Disasters are not inevitable: social vulnerability, hazard losses, and adaptive learning in communities of the Atlantic and Gulf coastal watersheds

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Abstract

Disasters are not inevitable: social vulnerability, hazard losses, and adaptive learning in communities of the Atlantic and Gulf coastal watersheds

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Hazard losses in the United States have increased over the past several decades. With over one-third U.S. residents living in coastal counties, the potential impacts from hazards related to coasts are a particular concern. The focus on social vulnerability is meant to address potential gaps disaster management; research and policy intends to limit exposure or decrease biophysical vulnerability. However, social vulnerability will need to be addressed for communities to more resilient. This study analyzes Atlantic and Gulf of Mexico coastal watershed counties quantitatively to see if social vulnerability changes after multiple hazard events over ten years. It also provides a review of adaptive learning as a potential method for improved disaster management. 407 counties where at least one event occurred between 2000 and 2010 were analyzed for hazard losses and social vulnerability. Using the Spatial Hazard Events and Losses Database for the United States (SHELDUS), eight variables were assessed to understand hazard impacts. For social vulnerability, 12 indicators for 2000 and 2010 were used using data from the Agency for Toxic Substances & Disease Registry (ATSDR) and U.S. Census Bureau. The SV variables were standardized and combined to see the change in 2010 from 2000. The change in social vulnerability results were then tested for correlation against hazard loss data. The results indicate that counties who experience a higher frequency of hazard events do not see a change

in social vulnerability. However, property damage per capita and social vulnerability change show a statistically significant relationship. While it currently seems as though communities do not learn from experience, adaptive learning offers ways to learn from previous experience to better prepare for the future.

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1.0 Introduction

Dennis Mileti (1999) described the construction of a disaster as being “designed.” A disaster is designed because it is the result of human decisions; disasters do not occur in isolation. Instead, disasters and hazard losses are the result of development patterns, cultural views, and attitudes towards the natural environment and technology (Mileti 1999). In the United States, disaster losses have increased substantially over the past fifty years with more people and assets at risk for hazard impacts (Gall et al. 2011). To change this pattern, communities will need to adjust views disasters and techniques to mitigate, prepare for, respond to, and recover from hazard events.

This study explores the relationship between hazard losses and social vulnerability to see if communities change based on hazard impacts. Communities where hazards occur with greater frequency would hopefully learn from the experience and address sources of vulnerability to better prepare for future impacts. Adaptive learning principles show the benefits of learning from experience. A quantitative analysis of hazard losses and social vulnerability indicators assesses whether or not coastal watershed counties learn from experience based on changes to social vulnerability over time.

1.1 Contextual Information

In this research, disasters are conceptualized as an outcome of interactions between hazards, exposure, and vulnerability. Impacts are typically considered in terms of injuries, deaths, damage to property, infrastructure, and natural resources as well as interruption of typical system (both human and ecological) function (IPCC 2014). A hazard is the event provoking impacts to life or property (Intergovernmental Panel on Climate Change 2014; Tierney 2014). *Hazards* can be natural, technological, or human-induced (e.g. terrorism), but for this project natural hazards are the focus, specifically those related to coastal environments. *Exposure* refers to people, properties, ecosystems, and other resources potentially subject to harm (Mileti 1999; IPCC 2014; Tierney 2014). *Vulnerability* is the third factor, and the focus of study in this thesis. The IPCC defines vulnerability as “the propensity or predisposition to be adversely affected” (2014, 5). It describes the system’s adaptive capacity, or ability to adjust to change (Brooks, Adger and Kelly 2005).

Addressing vulnerability is one of the main disaster risk reduction strategies. Vulnerability is also divided into two types, physical vulnerability and social vulnerability. Physical vulnerability (or biophysical vulnerability) refers to threats to structures, infrastructure systems, and the natural environment as well as the related economic losses (National Research Council 2006). More specific topics within physical vulnerability include structural vulnerability, i.e. building design and materials ability to withstand impacts of a hazard agent, (NRC 2006) and ecosystem function, i.e. wetlands role as flood protection, (Tierney 2014). Social Vulnerability encompasses the threats to human populations and the related economic losses; it includes the potential for harm based on subgroups related to socioeconomic status, age, gender, race and ethnicity, and family structure among other demographic factors (NRC 2006).

Adaptive learning provides one potential pathway for communities to lower vulnerability. Tidball et al. (2010) profiled a post-Katrina tree planting project in New Orleans. Some neighborhoods found project provided a way to remedy past mistakes in natural resource management and social change. The Tremé neighborhood saw the project not only addressing natural environment improvements, but social issues. Highway development decades before the storm led to the removal of huge Oak trees along Claiborne Avenue. Local knowledge and experience with development impacts, tree loss, and decreased social connections was a key motivator during recovery efforts (Tidball et al. 2010).

Another study found previous hurricane experiences to prepare for future storm impacts at an institutional level (Torres and Alsharif 2016). Torres and Alsharif studied news coverage of Florida Power and Light to see if learning and memory themes played a role in recovery actions. Learning from Hurricane Wilma did seem to shape the utility provider's response. The firm brought in a Dutch company to study the system and give recommendations for ongoing maintenance (Torres and Alsharif 2016).

Coastal regions are a region where the change in vulnerability over time are particularly important to consider. In the United States, 52% of the population lived in coastal counties as of 2010 (National Oceanic and Atmospheric Administration 2013). The coastal counties have much higher density than other parts of the country, and between 2010 and 2020, population is projected to increase by 10 million (NOAA 2013). Large populations in coastal counties means there is a large portion of the population exposed to potential coastal hazards (Donner and Rodríguez 2008). Specific definitions are used for coastal areas in this paper and are based on definitions from NOAA (2013). Coastal shoreline counties are adjacent to large, open bodies of water. Coastal watershed counties are places where the land area has significant intersections with the watershed and thus, human activity has a major influence on the quality and behavior of the watershed (NOAA 2013).

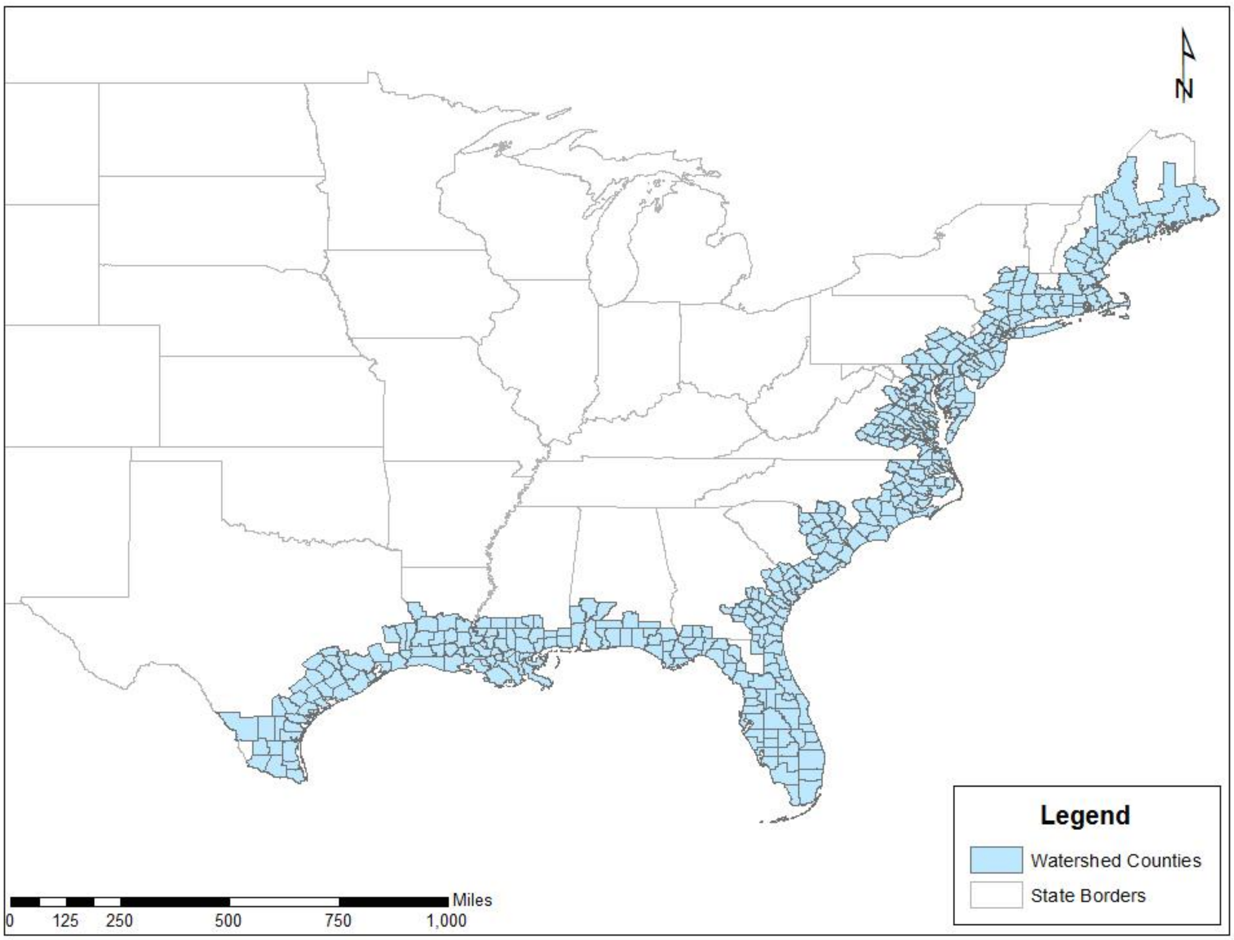

Figure 1. Coastal Watershed Counties

The potential for coastal hazards including erosion and high tides; hurricanes and tropical storms; and flooding need to be a concern for planners in these communities from a disaster risk reduction perspective. The combination of concentrated populations, existing potential hazards, climate change, and environmental degradation (loss of natural ecosystem functions and protection) illustrates the need for more adaptive responses in hazard planning (Adger et al. 2005; Dolan and Walker 2006).

Resilience acts as an overarching theme for this investigation (Adger et al. 2005; Adger 2006; Cutter and Emrich 2006; Berkes 2007). In the last few years, resilience has been a buzzword in the planning world, and its application can be rightfully debated (Cutter, Ash, and Emrich 2014). It remains to be seen if the framework will be more than just the latest fad. There is a lack of clarity over how to define resilience. The diverse approaches reflect the range of applications and fields involved (Holling 1996; Berkes and Ross 2012; Tierney 2014). For this research, resilience refers to the ability to withstand

The interdisciplinary nature of resilience is one of its key assets, but it is also a source of confusion. However, common themes are seen throughout the literature, including the role of complex systems. The concept of social-ecological systems influences this study as a way to conceptualize the relationship between humans and the environment (Holling 1973; Adger 2000; Folke 2006); Fikret Berkes and Carl Folke defined social-ecological systems as “complex integrated systems in which humans are part of nature” (The Resilience Alliance n.d.). Understanding the connections between humans and nature is vital to effective hazard planning.

Research on disaster resilience developed separately from other fields (Tierney 2014), including the ecology-based approach described previously, but it arrived at similar conclusions. For hazard research, resilience is seen as a way to limit disaster losses (Tierney 2014). Disaster management has traditionally focused on the response stage of the cycle where the threat is imminent or immediate relief is necessary. Resistance is another typical approach. Making a community resistant focuses on measures like building practices to decrease hazard losses (Tierney 2014). However, the emphasis on resistance did not fully answer questions about disaster risk reduction and what its purpose should be.

Disaster resilience gained popularity at the same time sustainability and sustainable development became central discussions (Cutter, Ash, and Emrich 2014; Tierney 2014). While there are variations between researchers focused on social-ecological systems and disaster researchers, the underlying principle is similar across the spectrum: it is the ability of a system (or individual) to bounce back after an interruption. Researchers outside the hazards arena have described it as the capacity of a social-ecological system to absorb disturbances and maintain structure and functions. The system is capable of self-organization, learning, and adaptation. Disaster resilience has been defined in a variety of way, but the definition from a 2012 National Research Council report illustrates the general approach to the concept within the field. It states, “resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events” (National Research Council 2012, 1). There is a common thread to each of these approaches: resilience describes the capacity to deal with change. The view of resilience presented by Tierney and the National Research Council publication and resilience theory concept of social ecological systems will guide my work throughout this project.

1.2 Research Question

This research intends to widen understanding of the relationship between hazard losses and social vulnerability by analyzing Atlantic and Gulf of Mexico coastal watershed counties. The county sample includes the two types of coastal counties: shoreline and watershed. It encompasses 19 states and Washington, D.C. The area is based on the comparability of potential hazards and coastal zone characteristics. As communities face multiple hazards over time, the experience should provide an opportunity to learn and change. Learning from experience can allow communities to be more prepared for future hazard events.

Mitigation has traditionally relied on structural solutions including levees, seawalls, and other “hard” engineering techniques. More recently, focus has shifted towards policy options (Brody et al. 2009). This shift should provide greater opportunity to learn from experience. By not relying solely on major engineering projects, communities can adjust and change their approach to disaster management by learning what works through experience. In places where hazard events occur more frequently or result in repeated losses, this can be especially useful. Studying social vulnerability is one method of measuring whether or not these changes are taking place. The focus on social vulnerability is due to limitations on mitigation efforts reducing physical vulnerability or exposure and following resilience theory.

Social-ecological systems conceptualizes how people are not separate from the environment and recognizes the unique variations in environmental conditions based on location. From a disaster research perspective, this reiterates the role of space and place in vulnerability. The regularity of event repetition (Brody et al. 2009) is helpful to studying learning opportunities and potential change. Lessons from coastal communities ongoing experience will be important for future hazard mitigation efforts as well as responding to climate change impacts.

Based on the parameters for the topic and study area, the central questions of this thesis ask: Do communities that experience a higher frequency of hazard events learn from their experiences resulting in lower of social vulnerability over time? And, what strategies are available to communities to implement these changes? Statistical analysis of hazard losses and social vulnerability indicators will be used to answer the first question. The second question will be addressed through a review of existing scholarship.

1.3 Research Objective

If communities are learning from experiencing repeated hazards over the 10-year period, there should be a reduction in social vulnerability. Addressing social vulnerability is an important component of hazard mitigation and planning and can act as an opportunity to apply resilience principles through adaptive learning and management.

To answer the research question data illustrating hazard losses and social vulnerability will be collected and tested for a statistically significant relationship.

The data on hazard losses follows the practices outlined by the National Weather Service (NWS) and the National Centers for Environmental Information (NCEI) in *Storm Data*. Disaster research will frequently follow the guidelines described in the publication or use the available data directly (Brody et al. 2009; Zahran et al. 2008; Emrich and Cutter 2011; Kim and Marcouiller 2015). There are alternative methods with more specific data available through resources including the National

Hurricane Center (NHC); Pielke Jr. et al. 2008 used this approach to normalize losses due to hurricanes/tropical storms in the United States between 1900 and 2005.

The social vulnerability indicators used in this study are based on the work of Cutter, Boruff, and Shirley (2003); Flanagan et al. (2011); and principles outlined by the Centers for Disease Control and Prevention (CDC). Social characteristics are quantified using Census data. Using indicators is a popular technique for measuring social conditions that might be difficult to study otherwise. It is a common practice in social science and within the urban planning field. This project involves two sets of vulnerability variables classified by year. The two datasets will show the counties within the study area before and after hazard events over time.

1.4 Research Structure

This thesis is organized into five chapters including the introduction. Chapter 2 explores the development of hazards research and disasters as the result of human-decision-making over time and the concept of social vulnerability within the disaster research field. Throughout the chapter, the role of planning in the interactive structure of a disaster is addressed. Chapter 3 presents the methodology used to complete this thesis. It specifies how hazard losses are measured and data obtained from the Hazards and Vulnerability Research Institute at the University of South Carolina. The section also details the social vulnerability variables in use and their application. Chapter 4 details the results of statistical analysis measuring the change in social vulnerability over time in counties where multiple hazards occur over ten years. Chapter 5 is dedicated to interpreting the results based on the hypothesized outcome and their connection to the research problem. I will also connect the information to the broader applications of adaptive management and adaptive learning. The chapter also offers directions for future research and planning options based on the results of this project.

2.0 Literature Review

Disasters are often portrayed as natural albeit unfortunate events. The phrasing “natural disaster” is misleading, and it can result in assuming few options are available to minimize harm. Events can arise as the result of natural processes, but the level of impact is the result of human behavior and decisions over time. Disasters and the related losses is influenced by three key factors: earth’s physical systems, changes to demographics in both size and distribution, and changes to the built environment with increased density, more complex infrastructure systems, and changes to local ecosystems (Mileti 1999). To understand the relationship between social vulnerability and hazard losses, it is important to understand the way a disaster is defined and handled. In *Disasters by Design* (1999), Dennis Mileti argued in favor of changing the way hazards are viewed:

> “Human beings, not nature, are the cause of disaster losses. The choices that are made about where and how human development will proceed actually determine the losses that will be suffered in future disasters.” (Mileti 1999, 27).

The impacts from disasters are not isolated incidents. Instead, the effects are symptoms of larger problems. Mileti (1999) argued the nation’s inability to reduce hazard losses is the result of narrow views of the relationship between people and the natural environment. Part of improving the response to disasters will require rethinking the relationship between people and their surroundings. Considering the connections between social and ecological systems also provides a way to link resilience theory to issues within disaster management.

2.1 Disaster Research Terminology

A disaster is the result of realized risk. In broad terms, risk describes the potential for loss (Tierney 2014). It can be realized in response to a variety of changing conditions, including natural hazards, and emerges from the combination of a hazard, exposure, and vulnerability. To reiterate the definitions provided in Chapter 1, Table 1 provides a description of "hazard," "exposure," and "vulnerability."

Table 1. Key Definitions

Term	Definition
Hazard	"The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources." (IPCC 2014, 5)
Exposure	"The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected." (IPCC 2014, 5)
Vulnerability	"The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt." (IPCC 2014, 5)

Source: Intergovernmental Panel on Climate Change "Summary for Policymakers"

Hazards are the feature most associated with a disaster, e.g. hurricanes, tornadoes, fires, floods. The threat of natural hazards is an ongoing challenge for communities. As defined above, exposure describes the assets present in the location of concern. Exposure can be widespread in a community, but also may vary within the population once the hazard agent emerges. Vulnerability can be divided into two distinct categories: physical and social. Both types need to be considered in disaster management. As defined in Chapter 1, physical vulnerability refers to the natural environment, the built environment of physical structures and infrastructure, and economic losses (NRC 2006). Social vulnerability encompasses threats to human populations. This includes deaths, injuries, disruption to typical behavior and system function (NRC 2006).

Addressing physical vulnerability has frequently the focus of emergency management, and it is a key aspect of the process. It is important to take actions to minimize harm from the hazard based using structural solutions (Zahran et al. 2008). However, it is not the only form of vulnerability and should not be the only focus of mitigation efforts to minimize its role in risk. Considerations for social vulnerability can help improve each phase pf the disaster cycle (Flanagan et al. 2011).

2.2 The Disaster Cycle

Researchers and emergency management professionals typically view disasters as an ongoing process with four steps: mitigation, preparedness, response, and recovery.

Figure 2. The Disaster Cycle

Mitigation includes the actions taken prior to an event to prevent or reduce harm. These efforts can include both structural and nonstructural solutions. Typically, mitigation is a process meant to occur prior to a threat, but principles of mitigation can be used during each step to minimize harm. Preparedness includes the actions taken before a disaster to deal with emergency response. It includes the creation of disaster plans, training of first responders, and public education. Response refers to the activities related to establishing a state of readiness to respond to extreme events. It includes information about predictions and warnings; evacuations; mobilization of emergency personnel, volunteers, and resources; care for casualties and survivors; damage assessments; restoration of essential services; dissemination of public information; and maintenance of political and legal systems. Disaster recovery is the process meant to re-establish pre-disaster activities (NRC 2006).

2.3 Risk and Disaster Research

To understand the different ways to react to potential disasters, the different ways of interpreting risk need to be clarified. Risk is produced through the interactions between hazards, exposure, and vulnerability. Risk entails something of value is at stake and the outcome is uncertain. Both Tierney (2014) and the IPCC (2014) define risk with both points: “The potential for consequences where something of value is at stake and where the outcome is uncertain.” Risk is a combination of possibilities and probabilities in the future where there are not clear absolutes. It is important to consider the different ways different actors may respond in the face of risk. For disasters, the questions often surround when to act on potential hazards and which mitigation strategies should be used, if any.

One interpretation understands “risk as a by-product.” In this case, risk simply exists, and it should be avoided. This explanation can have important implications for responding to a disaster for it lacks an assumption of responsibility, and it does not recognize or consider disparities in the ability of individuals, groups, or communities to respond. Similarly, calls to avoid risk can contribute to the assumption technological advancements can solve the problem. Recognizing risk as more than a by-product is a necessary step in risk reduction research and practice. Tierney (2014) offered three questions to clarify what risk means in the context of disasters: “What can go wrong? How likely is it? And what are the consequences?” (11). The questions tie together common themes from risk literature where the frequency and expected impacts of events are the main focus of study (Tierney 2014).

2.3.1 Risk Perception

The ways risk is understood has changed over time. It is frequently associated with a risk perception framework (Tierney 2014). This concept describes ways different actors see the magnitude of a threat; there is a “perceived risk” and a “real risk.” Risk perception provided a way to manage potential challenges from a policy standpoint because it allowed individuals and groups to work towards finding the acceptable level of risk (Tierney 2014). In the late 1970s, research on risk perception focused on why different segments of the population view risk differently. Views on risk were shaped by judgements as to whether a risk was voluntary or imposed; known/familiar or unknown; controllable or uncontrollable; immediate effect versus delayed; and the level of severity of the effects (Tierney 2014). The perception framework is used in most discussions about risk, especially when policies need to be crafted to address the problem.

Later studies followed a similar trend by focusing on the differences between "experts" and "non-experts." The variations in how risk is understood has been argued to be a result of a lack of understanding or a "technological ignorance" (Fothergill and Peek 2004). This opinion does not account for the outside influences shaping someone's experience, and ultimately, their willingness to react to certain risks. Gaps in the risk perception framework mean power dynamics and resource access are not addressed adequately. Inclusion of these larger social conditions is important because people will respond to risk based on the availability of information and other resources as well as political and economic structures.

2.3.2 Social Construction of Risk

The literature surrounding risk developed alongside advancements in technology with the chemical and nuclear industries. The consequences were not fully understood, and there were wide gaps in risk perception among different groups. Efforts to understand risk emphasized the disconnect between experts and laypeople, and concerns of non-experts were often viewed as overblown or irrational (Tierney 2014, 17). Later investigations argued the results showed a need for better communication and public participation (Fothergill and Peek 2004). Access to information shapes the way risk is perceived. The types of information recognized and shared by those in positions of power will also shape reactions. Risk and the related losses are the results of decisions and non-decisions at every level—individuals, communities, organizations, societies. The decisions made (or not made) over time create future consequences (Mileti 1999).

In her review of risk research, Tierney (2014) focused on the work of Blaikie et al. in *At Risk: Natural Hazards, People's Vulnerability and Disasters.* Tierney outlined the authors a framework based on root causes, dynamic pressures, and unsafe conditions. Root causes consist of political and economic systems and similar characteristics. The dynamic pressures are created by the root causes. Potential root causes include population growth, urbanization, and debt restructuring requirements. These dynamic pressures manifest as unsafe conditions: settlements in hazardous locations, unsafe construction practices, and population vulnerability due to a lack of power (Tierney 2014). For Blaikie et al., risk builds over time, and, eventually, will need to be released (pressure and release model).

Disasters do not create new dilemmas; they exacerbate existing social problems. Disasters emerge due to a potential risk being realized. Risk is a function of exposure, vulnerability, and a hazard. The level of risk is shaped by the magnitude of each part as it interacts with others.

2.3.3 Reducing Risk Through Mitigation?

Addressing the problems related to possible disasters tends to rely on engineering solutions. The risk is recognized, but the reaction does not fully consider the different interactions between hazards, exposure, and vulnerability.

There is an assumption that disasters will cease to exist as soon as technology allows. Technology has an important role in managing the problem. Modelling hurricanes can improve response time for evacuations, changes to building practices can prevent collapse in earthquakes, and warning systems can prevent deaths from tornados. Technology can reduce the number of casualties and limit damage to property. Reliance on technology, however, can caused the risk to be discounted and behavior to gravitate towards unsafe practices (Tierney 2014). This was the case in New Orleans before Hurricane Katrina. It continues to be the case in other parts of the country.

Raymond Burby (2006) studied the safe development paradox in New Orleans. Protective levees were constructed as a safeguard against hurricanes. The levees allowed urban development to occur an area that would not have been “safe” otherwise, and because protection was in place, flood insurance was available at a subsidized rate (Burby 2006). While New Orleans seemed to mitigate the problem, actions created a higher level of risk. Yet, the problem is not limited to engineering. Policy needs attention because it can lead to uneven impacts from disasters and support potential harmful patterns of development or behavior prior to an acute hazard event.

The safe development paradox refers to the actions of the federal government to enhance safety of an intrinsically hazardous area allowing for development and leaving the communities more sensitive to devastating hazard impacts (Burby 2006). Implementing certain mitigation measures can lead to an assumption of safety that does not align with reality where potential hazards remain the same, but more people and assets are exposed. Under the cost-benefit analysis used by the Army Corps of Engineers justification for flood protection required more development in the area at risk (Burby 2006). The benefit for New Orleans was based future development, not the existing conditions.

The local government paradox describes how local governments do not give hazards adequate time or attention to hazards while allowing development to occur in potentially dangerous areas; it is magnified by their direct connections to the citizens who experience the burden of loss (Burby 2006). Development occurred in eastern New Orleans, simultaneously, the Orleans Parish Levee Control Board was uninterested in financing higher levels of hurricane protection (Burby 2006). Burby found the two paradoxes work in tandem to increase the frequency and magnitude of natural disasters. Development practices promoted population growth in risky areas, and local governments were not in the position to provide necessary assistance when a hazard event emerged.

2.4 Vulnerability

Vulnerability has typically been researched based on two definitions: biophysical vulnerability and social vulnerability. Both components need to be considered to find effective strategies to respond to hazards. Recognizing both forms of vulnerability connects to the broader resilience framework of social-ecological systems where humans and nature are linked.

Vulnerability can be divided into two distinct categories: physical and social. Again, physical vulnerability refers to both the natural environment and the built environment of physical structures and infrastructure and their related potential economic losses (NRC 2006). Social vulnerability encompasses threats to human populations including deaths, injuries, disruption to typical behavior and system function (NRC 2006). Addressing physical vulnerability has frequently the focus of emergency management, and it is a key aspect of the process. However, it is important to also address social vulnerability because it is created and reinforced through both intentional and unintentional actions related to the distribution of power and resources (Adger 2006).

2.4.1 Vulnerability of Place

Vulnerability has been defined and analyzed in different ways. In some cases, vulnerability is seen as a function of underlying social conditions separate from the event while exposure is treated as a given (Cutter, Mitchell, and Scott 2000; Cutter Boruff, and Shirley 2003; Wu et al. 2002; Cutter et al. 2008). Others view vulnerability based on proximity to the hazard sources. Research based on this interpretation has focused on the impacts of specific system disruptions from hazardous events (Wu et al. 2002). A third approach views vulnerability as a combination of biophysical conditions and social response and how the two influence one another locally; this is known as the hazardousness of place (Cutter et al. 2008).

The hazards-of-place model of vulnerability model provided by Cutter, Boruff, and Shirley (2003) provides a way to study social vulnerability while recognizing the importance of geography. Risk interacts mitigation to create the potential for a disaster. Geography can increase or decrease this potential based on the site, situation, and proximity (Cutter, Boruff, and Shirley 2003). The social conditions of the location also affect the way a hazard event is experienced by shaping a community's ability to respond, to recover, and to adapt (Cutter, Boruff, and Shirley 2003). The combination of social and biophysical conditions produces an overall place vulnerability.

The space and place of disaster vulnerability can be seen at multiple levels. Different locations more prone to exposure to certain hazards, for example, the California, Oregon, and Washington are more likely to experience earthquakes compared to New England; the southeast is more vulnerable to hurricanes than the Midwest (Tierney 2014). Vulnerability of specific locations can also vary at a more local level. The organization of the built environment and condition of the natural systems can both contribute to hazard impacts (Tierney 2014).

In this thesis, vulnerability is treated as through the hazardousness of place lens. The model influenced the choice of coastal areas as a specific focus area and using social indicators in this research. Due to time limitations, this thesis will focus on the social conditions influencing vulnerability. The study of both natural and human systems is a crucial component of resilience and disaster research; but, due to time limitations, the focus of this research is social vulnerability.

2.4.2 Social Vulnerability

Vulnerability can be divided into two distinct categories: physical and social. Both types need to be considered in disaster management. Physical vulnerability refers to the natural environment, the built environment of physical structures and infrastructure and economic losses (NRC 2006). Social vulnerability encompasses threats to human populations. This includes deaths, injuries, disruption to typical behavior and system function (NRC 2006).

Addressing physical vulnerability has frequently the focus of emergency management, and it is a key aspect of the process. It is important to take actions to minimize harm from the hazard based using structural solutions (Zahran et al. 2008). However, reducing physical vulnerabilities only addresses some of the reasons creating vulnerability. The place vulnerability model shows the importance of both forms of vulnerability: biophysical and social. Under this paradigm, addressing vulnerability and risk requires actions addressing both types. Doing so can help improve each phase of the disaster cycle (Flanagan et al. 2011).

Cutter and Finch (2008) defined social vulnerability as "a measure of both the sensitivity of a population to natural hazards and its ability to respond to and recover from the impacts of hazards." The differences in the ability to respond to hazard impacts are a reflection of wider social stratification. Wealth, power, and status are not experienced evenly. The resulting inequities can shape experience during disasters through preparations, impacts, and recovery (Mileti 1999). Low-income groups have the highest disaster mortality and morbidity rates. They are also disproportionately female and non-white. The poor are likely to live in lower-quality housing that is more likely to be damaged. Additionally, housing vulnerability and race/ethnicity has an inextricable relationship in the United States due to segregated residential development (Mileti 1999). Ethnic minorities are less likely to receive warnings and are more likely to have language barriers to information received (Mileti 1999). Social characteristics result in certain groups being more vulnerable than others.

The challenge for social vulnerability research, like other social research, has been quantifying the issues (Cutter, Boruff, and Shirley 2003). Social vulnerabilities may be known to influence impacts, but determining its role is difficult to see in traditional cost/loss estimation reports (Cutter, Boruff, and Shirley 2003). The Social Vulnerability Index is meant to provide a way to measure social vulnerability to environmental hazards. It was developed by Cutter, Boruff, and Shirley (2003) using census data. The characteristics most frequently associated with social vulnerability include age, gender, race and ethnicity, and socioeconomic status. Special needs populations are also included in the paradigm. The Index is not limited to typical social characteristics: built environment qualities are considered due to their linkages to other social factors (Cutter, Boruff, and Shirley 2003). The categories of social vulnerability defined by the authors are described in Table 2. The application of social vulnerability factors as they pertain to this paper will be detailed in Chapter 3.

Table 2. Vulnerability Indicators

Vulnerability Indicator	Description
Personal Wealth	Widely agreed to be a key social vulnerability factor, higher levels of wealth allow communities to absorb a shock and recover and a lack of wealth can have the opposite effect
Age	The elderly and children have been found to see more impacts from disasters than other demographics considering the ability to move out of harm's way. Impacts to childcare facilities and schools can affect the ability of parents to return to work.
Density of the Built Environment	Based on the different types of land uses and the number of units in the area
Single-Sector Economic Dependence	Relying on one industry for income generation can make a county's population more prone to hazard impacts if operations are interrupted
Housing Stock and Tenancy	Quality and ownership status of housing
Race and Ethnicity	Based on lack of access to resources, cultural differences, and social/economic/political marginalization
Occupation	Counties with more low-wage/personal service as their employment bases tend to see higher losses and slower recoveries
Infrastructure Dependence	The economic vitality and revenue-generating capability of a county

Source: Cutter, Boruff, and Shirley 2003

The development of an indicator-based system gives a way to study vulnerability of a community over time and across different locations (Cutter, Boruff, and Shirley 2003). While social vulnerabilities cannot be taken as absolutes, these populations will always see negative outcomes, the indicator framework can provide a multidimensional approach to identify potential concerns for mitigation, preparation, response, and recovery to natural hazards (Cutter, Boruff, and Shirley 2003).

Social vulnerability has the potential to influence each stage of the hazard cycle. The literature shows differences among socially vulnerable groups ability to cope with a potential disaster and its aftermath. Poverty has been found to play a significant role in pre-and post-disaster phases (Fothergill and Peek 2004). Lower socioeconomic status is associated with being less likely to prepare for hazards or purchase insurance; lower response to warnings; higher likelihood of loss of life and injury; higher material losses; greater chance of experiencing psychological trauma; and more obstacles post-hazard event (Fothergill and Peek 2004).

Even when the level of exposure is similar to their wealthier counterparts, those with a lower socio-economic status will have greater difficulty in a disaster (or its long-term recovery). With Hurricane Katrina, most neighborhoods, 83 percent of census tracts were inundated after the levees failed, in New Orleans experience some level of flooding socioeconomic makeup or elevation (Finch et al. 2010).

The differences in New Orleans were based less on exposure than vulnerability of impacted populations; the ability to cope was uneven through the city. Difficulties in the long-term recovery of New Orleans are well-documented. To a certain degree, the severity of the storm does play a role by adding complexity, but existing disparities in race, class, gender, and age each contributed to the uneven impacts of the storm (Finch et al. 2010). Areas with high social vulnerability and high flood inundation were found to struggle with recovery. Difficulties with long-term recovery are not unique to Hurricane Katrina. There are similar cases in Florida and Texas following Hurricane Andrew and Hurricane Ike, respectively. Peacock et al. (2015) studied long-term recovery by analyzing appraisal value of single-family structures for differences between renter- and owner-occupied structures. Owner-occupied properties and neighborhoods with higher incomes were found to experience less damage and recover faster in Miami and Galveston.

2.5 Adaptation

An ongoing challenge in hazard mitigation and urban, and environmental planning more broadly, is uncertainty. Decisions need to be made in a situation where all the information simply is not available. Thinking in terms of adaptation can provide direction in this challenging context.

Smit and Wandel (2006) defined adaptation, stating it is “the process, action, or outcome in a system to cope with, manage, to adjust to some changing condition stress, hazard, risk, or opportunity." Similarly, Berkes (2007) offers a way to understand adaptation in the context of vulnerability as a means to better absorb shocks to the system. Implementing adaptation methods can be difficult, however, due to its ongoing, ever-evolving practice.

Adaptation is a process; at times, it seems as though adaptation is the new name for the same responses used under previous methods without considering the connection to resilience more broadly (Tschakert and Dietrich 2010). This has been illustrated in climate change response efforts where efforts fixate on addressing the impacts without considering underlying vulnerabilities (Tschakert and Dietrich 2010). Disaster risk reduction and hazard mitigation efforts continue to face similar challenges. where the response becomes so focused on the impacts a disaster on the biophysical environment, the influence of existing social structures on hazard impacts can fade away. Frameworks from adaptation and resilience can guide action by providing opportunities to consider social factors and experiences.

2.5.1 Adaptive Management

Adaptive management (sometimes called "adaptive co-management") is a framework for applying resilience principles to practice (Olsson, Folke, and Berkes 2004). At its most basic level, adaptive management is the implementation of policies as experiments (Lee 1999). The Resilience Alliance (n.d.) describes it as a tool to identify uncertainties and create methodologies to test a variety of hypotheses based on those uncertainties. It is an iterative process where actors can learn and alter decisions or behaviors in response to changing situations. Adaptive management is an alternative to the more traditional approach of informed trial-and-error (Resilience Alliance n.d.).

The framework differentiates itself from other management styles through the involvement of a wide range of stakeholders. In contrast to other methods, adaptive management relies on input from sources who likely would not be considered in other situations. This is part of the framework's emphasis on accepting different types of knowledge. Science remains the underlying principle, but there is an opportunity to integrate other information (Berkes and Turner 2006; Smit and Wandel 2006; Berkes 2009; López-Marrero and Tschakert 2011).

Adaptive management is seen as one of the best frameworks for its potential to enable policy learning (Brody et al. 2009). For planners, application of adaptive management can function as a specific method to respond to conditions and change as needed. It shifts away from the top-down approach to promote collaboration and participation from a variety of stakeholders (Wollenberg et al. 2000).

Given the interdisciplinary tendencies of resilience theory, adaptive management has been applied in other fields, particularly conservation biology including fisheries and forestry (Wollenberg et al. 2000) science. It has also been considered in public health (Hess et al. 2012).

2.5.2 Role of Learning

Adaptive learning is the core of adaptive management. Davidson-Hunt and Berkes (2003) used the term to describe “the two-way relationship between people and their social-ecological environment.” The exact terminology can vary throughout the literature. Social learning and anticipatory learning are also used frequently.

Social learning describes, “learning by doing through experience in successful group processes” (Cumming et al. 2013). It should demonstrate a change in understanding; that change can extend beyond the individual to a wider community; and the change arose from social interactions (Reed et al. 2010; Cumming et al. 2013). Social learning affords an important opportunity for responding to disasters through collective memory (Cumming et al. 2013). Torres and Alsharif (2016) studied the role of learning and memory in Broward County, Florida for Hurricane Wilma recovery. Their study of news articles showed the importance of residents’ experiences with previous storms (e.g. Hurricanes Andrew, Charley, Ivan, and Jeanne). While the main focus of reports tended to look at individual actions, like owning a generator, coverage also considered institutional lessons for infrastructure and planning (Torres and Alsharif 2016).

Anticipatory learning is a concept from action learning. For adaptation, it emphasizes learning about future risks and uncertainties before impacts occur (Tschakert and Dietrich 2010). The focus on risk and uncertainty has provided an important window for community disaster planning efforts (Henly-Shepard et al. 2015).

Key points seen across the three approaches include: recognition of different types of knowledge; learning through experience and social interaction; allowing for mistakes; recognizing uncertainty; and responding to new information as it becomes available. All three approaches to learning work towards similar goals for adaptation.

Each perspective also connects to resilience, and fits in the typical styles of learning associated with resilience: fast and slow cycles. Fast cycles of learning are focused on more immediate challenges. Slower cycles describe long-term efforts for adaptation and resilience (Voss and Wagner 2010; Henly-Shepard et al. 2015). To successfully implement adaptation efforts, communities will need to be able to consider both levels. Understanding adaptation principles can influence the success of the community's recovery after an event.

2.6 Summary

The existing scholarships on disasters shows hazard impacts cannot be considered entirely natural events. The impacts are shaped by human action. Understanding risk provides one way to better respond to disasters, but there needs to be knowledge of underlying context as well. Geography contributes to the level of vulnerability of a community not only due to natural surroundings, but through human organization of the built and social landscape. Social vulnerability plays a key role in the outcome of hazard events because it reflects existing social inequities with the potential to become more pronounced. Research also shows ways the challenges of risk and vulnerability can be addressed through policy. Concepts from adaptation and resilience regarding adaptive management and adaptive learning provide potential solutions.

3.0 Methodology

This chapter outlines the data used to study the relationship between hazard losses and social vulnerability. One of the ways to think about the data needs for this project is through the risk construction framework laid out in the previous chapter. The hazard, exposure, and vulnerability work in congruity to create risk and, ultimately, a disaster. Therefore, the data will need to address the hazard event, the exposure, and the vulnerability level and type.

Hazards are conceptualized based on direct property losses, crop losses, injuries, and fatalities. Exposure is based on location, in this case, counties. Vulnerability is studied using indicators from Agency for Toxic Substances and Disease Registry, part of the Centers for Disease Control and Prevention. Using counties as the unit of analysis is based, in part, on the nature of hazard events. Hazard events rarely following municipal boundaries and management would benefit from a regional perspective to improve effective mitigation, preparation, response, and recovery.

The research question for this study states: Do communities that experience a higher frequency of hazard events learn from their experiences resulting in lower social vulnerability over time? And, what strategies are available to communities to implement these changes?

3.1 Conceptual Framework

The conceptual framework in Figure 2 illustrates a basic model for this study. Social vulnerability in the year 2000 is the starting point. Social vulnerability in 2010 is calculated as an endpoint. Over ten years, different hazard events arise in the study area and contribute to a change in social vulnerability. This change in social vulnerability is the main focus of the research question and analysis.

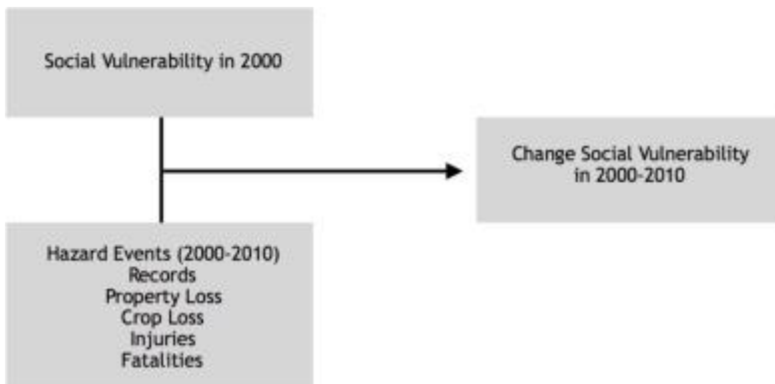

Figure 3. Conceptual Framework

Communities where more hazard events occur during the ten-year period should learn from the experience. In this study, learning is measured as the change in social vulnerability. Therefore, there should be a decrease in social vulnerability in counties with higher record counts.

3.2 Study Area

Geography provided a starting point for this research. Coastal counties are the main unit of analysis and provide a way to find data on hazard losses and social vulnerability. The counties were chosen based on specific definitions used by NOAA and potential geological and meteorological hazards. Specific hazards related to coastal processes were also chosen. Coastal hazards, flooding, and hurricanes and tropical storms are used due to their close connection to the natural function of coastal watersheds. Social vulnerability factors included in this research cover relevant sources of vulnerability for the coastal study area. The variables use economic, household composition, race and ethnicity, and housing and transportation information as indicators for vulnerability to hazards.

3.2.1 Coastal Counties

This study is focused on the effects of hazard events in coastal communities. Over a third of the U.S. population leaves in coastal counties, and coastal shoreline counties have much higher population density than other parts of the country (NOAA 2013). For this project, the study area has a total population over 82.5 million in 2000 and 89.7 million in 2010. There are significant implications for planners with coastal communities. These regions already face extreme events, and will also feel the direct effects of climate change more acutely (Boruff et al. 2005; Duxbury and Dickinson 2007; Moser, Williams, and Boesch 2012; Macintosh 2013).

NOAA has specified two types of coastal county: coastal shoreline and coastal watershed. Coastal shoreline counties are counties “adjacent to the open ocean, major estuaries, and the Great Lakes (NOAA 2013). Coastal Watershed Counties are counties where “a substantial portion of their land intersect coastal watersheds, and consequently represent where land use changes and water quality impacts most directly impact coastal ecosystems” (NOAA 2013, 2). The delineation of these two county types is shoreline counties being the places most affected by coastal processes, and watershed county populations affecting natural processes. At first glance, it seems more appropriate to focus on coastal shoreline counties for a risk analysis, however, the impacts of hazards are regionally and the land use decisions in neighboring areas often shape the experience of communities elsewhere. In addition to removing Pacific coastal counties, the Great Lakes were eliminated from this study to focus on the Atlantic and Gulf coasts.

Coastal oceanography helped delineate the study area as well because the type of coast affects the potential natural hazards. The Pacific coast — Alaska, California, Hawaii, Oregon, and Washington — faces different issues than their Atlantic and Gulf counterparts. Coastal zones are influenced by tectonics; wave, wind, and current exposure; tidal range; sediment supply and transport; and climate (NRC 1994). At a geological level, differences between the east and west coasts of the United States influence potential hazards. The west coast functions as collision coast. It was shaped by tectonic action opposed to the Atlantic coast which is part of a divergent boundary. Geologic hazards pose a larger risk to the region compared to the storms seen in the south or along the east coast. The west and east coasts differ in weather patterns as well. Climatic variations help determine hazard potential and exposure. Focusing on the Atlantic and Gulf coasts allows for better comparisons due to similar conditions, in contrast to the West Coast.

NOAA also includes the Great Lakes region in coastal county definitions. Counties in Minnesota, Illinois, Indiana, Ohio, Wisconsin, and New York and Pennsylvania are part of the coastal watershed, but this project is focused on oceanic coasts. For New York and Pennsylvania, however, eastern counties within the Atlantic watershed are included.

3.3 Hazard Type

With a focus on coastal counties, there are certain types of hazards that are more prevalent than others. The types of hazards studied in this paper is directly related to the counties profiled. The influence of geography on hazards results provides a slight causality dilemma: studying coastal counties requires a focus on certain types of hazards and studying certain types of hazards means focusing on coastal counties. Applying the place vulnerability model helps recognize the close ties between hazard and location.

3.3.1 Coastal

The SHELDUS database includes a classifies a variety of issues as "coastal" hazards. Potential coastal hazard events include: coastal flooding and erosion; high tide and heavy rain; high winds and seas; astronomical low tide; blizzard, rough surf; riptides; and storm surge. The full list of events classified as coastal hazards by SHELDUS is available in Appendix II. While several coastal hazards will occur in relation to a hurricane or tropical storm, events classified as "coastal" in SHELDUS and by NOAA and the National Weather Service are separate from the coastal hazards, e.g. storm surge, resulting from hurricanes or tropical storms.

3.3.2 Flooding

A flood is "any high flow, overflow, or inundation by water which causes or threatens damage" (NWS 2016). A flood occurs when water enters an area which is normally dry. The classification for SHELDUS data includes both flash and riverine flooding.

3.3.3 Hurricane/Tropical Storm

Hurricanes and tropical storms are the hazard most associated with the Atlantic and Gulf Coasts. The events provide an important flashpoint for understanding the problems associated with natural hazards. The definitions used in the SHELDUS database for hurricanes and tropical storms are based on NOAA's National Centers for Environmental Information (NCEI n.d.), previously known as the National Climatic Data Center (HVRI 2016). The data reports from NCEI are a collection of information from NWS who receive their information from a variety of sources including county, state, and federal emergency management officials, newspaper clippings, NWS damage surveys, and the insurance industry (NCEI n.d.). Hazard definitions and policies for documenting losses are determined by the National Weather Service's Directive NWSPD10-16.

A hurricane is an event with maximum 1-minute sustained surface wind speed of 74 miles per hour or greater. There are a number of related hazards with hurricanes including storm surge, freshwater flooding, tornadoes, and rip currents, (NWS 2016). The Saffir-Simpson Hurricane Scale is divided into five categories based on wind speed. The characteristics of each classification are explained in Table 3. It is possible to estimate flooding and damage, but additional factors prevent these issues from being absolute i.e. the slope of the continental shelf influences the storm tide, but wind speed is the key factor in classifying tropical cyclones.

Table 3. Saffir-Simpson Hurricane Scale and Expected Impacts

Category	Wind Speed	Storm Tide	Damage
1	74-95 mph (64-82 knots [kts])	4-5 feet	Minor
2	96-110 mph (83-95 kts)	6-8 feet	Moderate
3	111-130 mph (96-113 kts)	9-12 feet	Major
4	131-155 mph (114-135 kts)	13-18 feet	Severe
5	> 155 mph (135 kts)	> 18 feet	Catastrophic

Source: National Oceanic and Atmospheric Administration and the National Weather Service 2016

The impacts of a storm are not always based on the severity of the storm itself. Hurricane Katrina was a Category 3 when it made landfall in New Orleans. However, Hurricane Andrew, the costliest storm in U.S. history prior to 2005, was a category 5. To date, the most destructive tropical storms are Katrina (2005), Sandy (2012), Ike (2008), Wilma (2005), and Andrew (1992). Only Wilma and Andrew were category 5 storms; this demonstrates how the impacts are the result of factors beyond the intensity of the event itself.

A tropical storm is a cyclone with sustained wind speeds ranging from 39 mph (34 knots) to 73 mph (63 knots). While the wind speeds are lower and warning requirements differ from a hurricane, the corresponding hazards remain the same.

The impacts from storm surge are included in hurricane and tropical storm data or coastal data depending on the precipitating event. Storm surge is the vertical rise in water level. Storm tide is the storm surge added to the astronomical tide (NWS 2016).

3.4 Social Vulnerability

This study focuses on four forms of social vulnerability, and builds off the characteristics identified in social science literature as having the potential to limit a community's capacity to respond. As described by the Agency for Toxic Substances & Disease Registry (ATSDR), the themes are socioeconomic, household composition, minority status and language proficiency, and housing and transportation. Under these four umbrella terms, the variables used in this research are poverty status; unemployment; per capita income; no high school diploma; under age 17; single parent households; minority (non-white) status; limited English proficiency; mobile homes; crowded housing; no vehicle access; and, group quarters. The variables are described in Table 4.

The ATSDR created the Social Vulnerability Index based on hazard vulnerability scholarship, including the work described in Chapter 2 (Flanagan et al. 2011). The information is a collection of Census data related to social factors with the potential to affect emergency response. The data is intended to give local officials insight on members of the community who may require greater assistance to prepare for, respond to, and recover from a disaster. The agency says their index can be used to allocate emergency preparedness funding; estimate the amount and type of needed supplies; help determine the number of emergency personnel necessary to assist people; identify areas in need of emergency shelters; help plan for evacuations while accounting for populations with special needs; and, identify who may require continued support during recovery (CDC 2014).

3.5 Data Collection

Data collection for this project began with the decision to focus on the county level. This provided clear direction on the types of data available. The project required finding information on hazard impacts and social characteristics. For hazards, impacts are represented by the number of events and total losses including: damage to property and crops, injuries and fatalities, and time. Demographic information gives insight on the population makeup of each county in the study area. The social variables needed to address the range of factors known to influence an individual's or community's level of vulnerability. This includes economic, household composition, minority status, and housing and transportation indicators. I first focused on hazard, then shifted my focus to social vulnerability indicators. After collecting the social vulnerability data, matched the counties to the corresponding hazard data.

3.5.1 Hazard Loss Data

The Spatial Hazard Events and Losses Database for the United States (SHELDUS) was the main resource used for gathering information on disaster impacts. The Hazards and Vulnerability Research Institute (HVRI) at the University of South Carolina manages the database. The database can be searched in four ways: Named Events, Location and Data, GLObal IDEntifier Number (GLIDE), and Presidential Disaster Declaration. The name and location option was used for this thesis. The information is part of Version 15.2, which was launched in November 2016. Version 15.2 includes 870,897 direct loss records and 2,561,882 crop indemnity records (HVRI 2016). The database is updated annually.

The SHELDUS datasets were reported natural hazards and perils at the county level. The data include the date, location, and the directs losses caused by the event – deaths, injuries, property damage, and crop damage (HVRI 2016). SHELDUS provides information on a variety of hazards and perils. For hazards, users can search by the following hazard types: avalanche, coastal, drought, earthquake, flood, fog, hail, heat, hurricane/tropical storm, landslide, lightning, severe thunderstorm, tornado, tsunami/seiche, volcano, wildfire, wind, and winter weather.

I downloaded the data for my study area by first selecting to search the database by location and date. Then, I selected the relevant states and counties. The map in Figure 4 displays all coastal watershed counties for Atlantic and Gulf coast states.

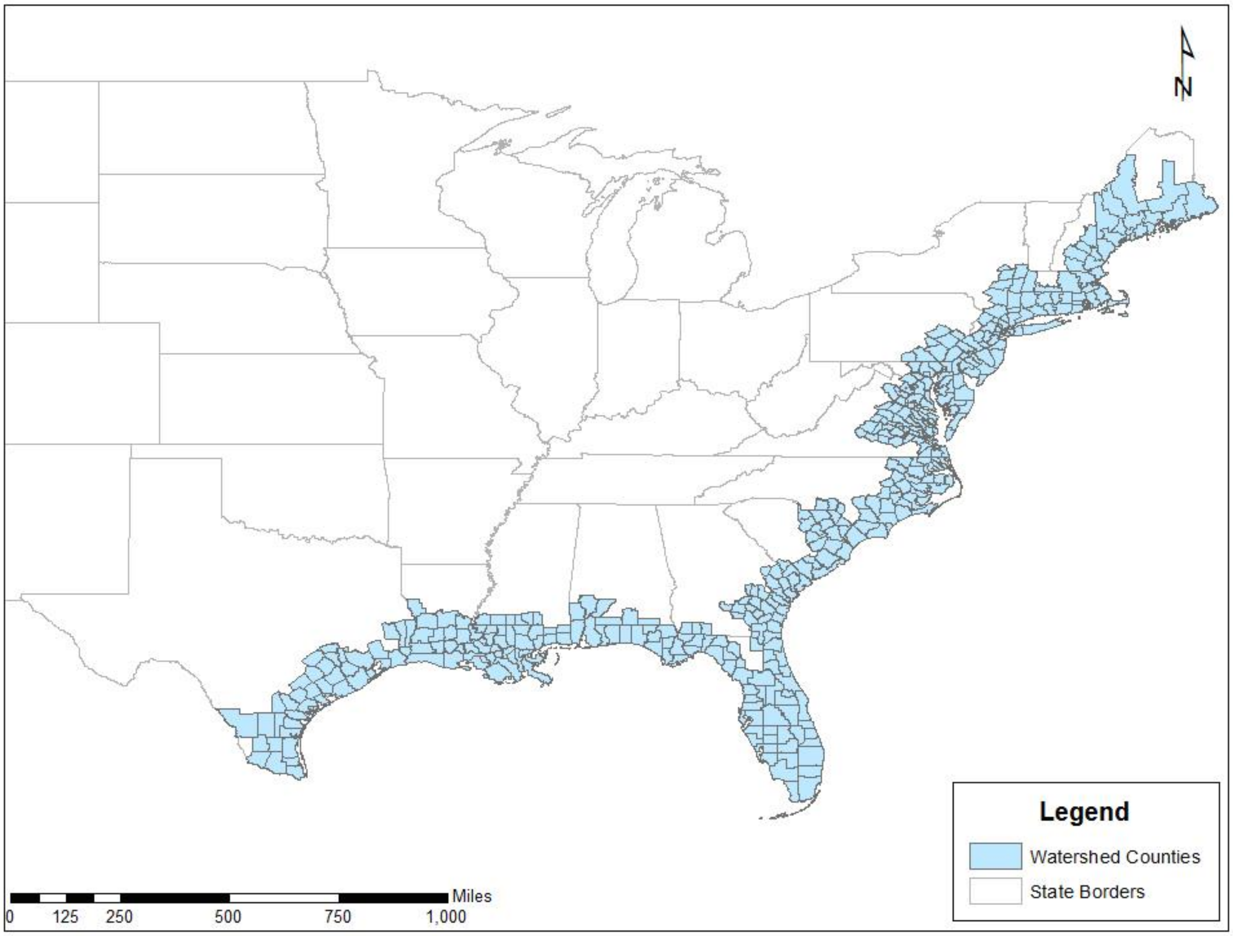

Figure 4. Coastal Watershed Study Area

After narrowing down the locations, I set a date range, January 1, 2000 through December 31, 2009. The dates were based on creating the pre-event and post-event timeline seen in my conceptual framework. After setting the date range, I selected specific hazards followed by loss types: coastal, flooding, and hurricane/tropical storm. I then aggregated the data by county, year, and hazards and adjusted inflation to 2015. I later totaled all hazard types by collapsing the data in Stata Data Analysis and Statistical Software (14th Edition).

3.5.2 Social Vulnerability Indicators

The concept of social vulnerability has been thoroughly described by Cutter and others. This project uses four types of social vulnerability: socioeconomic, household composition, minority status and language, housing and transportation. The specific variables within each category will be detailed later in this chapter. Both the categories and variables used in this research are based on parameters used by the CDC's Agency for Toxic Substances and Disease Registry (CDC 2014).

The Geospatial Research, Analysis & Services Program operates with the ATSDR to provide social vulnerability information to local jurisdictions. The ATSDR maintains datasets based on the 2000 Census, 2010 Census, and the five-year estimates from the American Community Survey for 2006 to 2010. The agency's indices for 2000 and 2010 will be used for analysis in this paper. ATSDR provided both tract and county level data for 2010, however, the 2000 dataset was only available at the tract level. To accurately match hazard loss data to social vulnerability data and ensure comparability between years, population figures from 2000 needed to be converted to the county level. This was possible through American FactFinder database from the U.S. Census Bureau. Data downloaded as census tables were the following: occupied housing units, below poverty, unemployment, population over age 25, population over age 5, and single parent households/households with children under age 18. Using census data allows for comparison of the same county over time. The time scale also provides enough time for the community to see the effects of long-term recovery after a hazard event. Table 4 details each indicator used in this study.

Table 4. Social Vulnerability Descriptions

SV Indicator	Description	Study Variable
Income and Poverty	Income level is the clearest indication of socioeconomic status. It can shape the population's ability to prepare prior to an event and recover afterwards. Damage to property among economically disadvantaged populations can have more severe effects because it represents a larger proportion of household assets.	Below Poverty, Per Capita Income
Employment	Unemployment is part of the equation because of its close ties to benefits like health and life insurance. The income provided by employment can allow for someone to access important resources to prepare before an event and deal with the aftermath.	Unemployment
Education Level	Education is closely tied to income and poverty. Lower educational attainment means someone is more likely to have lower income. Evidence shows people with higher levels of education tend to have access to information on hazards and to act in response.	No High School Diploma, Age 25+
Age	Children are more vulnerable have unique challenges during hazard events due to their need for caretakers. Studies have shown minors lack the resources and knowledge to protect themselves and cope with the situation	Age 17 and Under
Single Parents	Single parent households are included due to the frequency of these household also holding a lower socioeconomic status. A disaster can also strain the household where one parent is responsible for all caretaking duties.	Single Parent Households
Race and Ethnicity	Long-term marginalization of different groups based on race and ethnicity has led to minority populations being more vulnerable during each phase of the disaster cycle. In the United States, African Americans have been found to be more vulnerable than other groups. Hispanic and Native American ethnicities have also greater social vulnerability	Minority Status
English Proficiency	Similarly, low levels of English proficiency can complicate emergency communication efforts when translators or materials are not readily available in the necessary language. These groups are more likely to rely on social networks for information	Speak English "Less than Well," Age 5+
Mobile Homes	Mobile homes are not structurally designed to withstand extreme events. The location of mobile homes can often create higher vulnerability due to the tendency to cluster units and their frequent separation from urban areas	Mobile Housing Units
Overcrowding	Overcrowded housing units are studied in the context of social vulnerability due to the potential for complicating evacuation efforts It may also be a sign of other sources of vulnerability e.g. socioeconomic status or age.	Crowded Housing Units
No Vehicle Access	Vehicle ownership tends to be lower in cities, especially among lower income brackets. Typical evacuation efforts rely on the expectation people can find their own way out of the area.	No Vehicle Access by Household

SV Indicator	Description	Study Variable
Group Quarters	Populations of group homes often have specialized needs. These residences include psychiatric institutions, jails and prisons, college dormitories, and nursing homes and long-term care facilities. Apart from college students, these populations often require specialized vehicles for transport and staffers to continue care or surveillance.	Group Quarters

Source: Cutter, Boruff, and Shirley 2003; Flanagan et al. 2011; CDC 2014

3.6 Data Analysis Procedures

To complete this research, the results for hazard loss data and social vulnerability needed to be prepared individually prior to testing for a relationship between their variables. As the dependent variable, social vulnerability needed to be standardized for accurate comparisons. Score standardization converted each variable in 2000 and 2010 to a z-score. The results could then be combined to find change in social vulnerability and measured against hazard loss data using correlation analysis.

3.6.1 Standardized Scores

The social vulnerability data provided by ATSDR includes both the raw population counts and population proportions. The population proportions are used in this project to allow for comparisons between different years and locations. The proportions are used for all social variables except per capita income.

To get an overall social vulnerability score, the 12 variables for 2000 and 2010 are combined as z-scores for the respective year. Z-scores measure standard deviations in relation to a data point. Looking at standard deviations gives a way to see how social vulnerability in each county compares to others in the same year and offers comparisons for the same county in different years. Using this method will provide a way to test for a change in 2010 from 2000 while controlling for issues like population change. Variables are standardized individually prior to being added to one another based year. The total score for 2000 is subtracted from the total score for 2010 for the change in social vulnerability.

Standardization also applies to the hazard data. Per capita property damage is used opposed to total property damage. It measures the damage in relation to the population instead of purely focusing on the raw value of damages. It is adjusted to its 2015-dollar value.

3.6.2 Correlation Analysis

The overall social vulnerability scores for 2000 and 2010 were tested for correlation against different hazard variables. This is meant to evaluate the relationship between social vulnerability and hazards.

3.6.3 Statistical Limitations

Due to changes with data collection from the U.S. Census Bureau, there are differences in the raw data for the 2000 and 2010 datasets. In 2010, the Census Bureau did not use the long format used in previous years. Data from the American Community Survey was used to complete gaps in information.

There is some additional information included in the hazards data is the result of how it is maintained in SHELDUS. Some losses are caused by multiple hazards and the effects are divided between types. As a result, wind and severe storm/thunderstorm data are included in the record counts. There are 38 cases for wind over the 10-year period. These cases are part of the record counts for counties in Florida (9 counties), North Carolina (1 county), Louisiana (10 parishes), Maine (2 counties), Maryland (1 county), Massachusetts (5 counties), New Hampshire (1 county), and Pennsylvania (3 counties). There were three severe storm/thunderstorm records included in the set. While this data could have been excluded from the final count, these cases were left in place because of connections to other hazards and coastal locations.

Additionally, this study is limited to coastal counties with at least one hazard record between 2000 and 2010. Based on this parameter, some coastal watershed counties were not analyzed for social vulnerability.

3.7 Methodology in Summary

This study is based on a combination of geography, hazards, and social vulnerability. The focus on coastal watershed counties results in coastal hazards as the main source for hazard loss data. Information on hazard losses came from SHELDUS and the Hazard and Vulnerability Research Institute at the University of South Carolina. Social vulnerability data includes variables related to economic, household composition, minority status, and housing and transportation characteristics; it was obtained from the ATSDR at the CDC and the U.S. Census Bureau. For comparability between years and against the independent hazard loss variables, social vulnerability variables were standardized. Statistical analysis of the data collected utilizes correlation as a test for significance in the relationship between variables.

4.0 Results

Statistical analysis of the data on hazard losses and social vulnerability provided insight on the experiences of the 407 coastal watershed counties between 2000 and 2010. Prior to studying the relationship between the two variable types, needed to be studied and prepared independently. Summary statistics for hazard loss data show where events took place between 2000 and 2010 and typical impacts. Social vulnerability data summary statistics from 2000 and 2010 give context to the study, but results were standardized to allow for comparisons between years and analysis with hazard data.

4.1 Distribution of Hazards

Out of 407 coastal counties, 142 had above average record counts. The remaining were below the mean. The standard deviation was 9.769.45 counties were at the minimum with one event. Harris County, Texas was the maximum with 65 records. The median record count was six. The sum of all records for the 407 counties equaled 3891. Flooding was the most frequent hazard, followed by hurricanes and tropical storms, then coastal.

Property loss was also measured. Total property damage and property damage per capita were measured. Between 2000 and 2010, coastal hazards $143,079,357,752.89 (adj. 2015). The mean per capita property damage 5577.27 with a standard deviation of 19729.1. There were 402 cases with property damage greater than 0. Controlling for cases without property damage, the mean remains relatively unchanged at 5646.64.

Crop damage acted as another hazard loss variable. Most counties studied did not have this type of loss. 154 counties out of 407 in the study area had instances of crop damage. The total crop damage equaled $3,508,643,637.02; per capita crop damage averaged 101.3475. When isolated to those 154 counties, the mean crop damage per capita is approximately 267.85. Duration days, injuries, and fatalities were also considered. There were approximately 1432 injuries and 1330 fatalities. Duration days for all events between 2000 and 2010 averaged 10.58 with a standard deviation of 8.75. Table 5 displays the summary statistics for the hazards data.

Table 5. Hazard Losses for Atlantic and Gulf of Mexico Coastal Watershed Counties, 2000-2010

Variable	N	Mean	Std. Deviation	Min	Max
Records	407	9.56	9.77	1	65
Property Damage (adj. to 2015)	407	3.52E+08	1.10E+09	0	7.40E+09
Property Damage Per Capita (adj. to 2015)	407	5577.27	19729.1	0	259733
Crop Damage (adj. to 2015)	407	8620746	5.19E+07	0	8.29E+08
Crop Damage Per Capita (adj. to 2015)	407	101.35	421.07	0	5517.02
Injuries	407	3.52	18.34	0	156.80
Fatalities	407	3.27	26.40	0	510.14
Duration Days	407	10.58	8.76	1	48

Source: Primary Data Analysis

4.2 Social Vulnerability

The social vulnerability scores for all 407 counties are based on 12 variables related to socio-economic status, household makeup, minority identification, and housing and transportation characteristics. The data sources for these variables are the U.S. Census Bureau and the Centers for Disease Control and Prevention. To compare variables, population proportions were used. Per capita income is used as its resulting value.

Three variables were measured based on the total population of the county: the proportion age 17 and under, minority (non-white) proportion, and the proportion of the population living in group quarters. The proportion of the population below poverty is based on the poverty estimate. The unemployment proportion is based on the civilian labor force age 16 and older. Per capita income is used without further modification. The proportion of single-parent households counts cases with one adult with own children under 18 living in the home out of total households. Limited English Speakers counts the population over age 5 who speak English “Less Than Well.” Proportion of mobile homes is the total mobile units out of total housing units. Crowded households have more occupants than rooms; its proportion is based on total occupied units. Households without access to a vehicle are measured in relationship to total households.

Originally, variables regarding age over 65 and multi-family housing with 10 or more units was part of the dataset. The data from 2000 also contained information on disability status. These three variables were not used in the final version of my data analysis, and I will discuss the obstacles with each in the limitations section. The summary statistics of each variable for 2000 and 2010 are available in Table 6.

Table 6. Social Vulnerability Summary Statistics 2000 and 2010

Variable	N	Mean		Std. Deviation		Minimum		Maximum	
		2000	2010	2000	2010	2000	2010	2000	2010
Below Poverty	407	0.14	0.15	0.07	0.07	0.03	0.04	0.52	0.43
Unemployed (Civilians age 16+ in workforce)	407	0.06	0.08	0.03	0.03	0.02	0.02	0.42	0.18
Per Capita Income	407	19612	25595	5663.85	7854.80	7069	10800	42922	59149
No HS Diploma (age 25+)	407	0.23	0.17	0.09	0.08	0.04	0.04	0.65	0.52
Age 17 & Under	407	0.25	0.23	0.03	0.03	0.10	0.09	0.37	0.35
Single Parent Households	407	0.09	0.12	0.02	0.03	0.04	0.04	0.22	0.25
Minority (Non-White)	407	0.31	0.34	0.19	0.19	0.02	0.03	0.98	0.97
Limited English Proficiency (age 5+)	407	0.02	0.03	0.03	0.04	0.00	0.00	0.27	0.29
Mobile Home	407	0.15	0.14	0.13	0.12	0.00	0.00	0.57	0.57
Crowded Housing Units	407	0.04	0.02	0.04	0.02	0.00	0.00	0.26	0.16
No Vehicle Access	407	0.09	0.08	0.07	0.07	0.02	0.01	0.77	0.78
Group Quarters	407	0.04	0.04	0.04	0.04	0.00	0.00	0.38	0.34

Source: Primary Data Analysis

The summary statistics presented in Table 6 provides results based on population proportions of each variable by county. Most variables had similar means and a wide range in both datasets. It is worth noting an outlier in 2000 dataset for unemployment. The unemployment proportion for Williamsburg, Virginia was 0.4167. While this may be accurate, there is also potential for a data collection error.

Standardizing the variables to create a composite SV score allows for the data to be considered in terms of my research question: Do communities that experience a higher frequency of hazard events learn from their experiences resulting in lower of social vulnerability over time? After creating standardized scores to reflect each county's level of social vulnerability, correlation tests were used to better understand the relationship between hazard impacts (measured as records and per capita damage) and social vulnerability.

4.3 Correlation Measurements

Standardizing the social vulnerability data for 2000 and 2010 allowed the information to be combined and applied to other tests. Using z-scores provided for control and comparability. Correlation analysis tested the relationship between social vulnerability change and hazard loss variables. The majority of variables did not have statistically significant results, including records, the main representation for hazard frequency. Initially, property damage per capita showed the only significant correlation to social vulnerability change.

Table 7. Social Vulnerability Change and Hazard Loss Correlations

	Social Vulnerability Change
Records	0.0177
Property Damage Per Capita (adj. 2015)	-0.1393**
Crop Damage Per Capita (adj. 2015)	-0.0894

*Significant at $p \leq 0.01$
Source: Primary data analysis

The results in Table 7 are based all 407 counties. In the correlation coefficient is listed along the top rows with its significance recorded underneath. Only Property Damage Per Capita has a statistically significant correlation with SV change. Records, Fatalities, Injuries, and Duration Days are not statistically significant at the 0.05 (2-tailed level). Crop Damage Per Capita did not show a significant correlation across all counties, however, only 154 counties out of 407 (approximately 38%) had crop damage per capita greater than 0. When testing only those counties, there is a significant correlation. The results are shown in Table 8.

Table 8. Correlation Test for Social Vulnerability Change and Crop Damage Per Capita

	Social Vulnerability Change
Crop Damage Per Capita (adj. 2015)	-0.162*

**Significant at* $p \leq 0.01$
Source: Primary Data Analysis

A second correlation test was completed for Property Damage Per Capita following similar guidelines (tested cases where Property Damage Per Capita ≠ 0). The results are provided in Table 9.

Table 9. Correlation Test for Social Vulnerability Change and Property Damage Per Capita

	Social Vulnerability Change
Property Damage Per Capita (adj. 2015)	-0.1377**

*** Significant at* $p \leq 0.01$
Source: Primary Data Analysis

Social vulnerability change and property damage per capita continue to be correlated with statistical significance when only counties with property damage above zero are tested. This is not surprising; the number of cases tested under these parameters is 402 (out of a total of 407 cases).

4.4 Summary of Results

Based on the correlation test of social vulnerability change and hazard loss variables, coastal watershed counties do not appear to learn from experience. Records, the variable represent hazard events did not have a statistically significant relationship with the change in social vulnerability between 2000 and 2010. However, property damage per capita and social vulnerability change did result in a statistically significant relationship at the alpha level $p \leq 0.01$. Crop damage per capita also showed significance when the test was isolated to counties with crop damage greater than zero. The correlation in this case had significance at $p \leq 0.05$. Hazards are a challenge for counties within the study area, however, with 9.56 as the mean record count. While learning may not have been seen in this study, there are ways to apply past experience to future hazards.

5.0 Discussion and Conclusions

Overall, there was little change in social vulnerability scores between 2000 and 2010. Out of 407 counties, 99 had no change in their total score. The social vulnerability change found 74 counties decreased their combined score. The social vulnerability change in 76 counties showed an increased score. The number of records (representing the number of events) had little effect on the social vulnerability at the end of the decade. These coastal counties, however, continue to be at risk due to their geography and wider demographic trends. Coastal hazards continue to threaten the area, and the population exposed is growing (351 out of 407 counties experienced population growth during the 10 year-period). The area also hosts major population centers with 15 counties with populations over 1 million in 2010, and several of the most populous metropolitan areas in the United States. From a planning and management perspective, these locations are a chief concern.

Vulnerability gives insight to pre-event conditions. It is vital to understand the situation in the community prior to the emergence of a hazard to minimize potential harm (Cutter et al. 2008). To be resilient to hazards, communities need to be able to absorb the impacts and respond to changing conditions. This is an ongoing process. There are a variety of strategies to aid vulnerability reduction efforts. One way is by focusing on adaptation and its corresponding methods including adaptive learning and self-organization.

As described in Chapter 2, there is little control over the hazard events included in this study. Coastal hazards, flooding, and hurricanes/tropical storms are part of natural ecosystem function and will occur at one time or another. With the current populations and importance of coastal cities, focusing on limiting exposure is inadequate. The population is exposed to the hazard; the regional geography helps create place vulnerability. Therefore, considerations for social vulnerability are key to learning from previous experience and preparing for the future. Studying social vulnerability provides a way to better understand how different groups may be adversely affected by hazard events. It recognizes the ability of existing social structures to shape how disasters are experienced within a population, and a better understanding can ameliorate challenges. Integrating social vulnerability will hopefully allow for communities to ultimately become more resilient. However, knowledge of vulnerable populations and action are separate issues. Uncertainty over losses, timing, and severity continue to create challenges for planners. Simply creating and following a plan even if it is ineffective does not promote resilience. Not taking action is another typical response. As Mileti said in *Disasters by* Design (1999), non-decisions are just as important as just as important to the creation of hazard impacts.

The results of this study show communities may not learn from experience. Multiple hazard events over ten years did not have a statistically significant correlation to a change in social vulnerability. Property damage per capita and social vulnerability change showed a significant correlation, in contrast. There is an opportunity to learn from these experiences before greater hazard losses necessitate change; adaptive learning provides guidance to potentially improve outcomes.

5.1 Adaptive Learning

Part of this process will require accepting uncertainty. It is uncomfortable and potentially expensive to make decisions about something that may not happen as expected. In some cases, the inability to say when and where an event is going to occur with absolute certainty decreases support for taking any action. It can be difficult to respond when there are many unknowns involved in the process (Tierney 2014).

This has been a major challenge in Harris County, Texas. The county is home to the City of Houston, and it is familiar with repeated coastal hazard events. In this study, the county had the highest event record count for all coastal watershed counties between 2000 and 2010 with 65 event records.

Hurricane Ike, the third costliest storm in U.S. history, had a major impact on Galveston in 2008, and just missed a direct hit on Harris County. Some hoped the close call would spurn action, however, there has been little change in the years since the storm. (Satija et al. 2016a). Many of the debates have centered on structural responses including the “Ike dike” and the more expansive coastal spine. The coastal spine would extend the Galveston seawall along the entire island and Bolivar peninsula, and it would install floodgates to prevent storm surge from entering Galveston Bay (Satija, Collier, and Shaw 2016a). The Houston area experiences a major storm approximately every 15 years, but there is little political motivation to act despite storm frequency falling within the timeframe frequently associated with social memory (Berkes 2007). Houston exemplifies some of the barriers to adaptive action. Political and economic dynamics create a cognitive dissonance allowing probability of the possible hazard impacts to be ignored. Mitigation has been a source of political in-fighting at the local level (Satija, Collier, and Shaw 2016a). Local officials disagree with one another and criticize scientists for not proving one plan. Federal representatives say they are waiting for the state to make a decision (Satija, Collier, and Shaw 2016a). Additionally, proposed projects will likely take decades to complete which decreases willingness to act. But more are exposed as well; the population has increased since Hurricane Ike with nearly one million people moving to the area (Satija, Collier, and Shaw 2016a). Growth leaves more people exposed to potential hazards, but vulnerability reduction efforts are labeled "anti-development" (Satija, Collier, and Shaw 2016b). Development patterns in Harris County follow the Local Government Paradox (Burby 2006). Major hazards are viewed as a remote possibility, but continued growth is beneficial. This is a challenge for many communities.

While the mitigation actions under consideration in Greater Houston would be structural and physical vulnerability, the decision-making process shows potential barriers for adaptation and adaptive management. There are clear lessons and future needs based on previous experience, but it will only be helpful if it is accepted as valid form of knowledge. There will never be perfect information about social or ecological systems. In order to deal with this ongoing policy and management challenge, different potential futures based on probable situations need to be considered and planned for accordingly (Berkes 2007).

5.1.1 Different types of knowledge

Recognizing the place of alternative views can open new opportunities for collaboration (Berkes 2007). Efforts to incorporate different views has become increasingly prominent in planning, climate science and conservation (Berkes 2007; Berkes, Colding, and Folke 2007; Tidball et al. 2010). It may be accomplished by including local knowledge (Tidball et al. 2010). Incorporating ideas from traditionally marginalized populations can also allow for applying theory to practice (Berkes, Colding, and Folke 2007; Berkes 2009).

5.1.2 Opportunities for Self-Organization

Self-organization is important part reducing vulnerability on multiple levels. It can be applied to community-based management, development of cross-scale management, strengthening of institutional memory, and promotion of learning and adaptive co-management (Berkes 2007). Each opportunity for self-organization works in unison in building resilience. One of the main concerns with vulnerability is its influence on an individual or community's ability to respond to a disaster. Community-based management will need to be considered in terms of self-organization, but they will need to be supported by governance structures. In Cumberland County, Maine, officials worked with community groups in an effort to create a more comprehensive process.

One of the challenges to self-organization is the tendency to follow structured procedures and reluctance to deviate from centralized decision-making. However, some there are important examples where a more successful response is characterized by its decentralized approach. The Coast Guard was one of the few institutional actors who earned praise for their work during Hurricane Katrina response efforts. The Coast Guard has a unique operating procedure known as "principle of on-scene initiative." It gives members latitude to act quickly and decisively within their authority within the scope of their authority without having to rely on chain of command (Tierney 2014, 215). The agency trusts its members to act decisively based on their own understanding and assessment of the situation. Taking new approaches to solve a problem is rewarded which allows adaptive resilience to build, and allow the organization to be more prepared for future crises.

Self-organization also relies on a learning process. The concept of self-organization itself is the result of learning from experience, but its implementation requires learning to continue to support further advancements. Dynamic learning can act as the baseline to more adaptive behaviors at an institutional level through adaptive co-management (Berkes 2007).

5.1.3 Connection to Adaptive Management

Adaptive management falls within adaptive learning. It promotes the learning process at the institutional level. As communities move towards policy-based mitigation efforts instead of structural solutions to minimize risk from hazards, policy decisions rely on a certain level of trial and error.

Implementing new policies is used as a way to reduce damage from events (Brody et al. 2009). The management process then acts like an experiment where actors can hypothesize a certain result and test different variables, for example policy changes.

In adaptive management, policies and tools can be tested and adjusted over time in response to changing conditions and when new information surfaces (Brody et al. 2009). Adaptive management has been promoted for providing a clear framework for policy learning (Brody et al. 2009). Its principles emphasizing experimentation allow for different policy efforts to be implement and adjusted over time providing a way to react to changing environmental and political conditions. Adaptive management and adaptive learning both attempt to provide a way to handle changing system conditions. These processes can be highly interconnected with parts of crossing over one another.

An alternative to adaptive management is scenario planning. Like adaptive learning and adaptive management, it has been framed as a way to respond and plan in the face of uncertainty. It also requires the ability to learn and adjust in response, but the framework differs from management in its focus on situations where experimentation is not a practical option (Peterson 2003). Scenarios are a way to consider a variety of possible future situations.

In scenario planning, a central issue is identified and ways to respond to the problem are considered for how changes may take place and affect other issues. In practice, scenario planning efforts have provided a clear way to separate knowable and unknowable futures (Peterson 2003). Scenario planning is focused on breaking down the knowable from the unknowable to give actors a way to find alternatives. Being able to parse out uncertainty into smaller pieces allows for different options to be considered depending on interactions between different components of the system. The scenario planning process offers a chance to continue the learning process through building and testing scenarios (Peterson 2003).

The scenarios are tested for consistency and their effectiveness relies on the plausibility. By moving through different scenarios repeatedly, discrepancies and obstacles become clear and actors can begin to see potential policy options (Peterson 2003). While the details of the scenario planning process differ from adaptive management/adaptive co-management, both approaches intend to promote learning opportunities. Effective adaptation efforts require being able to learn in different ways as needed. Having to make adjustments is why it is helpful to accept sources of knowledge outside traditional venues. It is also why having the ability to self-organize outside rigid procedures can allow for a more effective response. Learning through doing can also better support a diversity by requiring actors to make new connections and partnerships. In adaptive management, actors are creating and trying new policies that are going to affect different constituencies. Understanding the successes and failures will need to be assessed. Scenario planning can promote working with others to evaluate what is plausible and how to practically respond to the situation.

Anticipatory governance has also emerged as framework for working in uncertain conditions (Berke et al. 2014). Like adaptive management and scenario planning it centers around providing flexibility to respond to change. Planning based on the pre-disaster context of the community and potential post-disaster situations is part of minimizing possible harm. Reducing vulnerability relies heavily on context, however, so apparent changes are not always the result of increased resilience.

One clear pattern in changes to social vulnerability scores in 2010 from 2000 measurements was in Louisiana, particularly the parishes within the New Orleans-Metairie Metropolitan Statistical Area. Given the timeframe of this project the changes are likely a reflection of the impacts of Hurricane Katrina. Orleans Parish, Plaquemines Parish, and St. Bernard Parish each lost several thousand residents between 2000 and 2010. The Katrina diaspora is well-documented in disaster literature. For Orleans and Plaquemines, the social vulnerability score has decreased. In 2000, Orleans Parish was above the first standard deviation; it was less than one standard deviation in 2010. Plaquemines Parish is almost close to zero in 2010.

The social vulnerability score for St. Bernard Parish was higher in 2010. Population decreased by over 40 percent, and the proportions for most vulnerability indicators were greater than the previous set. Simply looking at the scores does not tell the whole story. Without knowing the context, the cases would be seen as trending in the right direction. However, the changes are not the result of improving the area's resilience. The changes are the result of a disaster making the community's lack of resilience abundantly clear. The context may present an extreme example given Katrina's catastrophic impact, and most events will not have the same magnitude. But, the lessons are important to future efforts.

5.2 Limitations

Looking at social vulnerability at the county level does not yield as detailed results as some other approaches. Looking at smaller divisions like census tracts or block groups would provide important insight on how the population is distributed within the county. Using a smaller unit for population data can be helpful on multiple levels. It adds specificity to social vulnerability because it is based on smaller sections of the population.

While compiling and analyzing the data, one of the major concerns for this project was losing details about social vulnerability within a county by aggregating the information at a county level. There can be significant variation in the social vulnerability within a county, and there are likely cases where different variables are disproportional. It would be helpful to learn more, and check for concentrations of social vulnerability, especially in counties with otherwise low SV scores. This is partially due to disproportionate demographic features of coastal counties, particularly those designated as coastal shoreline. Their average social vulnerability is below the mean. Additionally, income distribution does not follow some of the same patterns as their inland counterparts (NOAA 2013). Instead, shoreline counties skew towards higher incomes. There are differences in the typical education levels as well (NOAA 2013).

This leads to the next limitation: hazard impacts. For this project, my hazard data relied on tracking the event records over a ten-year period, the total property and crop damage, and casualties. The information was broad and provided the necessary context while showing the overall trends. However, it does not provide information on specific impacts within the county which, in turn, shaped the social vulnerability assessment. This may be beyond the scope of this investigation, but it is important to consider upon further study of social vulnerability.

One concern with the 2010 data is the effect of the proportion unemployment on the county's overall social vulnerability score. This needs to be considered in a broader economic context. The data was collected amid the Great Recession. Economic stability is important to resilience (opposed to the market fluctuations of the crash) and the variables had a heavy influence on results. Florida counties were a particular concern because the state was heavily impacted by the crash of the housing market.

The level of unemployment would affect the level of vulnerability at the time, but the long-term effect of these changes on long-term planning requires more study.

Another concern regarding changes to social vulnerability can be seen in communities with low scores in the starting year. Most counties who started at least one standard deviation below the mean remained below the mean in 2010. Within this group there were several counties whose scores moved further away from the mean. This is concerning because it stands in contrast to many counties between -1 and +1 standard deviation. Communities who may require greater efforts to reduce vulnerability may not have their needs addressed. At the same time, communities where social vulnerability was below average before hazard events emerged seem more likely to implement vulnerability reduction tactics even though the relative need is lower.

5.3 Summary of Findings

There is a clear role for planners in disaster management efforts. Within a social-ecological system where there is an ongoing potential for natural hazards, land use decisions shape realized risk through hazard losses. Planning policies help shape the impacts of disasters; reducing vulnerability gives clear focus to meeting risk reduction objectives. But, it is important to consider how vulnerability is defined. Concentrating on physical vulnerability is not enough if the ultimate goal of the community is building resilience to better cope with disturbance. The social vulnerability also needs to be considered to handle hazard impacts effectively. As a wide body of disaster research shows, different portions of the population have different capacities to deal with changes in the system.

The results of this investigation show coastal counties where hazard events occurred over a ten-year period saw little change in the level of social vulnerability in the community. The number of events made little difference in the change in social vulnerability scores from 2000 to the scores in 2000. Property damage per capita was the only variable with statistically significant results for all cases. It also had a negative correlation. The results imply communities are not learning from their experience with repeated hazard events. However, there needs to be further study before making any conclusive determinations.

Adaptive management and adaptive learning hold promise for implementing ideas from resilience theory. The principles of respecting different forms of knowledge, opportunities for self-organization.

5.4 Future Directions for Research

Using this study as a baseline, it would be beneficial to extent the time period of study. I looked at a decade of social vulnerability and hazard loss data. Expanding the scale to include earlier decades i.e. 1990s, 1980s, and earlier and more recent years i.e. 2010 through 2015. This would give a better sense of data trends in social vulnerability and hazard losses. Furthermore, newer data may also provide an indication on counties where ideas about resilience and adaptive management are being implemented. The period of study and the growth in popularity of resilience theory took place almost simultaneously. At the time, policies may not have reflected the concepts, but ideas may have been incorporated in subsequent years. It could also be beneficial to explore specific planning polices within the study area. In my own rudimentary survey of county planning documents, there were clear differences between counties, as illustrated by the Charleston regional plan and Cumberland County, Maine juxtaposed to Harris County, Texas. Researching different approaches and styles of planning is worthy of further examination.

5.5 Final Thoughts

One of the main motivations behind this project was my interest in seeing disasters through a regional perspective. For hazard impacts, this remains important since disasters simply do not follow jurisdictional boundaries. However, people are organized at a smaller level; and to find a more complete understanding of social vulnerability will need an appreciation for this scale in order to see the subtle variations. The challenge will be fusing the two disparate scales in policy.

Appendix I. Data Dictionary

i. SHELDUS Hazard Loss Data

Hazard Variable	Data Format	Description
CropDmg	Currency	Damage to crop in U.S. dollars (current year), no decimal places
CropDmg (Adj. 2015)	Currency	Damage to crop in adjusted U.S. dollars (selected base year), 2 decimal places
CropDmgPerCapita (Adj. 2015)	Currency	Damage to crop in adjusted U.S. dollars (base: 2015) divided by the annual county population; per capita calculations are based on current population; 6 decimal places
County Name	Text	Name of County
County FIPS	Text	5-digit Federal Information Processing Standard code (FIPS), which uniquely identifies counties and county equivalents in the U.S.
Duration_Days	Integer	Length of events with a loss expressed in number of days
Fatalities	Number	Count of people killed
FatalitiesPerCapita	Number	Count of people killed/divided by the annual county population; per capita calculations are based on current population; 6 decimal places
Hazard	Text	Classification of the event into one or more of the 18 SHELDUS hazard types
Injuries	Number	Count of people injured
InjuriesPerCapita	Number	Count of people injured/divided by the annual county population; per capita calculations are based on current population; 6 decimal places
Injuries_Duration	Integer	Length of events with injuries expressed in number of days
PropertyDmg	Currency	Damage to property in U.S. dollars (current year), no decimal places
PropertyDmg (Adj. 2015)	Currency	Damage to property in adjusted U.S. dollars (selected base year), 2 decimal places
PropertyDmgPerCapita (Adj. 2015)	Currency	Damage to property in adjusted U.S. dollars (base: 2015) divided by the annual county population; per capita calculations are based on current population; 6 decimal places
Records	Integer	Count of the underlying raw data records that were used to generate the aggregated loss values. Note: When selecting aggregation by hazard type, the sum of values in the RECORDS column will be higher than the actual number of underlying raw data records. In cases, where the loss was caused by multiple but different hazard types (e.g., flooding and wind), the record will be both counted in the Flood and Wind category.
State Name	Text	Name of State

(Hazards & Vulnerability Research Institute 2015)

ii. Social Vulnerability Data

Variable	Description	Calculation
Below Poverty	Proportion of persons below poverty estimate	Individuals below poverty= "under .50" + ".50 to .74" + ".75 to .99." The denominator is the total population where poverty status is checked
Unemployed	Proportion of civilians unemployed (age 16+)	Civilian unemployed 16+/ Total civilian population in workforce
Per Capita Income		
No HS Diploma	Proportion of the population over 25 without a high school diploma	No HS Diploma (25+)/Total Population (25+)
Age 17 and Under	Proportion of population age 17 or younger	17 and under/Total Pop
Single Parent HHs	Proportion of single parent households with children under 18	Single Parent/Total Households
Minority	Non-white population including	Non-white/Total Pop
Limited English	Population over age 5 who speak English "Less than well"	Population age 5+ who speak English "Less than well"/ Total population age 5+
Mobile Units	Number of mobile housing units	Mobile Units/Total Housing Units
Crowded Units	Proportion of households with more people than rooms	
No Vehicle Access	Proportion of households without a vehicle available	
Group Quarters	Proportion of the population living in institutionalized group quarters (including correctional facilities and nursing homes) and non-institutionalized facilities (including college dorms and military quarters)	

iii. Map Data

Data	Source	Key Attributes	Projection System
SVI Tract Shapefile	CDC	Jurisdictional boundaries for all U.S. counties and Census Tracts	North American Datum of 1983

Appendix II. Coastal Hazard Types

Coastal Hazard Type	
Astronomical low tide	Rip currents, heavy surf
Beach erosion	Rogue wave
Blizzard, wind, surf	Rough seas
Coastal	Rough seas & surf
Coastal flood, heavy surf	Rough surf
Coastal flood, high seas	Sea swell
Coastal flooding, beach erosion	Snow, icing, tidal
Coastal flooding, erosion	Snow, strong winds, high tides
Coastal storm, high winds, high tide	Snow, wind, rain, tide
Coastal wind, high tides	Snow, wind, tide
Cyclone, high wind, tides	Spring tide and intense, slowly moving offshore storm wind, rough seas, coastal flooding
Extra tropical coastal storm tide and wave action	Storm surge/tide
Flash flooding, high surf	Storm tides, torrential rains, windstorms, tornado
Flooding, beach erosion	Storm tides, wind, rain
Flooding, erosion, lightning	Strong wind, high seas
Gale winds, high tides, heavy rain	Strong wind, rough seas
Heavy rain, wind, high tides	Strong windstorm accompanied by violent wave action
Heavy seas	Surf
Heavy snow, blizzard, tidal flooding	Surf, high seas
Heavy surf	Surf, rain, wind
Heavy surf and high tides	Tidal
Heavy surf and wind	Tidal wave
Heavy surf, coastal flooding	Tidal wave (seismic origin)
Heavy surf/high surf	Tidal, wind
Heavy surge	Tidal, wind, rain
Heavy swell	Tide
Heavy wave	Tide and wind
High seas	Unprecedented tidal and wave destruction, high winds, heavy rains and extensive tidal flooding
High surf	Wind & high tides
High surf and waves	Wind and high seas
High tide, coastal storm	Wind and waves
High tide, wind, beach erosion	Wind generated waves
High tides	Wind storm and tides
High tides and flash flooding	Wind, beach erosion
High tides and flooding	Wind, coastal storm, high tides
High tides, heavy rain	Wind, high seas, and tides
High tides, wind, and rain	Wind, high tides, beach erosion
High wave erosion and flooding	Wind, high tides, flooding
High waves, flooding	Wind, rain and high tide
High waves, surf	Wind, rain, flooding, beach erosion
High waves, tropical storm Diana	Wind, rain, floods, surf, and thunderstorms
High wind and coastal flood	Wind, rain, high tides, snow
High wind and shore erosion proxigean spring tide and heavy rain	Wind, rain, tidal flooding
High wind, high surf, flood	Wind, rain, tide
High wind, rough sea, minor coastal flood wind and heavy seas	Wind, riptides
High wind, rough seas	Wind, rough seas
High winds and high seas	Wind, rough seas, rain
High winds and rough seas	Wind, sea swell
High winds and seas flooding/wave/wind	Wind, snow, rain, surf
High winds and tides	Wind, storm tide
High winds, high tide	Wind, surf

High winds, seas	Wind, tidal, rain
High winds/seas, blizzard	Wind, tide
Hurricane Erin, rip current strong winds, high seas	Wind, tide, snow
Hurricane-generated swells	Wind, tides, rain
Hurricane, high tides and wind	Wind, tides, waves
Hurricane/rain/tide/wind	Wind, waves
Local floods, and mud slides, storm tide	Wind, waves and high tides
Marine accident	Wind, waves, icing
Minor coastal flood and wind	Winds & tidal wave
Proxigean spring tide and high winds	Windstorm accompanied by strong wave action snow, tidal
Rain & heavy surf	Windstorm and high tide
Rain, wind, surf	Windstorm and rough sea
Record high tide	Winter coastal storm, wind, high tide, storm surge high tide – coastal storm
Rip current	Winter storm, flooding, wind, heavy rain, heavy snow, tides strong wind, high sea

Source: Hazards and Vulnerability Research Institute 2013

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