Blacks.[8] It is important to note that (although not displayed in Table 3) in equations that include the proportion of whites, rather than minority proportions, the effect was negative and statistically significant, providing additional evidence that housing in minority neighborhoods were disproportionately impacted with higher levels of damage compared to white areas, after controlling for physical and structural vulnerability. Similarly, the findings also suggest that lower-socioeconomic-status homes suffered disproportionately, as reflected by the negative effect on damage found for the assessed home value. Specifically, after controlling for other factors, the levels of damage decreased as the assessed home value increased. The spatial patterns for minority populations and lower-valued homes show a distinct overlap, as well as significant pairwise correlations between assessed value and minority population ($r = -0.27$ for Hispanics, $r = -0.31$ for blacks; $p < 0.0001$). The compounding effects of social vulnerability assessed in terms of race/ethnicity and socioeconomic status are clearly evident in this damage analysis. It is also worth noting that our sample excludes multifamily residences and thus likely underestimates (perhaps grossly) the disproportionate impact on minorities and low-income households, which are much more likely to be renters. The disproportionate impact on racial and ethnic minorities is also likely to mean that these populations are more likely to be slower to recover and that these neighborhoods may be at risk of total redevelopment if displaced households are unable to return, as has been seen in New Orleans following Hurricane Katrina (Bullard and Wright 2009; Bates and Green 2009; Brunsma, Overfelt, and Picou 2007). As a result, the social geography of the community may change in ways that compound preexisting social and economic disparities.

It is important to recognize that the characteristics of damage agents in every hazard are variable. In the case of Hurricane Ike, a storm surge was a far greater cause of damage relative to wind. As a result, structures that were more vulnerable to flooding, typified by lack of elevation, location in designated flood zones, absence of protection from a seawall, and greater proximity to the water source, received on average increased damage. The spatial pattern and development pressures, as well as hazard risks, that occur in areas such as Galveston Island and Bolivar Peninsula may be considerably different from those found in typical urban and rural areas. The barrier island and long peninsula that make up our study area are high in demand for second homes and cater to a tourism-based economy. These characteristics tend to place higher-valued, newer homes in more hazard-prone areas. Nonetheless, the relationships of damage with home age, race, and improvement value affirm many of the same patterns that previous studies have found in reference to social vulnerability.

Conclusions

Communities that exist along the coast have relatively well-known risks and vulnerabilities that should be employed to shape the nature of mitigation and comprehensive planning efforts. This research points to significant relationships between damage and hazard exposure, structural characteristics, and social characteristics, which clearly imply the need to address hazard exposure and physical/structural and social vulnerabilities as part of the fact basis undergirding planning efforts. Planners, public officials, and policy makers have an obligation to facilitate planning efforts that help guide and shape community growth in a way that does not exacerbate risk, by limiting new development (and redevelopment) in areas that are at greater risk. Simultaneously, they need to encourage or require builders, developers, and residents to (re)construct homes that are both safe and resilient. Land use planning is often identified as an important tool in hazard planning and mitigation, guiding development to safer locations and limiting or restricting it completely in others. However, the effectiveness of land use controls in areas where the vast majority of areas are at risk is greatly diminished. Building codes used in tandem with incentive programs for home elevation and structural enhancement can encourage residents and builders to make positive changes to their homes when undertaking rebuilding. Housing will continue to be constructed in these areas but should be built at elevations with generous built-in "error," commonly referred to as freeboard. The cities affected by Hurricane Ike in our study area, as well as unincorporated Galveston County, simply require NFIP minimum standards for construction in A and V zones; that is, structures must be built to the base flood elevation. Not only are these requirements the minimum standards; they are also often based on outdated flood insurance rate maps. Requiring newer construction to include generous freeboard would result in reduced damage to many homes.

Our study provides initial evidence to suggest that changing building codes and standards played important roles in shaping damage. Retroactively altering a home, and realistically entire neighborhoods, to conform to new building codes is economically prohibitive and politically infeasible. Typically, structures are only brought up to a newer code when substantial (more than 50 percent of the structure value) damage occurs or renovation is undertaken. Enacting local regulations to lower this threshold either on a one-time basis or cumulatively over time would open a window of opportunity to appropriately retrofit homes under more effective building codes and encourage redevelopment in less vulnerable areas. Such a step would increase the turnover rate of vulnerable and poorly built housing stock.

Finally, planners and policy makers must be aware of the social inequities wrought by the impacts of such disaster events. It has long been assumed that racial and ethnic minorities experienced greater damage because they lived in more structurally vulnerable (i.e., poorer quality) homes in more physically vulnerable (e.g., lower-lying) areas. Our findings indicate an independent effect for minority status and lower incomes. While additional research is needed, we suspect that greater damage stems from disinvestment in the community—poorer upkeep, a lack of infrastructure, and regular maintenance, etc. The causes of disinvestment in poor, minority neighborhoods are complex, but the finding that greater damage may be a consequence adds to the evidence that both mitigation and recovery resources should be prioritized in areas where they can have the greatest impact. Targeting of resources, particularly public resources, is a critical step in preventing a rapid turnover of the population and the loss of affordable housing stock to avoid the exacerbation of preexisting inequalities.

Planning for resilient communities means taking into account hazard exposure and physical/structural and social vulnerability to both acute and diffused threats. As communities face escalating losses from both natural hazards and the forces of climate change, the urgency of developing smartly grows. In this research, we provide empirical evidence of significant and independent effects for all three aspects of vulnerability. It is not enough to merely strengthen building codes. Nor is it politically or financially feasible to restrict development in sensitive areas. In areas like the Texas coast, which experiences tremendous growth pressures, resilience requires a comprehensive and equitable approach to regional development.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by funding from the National Science Foundation (CMMI 0901605 and CMMI 0928926). Any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Notes

1. Sampling on Bolivar Peninsula following Ike presented numerous challenges in the form of navigating without known references, presence of foreign/hazardous objects, and locating selected structures. Much of the Bolivar area was completely destroyed.
2. Post-FIRM structures are those built after the first effective flood insurance rate map (FIRM) and must conform to the National Flood Insurance Program requirements.
3. Some caution is warranted when drawing conclusions on the spatial patterns of data collected at the census block compared to the individual-level data for other variables.
4. The improvement value was log-transformed.
5. Running independent models for each block of variables are as follows: physical/hazard exposure, $R^2 = .269$; structural, $R^2 = .058$; and social vulnerability, $R^2 = .258$.
6. Wald statistic of $6.18_{(1,927)}$, $p = .013$.
7. The role of home age as a determinant of hurricane damage is important, and we have taken great care to explore this relationship to the fullest extent. It seems likely that home age relates to building codes and styles, yet we urge caution in making this link without more data. Future research would benefit greatly from transferring home age to the respective building codes. Finally, the nonlinear relationship of home age with damage is a step forward in modeling data from damage assessments. We urge researchers to explore, with caution, relationships beyond those that appear to be simply linear.
8. Wald statistic of $1.83_{(1,927)}$, $p = .176$.

References

Bates, L., and R. A. Green. 2009. “Housing Recovery in the Ninth Ward: Disparities in Policy, Process, and Prospects.” In *Race, Place, and Environmental Justice after Hurricane Katrina*, Chapter 11, edited by R. D. Bullard and B. Wright, 229–48. Boulder, CO: Westview.

Berg, R. 2009. *Tropical Cyclone Report: Hurricane Ike*. Miami, Florida: National Hurricane Center.

Blaikie, P., T. Cannon, I. Davis, and B. Wisner. 1994. *At Risk: Natural Hazards, People’s Vulnerability, and Disasters*. London: Routledge.

Bolin, R. 1986. “Disaster Impact and Recovery: A Comparison of Black and White Victims.” *International Journal of Mass Emergencies and Disasters* 4:35–50.

Bolin, R., and P. Bolton. 1986. *Race, Religion, and Ethnicity in Disaster Recovery*. Program on environment and behavior, Monograph 42. Colorado: Institute of Behavioral Science, University of Colorado.

Bolin, R., and L. Stanford. 1998. “The Northridge Earthquake: Community-based Approaches to Unmet Recovery Needs.” *Disasters* 22:21–38.

Brunsma, D. L., D. Overfelt, and J. S. Picou. 2007. *The Sociology of Katrina*. Boulder, CO: Rowman & Littlefield.

Burby, R. J. 1998. *Cooperating with Nature: Confronting Natural Hazards with Land-Use Planning for Sustainable Communities*. Washington, DC: Joseph Henry Press.

Bullard, R. D., and B. Wright. 2009. *Race, Place, and Environmental Justice after Hurricane Katrina*. Boulder, CO: Westview.

Charles, C. Z. 2003. “The Dynamics of Racial Residential Segregation.” *Annual Review of Sociology* 29:167–207.

Comerio, M. C. 1997. “Housing Issues after Disasters.” *Journal of Contingencies and Crisis Management* 5:166–78.

Cutter, S. L. 1996. “Vulnerability to Environmental Hazards.” *Progress in Human Geography* 20 (4): 529–39.

Cutter, S. L., B. J. Boruff, and W. L. Shirley. 2003. “Social Vulnerability to Environmental Hazards.” *Social Science Quarterly* 84:242–61.

Cutter, S. L., J. T. Mitchell, and M. S. Scott. 2000. “Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina.” *Annals of the Association of American Geographers* 90 (4): 713–37.

Daniels, T., and K. Daniels. 2003. *The Environmental Planning Handbook for Sustainable Communities and Regions*. Chicago: American Planning Association.

Deyle, R. E., S. P. French, R. B. Olshansky, and R. G. Paterson. 1998. “Hazard Assessment: The Factual Basis of Planning and Mitigation.” In *Cooperating with Nature: Confronting Natural Hazards with Land Use Planning*, edited by R. J. Burby. Washington, DC: Joseph Henry Press.

Foley, D. L. 1980. “The Sociology of Housing.” *Annual Review of Sociology* 6:457–78.

Fothergill, A., and L. A. Peek. 2004. "Poverty and Disasters in the United States: A Review of Recent Sociological Findings." *Natural Hazards* 32 (1): 89–110.

Fothergill, A., E. Maestras, and J. D. Darlington. 1999. "Race Ethnicity and Disasters in the U.S.: A Review of the Literature." *Disasters* 23 (2): 156–73.

Fronstin, P., and A. G. Holtmann. 1994. "The Determinants of Residential Property Damage Caused by Hurricane Andrew." *Southern Economic Journal* 61 (2): 387–97.

Godschalk, D. R., T. Beatley, P. Berke, D. J. Brower, and E. J. Kaiser. 1999. *Natural Hazard Mitigation: Recasting Disaster Policy and Planning*. Washington, DC: Island Press.

Greene, M. 1992. "Housing Recovery and Reconstruction: Lessons from Recent Urban Earthquakes." In: *Proceedings of the 3rd U.S./Japan Workshop on Urban Earthquakes*, Oakland, CA: Earthquake Engineering Research Institute (EERI) Publication No. 93-B.

Lindell, M. K., C. Prater, and R. W. Perry. 2007. *Introduction to Emergency Management*. Hoboken, NJ: Wiley.

Logan, J. R., and H. L. Molotch. 1987. *Urban Fortunes: The Political Economy of Place*. Berkeley: University of California Press.

Massey, D. D., and N. A. Denton. 1993. *American Apartheid: Segregation and the Making of the Underclass*. Cambridge, MA: Harvard University Press.

Mileti, D. 1999. *Disasters by Design*. New York: Joseph Henry Press.

Morrow, B. H. 1999. "Identifying and Mapping Vulnerability." *Disasters* 23 (1): 1–18.

Peacock, W. G., N. Dash, and Y. Zhang. 2006. "Shelter and Housing Recovery Following Disaster." In *The Handbook of Disaster Research*, edited by Havidan Rodriguez, E. L. Quarantelli, and Russell Dynes, 258–74. New York: Springer.

Peacock, W. G., and C. Girard. 1997. "Ethnic and Racial Inequalities in Hurricane Damage and Insurance Settlements." In *Hurricane Andrew: Ethnicity Gender and the Sociology of* Disasters, edited by W. G. Peacock, B. H. Morrow, and H. Gladwin, 171–90. London: Rutledge.

Peacock, W. G., B. H. Morrow, and H. Gladwin. 1997. *Hurricane Andrew: Ethnicity Gender and the Sociology of Disasters*. London: Rutledge.

Peacock, W. G., S. Van Zandt, D. Henry, H. Grover, and W. Highfield. 2012. "Social Vulnerability and Hurricane Ike: Using Social Vulnerability Mapping to Enhance Coastal Community Resiliency in Texas." In *Lessons from Hurricane Ike*, edited by P. B. Bedient, chapter 7. College Station, TX: Texas A&M Press.

Perry, R. W., and A. H. Mushkatel. 1986. *Minority Citizens in Disasters*. Athens: University of Georgia Press.

Phillips, B. D. 1993. "Culture Diversity in Disasters: Sheltering, Housing and Long-Term Recovery." *International Journal of Mass Emergencies and Disasters* 11:99–110.

Phillips, B. D., and M. Ephraim. 1992. "Living in the Aftermath: Blaming Processes in the Loma Prieta Earthquake." Working Paper No. 80, Natural Hazards Research and Application Information Center, University of Colorado, Boulder.

Schwab, J. 1998. *Planning for Post Disaster Recovery and Reconstruction. PAS Rep. No. 483/484*. Chicago: American Planning Association.

Van Zandt, S. 2007. "Racial/Ethnic Differences in Housing Outcomes for First-Time, Low-Income Home Buyers." *Housing Policy Debate* 18 (2): 431–74.

Van Zandt, S., W. G. Peacock, D. Henry, H. Grover, W. Highfield, and S. Brody. 2012. "Mapping Social Vulnerability to Enhance Housing and Neighborhood Resilience." *Housing Policy Debate* 22 (1): 29–55.

Zahran, S., S. D. Brody, W. G. Peacock, A. Vedlitz, and H. Grover. 2008. "Social Vulnerability and the Natural and Built Environment: A Model of Flood Casualties in Texas 1997-2001." *Disasters* 32 (4).

Zhang, Y., and W. G. Peacock. 2010. "Planning for Housing Recovery? Lessons Learned from Hurricane Andrew." *Journal of the American Planning Association* 76 (1): 5–24.

Author Biographies

Wesley E. Highfield is an assistant professor in the Department of Marine Sciences at Texas A&M University at Galveston. His research focuses on natural hazards and spatial sciences.

Walter Gillis Peacock is a professor in the Department of Landscape Architecture & Urban Planning and the Director of the Hazard Reduction and Recovery Center at Texas A&M University. His research focuses on natural hazards, emphasizing social vulnerability and resiliency, evacuation, and the sociopolitical ecology of long-term recovery and mitigation.

Shannon Van Zandt is an associate professor in the Department of Landscape Architecture & Urban Planning and the Director of the Center for Housing & Urban Development at Texas A&M University. Her research focuses on the spatial distribution of housing and its consequences for vulnerable populations.