MEASURING THE SOCIAL-ECOLOGICAL RESILIENCE OF COASTAL AND SMALL ISLAND COMMUNITIES TO INFORM POLICY, PLANNING, AND PRACTICE

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This study was developed in order to arrive at a set of interrelated concepts and empirical ways of measuring social-ecological resilience that are concretely applicable for policy, as well as for developing intervening programs for social change. The outcome of this research is a set of empirical indicators to measure the concept of social-ecological resilience. The measurement model is developed and applied to U.S. Caribbean and Pacific small island communities and U.S. Gulf of Mexico coastal counties (n=229), but is intended to be applicable across different types of communities with minor adjustments for the specific context.

The first phase of this research resulted in a conceptual framework for the social ecological system and the property of resilience. Next, multiple methodological approaches to indicator construction were applied and directly compared. An iterative methodology was selected and applied to arrive at seven composite indicators of social-ecological resilience: *Land cover and use*, *Waste accumulation and treatment*, *Housing adequacy*, *Economic security*, *Access to support services*, *Education*, and *Population diversity*. Upon construction, the indicators were applied with two distinct samples of communities. Finally, the indicators were used to construct

a community typology to account for the different strengths and weaknesses of small island and coastal communities as assessed by the indicators of social-ecological resilience.

Communities with high scores on social dimensions of resilience have a greater likelihood of having low scores on ecological dimensions. This finding adds evidence to the notion that social and ecological systems are oppositional, but also provides a counterpoint – there are communities that manage to score well in both areas. While societal development and ecological condition may operate with a firm tension, communities are navigating the tension and finding ways to successfully maintain characteristics of resilience. This research is a necessary first step to investigating how some communities are able to balance their social-ecological system while others are not. Ultimately, the measurement of resilience can provide communities of island and coastal states with a way of evaluating their ability to implement, adapt, and/or support policies for change.

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1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The issues that arise at cross points of public health, the environment, and economic development are not only fascinating, they can and often do provide the basis for groundbreaking research and policy making. This dissertation project works at the boundary of research and policy in a way that makes possible movement and transition between the two. The underlying conceptual framework for this project arises from theoretical work about the capacity of social-ecological communities to change, both in response to and in anticipation of a shift in the broader system. The project was developed in order to arrive at a set of interrelated concepts and empirical ways of measuring these concepts that are concretely applicable for policy, as well as for developing intervening programs for social change.

This project arises from the consideration of innovative ways in which social science can be applied to understanding and addressing complex problems facing human communities throughout the world. Some of the most intractable problems occur at the points of intersection between human communities and natural environments. Such problems demand an integrated approach. Frameworks like social-ecological models are valuable for putting the pieces together; these frameworks orient the multiple dimensions, levels, and causal pathways that are part of the broader context in which the problem has arisen. Attempts to work within a social-ecological model require concepts that extend between the two spheres, the social world and the natural world, which have previously been separated by academic disciplines, research programs, and language, among other things. One way to address this separation is to develop and clarify concepts that are already in existence and being used by both sides. The right concepts will fill the theoretical gap, but will also fill the gap in practice by being applicable beyond metaphor. Social-ecological resilience is one such concept.

The goal of this research is to produce a set of valid empirical indicators of social-ecological resilience. Ultimately, the evaluation of a community's potential to implement, adapt, and/or support change for policies that are recommended will be made possible by the development of a measure of social-ecological resilience that can be utilized in applied settings, particularly by policy makers and others with interest in community development. In addition, this research promotes theoretical development of the concept of social-ecological resilience by delineating more systematic relationships within which the concept can be studied and advanced. Both the conceptualization and valid measurement of social-ecological resilience hold great potential utility for providing insights about the ways in which communities anticipate and respond to changing conditions (Adger 2000; Adger 2006; Carpenter et al. 2001).

1.2 SOCIAL-ECOLOGICAL RESILIENCE AS THE CONCEPT OF FOCUS

The literature review has revealed 'social-ecological resilience' to be an ideal organizing concept for this project. The concept has been selected for a number of reasons, including the:

- Multidisciplinary use[1] of the term (Adger 2000; Carpenter et al. 2001; Cumming et al. 2005);
- Intended application inherent in conceptual development and application, contrasting the use of the concept as a purely theoretical construct (Berkes and Folke 1998; Folke and Berkes 1995; Gunderson 2000; Young and McKay 1995);
- Application of the concept at the level of the community (Adger 2000; Adger et al. 2005; Gunderson 2000);
- Utility of the concept as a substitute for concepts that are similar (e.g., human well-being, vulnerability, adaptive capacity), but not as multi-dimensional (Adger 2006; Carpenter et al. 2001; Walker et al. 2006b);
- Captures and/or represents a common property of both social and ecological systems (Gunderson and Holling 2002; Levin 1999; Redman, Grove, and Kuby 2004) and therefore serves as a critical link between ecology and society (Adger 2000; Norgaard 1994);

[1] The multidisciplinary use of resilience and in particular, social-ecological resilience enhances the utility of the concept in critical areas of research. The integration of ecological and social sciences is becoming a central part of methodological strategies to address global issues like climate change (e.g., Adger et al. 2002; Berkes and Seixas 2005; Gunderson and Holling 2002; Liu et al. 2007).

- Emphasizes the importance of ecology (i.e., space) in the examination and analysis of communities, through extension of the concept of ecological resilience;
- Duality of resilience as both reactive and proactive, reactionary and revolutionary (Carpenter et al. 2001).

Ultimately, this work demonstrates that social-ecological resilience serves an important and timely purpose. Research and policy are both in need of an agenda that more effectively links the social and ecological systems of the world together in a way that advances our understanding, planning, and response to major crises like climate change and human development (Krieger 2008; Redman 1999). While social-ecological resilience research does not make up the agenda, it significantly contributes to the advancement of inter- and multidisciplinary research focused on the intersection of social and ecological systems. Social-ecological resilience is a concept capable of operating in the social and ecological systems, as well as in the space between.

Brand and Jax (2007) suggest that resilience has much to offer as a boundary concept. Boundary concepts facilitate communication across disciplinary lines by creating shared language, even where differences in understanding and values may remain (Star and Griesemer 1989). There are potential drawbacks (e.g., scientific progress) to an increasingly vague and malleable concept of resilience because advancement of empirical research depends upon a clearly defined concept and operational measure. However, the gains of boundary concepts can include political success (Eser 2002) when through the use of concepts like social-ecological resilience, researchers formerly at odds with one another are able to find common ground (Brand and Jax 2007). Likewise, this process of creating a shared language and ultimately, a shared agenda, makes possible the reconciliation of competing interests of industrial and developing countries (UNEP 2002). Up to the present moment, resilience has maintained a life as a boundary concept. This serves as a past advantage that translates into increased familiarity and interest in the future of the concept, perhaps leading to increased collaboration in the development of reliable empirical measures of resilience. However, this is also a disadvantage, for the concept of social-ecological resilience will likely endure as a boundary concept, despite all efforts to create an empirical measure of a precisely defined concept. While measuring social-ecological resilience can contribute to the empirical study of resilience, the boundary concept can contribute to the broader significance of the measure.

1.3 STATEMENT OF THE PROBLEM

Research is needed to move the science of social-ecological systems forward while also providing policy makers with a means of determining which communities are best able to withstand change. As governmental agencies, non-governmental organizations, and others identify resilience as a worthy goal, it is critical to ensure a means of measuring progress toward this goal. Additionally, it is important to ensure that policy decisions do not erode the resilience a community already possesses. By developing a model and conceptual tools that are directly applicable for policy analysis and formulation, resource management, and community development and planning, this work is positioned to inform the decisions and actions of coastal communities.

The examination of the challenges associated with the concept and measurement of resilience occur in two streams: one conceptual and one methodological. At the conceptual level, the focus is on definitions, distinctions between resilience and related concepts, and the theoretical frameworks that underlie usage of the concept. At the empirical level, the examination of resilience will be centered on the methodological challenges associated with research on resilience as well as previous attempts to operationalize and measure resilience.

1.3.1 The Conceptual Problem

Due to the increasing interactions across scales and among even geographically distant systems, a result of escalating globalization (Liu and Diamond 2005; Liu et al. 2007; Young et al. 2006), I believe that the problems occurring at the intersection of human communities and natural environments represent some of the most challenging problems facing social and health policy analysts and scientists. Redman notes, “it is by working at the junction of these domains [“biotic,” “human,” “geologic,” and “built”] that processes can be best understood and the greatest scientific breakthroughs will be made” (1999:296).

Frameworks like social-ecological models[2] are valuable for putting the pieces together; these frameworks orient and integrate the multiple dimensions, levels, and causal pathways that are

[2] The term ‘social-ecological model’ is used to cover a broad array of frameworks, including eco-social theory (Krieger 1994), eco-epidemiology (Susser and Susser 1996), and social-ecological systems perspective (McMichael 1999), that provide a means of organizing both ecological and social systems while acknowledging the inherent complexity of multiple levels, dimensions, and causal pathways (Krieger 2001).

part of the broader context in which the problem has arisen (in social epidemiology, see: Krieger 2001; McMichael 1999; Susser and Susser 1996; in sociology, see: Burch and DeLuca 1984; Duncan 1961; Duncan 1964; Field and Burch 1988; Machlis, Force, and Burch 1997). Krieger proposed a version of a social-ecological model as a way to "envision a more systematic integrated approach capable of generating new hypotheses, rather than simply reinterpreting factors identified by one approach (e.g., biological) in terms of another (e.g., social) (2001:673).

Attempts to work within a social-ecological model require concepts that extend between the two spheres, the social world and the ecological world, which have previously been separated by academic disciplines, research programs, and language (Liu et al. 2007; Redman 1999; Redman et al. 2004; Westley et al. 2002). The result of this separation is that researchers have neglected the relationship between the two (Redman et al. 2004) until very recently, when it has become increasingly obvious that to study ecological and social systems in isolation from one another produces trivial or useless results, particularly when these results are used to shape policy (Gunderson and Holling 2002; Kinzig 2001; Krieger 2008; Low et al. 1999; Redman 1999).

The most parsimonious way to address this separation is to develop and clarify concepts that are already in existence and use by analysts and researchers from both perspectives (Michener et al. 2001; Redman et al. 2004; van der Leeuw and Redman 2002). Certain extant concepts can fill the theoretical gap, as well as fill gaps in practice by being applicable beyond metaphor: i.e., to be measurable and quantifiable in real world contexts versus useful in explaining the world in an abstract way. Social-ecological resilience serves as one such bridging concept.

The concept of social-ecological resilience emerges repeatedly from the examination of literature addressing linkages between a number of aspects of social and ecological systems. Examples include:

- human health and well-being; ecosystem biodiversity (e.g., Corvalan, Hales, and McMichael 2005)
- human health and well-being; climate change (e.g., McMichael et al. 2008)
- economic development; ecosystem health (e.g., Gjertsen 2005)
- social conflict/social movements; environmental illness (e.g., Brown et al. 2002)
- sustainable development; environment (e.g., Folke et al. 2002a)
- social conflict; resource management style (e.g., Pollnac and Crawford 2000)
- institutions and social capital; environment (e.g., Pretty and Ward 2001)

In fact, Brand and Jax (2007) argue that recent studies of resilience are increasingly focused on the social, political, and institutional dimensions of resilience (e.g., Folke, Colding, and Berkes 2002b; Janssen 2006; Olsson, Folke, and Berkes 2004; Olsson et al. 2006) and aim to address entire social-ecological systems (e.g., Adger et al. 2005; Folke 2006; Hughes et al. 2005; Walker et al. 2006a), marking a departure from the purely ecological studies of the past. The link between social and ecological systems is particularly meaningful for social-ecological resilience research. The Resilience Alliance, a multidisciplinary research group comprised of scientists and practitioners from many disciplines, based in universities, NGOs, and government agencies in several countries exploring the dynamics of social-ecological systems using the concepts of resilience, adaptability and transformability, says the following: "Humans are part of the natural world. We depend on ecological systems for our survival and we continuously impact the ecosystems in which we live from the local to global scale. Resilience is a property of these linked social ecological systems" (RA 2009a).

1.3.2 The Methodological Problem

A lengthy exploration of literature dealing with the general areas of human health and well-being, society, and environment was based on the social-ecological model, developed first in the discipline of sociology and used now primarily in epidemiology, other public health disciplines, and other fields (e.g., Krieger 2001; McMichael 1999; McMichael 2008). These models provide a means of organizing both ecological and social systems into a comprehensive framework with multiple levels, dimensions, and causal pathways (Krieger 1994; Krieger 2001; McMichael 1999; Susser and Susser 1996). The development of an integrated framework for the study of social-ecological systems, assumes that all social and ecological systems share a number of identifiable common properties, including resilience and complexity (Gunderson and Holling 2002; Levin 1999). Based on this assumption, literature that attempted to address the complexity of interacting systems, while dealing with problems of scale (organizational, spatial, and temporal), causality, and cross-scale mismatches was examined (e.g., Adger et al. 2005; Anderies, Walker, and Kinzig 2006; Cumming, Cumming, and Redman 2006; Gunderson et al. 2006; Krieger 2001, 2008; Redman et al. 2004). Among the features repeatedly encountered within this body of work is significant concern with problems of empirical measurement. Despite the challenging work of researchers from a variety of fields and disciplines, few have successfully tackled the daunting task of measurement (for social-ecological systems, see Carpenter et al. 2001; Carpenter, Westley, and Turner 2005 and for social-ecological models, see: Krieger 2001; McMichael 1999; and Susser and Susser 1996). Thus, much work remains at the level of metaphor and theory with occasional efforts to interpret a case study within the central metaphor or conceptual framework that is proposed (Carpenter et al. 2001). Carpenter et al. (2001) cite some cases where resilience has been operationalized in the context of a model of a particular system (e.g., Carpenter, Brock, and Hanson 1999; Janssen et al. 2000; Peterson 1999; Peterson, Allen, and Holling 1998; Scheffer et al. 2001). Similarly, researchers have initiated the process of measure development for select aspects of the broader social-ecological system such as lagoons, grasslands, and lakes (e.g., Berkes and Seixas 2005; Janssen et al. 2006; Liu et al. 2007). The consequence of this work is a concept with limited applicability and low efficacy for policy impact.

1.4 PURPOSE OF THE STUDY

Empirical studies of resilience have failed to integrate the social and ecological dimensions into a cohesive measure. Even when the social dimensions are incorporated into proposed frameworks for assessing resilience, all too often what gets termed a social indicator of resilience is actually a much narrower economic indicator (e.g., Carpenter et al. 2001). That is, when not dealing with the physical or biophysical domains, much of resilience research ends up being solely about economic factors, as opposed to the much broader, more complex sets of social factors (e.g., factors related to institutions, social demographics, sociocultural/non-material resources). This study advances resilience research by establishing a more comprehensive set of social indicators (including economic measures) that can be integrated with ecological indicators. Also, by employing multiple methodological strategies, the valid measurement model of resilience is applicable across different communities. Standardized comparisons of community resilience, the prioritization of policies and interventions, and improved planning at higher levels of governance (e.g., county, state, nation) will be possible.

The comprehensive measure of social-ecological resilience developed in this study includes key social, economic, and biophysical indicators. The integration of ecological and social sciences has become a central part of methodological strategies to address complex problems like pollution, mass migration, resource depletion, and climate change (e.g., Adger et al. 2002; Berkes and Seixas 2005; Dasgupta 2001; Gunderson and Holling 2002; Krieger 2001; Liu et al. 2007). The problems that impact the environment are also the problems that impact human societies. Fragmented efforts and approaches cannot adequately address the complexity of the problems we face. Theoretical and conceptual integration, the development of comprehensive multidisciplinary measures, and coordinated research and action must be part of the new approach.

1.4.1 Research Questions

The research questions forming the basis for this work include the following:

Q1: How do small island and coastal communities anticipate and respond to changing social and ecological conditions?

Q2: Are there ways to assess the resilience of small island and coastal communities that take into account the community as a composition of social, ecological, and social-ecological systems?

Q3: How can policy makers and others working in community development determine which communities can withstand significant change without trauma? Alternately stated, how can we provide a rationale for targeted policy change among communities?

Q4: Which social and ecological characteristics contribute to the social-ecological resilience of a community?

1.5 IMPORTANCE OF THE STUDY

The conceptualization and valid measurement of social-ecological resilience has great potential utility for giving us insights about the ways in which communities anticipate and respond to changing conditions (Adger 2000, 2006; Carpenter et al. 2001). This study is highly innovative in that it: 1) utilizes of a community level of analysis, 2) operates within a systems approach, 3) focuses on resilience as being about more than disaster mitigation, and 4) aims to quantify a comprehensive measure of social-ecological resilience. Most importantly, this study addresses the qualities that determine how communities respond to change and reorganize after change, a necessary component of emerging science focused on integrated studies of human, community, and environmental health. As argued by Adger, "emerging insights into the resilience of social-ecological systems complement and can significantly add to a converging research agenda on the challenges faced by human environment interactions under stresses caused by global environmental and social change" (2006:268).

While this research grows out of a social science perspective, its goals and recommendations are aimed at policy makers, communities, and others for whom a measure of social-ecological resilience would be useful and advantageous. The evaluation of a community's potential to implement, adapt, and/or support change for policies that are recommended are made possible by outputs of this study, which could include:

- variables and/or indices for measuring the social-ecological resilience of a community);
- application of this measure in various settings and suggested future uses of the measure;
- and a framework demonstrating the ways in which the measure can be developed and applied based on various factors, including data available, purpose of assessment, and geographic location of community.

A measure of social-ecological resilience would assist decision makers in identifying the factors that threaten community sustainability and stability. Holling (2001) suggests that out of an understanding of the cycles of transformation and change as well as their corresponding scales emerges a parallel understanding of the contribution of such cycles to sustainability. Ultimately, this leads to the identification of "points at which a system is capable of accepting positive change and the points where it is vulnerable…[i]t then becomes possible to use those leverage points to foster resilience and sustainability within a system." The very crux of this project is the identification of communities' points of change and vulnerability. By locating the leverage points for a community and aligning policy recommendations with this information, social-ecological resilience can be fostered and protected when necessary. The development and integration of indicators related to the social and ecological components of the overarching SES will strengthen assessments of resilience and "justify the selective targeting of communities for mitigation based on good social science, not just political whim" (Cutter, Boruff, and Shirley 2003).

An improved understanding of social-ecological resilience is important for community planning, management, and response to global issues with far reaching impacts like climate change and HIV/AIDS, as well as for issues at more proximate scales like economic decline and access to safe drinking water. Government and non-government entities have identified improved resiliency of ecosystems, communities, and economies as a policy goal. For example, the National Ocean Service Priorities Roadmap (NOAA 2014), USAID's Resilience Agenda (USAID 2012), The National Academies agenda (2012), the United States' security strategy (National Security Strategy 2010), interagency recommendations for US ocean policy (White House Council on Environmental Quality 2010), and foundation initiatives for sustainable environments and communities (American Red Cross 2011; Packard Foundation 2009). The broader significance of this work on social-ecological resilience can be viewed in current trends and priorities in funding, as well as the breadth of the applicability of this measure across academic disciplines, professional fields, and policy arenas.

1.6 SCOPE OF STUDY

The quantitative measurement model is applied using a social-ecological systems approach for understanding community resilience in small island states of the Caribbean and Pacific and coastal states of the Gulf of Mexico, though the model is intended for application in various geographic regions. Island and coastal communities face a unique set of challenges, due in part to their intimate connection with the environment. These communities are on the front line of major environmental changes (e.g., rising sea levels, more severe storms). They are also places where the tension between development and preservation is great. Understanding and navigating social and environmental change and the corresponding interactions is critical for coastal communities. While linkages between a community's social and environmental conditions are intuitive, the assessment of these relationships at a community level is uncommon (Corvalan et al. 2005). Coastal communities clearly have both a positive and negative connection to the environment. When positive, the provision of ecosystem services is plentiful and steady; when negative, ecosystem services are lost or disrupted. The linkage of community and environment raises many questions. Are fishing communities less resilient because they are more connected to the environment? Do communities that experience more severe weather events have more resilience due to an improvement in adaptive capacity? The relationship between a community's dependence on the environment and its resilience is among the dynamics investigated in this study.

1.7 SOCIAL SCIENCE CONNECTIONS

This research links social science concepts, such as community resources, institutions, and social learning and social science methodological approaches such as measurement construction and theory testing with the areas of ecology and environmental science. Using theories and/or conceptual frameworks of complex systems, human ecology, and social-ecological models, this work draws from disciplines as distinct as ecology, epidemiology, and sociology. Utilizing an ecological[3] approach within social science disciplines is not new. Among the early proponents of an ecological approach were Montesquieu, Durkheim, Cooley, and Park of the Chicago School (Duncan 1964). In 1925, Park coined the term human ecology (Duncan 1964). , Research in this area continued with the work of Otis Dudley Duncan and Amos Hawley (e.g., Hauser and Duncan 1959; Hawley 1944, 1950, 1973). The disciplines advancing human ecology[4] in the 1960s included: anthropology (Barrows 1923), geography (Wagner 1960), epidemiology (Gordon 1958; Rogers 1962), and psychology (Barker 1960). More recently, in the 1980s, interest in ecology arose in rural sociology, sociological studies of natural resources, and environmental sociology (e.g., Dunlap and Catton Jr. 1979; Dunlap and Marshall 2007; Field and Burch 1988); this interest continues to be strong in fields such as public health (e.g., Krieger 2001; McMichael 2008).

This research uses a community level of study with a strong ecological orientation. Like sociological studies of community that pre-date the 1970s (Brown 2003), this work focuses on substantive issues but also includes the mapping of territories and space. In this way, community

[3] Interestingly, in light of the emphasis of social science survey research on the household level of analysis (e.g., US Census), the word ecology comes from the Greek word ‘oikos’, meaning household (Duncan 1964).

[4] Duncan pointed to two major influences on the development of human ecology in sociology that emerged after the 1950s (1964). First, investigations of social organization from an ecological standpoint began using empirical studies with increasing methodological sophistication. Second, growing interest in human ecology and the productivity of other non-sociologist scientists in this area of scholarship led to increasing pressure among sociologists (Duncan 1964).

is understood as being ecological, in the true sense of the term.[5] This work also draws on social indicators methods to develop a measurement model for social-ecological resilience. Indicators are "quantitative or qualitative measures derived from a series of observed facts that can reveal relative position in a given area and, when measured over time, can point out the direction of change" (Freudenberg 2003:7). The use of indicators spans a variety of disciplines and fields, making this an advantageous approach for the integrated research required. Examples of indicators appear regularly in international and community development, public health, and education to track development, outcomes and performance (Dillard et al. 2013).). Indicators are also used in environmental sciences and natural resource management for measuring and monitoring biophysical phenomena (Dillard et al. 2013). By simultaneously employing methodological approaches derived from sociology and ecology, the strengths of each discipline's methodological tools can contribute to the breadth and depth of analysis. Overall, the project represents an expansion of sociology into a significant area of research that exists at the crossroads of society and ecology, where climate change and other major global problems are emerging.

[5] This stands in contrast to the current period, in which community is typically understood in terms of the creation or transformation of identity as evidenced in the emergence of multiculturalism and postcolonialism and in the growing significance of the study of new social movements (Brown 2003).

2 LITERATURE REVIEW

2.1 THEORETICAL BACKGROUND

Systematic attention to the concept of resilience originated in the 1970s with the work of the ecologist, C. S. Holling (1973). Holling defined resilience as a measure of the persistence of a system and its ability to absorb change and disturbance over time while maintaining the same relationships between populations or state variables (Holling 1973). Since that time, the concept has gained wide popularity and use among researchers in a variety of disciplines including the social sciences (e.g., Adger 2000; Allenby and Fink 2005; Perrings 2006), natural sciences (e.g., Berkes and Seixas 2005; Gunderson and Holling 2002; Walker et al. 2002; Walker et al. 2006b), and applied sciences (e.g., Folke et al. 2002a; Olsson et al. 2004; Reynolds 1998). In the early 2000s, the concept expanded its referents to include more than just the ecological system but the social system as well. At that time, social-ecological systems became a new area of focus for those doing cutting edge epidemiological, population health, and ecosystems research. In recent years, the concept has evolved into a significant component of social-ecological systems studies and is sometimes referred to as a theory (e.g., Cumming et al. 2005) and even its own science (e.g., Adger 2006), though some argue that it is best thought of as a framework for interpreting complex systems (e.g., Anderies et al. 2006).

2.1.1 Definitions of Resilience

Conceptual definitions are often the grounds for heated discussion and debate. The concept of resilience is no different. There are multiple definitions of resilience and as a result, multiple implications for science and policy (Adger 2000; Carpenter et al. 2001; Gunderson and Folke 2005). The following sections present the definitions of resilience most closely derived from Holling's work in ecology, then move on to a discussion of definitions of resilience used in other fields and disciplines, and finally conclude with a brief overview of definitions of resilience that appear in the policy arena. The contributions of the definitions are evaluated in order to arrive at a working definition of social-ecological resilience.

Within the broader discipline of ecology, there are two primary ways in which resilience has been defined (Gunderson 2000). The first, sometimes called "engineering resilience," defines resilience as "the time required for a system to return to an equilibrium or steady-state following a perturbation"[6] (Gunderson 2000:426). Clearly, this definition emphasizes resilience as a static property of systems; resilience suggests return to a single, global state of equilibrium (i.e., the initial equilibrium). Resilience is measured by distance in time that the system has traveled from the global equilibrium and how quickly it returns. The use of this definition is largely concentrated in the fields of physics, control system design, and material engineering. One such usage comes from Allenby and Fink (2005) who offer the following definition of resilience: "the capability of a system to maintain its function and structure in the face of internal and external change and to degrade gracefully when it must" (2005:1034).

Alternately, resilience can be defined as "the magnitude of disturbance that a system can absorb before it changes stable states" (i.e., before the system flips into another regime of behavior) (Gunderson 2000:427). This definition, referred to as "ecological resilience," emphasizes the presence of instability, multiple equilibriums or stable states, and tolerance for transitions between stable states (Holling 1996a; Holling 1973; Ludwig, Walker, and Holling 1996). Here, resilience is a dynamic property of systems and is measured by the magnitude of disturbance absorbable before the system changes control variables and processes, ultimately redefining its structure.

Resilience, when applied to ecological or social-ecological systems, has been defined by the following three properties: 1) amount of change that can be absorbed while still maintaining control of function and structure, 2) degree to which the system can self-organize, and 3) the capability of the system to build capacity for learning and adaptation (Ahmed 2006; Carpenter et al. 2001; Folke et al. 2002b; Holling 1973; Holling 1996b). The level of resilience is determined by the degree to which the system contains/embodies these properties.

Though still working within an ecological framework of resilience, Pimm (1984) defines resilience as the ability of a system to resist disturbance, as well as the rate at which a system

[6] For examples of engineering resilience see, Neubert and Caswell 1997; Ives 1995; Mittelbach, Turner, Hall, et al. 1995; Tilman and Downing 1994; Pimm 1991.

returns to its stable state following a disturbance. Though Pimm's definition is much closer to engineering resilience, it is applied within an ecological context. Gunderson and Holling (2002) offer a contrasting definition that emphasizes the persistence of systems, as opposed to resistance. In their definition, resilience is the capacity of a system to experience disturbances and maintain its functions and controls, without changing states – to persist, despite disturbance. Carpenter et al. (2001) argue that persistence is the key criterion of resilience, whereas resistance is a complementary attribute of resilience.

2.1.2 Resilience in Other Fields and Disciplines

Though resilience first took hold in ecology, Walker et al. (2006a) note that the concept of resilience has undergone a parallel evolution in fields such as psychology (Deveson 2003) and mental health (Walsh 2003). "Over the last decade, however, much work has been done to expand and test the applicability of these concepts to fields that are linked to ecology" (Walker et al. 2006a:12). The ever expanding uses of resilience reflect great variety with respect to the disciplines and fields in which the concept is applied, as well as to the degree of normativity evident in the definitions (Brand and Jax 2007). The following examples illuminate the uses of resilience in other fields of research.

2.1.2.1 Disaster research. Resilience exists as a critical concept for examining natural disasters like hurricanes, floods, earthquakes (Manyena 2006) and technological disasters like Three Mile Island and space shuttle failures (Kendra and Wachtendorf 2003), as well as plans for disaster recovery or future management. The following definitions of resilience come from the area of disaster research. Dennis Miletti claims that, "[r]esilience is rooted in making choices about future losses when development decisions are made. Choosing what is lost in future disasters is absolutely a new way to view those losses since it places 100% responsibility for those losses on people versus nature" (Manyena 2006:436). Another definition arising from disaster research points to resilience as "[t]he ability to respond to singular or unique events" (Kendra and Wachtendorf 2003:71). Local resilience in the face of disasters is the focus of Miletti's[7] contention that local resilience means that a locale can "withstand an extreme natural

[7] Miletti, Dennis S. 1999. *Disasters by Design: A Reassessment of Natural Hazards in the United States*. Joseph Henry Press, Washington, DC.

event without suffering devastating losses, damage, diminished productivity, or quality of life without a large amount of assistance from outside the community" (Manyena 2006:437). With respect to coastal disasters, Adger et al. define resilience as the capacity of social-ecological systems to "absorb recurrent disturbances…so as to retain essential structures, processes, and feedbacks" (2005:1036; see also Holling 1973, Walker et al. 2004).

The limitation of resilience within disaster studies results from an exclusive emphasis on major catastrophe (e.g., hurricane, flood, nuclear accident) as opposed to subtler, more frequent changes that impact a community (e.g., factory closing, rezoning, fishery closure). Though large scale disasters have large scale impact and are viewed as significant threats to communities, the smaller scale changes that happen on a daily basis have both an immediate and long term, independent and cumulative impact. Cutter and colleagues (2003) suggest this is an important distinction for declarations of disaster "represent larger, singular events rather than smaller, more chronic losses" (256). The potential for disaster declaration and response to be mixed up with political motive as opposed to being driven by risk or impact is great (Downton and Pielke 2001). As a result, the utility of assessing resilience only in these special cases (i.e., large scale disasters) is greatly diminished.

Within studies of climate change, resilience has been linked to vulnerability. Tompkins and Adger conclude that reductions in social vulnerability through the extension and consolidation of social networks, at local, regional, national, or international scales, can contribute to increased ecosystem resilience (2004). There are significant problems with equating increases in resilience to decreases in vulnerability, particularly when vulnerability is used to refer only to social systems and resilience only to ecosystems. The greatest of these challenges is that resilience is a property of a social-ecological system (Gallopin 2006) and should be considered from both social and ecological angles.

2.1.2.2 Sociology. The concept of resilience has been used in social science within the following topical areas: children and families (e.g., Landau 2007), youth (e.g., Ungar and Teram 2000), aging and the life course (Schoon and Bynner 2003), social problems (e.g., Clauss-Ehlers and Levi 2002), class and urban studies (e.g., Sánchez-Jankowski 2008), rural sociology (e.g., Varghese et al. 2006), disaster recovery and management (e.g., Stallings 2006), terrorism and security (Shamai, Kimhi, and Enosh 2007), victimization (e.g., Doron 2005), and cultural change and adaptation (e.g., Porter et al. 2008). However, few sociological applications of the concept of resilience address the community level in any substantive manner. Moreover, measurement of resilience is limited in that resilience is rarely quantified in a systematic manner at the individual or community level.

Despite these tendencies within sociological research on resilience (e.g., individual focus of research, lack of quantifiable measures of resilience), it is important to note that the concept of resilience, as derived from ecology, has been applied by a small group of sociologists working in conjunction with other researchers on multi- or interdisciplinary examinations of various intersecting phenomena (e.g., Adger 2000). But because participating sociologists are often operating within inter- and multi-disciplinary applied research centers, their work is not reflected by broader trends within the discipline. Current practice suggests that the future of the concept and its measurement will be advanced by research conducted by multi- or interdisciplinary teams that include social scientists, along with those from the natural sciences. The absence of resilience research at the community level within the social sciences may be a result of the broader trends in these disciplines during the time period in which the concept of resilience first emerged.

2.1.2.3 Policy and practice. Finally, resilience has also been defined by organizations and agencies working to address social and environmental problems at all scales. These policy-oriented definitions are closely related to the definitions that originate in ecology. One example comes from the United Nations, which defines resilience for social systems as "the capacity of a system, community, or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure" (UNISDR 2005). According to the UN, the resilience of a social system is determined by many of the same factors (e.g., ability to self-organize for capacity building, the capacity to learn from past experiences in order to inform future response) that originated in ecology with Holling's work (1973, 1996). The Subcommittee on Disaster Reduction within the US National Science & Technology Council uses an almost identical definition of disaster resilience to the United Nations (National Science and Technology Council 2005). In 2003, Representative Patrick J. Kennedy (Democrat-RI), a member of the US Congress House Appropriations Subcommittee on Labor, Health and Human Services and Education, proposed the National Resilience Development Act (OLPA

2009). This proposal cited the need for an improved understanding of the psychological aspects of terrorism and corresponding psychological care and services. The pending legislation uses the concept of resilience to refer to the ability of the nation-state to psychologically recover from trauma.

Another example of the concept of resilience in policy comes from a Canadian organization focused on community economic development. According to the Centre for Community Enterprise, a resilient community is "one that takes intentional action to enhance the personal and collective capacity of its citizens and institutions to respond to, and influence the course of social and economic change" (Colussi 2000). Among the behaviors of a resilient community the Centre outlines are a "multi-functional approach to create a sustainable (economically, ecologically, politically, and socially) development system with the community" (Colussi 2000). These definitions share a focus on the role of institutions and other social structures in maintaining a community's resilience, referring to both social and ecological components; this focus represents quite a contrast from definitions emphasizing a highly individual view of resilience. Several definitions within this group propose qualities of resilient communities. These qualities are of great interest to the project ahead as they may form the basis for components of a measure of resilience.

A final example of a resilience definition from the policy arena comes from the Resilience Alliance, a multidisciplinary research group that explores the dynamics of complex adaptive systems with the intention of informing adaptive management of natural resources (RA 2009a). The Resilience Alliance defines ecological resilience as "the capacity of an ecosystem to tolerate disturbance without collapsing into a qualitatively different state that is controlled by a different set of processes" (2009b). The Alliance adds that resilient ecosystems are able to absorb shocks and rebuild when necessary. In social systems, resilience is argued to gain strength from the capacity of humans to anticipate and plan for the future (2009b). The Resilience Alliance emphasizes theoretical advancement, rigorous testing of theory through various methodological approaches, and the development of practical guidelines and principles for policy and practice (RA 2007a, 2007b). However, the approach of the Resilience Alliance contains a significant flaw in that they claim only to examine complex adaptive systems, which are defined in part as resilient systems. If only resilient systems are being studied in the process of trying to understand resilience, then resilience has already been defined deductively with little room for positive or negative verification through observation as the only cases being selected are known to fit the definition. Throughout their literature, the Resilience Alliance seems to present the concept of adaptive capacity as primary and the concept of resilience as secondary, which allowed for this confused approach of studying only adaptive systems in an effort to better understand resilience.

2.2 THE CONCEPTUAL EVOLUTION OF RESILIENCE

The concept of resilience has been altered with time and usage. The original concepts were already distinctly applied in fields of engineering (to mechanical systems) and ecology (to ecosystems) when a new direction emerged. The introduction of social resilience moved the concept away from its purely mechanical and ecological origins and applied the idea of resilience to social systems. And now, in an effort to bring the concept further along its evolutionary path, the ecological and the social have been brought together. The resulting concept is social-ecological resilience, a way of thinking about resilience as a state of an entire social-ecological system. The importance of this latest move is best captured in the integration of the social and ecological in a unifying concept that accounts for the state of a social-ecological system (e.g., community) as a whole.

2.2.1 Social Resilience

The concept of resilience, once exclusively applied to ecological systems, has been naturally extended to social-ecological systems (see Gunderson, Holling, and Light 1995; Berkes and Folke 1998; Adger 2000; Gunderson and Holling 2002; Berkes et al. 2003; Davidson-Hunt and Berkes 2003). Social resilience has been defined as a unique concept, though it is closely modeled after ecological resilience. Adger defines social resilience as "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political, and environmental change" (2000:347). This definition closely links social resilience with ecological resilience, especially for communities that are dependent on the natural environment and its resources for their livelihoods (Adger 2000). One of the most critical aspects of this definition is that "[s]ocial resilience is institutionally determined," meaning that social resilience comes into being within the social system (2000:354). The connection between social and ecological resilience has been suggested in a variety of disciplines including human geography, social (or human) ecology and ecological economics (Levin et al. 1998; Gunderson et al. 1997; Zimmerer 1994) and tested in a number of others (e.g., Peluso, Humphrey, and Fortmann 1994; Cuc and Rambo 1993; Bayliss-Smith 1991; Blaikie and Brookfield 1987). Adger (2000) states that "the resilience of social systems is related in some (still undefined) way to the resilience of the ecological systems on which social systems depend," which is "most clearly exhibited within social systems that are dependent on a single ecosystem or single resource" (350).

Adger (2000) claims that the concept of resilience as used in ecology should not be directly applied to social systems without carefully examining the assumption that there are no significant differences in the behavior and structure of socialized institutions and ecological systems; an assumption Adger admits to be highly contested in the social sciences. However, other disciplines have suggested, and in some cases, empirically tested, parallels between ecosystem resilience and social resilience (Adger 2000). These disciplines include human geography, human ecology and ecological economics (Zimmerer 1994; Gunderson et al. 1997; Levin et al. 1998) as well as specific testing within the areas of land degradation (Blaikie and Brookfield 1987), agricultural systems (Bayliss-Smith 1991; Cuc and Rambo 1993) and coastal livelihood systems (Peluso et al. 1994). Furthermore, Norgaard and colleagues (1994, 1984) have drawn comparisons between social and ecological systems, suggesting that the links between these systems are comparable to synergistic and coevolutionary relationships. In other words, if both the social and ecological systems are evolving, then it is possible to have synergies, symbiosis, and coevolution between them. While in ecology, coevolution refers to the simultaneous evolution of interacting ecosystems, economists use coevolution to refer to the mutual adjustment and development of ecological and economic systems (Erickson and Gowdy 2000; Adger 1999; Fairhead and Leach 1995). Paavola and Adger (2005) state that "[l]earning, adaptation, and selection processes 'fine-tune' economic systems to their resource base. The resource base is not a given but rather co-evolves with human use" (361). Correspondingly, social systems reflect the constraints of the resources on which they depend (e.g., Harris 1974). Such synergies present additional evidence for the connectedness of social and ecological systems, thereby substantiating the need for concepts and frameworks that straddle both systems (e.g., resilience). Despite the overemphasis on the social as solely economic, the notion of coevolutionary systems offers a nice theoretical account of the interaction between the social and ecological.

2.2.2 Social-Ecological Resilience

2.2.2.1 Social-ecological systems. Shifting from social resilience to social-ecological resilience requires an understanding of the concept of social-ecological system (SES)[8]. According to Adger (2006), the "concept of a social-ecological system reflects the idea that human action and social structures are integral to nature and hence any distinction between social and natural systems is arbitrary" (268). The melding of the social and ecological systems into a singular unit is not without challenge. Berkes and Folke (1998) admit, "there is no single universally accepted way of formulating the linkages between human and natural systems" (9). A number of areas of research in the human–environment interaction (e.g., common property, ecological economics or adaptive management) have conceptualized social-ecological linkages[9] in their own, unique ways. Field and Burch (1988) provide an example of one such conceptualization with their presentation of the definitional components of natural resources in a SES. Within a given community, the combination of culture interaction with the biophysical environment produces the social environment. Adaptation is enacted through the SES, which leads to the definition of natural resources (Figure 2.1).

Whereas previous researchers used the term 'human ecosystem' (e.g., Duncan 1964; Hauser and Duncan 1959; Hawley 1950), the term 'social-ecological system' better emphasizes the "coequal interaction of the forces acting in these two domains" (Redman et al. 2004:163). Drawing from the work of Machlis et al. (1997) and Burch and De Luca (1984), Redman et al. (2004) define a SES as having the following characteristics:

- Coherent, with regularly interacting biophysical and social factors;

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[8] The acronym 'SES' will be used in the remainder of this work to refer to a social-ecological system. Although this acronym is already familiar to social scientists as referring to socio-economic status, 'SES' is commonly used throughout the resilience literature and has become part of the shared vocabulary of resilience researchers.

[9] For example, the common property resource tradition is focused on the social, political and economic organizations in social-ecological systems and views institutions as mediating factors governing the relationship between the social systems and ecosystems (Dolsak and Ostrom, 2003). Ecological economics analyzes the interactions and substitutability of natural capital with other forms of capital (e.g., human, social and physical) (Adger 2006; Daly and Farley 2004). And, adaptive management addresses unpredictable interactions between coevolving humans and ecosystems and emphasizes the scientific explanation of social and natural systems learn through experimentation (Berkes and Folke1998).

- Defined at numerous scales (e.g., spatial, temporal, and organizational) that may be hierarchically connected;
- Composed of a set of essential resources (e.g., natural, socioeconomic, and cultural) regulated by a combination of ecological and social systems;
- And, most importantly, a social-ecological system is a dynamic, complex system continually undergoing change (Machlis et al. 1997; Burch and DeLuca 1984).

Despite the integration of the social and ecological systems, Redman et al. (2004) highlight the importance of understanding the unique qualities of each system. For example, the social system is made up of social institutions, social cycles, and social order (Redman et al. 2004; Machlis et al. 1997; Burch and DeLuca 1984). Furthermore, the "human component is complex and cannot be treated as an organism with consistent reactions to external stimuli" (Redman et al. 2004:163). While continuing to explore the unique qualities of each system, the interdependency (Figure 2.2) of the social and ecological systems (Field and Burch 1988) must remain at the forefront. One example of a SES is a community (e.g., a neighborhood or a US Census tract). This research represents an attempt at including dimensions of both social and ecological systems within a single model. Throughout this work, the level of system being referred to is that of the community[10], which represents an ideal social-ecological system because it is territorially fixed as well as physically and socially defined.

Coupled human and natural systems refer to integrated systems in which people and nature "interact reciprocally and form complex feedback loops" (Liu et al. 2007:1513). Coupled systems encompass separate systems like social and ecological systems and their interactions (Liu et al. 2007). Complex systems are, by definition, systems composed of interconnected parts that exhibit properties as a collective that cannot be derived from the individual parts. This phenomenon is called emergence; the properties of the system are called emergent properties.[11]

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[10] The particular use of community is important to present and future work on social-ecological resilience. In this research, community refers to a type of social-ecological system that is spatially defined (e.g., neighborhood, US Census block) in which people are connected by the social and ecological context of their environment. This conception of community correlates to such factors as social class, race, income, and resources.

[11] Resilience takes on increased significance in complex, coupled systems. In 1984, Charles Perrow presents one of the challenges of complex systems through his notion of the normal accident. A normal or system accident is defined as "a failure in a subsystem, or a system as a whole, that damages more than one unit and in doing so, disrupts the ongoing or future activities of the system" (Perrow 1984:66). Perrow (1984) argues that in complex, tightly coupled systems, there are more normal accidents because coupling decreases the buffer between the two components of a system. Tight coupling is a mechanical term that refers to a lack of a buffer between two components of a system. Within a tightly coupled, complex system there is little space or time for failure, response,

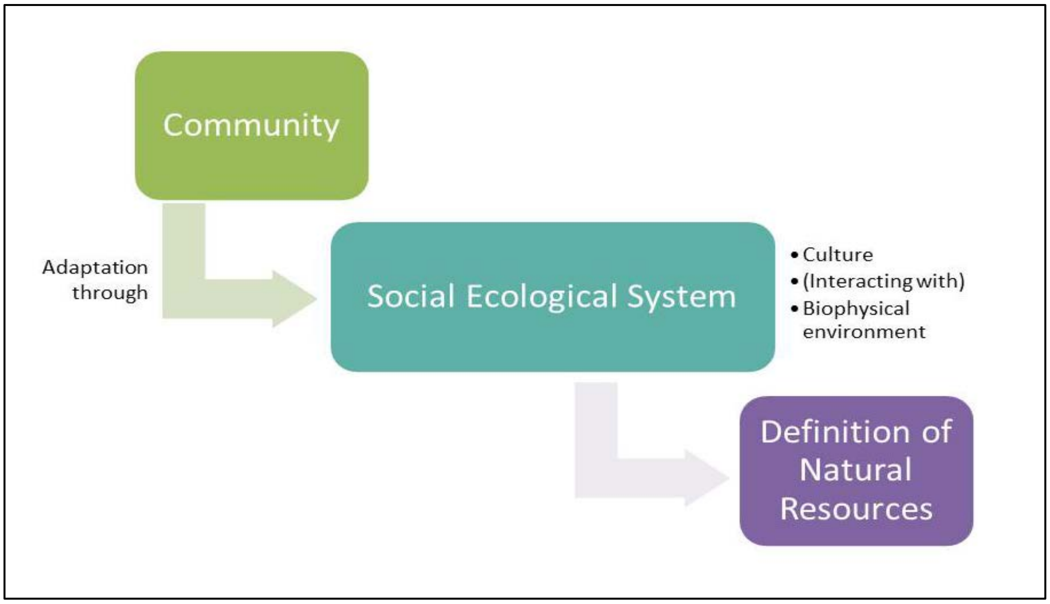

Figure 2.1: Definitional Components of Natural Resources in a Social-Ecological System. *Note:* Adapted from Figure 2, Field and Burch (1988:22).

Figure 2.2: A Social Ecological Model of the Interdependency Between Community (Social System) and Natural Resource Ecosystem (Ecological System). *Note:* Adapted from Figure 3, Field and Burch (1988:26).

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and recovery. And because of the composition of the system, when a disaster happens, it is rarely a minor incident (Perrow 1984). When the coupling is loose, the system exhibits great resilience. Loosely coupled systems are able to respond to perturbations without complete destabilization.

2.2.3 Social-Ecological Resilience Defined and Examined

Resilience in ecological systems refers to the ability to withstand shocks and rebuild; resilience in social systems includes the added capacity of humans to anticipate and plan for the future (RA 2009b). Hence, resilience can be considered a property of these linked social-ecological systems and when applied to integrated systems of people and the natural environments, has the same defining characteristics as when applied to an ecosystem or social system alone (RA 2009b).

A number of properties have been identified as being part of social-ecological resilience. Most importantly, social-ecological resilience is a property of the linkage between ecosystems and human systems (Ahmed 2005; Walker et al. 2006b). Social-ecological resilience should be understood as dynamic and always changing, in contrast to engineering resilience, which reflects a static state with a single equilibrium (Carpenter et al. 2001). Resilience has persistence as a key criterion and resistance as a complementary attribute (Carpenter et al. 2001). Within this single concept are features of persistence and flexibility that are linked to both the ability to remain in the same state and to change to a new one.

Persistence over time means the system endures with changes, adaptations, and alterations to internal and external stimuli, while retaining its core control structures and functions (Holling 1973). This is not equivalent to maintaining the current state, as is. The change that occurs is not disorganized; rather, the change is managed by a controlling structure at the initiative of the internal system (Carpenter et al. 2001; Gunderson 2000; Holling 1973). Resilience involves building up internal and external resources that allow for change, adaptation, and preparation for surprises. The relationship between resilience, resistance, and persistence is best understood as part of a spectrum where resistance forms one end and persistence the other (Figure 2.3). In this spectrum, one end (resistance) is more negative and the other end (persistence) is more positive. Resistance represents rigidity and low adaptive capacity, which can lead to stasis, while persistence represents the flexibility and continuity of a system, though does not necessarily imply continuation in the same state. While resilience can be negative or positive, it cannot include the end of the spectrum where resistance lies, as the very definition of resilience implies flexibility and continual change.

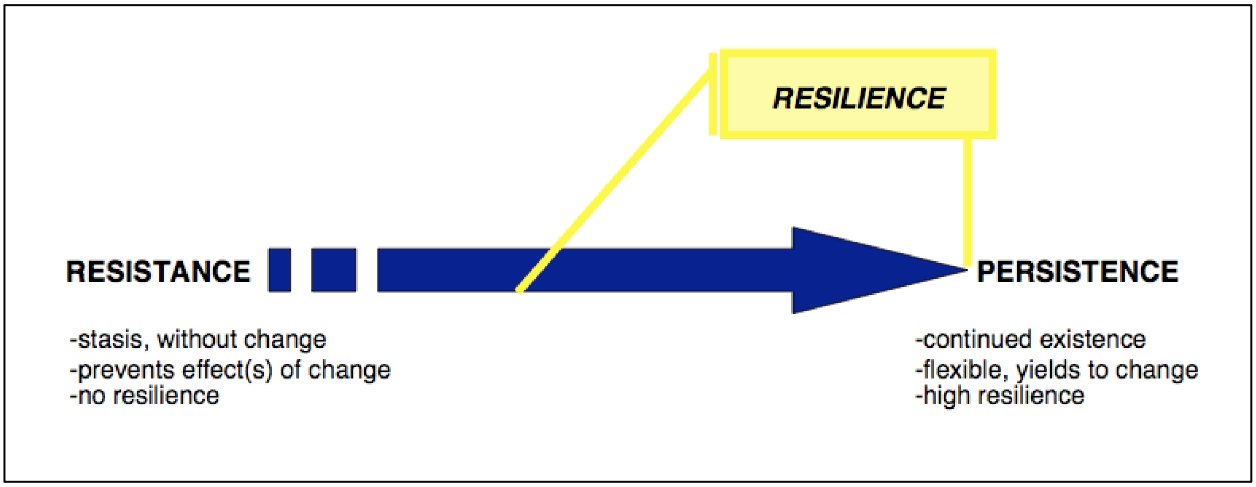

Figure 2.3: The Spectrum of Social-Ecological System States.

Social-ecological resilience can be positive or negative (Carpenter et al. 2001). For example, it is possible for a system to have high resilience and low social acceptability or the opposite; such qualities of a system vary and not always together (Redman 1999; Carpenter et al. 2001, Redman et al. 2004). Furthermore, resilience can be both creative and destructive; proactive and reactive; reactionary and revolutionary – it can exist in a multitude of forms because it is not one singular state or equilibrium. Resilience is about change, adaptation, movement, and flexibility. Resilience has the great advantage of being the best way to cope with surprise; it provides the social flexibility to change and adapt to significant alterations in the system (Carpenter et al. 2001). "Resilient social-ecological systems have the capacity to change as the world changes, while still maintaining their functionality." (Walker and Salt 2006:12).

Resilience is a property attributable to systems or communities, as opposed to individual members or components. While some properties of a community may be reducible to the individual members, other properties, known as emergent properties, arise out of the collectivity and are not reducible to individuals. These emergent properties include resilience. Gunderson states, "[r]esilience is an emergent property of ecosystems and is related to self-organized behavior of those ecosystems over time" (2000:430). Gunderson's argument can be extended to resilience in social and to social-ecological systems, as well. By virtue of this and other factors, the community is the necessary level of analysis for any resilience project.

2.3 CONCEPTS LINKED TO RESILIENCE

Though the concept of social-ecological resilience is the focus of this work, a number of other concepts are closely related, enhancing the potential utility of social-ecological resilience as a boundary concept that links concepts in a number of distinct disciplines and fields, but posing definitional problems, some of which this work attempts to clarify. The measurement of social-ecological resilience is also challenged and made confusing by these cognate concepts. Therefore, these concepts, including community capacity, human and community well-being, vulnerability, and adaptive capacity, will be defined and distinguished from social-ecological resilience. Relationships between these concepts should contribute to a more coherent understanding of resilience in social-ecological systems.

2.3.1 Community Capacity

Community capacity is another concept with multiple definitions, which have evolved over time. While community capacity has often been used interchangeably with concepts such as community empowerment, competence, and readiness (Goodman et al. 1998), there have been efforts to clarify its usage. A 1995 Center for Disease Control symposium was convened largely to reach consensus about the concept of community capacity (McLeroy 1996). The symposium generated the following understanding: community capacity is a multidimensional concept that includes participation and leadership, skills, resources, social and interorganizational networks, sense of community, understanding of community history, community power, community values, and critical reflection (Goodman et al. 1998). This capacity exists as a potential state that operates at multiple levels (e.g., individual, group, organizational, community, policy levels), is context specific, reflects both a process and an outcome, and exists as a dynamic state in the sense that communities can gain or lose capacity (Goodman et al. 1998).

Community capacity is linked to resilience in an important manner. Social-ecological resilience depends in part upon a community's ability to build capacity for learning and adaptation. Therefore, high community capacity is a property of a resilience system. Resilient communities are able to call upon or enact their community capacity in order to respond to disturbance. Enacted community capacity further strengthens the social-ecological resilience of a community.

2.3.2 Human and Community Well-being

Human well-being has been defined in many different ways (Alkire 2002), like the other concepts presented. Many of the definitions include the following key components "the basic material needs for a good life, freedom and choice, health, good social relations, and personal security" (Reid et al. 2005:73). The experience and expression of well-being are context dependent, meaning that local, social, and personal factors (e.g., geography, ecology, age, gender, culture) are involved (Prescott-Allen 2001). The assessment of well-being is admittedly complex and requires an understanding of the many components and the scale at which assessment should occur. In some cases, the concept of human well-being has been extended to the community or societal level. Pollnac and Crawford (2000) utilize measures of general development and quality of life to assess human well-being in communities surrounding marine protected areas. Dillard and colleagues (2013) develop a framework for measuring community well-being in relation to environmental condition for the Gulf of Mexico.

Like community capacity, social-ecological resilience and community well-being are most likely co-variants. Community well-being both contributes to and results from high levels of social-ecological resilience. In cases of high social-ecological resilience and low community well-being, an imbalance of power, wealth, and other resources can be expected. Adger (2006) suggests that human well-being ultimately depends upon both social resilience and the resilience of ecosystems, in other words on social-ecological resilience. This argument stems from the notion that human well-being in communities highly dependent upon natural resources is closely tied to the well-being of the environment as well as of the social system (Adger 2006). The well-being of all systems, social and ecological, depends upon the response of such systems to disturbance.

2.3.3 Vulnerability

Vulnerability refers to the potential for loss or harm (Mitchell 1989) in a system resulting from exposure to excessive risk, shock, or some other stressor (Gunderson et al. 1995). Alternately, in the definition provided by McCarthy et al. (2001), vulnerability is characterized by the degree to which a system is susceptible to and unable to cope with adverse effects of some major change or trauma (e.g., climate change). Regardless of the subtleties of definition, Adger (2006) suggests that the key parameters of vulnerability are “stress to which a system is exposed, its sensitivity, and its adaptive capacity” (269). In natural systems, vulnerability can result from stress placed on individuals or communities of species and from environmental changes that cause potentially irreversible changes (Adger 2000). Most importantly, vulnerability exists as a potential state (i.e., one that does not automatically signify loss or harm within a system, but the possibility of).

Vulnerability and resilience are closely linked in research on disasters in both physical and social systems. The proposed relationship between vulnerability and resilience has taken a variety of forms, the most common being that reductions in vulnerability will result in increased resilience. Reducing social vulnerability through the extension or consolidation of social networks at various scales has the advantage of contributing positive gains in resilience (Tompkins and Adger 2004). When vulnerability is used in reference to social systems, the concept of social vulnerability is employed. Social vulnerability refers to the “exposure of groups of people or individuals to stress as a result of the impacts of environmental change” (Adger 2000:348). Stress can include any disruption of livelihood or forced adaptation to a changing environment. As a concept, vulnerability has become a “powerful analytic tool for describing states of susceptibility to harm, powerlessness, and marginality of both physical and social systems, and for guiding normative analysis of actions to enhance well-being through reduction of risk” (Adger 2006:268).

Vulnerability has also become synonymous with the potential for disaster or high risk and is relied on as an example of a complex concept that can be measured (e.g., Cutter and Fitch 2008; Cutter et al. 2003; Kelly and Adger 2000). This is not to say that resilience and adaptive capacity cannot be measured. Instead, it is to say that vulnerability has been quantified and tested empirically (e.g., Cutter et al. 2003; Baker 2009); hence vulnerability is understood as being measurable (Cutter et al. 2003; Baker 2009; Adger 2006). The methodological advancement of vulnerability over resilience can be plausibly explained by the advances occurring in one area of research prior to the other. Vulnerability has not been conceptualized with the same complexity as resilience; for example, vulnerability is applied to only the social system, as opposed to the entire SES, and does not seek to combine social, ecological, and social ecological processes and patterns in its measurement.[12]

Resilience and vulnerability have often been treated as inversely related by researchers who study social-ecological systems, disasters, and other aspects of coupled human and natural systems (e.g., Resilience Alliance 2009b; Adger 2006; Adger et al. 2005; Folke et al. 2002b). For example, Adger argues that because resilience increases the capacity of a system to cope with stress, resilience is “a loose antonym for vulnerability” (2000:348). The relationship between social-ecological resilience and vulnerability remains hazy. A more vulnerable society may in fact prove to be more resilient (e.g., coastal communities) (Adger et al. 2005). The possibility exists for high levels of vulnerability to translate into increased experience of major change or disaster, which allows for community self-learning from experience, and in the long run, this may result in increased social-ecological resilience (Holling 1973, 1986). This outcome counters the reasonable expectation that a community’s social-ecological resilience may increase as its vulnerability decreases, particularly given the current understanding of the importance of self-learning to the resilience of a system.

Ultimately, vulnerability research and resilience research share a common interest in the shocks and stresses experienced by the social-ecological system, the system response, and the capacity for adaptive action in the face of disturbance (Adger 2006). The commonalities extend far enough for Adger (2006) to claim that the “points of convergence are more numerous and more fundamental than the points of divergence” (269). Though Adger’s claim overstates the relationship between vulnerability and resilience, it is reasonable to think that the parallels between the concepts of vulnerability and resilience offer an avenue for advancing the measurement and quantification of resilience. This may be true because useful research has been done under the rubric of vulnerability or adaptive capacity research, despite the fact that the researchers have often confused the concepts (and what is being measured) with resilience.

[12] In a current project being conducted by NOAA’s National Centers for Coastal Ocean Science, a method for integrated vulnerability assessments of coastal communities is being developed to examine existing vulnerabilities in relation to climate change impacts (NCCOS 2015).

2.3.4 Adaptive Capacity

Adaptive capacity should be seen as a property of resilient systems. Adaptive capacity contributes positively and thereby strengthens resilience. Systems with high adaptive capacity are able to re-organize themselves without significant declines in essential functions (RA 2009b). Adaptive capacity reflects a system's ability to learn from experience (Carpenter et al. 2001; Gunderson 2000), among other things. Based on the view put forth by Adger et al. (2002), "communities are constantly changing" and as a result, communities "focus on their capacity to deal with external shocks" (358) arising from such changes. Resilient communities may be able to absorb the shocks, and through adaptive capacity, respond positively to them. Communities with low resilience are much less able to respond positively to shocks (Adger et al. 2002). Adaptive capacity in ecological systems is related to diversity (Bengtsson et al. 2002; Carpenter et al. 2001; Peterson et al. 1998). In social systems, adaptive capacity arises from institutions and networks that learn and store knowledge and experience, create flexibility in problem solving, and balance power among interest groups (Berkes, Colding, and Folke 2003; Scheffer, Brock, and Westley 2000). Adaptive capacity does not necessarily convert into action. Much like vulnerability, adaptive capacity is about the potential for the adaptation to occur when required by the system.

Adaptive capacity and resilience are often tightly linked in the social-ecological resilience literature (e.g., Carpenter et al. 2001; Holling 2001; Walker et al. 2004) so much so, in fact, that the two are easily conflated (Gallopin 2006) For some researchers (e.g., Holling 2001), adaptive capacity, like resilience, is thought to be the opposite of vulnerability. There should be little question that adaptive capacity within a system has the potential to positively contribute to that system's resilience, for adaptive capacity is one mechanism by which resilience can be achieved (Holling 2001). However, it is not correct to suggest that resilience produces adaptive capacity, though it does enhance existing adaptive capacity through a feedback loop, of sorts. Adger et al. (2005) argue that adaptive capacity can be enhanced through intentional action; the same is true of social-ecological resilience. However, the complexity of achieving such enhancement must not be underestimated. Structural factors play a significant role in the achievement of resilience and adaptive capacity within a community and these factors are not controlled by intention[13] alone.

2.3.5 Untangling Resilience, Vulnerability, and Adaptive Capacity

Pulling apart the interrelated, often conflated concepts of resilience, adaptive capacity, and vulnerability is a daunting task, with much of the literature and research adding complication to the already complex and often, unclear picture (Gallopin 2006). The conflation between concepts of resilience and vulnerability, as well as resilience and adaptive capacity misses the possibility of different (and somewhat counterintuitive) relationships between these concepts. While resilience can be either positive or negative (Carpenter et al. 2001), the same cannot be said of adaptive capacity or vulnerability. Adaptive capacity is only a potential state and should not be treated as positive or negative until enacted. Most theorists would argue that the presence of significant adaptive capacity, and especially the enactment of this capacity, is positive by virtue of its connection to resilience (e.g., Holling 2001). Conversely, vulnerability is never held to represent a positive attribute; vulnerability itself is a negative property of a system, even when the system is not actively experiencing the negative consequences of being highly vulnerable (Adger 2006; McCarthy et al. 2001). The same negative conception of vulnerability holds when the system later benefits from vulnerability through self-learning and experiences an increase in resilience. For visual clarification of this relationship, see Figure **2.4** in which both vulnerability and adaptive capacity contribute either positively or negatively to resilience, but exist at a lower conceptual level than resilience.

The final, and perhaps most critical, distinction between resilience and the concepts of vulnerability and adaptive capacity is that resilience is an actual state whereas vulnerability and adaptive capacity are mere potentialities. Vulnerability is repeatedly defined as the *potential* for loss, harm, or disaster within a system (e.g., Mitchell 1989). The vulnerability of a system exists whether or not the potential is ever actualized. However, a system's resilience exists whether or not the circumstances require it. Similarly, adaptive capacity points to a capacity, which is the (*potential*) ability of a system to be adaptive when necessary. The system may not ever call upon

[13] Here, the use of intention, particularly with respect to action, closely resembles the sociological concept of agency (see, Davidson 1977). When an individual performs an action that can be considered intentional, he or she is said to have agency.

this capacity. If it does, the capacity is actualized and the system can be called adaptive. Until then, the system can only possess the capacity to be adaptive. While the concepts of resilience, vulnerability, and adaptive capacity are often conflated, there is a strong basis for fighting the imprecise use of the concepts. The difference between concepts that embody actual versus potential states is a critical starting point to conceptual refinement. As research continues to clarify the relationship between social-ecological resilience and related concepts like vulnerability and adaptive capacity, theoretical clarification and empirical findings may well contribute to the advancement of broader debates about resilience and other concepts, and ultimately, to the advancement of human and ecological well-being (Adger 2006).

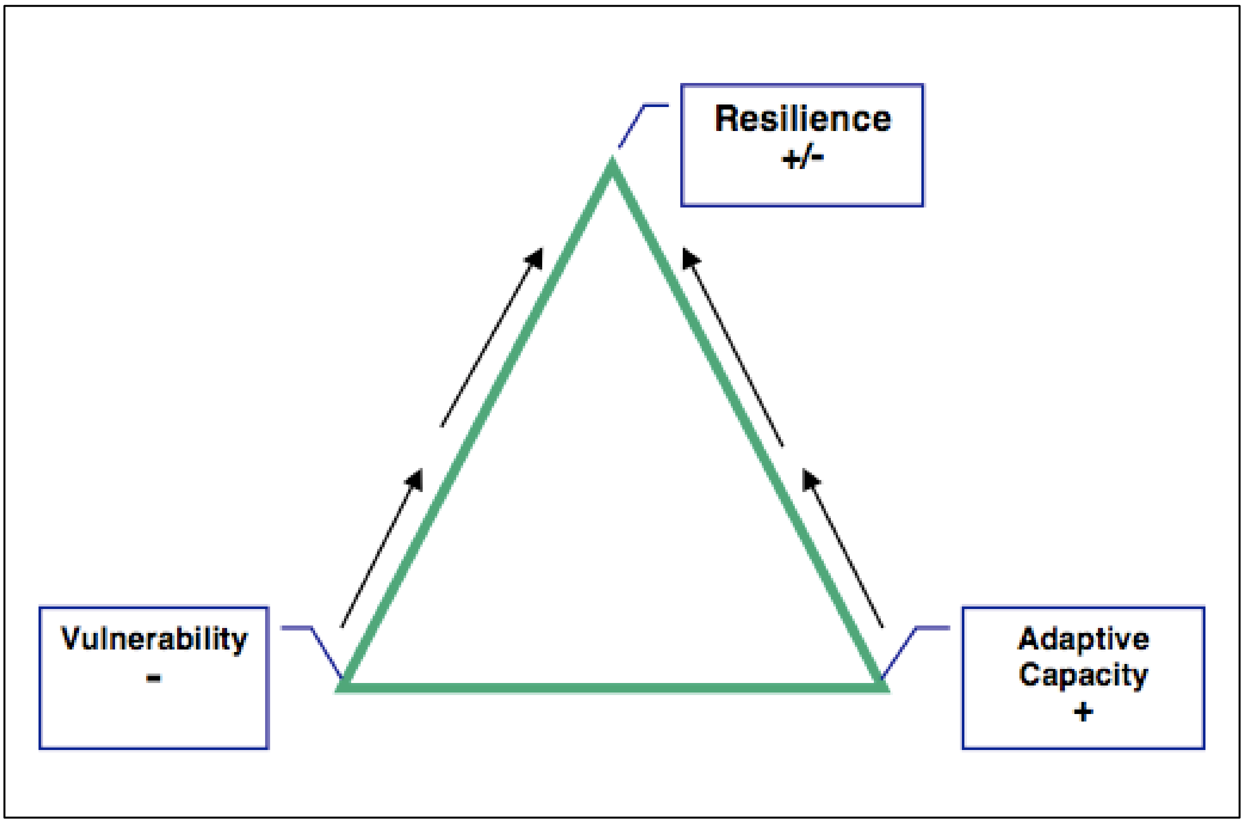

Figure 2.4: Linking Resilience, Vulnerability, and Adaptive Capacity.

2.4 DEFINITION OF RESILIENCE

Combining elements of definitions developed by key resilience researchers, ***social-ecological resilience will be defined here as the community's ability to absorb recurring disturbances in a***

way that allows essential structures, processes, and feedbacks to be maintained. Resilient systems and their components respond productively to significant change that disrupts expected patterns "without engaging in an extended period of regressive behavior" (Horne and Orr 1998). ***The defining characteristics of a resilient community include coping with change while retaining: 1) the same controls on function and structure, 2) the capability for self-organization, and 3) the ability to build and thereby increase the community's adaptive capacity for learning and adaptation to the changing conditions*** (RA 2009b). In this context, the term 'community' will refer to a geographically bounded, integrated social-ecological system of people and the natural environment. This should stand in opposition to a purely social sense of community, which typically lacks reference to the physical environment, natural or built (Brown 2003; Duncan 1964). The terms 'social' and 'ecological' can be deconstructed into people/society and environment/nature. However, the composition of the two together is intended to indicate something beyond the simple addition of people and environment. The use of the term 'ecological' is intended to reference both nature and the interaction of the social system with and within a particular space or physical environment.

2.4.1 Properties and Relationships of Resilience

Social-ecological resilience is defined as a property of the linkage between ecosystems and human systems (Ahmed 2006; Walker et al. 2006b). The interactions within the social ecological system also contribute to the understanding of the relative functions of resilience. Several theoretical propositions about the properties and relationships of resilience drove this research.

The very definition of resilience includes that communities will have characteristics that are associated with the ability to respond to change without complete collapse. For example, the ability to maintain controls of function and structure, to self-organize, and to increase the capacity for learning and adaptation to change are all part of a resilient community. This does not mean that resilient communities are stagnant; instead, it means that communities are highly flexible and able to cope with varying amounts of change. The resilience of a community predicts its ability to change, adapt, and prepare for surprises while continuing to maintain functionality. As a result, climate change, economic decline, and other changes impacting the social-ecological system are better dealt with by more resilient communities.

Resilience is both positive and negative; creative and destructive; proactive and reactive; reactionary and revolutionary. The resilience of a community can exist in a multitude of forms because it is not one singular state or equilibrium. Resilience is about change, adaptation, movement, and flexibility. Therefore, it may not always have a consistently linear relationship with an indicator. For example, resilience may increase with a highly authoritarian regime up to a point, but this relationship likely has a peak at which the regime begins to cause a decline of resilience. As a result, resilience may have a nonlinear relationship with some indicators, for it has duality as a key characteristic.

Resilience is related to both persistence and resistance. Persistence and resilience are expected to be positively correlated, while resistance and resilience are expected to be negatively correlated. Resilience has persistence as a key criterion and resistance as a complementary attribute (Carpenter et al. 2001). Persistence over time means the system endures with changes, adaptations, and alterations to internal and external stimuli, while retaining its core control structures and functions (Holling 1973). This relationship can be understood pictorially through Figure **2.3**.

Resources are connected to resilience, but not in the limited way of thinking of resources as purely economic. A social-ecological system's resources include both social (e.g., culture, language, educational institutions) and ecological (e.g., plants, animals, land, climate) components. The ways in which resources are protected and used is as important as the presence of these resources for the resilience of the community. Ultimately, the resilience of a community is positively correlated with its internal and external resources, as well as its ability to grow these resources.

The emergent properties of resilience, vulnerability, and adaptive capacity are interrelated. Both vulnerability and adaptive capacity can contribute to the overall resilience of a community and therefore, will be correlated with resilience. However, due to the complicated relationship between vulnerability and resilience, there is space for both a negative and a positive relationship to exist. In other words, this relationship may be nonlinear. Alternately, adaptive capacity should in all cases be positively correlated with resilience. The hypothesized linkages between the concepts can be summarized by Figure **2.4**.

2.4.2 From Theory to Methods

Currently, resilience has wide use in interdisciplinary work concerned with the interactions between people and the environment (Carpenter et al. 2001). The examination of the theoretical underpinnings of the concept of resilience and its usage in a variety of disciplines and fields is an essential step in the clarification of the concept of social ecological resilience. Researchers using the concept of resilience have proceeded in different ways, though few researchers have attempted its quantification.

The theoretical examination forms the initial phase of this study. In the next phase, indicators of social-ecological resilience will be identified and operationalized. From this theoretical discussion, the focus shifts to the methodological approach needed for the development of both a conceptual framework and operationalized measurement model for resilience.

3 METHODOLOGY

3.1 INTRODUCTION

As a result of the increasing importance of the concept of resilience as a policy goal, there is need for the development of a set of empirical indicators that can be used to operationalize resilience. Ideally, the operationalization of social resilience would make possible the application of a measure across communities with only small adjustments for the specific context of the particular type of community being examined. The measurement of resilience would provide communities of island and coastal states with a way of evaluating their ability to implement, adapt, and/or support policies for change. These indicators would also assist decision makers in identifying factors that threaten community sustainability and stability. Ultimately, both conceptualization and valid measurement of social-ecological resilience hold great potential utility for providing insights about the ways in which communities anticipate and respond to changing conditions (Adger 2000, 2006; Carpenter et al. 2001). With an integrated understanding of societies and environments, better policy, governance, management, and science can emerge.

3.2 RESEARCH DESIGN

The overarching goal of resilience research is to simultaneously inform action through policy, governance, and management strategies as well as to advance science (RA 2009a). This requires pushing beyond the boundaries of disciplinary and methodological paradigms. As a result, this research employs a social-ecological systems perspective combined with social science methodologies to study the social-ecological resilience of small island and coastal communities.

Multiple methods of analysis and types of data will be incorporated in the development of a valid, reliable, and utilitarian measure of resilience.[14]

This study is composed of four primary phases of research.

- **Phase 1: Development of the Conceptual Model** is focused on the theoretical aspects of the concept of social-ecological resilience, as well as the concept's empirical application. In this phase, a conceptual framework for social-ecological resilience was developed.
- During **Phase 2: Indicator Development** data from multiple secondary sources was collected and synthesized in a central database in order to conduct measurement modeling. Indicators were then constructed using several different methods. The methods and results were compared before a final selection was made for the measurement of social-ecological resilience in small island and coastal communities.
- In **Phase 3: Application of Measurement Model**, the measurement model was applied in order to examine similarities and differences across the two samples. Additionally, associations between indicators of social-ecological resilience were examined.
- Finally, in **Phase 4: Extensions of the Measurement Model**, the analysis turned to the development of a community typology using the indicators. In this phase, the model was also assessed for generalizability.

The first phase of this research began by clarifying the theoretical understanding of the concept of social-ecological resilience and its empirical application. The remaining phases of the research use the conceptualization of social-ecological resilience to develop and apply a valid empirical measure of social-ecological resilience. The model serves as a quantitative assessment of social-ecological resilience of communities as distinct social-ecological systems.

3.2.1 Study Area

Most broadly, the study area is focused on coastal communities. From there, a distinction is made between the communities found on small island developing states and mainland US coastal communities. Coastal and island communities are unique in the way in which they noticeably

[14] The approach was designed to achieve the research and applied goals of: 1) a measurement model (with related variables and indices) for assessing the social-ecological resilience of a community; 2) application of this measure in various settings and suggested future uses of the measure; and 3) a framework demonstrating the ways in which the measure can be developed and applied based on various factors, including data available, purpose of assessment, and geographic location of community.

and often, forcefully couple social and ecological systems. “The complexity of the intersection of social and environmental forces is pronounced in coastal communities…because culture and economy are tied to marine resources, coastal communities are often defined by this intersection. As a result, the well-being of a coastal community is caught up in the health of its environment, the stability of its economy, the provision of services to its residents, and a multitude of other factors.” (Dillard et al. 2013). The same can be said for the social-ecological resilience of a coastal community.

The goal of this study is to conceptualize, develop, and apply an approach for the assessment of resilience of coastal and island communities in relation to a variety of social and ecological disruptions and associated interventions. By examining two distinct types of coastal communities in very different regions, this project informs future investigation and evaluation of social-ecological resilience for all coastal communities. The study area crosses boundaries of many kinds in order to assess resilience for communities of the US Gulf of Mexico, the Caribbean, and the Pacific.

3.2.1.1 Small island states communities. Small island developing states (SIDS) are ideal settings for the initial testing of a measurement model of resilience because the social and ecological boundaries are explicitly defined and therefore quantifiable. Likewise, the communities of SIDS are at risk of disproportionate impacts from environmental problems like global climate change, increased pollution, and water scarcity. Despite the great social and cultural diversity represented by these communities, their similarities make them vulnerable to the most severe consequences of environmental change. The United Nations defines SIDS in the following way:

> ...small island and low-lying coastal countries that share similar sustainable development challenges, including small population, lack of resources, remoteness, susceptibility to natural disasters, excessive dependence on international trade and vulnerability to global developments. In addition, they suffer from lack of economies of scale, high transportation and communication costs, and costly public administration and infrastructure. (UN 2007)

Presently, there are just over 50 small island developing states and territories included in the list used by the United Nations Department of Economic and Social Affairs in the implementation of the Barbados Programme of Action (UN 2007).

In SIDS, the inter-connectedness of the issues of economy, development, environment, and human well-being makes it impossible to address social and environmental problems in isolation from one another, which makes these settings ideal “real-world” laboratories for studying resilience. In addition, SIDS are ideal sites for the study of resilience because:

- the unique difficulties and challenges of islands may lead to advantageous outcomes related to discovering and implementing solutions (e.g., local, small-scale, renewable energy sources, locally sustainable resource management) (Kelman 2010);
- the compactness and isolation of islands allows for more complete exploration and analysis of the relationships between resilience, vulnerability, sustainability, and adaptability;
- and, there is great potential for lessons to be transferable from islands to other non-island geographies (Kelman 2010).

Small island developing states (SIDS) face unique issues due to the intimate connection between the people and the environment. Kelman and Lewis note that “islands often experience longer-term, more chronic vulnerabilities” (2005:8). Both disasters and more chronic changes pose a distinct, and perhaps greater, challenge to SIDS and the social-ecological communities that reside on these islands when compared to other locations experiencing similar conditions.

The initial sample of communities was drawn from the small island states that are US jurisdictions. The six small island states that fit within this category also happen to be jurisdictions that are managed for their coral reefs. US coral reef habitats are associated with great economic value (Brander and van Beukering 2013). However, the importance of coral reefs goes beyond simple economics to encompass a range of ecosystem services such as biodiversity, fisheries, storm protection, medicine, tourism and recreation. Many of the people who live on these islands are dependent on coastal resources, whether for jobs, food, cultural traditions, or tourism (Loper et al. 2008). As a result, the declining quality of coral reefs corresponds to potential negative impacts for these communities. Small island communities are vulnerable for other reasons, as well. With determinant boundaries come limited opportunities and resources for both the social and ecological systems.

Geographically and otherwise, the US territories and outlying islands are a diverse group. The island states cover two general regions. Puerto Rico and the US Virgin Islands are located in the Caribbean, while American Samoa, Guam, the Commonwealth of the Commonwealth of the

Northern Mariana Islands, and Hawaii are in the Pacific. These island states feature distinct social characteristics, including population size, racial and ethnic composition, birthplace of residents, and common economic sectors. Furthermore, the island states exhibit variation on ecological characteristics like landcover, elevation, and coral habitat (Crossett, Clement, and Rohmann 2008).

3.2.1.2 Gulf of Mexico coastal communities. To go beyond small island states to examine the broader applicability of the model, mainland US coastal communities along the Gulf of Mexico were included. Coastal counties in this particular region provide excellent comparisons to island states. Based on history, the GoM faces a similar disproportionate threat from natural and technological disasters and more chronic changes. The region has been impacted by extremely costly tropical storm and hurricane events, oil spills, harmful algal blooms, coastal erosion, and land subsidence, just to name a few (Blake et al. 2011; Bricker et al. 2008; Morton, Buster, and Krohn 2002; Pennock et al. 2004). The consequences of these events tend to be a combination of damage to the natural environment or human built infrastructure and damage to the local economy and sociocultural systems (e.g., Elliott and Pais 2006, Pennock 2004). As a result, this region is highly challenged area in terms of social -ecological issues. As with US territories and outlying islands, the GoM region has a complex history that informs the present day context. Similarities include population diversity, economic disparity, and social conflict.

Five US states span the approximately 47,000 miles of shoreline along the Gulf of Mexico - Texas, Louisiana, Mississippi, Alabama and Florida (NOAA 2011). Nearly 21 million people lived in the Gulf Coast region in 2010. Coastal communities in all regions are experiencing dramatic population growth, which suggest that the size of the Gulf Coast populations will only increase with time (NOAA 2013). The Gulf Coast region includes all counties within the coastal watershed of the Gulf of Mexico (NOAA 2011). In this region, the populations depend on a range of ecosystem services or benefits that include food, clean water, jobs, recreation, and storm protection. However, these benefits are threatened by coastal development, resource extraction, and climate change (NOAA 2011). As in all coastal communities, the well-being of the environment and the people are tightly bound in the Gulf of Mexico.

The Gulf of Mexico is a region with great ecological, economic, social, and cultural importance. The GoM serves as nursery grounds for economically and ecologically important fish species and rich habitat for coastal wildlife (Giattina and Altsman 1999). The Gulf of Mexico contains more than half of the coastal wetlands in the mainland United States (Field et al. 1991). The region provides over 90% of the region's annual commercial fisheries landings and is a major destination for recreational fishers from all over the country (NOAA 2011). The reliance on the environment is evident in the GoM's most important industries, which are oil and gas, commercial fishing, marine transportation and shipping, and recreation/tourism (including recreational fishing) industries (Adams, Hernandez, and Cato 2004). Collectively, the unique habitat, resources, and industries are socially and culturally significant for the communities of the GoM. "[T]he Gulf of Mexico is rich in natural resources that are highly valued by people, from crude oil to white sand beaches" (Dillard et al. 2013).

3.2.2 Unit of Analysis

Among the critical aspects of the development of a measure of social-ecological resilience is the determination of the operationalized level of analysis, i.e., what practically and meaningfully composes a community or social-ecological system. Community may be defined in a number ways using legal, political, physical or symbolic criteria (Clay and Olson 2008; Cohen 1985). In social science research, communities are often identity-based and defined by sociocultural factors (e.g., the gay community, the African-American community, the Catholic community). For example, a community may be defined by a group's subjective identity, such that the community members decide what constitutes the community and how outsiders qualify for membership (Clay and Olson 2008; Jacob et al. 2002). Alternatively, a community may be defined by some form of social behavior, such as participation in an activity or engagement in social networks (Putnam 2000; Tropman, Erlich, and Rothman 2001). Definitions of community do not necessarily include a geographical boundary (Gusfield 1975).

According to Raudenbush and Sampson (1999), only recently has there been an effort to develop scientifically rigorous methods for the assessment of human-ecological settings such as neighborhoods and schools. Even in organizational studies the measures have historically been studied psychometrically at the level of the individual respondent rather than "ecometrically" at the level of the organization, even when the unit of analysis used in structural models was that of the organization (Sirotnik 1980).[15] For this reason, it is critical to assess the social-ecological system in a way that best captures the functional interaction of the social and ecological components. In this research, primacy will be given to socially and ecologically meaningful communities that correspond to units used in policy-making. Ecological meaning can be obtained through communities composed of geographically contiguous units with some internal homogeneity on key social and ecological indicators. Alternately, social meaning can be obtained by taking into consideration pre-existing definitions of community and identity-based community boundaries. Therefore, the unit of analysis is the community or social-ecological system operationalized as the county or a county-equivalent.

The county or county equivalent unit of analysis was chosen for several key reasons. First, the county or county equivalent was determined to be the best unit of analysis for an effective impact on policy, planning, and political action. Second, counties and their equivalents are temporally consistent administrative units. Next, these units are nested geographically, such that aggregation upward can be used to examine trends at the regional, state/jurisdiction or national level for an understanding of broader dynamics. Also important, counties or county equivalents have geospatial dimensions connected to the monitoring and management of the environment. Finally, these units are associated with a broad range of existing, secondary data. By selecting a unit that exists in multiple geographies, within the mainland US and beyond, the methodology gains transferability.

3.2.3 Sample Selection

Within each broader geographic unit (e.g., state, island), a sample of communities will be defined/identified. Through this process, a sampling frame will be created employing numerous criteria to guide the process of case selection.

Criteria for sample selection:

- The emphasis will be on coastal communities and other communities with an obvious, intimate, pre-existing relationship between people and the natural resources originating in that ecological unit. By focusing entirely on small islands and coastal communities, this criterion will be more easily met while still maintaining variability among the cases (e.g.,

[15] For a complete discussion of "ecometrics," a term derived from the application of psychometric tools to the assessment of ecological constructs, see Raudenbush and Sampson 1999.

due to geographic/physical proximity or to economic dependence some communities will be more directly connected to natural resources than others).

- The availability of data in the best and most accessible form will be the most critical determinant of the sample selection.
- Human population inhabits geographic unit.
- Population is large enough to avoid complications associated with data suppression.
- Part of a broader geographic unit for which data can be obtained in order to conduct multi-level modeling.[16]

3.2.3.1 Final samples. This research set out to focus explicitly on small island developing states. Data were collected and examined for 19 SIDS, ranging from islands in Latin America and the Caribbean to Africa to Asia and the Pacific. In order to achieve the most comparable data across the cases, a decision was made to focus on the 6 US outlying islands and territories. The Island States Communities Sample refers to the data compiled for the county equivalent units in the 6 US outlying islands and territories: American Samoa, Commonwealth of Commonwealth of the Commonwealth of the Northern Mariana Islands, Guam, Hawaii, Puerto Rico, and US Virgin Islands (Figures **3.1-3.4**). The Island States Communities Sample includes counties and county equivalent units for an n=94.

An additional sample was also included in the research to enhance the statistical analyses and to explore the extension of the measurement model to non-island communities. The US Gulf of Mexico (GoM) Coastal Counties Sample refers to the data compiled for a selection of coastal counties from the states bordering the US Gulf of Mexico: Alabama, Florida, Louisiana, Mississippi, and Texas. The coastal counties of the GoM Region were determined to be all those counties falling within the boundary of what NOAA terms "coastal counties" (Figure **3.5**). NOAA's coastal county designation includes counties both directly on the shoreline, as well as those with a substantial land area in the coastal watershed (NOAA, n.d.). This definition allows the GoM counties to align well with the small island counties and county equivalents included in the sample, as there are both inland and shoreline adjacent units included for both small island

[16] Multi-level modeling is among the future goals of this research and represents an ideal extension of the measurement model.

and GoM states. The GoM Coastal Counties Sample includes an n=135 coastal counties. The complete list of cases is presented in Appendix A, Tables **A1-A2**.

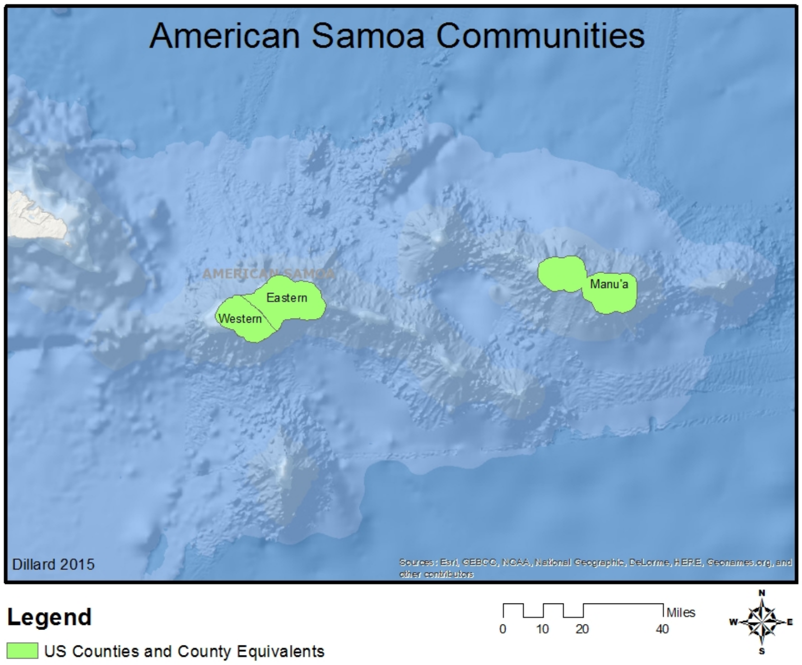

Figure 3.1: Map of American Samoa Communities.

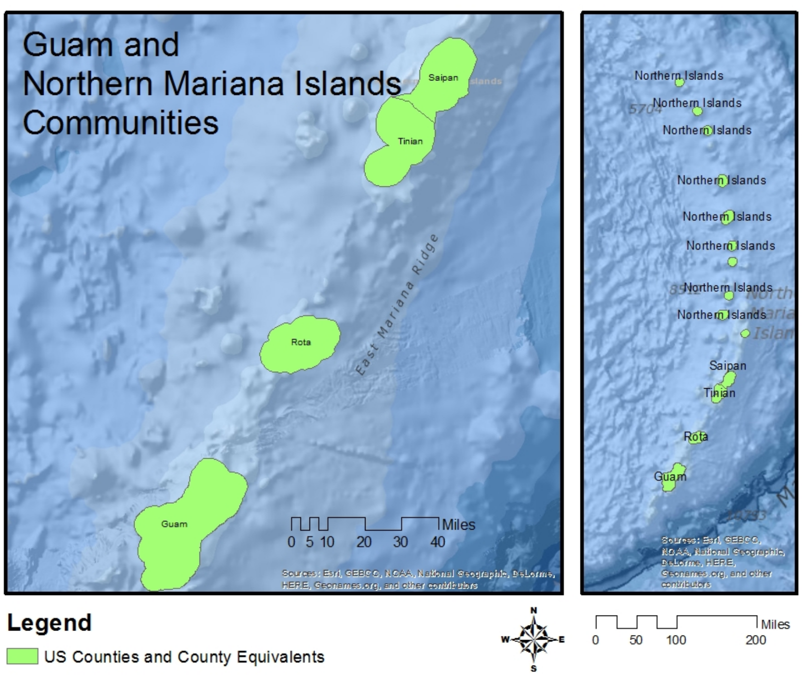

Figure 3.2: Map of Guam and Northern Mariana Island Communities.

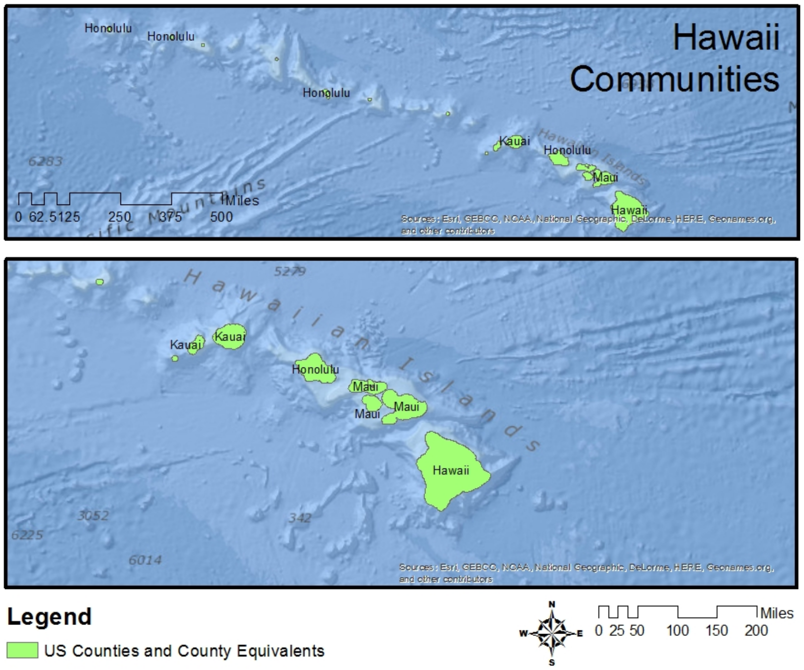

Figure 3.3: Map of Hawaii Communities.

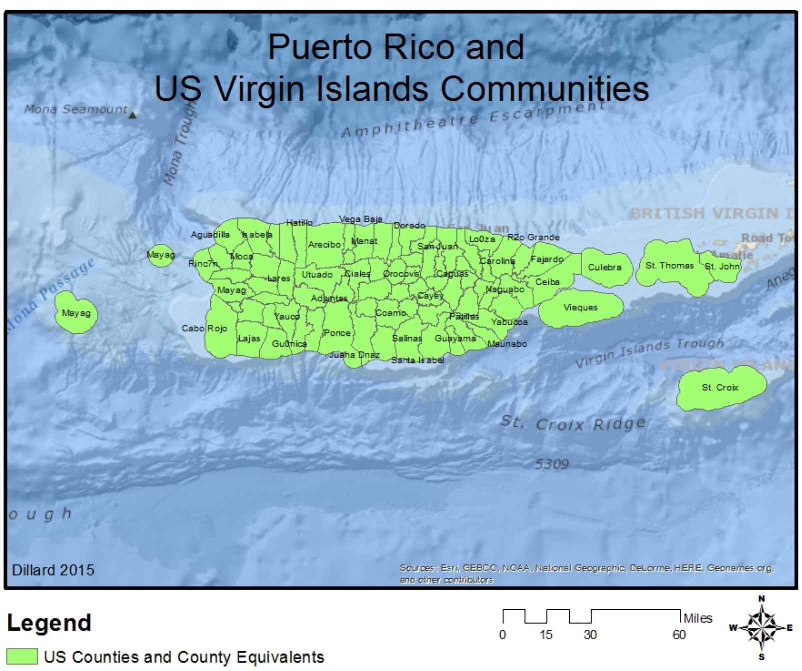

Figure 3.4: Map of Puerto Rico and US Virgin Islands Communities.

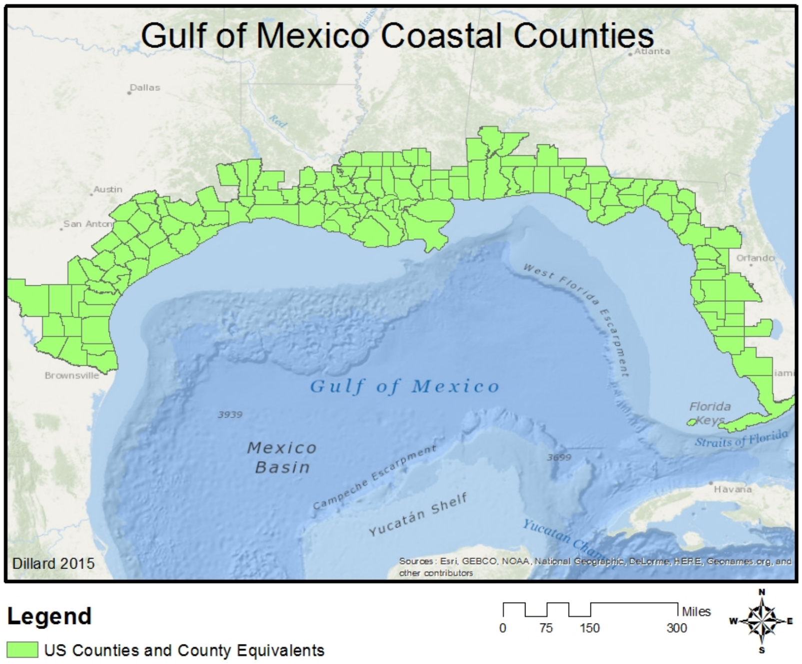

Figure 3.5: Map of Coastal Counties in the Gulf of Mexico.

3.3 DATA

This study relied solely on secondary data, which are data collected by someone other than the secondary user, often for a purpose different than the secondary use (Schutt 2001). Many of the data sources used in this study are part of federal government data collections (see Appendix B, Tables **B1-B2**). Secondary data generally references quantitative data (Schutt 2001), as is the case for this project.

There are pros and cons to using secondary data to assess social-ecological resilience. One major advantage of using secondary data is related to the likelihood of procuring consistent data across uniformly-defined geographic areas, such as a state, territory, region, or county. The U.S. Census Bureau, for example, collects data consistently across the U.S. (including the territories and outlying islands) at a variety of geographic scales. Cost effectiveness is a second major advantage to using secondary data. Secondary data serves as a relatively inexpensive way to obtain a large quantity of useful data. The costs of collecting comparable primary data would be much greater. Both the likelihood of uniform collection and cost effectiveness associated with secondary data make it possible for many more researchers to work across large geographic areas. The advantages are amplified when the intention is to continue to collect and analyze similar data over time. Some secondary data are collected over time, which makes the design and implementation of time series studies possible.

Secondary data comes with challenges, as well.[17] The availability of current data is often an important constraint of using secondary data. Substantial lag times between releases of new data are common. The delays often correspond to the geographic scale of the collection, which translates into more time needed to process and clean data. Additionally, there are fiscal and administrative challenges associated with maintaining a long term data collection. The availability of current secondary data may appear as a limitation for this study. Although the data collection phase of this work spanned 2010-2013, the most recent data for the U.S. Decennial Census and other necessary collections were not available for island areas. As a result, this effort relied on available data to develop a methodological approach that can be used to measure and track the resilience of island and coastal communities well into the future, as new data become available.

Apart from delays in the release of current data, the most difficult challenge of working with secondary data is that ideal measures are not always available. Mostly, this occurs because the original data collections are driven by a purpose that does not match the current use of the data. In the case of the present project, data were not tailored to the measurement of social-ecological resilience. As a result, the development of a research design to measure resilience with secondary data required diligence, flexibility, and creativity in using available measures to reach the desired indicators. To ensure the development of a rigorous methodology, criteria were employed in the selection of secondary data used in this study. Ultimately, the benefits far outweigh the challenges when it comes to the use of secondary data.

3.3.1 Criteria for Secondary Data Sources

Several characteristics make existing datasets ideal for secondary analyses. It is important to seek high quality datasets such that data were reliably collected using well designed, transparent methods. In the development of indicators that are intended to have long term policy application,

[17] See McCaston 2005 for a review of considerations specific to the use of secondary data.

it is desirable to locate datasets that have been collected consistently over long periods. This is especially true in cases where time series analyses are anticipated. For example, future analyses of resilience may be well served by the flexibility to look back (retrospective) to measure changes in resilience in relation to specific event, as well as forward (prospective) to predict the resilience of communities in light of particular changes that have already been experienced. Datasets that are collected, maintained, and served by stable public agencies (e.g., federal government, state agencies) hold many advantages, including the greater likelihood for those datasets to continue to be available in the future. Many of these data collections are mandated by legislation with further increases confidence in their longevity. The datasets used for the present study met these critical criteria. Additional criteria used to evaluate datasets for inclusion in the present study include the following (Dillard et al. 2013):

- Documentation - Does the dataset have clear and appropriate documentation?
- Accessibility - Is the dataset accessible online and available for download in standard data file formats?
- Geographic coverage - Does the dataset represent broad geographic coverage both within the study area and beyond?
- Quality - Has the dataset been subject to a quality assurance and quality control process (i.e., data are clean, without missing values and ready for use)?
- Unique information - Does the dataset contain data that are unique or uniquely compiled?

These criteria were established and implemented in order to require careful consideration and justification for the data selected for this research. The choice to utilize secondary data often means collecting and synthesizing a wealth of data that may or may not be used in the final analyses. In many cases, the data must be thoroughly explored before being able to make the final determination regarding its inclusion. Secondary data collection and analysis also require awareness and sensitivity of methodological challenges associated with data from US outlying islands and territories. The methodological challenges are part of the reason for including the Gulf of Mexico coastal counties as an additional sample. By studying both sets of communities and comparing social-ecological resilience across two samples, the impact of issues related to data availability, reliability, and the like was more fully assessed.

3.3.2 Synthesizing Data from Multiple Sources

The quantitative data were identified and obtained from publicly available data sources, including federal, state, and local government agencies as well as non-governmental organizations and academic institutions. Data sources include US Census Bureau, Environmental Protection Agency (EPA), United Nations (UN), National Oceanic and Atmospheric Administration (NOAA), Federal Emergency Management Agency (FEMA), and The World Bank, among others. The datasets and sources from which the final measures were obtained are described in Appendix B. Table **B3**. In order to build the database necessary for this research, available data sources were identified and organized by type, year(s), and format for each case of the sample. The initial data collection and compilation consolidated numerous formats and sources so as to produce a single database with appropriate metadata documenting the original sources and any modifications. The units for which the data are collected range from individuals to households to counties. The final US Island States Dataset draws from over 20 data sources and includes more than 300 measures, while the US Gulf of Mexico States Dataset includes more than 200 measures and was extracted from a larger database that contains more than 50 data sources. Data from various sources were synthesized into a unified database using Microsoft Excel and IBM SPSS Statistics 19 software.

In combining data from a variety of states, territories, communities, and sources, methodological strategies for ensuring comparability are essential (Kohn 1989). Data cleaning ensures the comparability of variables across cases. This includes procedures for imputing data for missing values, recoding, and the creation of new variables (e.g., population rates). The variables were not transformed prior to import into the database; instead, data transformations occur in separate software are saved within new data files so that the original data can be retrieved at any time. Data were generally downloaded in a standard data file format (e.g., csv, xls, txt) and then cleaned and edited in order to prepare for entry into the database. Quality assurance for the secondary data compiled was tied back to the original source, though additional methods were contributed to ensure the quality of the collection. Data were downloaded from original sources, along with relevant reference materials (e.g., data manuals, codebooks, and other documentation). The data were then imported into a comprehensive database where data cleaning and transformations could be performed and recorded. The variables are coded to signify data source, data year, and a variable label. Careful documentation of all data downloads and edits have been maintained in a data log, along with a clean set of original data files for reference.

3.4 MEASURE DEVELOPMENT AND DATA ANALYSIS

This study is focused on the development of a measurement model that can be used to evaluate and compare social-ecological resilience across island and coastal communities. As social-ecological resilience is a complex concept with social, economic, and ecological components, the use of indicators was identified as a means of capturing the multiple dimensions. Additionally, indicators have been proposed in existing work on resilience, so the need for indicators is well established in resilience research.

In this study, quantitative data was analyzed using a variety of social science methods for measure construction, application, and for exploring extensions of the model. First, data was analyzed using descriptive and correlation analysis in order to explore the characteristics of the cases as well as the characteristics of the potential variables for operationalizing social-ecological resilience. Second, various indicator development methods were utilized and compared. These methods include: confirmatory factor analysis, two types of exploratory factor analysis (principal components analysis and principal axis factoring), and an iterative methodology that combined theoretical, methodological and statistical factors to create composite indicators using a general linear scaling technique and an additive index equation. Following the comparison, the methodological approach for the development of the indicators was selected. Next, the indicators were constructed and applied. During application of the measurement model, all cases were scored for each indicator of social-ecological resilience and examined on the basis of their scores. This portion of the analysis included examinations of the distribution, central tendency, and dispersion of scores for each sample, as well as correlation analyses to examine associations among indicators of social-ecological resilience for each sample. Finally, working toward the development of a typology, the two samples of communities were examined using k-means cluster analysis. Additional extensions of the measurement model were also explored in the final phase. All analyses were conducted using IBM SPSS Statistics 19 and IBM SPSS AMOS 20. Data visualizations were created in Microsoft Excel and ESRI ArcGIS 10.2.1.

3.5 IRB AND ETHICAL ISSUES

This study meets all requirements of the University of Pittsburgh, Institutional Review Board. As the unit of analysis of this research is not the individual, the study meets the requirements for exempt status of research not involving human subjects. The principal investigator (PI) of this study has completed required University of Pittsburgh IRB modules and is certified for human subjects research. Phase 1 of the study examining the conceptual and theoretical applications of resilience did not require IRB approval and was covered as exploratory work. The remaining phases of the research, Phases 2-4, rely on public use data files and other secondary data that is currently in existence, recorded anonymously, and aggregated at a county or county-equivalent level. These phases met all requirements for exempt status. While this study does not require the collection of any sensitive information, procedures will be in place such that all reasonable and appropriate protections are implemented and risks related to invasion of privacy and breaches of confidentiality remain minimal. The IRB submission was approved as an exempt study in 2010 and was approved for an extension in 2013.

4 CONCEPTUAL FRAMEWORK

4.1 CHALLENGES OF MEASURING AND STUDYING RESILIENCE

The methodological challenges to developing theoretically based indicators are, in large part, the reason that resilience research has not advanced beyond the level of metaphor to empirical measurement (Carpenter et al. 2001). Methodological challenges including, studying complex, coupled systems; integrating distinct disciplines and fields of research; and, dealing with issues of scale, level, and causality are examined in this chapter. Adger acknowledges that such challenges are common to the research "domains of vulnerability, adaptation and resilience" (2006:277). Confronting these issues is pre-requisite to the measurement of social-ecological resilience.

4.1.1 Incorporating an Ecological Approach into Social Science

The incorporation of the prefix or term 'eco' in the various names used to refer to social ecological models is important because of the emphasis placed on an ecological approach and the explicit differentiation of these frameworks from a simple "substitute or metaphor for social analysis" (Krieger 2001:672).[18] Ecology is the science concerned with the study of the evolving interactions between living organisms and their environment across space and time (Peterson and Parker 1998; Roughgarden 1998). Krieger (2001) identifies the following five components that characterize an ecological approach:

- Scale – "quantifiable dimensions of observed spatiotemporal phenomenon"
- Level of organization – "theorized and inferred, in relation to specified nested hierarchies"

[18] Social ecological models are distinct from other theoretical perspectives that have utilized the term 'ecology' as a metaphor (e.g., social ecology, human ecology) and as a result, are often criticized for naturalizing social divisions and processes (e.g., racial segregation) (Alihan 1964; Krieger 2001).

- Dynamic states – “combined interplay of specified animate and inanimate ‘inputs’ and ‘outputs’
- Mathematical modeling – “to render complexity intelligible and because large scale experiments are rarely feasible”
- Understanding unique phenomena in relation to general processes (2001:672).

These core components of an ecological approach form the basis of a number of challenges to research on social-ecological resilience. The following discussion provides addresses the most critical methodological challenges.

4.1.2 Specific Challenges Include Scale, Level, and Causality

While in ecology scale refers to spatial and temporal dimensions, “sociological scale includes the representative nature of social structures from individuals to organizations as well as the social institutions, i.e., rules, laws, policies, and formal and informal cultural norms, that govern the spatial and temporal extent of resource access rights and management responsibilities”[19] (Cumming et al. 2006:15). Where most studies attempt to examine phenomena and processes at one scale, studies of social-ecological systems require the examination of social and ecological spheres, as well as their interaction, across a variety of scales (Carpenter et al. 2001; Gunderson 2001; Holling 2001). The temporal, spatial, and social scale at which various aspects of resilience are measured impacts the outcome (Carpenter et al. 2001). A social-ecological system may be more resilient at particular spatiotemporal scales than others (Carpenter et al. 2001), hinting at both the importance of specifying the scale at which resilience is being measured, as well as the complexity of both the system and the phenomenon of resilience.

The problem of scale surfaces with respect to social and ecological system interactions because social and ecological scales are not always aligned (Cumming et al. 2006). “Although spatial and temporal location determine the context for social and ecological dynamics, social ecological interactions can create dynamic feedback loops in which humans both influence and are influenced by ecosystem processes” (Cumming et al. 2006:15; Levin 1999). Krieger, an epidemiologist who employs an ecosocial approach,[20] suggests that select problems of scale,

[19] For more on scale in sociology, see Barbier 1997, Chidumayo 2002, Ziker 2003, Bodin and Norberg 2005.

[20] An ecosocial approach is among the frameworks that falls within the broader category of social ecological models examined in this work.

among others, result from the use of faulty terminology in causal analyses. To illuminate this point, Krieger (2008) presents a number of strong arguments about the problems related to causation within a social ecological approach. Specifically, Krieger examines the conflation of "measures of space, time, level, and causal strength" (2008:221).

As a result of Krieger's examination of analyses of causation identifies several common problems. These problems represent unique challenges to research combining social and ecological approaches and are, therefore, issues for research on social-ecological resilience. First, Krieger points to the conflation of spatiotemporal scale (e.g., forest size, community size) with level (e.g., a forest, a community) in analyzing causation as a major challenge for work within social ecological models (2008). While spatiotemporal scales can be talked about in terms of distance, it is incorrect to talk about levels in terms of distance as it leads to problematic assumptions about causality. Second, the existence of "nonlinear causal pathways with immediate and long-term effects" is a critical issue in understanding causation because "…events at one level can profoundly affect nonadjacent levels, instantly and persistently, without intermediaries" [21](Krieger 2008:225). Talking about causal pathways as being related to space necessary implies intermediary causal forces that allow things on one level to interact with things on another. However, this notion restricts the possibility for events at one level to profoundly affect events that another level without intermediaries. Hence, Krieger argues that the proximal-distal divide in causal analyses is not at all compatible with multi-level thinking, which is critical to any ecological approach (2008).

For Krieger, "[l]evels coexist simultaneously, not sequentially, and exert influence accordingly" (2008:227). As the proximal-distal divide "inherently cleaves levels rather than connects them" it obscures "the intermingling of ecosystems, economics, politics, history, and specific exposures and processes at every level, macro to micro…" (Krieger 2008:227). This cleaving or segregation of levels complicates any attempt to study social-ecological systems and to illuminate the causal processes at work within such systems. Instead, when elaborating on causation, particularly within a social ecological approach, reference should be made to causal levels, pathways, and power (Krieger 2008).

Resilience and vulnerability research, among others, aim to explicate the "nature of social ecological systems while using theories with explanatory power for particular dimensions of

[21] See also Gunderson and Holling 2002.

human–environment interactions” (Adger 2006: 269). Ultimately, research that includes social dimensions alongside the ecological faces the challenge of measuring concepts like resilience “within a robust conceptual framework” while also addressing issues related to vulnerability, risk, and governance (Adger 2006:277). In taking on the methodological challenges, a greater understanding of resilience will emerge.

4.2 EMPIRICAL STUDIES OF RESILIENCE

The concept of resilience has taken hold in fields as diverse as ecology, development, disaster management and recovery, security policy and studies, and in counseling and mental health. Despite this broad reach, resilience has generated little interest in sociology. Currently, resilience has wide use in interdisciplinary work concerned with the interactions between people and nature (Carpenter et al. 2001). Researchers using the concept of resilience have proceeded in different ways. Some researchers have moved from theory to operationalization to empirical testing and analysis (e.g., Baker 2009). Others have hovered between the theoretical or metaphorical use of the concept and its operationalization, staying closer to the metaphorical use of the concept and applying it to carefully selected studies in conjunction with some theoretical framework (Allenby and Fink 2005; Berkes and Seixas 2005; Carpenter et al. 2001; Turner et al. 2003). Among the challenges Adger highlights as being common to the domains of resilience, vulnerability, and adaptation, especially within the study of human dimensions, is that of measurement within a framework that supports the complexity of the concepts and the social-ecological systems (2006).

Though the focus of this work is the concept of social-ecological resilience, it is useful to examine the collection of scholarship around resilience, more broadly. In both ecological and social ecological applications of resilience, a unit of analysis greater than the individual is utilized. As the work on social resilience is limited and has not advanced at the same pace as other types of resilience research, this broader work on resilience holds potential for an increased understanding of social-ecological resilience.

Few researchers have attempted to quantify ecological resilience (Carpenter et al. 2001). Operational indicators of resilience have largely been ignored in the literature; most resilience related research has used the concept only as metaphor or theoretical construct (Carpenter et al.

2001). There is an inherent difficulty in operationalizing an abstract, multidimensional concept like resilience because there is no easy way to identify the factors that lead to resilience in a complex system or the variables that should be measured in a study of resilience (Cumming et al. 2005). On a few occasions when the concept has been defined operationally, generally in the process of developing a framework or model for a particular case study (e.g., a specific ecosystem), the definitions are not typically generalizable to other contexts (Carpenter et al. 2001). The ideal operationalization of social resilience would make possible the application of a measure across communities with only small adjustments for the specific context of the community being examined. Another problem with the empirical application of the concept is the noticeable distance between theory and operationalization. Carpenter et al. (2001) argue that definitions of resilience should be consistent with metaphorical or theoretical uses of the term.

4.2.1 Frameworks for Examining Resilience

A number of researchers have defined resilience operationally in order to apply the concept in a system specific case (e.g., Carpenter et al. 1999; Janssen et al. 2000; Peterson 1999; Peterson et al. 1998; Scheffer et al. 2000). Others have done so in order to establish a framework for the measurement and further analysis of resilience (e.g., Adger 2000; Bennet, Cumming, and Peterson 2005; Berkes and Seixas 2005; Carpenter et al. 2001; Cumming et al. 2005; Janssen et al. 2006; Redman et al. 2004). Operational schemes for defining resilience have been proposed for the purpose of systematic comparison of social-ecological systems (e.g., Anderies, Janssen, and Ostrom 2004; Walker and Meyers 2004; Walker et al. 2002). Despite the efforts of researchers, there remains a question as to whether any of these objectives have been realized. Janssen et al. claim that social-ecological systems still lack the “guidance of a clear framework” and “formal description of structural changes” (2006:15). The components of some leading proposed frameworks are presented in Table 4.1 and discussed below.

Table 4.1: Proposed Resilience Indicators

Category	Indicators	Source
Indicators of a loss of resilience		Seixas and Berkes 2003, Berkes and Seixas 2005
	breakdown of local institutions and the traditional authority system	
	rapid technological change	
	rapid socio-economic change through regional, national, and international economic integration	
	institutional instability throughout the political scale.	
Indicators of a positive gain in resilience		Seixas and Berkes 2003, Berkes and Seixas 2005
	strong institutions	
	cross-scale interaction and communication (i.e., vertical interplay across levels)	
	political space for experimentation	
	Equity	
	use of local indigenous knowledge as memory and as a source of novelty	
Institutional change and economic structure indicators		Adger 2000
	boom and bust markets	
	environmental variability	
	stability, emphasis on livelihood stability	
	equitable distribution of assets within populations	
Demographic change indicators		Adger 2000
	type of migration with an emphasis on related factors such as external stress and food security	
Resilience of what		Carpenter et al. 2001
Resilience to what		Carpenter et al. 2001
Biophysical field measures		Carpenter et al. 2001
	Shrub:wood ratio (mass/area: mass/area)	
Socioeconomic field measures		Carpenter et al. 2001
	Leaseholder flexibility to obtain income from shrub clearing; low discount rate	
Learning to live with change and uncertainty		Berkes and Seixas 2005
	Learning from crises	
	Building rapid feedback capacity to respond to environmental change	

Category	Indicators	Source
	Managing disturbance	
	Building a portfolio of livelihood activities	
	Developing coping strategies	
Nurturing diversity for reorganization and renewal		Berkes and Seixas 2005
	Nurturing ecological memory	
	Nurturing a diversity of institutions to respond to change	
	Creating political space for experimentation	
	Building trust among users	
	Using social memory as a source of innovation and novelty	
Combining different kinds of knowledge		Berkes and Seixas 2005
	Building capacity to monitor the environment	
	Building capacity for participatory management	
	Building institutions that frame learning, memory and creativity	
	Creating cross-scale mechanisms to share knowledge	
	Combining local and scientific knowledge	
Creating opportunity for self-organization		Berkes and Seixas 2005
	Building capacity for user self-organization	
	Building conflict management mechanisms	
	Self-organizing for equity in resource access and allocation	
	Self-organizing in response to external drivers	
	Matching scales of ecosystem and governance	
	Creating multi-level governance	
Primary types of resilience surrogates		Bennet et al. 2005
	state of the system in relation to the threshold location	
	level of system sensitivity to movement toward the threshold	
	system's rate of movement toward the threshold	
	rate and direction of the threshold's movement	
	distance of the system from the threshold that will cause a change to an alternate state	
Mediating interactions (social and ecological)		
	Land use decisions	
	Changes in land cover, land surface, and biodiversity	
	Production systems	
	Consumption patterns	

Category	Indicators	Source
	Disposal networks	
Ecological patterns/processes		Redman et al. 2004
	Pattern and control of primary production	
	Spatial and temporal populations distribution	
	Pattern and control of organic matter accumulation	
	Patterns of inorganic outputs and movements	
	Patterns and frequencies of site disturbances	
Social patterns/processes		Redman et al. 2004
	Demography	
	Economic growth	
	Political and social institutions	
	Culture	
	Knowledge and information exchange	
Social vulnerability index		Cutter et al. 2003
	Socioeconomic status (income, political power, prestige)	
	Gender	
	Race and ethnicity	
	Age	
	Commercial and industrial development	
	Employment loss	
	Rural/urban	
	Residential property	
	Infrastructure and lifelines	
	Renters	
	Occupation	
	Family structure	
	Education	
	Population growth	
	Medical services	
	Social dependence	
	Special needs populations	
People		Colussi 2000
	Leadership is representative of community	

Category	Indicators	Source
	Elected community leadership is visionary, shares power, and builds consensus	
	Community members are involved in significant community decisions	
	The community feels a sense of pride	
	People feel optimistic about the future of the community	
	There is a spirit of mutual assistance and cooperation in the community	
	People feel a sense of attachment to their community	
	The community is self-reliant and looks to itself and its own resources to address major issues	
	There is a strong belief in and support for education at all levels	
Organizations		Colussi 2000
	There is a variety of community economic development orgs in the community such that the key economic development functions are well served	
	Orgs in the community have developed partnerships and collaborative working relationships	
Resources		Colussi 2000
	Employment in the community is diversified beyond a single large employer	
	Major employers in the community are locally owned	
	The community has a strategy for increasing independent local ownership	
	There is openness to alternative ways of living and economic activity	
	The community looks outside itself to seek and secure resources (skills, expertise, finance) that will address identified areas of weakness	
	The community is aware of its competitive position in the broader economy	
Community Process		Colussi 2000
	The community has an economic development plan that guides its development	
	Citizens are involved in the creation and implementation of the community vision and goals	
	There is ongoing action towards achieving the goals in the economic development plan	
	There is a regular evaluation of progress towards the community's strategic goals	

Category	Indicators	Source
	Organizations use the economic development plan to guide their actions	
	The community adopts a development approach that encompasses all segments of the population	
Resilience Elements		U.S. Indian Ocean Tsunami Warning System Program (2007)
	Governance	
	Society and Economy	
	Coastal Resource Management	
	Land Use Management and Structural Design	
	Risk Knowledge	
	Warning and Evacuation	
	Emergency Response	
	Disaster Recovery	

4.2.1.1 Indicators of resilience. Adger (2000) argues that there is a complex relationship between social resilience and dependency on natural resources, which requires the development of a set of parameters for observing social resilience. Proxy indicators are proposed as one way to examine social resilience. These indicators fall under the following categories: institutional change, economic structure, and demographic change. Adger claims that "no single indicator captures the totality of resilience" (2000:357). However, he goes on to state that resilience can be examined both temporally and spatially using such indicators as the presence of boom and bust markets, environmental variability, livelihood stability, and equitable distribution of assets within populations (Adger 2000). Adger's proposed indicators place a heavy weight on economic factors, as opposed to considering the social sphere in a more holistic way. The ecological and the economic are presented as two sides of a unified system while other aspects of the social system are lost from the analysis and the proposed measurement of resilience. This over reliance on the economic to explain away the social is not uncommon and is demonstrated by other resilience researchers (e.g., Carpenter et al. 2001).

Carpenter et al. (2001) suggest that even within their comparison of resilience for different cases, there are similar requirements that extend to all assessments of resilience. For example, in all cases, "it is crucial to specify what system state is being considered (resilience of what) and what perturbations are of interest (resilience to what)" (2001:777). Additionally, in determining indicators of resilience it is important to emphasize slow changing variables in assessing the likelihood that a social-ecological system will stay within its domain of stability[22] (Carpenter et al. 2001). Also important are indicators of the system's ability to self-organize (Folke et al. 1998). Assessment of a community's ability to self-organize must distinguish between forced, context driven action and voluntary self-organized action because in some circumstances, economic and institutional constraints place limitations on a community's ability to organize in ways that would improve ecological health (Carpenter et al. 2001). Finally, indicators of adaptive capacity should address the social-ecological system's ability to cope with change (Carpenter et al. 2001).

Carpenter et al. (2001) classify indicators of resilience as either biophysical field measures or socioeconomic field measures. This is particularly narrow considering the complexity of the individual systems (i.e., social and ecological) and the interaction between the two, which seems to be absent from this framework. The classification of proposed indicators, designed to lead to specific and measurable variables, does not offer much of a sense of what should be measured. Carpenter et al. (2001) suggest that only a small number of fixed variables need to be measured. Yet, in attempting to assess resilience of social-ecological systems, a few fixed variables are incapable of providing the means to address the inherent complexity. Furthermore, it is unclear as to whether the types of indicators proposed (e.g., ratio of shrubs to woods, leaseholder flexibility in obtaining income from shrub clearing) are generalizable measures for capturing ecological resilience in other contexts, let alone capable of reflecting the complexity of social-ecological resilience. Finally, the social components of a social-ecological system are once again included only through economic measures. While this has become common practice in the development of indicators of resilience, it does little to reflect the wide ranging significance of social factors and the multidimensional nature of the interaction between the ecological and social components of the overarching social-ecological system.

[22] Gunderson and Holling (2002) described the domain of stability or domain of attraction using the example of a fixed weight placed on top of an occupied raft. They state, "[t]he range of possible movements of the occupants that do not lead to tipping is called the domain of stability or domain of attraction of the upright state. If the amount of the fixed weight is gradually increased, the balance becomes more precarious and hence the domain of attraction will shrink. Eventually the weight becomes large enough so that there is no domain of stability" (2002:10).

Within social systems, resilience has been linked to both the existence of networks that increase flexibility in problem solving and the equitable distribution of power among interest groups (Scheffer et al. 2000) as well as to the generation and transmission of local ecological knowledge (Folke et al. 1998), but specific indicators that reflect these factors are ignored. This suggests that understanding the dynamics of social-ecological systems would provide a basis for building resilience (Kinzig 2001; Scheffer et al. 2000). In social systems, resilience has also been closely connected to social learning (e.g., Berkes and Seixas 2005; Carpenter et al. 2001), which is advanced, in part, by the ability of institutions to experiment, assess, and modify policy as new knowledge is gained (Carpenter et al. 2001). Though these attributes are not easily operationalized, they retain value as general features of social-ecological resilience. If things like local ecological knowledge and social learning are seen as essential to social-ecological resilience and are therefore considered essential components of assessment, the community may come to have increased value for their existence and reproduction. Measurement of the community's efforts to nourish local ecological knowledge and social learning may serve as a useful proxy for aspects of social-ecological resilience.

Redman et al. (2004) propose the following indicator types: mediating interactions (social and ecological), ecological patterns and processes, and social patterns and processes. Unlike other frameworks, Redman et al. (2004) include a list of social patterns and processes that goes beyond economic indicators, even taking political and social institutions and culture into account. The conceptual framework includes two sets of external conditions: political and economic on the human system side and biogeophysical conditions on the ecological system side (2004). The framework proposed by Redman et al. (2004) makes an important advance by including the interactions as well as the patterns and processes of both social and ecological systems.

In order to apply this social-ecological systems framework to empirical cases, data is needed to highlight three pivotal components of the framework:

- Collecting background information on "external" biogeophysical, political, and economic conditions that set the stage;
- Describing and monitoring changes in both ecological and social patterns and processes that drive the system; and
- Investigating the nature of and monitoring changes in the interactions resulting from the operation of the patterns and processes. (Redman et al. 2004:165)

The framework proposed by Redman et al. (2004) clearly represents a move in the right direction for its indicators of social-ecological resilience emphasize interaction between ecological and social systems, as well as patterns and processes of these systems. This takes the place of examining more stagnant variables. While developing appropriate measures may be methodologically challenging, such indicators provide a better capture of social-ecological resilience.

Overall, the limitations of most indicators proposed by resilience researchers to date can be traced back to the methodological challenges previously discussed: namely, the inherent challenges of complex, coupled systems, and the problems encountered when research is not effectively integrated. The indicators often represent either the strong influence of an ecological or a social perspective (and in the latter case, a highly economic perspective). Where the indicators gain strength is in the frameworks of those like Redman and colleagues (2004) who emphasize the interactions of the social and ecological systems and specifically, the general patterns and processes within the systems' interaction.

4.2.1.2 Surrogates for resilience. Apart from indicators of resilience, the term 'surrogate' has been evoked to represent another possibility in the measurement of resilience. Berkes and Seixas (2005) note "[s]urrogates are different from indicators because they are forward-looking, rather than measures of the current or past state" (967). Because resilience is forward looking (Folke et al. 2002b), operationalization (i.e., the movement from theory to practice) requires "estimators or measures of resilience" (Berkes and Seixas 2005:967). Both Bennet et al. (2005) and Berkes and Seixas (2005) provide frameworks based on surrogates of resilience. Carpenter et al. (2005) define surrogates as proxies used to assess resilience in social-ecological systems. These proxies must have the following characteristics: they must be forward looking, come in mutually reinforcing multiples or clusters, be mapped onto resilience theory, and be consistent and repeatable (Carpenter et al. 2005). Since resilience surrogates are often context-dependent, the nature of the dependency must be explicated. Additionally, any surrogate must be able to be assessed for a range of social-ecological systems and across a range of time (Carpenter et al. 2005). The examples below are intended to carry resilience forward in its transition from theory to practice by using surrogates. However, there are limitations within each example that prevent the surrogates from fulfilling this methodological gap.

Seixas and Berkes (2003) enumerated factors affecting resilience or surrogates, both in positive and negative ways, by integrating findings from four other lagoon systems to develop a set of factor clusters for all lagoon social-ecological systems (Berkes and Seixas 2005). These factor clusters include, “learning to live with change and uncertainty,” “nurturing diversity for reorganization and renewal,” combining different kinds of knowledge,” and “creating opportunity for self-organization” (2005:971). The factors for building resilience presented by Berkes and Seixas (2005) are not intended as surrogates of resilience and therefore, do little to advance the measurement of resilience. The greatest limitation of the work conducted by Berkes and Seixas (2005) is that they do not provide a sense of how to transform the factors of resilience they present into measurable indicators or surrogates, though they suggest this is the next step. Like the proposed indicators, many (possibly most) surrogates are difficult to measure – a challenge acknowledged by Berkes and Seixas (2005). Other challenges with the use of surrogates involve the use of different methods of measurement, depending on the surrogate (e.g., qualitative versus quantitative assessment), and selection of surrogates based on data available at the correct scale (e.g., data only available at the national or regional level).

Bennet et al. (2005) developed surrogates for use in case studies. In addition, Bennet et al. provide a methodological approach for determining these surrogates: 1) Assess and Define Problem, 2) Identify Feedback Processes, 3) Design a Systems Model, and 4) Use the Model to Identify Surrogates. This work relies on the use of “system archetypes,” which are “representations of patterns that appear repeatedly in many different systems” (2005:950). These system archetypes are used as models for the examination of resilience surrogates (2005). Bennet et al. admit that these surrogates will not work for all systems. However, the approach used by Bennet et al. (2005) represents a step in the right direction because of its emphasis on recurring patterns across different systems, which allows for a measure that contains core factors applicable in a range of social-ecological systems. In response to the complexity of measuring resilience, Bennet et al. suggest that “[a] practical approach towards quantifying system resilience may be identification and measurement of resilience surrogates, quantifiable proxies derived from theory for use in assessing the resilience of social ecological systems” (2005:955).

Cumming et al. (2005) develop a framework based on a definition of resilience that emphasizes the identity of the system. In this view, system identity is dependent on the system components, the relationships between the components, the continuity of the components and relationships through space and time, and innovation and self-organization. Again, the general notion of surrogates for resilience is addressed in this work, though specifics are not provided. The five elements of the research design include the following:

- Define the current system,
- Define possible future systems with identities that are either the same or different,
- Clarify trajectories of change,
- Assess the likelihoods of alternate futures, and
- Identify the mechanisms and levers for change.

Like many other resilience researchers, Cumming et al. use a specific case study to elucidate the steps of the design and to present the potential of their framework. According to Cumming et al., the ultimate goals of the empirical application of resilience theory are “to test resilience concepts and develop a broader and more robust body of theory…and…to contribute in a relevant way to policy and management by exploring mechanisms and alternatives for change…” (2005:985). The framework is highly dependent on the identification of possible futures and associated likelihoods of each future. This seems highly problematic when studying resilient systems, which are constantly changing, making any effort to pin down the current identity and the range of possible futures for that system a complicated one. Additionally, the primary emphasis on system identity seems to result in a less precise, although more flexible, measurement of resilience. Overall, this approach places great weight on being able to define and clarify several aspects of complex, coupled systems, many of which are future oriented, as opposed to being able to measure existing features of these systems in a manner that contributes to improved understanding of the system and to the assessment of social-ecological resilience.

In sum, there are a number of methodological issues with developing and using surrogates for resilience (Carpenter et al. 2005). Often, these surrogates are system specific, limiting their use in diverse settings and adding to the challenge of developing an empirical measure of resilience applicable across a variety of social-ecological systems. In addition, the surrogates tend to be categorized in distinct ways by researchers, increasing the challenge of identifying a single system of surrogates for use in resilience research. Their proponents admit that the challenges associated with surrogates are great. Most important, perhaps, is that proposed surrogates are not always quantifiable or otherwise measurable. If the intended purpose of moving the operationalization of resilience forward is not achieved, then the utility of surrogates comes into question along with the ability of surrogates to substantively contribute to policy and management.

The proposed frameworks for assessing resilience in social-ecological systems include social indicators alongside the ecological. However, all too often what gets termed a social indicator of resilience is actually an economic indicator (e.g., Carpenter et al. 2001). That is, when not dealing with the physical or biophysical domains, much of resilience research ends up being solely about economic factors, as opposed to social factors generally. Carpenter et al. (2001) demonstrate how easily one can be deceived into thinking that non-biophysical resilience is economic resilience or, worse yet, that social resilience is determined solely by economic resilience. In order to ensure that the social aspects of social-ecological systems are addressed not only through the use of economic indicators, an understanding of what is meant by social and how the 'social' should be measured is required. From there, a more comprehensive set of social indicators can be established. It is also critical that the pendulum does not swing too far from the integrative approach central to the study of social-ecological systems and overemphasize a narrowly sociological perspective of what matters most for indicators of social-ecological resilience (Brand and Jax 2007). The development of a measure of social ecological resilience must carefully incorporate economic, other social, and biophysical indicators.

4.2.2 Measuring Vulnerability: Utility of the Approach and Indicators

Due to the limited empirical studies of resilience, vulnerability research may serve as a guide in the process of moving from concept to operationalized measure. The work of Cutter and colleagues (2003) is an example of vulnerability research that can be applied to the development of a measure of social-ecological resilience. By understanding social vulnerability as being about both social inequalities, as well as place inequalities, Cutter and colleagues take seriously the development of a measure that reflects both types of data (2003). In order to create the Social Vulnerability Index, Cutter and colleagues used county level US Census data to convert independent socioeconomic and demographic variables into the following factors: personal wealth, age of population, density of built environment, single sector economic dependence, housing stock and tenancy, race (includes African American and Asian), ethnicity (includes Hispanic and Native American), occupation, and infrastructure dependence (Cutter et al. 2003). The Social Vulnerability Index is additive (i.e., the scores for each factor are simply added together without weighting) and provides a score for each county analyzed. The counties are then categorized as most vulnerable, average, or least vulnerable by comparisons to the mean scores on the Social Vulnerability Index. Many of the 42 variables included in the factor analysis are also related to social-ecological resilience in communities and were considered when developing the measure of resilience. Additionally, the concepts and metrics commonly used in social vulnerability research are similar to the metrics of various indicators of resilience (see Cutter et al. 2003, Table **4.1**).

Interestingly, the hazards of place model[23] used to guide the development of the Social Vulnerability Index includes the 'social fabric', a component that bears a some resemblance to social-ecological resilience[24] in its emphasis on community learning through experience and adaptive capacity, as well as a 'geographic filter' which represents the physical site and situation of the place. The hazards of place model has the potential to be the basis for a model of social-ecological resilience. Cutter and colleagues identify the next step for vulnerability research as one that will involve adding biophysical variables in the model so as to assess both the social vulnerability and the ecological vulnerability[25] of a county (as a measure of "overall place vulnerability") and to study the complex interaction of the social and ecological vulnerability (2003:243). At present, the model does not include ecological components, which means that it cannot address the social-ecological system. However, if combined with biophysical data, use of the current index would mean that "mitigation efforts can be targeted at the most vulnerable groups or counties" (2003:258). Instead of allowing policy decisions to be based on the volatility of political interests and other intermediary factors, data summarizing the vulnerability or social-ecological resilience can be used to more effectively guide policy impact and outcome.

[23] The hazards of place model of vulnerability (Cutter 1996; Cutter, Mitchell, and Scott 2000; Heinz Center for Science, Economics and the Environment 2002) posits that risk and mitigation interact to produce the hazard potential of a place. Both the geographic filter and the social fabric interact to have either an enhancing or moderating effect on the hazard potential. The vulnerabilities inherent to the social and the geographic contexts then interact to produce the total place vulnerability.

[24] The term 'social fabric' is used to refer to "community experience with hazards, and community ability to respond to, cope with, recover from, and adapt to hazards, which in turn are influenced by economic, demographic, and housing characteristics" (Cutter et al. 2003:243).

[25] Cutter and colleagues (2003) use the term 'environmental vulnerability', as opposed to ecological vulnerability. In order to discuss the relevance of this work and make clear the potential applications, the terms 'social vulnerability' and 'ecological vulnerability' are used.

As with resilience research, there is both widespread interest in the concept of vulnerability and some consensus about the major factors affecting vulnerability. However, there is also little agreement about how to operationalize these factors with specific variables. Again, the measurement of complex concepts like resilience and vulnerability lags behind the theoretical usage, a problem that seems to be especially highlighted in the infrequent attempts to include social indicators in measures of these concepts[26]. The attempt of Cutter and colleagues (2003) to provide a robust and replicable set of indicators for social vulnerability is a step in the right direction, particularly in light of their interest in developing an index that will contribute to policy decisions.[27] Despite the importance of distinguishing between concepts of resilience and vulnerability, there is utility to be derived from the examination of select attempts to develop measures of related concepts like social vulnerability. In fact, the great utility of vulnerability and adaptive capacity research is often a result of the researchers confusion of these concepts (and therefore, what is being measured) with resilience.

4.2.3 Measurement of Resilience in Applied Fields

Though resilience research has been slow to transition from the theoretical to the empirical, there have been advances on the policy side that apply the concept of resilience to various types of community assessment. In many cases, applications of resilience[28], often as a collection of measurable indicators, have outpaced the development of empirical measures. This rapid adoption of the concept of resilience and corresponding efforts to turn it into a measurable component of assessment is a result of the plausibility and intuitive power of the concept for those working in various areas of community development, social change, and natural resource management. Resilience seems to naturally encompass a wealth of desirable community

[26] Cutter et al. (2003) identify the historical rise and fall of the use of social indicators in social science research as part of the explanation for why social aspects of vulnerability have been often ignored. The measurement of social indicators of vulnerability at the individual level, as opposed to the community level, has contributed to a lack of knowledge about social vulnerability.

[27] In subsequent work by Cutter and colleagues, a framework of disaster resilience is put forth (2010). This model includes 36 variables summarized in five subcomponents: Social resilience, Economic resilience, Institutional resilience, Infrastructure resilience, and Community Capital (Cutter, Burton, and Emrich 2010). Like the previous work on vulnerability, this model does not include ecological components. However, some of the indicators of disaster resilience are relevant to a broader concept of social-ecological resilience.

[28] In many cases, the applications take the form of community toolkits (e.g., Hegney et al. 2008; National Disaster Preparedness Training Center 2011).

attributes, while being something that can be altered; resilience can be strategically strengthened with effective community programs and policy or weakened by changing conditions and ineffective response to them.

4.2.4 Applying Past Work

Existing applications of a measure of resilience contribute to the transition from concept to measurement, though neither of those described provides for a complete assessment of both social and ecological resilience, as well as the interaction of the two. Therefore, measuring social-ecological resilience remains an unachieved aim. The benefit of relying on multiple and varied attempts at measuring resilience can be viewed in the proposed indicators and the possible metrics. Each set of indicators and metrics presented offers another potential avenue or a starting point from which a measure of social-ecological resilience can be reached. The applied tools for assessment of community resilience and resilience in natural resource systems are as vital to the project ahead as previous empirical research on resilience, regardless of the limits of these efforts when taken in isolation.

4.3 MEASURE DEVELOPMENT

Indicators have been identified as the ideal approach for measuring the multiple dimensions of social-ecological resilience, a concept with social, economic, and ecological components. Indicators can be constructed in a variety of ways. Composite indicators, aggregations of multiple measures using mathematical computation to produce a single value (Saisana and Tarantola 2002), represent one approach to the construction of indicators. This type of indicator is used for its ability to simultaneously simplify complex measurement, while communicating the underlying complexity. Composite indicators respond to a highly pragmatic need - "to rate individual units… for some assigned purpose" (Paruolo, Saisana, and Saltelli 2013: 1).

Due to the complexity of the latent constructs that form the indicators of social-ecological resilience, the indicators are assessed with multiple measures. Each composite indicator represents a multidimensional concept that could not be adequately assessed by a single measure, so instead is represented by a collection of measures (Nardo et al. 2008). For example, visually depicted in Figure 4.1, the indicator of *Economic Security* is defined as an economy that is able to resist harm and remain productive at the level of industry, population, and household, despite change. No single measure could be identified to assess this range of economic activity, so measures for each aspect of economic security were identified and combined to assess the whole concept. In this example, three measures were used to operationalize *Economic Security*; these include measures of the diversity of economic sectors, population poverty, and household income.

Composite indicators are used to measure concepts related to social-ecological resilience, including social vulnerability to hazards (e.g., SoVI, Cutter et al. 2003), disaster resilience (e.g., Cutter, Burton, and Emrich 2010; Peacock et al. 2010), sustainable development [e.g., Human Development Index (UNDP 1990); Environmental Sustainability Index (Esty et al. 2005)], national well-being (e.g., Prescott-Allen 2001), coastal community well-being (Dillard et al. 2013), and climate vulnerability (e.g., Boruff, Emrich, and Cutter 2005; Pethick and Crooks 2000). Composite indicators are increasingly used in policy making and public communication contexts, in part because they simplify complex information for the purpose of informing decision-making. Social indicators, which have an explanatory or theoretical function, have been linked with the idea of monitoring social change in order to introduce a policy intervention, when possible (Duncan 1974). Uses of composite indicators include many types of evaluation and other community planning purposes (Saisana and Cartwright 2007). In this case, composite indicators are used to assess drivers of resilience at the community level.

4.3.1 Indicator Selection

Theoretical and methodological factors were used in the process of indicator selection and prioritization. First, there was great reliance on existing theory on social-ecological resilience, as a general concept, as well as literature on which component indicators are essential for conceptualizing social and ecological resilience independently. Specifically, effort was focused on the operationalization of indicators that would be consistent with proposed conceptual models and frameworks. The key conceptual models and frameworks influencing the present research included those presented by Berkes and Seixas 2005, Redman and colleagues 2004, Cutter and colleagues 2003, and Colussi 2000, among others (see Table 4.1).

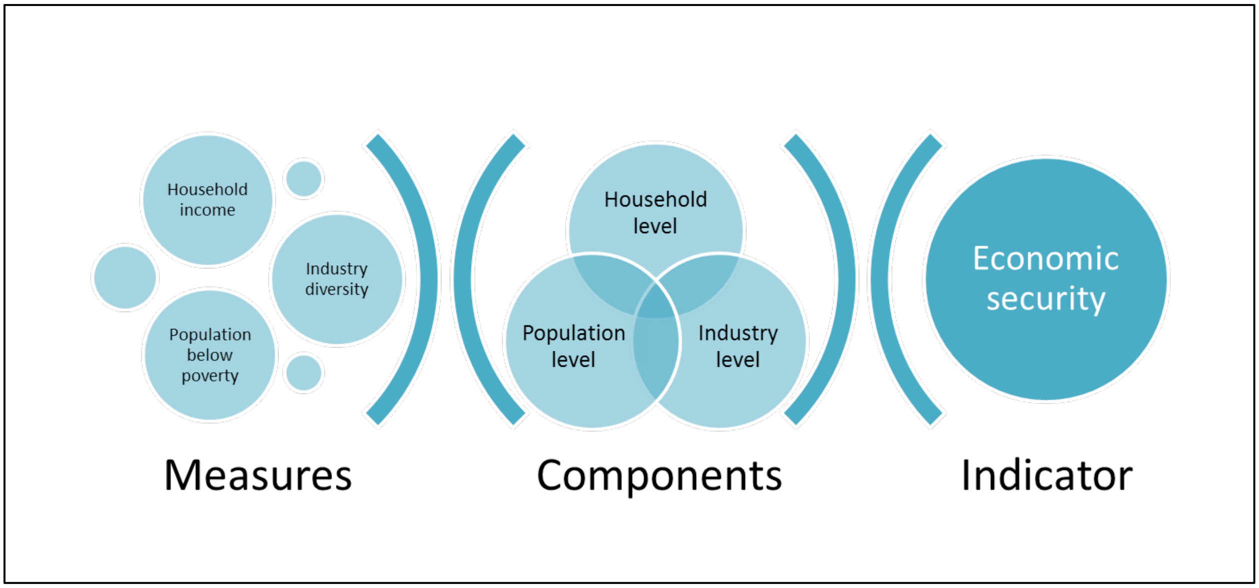

Figure 4.1: Illustration of the construction of indicators.

Secondly, alignment with existing indices of related concepts, such as vulnerability and well-being. This included careful evaluation of how indices for related concepts are constructed and applied, particularly for informing and evaluating decisions. An important consideration of final indicator selection was the identification of points of consensus across fields and disciplines where resilience and related concepts are used.

Data availability, consistency, feasibility, and utility were among the methodological determinants used in the final selection of indicators. The level of analysis was also an important consideration. In order for the indicators to be relevant, they needed to measure meaningful aspects of the resilience of the county or equivalent, whether focused on an aspect of society or the environment. Additionally, all indicators needed to be comparable and useful across all geographies, regardless of location (e.g., Caribbean vs. Pacific) and type (e.g., outlying island/territory vs. coastal state).

4.3.2 Indicator Operationalization

Operationalization involves developing a specific measurement for a given concept or indicator, often one that is not directly measurable (Schutt 2001). The possible measures used to operationalize each indicator were first identified through literature or inclusion in a related index/conceptual model, as well as data availability, maintaining both a theoretical and methodological basis for the initial list (see Appendix C, Table **C1**). As previously discussed, the use of secondary data comes with limitations, including that of a fixed list of potential measures. However, it is important to note that a wealth of data were compiled and evaluated. Between the two samples, over 500 measures were evaluated for inclusion in the measurement model. The indicator development process was tracked, in part, through a database containing indicators, possible and ideal measures of the indicators, data sources, and relevant notes. By first allowing for the collection of data from the broadest possible range of sources, the measure selection process was enhanced.

Upon completion of data collection, the indicator operationalization process began. In this case, the indicator operationalization or measure selection process was dependent on three sets of factors that were taken into account with each decision regarding the identification of variables to operationalize each indicator of social-ecological resilience. The following outline represents the theoretical, methodological, and statistical determinants and the corresponding questions used to evaluate a given measure. Figure **4.2** provides a visual depiction of the same process, adapted from Dillard et al. 2013.

Process for Indicator Operationalization (Adapted from Dillard et al. 2013)

1) Theoretical Factors
    a) Literature
        i) What does the literature say about the relationships between these measures and indicators of social-ecological resilience?
    b) Prior study support
        i) How are the measures used in other indices that measure resilience or related concepts?
    c) Face validity
        i) Do the measures make sense together to address the given concept?
2) Methodological Factors
    a) Data availability
        i) Does the data exist across all geographies?
        ii) What are the issues of comparability across geographies?
    b) Consistency and reliability of data collection
        i) Is the data collected in a reliable manner with transparent methods?

        ii) What does the collection look like over time? Is it likely to continue?
    c) Utility in applied setting
        i) Are the measures easy to understand and communicate?
        ii) Do the measures align with policy sectors?
3) Statistical Factors
    a) Descriptive analyses
        i) What shape does the distribution take?
        ii) What is the central tendency?
        iii) How are the data dispersed?
    b) Correlation analyses
        i) Which measures are significantly related to each other?
        ii) In what direction and how strongly are they related?
    c) Factor analyses
        i) How do the measures combine using statistical properties alone?
        ii) Are the indicators a combination of numerous factors?
        iii) Is there model fit/convergence?

Though indicator operationalization is presented in the outline above and in the corresponding figure (Figure 4.2), as a linear process, the process is highly iterative and therefore, adaptive to the findings at each step. Appendix C, Table C1 displays the indicators and the initial operationalization for the measurement model. In the chapters remaining, options for the specific formulation of a measurement model are presented and discussed along with the selection of a final method for model development.

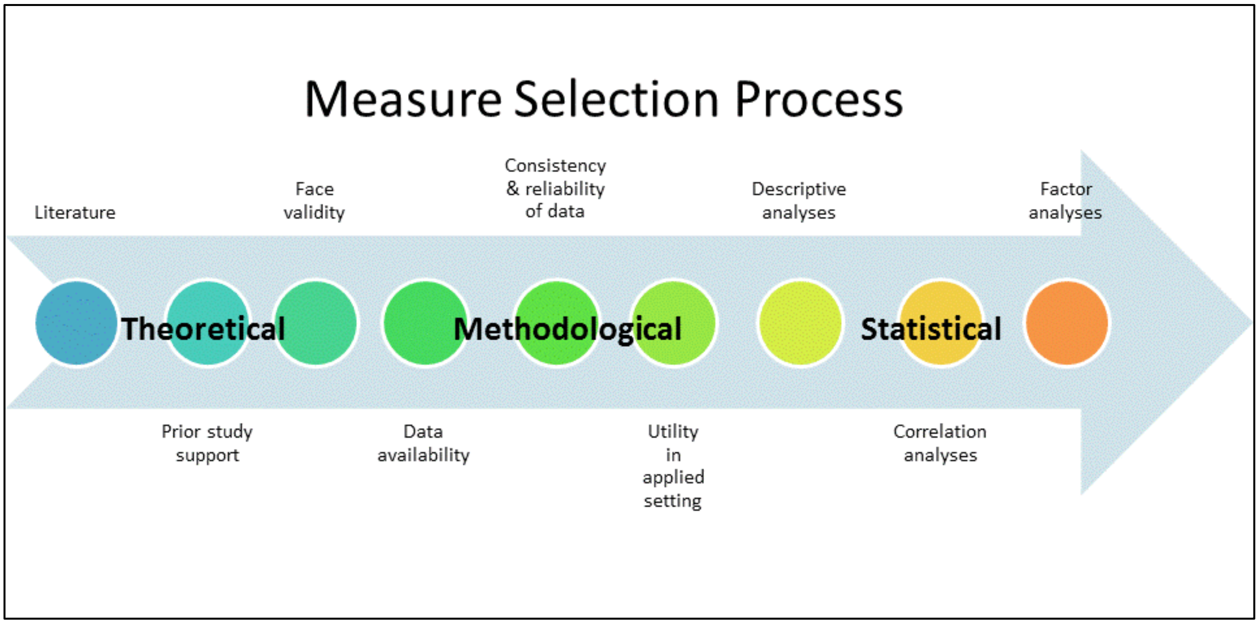

Figure 4.2: Illustration of the measure selection process.

4.3.3 Framework Presentation

In order to develop a measurement model for social-ecological resilience, the social ecological system needed to be better understood in terms of its components, causal levels, and the interconnecting pathways. Systems thinking, which refers to the approach to understanding a system through an understanding of its components and their relationships (Miller and Page 2007; von Bertalanffy 1976), is highly advantageous, both in theoretical and methodological terms. By defining communities as social-ecological systems, a complex systems approach can be used to understand the interactions between social and ecological components. A simplistic view of this system places the components and their interaction on the same plane with no demonstration of causal pathways (Figure 4.3). However, systems thinking is also consistent with what has become commonly understood as an ecological approach, consisting of an emphasis on scale, level of organization, dynamic states, mathematical modeling, and an understanding of unique phenomena in the context of general processes (Krieger 2001). An ecological approach generates a very different model.

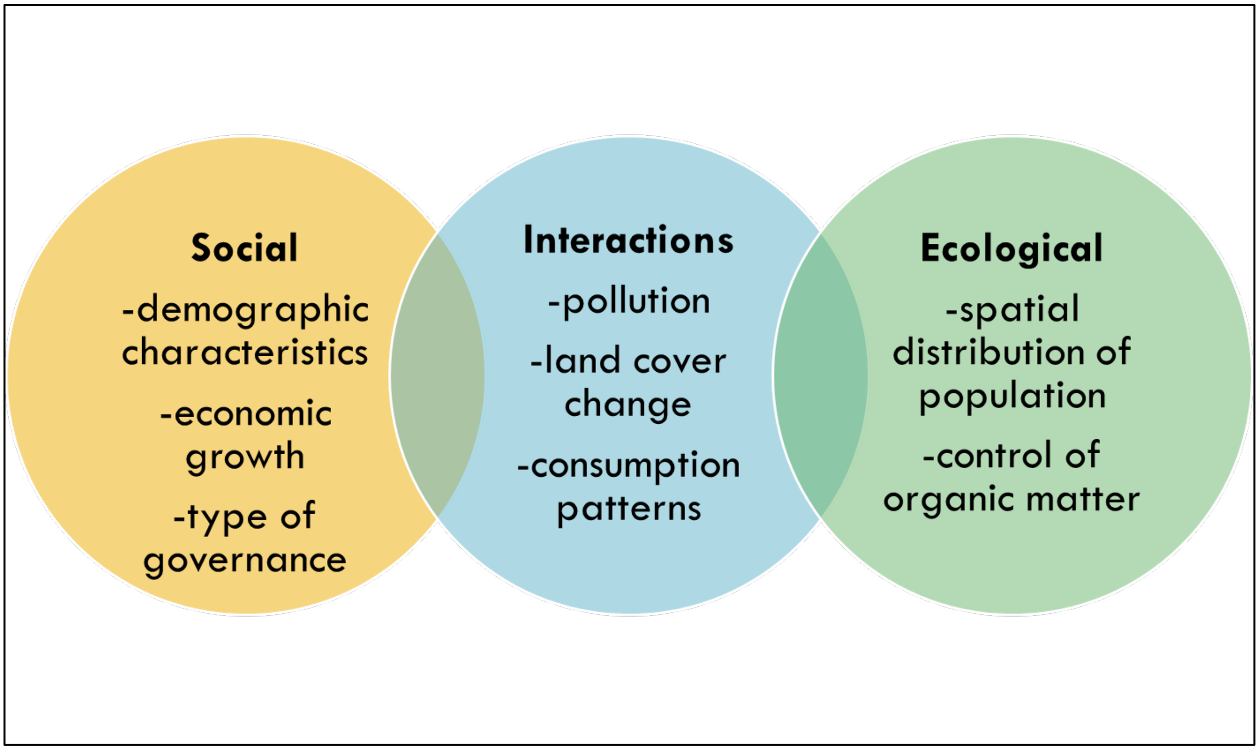

Figure 4.3: Simple social-ecological system model.

The following model depicts a potential approach to further investigation of resilience within the social-ecological system as a function of resilience at different levels (Figure 4.4). The proposed measurement of resilience can be situated within this model (see circled box and linked variables of study). Theoretically, the components of the model could be used as means of assessing the overarching resilience of the system which would then allow for improved prediction of a variety of system outcomes. The outcomes of this system might include the response and recovery to a natural disaster or a reorganization of institutions following after a new law is passed. The outcome is how the system responds to some combination of conditions and stressors at each level.

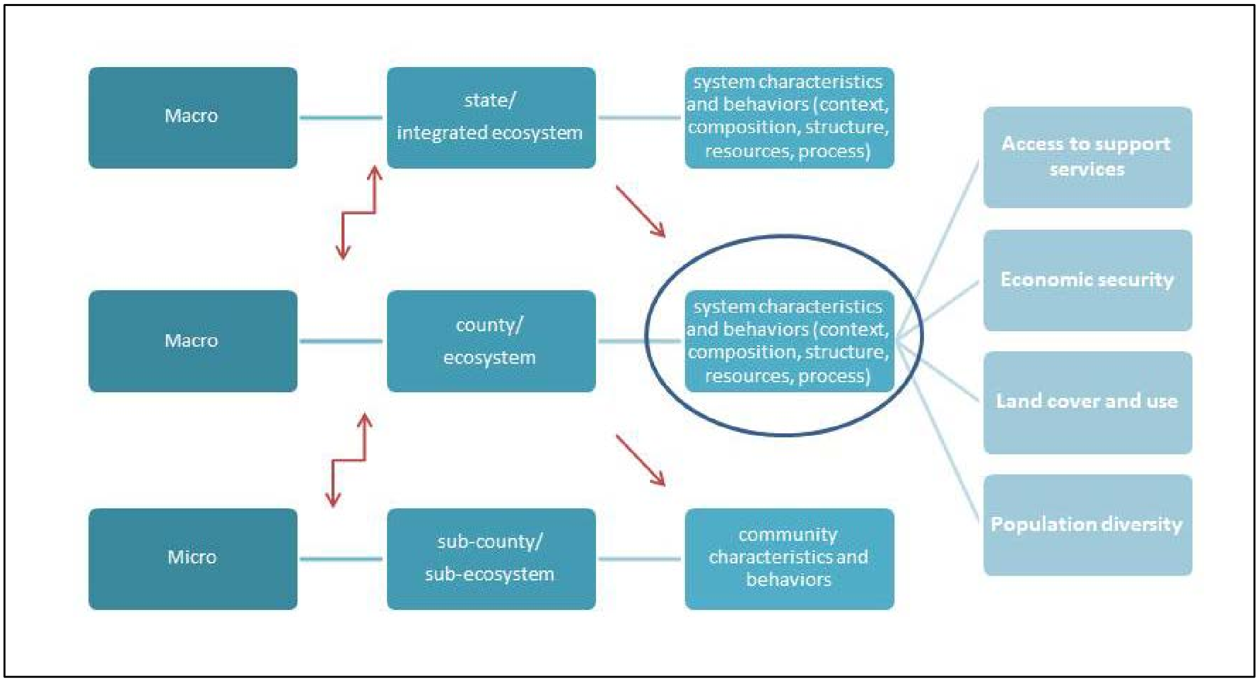

Figure 4.4: Multi-level model for social-ecological systems.

4.3.4 Moving Forward with Measurement

In developing a framework for the social ecological system while working simultaneously toward the measurement model of social-ecological resilience, a solid theoretical and conceptual foundation has been established. This foundation makes possible the next step, which is the measurement of social-ecological resilience. The development of the measurement model will advance the indicator selection and initial operationalization by testing a variety of measure construction methods and then selecting one to utilize. Ultimately, the measurement will be applied in order to assess the resilience of specific SESs in island and coastal states.

5 MEASUREMENT CONSTRUCTION RESULTS

5.1 INTRODUCTION

This research design closely follows that of indicator development efforts in a variety of applied research fields, ranging from international development to public health (see specifically, Booske et al. 2010; Nardo et al. 2008). However, in this design, numerous methods of aggregation of the proposed measures were explored and compared before selecting an approach. This chapter details the comparison of these methodologies.

Using the conceptual model as a guide, proposed indicators of social-ecological resilience were selected and operationalized. Once the data collection was complete for all measures, including all necessary data cleaning, data analyses began. Exploratory analyses were used to investigate the general structure of the measures, assess their suitability, and to examine relationships between measures being considered for the model. The measures were standardized to account for issues of population size and to ensure meaningfulness at the county or county-equivalent level. Then, a suite of methods for indicator construction were applied to the measures selected during the operationalization process. Ultimately, a final method was selected for the development of the measurement model of social-ecological resilience.

5.2 EXPLORATORY ANALYSES

In composite indicator development, as in many other measure construction methodologies, theoretical and statistical determinants of indicator operationalization are taken into account. In this study, methodological determinants also figure prominently into the process. The following analyses contributed to the necessary background statistical work for indicator operationalization.

Initial analyses included a range of descriptive and exploratory work. Case summaries and descriptive statistics were run for all variables being considered for a potential role in the measurement model for social-ecological resilience. These analyses were important for exploring the distribution of values across sample, as well as the presence of missing values across the cases. Next, correlation analyses were used as a means of exploring connections between variables. Correlations are particularly valuable for identifying items that might load strongly onto the same factor due to high correlation but be explaining the same variance. Also, correlation analyses are critical for identifying unexpected links between variables that should be figured into measurement construction decisions.

Along with correlations, numerous runs of PCA and PFA were performed in order to fully explore the variety of measures that might be used to assess dimensions of resilience. Both US Island States and US Gulf of Mexico States Datasets were used. These initial analyses were crucial to the selection of the best set of measures that would correspond to and provide a means of testing the theoretical work surrounding the concept.

5.3 STANDARDIZATION OF VARIABLES

Prior to further analysis, all measures were standardized for the county or county equivalent level of measurement. The standardization of all variables for the county or county-equivalent level of measurement is a critical step in the development of composite indicators. With some variables, this required adjusting for population size so that the value can be presented as a rate. For example, the variable “total wastewater treatment facilities” became the “number of wastewater treatment facilities per 100 households.” This transformation ensured that all variables were standardized for the unit of analysis and could therefore, be compared without concern for the differences of population size, land area, and other key characteristics, which vary significantly across the sample communities. Next, a variety of analytical approaches to indicator construction were explored.

5.4 PROS AND CONS OF MEASURE CONSTRUCTION METHODS

The tradeoffs between the varied methods of index construction (Booske et al. 2010; Costello and Osborne 2005; Freudenberg 2003; Nardo et al. 2008; Salzman 2003; Thompson 2004) were reviewed and considered. A range of methods and opinions on best practices exist. Instead of selecting and applying a single methodology, several social science methods were employed in the construction of indicators of social-ecological resilience. Their comparison added significantly to the outcomes of this study.

5.4.1 Confirmatory Factor Analysis

The original intent of this study was to utilize structural equation modeling (SEM). SEM was favored because SEM "offers great potential for theory development and construct validation in...the social sciences" (Anderson and Gerbing 1988:422); is "a comprehensive, flexible approach to modeling relations among variables" (Hoyle and Smith 1994:429); and is a hypothesis driven method which tests a qualitative theory of structural or causal relationships between variables.

Due to the complexity of measuring and modeling social-ecological resilience within communities, SEM was identified as particularly beneficial. The utility of SEM methods is best seen with hypotheses that are "difficult or impossible" to test with traditional methods such as ANOVA, multiple regression, or factor analysis (Hoyle and Smith 1994:429). SEM allows for both observed and unobserved (latent) variables in analyses and makes possible the modeling of multivariate relationships and indirect effects (Bollen 1989; Byrne 2009). Because social-ecological resilience is a latent variable, that is an unobserved construct only indirectly measurable by way of observable indicators, SEM stood out as an ideal method.

A two-step SEM approach would involve conducting measurement modeling (e.g., factor analysis) and structural modeling (e.g., general linear model) as distinct components of the study (Anderson and Gerbing 1988; Joreskog and Sorbom 1984). During step two, various SEM methods may be employed in the process of building the structural model of resilience. A structural model is the causal relationships between resilience and other variables.

The combination of a measurement model and a structural model enables a comprehensive, confirmatory assessment of construct validity (Bentler 1978).

For all of the advantages of SEM methods, CFA has several drawbacks. For one, the method requires a large sample size. All factor analysis benefits from a larger sample, but CFA is particularly constrained by a small sample. This method is heavily dependent on the researcher and existing theory for the initial model specification. This assumes that the researcher has some knowledge of the underlying latent variable structure. With CFA, statistical fit can be achieved whether or not the model fits reality. The issue of fit is made more challenging by the potential for multiple models to have good fit. Alternately, when model fit is not achieved, re-specification of the model tends to become exploratory, leading to the use of EFA.

5.4.2 Exploratory Factor Analysis

Whether drawn to exploratory factor analysis (EFA) for its benefits alone or as a result of model re-specification[29], EFA has its own pros and cons. As with SEM, EFA represents a group of methods that can be used to perform factor analysis. With EFA methods, the links between the latent and observed variables are assumed to be unknown and uncertain. A researcher can enter the analysis with expectations, but these do not drive the analysis. Using multiple EFA methods is often considered best practice and even within the analysis, multiple choices should be explored, from the number of factors to extract to the rotation used (Thompson 2004). EFA methods are still dependent on the researcher to direct aspects of the analysis, but the results are more purely derived by the statistical qualities of the data. That said, a weakness of EFA is that is can be performed and interpreted without good conceptual grounding, particularly when EFA is being used for the purpose of developing a theory about latent constructs.

As with all factor analysis methods, the subject to item ratio is critical; a small sample with multiple variables entered for the factor analysis will not produce a strong solution. A 10:1 ratio is an acceptable target, though a superior ratio is 20:1. The importance of this ratio to the overall solution represents a downside of this approach, given the small size of the samples relative to the complexity of the concept of social-ecological resilience. In EFA, even with large sample sizes, the method is error prone (Costello and Osborne 2005).

5.4.2.1 Principal components analysis. Principal components analysis (PCA) with varimax rotation is a commonly used method of factor analysis (Thompson 2004). PCA is regularly used in indicator construction, especially within the social sciences. However, despite the regular use, this method may not always be ideal, particularly with social science data, which often fails to meet the necessary assumptions. For example, this method assumes perfect reliability of the data

[29] Exploratory factor analysis is routinely used in conjunction with confirmatory factor analysis, particularly when model fit cannot be achieved.

(Thompson 2004). In fact, statistical theorists have varying perspectives from about whether PCA should be used for factor analysis (Costello and Osborne 2005). These differing opinions arise out of the fact that PCA is actually a data reduction method. Although data reduction can be a research goal, it is not the intended goal of this study. PCA method calculates the components without taking into account an underlying structure. Furthermore, the analysis is focused on reproducing the variance in the sample (Ford, MacCallum, and Tait 1986; Thompson 2004). The varying perspectives include the argument that the results of PCA and factor analyses are similar enough to be comparable (Velicer and Jackson 1990). The lack of consensus on the issue, combined with the consistent application of PCA in social science research and the need to be able to compare results along a range of methodological choices, this method was one of the EFA approaches utilized.

5.4.2.2 Principal axis factoring. In researching best practices, Costello and Osborne (2005) suggest the use of a true factor analysis extraction method with oblique rotation, scree plots, and multiple test runs to determine the number of factors to be extracted. From this approach, they suggest that results will be representative of the population and generalizable to others. Principal axis factoring (PAF) with oblique rotation and a default delta was determined to be an advantageous approach for indicator construction. By utilizing a scree plot to select a fixed number of factors, this method allows the retention of only the ideal number of factors instead of anything above an Eigen value of 1. PAF is driven by the latent constructs within the data, which aids in decisions about the treatment of the observed variables. Both components analysis and common factor analysis allow for the examination the distribution of variance, but components analysis is focused on maximizing the explanation of variance of the observed variables. Alternately, common factor analysis is best applied when the assumption is that the observed variables are linear functions of latent constructs (Ford et al. 1986).

5.4.3 Iterative Indicator Development Method

The final indicator construction approach considered is an iterative methodology that first draws on the input of theoretical, methodological, and statistical factors to derive the components to be aggregated for each composite indicator and then employs select approaches to normalization, weighting, and aggregation to complete the development of indicators. The evaluation of theoretical, methodological, and statistical factors ranges from the examination of existing theory and conceptual models to the performance of variables in statistical analyses (see 5.4.3.1). By allowing for things other than mathematical solutions to be prioritized in the construction of indicators, the conceptual and theoretical inputs have a role that goes beyond interpretation of statistics. Additionally, methodological factors such as the utility of the composite indicators and their meaningfulness to sectors of policy making can be accounted for.

With this method, the most sensitive step is the aggregation of measures to create composite indicators. While there are clear advantages to removing limitations associated with statistical procedures, such as sample size and sampling error, this method is not void of statistical inputs. In fact, this method aims to integrate and balance a range of factors that correspond to the validity, performance, replicability, and utility of the constructed indicators. For example, this method incorporates the results of correlation analyses and EFA with modifications that enhance the utility of the indicators. This method draws on many of the pros of the other methods and avoids some of the cons associated with a method too heavily focused on statistical behavior of variables and not on utility of application.

The challenges of this method include that it comes with a substantial requirement of diligence. The researcher must thoughtfully work through the process laid out in the indicator operationalization section (see Chapter 4). This method is reliant on the process and factors driving it. The necessity of ongoing testing and evaluation helps ensure that the indicator components are the appropriate ones. This approach most closely aligns to what would be done following a CFA with good model fit; one exception is that this method takes into account a great deal of statistical evidence prior to aggregation. As a result of this similarity, this method comes with a future demand - the model constructed will need to be tested through CFA with a much larger sample to ensure goodness of fit. In the interim, important evaluation of hypothesized indicators and measures can continue. This delay also allows for development of the applications of the model.

5.4.3.1 Decision Process for Aggregation

1) Theoretical Factors
    a) Literature

        i) What does the literature say about the relationships between these measures and indicators of social-ecological resilience?
    b) Prior study support
        i) How are the measures used in other indices that measure resilience or related concepts?
    c) Face validity
        i) Do the measures make sense together to address the given concept?
2) Methodological Factors
    a) Utility in applied setting
        i) Are the indicators and underlying constructs easy to understand and communicate?
        ii) Do the indicators and underlying constructs align with policy sectors?
3) Statistical Factors
    a) Correlation analyses
        i) Which measures are significantly related to each other?
        ii) In what direction and how strongly are they related?
    b) Factor analyses
        i) How do the measures combine using statistical properties alone?
        ii) How do the hypothesized indicators align with the resulting factors?
        iii) Is there model fit/convergence?

Normalization of the component measures can be achieved through the linear scaling technique. Following standardization, data values are still expressed in a number of forms including rates, percentages, dollars, and housing units. In order to convert all original reporting units from the raw data into values that could be compared and combined into composite indicators, a statistical operation is needed. With the linear scaling technique, the following equations are used to scale the variables. In Equations **5.1** and **5.2**, x is the value of a given variable, *min* is the minimum value in the distribution, and *max* is the maximum value in the distribution.

Positive Component Measure.

$$\frac{\mathrm{x}-\min}{max-min}=x_{norm} \qquad 5.1$$

Negative Component Measure.

$$\frac{max-x}{max-min}=x_{norm} \qquad 5.2$$

The linear scaling technique, which uses a normalization equation, is recommended as a best practice in the creation of composite indicators for the reasons associated with weighting and directionality (Salzman 2003). Linear scaling assigns the lowest implicit weights of a variety of possible standardizing procedures because it standardizes the range. The influence of weights not intentionally added to the components of an indicator can be dramatic and misleading, allowing a variable with great variance to have a much stronger effect on the indicator. Additionally, this technique also provides a means of dealing with directionality issues. Component measures contribute differently to the composite constructs that contribute to social-ecological resilience. Positive component measures are those that contribute positively to social-ecological resilience, (i.e., higher values are better). Negative component measures are those where a higher value corresponds to less social-ecological resilience (i.e., lower values are better). The general linear scaling method allows for all components to be scaled in the same direction prior to being combined in a composite indicator. Linear scaling provides a consistent way to aggregate diverse sets of variables (Salzman 2003).

Based on the decisions about which measures to aggregate, new, normalized scores for each of the component measures can be combined in an additive composite indicator. *A priori* equal weights are assigned to the component measures such that each measure combined to create a composite indicator is assigned the same weight. An alternate weighting scheme would involve weighting some measures greater than others in terms of their overall contribution to social-ecological resilience. The assignment of equal weights is an explicit weighting scheme. An equal weighting approach keeps the discussion of measure importance and inclusion on a more fundamental level (Salzman 2003). Decisions related to weighting must be engaged with caution

(Freudenberg 2003; Salzman 2003). With weighting, models have the potential to be unduly influenced by the normative views of the researchers (Paruolo et al. 2013), which reduces their methodological soundness.

The assignment of weights is often perceived as indicative of the relative importance of measures. Unfortunately, the perception that weighting is a function of importance is not based on the statistical reality of how variables behave collectively and in relation to one another (Paruolo et al. 2013). The use of an equal weighting scheme does not reflect an assumption that all variables have an equal contribution to social-ecological resilience. Some aspects of resilience will certainly have more influence than others and an equal weighting approach does not reflect this relativity. The differential impact of variables may be a consequence of some external reality or the statistical behavior of variables in relation to one another. However, until this differential impact can be investigated and quantified, an equal weighting scheme avoids the premature prioritization of components of resilience. Refinement of the weighting scheme would be a natural progression to strengthen the statistical performance of the indicators toward the development of a more robust measurement model for social-ecological resilience.

The composite indicators are aggregated to produce scores using the following additive equation (Equation 5.3).

Composite score development.

$$\text{Indicator}_x = ((C_1 + C_2 + C_3 + C_4 + C_n) / \textstyle\sum_n) * 100 \qquad 5.3$$

Where $_x$ is the indicator for which the composite is being developed,
C is a component measure, and
$\sum_n$ is the total number of component measures.

The scores are derived by summing the component measures, dividing by the total number of components and then multiplying the result by 100. The conversion of the sum of the components into a score out of 100 allows for comparisons and visual representation of all composite indicator scores, each of which has a different number of component measures. To summarize, with the iterative indicator development method, upon selection for the model, each composite indicator's component measures are standardized, normalized through the linear scaling method, and then summed as scores out of 100.

5.5 RESULTS OF MEASURE CONSTRUCTION METHODS

Upon identification of a suite of variables that would serve as components of a measurement model of social-ecological resilience, several methods for indicator development were applied and directly compared. First, confirmatory factor analysis was attempted. Next, two types of exploratory factor analysis were employed with the GoM and Island datasets – principal components analysis (PCA) and principal axis factoring (PAF). Following the factor analyses, a fourth method was employed. This method is an iterative approach that draws on the input of theoretical, methodological, and statistical factors to derive the components that should be aggregated for each indicator before employing the general linear scaling technique and an additive index equation to produce the indicator values. By examining several different methods and results for combining variables to create resilience indicators, the indicator construction was well informed.

5.5.1 Confirmatory Factor Analysis Results

Confirmatory factor analysis as the mechanism for measurement modeling was explored extensively with data for both samples. Using theoretical and conceptual models of social-ecological resilience as the basis for the selection of variables, CFA was attempted using AMOS. After multiple attempts, model fit could not be achieved for either sample. Close examination of the data led to the conclusion that the nature of the data would make model fit highly difficult. Issues included small sample, impact of jurisdiction membership (e.g., large number of cases from a single jurisdiction), and variables with non-normal distributions. Future attempts would ideally include a larger sample of cases. Furthermore, for both samples, a greater diversity of mainland and island states may help weaken the effect of membership. The use of exploratory methods for model development ultimately provided a better fit given the complexity of the concept of social-ecological resilience and the innovative nature of this work.

5.5.2 Exploratory Factor Analysis Results

5.5.2.1 Principal components analysis for Gulf of Mexico coastal counties

Table 5.1: Results of KMO and Bartlett's Test.

		GoM Coastal Counties	Island State Communities
KMO Measure of Sampling Adequacy		.726	.615
Bartlett's Test of Sphericity	***Approx. Chi-Square***	3148.680	2247.546
	df	325	210
	Sig.	.000	.000

For both the GoM Coastal Counties and the Island States Communities datasets, the KMO and Bartlett's Test indicated that a factor analysis would be useful (Table 5.1). For the GoM Coastal Counties, the Kaiser Meyer Olkin Measure of Sampling Adequacy was 0.726 while Bartlett's Test of Sphericity was significant at the 0.000 level. Likewise, for the Island States Communities, the Kaiser Meyer Olkin Measure of Sampling Adequacy was 0.615 while Bartlett's Test of Sphericity was significant at the 0.000 level. These statistics established that factor analysis could be pursued with both samples. For ease of comparison, the same measures were used for both samples. Additionally, all analyses had a 5:1 subject to item ratio. This smaller subject to item ratio was allowed during the course of this investigation in order to explore the development of a model that would account for the complexity of the concept. The EFA methods employed were principal axis factoring (PAF) with oblique rotation and principal components analysis (PCA) with an orthogonal rotation using the varimax method.

5.5.2.2 Principal axis factoring for Gulf of Mexico coastal counties. For the GoM dataset, a total of 26 variables were entered into the PAF procedure; oblique rotation was applied. Using the scree plot as a guide to determining the number of factors to extract, the analysis was set to extract five factors (see Figure 5.1). The structure matrix yields five factors that cumulatively explain 67% of the variance. Factor component loadings of at least 0.30 are examined below. However, any component that loads less than 0.50 is flagged. The only variable that fell out of the model was the measure of support establishments (number of hospital beds per 1000 people) due to a low factor loading. The first factor, explaining 30.6% of the variance, is comprised of variables that most closely reflect economic and social class related metrics. For example, this factor includes median income, lack of transportation, and unemployment, among others. The second factor is a mix of environmental and education related metrics. Here, variables that capture the level of development (developed land cover and housing distribution) and air pollution (total emissions) load alongside education to explain 12.5% of the variance. The third factor is also a combination of environmental and education metrics, but this time racial diversity is included. This factor explains 12% of the variance. The fourth factor encompasses the diversity of the population in terms of sex and age, as well as economic activity to explain 6.4% of the variance. And in the final factor, metrics for the median age of the housing and the proportion of wastewater treatment facilities per 100 households combine to explain 5.5% of the variance. The results of the PAF analysis are presented in Table **5.2**.

When examining positive and negative loadings in Table 5.2, several of the variables load as expected in relation to one another. For example, in the first factor comprised of economic and social class variables, components like the level of poverty, lack of phone service and transportation, and unemployment load positively while median income and home value load negatively. However, in the second factor, educational attainment loads both positively (college education) and negatively (high school education). The third factor showcases the interesting interaction between land cover and social variables. Here, vegetated land cover loads negatively, while wetland landcover loads positively alongside racial diversity and water source.

Table 5.2: Principal Axis Factoring (PAF) Results for Gulf of Mexico Coastal Counties.

Variable	Factor				
	1	**2**	**3**	**4**	**5**
Total population below poverty level	.951				
Median household income in 1999	-.818				
HHs with no phone service available	.787				
HHs without complete plumbing	.710				
Monthly costs of housing	-.708				
Individuals in poverty participating in SNAP	.707				
Unemployment rate for civilian labor force	.701				
Median value of housing unit	-.688				
HHs with no vehicle available	.686				
HHs without complete kitchens	.686				
Developed landcover		.783			
Housing units per square mile		.779			
Adult population with college education		.686			
Total emissions per year		.663			
Adult population with high school education		-.562			
HHs on public water			.800		
Wetland landcover			.789		
Vegetated landcover			-.741		
Racial diversity			.679		
K-12 school enrollment			-.374		
Sex diversity				.930	
Age diversity				.660	
Economic diversity				.337	
Age of housing unit					-.637
Wastewater facilities per 100 HHs					-.340
Hospital beds per 1000 people					-.238
Initial Eigenvalues	7.958	3.246	3.116	1.658	1.433
% of variance explained	30.609	12.483	11.984	6.376	5.513

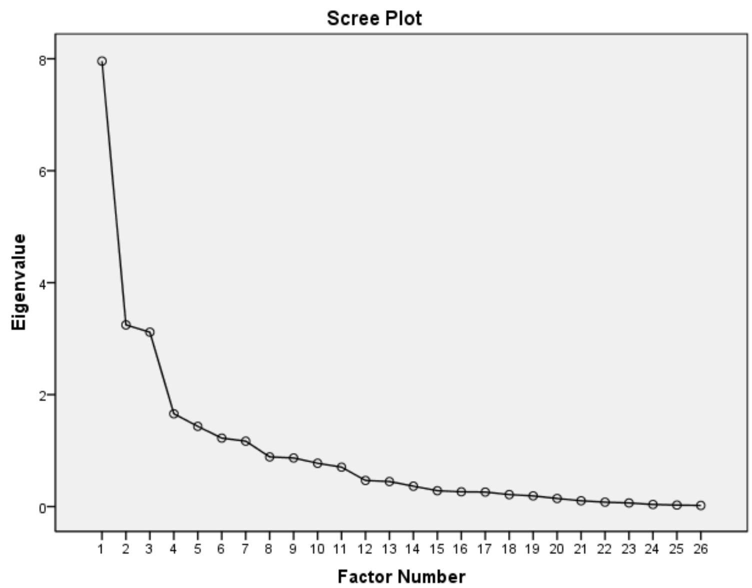

Figure 5.1: Scree Plot for Gulf of Mexico Coastal Counties.

5.5.2.3 Principal components analysis for Gulf of Mexico coastal counties. The PCA included 26 variables and the solution was rotated using a Varimax procedure. The rotated components matrix yields seven factors that cumulatively explain 76% of the variance. All components load 0.60 or higher. The initial factors extracted from the PCA closely mimic the PAF results with a couple of exceptions. The results of the PCA are presented in Table 5.3.

The first factor again explains 30.6% of the variance and is comprised of variables that most closely reflect economic and social class related metrics. For example, this factor includes median income, lack of transportation, and unemployment, among others. The second factor is a combination of environmental and education metrics with racial diversity included to explain 12.5% of the variance. The third factor is made up of environmental related metrics. Variables that capture the level of development (developed land cover and housing distribution) and air pollution (total emissions) explain 12% of the variance. In the fourth factor, the diversity of the economy loads alongside housing measures of monthly cost and value, as well as the percent of the population with a college education to explain 6.4% of the variance. The fifth factor encompasses the diversity of the population in terms of sex and age to explain 5.5% of the variance. Unlike the PAF results, the sixth factor combines the number of hospital beds per 1000 people with a measure of K-12 education enrollment to account for 4.7% of the variance. And in the final factor, metrics for the median age of the housing and the proportion of wastewater treatment facilities per 100 households combine to explain 4.5% of the variance.

Positive and negative loadings in Table 5.3 follow many of the same patterns as the previous factor analysis. As before, median income loads negatively in relation to measures that focus on lower economic conditions and social class. The surprising results include the negative loading of economic diversity in Factor 4, indicating that a less diverse economy may be associated with high median housing values and monthly housing costs, as well as a greater proportion of college educated adults. Another unexpected result is the strong, but oppositional loading of social service support establishments and educational enrollment in Factor 6.

Table 5.3: Principal Components Analysis (PCA) Results for Gulf of Mexico Coastal Counties.

Variables	**Component**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Total population below poverty level	.882						
Unemployment rate for civilian labor force	.777						
Individuals in poverty participating in SNAP	.777						
HHs with no vehicle available	.746						
HHs with no phone service available	.743						
Median household income in 1999	-.709						
HHs without complete plumbing	.683						
HHs without complete kitchens	.645						
Wetland landcover		.872					
HHs on public water		.737					
Vegetated landcover		-.734					
Adult population with high school education		.623					
Racial diversity		.623					
Housing units per square mile			.872				
Developed landcover			.853				
Total emissions per year			.750				
Monthly costs of housing				.722			
Median value of housing unit				.645			
Adult population with college education				.611			
Economic diversity				-.601			
Age diversity					.847		
Sex diversity					.847		
Hospital beds per 1000 people						.735	

Variables	Component						
	1	**2**	**3**	**4**	**5**	**6**	**7**
K-12 school enrollment						-.725	
Wastewater facilities per 100 HHs							.760
Age of housing unit							.729
Initial Eigenvalues	7.958	3.246	3.116	1.658	1.433	1.223	1.168
% of variance explained	30.609	12.483	11.984	6.376	5.513	4.705	4.492

5.5.2.4 Principal axis factoring for Island State communities. For the Island dataset, a total of 21 variables were entered into the PAF procedure; oblique rotation was applied. A scree plot was used as a guide for determining the number of factors to extract (see Figure 5.2). As a result, the structure matrix was set to yield six factors that cumulatively explain 84% of the variance. Factor component loadings are at least 0.30 are examined below. However, any component that loads less than 0.50 is flagged. The results of the PAF analysis are presented in Table 5.4**.**

For island communities, the first factor is also comprised of economic and social class metrics. In addition to measures such as median income, housing value, and poverty, racial diversity and the proportion of high school graduates in the population load onto this factor and help to explain 27.7% of the variance. The second factor includes completeness of plumbing and kitchen facilities along with metrics that account for water supply, transportation access, and reach of public assistance programs. This factor explains 21.5% of the variance. The third factor includes measures of population diversity with respect to age and sex, as well as the proportion of wastewater treatment facilities per 100 households; this factor explains 15.2% of the variance. Measures of K-12 education enrollment and economic diversity load on the fourth factor to explain 8% of the total variance. Finally, the fifth factor encompasses measures of college education, housing distribution, and availability of health and social service establishments. This final factor explains 6.3% of the variance.

Positive and negative loadings in Table 5.4 follow many of the same patterns as the factor analyses for the GoM coastal counties. In Factor 1, variables for level of poverty and access to communication load negatively in relation to measures that focus on higher economic conditions and social class such as housing value and median income. Racial diversity loads positively onto this factor, which is somewhat surprising and reflective of a substantial difference in population composition for island and mainland coastal communities.

Table 5.4: Principal Axis Factoring (PAF) Results for Island State Communities.

Variables	**Factor**				
	1	**2**	**3**	**4**	**5**
Median value of housing unit	.941				
Median household income in 1999	.939				
Total population below poverty level	-.852				
Monthly costs of housing	.794				
HHs with no phone service available	-.744				
Racial diversity	.663				
Adult population with high school education	.477				
HHs without complete kitchens		-.974			
HHs without complete plumbing		-.948			
HHs on public water		.608			
HHs with no vehicle available		.574			
Individuals in poverty receiving public assistance income		.557			
Age diversity			.921		
Sex diversity			.905		
Age of housing unit			-.676		
Wastewater facilities per 100 HHs			.334		
K-12 school enrollment				.846	
Economic diversity				.589	
Adult population with college education					.775
Housing units per square mile					.695
Healthcare and social assistance establishments per 100					.554
Initial Eigenvalues	5.819	4.513	3.200	1.709	1.316
% of variance explained	27.708	21.490	15.238	8.139	6.267

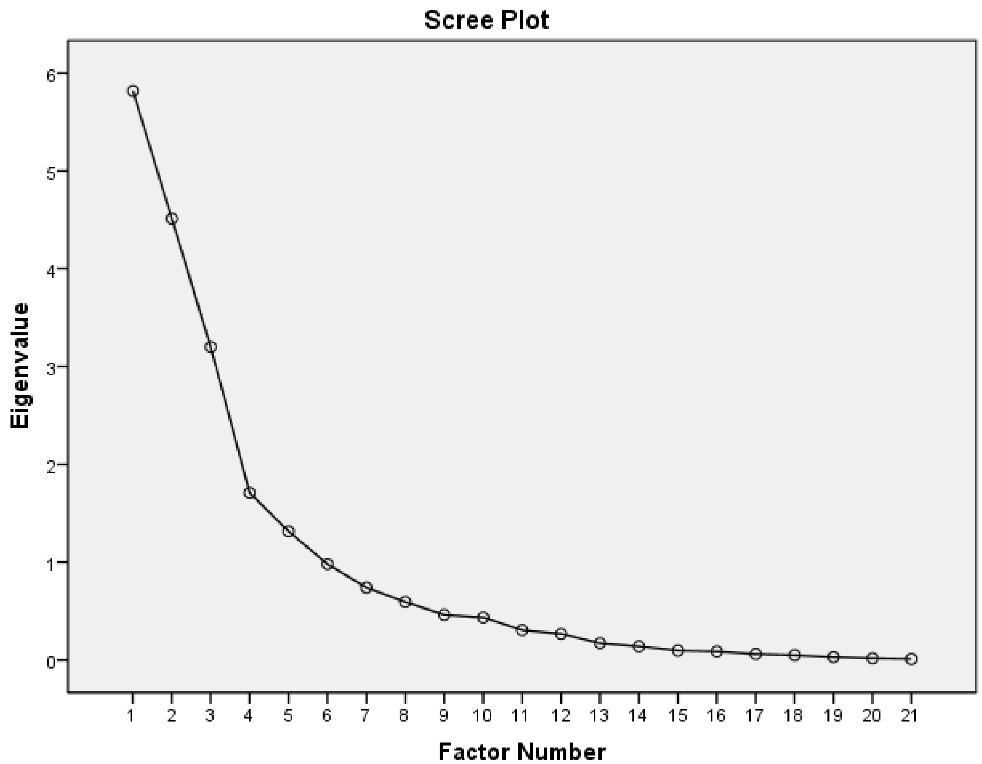

Figure 5.2: Scree Plot for Island State Communities.

5.5.2.5 Principal components analysis for Island State communities. The PCA included 21 variables and the solution was rotated using Varimax. The rotated components matrix contains five factors that cumulatively explain 79% of the variance. All components load 0.40 or higher. The results of the PCA share strong similarities with those of the PAF. Again, the first factor is well aligned with common economic and social class metrics, such as median income, housing value, and poverty, as well as the racial diversity of the population. Collectively, these measures help to explain 27.7% of the variance. The results of the PCA are presented in Table 5.5.

The second factor is the same as that of the previous analysis. It includes completeness of plumbing and kitchen facilities along with metrics that account for water supply, transportation access, and reach of public assistance programs to explain 21.5% of the variance. The third factor is also the same as the result of the previous analysis. The final two factors mark a very slight departure from the PAF. In the fourth factor, housing distribution, availability of health and social service establishments, and education measures combine to explain 8% of the variance. The fifth factor mirrors a factor result in the PAF and contains only economic diversity and K-12 education enrollment to account for 6.3% of the variance.

Factor loadings in Table 5.5 align with those in Table 5.4. Similar to the loadings for the PAF with GoM coastal counties, educational attainment loads both positively (college education) and negatively (high school education) in Factor 4. The first factor still includes a mix of negative (level of poverty and access to communication) and positive (housing value and median income) loading components that come together to form a mostly economic and social class related factor. Racial diversity maintains a positive loading in the first factor, showing consistency between PAF and PCA approaches.

Table 5.5: Principal Components Analysis (PCA) Results for Island State Communities.

Variables	**Component**				
	1	**2**	**3**	**4**	**5**
Median value of housing unit	.930				
Median household income in 1999	.901				
Total population below poverty level	-.845				
Monthly costs of housing	.839				
HHs with no phone service available	-.762				
Racial diversity	.743				
HHs without complete kitchens		-.935			
HHs without complete plumbing		-.921			
HHs on public water		.691			
HHs with no vehicle available		.627			
Individuals in poverty receiving public assistance income		.598			
Sex diversity			.923		
Age diversity			.886		
Age of housing unit			-.702		
Wastewater facilities per 100 HHs			.420		
Housing units per square mile				.846	
Adult population with college education				.637	
Healthcare and social assistance establishments per 100				.483	
Adult population with high school education				-.471	
K-12 school enrollment					.859
Economic diversity					.563
Initial Eigenvalues	5.819	4.513	3.200	1.709	1.316
% of variance explained	27.708	21.490	15.238	8.139	6.267

5.5.2.6 Discussion of exploratory factor analyses. Because the aim of this research is to develop a single model of social-ecological resilience that can be applied to various types of communities, it was valuable to examine the results of the exploratory factor analyses as a whole. In all analyses, regardless of dataset, wastewater treatment facilities behaved interestingly; this measure tended to load with housing age, both of which load negatively. While it is true that communities with an older average housing stock and fewer wastewater treatment facilities would likely be less resilient, it is interesting that the measures pair together. Possible explanations include the connection between the property tax base and infrastructure investments. Some of these communities, which may generally be older, could be dependent on well water and septic systems.

Housing distribution was closely linked to measures of development, whether social or ecological (availability of support services and developed land cover) and tended to link tightly with education related measures. For both GoM and Island samples, educational attainment measures tended to load onto multiple factors with a value of more than 0.30. This suggests that educational attainment could easily be part of several different indicators of resilience. For the Island dataset, wastewater treatment and economic diversity loaded onto multiple factors.

Land use variables were not extensively explored across both datasets due to the lack of available data for Island State Communities in Puerto Rico. The landcover dataset for Puerto Rico is in development, along with an update for the US Virgin Islands[30], so there was great utility in including landcover variables for the remaining communities in the sample. For island communities, land cover variables had to be excluded from the factor analyses. However, the behavior of these variables for the GoM dataset provides some indication of how they would behave for Island State communities.

5.5.3 Iterative Indicator Development Method Results

The final indicator construction approach applied in this phase was an iterative methodology that first draws on the input of theoretical, methodological, and statistical factors to derive the components to be aggregated for each composite indicator and then employs the general linear scaling technique for normalization and an unweighted additive index equation to produce the

[30] Nate Herold, email correspondence, January 24, 2014.

indicator values. Upon application of the iterative methodology, seven composite indicators were developed (Figure 5.3). These indicators are: *Land cover and use, Waste accumulation and treatment, Housing adequacy, Economic security, Access to support services, Education,* and *Population diversity*. The final equations used to construct these indicators are presented below.

When comparing results from PCA and PAF to the results of the iterative method, it is clear that choices about aggregation took a different direction in the latter method. In both the PCA and PAF results, the strongest factor to emerge was a social and economic class indicator. This factor was comprised of variables that span social, economic, and demographic categories. This factor was not computed as a single indicator. Instead, the components were crafted into *Economic security*, *Access to support services*, and *Population diversity* indicators. The final aggregation of measures was informed by one of the primary aims of this study – to develop indicators that are useful for policy and other applications. By separating the measures into indicators that are aligned to distinct policy sectors (e.g., health and human services, housing and urban development), policy decisions can be better informed and evaluated.

5.5.3.1 Equations and indicator components for Gulf of Mexico coastal counties

Indicator: Land cover and use Landuse = $((C_1 + C_2 + C_{3} + C_4) /4) *100$		
Components	**Measure Description**	**Contribution**
Distribution of housing	Housing units per square mile	-
Developed landcover	Percent of all landcover that is impervious	-
Vegetated landcover	Percent of all landcover terrestrial vegetated	+
Wetland landcover	Percent of all landcover that is wetland	+

Indicator: Waste accumulation and treatment Waste = $((C_1 + C_2 + C_{3} + C_4 + C_5) /5) *100$		
Components	**Measure Description**	**Contribution**
Water source	Proportion of all HHs on public water	+
Plumbing	Proportion of all HHs without complete plumbing	-
Kitchen facilities	Proportion of all HHs without complete kitchens	-
Wastewater treatment	Wastewater facilities per 100 HHs	+
Total emissions	Total emissions per year	-

Indicator: Population diversity Diverse = $((C_1 + C_2 + C_3) / 3) *100$		
Components	**Measure Description**	**Contribution**
Sex diversity	Sex diversity index (examines male and female proportions)	+
Age diversity	Age diversity index (examines proportion of age groups)	+
Race diversity	Racial diversity index (examines proportion of Black, White, Asian, American Indian, and Hispanic/Latino)	+

Indicator: Economic security Access = $((C_1 + C_2 + C_{3} + C_4) /4) *100$		
Components	**Measure Description**	**Contribution**
Industry diversity	Economic diversity index (examines diversity across10 industries)	+
Population in poverty	Percent of total population below poverty level	-
Household economic security	Median household income in 1999	+
Individual economic security	Unemployment rate for civilian labor force	-

Indicator: Housing Adequacy House = $((C_1 + C_2 + C_3) / 3) *100$		
Components	**Measure Description**	**Contribution**
Value	Median value of housing unit	+
Costs	Median monthly costs of housing for all owner occupied units	-
Age	Median age of housing unit	-

Indicator: Access to support services Access = $((C_1 + C_2 + C_3 + C_4) /4) *100$		
Components	**Measure Description**	**Contribution**
Communication	Proportion of HHs with no phone service available	-
Transportation	Proportion of HHs with no vehicle available	-
Support establishments	Hospital beds per 1000 people	+
Public assistance	Proportion of population in poverty participating in SNAP	+

Indicator: Education Educ = $((C_1 + C_2 + C_3) / 3) *100$		
Components	**Measure Description**	**Contribution**
School enrollment	Proportion of total population 18 and under enrolled in school, grades K-12	+
Educational attainment - high school	Percent of population 25 years and older with high school or equivalent as highest level of attainment	+
Educational attainment - college	Percent of population 25 years and older with bachelor's degree or higher as highest level of attainment	+

Note: *For *Population diversity*, because the equation scales all component values in the same manner, this index represents a simple composite divided by the total components and multiplied by 100. General linear scaling was not required. All values were calculated using the Diversity Index (Chang and Yamamura 2005, Meyer and McIntosh 1992).

5.5.3.2 Equations and indicator components for Island State communities

Indicator: Land cover and use Landuse = $((C_1 + C_2 + C_3 + C_4) / 4) *100$		
Components	**Measure Description**	**Contribution**
Distribution of housing	Housing units per square mile	-
Developed landcover	Percent of all landcover that is impervious	-
Agriculture land	Percent of all landcover for cultivated crop land/pasture and hay	+
Vegetated forest landcover	Percent of all landcover that is forest	+

Indicator: Waste accumulation and treatment Waste = $((C_1 + C_2 + C_3 + C_4) / 4) *100$		
Components	**Measure Description**	**Contribution**
Water source	Proportion of all HHs on public water	+
Plumbing	Proportion of all HHs without complete plumbing	-
Kitchen facilities	Proportion of all HHs without complete kitchens	-
Wastewater treatment	Wastewater facilities per 100 HHs	+

Indicator: Population diversity Diverse = $((C_1 + C_2 + C_3) / 3) *100$		
Components	**Measure Description**	**Contribution**
Sex diversity	Sex diversity index (examines male and female proportions)	+
Age diversity	Age diversity index (examines proportion of age groups)	+
Race diversity	Racial diversity index (examines proportion of Native Hawaiian and Other Pacific Islander, Asian, White, Black, and Other ethnic origin or race groups)	+

Indicator: Economic security Econ = $((C_1 + C_2 + C_3) / 3) *100$		
Components	**Measure Description**	**Contribution**
Industry diversity	Economic diversity index (examines diversity across10 industries)	+
Population in poverty	Percent of total population below poverty level	-
Household economic security	Median household income in 1999	+

Indicator: Housing Adequacy House = $((C_1 + C_2 + C_3) / 3) *100$		
Components	**Measure Description**	**Contribution**
Value	Median value of housing unit	+
Costs	Median monthly costs of housing for all owner occupied units	-
Age	Median age of housing unit	-

Indicator: Access to support services Access = $((C_1 + C_2 + C_3 + C_4) / 4) *100$		
Components	**Measure Description**	**Contribution**
Communication	Proportion of HHs with no phone service available	-
Transportation	Proportion of HHs with no vehicle available	-
Support establishments	Healthcare and social assistance establishments per 100	+
Public assistance	Estimate of proportion of all individuals in poverty receiving public assistance income	+

Indicator: Education Educ = $((C_1 + C_2 + C_3) / 3) * 100$		
Components	**Measure Description**	**Contribution**
School enrollment	Proportion of total population 18 and under enrolled in school, grades K-12	+
Educational attainment - high school	Graduates of high school or equivalent per 100 people	+
Educational attainment - college	Graduates of a bachelor degree program per 100 people	+

Note: *For *Population diversity*, because the equation scales all component values in the same manner, this index represents a simple composite divided by the total components and multiplied by 100. General linear scaling was not required. All values were calculated using the Diversity Index (Chang and Yamamura 2005; Meyer and McIntosh 1992).

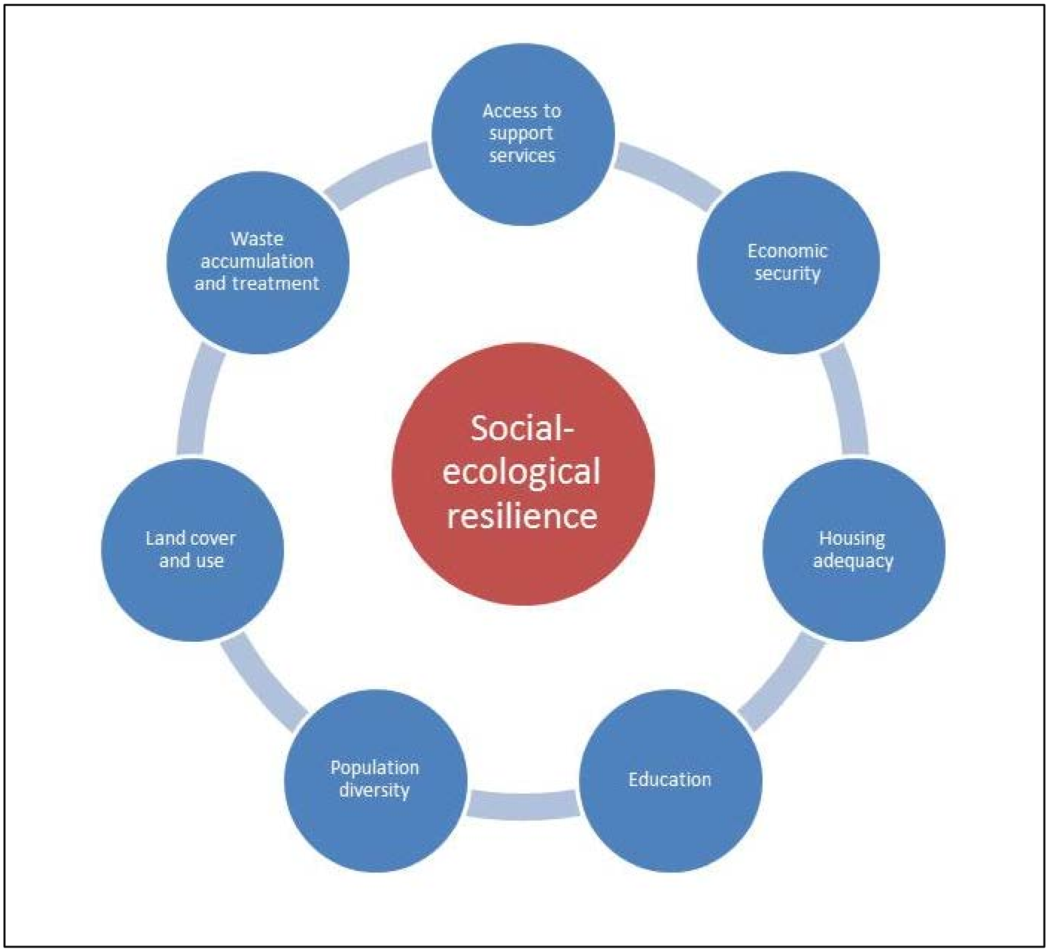

Figure 5.3: Social-ecological resilience framework.

5.6 SELECTION OF A METHOD

Ultimately, the indicators were constructed using the iterative methodology with the general linear scaling technique and additive index equation. The seven composite indicators that were constructed represent a subset of the hypothesized indicators. However, given the methodological constraints, largely data related, this was the strongest set that could be developed. By examining several different methods and results for combining variables to create resilience indicators, the indicator construction process was well informed.

The iterative method for indicator construction was selected for many of its strengths. This method integrates and balances a range of factors that correspond to the validity, performance, replicability, and utility of the constructed indicators. By allowing for things other than mathematical solutions to be prioritized in the construction of indicators, conceptual and theoretical inputs had a more significant role. Additionally, methodological factors were better accounted for. The final method selection was informed by one of the primary aims of this study—to develop indicators that are useful for policy and other applications. By crafting a hybrid methodology that allowed for the indicators to align with distinct policy sectors (e.g., health and human services, housing and urban development), the indicators have utility for policy development and evaluation. The indicators fall directly and in many cases, uniquely, under the purview of a particular federal, state, and/or local agency.

6 INDICATOR RESULTS

6.1 INTRODUCTION TO INDICATOR RESULTS

This chapter is focused on an examination of the results that follow from application of the selected measure development method. The social-ecological resilience indicators are computed and presented in a variety of formats, in order to fully examine both the results and the potential utility. First, the descriptive statistics for each sample are examined. Then, indicator scores and percentile ranks are presented. Finally, visual displays of the data are used to help interpret the data for individual cases and across geographic regions.

6.2 DESCRIPTIVE STATISTICS FOR INDICATORS

The following tables (Tables **6.1** and **6.2**) present descriptive statistics for the indicators within each sample, including mean, standard deviation, median, skewness, range, and percentiles. These statistics allow for the assessment of the distribution of indicator scores for each sample, as well as central tendency and dispersion. Understanding the spread of cases across the indicator scores is important to determining how these cases compare in terms of social-ecological resilience.

For the Gulf of Mexico coastal counties, three of the indicators have skewed distributions. Land cover & use, Population diversity, and Economic security are all negatively skewed. Economic security has the greatest range, followed by Land cover & use. The mean scores for Economic security and Education fall below 50, while mean scores for only Land cover & use and Population diversity top the 60 mark.

For Island State Communities, Waste accumulation & treatment, Economic security, and Access to support services have skewed distributions. With this sample, Economic security and Access to support services are positively skewed, while Waste accumulation & treatment is negatively skewed. Economic security has the greatest range, followed by Access to support services. The mean values for Access to support services, Land cover & use, and Economic security indicators all fall below a score of 50. The mean score for Waste accumulation & treatment hits the above 60 mark.

6.2.1 Gulf of Mexico Coastal Counties

Table 6.1: Indicator Descriptive Statistics for Gulf of Mexico Coastal Counties

Indicators		Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
N		135	135	135	135	135	135	135
Mean		68.60	53.47	62.23	48.42	53.39	51.47	41.58
Median		72.24	54.27	64.26	48.99	54.01	53.63	41.65
SD		10.17	9.56	10.82	9.53	6.53	11.57	7.10
Skewness		-2.81	.21	-2.04	-1.10	-.59	-.46	-.32
SE of Skewness		.21	.21	.21	.21	.21	.21	.21
Range		70.44	43.20	56.20	72.51	40.46	54.52	41.01
Percentiles	25	64.70	45.98	60.39	43.94	49.94	42.68	36.94
	50	72.24	54.27	64.26	48.99	54.01	53.63	41.65
	75	74.90	60.66	69.65	54.08	57.30	60.42	46.26

6.2.2 Island State Communities

Table 6.2: Indicator Descriptive Statistics for Island State Communities

Indicators		Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
N		15	94	94	94	94	94	94
Mean		47.50	73.47	58.52	44.05	54.71	47.85	51.88
Median		49.91	74.90	57.43	41.11	55.11	46.70	51.14
SD		12.93	7.82	6.33	13.92	5.73	11.10	6.22
Skewness		.61	-1.95	.72	1.61	.12	1.50	.71
SE of Skewness		.58	.25	.25	.25	.25	.25	.25
Range		41.56	47.34	29.97	81.13	39.15	66.43	32.95
Percentiles	25	36.67	73.09	53.76	36.37	51.62	41.72	47.06
	50	49.91	74.90	57.43	41.11	55.11	46.70	51.14
	75	52.52	77.01	62.23	49.45	57.24	52.01	54.33

6.3 CORRELATION MATRICES FOR INDICATORS

In order to examine relationships between the indicators, correlation analyses were run with the indicators produced for each sample (Tables 6.3 and 6.4). Among the correlations that are significant for Island State Communities, the Economic security indicator correlates positively with Population diversity, Housing adequacy, Access to support services, and Education. Waste accumulation & treatment is negatively correlated with Economic security, Housing adequacy, Access to support services, and Education. Population diversity correlates positively with Access to support services and Education. Likewise, Access to support services and Education are significantly and positively correlated.

For small island communities, Waste accumulation & treatment accounts for interactions between social and ecological systems and signals the tension between the needs of society and environment. Its negative association with a variety of social indicators suggests that societal advances come at a cost in small island state communities. This indicator serves a similar role to Land cover & use for the GoM Coastal Counties.

With the GoM Coastal Counties, as with the Island State Communities, Economic security indicator correlates positively with Population diversity, Access to support services, and Education ($p \leq .01$).Waste accumulation & treatment is negatively correlated with Population diversity and positively correlated with Land cover & use. Alternately, Land cover & use correlates negatively with Access to support services and Economic Security. The indicator for Access to support services correlates significantly and positively with Housing adequacy and Education ($p \leq .01$). Finally, Population diversity and Education are significantly and positively correlated.

For the GoM sample, the positive correlation of the indicators, Land cover & use and Waste accumulation & treatment is ideal for these indicators are explicitly accounting for the interactions between the social and ecological systems. The negative association of Land cover & use with Access to support services and Economic Security is indicative of the tensions between societal development and sustainable land use. These indicators point to the important tradeoffs that must be balanced in decision making.

Both samples provide evidence for an association between Population diversity, Economic Security and Education. Communities with greater diversity of race, sex, and age categories are associated with communities that have higher scores for Economic Security and Education.

Similarly, for both samples, there are positive correlations between scores for Economic Security, Access to support services, and Education.

6.3.1 Island State Communities

Table 6.3: Indicator Correlation Analysis for Island State Communities

Correlations

		diverse	landuse	waste	econ	house	access	educ
diverse	Pearson Correlation	1						
	Sig.							
	N	94						
landuse	Pearson Correlation	.333	1					
	Sig.	.226						
	N	15	15					
waste	Pearson Correlation	-.024	.288	1				
	Sig.	.821	.298					
	N	94	15	94				
econ	Pearson Correlation	**.648****	.101	**-.257***	1			
	Sig.	.000	.720	.012				
	N	94	15	94	94			
house	Pearson Correlation	.126	-.141	**-.256***	**.303****	1		
	Sig.	.228	.616	.013	.003			
	N	94	15	94	94	94		
access	Pearson Correlation	**.213***	.368	**-.249***	**.668****	-.055	1	
	Sig.	.039	.177	.016	.000	.599		
	N	94	15	94	94	94	94	
educ	Pearson Correlation	**.541****	.227	**-.217***	**.759****	.200	**.524****	1
	Sig.	.000	.416	.036	.000	.054	.000	
	N	94	15	94	94	94	94	94

Notes: **Correlation is significant at the $p \leq 0.01$ level (2-tailed); *Correlation is significant at the $p \leq 0.05$ level (2-tailed).

6.3.2 Gulf of Mexico Coastal Counties

Table 6.4: Indicator Correlation Analysis for Gulf of Mexico Coastal Counties

Correlations

		diverse	landuse	waste	econ	house	access	educ
diverse	Pearson Correlation	1						
	Sig.							
	N	135						
landuse	Pearson Correlation	-.002	1					
	Sig.	.980						
	N	135	135					
waste	Pearson Correlation	**-.360****	**.431****	1				
	Sig.	.000	.000					
	N	135	135	135				
econ	Pearson Correlation	**.340****	**-.217***	-.167	1			
	Sig.	.000	.012	.052				
	N	135	135	135	135			
house	Pearson Correlation	.084	**.246****	**-.334****	.094	1		
	Sig.	.332	.004	.000	.280			
	N	135	135	135	135	135		
access	Pearson Correlation	.168	**-.241****	-.156	**.774****	**.240****	1	
	Sig.	.052	.005	.072	.000	.005		
	N	135	135	135	135	135	135	
educ	Pearson Correlation	**.346****	.020	-.057	**.453****	.122	**.418****	1
	Sig.	.000	.814	.514	.000	.158	.000	
	N	135	135	135	135	135	135	135

Notes: **Correlation is significant at the $p \leq 0.01$ level (2-tailed); *Correlation is significant at the $p \leq 0.05$ level (2-tailed).

6.4 INDICATOR SCORES

For the purposes of presenting results, the indicators are first presented as simple scores with the best possible score=100 and the lowest possible score=0 (Appendix D, Tables **D1-D2**). This allows for the indicators to be displayed on the same scale, despite the number of component measures. For example, these scores can be presented together in a single radar graph (Figures 6.1-6.6). By drawing on a familiar scale, interpretability of the indicators is enhanced.

6.4.1 Indicator Scores Presented in Radar Graphs

The indicator scores for select cases are presented in radar graphs as a means of visualizing the results in a single space. In radar graphs, the scores for an individual case are presented alongside the sample average, which is used to provide context. For example, Figure 6.1 displays indicator scores for Honolulu, Hawaii, as well as the average scores for the Island State Communities sample. The average scores are presented as the sample mean. Radar graphs are useful when the categories are not directly comparable, but the values are scaled in the same manner and are oriented in relation to a center point. Though the resilience indicators contribute to a complete picture of the social-ecological resilience of a community, there remains much to be investigated with respect to the contribution of each indicator (e.g., differential contributions, mechanisms for contribution, function of indicators). As a result, direct comparison of the indicator scores to each other is not the intention of the results. Instead, the focus of the results is on the relative position of each case to the sample, as well as broader trends in the samples that contribute to a community typology.

In Figure 6.1, Honolulu County differs substantially from the sample mean on all indicators of social-ecological resilience with the exception of Housing adequacy and Waste accumulation and treatment. For these indicators, the community aligns closely with the average score for the sample. This Hawaii community has higher values on various social indicators, particularly on Economic security (94.42) and Access to support services (82.64), when compared to the average island state community in the sample (44.05 and 47.85, respectively). However, on two dimensions of social-ecological resilience, this community exhibits a lower than average score. Honolulu County has a score of 31.91 for Land cover and use and a score of 51.11 for Housing adequacy.

In Figure 6.2, Saipan Municipality, Commonwealth of the Northern Mariana Islands is above the sample average on some indicators of social-ecological resilience and below the average on others. Saipan Municipality scores higer on most social dimensions (Education, Housing adequacy, Economic security, and Population diversity), but lower on Access to support services, as well as on both ecological dimensions - Waste accumulation and treatment and Land cover and use. The similarity between Honolulu County and Saipan Municipality is in the position of these communities in relation to the island state to which they belong. Both communities are the most populated of their island states. As a result, these communities tend to score higher on social dimensions of resilience, while performing lower on ecological dimensions. The concentration of population equates to greater amounts of development, more support services, and better instutitional structure (at least in terms of resources). Meanwhile, these positive features for the social system tend to be negative features for the ecosystem, resulting in greater waste accumulation, developed landcover, and overall population pressure. The results highlight the very real tension between societal development and environmental conservation and preservation. Some balance between competeing interests is needed to ensure the ongoing provision of ecosystem services for the population, particularly in small island and coastal communities where the degree of reliance is considerable.

The final example for the island state communities is St. Thomas, US Virgin Islands, displayed in Figure 6.3. Here, the community scores differently from the previous with much closer alignment to the sample mean. Scores for Education, Access to support services, Housing adequacy, and Population diversity are nearly equal for St. Thomas and the average island state community in the sample. Where St. Thomas diverges from the sample mean, it scores lower on ecological dimensions and more than 20 points higher on Economic security.

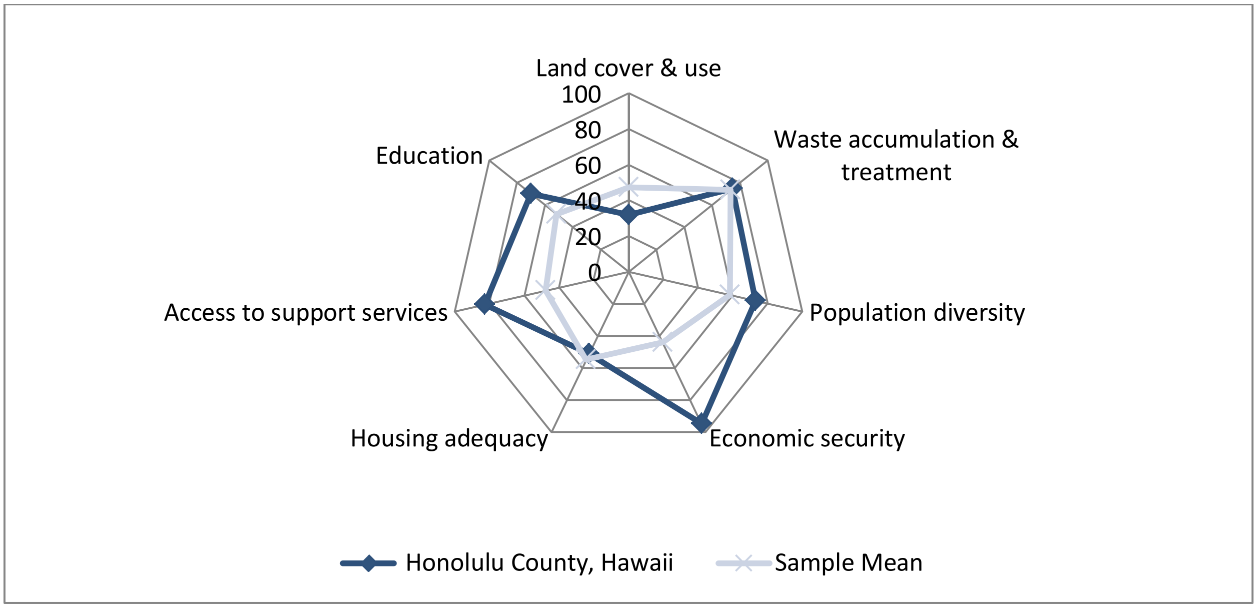

Figure 6.1: Indicator Score Radar Graph for Honolulu, Hawaii

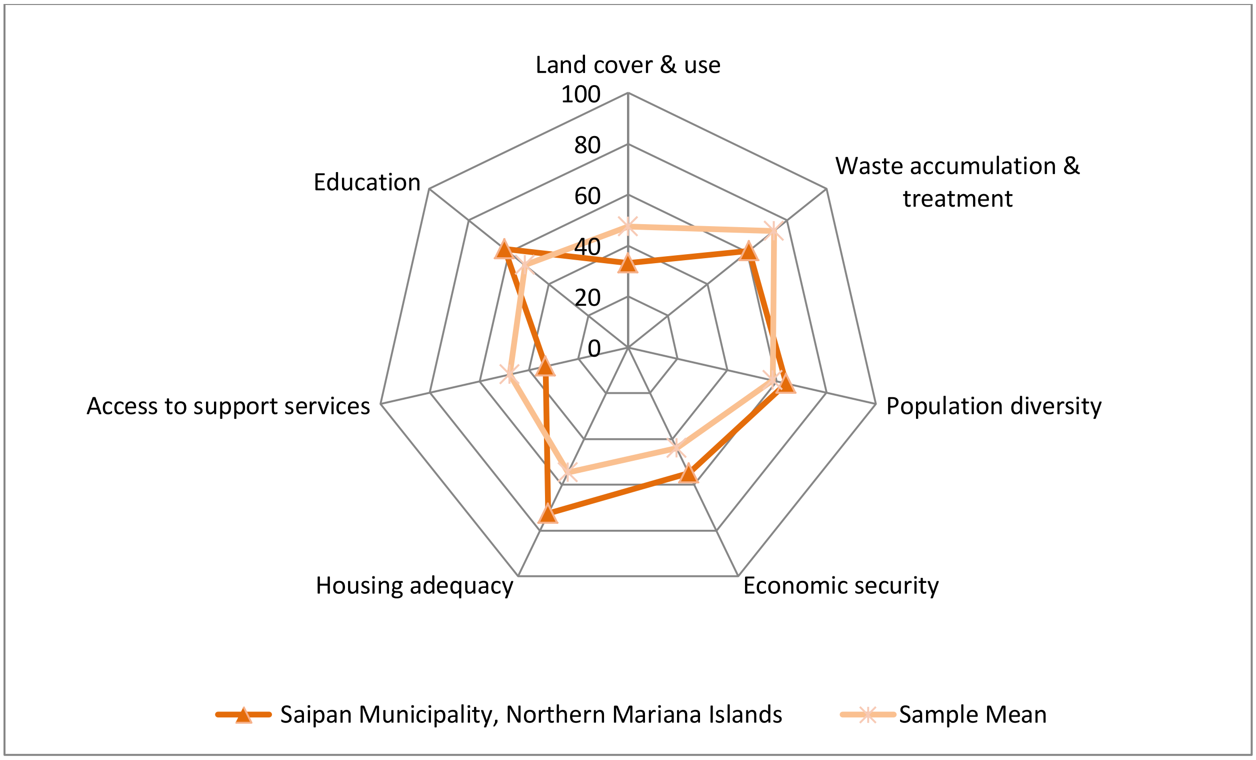

Figure 6.2: Indicator Score Radar Graph for Saipan, Commonwealth of the Northern Mariana Islands

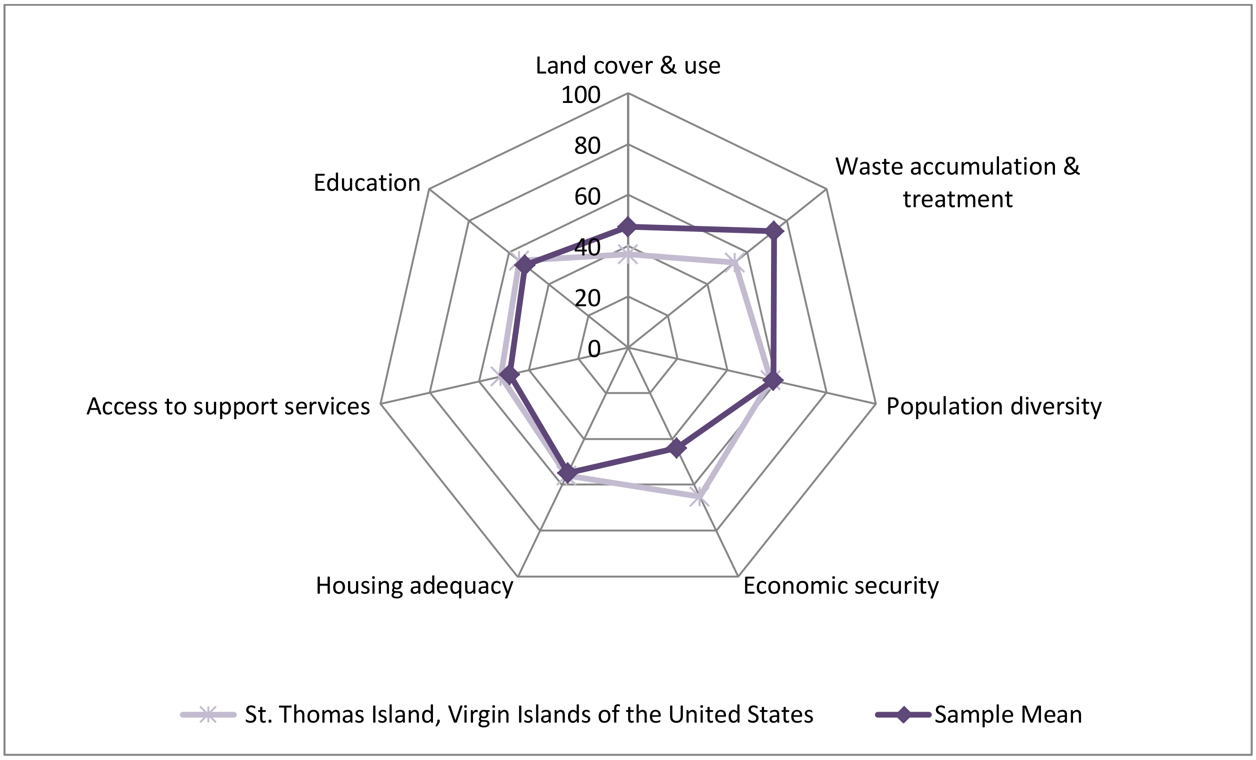

Figure 6.3: Indicator Score Radar Graph for St. Thomas, US Virgin Islands

Like St. Thomas, Gulf County, Florida closely follows the sample mean scores (Figure 6.4). The exceptions are few and represent only slightly higher scores. For example, Gulf County scores 70.56 (compared to the sample average of 62.23) on Population diversity. Likewise, for Education and Access to support services there is approximately a 10 point difference between the sample mean and the score for Gulf County.

Alternately, New Orleans Parish scores much lower than the average Gulf of Mexico coastal commuinity in the sample (Figure 6.5). For this coastal community, the scoring is not differentiated by being higher on either social or ecological dimensions. Instead, the scores are lower across all dimensions. Interestingly, the one exception is Population diversity. With this indicator, New Orleans Parish has a score of nearly 70, which represents about 8 points more diversity than the sample average. With this case, the relationship between Population diversity and resilience comes into question. If Population diversity is high and all other dimensions of social-ecological resilience are low, what does that mean for the community's ability to respond to disruption? New Orleans Parish certainly provides for a unique case study, given its history of severe storms (e.g., Hurricane Katrina) and technological disasters (e.g., Deepwater Horizon Oil Spill).

Galveston County, Texas behaves more like Honolulu County in its scores on social-ecological resilience indicators (Figure 6.6). Galveston County scores lower than average only on the same two indicators as Honolulu County - Housing adequacy and Land cover and use. For all other indicators, Galveston County is higher than the sample mean, even if only by a few points as is the case with Population diversity, Access to support services, and Waste accumulation and treatment. The combination of higher than average Economic security scores and lower Land cover and use scores ties into the negative, significant correlation between these indicators for the Gulf of Mexico coastal counties sample. These results suggest that common patterns of economic activity do not reinforce sustainable land use practices.

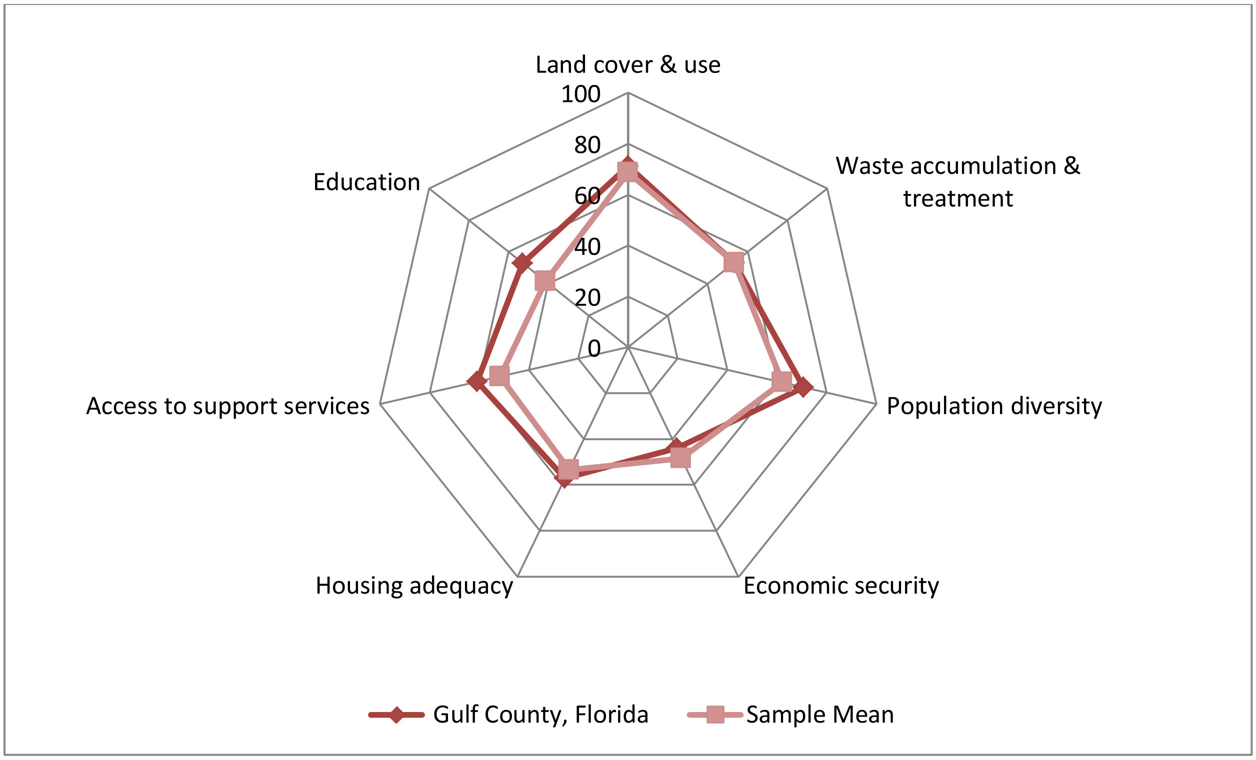

Figure 6.4: Indicator Score Radar Graph for Gulf County, Florida

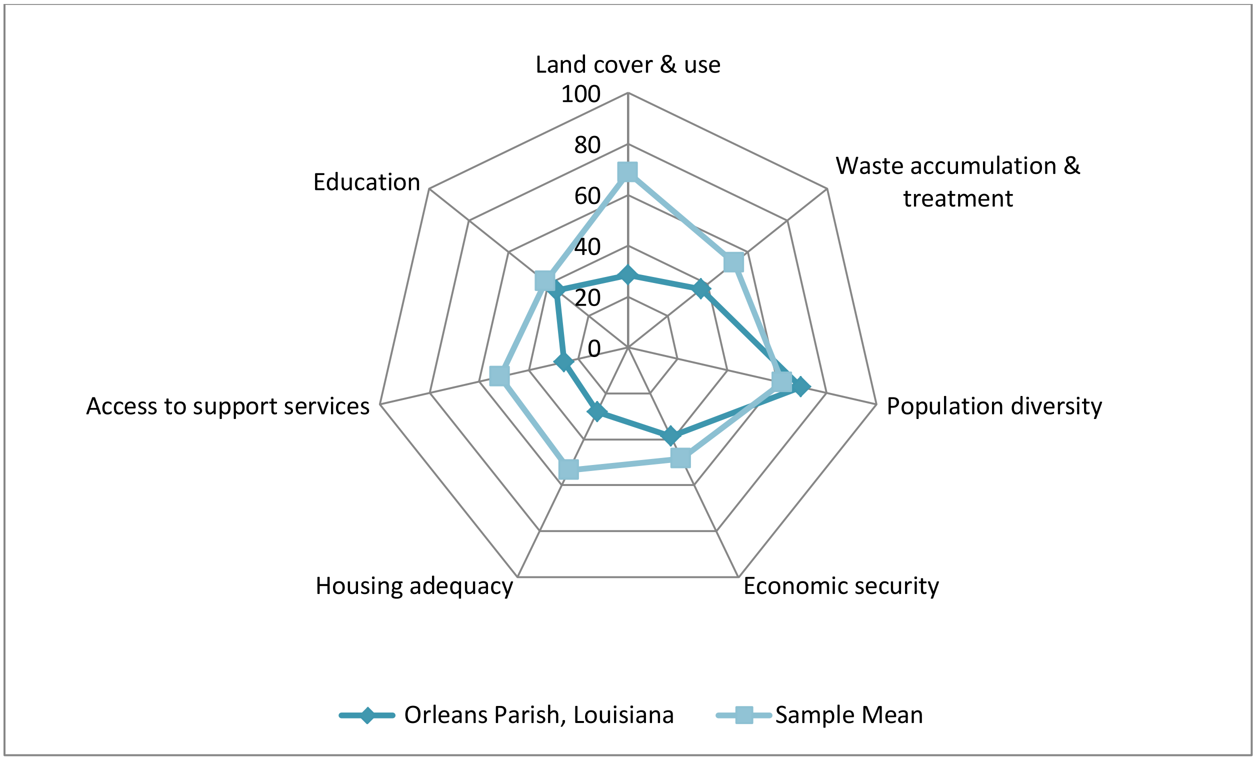

Figure 6.5: Indicator Score Radar Graph for Orleans Parish, Louisiana

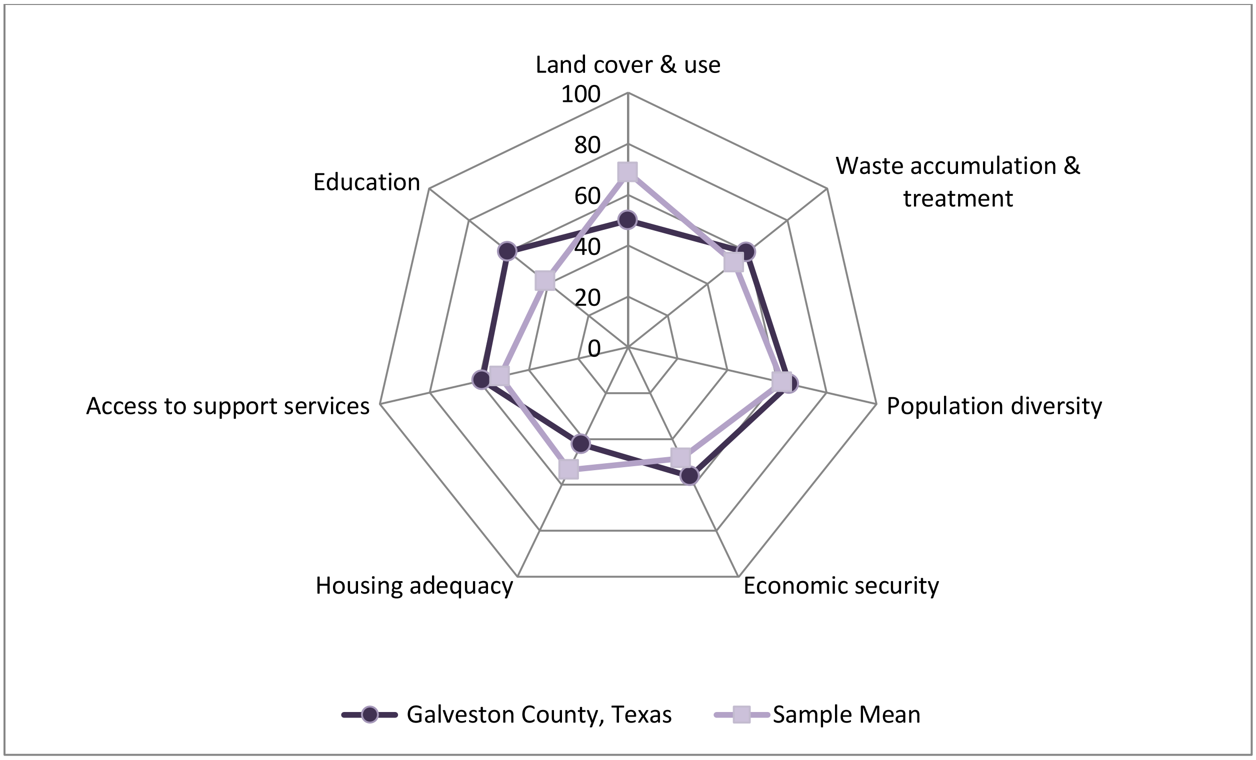

Figure 6.6: Indicator Score Radar Graph for Galveston County, Texas

6.4.2 Indicator Quintile Rankings

For the purposes of presenting results, the indicator scores were used to produce quintile rankings of the sample cases (Appendix D, Tables D3-D4). Quintile rankings are a form of percentile ranks that utilize the rank order of the scores for a given indicator to assign percentiles to the cases. Quintile rankings allow for the representation of general trends for maps and other visual displays. Percentile rankings are a common approach to the presentation of composite indicator data (Nardo et al. 2008, Paruolo et al. 2013). The percentile rank communicates complex information by highlighting relationships between the cases and is also beneficial for displaying change over time (WEF 2012). Effective presentation of indicator results is central to projects like this one where the aim is to develop an approach to the measurement of a complex concept that yields comprehensible and user friendly results (Bobbit et al. 2005).

6.4.3 Indicator Quintile Ranks Presented Spatially

Maps are used to spatially display indicator quintile rankings in order to emphasize the utility of this data for comparisons across space. For example, counties within a state or a region can be viewed in relation to one another. Spatial representation often highlights relationships that are geographically influenced. Also, maps provide a visual of the distribution of the values across the island or mainland states. Particularly given the ecological principles underpinning much of this study, the spatial dimension is an important one to investigate.

Figures 6.7-6.11 depict the indicator Access to support services for all island state communities and coastal counties. The scale goes from 1 (green) to 5 (red) in correspondence with the quintile rankings. The more remote Pacific communities tend to score similarly with the communities in the same island state, though there are exceptions. For example, all of the American Samoa communities are ranked 1 or 2 when evaluated against the rest of the island state communities in the sample. However, the more populated communities of the Commonwealth of the Northern Mariana Islands receive a rank of 5 in contrast to the Northern Islands Municipality, which is ranked 2. There is some variability in rankings within Hawaii. Here, Kalawao County ranks as a 5 while the rest of the Hawaiian counties rank as 1.Within Puerto Rico there is more variation between communities. For Puerto Rico, the largest concentration of low rankings is inland within the valley, though there are some extremes on the coast for communities like Guanica. Also, islands off the northeast coast of Puerto Rico (Vieques and Culebra) are among the communities with the lowest ranking. For the US Virgin Islands, St. John received the highest ranking on Access to Support Services, despite it being the least developed and least populated island. The Gulf of Mexico coastal counties are also varied in their rankings. Texas and Louisiana have some of the largest concentrations of low ranked coastal counties for Access to Support Services. Conversely, Florida has the most highly ranked coastal counties when compared to the sample of coastal counties. With the Gulf of Mexico and Puerto Rico, there is a general pattern of the inland communities being lower ranked than the communities that are directly adjacent to the coast. These types of patterns are not replicated throughout the samples because of the unit of analysis. It is likely that the small island states have a similar internal variability that could be detected if data were collected for a smaller unit (e.g., the village level in American Samoa). These examples for a single resilience indicator demonstrate the utility of alternate visualizations of the indicators for beginning to deconstruct the social-ecological patterns and processes underlying the values. For the complete series of indicator quintile rankings presented spatially, see Appendix E.

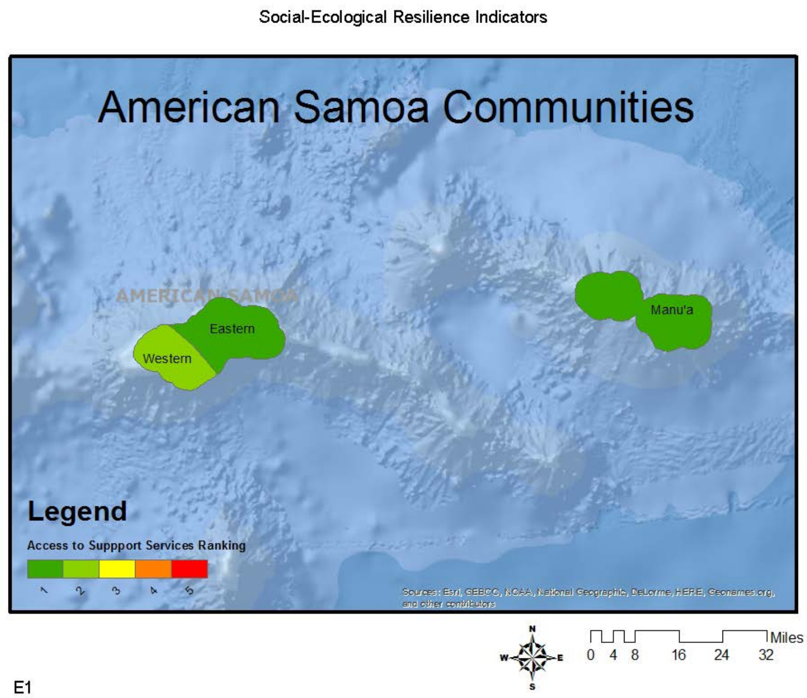

Figure 6.7: Access to Support Services in American Samoa Communities.

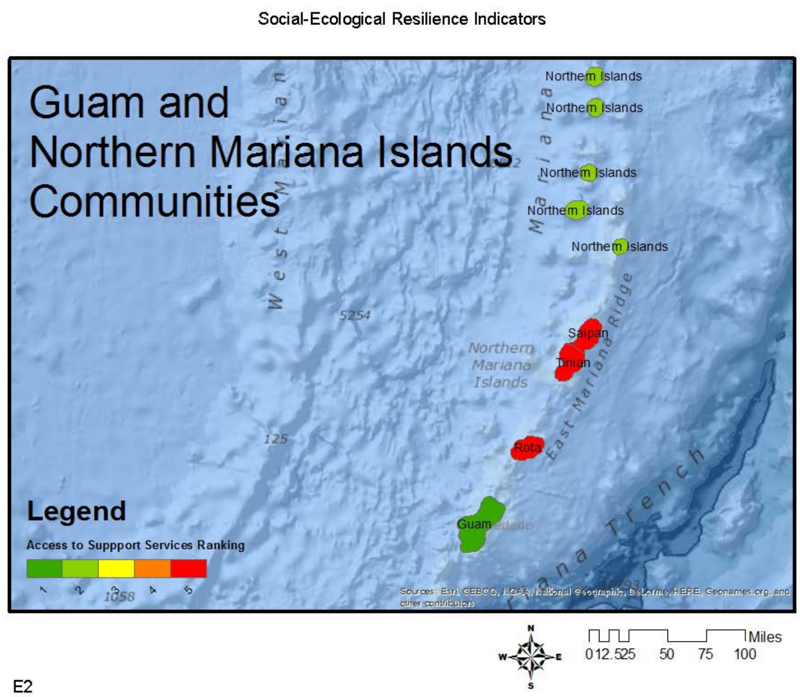

Figure 6.8: Access to Support Services in Guam and the Commonwealth of the Northern Mariana Islands Communities.

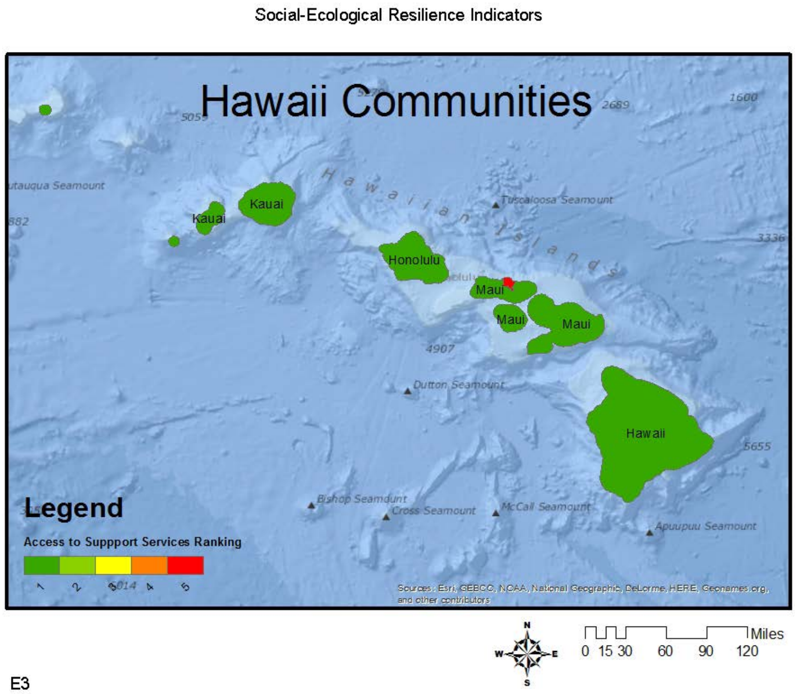

Figure 6.9: Access to Support Services in Hawaii Communities.

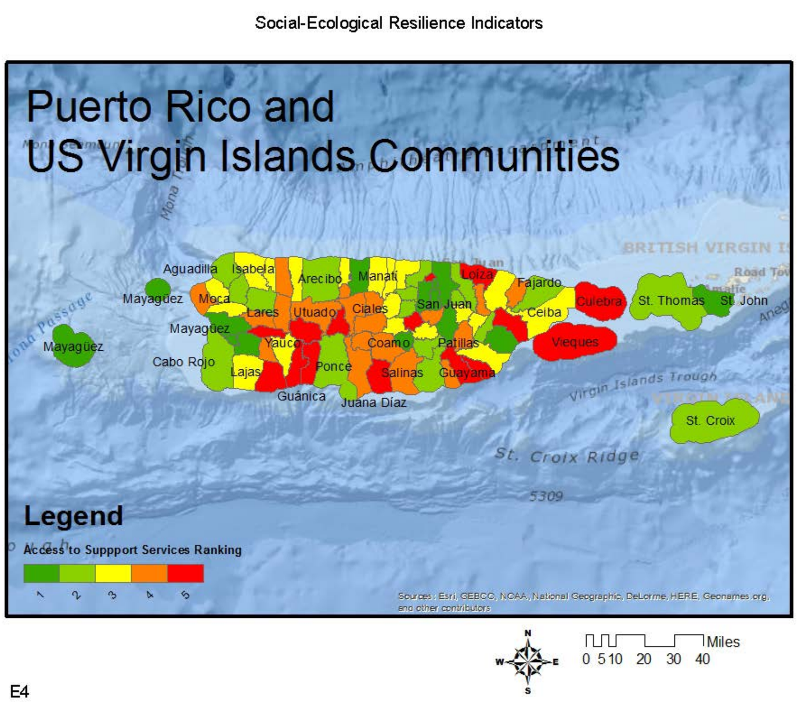

Figure 6.10: Access to Support Services in Puerto Rico and the US Virgin Islands Communities.

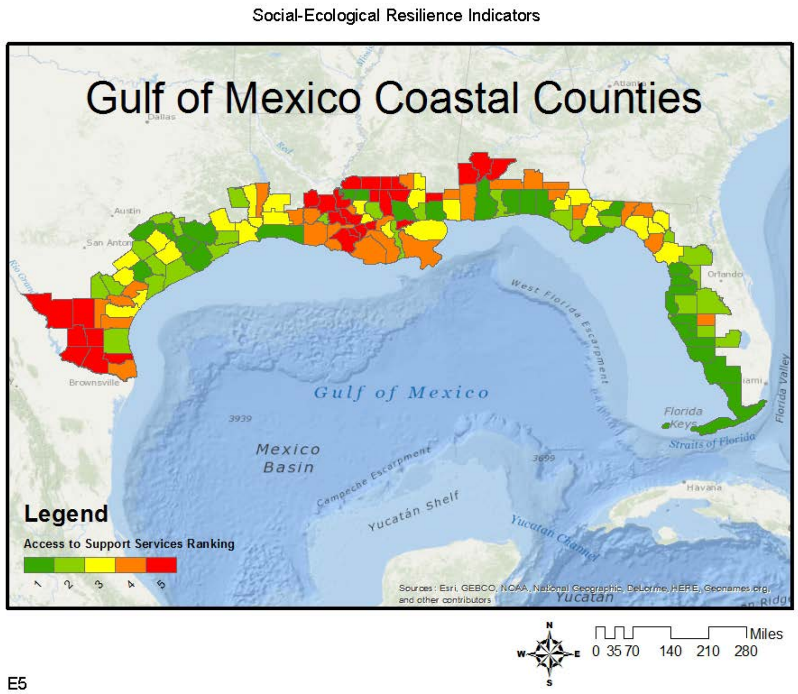

Figure 6.11: Access to Support Services in the US Gulf of Mexico Coastal Counties.

6.5 USING INDICATORS FOR ASSESSMENT

The utility of the indicators for conducting a broad range of analyses and empirical investigations can be enhanced by choices about how to score the cases being assessed (e.g., value out of 100, rank, percentile rank) and whether to include a spatial component as part of the assessment. Additionally, depending on the purpose of the investigation, cases can be compared within a sample or examined independently, as with the radar graphs, to create community profiles. The potential applications of the indicators are as numerous as the range of presentation and visualization options.

7 TYPOLOGY RESULTS

7.1 DEVELOPING A TYPOLOGY OF COMMUNITIES

Alessa, Kliskey, and Altaweel (2009) develop a typology of what they call "messy SESs" in order to address the true complexity of social ecological systems. Using a Delphi method to create the framework for the typology, SESs are first assessed with a suite of the indicators at a variety of scales and then assigned a category - transitional/mixed, resilient, or vulnerable (Alessa et al. 2009). Winch (1947) distinguishes between heuristic and empirical typologies. This study will employ the use of an empirical typology in which the data (the indicator scores) will be summarized in order to categorize island state and coastal communities of both samples.

7.2 CLUSTER ANALYSIS

Following the construction of the measurement model for social-ecological resilience, the cases were explored using various types of cluster analysis. Cluster analysis is often used in conjunction with a predictive model, where the predictions are dependent on the cluster membership. In this case, cluster analysis provided an appropriate mechanism for beginning to understand community scores on different dimensions of resilience. The results of the cluster analysis will lead to predictive modeling with the clusters being expected to perform differently in terms of their response to change and disturbance.

Ultimately, k-means clustering was found to be the most effective analysis for providing meaningful community profiles regarding resilience. This type of cluster analysis uses the mean or centroid of each observation to assign clusters. In k-means clustering, cases are assigned into clusters that minimize the distance between the cases and the cluster mean (k-mean). The analysis runs in iterations until a solution is reached. K-means cluster analysis is particularly useful with large datasets. Because the number of clusters is a required input of this analysis, it is important to run a variety of diagnostic checks to determine the most natural partitioning of the data.

7.2.1 Clusters

For both the GoM and Island datasets, the data clearly cluster into three groups. The clusters differ slightly from one geography type to another, but correspond well to three overarching profiles for social-ecological resilience. The clusters are defined as follows:

> *High social dimensions*– This cluster of communities shows evidence of being high in dimensions of resilience that fall into the social category, but low on those dimensions that are ecological.
>
> *High ecological dimensions* – This cluster of communities is the opposite of the previous; the clustering occurred around high values for the dimensions of resilience that fall into the ecological category and around low values on social dimensions.
>
> *Balanced social and ecological dimensions* – This cluster reflects a balance of social and ecological dimensions of resilience. The cluster centers are not always the highest, but the cluster centers collectively showcase the combination of social and ecological dimensions that a communities need to achieve resilience. For island communities, the cluster centers are the highest for five of seven dimensions and next highest on the remaining two; while for Gulf of Mexico coastal counties, the cluster centers are highest for two of seven dimensions and next highest on the remaining five.

The communities that cluster under Balanced social and ecological dimensions are determined to be the highest in social-ecological resilience because these communities more effectively capture the range of resilience characteristics necessary for a range of disruptions. These communities are not only effective in terms of Land cover and use and Waste accumulation and treatment, they also have high scores in terms of providing access to support services and adequate housing, as well as diverse and well educated populations.

7.2.2 Cluster Results

Results of the cluster analyses for each sample are depicted in Tables 7.1-7.3 (GoM coastal counties) and 7.7-7.9 (Island state communities). For GoM Coastal Counties, Population diversity, followed by Access to support services and Economic security are the most influential indicators in determining the clusters. For Island State Communities, the clusters are most driven by Economic security, Access to support services, and Education. The clusters that are most dissimilar vary by sample. For island state communities, the clusters defined as *Balanced social and ecological dimensions* and *High ecological dimensions* have the most distance between final cluster centers, while *High social dimensions* and *High ecological dimensions* clusters are the most different for GoM Coastal Counties. Within the US Gulf of Mexico, 52 coastal counties fall within the *Balanced social and ecological dimensions* cluster. Only 10 counties cluster in a group defined by scores associated with *High ecological dimensions*. Finally, 73 coastal counties fall into the cluster that has indicator values representative of *High social dimensions*. For the Island State Communities, 32 communities cluster on scores associated with *High social dimensions*, 6 on scores that represent *Balanced social and ecological dimensions* and 56 communities fall into the *High ecological dimensions* cluster. Descriptive statistics for each cluster are presented in Tables 7.4-7.6 and 7.10-7.12. A combination of demographic variables and indicator component measures are included in the descriptive statistics tables in order to better understand the clusters and to build cluster profiles.

7.2.2.1 Gulf of Mexico Coastal Counties

Cluster: Balanced social and ecological dimensions For the GoM coastal counties, Cluster #1 captures social-ecological resilience. The communities in this cluster have a balance of social and ecological dimensions that contribute to their overall resilience. Although these communities may not score the highest on every dimension (in fact, their scores are often middle of the road), they are better positioned to respond and recover from a range of disturbance types.

Cluster #1 has the smallest total population, on average, but a mean population density that falls between Clusters #2 and #3. On average, Cluster #1 sits between Clusters #2 and #3 on various measures, including the rural population, the percent of young children and seniors in the population, and the level of childhood poverty. Additionally, average values for Cluster #1 are firmly situated between the other two clusters on measures of median housing value, median income, and public assistance. This middle scoring position reflects the tendency of this group of coastal counties to exist in between the extremes and to have a better balance of social and ecological dimensions.

Cluster: High ecological dimensions Cluster #2 has high ecological resilience, but lacks in the dimensions of social resilience. For example, these communities score lowest on Housing adequacy, Economic security, Access to support services, Education, and Population diversity and highest on Land cover and use and Waste accumulation and treatment.

Cluster #2 has the lowest average population density (x=97.00) and a mid-sized urban population. The low population density certainly reinforces the likelihood of greater resilience of the ecological system. However, the low density is not as supportive of social dimensions of resilience. Cluster #2 has the lowest average percent of developed land cover. This cluster represents a younger population with the largest population of young children and the lowest population 65 years and older. This cluster has the lowest mean values for measures of median home value, median income and high averages for lack of access to transportation, poverty, and public assistance. This cluster has the highest level of childhood poverty (x=39.28%) and therefore, shows evidence of being lower on social resilience than other clusters.

Cluster: High social dimensions Cluster #3 is high on social dimensions of resilience, but low on ecological dimensions. The communities in this cluster score lower than others on Land cover & use and Waste accumulation & treatment, while they have strong scores for social dimensions such as Housing adequacy, Economic security, Access to support services, and Education.

Cluster #3 has the largest mean total population and population density (x=260.92) of all GoM clusters, along with the highest average percent of developed land cover. High population density translates into many positive benefits for the resilience of the social system (Cutter et al. 2010), while it is commonly viewed as a negative pressure for the natural environment (de Sherbinin et al. 2007). This cluster has the highest mean values for measures of median home value, median income and college level educational attainment. Lack of transportation is much less an issue with this cluster. This cluster has the largest average senior population and smallest average population of young children. This cluster has the smallest average level of childhood poverty, population poverty, and public assistance. A low level of childhood poverty and a lower proportion of older residents in a community are characteristics expected with higher levels of resilience within the social system.

7.2.2.2 Island state communities.

Cluster: Balanced social-ecological dimensions For Island areas, Cluster #2 captures the highest levels of social-ecological resilience. Unlike the GoM coastal counties, the Island communities tend to have the highest scores on every dimension of resilience. However, it is still the balance of the social and ecological dimensions that contribute to overall resilience for these communities.

Cluster #2 has the highest mean total population, but the lowest mean population density of all clusters. Again, this cluster is also heavily urban based. The lowest average level of childhood poverty is associated with this cluster, when compared to the other clusters. There is a much greater difference between the average percent of the population that is 5 years and younger and the 65 years and older, with a higher value for the senior population. Of the island areas clusters, this cluster has the highest average median home value and college level educational attainment. This cluster has the highest mean public assistance value, such that on average, more than half of those in poverty are receiving public assistance. Cluster #2 has the lowest average level of poverty and the highest average median income.

Cluster: High ecological dimensions Cluster #3 has high scores on ecological dimensions of resilience and is lacking in its social scores. These island communities score high on Land cover and use and Waste accumulation and treatment, but extremely low on social dimensions.

Cluster #3 has the smallest average total population and the smallest concentration of people in urban areas. This cluster, like Cluster #2 for the GoM coastal counties, has the highest level of childhood poverty, on average (x=86.83%). The average percentage of the total population in poverty is also highest of the clusters. This cluster falls between Clusters #1 and #2 on the senior population and yet it has the greatest range of values for the percent of the population 65 years and older (R=32). This cluster has the lowest average median home value at $66,460 and the lowest average value for access to transportation with nearly 30% of the population lacking access to a vehicle. However, on average, these communities have some of the least developed and least farmed land.

Cluster: High social dimensions Cluster #1 has higher scores on social dimensions of resilience, but is clearly lacking in ecological dimensions. For the island communities, this cluster had centers that were the next highest on the social dimensions of Housing adequacy, Economic security, Access to support services, Education, and Population diversity.

Cluster #1 exhibits the highest mean population density of all clusters (x=1869.00) with the population largely residing in urban areas. On average, this cluster has the most developed land cover with a moderate amount of farming land use. The childhood poverty level is better than Cluster #3, but not as good as Cluster #2. Largely, the mean values for Cluster #1 fall in between the other clusters for variables like median home value, college educational attainment, access to transportation, public assistance, and median income. The population has nearly equal proportions of young children and seniors, x=8.33% and 9.18%, respectively. The populations represented by this cluster do not reside in the more isolated rural areas and are therefore more likely to be connected.

Table 7.1: Final Cluster Centers for the Gulf of Mexico Coastal Counties.

Final Cluster Centers			
	Cluster		
	1	2	3
Land cover and use	72.10	70.44	65.85
Waste accumulation and treatment	53.28	62.69	52.34
Population diversity	67.41	30.69	62.87
Economic security	43.86	29.65	54.23
Housing adequacy	52.55	51.17	54.29
Access to support services	42.59	33.97	60.19
Education	41.01	30.93	43.45

Table 7.2: Distance between Final Cluster Centers for Gulf of Mexico Coastal Counties.

Distances between Final Cluster Centers			
Cluster	1	2	3
1		42.653	22.064
2	42.653		51.205
3	22.064	51.205	

Table 7.3: Analysis of Variance for Gulf of Mexico Coastal Counties Clusters.

ANOVA

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Land cover and use	612.537	2	95.815	132	6.393	.002
Waste accumulation and treatment	473.134	2	85.559	132	5.530	.005
Population diversity	5686.068	2	32.644	132	174.186	.000
Economic security	3533.060	2	38.714	132	91.260	.000
Housing adequacy	72.844	2	42.140	132	1.729	.182
Access to support services	6356.443	2	39.582	132	160.590	.000
Education	703.159	2	40.505	132	17.360	.000

Table 7.4: Cluster Demographics for Cluster #1 Balanced social-ecological dimensions, Gulf of Mexico Coastal Counties.

Variables	**N**	**Range**	**Mean**		**SD**	**Skewness**	
	Statistic	Statistic	Statistic	SE	Statistic	Statistic	SE
total population	52	476846.00	50767.04	11485.37	82822.20	4.44	.33
population density	52	2674.12	109.83	50.99	367.72	7.00	.33
urban population	52	213357.00	12839.40	4730.97	34115.54	5.04	.33
rural population	52	29395.00	8363.63	725.07	5228.52	2.02	.33
percent of pop under 5	52	2.80	6.81	.11	.81	-.34	.33
percent of pop 65 and over	52	11.10	13.08	.32	2.27	.23	.33
percent of pop under 18 in poverty	52	16.60	26.58	.55	3.97	.75	.33
median home value	52	67500.00	66905.77	1805.03	13016.24	.57	.33
proportion of pop with no access to vehicle	52	.20	.09	.00	.03	3.02	.33
college graduate as highest level of education	52	20.30	11.19	.44	3.15	2.21	.33
percent of developed land cover	52	20.09	3.06	.43	3.10	3.90	.33
percent of wetland cover	52	68.22	30.53	1.97	14.24	.65	.33
percent of population in poverty	52	15.80	19.52	.45	3.22	1.05	.33
median income	52	18629.00	29872.71	544.47	3926.20	.14	.33
proportion of pop in poverty receiving public assistance through the Supplemental Nutrition Assistance Program	52	.58	.65	.02	.12	.17	.33

Table 7.5: Cluster Demographics for Cluster #2 High ecological dimensions, Gulf of Mexico Coastal Counties.

Variables	**N**	**Range**	**Mean**		**SD**	**Skewness**	
	Statistic	Statistic	Statistic	SE	Statistic	Statistic	SE
total population	10	564182.00	126873.80	59541.89	188287.97	1.83	.69
population density	10	365.46	97.00	45.26	143.13	1.71	.69
urban population	10	178838.00	37960.90	18922.49	59838.16	1.92	.69
rural population	10	14692.00	5084.10	1519.47	4805.00	1.46	.69
percent of pop under 5	10	3.20	8.81	.39	1.22	.49	.69
percent of pop 65 and over	10	7.10	11.47	.79	2.50	-.14	.69
percent of pop under 18 in poverty	10	23.50	39.28	2.35	7.42	.73	.69
median home value	10	46000.00	44110.00	4400.52	13915.65	1.17	.69
proportion of pop with no access to vehicle	10	.08	.11	.01	.02	1.31	.69
college graduate as highest level of education	10	13.60	11.11	1.33	4.21	1.16	.69
percent of developed land cover	10	10.12	3.01	1.08	3.42	1.72	.69
percent of wetland cover	10	9.32	2.84	.96	3.05	1.26	.69
percent of population in poverty	10	18.50	30.57	1.85	5.85	.83	.69
median income	10	11716.00	24833.50	1231.47	3894.25	-.58	.69
proportion of pop in poverty receiving public assistance through the Supplemental Nutrition Assistance Program	10	.19	.77	.02	.06	.62	.69

Table 7.6: Cluster Demographics for Cluster #3 High social dimensions, Gulf of Mexico Coastal Counties.

Variables	**N**	**Range**	**Mean**		**SD**	**Skewness**	
	Statistic	Statistic	Statistic	SE	Statistic	Statistic	SE
total population	73	3400164.00	188436.85	49673.47	424410.34	6.35	.28
population density	73	3291.66	260.92	57.08	487.71	4.31	.28
urban population	73	1275776	70951.11	19484.10	166472.20	5.73	.28
rural population	73	49829	11807.40	1142.35	9760.25	2.18	.28
percent of pop under 5	73	5.4	6.21	.13	1.13	-.15	.28
percent of pop 65 and over	73	29	15.22	.76	6.47	1.18	.28
percent of pop under 18 in poverty	73	23.10	20.03	.54	4.59	.55	.28
median home value	73	218700.00	87016.44	3361.41	28719.87	2.30	.28
proportion of pop with no access to vehicle	73	.07	.06	.00	.02	.40	.28

Variables	N	Range	Mean		SD	Skewness	
	Statistic	Statistic	Statistic	SE	Statistic	Statistic	SE
college graduate as highest level of education	73	34.50	16.97	.81	6.95	1.11	.28
percent of developed land cover	73	39.95	6.54	.91	7.80	2.20	.28
percent of wetland cover	73	71.66	25.78	1.83	15.62	.45	.28
percent of population in poverty	73	13.60	13.84	.40	3.38	.23	.28
median income	73	41983.00	36888.63	753.78	6440.28	1.77	.28
proportion of pop in poverty receiving public assistance through the Supplemental Nutrition Assistance Program	73	.43	.42	.01	.10	-.29	.28

Table 7.7: Final Cluster Centers for the Island State Communities.

Final Cluster Centers			
	Cluster		
	1	2	3
Land cover and use	41.72	51.55	50.98
Waste accumulation and treatment	71.42	66.25	75.42
Population diversity	58.82	72.05	56.90
Economic security	49.96	84.59	36.32
Housing adequacy	56.19	58.09	53.50
Access to support services	50.98	77.34	42.90
Education	55.06	64.88	48.67

Table 7.8: Distance between Final Cluster Centers for Island State Communities.

Distances between Final Cluster Centers			
Cluster	1	2	3
1		47.891	20.111
2	47.891		64.139
3	20.111	64.139	

Table 7.9: Analysis of Variance for Island State Communities Clusters.

ANOVA						
	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Land cover and use	167.673	2	167.205	12	1.003	.396
Waste accumulation and treatment	329.866	2	55.302	91	5.965	.004
Population diversity	624.473	2	27.234	91	22.930	.000

ANOVA						
	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Economic security	7160.936	2	40.739	91	175.778	.000
Housing adequacy	110.075	2	31.124	91	3.537	.033
Access to support services	3451.335	2	49.975	91	69.061	.000
Education	956.305	2	18.516	91	51.647	.000

Table 7.10: Cluster Demographics for Cluster #1 High social dimensions, Island State Communities.

Variables	**N**	**Range**	**Mean**		**SD**	**Skewness**	
	Statistic	Statistic	Statistic	SE	Statistic	Statistic	SE
total population	32	431091.00	76977.78	14877.91	84162.17	2.86	.41
population density	32	8987.06	1795.80	320.65	1813.86	2.50	.41
urban population	32	182101.00	32488.81	6056.37	34260.00	2.91	.41
rural population	32	4951.00	1224.75	244.47	1382.95	1.39	.41
percent of pop under 5	32	7.31	8.25	0.30	1.67	2.34	.41
percent of pop 65 and over	32	13.35	9.57	0.65	3.68	-.91	.41
percent of pop under 18 in poverty	32	58.43	69.63	2.45	13.85	-.36	.41
median home value	32	133654.00	90163.97	5736.79	32452.18	1.27	.41
proportion of pop with no access to vehicle	32	0.35	0.24	0.01	0.08	-1.66	.41
college graduate as highest level of education	32	12.73	8.06	0.44	2.48	-.06	.41
percent of developed land cover	6	9.75	7.70	1.66	4.06	-.27	.85
percent of land used for agriculture	6	7.30	3.69	1.06	2.61	-.12	.85
percent of population in poverty	32	35.16	43.50	1.44	8.13	.10	.41
median income	32	16933.00	17578.44	809.48	4579.09	.81	.41
proportion of pop in poverty receiving public assistance	32	0.42	0.35	0.02	0.11	-1.53	.41

Table 7.11: Cluster Demographics for Cluster #2 Balanced social-ecological dimensions, Island State Communities.

Variables	**N**	**Range**	**Mean**		**SD**	**Skewness**	
	Statistic	Statistic	Statistic	SE	Statistic	Statistic	SE
total population	6	871959.00	228398.67	131727.84	322665.98	2.27	.85
population density	6	1421.65	440.71	228.29	559.19	1.58	.85

Variables	N	Range	Mean		SD	Skewness	
	Statistic	Statistic	Statistic	SE	Statistic	Statistic	SE
urban population	6	859365.00	209183.67	132134.23	323661.44	2.32	.85
rural population	6	60414.00	19215.00	8773.48	21490.55	2.14	.85
percent of pop under 5	6	4.70	7.22	.74	1.80	2.28	.85
percent of pop 65 and over	6	8.50	10.78	1.49	3.66	-.88	.85
percent of pop under 18 in poverty	6	25.43	24.50	4.14	10.15	.90	.85
median home value	6	119200.00	217451.83	18823.75	46108.59	-.33	.85
proportion of pop with no access to vehicle	6	.15	.10	.02	.06	1.71	.85
college graduate as highest level of education	6	4.25	10.31	.71	1.73	.26	.85
percent of developed land cover	6	12.76	5.75	2.01	4.94	.94	.85
percent of land used for agriculture	6	16.50	8.09	2.79	6.84	-.17	.85
percent of population in poverty	6	12.89	14.44	2.15	5.26	.70	.85
median income	6	19432.00	43004.50	2944.19	7211.76	-.21	.85
proportion of pop in poverty receiving public assistance	6	.65	.54	.10	.23	-1.70	.85

Table 7.12: Cluster Demographics for Cluster #3 High ecological dimensions, Island State Communities.

Variables	N	Range	Mean		SD	Skewness	
	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error
total population	56	64679.00	28149.25	1924.76	14403.58	.15	.32
population density	56	6212.92	823.68	111.99	838.08	4.98	.32
urban population	56	24882.00	9081.14	694.29	5195.61	.44	.32
rural population	56	4119.00	1109.55	124.92	934.78	1.01	.32
percent of pop under 5	56	13.72	7.91	.24	1.81	-2.48	.32
percent of pop 65 and over	56	31.97	10.34	.47	3.51	3.92	.32
percent of pop under 18 in poverty	56	109.73	86.83	1.95	14.59	-4.09	.32
median home value	56	174325.00	66460.57	3402.69	25463.38	4.89	.32
proportion of pop with no access to vehicle	56	.40	.29	.01	.07	-2.64	.32
college graduate as highest level of education	56	10.20	5.73	.20	1.48	-1.24	.32
percent of developed land cover	3	.29	.16	.09	.15	-1.09	1.22
percent of land used for agriculture	3	1.86	.63	.61	1.06	1.73	1.22
percent of population in poverty	56	46.50	57.24	.92	6.92	.37	.32
median income	56	17007.00	12071.43	322.02	2409.75	3.88	.32
proportion of pop in poverty receiving public assistance	56	.55	.42	.01	.10	-2.68	.32

7.2.3 Internal Variation within the Clusters

Overall, the Gulf of Mexico Coastal Counties exhibit more variation within clusters than Island State Communities. This may be associated with more fluid physical boundaries for the GoM coastal counties. Such boundaries increase the range of possible interactions that might shape the social-ecological system differently. The island state communities experience a more limited range of possible interactions due to the bounded nature of the systems. Much as expected, the *High social dimensions* cluster has less variation with indicators for Economic security, Housing adequacy, and Access to support services. The *High ecological dimensions* cluster has less variation with indicators of Land cover and use and Waste accumulation and treatment. Communities in the *Balanced social-ecological dimensions* cluster score more similarly on Population diversity and Education. Perhaps these indicators are among the most consistent dimensions of resilience while the combination of Economic security, Housing adequacy, Access to support services, Land cover and use, and Waste accumulation and treatment is more flexible.

For all three of the Island State Communities clusters, the communities score more similarly on indicators of Population diversity and Education than other indicators. Communities within the *Balanced social-ecological dimensions* cluster score more similarly on Population diversity, Education, and Housing adequacy. As with the Gulf of Mexico Coastal Counties, there seems to be a consistency in the particular indicators of Education and Population diversity, though Housing Adequacy is also part of this group for Island State Communities. Whether these indicators are necessary conditions for higher levels of social-ecological resilience or are simply less likely to vary among communities that have more balanced social and ecological dimensions is an area for future investigation. The *High social dimensions* cluster has communities that score most closely on Land cover and use, Population Diversity, and Economic security. Finally, Land cover and use indicator scores exhibit the lowest variability between cases in the *High ecological dimensions* cluster. While many of these findings are expected (e.g., low variation on indicators that defined the cluster), they suggest that communities that score high on particular dimensions of resilience may have a less coherent set of scores on the other dimensions. For example, a *High ecological dimensions* community may actually score high on some social dimensions and low on others. This lack of consistency suggests that communities are often operating in a much less clear space with respect to being resilient or not. The value of being able to examine the variability of scores for specific indicators is significant for improving understanding of how resilience is built and enhanced or lost and degraded.

7.2.4 Examining Cases within the Clusters

In this section, specific cases will be examined in relation to their cluster membership. By taking a closer look at individual communities, examples of variation within the clusters will be revealed. Similarly, this examination also highlights general characteristics that hold true across cases within the same cluster group. Cases were selected from different island and coastal states to help ensure that the examination adds rich contextualization to the results already presented.

7.2.4.1 High social dimensions. Gulf of Mexico coastal counties Sarasota County, FL is one of the counties within the *High social dimensions* cluster. Sarasota County scores higher than the cluster average on Economic security, Access to social services, and Education and lower than average on Land cover and use and Waste accumulation and treatment. The population size is approximately 326,000 with 570 people per square mile. This county is among the more heavily populated of the cluster. Sarasota County has an extremely large population that is over 65 years of age. The population has been steadily rising for the last several decades (NACo 2014). The per capita income is much higher than the state average. Poverty among children is not a significant issue for this county, when compared to the rest of the Gulf of Mexico. The main economic sectors are education/health services and retail (The Economic Development Corporation of Sarasota County 2014).

7.2.4.2 High ecological dimensions. Gulf of Mexico coastal counties Starr County, TX includes the Rio Grande micropolitan area and is a sparsely populated area with only about 54,000 people (US Census Bureau 2015). However, the population of Starr County has more than doubled since 1980 (NACo 2014). The population density is also very low with only 44 people per square mile. This county has very high scores on Land cover and use and Waste accumulation and treatment, but scores low on Population diversity, Economic security, Access to social services, and Education. In fact, Starr County is lower than the cluster average on all social indicators except for Housing adequacy. The population is younger with a small percentage of seniors. The child poverty rate is 54% and the per capita income is among the lowest of all US counties.

7.2.4.3 Balanced social-ecological dimensions. Gulf of Mexico coastal counties Mobile County, AL has a population of approximately 400,000 people, many of whom reside in the urban areas of the county. The county seat of Mobile County is the city of Mobile, a large metropolitan area and the only saltwater port in Alabama (Encyclopedia Britannica 2013). Though the city of Mobile is often referred to as a smaller version of New Orleans, it does have tourism associated with its Carnival celebrations and Mardi Gras parades. Mobile County has higher than average scores for the cluster on Economic security and Access to support services, but slightly lower than average on Housing Adequacy and Education. The Population Diversity score is quite high at 71. The county scores lower than the average county in the cluster on Land cover and use and Waste accumulation and treatment. There is a child poverty rate of 24%, which is slightly lower than this cluster's average.

7.2.4.4 High social dimensions. Island State communities San Juan Municipio, PR contains an extremely busy, large port that serves as the center of Caribbean shipping. In addition, the community is responsible for a variety of products including pharmaceuticals and tobacco and is the largest processing center of the island with facilities for petroleum, sugar refining, brewing, and distilling (Rivera 2015). This municipio includes San Juan, the capital and most populous city in Puerto Rico. San Juan Municipio scores higher on Access to support services, Economic security, Education, and Population diversity than the cluster average. However, the municipio scores more than 10 points lower than the average for Housing adequacy. There is a much larger older population in this very urban community characterized by high population density. Despite its clustering in the '*High social dimensions* group, San Juan Municipio has a larger than average percentage of children in poverty (77%), when compared to the other cluster cases. However, on most of the social dimensions of resilience, San Juan Municipio scores higher than the cluster mean.

7.2.4.5 High ecological dimensions. Island State Communities Rincon Muncipio is known as the surfing town of Puerto Rico. Located in the western coastal valley of the island state, Rincon is situated between La Cadena Mountains and a series of beaches that face either the

Atlantic Ocean or the Caribbean Sea. The coral reef lined beaches are now a winter destination for surfers (and surf fans) from all over the world. Beyond the surf breaks, the natural resources that make this municipio special include winter visits from endangered humpback whales (Rivera 2015). The population is about 15,000 with a population density of just over 1,000 people per square mile. In this community, the median income of $11,460 is lower than the median income for Puerto Rico, which is just under $20,000; similarly, there is a higher total and child poverty rate in Rincon. Economic security and Access to support service scores are low compared to the sample means, but are well-aligned to the average for this cluster. Rincon Muncipio scores 77 on Waste accumulation and treatment, a few points higher than the cluster average.

7.2.4.6 Balanced social-ecological dimensions. Island State Communities St. John Island has a population that is, on average, the most wealthy of the US Virgin Island communities. The majority of the island is national park land under the purview of the US National Park Service (VI Now 2015). The low amount of development combined with the low population, but high density make for the ideal ecological situation. In a sense, the National Park Service mandates the balance between social and ecological systems by maintaining and enforcing the boundary between the two. This community has close proximity to St. Thomas Island by ferry for necessities like medical services, shopping, transportation, and even jobs. Of the cases in this cluster, St. John Island exhibits lower scores on Economic security, Access to support services, and Population diversity. However, this community has the highest Housing adequacy score (69) and a near average score on Education (64). Interestingly, unlike several cases in this cluster, St. John has consistent scores across both Land cover and use and Waste accumulation indicators.

7.3 FURTHER APPLICATIONS OF THE TYPOLOGY

By first constructing indicators of social-ecological resilience and then employing these indicators to create a typology, a variety of communities were able to be assessed and then categorized. Given the volume of data, using the clusters to summarize the results proved to be an effective approach. In part, the cluster analyses help to validate the indicators as the same clusters emerged from the analyses of both samples. While the communities differ substantially in terms of their social and ecological context, the resilience indicators group together similarly. The typology sets the stage for conducting in depth case studies of a sample of cases within each category as a means of further exploring resilience in small island and coastal communities.

8 DISCUSSION

8.1 SUMMARY

The study consisted of four primary phases of research: Phase 1: Development of the Conceptual Model, Phase 2: Indicator Development, Phase 3: Application of Measurement Model, and finally, Phase 4: Extensions of the Measurement Model. The first phase resulted in a conceptual framework for the social ecological system and the property of resilience. Multiple methodological approaches to indicator construction were applied and directly compared in Phase 2. The selected method was the iterative methodology; it resulted in seven composite indicators of social-ecological resilience: *Land cover and use*, *Waste accumulation and treatment*, *Housing adequacy*, *Economic security*, *Access to support services*, *Education,* and *Population diversity*. Upon construction, the indicators were applied in Phase 3 with two distinct samples – small island communities and coastal counties. The indicator scores and associated products were derived from Phase 3. The indicator scores were used to construct a community typology, which was constructed to account for the different strengths and weaknesses of communities as assessed by the indicators of social-ecological resilience. This typology, applied to both small island communities and coastal counties is the result of Phase 4.

Caribbean and Pacific small island communities and Gulf of Mexico coastal counties shared a typology in which communities clustered in three groups: *Balanced social and ecological dimensions*, *High ecological dimensions* and *High social dimensions.* The clusters differ slightly from one geography type to another, but correspond well to three overarching profiles for social-ecological resilience. Slightly more than half of the GoM coastal counties sample and just over one-third of the Island State communities cluster within the High social dimensions group. Less than a tenth (7.4%) of the sample of GoM coastal counties is in the High ecological dimensions cluster. In contrast, the Island State communities sample is dominated by the High ecological dimensions profile with 60% of the communities in this cluster. Finally, the most prized cluster is characterized by a balance of both social and ecological dimensions. Here, 38.5% of the sample of Gulf of Mexico coastal counties and only 6.4% of the sample of Island State communities fall in the Balanced social and ecological dimensions cluster, indicating the highest level of social-ecological resilience.

While some indicators seem to covary, more work is required to assess the dynamics and drivers of these relationships. Ecological indicators often have an inverse relationship with social indicators, but this finding fails to be consistent across all sample communities. The exceptions to this dynamic suggest that there may be a balance of societal development and economic advancement with environmental protection. The examination of the resilience characteristics of island state and coastal communities has produced many insights which will be discussed below.

8.1.1 Addressing the Research Questions

Q1: How do small island and coastal communities anticipate and respond to changing social and ecological conditions?

The question of how small island and coastal communities anticipate and respond to changing social and ecological conditions is not entirely answered by this work. However, the conceptual work on resilience strongly suggests that much is known about the factors that make a community more or less likely to respond positively and adapt to change. These factors are now operationalized in a manner that makes possible continued assessment of SESs and future testing of hypotheses related to community response to social or ecological disruption.

Q2: Are there ways to assess the resilience of small island and coastal communities that take into account the community as a composition of social, ecological, and social-ecological systems?

This study establishes at least one approach to the assessment of resilience of small island and coastal communities that takes into account the community as a composition of social, ecological, and social-ecological systems.[31] While there is room for methodological advancement, the quantitative assessment of dimensions of the social-ecological system for small island and coastal communities is now possible. Developing indicators that allow for the examination of points of interaction in the SES and creating a suite of composite indicators that span different levels of causality are contributions of this work.

[31] The work went further by evaluating multiple methodological approaches, which suggests that there are numerous ways in which resilience might be assessed.

Q3: How can policy makers and others working in community development determine which communities can withstand significant change without trauma? Alternately stated, how can we provide a rationale for targeted policy change among communities?

Using this assessment of resilience to compare communities to one another is critical for providing a rationale for targeted policy change among communities. The assessment allows for the evaluation of which communities are more or less likely to respond positively to additional change/stress based on their present scores and clustering on indicators of social-ecological resilience. The assessment may also point out which aspects of the communities can be buffered and/or supported with investments of resources in order to bolster a community's ability to accept new change/stress.

Q4: Which social and ecological characteristics contribute to the social-ecological resilience of a community?

For each of the composite indicators of social-ecological resilience, there are a variety of component measures that are used to assess the community on *Land cover and use, Waste accumulation and treatment, Housing adequacy, Economic security, Access to support services, Education,* and *Population diversity* (see Appendix B, Tables **B1-B2**). The component measures are supported by previous theoretical and conceptual work that focused on the social and ecological features that would be present in a community with high resilience.

As previously discussed, communities with high scores on social dimensions of resilience have a greater likelihood of having low scores on ecological dimensions. This finding adds evidence to the notion that social and ecological systems are oppositional, but also provides a counterpoint – there are communities that manage to balance the scores. While societal development and ecological condition may operate with a firm tension, communities are navigating the tension and finding ways to successfully maintain characteristics of resilience. This research is a necessary first step to investigating how some communities are able to balance their social-ecological system while others are not. Studying the types of governance, legal structures, and cultural features support the balance may inform programs, policies, and investments in building resilience.

Building a community's resilience in only one direction can translate into dramatic consequences depending on the change(s) ahead. For example, resource management cannot ignore the importance of the social system, even if improvement in social dimensions seems to correspond to declines in the ecological. In fact, the relationships are far more complicated and dynamic (e.g., Kittinger et al. 2012). A large population in poverty will be more in need of natural resources for subsistence and may deplete the resource base more quickly. Likewise, high poverty and a lack of social support services triggers a rise in illegal activity, which may include violations associated with no-take fishing zones and restricted species. Hence, there is a need for all parties to operate with at least an awareness of the interconnections of the social-ecological system.

8.2 CONCLUSIONS

Many earlier researchers in this field have identified the integration of social and ecological perspectives and concepts as essential to the next phases of cutting edge work (e.g., Adger et al. 2002; Berkes and Seixas 2005; Gunderson and Holling 2002; Krieger 2001; Liu et al. 2007). In this work, the integration of social and ecological extended to the indicators themselves and became the means of assessing small island and coastal communities. The use of a social ecological model propels future work forward so that it will not be hindered by a narrow focus on social or eco-systems and will be able to capture dynamic states, multiple levels of organization and scale, among other things.

The definition of social-ecological resilience utilized in this research combined elements of many key resilience researchers. Social-ecological resilience was defined as the community's ability to absorb recurring disturbances in a way that allows essential structures, processes, and feedbacks to be maintained. Resilient systems and their components should respond productively to significant change that disrupts expected patterns "without engaging in an extended period of regressive behavior" (Horne and Orr 1998). By determining a suite of characteristics or properties of systems that exhibit greater resilience, a framework for measuring resilience was developed.

In measuring characteristics of small island and coastal communities that comprise a more resilient system, valuable results were achieved. From the most simple information (knowing which communities exhibit an overall tendency to higher levels of resilience) to the more complex (discovering which characteristics of a community should be strengthened in order to enhance resilience) to the nuanced (examining patterns between indicators of resilience to identify potential interactions that enhance or suppress resilience within the system), the quantitative measurement grants access to investigations at a much larger scale than previous resilience research.

This work overcame several of the challenges associated with previous studies of resilience and social-ecological systems (SESs). First, the body of research was lacking examples of empirical measurement for both resilience and other aspects of SESs. This work moved from the level of metaphor and theory to operationalized indicators of resilience. Further, the measurement of resilience was accomplished for a SES in totality without focus on a single resource, ecosystem, or social group. The measurement relied exclusively on secondary data and was applied to two samples of communities; this is a departure from the use of case studies and in depth field research. These departures from previous work equate to expanded applicability of the measurement model and potential for policy impact.

With the explosion of scientific study focused on the intersection of social and ecological systems, there are now better examples of how to develop a model that captures components of each system and explains the relationships. For example, Cinner and colleagues (2009) crafted an innovative study that examined the intersection of the ecological and the social systems by analyzing village level infrastructure, human population density, and the rugosity of reef habitat (i.e., a measure of the health of coral reefs) in sites selected based on the status of their fishery. The purpose of the study was to determine the drivers of biomass of reef fishes. By examining specific relationships within a SES and focusing on a particular resource, the relationship between components of the system can be quantitatively modeled. Furthermore, the outcomes are impressive. However, as suggested by Alessa and colleagues (2009), this tendency to focus SES analysis on “neat” systems that involve single resources, user groups, and governance systems results in studies that are of limited use with highly complex or “messy” systems. This study and its focus on the assessment of the complexity of SESs and the resilience of these systems is an attempt at quantitatively measuring the mess.

8.2.1 Implications of Results

The results of this study have broad ranging implications for science, policy, and ultimately for practice. The results of this research include: indicators for measuring the social-ecological resilience of a community; a demonstration of the measure development process as well as the application of the indicators in two unique settings; and, a typology of communities based on the indicator scores. Additionally, the results include findings related to the patterns of community characteristics, specifically with respect to the different dimensions of resilience. In terms of the scientific contributions, this study serves as proof of concept of the quantitative assessment of resilience for a social-ecological system. The application of this measurement model and the corresponding typology may provide policy makers with a means of classifying communities according to their resilience. Additionally, this activity may lead to an understanding of how the social-ecological resilience of communities is built, translating into practical guidelines to be used by community organizers and others.

8.2.1.1 Science implications. This study contributes to "emerging insights into the resilience of social ecological systems" which "complement and can significantly add to a converging research agenda on the challenges faced by human environment interactions" (Adger 2006:268). The challenges of this work included operationalizing a systematic conceptual framework, integrating distinct disciplines and fields of research, and determining the most important and effective indicators of social-ecological resilience. Despite the challenges of the quantitative measurement of social-ecological resilience, this study has demonstrated an approach to the conceptualization and operationalization of the concept for small island and coastal communities.

The operationalization and measurement of resilience for social-ecological systems has several important implications for the broader area of research focused on intersections of human and environment. First, this work provides an example of how to think in more systematic, integrated terms about a social-ecological system, as well as a way to evaluate the strengths and weaknesses of that system. Second, the work provides an approach for assessment of change in community status following some disruption, whether a new policy, severe storm, or loss of a major industry. Finally, this research has resulted in the beginnings of a framework for examining social-ecological systems that incorporates multiple scales or levels and mathematical modeling in order to understand understanding of unique phenomena in the context of general processes.

This effort was both theoretical and applied. As a result, it is important to discuss the intended accomplishments of the quantitative component of this project. The measurement and modeling of resilience should serve as an example of how this type of work can be done. Though the measurement of resilience does not represent the perfect quantification of the concept; this measurement model is a solid attempt at thinking in terms of quantitative measurement of a concept that has been heavily theorized, but not operationalized. The components of the measurement model provide starting points for a longer process of exploring and testing the best indicators and measures of resilience. The model has been designed to accommodate expansion and contraction, based on factors such as availability of data, specific project needs and questions, and geographic context.

These statements do not mean that the results of the application of the measurement model are without value. Quite the opposite is true. The results provide proof of concept, concrete depictions of the dimensions of social-ecological resilience for island and coastal communities. For example, examining the indicator scores as presented in the radar graphs or the quintile rankings provided in the maps uncovers the diversity between communities, but also within a community, in terms of the composition of values across the different dimensions of resilience. The results offer a glimpse into the status of communities in terms of the social system, the ecological system, and the interactions between the two.

8.2.1.2 Policy implications. While this research grows out of a social science perspective, its goals and recommendations are aimed at policy makers, communities, and others for whom a measure of social resilience would be useful. A great advantage of the concept of resilience is that the dividing line between scholarly research and real world application is blurred. Resilience, as a concept, and more importantly, as a measure, is believed to hold great potential for understanding and changing human and ecological communities.

The measurement of resilience in a community rests on certain assumptions. First, measurement implies that what contributes to and what takes away from resilience can be estimated, if not absolutely known. This is critical information for the community seeking to sustain its resilience and/or to build more. Second, the assessment of resilience assumes researchers have (or can acquire) an idea of the current state of the community (i.e., where vulnerabilities, rigidities, and strengths exist, a sense of the kind and degree of change that can be withstood, etc.). Third, it assumes that this knowledge can be included in policy-making decisions so as to protect the more fragile communities from excessive change and to enact change in the more resilience communities. Finally, it assumes that awareness of the level of resilience relative to surrounding communities will open up new opportunities for collaboration, alliance building, and resource sharing among less resilient communities as a means of enhancing resilience. Overall, assessment and communication of a community's social-ecological resilience allow for the possibility for change in resilience levels.

The measurement of social-ecological resilience should assist decision makers in identifying the factors that threaten community sustainability and stability. By aligning policy impacts and outcomes with a community's social-ecological resilience, both policy and the state of communities can be dramatically improved. Holling (2001) suggests that by understanding the cycles of transformation and change as well as their corresponding scales, a parallel understanding of the contribution of such transformation and change to sustainability will emerge. Ultimately, this will lead to the identification of "points at which a system is capable of accepting positive change and the points where it is vulnerable…[i]t then becomes possible to use those leverage points to foster resilience and sustainability within a system" (Holling 2001:392). Identifying these points is the very crux of this project; social-ecological resilience can be fostered and protected, when necessary, by locating the leverage points for a community and aligning policy recommendations with this information. By developing and integrating indicators related to the social and ecological components of the overarching system, the assessment of resilience is strengthened. Consequently, this allows for the justification of "selective targeting of communities for mitigation based on good social science, not just political whim" (Cutter et al. 2003:258).

8.3 LIMITATIONS

In a sense, the biggest limitation of this work is also one of the greatest assets. The use of secondary data represents a great efficiency, but it also poses a challenge for assessing the many dimensions of social-ecological resilience. The availability of secondary data, particularly for the small islands, is a weakness that may only be fully overcome by supplementing secondary data with primary data collection efforts. While the study aimed for a community unit of analysis, it could be argued that the ideal conception of community might require taking the analysis to an even smaller geographic unit. This decision should be carefully weighed in relation to data availability and policy impact. While smaller units of analysis would be ideal from the perspective of getting closer to the human-environment interactions, the smaller unit would substantially diminish the data richness. Even with the county equivalent level, there were data availability issues that could not be overcome. Furthermore, the county and equivalent unit has meaning as a unit for which policy is made and governing structures are present. Use of a smaller unit the unit of analysis may necessitate the aggregation of the scores so as to align to appropriate socio-political boundaries. When adding new time points to this data set in order to evaluate the change over time, the lag associated with release of updated datasets will be a challenge, particularly to the currency of the assessment of social-ecological resilience.

The data constrained the operationalization and assessment of indicators such as strong institutions, culture, and ecosystem management (see Appendix C, Table **C1**). While developing a model for measuring resilience of small island state communities, many factors were intentionally omitted. Contextual factors are among those that were set aside, yet their importance is undeniable. Historical conditions, legal codes, and sociocultural institutions are linked to the resilience of island communities. These factors play a critical role in shaping present and future conditions for communities and their resources. However, measurement and inclusion in quantitative models is challenged by the types of data routinely collected for such communities. Once again, this suggests that some combination of primary and secondary data would begin to address the inclusion of dimensions of social-ecological systems such as culture, history, and law.

Sample size represents an additional limitation of the study. This limitation is highly technical in that it is largely a function of rules and best practices for statistical analysis. The methodologies typically used in measurement construction, such as EFA and CFA, are reliant on large sample sizes. In research on communities, the challenge is not associated with representing the total population of communities adequately, as this may be done without a large sample (depending on population size). Instead, the challenge is in being able to use statistical procedures that need large numbers of cases. By adding a second sample of coastal counties, this study addressed this challenge without sacrificing the ultimate goal to measure social-ecological resilience for communities with strong connections between social and ecological systems.

In many respects, the results of this study serve to position researchers for the next challenge of testing to see if the dimensions of the SES that have been measured actually translate into more or less resilience in the face of a large or small scale change and disturbance to the system. All along, researchers were in need of a means of evaluating these hypothesized relationships. Now, the means has been established. This research has produced one way of constructing indicators that can be employed to analyze longitudinal data to test for these associations and relations.

8.4 RECOMMENDATIONS FOR FUTURE RESEARCH

As Krieger (2001) proposed in her work, the benefit of creating a combined model for the social and ecology system is that new hypotheses can be generated in relation to the measurement of the system. Based on the outcomes of this study, there are several potential directions for future research. Three of these directions will be highlighted and briefly described. Though it would be ideal to expand the research in all three directions, each option provides an independent way forward. Also, these options can be scaled to the resources available. Each option provides new opportunities to develop and test hypotheses that build upon the previous work.

One option for the advancement of this research is focused on the addition of time points in order to conduct longitudinal modeling and pre-post event assessment of changes in resilience indicators. This effort would ensure the specification of causal relationships between indicators of social-ecological resilience and other variables. Additionally, the pre-post event assessment would provide a means of testing the responsiveness of the indicators to changes in communities. Similarly, the longitudinal assessment aids the determination of leading or lagging indicators of social-ecological resilience.

A second direction for future research would involve the use of mixed methods to further investigate the sample communities. Using the typology, a representative sample of communities from each group or cluster would be selected for in depth case studies. The case studies should combine some ground truthing or validation of the data itself, as well as investigation of dimensions of resilience that were not assessed using secondary data. The term ‘ground truth’ is borrowed from the remote sensing field where it is defined as data collected on location for the purpose of validating data collected via remote sensing methods, such as aircraft or satellite (ESRI 2015). In the context of this research, ground truthing would involve physically traveling to the communities being studied in order to collect data to validate data collected through secondary sources.[32] Ultimately, these case studies would provide another means of validating the resilience indicators.

The final option for future research is discussed as a series of proposed next steps that pertain to the advancement of the modeling of social-ecological resilience utilizing SEM methods. Despite the outcomes of the method selection process for this study, there remains strong evidence to support the use of structural equation modeling (SEM) methods with this type of work. First, to test the measurement model using confirmatory factor analysis (CFA) procedures, a larger sample of communities must be identified and selected. These communities might span new island and mainland states. Alternately, the sample could be focused entirely on coastal communities in the mainland US in order to minimize the data challenges and maximize the sample size. Second, following CFA, structural modeling would be conducted. Using SEM methods, causal relationships between resilience and other variables would be investigated and established. Finally, the outcomes of this work would inform the development of a multi-level model (e.g., state, region, community) to explain a specific outcome that is expected to be influenced by the resilience level of the system.

8.5 THE CHARGE

The protection of both human and environmental health and well-being requires that communities are able to anticipate social and ecological disruptions and respond to changing conditions, including changes in climate, natural resources, economy, government, or social support. The act of protecting human and environmental health is neither singular nor short term. Instead, it requires sustained effort across time and space, within social, ecological, and social-ecological realms. Ongoing study and assessment of resilience as a means of informing action exemplifies a commitment to sustainable solutions for managing the health and well-being of

[32] A similar approach to ground truthing indicators for communities has been previously employed in the work of Jepson and Colburn 2013 and Pollnac 2012.

society and the environment. This research represents a strong step forward in the study and quantitative assessment of the social-ecological resilience of communities.

APPENDIX A
SAMPLE COMMUNITIES

(Tables A1-A2)

Table A1: Island State Community Sample

US Island States Communities Sample (county equivalents), n=94			
FIPS code	***Name***	***FIPS code***	***Name***
15001	Hawaii County, Hawaii	**72067**	Hormigueros Municipio, Puerto Rico
15003	Honolulu County, Hawaii	**72069**	Humacao Municipio, Puerto Rico
15005	Kalawao County, Hawaii	**72071**	Isabela Municipio, Puerto Rico
15007	Kauai County, Hawaii	**72073**	Jayuya Municipio, Puerto Rico
15009	Maui County, Hawaii	**72075**	Juana Díaz Municipio, Puerto Rico
60010	Eastern District, American Samoa	**72077**	Juncos Municipio, Puerto Rico
60020	Manua District, American Samoa	**72079**	Lajas Municipio, Puerto Rico
60050	Western District, American Samoa	**72081**	Lares Municipio, Puerto Rico
66010	Guam, Guam	**72083**	Las Marías Municipio, Puerto Rico
69085	Northern Islands Municipality, Northern Mariana Islands	**72085**	Las Piedras Municipio, Puerto Rico
69100	Rota Municipality, Northern Mariana Islands	**72087**	Loíza Municipio, Puerto Rico
69110	Saipan Municipality, Northern Mariana Islands	**72089**	Luquillo Municipio, Puerto Rico
69120	Tinian Municipality, Northern Mariana Islands	**72091**	Manatí Municipio, Puerto Rico
72001	Adjuntas Municipio, Puerto Rico	**72093**	Maricao Municipio, Puerto Rico
72003	Aguada Municipio, Puerto Rico	**72095**	Maunabo Municipio, Puerto Rico
72005	Aguadilla Municipio, Puerto Rico	**72097**	Mayagüez Municipio, Puerto Rico
72007	Aguas Buenas Municipio, Puerto Rico	**72099**	Moca Municipio, Puerto Rico
72009	Aibonito Municipio, Puerto Rico	**72101**	Morovis Municipio, Puerto Rico
72011	Añasco Municipio, Puerto Rico	**72103**	Naguabo Municipio, Puerto Rico
72013	Arecibo Municipio, Puerto Rico	**72105**	Naranjito Municipio, Puerto Rico
72015	Arroyo Municipio, Puerto Rico	**72107**	Orocovis Municipio, Puerto Rico
72017	Barceloneta Municipio, Puerto Rico	**72109**	Patillas Municipio, Puerto Rico
72019	Barranquitas Municipio, Puerto Rico	**72111**	Peñuelas Municipio, Puerto Rico
72021	Bayamón Municipio, Puerto Rico	**72113**	Ponce Municipio, Puerto Rico
72023	Cabo Rojo Municipio, Puerto Rico	**72115**	Quebradillas Municipio, Puerto Rico

Table A1: Island State Community Sample

US Island States Communities Sample (county equivalents), n=94			
FIPS code	***Name***	***FIPS code***	***Name***
72025	Caguas Municipio, Puerto Rico	**72117**	Rincón Municipio, Puerto Rico
72027	Camuy Municipio, Puerto Rico	**72119**	Río Grande Municipio, Puerto Rico
72029	Canóvanas Municipio, Puerto Rico	**72121**	Sabana Grande Municipio, Puerto Rico
72031	Carolina Municipio, Puerto Rico	**72123**	Salinas Municipio, Puerto Rico
72033	Cataño Municipio, Puerto Rico	**72125**	San Germán Municipio, Puerto Rico
72035	Cayey Municipio, Puerto Rico	**72127**	San Juan Municipio, Puerto Rico
72037	Ceiba Municipio, Puerto Rico	**72129**	San Lorenzo Municipio, Puerto Rico
72039	Ciales Municipio, Puerto Rico	**72131**	San Sebastián Municipio, Puerto Rico
72041	Cidra Municipio, Puerto Rico	**72133**	Santa Isabel Municipio, Puerto Rico
72043	Coamo Municipio, Puerto Rico	**72135**	Toa Alta Municipio, Puerto Rico
72045	Comerío Municipio, Puerto Rico	**72137**	Toa Baja Municipio, Puerto Rico
72047	Corozal Municipio, Puerto Rico	**72139**	Trujillo Alto Municipio, Puerto Rico
72049	Culebra Municipio, Puerto Rico	**72141**	Utuado Municipio, Puerto Rico
72051	Dorado Municipio, Puerto Rico	**72143**	Vega Alta Municipio, Puerto Rico
72053	Fajardo Municipio, Puerto Rico	**72145**	Vega Baja Municipio, Puerto Rico
72054	Florida Municipio, Puerto Rico	**72147**	Vieques Municipio, Puerto Rico
72055	Guánica Municipio, Puerto Rico	**72149**	Villalba Municipio, Puerto Rico
72057	Guayama Municipio, Puerto Rico	**72151**	Yabucoa Municipio, Puerto Rico
72059	Guayanilla Municipio, Puerto Rico	**72153**	Yauco Municipio, Puerto Rico
72061	Guaynabo Municipio, Puerto Rico	**78010**	St. Croix Island, Virgin Islands of the United States
72063	Gurabo Municipio, Puerto Rico	**78020**	St. John Island, Virgin Islands of the United States
72065	Hatillo Municipio, Puerto Rico	**78030**	St. Thomas Island, Virgin Islands of the United States

Table A2: Gulf of Mexico Coastal County Sample

US Gulf of Mexico Coastal Counties Sample (coastal counties), n=135			
FIPS Code	***Name***	***FIPS Code***	***Name***
1003	Baldwin County, Alabama	**22089**	St. Charles Parish, Louisiana
1025	Clarke County, Alabama	**22091**	St. Helena Parish, Louisiana
1039	Covington County, Alabama	**22093**	St. James Parish, Louisiana
1053	Escambia County, Alabama	**22095**	St. John the Baptist Parish, Louisiana
1061	Geneva County, Alabama	**22097**	St. Landry Parish, Louisiana
1097	Mobile County, Alabama	**22099**	St. Martin Parish, Louisiana
1099	Monroe County, Alabama	**22101**	St. Mary Parish, Louisiana
1129	Washington County, Alabama	**22103**	St. Tammany Parish, Louisiana
12005	Bay County, Florida	**22105**	Tangipahoa Parish, Louisiana
12013	Calhoun County, Florida	**22109**	Terrebonne Parish, Louisiana
12015	Charlotte County, Florida	**22113**	Vermilion Parish, Louisiana
12017	Citrus County, Florida	**22117**	Washington Parish, Louisiana
12021	Collier County, Florida	**22121**	West Baton Rouge Parish, Louisiana
12027	DeSoto County, Florida	**22125**	West Feliciana Parish, Louisiana
12029	Dixie County, Florida	**28005**	Amite County, Mississippi
12033	Escambia County, Florida	**28039**	George County, Mississippi
12037	Franklin County, Florida	**28045**	Hancock County, Mississippi
12039	Gadsden County, Florida	**28047**	Harrison County, Mississippi
12041	Gilchrist County, Florida	**28059**	Jackson County, Mississippi
12043	Glades County, Florida	**28073**	Lamar County, Mississippi
12045	Gulf County, Florida	**28091**	Marion County, Mississippi
12049	Hardee County, Florida	**28109**	Pearl River County, Mississippi
12053	Hernando County, Florida	**28113**	Pike County, Mississippi
12057	Hillsborough County, Florida	**28131**	Stone County, Mississippi
12059	Holmes County, Florida	**28147**	Walthall County, Mississippi
12063	Jackson County, Florida	**28157**	Wilkinson County, Mississippi

Table A2: Gulf of Mexico Coastal County Sample

US Gulf of Mexico Coastal Counties Sample (coastal counties), n=135			
FIPS Code	***Name***	***FIPS Code***	***Name***
12065	Jefferson County, Florida	**48007**	Aransas County, Texas
12067	Lafayette County, Florida	**48015**	Austin County, Texas
12071	Lee County, Florida	**48025**	Bee County, Texas
12073	Leon County, Florida	**48039**	Brazoria County, Texas
12075	Levy County, Florida	**48047**	Brooks County, Texas
12077	Liberty County, Florida	**48057**	Calhoun County, Texas
12079	Madison County, Florida	**48061**	Cameron County, Texas
12081	Manatee County, Florida	**48071**	Chambers County, Texas
12083	Marion County, Florida	**48089**	Colorado County, Texas
12087	Monroe County, Florida	**48123**	DeWitt County, Texas
12091	Okaloosa County, Florida	**48131**	Duval County, Texas
12101	Pasco County, Florida	**48149**	Fayette County, Texas
12103	Pinellas County, Florida	**48157**	Fort Bend County, Texas
12105	Polk County, Florida	**48167**	Galveston County, Texas
12113	Santa Rosa County, Florida	**48175**	Goliad County, Texas
12115	Sarasota County, Florida	**48201**	Harris County, Texas
12119	Sumter County, Florida	**48215**	Hidalgo County, Texas
12121	Suwannee County, Florida	**48239**	Jackson County, Texas
12123	Taylor County, Florida	**48241**	Jasper County, Texas
12129	Wakulla County, Florida	**48245**	Jefferson County, Texas
12131	Walton County, Florida	**48247**	Jim Hogg County, Texas
12133	Washington County, Florida	**48249**	Jim Wells County, Texas
22001	Acadia Parish, Louisiana	**48261**	Kenedy County, Texas
22005	Ascension Parish, Louisiana	**48273**	Kleberg County, Texas
22007	Assumption Parish, Louisiana	**48285**	Lavaca County, Texas
22011	Beauregard Parish, Louisiana	**48291**	Liberty County, Texas

Table A2: Gulf of Mexico Coastal County Sample

US Gulf of Mexico Coastal Counties Sample (coastal counties), n=135			
FIPS Code	***Name***	***FIPS Code***	***Name***
22019	Calcasieu Parish, Louisiana	**48297**	Live Oak County, Texas
22023	Cameron Parish, Louisiana	**48321**	Matagorda County, Texas
22033	East Baton Rouge Parish, Louisiana	**48351**	Newton County, Texas
22037	East Feliciana Parish, Louisiana	**48355**	Nueces County, Texas
22039	Evangeline Parish, Louisiana	**48361**	Orange County, Texas
22045	Iberia Parish, Louisiana	**48391**	Refugio County, Texas
22047	Iberville Parish, Louisiana	**48409**	San Patricio County, Texas
22051	Jefferson Parish, Louisiana	**48427**	Starr County, Texas
22053	Jefferson Davis Parish, Louisiana	**48457**	Tyler County, Texas
22055	Lafayette Parish, Louisiana	**48469**	Victoria County, Texas
22057	Lafourche Parish, Louisiana	**48473**	Waller County, Texas
22063	Livingston Parish, Louisiana	**48477**	Washington County, Texas
22071	Orleans Parish, Louisiana	**48479**	Webb County, Texas
22075	Plaquemines Parish, Louisiana	**48481**	Wharton County, Texas
22077	Pointe Coupee Parish, Louisiana	**48489**	Willacy County, Texas
22087	St. Bernard Parish, Louisiana		

APPENDIX B

FINAL OPERATIONALIZATION AND DATA SOURCES

(Tables B1-B5)

Table B1: Indicators and Measures for Island State Communities

SOCIAL-ECOLOGICAL RESILIENCE COMPOSITE INDICATORS				
Components	**Measure Description**	**Contribution to SER**	**Source**	**Time Point**
Access to support services				
Communication	Proportion of HHs with no phone service available	-	US Census Bureau, Decennial Census	2000
Transportation	Proportion of HHs with no vehicle available	-	US Census Bureau, Decennial Census	2000
Support establishments	Healthcare and social assistance establishments per 100	+	US Census Bureau, Economic Census	2000
Public assistance	Estimate of proportion of all individuals in poverty receiving public assistance income	+	US Census Bureau, Decennial Census	2000
Economic security				
Industry diversity	Economic diversity index (examines diversity across10 industries)	+	US Census Bureau, Economic Census	2007
Population in poverty	Percent of total population below poverty level	-	US Census Bureau, Decennial Census	2000
Household economic security	Median household income in 1999	+	US Census Bureau, Decennial Census	2000
Housing Adequacy				
Value	Median value of housing unit	+	US Census Bureau, Decennial Census	2000
Costs	Median monthly costs of housing for all owner occupied units	-	US Census Bureau, Decennial Census	2000
Age	Median age of housing unit	-	US Census Bureau, Decennial Census	2000
Education				
School enrollment	Proportion of total population 18 and under enrolled in school, grades K-12	+	US Census Bureau, Decennial Census	2000

Table B1: Indicators and Measures for Island State Communities

SOCIAL-ECOLOGICAL RESILIENCE COMPOSITE INDICATORS				
Components	**Measure Description**	**Contribution to SER**	**Source**	**Time Point**
Educational attainment - high school	Graduates of high school or equivalent per 100 people	+	US Census Bureau, Decennial Census	2000
Educational attainment - college	Graduates of a bachelor degree program per 100 people	+	US Census Bureau, Decennial Census	2000
Population diversity				
Sex diversity		+		
	Percent of population that is female		US Census Bureau, Decennial Census	2000
Age diversity		+		
	Percent of population 65 years of age and over		US Census Bureau, Decennial Census	2000
	Percent of population18 years of age and under		US Census Bureau, Decennial Census	2000
Racial diversity		+		
	Percent Native Hawaiian and Other Pacific Islander		US Census Bureau, Decennial Census	2000
	Percent Asian		US Census Bureau, Decennial Census	2000
	Percent White		US Census Bureau, Decennial Census	2000
	Percent Black		US Census Bureau, Decennial Census	2000
	Percent Other ethnic origin or race		US Census Bureau, Decennial Census	2000
Land cover and use				
Distribution of housing	Housing units per square mile	-	US Census Bureau, Decennial Census	2000
Developed	Percent of all landcover that is impervious	-	National Oceanic and Atmospheric	2001-07

Table B1: Indicators and Measures for Island State Communities

SOCIAL-ECOLOGICAL RESILIENCE COMPOSITE INDICATORS				
Components	**Measure Description**	**Contribution to SER**	**Source**	**Time Point**
landcover			Administration, CCAP	(various)
Agriculture land	Percent of all landcover for cultivated crop land/pasture and hay	+	National Oceanic and Atmospheric Administration, CCAP	2001-07 (various)
Vegetated forest landcover	Percent of all landcover that is forest	+	National Oceanic and Atmospheric Administration, CCAP	2001-07 (various)
Waste accumulation and treatment				
Water source	Proportion of all HHs on public water	+	US Census Bureau, Decennial Census	2000
Plumbing	Proportion of all HHs without complete plumbing	-	US Census Bureau, Decennial Census	2000
Kitchen facilities	Proportion of all HHs without complete kitchens	-	US Census Bureau, Decennial Census	2000
Wastewater treatment	Wastewater facilities per 100 HHs	+	Federal Emergency Management Agency, Critical Facilities	2011

Table B2: Indicators and Measures for Island State Communities

ADDITIONAL MEASURES				
Components	**Measure Description**	**Contribution to SER**	**Source**	**Time Point**
Measures used to adjust for county level of analysis:				
Population	Total population	N/A	US Census Bureau, Decennial Census	2000
Housing units	Total housing units	N/A	US Census Bureau, Decennial Census	2000
Owner occupied housing units	Total owner occupied housing units	N/A	US Census Bureau, Decennial Census	2000
Population under 18 yrs/ School age population	Total population under 18 years of age	N/A	US Census Bureau, Decennial Census	2000
Population in poverty	Total individuals in poverty	N/A	US Census Bureau, Decennial Census	2000
Average household size	Average household size	N/A	US Census Bureau, Decennial Census	2000
County area (sq mi)	County area (sq mi)	N/A	National Oceanic and Atmospheric Administration, CCAP	2001-07 (various)

Table B3: Indicators and Measures for GoM Coastal Counties

SOCIAL-ECOLOGICAL RESILIENCE COMPOSITE INDICATORS				
Components	**Measure Description**	**Contribution to SER**	**Source**	**Time Point**
Access to support services_				
Communication	Proportion of HHs with no phone service available	-	US Census Bureau, Decennial Census	2000
Transportation	Proportion of HHs with no vehicle available	-	US Census Bureau, Decennial Census	2000
Support establishments	Hospital beds per 1000 people	+	Area Resource File	2000
Public assistance	Proportion of population in poverty participating in SNAP	+	US Department of Agriculture	2000
Economic security				
Industry diversity	Economic diversity index (examines diversity across10 industries)	+	US Census Bureau, Censtats	2007
Population in poverty	Percent of total population below poverty level	-	US Census Bureau, Decennial Census	2000
Household economic security	Median household income in 1999	+	US Census Bureau, Decennial Census	2000
Individual economic security	Unemployment rate for civilian labor force	-	US Census Bureau, Censtats	
Housing adequacy				
Value	Median value of housing unit	+	US Census Bureau, Decennial Census	2000
Costs	Median monthly costs of housing for all owner occupied units	-	US Census Bureau, Decennial Census	2000
Age	Median age of housing unit	-	US Census Bureau, Decennial Census	2000

Table B3: Indicators and Measures for GoM Coastal Counties

SOCIAL-ECOLOGICAL RESILIENCE COMPOSITE INDICATORS				
Components	**Measure Description**	**Contribution to SER**	**Source**	**Time Point**
Education				
School enrollment	Proportion of total population 18 and under enrolled in school, grades K-12	+	US Census Bureau, Censtats	2000
Educational attainment - high school	Percent of population 25 years and older with high school or equivalent as highest level of attainment	+	US Census Bureau, Decennial Census	2000
Educational attainment - college	Percent of population 25 years and older with bachelor's degree or higher as highest level of attainment	+	US Census Bureau, Decennial Census	2000
Population diversity				
Sex diversity		+		
	Percent of population that is female		US Census Bureau, Decennial Census	2000
Age diversity		+		
	Percent of population 65 years of age and over		US Census Bureau, Decennial Census	2000
	Percent of population18 years of age and under		US Census Bureau, Decennial Census	2000
Racial diversity		+		
	Percent American Indian		US Census Bureau, Decennial Census	2000
	Percent Asian		US Census Bureau, Decennial Census	2000
	Percent White		US Census Bureau, Decennial Census	2000
	Percent Black		US Census Bureau, Decennial Census	2000
	Percent Hispanic/Latino		US Census Bureau, Decennial Census	2000
Land cover and use				
Distribution of	Housing units per square mile	-	US Census Bureau, Decennial Census	2000

Table B3: Indicators and Measures for GoM Coastal Counties

SOCIAL-ECOLOGICAL RESILIENCE COMPOSITE INDICATORS				
Components	**Measure Description**	**Contribution to SER**	**Source**	**Time Point**
housing				
Developed landcover	Percent of all landcover that is impervious	-	National Oceanic and Atmospheric Administration, CCAP	2001
Vegetated landcover	Percent of all landcover terrestrial vegetated	+	National Oceanic and Atmospheric Administration, CCAP	2001
Wetland landcover	Percent of all landcover that is wetland	+	National Oceanic and Atmospheric Administration, CCAP	2001
Waste accumulation and treatment				
Water source	Proportion of all HHs on public water	+	US Geological Survey, National Water Use	2000
Plumbing	Proportion of all HHs without complete plumbing	-	US Census Bureau, Decennial Census	2000
Kitchen facilities	Proportion of all HHs without complete kitchens	-	US Census Bureau, Decennial Census	2000
Wastewater treatment	Wastewater facilities per 100 HHs	+	Federal Emergency Management Agency, Critical Facilities	2011
Total emissions	Total emissions per year	-	Environmental Protection Agency, AirData	2000

Table B4: Indicators and Measures for GoM Coastal Counties

ADDITIONAL MEASURES				
Components	**Measure Description**	**Contribution to SER**	**Source**	**Time Point**
Measures used to adjust for county level of analysis:				
County population	Population estimate/count	N/A	US Census Bureau, Decennial Census	2000-01
County housing units	Housing unit total	N/A	US Census Bureau, Decennial Census	2000-01
County population under 18 yrs/ School age population	Population under 18 years of age	N/A	US Census Bureau, Decennial Census	2000-01
County population in poverty	Poverty estimate	N/A	US Census Bureau, Decennial Census	2000
County average household size	Average household size	N/A	US Census Bureau, Decennial Census	2000
County area (sq mi)	County area (sq mi)	N/A	US Census Bureau, National Oceanic and Atmospheric Administration, CCAP	2001

Table B5: Data Sources

Data Sources for Social-Ecological Resilience Composite Indicators		
Source	**Uniform Resource Locator (URL)**	**Description**
Area Resource File (ARF), U.S. Department of Health and Human Services, Health Resources and Services Administration, Bureau of Health Professions, National Center for Health Workforce Analysis.	http://arf.hrsa.gov/	Area Resource File (ARF) 2009-2010 Release, Version 2: The Area Resource File (ARF) system is a computer based health information system with broad analytical capabilities. It utilizes health personnel and related secondary data that are available on a compatible basis for all counties in the U.S. The Area Resource File is made available by the Bureau of Health Professions, though original data are compiled from a variety of sources including: American Dental Association, the American Hospital Association, the American Medical Association, and InterStudy.
Economic Diversity Index.	http://www.coastalscience.noaa.gov/	Economic Diversity of County Employment and Earnings: Using the US Census Bureau, Censtats, USA Counties collection for 2001 through 2007, measures of economic diversity were calculated by NOAA Hollings Scholar, Jason Wong in conjunction with NOAA social scientists (NOS/NCCOS/HML) using two methods, the Ogive (Oi) and National Average (Ni) for both employment and earnings by industry. The Ni here measures deviation from the State's industrial composition; and the Ogive measures deviation from an equiproportional standpoint (assuming highest diversity is when each of the industries employ equal share of the economy). Data are originally taken from BEA and therefore, reflect only non-farm industry.

Table B5: Data Sources

Data Sources for Social-Ecological Resilience Composite Indicators		
Source	**Uniform Resource Locator (URL)**	**Description**
Environmental Protection Agency (EPA), AirData.	http://www.epa.gov/airdata/	Environmental Protection Agency (EPA), AirData: The AirData Web site gives you access to air pollution data for the entire United States. AirData produces reports and maps of air pollution data based on user specified criteria. AirData presents annual summaries of air pollution data from two EPA databases: 1) AQS (Air Quality System) database provides air monitoring data - ambient concentrations of criteria and hazardous air pollutants at monitoring sites, primarily in cities and towns. 2) NEI (National Emission Inventory) database provides estimates of annual emissions of criteria and hazardous air pollutants from all types of sources. The NEI database in 2002 replaced two separate EPA databases for emissions of criteria air pollutants (National Emission Trends, or NET) and hazardous air pollutants (National Toxics Inventory, or NTI). Data are extracted periodically from these databases for use in AirData.
Federal Emergency Management Agency (FEMA), HAZUS Database.	http://www.coast.noaa.gov/digitalcoast/	Federal Emergency Management Agency (FEMA), HAZUS Database, Critical Facilities: Critical facilities data is drawn from the FEMA's HAZUS database, circa 2011. A critical facility is defined as a structure that, if flooded, would present an immediate threat to life, public health, and safety. The data are aggregated into Coastal US States and Territories.
National Oceanic and Atmospheric Administration (NOAA), Coastal Change Analysis Program (CCAP).	http://www.coast.noaa.gov/digitalcoast/	National Oceanic and Atmospheric Administration, Coastal Change Analysis Program (CCAP) Regional Land Cover Data (2012): The Coastal Change Analysis Program (C-CAP) produces a nationally standardized database of land cover and land change information for the coastal regions of the U.S. C-CAP products are developed using multiple dates of remotely sensed imagery and consist of raster-based land cover maps for

Table B5: Data Sources

Data Sources for Social-Ecological Resilience Composite Indicators		
Source	**Uniform Resource Locator (URL)**	**Description**
		each date of analysis, as well as a file that highlights what changes have occurred between these dates and where the changes were located. NOAA produces high resolution C-CAP land cover products, for select geographies. GIS and tabular data was accessed June 2012 and prepared for the project by NOAA Coastal Services Center, Charleston SC (http://www.csc.noaa.gov/digitalcoast/data/ccapregional).
National Oceanic and Atmospheric Administration, National Weather Services (NWS), Storm Data.	http://www.ncdc.noaa.gov/stormevents/	National Oceanic and Atmospheric Administration, National Weather Service Storm Event Data: Available through the National Climatic Data Center (NCDC), Storm Data is an official publication of the National Oceanic and Atmospheric Administration (NOAA) which documents the occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce. In addition, it is a partial record of other significant meteorological events, such as record maximum or minimum temperatures or precipitation that occurs in connection with another event. Some information appearing in Storm Data may be provided by or gathered from sources outside the National Weather Service (NWS), such as the media, law enforcement and/or other government agencies, private companies, and individuals.

Table B5: Data Sources

Data Sources for Social-Ecological Resilience Composite Indicators		
Source	**Uniform Resource Locator (URL)**	**Description**
U.S. Census Bureau, Censtats, USA Counties.	http://censtats.census.gov/usa/usa.shtml	Censtats, USA Counties Data: The USA Counties collection encompasses overs 6,800 data items from the states and counties from federal agencies including the U.S. Census Bureau, the Bureau of Economic Analysis, the Bureau of Labor Statistics, the Federal Bureau of Investigation, and the Social Security Administration. The files include data published for 2009 estimates and many items from the 2000 Census of Population and Housing, the 1990 census, the 1980 census and the 2002, 1997, 1992, 1987, 1982 and 1977 economic censuses.
U.S. Census Bureau, Decennial Census.	http://factfinder2.census.gov/	U.S Census Bureau, Decennial Census Data: U.S. Census Bureau, 2000 Census, Summary Files 1 and 3; The U.S. Census counts every resident in the United States. It is mandated by Article I, Section 2 of the Constitution and takes place every 10 years. The data collected by the decennial census determine the number of seats each state has in the U.S. House of Representatives and is also used to distribute billions in federal funds to local communities. Census 2000/2010 Summary File 1 (SF 1) presents counts and basic cross-tabulations of information collected from all people and housing units. SF 1 provides population counts for 63 race categories and Hispanic or Latino, and population counts for many detailed race and Hispanic or Latino categories, and American Indian and Alaska Native tribes [Urban/rural data are on the final national file]. Census 2000/2010 Summary File 3 (SF 3) contains tables with social, economic and housing characteristics compiled from a sample of approximately 19 million housing units (about 1-in-6 households) that received the Census 2000 long-form questionnaire. Many tables are given for nine major race and Hispanic or Latino groups. Ancestry group population counts are included.

Table B5: Data Sources

Data Sources for Social-Ecological Resilience Composite Indicators		
Source	**Uniform Resource Locator (URL)**	**Description**
U.S. Census Bureau, County Business Patterns.	http://www.census.gov/econ/cbp/	U.S. Census Bureau, County Business Patterns Data: These data provide annual statistics for businesses with paid employees within the U.S., Puerto Rico, and Island Areas (Guam, American Samoa, the Commonwealth of the Northern Mariana Islands, and the U.S. Virgin Islands) at a detailed geography and industry level. This program is authorized under the United States Code, Titles 13 and 26. County Business Patterns provides subnational economic data by industry each year. This series includes the number of establishments, employment during the week of March 12, first quarter payroll, and annual payroll. This data is useful for studying the economic activity of small areas; analyzing economic changes over time; and as a benchmark for other statistical series, surveys, and databases between economic censuses. ZIP Code Business Patterns data are available shortly after the release of County Business Patterns. It provides the number of establishments by employment-size classes by detailed industry in the U.S.
U.S. Census Bureau, Economic Census.	http://www.census.gov/econ/census/	U.S. Census Bureau, Economic Census: The Economic Census is the U.S. Government's official five-year measure of American business and the economy. It is conducted by the U.S. Census Bureau, and like the Decennial Population and Housing Census, response is required by law. Data collection includes large, medium and small companies representing all U.S. locations and industries. Respondents are asked to provide a range of operational and performance data for their companies.

Table B5: Data Sources

Data Sources for Social-Ecological Resilience Composite Indicators		
Source	**Uniform Resource Locator (URL)**	**Description**
U.S. Department of Agriculture (USDA), Economic Research Service (ERS) and Food & Nutrition Service (FNS), Supplemental Nutrition Assistance Program (SNAP).	http://www.fns.usda.gov/pd/snapmain.htm	Supplemental Nutrition Assistance Program (SNAP) Data: The states report SNAP "participation counts" twice per year: January and July. States report counts by "project area," which is usually the same as a county because benefits are typically issued from county social service offices. Data files are drawn from the NATIONAL DATA BANK VERSION 8.2 - SUPPLEMENTAL NUTRITION ASSISTANCE PROGRAM, STATISTICAL SUMMARY OF OPERATIONS - FNS 388A - By State (SNAP-R19), Calc: FSP Total PA and Non-PA People-STATE BY PROJECT AREA 20XX, SNAP-R19 - Submission Data. Data were provided by SNAP Program, U.S. Department of Agriculture, Food & Nutrition Service (FNS), Office of Research and Analysis for the project in November 2011.
U.S. Geological Survey (USGS), National Water Use Information Program.	http://water.usgs.gov/watuse/	US Geological Survey (USGS), National Water Use Information Program: This program compiles and publishes the Nation's water-use data. Public access to some of these data is provided via the USGS Water Data for the Nation site. Water use refers to water that is used for specific purposes. Water-use data is collected by area type (State, county, watershed or aquifer) and source such as rivers or groundwater, and category such as public supply or irrigation. Water-use data has been reported every five years since 1950, for years ending in "0" and "5". The USGS works in cooperation with local, State, and Federal agencies as well as academic and private organizations to collect and report total withdrawals.

APPENDIX C
PROGRESS TO OPERATIONALIZATION

(Table C1)

Table C1: Indicator Selection and Operationalization.

OPERATIONALIZATION				DATA SOURCES	
Indicators	**Proposed components**	**Expected contribu-tion**	**Measures**	**Island States**	**US States***
Ecosystem health					
	species richness	+	threatened fish and mammal species	World Bank (state level)	
	water quality	+			Environmental Protection Agency
	sediment quality	+			Environmental Protection Agency
	fish stocks	+			
Resource levels					
	coral abundance	+			
	decline in biodiversity	-			
	improved fish stocks	+			
Waste accumulation & treatment					
	water source	+	population using public water, population using combined water sources	US Geological Survey, US Census Bureau	US Geological Survey
	sewage system	-	total housing units lacking complete plumbing	US Census Bureau	US Census Bureau
	cooking/food storage	-	lacking complete kitchen facilities	US Census Bureau	US Census Bureau

Table C1: Indicator Selection and Operationalization.

OPERATIONALIZATION				DATA SOURCES	
Indicators	**Proposed components**	**Expected contribu-tion**	**Measures**	**Island States**	**US States***
	pollution incidents	-	percent of monitored beaches affected by beach action	Environmental Protection Agency	Environmental Protection Agency
	waste management	+	wastewater management facilities	US Census Bureau	US Census Bureau
Land cover and use					
	agriculture land	?	square miles of landcover with cultivated crop land/pasture and hay land classes	National Oceanic and Atmospheric Administration	National Oceanic and Atmospheric Administration
	building permits issued	?	total building permits		US Census Bureau
	developed land	-	square miles of landcover with developed land classes	National Oceanic and Atmospheric Administration	National Oceanic and Atmospheric Administration
	distribution of housing	?	total housing units	US Census Bureau	US Census Bureau
	shoreline serving as buffer	+	percent shoreline type (rocky, flats, beach, vegetated, amored)	National Oceanic and Atmospheric Administration (state level)	National Oceanic and Atmospheric Administration (state level)
	vegetated forest land	+	square miles of landcover with vegetated land classes	National Oceanic and Atmospheric Administration	National Oceanic and Atmospheric Administration

Table C1: Indicator Selection and Operationalization.

OPERATIONALIZATION				DATA SOURCES	
Indicators	**Proposed components**	**Expected contribu-tion**	**Measures**	**Island States**	**US States***
Management					
	permitting process	+			
	enforcement	+			
	responsiveness	+			
	strategies to protect resources	+	total marine protected areas (MPAs), oldest MPA	National Oceanic and Atmospheric Administration	National Oceanic and Atmospheric Administration
	management plans	+	MPAs without management plan, comprehensive plans in place, age of comprehensive plan	National Oceanic and Atmospheric Administration, County governments	National Oceanic and Atmospheric Administration, County governments
Strong institutions					
	mechanisms for institutional response	+			

Table C1: Indicator Selection and Operationalization.

OPERATIONALIZATION				DATA SOURCES	
Indicators	**Proposed components**	**Expected contribu-tion**	**Measures**	**Island States**	**US States***
	connection to community	+	average tenure in housing unit	US Census Bureau	US Census Bureau
	modes of information and access (communication)	+	no vehicle, no phone service	World Bank, US Census Bureau	US Census Bureau
	participation	+	voter turnout		Leip Election Atlas
Culture					
	language	?		US Census Bureau	US Census Bureau
	religion	?			National Center for Charitable Statistics, Association of Religious Data Archives
	family and household structure	?	average family and household size	US Census Bureau	US Census Bureau
	preservation of heritage	+	cultural heritage is primary conservation focus of MPA	National Oceanic and Atmospheric Administration	National Oceanic and Atmospheric Administration
Diversity					

Table C1: Indicator Selection and Operationalization.

OPERATIONALIZATION				DATA SOURCES	
Indicators	**Proposed components**	**Expected contribu-tion**	**Measures**	**Island States**	**US States***
	sex (female)	+	total population female	US Census Bureau	US Census Bureau
	age (elderly, youth)	+	total population 65 years and older, total population 18 years and younger	US Census Bureau	US Census Bureau
	race/ethnicity	+	total population in each racial/ethnic category	US Census Bureau	US Census Bureau
Housing					
	value	+	median value of housing unit	US Census Bureau	US Census Bureau
	cost of housing	-	median monthly selected housing costs for housing units with and without a mortgage	US Census Bureau	US Census Bureau
	age of house	-	median year built	US Census Bureau	US Census Bureau
	plumbing, flush toilet, kitchen facilities	+	lacking complete plumbing	US Census Bureau	US Census Bureau
	materials used for roof, outer walls	?	materials used for housing unit	US Census Bureau (partial)	
Economic health					
	household income	+	median household income	US Census Bureau	US Census Bureau

Table C1: Indicator Selection and Operationalization.

OPERATIONALIZATION				DATA SOURCES	
Indicators	**Proposed components**	**Expected contribu-tion**	**Measures**	**Island States**	**US States***
	poverty	-	population with income below poverty line; population under 18 with income below poverty line	US Census Bureau	US Census Bureau
	resource dependent jobs	-	jobs dependent on tourism	US Census Bureau	US Census Bureau
	revenues by industry	?		US Census Bureau	US Census Bureau
	bankruptcy	-	total bankruptcy filings for business and non-business entities	Public Access to Court Electronic Records (partial)	Public Access to Court Electronic Records
	economic diversity	+	diversity of establishments by industry	US Census Bureau	US Census Bureau
	unemployment	-		US Census Bureau	US Census Bureau
Population change					
	population change	?		World Bank (state level)	US Census Bureau
	in migration	-		US Census Bureau	US Census Bureau
	out migration	-		US Census Bureau	US Census Bureau
	births/deaths	?		US Census Bureau	US Census Bureau

Table C1: Indicator Selection and Operationalization.

OPERATIONALIZATION				DATA SOURCES	
Indicators	**Proposed components**	**Expected contribu-tion**	**Measures**	**Island States**	**US States***
	population density			US Census Bureau	US Census Bureau
Health					
	fertility or adolescent fertility rate	?		World Bank (state level)	US Census Bureau
	morbidity	-			County Health Depts
	infant mortality rate	-			US Census Bureau
	life expectancy	+		World Bank (state level)	Institute for Health Metrics and Evaluation
Support services					
	insured population	+			
	public assistance or remittance	?	households with public assistance or remittance income	US Census Bureau	US Census Bureau
	medical services and facilities	+	healthcare and social assistance establishments, hospital beds/physicians per 1000	World Bank (state level)	US Dept of Health and Human Services
	access to transportation	+	households with no vehicle	US Census Bureau	US Census Bureau

Table C1: Indicator Selection and Operationalization.

OPERATIONALIZATION				DATA SOURCES	
Indicators	**Proposed components**	**Expected contribu-tion**	**Measures**	**Island States**	**US States***
	access to communication	+	households with no phone service	World Bank, US Census Bureau	US Census Bureau
Education					
	high school attainment	+	individuals with highest education level of high school	US Census Bureau	US Census Bureau
	college (4 years) attainment	+	individuals with highest education level of bachelor's degree	US Census Bureau	US Census Bureau
	graduate (4+ years) attainment	+	individuals with highest education level of graduate degree	US Census Bureau	US Census Bureau
	expenditure	+	per student expenditure in grades K-12		National Center for Education Statistics
	enrollment	+	school age children enrolled in grades K-12	US Census Bureau	US Census Bureau

Note: * indicates that the data source applies to FL, AL, MS, LA, TX and HI counties.

APPENDIX D

INDICATOR SCORES AND QUINTILE RANKS

(Tables D1 - D4)

Table D1: Indicator Scores for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Baldwin County, Alabama	68.46	47.20	62.48	59.54	66.08	68.37	44.23
Clarke County, Alabama	76.65	44.64	70.85	41.78	53.34	31.12	44.48
Covington County, Alabama	74.41	45.53	62.60	42.30	50.07	43.82	42.51
Escambia County, Alabama	74.25	47.95	72.13	45.00	52.94	42.84	39.05
Geneva County, Alabama	74.88	53.10	62.31	45.88	54.19	48.43	34.45
Mobile County, Alabama	63.18	40.82	70.74	48.70	49.13	46.89	38.63
Monroe County, Alabama	76.20	55.76	71.02	43.94	56.00	29.82	38.56
Washington County, Alabama	76.59	58.41	71.41	45.99	56.69	41.03	49.15
Bay County, Florida	63.22	42.45	64.53	51.90	58.59	57.28	44.24
Calhoun County, Florida	76.15	59.45	67.67	44.07	58.27	48.04	45.46
Charlotte County, Florida	63.19	43.51	56.84	56.57	59.53	73.59	53.31
Citrus County, Florida	63.33	46.71	56.06	50.88	64.03	65.08	50.19
Collier County, Florida	73.32	40.23	58.17	62.72	63.29	70.80	46.26
DeSoto County, Florida	75.74	55.17	64.39	69.61	58.12	60.67	35.54
Dixie County, Florida	72.82	54.67	63.21	43.01	60.14	45.52	46.50
Escambia County, Florida	58.73	37.91	69.63	50.82	53.44	59.27	40.14
Franklin County, Florida	65.65	48.10	64.03	50.16	57.30	65.06	42.17
Gadsden County, Florida	75.23	55.53	71.18	48.99	53.93	53.57	40.71
Gilchrist County, Florida	74.88	56.40	61.99	53.50	63.66	60.38	45.36
Glades County, Florida	75.49	50.76	66.27	50.52	59.19	57.56	29.04
Gulf County, Florida	71.19	53.28	70.56	43.85	57.06	60.86	52.93
Hardee County, Florida	75.94	55.95	58.80	46.34	54.52	42.68	33.30
Hernando County, Florida	61.68	41.12	56.88	52.64	63.32	66.34	46.23
Hillsborough County, Florida	49.90	36.22	65.21	57.74	53.21	57.82	42.02
Holmes County, Florida	76.52	57.04	62.60	45.82	58.87	42.26	51.49
Jackson County, Florida	75.00	55.29	70.88	46.84	54.61	52.21	41.50
Jefferson County, Florida	77.02	58.37	72.66	55.00	56.50	44.64	39.59

Table D1: Indicator Scores for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Lafayette County, Florida	78.14	55.84	68.27	53.18	56.03	52.68	45.11
Lee County, Florida	46.62	41.63	59.75	58.63	58.34	70.44	46.66
Leon County, Florida	70.72	42.08	71.11	56.94	56.01	63.17	48.88
Levy County, Florida	70.89	53.29	62.55	48.02	63.17	55.43	48.70
Liberty County, Florida	79.09	52.53	70.79	48.15	56.05	55.55	50.87
Madison County, Florida	77.01	54.96	72.71	46.87	53.78	45.92	42.25
Manatee County, Florida	62.22	39.05	60.39	59.15	54.64	64.93	45.28
Marion County, Florida	70.10	46.98	62.26	50.93	62.69	60.61	45.03
Monroe County, Florida	57.91	38.17	61.41	61.49	56.57	63.54	47.28
Okaloosa County, Florida	65.87	39.71	64.90	58.97	58.82	67.23	45.93
Pasco County, Florida	60.45	41.98	56.74	54.32	57.81	62.87	46.60
Pinellas County, Florida	8.65	35.80	62.19	57.17	47.17	62.23	42.60
Polk County, Florida	66.61	41.03	63.96	52.70	55.93	56.37	42.18
Santa Rosa County, Florida	68.81	41.09	60.95	58.93	62.83	64.82	47.47
Sarasota County, Florida	53.24	41.95	57.03	61.63	55.24	71.68	49.48
Sumter County, Florida	75.87	49.11	64.97	50.83	68.45	60.42	48.12
Suwannee County, Florida	73.34	54.27	63.27	50.72	62.13	53.56	45.39
Taylor County, Florida	73.66	55.60	67.75	47.47	55.65	50.49	52.01
Wakulla County, Florida	73.54	51.27	64.26	56.66	63.44	59.02	51.96
Walton County, Florida	70.58	41.29	62.88	51.61	66.26	63.09	41.57
Washington County, Florida	74.42	58.55	66.20	45.97	59.00	51.98	49.29
Acadia Parish, Louisiana	70.48	48.32	64.69	41.83	49.10	42.01	35.82
Ascension Parish, Louisiana	65.48	56.27	66.23	58.08	61.81	54.87	49.85
Assumption Parish, Louisiana	74.42	48.08	69.56	45.51	54.08	38.03	40.19
Beauregard Parish, Louisiana	73.87	50.63	64.24	49.93	54.39	51.98	47.64
Calcasieu Parish, Louisiana	65.63	41.56	68.01	51.16	50.81	55.32	43.29
Cameron Parish, Louisiana	69.81	54.92	58.76	57.42	49.14	64.56	47.41

Table D1: Indicator Scores for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
East Baton Rouge Parish, Louisiana	49.73	37.27	72.23	52.15	51.76	54.68	39.97
East Feliciana Parish, Louisiana	76.77	47.76	73.92	45.26	55.09	68.25	33.94
Evangeline Parish, Louisiana	72.63	42.79	68.83	35.77	51.08	35.45	29.94
Iberia Parish, Louisiana	62.99	45.98	69.95	44.81	50.52	41.19	43.82
Iberville Parish, Louisiana	77.25	49.88	72.58	41.35	50.60	34.08	37.14
Jefferson Parish, Louisiana	42.47	39.02	68.98	52.93	48.75	57.91	30.00
Jefferson Davis Parish, Louisiana	70.05	46.93	64.70	44.22	46.62	46.22	44.31
Lafayette Parish, Louisiana	51.18	57.12	68.22	53.93	56.09	57.16	39.37
Lafourche Parish, Louisiana	68.37	45.95	64.57	52.67	51.53	48.38	41.65
Livingston Parish, Louisiana	71.81	48.50	58.45	54.19	60.99	57.33	53.52
Orleans Parish, Louisiana	28.35	36.65	69.66	38.79	27.99	25.75	36.01
Plaquemines Parish, Louisiana	57.65	48.03	69.98	51.00	50.99	44.33	36.94
Pointe Coupee Parish, Louisiana	74.92	58.25	70.78	45.35	51.49	39.84	38.71
St. Bernard Parish, Louisiana	55.74	42.16	61.41	50.91	50.32	54.15	31.28
St. Charles Parish, Louisiana	65.34	45.97	67.96	57.83	54.69	55.23	47.88
St. Helena Parish, Louisiana	75.18	55.96	71.21	42.06	59.89	26.31	33.77
St. James Parish, Louisiana	72.00	43.75	71.25	45.16	51.60	34.98	51.07
St. John the Baptist Parish, Louisiana	63.92	48.84	71.41	48.17	56.33	44.78	34.72
St. Landry Parish, Louisiana	73.60	47.46	70.69	35.87	49.94	32.65	34.35
St. Martin Parish, Louisiana	76.04	48.78	70.11	44.69	56.92	40.32	36.87
St. Mary Parish, Louisiana	64.60	49.66	70.78	40.94	48.95	32.72	43.74
St. Tammany Parish, Louisiana	65.56	54.03	62.25	62.30	61.03	66.31	41.47
Tangipahoa Parish, Louisiana	72.13	54.28	68.93	40.35	57.94	38.53	43.86
Terrebonne Parish, Louisiana	64.70	41.05	68.45	51.25	51.64	48.26	40.85
Vermilion Parish, Louisiana	69.84	58.41	64.25	46.40	51.26	49.32	38.33
Washington Parish, Louisiana	74.63	47.75	69.65	38.16	50.50	36.81	45.57
West Baton Rouge Parish, Louisiana	71.55	58.41	70.82	53.08	53.80	47.73	43.81

Table D1: Indicator Scores for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
West Feliciana Parish, Louisiana	75.30	44.77	78.14	46.52	56.74	61.74	33.47
Amite County, Mississippi	75.30	59.18	71.31	42.90	53.84	35.37	26.41
George County, Mississippi	75.82	51.82	61.06	45.20	56.79	49.70	45.97
Hancock County, Mississippi	69.54	48.60	61.19	51.47	57.06	59.72	34.79
Harrison County, Mississippi	58.64	47.08	69.11	51.17	51.84	61.82	36.17
Jackson County, Mississippi	64.61	46.84	67.83	51.03	49.83	54.79	43.80
Lamar County, Mississippi	73.44	44.83	63.11	53.43	61.69	53.21	45.95
Marion County, Mississippi	74.94	50.39	69.50	38.31	52.96	42.68	37.14
Pearl River County, Mississippi	75.08	49.91	63.09	45.13	59.05	53.24	37.47
Pike County, Mississippi	71.70	56.89	71.00	36.20	50.78	40.88	37.24
Stone County, Mississippi	75.92	55.04	66.26	43.14	56.06	40.08	39.25
Walthall County, Mississippi	74.54	46.64	71.02	34.60	56.22	34.11	36.02
Wilkinson County, Mississippi	75.30	61.10	70.69	25.40	58.36	37.82	33.98
Aransas County, Texas	61.75	60.66	57.70	47.57	54.01	55.17	35.87
Austin County, Texas	74.64	64.82	61.23	58.92	50.04	63.60	53.34
Bee County, Texas	73.84	67.41	56.54	36.17	46.62	56.45	41.60
Brazoria County, Texas	69.81	63.04	61.56	59.58	49.22	65.67	40.08
Brooks County, Texas	74.69	61.85	26.79	25.92	42.71	19.20	26.89
Calhoun County, Texas	62.41	64.88	54.21	51.68	44.82	57.62	40.74
Cameron County, Texas	59.35	60.50	31.00	30.84	54.82	41.67	29.08
Chambers County, Texas	66.13	75.45	62.08	63.12	50.57	59.82	39.63
Colorado County, Texas	74.54	73.41	62.56	53.19	44.22	54.68	44.40
DeWitt County, Texas	74.87	67.13	60.77	47.07	40.07	50.94	55.49
Duval County, Texas	74.28	58.95	30.16	38.28	49.02	29.05	40.96
Fayette County, Texas	74.44	66.34	58.97	59.49	42.33	61.48	47.45
Fort Bend County, Texas	65.95	64.01	69.89	73.74	52.58	73.72	44.83
Galveston County, Texas	49.96	59.65	64.97	56.16	42.40	58.82	60.24

Table D1: Indicator Scores for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Goliad County, Texas	75.07	62.36	54.89	62.94	47.76	53.63	41.54
Harris County, Texas	28.96	44.97	65.33	54.74	45.14	62.55	39.15
Hidalgo County, Texas	64.07	59.40	28.63	25.13	58.97	40.68	27.47
Jackson County, Texas	74.34	75.09	58.43	56.08	43.35	57.31	51.00
Jasper County, Texas	74.92	62.91	65.41	42.46	54.41	50.77	50.38
Jefferson County, Texas	61.92	58.28	71.91	45.20	38.93	55.44	43.15
Jim Hogg County, Texas	74.90	65.41	28.29	37.43	52.35	32.28	33.39
Jim Wells County, Texas	73.69	66.04	36.47	40.88	46.45	43.37	39.57
Kenedy County, Texas	67.94	60.69	37.44	61.20	55.56	60.48	26.69
Kleberg County, Texas	69.44	63.29	46.16	40.05	40.96	42.22	37.26
Lavaca County, Texas	75.20	67.99	58.57	59.71	43.34	60.91	29.81
Liberty County, Texas	75.76	65.57	63.19	48.50	53.02	55.61	43.15
Live Oak County, Texas	72.24	64.29	55.01	49.58	54.42	61.33	35.63
Matagorda County, Texas	67.87	64.23	61.26	46.60	46.91	57.64	39.38
Newton County, Texas	76.06	58.38	67.56	37.94	54.81	45.74	46.04
Nueces County, Texas	60.15	59.11	49.12	45.83	41.25	51.84	36.78
Orange County, Texas	63.29	67.09	61.49	48.23	47.25	52.43	47.86
Refugio County, Texas	74.07	79.00	53.32	49.39	36.11	44.17	44.45
San Patricio County, Texas	71.68	67.86	50.16	45.57	46.04	43.98	40.49
Starr County, Texas	73.07	62.74	21.93	1.23	62.67	24.74	19.24
Tyler County, Texas	76.36	64.52	64.02	43.20	52.68	60.14	52.32
Victoria County, Texas	73.23	61.79	54.79	54.08	47.65	62.31	35.66
Waller County, Texas	73.84	71.83	69.15	52.09	53.61	57.37	52.13
Washington County, Texas	73.89	62.60	66.00	55.52	50.44	59.14	40.99
Webb County, Texas	72.69	61.55	24.73	35.76	56.91	37.05	26.22
Wharton County, Texas	74.72	64.37	60.74	51.69	41.55	55.46	39.65
Willacy County, Texas	68.25	67.21	32.73	21.03	46.85	29.40	29.27

Table D2: Indicator Scores for Island State Communities

Island Communities	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Hawaii County, Hawaii	73.48	65.22	75.34	82.00	55.72	85.23	66.92
Honolulu County, Hawaii	31.91	74.66	73.05	94.42	51.11	82.64	70.04
Kalawao County, Hawaii	52.34	69.55	68.69	19.59	34.54	39.57	37.09
Kauai County, Hawaii	64.28	71.14	73.85	87.40	59.27	89.53	63.96
Maui County, Hawaii	65.58	72.45	74.44	91.70	56.51	84.97	67.18
Eastern District, American Samoa	*a*	48.53	52.18	44.25	53.67	54.94	46.33
Manua District, American Samoa	49.91	45.57	46.81	26.52	67.75	61.28	46.60
Western District, American Samoa	39.10	53.42	52.12	42.39	63.09	51.54	42.97
Guam, Guam	33.98	69.74	70.18	77.96	57.33	66.42	57.60
Northern Islands Municipality, Northern Mariana Islands	50.69	57.81	45.37	13.29	38.30	50.00	62.22
Rota Municipality, Northern Mariana Islands	51.47	55.13	69.48	62.23	65.69	32.99	60.57
Saipan Municipality, Northern Mariana Islands	33.05	60.84	63.75	54.92	72.56	33.26	62.01
Tinian Municipality, Northern Mariana Islands	52.52	77.02	72.20	55.81	73.69	23.09	66.50
Adjuntas Municipio, Puerto Rico	*a*	73.96	50.03	32.32	49.18	40.95	44.13
Aguada Municipio, Puerto Rico	*a*	74.90	54.46	35.49	51.14	46.89	47.06
Aguadilla Municipio, Puerto Rico	*a*	75.19	57.27	40.01	43.86	51.37	52.01
Aguas Buenas Municipio, Puerto Rico	*a*	72.43	57.63	41.72	55.54	43.14	47.70
Aibonito Municipio, Puerto Rico	*a*	78.59	54.04	41.59	56.24	54.57	54.23
Añasco Municipio, Puerto Rico	*a*	72.66	56.16	42.10	51.13	44.24	50.69
Arecibo Municipio, Puerto Rico	*a*	73.71	54.06	42.04	53.39	52.83	55.91
Arroyo Municipio, Puerto Rico	*a*	73.19	68.52	36.79	54.99	41.42	54.87
Barceloneta Municipio, Puerto Rico	*a*	75.44	58.26	36.80	55.28	44.32	48.28
Barranquitas Municipio, Puerto Rico	*a*	78.37	53.63	34.34	58.68	47.73	47.62

Table D2: Indicator Scores for Island State Communities

Island Communities	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Bayamón Municipio, Puerto Rico	*a*	74.40	56.02	55.83	49.72	62.72	58.73
Cabo Rojo Municipio, Puerto Rico	*a*	75.42	54.09	44.56	59.58	52.01	52.74
Caguas Municipio, Puerto Rico	*a*	75.18	55.60	49.90	52.70	58.04	55.56
Camuy Municipio, Puerto Rico	*a*	77.07	52.64	41.24	58.06	43.07	48.92
Canóvanas Municipio, Puerto Rico	*a*	73.77	65.62	40.28	55.42	42.20	46.29
Carolina Municipio, Puerto Rico	*a*	74.02	62.22	57.87	50.55	52.01	60.78
Cataño Municipio, Puerto Rico	*a*	73.68	63.75	45.07	46.85	37.96	50.08
Cayey Municipio, Puerto Rico	*a*	75.39	54.46	43.31	54.17	48.94	52.79
Ceiba Municipio, Puerto Rico	*a*	80.74	65.61	51.55	54.55	48.20	52.12
Ciales Municipio, Puerto Rico	*a*	79.52	52.31	33.60	58.10	41.73	43.00
Cidra Municipio, Puerto Rico	*a*	78.25	57.72	46.61	58.21	46.80	52.91
Coamo Municipio, Puerto Rico	*a*	73.43	58.22	38.37	57.61	41.28	52.06
Comerío Municipio, Puerto Rico	*a*	80.10	54.62	32.93	52.24	36.81	43.07
Corozal Municipio, Puerto Rico	*a*	77.00	52.55	37.03	55.85	46.60	46.65
Culebra Municipio, Puerto Rico	*a*	72.62	68.43	49.39	56.03	25.76	53.22
Dorado Municipio, Puerto Rico	*a*	74.96	61.28	50.49	54.32	48.08	54.02
Fajardo Municipio, Puerto Rico	*a*	76.73	61.03	49.17	53.35	53.74	56.21
Florida Municipio, Puerto Rico	*a*	72.73	52.19	35.79	56.95	41.96	46.61
Guánica Municipio, Puerto Rico	*a*	72.14	56.57	34.06	54.01	37.24	46.05
Guayama Municipio, Puerto Rico	*a*	71.86	61.89	41.00	53.33	50.38	53.43
Guayanilla Municipio, Puerto Rico	*a*	75.01	58.53	37.09	53.10	39.50	51.54
Guaynabo Municipio, Puerto Rico	*a*	74.11	58.48	64.39	52.32	60.48	64.15
Gurabo Municipio, Puerto Rico	*a*	76.75	60.25	50.86	58.17	46.29	53.78
Hatillo Municipio, Puerto Rico	*a*	73.27	52.92	37.02	57.33	47.02	49.14
Hormigueros Municipio, Puerto Rico	*a*	77.06	54.73	49.62	56.40	55.71	57.95
Humacao Municipio, Puerto Rico	*a*	75.52	62.86	45.85	54.61	56.99	53.96
Isabela Municipio, Puerto Rico	*a*	74.34	54.57	38.22	56.59	46.80	51.53

Table D2: Indicator Scores for Island State Communities

Island Communities	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Jayuya Municipio, Puerto Rico	*a*	75.50	52.39	31.31	56.80	38.38	46.63
Juana Díaz Municipio, Puerto Rico	*a*	73.67	59.77	38.45	57.23	42.00	54.11
Juncos Municipio, Puerto Rico	*a*	78.29	56.46	38.87	56.27	45.51	50.59
Lajas Municipio, Puerto Rico	*a*	79.23	55.37	37.23	48.74	44.52	49.78
Lares Municipio, Puerto Rico	*a*	75.35	50.00	29.90	49.64	43.26	44.06
Las Marías Municipio, Puerto Rico	*a*	77.66	52.12	29.42	52.88	42.25	44.58
Las Piedras Municipio, Puerto Rico	*a*	73.94	57.06	45.38	57.47	49.47	49.94
Loíza Municipio, Puerto Rico	*a*	79.23	65.13	35.27	57.29	31.65	46.78
Luquillo Municipio, Puerto Rico	*a*	76.59	63.73	43.92	55.22	43.08	51.17
Manatí Municipio, Puerto Rico	*a*	74.91	55.51	41.84	54.32	61.74	50.70
Maricao Municipio, Puerto Rico	*a*	91.60	53.25	30.55	51.55	32.97	40.50
Maunabo Municipio, Puerto Rico	*a*	86.49	66.40	35.72	48.49	38.52	49.74
Mayagüez Municipio, Puerto Rico	*a*	75.79	56.94	41.64	51.65	55.04	52.40
Moca Municipio, Puerto Rico	*a*	74.49	53.13	36.68	51.27	48.20	49.49
Morovis Municipio, Puerto Rico	*a*	82.11	51.89	36.45	59.87	41.68	44.73
Naguabo Municipio, Puerto Rico	*a*	76.18	61.08	38.01	54.36	36.48	50.35
Naranjito Municipio, Puerto Rico	*a*	78.04	52.74	37.77	56.37	50.47	46.62
Orocovis Municipio, Puerto Rico	*a*	81.56	58.65	31.13	58.40	41.65	46.55
Patillas Municipio, Puerto Rico	*a*	78.16	64.92	36.00	48.65	41.14	53.33
Peñuelas Municipio, Puerto Rico	*a*	76.81	57.01	38.07	59.56	39.63	48.53
Ponce Municipio, Puerto Rico	*a*	72.78	56.63	43.02	52.02	53.63	55.75
Quebradillas Municipio, Puerto Rico	*a*	75.68	51.26	39.41	56.23	48.00	48.65
Rincón Municipio, Puerto Rico	*a*	76.56	53.31	36.14	59.13	43.23	52.30
Río Grande Municipio, Puerto Rico	*a*	80.19	64.83	45.02	57.16	44.67	51.11
Sabana Grande Municipio, Puerto Rico	*a*	77.45	53.84	41.22	49.13	43.40	52.91
Salinas Municipio, Puerto Rico	*a*	74.55	60.86	36.88	55.75	41.90	51.07
San Germán Municipio, Puerto Rico	*a*	74.70	55.15	42.82	56.85	55.99	57.11

Table D2: Indicator Scores for Island State Communities

Island Communities	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
San Juan Municipio, Puerto Rico	*a*	73.68	60.40	52.81	44.74	56.56	61.10
San Lorenzo Municipio, Puerto Rico	*a*	74.02	58.48	38.74	55.01	43.38	46.87
San Sebastián Municipio, Puerto Rico	*a*	76.12	51.52	35.74	50.35	50.61	46.22
Santa Isabel Municipio, Puerto Rico	*a*	75.45	61.03	38.82	54.64	38.80	53.26
Toa Alta Municipio, Puerto Rico	*a*	78.11	57.66	52.78	59.69	50.23	52.55
Toa Baja Municipio, Puerto Rico	*a*	73.51	60.73	52.70	53.40	49.24	53.77
Trujillo Alto Municipio, Puerto Rico	*a*	73.41	59.65	58.46	55.28	50.98	57.32
Utuado Municipio, Puerto Rico	*a*	74.92	50.76	32.66	49.00	42.01	47.05
Vega Alta Municipio, Puerto Rico	*a*	74.69	53.80	42.42	56.39	47.10	44.73
Vega Baja Municipio, Puerto Rico	*a*	74.05	54.42	41.83	54.82	46.95	48.02
Vieques Municipio, Puerto Rico	*a*	84.66	62.28	30.62	53.92	37.14	50.64
Villalba Municipio, Puerto Rico	*a*	75.09	58.28	34.80	50.13	43.16	47.96
Yabucoa Municipio, Puerto Rico	*a*	72.60	64.36	38.50	45.80	45.46	49.29
Yauco Municipio, Puerto Rico	*a*	72.67	53.57	37.45	47.57	46.45	51.72
St. Croix Island, Virgin Islands of the United States	37.50	53.35	60.72	57.62	56.38	53.42	48.91
St. John Island, Virgin Islands of the United States	40.07	44.27	65.47	74.08	68.62	55.28	63.58
St. Thomas Island, Virgin Islands of the United States	36.67	53.70	57.59	65.30	55.91	51.35	54.65

Notes: For Land cover & use, *a* indicates that a score was not computed due to lack of available data.

Table D3: Indicator Quintile Rankings for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Baldwin County, Alabama	4	4	4	1	1	1	2
Clarke County, Alabama	1	5	1	5	3	5	2
Covington County, Alabama	2	4	3	5	4	4	3
Escambia County, Alabama	2	4	1	4	3	4	4
Geneva County, Alabama	2	3	4	4	3	4	5
Mobile County, Alabama	5	5	1	3	4	4	4
Monroe County, Alabama	1	3	1	4	2	5	4
Washington County, Alabama	1	2	1	4	2	5	1
Bay County, Florida	5	5	3	2	1	2	2
Calhoun County, Florida	1	2	2	4	2	4	2
Charlotte County, Florida	5	5	5	1	1	1	1
Citrus County, Florida	4	4	5	3	1	1	1
Collier County, Florida	3	5	5	1	1	1	2
DeSoto County, Florida	1	3	3	1	2	2	5
Dixie County, Florida	3	3	3	4	1	4	2
Escambia County, Florida	5	5	2	3	3	2	3
Franklin County, Florida	4	4	3	3	2	1	3
Gadsden County, Florida	1	3	1	3	3	3	3
Gilchrist County, Florida	2	2	4	2	1	2	2
Glades County, Florida	1	3	2	3	1	2	5
Gulf County, Florida	3	3	2	4	2	2	1
Hardee County, Florida	1	3	4	4	3	4	5
Hernando County, Florida	5	5	5	2	1	1	2
Hillsborough County, Florida	5	5	3	1	3	2	3
Holmes County, Florida	1	2	3	4	1	4	1
Jackson County, Florida	2	3	1	3	3	3	3
Jefferson County, Florida	1	2	1	2	2	4	4

Table D3: Indicator Quintile Rankings for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Lafayette County, Florida	1	3	2	2	2	3	2
Lee County, Florida	5	5	4	1	2	1	2
Leon County, Florida	3	5	1	1	2	1	1
Levy County, Florida	3	3	4	3	1	3	1
Liberty County, Florida	1	3	1	3	2	3	1
Madison County, Florida	1	3	1	3	3	4	3
Manatee County, Florida	5	5	4	1	3	1	2
Marion County, Florida	3	4	4	3	1	2	2
Monroe County, Florida	5	5	4	1	2	1	2
Okaloosa County, Florida	4	5	3	1	1	1	2
Pasco County, Florida	5	5	5	2	2	1	2
Pinellas County, Florida	5	5	4	1	5	1	3
Polk County, Florida	4	5	3	2	2	2	3
Santa Rosa County, Florida	4	5	4	1	1	1	1
Sarasota County, Florida	5	5	5	1	3	1	1
Sumter County, Florida	1	4	3	3	1	2	1
Suwannee County, Florida	3	3	3	3	1	3	2
Taylor County, Florida	3	3	2	3	2	3	1
Wakulla County, Florida	3	3	3	1	1	2	1
Walton County, Florida	3	5	3	2	1	1	3
Washington County, Florida	2	2	3	4	1	3	1
Acadia Parish, Louisiana	3	4	3	5	4	4	5
Ascension Parish, Louisiana	4	2	2	1	1	3	1
Assumption Parish, Louisiana	2	4	2	4	3	5	3
Beauregard Parish, Louisiana	2	3	3	3	3	3	1
Calcasieu Parish, Louisiana	4	5	2	2	4	3	3
Cameron Parish, Louisiana	4	3	4	1	4	1	2

Table D3: Indicator Quintile Rankings for Gulf of Mexico Coastal Counties

Coastal Counties	**Land cover & use**	**Waste accumulation & treatment**	**Population diversity**	**Economic security**	**Housing adequacy**	**Access to support services**	**Education**
East Baton Rouge Parish, Louisiana	5	5	1	2	4	3	4
East Feliciana Parish, Louisiana	1	4	1	4	3	1	5
Evangeline Parish, Louisiana	3	5	2	5	4	5	5
Iberia Parish, Louisiana	5	4	2	4	4	4	3
Iberville Parish, Louisiana	1	3	1	5	4	5	4
Jefferson Parish, Louisiana	5	5	2	2	5	2	5
Jefferson Davis Parish, LALouisiana	3	4	3	4	5	4	2
Lafayette Parish, Louisiana	5	2	2	2	2	2	4
Lafourche Parish, Louisiana	4	4	3	2	4	4	3
Livingston Parish, Louisiana	3	4	4	2	1	2	1
Orleans Parish, Louisiana	5	5	2	5	5	5	4
Plaquemines Parish, Louisiana	5	4	2	3	4	4	4
Pointe Coupee Parish, Louisiana	2	2	1	4	4	5	4
St. Bernard Parish, Louisiana	5	5	4	3	4	3	5
St. Charles Parish, Louisiana	4	4	2	1	3	3	1
St. Helena Parish, Louisiana	1	3	1	5	1	5	5
St. James Parish, Louisiana	3	5	1	4	4	5	1
St. John the Baptist Parish, Louisiana	4	4	1	3	2	4	5
St. Landry Parish, Louisiana	3	4	1	5	4	5	5
St. Martin Parish, Louisiana	1	4	2	4	2	5	4
St. Mary Parish, Louisiana	4	3	1	5	5	5	3
St. Tammany Parish, Louisiana	4	3	4	1	1	1	3
Tangipahoa Parish, Louisiana	3	3	2	5	2	5	2
Terrebonne Parish, Louisiana	4	5	2	2	4	4	3
Vermilion Parish, Louisiana	4	2	3	4	4	4	4

Table D3: Indicator Quintile Rankings for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Washington Parish, Louisiana	2	4	2	5	4	5	2
West Baton Rouge Parish, Louisiana	3	2	1	2	3	4	3
West Feliciana Parish, Louisiana	1	4	1	3	2	1	5
Amite County, Mississippi	1	2	1	4	3	5	5
George County, Mississippi	1	3	4	4	2	4	2
Hancock County, Mississippi	4	4	4	2	2	2	5
Harrison County, Mississippi	5	4	2	2	4	1	4
Jackson County, Mississippi	4	4	2	3	4	3	3
Lamar County, Mississippi	3	4	3	2	1	3	2
Marion County, Mississippi	2	3	2	5	3	4	4
Pearl River County, Mississippi	2	3	3	4	1	3	4
Pike County, Mississippi	3	2	1	5	4	5	4
Stone County, Mississippi	1	3	2	4	2	5	4
Walthall County, Mississippi	2	4	1	5	2	5	4
Wilkinson County, Mississippi	1	2	1	5	2	5	5
Aransas County, Texas	5	2	5	3	3	3	4
Austin County, Texas	2	1	4	1	4	1	1
Bee County, Texas	3	1	5	5	5	2	3
Brazoria County, Texas	4	1	4	1	4	1	4
Brooks County, Texas	2	2	5	5	5	5	5
Calhoun County, Texas	5	1	5	2	5	2	3
Cameron County, Texas	5	2	5	5	3	4	5
Chambers County, Texas	4	1	4	1	4	2	4
Colorado County, Texas	2	1	4	2	5	3	2
DeWitt County, Texas	2	1	4	3	5	3	1
Duval County, Texas	2	2	5	5	4	5	3

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Table D3: Indicator Quintile Rankings for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Fayette County, Texas	2	1	4	1	5	1	2
Fort Bend County, Texas	4	1	2	1	3	1	2
Galveston County, Texas	5	2	3	1	5	2	1
Goliad County, Texas	2	2	5	1	5	3	3
Harris County, Texas	5	4	3	2	5	1	4
Hidalgo County, Texas	4	2	5	5	1	5	5
Jackson County, Texas	2	1	5	2	5	2	1
Jasper County, Texas	2	1	3	4	3	3	1
Jefferson County, Texas	5	2	1	4	5	3	3
Jim Hogg County, Texas	2	1	5	5	4	5	5
Jim Wells County, Texas	3	1	5	5	5	4	4
Kenedy County, Texas	4	2	5	1	2	2	5
Kleberg County, Texas	4	1	5	5	5	4	4
Lavaca County, Texas	1	1	4	1	5	2	5
Liberty County, Texas	1	1	3	3	3	3	3
Live Oak County, Texas	3	1	5	3	3	2	5
Matagorda County, Texas	4	1	4	3	5	2	4
Newton County, Texas	1	2	2	5	3	4	2
Nueces County, Texas	5	2	5	4	5	3	4
Orange County, Texas	4	1	4	3	5	3	1
Refugio County, Texas	2	1	5	3	5	4	2
San Patricio County, Texas	3	1	5	4	5	4	3
Starr County, Texas	3	1	5	5	1	5	5
Tyler County, Texas	1	1	3	4	3	2	1
Victoria County, Texas	3	2	5	2	5	1	5
Waller County, Texas	2	1	2	2	3	2	1
Washington County, Texas	2	1	3	2	4	2	3

Table D3: Indicator Quintile Rankings for Gulf of Mexico Coastal Counties

Coastal Counties	Land cover & use	Waste accumulation & treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Webb County, Texas	3	2	5	5	2	5	5
Wharton County, Texas	2	1	4	2	5	3	4
Willacy County, Texas	4	1	5	5	5	5	5

Table D4: Indicator Quintile Rankings for Island State Communities

Island Communities	Land cover and use	Waste accumulation and treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Hawaii County, Hawaii	1	5	1	1	3	1	1
Honolulu County, Hawaii	5	3	1	1	5	1	1
Kalawao County, Hawaii	2	5	1	5	5	5	5
Kauai County, Hawaii	1	5	1	1	1	1	1
Maui County, Hawaii	1	5	1	1	2	1	1
Eastern District, American Samoa	*a*	5	5	2	4	1	5
Manua District, American Samoa	3	5	5	5	1	1	5
Western District, American Samoa	4	5	5	3	1	2	5
Guam, Guam	5	5	1	1	2	1	1
Northern Islands Municipality, Northern Mariana Islands	3	5	5	5	5	2	1
Rota Municipality, Northern Mariana Islands	2	5	1	1	1	5	1
Saipan Municipality, Northern Mariana Islands	5	5	2	1	1	5	1
Tinian Municipality, Northern Mariana Islands	2	2	1	1	1	5	1
Adjuntas Municipio, Puerto Rico	*a*	4	5	5	5	5	5
Aguada Municipio, Puerto Rico	*a*	3	4	5	4	3	4
Aguadilla Municipio, Puerto Rico	*a*	3	3	3	5	2	3
Aguas Buenas Municipio, Puerto Rico	*a*	5	3	3	3	4	4
Aibonito Municipio, Puerto Rico	*a*	1	4	3	2	1	2
Añasco Municipio, Puerto Rico	*a*	4	3	3	4	3	3
Arecibo Municipio, Puerto Rico	*a*	4	4	3	4	2	2
Arroyo Municipio, Puerto Rico	*a*	4	1	4	3	4	2
Barceloneta Municipio, Puerto Rico	*a*	2	3	4	3	3	4
Barranquitas Municipio, Puerto Rico	*a*	1	4	5	1	3	4
Bayamón Municipio, Puerto Rico	*a*	3	3	1	5	1	1

Table D4: Indicator Quintile Rankings for Island State Communities

Island Communities	Land cover and use	Waste accumulation and treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Cabo Rojo Municipio, Puerto Rico	*a*	3	4	2	1	2	2
Caguas Municipio, Puerto Rico	*a*	3	4	2	4	1	2
Camuy Municipio, Puerto Rico	*a*	2	5	3	1	4	4
Canóvanas Municipio, Puerto Rico	*a*	4	1	3	3	4	5
Carolina Municipio, Puerto Rico	*a*	4	2	1	5	2	1
Cataño Municipio, Puerto Rico	*a*	4	2	2	5	5	3
Cayey Municipio, Puerto Rico	*a*	3	4	2	4	2	2
Ceiba Municipio, Puerto Rico	*a*	1	1	2	3	3	3
Ciales Municipio, Puerto Rico	*a*	1	5	5	1	4	5
Cidra Municipio, Puerto Rico	*a*	1	3	2	1	3	2
Coamo Municipio, Puerto Rico	*a*	4	3	4	2	4	3
Comerío Municipio, Puerto Rico	*a*	1	4	5	4	5	5
Corozal Municipio, Puerto Rico	*a*	2	5	4	3	3	4
Culebra Municipio, Puerto Rico	*a*	5	1	2	3	5	2
Dorado Municipio, Puerto Rico	*a*	3	2	2	3	3	2
Fajardo Municipio, Puerto Rico	*a*	2	2	2	4	2	1
Florida Municipio, Puerto Rico	*a*	4	5	4	2	4	5
Guánica Municipio, Puerto Rico	*a*	5	3	5	4	5	5
Guayama Municipio, Puerto Rico	*a*	5	2	3	4	2	2
Guayanilla Municipio, Puerto Rico	*a*	3	3	4	4	5	3
Guaynabo Municipio, Puerto Rico	*a*	3	3	1	4	1	1
Gurabo Municipio, Puerto Rico	*a*	2	2	2	1	3	2
Hatillo Municipio, Puerto Rico	*a*	4	5	4	2	3	4
Hormigueros Municipio, Puerto Rico	*a*	2	4	2	2	1	1
Humacao Municipio, Puerto Rico	*a*	2	2	2	3	1	2
Isabela Municipio, Puerto Rico	*a*	3	4	4	2	3	3
Jayuya Municipio, Puerto Rico	*a*	2	5	5	2	5	5

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Table D4: Indicator Quintile Rankings for Island State Communities

Island Communities	Land cover and use	Waste accumulation and treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
Juana Díaz Municipio, Puerto Rico	*a*	4	2	3	2	4	2
Juncos Municipio, Puerto Rico	*a*	1	3	3	2	3	3
Lajas Municipio, Puerto Rico	*a*	1	4	4	5	3	4
Lares Municipio, Puerto Rico	*a*	3	5	5	5	4	5
Las Marías Municipio, Puerto Rico	*a*	2	5	5	4	4	5
Las Piedras Municipio, Puerto Rico	*a*	4	3	2	2	2	3
Loíza Municipio, Puerto Rico	*a*	1	1	5	2	5	4
Luquillo Municipio, Puerto Rico	*a*	2	2	2	3	4	3
Manatí Municipio, Puerto Rico	*a*	3	4	3	3	1	3
Maricao Municipio, Puerto Rico	*a*	1	4	5	4	5	5
Maunabo Municipio, Puerto Rico	*a*	1	1	5	5	5	4
Mayagüez Municipio, Puerto Rico	*a*	2	3	3	4	1	3
Moca Municipio, Puerto Rico	*a*	3	5	4	4	2	4
Morovis Municipio, Puerto Rico	*a*	1	5	4	1	4	5
Naguabo Municipio, Puerto Rico	*a*	2	2	4	3	5	3
Naranjito Municipio, Puerto Rico	*a*	1	5	4	2	2	5
Orocovis Municipio, Puerto Rico	*a*	1	2	5	1	4	5
Patillas Municipio, Puerto Rico	*a*	1	1	4	5	5	2
Peñuelas Municipio, Puerto Rico	*a*	2	3	4	1	5	4
Ponce Municipio, Puerto Rico	*a*	4	3	2	4	2	2
Quebradillas Municipio, Puerto Rico	*a*	2	5	3	2	3	4
Rincón Municipio, Puerto Rico	*a*	2	4	4	1	4	3
Río Grande Municipio, Puerto Rico	*a*	1	1	2	2	3	3
Sabana Grande Municipio, Puerto Rico	*a*	2	4	3	5	4	2
Salinas Municipio, Puerto Rico	*a*	3	2	4	3	4	3
San Germán Municipio, Puerto Rico	*a*	3	4	2	2	1	1
San Juan Municipio, Puerto Rico	*a*	4	2	1	5	1	1

Table D4: Indicator Quintile Rankings for Island State Communities

Island Communities	Land cover and use	Waste accumulation and treatment	Population diversity	Economic security	Housing adequacy	Access to support services	Education
San Lorenzo Municipio, Puerto Rico	*a*	4	3	3	3	4	4
San Sebastián Municipio, Puerto Rico	*a*	2	5	4	5	2	5
Santa Isabel Municipio, Puerto Rico	*a*	2	2	3	3	5	2
Toa Alta Municipio, Puerto Rico	*a*	1	3	1	1	2	3
Toa Baja Municipio, Puerto Rico	*a*	4	2	1	4	2	2
Trujillo Alto Municipio, Puerto Rico	*a*	4	2	1	3	2	1
Utuado Municipio, Puerto Rico	*a*	3	5	5	5	4	4
Vega Alta Municipio, Puerto Rico	*a*	3	4	2	2	3	5
Vega Baja Municipio, Puerto Rico	*a*	4	4	3	3	3	4
Vieques Municipio, Puerto Rico	*a*	1	2	5	4	5	3
Villalba Municipio, Puerto Rico	*a*	3	3	5	5	4	4
Yabucoa Municipio, Puerto Rico	*a*	5	1	3	5	3	4
Yauco Municipio, Puerto Rico	*a*	4	4	4	5	3	3
St. Croix Island, Virgin Islands of the United States	4	5	2	1	2	2	4
St. John Island, Virgin Islands of the United States	3	5	1	1	1	1	1
St. Thomas Island, Virgin Islands of the United States	4	5	3	1	3	2	2

Notes: For Land cover & use, *a* indicates that a score was not computed due to lack of available data.

APPENDIX E

MAPS OF INDICATORS

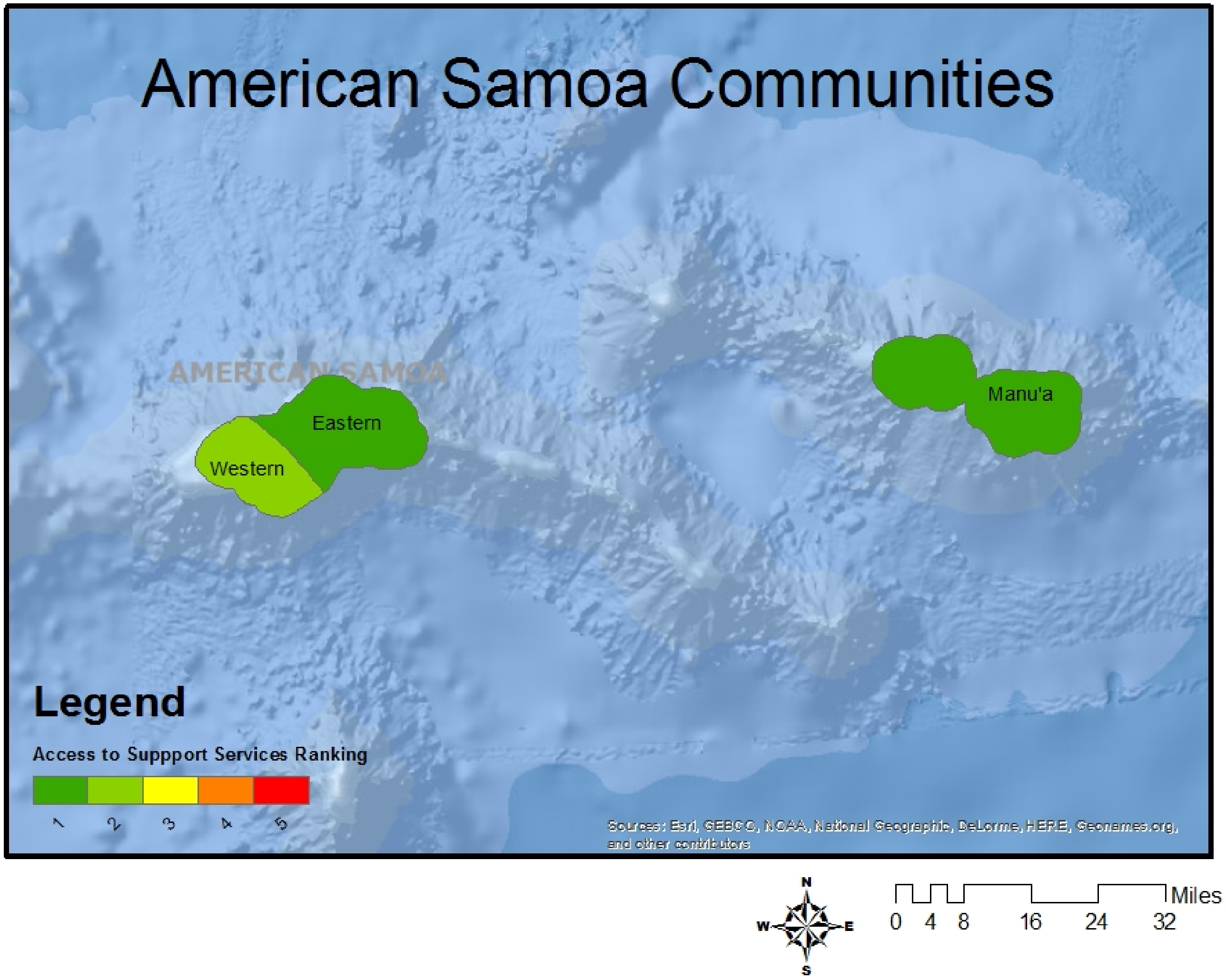

Figure E1: Social -Ecological Resilience Indicators: Access to Support Services Ranking for American Samoa Communities.

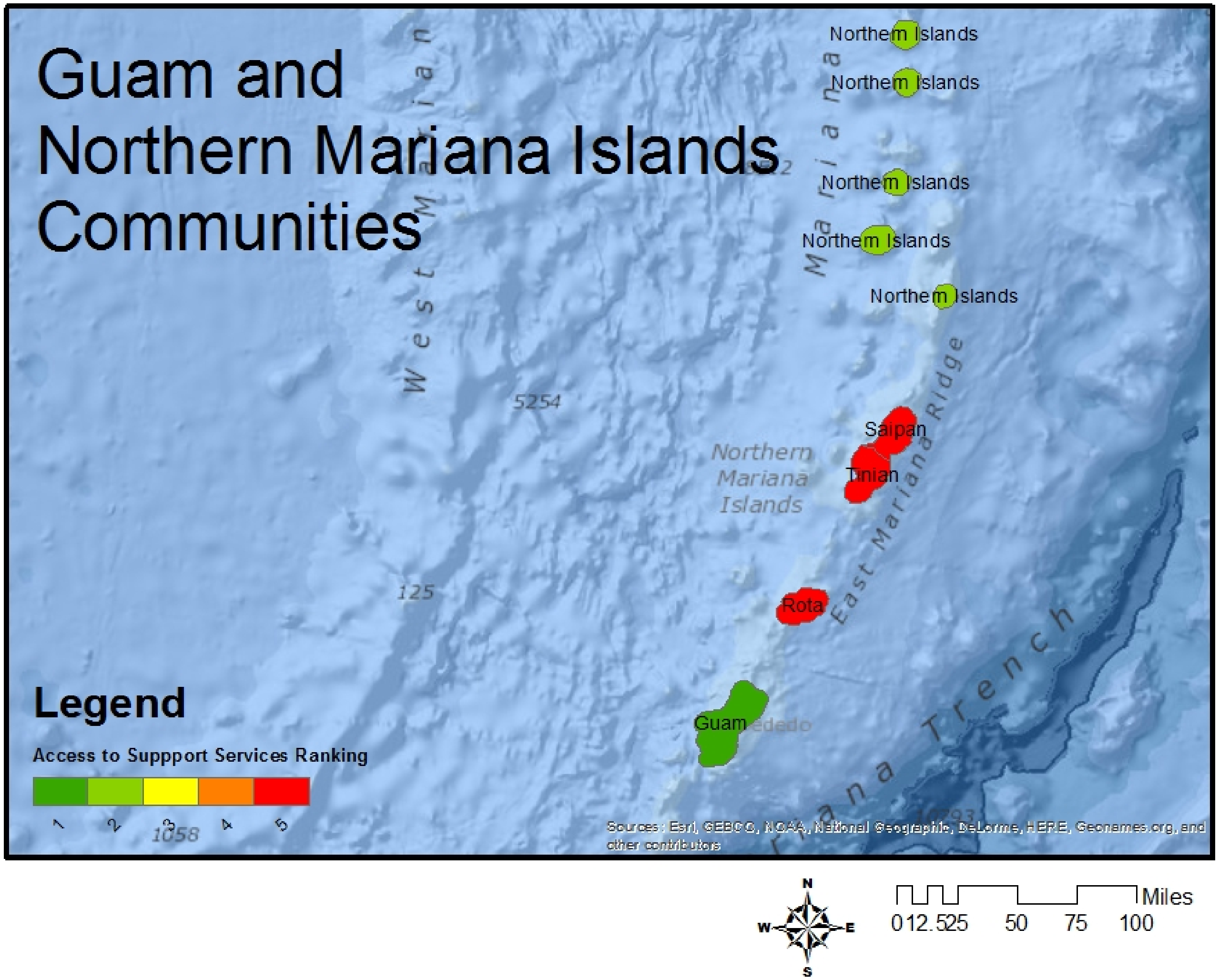

Figure E2: Social -Ecological Resilience Indicators: Access to Support Services Ranking for Guam & CNMI Communities.

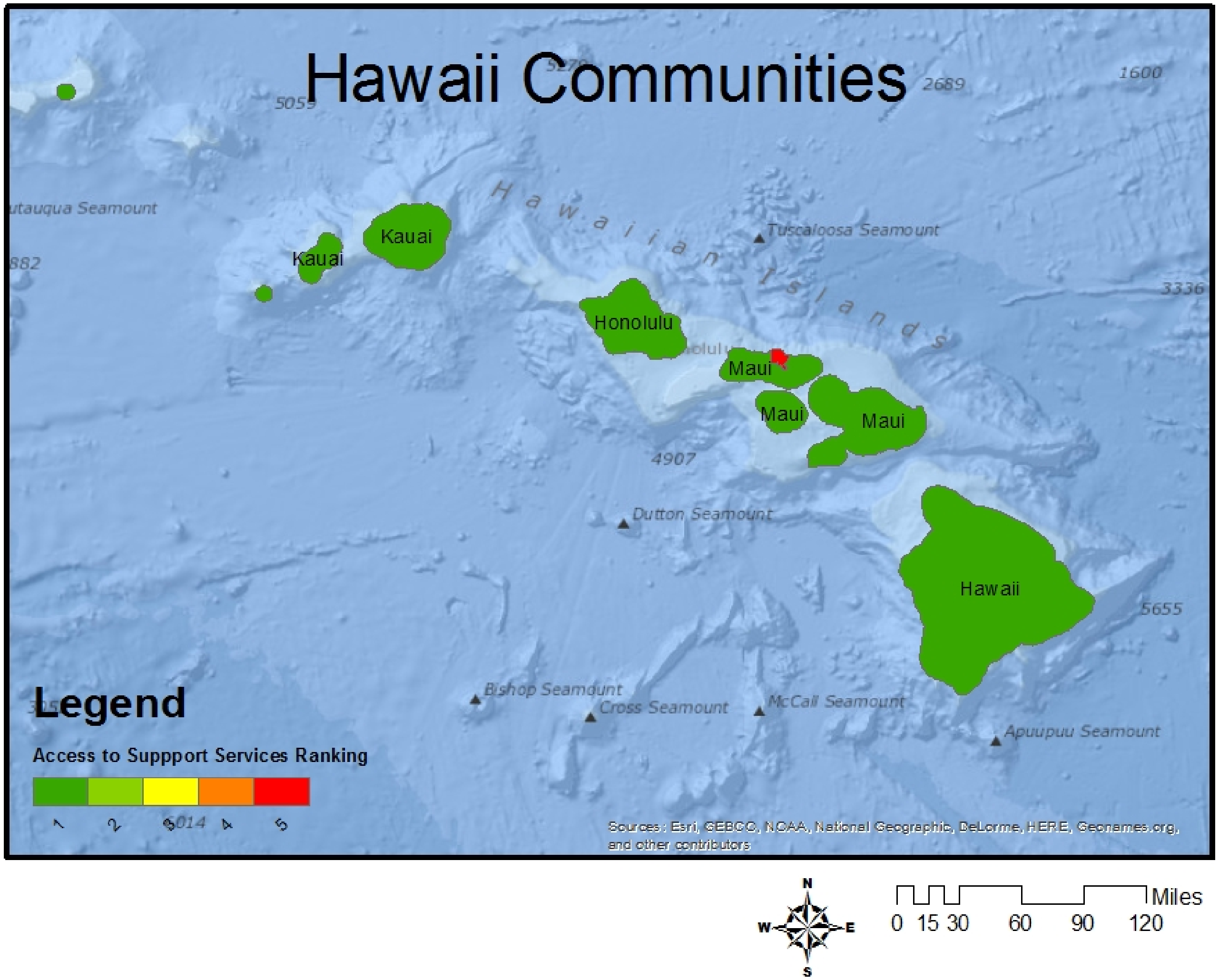

Figure E3: Social -Ecological Resilience Indicators: Access to Support Services Ranking for Hawaii Communities.

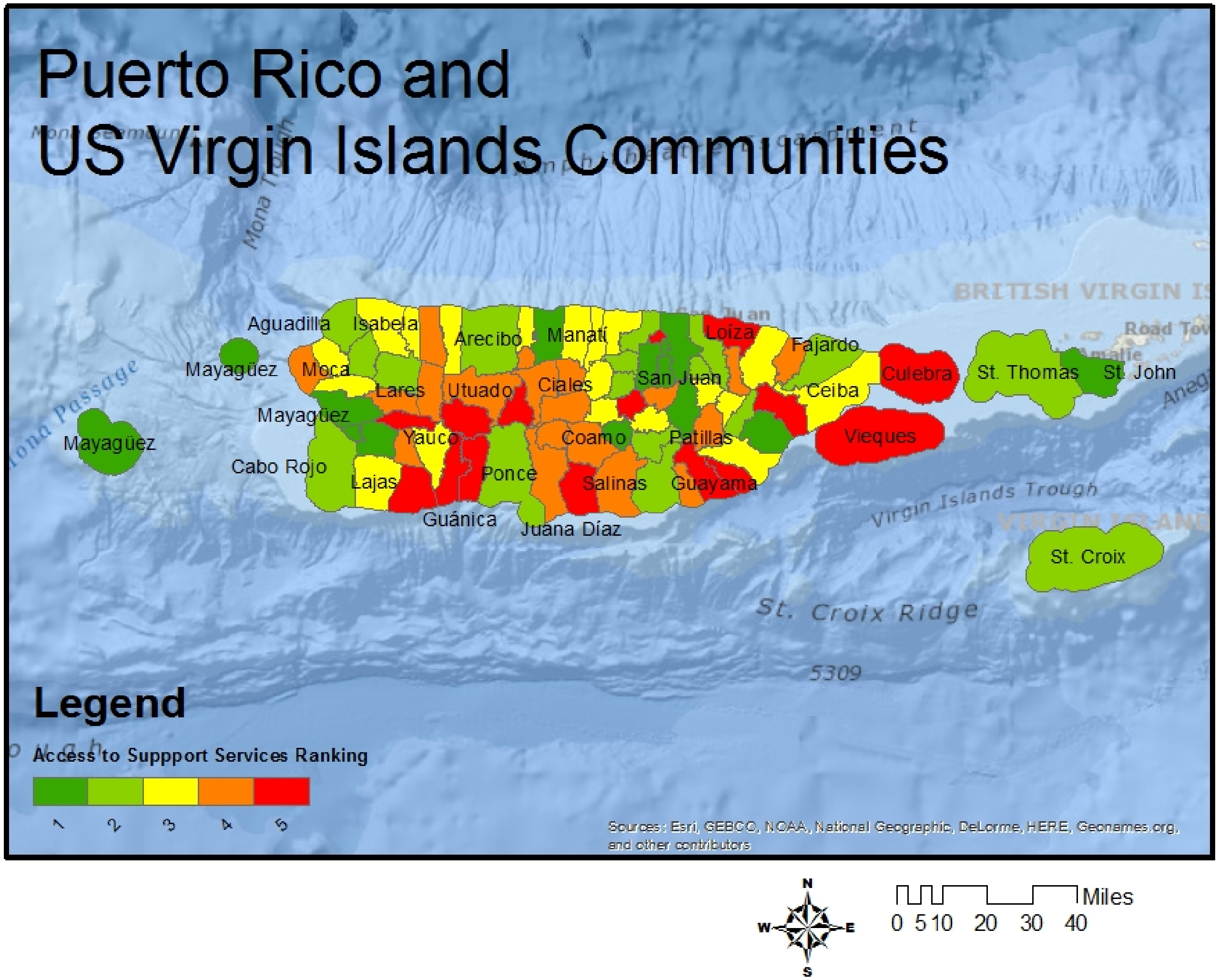

Figure E4: Social -Ecological Resilience Indicators: Access to Support Services Ranking for Puerto Rico & USVI Communities.

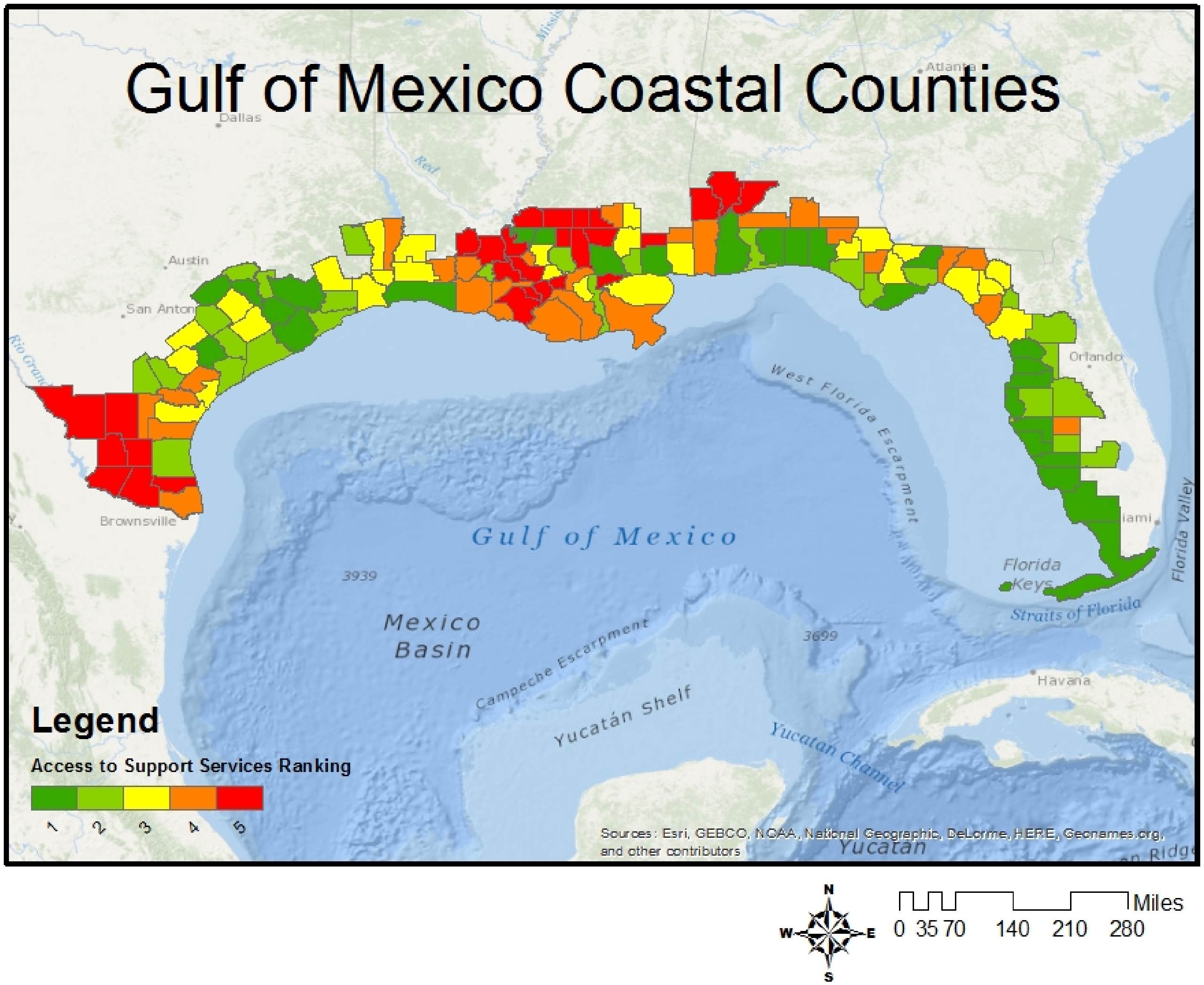

Figure E5: Social -Ecological Resilience Indicators: Access to Support Services Ranking for Gulf of Mexico Communities.

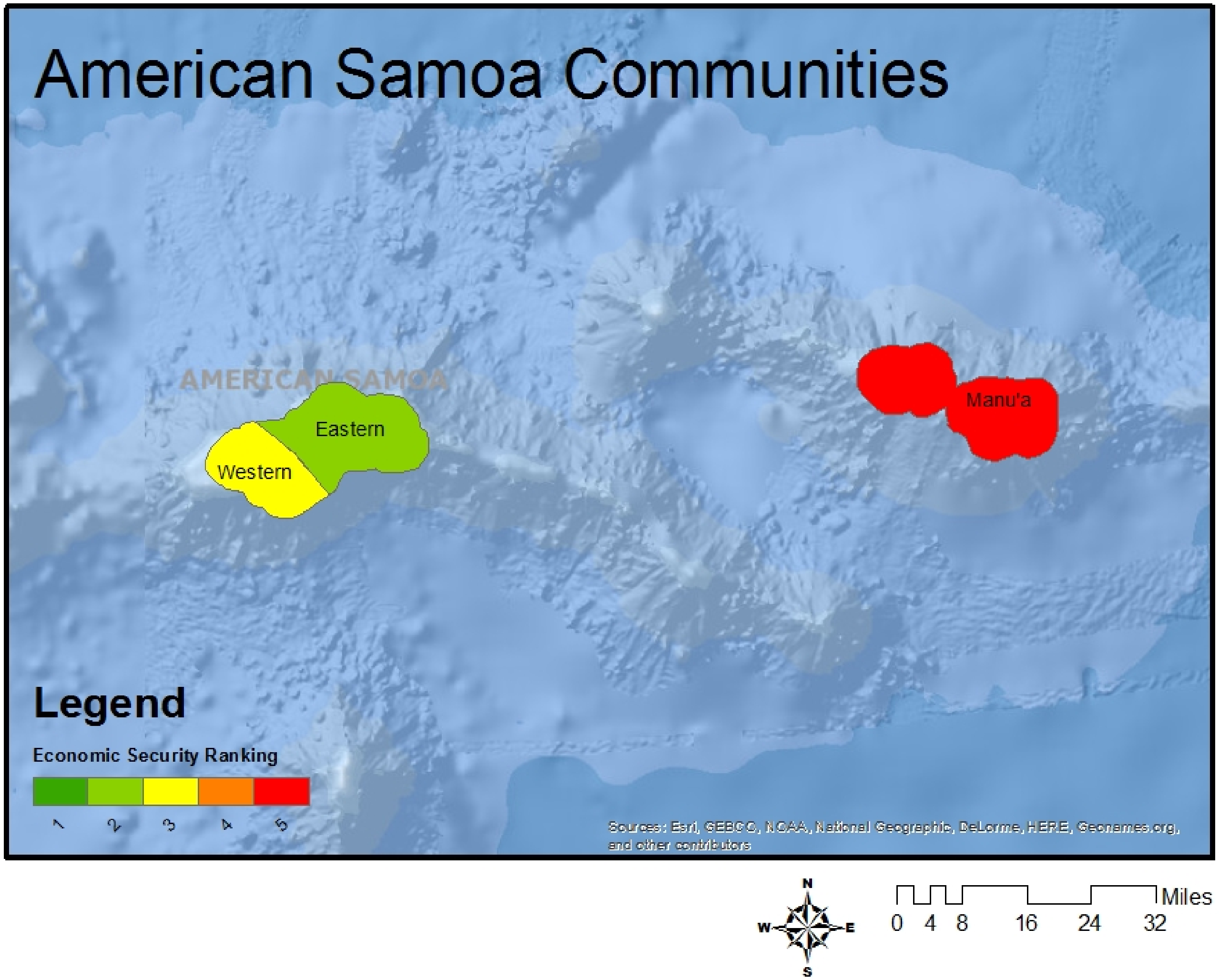

Figure E6: Social -Ecological Resilience Indicators: Economic Security Ranking for American Samoa Communities.

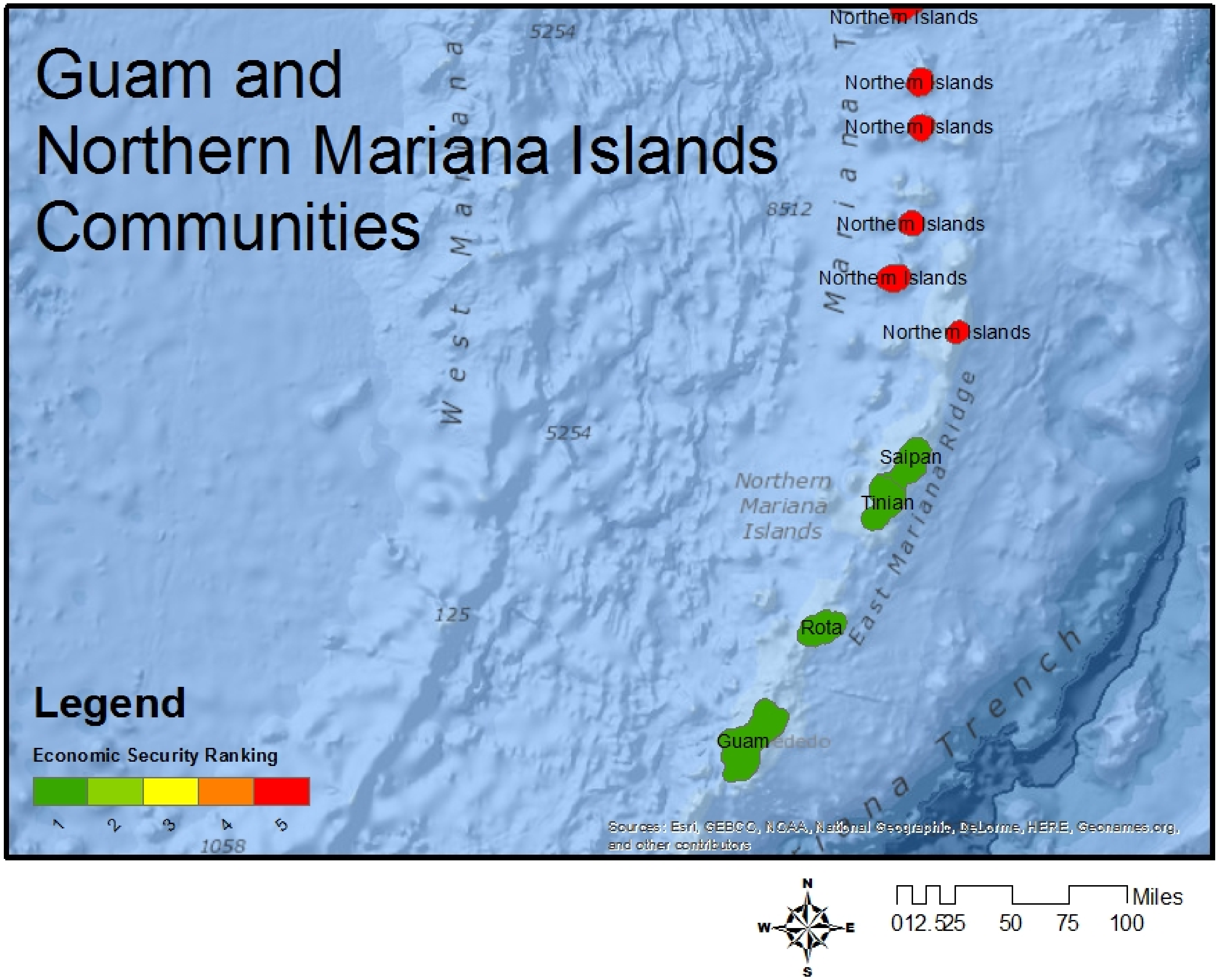

Figure E7: Social -Ecological Resilience Indicators: Economic Security Ranking for Guam & CNMI Communities.

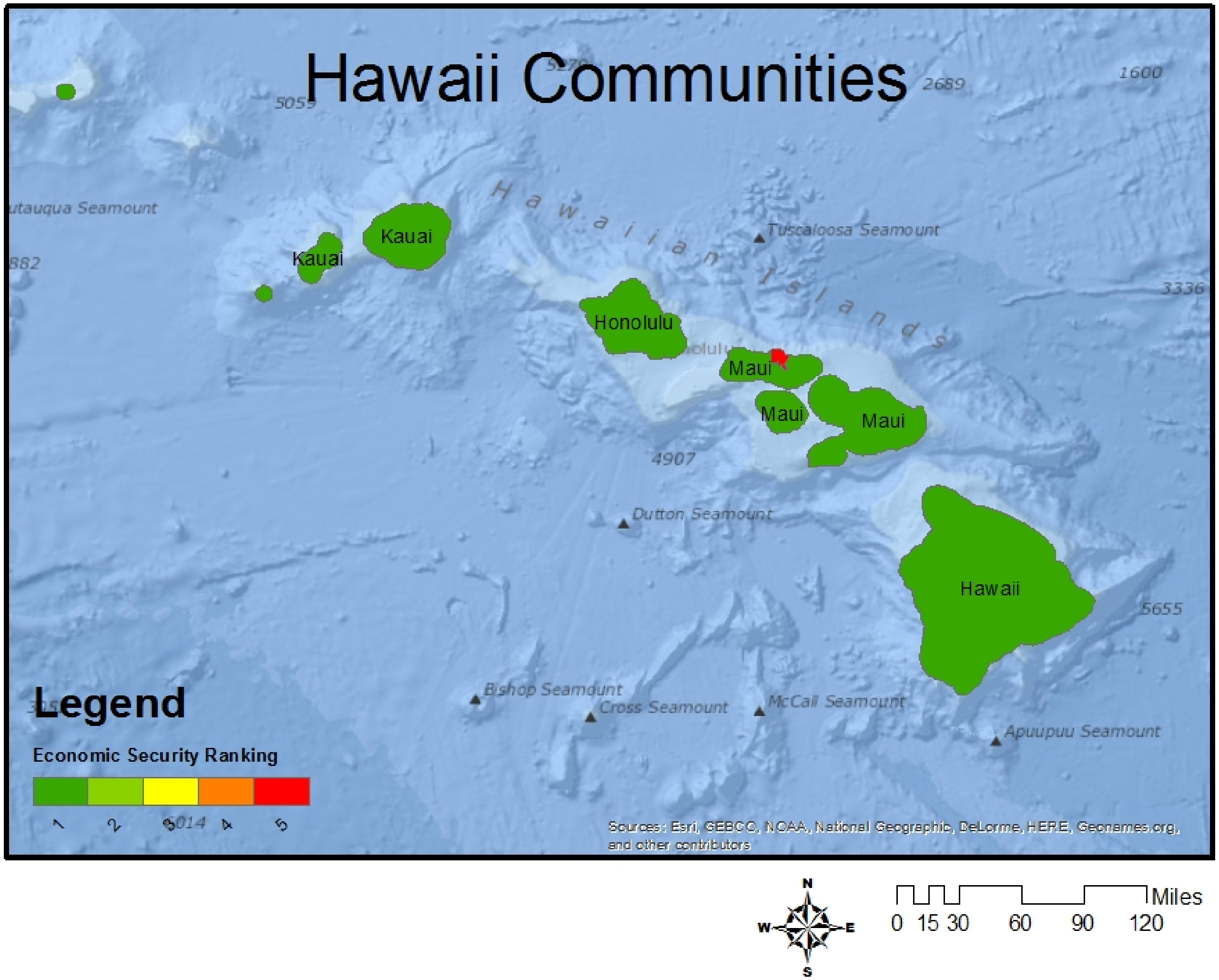

Figure E8: Social -Ecological Resilience Indicators: Economic Security Ranking for Hawaii Communities.

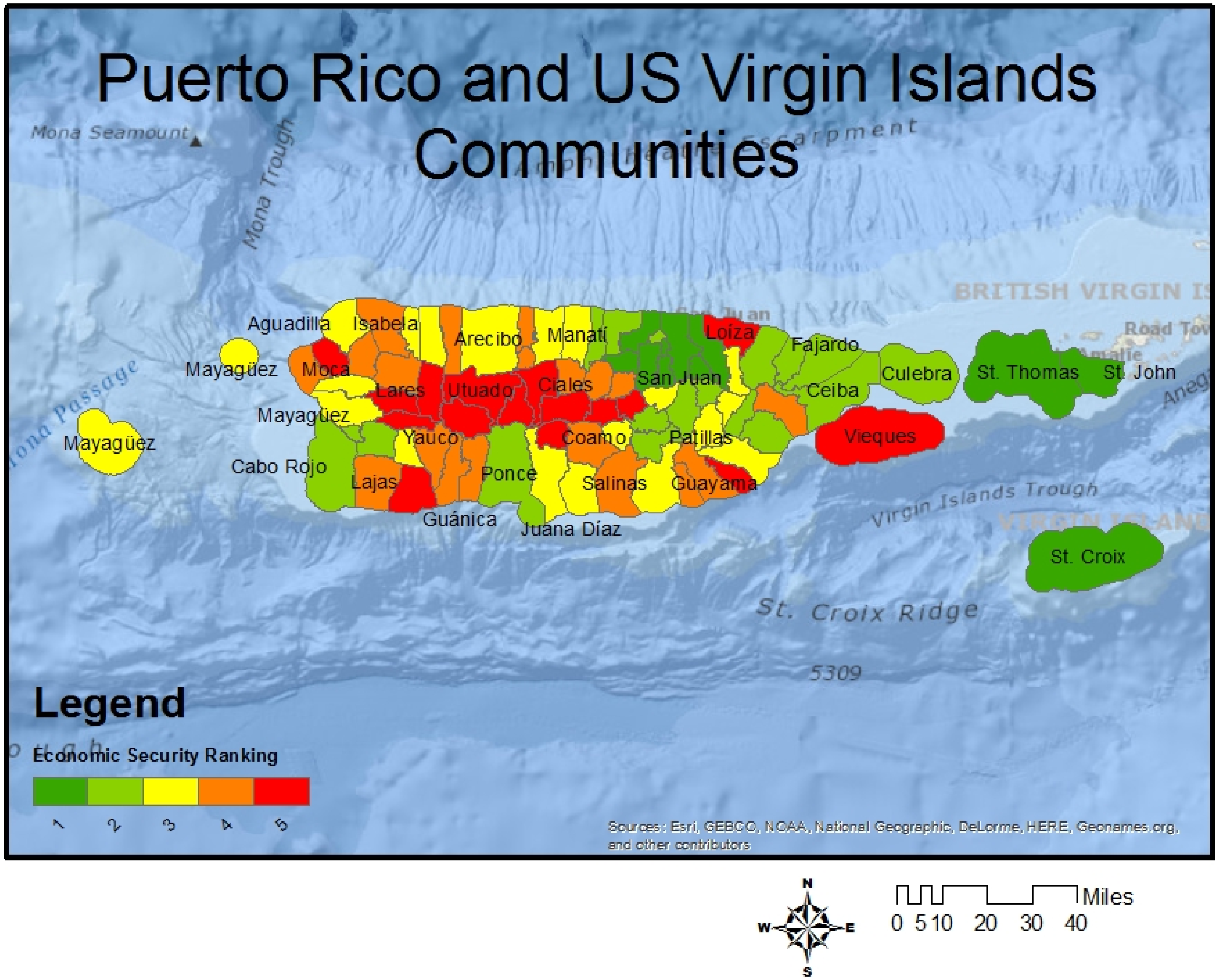

Figure E9: Social -Ecological Resilience Indicators: Economic Security Ranking for Puerto Rico & USVI Communities.

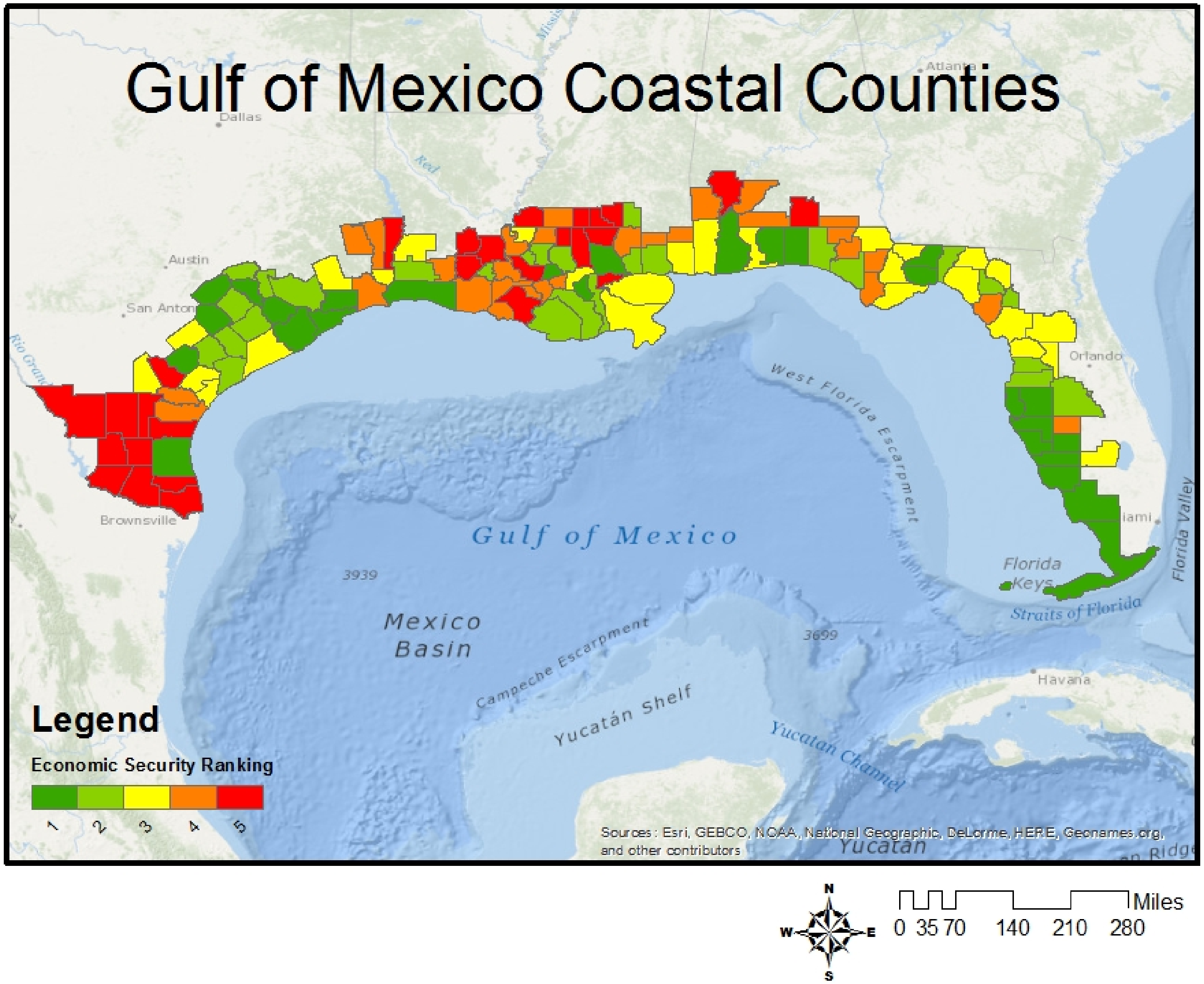

Figure E10: Social -Ecological Resilience Indicators: Economic Security Ranking for Gulf of Mexico Communities.

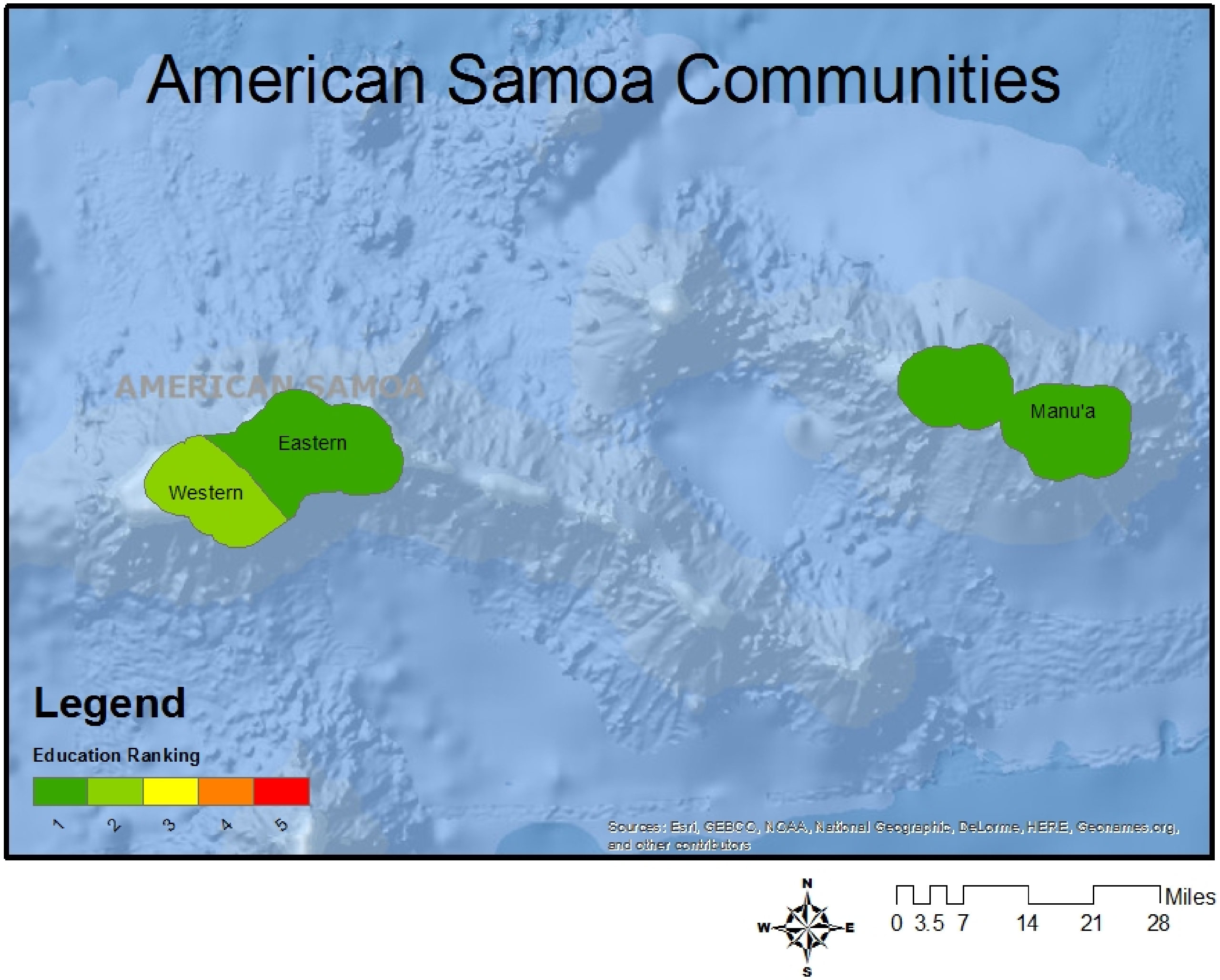

Figure E11: Social -Ecological Resilience Indicators: Education Ranking for American Samoa Communities.

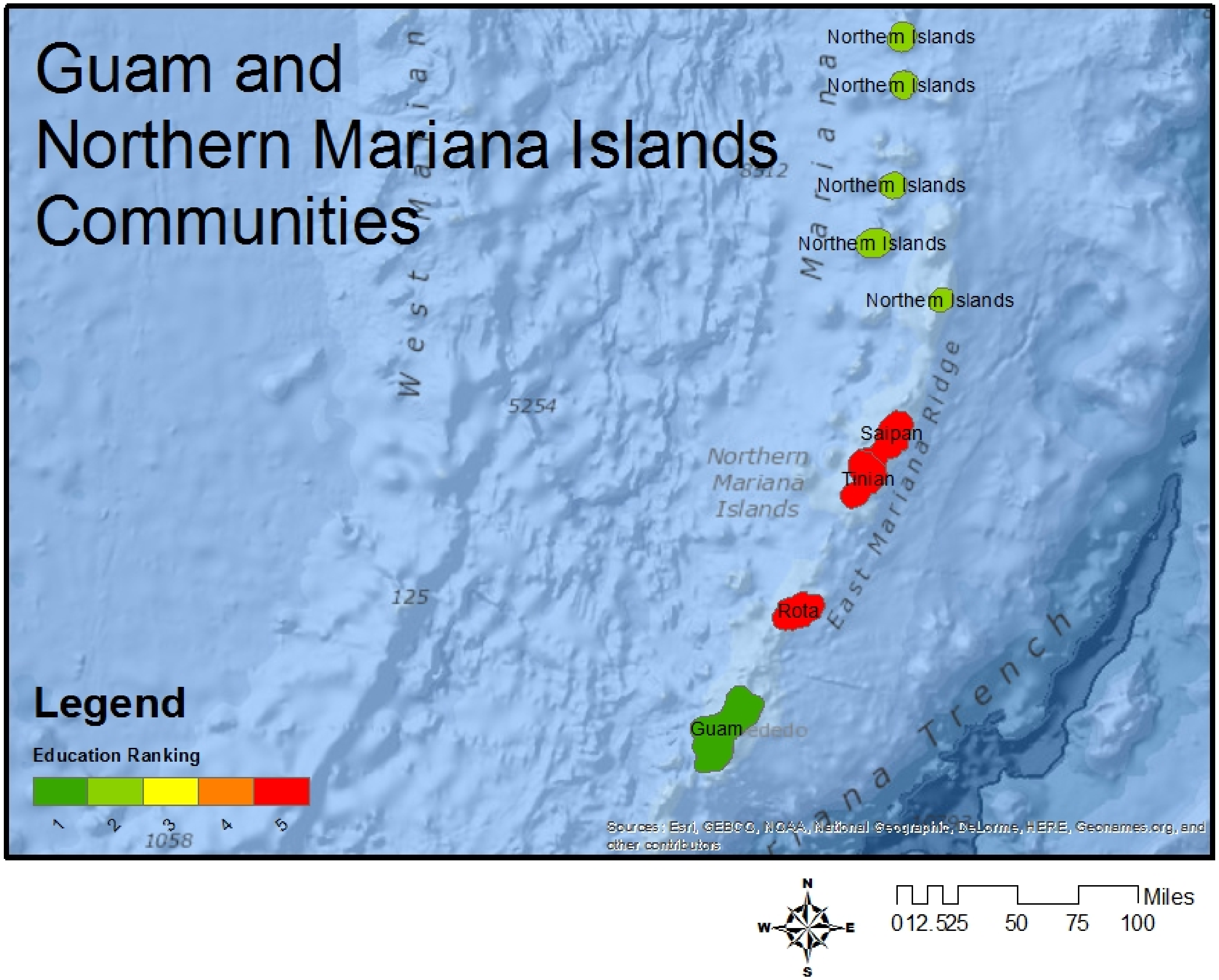

Figure E12: Social -Ecological Resilience Indicators: Education Ranking for Guam & CNMI Communities.

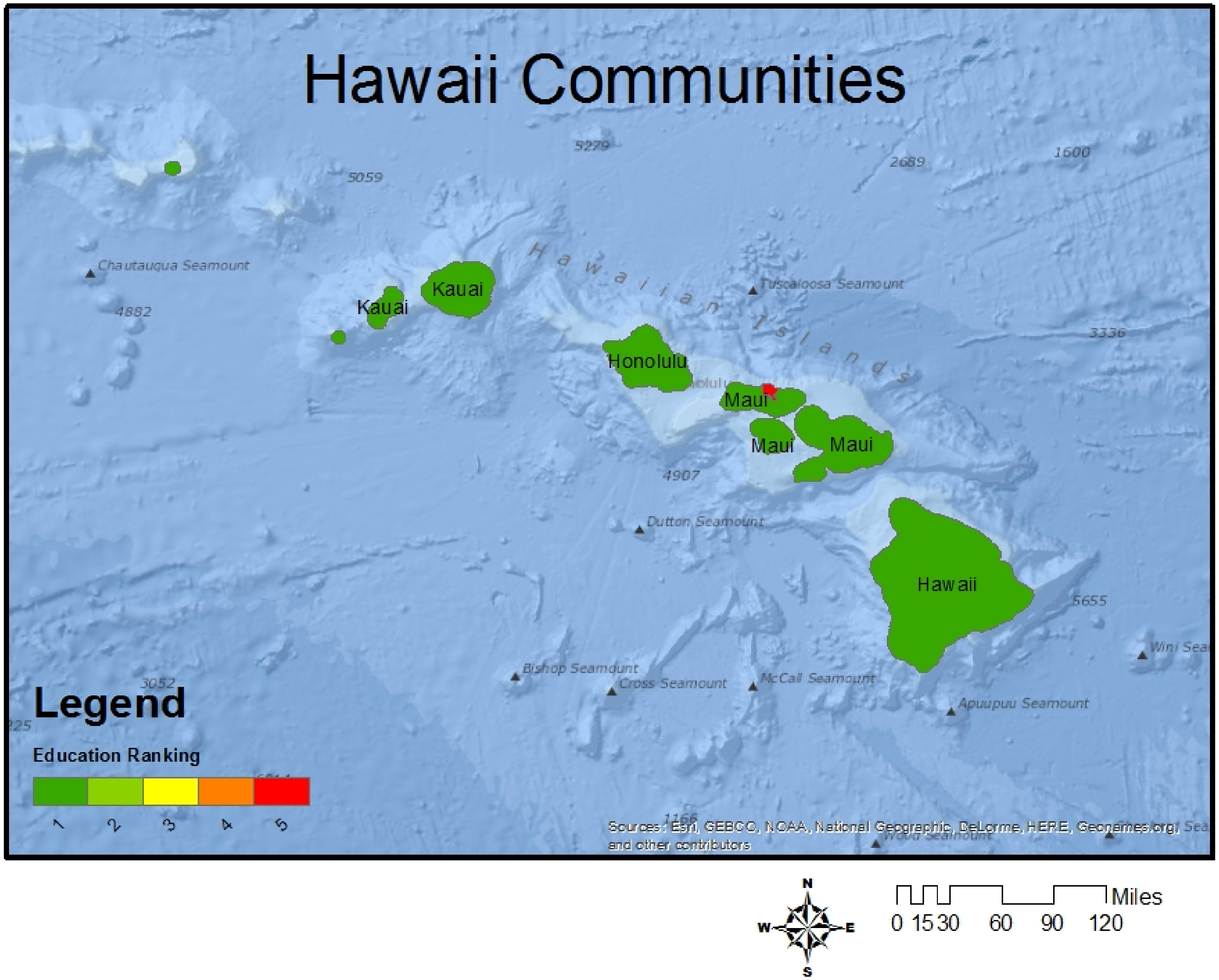

Figure E13: Social -Ecological Resilience Indicators: Education Ranking for Hawaiii Communities.

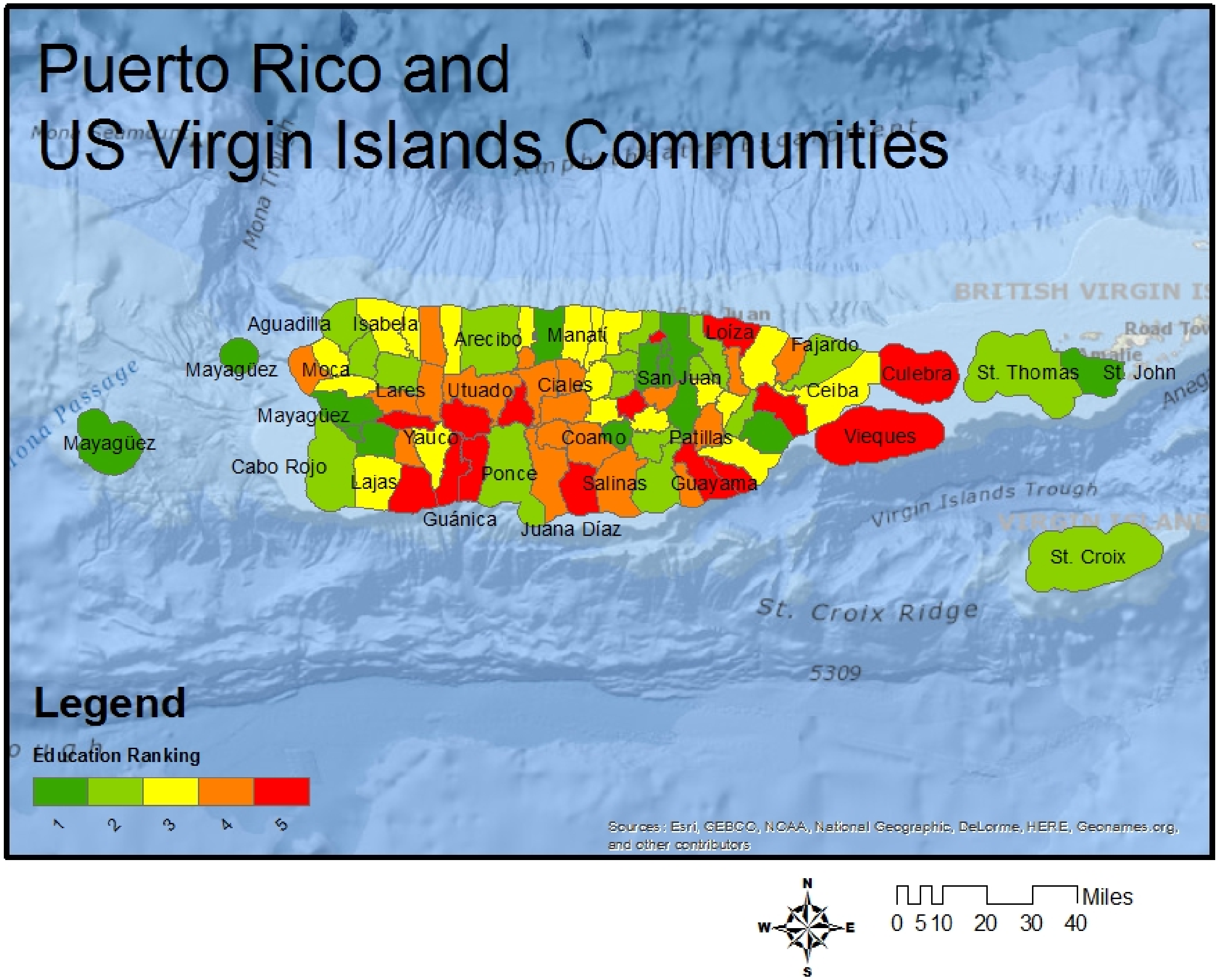

Figure E14: Social -Ecological Resilience Indicators: Education Ranking for Puerto Rico & USVI Communities.

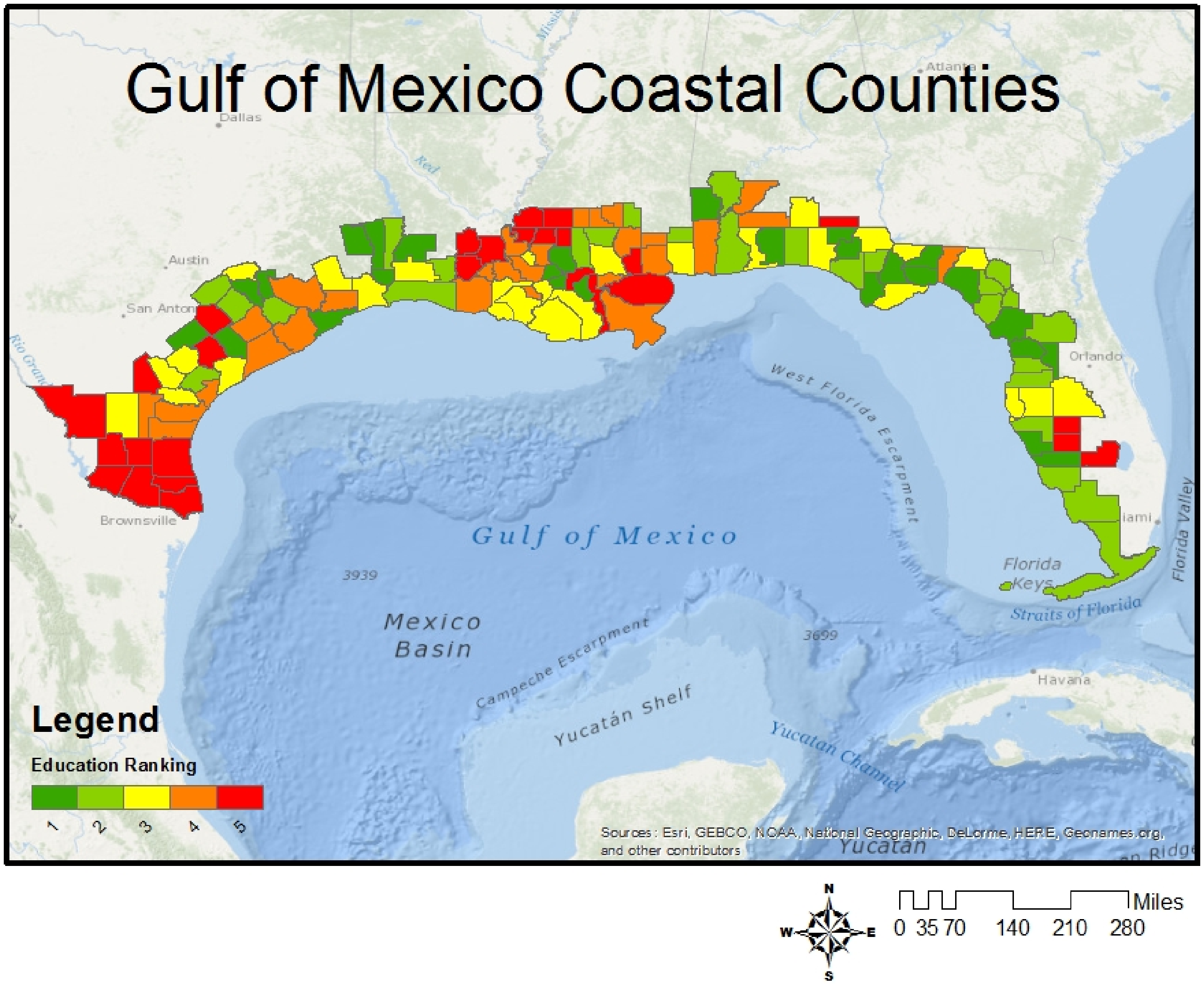

Figure E15: Social -Ecological Resilience Indicators: Education Ranking for Gulf of Mexico Communities.

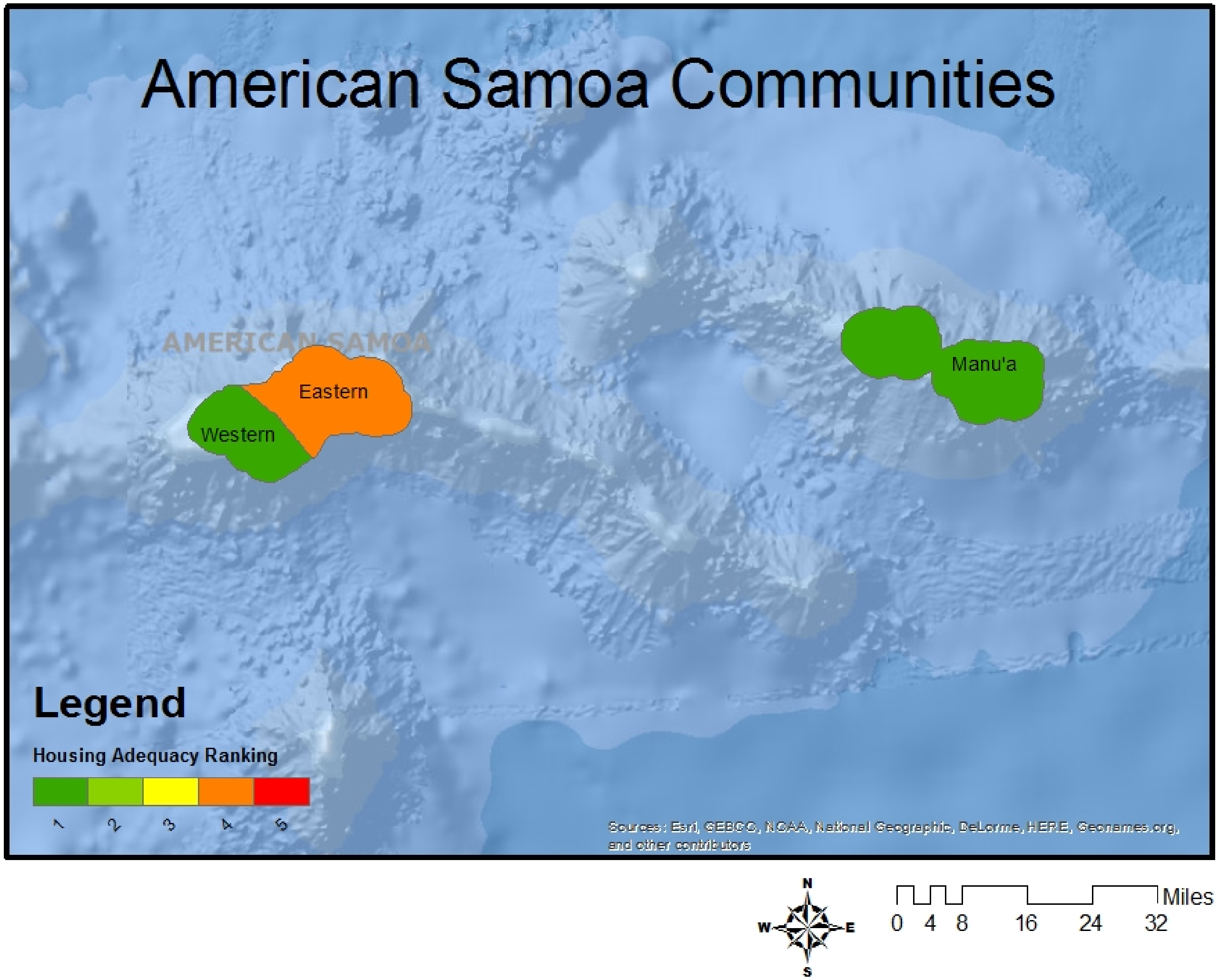

Figure E16: Social -Ecological Resilience Indicators: Housing Adequacy Ranking for American Samoa Communities.

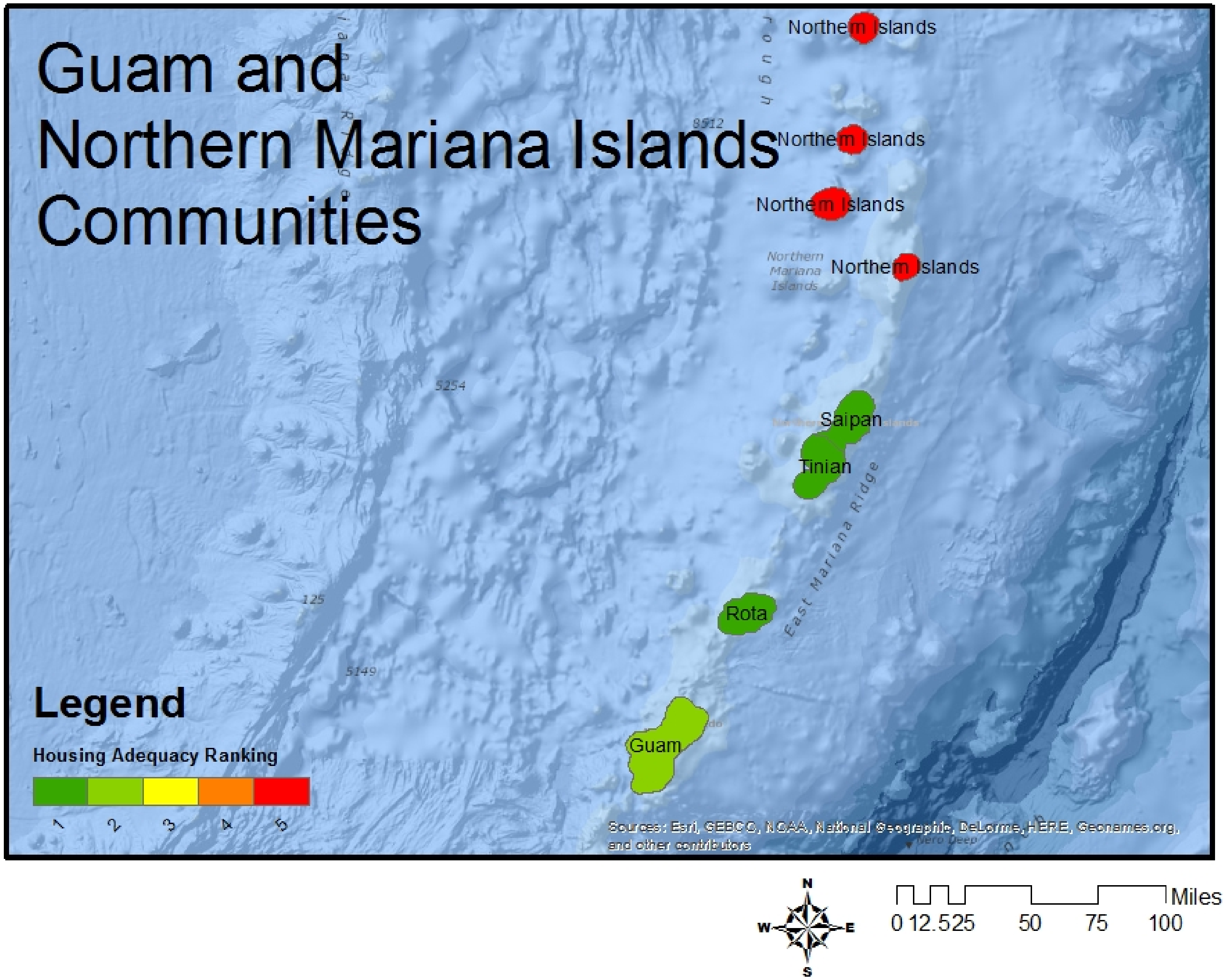

Figure E17: Social -Ecological Resilience Indicators: Housing Adequacy Ranking for Guam & CNMI Communities.

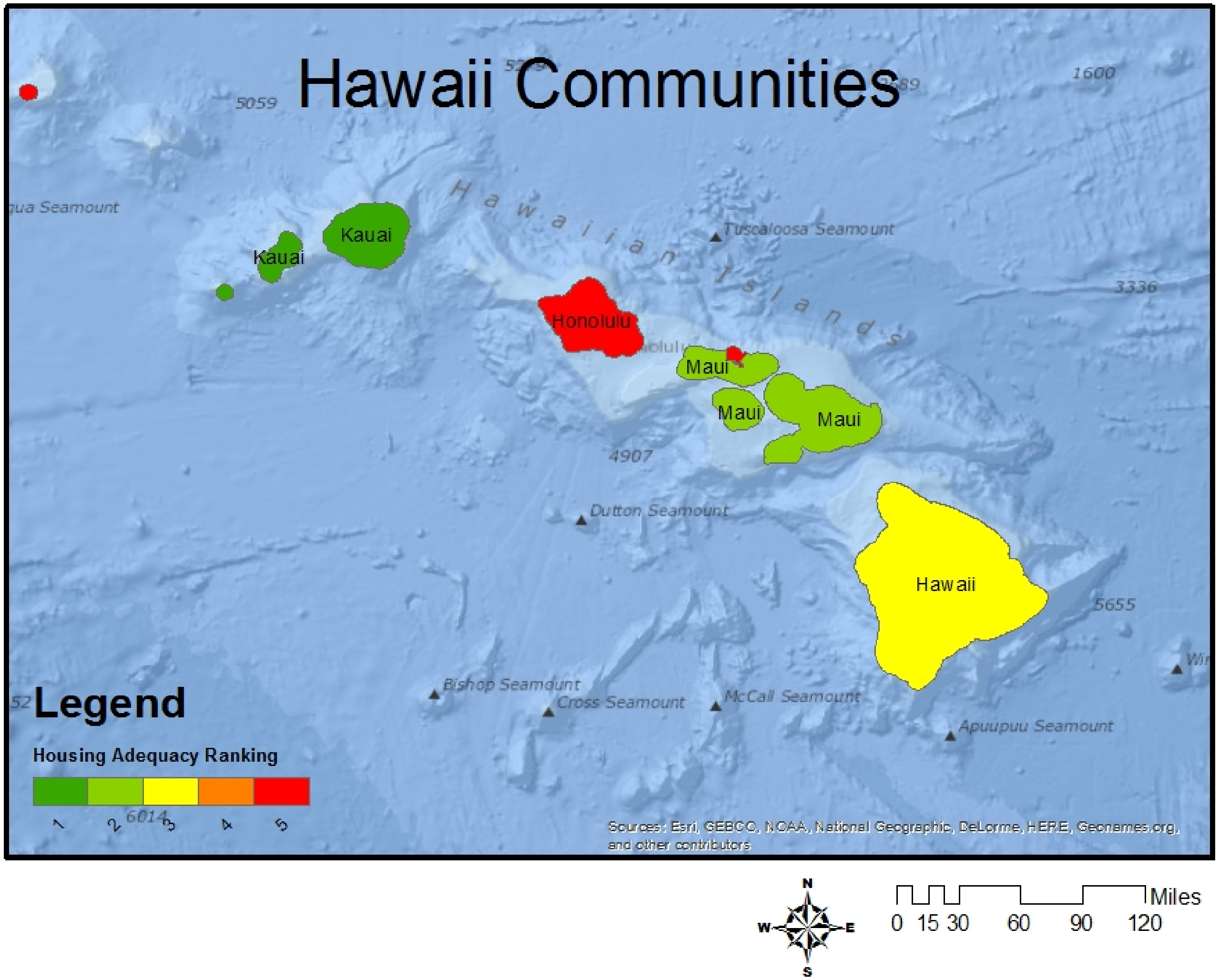

Figure E18: Social -Ecological Resilience Indicators: Housing Adequacy Ranking for Hawaii Communities.

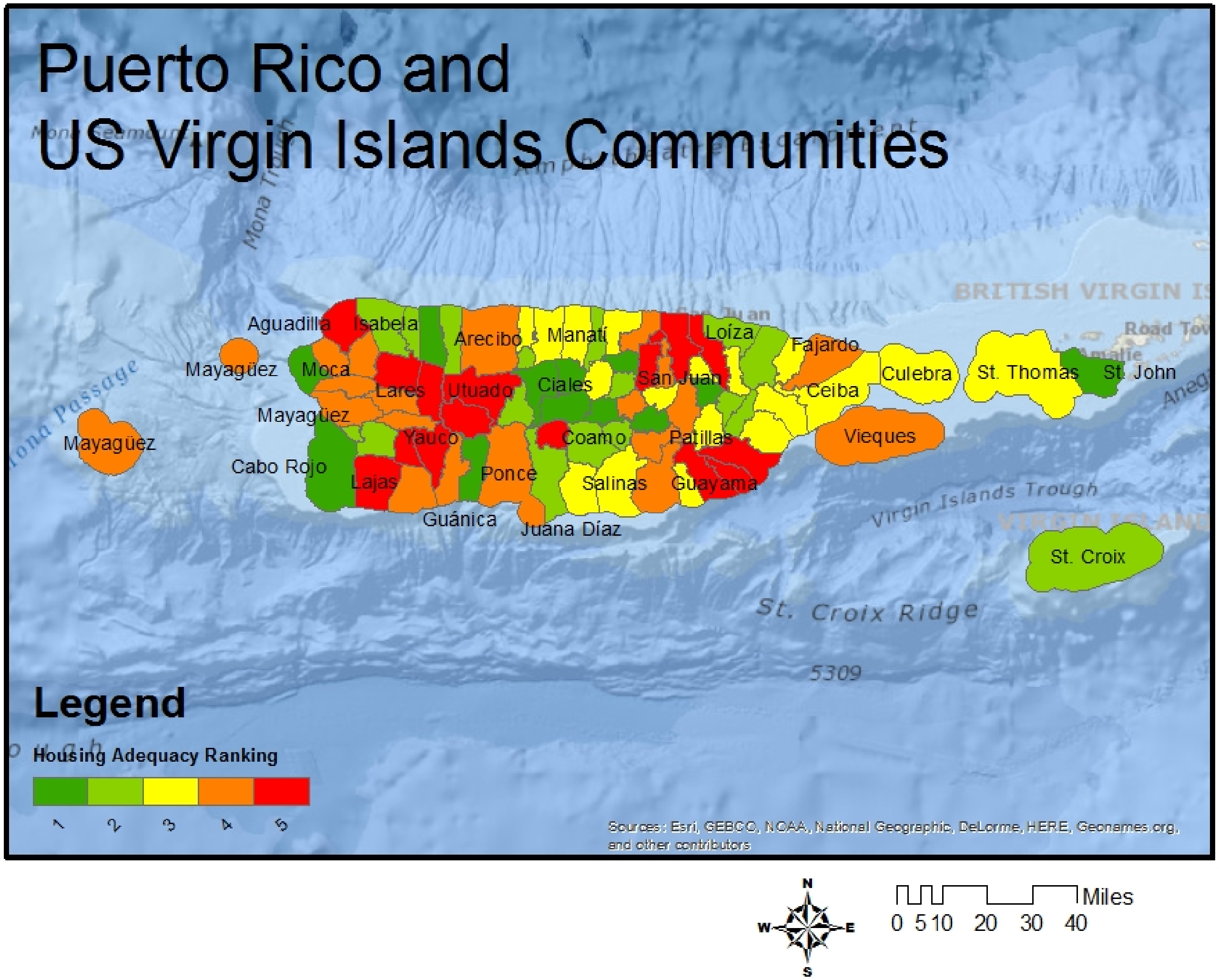

Figure E19: Social -Ecological Resilience Indicators: Housing Adequacy Ranking for Puerto Rico & USVI Communities.

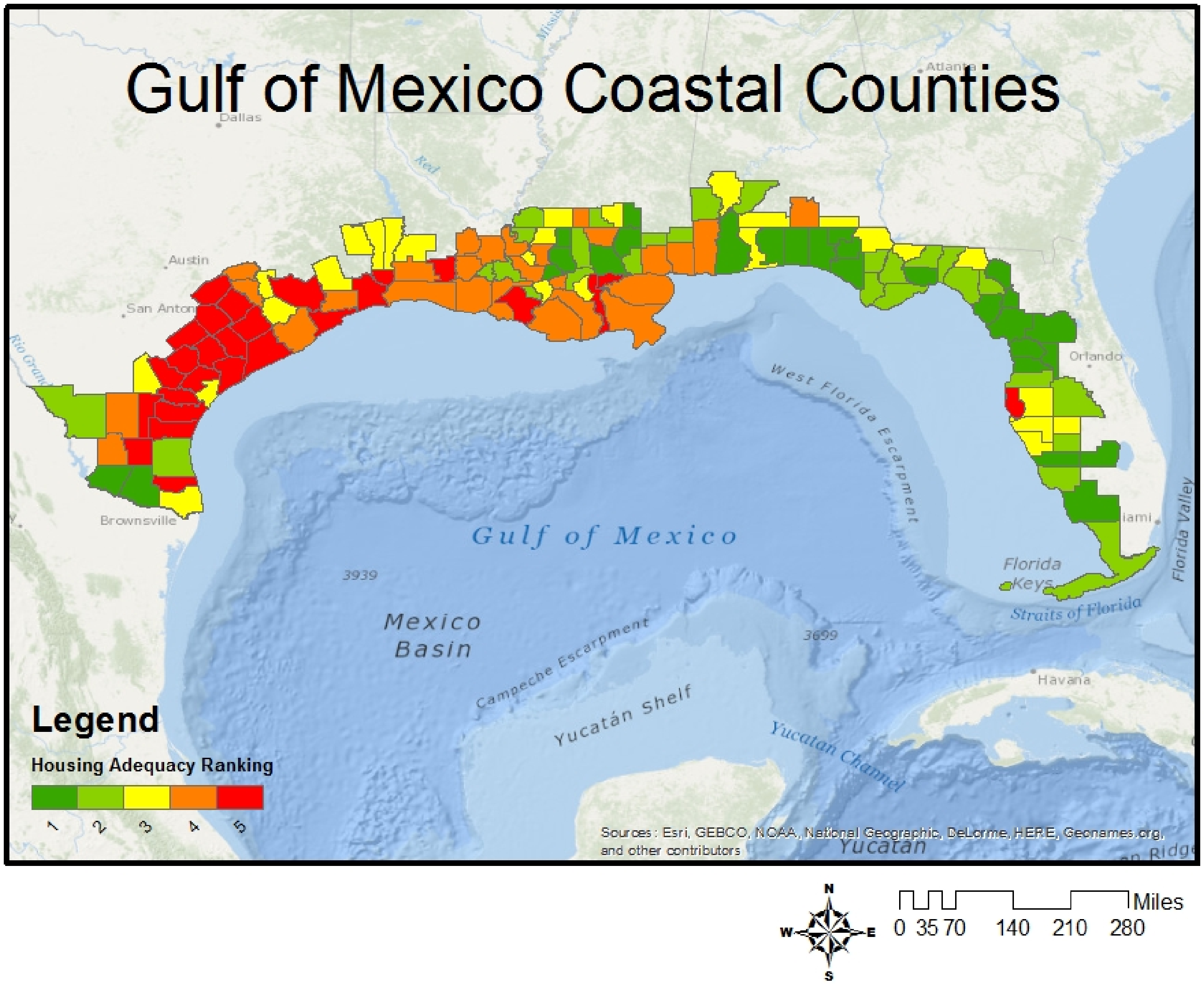

Figure E20: Social -Ecological Resilience Indicators: Housing Adequacy Ranking for Gulf of Mexico Communities.

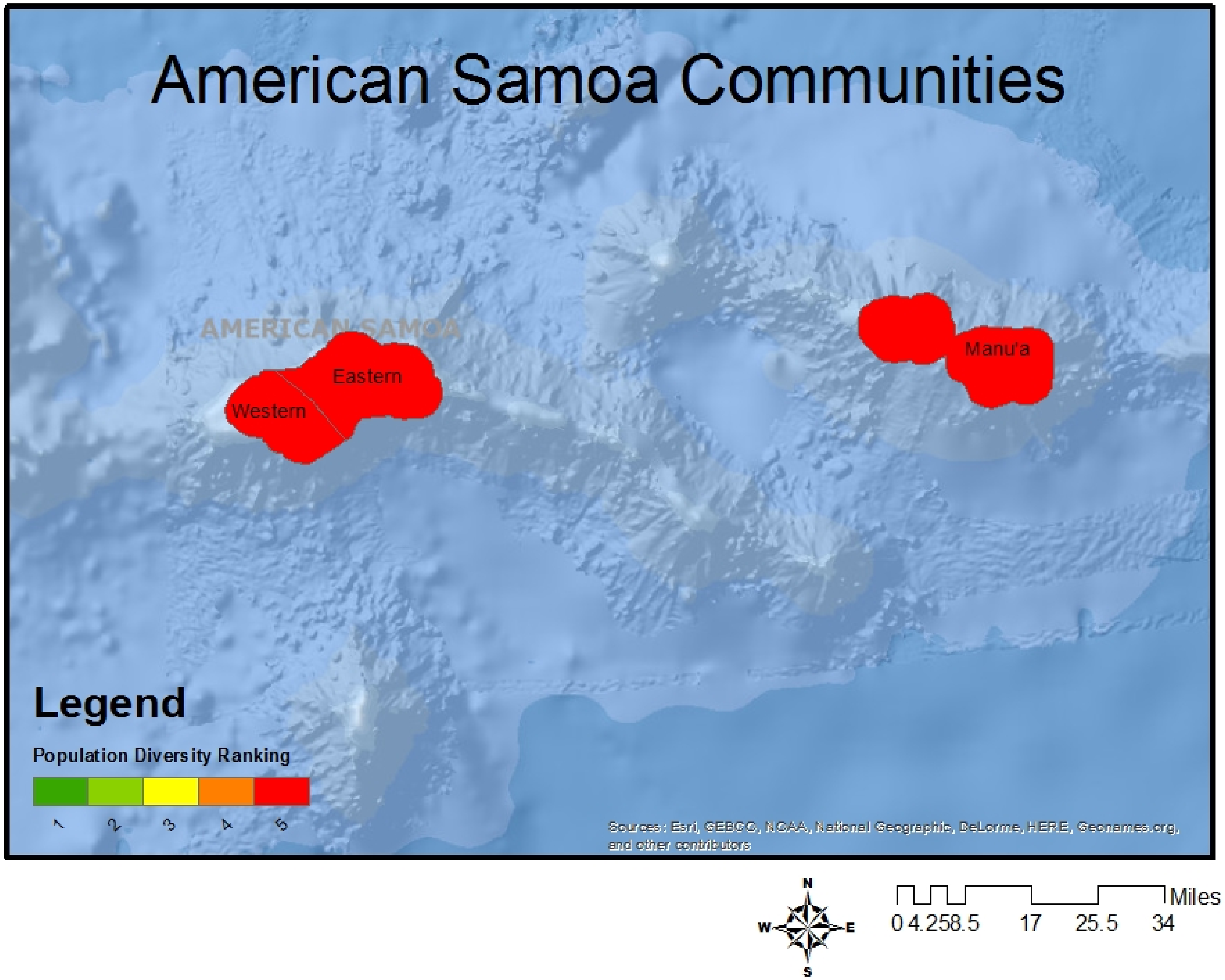

Figure E21: Social -Ecological Resilience Indicators: Population Diversity Ranking for American Samoa Communities.

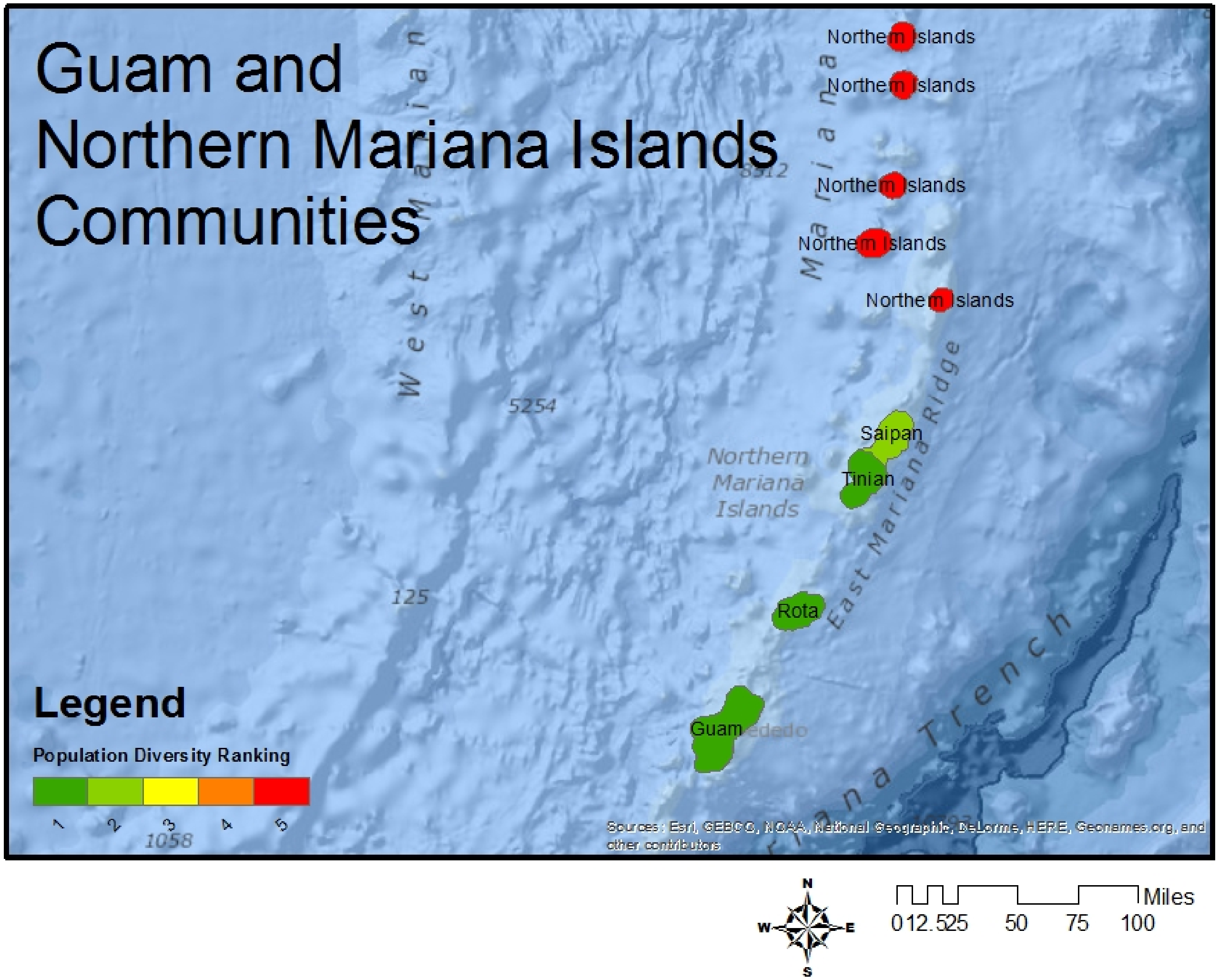

Figure E22: Social -Ecological Resilience Indicators: Population Diversity Ranking for Guam & CNMI Communities.

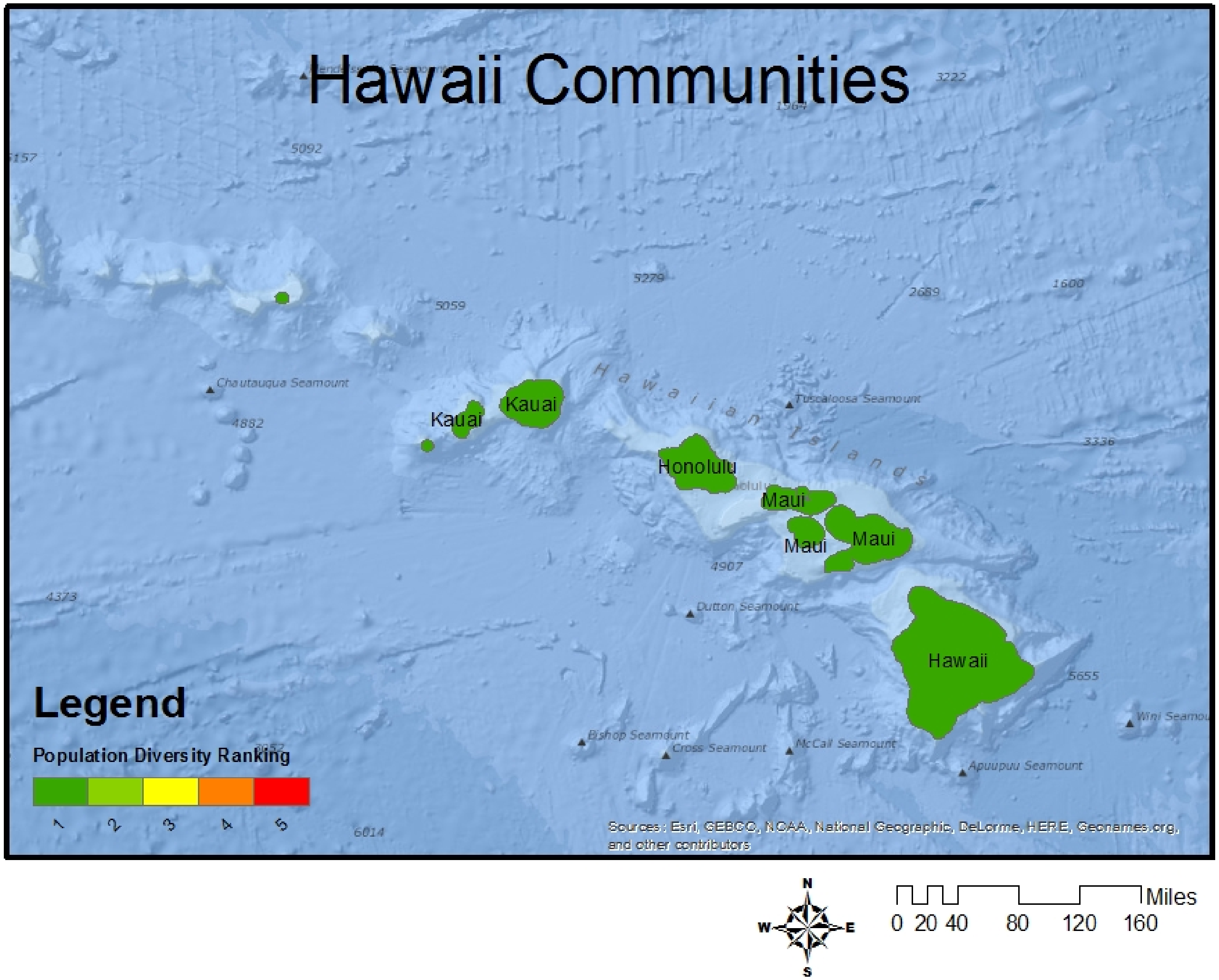

Figure E23: Social -Ecological Resilience Indicators: Population Diversity Ranking for Hawaii Communities.

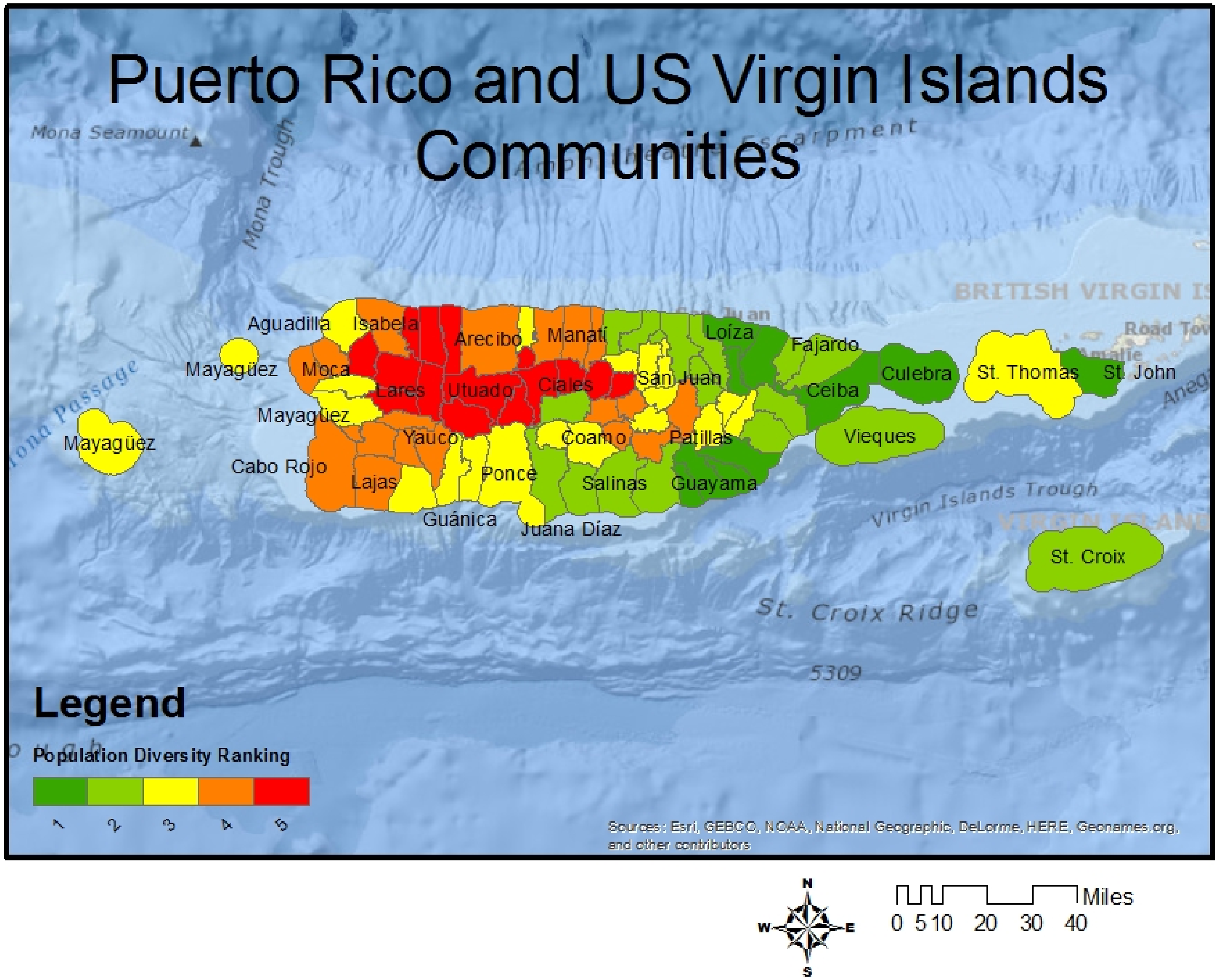

Figure E24: Social -Ecological Resilience Indicators: Population Diversity Ranking for Puerto Rico & USVI Communities.

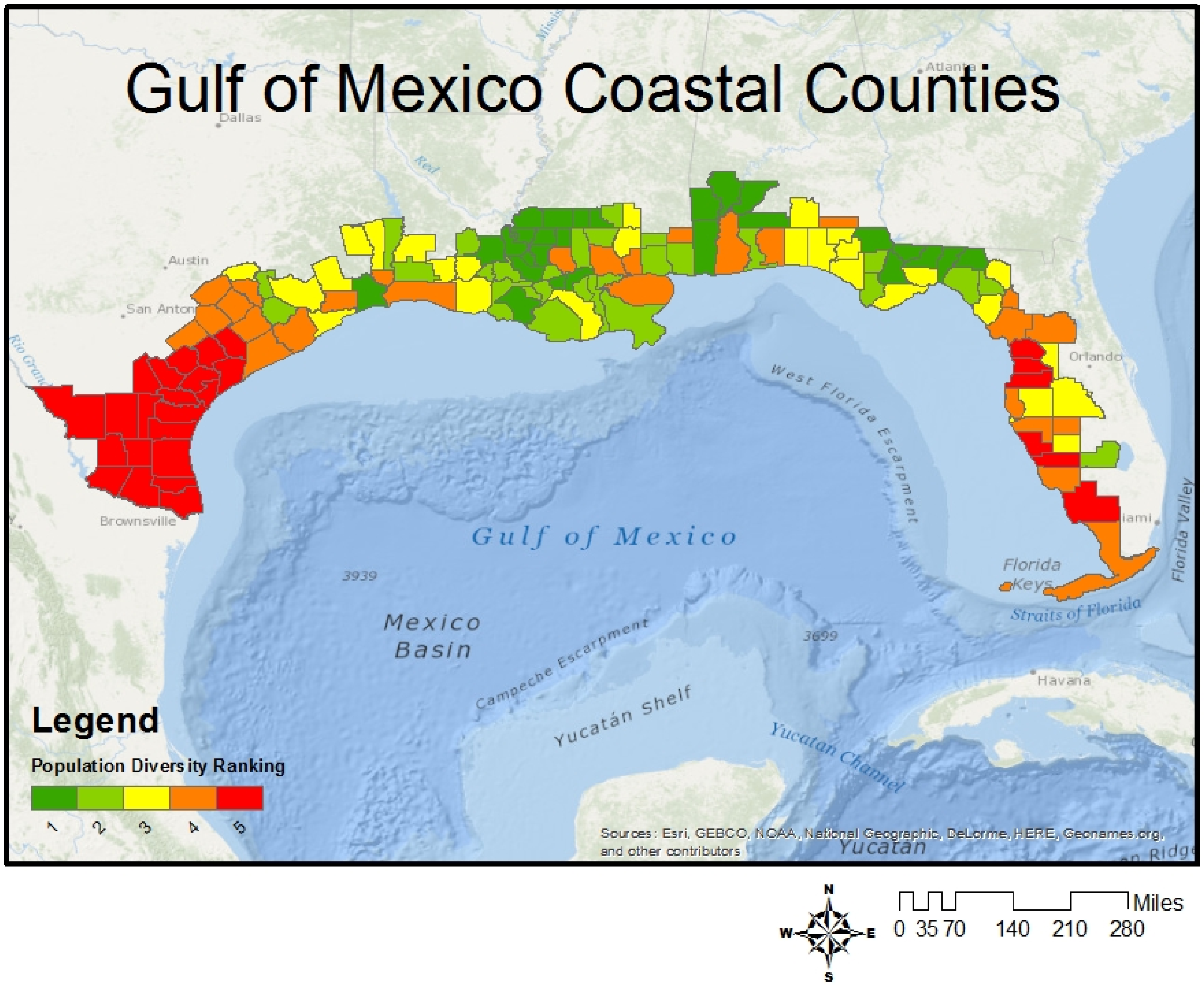

Figure E25: Social -Ecological Resilience Indicators: Population Diversity Ranking for Gulf of Mexico Communities.

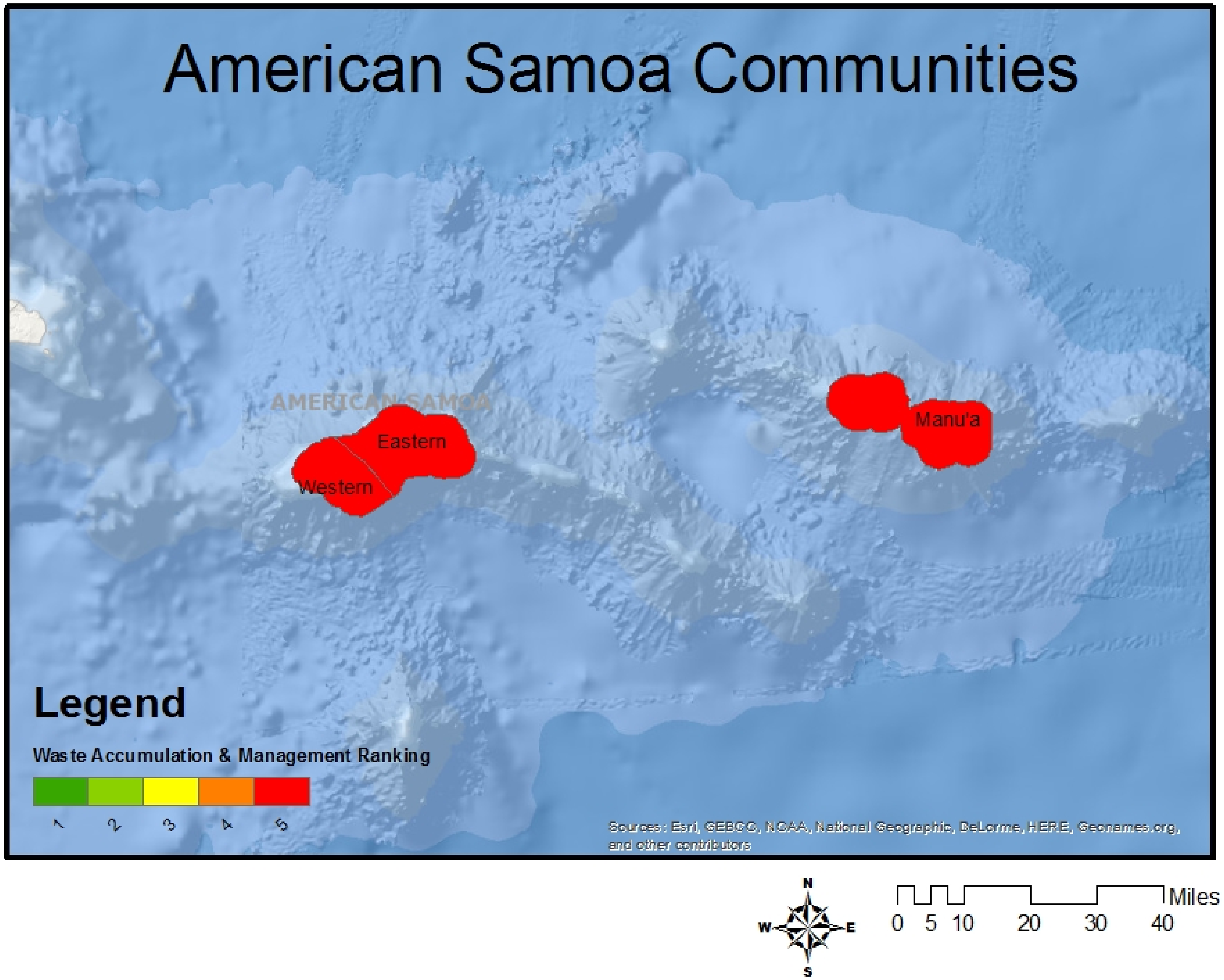

Figure E26: Social -Ecological Resilience Indicators: Waste Management Ranking for American Samoa Communities.

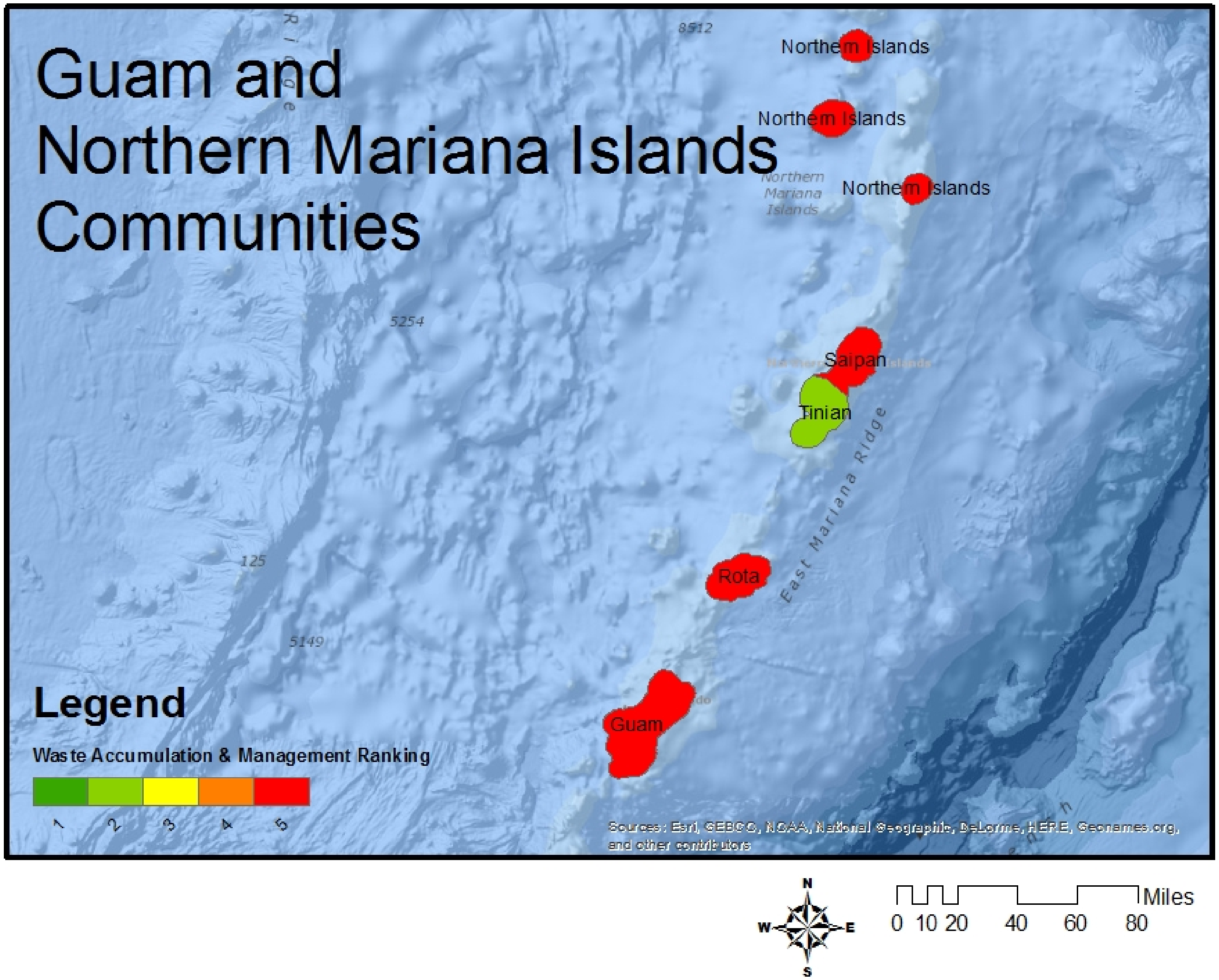

Figure E27: Social -Ecological Resilience Indicators: Waste Management Ranking for Guam & CNMI Communities.

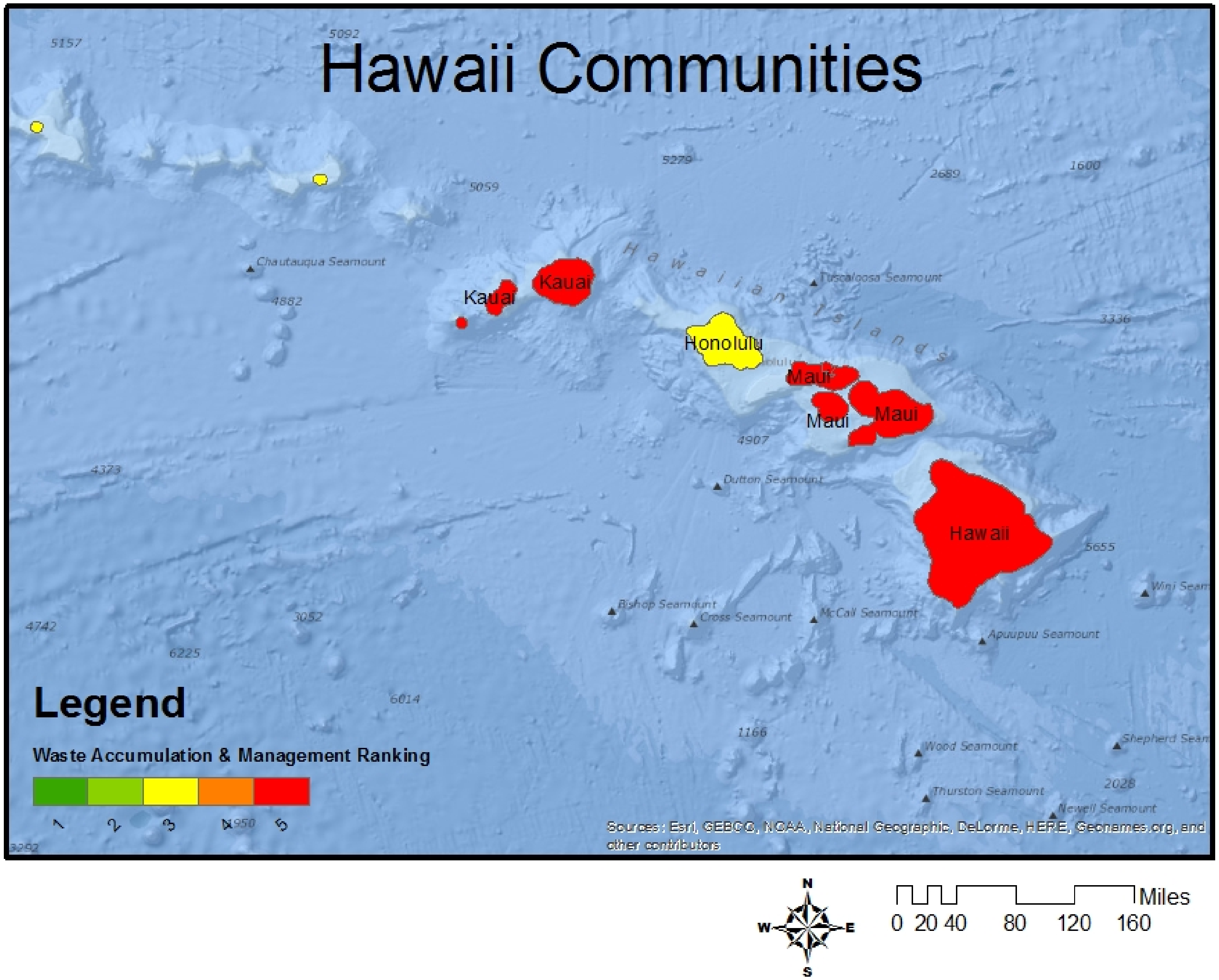

Figure E28: Social -Ecological Resilience Indicators: Waste Management Ranking for Hawaii Communities.

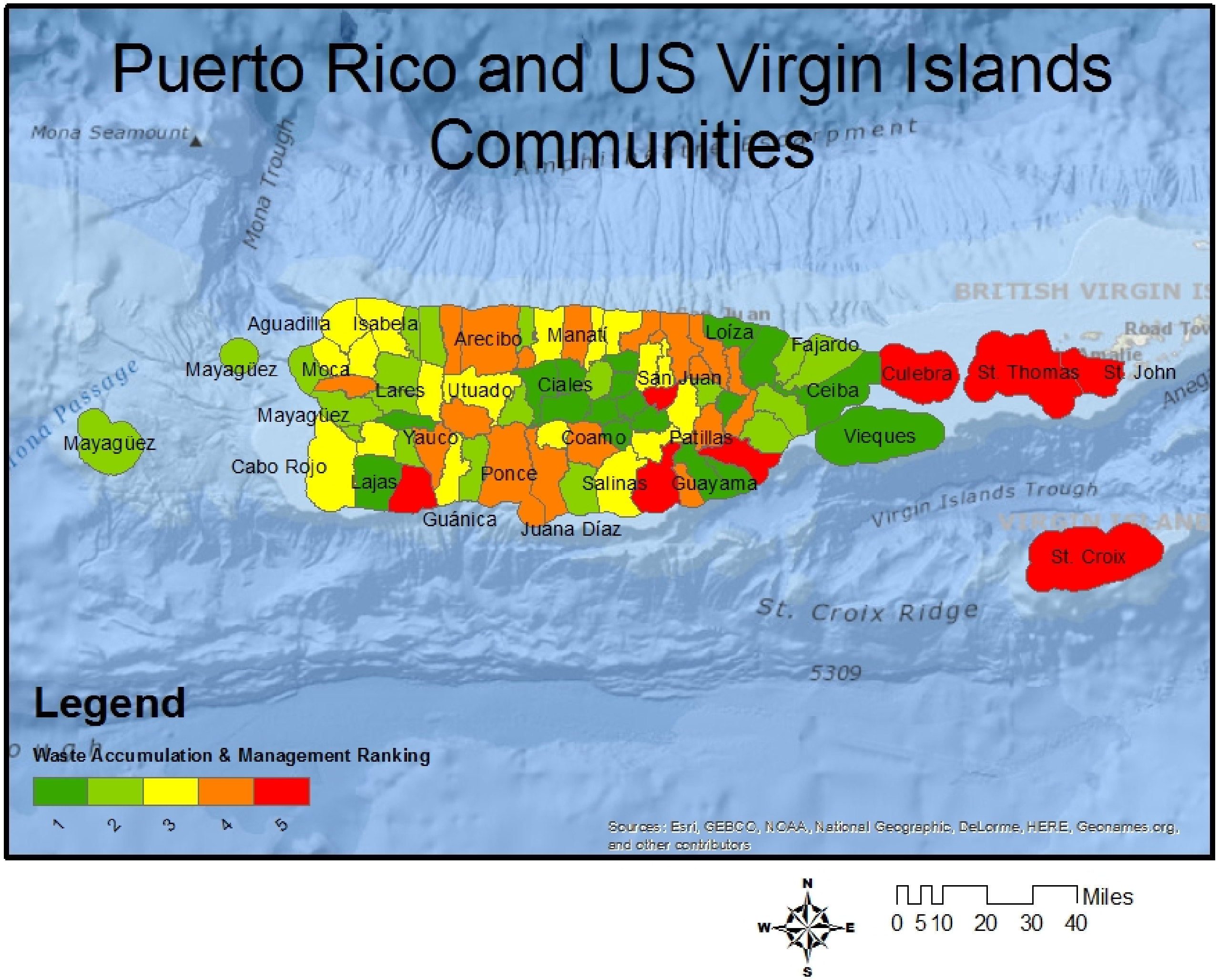

Figure E29: Social -Ecological Resilience Indicators: Waste Management Ranking for Puerto Rico & USVI Communities.

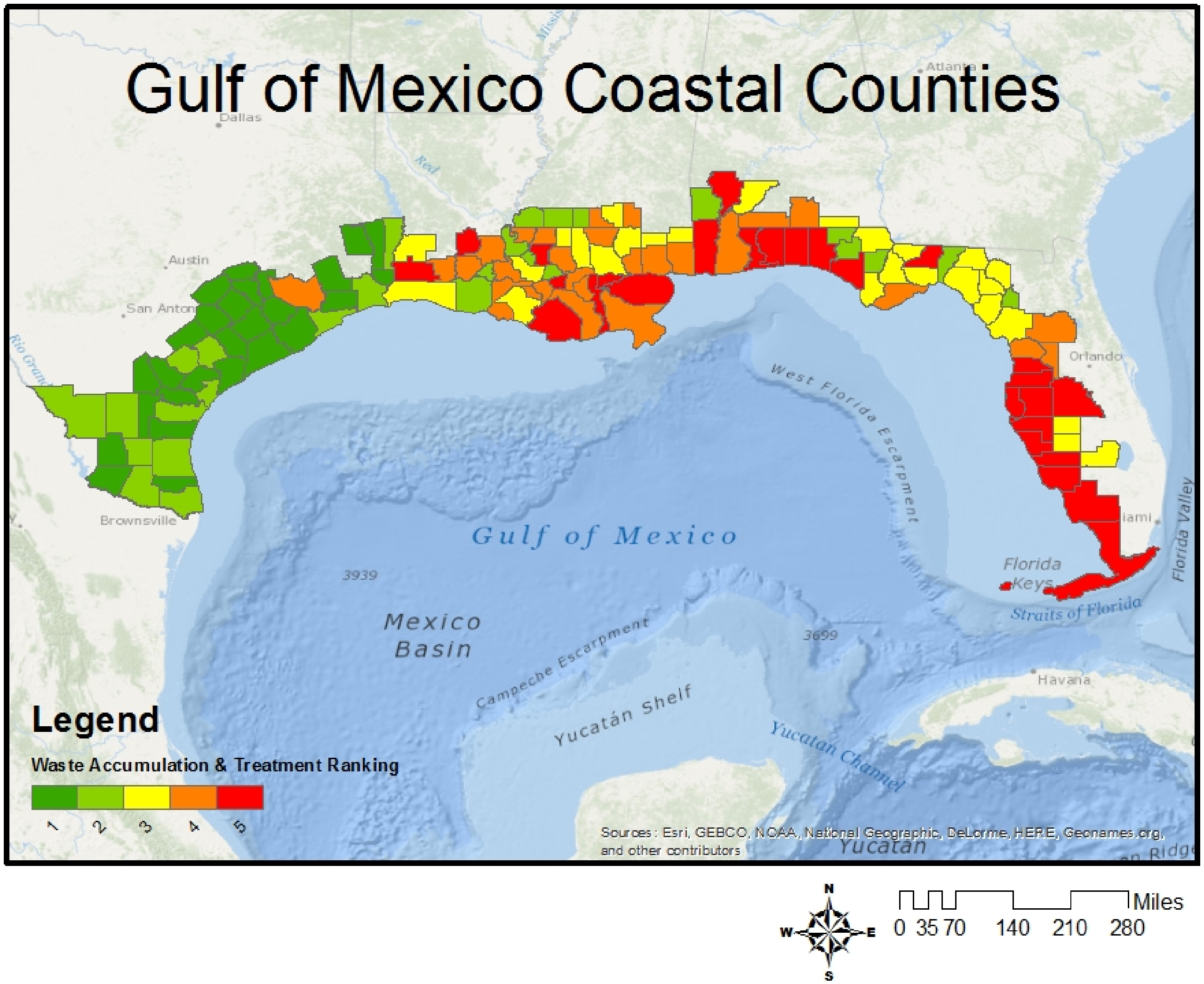

Figure E30: Social -Ecological Resilience Indicators: Waste Management Ranking for Gulf of Mexico Communities.

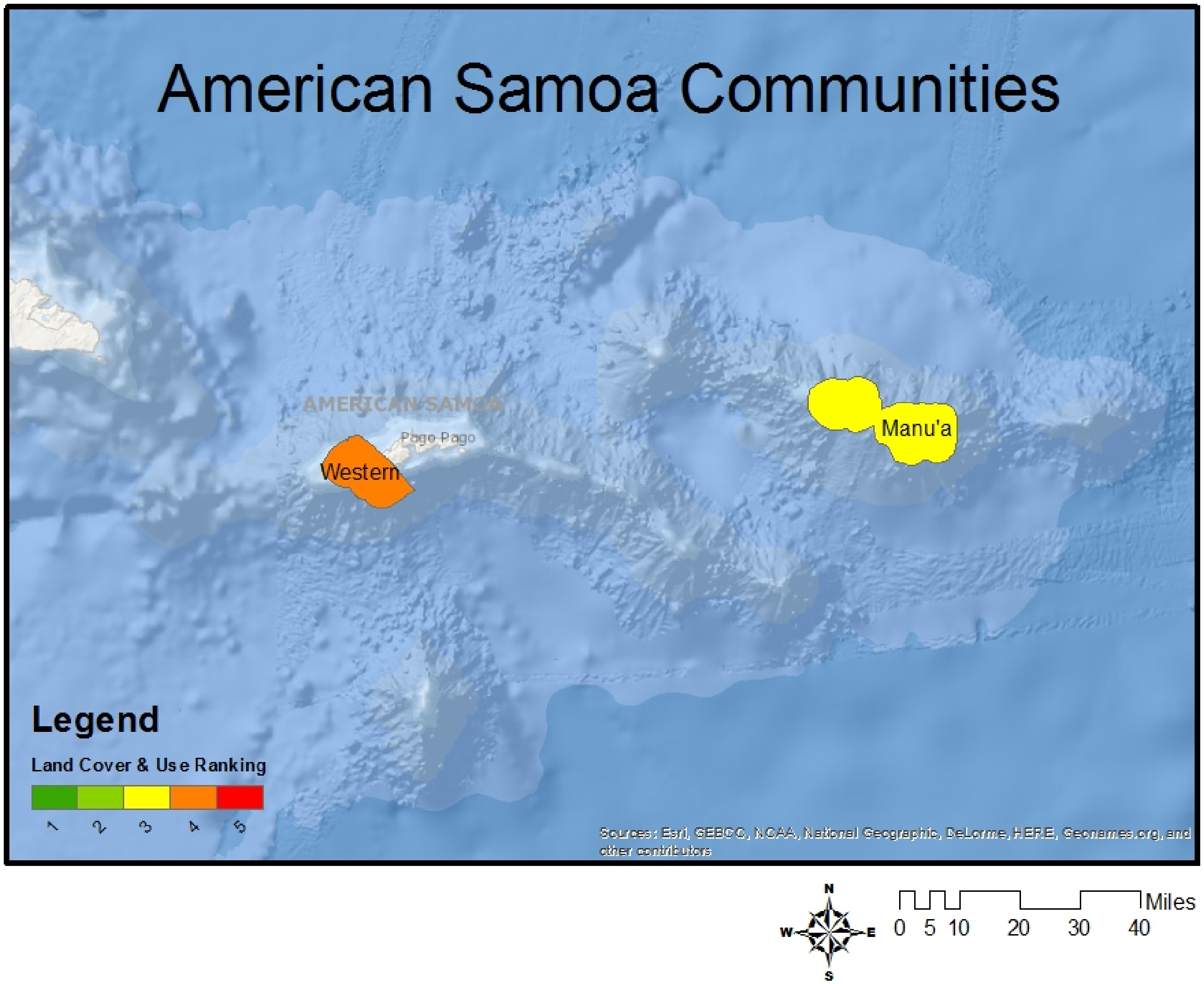

Figure E31: Social -Ecological Resilience Indicators: Land Cover & Use Ranking for American Samoa Communities.

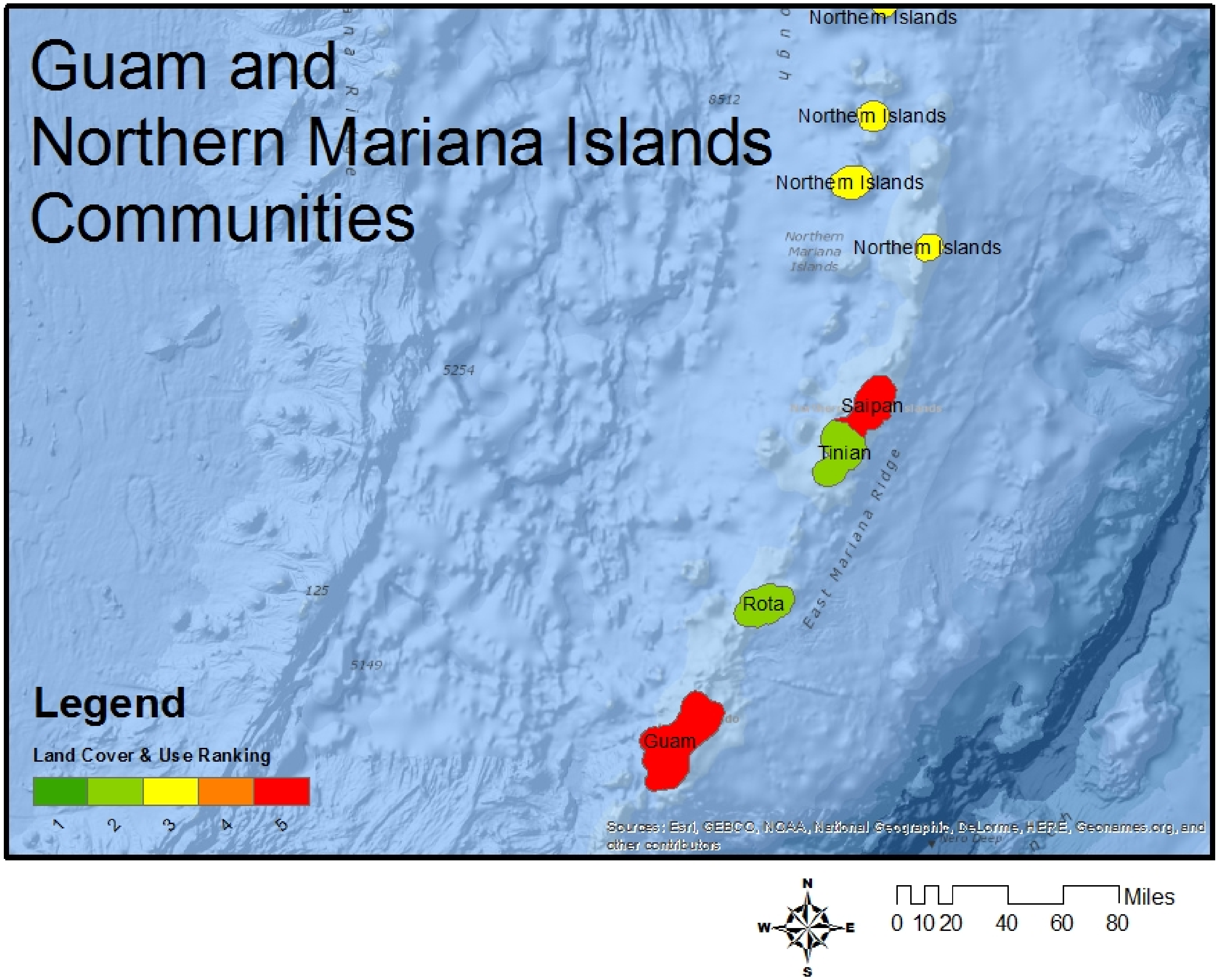

Figure E32: Social -Ecological Resilience Indicators: Land Cover & Use Ranking for Guam & CNMI Communities.

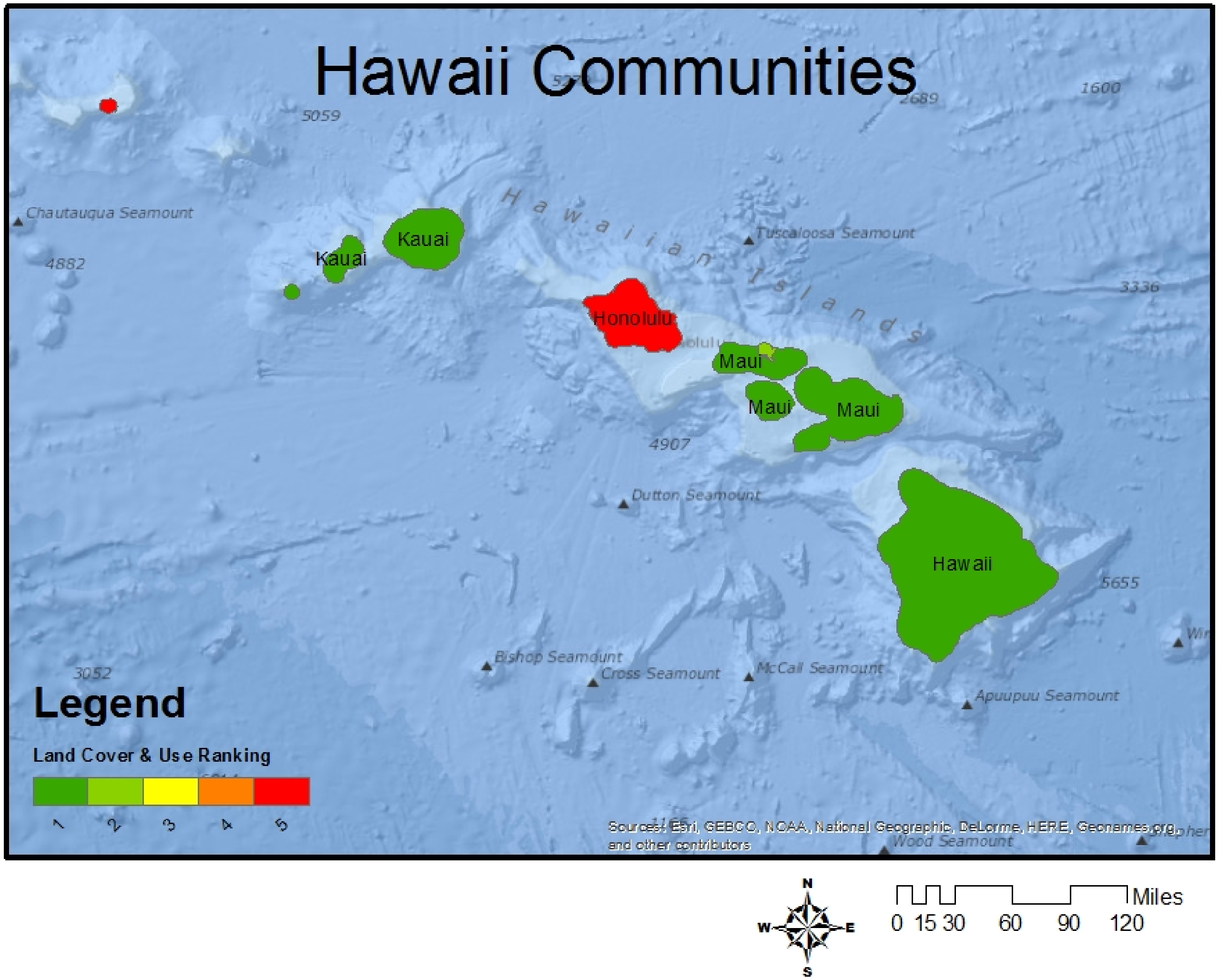

Figure E33: Social -Ecological Resilience Indicators: Land Cover & Use Ranking for Hawaii Communities.

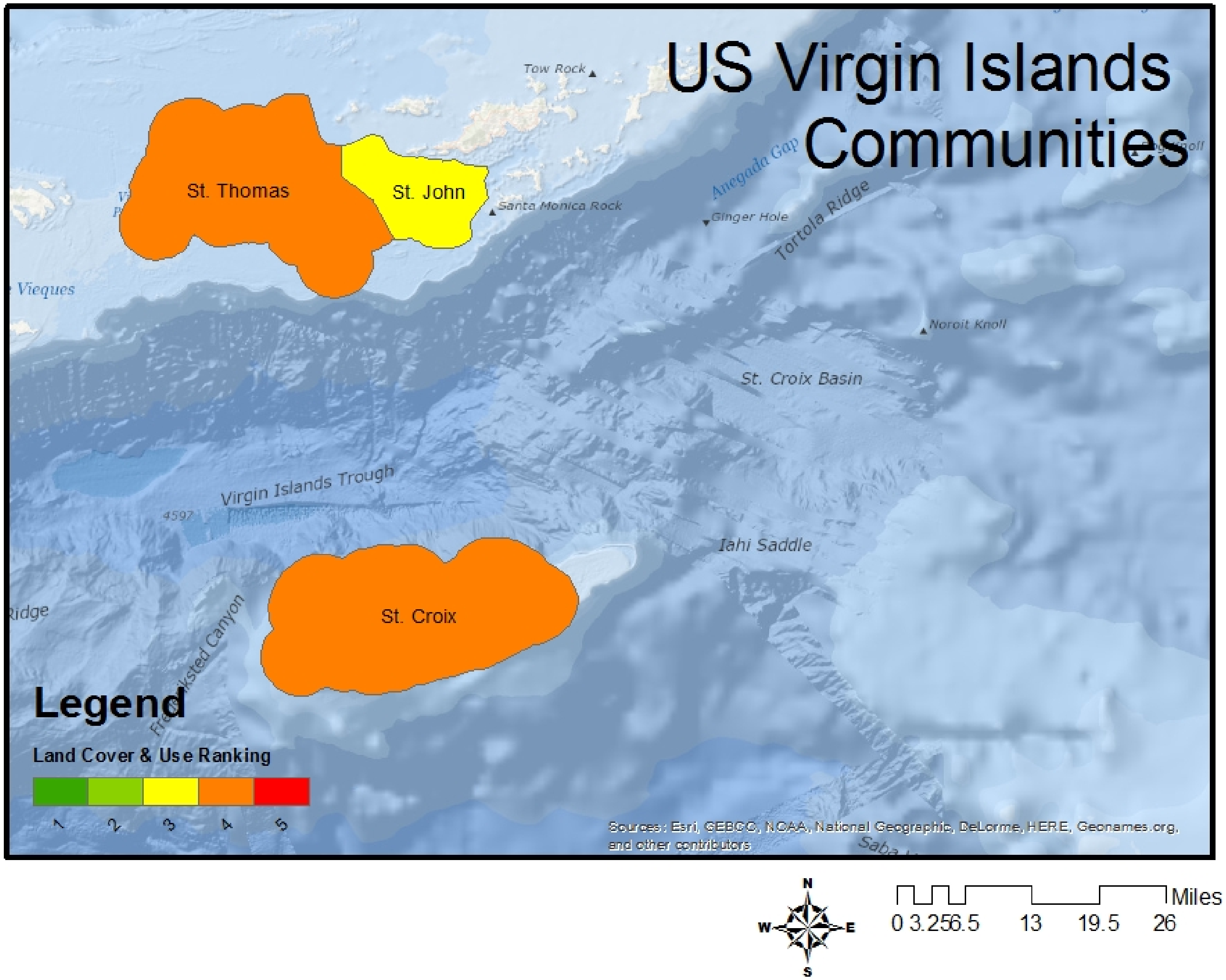

Figure E34: Social -Ecological Resilience Indicators: Land Cover & Use Ranking for USVI Communities.

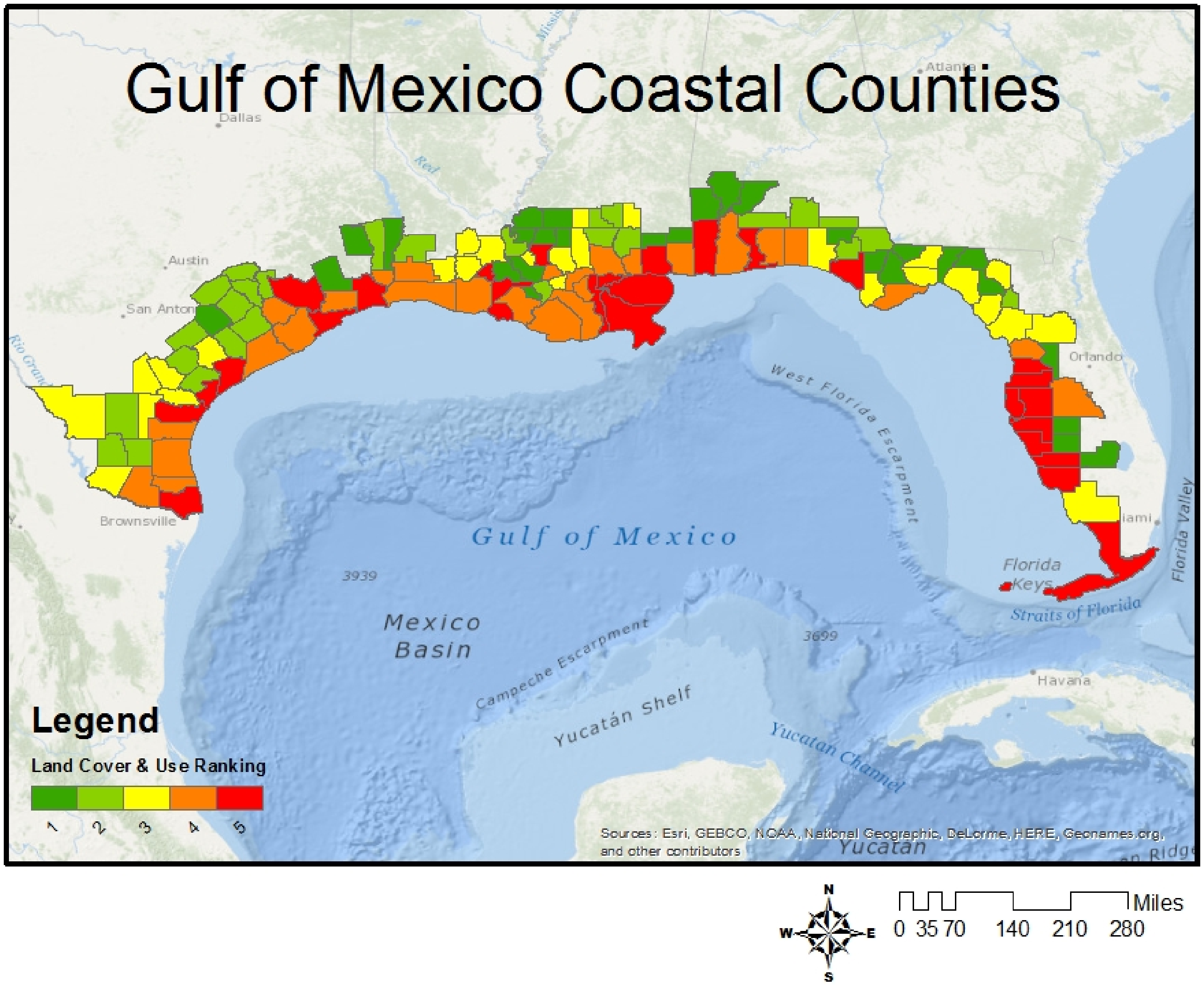

Figure E35: Social -Ecological Resilience Indicators: Land Cover & Use Ranking for Gulf of Mexico Communities.

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