SOCIAL VULNERABILITY:

SOCIAL SCIENCE PERSPECTIVES ON CLIMATE CHANGE, PART 1

Dean Hardy, Heather Lazrus, Michael Mendez, Ben Orlove, Isabel Rivera-Collazo, J. Timmons Roberts, Marcy Rockman, Kimberley Thomas, Benjamin P. Warner, Robert Winthrop

April 2018

Disclaimer. *These white papers are the products of a workshop hosted in part by the U.S. Global Change Research Program's Social Science Coordinating Committee. They were developed by multidisciplinary teams comprising scientists and researchers from federal agencies and academia. These papers and their conclusions do not necessarily reflect the policy or views of the federal government, the Social Science Coordinating Committee, or the U.S. Global Change Research Program.*

Author Information. Dean Hardy, SESYNC, University of Maryland, dhardy@sesync.org; Heather Lazrus, National Center for Atmospheric Research, hlazrus@ucar.edu; Michael Mendez, Yale University, michaelmendez101@gmail.com; Ben Orlove, Columbia University, bso5@columbia.edu; Isabel Rivera-Collazo, University of California, San Diego, iriveracollazo@ucsd.edu; J. Timmons Roberts, Brown University, J_Timmons_Roberts@brown.edu; Marcy Rockman, National Park Service, marcy_rockman@nps.gov; Kimberley Thomas, Pennsylvania State University, kimthomas@psu.edu; Benjamin P. Warner, University of New Mexico, bpwarner@unm.edu; and Robert Winthrop, University of Maryland, rwinthro@umd.edu.

Suggested citation. D. Hardy, H. Lazrus, M. Mendez, B. Orlove, I. Rivera-Collazo, J. T. Roberts, M. Rockman, K. Thomas, B. P. Warner, R. Winthrop. (2018). Social vulnerability: Social science perspectives on climate change, part 1. Washington, DC: USGCRP Social Science Coordinating Committee. https://www.globalchange.gov/content/social-science-perspectives-climate-change-workshop.

Abstract

Recent extreme weather events in the United States exemplify the uneven impacts of climate change on populations, even within relatively small geographic regions. Differential human vulnerability to environmental hazards results from a range of social, economic, historical, and political factors, all of which operate at multiple scales. While adaptation to climate change has been the dominant focus of policy and research agendas, it is essential to ask as well why some communities are disproportionately exposed to and affected by climate threats. The cases and analysis presented here consider four key themes—resource access, culture, governance, and information—and identify actionable steps that will help reduce vulnerability. Social scientific approaches to human vulnerability draw vital attention to the root causes of climate change threats and the reasons that people are forced to adapt to such threats. Because vulnerability is a multidimensional process rather than an unchanging state, a dynamic social approach to vulnerability is most likely to improve mitigation and adaptation planning efforts.

Introduction

Efforts to reduce climate-related hazards will be more effective when federal, state, local, and tribal governments recognize the social dimensions of vulnerability. Natural hazards only become disasters when an extreme physical event impinges upon a vulnerable population (O'Keefe, Westgate, & Wisner, 1976). Many scientific organizations and federal agencies, including the U.S. Global Change Research Program (USGCRP), have addressed vulnerability primarily through a natural science approach that emphasizes physical factors. As an example, the Third National Climate Assessment defines vulnerability as

> [t]he degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (Melillo, Richmond, & Yohe, 2014, p. 672).

Many other definitions of vulnerability are in circulation (Birkenholtz 2012; O'Brien, Eriksen, Nygaard, & Schjolden, 2007; Otto et al., 2017). In this paper we use a definition similar to the one above in that vulnerability is understood as a function of exposure, sensitivity, and adaptive capacity (Smit & Wandel, 2006; Engle, 2011), but we pay particular attention to the sociocultural aspects of these components. Exposure, sensitivity, and adaptive capacity are interrelated, as presented in Figure 1: for example, "adaptive capacity affects vulnerability by modulating exposure and sensitivity" (Engle 2011, p. 649).

While everyone is vulnerable to climate impacts, some social groups experience greater loss of resources and greater impacts to livelihoods than others. This differential susceptibility to comparable levels of physical change is primarily a function of social rather than physical factors. In this report, therefore, we focus on these crucial but often neglected aspects of vulnerability. We ask: who is most affected by weather and climate-related impacts and disasters, and why? We highlight evidence that social scientists have produced, which indicates that access to resources and the ability to avoid exposure to climate hazards are not randomly distributed across society but are in fact drivers of uneven vulnerability based on social difference. Social science modes of investigation improve our understanding of the reasons that uneven vulnerability exists and offer practical insights into how to minimize it before hazards become disasters.

By "exposure," we refer to the conditions of the physical environment and the social contexts that place people in harm's way. For example, the reasons that people live on a mudslide-prone hillside or in an area with recurrent severe-flood conditions may be linked to both historic systemic inequality that put them there as well as social and/or economic limits to mobility that keep them in place.

"Sensitivity" means here the degree to which exposure to a hazard, such as a hurricane or extreme drought, affects an individual, a household, or a community. The sensitivity of vulnerability is modulated by a person's or group's capabilities to provision basic needs and protection from harm. These capabilities in turn are embedded in the context of the social-protection and power relations of the larger social structure. For example, within a given coastal

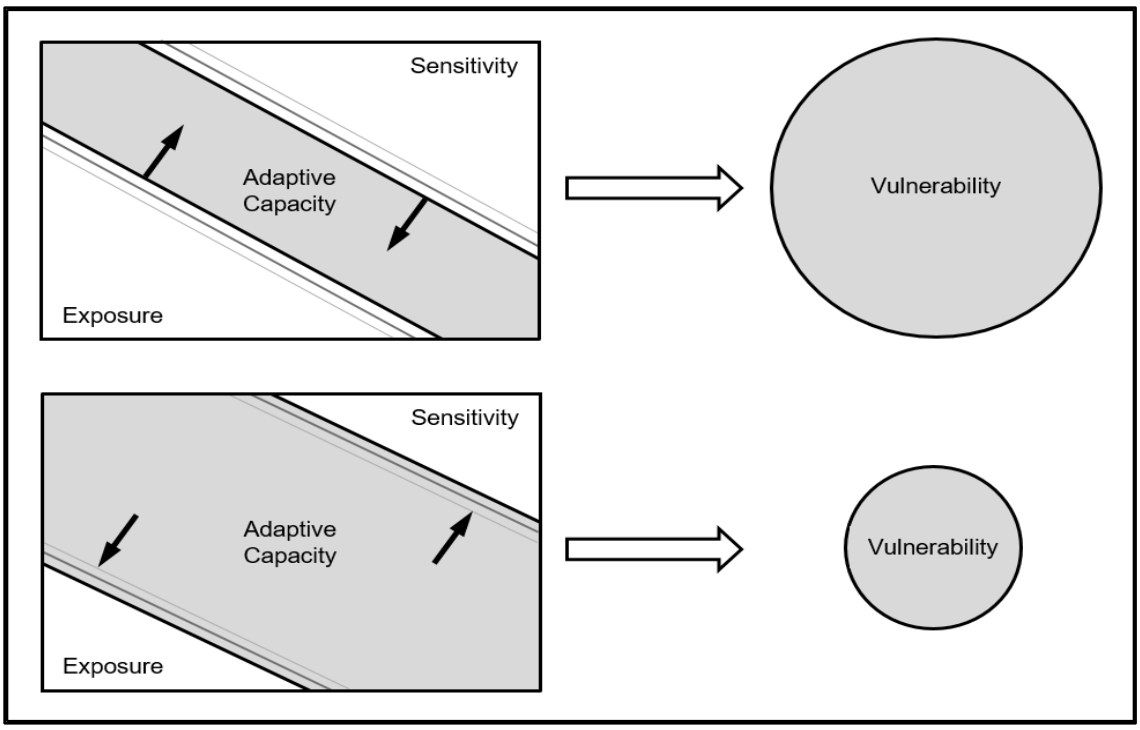

Figure 1: Conceptual model of the relationship of vulnerability to three components. 1a, top: How adaptive capacity that is low, relative to exposure and sensitivity, contributes to high vulnerability. 1b, bottom: How higher adaptive capacity helps reduce the effects of exposure and sensitivity, and in turn reduces vulnerability. Figure adapted from Engle (2011) and reproduced with permission of Elsevier Science.

area, a marginalized community dependent on fishing would be more sensitive to the impact of coastal flooding or sea-level rise than an affluent community of retirees or second-home owners. The latter would have their primary homes elsewhere and likely the resources to rebuild if their coastal residence were affected. In contrast, the fishing community would suffer loss of livelihood security and, having no other home to which to retreat, would more likely suffer health risks or loss of life, all of which could occur while attempting to defend their home during a weather disaster.

While everyone is vulnerable to climate impacts, some social groups experience greater loss of resources and greater impacts to livelihoods than others.

"Adaptive capacity" refers to the characteristics and assets of an individual, household, or community that shape their ability to prepare for, cope with, or respond to impacts. For example, communities with active networks of social-aid organizations and frequent interactions between neighbors are more likely to account for and protect their most vulnerable members. At least 700 people died in the 1995 heat wave in Chicago out of about 2.7 million people (Semenza et al., 1996), while over 1,800 of about 2.3 million residents of Paris died in a similar event (Vandentorren et al., 2004). These differences are partially attributable to duration: the Paris heat wave was much longer at nearly three weeks than Chicago's approximately one-week event. In both Chicago and Paris another significant contributor, along with poverty and age, was social

connectedness. Elderly people with limited social networks were more vulnerable than their peers with more extensive networks (Klinenberg, 2002; Keller, 2015).

Recognizing that many factors influence vulnerability and its component parts, we identify four broad themes as particularly helpful for understanding the social aspects of vulnerability, and structure our report around these themes: resource access, culture, governance, and information. We bring to our analysis multiple disciplinary perspectives—cultural anthropology, archaeology, geography, and sociology. We selected these four themes because in our disciplines they are frequently applied as analytical framings for investigating vulnerability. These themes do not map exclusively to any one discipline. Together they provide a more comprehensive, interdisciplinary social science framework for analyzing and understanding uneven vulnerability across social difference. Any effort to reduce uneven vulnerability requires understanding why it exists in the first place, a subject for which these disciplines, with their established approaches to examining issues of power and social difference, are especially well suited.

Social science methods and techniques that can be used to identify vulnerability include but are not limited to interviews, focus groups, surveys, network analysis, household censuses, participant observation, and the analysis of material culture. Using methods and techniques such as these makes possible a more robust understanding of the social dimensions of vulnerability. They can be used to examine such things as the income and subsistence elements of livelihoods; the social networks linking households, churches, businesses, and local governments; and the extent to which governments provide social protections.

Interventions can reduce harm and mortality that extreme weather events cause in socially vulnerable groups. Such interventions are far more effective at determining where and how to allocate resources when they account for the ways that this paper's four themes—access, culture, governance, and information—interact with the three components of vulnerability—exposure, sensitivity, and adaptive capacity. Attention to these issues will support the development of emergency responses and longer-term adaptation strategies that minimize exposure and sensitivity, and that elevate adaptive capacity under a changing climate. This report provides an essential road map for such an endeavor.

Four Themes of Vulnerability

Within the four thematic sections that follow, we first examine access to resources, considering how they vary in society and how disparities drive differential sensitivity to climate impacts. Social processes of marginalization and disenfranchisement play important roles in creating patterns of unequal resource access. One key area is the systematic underinvestment in critical infrastructure and services in some cities and neighborhoods, such as Detroit or the Outer Boroughs of New York City. The lack of those critical components makes populations in these areas more vulnerable than others (Pearsall, 2010; Safransky, 2014; Smith, 1982). Climate change will increase the exposure of populations to environmental hazards, exacerbating the existing unevenness in vulnerability across axes of social difference such as race, class, ethnicity, and gender (Denton, 2002; Leichenko & Silva, 2014; Shepherd & KC, 2015). Designing and implementing effective disaster risk reduction interventions requires consideration of these inequalities in the context of ongoing social changes.

Second, we ask: what is the role of culture in shaping vulnerability? Culture frames how individuals perceive and explain their environments, and shapes who is exposed and how they experience exposure. As it informs perceptions of risk, culture also affects the adaptive capacity of those exposed and shapes the ways in which related equity and environmental justice issues are weighed. As we consider relief agencies' unique institutional cultures, we also explore how culture clashes between communities and aid institutions can render response and mitigation ineffective. Because the impacts of climate change are experienced where people live, many aspects of exposure, sensitivity, and adaptive capacities are context-specific. Learning (and sometimes forgetting) about past place-based hazards shape local vulnerability. Communities have developed complex ways to adapt to climate risks. Recognizing these adaptation practices will help them prevent the next disaster.

Third, we consider how governance affects vulnerability to climate change: how local governments, private firms, and civil society plan for and manage climate change risk. Many effective approaches for addressing vulnerability focus on developing co-benefits. For example, the National Oceanic and Atmospheric Administration's (NOAA) Regional Integrated Sciences and Assessments Program has found that connecting expert science with local organizations through knowledge networks increases both knowledge sharing between government and communities, and related benefits, including trust (Bidwell, Dietz, & Scavia, 2013). Using such networks also improves stakeholder engagement by bringing vulnerable communities into planning (Phadke, Manning, & Burlager, 2015).

Finally, we examine the multidimensional nature of information about and forecasts of climate risk. We advocate moving beyond the knowledge-deficit model because it implies that emergency management and climate risk agencies need only share more information, such as by presenting scientific findings on climate change-related threats and hazards. Instead, we emphasize that information is necessary but not sufficient for reducing vulnerability. We highlight examples that show the importance of social networks and boundary organizations for facilitating the creation and two-way sharing of knowledge.

Vulnerability, rather than an unchanging state, is a multidimensional process affected by social, political, and economic forces interacting from local to federal scales. People in poverty are more vulnerable than others exposed to an equal level of hazard not only because of poverty but also because of their social networks, access to resources and information, and types of governance used to alleviate their poverty. We explore dynamic social approaches to vulnerability, arguing that such approaches can improve mitigation and adaptation planning (McNeeley et al., 2017).

Access to Resources

Climate change occurs not on a blank slate but rather on a well-marked one: climate effects arrive on an already-complex social landscape populated by groups with different vulnerabilities and access to resources (Kasperson & Kasperson, 2001). Resource access influences vulnerability by augmenting or reducing exposure, sensitivity, and adaptive capacity. Relevant resources comprise tangible and intangible goods, including disaster warning systems, emergency response, alternative housing, first-aid supplies, insurance, food stores, evacuation support, durable infrastructure, transportation, and information and communication networks.

Inequalities in such resources can be seen across regions of even the wealthiest countries, and across communities and neighborhoods within the same city. In this context, a hurricane only becomes a disaster when some groups lack the adaptive capacity to protect themselves from it. In other words, "natural" disasters are actually human disasters. When Hurricane Sandy hit New York and New Jersey in 2012, over 100 people were killed. These deaths were concentrated among the elderly in part because they lacked access to healthcare and transportation. By comparison, Hurricane Katrina killed about 1,800 people in the relatively impoverished coastal areas of Louisiana and Mississippi, where the flood management infrastructure was compromised by engineering flaws and inadequate maintenance. Here too, a majority of the victims was elderly, but in New Orleans a large group was also poor and black, especially in the Lower Ninth Ward, close to where the levees were breached (Brunkard, Namulanda, & Ratard, 2008; Diakakis, Deligiannakis, Katsetsiadou, & Lekkas, 2015; Jonkman, Maaskant, Boyd, & Levitan, 2009). Most of those affected lacked the means to prepare adequately for the storm, evacuate, weather the event in their homes, or reach and stay in an emergency shelter. Hurricane Katrina's effects were not "natural": the storm only became a disaster because the infrastructure failed, poverty and segregation were common in New Orleans, and many people lacked the resources to prepare for, avoid, and recover from it.

Climate effects arrive on an already-complex social landscape populated by groups with different vulnerabilities and access to resources.

> Global environmental risks will not be the first insult or perturbation in the various regions and locales of the world; rather, they will be the latest in a series of pressures and stresses that will add to (and interact with) what has come before, what is ongoing, and what will come in the future (Kasperson & Kasperson, 2001, p. 2).

There are similar inequalities in adaptive capacity: some communities recover more quickly than others from hurricanes or floods (Logan, Sukriti, & Xu, 2016). Recognizing and understanding differential vulnerability among communities is a key factor in understanding the meaning of climate change (Kasperson & Kasperson, 2001, p. 2).

Poverty

Poor people suffer the greatest losses from climate-related disasters. Their suffering becomes even more apparent when we examine the mental-health ramifications of disasters. In post-Katrina New Orleans, diagnoses of serious mental illness doubled among the poor, approximately half of whom had symptoms of posttraumatic stress disorder (Rhodes et al., 2010). These rates were much higher and lasted much longer among poor people without access to prevention and recovery resources than among other populations.

Poverty affects access to resources in several ways (Blaikie, Cannon, Davis, & Wisner, 1994; Peacock, Morrow, & Gladwin, 1997). Disaster preparedness typically involves developing disaster plans, assembling supplies, obtaining insurance, and seeking information. It is more difficult for poor households and communities to prepare for climate threats because they lack the required income, time, language abilities, and knowledge of resources and how to access them (Mileti, 1999).

Disaster warnings are less useful for poor communities. Before Hurricane Andrew in 1992, most poor residents of southern Florida heard and understood the storm warnings and evacuation recommendations but could not act on them because they lacked the money for provisions or transportation (Morrow & Enarson, 1996; Gladwin & Peacock, 1997).

The built environment where poor people reside is less resistant to the impacts of weather and climate change. Cheaper, less-desirable housing sites are often more exposed to climate hazards. Buildings may be poorly constructed, increasing sensitivity to climate impacts, as research on numerous types of climate-related disasters has shown (Austin & Schill, 1994; Bolin, 1986; Greene, 1992; Phillips, 1993; Hallegatte, 2012).

Recovery from climate-related disasters is more challenging for the poor. After Hurricane Andrew, although the Federal Emergency Management Agency (FEMA)—the primary disaster response agency in the United States—opened disaster-assistance centers, fewer poor victims got relocation assistance there because it was hard to get transportation and childcare, and to take time off work (Dash, Peacock, & Morrow, 1997). In recovering from climate-related disasters in the United States, the biggest challenges the poor face are often to secure safe housing and to relocate (Fothergill & Peek, 2004).

Race

Structural racism, involving "the totality of the social relations and practices that reinforce white privilege" (Bonilla-Silva, 2013, p. 9), contributes to increased vulnerability among U.S. non-white populations. In the United States in 2014 white households earned 65% more income and possessed 13 times greater wealth than African American households (Pew Research Center, 2016). African American households are more likely than white households to suffer home foreclosure (Rugh & Massey, 2010). Rather than through overt acts of racial discrimination, structural racism creates racial disparities in educational attainment, income, and wealth in more subtle ways by perpetuating uneven access to the resources needed to adapt to a changing climate (Bonilla-Silva 1997; Lopez 2003; Omi & Winant, 2015).

How can structural outcomes be mitigated in the context of climate change? One approach involves greater attention to the social context of racial disparities and the cultural framing of environmental hazards in underrepresented or marginalized communities. On the Eastern Shore of the Chesapeake Bay, Miller Hesed and Paolisso (2015) conducted a study of three African American communities that were frequently flooded. Using interview data to assess the factors shaping vulnerability, they found that the communities' isolation was a significant contributing factor. Furthermore,

> race and age both contribute to the social and political isolation that has limited these communities' access to sources of adaptive capacity at the extra-local level…. [I]n individual interviews issues of injustice related to race did surface, revealing how historical and cultural legacies of discrimination have simultaneously discouraged African Americans' participation in government decision-making processes and allowed their needs to be overlooked by government officials (Miller Hesed & Paolisso, 2015, p. 686).

Efforts to reduce vulnerability, therefore, can benefit from attention to differences of populations along lines of race and ethnicity.

Mobility

Groups have always migrated in response to environmental, economic, or social change, but even relatively static groups regularly move from place to place—from home to work, school, places of recreation, or homes of extended family. Drawing on the idea of constant movement, we extend vulnerability geographically beyond a house or a building to include mobility and activity space, "a geographic extent in which people move in the course of their daily activities" (Ren, 2016; see also Kwan, 2013; Kwan & Schwanen, 2016). Estimates of exposure to climate change impacts typically have been based on static populations, using the assumption that people live only where they reside. For example, in one study of the effects of future sea-level changes, Hauer, Evans, and Mishra (2016) estimate that in the United States by 2100 approximately 13.1 million people will be exposed to a 1.8m sea-level rise. In not accounting for daily activity spaces, however, this study likely underestimates the size of the affected population. Daily activity spaces affect health and exposure to environmental toxins (Perchoux, Chaix, Cummins, & Kestens, 2013), food accessibility (Widener & Shannon, 2014), and the capacity for long-distance travel (Silm & Ahas, 2014). Hurricane Katrina's aftermath showed that flooding disturbs toxins and in turn generates renewed and uncertain exposures (Bullard & Wright, 2012). As people face climate change impacts, their capacity to adapt to forced changes to their daily activity spaces depends on access to resources.

Rural and Urban Settings

The traditional dichotomy between "rural" and "urban" inadequately represents the diversity of relationships between people and the landscapes that strongly affect vulnerability (Lerner & Eakin, 2011). In areas of high population density, even if most people are affected similarly by exposure to a given local climate impact, various activity spaces will be affected differently and different people's capacities to adapt will likely vary considerably. These discrepancies were clearly revealed by the effects of Hurricane Sandy (Schmeltz et al., 2013).

People in agrarian communities and other areas with low population densities may be vulnerable to climate change for different reasons. The livelihoods of people engaged in agriculture depend directly on the environment. Climate impacts threaten not only their health and safety but also their ability to earn a living (Cutter, Mitchell, & Scott, 2000). People in these areas also may have less access to medical care and disaster-response resources than people in higher-population-density areas (Morrow, 1999). In areas with lower population densities, diminishing resources are associated with the privatizing of public services and with limited social-service delivery, although these trends vary across the United States (Lobao, Adua, & Hooks, 2014). For all these reasons, programs to reduce vulnerability to climate change should be designed for specific geographic, demographic, and social contexts.

Power

Vulnerability occurs not only because of the marginalization or poverty of particular social groups but also through the processes that perpetuate marginalization and poverty, potentially

including adaptation planning (Anguelovski et al., 2016). Groups with more political power or social capital (including trust and cooperation among neighbors) are more likely to secure funding to plan for, cope with, and respond to climate-related impacts. It is possible to increase inequalities in adaptive capacity by enabling "powerful geographical groups of people to minimize negative environmental externalities and appropriate positive environmental externalities in particular places, with unjust socio-environmental consequences" (Collins 2010, p. 265).

Groups with more political power or social capital are more likely to secure funding to plan for, cope with, and respond to climate-related impacts.

In the case of coastal impacts of climate change, such inequalities are increased financially through the unequal expenditure of adaptation funds, and physically through the construction of sea walls or other coastal protections that literally shift the problem down the road or across the river.

> The high concentration of the Nation's population and resources in coastal areas means that impacts to these areas can easily disrupt critical social, economic, and natural systems throughout the United States, disruptions that are likely to become more frequent and/or costly, given the growing risk of harmful climate-related hazards in coastal areas (Coastal Green Infrastructure 2015, p. 5).

In many cases of coastal erosion, the construction of a sea wall and other "gray infrastructure" can temporarily protect structures behind the wall while accelerating beach erosion on the ocean side. Thus in many cases the choice lies between preserving access to private property or preserving access to common-pool resources such as beaches. In Matunuck, Rhode Island, accelerating coastal erosion and sea-level rise risked undermining a coastal road. The state Department of Transportation approved a 200-foot-long seawall that protects "the only access to 250 homes and …the water supply for 1,600 homes…. This construction, however, comes at the expense of keeping a beach in favor of protecting the road" (Haas 2014).

Culture and History

Recognizing the importance of culture—the shared and patterned meanings of social groups—is vital to understanding climate change vulnerability. The human experience of nature and environmental change is mediated by culture. "Nature is seen by humans through a screen of beliefs, knowledge, and purposes, and it is in terms of their images of nature, rather than of the actual structure of nature, that they act," ecological anthropologist Roy Rappaport pointed out (1979, p. 97). Multiple cultural screens or perspectives characterize specific social groups and distinguish them from one another. Thus, the cultural screen through which the Chesapeake Bay's watermen, whose livelihood depends on crabbing, view the threatened blue crabs both overlaps with and sharply diverges from the perspective of marine scientists who study the bay's ecosystem (Paolisso, 2002). When we neglect to consider culture in assessments of vulnerability, we risk missing many factors that contribute to vulnerability and suboptimal adaptation measures.

Culture and social organization shape vulnerability to climate change in terms of who and what are exposed and how they are sensitive. If a hurricane hits a poor community in a developing country – for example, in Mexico's Yucatan Peninsula – women would be three to four times more likely than men to die. This drastically different fatality rate is partly explained by disparities in men's and women's learning and expected behavior. Many women are excluded "from survival skill learning, such as tree climbing and swimming, which help during floods; [and] restrictions on women's movement in times of crisis…[dissuade] women from leaving the home without a male's permission" (Crate & Nuttall, 2009, p. 15).

History comprises the global sequence and ramifications of past events. "Path dependence," at any spatial and temporal scale, means the ways a set of past events may constrain future actions. History explains some reasons for exposure, such as how communities emerged in locations that experienced or continue to experience natural hazards. For example, political and economic forces were instrumental in enforcing the early settlement of Pensacola, Florida, despite settlers' experiences with hurricanes and other stresses (Box 1).

1. HAZARDS AND SETTLEMENT: AN EXAMPLE FROM PENSACOLA BAY, FLORIDA

The history and archaeology of Pensacola show the hazard-learning process as experiences of exposure and vulnerability interacted with political and economic forces (Laracuente 2008, 2010). The first European attempt at settlement there was made via a Spanish convoy that arrived in 1559 to support Native American religious conversion and Spanish colonization. A hurricane struck while the new arrivals were unloading their ships, and sank eight of their 11 vessels. After the sick, starving survivors left in 1561, Spaniards next returned 140 years later. Spain undertook new settlement on royal order in 1698 after learning of French efforts to colonize the Gulf Coast. The new settlement, placed on high bluffs near the bay's mouth, suffered fires, rotting timbers, supply shortages, and raids by Native Americans; the settlers surrendered to the French in 1719. Spain established another settlement in the bay in 1722 on a barrier island, which was damaged by a hurricane in 1740, a series of weak hurricanes in 1751, and another series of hurricanes in 1752. These storms eroded almost all the barrier island, leaving "almost nothing to live on" (Laracuente, 2010, p. 9). Survivors moved to a mainland location that was less defensible but higher and less flood prone, which became modern Pensacola (Laracuente, 2008, 2010).

Studying past events also helps explain underlying reasons for sensitivity and adaptive response. Water crises have become widespread in the developing world; many are legacies of colonial-era domination and subordination. In East Africa, for example, racial segregation characterized the British colonial development of Dar es Salaam, Tanzania and Nairobi, Kenya, where the colonial rulers allocated resource-poor areas to black residents, a legacy that remains in the inadequate access to water in poorer areas even today (Dill & Crow, 2014).

Studying culture also helps clarify how adaptive capacity works, including the ways in which a situation is understood or perceived and viable options for adaptive response to that situation. Cultural and social practices such as forging close kin-based or neighborhood networks can increase the capacity to cope with a threat, as network members share access to information, transportation, or other resources.

These cases from Florida and East Africa suggest questions relevant elsewhere: What social, economic, or cultural forces presented barriers to adaptation to previous hazards? What do current community residents know about the local history of hazards? Responses to such questions can provide counterpoints to cultural expectations and legal incentives to rebuild in the pre-disaster place or manner. Furthermore, such histories may highlight inequalities in exposure that communities have been asked to endure on behalf of society at large.

Tangible and Intangible Factors

Social vulnerabilities to climate change are both tangible and intangible. Consistent with natural-disaster preparedness, assessments of climate change vulnerability focus on the tangible: infrastructure, such as roads and dwellings, and the material bases for survival and health, such as food supply and clean water. Climate change also indirectly disrupts life's intangible aspects, including social systems, cultural knowledge, and the practices of daily life, by directly modifying the material conditions that support them.

Climate change disrupts life's intangible aspects, including social systems, cultural knowledge, and the practices of daily life, by modifying the material conditions that support them.

Culturally shaped daily practices are critical to learning and transmitting cultural knowledge. In many societies, hunting, fishing, and gathering not only provide for material needs but also help maintain social groups and networks through acts of exchange. Subsistence practices likewise preserve critical bodies of knowledge about plants' and animals' characteristics, mythic associations, and spiritual significance; and the attributes of the cultural landscapes where they are found (Winthrop, 2002, p. 168). These bodies of knowledge are often locally specific. "The most important dimension of local knowledge may not even be specific information per se but particular strategies for learning about the natural world and applying the resulting insights—practices which may themselves differentiate indigenous from scientific knowledge" (Kirsch, 2001, p. 173). Gaining and applying knowledge in this way can be seen in children's initiation into hunting in the United States, which depends on the availability of an older companion and teacher: "A parent, close relative, or other responsible adult…act[s] in the role of teacher and…transmitter of the hunting culture…. [T]his intimate interaction with an older hunting companion…causes hunting to persist into adult life..." (O'Leary, Behrens-Tepper, McGuire, & Dottavio, 1987, p. 231).

Preserving and transmitting the intangible aspects of social life often depend upon conserving the tangible–both the natural and the built environment. The devastating 2011 earthquake and tsunami in the northeast region of Japan prompted renewed interest in the lessons of tsunami memorials or "tsunami stones," markers placed at elevations above the devastating flooding from previous tsunamis. For Itoko Kitahara, a specialist in the history of natural disasters, "'tsunami stones are warnings across generations, telling descendants to avoid the same suffering of their ancestors'" (quoted in Fackler, 2011; see also Suppasri et al., 2013, pp. 1013-1015).

Understanding the environmental history of places and landscapes by recovering and investigating the physical evidence of past experiences thus can help reduce vulnerability.

Cultural Framing

Culture underpins how people perceive risks, make protective decisions, and respond to threats. Failure to identify risk increases vulnerability: if people do not initially perceive risk from climate impacts, then they will not put measures in place to reduce potential harm, or otherwise change their behavior. Risk is the product not only of the likelihood and potential magnitude of loss but also of relationships and interactions between people and nature (Rayner & Cantor, 1987, p. 5). People tend to perceive risks when their ideal social organization or worldview is threatened (Douglas & Wildavsky, 1982). Risk is not simply an objective quality out in the physical world; instead, people see nature and its associated risks through their cultural lenses, including their beliefs, knowledge, and needs. It is those perceptions of risk to which people respond. Adaptation plans and projects that match the risk perceptions of those who will live with them are more likely to succeed. In California in 2010–2011, the Oakland Climate Action Coalition's work with local coastal communities succeeded because that adaptation effort incorporated community risk perceptions, as discussed below under Public and Private Governance.

People see nature and its associated risks through their cultural lenses, including their beliefs, knowledge, and needs.

Culture encompasses local systems of environmental knowledge, values, and practices, and influences the potential limits to adaptation. Adger and colleagues (2009) identify four main ways in which endogenous social limits to adaptation are manifested.

Adaptation is value laden. As a result, it is limited by people's goals, which depend on the differing values of diverse populations. For example, action to mitigate vulnerability to flooding may be more likely to protect high value, high tax real estate than to benefit impoverished communities (Martinich, Neumann, Ludwig, & Jantarasami, 2013).

Multiple sources of knowledge guide adaptation measures. While uncertainty over future climate change may constrain government action, climate change predictions are only one of several sources of knowledge that guide adaptation measures. The Quinault Indian Nation village of Taholah, Washington is located where the Quinault River joins the Pacific Ocean. Because of climate change and its proximity to the Cascadia Subduction Zone, the village is highly vulnerable to tsunamis, storm surge, and riverine flooding (Quinault Indian Nation, 2017b). In planning for climate change, village leaders drew on not only climate change projections provided by the State of Washington (2012) but also a variety of other information sources, including community perspectives, before proposing to relocate to a higher location inland (Environmental Protection Agency, n.d.). "Village-wide meetings were convened, along with completion of door-to-door and online surveys, to gain an understanding of conditions, community aspirations, and perceptions of risk" (U.S. Global Change Research Program, n.d.). The results are captured in the Relocation Master Plan (Quinault Indian Nation, 2017a).

*Shared knowledge, experience, and risk perception shape how adaptation takes place (*Adger et al. 2009, p. 346). Risk denial, political inertia, and social status can constrain individual and collective decision making, while valuing local social memory and encouraging people to use experiential knowledge tend to increase community action. The Coweeta Listening Project in

southwestern North Carolina "seeks to listen to residents of Southern Appalachia, integrate social and ecological science through the coproduction and democratization of knowledge, and build useful and meaningful connections between scientists and the public" (Rice, Burke, & Heynen, 2015, p. 256). The project recorded personal observations that revealed changes in weather across the years through concrete experiences.

> Clothes worn on the first days of school indicate changes in summer and fall weather. The depth at which one buries water pipes, the (in)ability to bury dead bodies, the fate of overwintering insects, and the extent to which snow remains on the ground all indicate the depth of hard frosts (Rice et al., 2015, p. 257).

Participatory and pluralistic approaches to climate adaptation offer alternatives to processes focused on expertise and climate literacy.

Place is systematically undervalued in much adaptation planning. The loss of physical places involves the related loss of cultural and social significance that is often invisible to those calculating climate change impacts (Adger et al., 2009, p. 348). Such undervaluing can be overcome through local engagement. For example, physical and social scientists funded by Louisiana Sea Grant worked with local indigenous communities to develop a coastal resource management plan based on a combination of natural sciences and traditional ecological knowledge, organized through a geographic information system, GIS (Bethel et al., 2014). The resulting information—which incorporated local community priorities and values—informs project planning and implementation for coastal restoration. When culture is considered central to reducing vulnerability, efforts are more likely to succeed.

Successful adaptation to climate change must reconcile scientific and local knowledge, interests, and values. "Expert-only politics runs the risk of excluding the knowledge of individuals who do not prioritize scientific explanations, who in some cases might also be the most vulnerable" (Rice et al., 2015, p. 260). Cultural factors shape the range of acceptable adaptation actions, community and individual capacities, and attachment to place. Issues of equity and environmental justice are always deeply embedded in crafting adaptation strategies. Ignoring or excluding attention to the differences that lead to differential vulnerability hampers trust, impedes the identification of risk, and increases the likelihood of inequitable outcomes.

Governance

The processes of governance—how problems are addressed by governments and other groups—both shape and respond to climate change vulnerability. The concept of governance extends well beyond formal governmental institutions, encompassing "the relationships between government and society including the means through which private actors, markets, and interest-based networks influence policy decisions" (Chaffin et al., 2016, p. 401). Climate change presents both acute and chronic challenges for effective governance, requiring responses to both sudden "pulse" events such as Hurricane Sandy and gradual "press" events such as sea-level rise (Collins et al., 2011, pp. 352-354).

Organizations that speak for vulnerable populations may challenge governmental policies on climate change, but partnerships between governments and local non-governmental

organizations can significantly increase the capacity for effective social action. The rise of climate issues on local governments' agendas is promoting new kinds of partnerships across sectors. For example, climate change has significant impacts on health, such as the increased incidence of asthma (Shea, Truckner, Weber, & Peden, 2008). As these causal relationships become better understood, hospitals, universities, and state health departments increasingly partner with social action organizations, labor unions, and environmental groups to develop programs addressing health and other aspects of environmental well-being (Rudolph, Gould, & Berko, 2015).

Scientifically sound and socially robust approaches to resilience efforts involve community groups in every stage of the process: identifying issues, designing responses, implementing actions, and evaluating results. The Centers for Disease Control and Prevention (CDC) uses a community-based participatory research model, which was developed for understanding and addressing health issues; that approach could be adapted to building resiliency (Simonds, Wallerstein, Duran, & Villegas, 2013). Other institutions have conducted numerous programs, similarly using iterative engagement, on issues such as water management in Colorado and responses to sea-level rise in Louisiana (Murphy et al., 2016). 0

As the cases we discuss here show, relationship building promotes accountability among experts and policy-makers and helps overcome the deficiencies of top-down decision making.

Public and Private Governance

Vulnerability reduction is a necessary goal of most organizations as they seek to avoid exposure, or threats of harm; to lessen sensitivity, or damage if harm arrives; and to improve adaptive capacity, response to threats. Governmental institutions, private firms, and non-governmental organizations, working separately or jointly, all engage in efforts to reduce vulnerability to climate change. Their activities involve establishing priorities for action, allocating resources, and developing and implementing plans, as well as ongoing operation for reducing vulnerability, which stems from multiple interacting drivers. Organizations often allocate little or no resources to vulnerability reduction because its potential future benefits cannot compete with immediate needs and short-term goals. These factors present challenges to the development and implementation of plans, which often focus on a subset of the sources of vulnerability (Weber, 1997).

Organizations often allocate little or no resources to vulnerability reduction because its potential future benefits cannot compete with immediate needs and short-term goals.

Climate change adaptation activities vary from locally autonomous endeavors to government-led projects. Regarding flood risk management, in many suburban communities homeowner associations are responsible for maintaining storm-water retention ponds and green infrastructure facilities that reduce flooding and protect local waterways. Associations often lack the funds and technical expertise for proper management of these features; that lack increases both vulnerability to water hazards and risks for downstream communities. Many coastal municipalities have built breakwaters, while a number of public-private partnerships have constructed more expensive seawalls and revetments. By contrast, larger-scale social

organizations composed of neighbors along marine, riverine, and lacustrine shorelines have organized coastal defenses. Regardless of the degree of self-organization, financial capacity may limit project development. Cities and states by necessity may assume final responsibility for funding adaptation measures, such as implementing costly improvements to coastal roads threatened by sea-level rise (Moser, Williams, & Boesch, 2012, pp. 64-68).

Organizational problems are obvious in many municipal efforts to reduce climate change vulnerability, particularly in relation to hazards and extreme events. Cities often operate within longer time frames than those of other organizations because urban stakeholders are closely tied to officials and because city governments have important investments in long-lasting infrastructure projects. Hazards and disasters can prompt cities to take resources from ongoing activities and allocate them to vulnerability reduction; gradual trends, though equally serious, often do not attract attention. In Chicago, a severe heat wave in 1995 prompted the city to develop outreach programs to particularly vulnerable populations, such as the elderly; after the programs were implemented, fewer people died during subsequent heat waves (Klinenberg, 2002).

The Chicago example notwithstanding, cities more often invest in visible, tangible, hard infrastructure. After a major flood in 1962, Norfolk, Virginia built a large sea wall rather than reduce residents' exposure by using buyouts and insurance to encourage them to relocate away from low-level areas, which remain highly vulnerable to sea-level rise (Norfolk, n. d.; National Research Council, 2004). This is an example of the "safe development paradox," where "increased safety induces increased development leading to increased losses" (Kates, Colten, Laska, & Leatherman, 2006, p. 14653). Similar disparities in protection can be seen elsewhere. In New York City, Lower Manhattan has been protected but Staten Island remains highly vulnerable, and in southern Louisiana, many homes and small communities are outside the levees that protect businesses and core infrastructure. Governance of climate risks can reduce vulnerability by addressing social inequities or exacerbate it by overlooking them.

The "safe development paradox" – increased safety induces increased development leading to increased losses.

The United States shows a dramatic disparity between cities actively addressing climate vulnerability and those ignoring it or deferring action. In adjacent cities or counties, the consequences of differences in governance systems may be glaringly obvious, particularly in times of climate disasters. Addressing those disasters and other environmental issues often requires large-scale action across an ecosystem or landscape; such action requires coordinated efforts not only between municipalities and states within a given nation but also between nations, such as those within the Columbia and Colorado River basins.

In a study of adaptation-related planning and action by more than 70 municipalities around San Francisco Bay, Moser and Ekstrom (2010; Ekstrom & Moser, 2014) found that towns showed wide variation, largely caused by differences in financial and staff resources. Although Governor Schwarzenegger had issued a 2008 executive order addressing climate risks in local planning, several municipalities had done little; the study helped them identify barriers to action. Respondents from five case study locations cited 170 institutional issues as barriers; the most frequently cited were. governance, resources, politics, and leadership. To help municipalities

2. COMMUNITY-BASED CLIMATE-ADAPTATION PLANNING IN OAKLAND, CALIFORNIA

The Oakland Climate Action Coalition, an alliance of community, labor, faith-based, and environmental justice groups, developed methods for analyzing neighborhood-scale climate impacts and helping safeguard socially vulnerable populations. The coalition's initiative supplemented the City of Oakland's Energy and Climate Action Plan, in which planning remained an unrealized goal because of limited resources and expertise. Through a community-based participatory research process, the coalition in partnership with the Pacific Institute think tank identified Oakland areas with heightened risks for projected climate impacts, including extreme heat events, flooding, and wildfires. Over 18 months in 2010–2011, the project developed adaptation models to help policy makers and communities focus on areas for which to develop climate-action programs. Decisions concerned types of climate impacts and vulnerability factors, interpreting research results, and sharing results with key audiences.

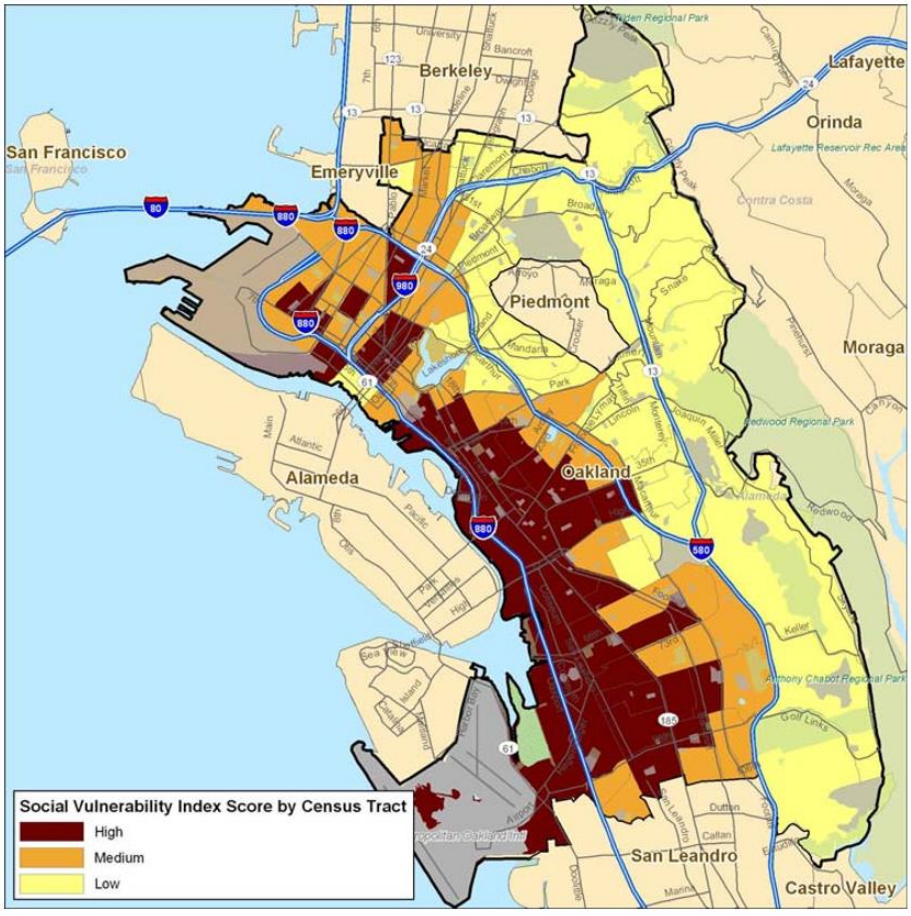

Figure 2. Social vulnerability to climate change in Oakland. Source: California Energy Commission (2012)

The coalition's approach involved obtaining geographic data on projected physical impacts of climate change that would shape exposure, selecting data on social

vulnerability indicators related to neighborhood-scale impacts, and overlaying vulnerability and exposure data to produce a composite. The adaptation planning process strongly emphasized local context and engaging community stakeholders in defining priorities and solutions. The strategy called for establishing early warning systems for extreme heat events, involving neighborhood outreach workers, and providing warnings in multiple languages (California Energy Commission, 2012, p. 58). The coalition helped improve adaptation planning by refining research questions, methods, and instruments. Its participation in data analysis significantly enhanced the interpretive validity of the research findings (California Energy Commission, 2012).

overcome such roadblocks, the Georgetown Climate Center (http://www.adaptationclearinghouse.org/) provides a clearinghouse on climate adaptation that groups resources by sector (water, coastal, transportation, infrastructure, and public health) and strategy (adaptation planning, policies, laws, and governance).

Louisiana's anti-erosion efforts offer an example of state-level planning that incorporates community engagement. The effects of long-term erosion on the Gulf of Mexico coastal region include economic and social losses, but stakeholders' complex and competing interests often impeded action. The coastal erosion resulted from sea-level rise, which was driven by climate change, and from infrastructure development, which reduced the coastal wetlands' resilience. Louisiana's Coastal Protection and Restoration Authority (CPRA) included in the state's Coastal Master Plan a decision-support tool that helped members of the public select combinations of actions, correlate likely impacts with different scenarios of sea-level rise, and calculate the costs of implementing related programs. By allowing the evaluation of effects on different economic sectors, geographic areas, and vulnerable populations, including the culturally distinct Acadian community, the tool promoted participatory discussions that ultimately led to a consensus on a set of projects, which the state legislature then funded (Groves et al., 2014; Groves & Sharon, 2013).

Civil Society Engagement

Incorporating the efforts of diverse groups, from soccer clubs and churches to social service organizations and protest movements, enhances communities' capacity to prepare for and respond to climate-related extreme events. Increased public engagement depends on people's understanding that climate risks are relevant to their own lives and challenges. How are heat waves and flooding, for example, connected to poor health and social isolation? Building community resilience requires efforts at multiple scales.

The array of institutions and initiatives involved in building resilience include climate action social movements, such as the 2014 People's Climate March; faith-based organizations; national and international networks, such as the Local Governments for Sustainability (formerly International Council for Local Environmental Initiatives, www.iclei.org); the U.S. Climate Action Network (USCAN), which convened groups before the Paris United Nations negotiations (http://unfccc.int/paris_agreement/items/9485.php); the Latino Network for Climate Action; and numerous indigenous groups. The last include the Institute for Tribal Environmental Professionals; the Indigenous Environmental Network; and the Arctic Circumpolar Council, which is composed of representatives from Eskimo Inuit in Canada, Greenland, and Russia.

Effective governance to reduce climate change vulnerability engages a range of actors from civil society and the private sector. Important issues for social scientists include: What are the bases of involvement in these groups and organizations? How do such groups influence negotiations and legislation? When does climate emerge as an issue that is taken up by existing social movements, and when does it create new social movements? How does consciousness about climate issues shape agenda setting and coalition formation (Caniglia, Brulle, & Szasz, 2015; McCright & Dunlap, 2015)? Each set of issues raise issues of equity and justice in climate governance, including procedural justice and fairly raising and distributing adaptation resources (Grasso, 2010).

Information and Forecasts

The knowledge that individuals, organizations, communities, and societies have of likely future climate conditions and their capacity to use this knowledge are key determinants of vulnerability. Reducing vulnerability involves anticipation of potential future harm, but it is difficult to prepare based on incomplete or inaccurate information. Preparation can be strengthened by prioritizing the creation of such information and by making it more accessible, comprehensible, and trustworthy. All these factors increase vulnerable communities' adaptive capacity and moderate their sensitivity. Information is necessary but not sufficient for vulnerability reduction, however; action also requires the mobilization of social, economic, and other material resources.

The heterogeneous quality of climate information contributes to uncertainty. Temperature and precipitation, for instance, vary across time scales from short-term such as daily and seasonal fluctuations through longer geological scales such as the Little Ice Age (Mann et al., 2009). Daily and seasonal variation more often correspond to expectations: noon will be warmer than midnight and July will be warmer than January in the continental United States. In yearly variations, one summer will be warmer or cooler than another, or the fluctuations from a so-called El Niño event may bring wetter or drier conditions. Short time scales apply to variability in weather, while longer ones—generally 30 or more years—apply to climate. Taking multiple time scales into account can help reduce vulnerability. Knowing a city's mean high summer temperature as it varies in a given decade, for example, will help predict the likelihood of a heat wave.

Forecasting relies on climate information in varied forms from correspondingly varied sources, such as that provided by U.S. government institutions. NOAA and the Naval Meteorology and Oceanography Command are among those that collect meteorological information from weather stations, satellites and other sources; analyze data using historical, dynamic, and statistical models; and issue forecasts on multiple temporal and spatial scales. In addition, several private firms provide climate forecasts, often tailored to the needs of clients in sectors such as energy, agriculture, and insurance.

Traditional, indigenous, and/or local environmental knowledge that is based on individual and collective experience, and employs indicators based on direct observation is an important element of forecasting. One such indicator is the parhelia, or sundogs, that are produced by humid air at high altitudes; these are often considered signs that storms will arrive within a day or two. Such knowledge can be incorporated into developing adaptations to ecosystem changes (Berkes, Colding, & Folke, 2000).

The archaeological record provides paleoenvironmental data and evidence of contemporaneous human behavior that can be connected to broader environmental events and trends at multiple temporal scales (Minc & Smith, 1989; Rick, Kirch, Erlandson, & Fitzpatrick, 2013; Schwadron, 2000). That information can be particularly useful for recovering detailed, locally relevant examples of past climate impacts and corresponding human responses. Together with climate scientists, other social scientists, and local communities, archaeologists can generate data and bring together local and traditional knowledge to develop culturally and locally sensitive adaptation or mitigation strategies (d'Alpoim Guedes, Crabtree, Bocinsky, & Kohler, 2016).

Learning and Transmission of Environmental Knowledge

Humans must learn their environments: knowledge of environmental cycles and hazards is not innate (Rockman, 2003). Such knowledge shapes the very concept of "hazard," informs decision making, and supports the identification of risks. Environmental knowledge does not require first-hand experience, but its accumulation and usefulness do depend on effective social transmission (Crumley, 2002). The effective response to the 2004 Asian tsunami on Simeulue Island, Indonesia drew on oral history of a 1907 earthquake and tsunami that killed as much as 70 percent of the island's population. Because they knew this history, in 2004 most residents headed to higher ground within minutes of the earthquake and so escaped the tsunami (McAdoo, Dengler, Eeri, Prasetya, & Titov, 2006). This case demonstrates how a single event can generate a useful memory that outlasts a single lifetime and can help shape public response to hazards. When local environmental knowledge extends beyond direct, individual experience, communities may draw on this knowledge to identify potential risks and implement innovative local adaptation and mitigation strategies faster and more effectively than if they wait for larger, non-local institutions to act (Evans, Milfont, & Lawrence, 2014; McDowell, Graham, Ford, & Jones, 2016).

Environmental knowledge does not require first-hand experience, but its accumulation and usefulness do depend on effective social transmission.

The pace of environmental learning depends on both the nature of environmental cycles and a community's capacity for remembering risks and responses. When knowledge transmission is robust, strategies for adapting to environmental change can persist for thousands of years, as shown by practices of foraging societies in the Levant and landscape memories of aboriginal societies in Australia (Rosen & Rivera-Collazo, 2012; Nunn & Reid, 2015). In other cases, economic or political factors may disrupt or override the use of established environmental knowledge. In Haiti, for instance, an earthquake-safe building code was implemented in the eighteenth century. The upheaval of the 1804 revolution and a shorter return cycle of hurricanes than of earthquakes combined to disrupt application of that code, as it appears to have no longer been in use by the time of the catastrophic Port-au-Prince 2010 earthquake, in which over 200,000 people died (Bilham 2010; Scherer 1912). As these and other examples show, social memory shapes not only communities' exposure to hazards but also their sensitivity to those exposures. Traditional environmental knowledge has been applied effectively in the territories of the Navajo Nation (Box 3).

3. TRADITIONAL ENVIRONMENTAL KNOWLEDGE

Indigenous and other communities' traditional environmental knowledge (TEK) includes information about weather and climate phenomena and their impacts. Collected and refined over generations, TEK withstands the test of time. Often very place-specific, it may also connect the natural world with social and cosmological processes (Anderson, 2014; Berkes, 1999; Basso, 2007). Indigenous communities are often the first and most drastically affected by climate change due to their location in marginal environments—including deserts, high-altitude regions, the circumpolar Arctic, and small islands—and their limited political power. Such communities may have systematic environmental knowledge, including knowledge of processes that can enhance their adaptive capacity. Collaborative analysis of combined TEK and mainstream science can yield critical insights into climate change and adaptation (Bennett et al., 2014). Collaborations must be based on relationships of trust; follow cultural, ethical, and legal protocols; and recognize that TEK is embodied in cultural practices and beliefs that are inseparable from deep cultural contexts (Maldonado et al., 2016).

The Navajo Nation, spanning portions of Arizona, New Mexico, and Utah, is vulnerable to weather extremes and climate change; that vulnerability is shaped by political marginalization, poverty, circumscribed water rights, and endangered cultural practices (Redsteer et al., 2013). Moreover, adaptation efforts are hindered by a severe shortage of meteorological data and other scientific observations that could supplement traditional knowledge. To provide additional information and promote adaptive responses that would be consistent with cultural priorities, more than 50 Navajo elders shared their observations about changing environmental conditions. As their observations agreed with point observations, the resulting data helped extend the observational record of changes in water availability, weather, and sand and dust storms (Redsteer, Kelley, Francis, & Block, 2010).

Figure 3. Several generations of Navajo Nation residents discuss the height of grass in the early twentieth century. Photograph by Margaret Hiza Redsteer, used with permission.

Information Production and Dissemination

Information about weather forecasts and climate predictions is communicated, received, and revised through multiple channels, including interpersonal communication, television, radio, the Internet, and social media (Morss et al., 2017). In some places, community weather- and climate-related knowledge is shared only with those best positioned to receive it, such as rain prophets in Brazil, but elsewhere it is widely shared, as in southern Uganda (Pennesi. 2011; Orlove, Roncoli, Kabugo, & Majugu, 2010). Scientific information that public and private agencies produce may be disseminated broadly to the public or restricted to specific users; one instance of the latter is the release of climate predictions to Colorado city park managers who rely on them in making long-term decisions about optimal flood-control plantings (Lazrus, Wilhelmi, Henderson, Morss, & Dietrich, 2017).

People receive, seek, and combine information from multiple sources, including social networks, before they make decisions (Sadri, Ukkusuri, & Gladwin, 2017). Social networks importantly help people access, personalize, and perceive the relevance of information. "Social amplification of risk" means that people are more likely to attend to a threat about which others in their social network express concern (Kasperson et al., 1988). When Hurricane Sandy threatened the U.S. East Coast, people with robust social networks, who tended to have greater access to relevant information and better understanding of the threat, were more likely to evacuate (Sadri et al., 2017; Lazrus et al., 2017). As social networks bolster adaptive capacities, they help people receive and evaluate information that can enable protective decision making. For example, in agricultural regions, farmers concerned about water availability may be more likely to utilize neighboring farmers' drought-related information.

"Social amplification of risk" means that people are more likely to attend to a threat about which others in their social network express concern.

Perception affects the application of information to mitigating harm and reducing vulnerability. Whether produced by public or private agencies or by community traditional knowledge holders, weather- and climate-related information is subject to assessment about its salience or relevance to the decision at hand; credibility, in terms of believability and accuracy; and legitimacy, or production with the decision maker in mind (Cash et al., 2003). Colorado's Urban Drainage and Flood Control District produces information that flood managers say they value because it is local, based on understandable rainfall measurements, and produced by a respected agency (Andrews, Graham, Lazrus, & Done, 2017).

Knowledge production, with overlapping local and scientific forms (Agrawal, 1995) is an iterative process that engages local stories, narratives, and formal and informal institutions, creating a productive space that is conducive to successful climate change adaptation because co-production of knowledge removes barriers to its transmission (Engle & Lemos, 2010; Moser &

Ekstrom, 2010; Dilling & Lemos 2011; Rice et al., 2015). In Saint Paul, Minnesota, a climate-vulnerability research team improved information sharing by working through local organizations connected with vulnerable communities, and by communicating findings with the local government (Box 4).

4. The Role of Boundary Organizations in Becoming Climate Ready and Resilient in Saint Paul, Minnesota

The Great Lakes Integrated Sciences + Assessments (GLISA, http://glisa.umich.edu/function/glisa-approach), through NOAA, acts as a boundary organization connecting science and researchers to end users and policy makers through knowledge networks and boundary chains (Bidwell et al., 2013; Lemos, Kirchhoff, & Ramprasad, 2014). Because climate change impacts usually disproportionately affect low-income communities and people of color (Shonkoff, Morello-Frosch, Pastor, & Sadd, 2011), who are underrepresented in climate change-adaptation planning, GLISA implemented the Ready and Resilient project for these communities in Saint Paul (Phadke, Manning, & Bardaglio, 2016).

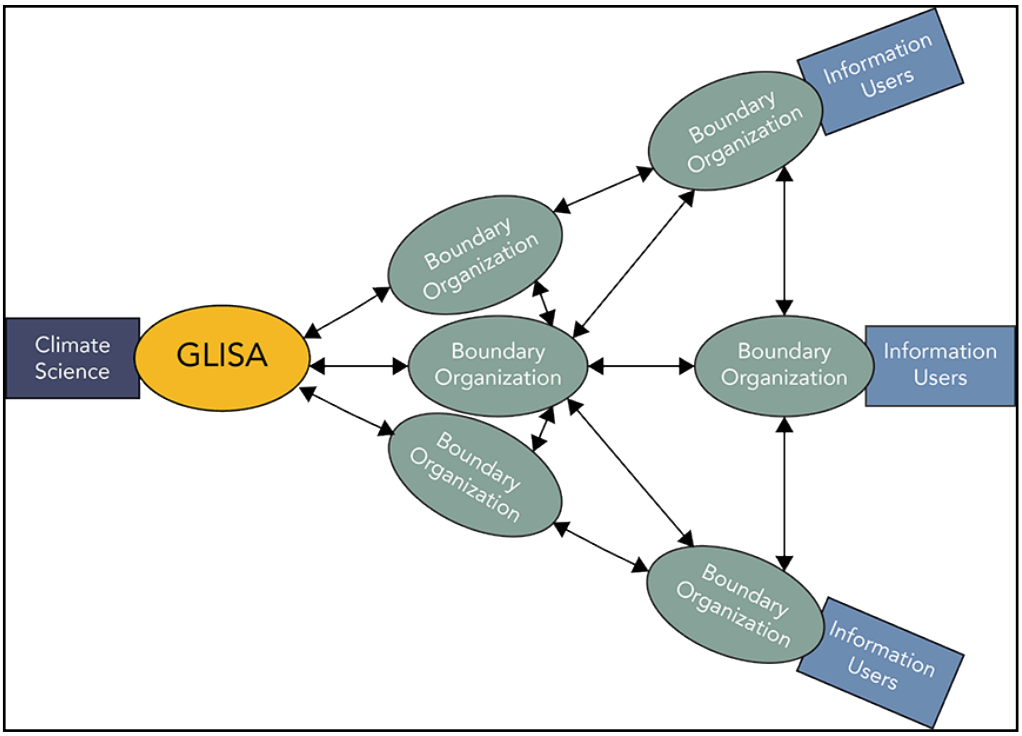

Figure 4. Networked boundary chain model. ©American Meteorological Society. Source: Lemos, et al. (2014)

The study team noted that its goal was to increase Saint Paul residents' capacity to act in the face of climate change. The project "aimed to meet this goal via two pathways: first, to reinvigorate community networks in the city and second, to eliminate barriers to participation that members of minority and low-income communities face" (Phadke, Manning, & Bardaglio 2016, p. 9). The project team created chains of boundary organizations that linked GLISA to local social networks via multiple community partner organizations that were working in four Saint Paul neighborhoods (Phadke, Manning, & Burlager, 2015). This approach facilitated trust and built on existing social networks that included community partners and local residents.

Intra-community processes of knowledge production and dissemination may privilege certain types of knowledge, such as scientific knowledge, or official discourses may be imposed; both tendencies may reduce or prevent transmission of local, environmentally relevant knowledge (Gilmartin, 1994). Shortening the depth of social memory, perhaps to only a few decades, may reduce the capacity to identify local risks, and thereby increase vulnerability (Bone, Alessa, Altaweel, Kliskey, & Lammers, 2011). In Puerto Rico, local environmental knowledge about hurricanes or tsunamis has traditionally been sustained via oral transmission within families and other networks. Yet history books used in Puerto Rico in the first half of the twentieth century portrayed local people as powerless; this view clashed with local memories and knowledge of hazards (Duany, 2010, 2017). Local knowledge was further eroded by outmigration and the failure to record and preserve the older generation's memories (Duany, 2010).

Archaeology, as it recovers memories lost through colonialism, migration, and abandonment, extends place-based knowledge of adaptation (Gullapalli, 2008; Nelson et al., 2016). Climate change, however, threatens the archaeological record as environmental change increases erosion rates and intensifies or accelerates the effects of flooding, wild fires, invasive species, and drought. These stresses add to ongoing pressures from development (Morgan, Rockman, Smith, & Meadow, 2016; Marzeion & Leverman, 2014).

In the Arctic, archaeological sites and sacred places—which serve as reminders of seal-hunting techniques, historical weather patterns, and community and family identity—are sensitive to damage by reductions in sea ice and permafrost. For example, Walakpa, Alaska is a modern hunting location where there are also preserved traces of human use extending back at least 4,000 years. After storms destroyed approximately half the recorded area of the site in 2014, a salvage excavation team collected samples the next year, but additional sections of the site were eroded away shortly after the team's visit (Kintisch, 2016).

For the United States, there are few detailed studies of the long-term climate change impacts on tangible cultural heritage, including archaeological sites, historic structures, and cultural landscapes. Evidence that National Park Service resource managers have gathered indicates that many types of cultural heritage across multiple ecosystems are now being damaged or destroyed at a greater rate than in the past (Morgan et al., 2016). Considering the social limits to adaptation and the cultural factors shaping decision-making facilitates the search for climate change solutions. That search is constrained by reducing the problem solely to natural science issues (Adger et al., 2009; Hulme & Mahony, 2010; Hulme, 2011). Climate reductionism, in overemphasizing the predictive power of the natural sciences (Hulme, 2011), decreases the potential to change the behaviors of individuals and institutions at multiple scales. Rather than depending on affect- or analysis-based decisions, utilizing "rule-based decisions that determine behavior based on moral or social responsibility may hold out the best prospects for sustainable action" (Weber, 2010, p. 332). Research on conditions that foster ethically or culturally grounded responses to climate change would be of great value.

Conclusion

Key Insights

Populations are not uniformly vulnerable to climate change. The reasons for vulnerability are largely social and economic, not merely a matter of different exposure to natural hazards. We have identified some factors responsible for differences in local-scale vulnerability to climate change and suggested a number of actions to reduce it.

Access to resources is one critical factor that shapes communities' ability to plan for and respond to the impacts of climate change. Addressing unequal access to resources involves a two-fold challenge: it requires both action on a community or project basis, and larger-scale structural change to reduce poverty and political marginalization. Cultural systems shape how people understand environmental change, while at a local or regional scale culture and history may constrain the feasible responses to climate change threats. Climate change presents both acute and chronic challenges for effective governance, exemplified by Hurricane Sandy and sea-level rise, respectively. The successful examples of environmental governance discussed here demonstrate the benefits of partnerships among governments, social movements, and organizations. Valid and timely information about weather and climate are necessary but not sufficient to promote effective action at a community scale. Putting into practice an iterative process in which researchers and community residents jointly shape the availability, dissemination, and use of information increases the likelihood that the information will meaningfully contribute to adaptive responses to climate change.

Future Opportunities

These considerations lead to insights for creating more effective responses to local-level climate change vulnerability.

Implementation.

Access to resources.

- When designing programs to help populations adapt to climate change, explicitly address the causes and impacts of social inequality for marginalized groups and identify mechanisms for mitigating these causes. Socially diverse team members and/or experts in poverty and other causes of marginalization can play important roles.

- Climate change adaptation programs should not be considered in isolation. Integrating or mainstreaming climate change into ongoing, inclusive planning efforts may reduce marginalized populations' unequal climate burdens.

- In planning to reduce any population's vulnerability, emphasize well-being and include preserving the objects and places that provide meaning in social life.

- There is no recipe in planning for equitable climate change adaptation. Planners should consider how climate change uniquely affects local contexts and cultures.

Culture and history.

- Develop or utilize local histories to contextualize vulnerability assessments. Seek information from a range of community members, including long-term residents. This procedure is particularly relevant in traditional and indigenous communities. Ask about the people who have lived there. When and why did the current form of the community take shape? What do people consider normal seasonal environmental conditions? What is the disaster history of the community, and what happened after these events? Use multiple ways of gathering community perspectives in identifying risks and hazards and in proposing risk mitigation and adaptation strategies.

- Include historic properties, archaeological sites, traditional cultural properties, and related intangible heritage in assessments of community assets at risk from climate change and other environmental forces.

Governance.

- Establish and support partnerships and coalitions that link federal, state, and/or local agencies with community groups, non-governmental organizations, and professional associations.

- Draw on participatory research techniques to initiate and support partnerships and coalitions.

- Work with partners to place vulnerability reduction and resilience on public agendas and to promote action on multiple levels.

- Emphasize the co-benefits of vulnerability reduction in such areas as public health and economic development.

- When possible, use engagement processes with multiple phases, which are more likely than one-off events to promote trust and transparency and to lead to effective partnerships and coalitions.

Information and forecasts.

- In working with vulnerable populations and communities, recognize that effective communication of information and forecasts is necessary but not sufficient for mitigating vulnerability to climate change.

- In adaptation planning and implementation processes, to improve the likelihood that vulnerable populations and communities will act on relevant information from federal agencies, ensure the equal participation of community members who have local or traditional ecological knowledge.

- When providing information and forecasts to decision makers at all levels, utilize information that people seek, receive, and combine from multiple sources, including their social networks.

- In communicating plans and practices regarding climate change vulnerability and mitigation, working with local governments and well-established, trusted local organizations can be more effective than working solely with vulnerable communities. Invest time in learning about and communicating with those organizations, thus enhancing the credibility, salience, and legitimacy of information and the likelihood that plans will be implemented.

Research. There are three particularly promising areas of research.

Mobility: Conventional analyses of the spatial extent of vulnerability are usually based on residence and ignore short-term mobility. Further research is needed about daily activity spaces as they affect health and exposure to environmental toxins, food accessibility, and the capacity for long-distance travel.

Uncertainty: Climate change predictions are only one of several sources of knowledge guiding adaptation. Despite uncertainty over climate change predictions, which may constrain governmental action, effective adaptation planning is nonetheless feasible. Additional research on the most effective frameworks for fostering effective adaptation decisions in the face of uncertainty will benefit planning.

Incremental change: Climate change presents both acute and chronic challenges for adaptation and requires responses to both pulse events, such as Hurricane Sandy, and press events, such as sea-level rise. While the threat of pulse events can prompt governments to re-allocate resources from routine activities to vulnerability reduction, gradual environmental change, though equally serious, less often provokes a significant response. Identifying strategies that can promote more effective engagement around the press aspects of climate change offers an important topic for interdisciplinary work.

Acknowledgments

This working group was facilitated by Susan Goodwin (Department of the Interior). Katie Reeves (USGCRP contractor) provided administrative support. Blenda Femenías edited the white paper.

Funding for the Social Science Perspectives workshop and follow-on activities was provided by the National Aeronautics and Space Administration (grant NNX17AG17G), the U.S. Bureau of Land Management, the American Anthropological Association, the American Association of Geographers, the American Sociological Association, and the Society for American Archaeology. The School of Forestry and Environmental Studies at Yale University hosted a writing session for this team. We also wish to acknowledge the helpful comments provided during and after the workshop by Chelsea Combest-Friedman, Michael Craghan, Emily Eisenhauer, Stacey Fritz, Anne Grambsch, Holly Hapke, Sam Higuchi, Fen Hunt, Anna Kerttula, Keely Maxwell, Tom McGovern, Andy Miller, Leah Nichols, and John Primo.

Context Statement

This white paper is a product of the workshop "Social Science Perspectives on Climate Change" held in Washington, DC in March 2017. Two other white papers resulted from the workshop:

> S. Fiske, K. Hubacek, A. Jorgenson, J. Li, T. McGovern, T. Rick, J. Schor, W. Solecki, R. York, A. Zycherman. (2018). Drivers and responses: Social science perspectives on climate change, part 2. Washington, DC: USGCRP Social Science Coordinating Committee. https://www.globalchange.gov/content/social-science-perspectives-climate-change-workshop.
>
> P. F. Biehl, S. Crate, M. Gardezi, L. Hamilton, S.L. Harlan, C. Hritz, B. Hubbell, T. A. Kohler, N. Peterson, J. Silva. (2018). Innovative tools, methods, and analysis: Social science perspectives on climate change, part 3. Washington, DC: USGCRP Social Science Coordinating Committee. https://www.globalchange.gov/content/social-science-perspectives-climate-change-workshop.

The workshop was organized by the U.S. Global Change Research Program's (USGCRP) Social Science Coordinating Committee in cooperation with the American Anthropological Association, the American Association of Geographers, the American Sociological Association, and the Society for American Archaeology. The workshop had three aims:

- demonstrate how the social sciences can add important methods, perspectives, and data to climate change mitigation and adaptation efforts;
- enhance collaboration between academic and federal social scientists, and between natural and social scientists; and
- develop products that support the 4th National Climate Assessment, USGCRP's Interagency Working Groups, and federal agencies.

The USGCRP, a confederation of the research arms of 13 federal departments and agencies, is charged with advancing global change science, coordinating federal research on global change, and producing a quadrennial National Climate Assessment. "Global change" as used here includes change involving climate, land use and land cover, atmospheric circulation, the carbon cycle, biodiversity, and other planetary-scale physical and biological systems, and the ways these phenomena are shaped by social systems.

The USGCRP's Social Science Coordinating Committee is charged with promoting the integration of the methods, findings, and disciplinary perspectives of the social and behavioral sciences into federal global change research. This goal was laid out in the USGCRP's 2012–2021 Strategic Plan, which led to the establishment of the Committee in 2014. The Committee is broadly multidisciplinary, and has included social scientists from archaeology, cultural anthropology, economics, geography, human ecology, political science, science and technology studies, social psychology, and sociology.

The workshop brought together about 30 academic, environmentally focused social scientists

from archaeology, cultural anthropology, human geography, and sociology, with some 60 federal staff involved in climate change-related activities. Each of those disciplines has developed a large body of research on the human dimensions of climate change that can complement federal climate change research, but is not often considered. The March 2017 workshop focused on three themes: identifying innovative tools, methods, and analyses to clarify the interactions of human and natural systems under climate change; describing key factors shaping differences in social vulnerability to climate change; and providing social science perspectives on drivers of global climate change.

The themes were identified in advance of the workshop by the SSCC and representatives from the four participating associations. The associations, in turn, recruited scholars from their disciplines to serve with SSCC members on interdisciplinary writing teams for each of the themes. The teams prepared preliminary drafts for use in the March 2017 workshop. There the writing groups met with federal participants, who offered reactions and ideas for improving the white papers. They have been extensively revised since the workshop.

References

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R.,…Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic Change, 93*(3–4), 335–354.

Agrawal, A. (1995). Dismantling the divide between indigenous and scientific knowledge. *Development and Change, 26*(3), 413–439.

Anderson, E. N. 2014. *Caring for Place: Ecology, Ideology, and Emotion in Traditional Landscape Management*. Walnut Creek, CA: Left Coast Press.

Andrews, D. G., Lazrus, H., & Done, J. (2017, January). Emerging decadal climate information: What's the potential for flood risk management? Paper presented at the Annual Meeting of the American Meteorological Society, Seattle, WA.

Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb,…Teicher, H. (2016). Equity impacts of urban land use planning for climate adaptation: Critical perspectives from the global North and South. *Journal of Planning Education and Research, 36*(3), 333–348.

Austin, R., & Schill, M. (1994). *Unequal protection*. San Francisco: Sierra Club Books.

Basso, K. H. (2007). *Wisdom sits in places: Landscape and language among the Western Apache*. Albuquerque: University of New Mexico Press.

Bennett, T. M. B., Maynard, N. G., Cochran, P., Gough, R., Lynn, K., Maldonado, J.,…Cozzeo, K. (2014). Indigenous peoples, lands, and resources. Climate change impacts in the United States. In J. M. Melillo, T. C. Richmond, & G. W. Yohe (Eds.). *Third National Climate Assessment* (pp. 297–317). Washington, DC: U.S. Global Change Research Program. doi:10.7930/J09G5JR1

Berkes, F. (1999). *Sacred ecology: Traditional ecological knowledge and resource management*. Philadelphia: Taylor & Francis.

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications, 10*(5), 1251–1262. DOI:10.1890/1051-0761(2000)010[1251:ROTEKA]2.0.CO;2

Bethel, M. B., Brien, L. F., Esposito, M. M., Miller, C. T., Buras, H. S., Laska, S. B.,…Richards, C. P. (2014). Sci-TEK: A GIS-based multidisciplinary method for incorporating traditional ecological knowledge into Louisiana's coastal restoration

decision-making processes. *Journal of Coastal Research, 30*(5), 1081–1099. http://www.jcronline.org/doi/abs/10.2112/JCOASTRES-D-13-00214.1
Bidwell, D., Dietz, T., & Scavia, D. (2013). Fostering knowledge networks for climate adaptation. *Nature Climate Change*, *3*(7), 610–611. http://www.nature.com/doifinder/10.1038/nclimate1931
Bilham, Roger. (2010). Lessons from the Haiti Earthquake. *Nature* 463:878-879.
Birkenholtz, T. (2012). Network political ecology: Method and theory in climate change vulnerability and adaptation research. *Progress in Human Geography, 36*(3), 295–315.
Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (1994). *At risk: Natural hazards, people's vulnerability, and disasters*. New York: Routledge.
Bolin, R. (1986). Disaster impact and recovery: A comparison of black and white victims. *International Journal of Mass Emergencies and Disasters, 4*(1), 35–50.
Bone, C., Alessa, L., Altaweel, M., Kliskey, A., & Lammers, R. (2011). Assessing the impacts of local knowledge and technology on climate change vulnerability in remote communities. *International Journal of Environmental Research and Public Health, 8*(3), 733–761.
Bonilla-Silva, E. (1997). Rethinking racism: Toward a structural interpretation. *American Sociological Review, 62*(3), 465–480. http://www.jstor.org/stable/2657316
Bonilla-Silva, E. (2013). *Racism without racists: Color-blind racism and the persistence of racial inequality in America*. Lanham, MD: Rowman & Littlefield Publishers.
Brunkard, J., Namulanda, G., & Ratard, R. (2008). Hurricane Katrina deaths, Louisiana, 2005. *Disaster Medicine and Public Health Preparedness*, *2*(4), 215–223. PMID 18756175. doi:10.1097/DMP.0b013e31818aaf55.
Bullard, R. D., & Wright, B. (2012). *The wrong complexion for protection: How the government response to disaster endangers African American communities*. New York: NYU Press.
Bunker, S. G. (1985). *Underdeveloping the Amazon*. Urbana-Champaign: University of Illinois Press.
California Energy Commission. (2012). Community-based climate adaptation planning: Case study of Oakland, California. A White Paper. Pacific Institute and Oakland Climate Action Coalition. http://www.energy.ca.gov/2012publications/CEC-500-2012-038/CEC-500-2012-038.pdf
Caniglia, B. S., Brulle, R. J., & Szasz, A. (2015). Civil society, social movements, and climate change. In R. E. Dunlap & R. J. Brulle (Eds.) *Climate change and society: Sociological perspectives* (pp. 235–268). New York: Oxford University Press.
Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H.,…Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences*, *100*(14), 8086–8091.
Chaffin, B. C., Garmestani, A. S., Gunderson, L. H., Benson, M. H., Angeler, D. G., Arnold, C. A.,…Allen, C. R. (2016). Transformative environmental governance. *Annual Review of Environment and Resources, 41*, 399–423.
Coastal Green Infrastructure and Ecosystem Services Task Force. (2015). *Ecosystem-service assessment: Research needs for coastal green infrastructure*. National Science and Technology Council. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/cgies_research_agenda_final_082515.pdf
Collins, S. L., Carpenter, S. R., Swinton, S. M., Orenstein, D. E., Childers, D. L., Gragson, T. L.,…Whitmer, A. C. (2011). An integrated conceptual framework for long-term social–

ecological research. *Frontiers in Ecology and the Environment, 9*(6), 351–357. doi:10.1890/100068
Collins, T. W. (2010). Marginalization, facilitation, and the production of unequal risk: The 2006 Paso del Norte floods. *Antipode, 42*(2), 258–288.
Crate, S. A., & Nuttall, M. (2009). Introduction: Anthropology and climate change. In S. Crate & M. Nuttall (Eds.). *Anthropology and climate change: From encounters to actions* (pp. 9–37). Walnut Creek, CA: Left Coast Press.
Crumley, C. (2002). Exploring venues of social memory. In J. Climo & M. Cattell (Eds.). *Social memory and history: Anthropological perspectives* (pp. 29–52). Walnut Creek, CA: Altamira Press.
Cutter, S. L., Mitchell, J. T., & Scott, M. S. (2000). Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Annals of the Association of American Geographers, 90*(4), 713–737.
d'Alpoim Guedes, J. A., Crabtree, S. A., Bocinsky, R. K., & Kohler, T. A. (2016). Twenty-first century approaches to ancient problems: Climate and society. *Proceedings of the National Academy of Sciences, 113*(51), 14483–14491.
Dash, N., Peacock, W. G., & Morrow, B. H. (1997). And the poor get poorer: A neglected black community. In W. G. Peacock, H. Gladwin, & B. H. Morrow (Eds.). *Hurricane Andrew: Ethnicity, gender, and the sociology of disasters* (pp. 206–225). New York: Routledge.
Denton, F. (2002). Climate change vulnerability, impacts, and adaptation: Why does gender matter? *Gender & Development, 10*(2), 10–20.
Diakakis, M., Deligiannakis, G., Katsetsiadou K. & Lekkas, E. (2015). Hurricane Sandy mortality in the Caribbean and continental North America. *Disaster Prevention and Management: An International Journal, 24*(1), 132–148. doi:10.1108/DPM-05-2014-0082
Dill, B., & Crow, B. (2014). The colonial roots of inequality: access to water in urban East Africa. *Water International*, *39*(2), 187–200. http://doi.org/10.1080/02508060.2014.894212
Dilling, L., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change, 21*(2), 680–689. http://dx.doi.org/10.1016/j.gloenvcha.2010.11.006
Douglas, M., & Wildavsky, A. (1982). *Risk and culture: An essay on the selection of technological and environmental dangers*. Berkeley: University of California Press.
Duany, J. (2010). *La nación en vaivén: Identidad, migración y cultura popular en Puerto Rico*. San Juan, Puerto Rico: Ediciones Callejón.
Duany, J. (2017). *Puerto Rico: What everyone needs to know*. Oxford: Oxford University Press.
Ekstrom, J. A., & Moser, S. C. (2014). Identifying and overcoming barriers in urban climate adaptation: Case study findings from the San Francisco Bay Area, California, USA. *Urban Climate*, *9*, 54–74.
Engle, N. L. (2011). Adaptive capacity and its assessment. *Global Environmental Change, 21*(2), 647–656. http://www.sciencedirect.com/science/article/pii/S0959378011000203
Engle, N. L., & Lemos, M. C. (2010). Unpacking governance: Building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change, 20*(1), 4–13. http://www.sciencedirect.com/science/article/pii/S0959378009000466
Environmental Protection Agency. (n.d.) Quinault Indian Nation plans for relocation. Climate Change Adaptation Resource Center. https://www.epa.gov/arc-x/quinault-indian-nation-

plans-relocation
Evans, L., Milfont, T. L., & Lawrence, J. (2014). Considering local adaptation increases willingness to mitigate. *Global Environmental Change, 25*(March), 69–75. doi:10.1016/j.gloenvcha.2013.12.013
Fackler, M. (2011, April 20 and 21). Tsunami warnings, written in stone. *New York Times*, p. A6. https://nyti.ms/2mOtlwF
Fothergill, A., & Peek, L. A. (2004). Poverty and disasters in the United States: A review of recent sociological findings. *Natural Hazards, 32*, 89–110.
Gilmartin, D. (1994). Scientific empire and imperial science: Colonialism and irrigation technology in the Indus Basin. *The Journal of Asian Studies, 53*(4), 1127–1149.
Gladwin, H., & Peacock, W. G. (1997). Warning and evacuation: A night for hard houses. In W. G. Peacock, H. Gladwin, & B. H. Morrow (Eds.). *Hurricane Andrew: Ethnicity, gender, and the sociology of disasters* (pp. 52–74). New York: Routledge.
Grasso, M. (2010). An ethical approach to climate adaptation finance. *Global Environmental Change, 20*(1), 74-81.
Greene, M. (1992). Housing recovery and reconstruction: Lessons from recent urban earthquakes. In *Proceedings of the 3rd U.S./Japan Workshop on Urban Earthquakes*. Oakland, CA: Earthquake Engineering Research Institute (EERI) Publication No. 93-B.
Groves, D. G., & Sharon, C. (2013). Planning tool to support planning the future of coastal Louisiana. *Journal of Coastal Research, 67*(sp1), 147–161. DOI:http://dx.doi.org/10.2112/SI_67_10
Groves, D. G., Fischbach, J. R., Knopman, D., Sharon, C., Johnson, D. R., Ortiz, D. S.,…Ostwald, J. (2014). Addressing coastal vulnerabilities through comprehensive planning. Research Brief. Santa Monica, CA: The Rand Corporation. http://www.rand.org/content/dam/rand/pubs/research_briefs/RB9600/RB9696-1/RAND_RB9696-1.pdf
Gullapalli, P. (2008). Heterogenous encounters: Colonial histories and archaeological experiences. In M. Liebmann & U. Rizvi (Eds.). *Archaeology and the postcolonial critique* (pp. 35–52). Plymouth: Altamira Press.
Haas, M. (2014). Building on borrowed time: How long can we live on the coast? Rhode Island Sea Grant, News, June 23. http://seagrant.gso.uri.edu/building-on-borrowed-time/
Hallegatte, S. (2012. An exploration of the link between development, economic growth, and natural Risk. *Policy Research Working Paper*, 6216 Washington, DC: World Bank.
Hauer, M. E., Evans, J. M., & Mishra, D. R. (2016). Millions projected to be at risk from sea-level rise in the continental United States. *Nature Climate Change, 6*, 691–694. http://dx.doi.org/10.1038/nclimate2961
Hulme, M. (2011.) Reducing the future to climate: A story of climate determinism and reductionism. *Osiris, 26*(1), 245–266. http://www.jstor.org/stable/10.1086/661274.
Hulme, M., & Mahony, M. (2010). Climate change: What do we know about the IPCC? *Progress in Physical Geography, 34*(5), 705–718. https://doi.org/10.1177/0309133310373719
Jonkman, S. N., Maaskant, B., Boyd, E., & Levitan, M. L. (2009). Loss of life caused by the flooding of New Orleans after Hurricane Katrina: Analysis of the relationship between flood characteristics and mortality. *Risk Analysis*, *29*(5), 676–698. doi:10.1111/j.1539-6924.2008.01190.x
Kasperson, R. E., & Kasperson, J. X. (2001). Climate change, vulnerability, and social justice.

Stockholm: Stockholm Environment Institute. http://stc.umsl.edu/essj/unit4/climate%20change%20risk.pdf
Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R.,…Ratick, S. (1988). The social amplification of risk: A conceptual framework. *Risk Analysis, 8* (2), 177–187.
Kates, R. W., Colten, C. E., Laska, S., & Leatherman, S. P. (2006). Reconstruction of New Orleans after Hurricane Katrina: A research perspective. *Proceedings of the National Academy of Sciences, 103*(40), 14653–14660.
Keller, R. C. (2015). *Fatal isolation: The devastating Paris heat wave of 2003*. Chicago: University of Chicago Press.
Kintisch, E. (2016). History is melting. *Hakai Magazine* (January 26), n. p. http://bit.ly/1PSoFxb
Kirsch, S. (2001). Lost worlds: Environmental disaster, "culture loss," and the law. *Current Anthropology, 42*(2), 167–178.
Klinenberg, E. (2002). *Heat wave: A social autopsy of disaster in Chicago.* Chicago: University of Chicago Press.
Kwan, M.-P. (2013). Beyond space (as we knew it): Toward temporally integrated geographies of segregation, health, and accessibility. *Annals of the Association of American Geographers, 103*(5), 1078–1086.
Kwan, M.-P., & Schwanen, T. (2016). Geographies of mobility. *Annals of the American Association of Geographers, 106* (2), 243–256.
Laracuente, N. R. (2008). *An analysis of Spanish Pensacola as a behavioral landscape*. M.A. thesis, Department of Anthropology, University of West Florida, Pensacola, FL. http://etd.fcla.edu/WF/WFE0000138/Laracuente_Nicolas_Ruben_200812_MA.pdf
Laracuente, N. R. (2010, January). Choosing the lesser evil: Traumatic events and settlement preference in first Spanish-period Pensacola. Paper presented at the Annual Meeting of the Society for Historical Archaeology, Amelia Island, FL.
Lazrus, H., Wilhelmi, O., Henderson, J., Morss, R. E., & Dietrich, A. (2017, January). Information as intervention: How can hurricane risk communication reduce vulnerability? Paper presented at the Annual Meeting of the American Meteorological Society, Seattle, WA.
Leichenko, R., & Silva, J. A. (2014). Climate change and poverty: Vulnerability, impacts, and alleviation strategies. *Wiley Interdisciplinary Reviews: Climate Change, 5*(4), 539–556.
Lemos, M. C., Kirchhoff, C. J., Kalafatis, S. E., Scavia, D., & Rood, R. B. (2014). Moving climate information off the shelf: Boundary chains and the role of RISAs as adaptive organizations. *Weather, Climate, and Society, 6*(2), 273–285. http://journals.ametsoc.org/doi/abs/10.1175/WCAS-D-13-00044.1
Lerner, A. M., & Eakin, H. 2011. An obsolete dichotomy? Rethinking the rural-urban interface in terms of food security and production in the global south. *Geographical Journal, 177*(4), 311–320. doi:10.1111/j.1475-4959.2010.00394.x
Lobao, L. M., Adua, L., & Hooks, G. (2014). Privatization, business attraction, and social services across the United States: Local governments' use of market-oriented, neoliberal policies in the post-2000 period. *Social Problems, 61*(4), 644–672. doi:10.1525/sp.2014.12180
Logan, J. R., Sukriti, I., & Xu, Z. (2016). Trapped in place? Segmented resilience to hurricanes in the Gulf Coast, 1970–2005. *Demography, 5*, 1511–1534.
Lopez, G. R. (2003). The (racially neutral) politics of education: A critical race theory perspective. *Educational Administration Quarterly*, 39(1), 68–94.

Maldonado, J., Lazrus, H., Bennett, S.-K., Chief, K., Dhillon, C. M., Gough, B.,…Whyte, K. P. (2016). The story of Rising Voices: Facilitating collaboration between Indigenous and Western ways of knowing. In M. Companion & M. Chaiken (Eds.). *Responses to disasters and climate change: Understanding vulnerability, building resilience* (pp. 15–26). Boca Raton, FL: CRC Press/Taylor & Francis Group. https:doi.org/10.1201/9781315315928-3

Mann, M. E., Zhang, Z., Rutherford, S., Bradley, R. S., Hughes, M. K., Shindell, D.,…Ni, R. (2009). Global signatures and dynamical origins of the Little Ice Age and medieval climate anomaly. *Science*, 326 (5957), 1256 LP-1260. DOI: 10.1126/science.1177303

Martinich, J., Neumann, J., Ludwig, L., & Jantarasami, L. (2013). Risks of sea level rise to disadvantaged communities in the United States. *Mitigation and Adaptation Strategies for Global Change*, *18*(2), 169–185.

Marzeion, B., & Levermann, A. (2014). Loss of cultural world heritage and currently inhabited places to sea-level rise. *Environmental Research Letters*, *9*(3), 34001. http://stacks.iop.org/1748-9326/9/i=3/a=034001

McAdoo, B. G., Dengler, L., Eeri, M., Prasetya, G., & Titov, V. (2006). Smong: How an oral history saved thousands on Indonesia's Simeulue Island during the December 2004 and March 2005 tsunamis. *Earthquake Spectra*, *22*(S3), S661-S669.

McCright, A. M., & Dunlap, R. E. (2015). Comparing two measures of social movement Identity: The environmental movement as an example. *Social Science Quarterly*, *96*(2), 400–416.

McDowell, G., Ford, J., & Jones, J. (2016). Community-level climate change vulnerability research: Trends, progress, and future directions. *Environmental Research Letters, 11*(3), 33001. doi:10.1088/1748-9326/11/3/033001

McNeeley, S. M., Even, T. L., Gioia, J. B. M., Knapp, C. N., & Beeton, T. A. (2017). Expanding vulnerability assessment for public lands: The social complement to ecological approaches. *Climate Risk Management, 16*, 106–119. doi:10.1016/j.crm.2017.01.005

Melillo, J. M., Richmond, T. C., & Yohe, G. W. (Eds.). (2014). *Climate change impacts in the United States: The Third National Climate Assessment*. Washington, DC: U.S. Global Change Research Program. doi:10.7930/J0Z31WJ2

Mileti, D. S. (1999). *Disasters by design: A reassessment of natural hazards in the United States*. Washington, DC: Joseph Henry Press.

Miller Hesed, C. D., & Paolisso, M. (2015). Cultural knowledge and local vulnerability in African American communities. *Nature Climate Change*, *5*(7), 683–687. http://dx.doi.org/10.1038/nclimate2668

Minc, L. D., & Smith, K. P. (1989). The spirit of survival: Cultural responses to resource variability in North Alaska. In P. Halstead & J. O'Shea (Eds.). *Bad year economics: Cultural responses to risk and uncertainty* (pp. 8–39). Cambridge: Cambridge University Press.

Morgan, M., Rockman, M., Smith, C., Meadow, A. (2016). *Climate change impacts on cultural resources. Cultural Resources Partnerships and Science.* Washington, DC: National Park Service.

Morrow, B. H. (1999). Identifying and mapping community vulnerability. *Disasters*, *23*(1), 11–18.

Morrow, B. H. & Enarson, E. (1996). Hurricane Andrew through women's eyes: Issues and recommendations. *International Journal of Mass Emergencies and Disasters, 14*(1), 5–

22.
Morss, R., Demuth, J., Lazrus, H., Palen, L., Barton, C., Davis, C.,…Watts, J. (2017). Hazardous weather prediction and communication in the modern information environment. *Bull. Amer. Meteor. Soc*., 98(12), 2653–2674. doi:10.1175/BAMS-D-16-0058.1
Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences, 107*(51), 22026–220231. doi: 10.1073/pnas.1007887107
Moser, S. C., Williams, S. J., & Boesch, D. F. (2012). Wicked challenges at land's end: Managing coastal vulnerability under climate change. *Annual Review of Environment and Resources, 37*, 51–78.
Murphy, D., Wyborn, C., Yung, L., Williams, D. R., Cleveland, C., Eby, L.,…Towler, E. 2016. Engaging communities and climate change futures with multi-scale, iterative scenario building (MISB) in the western United States. *Human Organization, 75*(1), 33–46.
National Research Council. (2004). *Reducing future flood losses: The role of human actions: Summary of a workshop, March 2, 2004, Washington, DC: A summary to the Disasters Roundtable*. Washington, DC: National Academies Press. https://doi.org/10.17226/11171
Nelson, M. C., Ingram, S. E., Dugmore, A. J., Streeter, R., Peeples, M. A., McGovern, T. H.,… Smiarowski, K. (2016). Climate challenges, vulnerabilities, and food security. *Proceedings of the National Academy of Sciences, 113*(2), 298–303.
Norfolk, Virginia, City of. (n. d.) *Coastal resilience strategy*. https://www.norfolk.gov/DocumentCenter/View/16292
Nunn, P. D., & Reid, N. J. (2015). Aboriginal memories of inundation of the Australian Coast dating from more than 7000 years ago. *Australian Geographer, 9182*: 1–37.
O'Brien, K. L., Eriksen, S., Nygaard, L. P., & Schjolden, A. (2007). Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy, 7*(1), 73–88.
O'Keefe, P., Westgate, K., & Wisner, B. (1976). Taking the naturalness out of natural disasters. *Nature, 260*, 566–567.
O'Leary, J. T., Behrens-Tepper, J., McGuire, F. A., & Dottavio, F. D. (1987). Age of first hunting experience: Results from a nationwide recreation survey. *Leisure Science, 9*, 225–233.
Omi, M., & Winant, H. (2015). *Racial formation in the United States.* Third ed. New York: Routledge.
Orlove, B., Roncoli, C., Kabugo, C., & Majugu, A. (2010). Indigenous climate knowledge in southern Uganda: The multiple components of a dynamic regional system. *Climatic Change, 100*(2), 243–265.
Otto, I. M., Reckien, D., Reyer, C. P. O., Marcus, R., Le Masson, V., Jones, L.,…Serdeczny, O. (2017). Social vulnerability to climate change: A review of concepts and evidence. *Regional Environmental Change, 17*(6), 1–12. DOI 10.1007/s10113-017-1105-9
Paolisso, M. (2002). Blue crabs and controversy on the Chesapeake Bay: A cultural model for understanding watermen's reasoning about blue crab management. *Human Organization, 61*(3), 226–239.
Peacock, W. G., Morrow, B. H., & Gladwin, H. (1997). *Hurricane Andrew: Ethnicity, gender, and the sociology of disasters*. New York: Routledge.
Pearsall, H. (2010). From brown to green? Assessing social vulnerability to environmental gentrification in New York City. *Environment and Planning C: Government and Policy,*

28(5), 872–886.
Pennesi, K. (2011). Making forecasts meaningful: Explanations of problematic predictions in Northeast Brazil. *Weather Climate and Society*, *3*(2), 90–105. https://doi.org/10.1175/WCAS-D-10-05005.1
Perchoux, C., Chaix, B., Cummins, S., & Kestens, Y. (2013). Conceptualization and measurement of environmental exposure in epidemiology: Accounting for activity space related to daily mobility. *Health and Place, 21*, 86–93. http://dx.doi.org/10.1016/j.healthplace.2013.01.005
Pew Research Center. (2016). On views of race and inequality, blacks and whites are worlds apart. Social & Demographic Trends (June 26), n. p. http://www.pewsocialtrends.org/2016/06/27/on-views-of-race-and-inequality-blacks-and-whites-are-worlds-apart/
Phadke, R., Manning, C., & Bardaglio, I. (2016). Ready & resilient: Climate preparedness in Saint Paul, Minnesota. In D. Brown, W. Baule, L. Briley, E. Gibbons, & I. Robinson (Eds.). *Project Reports*, 1–14. Saint Paul: Great Lakes Integrated Sciences and Assessments (GLISA) Center. http://glisa.umich.edu/media/files/projectreports/GLISA_ProjRep_Macalester_2015.pdf
Phadke, R., Manning, C., & Burlager, S. (2015). Making it personal: Diversity and deliberation in climate adaptation planning. *Climate Risk Management, 9*, 62–76. http://dx.doi.org/10.1016/j.crm.2015.06.005
Phillips, B. D. (1993). Cultural diversity in disasters: Sheltering, housing, and long term recovery. *International Journal of Mass Emergencies and Disasters*, *11*(1), 99–110.
Quinault Indian Nation. (2017b). Noskiakos: The Taholah Village Relocation Master Plan. Draft 3/7/2017. http://www.quinaultindiannation.com/planning/PlanDraft03-07-2017.pdf
Quinault Indian Nation. (2017a). Taholah Village Relocation Master Plan project. http://www.quinaultindiannation.com/planning/projectinfo.html
Rappaport, R. (1979). Ecology, meaning, and religion. Richmond, CA: North Atlantic Books.
Rayner, S., & Cantor, R. (1987). How fair is safe enough? The cultural approach to societal technology choice. *Risk Analysis, 7*(1), 3–9. doi:10.1111/j.1539-6924.1987.tb00963.x
Redsteer, M. H., Bemis, K., Chief, K., Gautam, M., Middleton, B. R., & Tsosie, R. (2013). Unique challenges facing southwestern tribes. In G. Garfin, A. Jardine, R. Merideth, M. Black, & S. LeRoy (Eds.). *Assessment of climate change in the Southwest United States: A report prepared for the National Climate Assessment, A report by the Southwest Climate Alliance* (pp. 385–404). Washington, DC: Island Press.
Redsteer, M. H., Kelley, K. B., Francis, H., & Block, D. (2010). Disaster risk assessment case study: Recent drought on the Navajo Nation, southwestern United States. In *2011 Global Assessment Report on Disaster Risk Reduction* (pp. 1–19). Geneva: United Nations Office for Disaster Risk Reduction. https://www.preventionweb.net/english/hyogo/gar/2011/en/bgdocs/Redsteer_Kelley_Francis_&_Block_2010.pdf
Ren, F. (2016). Activity space. In B. Warf (Ed.). *Oxford bibliographies: Geography*. New York: Oxford University Press. http://dx.doi.org/10.1093/obo/9780199874002-0137
Rhodes, J., Chan, C., Paxson, C., Rouse, C. E., Waters, M., & Fussell, E. (2010). The impact of Hurricane Katrina on the mental and physical health of low-income parents in New Orleans. *American Journal of Orthopsychiatry*, *80*(2), 237–247. http://dx.doi.org/10.1111/j.1939-0025.2010.01027.x

Rice, J. L., Burke, B. J., & Heynen, N. (2015). Knowing climate change, embodying climate praxis: Experiential knowledge in Southern Appalachia. *Annals of the Association of American Geographers, 105*(2), 253–262. http://dx.doi.org/10.1080/00045608.2014.985628

Rick, T. C., Kirch, P. J., Erlandson, J. M, & Fitzpatrick, S. M (2013). Archeology, deep history, and the human transformation of island ecosystems. *Anthropocene, 4*, 33–45. http://dx.doi.org/10.1016/j.ancene.2013.08.002

Roberts, J. T., & Parks, B. J. (2007). *A climate of injustice*. Cambridge, MA: MIT Press.

Rockman, M. (2003). Knowledge and learning in the archaeology of colonization. In M. Rockman & J. Steele (Eds.). *The colonization of unfamiliar landscapes: The archaeology of adaptation* (pp. 3–24). London: Routledge.

Rosen, A. M., & Rivera-Collazo, I. (2012). Climate change, adaptive cycles, and the persistence of foraging economies during the Late Pleistocene/Holocene transition in the Levant. *Proceedings of the National Academy of Sciences, 109*(10), 3640–3645. doi:10.1073/pnas.1113931109

Rudolph, L., Gould, S., & Berko, J. (2015). Climate change, health, and equity: Opportunities for action. Oakland, CA: Public Health Institute. https://www.phi.org/uploads/application/files/h7fjouo1i38v3tu427p9s9kcmhs3oxsi7tsg1fovh3yesd5hxu.pdf

Rugh, J. S., & Massey, D. S. (2010). Racial segregation and the American foreclosure crisis. *American Sociological Review, 75*(5), 629–651. http://journals.sagepub.com/doi/10.1177/0003122410380868

Sadri, A. M., Ukkusuri, S. V., & Gladwin, H. (2017). The role of social networks and information sources on hurricane evacuation decision making. *Natural Hazards Review, 18*(3). https://doi.org/10.1061/(ASCE)NH.1527-6996.0000244

Safransky, S. (2014). Greening the urban frontier: Race, property, and resettlement in Detroit. *Geoforum, 56*, 237–248. http://dx.doi.org/10.1016/j.geoforum.2014.06.003.

Scherer, J. (1912). Great earthquakes in the island of Haiti. *Bulletin of the Seismological Society of America, 2*(4), 161–180.

Schmeltz, M. T., González, S. K., Fuentes, L., Kwan, A., Ortega-Williams, A., & Cowan, L. P. (2013). Lessons from Hurricane Sandy: A community response in Brooklyn, New York. *Journal of Urban Health, 90*(5), 799–809. doi:10.1007/s11524-013-9832-9

Schwadron, M. (2000). Archaeological investigations at De Soto National Memorial: Perspectives on the site formation and cultural history of the Shaw's Point Site (8MA7), Manatee County, Florida. *The Florida Anthropologist, 53*(2-3), 168–188.

Semenza, J. C., Rubin, C. H., Falter, K. H., Selanikio, J. D., Flanders, W. D., Howe, H. L., & Wilhelm, J. L. (1996). Heat-related deaths during the July 1995 heat wave in Chicago. *New England Journal of Medicine, 335*(2), 84–90. http://dx.doi.org/10.1056/NEJM199607113350203

Shea, K. M., Truckner, R. T., Weber, R. W., & Peden, D. B. (2008). Climate change and allergic disease. *Journal of Allergy and Clinical Immunology, 122*(3), 443–453.

Shepherd, M., & KC, B. (2015). Climate change and African Americans in the USA. *Geography Compass, 9*(11), 579–591. http://dx.doi.org/10.1111/gec3.12244

Shonkoff, S., Morello-Frosch, R., Pastor, M., & Sadd, J. (2011). The climate gap: Environmental health and equity implications of climate change and mitigation policies in California—a review of the literature. *Climatic Change, 109*(1), 485–503.

http://dx.doi.org/10.1007/s10584-011-0310-7
Silm, S., & Ahas, R. (2014). Ethnic differences in activity spaces: A study of out-of-home nonemployment activities with mobile phone data. *Annals of the Association of American Geographers, 104*(3), 542–559.
Simonds, V. W., Wallerstein, N., Duran, B., & Villegas, M. (2013). Community-based participatory research: Its role in future cancer research and public health practice. *Preventing Chronic Disease, 10*, 120205. http://dx.doi.org/10.5888/pcd10.120205
Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change, 16*(3), 282–292. http://www.sciencedirect.com/science/article/pii/S0959378006000410
Smith, N. (1982). Gentrification and uneven development. *Economic Geography, 58*(2), 139–155.
Suppasri, A., Shuto, N., Imamura, F., Koshimura, S., Mas, E., & Yalciner, A. C. (2013). Lessons learned from the 2011 great East Japan tsunami: Performance of tsunami countermeasures, coastal buildings, and tsunami evacuation in Japan. *Pure and Applied Geophysics, 170*(6), 993–1018.
U.S. Global Change Research Program. (n. d.). U.S. climate resilience toolkit: Quinault Indian Nation plans for village relocation. https://toolkit.climate.gov/case-studies/quinault-indian-nation-plans-village-relocation
Vandentorren, S., Suzan, F., Medina, S., Pascal, M., Maulpoix, A., Cohen, J.-C., & Ledrans, M. (2004). Mortality in 13 French cities during the August 2003 heat wave. *American Journal of Public Health, 94*(9), 1518–1520. http://dx.doi.org/10.2105/AJPH.94.9.1518
Washington State. (2012). Preparing for a changing climate: Washington State's integrated climate response strategy. https://fortress.wa.gov/ecy/publications/summarypages/1201004.html
Weber, E. U. (1997). Perception and expectation of climate change: Precondition for economic and technological adaptation. In M. H. Bazerman, A. E. Tenbrunsel, & D. M. Messick (Eds.). *Environment, ethics, and behavior: The psychology of environmental valuation and degradation* (pp. 314–341). San Francisco: New Lexington Press.
Weber, E. U. (2010). What shapes perceptions of climate change? *Wiley Interdisciplinary Reviews: Climate Change, 1*(3), 332–342. https://doi.org/10.1002/wcc.41
Widener, M. J., & Shannon, J. (2014). When are food deserts? Integrating time into research on food accessibility. *Health and Place, 30*, 1–3. http://dx.doi.org/10.1016/j.healthplace.2014.07.011
Winthrop, R. H. (2002). Defining a right to culture, and some alternatives. *Cultural Dynamics,* 14(2), 161–183.