



RESEARCH ARTICLE

10.1029/2018GH000160

Key Points:

- An index of resilience to acute weather events has been developed
- The index has been applied to all counties in the United States
- The application allows the comparison of resilience of counties and the selections of counties provided best lessons learned for county resilience improvement

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Citation:

Summers, J. K., Harwell, L. C., Smith, L. M., & Buck, K. D. (2018). Measuring community resilience to natural hazards: The Natural Hazard Resilience Screening Index (NaHRSI)—Development and application to the United States. *GeoHealth*, 2, 372–394. <https://doi.org/10.1029/2018GH000160>

Received 11 JUL 2018

Accepted 12 NOV 2018

Accepted article online 16 NOV 2018

Published online 7 DEC 2018

This article was corrected on 15 JUL 2019. The online version of this article has been modified to include a Conflict of Interest statement.

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Measuring Community Resilience to Natural Hazards: The Natural Hazard Resilience Screening Index (NaHRSI)—Development and Application to the United States

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Abstract Natural disasters often impose significant and long-lasting stress on financial, social, and ecological systems. From Atlantic hurricanes to Midwest tornadoes to Western wildfires, no corner of the United States is immune from the threat of a devastating natural hazard event. Across the nation, there is a recognition that the benefits of creating environments resilient to adverse natural hazard events help promote and sustain county and community success over time. The challenge for communities is in finding ways to balance the need to preserve the socioecological systems on which they depend in the face of constantly changing natural hazard threats. The Natural Hazard Resilience Screening Index (NaHRSI; previously entitled Climate Resilience Screening Index) has been developed as an endpoint for characterizing county resilience outcomes that are based on risk profiles and responsive to changes in governance, societal, built, and natural system characteristics. The NaHRSI framework serves as a conceptual roadmap showing how natural hazard events impact resilience after factoring in county characteristics. By evaluating the factors that influence vulnerability and recoverability, an estimation of resilience can quantify how changes in these characteristics will impact resilience given specific hazard profiles. Ultimately, this knowledge will help communities identify potential areas to target for increasing resilience to natural hazard events.

Plain Language Summary NaHRSI (Natural Hazard Resilience Screening Index) is a tool for communities to evaluate their likely vulnerability and resilience acute meteorological events like hurricanes, tornadoes, droughts, floods, etc. The index has been applied to all counties of the United States and is comprised of five major parts examining risk of events, governance to address events, societal, built environment and natural environment attributes that will enhance recoverability for these types of events.

1. Introduction

Natural disasters can impose long-lasting and significant stress on social, financial, and ecological systems. From Western wildfires to Midwest tornadoes to Atlantic hurricanes, no portion of the United States is immune from the threat of a devastating meteorological event. Throughout the nation, the benefits of creating environments resilient to adverse weather or weather-related events are recognized as helping to promote and sustain county and community success. The true challenge is in finding ways to balance the preservation of socioecological systems on which communities depend in the face of the constant barrage of natural hazard threats.

The U.S. National Security Strategy suggests that impacts from adverse meteorological events represent a credible national security concern (National Security Strategy, 2015). By one accounting, the federal government has incurred more than \$357 billion in direct costs due to extreme weather and fire events alone over the last 10 years (Office of Management and Budget and Council on Environmental Quality, 2016). With the tempo and magnitude of natural disasters experienced in 2017, it is likely that a considerable spike will be observed in the federal expenditure for recovery and response efforts. Since 2013, the U.S. Government Accountability Office monitors the high-risk fiscal exposure to the federal government because of natural hazard-related events. Recognizing the sweeping impacts of natural disasters across the infrastructure, defense, agriculture, health, and local economies, the U.S. government is challenged with taking steps to better manage this fiscal risk (Government Accountability Office, 2017).

The concept of resilience has evolved from its initial emphasis on the general persistence of ecological system functions in a world that is subject to ongoing change (Holling, 1973), through an orientation

toward coupled socioecological systems and questions of adaptation of humans in nature (Carpenter et al., 1999, 2001; Walker, 1993; Walker et al., 2002). In general terms, resilience is a characteristic of human (or social/societal) and natural systems exhibiting a capacity to withstand and recover from an adverse shock or event (Keck & Sakdapolrak, 2013). In towns and cities, resilience is promoted through planning while in nature, this trait is assumed inherent (Meadows, 2008; National Research Council, 2012). While societal and ecological resilience are highly dependent on one another, an examination of resilience literature reveals that one is often described without appreciation of the other or in the context of their opposing roles (Handmer et al., 2012). Similarly, previous research suggests that positive aspects of county and community quality of life are linked to not only built environments but natural ones as well (Smith et al., 2012; Summers et al., 2012). Any discussion of resilience would be incomplete without considering the role of natural ecosystems, as they could influence many of a county's and community's vulnerability and recoverability characteristics (Summers et al., 2016, 2012, 2014).

In the context of the research presented here, vulnerability describes the propensity or predisposition to be adversely affected while resilience describes the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner (Intergovernmental Panel on Climate Change, 2012). Much of the existing resilience literature focuses on either vulnerability (risk) or recovery (e.g., Cutter et al., 2003; Frazier et al., 2014) as independent constructs of resilience. Summers, Smith, et al. (2017) suggest that a more holistic relationship exists, where an intersection of vulnerability and recoverability sits along a spectrum of resilience. The position of human and natural systems along this gradient reflects their ability or capacity for resilience. In terms of natural hazards, for example, both people and nature can absorb, recover from, and adapt to adverse events (Berkes & Ross, 2013; Gunderson, 2010); however, the degree of resilience is reflected in their mechanisms for recovery. This leads to the concept of basic resilience and recovery potential. Basic resilience can be determined by a direct relationship between risk of a natural hazard occurring and planning, regulation, and training by a community to be ready to face that risk (governance). Thus, basic resilience could be characterized by ratio of level of governance to the likelihood of risk (governance/risk). Similarly, a community's ability to recover from the realization of a natural, hazard event can be exacerbated or diminished by local factors relating to the social structure of the community, the natural environment, and the built environment (Berkes et al., 2003; O'Brien et al., 2009; Pelling & Manuel-Navarette, 2011). These concepts of basic resilience, adaptation, and transformation are included in the development of Natural Hazard Resilience Screening Index (NaHRSI) below.

Ecosystems have innate structures and functions (such as diversity and redundancy) to facilitate recovery from an adverse event (Holling, 1986; Melillo et al., 2014; National Fish, Wildlife and Plants Climate Adaptation Partnership, 2012). Human systems rely on planning and preparation to mitigate known natural hazard exposures and reduce vulnerabilities (Magus, 2010; Tobin, 1999). In both systems, the success of the recovery process is dependent on the robustness of the mechanism. This robustness refers to the system's ability to resist or tolerate change without adapting its initial stable configuration (Meadows, 2008). In the case of nature, ecological conditions may be the factor determining robustness of resilience while the depth and breadth in resilience planning or governance are pillars for resilience in built environments. In the context of governance and risk, the intersection of the status of society and the natural and built environments can modify actual local area resilience to natural hazard events. Understanding how different aspects of resilience reflect a community's capacity for adaptive management is critical for envisioning urban systems and natural ecosystems that can persist through extreme weather events.

A community's ability to endure and recover from abrupt system shocks is an important factor for sustainability. Natural hazard events (e.g., droughts, hurricanes, and floods) can impose long-lasting and significant effects that can impact people and the natural systems on which they depend for sustenance, protection, livelihoods, and recreation. As losses stemming from these events have continued to rise, there has been a notable increase in communities seeking economic, social, and ecological solutions to improve both their sustainability and resilience. The concepts of sustainability and resilience are closely tied as more county and community decision makers recognize that recurring and anomalous weather events may impede achieving their sustainability goals without appropriate and actionable preparation. Therefore, it is not surprising that interest in the subject of resilience related to natural disasters, both cyclic and evolving, is growing.

The concept of resilience has evolved over the past several decades, particularly given the increased interest in preparing for and addressing the current and future challenges we (nations, states, and cities) face, including threats posed by major meteorological events. However, the topic of resilience is a disputed and heavily debated subject regarding anthropogenic and natural systems (Patel et al., 2017). The varying ideas about community resilience generally align, but they are applied differently across the field of resilience research. These differences in application have historically made it difficult for policy makers to identify priorities for improving resilience (e.g., increased governance vs. enhancement of training and economic development, natural resource conservation versus enhancement of social services, and investment in the built environment vs. investment in risk reduction). Despite the differences in conception and application, there are well-understood elements that are widely proposed as important for a resilient community, agreeing that community resilience relates to the sustained ability of a community (a socioecological system) to utilize available resources to respond to, withstand, and recover from adverse difficulties or perturbations (Federal Emergency Management Agency, FEMA, 2011, 2012, 2017; RAND Corporation, 2017).

The NaHRSI was developed using publicly accessible data (e.g., databases available through websites) to help decision makers identify the characteristics that make resilience stronger and weaker. NaHRSI integrates the various viewpoints regarding resilience in terms of potential exposures to natural hazards, governance practices, and the conditions observed in societal, built, and natural systems to inform resilience planning efforts. The index focuses on county-scale measures, the policy action level that is most broadly applicable. While disaster event planning occurs at smaller spatial scales for some urban areas and communities, these data are generally not available for all areas of the Nation. The NaHRSI framework (Summers et al., 2017) serves as a conceptual roadmap to describe the potential impact of natural hazard events impact on a community in the context of exposures and county characteristics. By addressing the factors that influence vulnerability and recoverability, an estimate of resilience can gauge how changes in these characteristics could potentially impact a community's ability to recover from given specific hazard profiles. Ultimately, this knowledge can help communities identify areas to target for improvement to increase their resilience to natural hazard events.

2. Approach

2.1. Conceptualizing Resilience

As part of the conceptualization of NaHRSI, existing community resilience characterization methods and approaches were reviewed with the intent to identify mainstream resilience indicators and indices and determine the applicability of each within the scope of the development of NaHRSI (Summers, Smith, et al., 2017). In summary, an initial search produced 369 print and web publications, which was further reduced by using selected criteria (e.g., quantifiable, integrated, and focus on natural disasters). The resulting pool of 27 published indices representing 57 candidate indicators from this review demonstrated measures that favored an integrated socioeconomic and ecological development approach and showed notable trends toward the use of composite indices for the characterization of community resilience. The 27 published indices and their indicators, in relation to the likely NaHRSI domains, are shown in Table 1.

2.2. Determination of Natural Hazard Event Factors to Be Included in NaHRSI

The National Climate Assessment summarized the current and future impacts of climate change in the United States (<http://sca2014.globalchange.gov/report>). In the construction of this index, the likely changes in natural hazard events associated with geographic regions throughout the United States were assessed, as well as the infrastructure challenges these changes would likely create. Extended heat waves (with associated drought), more frequent heavy downpours (with associated flooding), sea level rise, enhanced insect outbreaks, increased wildfires, altered timing of streamflow, increased and faster sea ice and glacial loss, and increased major storm events (including hurricanes, tornadoes, and superstorms) were identified as impacts likely to be seen in the coming decade. Similarly, infrastructure issues were identified as likely contributors to the impacts of these weather-related events. Discussions with climate and natural hazard experts in each of the 10 Environmental Protection Agency regions, in conjunction with the information provided by the National Climate Assessment (Melillo et al., 2014) and the 100 Resilient Cities report (ARUP, 2014), yielded 12 natural hazards that would be included in NaHRSI:

Table 1
Summary of Literature Reviewed Index by Topical Areas of Interest for Development of NaHRSI

NaHRSI Relevance		Literature Review - Selected Index/Framework																												
Domains of Resilience	Topic of Interest	Candidate Measurement Categories	AWRVI	BRIC	CRI	CRISLR	CDRI1	CDRI2	CRest	CRIG	CRISKI	MCCR	MCR	MRR	M-RD	M-EI	DRI	EJSI	EPI	ESI	EVI	FRI	FVI	HRI	M-CRD	RFI	RIMM	SSI		
Natural Environment	Extent of Natural Areas Integrity	• Managed Lands																												
		• Ecosystem Type																												
		• Condition																												
Society	Economy	• Economic Diversity																												
		• Employment																												
		• Insurance																												
Society	Critical Services	• Safety and Security																												
		• Social																												
		• Labor/Trade																												
Built Environment	Characteristics	• Demographics																												
		• Health																												
		• Communication																												
Built Environment	Infrastructure Integrity / Continuity	• Transportation																												
		• Utilities																												
		• Non-Residential Residential																												
Governance	Preparedness	• Shelter																												
		• Planning																												
		• Investment																												
Risk	Response	• Expenditure																												
		• Time																												
		• Property																												
Risk	Losses	• Human																												
		• Geophysical																												
		• Technology Hazards																												

Existing Measures related to Topic of Interest

20+

10

5

3

Note. Intensity of color represents the number of potential indicators and metrics (lighter color—lower number to darker color—higher number). The numbers refer to the existing measures related to topic of interest. ARI = Agricultural Resilience Index (Ciani, 2012); AWRVI = Arctic Water Resource Vulnerability Index (Alessa et al., 2008); BRIC = Baseline Resilience Indicators for Communities (Cutter et al., 2014); CRI = City Resilience Index (ARUP, 2014); CRISLR = City Resilience Index to Sea Level Rise (Abdrabo & Hassaan, 2014); CDRI1 = Climate Disaster Resilience Index 2011 (Joerin & Shaw, 2011); CDRI2 = Community Disaster Resilience Index 2010 (Peacock et al., 2010); CRest = Community Resilience Index (Kafle, 2012, Renschler et al., 2010); CRIG = Community Resilience Index for the Gulf of Mexico (Baker, 2009); CRISKI = Community Risk Index (Daniell et al., 2010); MCCR = Composite measure of coastal community resilience (K. Li, 2011); MCR = Composite measure of community resilience (Meher et al., 2011); MRR = Composite measure of regional resilience (Martini, 2014); M-RD = Composite measure of resilience to disasters (Kusumastuti et al., 2014); M-EI = Composite measures of ecological integrity (Vickerman & Kagan, 2014); DRI = Displacement Risk Index (Esnard et al., 2011); EJSI-EJ SCREEN Index (U.S. Environmental Protection Agency, 2015); EPI = Environmental Performance Index (Hsu et al., 2016); ESI = Environmental Sustainability Index (Esty et al., 2005); EVI = Environmental Vulnerability Index (Pratt et al., 2004); FRI = Flood Resilience Index (Batca, 2015); FVI = Flood Vulnerability Index (Batca, 2012); HRI = Household Resilience Index (Cassidy & Barnes, 2012); M-CRD = Metrics for community resilience to disasters (Burton, 2015); RFI = Resilience Factor Index (Ainuddin & Routray, 2012); RIMM = Resilience Inference Measurement model (Lam et al., 2016; C. Li, 2013); SSI = Sustainable Society Index (van de Kerck & Manual, 2014).

1. Hurricanes
2. Tornadoes
3. Inland floods
4. Coastal flooding
5. Earthquakes
6. Wildfires
7. drought
8. High winds
9. Hail
10. Landslides
11. Low-temperature extremes
12. High-temperature extremes

2.3. The NaHRSI Conceptual Framework

No singular approach from the literature survey existing composite measures of natural hazard resilience met all of the expected needs for developing NaHRSI. Collectively, however, the reviewed literature provided many of the building blocks (e.g., suites of indicators, indicator groupings, and domains). A heat map table (Table 1) depicts the distribution of metrics used in the final 27 indices across resilience topics of interest to NaHRSI. To varying degrees, all of the existing indices offered patterns of indicator groupings, which were allocated into five domains to describe overall resilience: natural environment, built environment, society, governance, and risk. None of the indices reviewed provided all possible indicators necessary for the construction of NaHRSI. However, 10 of the reviewed publications included information relevant for describing the NaHRSI domains. Information pertaining to the Natural Environment, governance, and risk domains were most frequently excluded from existing indices. Five indices—BRIC, CDRI1, CDRI2, M-RD, and M-CRD (Burton, 2015; Cutter et al., 2014; Joerin & Shaw, 2011; Kafle, 2012; Kusumastuti et al., 2014; Peacock et al., 2010; Renschler et al., 2010)—offered fairly comprehensive descriptions of indicators relevant for quantifying NaHRSI domains. The Climate Disaster Resilience Index 2011 (CRDI1) contributed the most to the proposed NaHRSI structure, addressing all domains based on a suite of 18 indicators.

The final conceptualization of NaHRSI is discussed in Summers, Smith, et al. (2017) and includes five domains composed of 10 indicators, which, in turn, were derived from 117 unique metrics. Figure 1 depicts the final NaHRSI conceptual framework including the domains and indicators of the index. A summary of the domains, indicators, and types of metrics used in NaHRSI is provided in Table 2. The selection of the domains and indicators are completely described in Summers, Harwell, et al. (2017) and are summarized here for completeness. The domains included in NaHRSI include risk, governance, society, built environment, and natural environment. In accordance with the concept of basic community resilience to natural hazards being driven by the likelihood of an event occurring and the community's preparation for such an event, the domains of risk and governance are included at the base of the conceptual model (Figure 1) to denote basic resilience as some relationship between risk and preparedness. Exposure and losses comprise the indicators for risk (discussed below) and community and personal preparedness (Adager et al., 2005; Linnenluecke et al., 2012; Paton & Johnston 2001) and natural resource conservation (Strickland-Munro et al., 2010; Tompkins & Adger, 2004) represent the indicators for governance. Twenty metrics contribute to the two indicators for the risk domain and five metrics contribute to the three indicators for the governance domain (Table 2).

The remaining domains include elements that could exacerbate or diminish the vulnerability and recovery potentials of a community to an event or postevent. These include society, built environment, and natural environment. Societal indicators that can modify vulnerability or recovery include availability of social services (Dominelli, 2013), the type of available labor or trades within the community (Kirrane et al., 2013), safety and security requirements (Christopher & Peck, 2004; Keim, 2008), the socioeconomic and economic diversity of the community (Klein et al., 2003; Linnenluecke et al., 2012), the health characteristics and availability of health care access in the community (Ebi, 2011; Oven et al., 2012), basic demographic information concerning the community (Balbus & Malina, 2009), and the cohesiveness of the community (Baldwin & King, 2018; Meitzen et al., 2018; Sanchez et al., 2017). Fifty metrics are utilized to describe these indicators of society (Table 2). Built environment indicators that can modify vulnerability or recovery include multiple

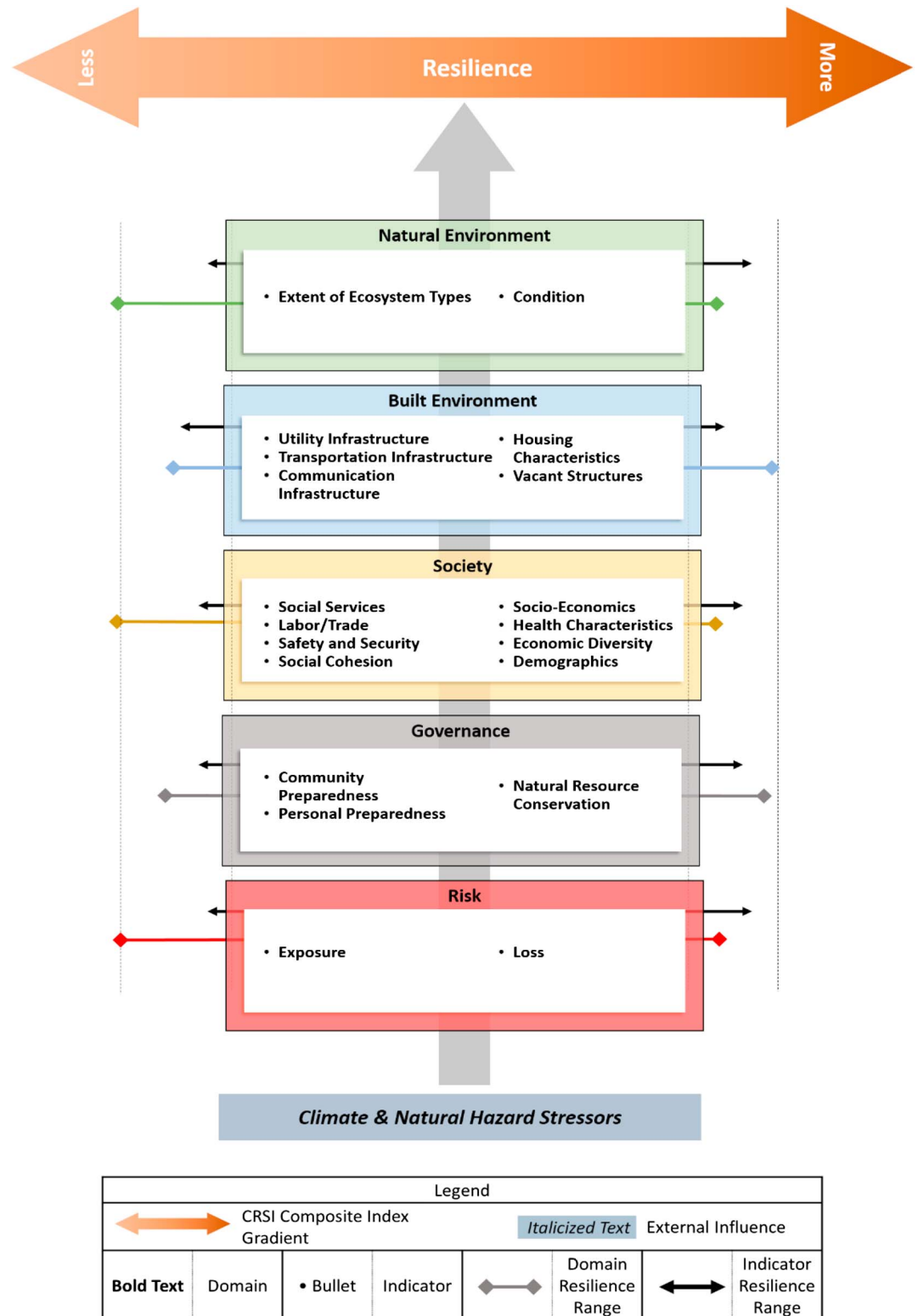


Figure 1. Final Natural Hazard Resilience Screening Index conceptual framework. Arrows projected from boxes to the left and right represent hypothetical increases and decreases in ranges for indicators (black arrows) and domains (colored arrows). CRSI = Climate Resilience Screening Index.

Table 2
List of NaHRSI Domains, Indicators, Scope, and Number of Metrics

Domain	Indicator(s)	Metric(s)		
Built Environment (5/24)	Communication Infrastructure	Communication continuity (7)		
	Housing characteristics	Structure vulnerability (5)		
	Transportation infrastructure	Transportation flow continuity (6)		
	Utility infrastructure	Utility continuity (3)		
	Vacant structures	Structure vulnerability (3)		
Governance (3/5)	Community preparedness	Community resilience strengthening (2)		
	Natural resource conservation	Natural Resource Recovery (1)		
	Personal preparedness	Personal property hazard protection (2)		
Natural Environment (2/18)	Condition	Biodiversity, using birds as a proxy (1)		
		Coastal condition (1)		
		Forest condition (1)		
		Inland lake condition (1)		
		Percentage of clean air days (1)		
		Rivers and streams condition (1)		
		Soil growth suitability (1)		
		Soil productivity (1)		
		Wetlands condition (1)		
		Agriculture area (1)		
		Forested area (1)		
		Grassland area (1)		
		Inland surface water area (1)		
	Marine/estuarine area (1)			
	Perennial ice/snow area (1)			
	Extent of ecosystem types	Protected areas (1)		
		Tundra area (1)		
		Wetland area (1)		
		Risk (2/20)	Exposure	Earthquake probability (1)
				Extreme high temperature incidents (1)
Extreme low temperature incidents (1)				
Flood probability (2)				
Hailstorm probability (1)				
Tornado probability (2)				
Hurricane probability (2)				
Landslide probability (1)				
Major toxics presence (1)				
Non-storm damaging wind incidents (1)				
Nuclear presence (1)				
RCRA sites (1)				
Superfund sites (1)				
Toxic release presence (1)				
Wildfire probability (1)				
Loss	Developed area loss (includes human and property measures) (1)			
	Natural area loss (1)			
	Dual-benefit area loss (includes cropland and managed area measures) (1)			
	Society (8/50)		Demographics	Vulnerable population (5)
				Economic diversity
		Health characteristics		Health problems that may impact personal Resilience (9)
		Labor and trade services		Construction recovery (8)
Safety and security		Provisioning of emergency and civil services (4)		
Social cohesion		Access to social support (4)		
Social services		Access provisioning to critical services (15)		
Socioeconomics		Employment opportunity (1)		
		Personal economics (2)		
		Communication continuity (7)		
Built Environment (5/24)	Communication infrastructure	Communication continuity (7)		
	Housing characteristics	Structure vulnerability (5)		
	Transportation infrastructure	Transportation flow continuity (6)		
	Utility infrastructure	Utility continuity (3)		
	Vacant structures	Structure vulnerability (3)		
Governance (3/5)	Community preparedness	Community resilience strengthening (2)		
	Natural resource conservation	Natural resource recovery (1)		

Table 2 (continued)

Domain	Indicator(s)	Metric(s)
Natural Environment (2/18)	Personal preparedness Condition	Personal property hazard protection (2)
		Biodiversity, using birds as a proxy (1)
		Coastal condition (1)
		Forest condition (1)
		Inland lake condition (1)
		Percentage of clean air days (1)
		Rivers and streams condition (1)
		Soil growth suitability (1)
		Soil productivity (1)
	Extent of ecosystem types	Wetlands condition (1)
		Agriculture area (1)
		Forested area (1)
		Grassland area (1)
		Inland surface water area (1)
		Marine/estuarine area (1)
		Perennial ice/snow area (1)
		Protected areas (1)
		Tundra area (1)
Risk (2/20)	Exposure	Wetland area (1)
		Earthquake probability (1)
		Extreme high temperature incidents (1)
		Extreme low temperature incidents (1)
		Flood probability (2)
		Hailstorm probability (1)
		Tornado probability (2)
		Hurricane probability (2)
		Landslide probability (1)
		Major toxics presence (1)
		Non-storm damaging wind incidents (1)
		Nuclear presence (1)
Society (8/50)	Loss	RCRA sites (1)
		Superfund sites (1)
		Toxic release presence (1)
		Wildfire probability (1)
		Developed area loss (includes human and property measures) (1)
Society (8/50)	Demographics Economic diversity Health characteristics Labor and trade services Safety and security Social cohesion Social services Socioeconomics	Natural area loss (1)
		Dual-benefit area loss (includes cropland and managed area measures) (1)
		Vulnerable population (5)
		Economic stability/recovery (2)
		Health problems that may impact personal Resilience (9)
		Construction recovery (8)
		Provisioning of emergency and civil services (4)
		Access to social support (4)
		Access provisioning to critical services (15)
		Employment opportunity (1)
Personal economics (2)		

Note. Numbers in parentheses for domains show the total number of indicators/total metrics in the domain. Numbers in parentheses for metrics for number of metrics. RCRA = Resource Conservation and Recovery Act.

infrastructure elements—communications (Martins et al., 2017; Wang & Wang, 2017; Zimmerman, 2017), utilities (Ma et al., 2018; Panteli & Mancarella, 2017; Zimmerman et al., 2017), and transportation (Linnenluecke et al., 2012; Wedawatta et al., 2010)—and housing characteristics (Cutter et al., 2008; Dominelli, 2013; Henstra, 2012; Smoyer, 1998). Twenty-four metrics are compiled to represent the built environment (Table 2). The natural environment domain describes the resilience of natural and managed ecosystems through measures of ecosystem extent (Adager et al., 2005; Foley et al., 2005; Smit et al., 2000) and condition (Foley et al., 2005; Stenseth et al., 2002; Walther et al., 2002). Eighteen metrics are combined to represent the indicators within the natural environment domain (Table 2).

Metric data are documented in Appendix A of Summers, Harwell, et al. (2017). This appendix characterizes the sources of the metric data, their ranges, and their directional relationship to the indicator and provided box-and-whisker plots of the county-level data.

2.4. Data Collection and Preparation

Secondary data from established, publicly accessible sources served as the data foundation in the development of NaHRSI. Nationally consistent, county-level, or equivalent-scale data available within the 2000–2015 time frame were targeted for culling. Where county-level data were not available (i.e., condition of ecological systems by county), imputed values were calculated to achieve desired spatial unit representation. In short, ecosystem condition data were only available from national probabilistic surveys. These data were imputed to provide an estimate of condition of each ecosystem type in each county. Metadata were reviewed to ascertain appropriateness for use in NaHRSI. Collected data were age, population, or land area weighted, as appropriate.

Ecological and distance-factored metrics were interpolated using the inverse distance weighting method to arrive at the spatial unit of interest (county). Distance weighted values were derived using preset distance buffers. Buffer values varied from 50 to 100 miles (roughly 80 to 160 km) depending on the ecological resource or attribute the data represented.

Finally, all standardized values were geolocated to county. Because contributed data were not annually consistent, standardized values were averaged across years within each county or county-equivalent unit. Mean data were normalized on a 0 to 1.0 scale to form the metric basis for NaHRSI. The complement of data represents 3,135 of 3,143 counties and county equivalents, excluding eight boroughs from Alaska that were not represented from secondary data sources.

2.5. Calculations

2.5.1. Risk Domain

The risk domain is a probabilistic calculation based on data provided by a partially derived multihazard model using proportional land area exposure extent and accompanying losses data described in Buck et al. (2018) and Summers et al. (2017). The metrics include historical and modeled exposures, basic likelihood of proximal exposures, potential anthropogenic exposures, and losses. All standardized exposure metrics summed for each county or county equivalent to calculate the exposure indicator. The loss indicator was derived from the sum of standardized loss values stemming from natural hazard events that included human, property, and crop monetary losses plus losses of natural lands to human development. Other sources of potential losses occur (e.g., costs of business activities lost and tourism dollars lost), but no broadly applicable data exist for these potential sources of loss. The risk domain measures were calculated for each county as the exposure indicator value multiplied by the loss indicator value. The approach used to calculate the risk domain scores is presented in Figure 2.

2.5.2. Built Environment, Governance, Natural Environment, and Society Domains

Indicators and domains, with the exception of risk (discussed separately), were derived using the following approach:

1. Metric data were adjusted for age, population, or spatial area, as appropriate, prior to standardization (e.g., number of hospitals in a county adjusted by the population of the county).
2. Indicator scores were determined using the average of related standardized metric values, and each indicator was standardized using the calculated range of the indicator.
3. Domain scores were determined from the average of appropriate standardized indicator values and then standardized in preparation for the final NaHRSI calculation.

2.5.3. The Final Steps to NaHRSI

All domains for each county, parish, and borough (all referred to as county below) were min-max standardized on a scale from 0.01 to 0.99. The final NaHRSI calculation begins as a scaled value for recoverability/vulnerability derived from governance and risk (basic resilience) with the basic resilience value being adjusted by the remaining domain scores for social, built environment, and natural environment to represent enhancement of or diminution of basic resilience to complete the calculation of NaHRSI as shown below:

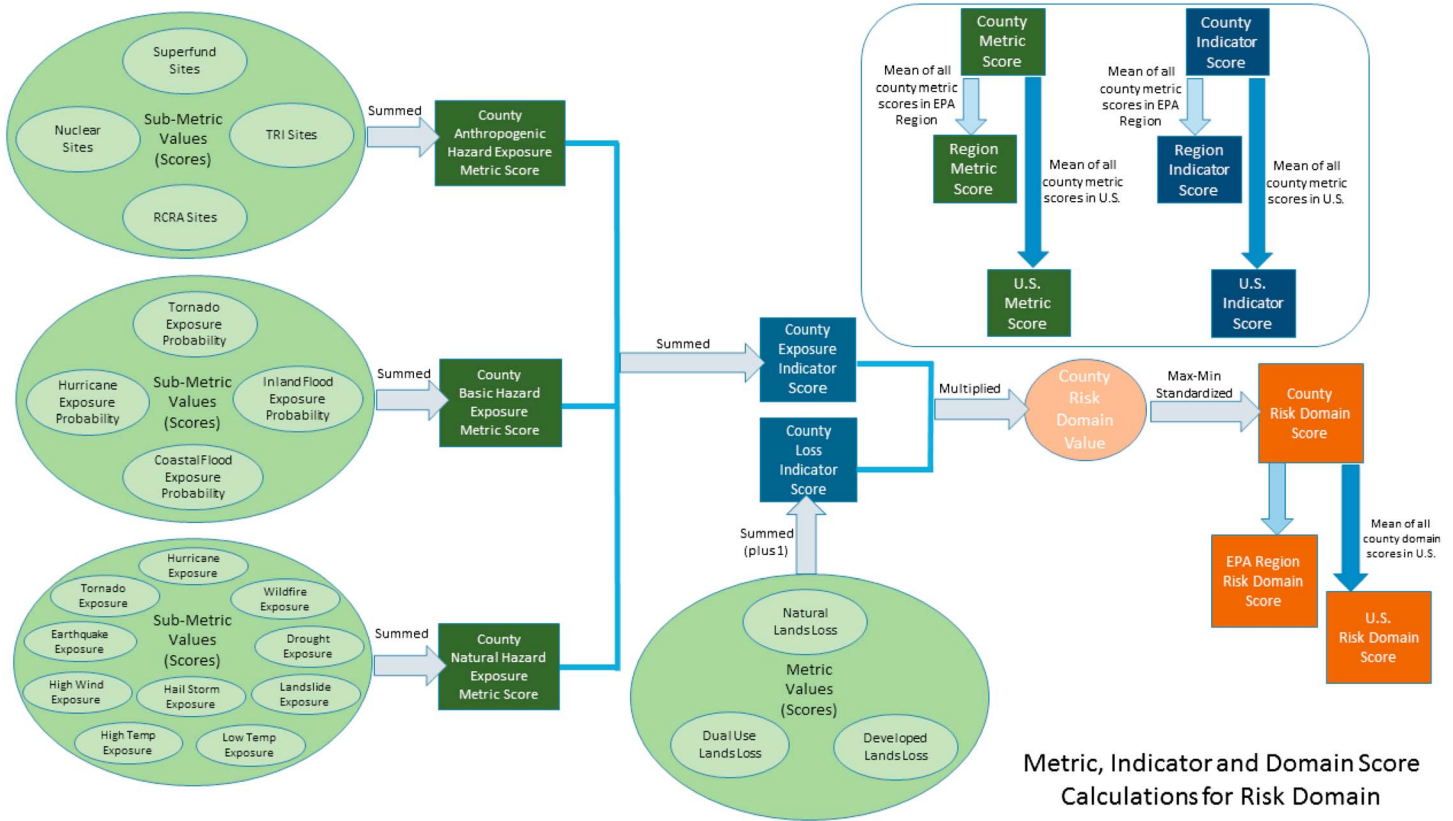


Figure 2. Representation of the metric, indicator, and domain scores for risk domain of Natural Hazard Resilience Screening Index.

$$CRSI(B)_i = R_i / V_i = G_{ov_i} / Risk_i$$

where $NaHRSI(B)_i$ = value of basic resilience (recovery/vulnerability or R_i/V_i) and R_i/V_i = governance in county i /risk in county i . The overall NaHRSI score is calculated as follows:

$$CRSI_i = (G_{ov_i} + Soc(a)_i G_{ov_i} + BE(a)_i G_{ov_i} + NE(a)_i G_{ov_i}) / Risk_i$$

where $NaHRSI_i$ = the value of NaHRSI or adjusted resilience for county i and $Soc(a)_i$, $BE(a)_i$, and $NE(a)_i$ are the adjustment multipliers for society, built environment, and natural environment in each county i and $Risk_i$ is the risk score for county i . The adjust factors are calculated as follows:

$$Soc(a)_i = \frac{(Soc_i - Soc_m)}{Soc_m}$$

where $Soc(a)_i$ is the adjustment multiplier for society in county i , Soc_i is the social domain score for county i , and Soc_m is the median social domain score for all counties:

$$BE(a)_i = \frac{(BE_i - BE_m)}{BE_m}$$

where $BE(a)_i$ is the adjustment multiplier for built environment in county i , BE_i is the built environment domain score for county i , and BE_m is the median built environment domain score for all counties:

$$NE(a)_i = \frac{(NE_i - NE_m)}{NE_m}$$

and where $NE(a)_i$ is the adjustment multiplier for natural environment in county i , NE_i is the natural environment domain score for county i , and NE_m is the median natural environment domain score for all counties.

The domains were weighted equally in the calculation of NaHRSI. An initial analysis was performed to assess whether the NaHRSI results associated with basic resilience (governance and risk) varied in a predictable way. Plotting the domain values of risk versus governance would, from a policy standpoint, be expected to have a positive relationship—greater risk should be accompanied by greater governance. This examination of a positive relationship between risk and governance was tested in three ways: (1) assessment analysis of risk domain versus governance domain scores, (2) examination of the cumulative distribution function of basic resilience (governance/risk), and (3) mapping basic resilience to examine potential patterns.

3. Results

3.1. Analyses of Basic Resilience (Governance/Risk)

An assessment of basic resilience is represented by the ratio of governance domain score to the risk domain score (governance/risk). The expected result of the assessment is a 45° angle from low risk-low governance to high risk-high governance. This finding would demonstrate that governance is developed in proportion to risk. Significant deviation from this finding could reflect an underreaction or overreaction to risk in terms of governance activities. Placing results into quantiles allows characterization of clusters of counties as overreacting or underreacting to risk in terms of governance. In this categorical relationship, generally any combination of risk and governance along the 45° angle (slope = 1.0) plus or minus one category would be in the expected range. A combination of high risk and low governance would suggest underreacting, whereas low risk and high governance would suggest overreacting. Mapping these risk-governance ratio categories by county demonstrates any clustering throughout the United States to detect spatial trends.

The assessment results based on normalized risk and governance domains are shown in Figure 3. These results indicate that the governance score is generally higher than the risk score. Only 181 counties (5.8% of the U.S. counties) have risk scores greater than their governance scores. This suggests that governance activities in the vast majority of counties outweigh the risk of exposure to extreme natural hazard events. This high governance to risk ratio is largely driven by a large number of counties with lower levels of risk to devastating natural hazard events. Figure 4 depicts four management action types: low risk-high governance (A), high risk-high governance (B), low risk-low governance (C), and high risk-low governance (D). Types B and C likely represent situations where the level of governance is commensurate with the level of risk. Type A represents the largest number of counties and indicates a level of governance that exceeds the probable level of risk. Type D indicates a level of governance that is significantly less than the level of risk. Type D counties are those most likely to demonstrate poor basic resilience to natural hazard events and would benefit from increased governance measures.

The distribution of basic resilience for the counties was examined using a ratio of the governance-risk domain scores to determine the roughly 500–1,000 counties with the largest risk to governance disparities. Figure 4 shows the county data from the assessment as a cumulative distribution function of basic resilience (governance/risk). Roughly 6% of counties have a basic level of resilience less than 1.0 indicating that risk is greater than governance suggesting that these counties could be poorly resilient to a natural hazard event. About 56% of counties have basic resilience scores of greater than 2.0 basic resilience suggesting clearly sufficient governance for the likely level of risk. While this result suggests that most counties in the United States would be resilient to natural hazard events, it can be misleading as will be discussed in the next section. The remaining percentage of counties (38%) with basic resilience values between 1 and 2 represent counties with a greater potential to demonstrate inadequate planning given their likely risk. Counties in this category (basic risk scores between 1 and 2) are characterized as more likely to depend on their community and natural resources to provide the adequate services to improve overall resilience.

These county basic resilience scores were mapped to explore the spatial distribution of the quintiles for any potential trends (Figure 5). Areas with the highest basic resilience scores tend to be in the northeast and scattered through Midwest. Areas with the lowest basic resilience scores appear along the West Coast in the southeast and Appalachia. Four counties (<1% of total) showed very low basic resilience scores of <0.25. All of these counties are located in the southeast. Twenty-three counties demonstrated risk scores that were twice their governance scores (i.e., <0.5) and again were predominantly located in southeast and lower Midwest. Eighty counties had basic resilience scores <0.75 where the southeast contained 90% of the

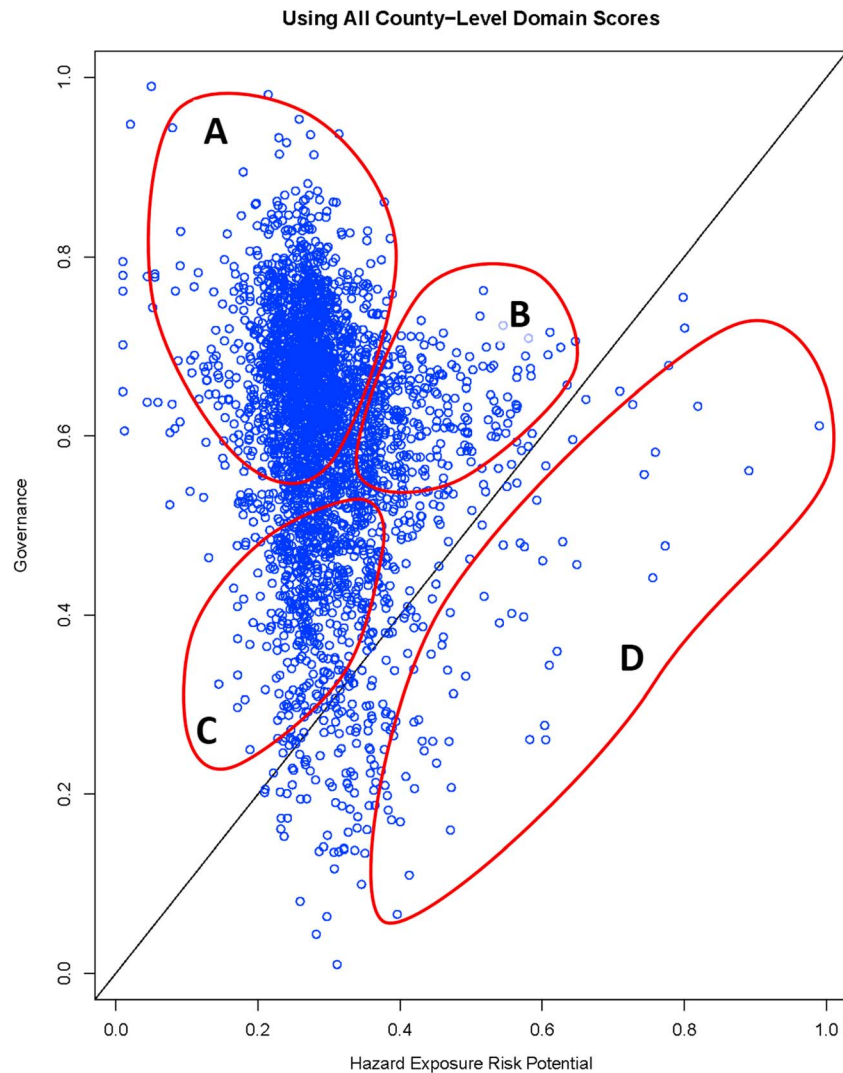


Figure 3. Linear assessment of risk versus governance based on domain scores. Ellipses represent differing management implications with A: low risk-high governance (little increased governance necessary other than improvements for selected below-average indicators); B: high risk-high governance (likely appropriate governance but any improvement in below-average indicators a likely improvement to resilience); C: low risk-low governance (likely appropriate governance for level of potential risk); D: high risk-low governance (improvements to governance and indicator of the Natural Hazard Resilience Screening Index domains necessary).

counties with the remaining counties in far west and southwest. Of all the counties in the United States with basic resilience scores <1 (risk exceeded governance), 85% were in the southeast, 9% the south central and southwest, 4% in the west, and < 1% in the Midwest.

3.2. National NaHRSI Results

Basic resilience is modified by social aspects and structures, the built environment, and the natural environment to represent overall resilience (the NaHRSI score). If these attributes are strong, then resilience (mainly through recoverability) is enhanced. If these attributes are weak, then resilience for an area is reduced. The following national results sections examine basic resilience as modified by societal, natural environment, and built environment factors to determine an overall NaHRSI score. These scores were examined both including and excluding the boroughs of Alaska. This modification was deemed prudent given the mixed levels of data available for the Alaskan boroughs (some boroughs had all levels of data while others did not).

The U.S. NaHRSI score is 2.71 based on the average of NaHRSI scores for all counties in the United States, excluding Alaska, ranging from -2.13 to 14.10 (including Alaska increases the max to 189.17). The NaHRSI

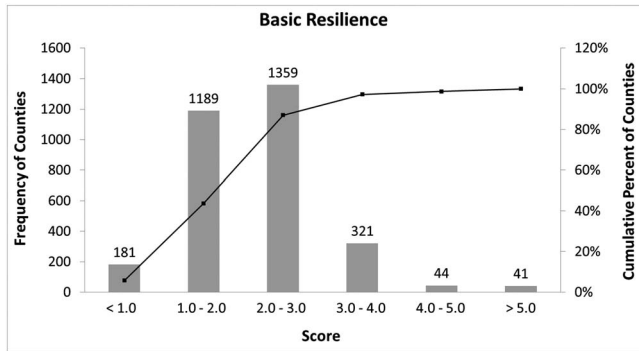


Figure 4. Distribution of county basic resilience scores (governance/risk). Bars equal frequency of basic resilience score for counties. Line indicates cumulative percentage of counties. Number represents number of counties in the basic resilience score range.

and domain scores for the nation are shown in Table 3. The distribution of overall NaHRSI values and the domain scores by county for the United States are shown in Figure 6. Examples of inferences that can be made from the maps are the following:

1. The western United States (east of the Rockies), the Great Lakes area, and the upper northeast have higher NaHRSI values (higher resilience to natural hazard events).
2. The western Midwest, the southeast, the southwest, and Appalachian region have lower NaHRSI values.
3. The lower northeastern coastal area, southeast/Gulf coasts, a small area associated with southern Lake Michigan, and southern far west have the highest risk domain scores albeit for different types of natural hazard events. Lower risk scores for natural hazard events are seen in the west and upper Midwest, Alaska, and Hawaii.
4. Higher governance scores are seen in the northeast, Mid-Atlantic, and Great Lakes areas of the U.S. lower governance scores related to natural hazards were observed in Appalachia, the deep south, and selected counties in the far west.
5. Higher society scores are seen in the upper Midwest and mountain west. Lower society scores are seen in Appalachia and the deep south.
6. Both built and natural environment domain scores were higher in the west, parts of deep south, and lower in the western Midwest and parts of the southeast.

Examining the 150 counties in the United States with the highest NaHRSI values, the Pacific Northwest, and Alaska have the most counties (48 counties of which 19 are in Alaska) followed by the upper west (44), the upper Midwest (23), and the northeast (14). Only the southeast and Mid-Atlantic areas do not have any counties in the top 150 NaHRSI county list. This provides state and counties with lower NaHRSI scores with several example counties to use as role models for the improvement of their scores. The 150 counties with the lowest NaHRSI scores are predominated by the southeast (86 counties) followed by the Mid-Atlantic (33), the south central United States, (13), the Midwest (9), and the Rocky Mountain states (7).

Risk due to natural hazard events across the United States is examined in more detail in Figure 7. The lowest risk domain scores all occur in Alaska, but if Alaska is excluded, the five lowest risk scores occur in the north-west (Montana, Idaho, and Washington). The highest risk scores occur throughout the United States, with two counties in Texas and one each in Colorado, Georgia, and Virginia. Natural exposures due to natural hazard

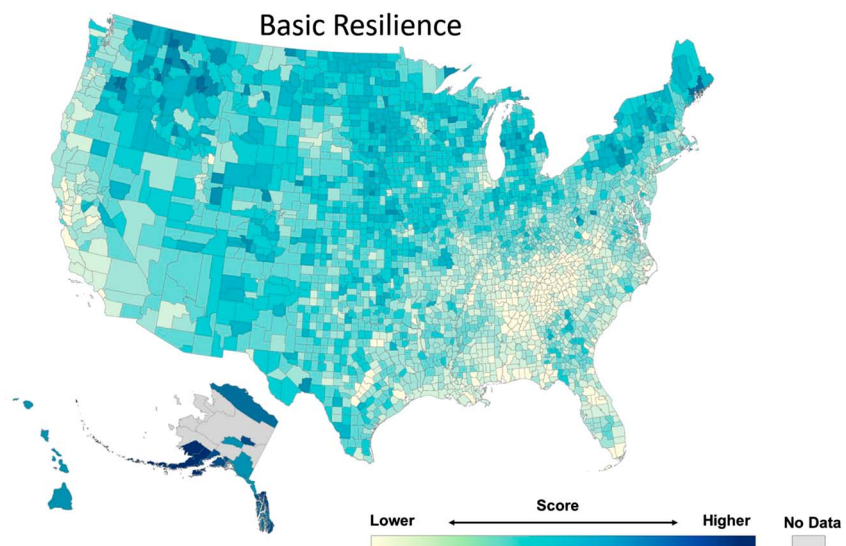


Figure 5. Map of the distribution of county scores for basic resilience.

Table 3
Summary of NaHRSI and Domain Scores for the United States, Both With and Without Alaska

Region	Inclusions and Exclusions	Risk	Governance	Built environment	Natural environment	Society	NaHRSI
National	Including Alaska	0.29590	0.59674	0.39320	0.41333	0.51561	2.71349
Average	Excluding Alaska	0.29758	0.59575	0.39262	0.41182	0.51587	2.37534

Note. NaHRSI = Natural Hazard Resilience Screening Index.

events are predominated by drought (99% of counties experiencing drought), extreme high and low temperatures (100%), inland flooding (99%), high winds (98%), and hail (98%). In short, the meteorological events depicted in NaHRSI, for the 2000–2015 period, are experienced largely throughout the United States with the exceptions of wildfires (52% of counties), landslides (39%), earthquakes (12%), coastal flooding (11%), and hurricanes (8%). Other types of anthropogenic exposure that could exacerbate natural hazard events impact most counties. Resource Conservation and Recovery Act sites and Toxic Release Inventory sites dominate the technological exposure indicator at 71% and 87%, respectively. Superfund sites were seen in 28% of counties, while nuclear facilities were located in 5% of counties. Losses due to natural hazard events of human life, property, and natural ecosystems occur in almost all counties, while losses of crops have occurred in 73% of counties.

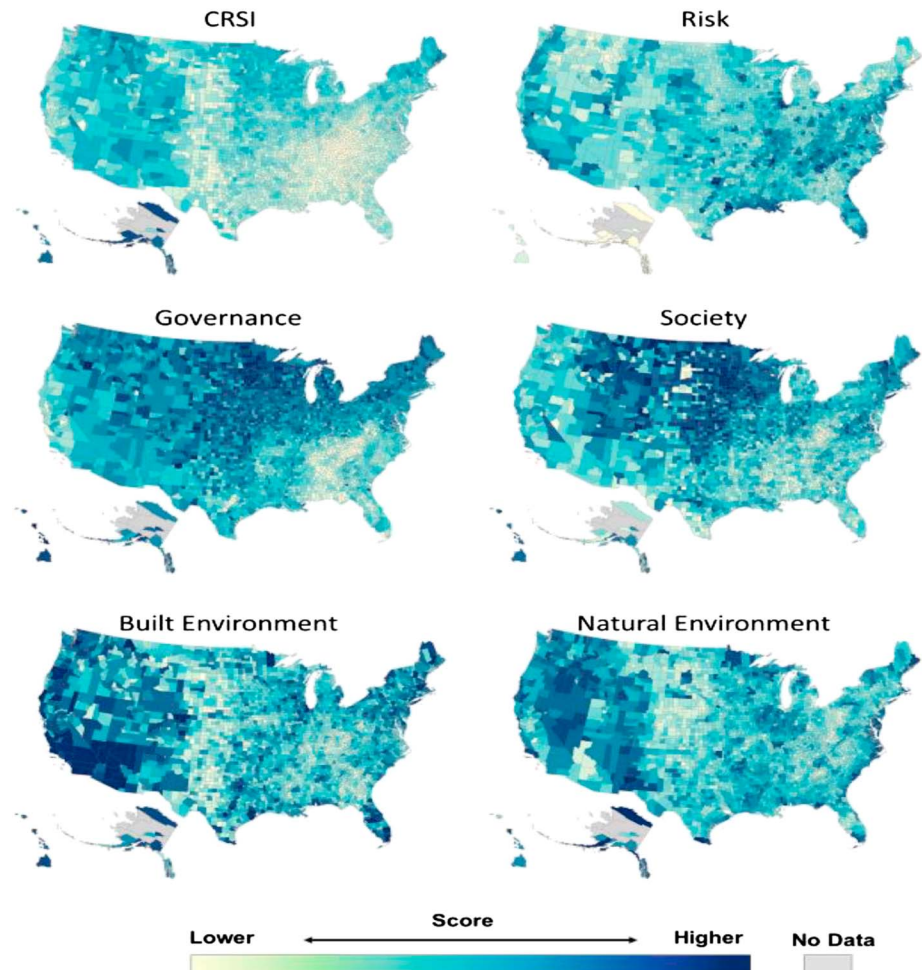


Figure 6. National Natural Hazard Resilience Screening Index values and domain scores (risk, governance, society, built environment, and natural environment). CRSI = Climate Resilience Screening Index.

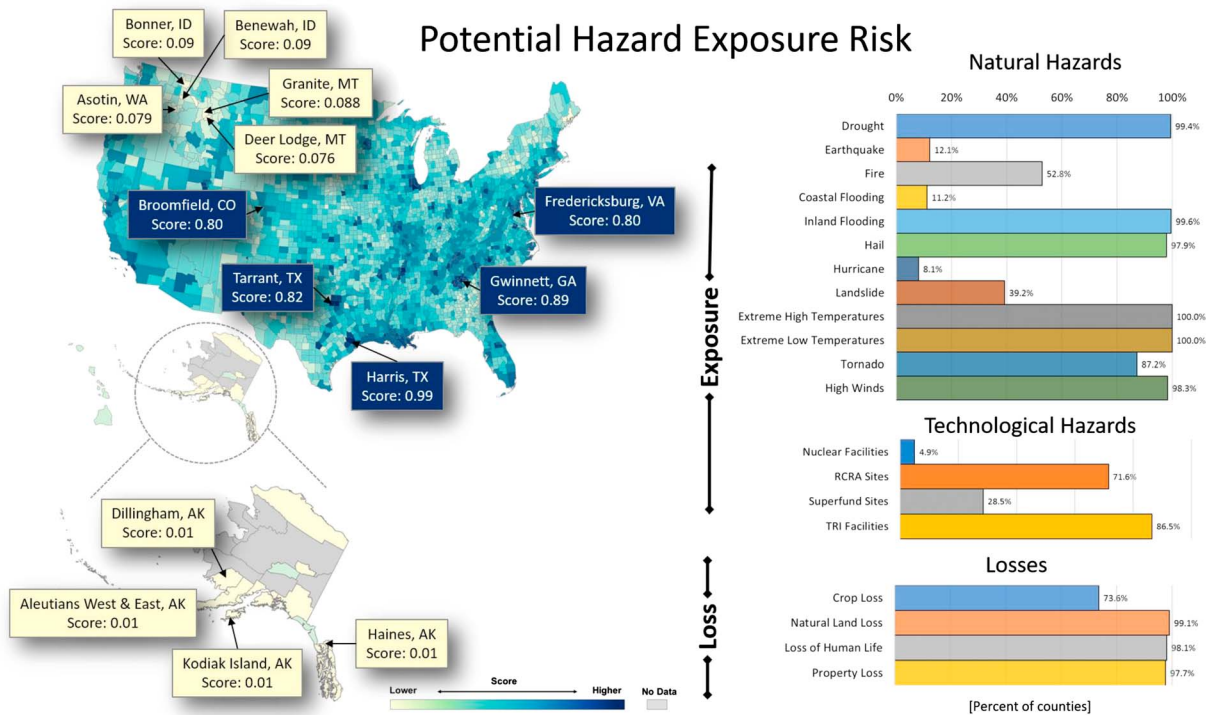


Figure 7. Map of risk domain scores delineating the five counties with the highest risk domain scores and the four lowest risk domain scores (all in Alaska) and the five lowest scores excluding Alaska. The percentage of counties experiencing each of the 11 natural hazard event types, the 4 technological hazards, and losses of human life and property. RCRA = Resource Conservation and Recovery Act; TRI = Toxic Release Inventory.

The contributions of the 20 indicators to the national domain scores are shown in Figure 8. Natural resource conservation (governance), number of vacant structures and housing characteristics (built environment), as well as demographic characteristics (society) most strongly influenced national domain scores. Secondary influences included levels of exposure (risk), socioeconomic characteristics, social cohesion, and economic diversity in the society domain, community, and personal preparedness (governance) and acreage of ecosystem types (natural environment).

4. Discussion

Every year, U.S. counties and communities face devastating losses caused by weather-related disasters. Fires, floods, storms, other hazards, and their associated consequences have significant impacts on counties and communities, especially, their economies, infrastructures, and the environments. The United States has recently experienced a number of large-scale and devastating natural disasters, including catastrophic wildfires, far-reaching floods, and damaging storms. The increasing prominence of extreme weather events makes it critical for governments, businesses, and individuals to examine their anticipatory adaptation and organizational resilience to these events (Linnenluecke et al., 2012). The private sector and all levels of government are embracing resilience as a holistic, proactive framework to reduce vulnerabilities, improve services, adapt to changing conditions, and empower citizens (e.g., National Disaster Resilience Competition; Housing and Urban Development, 2017; Leadership in Community Resilience; National League of Cities, 2016, 2017).

Unlike other resilience estimates, NaHRSI integrates all the major aspects of resilience through its five domains. Overall, NaHRSI values, domain scores, and indicator contributions all paint a picture for the United States of reasonable resilience to natural hazard events. However, the distribution of these scores is broad. While there are many relatively resilient counties in the United States, there are a number of counties in which overall resilience to natural hazard events is low or one or more of the domain scores are low. Therefore, more specific results and analyses should be examined for each of the regions.

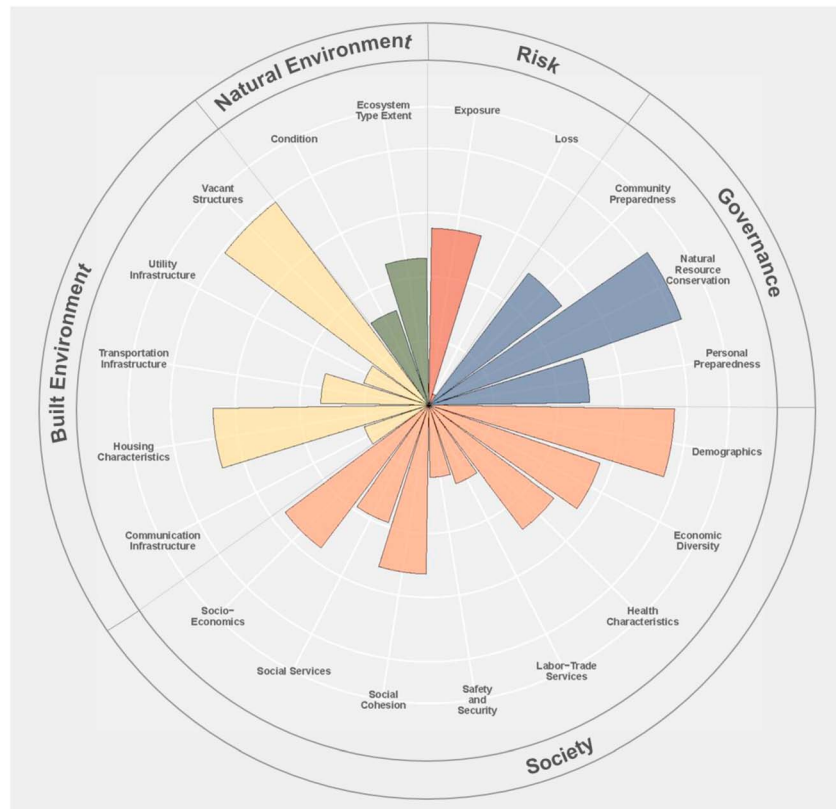


Figure 8. Polar plot showing the contribution of the 20 indicators associated with the domain scores for the nation. The length of the bars corresponds to the indicator score. Within a domain, the higher indicator scores show a greater contribution to the domain.

4.1. Potential Utility of NaHRSI

For over 50 years, hazards researchers have focused on a series of fundamental questions relating to “How do people respond to environmental hazard and what factors influence their choice of adjustments” (Cutter 1996, 2012). There are few examples of comparative measures of community health, well-being, resilience, or condition at the county level (Miringhoff & Miringhoff, 1999). The Social Vulnerability Index is one of the few county-level measures of social vulnerability to environmental hazards (Cutter, 2003).

This present paper outlines the approach and application of an index to examine the resilience of U.S. counties, regions, and the overall nation to natural hazard events, holistically, examining not only risk but including governance, social attributes, the built environment, and aspects of the natural environment. No other efforts to quantify county-level resilience have examined all five of these component domains. A number of studies have examined one or two of the domains, while a few have examined as many as three or four of the domains (see Table 1). BRIC (Baseline Resilience Indicators for communities, Cutter et al., 2014) provides the closest effort that includes all five of the domains. BRIC does not include a probability of risk event measure but does include measures associated with society (social, economic, and community capital indicators), the built, and natural environments and governance.

The highlights of BRIC (Cutter et al., 2014) suggest that inherent resilience and its drivers are spatially variable. Similarly, NaHRSI shows basic resilience (governance and risk) to be spatially variable as well as the recovery potential domains of society, built environment, and natural environment. BRIC demonstrates higher level of inherent resilience in the Midwest and northeast. NaHRSI shows the highest resilience in Alaska and Hawaii (not included in the BRIC assessment), the upper Midwest, northeast, and selected parts of the northwest (in contrast to BRIC). Some of these minor differences are likely due to the inclusion of risk in NaHRSI but not in BRIC. The lowest levels of resilience in BRIC are identified as Texas border counties, Appalachia, and the interior western United States. In NaHRSI, poorest resilience occurs in

Appalachia, much of the southeast, the Western Plains including border and west Texas counties. The extension of lower resilience scores into the southeast in NaHRSI appears to be driven by higher risk scores and lower society scores in this area.

BRIC found that resilience (defined in NaHRSI as the nonrisk domains) and vulnerability (defined in NaHRSI as the risk domain and by Cutter et al., 2008, as Social Vulnerability Index) were statistically related but not the obverse of one another. Clearly, social vulnerability and physical risk are not the same measure but a similar observation can be made for physical risk of a disaster event and resilience to such an event in NaHRSI. The concept used in NaHRSI of basic resilience being the ratio of governance and risk permits some high risk areas to offset that risk by increased governance to enhance resilience, while areas with high risk but lower governance display lower basic resilience.

Further research and application efforts to adapt NaHRSI for use within individual counties and communities would clearly be useful for the development of community-specific resilience plans. The potential of using NaHRSI-related information by state and local staff tasked with assessing resilience in their areas of the counties seems particularly useful. Supporting state and counties to assess risk, governance, societal attributes, the built environment, and natural environment in a holistic manner will be important in further development of local and county-level, and even state, resilience plans. Similarly, at the county level, states and counties can

1. Assess relative risks of differing weather-related events
2. Disassemble NaHRSI to determine why the resilience of certain counties is projected to be low and that of others are projected to be high
3. Provide lessons learned from one county to the next on governance and other activities that have increased local resilience to weather-related events
4. Provide a comparative database permitting one way to assess where investments might have the greatest return in terms of improved resilience
5. Provide a database that can be updated to include the most recent information on the NaHRSI metrics, indicators, and domains so that improvements can be tracked.

4.2. Example of NaHRSI Use—Hurricane Harvey

In August, 2017, Hurricane Harvey had two landfalls in Texas—Rockport, TX, in Aransas County and Port Aransas, TX, in Nueces County. In addition to wind damage, rainfall from Hurricane Harvey resulted in massive flooding in Houston and surrounding areas (Galveston, Harris, and Brazoria Counties) and Beaumont and surrounding areas (Jefferson and Chambers Counties). Some of the worst damage appeared to be in Rockport, a coastal city of about 10,000 that was directly in the storm's path. Many structures were destroyed and Rockport's roads were littered with toppled power poles. Extensive damage was also registered in Port Aransas, TX (site of the second Texas landfall). It is estimated that it will be a long time before the storm's catastrophic damage is repaired. Flooding in the Houston/Beaumont areas is the worst in history, displacing millions of people and with flood waters taking weeks to months to recede. As an exercise, NaHRSI results were examined (after the fact) to determine the magnitude and likely locations of extensive damage and low resilience along the Texas Gulf Coast (Table 4).

Of these counties, NaHRSI scores for Aransas, Calhoun, Chambers, Galveston, Harris, Jackson, Jefferson, and Refugio Counties are significantly below the national average for NaHRSI suggesting lower resilience to natural hazard events. All of these counties, plus Brazoria, Fort Bend, Jefferson, and Nueces, display risk domain scores greater than the national average suggesting a history that includes exposure and potential losses stemming from major natural hazard events. Aransas, Jackson, and Refugio Counties have significantly reduced built environment domain scores suggesting that if an event were to strike these counties, they would be more likely to suffer significant structural damages as a result of reduced public infrastructure and large proportions of vacant buildings. These three counties also possess society scores below the national average. This could indicate a lack of skills diversity to easily rebuild along with deficient security and security infrastructures. Hurricane Harvey also devastated Port Aransas, TX, in Nueces County. Nueces County has a significantly higher risk domain score than the national average associated primarily with historical hurricane paths. The county is dominated by Corpus Christi, TX, which avoided much of the devastation associated with the hurricane; however, Port Aransas suffered extensive structural damage. Port Aransas

Table 4
NaHRSI and Domain Scores for Select Counties Along the Texas Gulf Coast and National Average Scores (Excluding Alaska)

County	Risk	Governance	Built environment	Natural environment	Society	NaHRSI
Aransas	0.32889	0.57259	0.33419	0.52163	0.40423	1.68467
Brazoria	0.38408	0.66188	0.77630	0.54926	0.52368	4.22022
Calhoun	0.33956	0.50474	0.43549	0.49039	0.42868	1.79703
Chambers	0.41971	0.61495	0.51116	0.50005	0.43950	2.13280
Fort Bend	0.55134	0.64353	0.78479	0.42022	0.58024	2.64409
Galveston	0.47067	0.61040	0.60782	0.40844	0.47196	2.01258
Harris	0.99000	0.61143	0.83741	0.19155	0.49091	1.03005
Jackson	0.31103	0.58578	0.33742	0.48061	0.53769	2.14238
Jefferson	0.46213	0.53399	0.69823	0.44851	0.52149	2.29798
Matagorda	0.29963	0.54478	0.43992	0.50342	0.43102	2.28617
Nueces	0.32810	0.63902	0.69866	0.41923	0.47736	3.56655
Refugio	0.31287	0.63050	0.26566	0.46778	0.44307	1.46869
San Patricio	0.26694	0.61545	0.48926	0.44391	0.40174	2.73226
Victoria	0.23454	0.53276	0.51231	0.51035	0.54069	3.82251
National Including Alaska	0.29590	0.59674	0.39320	0.41333	0.51561	2.71349
Average Excluding Alaska	0.29758	0.59575	0.39262	0.41182	0.51587	2.37534

Note. Bold denotes significantly below national average for NaHRSI and above national average for domains. NaHRSI = Natural Hazard Resilience Screening Index.

is likely much more similar to Rockport, TX, in Aransas County, which demonstrates a significantly lower than average NaHRSI score.

The other counties with lower NaHRSI scores—Harris (1.03), Calhoun (1.79), Galveston (2.01), Chambers (2.13), and Jefferson (2.29)—all show high risk domain scores well above the national average. The Harris County risk score (the highest in the United States) is exacerbated by significant anthropologic risks located there (e.g., chemical and oil refinery facilities and Superfund sites). Chambers County, located southeast of Harris county, has a lower than average NaHRSI score but a significantly higher than average risk domain score. Four of these counties are at significant risk for flooding and all four counties significantly flooded due to the intense rainfall associated with Hurricane Harvey. Houston (in Harris County) is reported to have had historic flooding that did not recede for weeks or months in some areas. The region's flat topography, hard clay soil, and sprawl of new development combine to make for a drainage nightmare.

Resilience from the flooding in these counties appears to be driven by differing factors based on the NaHRSI and domain scores. Brazoria County has a higher than average resilience score that appears to be the result simply of a high risk, but all the remaining factors tend to reduce the risk and increase the resilience score to 4.22 (well above the national average). Harris County, on the other hand, has the highest risk scores in Texas (0.99) again associated with flooding and several exacerbating factors. The NaHRSI score for this county is significantly below the national average at 1.03 suggesting recovery from a major event could be a very long process. This lower resilience seems to be driven by a very low natural environment score (0.192) suggesting that increasing development in the last decade and loss of natural lands is significant (particularly to the north and west of Houston). Natural and open lands often provide a buffering impact to natural hazard events. They are usually damaged but tend to recover quickly while reducing the impact of the event on surrounding populated areas. This low level of natural ecosystems in the Houston area (often replaced by impervious surfaces) would enhance the impact of flooding. Chambers and Jefferson Counties also have high risks levels associated with flooding with both counties displaying significantly lower than average resilience scores (Chambers County—2.13 and Jefferson—2.29). However, the remaining domain scores in both counties suggest more rapid recovery than Harris County with Chambers County recovering at a slower rate than Jefferson County.

4.3. Where Can We Go From Here?

Our desire to have counties and communities that are minimally impacted by natural hazard events is nearly impossible without a strong recoverability plan and its execution following an event. These plans and their

execution maintain a community at a significant distance from ecological, economic, and social tipping points (e.g., stability, sustainability, joblessness, social inequity, and ecosystem condition). Little attention has been given to the interconnectedness of the vulnerability and recoverability—the basic aspects of resilience (Summers et al., 2014) as they relate to a community's natural hazard resilience. A community may be naturally vulnerable to natural hazard events or vulnerable through anthropogenic activities, but its resilience to these vulnerabilities is guided by the combination of environmental, social, economic, and governance drivers.

U.S. national, state, and local governments have recognized that an integrated, coordinated, and cooperative effort is required to enhance their capacities to withstand and recover from weather-related disasters and emergencies. A disaster-resilient community is one that works together to understand and manage the risks that it may confront. Resilience to disasters is the joint responsibility of all elements of society, including all levels of business, government, the nongovernment sector and individuals. If all these sectors work together with a shared focus and sense of responsibility, they will be much more effective in developing disaster resilience than the individual efforts of any one sector.

4.3.1. Potential Role of Governments

Governments, at all levels, must play a significant role in improving the nation's resilience to disasters:

1. Developing and implementing effective and useful land management and planning arrangements and other mitigation activities based on risk;
2. Having effective plans and policies in place to provide information to people about how to assess risks and reduce their vulnerability to hazards;
3. Having effective and clear education systems so people understand what choices are available and what the best course of action could be for responding to an approaching hazard;
4. Supporting counties and communities, as well as individuals, to prepare for extreme events;
5. Ensuring the most effective, well-coordinated response from our emergency services and volunteers when disaster hits; and
6. Working in a swift, compassionate and pragmatic way to help counties and communities recover from devastation and to learn, innovate and adapt in the aftermath of disastrous events.

Local, state, and national governments are working collectively to incorporate the principle of disaster resilience into aspects of natural disaster arrangements, including preventing, preparing, responding to, and recovering from disasters. Further future enhancements and local applications of NaHRSI can provide advancements in these disaster-related resilience activities.

The FEMA established the Strategic Foresight Initiative (FEMA 2012) to address the need. This initiative brings together significant elements of the emergency management community to discuss important future issues, trends, and other issues and to work through their implications. Working collaboratively, these groups are beginning to understand the full range of changes they might encounter and the nature of their likely future needs. Therefore, they can begin to develop and execute a shared action agenda for action. One of the first tasks of this initiative group should be to bring together the representative views of all governments, business, nongovernment sector and the community into a comprehensive National Disaster Resilience Strategy. This group should also be tasked with considering further those lessons arising from the recent bushfires, floods, tornadoes, and superstorms that could benefit from national collaboration.

4.3.2. Role of Business

Businesses can and do play a critical role in supporting a community's resilience to disasters. Businesses provide expertise, resources, and many essential services upon which the community depends. Businesses, particularly important infrastructure providers, contribute to understanding the risks that they face and ensuring that they can continue providing services during or soon after a disaster.

Insurance and reinsurance businesses are particularly important to county and community resilience (both planning and after an event). If insurance is not available for an area because of higher risk of a meteorological event or the has not been purchased to cover potential damage due to cost, negative impacts of events to communities and individuals become magnified and extended. Working with the insurance industry so that they more fully accept community resilience approaches could be a major influence for improving overall resilience. Having insurers take into account the efforts that governments take at all levels to enhance resilience to natural disasters could reduce overall costs, impacts, and losses.

4.3.3. Role of Individuals

Community disaster resilience is largely based on individuals taking their share of responsibility for preparing for, preventing, responding to, and recovering from natural hazard disasters. A community's constituents can do this by drawing on the resources, guidance, and policies of local government and community organizations. Individuals' resilience to these types of disasters is significantly increased by active planning and preparation for protecting life and property, including purchasing insurance at reasonable rates to cover potential losses. This planning and preparation should be based on an awareness of the threats relevant to their locality as well as being involved in local community disaster or emergency management arrangements. This involvement can often take the form of volunteerism.

4.3.4. Role of Nongovernment Organizations and Volunteers

Nongovernment and community organizations are at the forefront of strengthening disaster resilience in the United States. It is to them that Americans often turn for support or advice, and the dedicated work of these agencies and organizations is critical to helping counties and communities to cope with, and recover from, a disaster. Building and fostering partnerships between U.S. national, state, and local governments and these agencies and organizations is essential to communicate the disaster resilience message and to explore practical ways to strengthen resilience to natural disasters in the counties and communities they serve. Strengthening the disaster resilience of the United States is not a stand-alone activity that can be achieved in the short term. Similarly, it cannot be achieved without a common commitment and concerted effort by all sectors of society. But it is an effort that is worth making because building a more disaster resilient nation is an investment in our future.

5. Conclusions

The United States has and continues to cope well with natural disasters, through cooperative and established emergency management policies and plans, effective capabilities, and dedicated volunteer and professional personnel. Americans are renowned for their resilience to natural hazard events, including the ability to adapt and innovate a strong community spirit that supports those in need and the self-reliance to recover from disasters. Joint, collective responsibility is needed to build capacities for resilience at multiple scales effectively.

We believe that the use of NaHRSI can help the United States and its regions and counties to promote and address capacity building of resilience to natural hazard events by comparatively examining each county's resilience to these events and the deconstructed make-up of these county NaHRSI scores. Furthermore, using the overall and deconstructed scores can allow government entities charged with resilience capacity building to understand their specific strengths and shortcomings and locate others who have successfully addressed similar shortcomings.

Acknowledgments

The authors would like to acknowledge the remaining members of the NaHRSI team—James Harvey, Justin Bousquin, and Deborah Vivian. All are located at the Gulf Ecology Division, and all have played instrumental roles in the development and application of NaHRSI. The data used to develop NaHRSI are numerous and varied. Over six million data points comprise the characterization of individual metrics, indicators, domains, and eventually the NaHRSI scores. It is impractical to deposit these data in a single location for use by other researchers, and, in fact, some data are proprietary and cannot be posted. However, the sources of all data used in the construction and application of NaHRSI can be found in the NaHRSI (CRSI) report compiled by Summers, Harwell, et al. (2017) as Appendix A. This appendix provides the metadata for all metrics including the original source locations of all data. The views expressed in this article are those of the author(s) and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

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