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Evaluating Coastal Resilience and Disaster Response: The Case of Galveston and Texas Gulf Counties following Hurricane Ike

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This article investigates principles of social and ecological resilience to natural disasters considering areas of Texas affected by Hurricane Ike. In an effort to address the challenges and opportunities faced by coastal communities in response to natural hazards, a case study approach (incorporating primary and secondary data) following Beatley's (2009) best practices in planning for coastal resiliency was employed. Based on the case analysis and principled outlined, disaster-prone coastal communities need to implement new social and environmental planning strategies to potentially mitigate negative effects of natural disasters that incorporate long-term planning and implementation, coastal management, land use, and structural and non-structural designs.

Keywords comprehensive plan, environmental planning, green infrastructure, hazard mitigation plan, social capital, social network

Introduction

More than 50% of the U.S. population resides in coastal areas, comprising only 17% of the country's land area (Brody 2012; Parry et al. 2007). Over the last 40 years such areas have grown to approximately 50 million residents—an increase of roughly 46% (Crossett et al. 2004). By 2015, Crossett et al. (with the National Oceanic and Atmospheric Administration) expect the population in such regions to increase by an additional 7.1 million. In the state of Texas, the Houston-Sugarland-Baytown metropolitan statistical area (including Galveston) has shown the greatest percent of population change (i.e., nearly a 76% increase) between 2000 and 2012.

Low-elevation coastal areas with high-population concentrations are extremely vulnerable to rising sea levels and various coastal hazards. Along with people and property concentrations in coastal areas, climate change is expected to lead to more severe hurricane and rainfall, increased river discharges, and rising sea levels (Elsner, Kossin, and Jagger 2008; Intergovernmental Panel on Climate Change [IPCC] 2007; Pine 2009). Since coastal areas comprise land and structures of high property value, complex, interdependent

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infrastructure networks, and tend to experience higher growth rates than most other areas, fast and effective recovery after disasters is an important issue for such areas (Berke and Smith 2010; Blanco and Marina 2009).

The purpose of this article is to investigate the principles of social and ecological resilience to natural disasters employing a case study approach for Galveston—a coastal city in Texas that sits in the center of one of the most disaster-prone areas in the United States. More specifically, this article explores socioecological components of resilience that can contribute to improved disaster recovery. Together with the application of socioecological resilience principles to the study areas, this article attempts to accomplish the following research objectives:

- To select socioecological factors contributing to coastal resilience in Texas Gulf counties, recently affected by Hurricane Ike by using socioeconomic census data
- To examine whether the disaster response plan is effective in reducing disaster losses by surveying Galveston's business owners

Resilience in Coastal Communities

Peacock et al. (2012, 66) noted that

> This [growing residential and commercial development in coastal areas] contributes to increased hazard exposure and often results in the destruction of environmental resources such as wetlands, often increasing losses. In other words, many of the communities in our nation are becoming ever more vulnerable to "natural" hazards while simultaneously becoming less disaster resilient.

This passage emphasizes the fact that a number of expanding coastal communities and their corresponding developments are susceptible to natural hazards, along with environmental resource loss (Cutter 2003; Peacock et al. 2008). Further, this trend suggests that efforts of communities are essential to reduce vulnerability, enhance response and recovery, and strengthen resiliency to natural disasters (Zandt et al. 2012). Vulnerability can be regarded as the outcome of the interaction between exogenous factors determined by the incidence and intensity of natural disasters as well as the ability of a country/region to deal with the impact of endogenous elements or factors (Sadowski and Sutter, 2005; Zahran et al. 2008). In particular, when it comes to the role of social vulnerability, Blakie et al. (1994) and the Hines Center (2000) have stressed that "in recent years there has been an emerging recognition that a comprehensive understanding of vulnerability requires the addition of another critical dimension, social vulnerability, which is generally understood as the capacity of individuals or social systems of various scale to anticipate, cope, resist and recover from the impacts of a hazard agent" (as cited in Peacock et al. 2008, 5). In this regard, in an effort to address the challenges and opportunities faced by a community in response to natural hazards, this article attempts to focus more on investigating the principles of social and ecological resilience to natural disasters than those of disaster vulnerability.

From an ecological perspective, resilience is defined by Holling (1973) as, "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (17). More recently, Walker et al. (2004) described resilience as, "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (3). With an emphasis on disaster-resilient communities, Ersing (2012, 103) pointed out that "resiliency is described as the ability to 'bounce back' or to return to a state of functioning that was in place prior to exposure to a significant stressor such as a natural hazard." Over time, this general concept of resilience has been applied to diverse social–ecological systems in accordance with thematic domains like social and economic change, ecosystems, and environmental change; and individual, community, region, national, and international spatial domains.

If resilience is addressed in relation to social and environmental situations (or change), it can be represented as the capacity of individuals or communities to deal with external perturbations (i.e., disturbances, stresses) as a consequence of social, political, and ecological change (Berkes 2007; Nelson, Adger, and Brown 2007; Norris et al. 2008; Peacock et al. 2012). In addition to this definition, social and environmental resilience persists with the same controls on the function and structure of diverse changes (Berkes 2007; Cutter et al. 2008) and recovers or bounces back from the change (e.g., lack of water resources, biodiversity loss or extinction, population displacement) (Beatley 2009; Perrings 2006). For instance, in light of ecological systems, conserving, diversifying, and nurturing biodiversity can be helpful in increasing environmental resilience, stability, and its function (Adger 2000; Berkes 2007).

Given the dynamic association between social resilience and dependence on natural resources, resilience can be determined by institutional change, economic structure, and demographic change (Adger 2000). As a detailed indicator for this resilience measurement, both institutional change and economic structure factors include economic growth, income stability and distribution, and environmental variability (Adger 2000). At the local or community level, the resilience factor encompasses formal sector employment, crime rates, and demographic change factors (e.g., mobility, migration). Regarding demographic change, in particular, significant population movement can be evidence of instability or it could be a component of enhanced stability and resilience.

The measurement or indicator of social resilience can be more specifically observed in the work of Cutter et al. (2008). Based on community resilience to natural disasters from a variety of research perspectives, variables for measuring resilience were described in combination with the competence of ecological, social, economic, institutional, infrastructure, and community systems (Cutter et al. 2008; Kapucu et al. 2013; Peacock et al. 2012). In particular, under the attributes of natural disasters and disaster risk reduction (Cutter et al. 2008; Mercer et al. 2007), ecological and institutional systems are determined by factors like floodplain area, soil permeability, wetlands acreage and loss, erosion rates, impervious surfaces, precipitation, biodiversity (Brody and Gunn 2013), participation in hazard reduction programs, hazard mitigation plans, emergency services, zoning and building standards, emergency response plans, and continuity of operations plans (Cutter et al. 2008).

Similar to the social resilience factor proposed by Adger (2000), Cutter et al. (2008), and Peacock et al. (2012), social and economic factors, infrastructure, and community competence factors were suggested as resilience components. Social and economic resilience indicators can be addressed by demographics, social networks and embeddedness (i.e., social capital), community value-cohesion, faith-based organizations, employment, values of property, wealth generation, and municipal finance or revenues (Aldrich 2012; Ersing and Kost 2012; Nowell and Steelman 2013). Especially, among these indicators, at the community level, Ersing (2012, 104) highlighted that "social networking can play an integral part in the ability of the local area to return to a pre-disaster state of functioning." In addition, infrastructure resilience factors in the context of environmental hazards include lifelines and critical infrastructure, transportation networks, residential housing stock and age, and commercial and manufacturing establishments (Cutter et al. 2008). This resilience indicator addresses physical systems and dependence or interdependence on other infrastructures. Based on community attributes, indicators of community competence resilience involve health and wellness, quality of life, and absence of psychopathologies (Deshkar, Hayashia, and Mori 2011). A resilient system is forgiving of external shocks (i.e., disturbances). Resilience shifts attention from purely growth and efficiency to needed recovery and flexibility (Pine 2009; Walker and Salt 2006). In this regard, resilience can be defined as the capacity of a system to absorb disturbances and reorganize while undergoing changes so as to still retain essentially the same function, structure and feedbacks—and therefore the same identity.

Research Design and Method

Analytical Framework

Based on the literature review concerning indicators of socioecological resilience and as illustrated in Figure 1, an analytical framework was devised to address the empirical as well as theoretical approach for the case study. This framework embraces two phases: (1) examining social–ecological factors contributing to resilience within counties affected by a natural disaster (*Phase I*) and (2) among affected counties, applying resilience principles and evaluating Galveston's response to Hurricane Ike (*Phase II*). More specifically, with respect to *Phase I*, socioecological resilience characteristics encompassing various socioeconomic, ecological, and institutional situations can be determined in line with thematic domains like social and economic change, ecosystems, and environmental change and spatial domains such as individual, community, region, nation, and cross-country. In this article, we analyzed 34 counties (including Galveston county) affected by Hurricane Ike (2008) in an effort to determine socioecological resilience indicators. This phase is based on the available data collected from several official research sources such as recent county-level socioeconomic data from the U.S. Census Bureau.

These selected resilience indicators are also closely associated with resilience principles. With regard to *Phase II*, primarily based on Beatley's work (2009) in relation to the "tools and techniques for enhancing and strengthening coastal resilience" (72–96), this study attempts to address the application of resilience and the evaluation of Galveston's responses to the natural disaster. In so doing, we selected several disaster resilience principles suitable for the context of Galveston. In addition, with an emphasis on efficacy of emergency response plan for local businesses, this article addresses whether the response plan is effective in reducing physical losses by surveying business owners in Galveston. In this regard, this analytical process will be useful in providing important insights on how to make communities more resilient to the adverse impacts of natural disasters and in underscoring the critical importance of a local hazard mitigation plan or comprehensive plan in contributing to resilience.

Data Collection and Descriptive Analysis

For *Phase I*, in an effort to engage in research on coastal resilience and evaluate disaster responses in the study areas (34 Texas Gulf counties, which were all federally declared disaster areas in 2008) before and during Hurricane Ike (from 2005 to 2008), multiple secondary research sources were collected from official websites such as the National

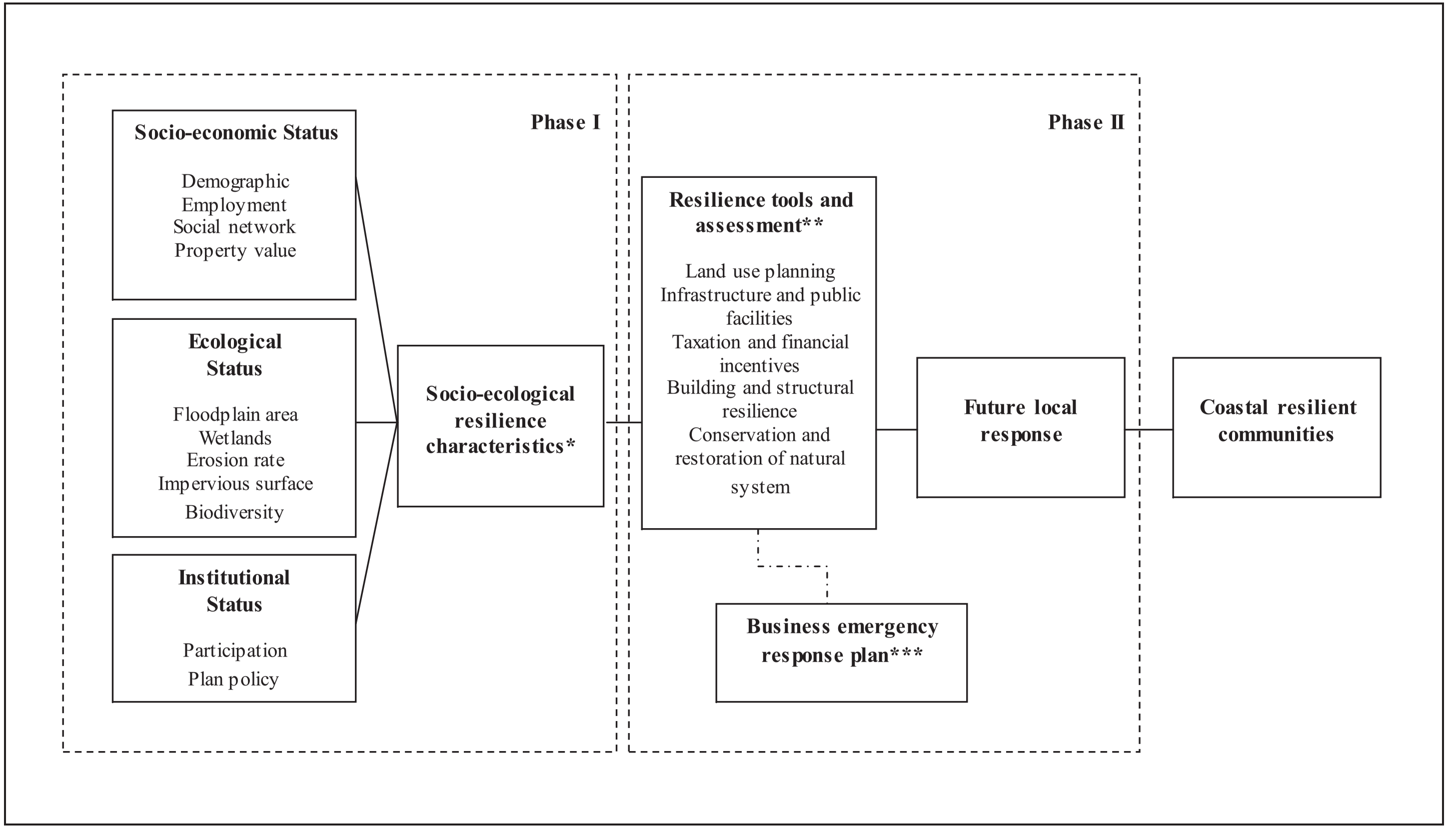

Figure 1. Analytical framework.
Note: *secondary data based analysis, **document based analysis, ***primary data based analysis.

Oceanic and Atmospheric Administration (NOAA), the Federal Emergency Management Agency (FEMA), the U.S. Census Bureau (USCB), and the Spatial Hazard Events and Losses Database for the United States (SHELDUS) at the Hazard Research Lab at the University of South Carolina. Additionally, in an effort to address resilience principles and evaluate Galveston's response to Hurricane Ike (as *Phase II*), we selected documents such as Galveston's comprehensive plan (completed in 2001) and hazard mitigation plan for resilience (completed in 2011). Each document includes diverse strategies for the community's long-term conservation, growth, and development.

In an effort to conduct the survey of business owners, in accordance with the 2007 2-digit North American Industry Classification System (NAICS), we stratified the population by industrial sectors (e.g., construction [23], manufacturing [31–33], wholesale trade [42], accommodation and food services [72], [] denotes industry with 2-digit number classified by NAICS) in Galveston. In addition, along with the sample size proportionate to the size of the stratum in the population, a random sample of businesses in each sector was selected. As a result, a total of 4,130 businesses (of the 5,073 total Galveston businesses according to County Business Pattern in 2009) were randomly selected to be part of the final study sample. Following the "tailored design method," the mailing of the questionnaire began seven months after Ike and was followed by a postcard reminder and then telephone calls to the businesses to solicit participation. A total of 250 business owners filled out the survey questionnaire, yielding a response rate of approximately 6%. The questionnaire included business characteristics (e.g., size, ownership, age), perceptions on physical damage, and preparedness (e.g., having an emergency plan).

Relying on a variety of data sources, descriptive analysis for *Phase I* focused on two characteristics of indicators associated with natural disaster losses within affected counties: socioeconomic characteristics and ecological characteristics. Based on the literature review, the numerous variables are presented in Table 1, together with the hypothesized effect of property damage (one of the main disaster losses) caused by natural disasters. First, as a dependent variable, the dollar value of property losses from Hurricane Ike (adjusted for inflation in 2012) aggregated to the county level was log transformed in order to better approximate a normal distribution. The socioeconomic characteristic variables before Ike (from 2005 to 2007) include age (percent of population over 65), income (median household income), race (percent of white population), educational attainment (percent of population with a bachelor's degree), and housing and vacancy characteristics (percent of housing units built after 2005, percent of vacancy of housing units). As a proxy of ecological characteristic variables, a coastal or disaster vulnerable variable (dummy-coded, whether or not the study areas are adjacent to coastal areas), was selected.

According to the county-level file from the U.S. Census Bureau (from 2007 to 2008), the median household income in Galveston County dropped from more than US$66,000 to US$59,000, and the residential vacancy rate grew from about 15% to 19%. In addition, in the year following Hurricane Ike, housing median prices dropped from more than US$181,000 to about US$128,000 (according to the 2013 Real Estate Center at Texas A&M University). Similar to the findings of Carbone, Hallstrom, and Smith (2006), hurricanes and resulting disasters have been shown to negatively impact the housing or labor markets.

As described in Table 1, to examine the role of business emergency response plans in reducing natural disaster damage, this study relies on a proxy measure—the business owners (respondents)' perception of natural disaster damage. Specifically, the perceived business damage variable was measured using a 7-point Likert scale ranging from "none" to "extremely severe." As various independent variables, the average age of businesses (primarily small-sized including on average 10 employees) was about 19 months. Regarding

Table 1
Descriptive statistics

Variable name	Definition/measurement	Obs	Mean	SD	Min	Max	Hypothesized effect	Source
Disaster damage characteristics: Respondent variable*								
Property damage	Property damage, 2008[a] ($)	34[b]	1.33E+08	1.44E+08	501,196.8	6.17E+08		SHELDUS
	log Property damage, 2008	34	7.42	1.12	5.70	8.79		
Explanatory variables*								
Socioeconomic characteristics								
% of white population	White population/total population, 2005–2007 (%)	34	75.62	8.75	55.10	91.20	–	USCB
% of Bachelor degree	Bachelor degree or higher/ total population, 2005–2007 (%)	34	17.45	6.86	7.50	37.90	–	
Household income	Median household income, 2005–2007 ($)	34	43,237	10,841	29,817	76,635	–	
Unemployment	Unemployment rate, 2005–2007 (%)	34	7.79	2.17	4.90	14.90	+	
% of New built housing	Built housing 2005 later /total housing units, 2005–2007 (%)	34	2.11	1.57	0.10	6.10	–	
% of Vacant housing	Vacant housing/total housing units, 2005–2007 (%)	34	15.75	6.50	5.80	30.00	+	
Housing tenure	Owner occupied/total housing units, 2005–2007 (%)	34	72.30	7.41	55.70	83.80	–	
% of population over 65	65 years and over /total population, 2005–2007 (%)	34	12.40	3.35	6.40	19.90	+	
Ecological characteristics								
Coastal	Coastal location (yes = 1, no = 0)	34	0.26	0.44	0	1	+	NOAA
Business disaster damage characteristics: Respondent variable**								
Business damage	Perception on the overall damage to business, 7-level Likert scale (1–7)	250	4.47	2.15	1	7		

(Continued on next page)

Table 1
Descriptive statistics *(Continued)*

Variable name	Definition/measurement	Obs	Mean	SD	Min	Max	Hypothesized effect	Source
Explanatory variables**								
Business characteristics								
Age	The number of months since the business started up (month)	250	18.97	21.67	1	169	+	Survey to the business owners in Galveston[a]
Size	The number of employee (person)	250	9.62	19.09	0	140	–	
Franchise	Dummy-coded, whether or not a firm is a kind of franchise (yes = 1, no = 0)	250	0.05	0.23	0	1	+	
Minority owned	Dummy-coded, whether or not minority owned a firm (yes = 1, no = 0)	250	0.01	0.12	0	1	+	
Woman owned	Dummy-coded, whether or not woman owned a firm (yes = 1, no = 0)	250	0.09	0.30	0	1	+	
Financial status	Perception on the financial condition before Ike, 5-level Likert scale (1–5)	250	3.86	0.75	1	5	–	
Manufacturing	Dummy-coded, whether or not a firm is a kind of manufacturing sector (yes = 1, no = 0)	250	0.04	0.19	0	1		
Emergency plan characteristics								
Emergency response plan	Dummy-coded, whether or not a firm had an emergency response plan before Ike (yes = 1, no = 0)	250	0.65	0.47	0	1	–	

Note: *selected variables for socioecological resilience across counties in Texas (*Phase I*), **selected variables for the efficacy of business emergency response plan in Galveston (*Phase II*), a: conducted seven month later Hurricane Ike affected), Units in parentheses. [a]inflation adjusted in 2012, [b]Texas counties (including Galveston) in federally declared disaster areas in 2008 (Hurricane Ike), Units in parentheses, NOAA: National Oceanic and Atmospheric Administration, SHELDUS: Spatial Hazard Events and Losses Database for the United States at the Hazard Research Lab at the University of South Carolina, USCB: US Census Bureau.

ownership in the selected business, the owner was primarily male and majority in race. Before Ike, the financial status in business was regarded as somewhat good. Especially, more than half of the selected businesses had an emergency response plan before HURRICANE Ike.

Study Area and Hurricane Ike

Hurricane Ike, the ninth named storm during the 2008 hurricane season, made landfall along the north end of Galveston Island, Texas. The combination of storm surge and heavy rainfall was particularly destructive to this area. Over 60% of buildings on the Bolivar Peninsular were destroyed and slightly less than 2% were undamaged or sustained minimal damage (FEMA 2009). Residential damage costs derived from wind and flood totaled roughly US$3.4 billion (Bedient and Sebastian 2012).

As of May 2013, Ike was the fourth costliest hurricane to hit the United States after Hurricanes Katrina (2005), Andrew (1992), and Sandy (2012), bringing about the largest search and rescue operation in U.S. history and resulting in the largest evacuation of Texans in state history (Blackburn, Colbert, and Shanley 2012; Hurricane Recovery Network, 2010). When it comes to the severe damage of Hurricane Ike, Blackburn, Colbert, and Shanley (2012, 156) estimated that "although Ike caused upwards of US$24 billion in damage, the damage could easily have reached US$100 billion if it had come ashore further south, in the San Luis Pass area." With an emphasis on property losses from natural disaster, 10% of all housing structures in Galveston were completely destroyed by Hurricane Ike (Brody 2012).

As discussed earlier, the increasing frequency and severity of storms along the Gulf of Mexico coasts have put a large number of people and resources at risk. The 34 selected counties in Texas were deemed ideal for investigating hurricane impacts on local social and economic status and examining social–ecological factors contributing to resilience given their comparatively long history of hurricanes and primarily because they were declared federally disaster areas after Hurricane Ike.

Galveston County was the most severely impacted area as a result of the hurricane. The county composed of three parts (Galveston Island and Bolivar Peninsula at the mouth of Galveston Bay, and land southwest of Galveston Bay) is low in elevation and experienced an extremely severe impact. In addition to these physical geographical characteristics, "Galveston, like most communities, is not homogeneous, but rather contains areas characterized by wealth, leisure, and privilege, as well as neighborhoods plagued by poverty, crime, and unemployment" (Peacock et al. 2012, 66).

According to the 2007–2011 American Community Survey (ACS) from the U.S. Census Bureau, Galveston county had a US$59,645 median household income which was slightly above that for Texas overall (US$50,920). In relation to adjacent coastal counties, Galveston County had a lower income than that of Brazoria County (US$67,018) and Chambers County (US$72,850). At the same time, Galveston County had a higher poverty rate (13.1%) than Brazoria County (10.7%) and Chambers County (8.3%) (ACS 2007–2011). This fact reflects that, overall, Galveston County has a lower potential to enhance its economic development. More than 18,000 businesses in Galveston County were damaged by Hurricane Ike, which put 53,000 employees out of work (FEMA 2008). The City of Galveston, the county's economic engine, lost 85% of its business base. The preliminary damage estimates on housing, infrastructure, hospital, ports, and beaches were put at US$2 billion for the City of Galveston (FEMA 2008).

Table 2
Log-linear model of socioecological resilience factors

Variable	Coefficient	T
Intercept	5.063(3.462)	1.462
% of white population	0.005(0.027)	0.188
% of Bachelor degree	−0.048(0.056)	−0.859
Household income	1.18204E-05 (5.97E-05)	0.198
Unemployment	0.239**(0.119)	1.999
% of New built housing	0.431(0.299)	1.439
% of Vacant housing	0.030(0.042)	0.705
Housing tenure	−0.011(0.049)	−0.224
% of population over 65	−0.037(0.087)	−0.428
Coastal	1.137**(0.551)	2.064
N	34[a]	
F(9, 24)	2.221*	
adj R-square	0.305	

Note: $^{*}p < .1$, $^{**}p < .05$, dependent variable: log *Property damage*, [a]Texas counties (including Galveston) in federally declared disaster areas in 2008 (Hurricane Ike), standard errors in parentheses

Results

Socioecological Factors Contributing to Resilience: Phase I

A regression model was used to isolate the impacts of selected socioecological resiliency components of hurricane losses throughout the study areas. As illustrated in Table 2, two factors played an important role in modifying the amount of property loss caused by Hurricane Ike. As supported by the research of Kellenberg and Mobarak (2008), the unemployment rate from 2005 to 2007 (before the natural disaster) significantly increases property damage ($p < .05$).

Counties vulnerable to natural disasters, in particular those with coastal characteristics, usually a strong indicator of natural disaster loss, have a discernible influence on maximizing the amount of hurricane damage ($p < .05$). The percentage of residents with bachelor's degrees and the number of homeowners from 2005 to 2007 were negatively correlated with residential damage, and were not statistically significant in the study areas. This finding indicates that a greater economic condition before the disaster occurs contributes to lower disaster losses. Given that a region has a stronger economic status before a disaster; it will experience fewer disaster losses than a region with a weaker economic condition.

Resilience Tools and Assessment of Galveston Responses: Phase II

In examining Galveston's structural and non-structural hazard mitigation plans as well as its comprehensive plan, an assessment of Galveston's response to Ike was undertaken following the work of Beatley (2009). Based on this work, specific tools and techniques for enhancing and strengthening resilience to natural disasters in Galveston were addressed. As illustrated in Figure 2, such tools and techniques include: (1) land use planning, (2) local infrastructure and public facilities, (3) taxation and financial incentives, (4) conservation and restoration of natural systems, and (5) building and structural resilience.

Resilience tools and current assessment				Future local response	Example
Land use planning (S+N+C)	Weak	Moderate	Strong	• Cluster zoning or land use conservation (e.g., dune system and wetlands) • Environmental erosion • Protecting dune vegetation and stability • Code revision (e.g., seawalls) • Insurance for residents and business (e.g., community rating system)	Worcester county and Crisfield (Maryland), Maui county (Hawaii), Palm Beach county (Florida)
Cluster zoning		√			
Hard mitigation strategy	√				
Complex wetland system	√				
Infrastructure and Public Facilities (S+C)	Weak	Moderate	Strong	• Retrofitting for wind resistance, • Elevating buildings (i.e., structural design) • Construction of an elevated emergency center (e.g., protecting public transportation system)	Worcester county (Maryland)
Retrofit for wind resistance	√				
Elevating building	√				
Emergency operation	√				
Taxation and financial incentives (N+C)	Weak	Moderate	Strong	• Creating incentives for the introduction of new single-family houses into these neighborhoods • Extending tax exemption along with tax credits or abatement	Collier county (Florida), Montgomery county (Maryland), Portland (Oregon)
Infill rehabilitation	√				
Tax exemption program	√				
Conservation and restoration of natural system (S+N+C)	Weak	Moderate	Strong	• Tree ordinance • Preservation of established native vegetation • Reestablishing typical barrier island defenses against coastal erosion forces (pursuing finding a bay restoration plan)	Charleston county (South Carolina)
Tree preservation	√				
Defense against coastal erosion faces	√				
Building and structural resilience (S+C)	Weak	Moderate	Strong	• Newly cleaned storm sewers • Increasing required erosion controls at construction sites • New regulations to require storm water retention system	Worcester county (Maryland)
Strom security system	√				
Structural mitigation strategy	√				

Figure 2. Tools for disaster resilience, current assessment, and future Galveston's response. S: Structural Hazard Mitigation Plan, N: Non-structural Hazard Mitigation Plan, C: Comprehensive Plan, Resilience tools in boldface, specific factors regarding resilience tools in italic characters.

Land use planning. As suggested by previous studies (Godschalk et al. 1998; Gruntfest 2000), local land use planning techniques, as one of the non-structural flood mitigation approaches, allows communities to be more resilient to flooding. Along with the emphasis on land use in natural disasters, Galveston, similar to other local governments (e.g., Worcester County in Maryland, Palm Beach County in Florida), has adopted a land use plan which has fostered greater resilience to, while incorporating responses to natural hazards like flooding. The city has reviewed zoning standards and subdivision regulations. One possible consideration may include the use of cluster zoning or other land use conservation measures for future development in accordance with the hazard mitigation strategy incorporating setbacks for natural resources (e.g., dune systems and wetlands) (Beatley 2009; Brody and Highfield 2013). In addition to cluster zoning, it is necessary that the city analyze environmental erosion issues as well as develop a response plan to cope with erosion in conjunction with the Texas General Land Office. Furthermore, protecting dune vegetation and dune stability should be deemed a priority in the coastal development ordinance in line with Galveston's disaster response plan and long-term recovery plan. Since the dune protection line is a buffer which protects the dune hydrology, Galveston should consider reviewing the current setback.

In addition, it is necessary that Galveston consider the impact of development located seaward of, and close to, the seawall structure. The seawall was designed to function as protection and mitigation against destructive flooding and surges (Blackburn, Colbert, and Shanley 2012). Through code revisions, it is important that the city evaluate the opportunities and challenges presented by further development of this area and determine specific standards and criteria for potential projects such as seawalls. In terms of climate change, it is necessary for Galveston to continue considering appropriate methods to reduce erosion on both the beach and bay fronts along with a climate adaptation plan to address other issues (e.g., rising temperatures, changing precipitation patterns, sea-level rise).

Appropriate insurance for community residents and businesses is vital for economic recovery from a natural disaster (Beatley 2009; Grossi and Kunreuther 2005). Galveston can encourage more residents and businesses to purchase adequate insurance by taking steps to reduce flood insurance rates. To accomplish the lower rates, it is necessary that the city become involved in the voluntary Community Rating System (CRS) of the National Flood Insurance Program (Beatley 2009). This insurance is designed to provide an insurance alternative to disaster assistance in meeting the escalating costs of repairing damage to buildings and their contents caused by floods (Brody 2012; Brody and Highfield 2013). Although Galveston has adopted a flood damage prevention ordinance, including provisions for building codes, the city should also consider joining the CRS.

Infrastructure and public facilities. A second tool is to design local infrastructure and public facilities for community resilience. The infrastructure element in the comprehensive plan provides resilient and adequate infrastructure linked with a hazard mitigation strategy to protect infrastructure in storm events and ensure quick recovery and use during emergency situations (City of Galveston comprehensive plan 2001; City of Galveston long term recovery plan 2009). This element calls for the alignment of land use decisions with public facilities and infrastructure investments determined by the city's carrying capacity, anticipated demands, and financial feasibility. Over time, many facilities in Galveston have been heavily damaged by flood waters. For more resilient facilities, it is necessary that the city assess all municipal facilities to determine if the structures can be strengthened or made more resistant to damage from catastrophic events. Similar to the case of Worcester County in Maryland (Beatley 2009), this would include retrofitting for wind resistance, elevating buildings, or raising critical mechanical systems above flood levels similar to other disaster-prone communities (Emmer et al. 2008; FEMA 2009).

In addition to the structural design for resilience, it is necessary that Galveston consider the construction of an elevated emergency operations center to provide a protected location for critical personnel and equipment as suggested by the comprehensive plan. In particular, the city must also update and protect the public transportation system. Buses and trolleys, in particular, were severely damaged by flooding in Hurricane Ike. For this reason, the city should establish a system to secure the municipal transportation system so that there is not a complete loss of the transit system in a disaster event.

Taxation and financial incentives. With regard to taxation and financial incentives, Galveston has tried to encourage small subdivisions on larger properties comprising a block or more of land. Encompassing an expedited development review, waivers of permit fees, potentially short-term abatement of property taxes for new homeowners and developers in these areas, and capital improvements to infrastructure systems and neighborhood amenities, such financial incentives may be relatively passive in nature.

Since infill development reinforces existing neighborhoods and supports existing commercial uses, it can be a particularly sustainable form of development and urban reinvestment (FEMA 2009; Porter 2000). In reality, in the aftermath of Hurricane Ike, Galveston has seen an increase in the number of demolitions and new vacant lots. For example, the Old Central/Carver Park neighborhood includes infill potential associated with a fragmented pattern of vacant lots. For this reason, it is necessary that the city create incentives for the introduction of new single-family houses into these neighborhoods that include older residential areas located near the island's Interstate 45 causeway entrance as noted by the comprehensive plan.

Furthermore, the present tax exemption program in Galveston encourages rehabilitation of commercial structures within designated historic districts. In an effort to apply the exemption to historic residential properties, it is necessary that the city consider extending this exemption along with tax credits or tax abatements like the case of Portland, Oregon (Beatley 2009). According to Galveston's comprehensive plan (2001), similar to the coastal localities such as Collier County in Florida and Montgomery County in Maryland (Beatley 2009), other financial tools and incentives that the city could consider include: tax relief for qualified rehabilitation and infill residential development (including property tax abatements, property tax credits, transfer of development, and property tax exemptions), tax reinvestment/tax increment financing, expansion of the city's receivership program, and revolving/low-interest loan programs.

Conservation and restoration of natural system. The fourth tool for meaningful responses to natural disasters is related to conservation and restoration of natural systems for coastal community resilience. Trees (canopy)—as a natural system—improve air quality, provide shade, protect against erosion, lessen the impact of storm water, and serve as wildlife habitat (Porter 2000). For instance, the storm surge associated with Hurricane Ike represents an estimated 47% loss in Galveston's tree canopy (see Galveston's comprehensive plan 2001). The West End of the city, especially, has fewer trees than the urban core, making the preservation of existing trees a high priority. In this situation, it is necessary that the city establish a tree ordinance addressing tree preservation on the West End and in the urban core.

In addition, by cooling and shading parking lots, the heat island effect of impervious surfaces can be reduced by trees. For this reason, Galveston should continue to update landscaping requirements to emphasize the preservation of established native vegetation and the use of locally native or naturalized and non-invasive plants. By restoring the natural bay environment, there will be a greater opportunity for the marshes and wetlands to provide a buffer from the wave action of the bay. Therefore, the natural system can reestablish the typical barrier island defenses against coastal erosion forces similar to the Charleston County's (South Carolina) effort to develop a comprehensive greenbelt with regard to a green infrastructure system (Beatley 2009).

According to previous studies (Berkes, Colding, and Folke 2003; Walker and Salt 2006), marshes and wetlands can absorb storm water runoff and provide flood control by holding water and releasing it slowly into the bay. In light of ecological resilience, wetlands provide vital habitat for many species of plants, fish, birds, and other wildlife and are an important source of nutrients and organic matter that becomes food for organisms throughout the estuary (Porter 2000; Walker and Salt 2006). For this reason, it is necessary that the city pursue funding for a bay restoration plan in the future as suggested by the comprehensive plan. This plan can provide a management framework to bring about the long-term restoration and protection of the marshes and bay wetlands.

Since the impact of rising global sea levels is anticipated to be greatest on low-lying barrier islands, such as Galveston Island, the city has taken important first steps toward such a response but much remains to be done to ensure that any future developments on the island are sustainable and resilient. On the other hand, in general, local support for open space acquisition and purchase of development rights could come from public and private sources such as community benefits' development incentives, planned giving, grants, general obligation bonds, sales taxes, and/or other dedicated taxes. Thus, it is necessary that Galveston continue to encourage public and private partnerships to maximize open space as noted by the comprehensive plan.

A less-costly alternative to the city would be to include open space acquisition as an expense item in the annual budget although this option requires annual reauthorization and does not constitute a clear commitment to the program. Another alternative action could be the purchase of development rights (i.e., conservation easement). Generally, a land trust, or another organization linked to the local government (e.g., coastal land trust of Maui in Hawaii) (Beatley 2009), offers to buy development rights to a parcel. Since the program will be voluntary, the property owner may choose to accept, refuse, or negotiate the price. If an agreement is made, a permanent deed restriction is placed on the property in perpetuity that restricts the types of activities that may take place on the land.

Building and structural resilience. A final tool is related to building and structural resilience. As a result of natural hazards like Hurricane Ike, significant deposits can be and were left in the storm sewer system. This causes a reduction in the capacity of the pipes and creates greater recurrences of flooding problems. In reality, in 2010, Galveston undertook a system-wide cleaning of the storm-related deposits with assistance from FEMA. For this reason, it is necessary that the city ensure that the newly cleaned storm sewers are maintained and regularly cleaned in the future. If additional cleaning is desired, the city must be willing to fund this type of work in the future. Any new or replacement storm sewers should be designed to facilitate ease of maintenance.

While flooding is associated with hurricane-deposited debris in the storm sewer system, other ongoing factors allow debris to enter the system. For this reason, the city should address the diverse factors (e.g., wind-driven sand, yard debris, lack of curbing, unpaved alleys, and the cleanliness of the gutters). To solve these problems, it is necessary that the city increase the required erosion controls at construction sites and study the effects of industrial traffic. Furthermore, similar to the example of Worcester County in Maryland (Beatley 2009), Galveston should consider new regulations to require storm water retention systems and address the impact of fill on surrounding properties. Storm water retention systems can reduce the demand on the storm sewer system during rain events (Emmer et al. 2008; FEMA 2009; Porter 2000). Thus, the city should encourage the use of rain gardens—landscaped areas that hold water until it can be absorbed into the ground—and rainwater harvesting systems as noted in its comprehensive plan.

Since Hurricane Ike, interest in and discussion of large-scale mitigation projects to protect Galveston and the surrounding area from the effects of future disasters has increased (see hazard mitigation plan 2011 and long-term recovery plan 2009). These large infrastructure projects provide a comprehensive regional storm surge protection plan, such as the Ike Dike (Khazai, Ingram, and Saah 2007). In conclusion, it is necessary that Galveston participate in all regional discussions regarding structural mitigation strategies to ensure that the interests of the city are represented and that the best solutions for the area are determined.

Role of Business Emergency Response Plan in Reducing Natural Disaster Damage: An Example in Phase II

As noted before, as one of coastal resilience principles, this article examines whether Galveston's disaster response plan is effective in reducing disaster damage. Focusing on Galveston' businesses, this study examines relationships between various business characteristics and the prevalence of businesses having an emergency plan prior to Ike on overall physical losses of businesses, employing ordered logit regression (see Table 3). More specifically, the age of the business variable, denoting that the number of months since the business began, is significant and has the expected signs (odds ratio is 0.072). The business size is significantly negative; that is, more employees are associated with less physical losses. Among business ownership variables, the minority business owners variable is significantly positive. Overall, businesses that had an emergency response plan before Ike have a negative influence on the disaster damage when controlling for other factors (odds ratio is 0.333). This result reflects that the emergency response plan or policy, as one of resilience tools, should be adopted and implemented within the study area in an effort to reduce the disaster damage.

Table 3

Ordered logit regression of efficacy of business emergency plan before Hurricane Ike

Variable	Coefficient	Odds ratio
Intercept 1	2.786**(0.681)	
Intercept 2	4.484**(0.757)	
Intercept 3	5.217**(0.779)	
Intercept 4	5.827**(0.792)	
Intercept 5	6.565**(0.802)	
Intercept 6	7.461**(0.813)	
Age	2.629**(0.541)	0.072
Size	−1.786**(0.441)	0.168
Franchise	0.716*(0.284)	2.048
Minority owned	2.034**(0.394)	0.131
Woman owned	0.297(0.271)	1.346
Financial status	−0.569(0.633)	0.566
Manufacturing	0.614(0.409)	1.848
Emergency response plan	−1.098*(0.342)	0.333
N	250	
Likelihood	157.033**	
Score/Wald	104.787**/109.197**	
AIC/SC	956.195/977.324	
−2Log L	944.195	

Note: *$p < .05$, **$p < .001$, dependent variable: *Business damage* (7-level Likert scale), standard errors in parentheses.

Conclusions

Galveston, located in the Gulf of Mexico coastal region, has experienced rapid social and ecological changes due to increasing surrounding urban development (e.g., Houston) combined with an increase in natural disasters resulting from hurricanes. Its social and ecological deterioration has reached an alarming level and therefore has led to negative effects in the coastal area. In an attempt to solve these social and ecological problems and promote a healthy and sustainable coastal community for the future, the city needs a resilient disaster approach along with its hazard mitigation plan and comprehensive plan. As an empirical result of socioecological factors contributing to resilience, greater economic conditions (e.g., low employment rate) before the disaster among Texas Gulf counties lead to lower disaster losses. In other words, if a region has a stronger economic status before a disaster, it will experience fewer disaster losses.

The social and ecological resilience plans, comprising diverse principles, scientific analysis, education, and institutional learning to manage environmental resources sustainably can be implemented through low impact development, a diverse local economy, long-term planning, a compelling vision of the future, preparation and advance planning, and preservation and restoration of ecosystems and ecological infrastructure. Particularly, in integrating social and ecological planning (or environmental planning) to alleviate negative effects on the coastal disaster-prone social or ecological conditions, new strategies encompassing these principles that incorporate long-term planning and implementation, coastal management, land use, and structural and non-structural designs are necessary.

It goes without saying that the process a community must engage in to become resilient involves numerous barriers. Such barriers are due to geographical location, political climate, and economic condition. With widespread natural disasters impacting multiple communities (i.e., due to transboundary rivers or coastlines), inter-community and transboundary cooperation is crucial before and after a disaster occurs. In addition, those local communities with traditional top-down decision-making will be at a disadvantage and need to embrace a bottom-up approach through participation of residents—especially those having prior experience with natural disasters. Furthermore, communities with minimal economic reserves may have difficulty implementing structural hazard mitigation plans. Based on the current study, businesses that had emergency response plans in place prior to Ike making landfall were effective in reducing disaster damage. This finding shows that the disaster preparedness plan should be adopted and implemented in order to reduce disaster losses.

The key lesson to be learned here is that with crucial disaster resilience practice—in collaboration with local responses to natural hazards, sharing hazard mitigation plans and comprehensive plans with regard to social and ecological issues—can improve local responses to natural disasters in the future and promote tools for resilience. Therefore, it is necessary that local communities implementing disaster resilience plans recognize the principles of social and ecological resilience and pursue specific tools and techniques for enhancing and strengthening responses to natural disasters in accordance with the characteristics (e.g., geographical, political, economic situation) of the community.

References

Adger, W. N. 2000. Social and ecological resilience: are they related? *Progress in Human Geography* 24 (3): 347–364.

Aldrich, D. P. 2012. *Building resilience: Social capital in post-disaster recovery*, Chicago and London: The University of Chicago Press.

Beatley, T. 2009. *Planning for coastal resilience: Best practices for calamitous times*, Washington, DC: Island Press.

Bedient, P. and A. Sebastian. 2012. Hurricane Ike. In *Lessons from Hurricane Ike*, ed. P. B. Bedient, 16–27. College Station: Texas A&M University Press.

Berkes, F. 2007. Understanding uncertainty and reducing vulnerability: Lesson from resilience thinking. *Natural Hazards* 41 (2): 283–295.

Berkes, F., J. Colding, and C. Folke. 2003. *Navigating social ecological systems: building resilience for complexity and change.* Cambridge, UK: Cambridge University Press.

Berke, P. and G. Smith. 2010. Hazard mitigation, planning, and disaster resiliency: Challenges and strategic choices for the 21st century. In *Sustainable development and disaster resiliency*, ed. F. Urbano, 1–2. Amsterdam, The Netherlands: IOS Press.

Blackburn, J., T. Colbert, and K. Shanley. 2012. Steps to the future. In *Lessons from Hurricane Ike*, ed. P. B. Bedient, 156–175. College Station: Texas A&M University Press.

Blaikie, P. T., T. Camon, I. Davis, and B. Wisner. 1994. *At risk: Natural hazards, people's vulnerability, and disasters*. London: Routledge.

Blanco, H. and A. Marina. 2009. Building capacity to adapt to climate change through planning. *Progress in Planning* 71 (4): 158–169.

Brody, S. D. 2012. Land-use change and increased vulnerability. In *Lessons from Hurricane Ike*, ed. P. B. Bedient, 138–155. College Station: Texas A&M University Press.

Brody, S. D. and W. E. Highfield. 2013. Open space protection and flood mitigation: A national study. *Land Use Policy* 32: 89–95.

Brody, S. D. and J. R. Gunn. 2013. Examining environmental factors contributing to community resilience along the Gulf of Mexico Coast. In *Disaster resiliency: Interdisciplinary perspectives*, eds. N. Kapucu, C. V. Hawkins, and F. I. Rivera, 160–177. New York and London: Routledge.

Carbone, J. C., D. G. Hallstrom, and V. K. Smith. 2006. Can natural experiments measure behavioral responses to environmental risks? *Environmental and Resource Economics* 33: 273–297.

City of Galveston Comprehensive Plan. 2001. Retrieved from City of Galveston website: http://www.cityofgalveston.org/city_services/planning_and_community_dev/plan_div.cfm (accessed October 15, 2011).

City of Galveston Hazard Mitigation Plan. 2011. Retrieved from City of Galveston website: http://www.cityofgalveston.org/administration/emergency/hazard_mitigation.cfm (accessed October 15, 2011).

City of Galveston Long Term Recovery Plan. 2009. Retrieved from Recovery Galveston website: http://recoverygalveston.org/documents/Galveston_Long-Term_Community_plan.pdf (accessed October 15, 2011).

Crossett, K. M., T. J. Culliton, P. C. Wiley, and T. R. Goodspeed. 2004. *Population trends along the coastal United States: 1980–2008*. Retrieved from National Oceanic and Atmospheric Administration website: http://oceanservice.noaa.gov/programs/mb/pdfs/coastal_pop_trends_complete.pdf (accessed September 20, 2011).

Cutter, S. L., ed. 2003. *American hazardscapes*. Washington, DC: Joseph Henry Press.

Cutter, S. L., L. Barnes, M. Berry, C. Burton, E. Evans, E. Tate, and J. Webb. 2008. A place-based model for understanding community resilience to natural disasters. *Global Environmental Change* 18 (4): 598–606.

Deshkar, S., Y. Hayashia, and Y. Mori. 2011. An alternative approach for planning the resilient cities in developing countries. *International Journal of Urban Sciences* 15 (1): 1–14.

Elsner, J. B., J. P. Kossin, and T. H. Jagger. 2008. The increasing intensity of the strongest tropical cyclones. *Nature* 455 (4): 92–95.

Emmer, R., L. Swann, M. Schneider, S. Sempier, T. Sempier, and T. Sanchez. 2008. *Coastal resiliency index: A community self-assessment*. Louisiana sea grant, Mississippi-Alabama sea grant consortium. Retrieved from NOAA Gulf Coast Service Center website: http://www.seagrant.noaa.gov/focus/documents/HRCC/resiliency_index_7-15-08. pdf (accessed September 20, 2011).

Ersing, R. L. 2012. Using social networks to build disaster-resilient communities: The strategy of CODE ONE. In *Surviving disaster: The role of social networks*, eds. R. L. Ersing and K. A. Kost, 100–113. Chicago: Lyceum Books.

Ersing, R. L. and K. A. Kost, eds. 2012. *Surviving disaster: The role of social networks*. Chicago: Lyceum Books, Inc.

FEMA. 2008. Hurricane Ike impact report, emergency support function #14 long-term community recovery. http://www.fema.gov/pdf/hazard/hurricane/2008/ike/impact_report.pdf (accessed October 15, 2011).

FEMA. 2009. Mitigation assessment team report: Hurricane Ike in Texas and Louisiana, Building performance observations, recommendations, and technical guidance. http://www.fema.gov/library/viewRecord.do?id=3577 (accessed October 15, 2011).

Godschalk, D. R., T. Beatley, P. Berke, D. J. Brower, E. J. Kaiser, C. C. Bohl, and R. M. Goebel. 1998. *Natural hazard mitigation: Recasting disaster policy and planning*. Washington, DC: Island Press.

Grossi, P. and H. Kunreuther. 2005. *Catastrophe modeling: A new approach to managing risk*. Heidelberg, Germany: Springer-Verlag.

Gruntfest, E. 2000. Nonstructural mitigation of flood hazards in Inland flood hazards: Human, riparian, and aquatic communities, In *Inland flood hazards: Human, riparian, and aquatic communities*, ed. E. E. Wohl, 394–410. Cambridge, UK: Cambridge University Press.

Hines Center. 2000. *The hidden costs of coastal hazards*. Washington, DC: Island Press.

Holling, C. S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4: 1–23.

Hurricane Recovery Network. 2010. Hurricane Ike fast facts. Houston, TX. http://www.houstonhurri canerecovery.org/node/163 (accessed February 7, 2012)

IPCC. 2007. Summary for policymakers. In *Climate change 2007: Mitigation, contribution of working group III to the fourth assessment report of the Intergovernmental Panel on Climate Change*, eds. B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, and L. A. Meyer, 99–116, Cambridge, UK: Cambridge University Press.

Kapucu, N., C. V. Hawkins, and F. Rivera. 2013. Disaster resiliency: Interdisciplinary perspectives, In *Disaster resiliency: Interdisciplinary perspectives*, eds. N. Kapucu, C. V. Hawkins, and F. I. Rivera, 1–14. New York and London: Routledge.

Kellenberg, D. K. and A. M. Mobarak. 2008. Does rising income increase or decrease damage risk from natural disasters? *Journal of Urban Economics* 63: 778–802.

Khazai, B., J. C. Ingram, and D. S. Saah. 2007. The Protective Role of Natural and Engineered Defense Systems in Coastal Hazards. Spatial Information Group, LLC Literature Review Report, USA.

Mercer, J., D. Dominey-Howes, I. Kelman, and K. Lloyd. 2007. The potential for combining indigenous and western knowledge in reducing vulnerability to environmental hazards in small island developing states. *Environmental Hazards* 7: 245–256.

Nelson, D. R., W. N. Adger, and K. Brown. 2007. Adaptation to environmental change: Contributions of a resilience framework. *Annual Review of Environment and Resources* 32: 395–419.

Norris, F., S. Stevens, B. Pfefferbaum, K. Wyche, and R. Pfefferbaum. 2008. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology* 41:127–150.

Nowell, B. and T. Steelman. 2013. The role of responder networks in promoting community resilience: Toward a measurement framework of network capacity. In *Disaster resiliency: Interdisciplinary perspectives*, eds. N. Kapucu, C. V. Hawkins, and F. I. Rivera, 232–257. New York and London: Routledge.

Parry, M. L., O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson. 2007. *Climate change 2007: Impacts, adaptation and vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press.

Peacock, W. G., H. Kunreuther, W. H. Hooke, S. L. Cutter, S. E. Chang, and P. R. Berke. 2008. Toward a Resiliency and Vulnerability Observatory Network: *RAVON. HRRC reports: 08-02R.archone.tamu.edu/hrrc/publications/researchreports/RAVON*

Peacock, W. G., S. V. Zandt, D. Henry, H. Grover, and W. Highfield. 2012. Using social vulnerability mapping to enhance coastal community resiliency in Texas. In *Lessons from Hurricane Ike*, ed. P. B. Bedient, 66–81. College Station: Texas A&M University Press.

Perrings, C. 2006. Resilience and sustainable development. *Environment and Development Economics* 11: 417–427.

Pine, J. C. 2009. *Natural hazards analysis: Reducing the impacts of disasters*. New York: CRC Press, Taylor & Francis Group.

Porter, D. 2000. *The practice of sustainable development*. Washington, DC: Urban Land Institute.

Sadowski, N. C. and D. Sutter. 2005. Hurricane fatalities and hurricane damages: Are safer hurricanes more damaging? *Southern Economic Journal* 72:422–432.

Walker, B. and D. Salt. 2006. *Resilience thinking: Sustaining ecosystems and people in a changing world*. Washington, DC: Island Press.

Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society* 9 (2): 5–13.

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. *Disasters* 32 (4): 537–560.

Zandt, S. V., W. G. Peacock, D. W. Henry, H. Grover, W. E. Highfield, and S. D. Brody. 2012. Mapping social vulnerability to enhance housing and neighborhood resilience. *Housing Policy Debate* 22 (1): 29–55.