The Pennsylvania State University

The Graduate School

College of Earth and Mineral Sciences

TRAPPED IN PLACE: THE VULNERABILITY OF THE ELDERLY TO HURRICANE HAZARDS IN SARASOTA, FLORIDA

A Thesis in

Geography

by

Chongming Wang

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

August 2011

The thesis of Chongming Wang was reviewed and approved* by the following:

Brent Yarnal
Professor of Geography
Thesis Advisor

Alexander Klippel
Assistant Professor of Geography

Karl Zimmerer
Professor of Geography
Head of the Department of Geography

*Signatures are on file in the Graduate School.

ABSTRACT

Although the elderly are commonly thought to be disproportionately vulnerable to natural hazards, the elderly populations of coastal communities in Florida and other areas exposed to natural hazards are continuing to grow. Because there is no empirical hazards work specifically addressing the vulnerable elderly in a spatial context, this thesis uses Sarasota County, Florida as a case study to address the question: how vulnerable are the elderly to hurricane hazards and are all elderly people equally vulnerable? To explore the spatial variations in degree and composition of vulnerability among this population, the research maps physical exposure to hurricane storm surge inundation and precipitation-induced flooding and creates social vulnerability indices by applying Principal Component Analysis to census block group data in a geographical information system. The results show that elderly inhabitants of barrier islands face a considerable physical threat from hurricane-induced storm surge and flooding but are less socially vulnerable because of their wealth; the elderly living inland are far less physically vulnerable but are poorer and consequently demonstrate high socioeconomic sensitivity and limited adaptive capacity to these hurricane hazards. The thesis concludes that the elderly are not equally vulnerable: there are many different types of elderly living in many different locations and their vulnerability varies by type and over space. Effective vulnerability-reduction measures should account for these differences among the elderly population.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

First and foremost, I owe my deepest gratitude to my advisor, Brent Yarnal, who has played a crucial role in the development and completion of this thesis. Dr. Yarnal has made available his support in many ways with his knowledge and patience. This thesis would not have been possible without his guidance and encouragement. I am also heartily grateful to my other committee members, Alexander Klippel and Gregory Knight. Dr. Klippel and Dr. Knight provided valuable input for the thesis proposal and continued to provide considerable advice for subsequent thesis research. I am thankful to Tim Frazier and Peter Howe for sharing the storm surge data on which much of my research depended. I would also like to thank Ratchanok Sangpenchan and David Retchless, who have offered constructive feedback on my work. Additionally, the thesis has benefitted from communication with and assistance from Carrie Werner of the Census Bureau, Rick Morrow, Todd Kerkering, Scott Montgomery, and Martin Duran of Sarasota County Government. The research was supported in part by funding from the National Oceanic and Atmospheric Sectoral Applications Research Program-Coasts and the Pennsylvania State University through the Ruby.S Miller Endowment Fund in Geography. Finally, I thank my family and friends for their constant love and support.

CHAPTER 1

INTRODUCTION

The elderly are commonly accepted as being vulnerable to natural hazards. Although the normative changes associated with aging might not apply to all members of this population, the elderly are generally at greater risk and more likely to be harmed throughout all stages of a disaster (Morrow, 1999). In the 2003 European heat wave, the worst natural disaster to affect the continent in the last 50 years, approximately 30,000 people died — primarily older people (Earth Policy Institute, 2003; United Nations Environment Programme, 2004). Two years later, when Hurricane Katrina hit the US Gulf Coast, most Katrina victims were elderly (Associated Press, Oct 23, 2005; The Times, Feb 18, 2006). Although they comprised only 15 percent of New Orleans' total population, over 70 percent of Hurricane Katrina-related deaths were among older people (AARP, 2006). As we saw most recently in Japan, the elderly bore the brunt of the initial impacts of the devastating earthquake and tsunami. The twin disaster took its heaviest toll on the elderly in Japan, where nearly 1 in 4 people is over 65 (Associated Press/The Huffington, March 17, 2011). Not only were the majority of deaths from the elderly population, but also at the time of this writing elderly survivors were still grappling with lost medication, hypothermia, dehydration, and respiratory diseases (The Guardian, March 17, 2011).

"We are aging — not just as individuals or communities but also as a world" (U.S. National Institute on Aging, 2007). Indeed, a notable demographic trend in the United States is the rapid aging of the population (Population Reference Bureau, 2005).

Because the Baby Boomer cohort (those born between 1946 and 1964) started entering their elderly years after 2010, there will be a significant growth in the nation's older population in ensuing decades (Figure 1-1). By 2030, the projected number of people 65 years and older will reach 72 million, nearly a 100 percent increase from the 2003 elderly population size (U.S. Census Bureau, 2005). As the U.S. population is graying rapidly, older people's concerns and needs should not be subsumed under the broad banner of vulnerable groups (Humanitarian Policy Network, 2005). Given that the older population will grow more diverse as it grows larger, there is a heightened need to understand the traits of the elderly and the basis for their vulnerability.

This chapter provides the background information and sets the stage for the research presented in this thesis. I begin with the introduction of the key concepts around which the thesis revolves, i.e., the elderly and vulnerability. I then provide an overview of literature that broadly addressed issues relating to vulnerability and go on to discuss challenges for contemporary vulnerability research. Next, I review prior work specifically concerning how the elderly are affected by natural disasters, weaving together threads of research from various disciplines: geography, sociology, psychology, and medicine. Finally, I identify the deficiencies in past literature and end with the research questions for and study area of this thesis.

1.1 Definitions and Key Concepts

1.1.1 Who are the elderly?

How old is old? Most industrialized countries accept the chronological age of 65 years as the definition of an older person while the United Nations refers to older people

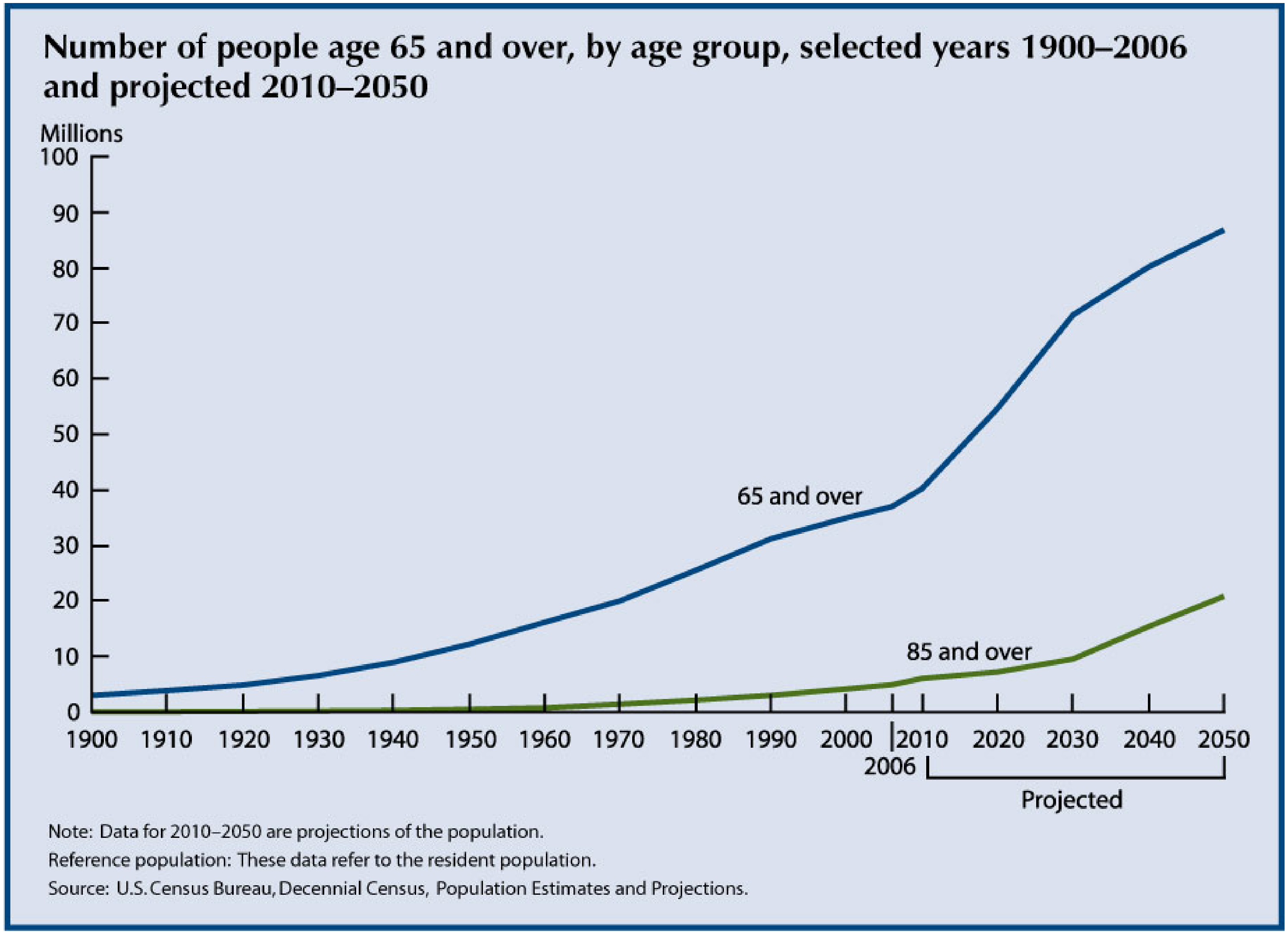

Figure 1-1. Trends in population aging in the United States

as those who are 60 and over. In contrast to the chronological milestones, old age in many developing countries is considered to start at the point when active contribution to society is no longer possible (Gorman, 1999). The blurring boundary between the old and the young in today's world makes it difficult to specify one universal numerical cutoff to mark later life. This research follows the developed nation standard and uses the chronological age of 65 and over as the definition of elderly.

1.1.2 What is vulnerability?

Vulnerability is a contested term. Broadly speaking, it refers to the potential of a system to be harmed (Cutter, 1996; Turner et al., 2003). Rooted in geography and natural hazards research, the term vulnerability has different disciplinary applications in fields like ecology, food security, public health, poverty and development, and climate change research (Füssel, 2007). Therefore, it is not surprising that the concept of vulnerability encompasses a variety of definitions. The range of definitions is a reflection of the various research traditions and is necessary to cover the full spectrum of the concept (Adger, 2006; Eakin and Luers, 2006; Gallopín, 2006).

This research adopts the hazards-of-place model of vulnerability (Cutter, 1996). Here, vulnerability is interpreted as the integration of physical and social vulnerability in a geographical domain. In this heuristic model, risks are offset or amplified by mitigation to produce a hazard potential. The hazard potential is modulated by the geographical context to create physical vulnerability. In parallel, the hazard potential is filtered through the social fabric to determine social vulnerability. The interaction and intersection of physical and social vulnerability lead to the overall vulnerability of the elderly population.

1.2 Review of Literature

1.2.1 Vulnerability Frameworks

Within the discipline of geography, researchers use different conceptualizations when the major approaches to vulnerability research vary significantly. The risk-hazard approach treats vulnerability as exposure to hazards driven by internal biophysical factors. Scholars following this lineage focus on assessing the exposure to hazards as well as the potential impacts on exposed populations. Political ecology sees vulnerability as a state constructed by socioeconomic, political, and cultural circumstances. Scholars adhering to this intellectual tradition focus on the root causes of vulnerability and stress the importance of access to resources and power before a disaster (Eakin and Luers, 2006). The two perspectives combine to produce Cutter's hazards-of-place model in which vulnerability is determined by both geographical and social contexts.

It is noteworthy that in a coupled human-environment system, people are open to multiple stressors. In one instance, the vulnerability to natural hazards is likely to be compounded by climate change. Climate change vulnerability research has become an important component of the discourse of vulnerability. In the field of climate change, the Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as a function of a system's exposure, sensitivity, and adaptive capacity to climate variations (IPCC, 2001). This framework identifies three major dimensions of vulnerability and offers valuable insights into the understanding of vulnerability dynamics for my research.

1.2.2 Vulnerability Assessment

One common theme and central tool in vulnerability research refers to the measurement of vulnerability. Scholars have assessed vulnerability to identify vulnerable areas or groups, to quantify and visualize vulnerability, and to prioritize mitigation or adaptation actions (Moss et al., 2001; Cutter et al., 2003; Brooks et al., 2005; Rygel et al., 2006; Kleinosky et al., 2007). Early research on people's vulnerability to natural hazards gave considerable attention to physical vulnerability (Blaikie et al., 1994; Mileti, 1999). People are vulnerable because they are exposed to potential hazards. In order to delineate physical vulnerability, researchers mapped the distribution of hazards and then overlaid the results with the human occupancy of hazard risk zones (Cutter et al., 1997). Accordingly, they evaluated the extent and degree of loss of life and property from a potential harmful event drawn upon the spatial intersection of society and hazards.

The appreciation of the role of socioeconomic profiles emerged later in the literature, as researchers realized that populations exposed to hazards are not equally vulnerable (Eakin and Luers, 2006). Individuals' socioeconomic and demographic status differentiates their sensitivity and adaptive capacity — along with exposure, the other two dimensions of vulnerability — to hazards. To improve understanding of how these factors influence vulnerability, scholars developed social vulnerability assessment. A social vulnerability assessment commonly ends up with a single social vulnerability index (Cutter et al., 2003) by summing the selected vulnerability indicators. Constructed from a set of social vulnerability indicators, social vulnerability indices provide unitless comparative values over space (Cutter et al., 2003; Rygel et al., 2006; Kleinosky et al., 2007; Cutter and Finch, 2008).

To inform a holistic understanding of the vulnerability of the elderly to one particular set of hazards at one particular place, I integrate physical and social vulnerability in the analysis. I assess physical vulnerability by examining the occupancy of hazard risk zones by the elderly. I measure social vulnerability based on the socioeconomic and demographic characteristics of the elderly.

There is general agreement about the major factors that affect social vulnerability, including age, poverty, social capital, physical limitations, infrastructure and lifelines, gender, and race (Enarson and Morrow, 1998; Fothergill et al., 1999; Morrow, 1999; Cutter et al., 2003; Fothergill and Peek, 2004). Because my research aims to assess the vulnerability of the elderly, I do not simply take into account generic vulnerability indicators from the academic vulnerability literature. I believe there is a need to identify viable indicators for vulnerability of the elderly by investigating academic research not specifically aimed at vulnerability. I also believe that non-academic publications are another essential resource for understanding social vulnerability. For example, reports from HelpAge International (a non-profit worldwide federation of more than 75 national organizations providing care and support for older people) can broaden our knowledge of disaster impacts on the elderly, as well as our understanding of the concerns and needs of the elderly in natural disasters, from a non-academic perspective.

1.2.3 Challenges for Vulnerability Research

1.2.3.1 Conceptualization

As noted earlier, researchers from various intellectual arenas specify the concept of vulnerability differently; even researchers within the same discipline use different conceptualizations. The concept of vulnerability has been used in a wide range of research contexts other than in geography. Finding a universal language for vulnerability has been one common challenge in vulnerability research. Füssel (2007) reviewed the range of definitions of vulnerability and argued that continued plurality would become a hindrance in interdisciplinary research. A common definition of vulnerability is much needed to advance the understanding of vulnerability, yet reaching consensus is challenging. Some scholars have argued that previous attempts to develop a shared vulnerability framework were superficial (Pickett et al., 1999; Newell et al., 2005). A more thoughtful attempt by O' Brien et al. (2007) distinguished outcome vulnerability and contextual vulnerability in climate change research. They argued the infeasibility of building an integrative conceptual model of vulnerability because the differences of framings and divergence of discourses underpinning the framings were too great to overcome. Although the concept of vulnerability is still multidimensional and contested, today many scholars agree that a comprehensive understanding of vulnerability entails the integration of geographical context and social fabric (Blaikie et al., 1994; Turner et al., 2003; Füssel, 2007; Polsky et al., 2007).

1.2.3.2 Risk Perception

One of the challenges for vulnerability research is to develop vulnerability measures incorporating human perceptions (Adger, 2006). Kusenbach et al. (2010) used the term "residual vulnerability" to represent the counterpart of objective vulnerability. In their research, the investigators followed residual vulnerability closely by including disaster experiences, perceived risk, and preparations that might hamper residents' evacuation readiness and consequently increase their vulnerability. Their findings revealed the paradox between the residents' willingness to evacuate and inadequate preparation for disaster evacuation. Similar to that of household residents, Howe (2011) observed the gap between risk perception and preparedness among business owners. The mismatch does not provide an optimistic outlook for developing a robust quantification of vulnerability. My research does not address the issue of risk perception and vulnerability but does consider risk perception as an important determinant of vulnerability for the elderly.

1.2.3.3 Scale

Vulnerability is scale-dependent and inherently heterogeneous. Spatially, a country at the national level can be highly vulnerable to climate change while one city, one community, or even one household in this country may not necessarily be vulnerable to the same degree and in the same way. Temporally, a currently vulnerable system, for example, may become less vulnerable in the future after the appropriate implementation of mitigation and adaptation actions. Determining an appropriate scale is another challenge in vulnerability research. On the one hand, vulnerability assessments are expected to be comparable so that decision makers are able to identify common leverage points to reduce vulnerability (Easterling et al., 2000; Frich et al., 2002). On the other hand, the proposition that vulnerability is place-based has been widely recognized. The determinants of vulnerability are dynamic, site specific and system specific (Smit and Wandel, 2006). Key information can be lost after statistical aggregation (Klein, 2004) and that is why research at broad scales has been criticized for obscuring the details at smaller scales. Responding to this criticism, my research analyzes the vulnerability of the elderly at a local level.

1.2.3.4 Variable Weighting

This challenge is in particular associated with quantitative assessment of social vulnerability. In this case, researchers create a social vulnerability index based on a suite of vulnerability indicators by applying certain weighting strategies. In their assessment of social vulnerability to environmental hazards in the United States, Cutter et al. (2003) selected eleven indicators to calculate a social vulnerability index using an additive model, assuming the equal contribution (i.e., equal weighting) of each indicator to social vulnerability. Brooks et al. (2005) collected experts' views through a focus group exercise and used different sets of weightings in the assessment of vulnerability to climate-related mortality at the national level. However, either weight averaging or expert-defined weights is problematic and subjective. Not all indicators affect vulnerability in the same way; the significance of the indicators can change from place to place.

Scholars in the vulnerability community have tossed around how vulnerability indicators should be weighted. Rygel et al. (2006) attempted to attack the variable weighting problem by applying Pareto ranking to an assessment of the vulnerability of the Hampton Roads, Virginia metropolitan region to storm surge. Pareto ranking enabled vulnerability to be ordered based on multiple objective optimizations without the arbitrary practice of weighting the various vulnerability indicators. A simpler approach that might be adopted is to avert the weighting process by constructing separate indices representing different elements of vulnerability (Adger et al., 2004). My research uses both a single index and separate indices and compares the results from the two methods.

1.2.4 Prior Work on Vulnerability of the Elderly

Research studies from sociology, psychology, and medicine have examined age-related vulnerability and demonstrated the patterns of disaster impacts on the elderly. Regarding the sociological impacts of disasters, the hypothesis of relative deprivation (Friedsam, 1961) indicates that elderly victims are more likely to over-report their disaster losses. Given that many older individuals have fixed incomes and their relative worth declines as they age, elderly victims of a disaster have a greater perception of loss than younger adults (Ngo, 2001). Moreover, research results from Kaniasty and Norris (1995) affirmed the “pattern of neglect,” a concept coined by Kilijanek and Drabek (1979), which stated that the elderly are less likely to receive external help including emotional support, informational support, and tangible support. In terms of the psychological impacts, there is no consensus reached on how vulnerable the elderly are. The inoculation hypothesis contends the elderly have lower psychological vulnerability resulting from their greater life experience and previous disaster exposure (Norris and Murrell, 1988; Ngo, 2001). Contradictorily, others postulate the elderly are not psychologically disaster-tolerant because of their diminished social circle from the multiple losses likely to occur in later life: deaths of spouses, friends, and relatives (Bell 1978; Oriol, 1999). The findings concerning the physiological impacts on the elderly are consistent in the literature. Old age is positively correlated with higher occurrences of mortality among the empirical studies. Degenerative diseases are common in the elderly and their presence has a positive influence on post-disaster mortality (Ngo, 2001).

In addition, disasters impacts are disproportionately severe on those elderly without adequate transportation means and personal support (Bolin and Klenow, 1988; Seplaki et al., 2006; Rosenkoetter et al., 2007). Evacuation entails financial and social capital, such as vehicles and connectedness with relatives. Therefore, those elderly individuals with low socioeconomic status and low social connectedness are highly vulnerable. Some authors have claimed that the most vulnerable older adults are those who are housebound and need routine in-home care and services (Mensah et al., 2005; McGuire, 2007) because disaster-induced breakdown in lifelines affects life-support equipment, such as oxygen generators or electric wheelchairs (Fernandez et al., 2002; California Department of Aging, 2004). Moreover, the elderly are less tolerant of changes in temperature (Shock, 1977) and more susceptible to dehydration (Papper, 1973).

A host of age-related characteristics and age-dependent changes can impair the capability of the elderly to prepare for a disaster, to process risk communication and evacuate in a disaster, and to recover after a disaster (Ngo, 2001; Mayhorn, 2005). Basically, factors that put the elderly at an increased risk include but not limited to the following: fixed retirement income, ambulatory difficulty, cognitive degradation, antecedent health problems, and lack of social network. It is even proposed that older adults on fixed incomes are more likely to reside in areas at higher risk, where buildings are older and more likely to suffer damage (California Department of Aging, 2004).

1.2.5 Deficiencies in Past Literature

Greater decline in mobility, health conditions, and socioeconomic status with age tends to erode the coping capacity of the elderly during the various stages of a disaster, amplifying their sensitivity to its effects while limiting their capacity to adapt, thereby shifting their vulnerability in varying ways with differing degrees. While sociologists, psychologists, and physiologists have widely studied age-related vulnerability, an appreciation of spatial contexts is missing in the research.

In contrast to other social scientists, geographers tend to be more concerned with spatial contexts and to argue that vulnerability is place-based and system-specific (Smit and Wandel, 2006; Eakin and Bojórquez-Tapia, 2008). Among the analyses of vulnerability, age is an important consideration and has been repeatedly cited as an indicator of vulnerability (O'Brien and Mileti, 1992; Hewitt, 1997; Morrow, 1999; Cutter et al., 2000; Wu et al., 2002; Cutter et al., 2003; Kleinosky et al., 2007; Cutter and Finch, 2008) because the elderly are more difficult to move and subject to health complications from certain hazard events (O'Brien and Mileti, 1992; Cutter et al., 2000). It is assumed that the higher the proportion of elderly in a community, the more vulnerable and less resilient it is (Cutter and Finch, 2008).

There is no empirical work, however, that specifically addresses the vulnerability of the elderly in a spatial context in the United States to confirm this critical assumption. As the elderly population continues to grow in size and diversify in characteristics, their vulnerability will also grow in complexity, so it is imperative that we attempt to confirm this assumption before the task grows more difficult. Consequently, my research uses

Sarasota County, Florida as a case study to analyze the vulnerability of the elderly to hurricane hazards.

1.3 Research Questions and Objective

The purpose of this research is to understand the vulnerability among the elderly in Sarasota County, Florida by incorporating physical and social aspects of vulnerability in the analysis. The analysis poses the overarching research question, how vulnerable are the elderly to hurricane hazards and are all elderly people equally vulnerable? To answer this central question, I ask three subsidiary questions:

1) What are important indicators of the vulnerability of the elderly?
2) How does geographical location shape vulnerability?
3) How do socioeconomic attributes shape vulnerability?

The first subsidiary question identifies viably important vulnerability indicators that capture the characteristics of the elderly during a hurricane and sets the stage for subsequent analyses of physical and social vulnerability. The second subsidiary question looks at the interaction between location and vulnerability. I inventory hurricane hazard risk zones and measure physical vulnerability by using a geographical information system (GIS) to overlay the locations of the elderly and the distributions of these risk zones. The third subsidiary question investigates the interplay of socioeconomic profiles and vulnerability. I conduct an indicator-based assessment of social vulnerability of the elderly and visualize the variations in vulnerable segments of the elderly spatially and quantitatively. The insights gained from those separate solutions to each subsidiary question will combine to elicit a comprehensive answer to my overarching research question.

1.4 Study Area

To address these research questions, this thesis presents a case study of the elderly in Sarasota County, Florida. Sarasota County is located on the west-central Gulf Coast of Florida. It has four incorporated cities and towns: the City of Sarasota, the City of North Port, the City of Venice, and the southern portion of the Town of Longboat Key (Figure 1-2). In addition to these incorporated areas, Sarasota County is home to many unincorporated areas such as Bee Ridge, Englewood, Southgate, and many others (not shown). The majority of Sarasota County is located within the Gulf Coastal Lowlands along which barrier islands, spits, and lagoons are developed. The county has a very flat topography with elevations ranging from mean sea level along the Gulf Coast and the lower Myakka River to a maximum of approximately 100 feet in the extreme northeastern part of the county (Campell, 1985). The northeast is generally higher than the southwest but elevations increase imperceptibly (Lane, 1973).

Because of its physical geography, this low-lying coastal county is vulnerable to hurricane hazards. Despite these hazards, population in Sarasota continues to grow. Boasting a desirable coastal location and pleasant climate, Sarasota had an approximate 17% increase in population from 325,957 in 2000 to 379,448 in 2010 (U.S. Census Bureau, 2011). In 2000, Florida had the highest percentage of population 65 and older and highest percentage of population 85 and older in the United States. Sarasota was among the top four counties in Florida with large proportions of older residents and large

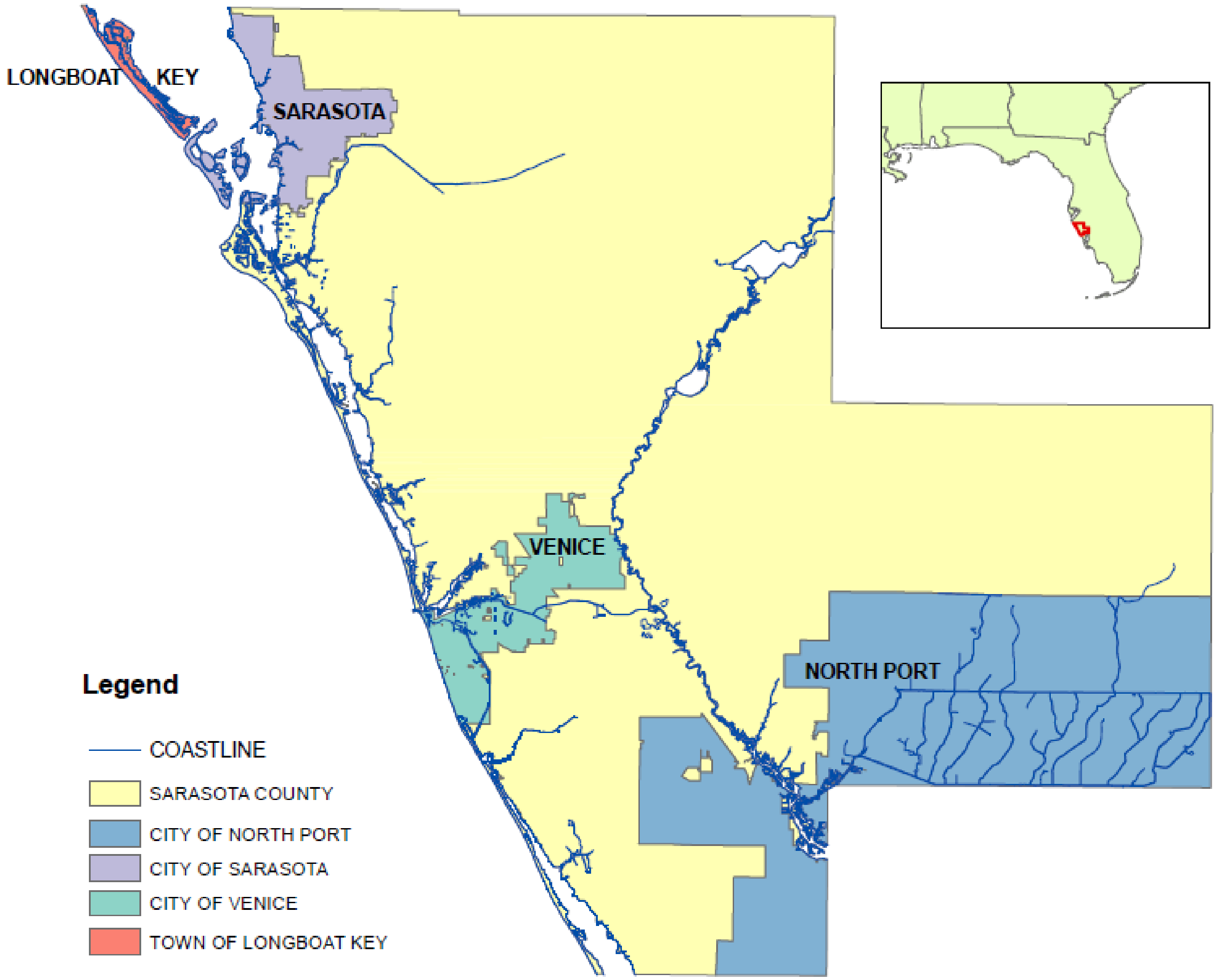

Figure 1-2. Map of Sarasota County, Florida

absolute older populations (U.S. Census Bureau, 2005). In 2010, the percentage of residents aged 65 and over in Sarasota County was over 30 percent while the average percentage in Florida was about 17 percent (U.S. Census Bureau, 2011). Perhaps more significantly, most of Sarasota County's elderly population tends to populate lowland areas along waterways and shorelines (Figure 1-3). Therefore, Sarasota County presents an excellent case for studying the vulnerability of the elderly to hurricane hazards.

1.5 Summary

In our aging society, as the elderly population is growing in size and diversifying in characteristics, it is imperative to understand the composition of the vulnerable elderly and the basis for their vulnerability to natural hazards. This thesis uses Sarasota County, Florida as a case study and addresses vulnerability at a local level. By performing a detailed analysis of vulnerability that targets the elderly population and synthesizes both the physical and social aspects of vulnerability, this study is expected to help inform well-tailored vulnerability-reduction measures by decision makers. The subsequent five chapters will detail the methods, findings, and conclusions of this thesis.

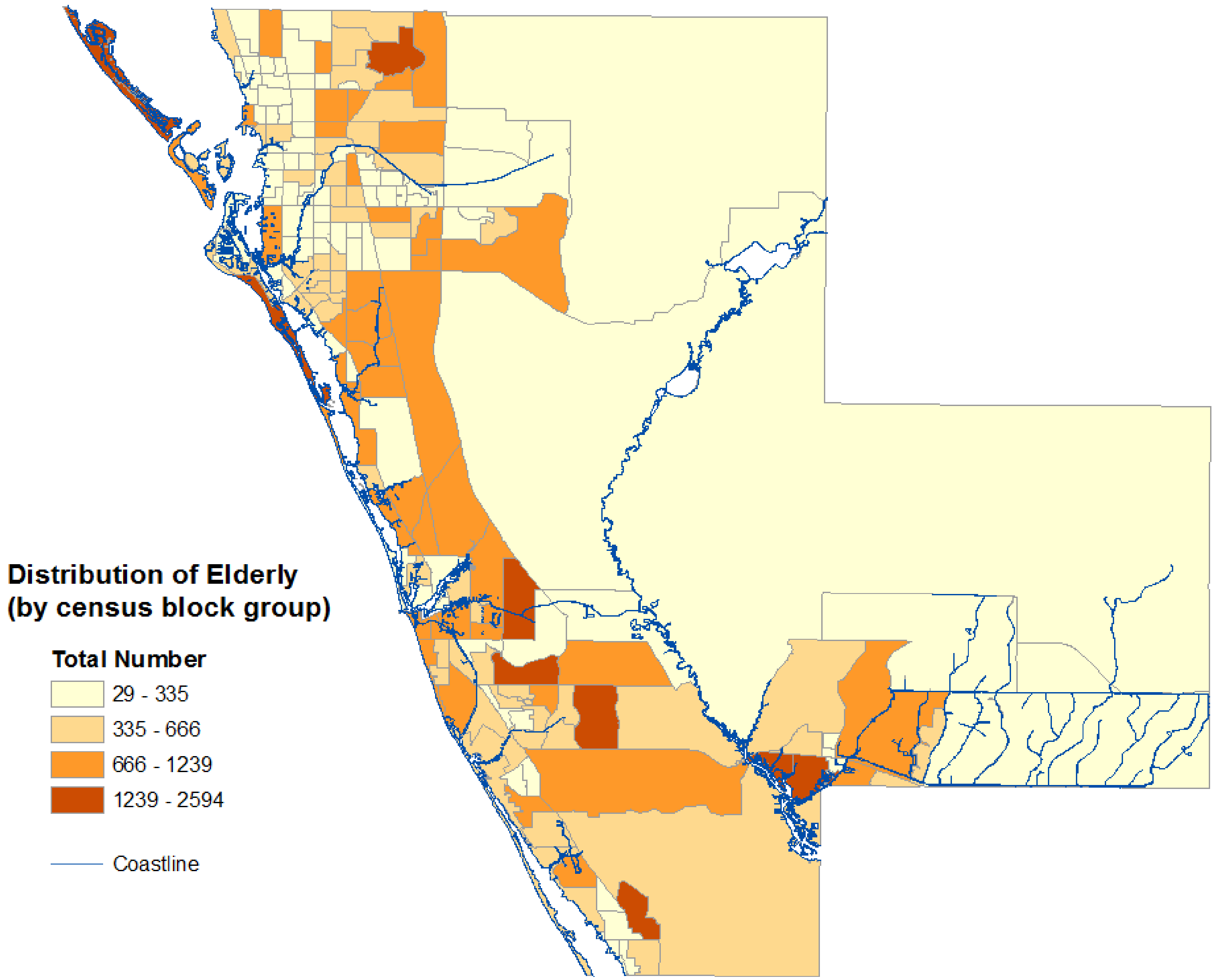

Figure 1-3. Distribution of the elderly in Sarasota County, Florida

CHAPTER 2

METHODS OVERVIEW

2.1 Introduction

How vulnerable are the elderly to hurricane hazards and are all elderly people equally vulnerable? To answer this overarching research question, this thesis addresses the three subsidiary research questions stated in Chapter 1. Corresponding to these secondary questions, the research implements a three-phase study corresponding to three chapters of the thesis. For the first phase, to answer the question about important vulnerability indicators, Chapter 3 explores indicators and proxy variables for the vulnerability of the elderly by using a four-stage typology (modified from the eight-stage typology of Fothergill et al., 1999). The chapter organizes the resulting indicators and variables using the Vulnerability Scoping Diagram (Polsky et al., 2007). For the second phase, to answer the question regarding location and vulnerability, Chapter 4 measures physical vulnerability by using GIS to overlay the locations of the elderly and hurricane risk zones to investigate whether the elderly are prone to hurricanes hazards because they concentrate in certain areas. For the third phase, to unveil how social standing affects vulnerability of the elderly across space, Chapter 5 performs a social vulnerability assessment and creates social vulnerability indices using Principal Component Analysis (PCA) to demonstrate the variations quantitatively and spatially in vulnerable segments of the elderly. The three phases are independent, but related because the results of the first phase of the research set the stage for the second and third phases. In Chapter 6, the insights gained from these separate solutions combine to provide a holistic basis for answering the grand research question.

It is important to note that this chapter does not provide a thorough explanation of how I applied the methods used in Chapters 3, 4, and 5. Instead, it provides the rationale for using those methods, as well as a brief literature review for the methods. I determined that providing details on the methods in the context of the indicator analysis, physical vulnerability assessment, and social vulnerability assessment (i.e., embedding details of the methods in Chapters 3, 4, and 5, respectively) would be more informative than isolating those details in a formal methods chapter.

2.2 Phase I: Indicator Identification and Selection

2.2.1 Four-stage Typology

In the first phase, Chapter 3, I identify viable vulnerability indicators and specify potential proxy variables for these indicators by applying a four-stage typology to findings from the literature and publications from HelpAge International. This typology is modified from an eight-stage analysis that Fothergill et al. (1999) and Fothergill and Peek (2004), respectively, employed to synthesize previous studies regarding patterns of race and ethnicity related to disaster and patterns of poverty related to disaster in the United States. Illustrating how the elderly as a group may be affected by disasters and how the elderly of different socioeconomic levels may be differentially affected by disasters, I organize the findings of the review into four categories based on the stages of a disaster event: preparedness, occurrence of the hazardous event, response, recovery and reconstruction. This four-stage typology facilitates the elucidation of the characteristics of the elderly during four different periods of a disaster and informs the selection of indicators of, and proxy variables for the vulnerability of the elderly.

2.2.2 Vulnerability Scoping Diagram (VSD)

Polsky et al. (2007) proposed a graphical representation of findings from multiple vulnerability assessments for comparative studies, namely, the Vulnerability Scoping Diagram (VSD). The schema is well suited for my research since it offers a methodological framework to guide the collection of data prior to the physical and social vulnerability assessments of the elderly. In addition, it orients my analysis toward contemporary vulnerability literature as it structures the vulnerability indicators into three dimensions of vulnerability: exposure, sensitivity, and adaptive capacity. Therefore, the process of fitting the resulting vulnerability indicators and proxy variables from the four-stage typology approach into each dimension of the VSD is essential.

The VSD is composed of a bull's-eye surrounded by three concentric rings; the general form is shown in Figure 2-1. The bull's-eye signifies the concept of vulnerability. The innermost ring relates to the three dimensions of vulnerability: exposure, sensitivity, and adaptive capacity. The intermediate ring presents the components of these three dimensions, i.e., the indicators of abstract characteristics that typify the dimensions. Finally, the outmost ring contains the measurements of the components, i.e. the proxy variables used to measure the indicators.

Using this scoping diagram to profile vulnerability requires specification of five key elements: (1) the hazard and associated outcome(s) of interest, (2) the exposure unit,

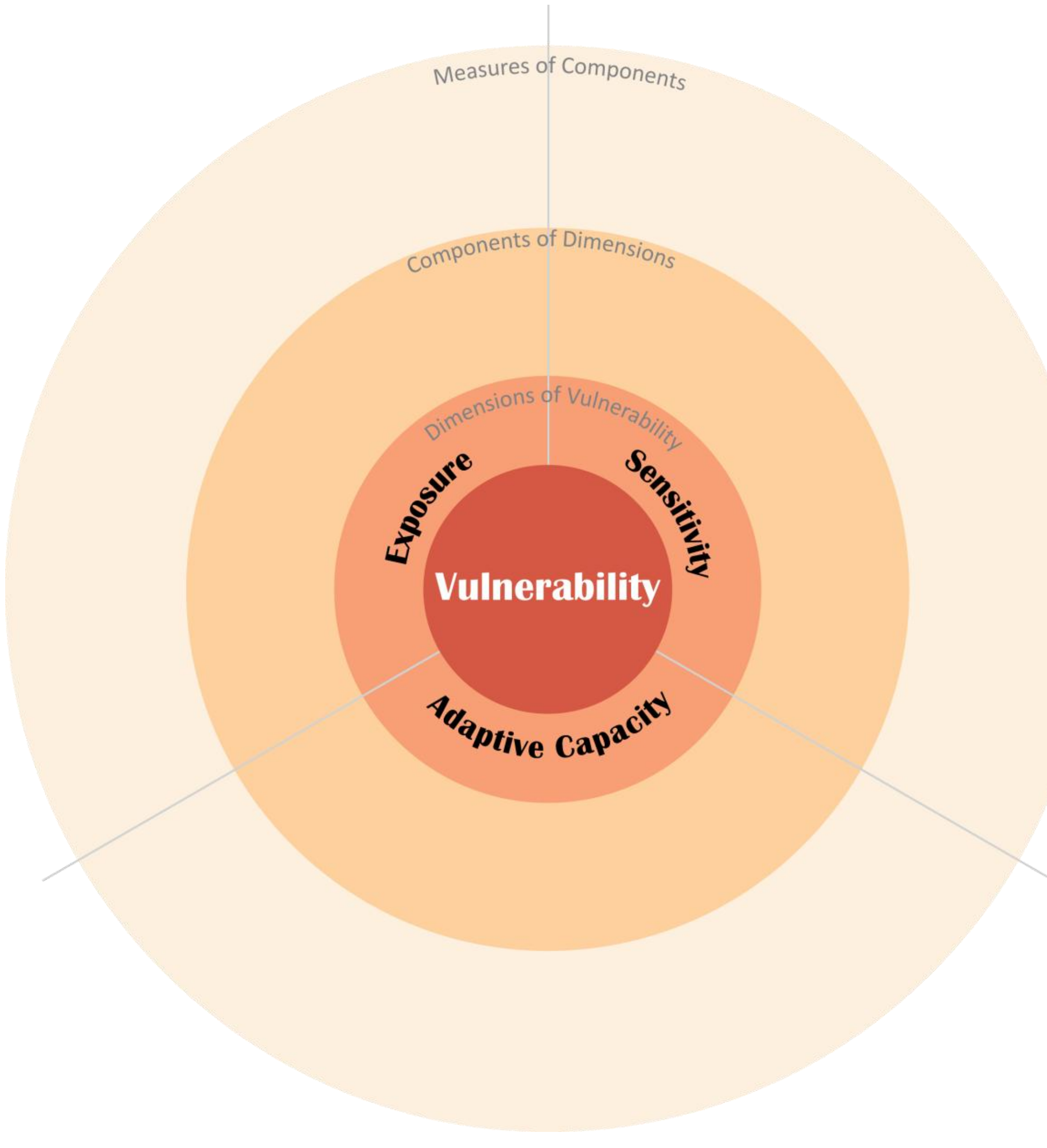

Figure 2-1. General form of the Vulnerability Scoping Diagram (VSD)

(3) dimensions, (4) components, and (5) measures of the vulnerability process in question (Polsky et al., 2007). In this research, the hazard refers to hurricanes and the associated outcomes include damage from hurricane winds, storm surge, rainfall and flooding. The exposure unit focuses on the elderly population. The dimension of exposure captures potential for loss of the elderly from biophysical factors whereas the dimensions of sensitivity and adaptive capacity exhibit the elderly's potential to be harmed associated with socioeconomic factors. The components and measures correspond to the vulnerability indicators and proxy variables, respectively, and can be quantitative or qualitative.

The VSD provides two major functions: (1) to act as a starting point for understanding the details of vulnerability of an entity and (2) to build a basis for meta-analyses of vulnerability assessments (Cutter, 2001, 2003; Polsky et al., 2007). In addition, it is a useful template for working with stakeholders to check the validity of components and measures so as to better inform policy-making. In one instance, Pearsall (2009) employed the VSD in consultation with local residents and planners to identify components and measures that contribute to vulnerabilities of New York City to the hazard of soil contamination. Similarly, Moreno and Becken (2009) applied the diagram to a climate change vulnerability assessment for coastal tourism in Fiji and used it to connect science and policy by engaging stakeholders in the activity. In the Human-Environment Regional Observatory (HERO) project, researchers adopted the VSD to compare the vulnerability of local water supply systems to the impacts of drought across four study sites with varying human and natural landscapes in the United States (Sorrensen et al., 2005; Polsky et al., 2007). More recently, a group of scientists are creating a web-based Vulnerability Assessment Support System (VASS) built on a participatory VSD (Yarnal and Howe, 2011 AAG; Coletti et al., 2010 AAG).

2.3 Phase II: Physical Vulnerability

In the second phase, Chapter 4, I measure physical exposure by defining hurricane risk zones in the ArcGIS environment. Typical hurricane hazards include storm surge, rainfall and flooding, and hurricane-force winds. According to the Federal Emergency Management Agency (FEMA) statement, hurricane-induced storm surge alone poses the highest threat to life and destruction throughout the United States and its territories (FEMA, 2010a). Heavy rainfall from hurricanes and ensuing floods can also wash away homes and inundate evacuation routes. Hurricane winds can destroy critical structures and can carry debris with lethal force. However, current wind-borne debris maps with wind speed for Sarasota County are too coarse and do not afford a refined analysis of wind risk zones. Modeling hurricane winds to produce such maps is well beyond the scope of this thesis. Therefore, I restrict the hurricane risk analyses to storm surge and floods.

2.3.1 Sea, Lake, and Overland Surge from Hurricanes (SLOSH) Model

To define exposure to storm surge, I use maps based on the outputs from the Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model encompassing Sarasota County. The SLOSH model accounts for storm surge values from a combination of a storm's windspeed, its motion, and the bathymetry of near-shore waters; it is best used for defining the potential maximum surge for a location (National Hurricane Center, 2010a). The model has been widely used to determine areas at risk from storm surge (Jelesnianski et al., 1992; Wu et al., 2002; Kleinosky et al., 2007) including Sarasota County (Frazier et al., 2010a).

Areas at risk from storm surge, i.e. storm surge risk zones, are generally delineated by hurricane categories, ranked on the Saffir-Simpson Hurricane Scale of Categories 1 through 5. For example, with the model for Sarasota County, storm surge can reach up to 6 feet above sea level in category 1 hurricanes and up to 19 feet above sea level in category 4-5 hurricanes (Sarasota County Hurricane Evacuation Map, 2008). Categorizing a geophysical phenomenon as a natural hazard, however, requires the interaction between the event and people. Consequently, I overlay the locations of the elderly and storm surge risk zones to interpret the occupancy of the elderly in these risk zones, and subsequently explain their physical vulnerability to storm surge.

One weakness associated with the SLOSH model is its exclusion of storm size or local topography when predicting storm surge. For this reason, the National Oceanic and Atmospheric Administration (NOAA) announced a new hurricane scale called the Saffir-Simpson Hurricane Wind Scale (National Hurricane Center, 2010b) without ties to specific storm surge effects for each hurricane category. In the new scale, storm surge forecasts will be re-expressed in terms of height above ground level. The new approach to storm surge prediction is not available in time for my research. I know about the weakness of tying storm surge to hurricane category but choose to stick with the Saffir-Simpson Hurricane Scale given (1) the older scale is still the standard being used by scientists and local stakeholders and (2) the uncertainty on when revised categories will be promulgated and how they will influence risk mapping.

2.3.2 Flood Insurance Rate Maps (FIRMs)

To define exposure to hurricane related rainfall and flooding, I use the FEMA Flood Insurance Rate Maps (FIRMs) for Sarasota County, with flood zones based on the severity and frequency of flooding. As one component of the National Flood Insurance Program (NFIP), FIRMs specify areas subject to flooding and serve as the basis for the actuarial rating of new or reconstructed buildings for flood insurance (FEMA, 2010b). Sarasota County's current FIRMs are also used to determine minimum development standards in designated flood zones.

In the FIRMs, FEMA assigns a character from the alphabet to each flood zone to define the severity and frequency of flooding. For instance, VE and AE have a 1 percent chance of meeting or exceeding the base flood (also referred to as the "100-year flood") in a given year. The VE zone represents a coastal storm surge that is the stillwater height plus a wave height of 3.0 ft or greater; if the wave height is less than the stillwater height plus a wave height of 3.0 ft, then it is designated an AE zone. In my analysis, I use the FIRMs to locate the geographical areas of Sarasota County in each FEMA flood zone. To avoid creating too many classes, I describe flood risk zones by regrouping each flood zone into three broad categories: (1) high risk coastal areas subject to flooding associated with storm waves, in addition to a 1.0 percent annual chance or greater flood event, (2) high risk areas subject to a 1.0 percent or greater annual chance of flooding with floodwater of varying depth, and (3) moderate-to-low risk areas between a 100-year (1.0 percent annual chance) flood and a 500-year (0.2 percent annual chance) flood, or those areas above the 500-year flood level. Then I overlay the locations of the elderly and flood risk zones to understand the elderly's physical vulnerability to potential flooding from intense rain associated with hurricanes. It is noted that the FIRMs should be used with caution because they are mainly designed for insurance rating and have not taken into consideration potential effects of climate change, such as rising sea level (Duran, personal communication, 2011).

2.4 Phase III: Social Vulnerability

The third phase, Chapter 5, centers on the social vulnerability of Sarasota County's elderly. In this phase, I perform a social vulnerability assessment and construct social vulnerability indices. The social vulnerability assessment is expected to unveil how socially vulnerable the elderly are and in what ways they are vulnerable. Vulnerability indicators and proxy variables for the indicators will have been identified in the first phase with the aid of the four-stage typology and the VSD. Then I look over the closest matches to the first-phase results in the 2000 Census and expand candidate proxy variables for the indicators whenever possible. All relevant variables will be derived at the census block group level and imported to PASW Statistics 18 (the Predictive Analytics Software, formerly SPSS). Next, a Principal Component Analysis (PCA) is carried out on a host of socioeconomic and demographic variables obtained from the Census.

2.4.1 Principal Component Analysis (PCA)

Principal components analysis (PCA) is a mathematical procedure used to reveal relationships among a multitude of original variables in terms of a smaller set of uncorrelated principal components that are linear combinations of the original variables

(Goddard and Kirby, 1976; Pett et al., 2003). The process seeks patterns of common variations among the input variables and offers an operational definition for an underlying process (Tabachnic and Fidell, 2007). In the context of social vulnerability assessment, a PCA reduces the number of proxy variables for vulnerability indicators and ranks the percentage of explainable variance accounted for by each variable contributing to each retained indicator (i.e., principal component). The result of this step is to identify a set of the most influential components as the major driving forces of social vulnerability and to prepare for the construction of social vulnerability indices.

This technique has been commonly used in work on vulnerability assessment. For example, Cutter and Finch (2008) used a PCA to study the spatial and temporal patterns in social vulnerability every ten years per county in the United States from 1960 to 2000. Using PCA to identify correlated variables and reduce hundreds of variables to a few components, they were able to find principal components (such as socioeconomic status, age, gender, and race) that consistently associated with increased social vulnerability for all periods. In an example of its application to biophysical vulnerability assessment in the Mid-Atlantic region, Tran et al. (2004) utilized a PCA in combination with the Analytic Network Process (ANP) to filter such key factors as land cover, population, roads, streams, air pollution, and topography, and ultimately accomplished the ranking of ecosystems to identify those systems in relatively poor condition or vulnerable to future deterioration.

2.4.2 Social Vulnerability Indices

Adger et al. (2004) generalized several approaches to developing an index of human or environmental vulnerability. One is to calculate a single index by aggregating all relevant indicators. However, this is problematic because how the indicators should be weighted continues to present an academic challenge in vulnerability research (Klein, 2004; see the discussion in Chapter 1 of this thesis for more detail on weighting methods for social vulnerability assessment). Given the absence of an agreed-upon, robust weighting strategy, I prefer to adopt another approach proposed by Adger et al. (2004), which is constructing separate indices representing different elements of vulnerability. The results of the PCA will identify a set of the most influential indicators (principal components) and prepare for the construction of these separate social vulnerability indices. Following the PCA, I use the component scores generated by the procedure to estimate each block group's ranking on the principal components and accordingly to produce a series of maps indicating the degree of social vulnerability by individual principal component. By analyzing social vulnerability disaggregated by component, I avert subjective weighting decisions as well as the loss of information in aggregation.

CHAPTER 3

INDICATOR IDENTIFICATION AND SELECTION

3.1 Introduction

This chapter corresponds to the first phase of the analysis. Although the major task is to identify indicators of the elderly's vulnerability to hurricane storm surge and flood hazards, I open with some terms used for the subgroups of the elderly and then follow with a discussion on the diversity of, and thus the differential vulnerability within the older population. These perspectives are necessary for the understanding of age-related issues and how they apply to vulnerability. Next, I transition from a more abstract discussion of concepts towards a more applied discussion, in which I examine and summarize vulnerability indicators and proxy variables for the elderly via a four-stage typology. I close with a VSD that visually represents the resulting indicators and variables. From this exercise, I conclude that a number of factors combine to shape the vulnerability of the elderly during a hurricane disaster.

3.2 Terms Related to Diversity within the Elderly Population

In 1974, sociologist and psychologist Bernice L. Neugarten coined the terms *young-old* and *old-old* to highlight the diversity within the older population. She categorized people between 55 to 74 years old as young-old and those 75 and older as old-old. Her seminal paper, "Age Groups in American Society and the Rise of the Young-Old," proclaimed that the elderly were as diverse as the younger generation. In that paper, she also made a distinction between those who are relatively healthy, affluent, independent, and active (the young-old) and those who do not have these traits in their later years (the old-old), arguing that social policies must be need-based rather than strictly age-based (Neugarten, 1974).

Since Neugarten's time, the terminology used to define the older population sub-groups has varied. Authors often use the ages of the group to define the population they are discussing. For example, sometimes the older population is divided into three subgroups, with the population ranging from 65 to 74 years defined as "the young old," the population 75 to 84 years called "the aged," and the population 85 years and over termed "the oldest old" (U.S. Census Bureau, 1996; Werner, personal communication, 2011). However, Neugarten (1981) thought it important to be aware that the classification of the older population solely in chronological terms is expedient but not necessarily accurate.

My research simply breaks the older population into two groups — the young-old (the population that is 65-74 years old) and the old-old (the population 75 years and over) — to probe how the elderly population differs within and across its component subgroups with respect to vulnerability. In most cases, the young-old are much less vulnerable than the old-old when facing a natural hazard. Nonetheless, when inventorying the vulnerability of the elderly, we should take into account multiple variables beyond chronological age because the elderly are as diverse demographically and socioeconomically as their younger counterparts, with variations attributable to differences not only in chronological age, but also in health status, sensory functions, financial resources, social capital, and so on. Some chronologically older elderly are healthy, strong, and immune to age-dependent diseases while some younger elderly depend on regular medical treatment to survive. Some of the elderly are financially well off, such as many of the "snowbirds" that spend the winter at their second home in Sarasota County, while some elderly permanent residents may live below the poverty line and receive government assistance. Some elderly live with or near their children, maintaining social interconnectedness, while others live alone, suffering widowhood. In short, the older population is mixed in needs, capabilities, and resources and therefore demonstrates differing degrees of vulnerability to natural hazards.

3.3 Vulnerability Indicators and Proxy Variables

There is general agreement about the major factors that place populations at greater risk: age, gender, race, poverty, and son on (Enarson and Morrow, 1998; Morrow 1999; Fothergill et al., 1999; Cutter et al., 2003; Fothergill and Peek, 2004). Because my research aims to assess the vulnerability of the elderly, I do not simply take into account generic vulnerability indicators drawn from social science research on vulnerability to hazards. Instead, I identify viable vulnerability indicators of the elderly by coupling findings from gerontology literature and HelpAge International. The following recounts (1) the results of indicator identification for vulnerability of the elderly using a four-stage analysis, and (2) the visual conveyance of the vulnerability indicators using the VSD.

3.3.1 Four-stage Typology

3.3.1.1 Stage I: Preparedness

Preparedness can be understood as proactive actions taken to reduce the potential negative effects from future disasters (Coppola, 2007). The willingness and effectiveness of preparation are associated with many factors. Perhaps chief among those items influencing the level of preparation among the elderly is the financial limitations associated with retirement.

- **Indicator 1: Financial Capital**

Most elderly retire from full-time employment and live on fixed income. Given inflation, the relative worth of older individuals living on fixed income declines as they age, so to maintain their capital they are less likely to cash in stocks or transfer funds from personal savings to purchase disaster supplies, such as water, food, and back-up power supply. Further limiting cash available for emergency preparation, latest analyses show drug prices now climb faster than inflation (AARP, 2010) and older people can be doubly disadvantaged because of the prevalence of age-dependent diseases and attendant health-care costs in later life stages. In addition, some older people, mainly women, act as caregivers to grandchildren and this grandparenting tends to add an additional burden on the elderly because of the extra claims on their limited financial resources (HelpAge International, 2000).

3.3.1.2 Stage II: Occurrence of the Hazardous Event

While a hurricane is passing an area, i.e., that period after preparedness and right before emergency response, the elderly are particularly vulnerable physically and perhaps psychologically. One factor that may increase that vulnerability is aging-in-place.

- **Indicator 2: Aging-in-place**

Aging-in-place is a concept emphasizing the importance of, as well as the strategies for supporting people so they can grow old at home as long and comfortably as possible (Rowles, 1993; Chapin and Dobbs-Kepper. 2001; Tang and Pickard, 2008). It is a movement, a policy approach, an industry, a housing and care alternative, a solution, and a dream to the approaching “silver tsunami” (AARP, 2005; Tenenbaum, 2010). Growing old at home offers alternative living and care arrangements for older people who prefer to stay at home or in a home-like environment. It also enables a growing segment of the elderly, particularly those with an independent mind, to delay or avert the move to institutional care. According to an NPR report, only 5 percent of Americans ages 65 and older live in long-term care institutions like nursing homes and 9 out of 10 older people want to grow old in their own homes after they retire (NPR, 2010).

However, aging-in-place is a double-edged sword from a vulnerability perspective. As people age, the incidence of illness and disability increases. For those living alone and staying put as they age, information flow and external assistance is generally reduced. Moreover, as a person ages, their home also ages; without home-retrofitting or original home design accommodating the special needs of older people, aging-in-place will increase the vulnerability of the elderly in a disaster even it caters to their dignity and pursuit of autonomy during non-disaster times. The uninstitutionalized older population is more vulnerable while the storm is occurring. First, nursing homes or formal assisted-living facilities are overseen by federal, state, and local jurisdictions and have to meet certain standards (Mitchell and Kemp, 2000), such as the enforcement of building codes. In contrast, high wind, flooding, and storm surge induced by a hurricane may wreak havoc on the aging homes of uninstitutionalized older people. Second, the uninstitutionalized population, let alone the sick and frail older people with physical limitations and sensory impairments, may not know how to react during a storm or make adjustments when facing a disaster without guidance. Third, during a power outage during and after the event, it is much easier to locate and reach institutionalized older people compared to those who are not affiliated with any institutions.

3.3.1.3 Stage III: Response

Emergency response refers to actions aimed at limiting injuries, loss of life, and damage to property and the environment that are taken as soon as it becomes apparent that a hazardous event is imminent. It includes not only those activities that address the immediate needs (first aid, search and rescue, and shelter) to ensure the survival of a maximum number of people affected, but also involves the rapid resumption of critical infrastructure (such as opening transportation routes, restoring communications and electricity, and ensuring food and clean water distribution) to allow recovery to take place (Coppola, 2007). There is a host of factors that has an impact on the capacity of older people to respond to a disaster at the individual level.

- **Indicator 3: Risk Perception**

As stated in Chapter 1, this research does not address the issue of risk perception and vulnerability, but it is undeniable that risk perception is a fundamental characteristic that influences the ability of the elderly to respond to a disaster. The elderly have a lifetime's accumulation so that they tend to perceive larger loss of material possessions than younger people do (Friedsam, 1961; Ngo, 2001). Moreover, many elderly people assume that after longtime residence at one place, they are more familiar with local weather-related anomalies and believe they can ride out the disaster as they did last time. Thus, because of their emotional attachments to material possessions and places of residence, and because of their previous experiences with disasters, the elderly tend to discount their need to comply with evacuation mandates (Arbore, 2007; Henderson et al., 2010).

- **Indicator 4: Health and Nutrition**

Survival largely relies on immediate access to relief following a disaster. Differentiated from other groups, the elderly have specific and special needs related to health and nutrition. They are disproportionately affected by a disaster unless disaster relief has been sensitized to the special concerns of this vulnerable group. Older people are more likely than younger people to have mobility problems and chronic illness such as diabetes and cardiovascular disease. In the event of a disaster, they often cannot walk long distances to access relief and service points or compete in queues for relief packages due to the limited physical strength (HelpAge International, 2000). In addition, they may not be able to chew and digest food supplies because of their worn-and-torn teeth. Currently, the Meals-Ready-to-Eat (MRE) packages made available to older people after a disaster usually contain too much sodium, fat, and calories and have the potential to send some into glucose shock from too much sugar or to raise their blood pressure from too much sodium (CDC Centers for Disease Control and Prevention, 2007).

- **Indicator 5: Physical and Mental Changes**

Age-dependent changes are associated with degradations in attention, memory, text comprehension, and decision-making (Mayhorn, 2005). Nerve endings may weaken and lose their sensitivity, which affects all the faculties. Poor vision and hearing can affect balance and mobility. Furthermore, the physical changes in the brain and nervous system may result in short-term memory loss and sometimes in acute confusion and disorientation, especially when familiar patterns and environments are disrupted (HelpAge International, 2000). Consequently, the elderly are more likely to become casualties due to their difficulty in processing risk communication and in evacuating an area during the response stage. For example, it is not easy for the elderly to discriminate between similarly colored objects and to adapt to darkness (Jackson et al., 1999). In another instance, auditory decline results in decreased sensitivity at higher auditory frequencies and hearing-impaired elderly are less able to hear warnings on the radio or TV (FEMA, 2008).

3.3.1.4 Stage IV: Recovery and Reconstruction

This stage pertains to the activities associated with getting the population back to normal life. Compared to response (taking hours to weeks), recovery is longer term (taking weeks to months) and refers to getting the infrastructure fully operating so that the socioeconomic system can function, at least at a rudimentary level. Reconstruction follows recovery, hypothetically extending from months after disaster to several years later (Fothergill et al., 1999; Fothergill and Peek, 2004; Coppola, 2007). It is the longestterm process and means putting the system back to its pre-disaster state or moving it to an improved, more resilient state.

During recovery and reconstruction, older people who are invisible during the response process are also disadvantaged and highly vulnerable. Research results show the elderly are disproportionately vulnerable because they suffer more severe losses and recover slowly (Friedsam, 1961; Glass et al., 1977; Bolin and Klenow, 1983, 1988; Tanida, 1996). Physical limitation, fixed retirement income, and lack of social network impair older people's recovery and reconstruction after a disaster (Ngo, 2001; Mayhorn, 2005). Good physical mobility means individuals can travel longer distances to access help when there is no regular transportation, but the physical limitations of many elderly people makes such travel difficult, if not impossible. Money buys older people food, housing, and medical treatment, but fixed incomes can put these expenditures beyond the grasp of some retirees. "Snowbirds" are able to shelter themselves in northern homes if disaster strikes their southern home, but permanent residents with no family or friends up north do not have this option. A social network provides people with information, connections, and emotional and practical support (Hoffman, 2005). Together with the aforementioned components, other contributing factors are reviewed in the following.

- **Indicator 6: Social Capital and Living Arrangement**

As people age, they may experience decreasing social interaction accompanying retirement and the loss of a spouse. According to Role Theory, individuals learn to perform new roles, adjust to changing roles, relinquish old ones, and therefore become integrated into society (Cottrell, 1942). The elderly are more likely to lose roles than to acquire new ones. Retirement and dependency take the place of relationships and roles typical of adulthood (Cavan et al., 1949) and retirement-derived erosion of social identity and decline in self-esteem (Rosow, 1985) facilitate the elderly's withdrawal from society (Cumming and Henry, 1961). The reduced social interaction later brings about social isolation, eventually causing the lack of social network for the elderly.

Loss of a spouse also accounts for the diminishing social capital of the elderly. Married couples of retirement age have several advantages over individuals. They share economic resources, which make them relatively financially sound. They provide care and support to each other and help expand family, friends, and community ties. The robustness and richness of connections to family, friends, neighbors, community, and services for the elderly provide protection and assistance in times of a disaster. Compared to other two-person households or single-person households, married-couple households are less vulnerable in disasters. Consequently, the majority of the young-old are less vulnerable to disasters than the old-old because the latter are more likely to have lost a spouse.

- **Indicator 7: Psychological Impacts**

As reviewed in Chapter 1, in terms of the psychological impacts of disasters, there is no consensus on how vulnerable the elderly are. The loss of family members and belongings are common to all age groups in disasters, but the consequences can particularly threaten the psychological wellbeing of older people. Negative feelings about losing family members are amplified by asset losses, physical displacement, and medical care interruption following a disaster. Older people may be physically set apart from younger people (e.g., in trailer parks that exclude younger people) because it is supposed that the elderly have special needs and concerns. However, separating older people from the young is potentially problematic when the elderly are excluded from the services and opportunities open to younger people (HelpAge International, 2000).

- **Indicator 8: Educational Attainment**

Educational attainment is another influential factor during recovery for the elderly. In general, people with a higher level of education tend to have greater income-generating ability and access to resources and services. For retirees, well-educated older people are better at dealing with bureaucracy and completing paperwork, which can be baffling to people with declining physical, mental, and social skills. Older people with high levels of education therefore may also be better at handling negotiations with FEMA, insurance companies, contractors, and other agencies or organizations.

3.3.2 Vulnerability Scoping Diagram (VSD)

The four-stage typology helps identify a wide range of factors indicating the social vulnerability of the elderly in disaster situations. But these vulnerability indicators are selective rather than exhaustive. For instance, gender is a confounding factor in constructing the vulnerability of the elderly. Men and women age differently. It is significant that women outlive men and women mostly marry men who are older than they are. As a result, older women are more likely to be widowed than older men are (U.S. Census Bureau, 1998). Widowhood can be a precursor to poverty and isolation because the minimized financial social networking puts older women in harm's way. At this point in the development of our understanding of the elderly, it is too complicated to handle the vulnerability of the elderly from a gender perspective, so that variable will not be part of my analysis.

Figure 3-1 is a VSD illustrating indicators of the elderly's vulnerability to hurricane hazards; the specific proxy variables that correspond to these broad vulnerability indicators are separately represented in Table 3-1 for clarity. As Polsky et al. (2007) pointed out, there is often ambiguity in where to place elements of the human environment system on the VSD. Many of the indicators can occur in more than one category. For example, social capital and living arrangement can straddle the dimension categories of sensitivity and adaptive capacity; that is, social capital and living arrangement can reveal the sensitivity of the elderly to hurricane hazards and, at the same time, determine their capacity to adapt in order to reduce future hurricane sensitivity. While the boundaries between various elements of the VSD are not clear-cut, the blurring of boundaries helps create an awareness of the interwoven relations in the real world.

The VSD shown in Figure 3-1 not only visualizes the indicators specified via the four-stage typology for the dimensions of sensitivity and adaptive capacity, but also incorporates the indicators accounting for the dimension of exposure. The inclusion of the exposure dimension informs the analysis of the occupancy of risk zones by the elderly and thereby lays the basis for the physical vulnerability assessment of Chapter 4. In like manner, the indicators and proxy variables explaining the dimensions of sensitivity and adaptive capacity enlighten the subsequent development of social vulnerability metrics in Chapter 5.

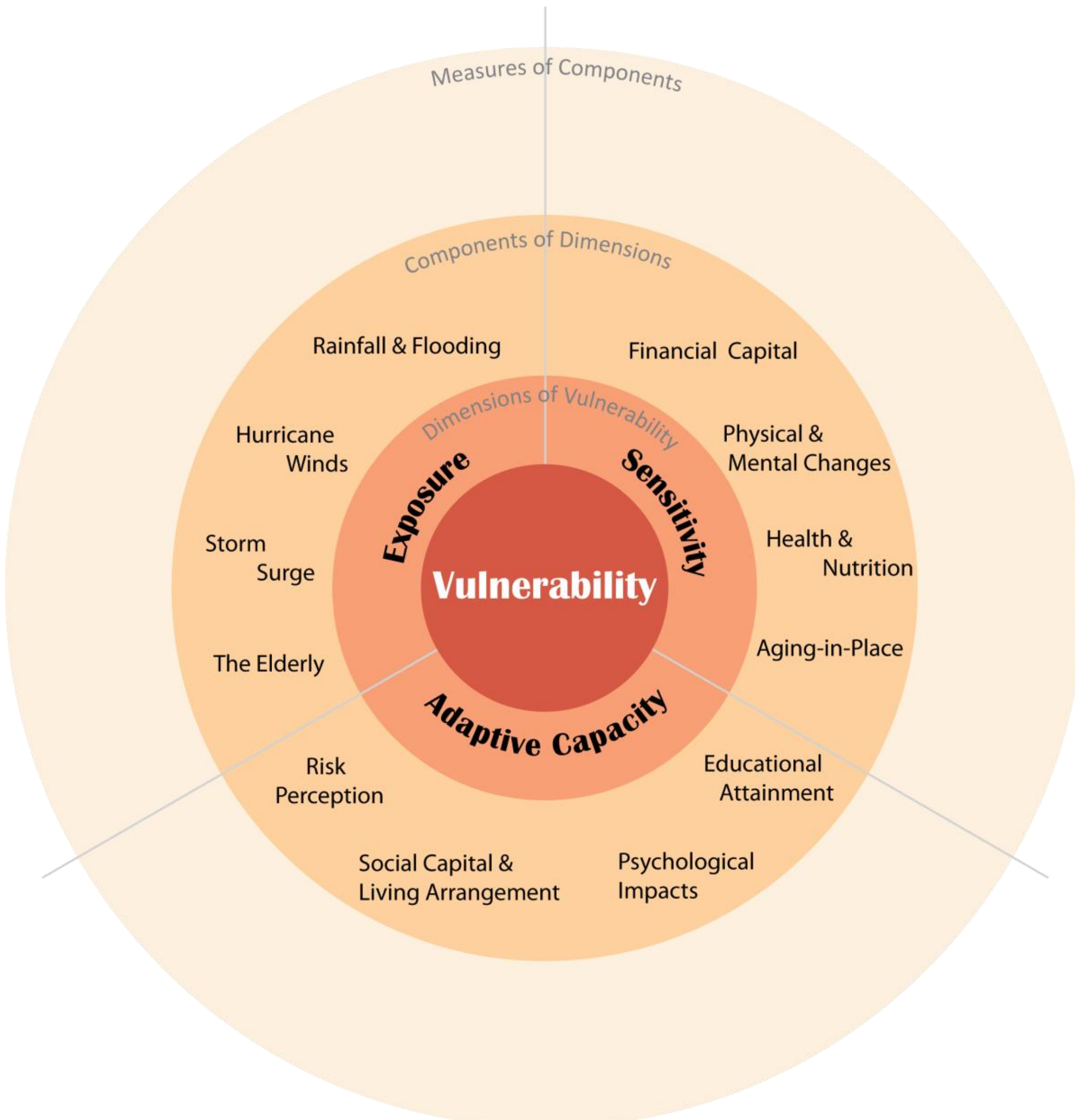

Figure 3-1. Vulnerability Scoping Diagram (VSD) for the elderly during hurricanes (see Table 3-1 for measures of components)

Table 3-1. List of proxy variables for vulnerability indicators

Dimensions	**Components (Indicators)**	**Measures (Proxy Variables)**			
Exposure	***S***torm Surge	SLOSH Model Outputs			
	Rainfall and Flooding	FEMA FIRMs			
	Hurricane Winds	Wind-borne Debris Region Map			
	The Elderly	Number of People	Location of People	Number of Institutions for the Elderly	Location of Institutions for the Elderly
Sensitivity	***F***inancial Capital	Poverty Status	Retirement Income	Personal Transport	Home Values
	Physical and Mental Changes	Physical Disability	Mobility Disability	Mental Disability	Sensory Disability
	Health and Nutrition	Self-care Disability	Dementia	Special Nutrition Needs	Chronological Age
	Aging-in-Place	Uninstitutionalized Population	Age of House	Occupancy Status	
Adaptive Capacity	***E***ducational Attainment	Literacy	English Proficiency		
	Psychological Impacts	Resettlement	Medical Care Interruption		
	Social Capital and Living Arrangement	Marital Status	Grand-parenting	Household Size	Household Composition
	Risk Perception	Years of Residence	Disaster Experience		

3.4 Summary

With the assistance of the four-stage typology and VSD, this chapter identified factors explaining the capability and efficacy of the elderly to prepare for, respond to, recover from, and reconstruct their world after a hurricane disaster. The social vulnerability indicators include financial capital, aging-in-place, risk perception, health and nutrition, physical and mental changes, social capital and living arrangement, psychological impacts, and educational attainment. At the same time, the vulnerability of the elderly to hazards is modulated by physical aspects of vulnerability — i.e., the elderly's occupancy of hurricane risk zones — which is the subject of Chapter 4.

CHAPTER 4

PHYSICAL VULNERABILITY

4.1 Introduction

Some scholars have defined physical vulnerability as the vulnerability of the physical environment (Pelling, 2003) and others have interpreted the term as whatever is physically at risk of being affected when people place themselves and the built environment in harm's way (Cutter et al., 2000). For example, people within the World Bank's Hazard Management Unit (Dilley et al., 2005) used the concept of physical vulnerability to represent the weakness of human-built physical systems (e.g., buildings and infrastructure) as a function of hazard severity whereas Cardona (2004) related physical vulnerability to a fusion of the degree of exposure, the fragility of the exposed elements, and the human settlements in hazard-prone zones. While the definitions of physical vulnerability vary, the term primarily refers to the exposure of an entity to a source of potential harm (Yarnal, 2007).

Although there is no definitive definition of physical vulnerability, it is clear that this aspect of vulnerability relates to location. For instance, Florida residents living in flood plains, low-lying areas, and barrier islands are highly physically vulnerable regardless of their socioeconomic profiles because they are exposed to hurricane hazards. As noted in the introduction to this thesis, classifying a geophysical phenomenon as a natural hazard requires the interplay of the event and something that people value. The assessment of physical vulnerability often involves the specification of the occurrence probability of a given hazard and the descriptions of areas likely to be influenced (Cutter et al., 1997). In this thesis, therefore, the level of exposure to hurricane hazards and the human occupancy of hurricane hazard risk zones determine the degree of physical vulnerability and, as a result, the measurement of physical vulnerability integrates the distribution of hurricane hazards and the elderly population within Sarasota County. In the following physical vulnerability assessment, I examine the spatial patterns of potential storm surge and flooding associated with hurricanes, depict the locations of critical structures, and combine the elderly's occupancy of the defined risk zones.

4.1.1 Hurricanes and Hurricane Hazards in the US

Hurricanes are a major concern along the East Coast and Gulf of Mexico. Particularly exposed to hurricane landfall are southern Florida, the Carolinas, and the Gulf Coast (Keller, 1999; Hyndman, 2006; Barnes, 2007). Human populations are concentrated along coasts (Adger et al., 2005) and coastal populations have become a rapidly growing segment of the world population. Globally, nearly one quarter of the world's population lives within 100 km of the coast (Small et al., 2003). Concern is mounting that population growth with climate change as a multiplier will compound the effects of hurricanes, thereby threatening the sustainability of coastal communities (Whitehead et al., 2000; Trenberth, 2005; Frazier et al., 2009; Frazier et al., 2010a).

Hazards presented by hurricanes include wind, torrential rain, flood, and storm surge. In this thesis, the analysis of physical vulnerability to hurricane hazards is limited to the exposure to potential storm surge and flooding. Depending on storm history and coastal bathymetry, even minor or moderate hurricanes can generate a major storm surge, destroying homes, businesses, and infrastructure in their paths. An example is the 2005

Hurricane Katrina, which was only a category 3 storm at landfall but produced a gigantic storm surge of up to 30 feet that inflicted staggering loss of life, property, and economy in Louisiana and Mississippi (National Hurricane Center, 2005; The White House, 2006; FEMA, 2010c).

Likewise, a weak tropical storm or hurricane can also produce a substantial amount of rainfall. While storm surge is often the greatest threat to population and property along the United States coastline, more than half of the deaths from 1970 to 2000 were from inland flooding associated with tropical cyclones (FEMA, 2010d; National Hurricane Center, 2011a). Indeed, inland floods bring great risks to interior communities that are normally buffered from the strongest winds and storm surges. Moreover, floods can rupture sewer and water lines and consequently cause water contamination and significant health problems (World Health Organization, 2006).

4.1.2 Hurricane History of Sarasota County

Despite Florida's reputation as a hurricane magnet, Sarasota County has been affected less often compared to many other parts of the state. It has not suffered a direct hit by a hurricane since 1944. Prior to that date, the 1921 storm (storms before 1950 were not named) was the first hurricane that wrought structural damage to the county in the twentieth century (Sarasota Herald Tribune, October 17, 2010a). The storm made landfall near Tarpon Springs, with Tampa being the hardest hit area, but the impacts went beyond the shores of Tampa Bay and Florida's west coast (Barnes, 2007). "In Sarasota the tidal surge of more than 7 feet inundated Casey, Siesta, St. Armand's, Longboat and Anna Maria Keys and sent the water from Sarasota Bay past Five Points in downtown

Sarasota." This incident as an unanticipated trigger transformed the county from a fishing village to a resort city, making its bayfront more attractive to tourists (Sarasota History Alive, 2011).

Hurricanes continued to bypass Sarasota after the 1921 storm until 1944. In 1944, a big storm known as the Havana-Florida Hurricane (Barnes, 2007) or the Florida-Cuba Hurricane (Sumner, 1944), came onshore south of Sarasota with gusts in excess of 100 mph at Vamo, near Nakomis. The category 3 storm maintained its strength northward while crossing the state and generated a considerable storm surge causing extensive damage in Florida. The most severe damage from the surge was seen along the Florida west coast. In Sarasota, the low-lying areas were inundated; statewide, the citrus crop was destroyed by the storm (Barnes, 2007). Although there was little loss of life in Florida, total property damage was over $100 million (Sumner, 1944).

Recent major hurricanes have had no significant impacts on Sarasota County through the 1950s and up to the present. Sarasota had a close call with Hurricane Donna in 1960 with hurricane-warning flags flying over the municipal pier (Sarasota Herald Tribune, October 17, 2010b) but the storm ultimately hit the Florida Keys and swept across the middle of the Florida peninsula (Barnes, 2007). Known as one of the most destructive hurricanes in Florida's history, Hurricane Donna just brushed Sarasota and therefore the county was spared extensive repercussions except for tree damage and flooding in Siesta Key. The county has not experienced significant impacts from storms in the new millennium. In 2004, Sarasota had a near miss with Hurricane Charley. This fifth costliest hurricane in U.S. history (CNBC, August 25, 2010; Insurance Information Institute, 2011) made a last-minute turn from a course aimed at Tampa toward Port

Charlotte in Charlotte County, which borders southern Sarasota County. Sarasota County was affected to a much lesser degree with two deaths and minor physical damage reported (Barnes, 2007).

Sarasota's immunity from hurricanes in the future remains uncertain. There is no scientific consensus of future characteristics of hurricanes but research results generally show that the future is likely to have more intense tropical cyclones in the context of climate change (Trenberth, 2005; IPCC, 2007). In addition to the changing geophysical processes, anthropogenic factors, such as the continuing trend of population increase and coastal development, may also contribute to the county's physical vulnerability to hurricanes (Cutter et al., 2000; Whitehead et al., 2000; Wu et al. 2002; Kleinosky et al. 2007; Frazier et al., 2010a).

4.2 Physical Vulnerability to Potential Storm Surge

4.2.1 Methods

I assess the exposure to potential storm surge based on the outputs from the SLOSH model developed by the FEMA, United States Army Corps of Engineers (USACE), and the National Weather Service (NWS). The SLOSH model is used to estimate storm surge depths from historical, hypothetical, or predicted hurricanes by taking into account a storm's pressure, size, forward speed, forecast track, and wind speeds. The model results are 80 percent accurate with plus or minus 20 percent error but are still helpful for emergency managers to determine evacuation areas (National Hurricane Center, 2011b). See Wu et al. (2002) and Kleinosky et al. (2007) for details of the model and Frazier et al. (2009) for its application to Sarasota County.

4.2.2 Results

Hurricane storm surge risk zones are usually delineated by hurricane categories, ranked on the Saffir-Simpson Hurricane Scale of categories 1 through 5. Figure 4-1 shows the storm surge risk zones for hurricanes of Saffir-Simpson categories 1, 2, 3, and a combination of 4 and 5 in order to follow Sarasota County's customary classifications. The "Category 1" represents the areas even affected by the weakest storms while "Category 4-5" stands for the areas only affected by the strongest storms (i.e., categories 4 and 5). Note that these storm surge risk zones are areas that could potentially suffer storm surge inundation from a hurricane of that category, but whether or not they flood depends on many factors, such as storm history and trajectory. Evacuation routes and hospitals are included in Figure 4-1 for later reference.

Figure 4-1 demonstrates that of Sarasota County's total land area of 1482 km^2, approximately 22 percent of the county is potentially exposed to storm surge from the strongest hurricanes. In contrast, for the weakest hurricanes, the storm surge risk zone occupies less than 4 percent of the entire county. Table 4-1 describes the total area of each storm surge risk zone and the corresponding percentage of the county's total area.

Hidden within these data are other useful facts. As shown in Figure 4-2, the entire southern portion of the Town of Longboat Key in Sarasota County is at risk of storm surge inundation from a category 1 hurricane. Similarly, all of Lido Key, St. Armands Circle, and Bird Key in the City of Sarasota are at risk of storm surge flooding from a category 1 hurricane. A small portion of the City of Venice is potentially vulnerable to storm surge produced by category 1 hurricanes. Despite its inland location, some areas in the City of North Port around the Myakka River are also susceptible to

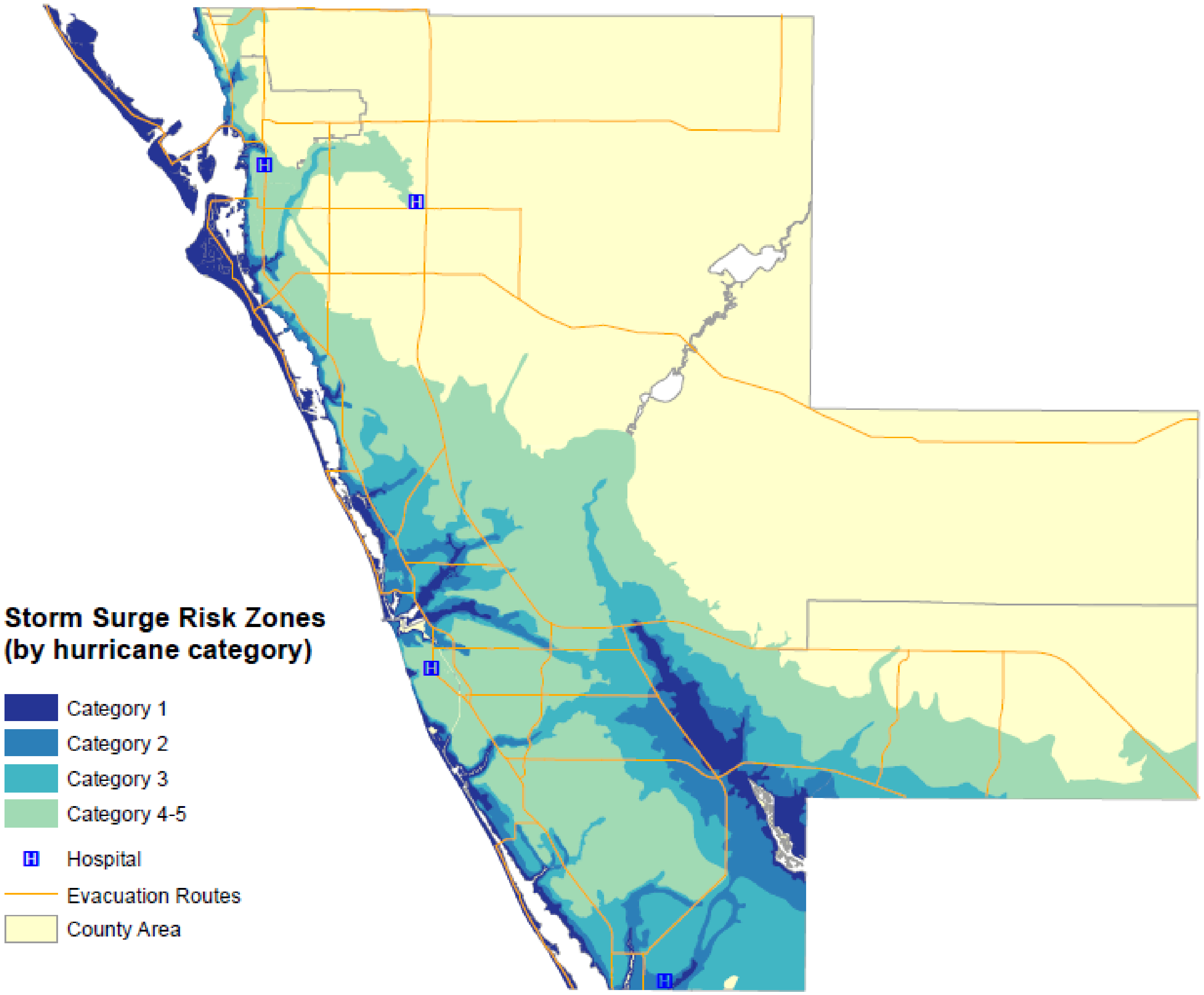

Figure 4-1. Storm surge risk zones in Sarasota County

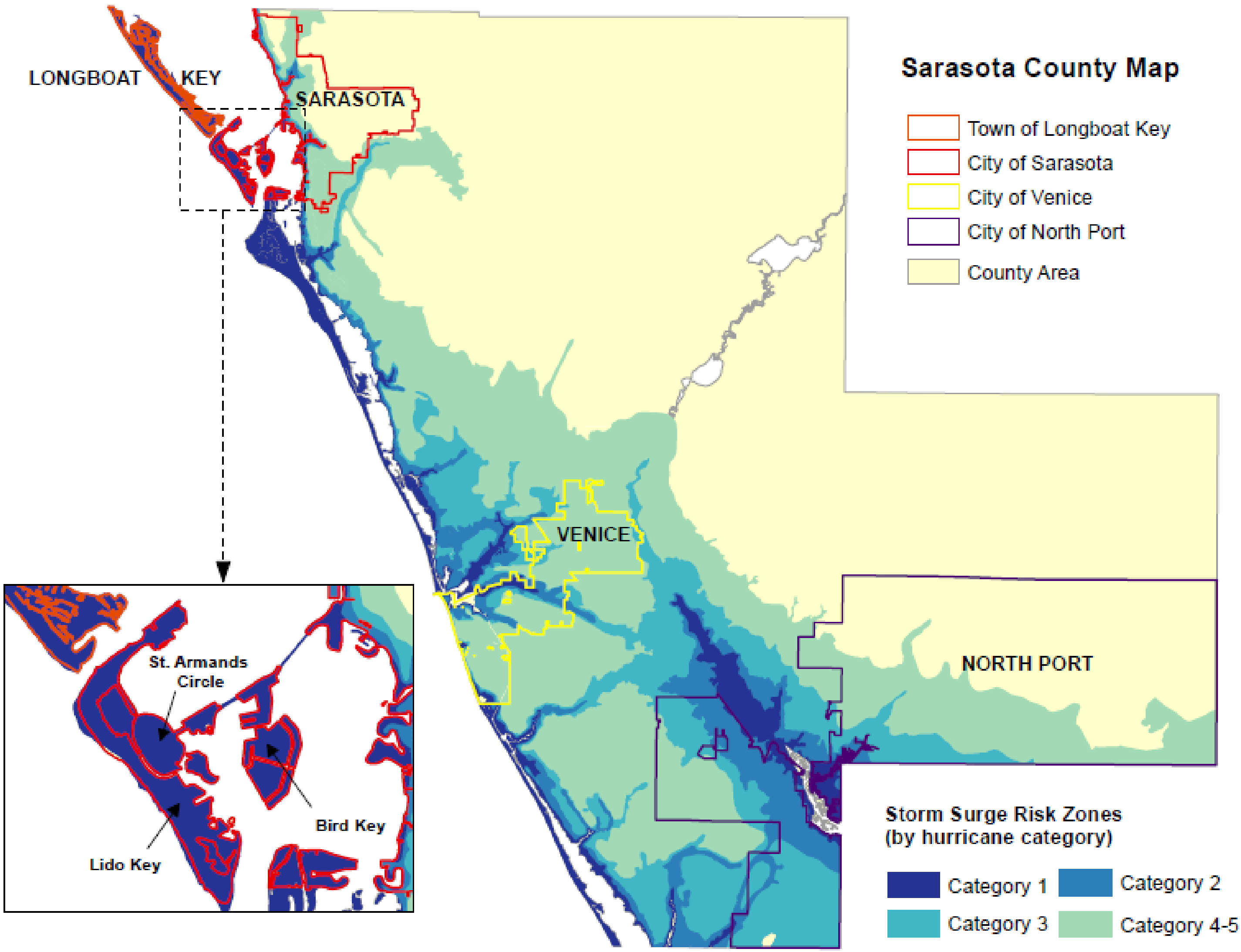

Figure 4-2. Cities or towns overlaid with storm surge risk zones in Sarasota County

Table 4-1. Storm surge risk zones by hurricane category

Hurricane category	Size of storm surge risk zones (km^2)	Percentage of the county's total area in storm surge risk zones (percent)
Category 1	57.21	3.86
Category 2	59.23	4.00
Category 3	148.10	9.99
Category 4-5	327.60	22.11

storm surge inundation from category 1 hurricanes. On the other end of the scale, about 32 km^2 in the City of Venice (75 percent of the city's total area) are at risk of storm surge flooding from a category 4-5 storm. For the City of North Port, the storm surge risk zone associated with category 4-5 hurricanes occupies about 27 percent of the city. The City of Sarasota suffers a similar fate with 26 percent of its total area at risk of inundation from a category 4-5 hurricane.

As for some critical structures in the county, storm surge produced by the strongest hurricanes can threaten most hospitals and wash out most evacuation routes. The physical robustness of hospitals in times of hurricanes matters to people of all ages. Englewood Community Hospital is located within the category 2 storm surge risk zone. The effects can spill over the county boundary because this hospital provides healthcare services to the residents of not only Sarasota County but also Charlotte County. Venice Region Medical Center and Sarasota Memorial Hospital – the county's biggest and only public hospital – are under the threat of storm surge flooding with category 4-5 hurricanes. Only Doctors Hospital of Sarasota is theoretically safe from storm surge because it is outside the storm surge risk zones. However, this 168-bed facility might have difficulty accommodating additional emergency medical services during a hurricane emergency.

Rapid access to hospitals is another big concern during hurricane emergencies. Major roads can be disrupted for several days first from evacuation and then from storm surge and inland flooding. The dysfunction of the road network not only can prevent disaster victims from receiving emergency medical treatment but also can shut down the flow of external resources into the hospitals. In Sarasota County, Longboat Key, Siesta Key, and Manasota Key are especially vulnerable because storm surge from weak hurricanes can flood all of the major roads on these barrier islands, including Gulf of Mexico Dr (SR 789), Ringling Causeway (SR 789), Siesta Drive (SR 758), Midnight Pass Road (SR 758), Stickney Pt. Road (SR 72), and Manasota Key Road. The only interstate freeway in Sarasota County, I-75, is outside the storm surge risk zone associated with category 3 hurricanes. However, the portion of I-75 south of Clark Road (SR 72) and north of Venice Avenue is at risk of category 4-5 storm surge. It is important to note that I-75 serves as the county's unofficial demarcation between urban coastal development to the west and rural countryside to the east; the overwhelming majority of the heavily developed and populated areas potentially affected by storm surge are west of I-75 (Frazier et al., 2010b).

After developing this sketch of Sarasota County's physical vulnerability to storm surge, I examined the distribution of the elderly population within the county to determine this group's storm surge risk. At 31.2 percent, Sarasota County has a higher-than-average percentage of elderly residents compared to Florida's average of 17.3 percent (U.S. Census Bureau, 2011), and Florida exhibits a greater percentage of elderly residents compared to the U.S. average. To provide a fine-grained description of the size and spatiality of the group, I mapped the total number of elderly population (obtained from 2000 Census) by census block group in ArcGIS (Figure 4-3). It is evident that there is a distinguishable spatial variation of the distribution of the elderly. Notably, Longboat Key, the southern part of Siesta Key, two block groups in Venice, three block groups in North Port, and a couple of block groups in unincorporated areas just west of I-75 manifest the largest numbers of elderly residents with values greater than 1.5 standard deviations.

Figure 4-3 gives a general sense of where the elderly live, but it does not make it possible to pinpoint the locations of the elderly individuals. To alleviate this problem, I overlaid the major institutions for the elderly, namely nursing homes and assisted living facilities, with the map of storm surge risk zones in Sarasota County to provide a view of eldercare institutions' storm surge risks (Figure 4-4). Although this step still cannot succeed in inventorying all elderly individuals, it at least locates the geographical concentrations of the elderly population not living in households. This group of the elderly enjoys assistance and guidance from trained staff in daily life but, apart from the important communal preparations of institutional staff on their behalf, is possibly left to face hurricanes without adequate individual preparedness. Institutionalized elderly are often physically and mentally fragile and are therefore especially helpless and vulnerable during and after hurricanes.

As seen in Figure 4-4, over half of the institutions for the elderly (48 out of 90) are in the category 4-5 storm surge risk zone. Six institutions (1 nursing home and 5

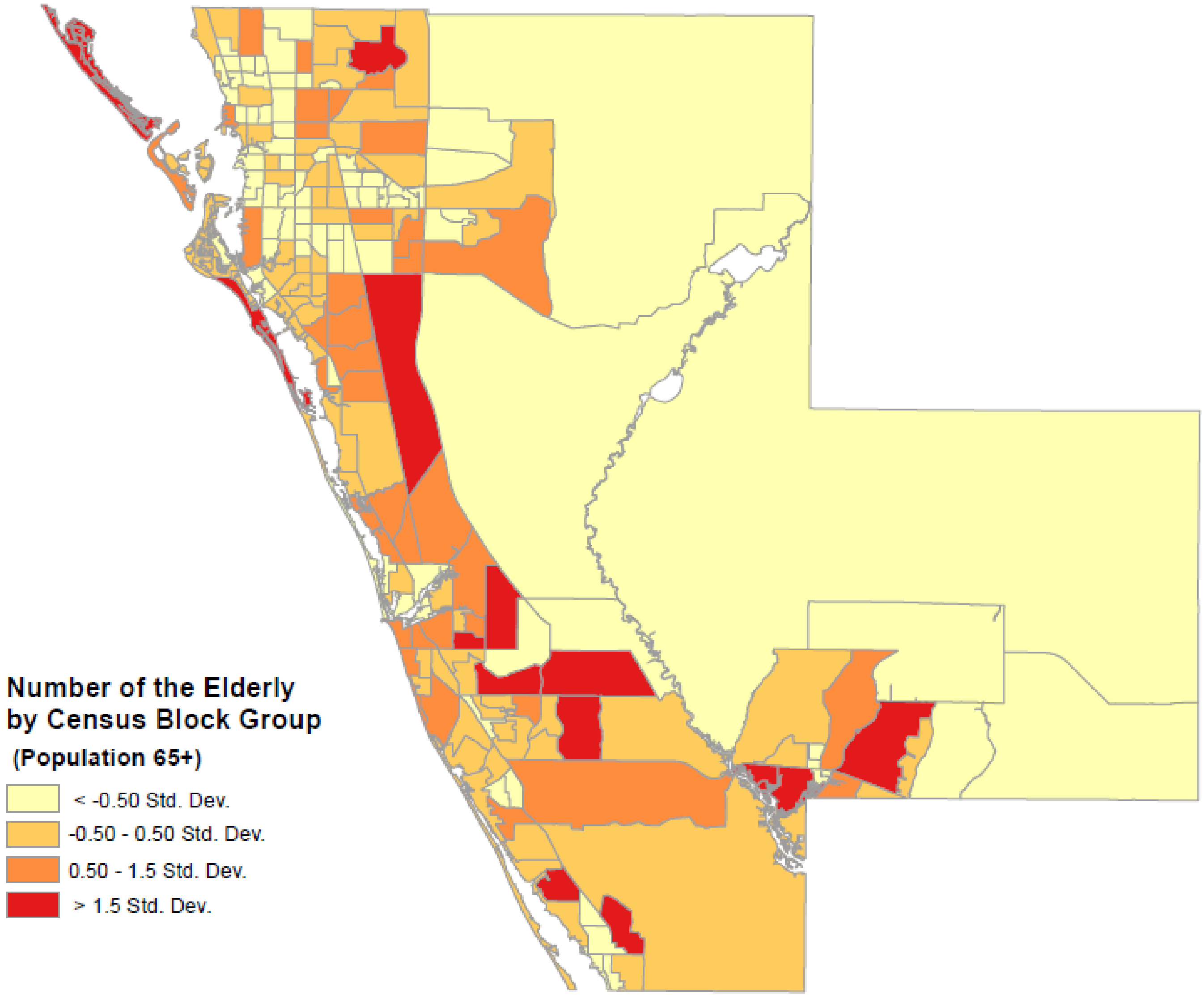

Figure 4-3. Distribution of the elderly in Sarasota County

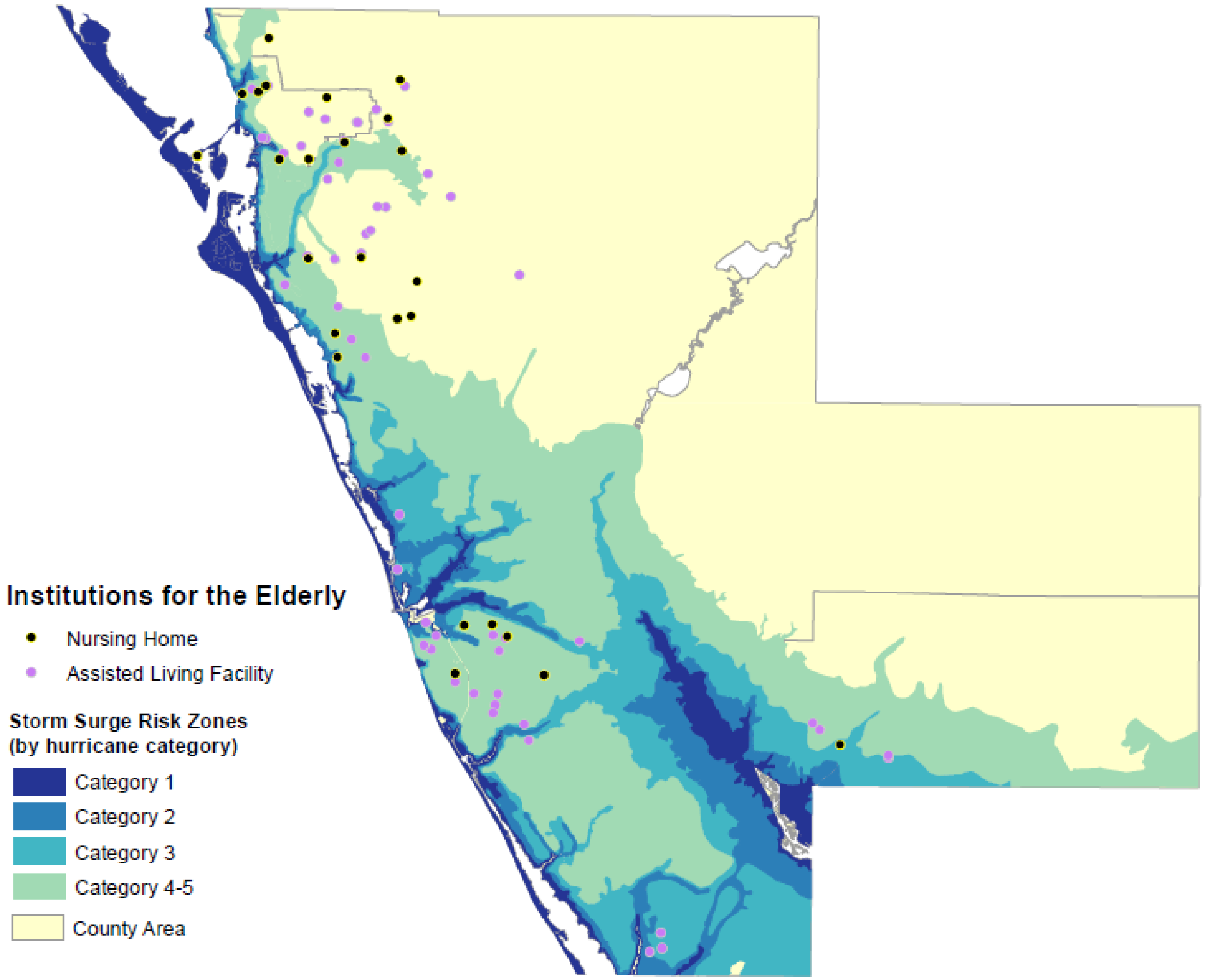

Figure 4-4. Distribution of institutions for the elderly in relation to storm surge risk zones within Sarasota County

assisted living facilities) are at risk of storm surge flooding from category 3 hurricanes. Four assisted living facilities are at risk from category 2 hurricanes (among which one is highly vulnerable in the sense that the effects of a hurricane strike in Charlotte County is likely to spill over the political boundary because this facility is near the county border). The most physically vulnerable elderly institutions (1 nursing home and 1 assisted living facility) subject to storm surge from category 1 hurricanes are located near the John Ringling Bridge over Sarasota Bay.

4.2.3 Summary of Storm Surge Risk Analysis

Placing maps of storm surge risk zones and institutions for the elderly over the distribution of the elderly provides an improved understanding of the elderly population's occupancy of these risk zones (Figure 4-5). Areas at risk of storm surge from category 1 hurricanes are considered highly vulnerable whereas areas only at risk of storm surge from category 4-5 hurricanes are considered to have lower physical vulnerability. Areas with greatest number of the elderly inside of category 1 storm surge risk zone are thus the most physically vulnerable. Under this criterion, the elderly living on Longboat Key, the southern portion of Siesta Key, and in North Port along the Myakka River top the list of the elderly most physically vulnerable to storm surge in Sarasota County.

4.3 Physical Vulnerability to Potential Flooding

4.3.1 Methods

Inland flooding resulting from intense rain delivered by hurricanes and tropical storms is also a physical threat to the elderly. Therefore, the second phase of the physical

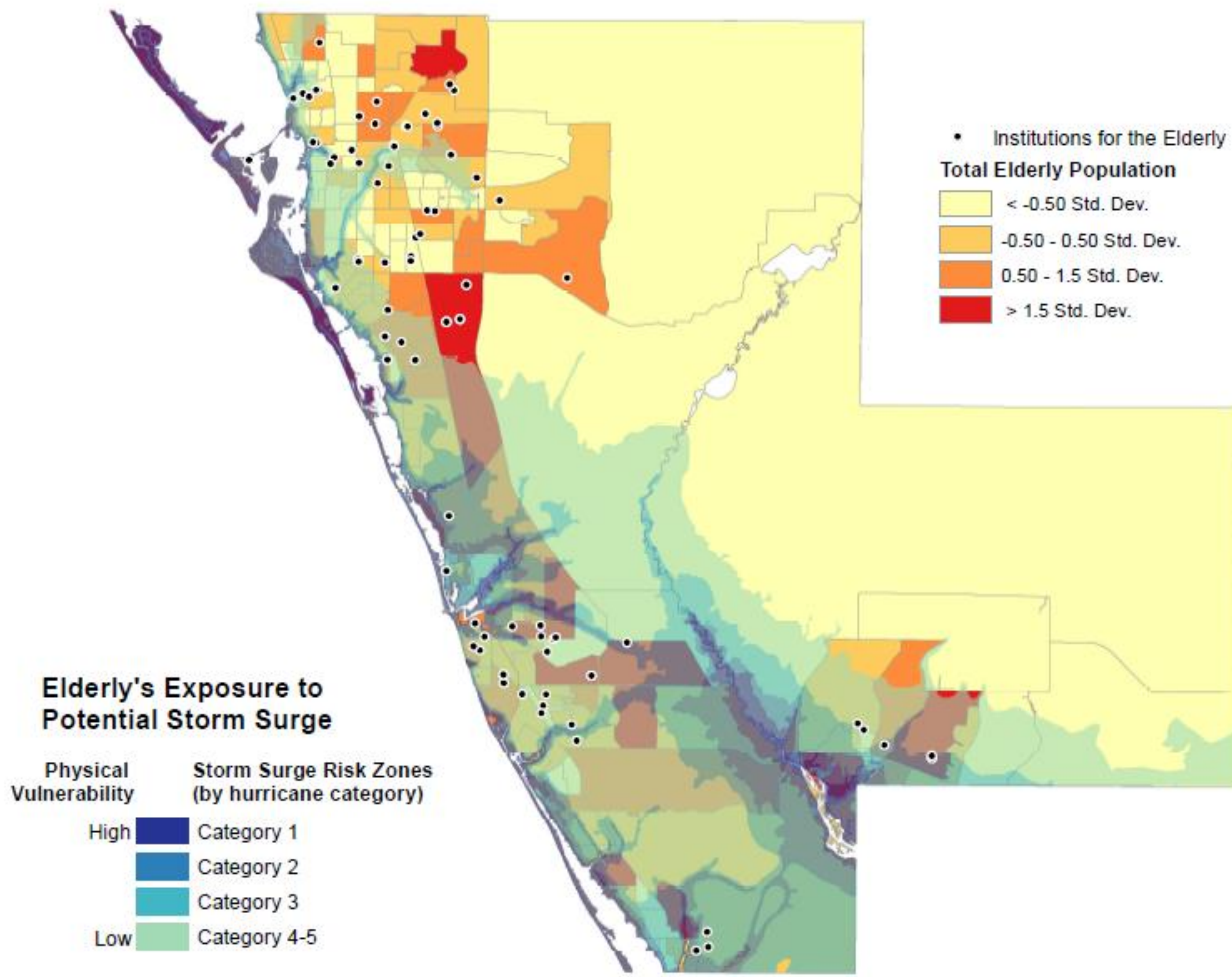

Figure 4-5. Physical vulnerability of the elderly to potential storm surge in Sarasota County

vulnerability assessment focuses on the elderly's risk of exposure to such inland flooding. To measure the exposure to hurricane-related flooding, I map the flood risk zones in ArcGIS based on the flood plains defined by FEMA for Sarasota County's Flood Insurance Rate Maps (FIRMs).

On all FIRMs, FEMA assigns a character from the alphabet to each flood zone that defines the severity and frequency of flooding (FEMA, 2010e), which was briefly introduced in Chapter 2. These designated flood zones can be regrouped into three broader categories: (1) high risk coastal areas, (2) high risk areas, and (3) moderate-to-low risk areas (FEMA, 2010e; FEMA, 2011). High risk coastal areas (Zones V, VE, or V1-V30) identify the areas vulnerable to flooding associated with storm waves, in addition to a 1.0 percent annual chance or greater flood event from heavy precipitation. High risk areas (Zones A, AO, AH, AE, A1-A30, A99, AR, AR/AE, AR/AO, AR/A1-A30, or AR/A) refer to the areas with a 1.0 percent or greater annual chance of flooding and varying depth of floodwater. High risk areas together with high risk coastal areas depicted on the FIRMs are called the Special Flood Hazard Areas (SFHA). Moderate to low risk areas (labeled Zone B or Zone X (shaded), and Zone C or Zone X (unshaded), respectively), are also indicated on the FIRMs to designate the areas between the limits of the 100-year (1.0 percent annual chance) flood and 500-year (0.2 percent annual chance) flood, and the areas of minimal flooding above the 500-year flood level. In the flood risk analysis, to avoid creating too many categories as well as to make categories more intuitive, I delineate flood risk zones by following FEMA's broader classification with descriptive class names attached to each flood zone.

4.3.2 Results

Figure 4-6 shows those areas of Sarasota County at risk of physical exposure to flooding. Table 4-2 indicates absolute and relative area of the incorporated places that are vulnerable to 1 percent or greater annual chance of flooding (i.e., high risk areas).

Table 4-2. Flood risk of Sarasota County cities or towns to 100-year flood events

City/Town	Total Area (km^2)	High Risk Areas (km^2)	High Risk Areas (percent)
Longboat Key	5.93	5.55	93.59
Sarasota	38.15	9.07	23.77
Venice	43	9.42	21.91
North Port	268.5	32.44	12.08

The SFHA accounts for more than 20 percent of the county's total land area. Similar to the findings conveyed in Figure 4-2 for storm surge, Longboat Key, the barrier islands and coastal areas of Sarasota City, and coastal Venice are most physically vulnerable to floods (Figure 4-6 and 4-7). Hence, these places are doubly physically vulnerable to a compound hazard of storm surge and flooding. Important here are those areas subject to floods that are not subject to storm surge risk. These additional physically vulnerable places consist of low-lying areas across the county and areas in the vicinity of the Myakka River and its tributaries.

Many of the evacuation routes are potentially intersected by floodwaters in the flood scenario of 1 percent annual chance or greater flood events, thereby greatly jeopardizing their efficacy; all hospitals but Englewood Community Hospital fall outside the SFHA (Figure 4-6). Eighty of 90 institutions for the elderly (nearly 90 percent) fall

Figure 4-6. Flood risk zones in Sarasota County

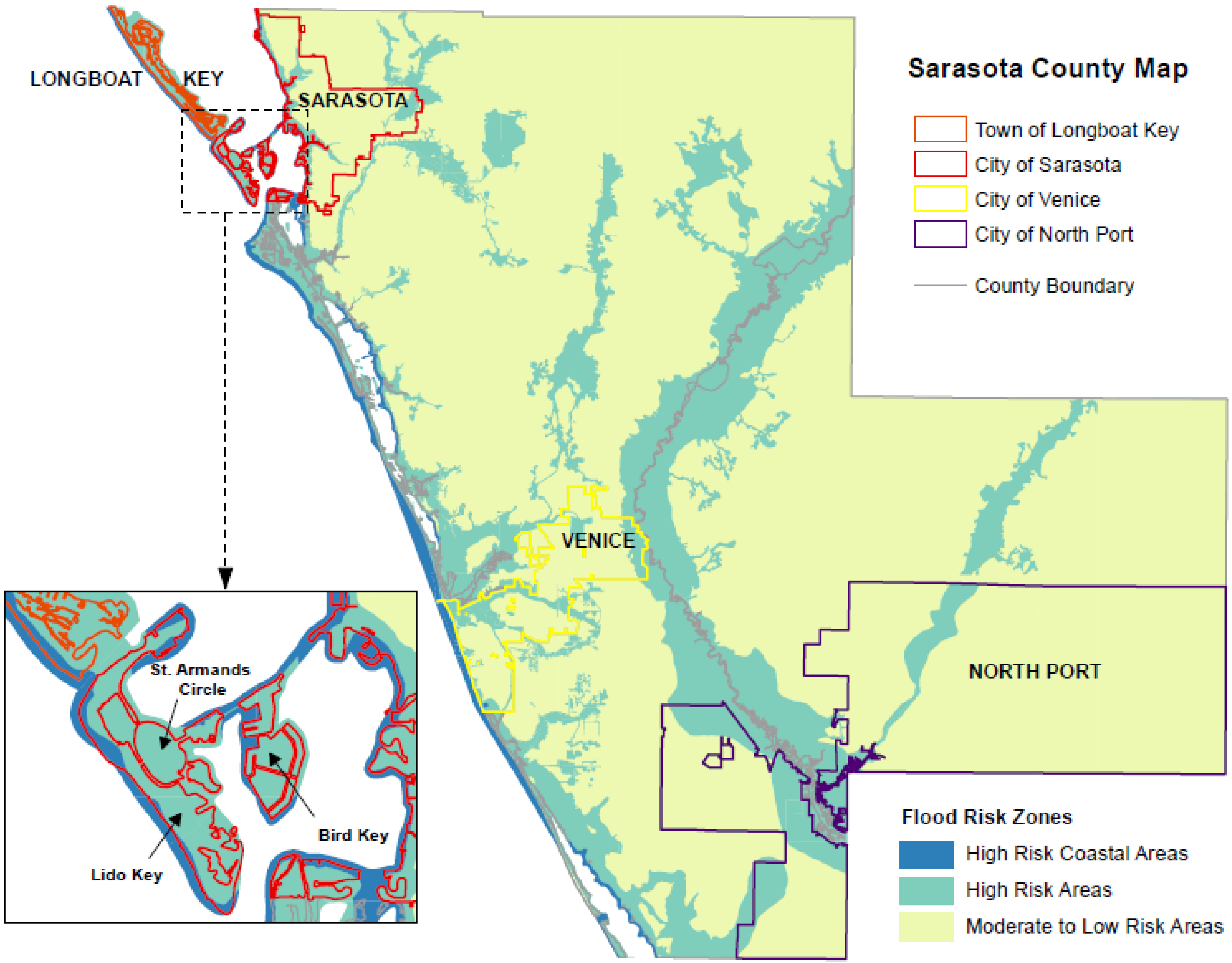

Figure 4-7. Cities or towns overlaid with flood risk zones in Sarasota County

outside the SFHA (Figure 4-8). However, if their exposure to storm surge is factored in, there will be a sharp decrease to only 29 institutions that are unaffected by both risks.

4.3.3 Summary of Flood Risk Analysis

An overlay of the flood risk zones, institutions for the elderly, and distribution of Sarasota County's elderly helps interpret the elderly's occupancy of the flood risk zones (Figure 4-9). Areas labeled "high risk coastal areas" are considered more physically vulnerable to flooding whereas areas at risk from less frequent flood events, labeled "moderate to low risk areas," are considered less physically vulnerable to flooding. Areas with the greatest number of the elderly inside the high coastal risk areas thus become the most physically vulnerable places. Following this criterion, the elderly living on Longboat Key and the southern portion of Siesta Key are the most physically vulnerable to potential flooding in Sarasota County.

4.4 Summary

Sarasota County's geography puts coastal areas and areas far inland at high risk of hurricane storm surge inundation and precipitation-induced flooding. The two-phase physical vulnerability assessment presented in this chapter shows that the elderly residing in the low-lying coastal portions of Sarasota County are most at risk of hurricane storm surge and flooding. Elderly residents on Longboat Key and the southern portion of Siesta Key are especially vulnerable to these hurricane hazards. Evacuation routes in these places can be flooded by storm surges produced by the weakest hurricanes as well as by heavy precipitation resulting from those hurricanes, thereby potentially preventing the

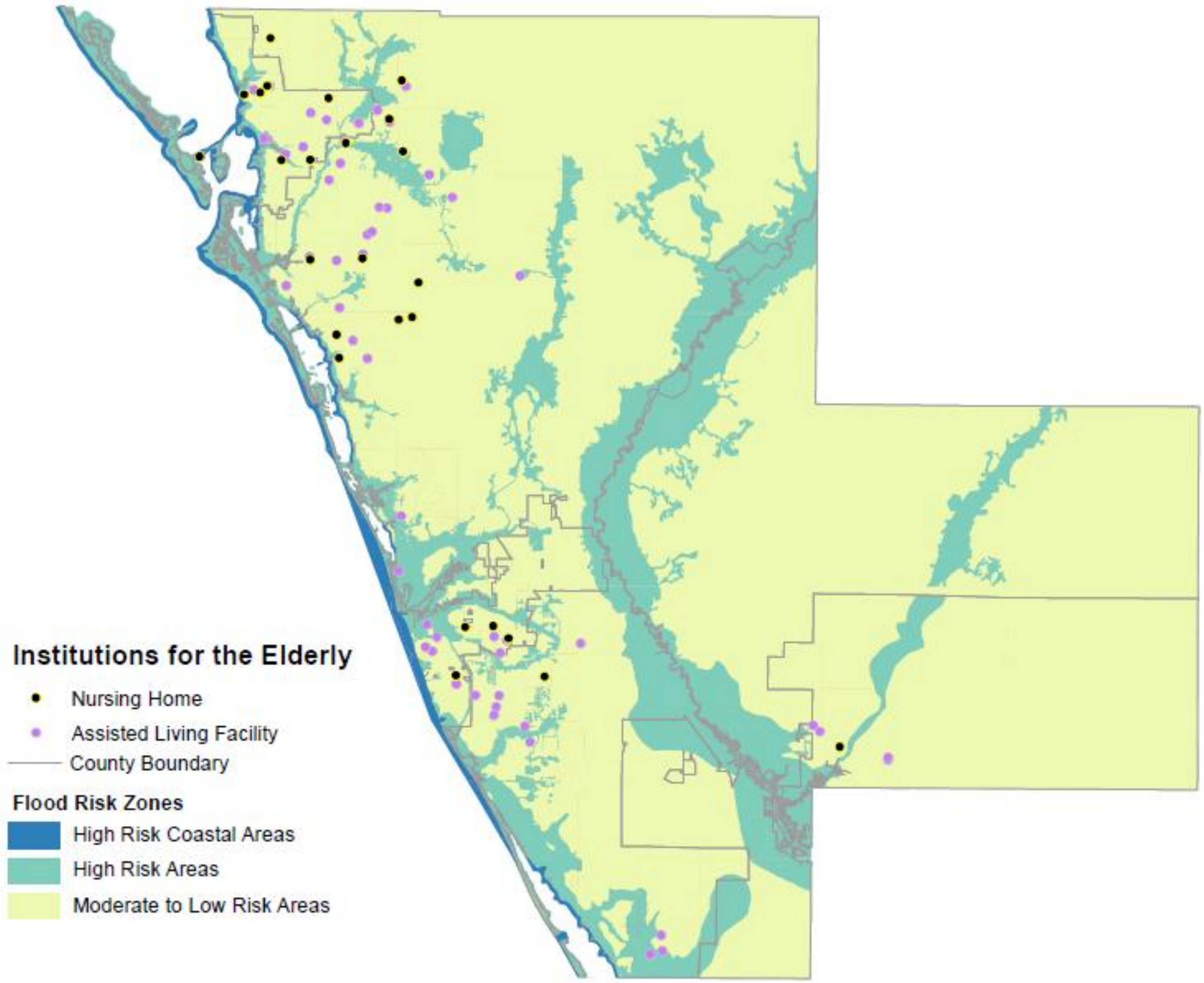

Figure 4-8. Distribution of institutions for the elderly in relation to flood risk zones within Sarasota County

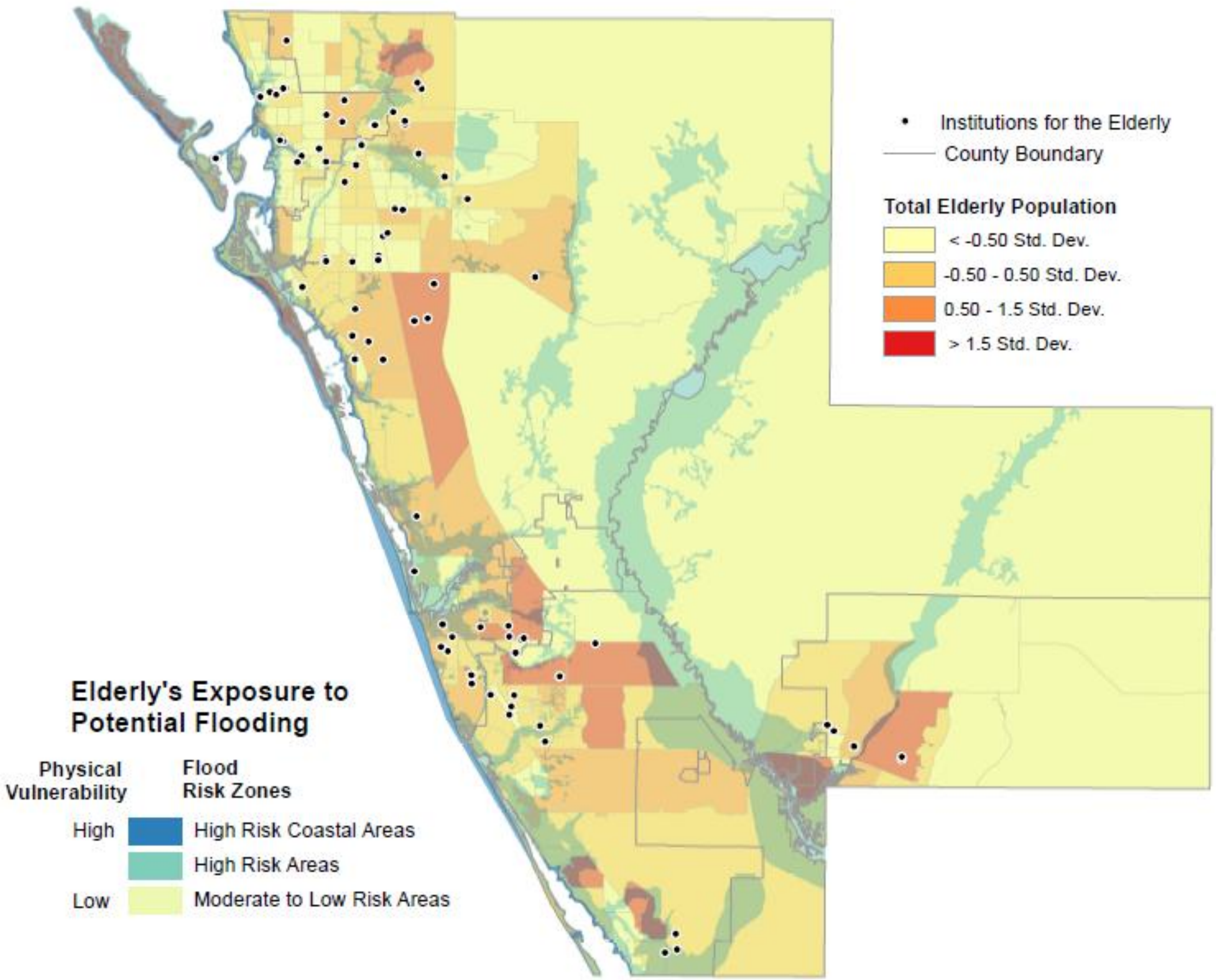

Figure 4-9. Physical vulnerability of the elderly to potential flooding in Sarasota County

elderly from timely evacuation.

Mapping and measuring the risk of physical exposure to storm surge and floods is a good start for vulnerability assessment but it is not sufficient to capture differentiated sensitivity and adaptive capacity among the elderly population at risk of exposure to hurricane hazards. Hence, the next chapter presents a quantitative social vulnerability assessment that considers the role of socioeconomic and demographic factors in creating differential vulnerability of elderly residents of Sarasota County.

CHAPTER 5

SOCIAL VULNERABILITY

5.1 Introduction

There are two fundamental aspects of vulnerability to hurricane hazards: physical vulnerability and social vulnerability. As examined in the previous chapter, physical vulnerability is primarily associated with the exposure to hazards, including the nature of hazards– magnitude, frequency, intensity, etc. The other aspect of vulnerability, social vulnerability, in general refers to the exposure of individuals or communities to damage or to insecurity as a function of social, economic, political, and cultural variables (Adger, 1999; Cutter et al., 2000; Pelling, 2003; Dilley et al., 2005). It includes elements of exposure but, for the most part, consists of the dimensions of sensitivity and adaptive capacity.

Social vulnerability can couple with physical vulnerability to provide even greater insights to the state of vulnerability among the older population in Sarasota County. For example, all elderly people on barrier islands are physically at great risk from hurricane hazards but individuals may exhibit markedly different degrees of social vulnerability. In another instance, some elderly may live in areas relatively far from the coast but may still be quite vulnerable to major hurricanes because they possess higher sensitivity and limited capacity to adapt. By investigating the socioeconomic standing of the elderly, I am able to differentiate their sensitivity and adaptive capacity so as to reveal a more holistic picture of their vulnerability to hurricane hazards. Therefore, in this chapter, I assess the effects of socioeconomic factors on the vulnerability of Sarasota County's elderly population.

5.2 Social Vulnerability Assessment

To measure the social vulnerability of Sarasota County's elderly, I employ a Principal Components Analysis (PCA) in the social vulnerability assessment. The PCA helps to identify the key vulnerability indicators out of a large number of proxy variables that represented the sensitivity and adaptive capacity of the elderly. Specifically, I use separate vulnerability indices based on the component scores generated by the PCA to compare the relative vulnerability of the elderly population across the county, distinguishing the most and least socially vulnerable elderly at the census block group level. The use of separate indices rather than a single composite social vulnerability index illustrates the ways in which the elderly are vulnerable and emphasizes the advantage of well-tailored vulnerability-reduction measures over one-size-fit-all policies.

5.2.1 Principal Component Analysis (PCA)

5.2.1.1 Variables Chosen for PCA

Because the elderly-specific vulnerability indicators and variables were identified earlier with the aid of the four-stage typology and the VSD (see Chapter 3), I started the social vulnerability assessment by locating the closest matches in the 2000 United States Census. All the variables were analyzed at the census block group level but derived from two different files: Summary File 1 (SF1) and File 3 (SF3). The SF1 contains 100-percent data, which is a compilation of information about every person and every housing unit in a census unit, whereas SF3 is based on a sample with an average sampling rate of 1 in 6 and subject to both sampling and non-sampling errors (U.S. Census Bureau, 2007).

After reorganization, I obtained 64variables with 204 cases (i.e., all census block groups in Sarasota County) per variable and chose them for inclusion in the PCA of social vulnerability. These variables embrace a range of topics including disability, income and poverty, living arrangement, language proficiency, telephone and vehicle availability, and types of housing tenure. The variables parallel the vulnerability indicators portrayed in the VSD such as financial capital, health and nutrition, physical and mental changes, social capital, and living arrangement. Some of the variables suggested by the VSD were left out of the PCA because data were unavailable. Table 5-1 lists the 64 items grouped by topic with names and descriptions.

Next, I utilized PCA to identify key components that encapsulate the characteristics of all the variables for the elderly's social vulnerability. PCA substitutes a succinct set of orthogonal components for a multitude of correlated variables and therefore summarizes a dataset in an efficient fashion. In that sense, PCA is a variable-reduction technique. Perhaps more important is that a rotated PCA identifies the main modes of variation in the dataset. The 64 variables regarding the elderly's sensitivity and adaptive capacity to hurricane hazards were entered and also standardized using Z scores in PASW Statistics 18 to meet the customary requirements of PCA.

Table 5-1. The 64 variables used in PCA to determine social vulnerability of the elderly

VARIABLE CATEGORY	***NAME***	***DESCRIPTION***
DISABILITY	S DB 65+	Civilian noninstitutionalized population 65 years and over with Sensory disability
	P DB 65+	Civilian noninstitutionalized population 65 years and over with Physical disability
	M DB 65+	Civilian noninstitutionalized population 65 years and over with Mental disability
	SC DB 65+	Civilian noninstitutionalized population 65 years and over with Self-care disability
	GOH DB 65+	Civilian noninstitutionalized population 65 years and over with Go-outside-home disability
	DB 65-74	Civilian noninstitutionalized population 65 to 74 years: With a disability
	N-DB 65-74	Civilian noninstitutionalized population 65 to 74 years: No disability
	DB 75+	Civilian noninstitutionalized population 75 years and over: With a disability
	N-DB 75+	Civilian noninstitutionalized population 75 years and over: No disability
INCOME	IC <10K 65-74	Households: Householder 65 to 74 years; Household income; Less than $10,000
	IC 10-45K 65-74	Households: Householder 65 to 74 years; Household income; $10,000 to $44,999
	IC 45-200K 65-74	Households: Householder 65 to 74 years; Household income; $45,000 to $199,999
	IC >200K 65-74	Households: Householder 65 to 74 years; Household income; $200,000 or more
	IC <10K 75+	Households: Householder 75 years and over; Household income; Less than $10,000
	IC 10-45K 75+	Households: Householder 75 years and over; Household income; $10,000 to $44,999
	IC 45-200K 75+	Households: Householder 75 years and over; Household income; $45,000 to $199,999
	IC >200K 75+	Households: Householder 75 years and over; Household income; $200,000 or more
LANGUAGE	S E 65+	Population 65 years and over: Speak Spanish; Speak English very well
	S N-E 65+	Population 65 years and over: Speak Spanish; Speak English not at all
	O E 65+	Population 65 years and over: Speak other languages; Speak English very well
	O N-E 65+	Population 65 years and over: Speak other languages; Speak English not at all
LIVING ARRANGEMENT	F HHer 65-74	Households: Family households; Householder 65 to 74 years
	F HHer 75+	Households: Family households; Householder 75 years and over
	N-F HHer 65-74	Households: Nonfamily households; Householder 65 to 74 years
	N-F HHer 75+	Households: Nonfamily households; Householder 75 years and over
	HH-1 60+	Households: Households with 1 person 60 years and over
	HH-2+ 60+	Households: Households with 2 or more people 60 years and over
	F HH-1 60+	Households: Family households with 1 person 60 years and over
	N-F HH-2+ 60+	Households: Nonfamily households with 2 or more people 60 years and over

Table 5-1(cont'd). The 64 variables used in PCA to determine social vulnerability of the elderly

LIVING ARRANGEMENT *(cont'd)*	HH-1 75+	Households: Households with 1 person 75 years and over
	HH-2+ 75+	Households: Households with 2 or more people 75 years and over
	F HH-1 75+	Households: Family households with 1 person 75 years and over
	N-F HH-2+ 75+	Households: Nonfamily households with 2 or more people 75 years and over
	IN HH 65+	Population 65 years and over: In households
	IN F HH 65+	Population 65 years and over: In households; In family households
	IN N-F HH 65+	Population 65 years and over: In households; In nonfamily households
	IN GQ 65+	Population 65 years and over: In group quarters
	IN GQ INS 65+	Population 65 years and over in group quarters: Institutionalized population
	IN GQ INS-NH 65+	Population 65 years and over in group quarters: Institutionalized population; Nursing homes
	IN GQ N-INS 65+	Population 65 years and over in group quarters: Noninstitutionalized population
POVERTY	BELOW PL 65-74	Population 65 to 74 years: Income in 1999 below poverty level
	BELOW PL 75+	Population 75 years and over: Income in 1999 below poverty level
	AT/ABV PL 65-74	Population 65 to 74 years: Income in 1999 at or above poverty level
	AT/ABV PL 75+	Population 75 years and over: Income in 1999 at or above poverty level
TELEPHONE	TEL 65-74	Occupied housing units: With telephone service available; Householder 65 to 74 years
	TEL 75+	Occupied housing units: With telephone service available; Householder 75 years and over
	N-TEL 65-74	Occupied housing units: No telephone service available; Householder 65 to 74 years
	N-TEL 75+	Occupied housing units: No telephone service available; Householder 75 years and over
TENURE	OWNER 65-74	Occupied housing units: Owner occupied; Householder 65 to 74 years
	OWNER 75+	Occupied housing units: Owner occupied; Householder 75 years and over
	RENTER 65-74	Occupied housing units: Renter occupied; Householder 65 to 74 years
	RENTER 75+	Occupied housing units: Renter occupied; Householder 75 years and over
VEHICLE	N-VEH 65-74	Occupied housing units: No vehicle available; Householder 65 to 74 years
	N-VEH 75+	Occupied housing units: No vehicle available; Householder 75 years and over
	VEH 65-74	Occupied housing units: 1 or more vehicles available; Householder 65 to 74 years
	VEH 75+	Occupied housing units: 1 or more vehicles available; Householder 75 years and over

Notes for Table 5.1:
1. Data source: Data in the category of LIVING ARRANGEMENT and TENURE is from SF1 while the other is from SF3.
2. Data interchangeability: Household size of population 60 years and over is used to represent that of population 65 years and over constrained by data availability.
3. Income re-groupings: Some pre-defined household income categories are combined to broader ranges tailored to the user's purpose.

5.2.1.2 PCA Extraction and Rotation

PCA extracted 10 components with eigenvalues greater than the usual default threshold of 1.0 and after inspecting the screeplot (Figure 5-1), I decided to retain five components for further analysis because of a prominent break in slope after the fifth component. As shown in Table 5-2, the five-component solution explained a total of 75.7% of the variance, with Component 1 (C1) contributing 53.6%, Component 2 (C2) contributing 10.2%, Component 3 (C3) contributing 4.3%, Component 4 (C4) contributing 4.0%, and Component 5 (C5) contributing 3.5%. I then performed a varimax rotation to minimize the number of variables loading high on multiple components for a simplified interpretation of the five components. Table 5-3 presents the factor loadings for the varimax rotated five-component solution.

Table 5-2. Percent of variance explained by the five components retained in PCA

	Initial Eigenvalues	
Component	% of Variance	Cumulative %
1	53.600	53.600
2	10.218	63.818
3	4.327	68.145
4	4.045	72.190
5	3.487	75.677

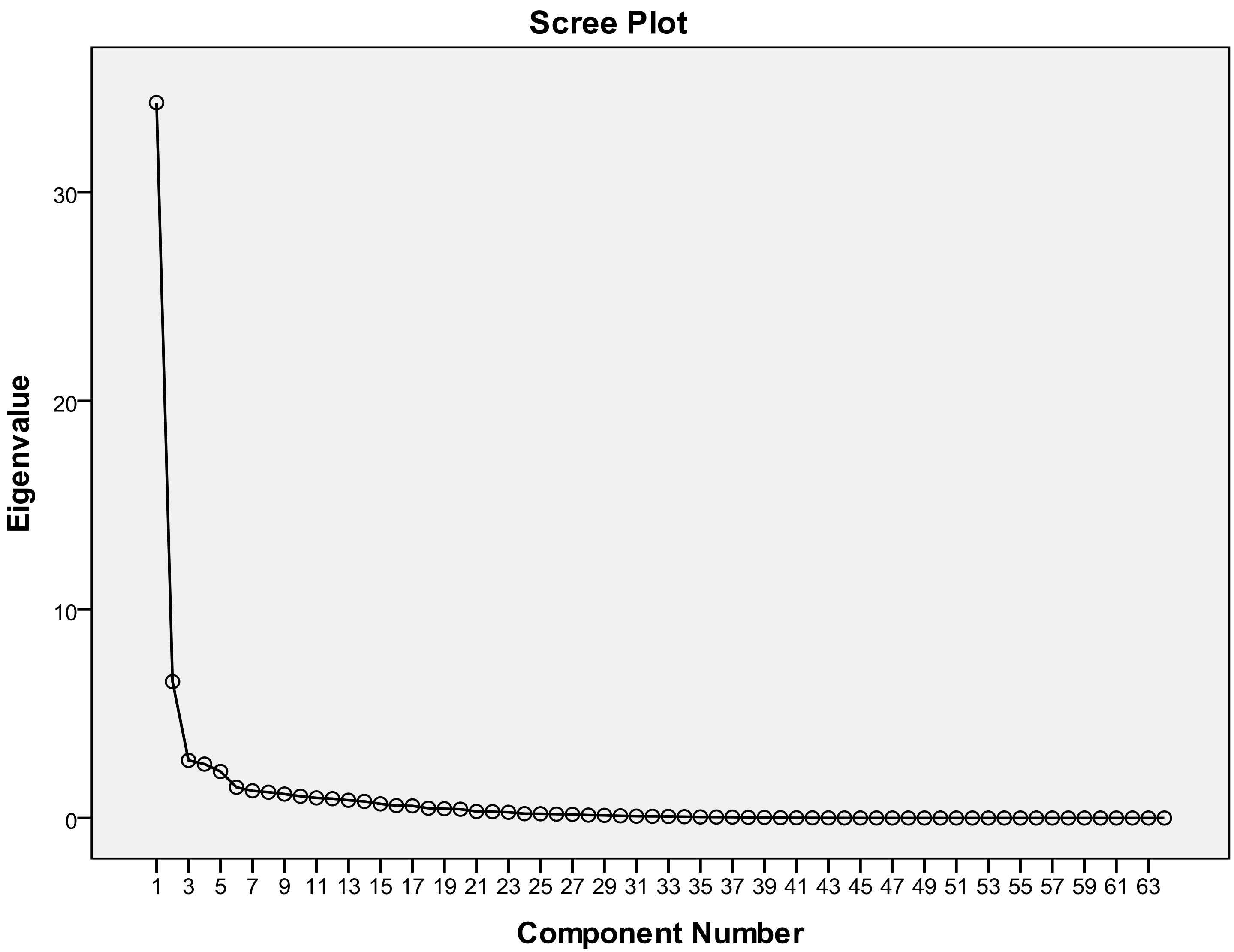

Figure 5-1. Screeplot generated by PCA

Table 5-3. Factor loadings based on five-component PCA with varimax rotation for the 64 items (N = 204)

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
OWNER 65-74	.979	.139	.023	.050	.005
F HHer 65-74	.978	.075	.017	.063	.027
F HH-1 60+	.978	.150	.024	.042	.006
HH-2+ 60+	.978	.161	.026	.043	.001
F HHer 65+	.970	.208	.009	.010	.016
F HHer 65+ CPL/N-C	.970	.197	-.002	-.003	.039
AT/ABV PL 65-74	.969	.134	-.001	.082	.038
IN F HH 65+	.968	.214	.010	.005	.009
N-DB 65-74	.966	.110	.001	.077	.113
DB 65-74	.963	.083	.001	.072	.149
VEH 65-74	.954	.096	.032	.153	-.029
TEL 65-74	.944	.114	.040	.197	-.017
F HH-1 75+	.926	.329	.006	-.037	-.020
IN HH 65+	.924	.367	.036	.024	.039
HH-2+ 75+	.922	.345	.009	-.035	-.024
IC 45-200K 65-74	.918	.011	.002	.059	.235
F HHer 75+	.908	.363	-.001	-.057	.002
OWNER 75+	.847	.467	.004	-.097	-.007
N-DB 75+	.840	.417	.023	-.059	.169
VEH 75+	.806	.506	.019	-.117	.057
AT/ABV PL 75+	.797	.558	.057	-.089	.059
N-F HHer 65-74	.759	.458	.083	.255	.076
N-F HHer 65+ N-LA	.748	.434	.077	-.006	-.094
IC 45-200K 75+	.741	.380	.018	-.086	.336
IC 10-45K 65-74	.734	.304	.045	.138	-.399
N-F HH-2+ 60+	.731	.406	.064	.041	-.101
TEL 75+	.725	.644	.059	-.079	.105
O E 65+	.672	.187	.000	.133	.089
P DB 65+	.651	.614	.026	.100	-.221
N-F HH-2+ 75+	.604	.580	.072	.026	-.079

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 10 iterations.

Table 5-3 (cont'd). Factor loadings based on five-component PCA with varimax rotation for the 64 items (N = 204)

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
F HHer 65+ CPL/C	.392	-.206	.083	.189	-.176
S E 65+	.310	.115	.109	.245	.217
HH-1 75+	.471	.840	.110	-.015	.164
N-F HHer 75+	.481	.838	.107	-.015	.154
N-VEH 75+	-.010	.800	.173	.125	.230
RENTER 75+	.023	.780	.177	.160	.302
N-F HHer 65+ LA	.585	.762	.105	.082	.149
N-F HHer 65+	.604	.753	.105	.078	.136
IN N-F HH 65+	.615	.747	.105	.077	.120
HH-1 60+	.596	.744	.108	.108	.150
DB 75+	.571	.736	.070	-.050	-.127
SC DB 65+	.237	.689	.139	.130	-.226
M DB 65+	.287	.686	.093	.164	-.186
GOH DB 65+	.492	.682	.128	.105	-.203
IC 10-45K 75+	.601	.668	.095	-.087	-.175
IC <10K 75+	.150	.646	-.062	.368	-.034
S DB 65+	.570	.621	.102	.004	-.194
BELOW PL 75+	.135	.599	-.121	.342	-.074
IN GQ N-INS 65+	-.072	.269	-.063	.056	-.095
IN GQ INS 65+	.001	.157	.973	.000	.017
IN GQ INS-NH 65+	-.003	.154	.971	-.008	.014
IN GQ 65+	-.014	.208	.947	.011	-.002
F HHer 65+ SGL/C	.030	-.026	.343	.062	-.043
BELOW PL 65-74	.146	.163	.083	.760	-.223
IC <10K 65-74	.189	.220	.058	.736	-.254
N-VEH 65-74	.038	.272	.108	.635	.171
RENTER 65-74	.124	.433	.114	.600	.316
O N-E 65+	.044	-.005	-.042	.392	.073
N-TEL 75+	-.148	.181	-.085	.240	.122
S N-E 65+	-.032	-.061	.012	.213	-.068

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 10 iterations.

Table 5-3 (cont'd). Factor loadings based on five-component PCA with varimax rotation for the 64 items (N = 204)

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
N-TEL 65-74	-.140	.142	.014	.170	.113
IC >200K 75+	.447	.061	-.043	-.016	.668
IC >200K 65-74	.533	-.139	-.031	.070	.595
F HHer 65+ SGL/N-C	.310	.304	.174	.215	-.398

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 10 iterations.

5.2.1.3 PCA Interpretation

Nearly half of the 64 items have strong loadings on C1. Here, I used 0.6 as an arbitrary threshold across which loadings were considered strong or high. The items with salient loadings on C1 refer predominantly to the young-old population (from 65 to 74 years old) who are, for example: (1) owners of their housing units (0.979); (2) at or above the poverty level (0.969); (3) disabled or not (0.963 and 0.966); and (4) with vehicle and telephone available (0.954 and 0.944). Each of these variables is consistent with one another because the ownership of housing units, telephones, and vehicles signify livelihood security, if not personal wealth. When a hurricane hits, this group perhaps is less sensitive to hurricane hazards for several reasons. First, they may have invested more in emergency preparedness and built higher coping capacity than elderly people without these attributes. Second, having a telephone enables these people to call first responders for help and to keep in touch with family members and friends during disastrous events. Having telephones available as a communication option helps people maintain information flow even though phone services can be unreliable in hard-hit areas. Third, this group can evacuate an area quickly because they possess personal transportation. In addition, owner-occupants, in contrast to renters, are more likely to undertake home maintenance (Galster, 1983; Sweeney, 1974). Consequently, owner-occupied dwellings will demonstrate higher structural resistance to the impacts of hurricane hazards than rented dwellings. Overall, these items reflect a young-old population with a solid financial base regardless of their disability status. It is therefore possible to label C1 "financially secure young-old."

It is noteworthy that there are other variables loading moderately high on C1. Interestingly, these variables are not clearly conceptually related to the aforementioned items. However, a common theme runs through a few of these variables. There are five items that represent an old-old population (75 years and older) who are: (1) family householders (0.908); (2) owners of their housing units (0.847); (3) with no disability (0.840); (4) have vehicles available (0.806); and (5) at or above poverty level (0.797). The co-residence within C1 of both the old-old and young-old population suggests analogous social vulnerability to hurricane hazards. It may further imply that being in good health and having intra-family resource sharing can counteract disadvantages among the old-old. Future studies could separate out these two groups with a closer examination.

The 16 items of C2 assemble a variety of items indicating the health, wealth, and living arrangement of the entire older population, but half of them substantially concern the characteristics of the old-old population. These eight items capture those individuals who are: disabled old-old (0.736); renters (0.780); below the poverty line (0.599, rounded to 0.6); with $10,000-$45,000 U.S. (0.668) or lower than $10,000 U.S. (0.646) yearly household income; living alone (0.840); in non-family households (0.838); and with no vehicles (0.800). The other half of the items with high loadings includes both the old-old and the young-old and pertains to different types of disability and living arrangements. C2 can thus be labeled "poor and disabled old-old with a limited social network."

The older people falling inside this category can be triply sensitive. Because the probability of losing family members increases as people age, the old-old are more likely to live by themselves and have limited family support. Simultaneously, disability minimizes their everyday activity space and accelerates the waning of social connections. The decreasing social capital and increasing health expenditure in later life further weaken economic safety nets when antecedent financial limitations associated with fixed retirement income has already put these elderly in harm's way. Therefore, this group of poor and disabled old-old deficient in social capital can be particularly disadvantaged during any phase of a disaster. For example, before the onset of a hurricane, they may have more difficulty processing risk communication because of sensory degradation. Once the hurricane hits, they perhaps have to be housebound because they have no private vehicles for evacuation or they have mobility problems. After the hurricane strike, they may find it extremely hard to negotiate the changed environment and relief bureaucracy.

Items loading significantly on C3 encompass the institutionalized elderly population living in group quarters generally (0.973) or in nursing homes particularly (0.971), and the elderly population (both institutionalized and noninstitutionalized) living in group quarters (0.947). The contents of these three items are relatively homogeneous so C3 can be labeled “elderly in group quarters.” The group comprising C3 is special not only because it casts light on the elderly not living in households, but also because the subsets of the group, institutionalized and noninstitutionalized elderly, are heterogeneous in terms of vulnerability. In the event of a hurricane, the institutionalized older populations are less socially vulnerable compared to those living in group quarters other than institutions. It is plain that tangible assets (for example, medical equipment and supplies) or intangible resources (for example, staff knowledge and skills) of nursing homes and other institutions matter to the elderly in their daily lives, let alone in times of an emergency.

Four high-loading items constitute C4, including young-old renters (0.600) without vehicles (0.635) that are either below the poverty level (0.760) or have household income less than $10,000 U.S. per year (0.736). Conceptual coherence simplifies the naming of C4: “poor young-old.” Despite the vulnerability primarily caused by poverty, better health and broader social networking that comes with being a member of the young-old population may offset the shortage of financial capital to some extent. Hence, the group may not be as vulnerable as the group making up C2, the “poor and disabled old-old with a limited social network.”

C5 is composed of two dominant items loading above or equivalent to 0.6. These items relate to the entire older population (the young-old and the old-old) that has annual household incomes greater than $200,000 U.S. Therefore, C5 can be labeled “financially affluent elderly.” Again, the level of available financial resources is an overwhelming contributor to the vulnerability of the elderly no matter what the chronological age and this group in excellent financial condition is definitely less socially vulnerable than other groups.

In summary, PCA with varimax rotation resulted in a five-component solution. The five components are "financially secure young-old," "poor and disabled old-old with a limited social network," "elderly in group quarters," "poor young-old," and "financially affluent elderly." "Financially secure young-old" is by far the strongest component and explains most of the variance among the variables. The interpretation of the five components is in accordance with the insights gained from the four-stage typology and the VSD: variations of vulnerability of the elderly are attributable to differences in chronological age, financial resources, disability, living arrangement, and social capital. The PCA results support the use of these indicators for assessing the elderly's social vulnerability to hurricane hazards in Sarasota County.

5.2.2 The Spatiality of Social Vulnerability

5.2.2.1 Social Vulnerability Indices (Component Scores)

I employed the component scores generated by PCA to estimate each block group's ranking on the five components. PASW18 offers three methods for computing component scores: regression, Bartlett, and Anderson-Rubin. Each has its own strength and weakness because of the different mathematics involved. I used the preselected regression-based approach to compute the scores of every census block group on a particular component. Under this process, the generated component scores are also normalized to means of 0 and standard deviations of 1.

Then I imported the scores into the ArcGIS10 environment and joined them with the geographical layers of Sarasota County (downloaded from the 2010 Census

TIGER/Line® Shapefiles). To understand the spatiality of social vulnerability within the study area, I mapped the component scores by census block group using a standard deviation classification method. In this manner, the actual component scores for the five components are not displayed, but the dispersions of the values above or below the means are represented. The subsequent maps illustrate the block group-based social vulnerability associated with the elderly population in Sarasota County. Note that the mathematical sign representing more social vulnerability varies from positive to negative with the component, so I will specify that sign in each case from figure to figure. Despite the discrepancies in mathematical sign, all of the maps adopt the same class breaks with red or blue at the two ends of the color spectrum always signifying a high or a low social vulnerability. The consistency of symbology (i.e., classification and color schemes) across the figures makes it easier to compare a block group's placement on each component of social vulnerability.

5.2.2.2 Social Vulnerability by Principal Component

Figure 5-2 depicts the component scores for C1, "financially secure young-old." Because younger and wealthier elderly are less vulnerable than the average older population, block groups with negative standard deviations are considered more vulnerable and the greater the deviations, the higher the vulnerability. The most remarkable aspect of the distribution is the large proportion of the City of Sarasota except Lido Key dominated by vulnerable block groups (beyond -1.5 standard deviations in red and beyond -0.5 in orange). Many of these block groups correspond to African-American, Hispanic, and Amish neighborhoods. One interesting finding is that St.

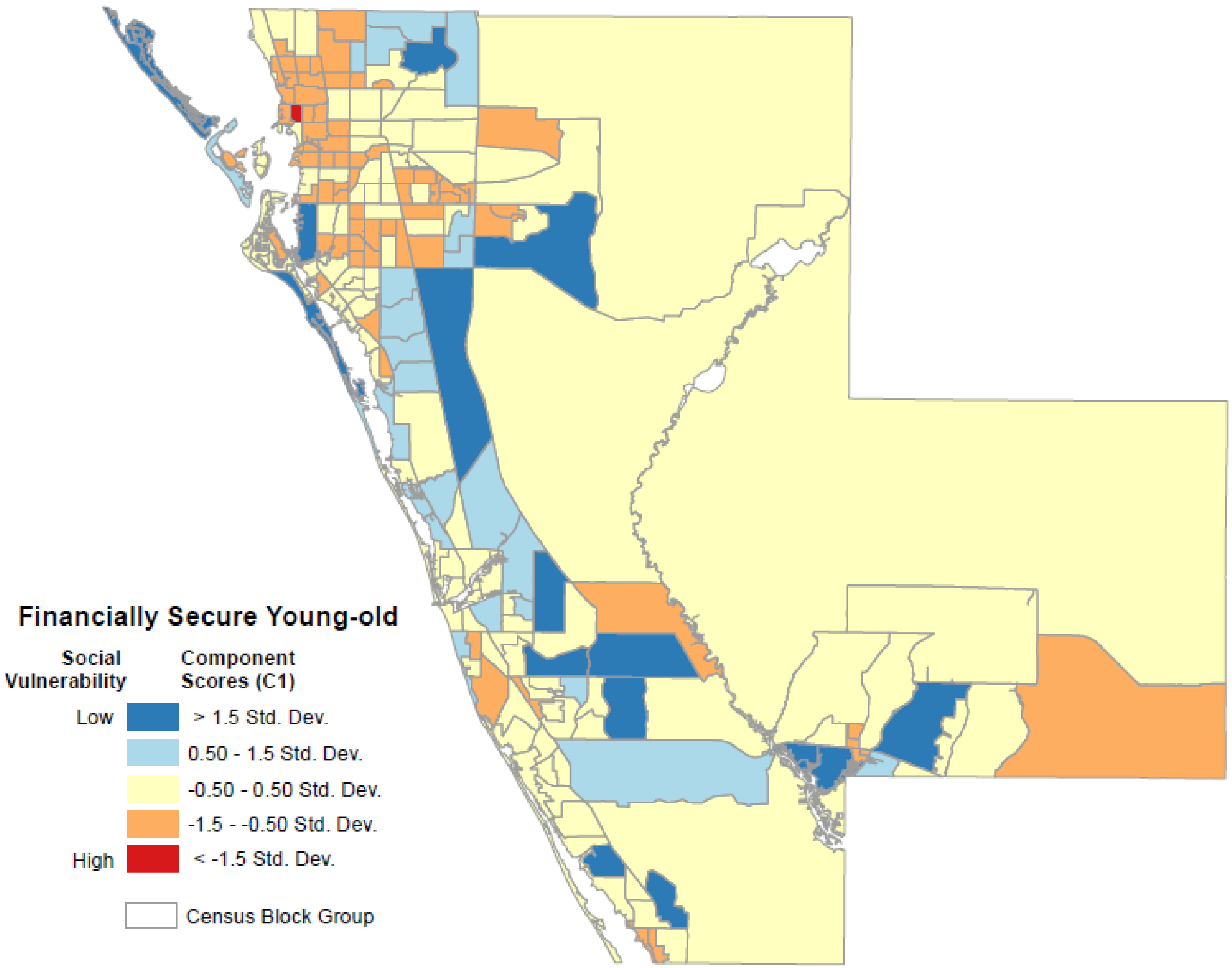

Figure 5-2. C1 component scores

Armands Circle falls into the second most vulnerable category. Renowned as a high-end island shopping center for affluent tourists nestled between Sarasota Bay and the Gulf of Mexico, St. Armands Circle's expected low social vulnerability is skewed by the more than 300 elderly residents of the not-for-profit Plymouth Harbor continuing care retirement community located on adjoining Coon Key, but in the same block group. Otherwise, the least vulnerable block groups (beyond 1.5 standard deviations in blue) tend to be found mostly in the inhabited part of the county, such as Palmer Ranch (an oversized block group next to the west of I-75), Longboat Key, and the southern portion of Siesta Key. Note that the young-old living on the keys are greatly physically vulnerable to hurricane hazards but their social vulnerability is at a lower level thanks to a sound financial condition.

Figure 5-3 visualizes the component scores on C2, "poor and disabled old-old with a limited social network." As noted earlier, the elderly who belong to this category are extremely vulnerable because C2 is a collection of individuals with characteristics likely to make them more vulnerable: poverty, disability, older chronological age, and declining social capital. The block groups marked by positively large standard deviations are the vulnerability hotspots. Numerous block groups express highest component scores (> 1.5 standard deviations in red) with many concentrated in the City of Venice or the City of Sarasota and some scattered around the unincorporated areas of the county. Some of the most vulnerable block groups in Venice relate to areas with high concentrations of mobile home parks (Figure 5-4) and the correspondence is not ungrounded considering mobile home parks can provide affordable housing alternatives for poorer elderly. Some of these block groups actually are considered to be less vulnerable in C1 and the sharp

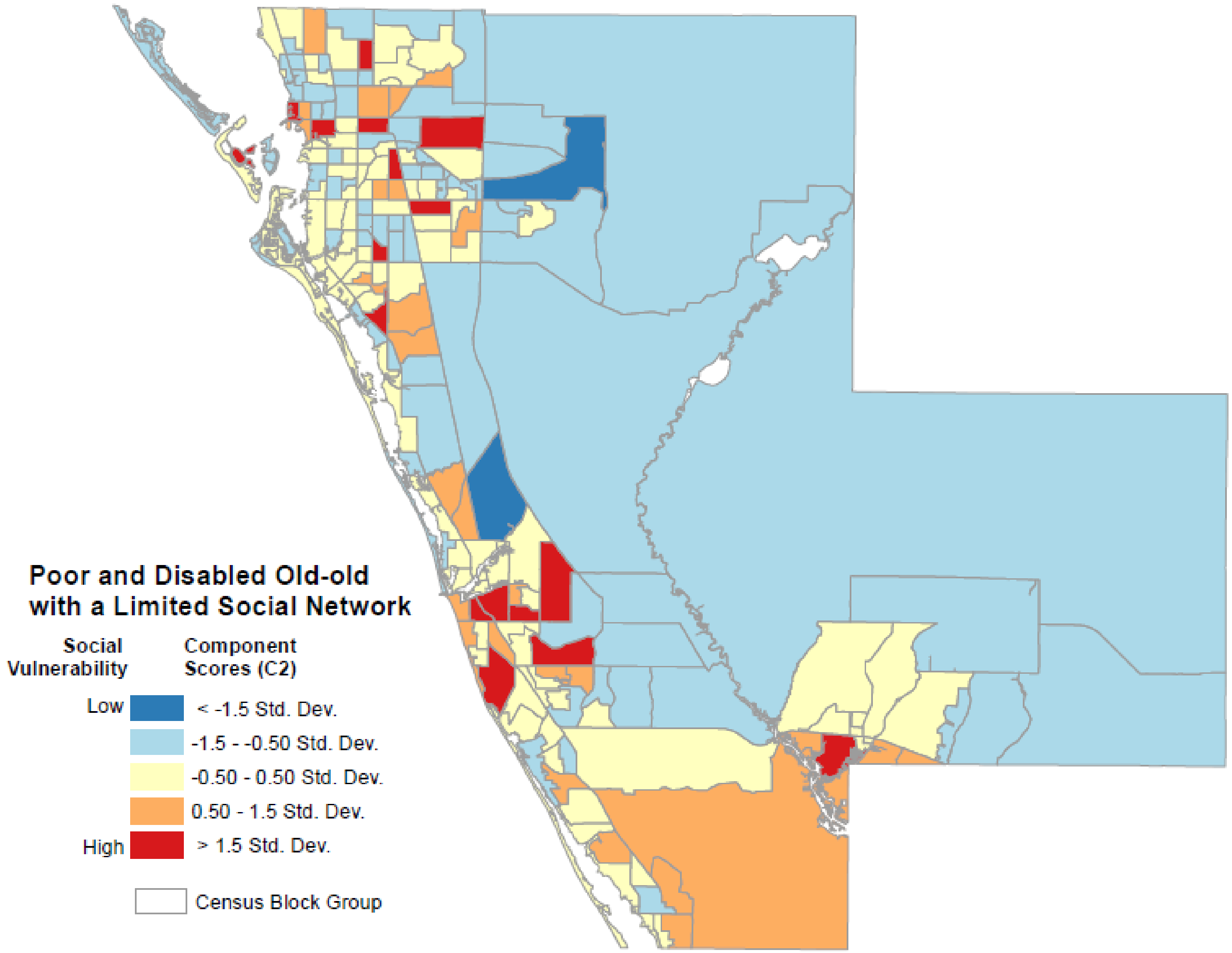

Figure 5-3. C2 component scores

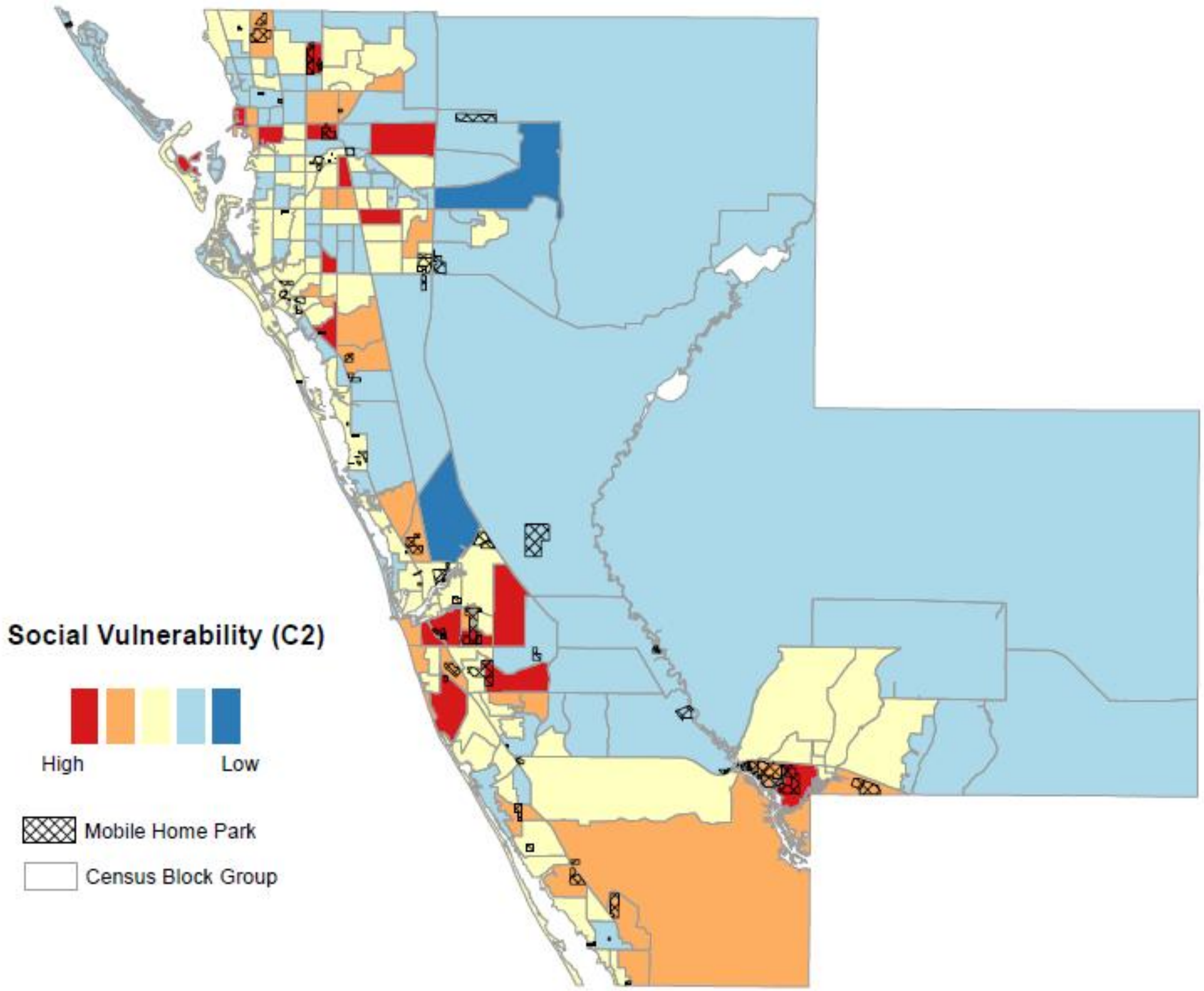

Figure 5-4. C2 social vulnerability overlaid with mobile home parks in Sarasota County

increase in degree of vulnerability from C1 to C2 suggests, at least for Venice, the young-old are better off whereas the disadvantaged old-old are the major driving force of the city's high social vulnerability. A similar relationship applies to one block group containing major mobile home parks in North Port near the county border. Within Sarasota City, St. Armands Circle reappears in the list of most vulnerable block groups for the reason noted above. Sarasota city's downtown area also displays extremely high vulnerability; presumably the old-old living in the 75 government-subsidized housing units at McCown Towers contribute to its greater scores on C2. Less vulnerable block groups (beyond -0.5 and -1.5 standard deviations) are predominantly located in the less inhabited and uninhabited areas (east and north of I-75), not excluding some populated areas such as Longboat Key, the northern part of Siesta Key, and Palmer Ranch.

The scores on C3, "elderly in group quarters," are mapped in Figure 5-5. Unlike those living in private households, the elderly residing in group quarters are unrelated persons so that the loose bonds they have with the wider community leads to low social cohesion. Moreover, they normally have severe physical or mental illness, requiring assistance for basic living activities and even long-term medical care. Generally speaking, the institutionalized elderly with access to authorized care are less vulnerable than the noninstitutionalized elderly living in group quarters other than institutions, although both tend to be more vulnerable than the elderly living in private households. In Figure 5-5, block groups with scores greater than positive 1.5 standard deviations on C3 are most vulnerable. Nearly a score of block groups comprise this category and again are most concentrated in poorer neighborhoods in the City of Sarasota at considerable distance from the coast. Other block groups that top the vulnerability list scatter across

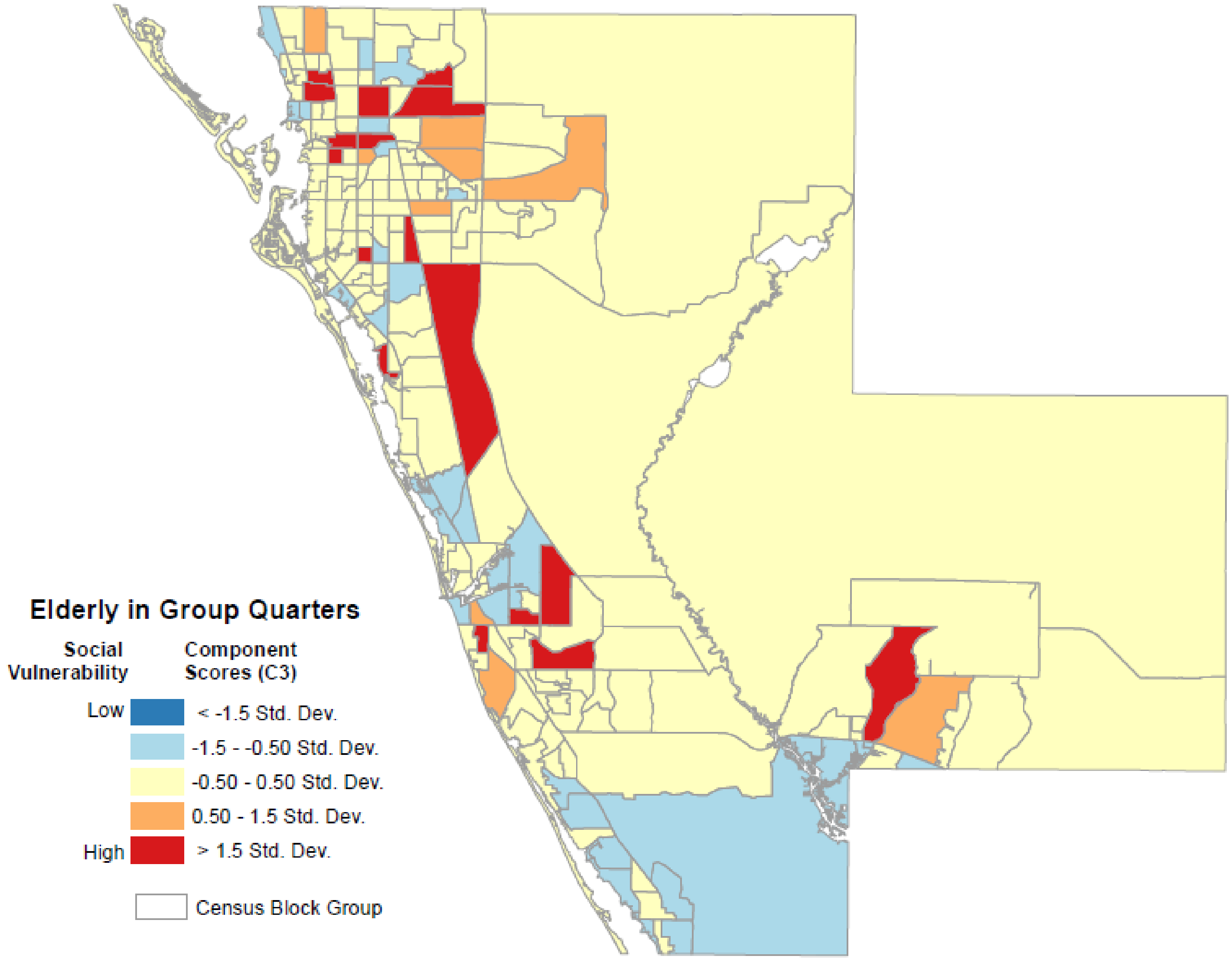

Figure 5-5. C3 Component Scores

inland areas of Sarasota County covering the City of Venice, the City of North Port, and in unincorporated areas such as Palmer Ranch. The locations of these vulnerability hotspots echo the distribution of nursing homes for the elderly identified in the previous chapter (Figure 5-6). No block group is classified into the lowest category (< -1.5 standard deviations) whereas quite a few are colored in light blue translating to a medium-to-low vulnerability. However, it is important to track these block groups because they can evolve to vulnerability hotspots when the elderly who opt for independent living at home ("aging-in-place") become less able to care for themselves.

Maps for C4 and C5, "poor young-old" and "financially affluent elderly," are delineated in Figures 5-7 and 5-8, respectively. For C4, the most vulnerable block groups (> 1.5 standard deviations) occur most often in the African-American and Hispanic parts of the City of Sarasota and some areas along the tributaries of the Myakka River in the City of North Port. In unincorporated areas, the vulnerability hotspots are situated in Palmer Ranch, again most likely because of the large mobile home estates in this area. Also of interest is the moderately high vulnerability demonstrated by the census units of Longboat Key (particularly the northern portion), Lido Key, and Siesta Key as they showed either a neutral or a low level of vulnerability in the first three components (C1 to C3). These areas are affluent and have a large number of automobiles. The explanation for this anomaly is that the renter population in these three desirable barrier island locations is so high that it overwhelms the other three variables that load highly on C4. With regard to C5, the lowest scores (< -1.5 standard deviations) represent the poorest elderly and thus the highest vulnerability. The vulnerability hotspots are overwhelmingly located in North Port close to the boundary between Sarasota and Charlotte County.

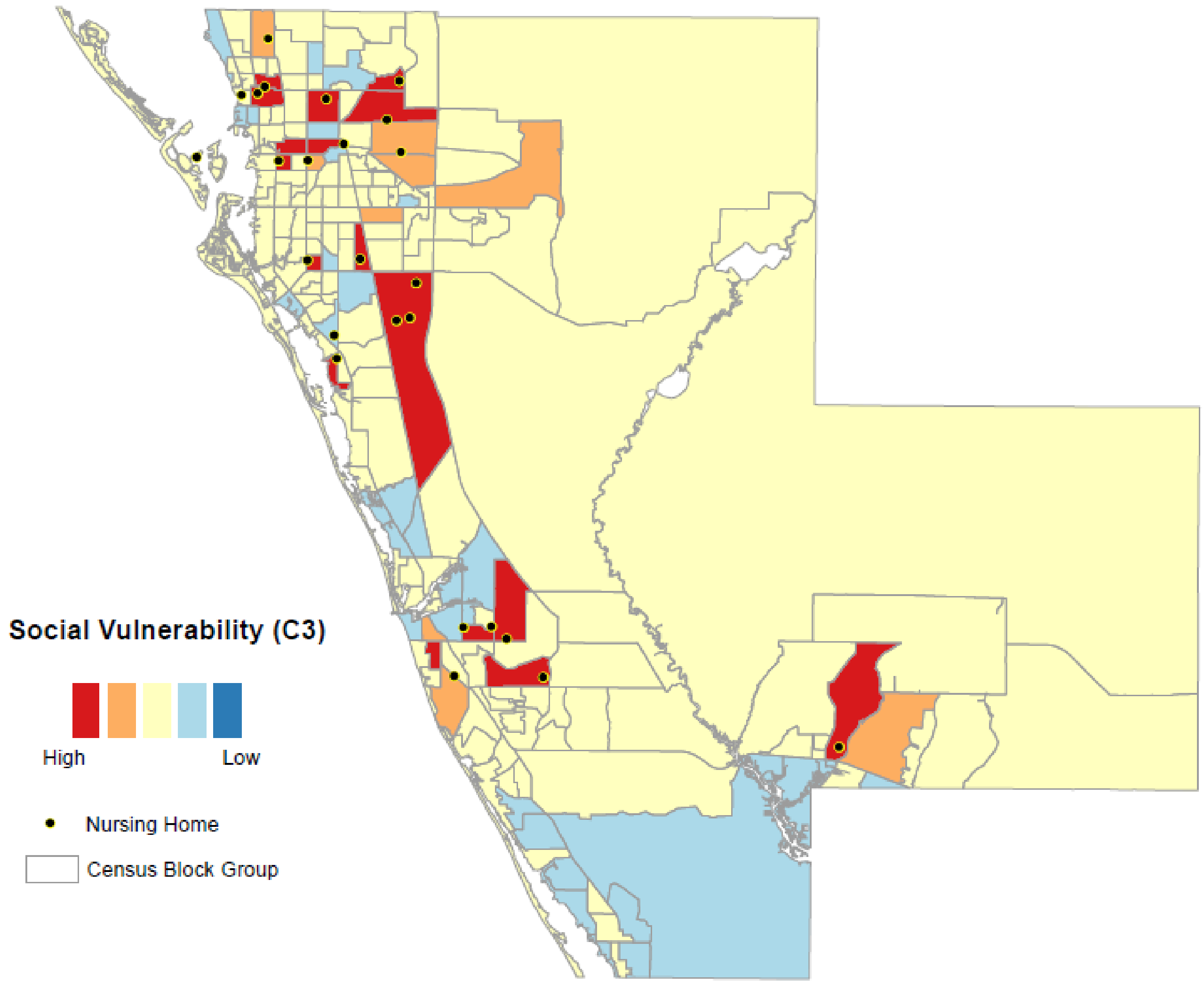

Figure 5-6. C3 social vulnerability overlaid with nursing homes in Sarasota County

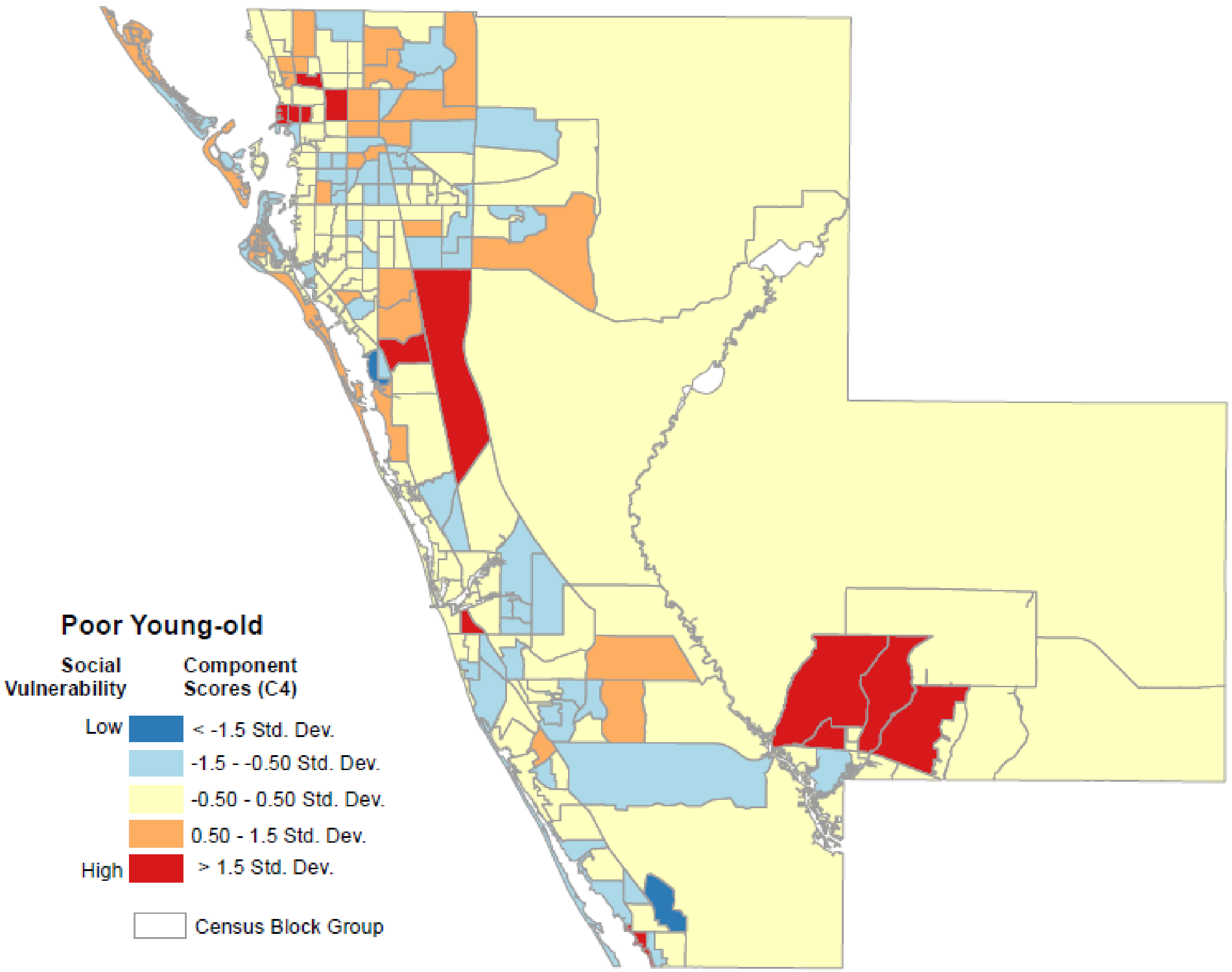

Figure 5-7. C4 component scores

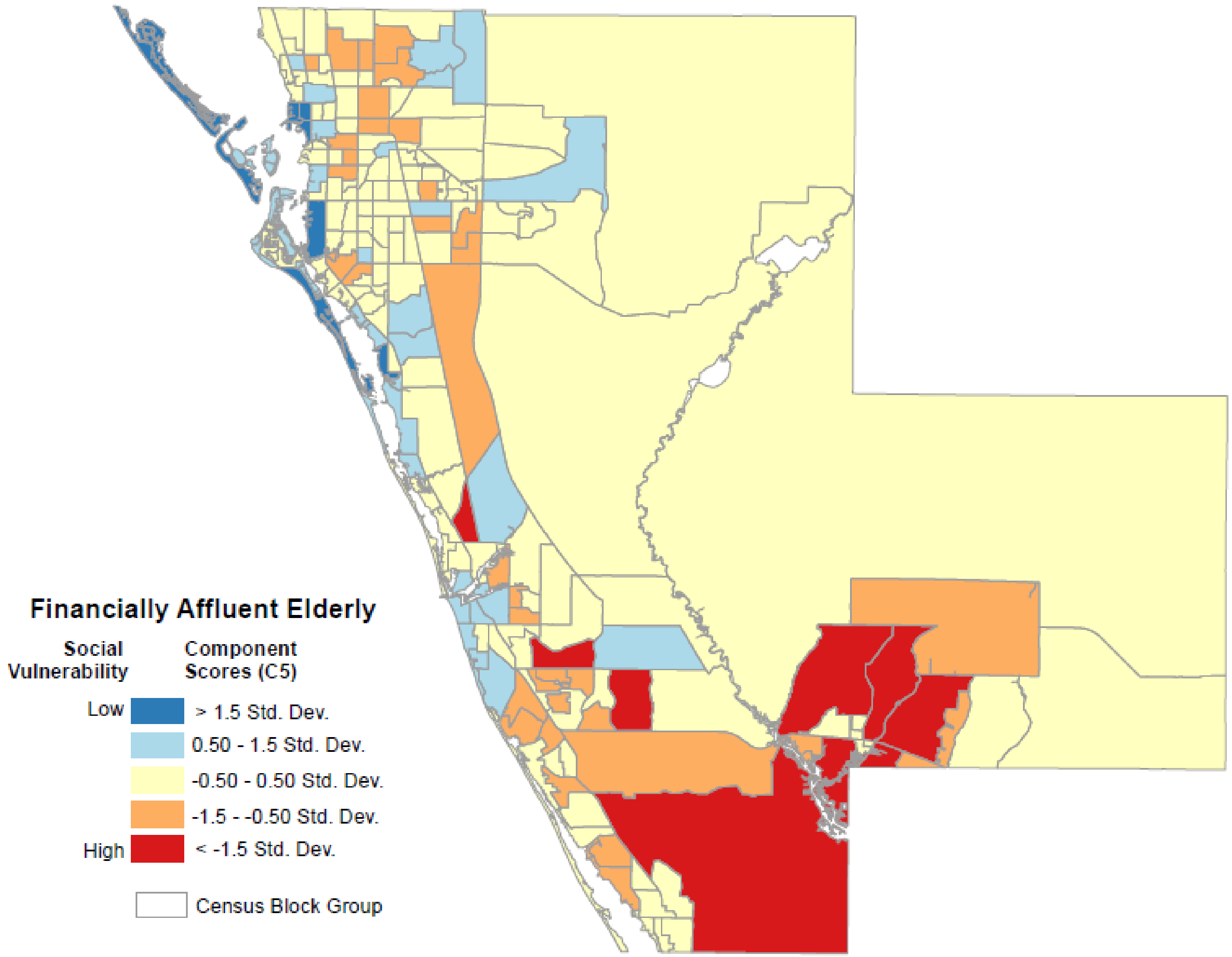

Figure 5-8. C5 component scores

5.3 Summary

This chapter performed an indicator-based analysis of potential social vulnerability of Sarasota's elderly population and produced five separate social vulnerability indices to assess the degree and composition of their social vulnerability. The five indices have their basis in the five principal components from the PCA, which extracts key socioeconomic and demographic determinants of the elderly's sensitivity and adaptive capacity. Note that there are more individual variables with high loadings on these components than the general names can express. Among the five components, higher positive scores on the "poor and disabled old-old with a limited social network" (C2), "elderly in group quarters" (C3), and "poor young-old" (C4) mean greater social vulnerability while higher absolute negative scores on "financially secure young-old" (C1) and "financially affluent elderly" (C5) translate into greater social vulnerability. Social vulnerability hotspots, including the most and second-most socially vulnerable block groups, are marked with red and orange, respectively, on the maps.

This analysis conducted at the census block group level allows a detailed, but limited illustration of the spatial variations in vulnerable segments of the older population. In general, for each component, the most socially vulnerable places in Sarasota County are situated inland, away from the most desirable and expensive coastal locations. Some of these socially vulnerable places may also be physically vulnerable because of their exposure to hurricane storm surge, especially block groups located in low-lying Venice and Northport. The City of Sarasota is of special interest because of the high density of social vulnerability hotspots (see Figure 5-9) across all the components, which correspond to the African-American, Hispanic, and Amish

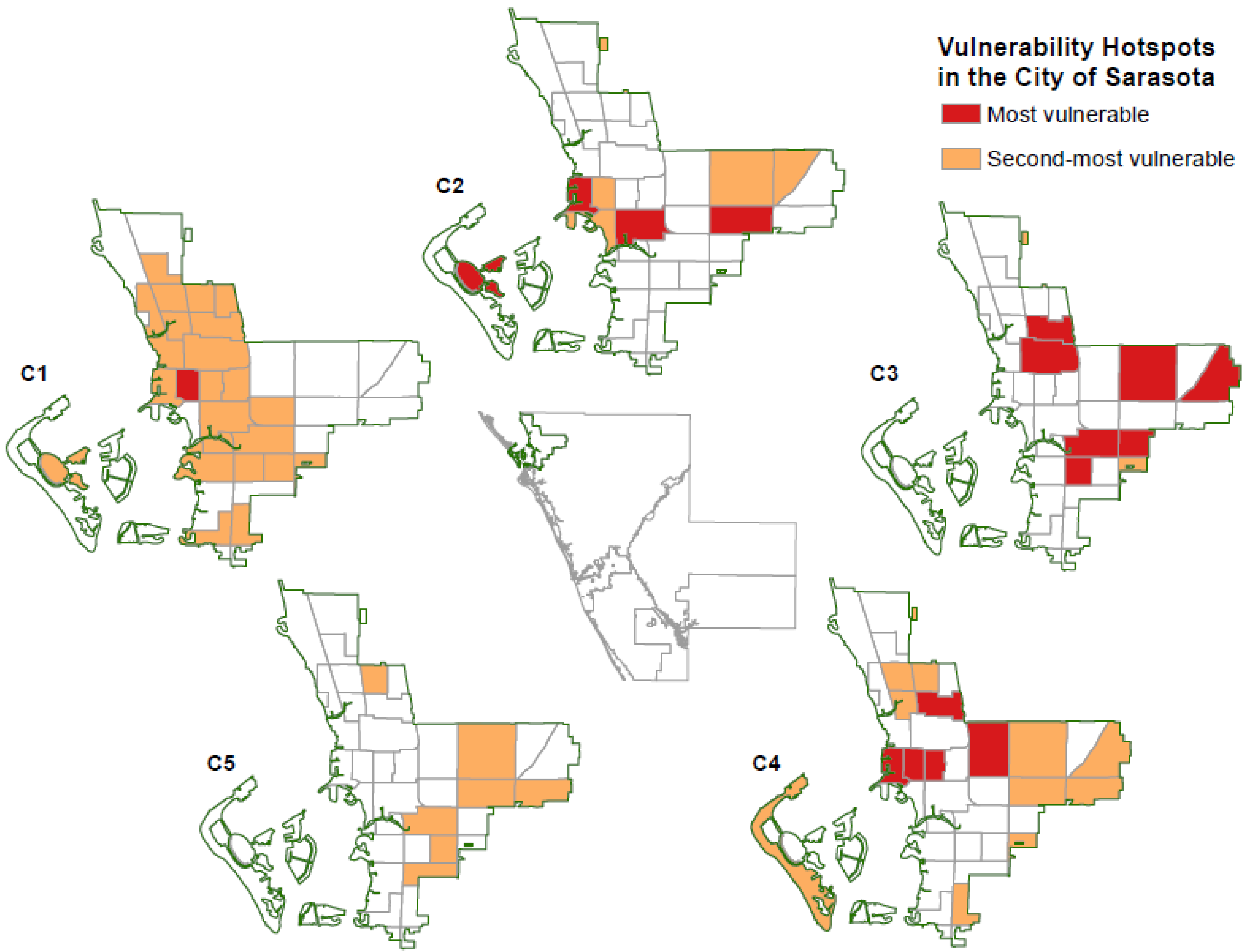

Figure 5-9. Social vulnerability hotspots associated with the elderly in the City of Sarasota

neighborhoods and to areas with high concentrations of mobile homes, nursing homes, and assisted living facilities.

This analysis uses separate vulnerability indices to respect the multidimensional nature of vulnerability of the elderly without obscuring key information by aggregation. Because the elderly in any one block group can have a high score for one component and a low score for another, aggregating component scores to build a single vulnerability index could counterbalance each other and, as a result, produce a neutral score for the block group that, in turn, could lead decision makers to conclude the elderly in that place are not socially vulnerable. To illustrate, Figure 5-10 is a map showing a composite social vulnerability index that assumes equal contribution (i.e., equal weighting) of each component to the overall social vulnerability. It is still possible to locate the most socially vulnerable places and it still describes the City of Sarasota as a top concern. However, the loss of understanding provided by the separate components is not negligible. For instance, Venice is neutrally vulnerable or less vulnerable measured by the composite index (Figure 5-10) whereas the city does have several block groups that rank high on C2 and C3 (Figure 5-3 and 5-5), meaning they are socially vulnerable because of the presence of the poorest old-old and the largest number of the elderly in group quarters.

To sum up, mapping the social vulnerability of Sarasota's elderly by individual principal component maintains the identity of the latent drivers of social vulnerability and emphasizes how and in what ways the elderly are vulnerable. It further provides the basis for enlightened vulnerability-reduction by decision makers.

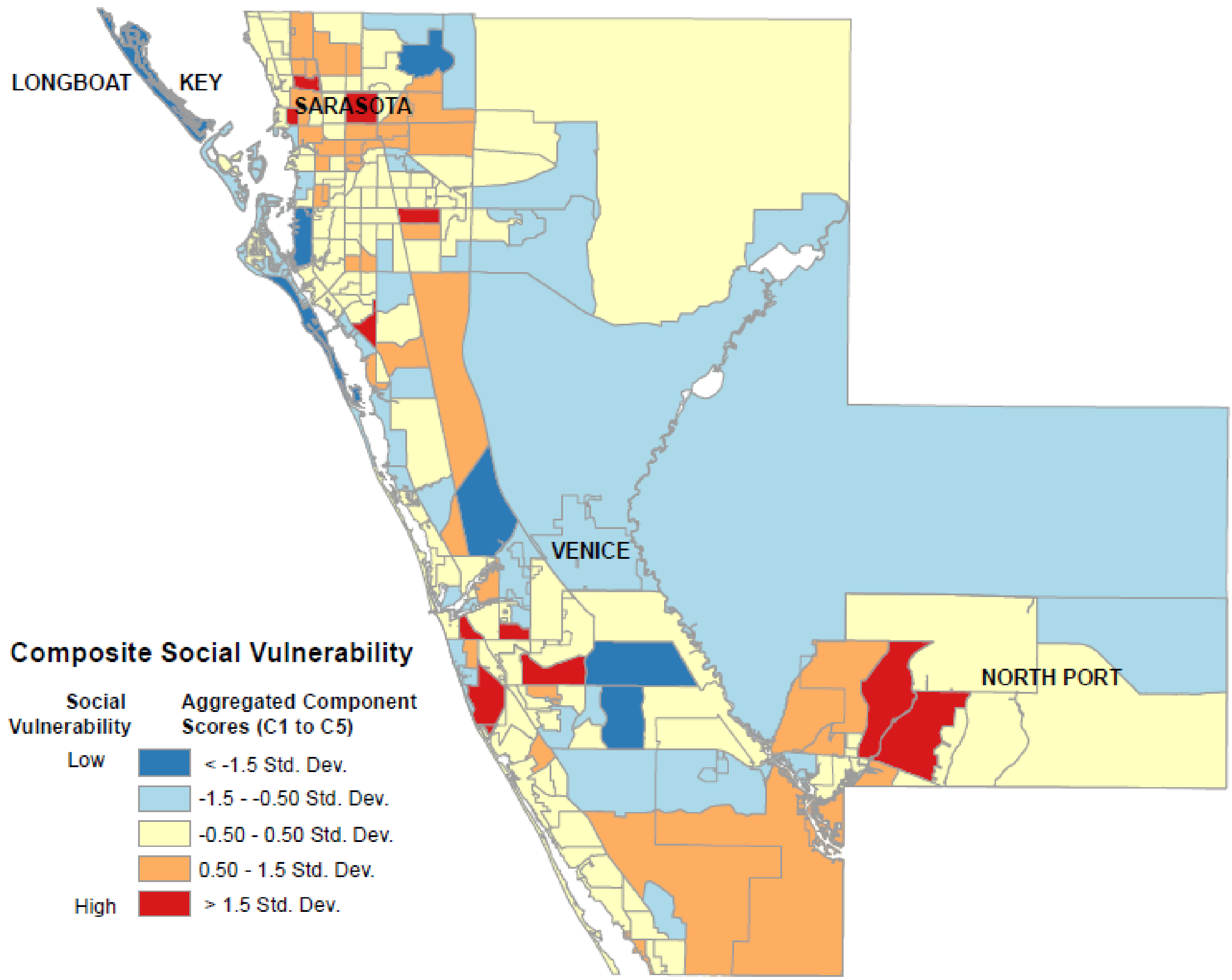

Figure 5-10. The composite social vulnerability of the elderly in Sarasota County

CHAPTER 6

CONCLUSIONS

6.1 Thesis Overview

The preceding chapters have investigated the vulnerability of the elderly to hurricane hazards in Sarasota County, Florida. In Chapter 1, I introduced the key concepts of elderly and vulnerability, reviewed the literature on the issue of vulnerability and elderly from different disciplinary perspectives, established the study problem, and presented my research questions. This thesis posed one overarching research question: How vulnerable are the elderly to hurricane hazards and are all elderly people equally vulnerable? To address the key central question, the thesis narrowed the focus to three subsidiary research questions: (1) What are important indicators of the vulnerability of the elderly? (2) How does geographical location shape vulnerability? (3) How do socioeconomic attributes shape vulnerability?

In Chapter 2, I briefly discussed the methods used to answer the research questions and provided the rationale for using those methods. Corresponding to the three secondary questions, this thesis implemented a three-phase study. Corresponding to the first phase, Chapter 3 had the objective of identifying viable vulnerability indicators for the elderly. In that chapter, I presented an indicator analysis summarizing the characteristics of the elderly during a hazardous event. I identified indicators and proxy variables by using a four-stage typology and organized the results with the aid of the Vulnerability Scoping Diagram. Corresponding to the second phase, Chapter 4 aimed to delineate the exposure of the elderly to hurricane hazards in the ArcGIS environment based on the outputs from the SLOSH model and FEMA FIRMs. In the chapter, I looked at the interplay of location and vulnerability and performed a physical vulnerability assessment by placing the elderly's distribution over the defined hurricane hazard zones. Corresponding to the third phase, Chapter 5 assessed the social vulnerability of the elderly by illustrating how socioeconomic and demographic profiles of the elderly affect their vulnerability. In the chapter, I created social vulnerability indices by applying Principal Component Analysis to census block group data and mapped those indices in the ArcGIS environment to represent the variations in vulnerable segments of the elderly over the county. This chapter (Chapter 6) synthesizes insights gained from Chapters 3 to 5 and summarizes the most important findings of the thesis. It also suggests some caveats to, and limitations of the thesis and includes opportunities for future work.

6.2 Research Findings

6.2.1 Phase I: Indicator Identification and Selection

This phase answered the first subsidiary research question concerning important vulnerability indicators and proxy variables for the elderly. The identification of suitable vulnerability indicators is an important task prior to vulnerability assessments. In this phase, I identified and selected indicators for the social vulnerability of the elderly. They are financial capital, aging-in-place, risk perception, health and nutrition, physical and mental changes, social capital and living arrangement, psychological impacts, and educational attainment.

Some of the more generic indicators, such as financial and social capital, have repeatedly appeared in social vulnerability analyses. Nonetheless, these indicators of social vulnerability can affect the elderly disproportionately in comparison with younger generations. For example, financial capital is a fundamental limitation to coping capacity among the elderly because the majority living on fixed retirement income will find it difficult to prepare for and recover from disasters without external assistance. Social capital and living arrangement is another critical indicator for the elderly's vulnerability because it is linked to income, health status, and the availability of caregivers. The elderly, particularly in their eighties or nineties, are more likely to experience a diminished social cycle associated with loss of spouse and retirement from full-time employment. Accordingly, they have limited social networks to activate for marshalling the resource to respond to and recover from a disaster.

In addition to these generic indicators, I proposed several elderly-specific indicators, such as the indicators of physical and mental changes, and aging-in-place. Some frailties accompany aging is age-dependent degradations in hearing, vision, cognition, and mobility. Relatively speaking, the elderly often have difficulty obtaining necessary assistance because of progressive physical and mental impairments and thus demonstrate a higher vulnerability throughout a disaster. Although aging-in-place allows the elderly to have a choice in their care and living arrangements, negative outcomes may arise from getting old at home. During a disaster, the elderly dependent on routine health care are vulnerable from service interruptions. Moreover, homes age as people age. With home design overlooking the special needs of the older people, aging-in-place can increase the vulnerability of those uninstitutionalized elderly during a disaster even though it attends to the need for autonomy.

6.2.2 Phase II: Physical Vulnerability

This phase dealt with the second subsidiary research question about the interaction between geographical location and vulnerability among the elderly. A physical vulnerability assessment of the elderly characterized this phase. I examined the spatial patterns of potential storm surge and flooding from hurricanes, and depicted the locations of critical structures and the elderly population. In accordance with the perspective treating physical vulnerability as a preexisting condition primarily caused by the dimension of exposure, the elderly are only considered vulnerable to hurricane hazards when they reside in the hurricane hazard zones in the analysis. To discern how the elderly place themselves in relation to storm surge and flood risk zones and in turn their physical vulnerability, I used a GIS to overlay the distributions of the elderly and hurricane hazards.

Because Sarasota County has very little relief, a large proportion of the county is vulnerable to storm surge and floods produced by hurricanes. The results showed the barrier islands, low-lying coastal areas, and inland areas in the vicinity of the Myakka River are most prone to these hurricane hazards. About 4 percent of the county is currently at risk of storm surge from the weakest (category 1) hurricanes whereas over 20 percent is susceptible to storm surge from the strongest (category 4-5) hurricanes. Precipitation-induced flooding from hurricanes may exacerbate the impacts caused by storm surge and affect locations much farther inland. Currently, approximately 20 percent of the county's total land area is located in the high risk zones subject to 100-year floods. The majority of the county's evacuation routes and hospitals can be exposed to a combined storm surge and flood risk in the worst cases.

It is evident that many of the elderly in Sarasota County have put themselves in harm's way by occupying the barrier islands and low-lying portions categorized as storm surge and flood risk zones. A substantial number of the elderly live on Longboat Key, the southern portion of Siesta Key, coastal Sarasota and coastal Venice, and parts of inland North Port around the Myakka River. These elderly are thus most physically vulnerable to the compound hazard of hurricane storm surge inundation and precipitation-induced floods. In addition, the county has a concentration of nursing homes or assisted living facilities for elderly built in the storm surge and flood risk zones. Future decision-making should steer the development of the institutions for the elderly away from these higher risk areas.

6.2.3 Phase III: Social Vulnerability

This phase responded to the third subsidiary research question regarding the interplay of socioeconomic status and vulnerability among the elderly. The impacts of hurricanes on the elderly depend on a set of interlocking factors, some of which have to do with location and some with the socioeconomic characteristics of the people living there. The social vulnerability assessment of this phase accounted for the dimensions of sensitivity and adaptive capacity of the elderly.

Here, the assessment created five social vulnerability indices in each census block group thereby making it possible to examine different elements of the elderly's social vulnerability. The five indices were based on the component scores generated in the Principal Components Analysis. The PCA with varimax rotation extracted five components including "financially secure young-old," "poor and disabled old-old with a limited social network," "elderly in group quarters," "poor young-old," and "financially affluent elderly." They together explained a total of 75.7% of the variance, suggesting the variations of the social vulnerability among the elderly, for the most part, were attributable to differences in chronological age, financial resources, disability, living arrangement, and social capital. Among the five principal components, "financially secure young-old" accounted for most of the variance among the variables and thus implied being younger and wealthier than the average older population mattered most in determining the social vulnerability of Sarasota's elderly.

These separate social vulnerability indices by individual principal component were well suited for illustrating both the degree and composition of the elderly's social vulnerability. For example, both the young-old and old-old in the City of North Port near the boundary between Sarasota and Charlotte County are most socially vulnerable because they in general tend to be poor. The elderly in the City of Venice are greatly socially vulnerable because many are disabled old-old who lack both financial and social capital. The City of Sarasota is of special interest because of its high density of socially vulnerable elderly. Within this city, a large proportion is occupied by socially vulnerable hotspots for different reasons: certain block groups near the beachfront have high concentrations of poor old-old while those situated farther inland have a greater number of the elderly (including young-old and old-old) in nursing homes and assisted living facilities. Overall, the elderly of highest social vulnerability are overwhelmingly located in the areas away from the coast, which correspond to the African-American, Hispanic, and Amish neighborhoods as well as the areas with major developments of mobile home parks and institutions for the elderly. The elderly on the barrier islands have relatively low social vulnerability because they are wealthier regardless of the chronological age.

6.3 Conclusions

This thesis analyzed the vulnerability of the elderly of Sarasota County, Florida to storm surge inundation and precipitation-induced floods resulting from hurricanes. The analysis synthesized both physical and social vulnerability to address the overarching research question: how vulnerable are the elderly to hurricane hazards and are all elderly people equally vulnerable? The message from the analysis is clear: the elderly in the study area are by no means equally vulnerable and they are vulnerable to hurricane hazards in different ways.

Hurricane-induced storm surge and flooding presents a considerable physical threat to the elderly inhabitants of the barrier islands. This segment of the older population is most exposed to hurricane hazards, but is in better financial condition and is thereby less socially vulnerable. In contrast, the elderly at significant distance from the beachfront are far less physically vulnerable but are most sensitive to the hazards and are least likely to cope in times of a disaster. The analysis calls attention to parts of the City of Sarasota and North Port. These locations are home to the most socially vulnerable elderly who may be spared from hurricane hazards caused by weak and moderate storms but can potentially suffer disproportionately when a stronger hurricane hits the area.

Vulnerability-reduction policies should be tailored to the patterns of the vulnerability among the elderly. For instance, perhaps for the elderly on barrier islands, it is imperative to have a well-designed road network to channelize traffic and preserve road accessibility so that they can be evacuated in a timely fashion during a hurricane; for those living farther inland, perhaps it is more important to ensure an equal access to resources and services during emergencies and non-disaster times by relating the policies to larger development planning for the community.

6.3.1 Significance and Contribution

The U.S. population is aging rapidly. The changing demographics have presented a challenge for emergency management professionals. Knowledge of where the vulnerable elderly are located within communities and the nature of their socioeconomic circumstances is an important step towards effective emergency management. This thesis, to the best of my knowledge, helps to fill a void in research on vulnerability of the elderly as the only analysis that specifically addresses the vulnerability of the elderly within a particular geographical domain.

The analysis has generated several important findings. First, it has located the elderly in coastal Florida, examined their occupancy of hurricane hazard risk zones, and illustrated how the elderly spatially intersect with vulnerable places. Second, by integrating the physical and social vulnerability in the analysis, the results have demonstrated the degree and composition of the vulnerability, highlighting the diversity of vulnerability of the elderly over space. Third, the analysis has provided information to local planners and emergency managers for developing well-tailored vulnerability-reduction for the elderly.

6.3.2 Limitations and Future Work

The thesis does not cover all aspects of the vulnerability of the elderly. In the analysis, I failed to pinpoint the exact locations of every elderly individual. We cannot assume the elderly are evenly distributed within each census block group. Moreover, I was not able to trade the more plentiful census block group data for the more limited, but higher spatial-resolution data at the census block level. The U.S. Census Bureau does not provide much socioeconomic data at a smaller scale out of concerns for privacy. Although higher-resolution data would permit a more accurate analysis, the coarser data at the census block group level were still adequate to make some basic points about the vulnerability of the elderly in the study area.

Several important aspects of vulnerability have not been addressed because they are beyond the scope of this thesis. Although the numerical metrics and measures have shed light on the physical and social vulnerability of the elderly, full understanding of the interactions between the two can only be achieved through subsequent field research and qualitative methods. The temporal aspects of vulnerability are also not addressed in the work. The temporal context will yield additional insights into the vulnerability of the elderly because the study area has a distinct seasonal flow of population and thus changing seasonal exposure to hurricane hazards. The potential impacts from climate change are not discussed, either. While projected increases in hurricane frequency and intensity are uncertain, future hurricane damages will be exacerbated by rising sea levels. Last but not least, gender and race can be confounding factors in the vulnerability of the elderly to hurricane hazards, pointing to another major remaining field of research.

REFERENCES

AARP. 2005. *Livable Communities & Aging In Place.* Available from http://www.aarpinternational.org/gra_sub/gra_sub_show.htm?doc_id=562789 (last accessed May 19, 2011).

AARP. 2006. *We Can Do Better: Lessons Learned for Protecting Older Persons in Disasters.* Available from http://assets.aarp.org/rgcenter/il/better.pdf (last accessed May 19, 2011).

AARP. 2010. *Rx Price Watch Report: Trends in Retail Prices of Brand Name Prescription Drugs Widely Used by Medicare Beneficiaries 2005 to 2009.* Available from http://assets.aarp.org/rgcenter/ppi/health-care/rxpricewatch.pdf (last accessed May 19, 2011).

Adger, W.N. 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *World Development* 27: 249–269.

Adger, W.N., Brook, N., Bentham, G., Agnew, M. and Eriksen, S., 2004. *New Indicators of vulnerability and adaptive capacity. Tyndall Centre for Climate Change Research*, *Technical Report 7*. School of Environmental Sciences, University of East Anglia, Norwich, UK. Available from http://www.nickbrooks.org/publications/TynRepIT1_11.pdf (last accessed May 19, 2011).

Adger, W. N., T. P. Hughes, C. Folke, S. R. Carpenter, and J. Rockstrom. 2005. Social-Ecological Resilience to Coastal Disasters. *Science* 309 (5737):1036-1039.

Adger, W. N. 2006. Vulnerability. *Global Environmental Change* 16 (3):268-281.

Arbore, P. 2007. Why do elders resist evacuation when natural disasters strike? *Healthcare and Aging* 14 (4). Winter 2007.

Associated Press. October 23, 2005. *Rich or poor, most Katrina victims were seniors.* Available from http://www.msnbc.msn.com/id/9797302/ns/us_news-katrina_the_long_road_back/t/rich-or-poor-most-katrina-victims-were-seniors/ (last accessed May 19, 2011).

Associated Press /The Huffington Post. March 17, 2011. *Earthquake 2011: Elderly Hard-Hit As Hope For Missing Fades.* Available from http://www.huffingtonpost.com/2011/03/17/japan-earthquake-2011-elderly-hard-hit_n_837117.html (last accessed May 19, 2011).

Barnes, J. 2007. *Florida's Hurricane History*. The University of North Carolina Press, pp. 103-308.

Bell, B. D. 1978. Disaster Impact and Response: Overcoming the Thousand Natural Shocks. *The Gerontologist* 18 (6):531 -540.

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

Bolin, R., and D. J. Klenow. 1982. Response of the elderly to disaster: an age-stratified analysis. *International Journal of Aging & Human Development* 16 (4):283-296.

Bolin, R., and D. J. Klenow. 1988. Older People in Disaster: A Comparison of Black and White Victims. *International Journal of Aging and Human Development* 26 (1):29-43.

Brooks, N., W. Neil Adger, and P. Mick Kelly. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environmental Change Part A* 15 (2):151-163.

California Department of Aging. 2004. *Disaster Assistance Handbook for Area Agencies on Aging and Adult Day Health Care Centers.* Available from http://www.cda.ca.gov/aaa/guidance/Disaster_Manual_for_AAAs.pdf (last accessed May 19, 2011).

Campell, Kenneth M. 1985. *Geology of Sarasota County, Florida*. Florida Geological Survey.

Cardona, O.D. 2004. *The Need for Rethinking the Concepts of Vulnerability and Risk from a Holistic Perspective: A Necessary Review and Criticism for Effective Risk Management.* In: Bankoff, G., Frerks, G., and Hilhorst, D. (eds.). Mapping Vulnerability, Disasters, Development, and People. Earthscan Publications, London.

Cavan R. S., E. W. Burgess, R. J. Havinghurst, and H. Goldhammer. 1949. *Personal Adjustment in Old Age.* Chicago: Science Research Associates.

Chapin, R., and D. Dobbs-Kepper. 2001. Aging in Place in Assisted Living. *The Gerontologist* 41 (1):43 -50.

CDC Centers for Disease Control and Prevention, 2007. CDC's Disaster Planning Goal: Protect Vulnerable Older Adults. Available from http://www.cdc.gov/aging/pdf/disaster_planning_goal.pdf (last accessed May 19, 2011).

CNBC. August 25, 2010. *12 Most Expensive Hurricanes in U.S.* Available from http://www.cnbc.com/id/26426796/12_Most_Expensive_Hurricanes_in_U_S_History (last accessed May 19, 2011).

Coletti, A., P. Howe, N. Wood, and B. Yarnal. 2010. *Architecture Definition of a Vulnerability Assessment Support System Software Web Service.* Poster Session: 2445 Topics in GIS. AAG Annual Meeting, Washington, DC. April 15, 2010.

Coppola, Damon P. 2007. *Introduction to International Disaster Management.* Burlington, MA: Elsevier.

Cottrell, L. S. 1942. The Adjustment of the Individual to his Age and Sex Roles. *American Sociological Review* 7:617–620.

Cumming Elaine, Henry William E. 1961. *Growing Old: The Process of Disengagement.* New York: Basic Books.

Cutter, S. L. 1996. Vulnerability to environmental hazards. *Progress in Human Geography* 20 (4):529-539.

Cutter, S. L., J. T. Mitchell, and M. S. Scott., 1997. *Handbook for Conducting a GIS-based Hazards Assessment at the County Level.* Prepared for South Carolina Emergency Preparedness Division. Available from http://webra.cas.sc.edu/hvri/docs/handbook.pdf (last accessed May 19, 2011).

Cutter, S. L., J. T. Mitchell, and M. S. Scott. 2000. Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. *Annals of the Association of American Geographers* 90 (4):713-737.

Cutter, S. L., 2001. A research agenda for vulnerability science and environmental hazards. *International Human Dimensions Program Update* 1 (2), 8–9.

Cutter, S. L., B. J. Boruff, and W. L. Shirley. 2003. Social Vulnerability to Environmental Hazards. *Social Science Quarterly* 84 (2):242-261.

Cutter, S. L., and C. Finch. 2008. Temporal and spatial changes in social vulnerability to natural hazards. *Proceedings of the National Academy of Sciences* 105 (7):2301-2306.

Dilley, M., Chen, R.S., Deichmann, U., Lerner-Lam, A.L., and Arnold, M. 2005. *Natural Disaster Hotspots. A Global Risk Analysis.* Publisher. World Bank.

Eakin, H., and A. L. Luers. 2006. Assessing the Vulnerability of Social-Environmental Systems. *Annual Review of Environment and Resources* 31 (1):365-394.

Eakin, H., and L. A. Bojórquez-Tapia. 2008. Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change* 18 (1):112-127.

Earth Policy Institute, 2003. *Record Heat Wave in Europe Takes 35,000 Lives: Far Greater Losses May Lie Ahead.* Available from http://www.earth-policy.org/index.php?/plan_b_updates/2003/update29 (last accessed May 19, 2011).

Easterling, D. R., G. A. Meehl, C. Parmesan, S. A. Changnon, T. R. Karl, and L. O. Mearns. 2000. Climate Extremes: Observations, Modeling, and Impacts. *Science* 289 (5487):2068 -2074.

Enarson, E., and B. Morrow. 1998. *The Gendered Terrain of Disaster*. New York: Praeger.

FEMA. 2008. *Interim Emergency Management Planning Guide for Special Needs Populations.* Available from http://serve.mt.gov/wp-content/uploads/2010/10/CPG-301.pdf (last accessed May 19, 2011).

FEMA. 2010a. *Hurricane Hazards: Storm Surge.* Available from http://www.fema.gov/hazard/hurricane/hu_surge.shtm (last accessed May 19, 2011).

FEMA. 2010b. *The National Flood Insurance Program.* Available from http://www.fema.gov/about/programs/nfip/index.shtm (last accessed May 19, 2011).

FEMA. 2010c. *About Hurricane Katrina*. Available from http://www.fema.gov/hazard/flood/recoverydata/katrina/katrina_about.shtm (last accessed May 19, 2011).

FEMA. 2010d. Inland Flooding. Available from http://www.fema.gov/hazard/hurricane/2010/inland_flooding.shtm (last accessed May 19, 2011).

FEMA. 2010e. Flood Zones. Available from http://www.fema.gov/plan/prevent/floodplain/nfipkeywords/flood_zones.shtm (last accessed May 19, 2011).

FEMA. 2011. *Definitions of FEMA Flood Zone Designation*. Available from http://msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=floodZones&title=FEMA+Flood+Zone+Designations (last accessed May 19, 2011).

Fernandez, L. S., D. Byard, C.-C. Lin, S. Benson, and J. A. Barbera. 2002. Frail elderly as disaster victims: emergency management strategies. *Prehospital and Disaster Medicine: The Official Journal of the National Association of EMS Physicians and the World Association for Emergency and Disaster Medicine in Association with the Acute Care Foundation* 17 (2):67-74.

Fothergill, A., E. G. M. Maestas, and J. D. Darlington. 1999. Race, Ethnicity and Disasters in the United States: A Review of the Literature. *Disasters* 23 (2):156-173.

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

Frazier, T., Wood, N., and Yarnal, B. 2009. *A framework for using GIS and stakeholder input to assess vulnerability to coastal-inundation hazards: a case study from Sarasota County, Florida.* In U. Paleo (ed.), *Building Safer Communities. Risk Governance, Spatial Planning and Responses to Natural Hazards*, U Fra Paleo, editor, IOS Press, Amsterdam, 226-245.

Frazier, T. G., N. Wood, B. Yarnal, and D. H. Bauer. 2010a. Influence of potential sea level rise on societal vulnerability to hurricane storm-surge hazards, Sarasota County, Florida. *Applied Geography* 30 (4):490-505.

Frazier, T. G., N. Wood, and B. Yarnal. 2010b. Stakeholder perspectives on land-use strategies for adapting to climate-change-enhanced coastal hazards: Sarasota, Florida. *Applied Geography* 30 (4):506-517.

Frich, P., L. V. Alexander, P. DellaMarta, B. Gleason, M. Haylock, A. M. G. K. Tank, and T. Peterson. 2002. Observed coherent changes in climatic extremes during the second half of the twentieth century. *Climate Research* 19 (3):193-212.

Friedsam, H. J. 1961. Reactions of Older Persons to Disaster-caused Losses: An Hypothesis of Relative Deprivation. *The Gerontologist* 1 (1):34 -37.

Füssel, H.-M. 2007. Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change* 17 (2):155-167.

Gallopín, G. C. 2006. Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change* 16 (3):293-303.

Glass, R. I., J. J. Urrutia, S. Sibony, H. Smith, B. Garcia, and L. Rizzo. 1977. Earthquake Injuries Related to Housing in a Guatemalan Village. *Science* 197 (4304):638 - 643.

Goddard, J., & Kirby, A. 1976. *An introduction to factor analysis.* Norwich, UK: Geo Abstracts.

Gorman M. 1999. *Development and the rights of older people.* In: Randel J, et al., eds. The ageing and development report: poverty, independence and the world's older people. London, Earthscan Publications Ltd.

HelpAge International. 2000. Older people in disasters and humanitarian crises: Guidelines for best practice. Available from http://www.globalaging.org/armedconflict/countryreports/haigiudelines.pdf (last accessed May 19, 2011).

Henderson, T. L., K. A. Roberto, and Y. Kamo. 2010. Older Adults' Responses to Hurricane Katrina. *Journal of Applied Gerontology* 29 (1):48 -69.

Hewitt, K. 1997. *Regions of Risk: A Geographical Introduction to Disasters.* Essex, U.K.: Longman.

Hoffman, R. 2005. Do Socioeconomic Mortality Differences Decrease with Age? *Demographic Research* 13: 35-62.

Howe, Peter D. 2011. Hurricane Preparedness as Anticipatory Adaptation: a Case Study of Community Businesses. *Global Environmental Change* doi:10.1016/j.gloenvcha.2011.02.001.

Humanitarian Policy Network. 2005. *Protecting and assisting older people in emergencies.* Available from http://www.odihpn.org/documents/networkpaper053.pdf (last accessed May 19, 2011).

Hyndman Donald and David Hyndman. 2006. *Natural Hazards and Disasters 2006 update.* Brooks Cole.

Insurance Information Institute. 2011. *TOP TEN MOST COSTLY HURRICANES IN THE UNITED STATES.* Available from http://www.iii.org/media/facts/statsbyissue/hurricanes/ (last accessed May 19, 2011).

IPCC. 2001. *Third Assessment Report - Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability.* Cambridge University Press.

IPCC. 2007. *Fourth Assessment Report- Climate Change 2007: Working Group II: Impacts, Adaptation and Vulnerability.* Cambridge University Press.

Jackson, G. R., C. Owsley, and G. McGwin Jr. 1999. Aging and dark adaptation. *Vision Research* 39 (23):3975-3982.

Jelesnianski, C., Chen, J., and Shaffer, W. 1992. SLOSH: Sea, lake, and overland surges from hurricanes, *NOAA Technical Report NWS 48*, Silver Spring, MD.

Kaniasty, K., and F. Norris. 1995. In search of altruistic community: Patterns of social support mobilization following Hurricane Hugo. *American Journal of Community Psychology* 23 (4):447-477.

Keller, E. A. 1999. *Introduction to environmental geology*. Prentice Hall.

Kilijanek, T. S., and T. E. Drabek. 1979. Assessing Long-term Impacts of a Natural Disaster: A Focus on the Elderly. *The Gerontologist* 19 (6):555 -566.

Klein, R.J.T. 2004. *Vulnerability Indices: An Academic Perspective.* Expert meeting ‘‘Developing a method for addressing vulnerability to climate change and climate change impact management: to index or not to index?’’ Germanwatch, Bonn, Germany, January 26, 2004.

Kleinosky, L., B. Yarnal, and A. Fisher. 2007. Vulnerability of Hampton Roads, Virginia to Storm-Surge Flooding and Sea-Level Rise. *Natural Hazards* 40 (1):43-70.

Kusenbach, M., J. Simms, and G. Tobin. 2010. Disaster vulnerability and evacuation readiness: coastal mobile home residents in Florida. *Natural Hazards* 52 (1):79-95.

Lane, B. E. 1973. *Geology of Sarasota County*. Unpublished Manuscript. Florida Bureau of Geology.

Mayhorn, C. B. 2005. Cognitive Aging and the Processing of Hazard Information and Disaster Warnings. *Natural Hazards Review* 6 (4):165-170.

McGuire, L. C., E. S. Ford, and C. A. Okoro. 2007. Natural disasters and older US adults with disabilities: implications for evacuation. *Disasters* 31 (1):49-56.

Mensah, G. A., A. H. Mokdad, S. F. Posner, E. Reed, E. J. Simoes, and M. M. Engelgau. 2005. When Chronic Conditions Become Acute: Prevention and Control of Chronic Diseases and Adverse Health Outcomes During Natural Disasters. *Preventing Chronic Disease* 2 (Special Issue).

Mileti, D. 1999. *Disasters by Design: A Reassessment of Natural Hazards in the United States.* Washington, D.C.: Joseph Henry Press.

Mitchell, J. M., and B. J. Kemp. 2000. Quality of life in assisted living homes: a multidimensional analysis. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences* 55 (2):P117-127.

Moreno, A., and S. Becken. 2009. A climate change vulnerability assessment methodology for coastal tourism. *Journal of Sustainable Tourism* 17 (4):473.

Morrow, B. H. 1999. Identifying and mapping community vulnerability. *Disasters* 23 (1):1-18.

Moss et al., 2001. *Vulnerability to Climate Change: A Quantitative Approach. Technical Report PNNL-SA-33642.* Prepared for the US Department of Energy. Available from http://www.globalchange.umd.edu/data/publications/Vulnerability_to_Climate_Change.PDF (last accessed May 19, 2011).

National Hurricane Center. 2005. *Tropical Cyclone Report, Hurricane Katrina, 23-30 August 2005.* Available from http://www.nhc.noaa.gov/pdf/TCR-AL122005_Katrina.pdf (last accessed May 19, 2011).

National Hurricane Center. 2010a. *Sea, Lake, and Overland Surges from Hurricanes (SLOSH).* Available from http://www.nhc.noaa.gov/ssurge/ssurge_slosh.shtml (last accessed May 19, 2011).

National Hurricane Center. 2010b. *The Saffir-Simpson Hurricane Wind Scale.* Available from http://www.nhc.noaa.gov/aboutsshs.shtml (last accessed May 19, 2011).

National Hurricane Center. 2011a. Inland Flooding. Available from http://www.nhc.noaa.gov/HAW2/english/inland_flood.shtml (last accessed May 19, 2011).

National Hurricane Center. 2011b. SLOSH MODEL. Available from http://www.nhc.noaa.gov/HAW2/english/surge/slosh.shtml (last accessed May 19, 2011).

Neugarten, B. L. 1974. Age Groups in American Society and the Rise of the Young-Old. *The Annals of the American Academy of Political and Social Science* 415 (1):187 -198.

Neugarten, B. L. 1981. Age Distinctions and Their Social Functions. *Chicago Kent Law Review* 57 (4):809-25.

Newell, B., C. Crumley, N. Hassan, E. Lambin, C. Pahl-Wostl, A. Underdal, and R. Wasson. 2005. A conceptual template for integrative human-environment research. *Global Environmental Change Part A* 15 (4):299-307.

Ngo, E. B. 2001. When Disasters and Age Collide: Reviewing Vulnerability of the Elderly. *Natural Hazards Review* 2 (2):80-89.

Norris, F. H., and S. A. Murrell. 1988. Prior experience as a moderator of disaster impact on anxiety symptoms in older adults. *American Journal of Community Psychology* 16 (5):665-683.

NPR. 2010. *Series Overview: Growing Old, At Home.* Available from http://www.npr.org/templates/story/story.php?storyId=129086147 (last accessed May 19, 2011).

O'Brien, P., and D. Mileti. 1992. ''Citizen Participation in Emergency Response Following the Loma Prieta Earthquake.'' *International Journal of Mass Emergencies and Disasters* 10:71–89.

O'Brien, K., S. Eriksen, L. P. Nygaard, and A. Schjolden. 2007. Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy* 7:73-88.

Oriol, W. 1999. *Psychosocial Issues for Older Adults in Disasters.* Available from http://store.samhsa.gov/shin/content/SMA11-DISASTER/SMA11-DISASTER-03.pdf (last accessed May 19, 2011).

Papper, S. 1973. The effects of age in reducing renal function. *Geriatrics* 28 (5):83-87.

Pearsall, H. 2009. Linking the stressors and stressing the linkages: Human-environment vulnerability and brownfield redevelopment in New York City. *Environmental Hazards* 8:117-132.

Pelling, M. 2003. *The Vulnerability of Cities. Natural Disasters and Social Resilience*. Earthscan Publications, London.

Pett, M.A., N. R. Lackey, and J. J. Sullivan. 2003. *Making Sense of Factor Analysis.* Sage Publications, Inc.

Pickett, S., Burch, and M. Grove. 1999. Interdisciplinary Research: Maintaining the Constructive Impulse in a Culture of Criticism. *Ecosystems* 2 (4):302-307.

Polsky, C., R. Neff, and B. Yarnal. August. Building comparable global change vulnerability assessments: The vulnerability scoping diagram. *Global Environmental Change* 17 (3-4):472-485.

Population Reference Bureau. 2005. *Global Aging: The Challenge of Success.* Available from http://www.prb.org/pdf05/60.1GlobalAging.pdf (last accessed May 19, 2011).

Rosenkoetter, M. M., E. K. Covan, B. K. Cobb, S. Bunting, and M. Weinrich. 2007. Perceptions of older adults regarding evacuation in the event of a natural disaster. *Public Health Nursing (Boston, Mass.)* 24 (2):160-168.

Rosow I. 1985. *Status and role change through the life cycle.* In: Binstock RH, Shanas E, editors. Handbook of aging and the social sciences. New York: Van Nostrand Reinhold, pp. 62–93.

Rowles, G. (1993). Evolving images of place in aging and "aging in place." *Generations* 17: 65–70.

Rygel, L., D. O'Sullivan, and B. Yarnal. 2006. A Method for Constructing a Social Vulnerability Index: An Application to Hurricane Storm Surges in a Developed Country. *Mitigation and Adaptation Strategies for Global Change* 11 (3):741-764.

Sarasota County Department of Emergency Management. *2008 Sarasota County Evacuation Map.* Available from http://media.myfoxtampabay.com/evac/sarasota.pdf (last accessed May 19, 2011).

Sarasota Herald Tribune. October 17, 2010a. *A short history of hurricanes.* Available from http://www.heraldtribune.com/article/20101017/COLUMNIST/10171002 (last accessed May 19, 2011).

Sarasota Herald Tribune. October 17, 2010b. *50 years ago, Hurricane Donna was the big one.* Available from http://realestatetoday.blogs.heraldtribune.com/11640/50-years-ago-hurricane-donna-was-the-big-one/ (last accessed May 19, 2011).

Sarasota History Alive. 2011. *Southwest Florida History Littered with Hurricanes.* Available from http://www.sarasotahistoryalive.com/stories/journals-of-yesteryear/southwest-florida-history-littered-with-hurricanes/?query=%28category.eq.Journals%20of%20Yesteryear%29.and.%28c ategory.eq.Journals%20of%20Yesteryear%29&back=StoriesSouthwest (last accessed May 19, 2011).

Seplaki, C. L., N. Goldman, M. Weinstein, and Y.-H. Lin. 2006. Before and after the 1999 Chi-Chi earthquake: traumatic events and depressive symptoms in an older population. *Social Science & Medicine (1982)* 62 (12):3121-3132.

Shock, N. 1977. *Systems integration.* In: Finch, C. and Hayflick, L. (eds.), Handbook of the Biology of Aging, pp. 639–665, New York: Van Nostrand Reinhold.

Small, C., and R. J. Nicholls. 2003. A global analysis of human settlement in coastal zones. *J Coast Res* 19:584-599.

Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16 (3):282-292.

Sorrensen, C., Polsky, C., Neff, R., 2005. The HERO REU experience: undergraduate research on vulnerability to climate change in local places. *Geographical Bulletin* 47 (2), 65–72.

Sumner, H. C. 1944. The North Atlantic hurricane of October 13-21, 1944. *Monthly Weather Review* 72 (11):221-223.

Sweeney, J. L. 1974. Housing unit maintenance and the mode of tenure. *Journal of Economic Theory* 8 (2):111-138.

Tabachnick, B. G., and Fidell, L. S. 2007. *Using Multivariate Statistics, 5th ed.* Boston: Allyn and Bacon.

Tang, F., and J. G. Pickard. 2008. Aging in Place or Relocation: Perceived Awareness of Community-Based Long-Term Care and Services. *Journal of Housing For the Elderly* 22 (4):404.

Tanida, N. 1996. What happened to elderly people in the great Hanshin earthquake. *BMJ : British Medical Journal* 313 (7065):1133-1135.

Tenenbaum, L. 2010. *Aging in Place- Scorecard.* Available from http://www.louistenenbaum.com/aging-in-place-scorecard/ (last accessed May 19, 2011).

The Guardian. March 17, 2011. *Japanese earthquake takes heavy toll on ageing population.* Available from http://www.guardian.co.uk/world/2011/mar/17/japanese-earthquake-toll-ageing-population-deaths (last accessed May 19, 2011).

The Times. February 18, 2006. *Katrina hit the old of all races.* Available from https://www.timesonline.co.uk/article/0,,11069-2045543,00.html (last accessed May 19, 2011).

The White House. 2006. *Federal Response to Hurricane Katrina Lessons Learned.* Available from http://library.stmarytx.edu/acadlib/edocs/katrinawh.pdf (last accessed May 19, 2011).

Tran, L. T., C. G. Knight, R. V. O'Neill, and E. R. Smith. 2004. Integrated environmental assessment of the Mid-Atlantic region with analytical network process. *Environmental Monitoring and Assessment* 94 (1-3):263-277.

Trenberth, K. 2005. Uncertainty in Hurricanes and Global Warming. *Science* 308 (5729):1753 -1754.

Turner, B. L., R. E. Kasperson, P. A. Matson, J. J. McCarthy, R. W. Corell, L. Christensen, N. Eckley, J. X. Kasperson, A. Luers, M. L. Martello, C. Polsky, A. Pulsipher, and A. Schiller. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences of the United States of America* 100 (14):8074-8079.

U.S. Census Bureau. 1996. *65+ in the United States.* Report Series: P23-190 Current Population Reports: Special Studies. Available from http://www.census.gov/prod/1/pop/p23-190/p23-190.pdf (last accessed May 19, 2011).

U.S. Census Bureau. 1998. *Gender and Aging, Mortality and Health.* Available from http://www.census.gov/ipc/prod/ib98-2.pdf (last accessed May 19, 2011).

U.S. Census Bureau. 2005. *65+ in the United States: 2005.* Available from http://www.census.gov/prod/2006pubs/p23-209.pdf (last accessed May 19, 2011).

U.S. Census Bureau. 2007. Summary File 1. 2000 Census of Population and Housing. Technical Documentation. Available from http://www.census.gov/prod/cen2000/doc/sf1.pdf (last accessed May 19, 2011).

U.S. Census Bureau. 2007. Summary File 3. 2000 Census of Population and Housing. Technical Documentation. Available from http://www.census.gov/prod/cen2000/doc/sf3.pdf (last accessed May 19, 2011).

U.S. Census Bureau. 2011. *Profile of General Population and Housing Characteristics: 2010.* 2010 Demographic Profile SF. Available from http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml (last accessed May 19, 2011).

United Nations Environment Programme. 2004. *Impacts of Summer 2003 Heat Wave in Europe.* Available from http://www.grid.unep.ch/product/publication/download/ew_heat_wave.en.pdf (last accessed May 19, 2011).

U.S. National Institute on Aging. 2007. *Why Population Aging Matters: A Global Perspective.* Available from http://www.nia.nih.gov/NR/rdonlyres/C13CE0FA-59E4-49CA-BAC2-10E35297BDFD/6580/WPAM.txt (last accessed May 19, 2011).

Whitehead, J. C., Maiolo, J. R., Wilson, K., Smith, K. T., Edwards, B., & Van Willigen, M. 2000. Heading for higher ground: factors affecting real and hypothetical hurricane evacuation behavior. *Environmental Hazards* 2, 133–142.

World Health Organization. 2006. *Communicable diseases following natural disasters. Risk assessment and priority interventions.* Available from http://helid.digicollection.org/pdf/s13416e/s13416e.pdf (last accessed May 19, 2011).

Wu, S., B. Yarnal, and A. Fisher. 2002. Vulnerability of coastal communities to sea-level rise: a case study of Cape May County, New Jersey, USA. *Climate Research* 22 (3):255-270.

Yarnal, B. 2007. Vulnerability and all that jazz: Addressing vulnerability in New Orleans after Hurricane Katrina. *Technology in Society* 29 (2):249-255.

Yarnal, B., P. Howe, and A. Coletti. 2011. *Developing and Testing a Vulnerability Assessment Support System.* Paper Session: 3538 Hazards and GIScience 1: Assessing Risk and Vulnerability. 2011 AAG Annual Meeting, Seattle, WA. April 14, 2011.