nature climate change

ARTICLES

PUBLISHED ONLINE: 8 JUNE 2015 | DOI: 10.1038/NCLIMATE2668

Cultural knowledge and local vulnerability in African American communities

Christine D. Miller Hesed* and Michael Paolisso

Policymakers need to know what factors are most important in determining local vulnerability to facilitate effective adaptation to climate change. Quantitative vulnerability indices are helpful in this endeavour but are limited in their ability to capture subtle yet important aspects of vulnerability such as social networks, knowledge and access to resources. Working with three African American communities on Maryland's Eastern Shore, we systematically elicit local cultural knowledge on climate change and connect it with a scientific vulnerability framework. The results of this study show that: a given social–ecological factor can substantially differ in the way in which it affects local vulnerability, even among communities with similar demographics and climate-related risks; and social and political isolation inhibits access to sources of adaptive capacity, thereby exacerbating local vulnerability. These results show that employing methods for analysing cultural knowledge can yield new insights to complement those generated by quantitative vulnerability indices.

Anthropogenic climate change already affects communities and landscapes with measurable impacts that will continue to increase in intensity and frequency in the coming years[1]. Regardless of mitigation measures taken to reduce the rate and magnitude of climate change impacts in the future, adaptation—actions undertaken to reduce the negative consequences of those impacts—is and will continue to be necessary. As resources available for adaptation to climate change impacts are limited[2] a great deal of attention has been focused on identifying regions and groups that are most vulnerable to climate change impacts[3,4]. Although there are different approaches to studying vulnerability (see Supplementary Information), three concepts are central: the risk of exposure to a disturbance, the sensitivity of the system to that disturbance, and the capacity of the system to adapt to the disturbance in such a way that the negative effects will be limited[5].

Much effort has been focused on quantifying climate change impacts through the development of vulnerability indices[4,6–10]. Typically, these indices measure vulnerability by aggregating already existing demographic data—such as income and race—with spatial data on risk of exposure to a given climate change impact. For example, the Social Vulnerability Index (SoVI) that is being used by the United States National Oceanic and Atmospheric Administration (NOAA) to consider social vulnerability to flooding in coastal areas is a metric based on 30 socio-economic variables drawn from national data sets, primarily the United States Census[11–13]. Indices such as these are useful for facilitating general comparisons of the differential vulnerability between geographic units of various scales; however, their general reliance on available data sets limits the selection of input variables and makes it difficult to capture subtle and complex aspects of vulnerability that are crucial for coping and survival[14–16].

A more integrated approach that includes qualitative data is required to more fully understand these subtle and complex dimensions of local vulnerability[14,15,17,18]. Specifically, community attributes such as social networks, trust in the government, institutional capacity, access to resources, and disaster readiness are difficult to quantify yet may strongly influence communities' susceptibility to loss and ability to adapt[16]. The form and dynamics of these community attributes are significantly influenced by historical experiences and shared cultural knowledge and values. Thus, tapping into local cultural knowledge—the shared cognitive frameworks and explicit beliefs and values that shape perceptions and influence behaviour (see Supplementary Information)—can reveal the ways in which both quantifiable and non-quantifiable dimensions of vulnerability relate and are actualized in the local setting.

There has been very little study of local vulnerability using systematic and formal qualitative research methods[19,20]. Here we present the results of a study that integrates qualitative and quantitative methods to elicit cultural knowledge on climate change and vulnerability and connect that cultural knowledge to a scientific vulnerability framework. We focus on African American communities as part of a broader interest in environmental justice. Specifically, we use methods from cognitive and environmental anthropology to examine the content and structure of shared beliefs about climate change in African American communities that are particularly vulnerable to flooding from sea-level rise.

Sea-level rise and African American study communities

Over the past 150 years, sea-level rise from both geologic and climate changes along US coasts has ranged from less than 1 to nearly 10 mm per year[21]. This rate will accelerate as global mean sea-level rise for 2081–2100 relative to 1986–2005 will probably be between 26 and 82 cm (ref. 22). In the United States, over half of the population lives within 50 miles of the coast, and coastal population density is expected to increase by approximately 9% by 2020 (ref. 23).

In this study, we analyse cultural knowledge of climate change and vulnerability among three African American communities on Maryland's Eastern Shore (Fig. 1). The Eastern Shore of the Chesapeake Bay is the fourth largest region vulnerable to sea-level rise along the Atlantic and Gulf coasts[24]. Sea level in this region has risen about 30 cm over the past century[25] and is predicted to rise another 110 cm this century[26], causing the bay shores along the central portion of the Eastern Shore to retreat by more than five to ten kilometres[24]. This region is home to a number of rural African American communities—predominantly settled by freed

Department of Anthropology, University of Maryland, 1111 Woods Hall, College Park, Maryland 20742, USA. *e-mail: cmillerh@umd.edu

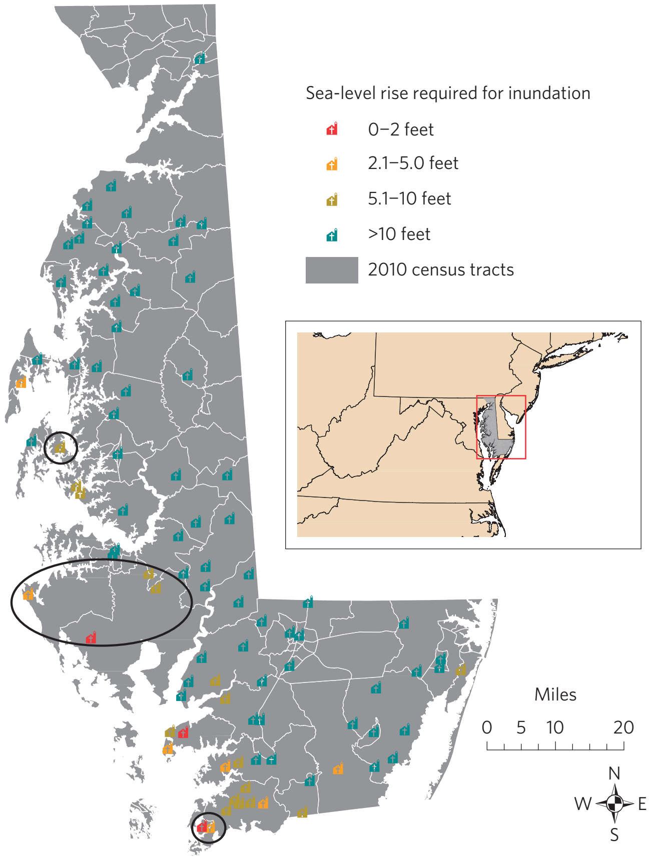

Figure 1 | African American communities at risk from sea-level rise on Maryland's Eastern Shore. United Methodist Churches on Maryland's Eastern Shore with a predominantly African American membership are colour-coded by the amount of sea-level rise required for the building to be inundated. Focal study communities are circled in black. From north to south these communities are St Michaels, Dorchester County and Crisfield. Data for the census tracts is from the US Census Bureau (https://www.census.gov/geo/maps-data/data/tiger-line.html); sea-level rise data is from the Maryland Department of Natureal resources (http://dnrweb.dnr.state.md.us/gis/data/data.asp).

slaves after the Civil War[27]—that are particularly vulnerable to the impacts of sea-level rise. These communities are small and dispersed; culturally and socially united by local African American churches; possess a range of knowledge on their social–ecological systems; and have participated in varying degrees in efforts to organize at various levels of governance[28]. As a result of the Eastern Shore's low topography and prevalence of water bodies, most of these communities are located close to wetland systems. Over the past century, the members of these communities have relied primarily on local resources for their livelihoods, working in commercial fisheries or agriculture[29,30]. Many of these communities are resource poor. The close proximity of these communities to wetland systems and their dependence on local resources make them particularly vulnerable to the impacts of climate change. Limited economic, social and political resources among these rural communities constrain options for adapting to sea-level rise.

This study focuses on the African American community in the town of St Michaels; the community composed of the settlements of Smithville, Aireys, Fork Neck, and Liner's Road in Dorchester County; and the African American community in Crisfield (Table 1). Local African American churches serve as the spiritual, sociocultural and organizational centre of these communities. These communities were selected for study because they are all vulnerable to flooding—measured as high by NOAA and SoVI (ref. 31)—but are situated differently within their social–ecological systems. The town of St Michaels, which is located on a narrow neck of land in Talbot County, has a thriving tourist industry and is at risk of being cut off from the main peninsula by flooding. The settlements in Dorchester County are rural, located among protected tidal wetlands, and already experiencing standing water on roads and yards at high tide. The community in Crisfield, in Somerset County, is struggling economically and was flooded by Hurricane Sandy in October of 2012. (See Supplementary Information for additional description of study communities.)

We find that, in general, the communities' cultural knowledge about climate change is consistent with the scientific framework for vulnerability that includes risks, sensitivities and adaptive capacities; however, despite sharing similar demographics and social histories, the communities differed in what social–ecological factors comprised each vulnerability category. We further find that these communities consider sensitivities to be primarily within the community and adaptive capacities primarily external to the community. These results show that a given social–ecological factor can greatly differ in the way in which it affects local vulnerability, even among communities with nearly identical demographics and climate-related risks, and local vulnerability is compounded by social and political isolation that inhibits access to sources of adaptive capacity. This study demonstrates how methods for systematically analysing cultural knowledge provide a straightforward approach for comparing the nuances of local vulnerability and generating new insights to complement understandings of vulnerability as produced by quantitative indices.

Eliciting cultural knowledge of climate change

To elicit cultural knowledge about climate change we employed the cognitive and psychometric methods of free listing, pile sorting, multidimensional scaling (MDS) and cluster analysis[32–35]. Together

Table 1 | Demographic information for study communities as compared with county, state and national data.

Geographies	Total population*	African American (%)*†	African Americans below poverty level (%)†‡
United States	308,745,583	13.6	25.2
Maryland	5,773,552	30.9	13.2
Talbot County	37,782	13.6	14.9
St Michaels	1,029	28.4	35.6
Dorchester County	32,618	28.9	25.3
Smithville, Aireys, Fork Neck and Liner's Road	~40	~100	~55
Somerset County	26,470	43.4	34.4
Crisfield	2,726	38.1	62.8

*Source: US Census, 2010: Profile of general population and housing characteristics: demographic profile data (DP-1). †Race alone or in combination with one or more races. ‡Source: 2006–2010 American community survey selected population tables, selected economic characteristics (DP03). Census values for Smithville, Aireys, Fork Neck and Liner's Road are unavailable. Estimates made on the basis of ethnographic research.

Table 2 | Free-listing terms that were categorized together in all three study communities.

Risk	Sensitivity	Adaptive capacity
Drought	Ageing	Federal government
Emergency	Diseases	Jobs
Erosion	Fear	Politics
Fish kill	Illness	Relocating
Floods	Isolation	
Forest fires	Poverty	
Melting ice		
Pollution		
Rising tides		
Storms		
Temperature		
Water		

Table 3 | Free-listing terms that were categorized differently by the three study communities.

	Dorchester County	Crisfield	St Michaels
Communication	S	A	?
Family members	S	A	S
Food	S	R	S
God	S	A	?
Knowledge	S	A	?
Roads	A	R	R
Self-preservation	S	A	A
Shelters	S	R	S

Terms that were categorized by a community as a risk are marked with 'R', terms categorized as a sensitivity with an 'S', and terms categorized as adaptive capacity with an 'A'. Terms that were not categorized in any of those three groups by a given community are marked with a '?'.

with ethnographic data, these methods allow us to visualize the content and structure of cultural knowledge about climate change. Specifically, we had individuals in each community sort terms related to climate change into piles, aggregated those piles, and then used MDS to visualize the relationships between the terms. We used ethnographic data, especially interviews with key informants (See Supplementary Information), to identify the meaning of word clusters and the cognitive dimensions that govern the overall distribution of data in the MDS plots (Supplementary Figs 1–3) and subsequently employed Johnson's hierarchical cluster analysis (Supplementary Figs 4–6) to mathematically define word clusters in the MDS plots[36].

In consultation with study participants, we found that there were three clusters of terms that remained together in all three communities (Table 2), and eight terms that were placed in different clusters by different communities (Table 3; also see Supplementary Figs 7–9). The large extent to which communities shared cultural knowledge on climate change is supported by the significantly high correlation (measured by quadratic assignment procedure—see Methods) between community MDS plots (mean $r = 0.707$, $p < 0.000$). The three clusters of terms correspond to the three components of vulnerability as defined by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change[37]. That is, the green cluster includes words that describe risk or environmental impacts of climate change and include terms such as temperature, storms, floods and rising tides. The red cluster includes terms that relate to the communities' sensitivity to climate change impacts, such as illness, ageing, fear and poverty. Finally, terms in the blue cluster are words that the community views as things that would affect their adaptive capacity to climate change, such as the federal government, jobs and relocating.

We further found that terms on the MDS plots are organized along a local to extra-local dimension (y axis) and a physical to social dimension (x axis; Fig. 2 and Supplementary Figs 7–9). The positions of the clusters of terms along the x and y axes reveal that the communities all consider climate change risks to be more physical than social, and to fall towards the middle of the local to extra-local spectrum. The sensitivity and adaptive capacity clusters both fall on the social end of the x axis, but sensitivity is considered in local terms whereas adaptive capacity is extra-local.

Assessing local risk

Despite having the same three main clusters, the communities differed in their level of agreement on how terms should be sorted as well as the final categorization of eight of the terms. Crisfield's MDS plot (Supplementary Fig. 8) differs the most from the other two (Supplementary Figs 7 and 9) with the MDS plots of Dorchester County and St Michaels having a higher correlation ($r = 0.812$, $p < 0.000$) than Crisfield's plot with either Dorchester County ($r = 0.634$, $p < 0.000$) or St Michaels ($r = 0.675$, $p < 0.000$). Whereas clusters within the St Michaels and Dorchester County MDS plots are relatively tightly grouped, indicating general agreement among workshop participants, the Crisfield MDS plot has looser clusters, indicating less similarity in the way Crisfield workshop participants sorted their terms. This difference matches our ethnographic data: six months before the workshops, Crisfield experienced extreme flooding from Hurricane Sandy, whereas the other two communities have not recently experienced significant flooding. Discussions with Crisfield workshop participants suggest that the recent experience of a climate-related event heightened their awareness of the complexity and interconnectedness of components of their social–ecological system (see Additional Discussion of Results in Supplementary Information), which resulted in more individuals sorting terms that ultimately fell in the risk cluster with terms that ultimately comprised the sensitivity or adaptive capacity clusters. This is evident in Crisfield's MDS plot, where the risk cluster extends farther towards the social end of the x axis.

Crisfield's risk cluster also includes more terms than the other two communities'. Of the three communities, marginalization of African Americans is most overt in Crisfield and, following Hurricane Sandy, African American residents talked about how sociopolitical circumstances increased their hardship after the storm. For example, several participants described how streets with a predominant African American population remained flooded for days longer than other streets because the city had failed to maintain floodgates in those areas. Other participants expressed frustration in getting access to food that was sent to the city by emergency response groups, as well as difficulty in finding housing while their homes were being repaired. Road conditions and the availability of food and shelter were not perceived to be a sensitivity internal to the community but rather an external perturbation over which they had little control. Accordingly, Crisfield workshop participants grouped the terms roads, food and shelter with terms in the risk cluster (Supplementary Fig. 8).

In contrast, the study communities in Dorchester County and St Michaels include food and shelter as part of the cluster that corresponds to community sensitivity, indicating that they see the relative availability and condition of these resources less as a possible external impact and more as a part of what continuously characterizes their local community conditions. In considering roads, however, St Michaels is similar to Crisfield in that roads occurs within the risk cluster, whereas in Dorchester County roads is found within the adaptive capacity category. In Dorchester County, although some roads already have several inches of water on them during high tide, community residents know alternative routes to get from place to place and using the roads to temporarily relocate is seen as a key adaptive response to climate change impacts.

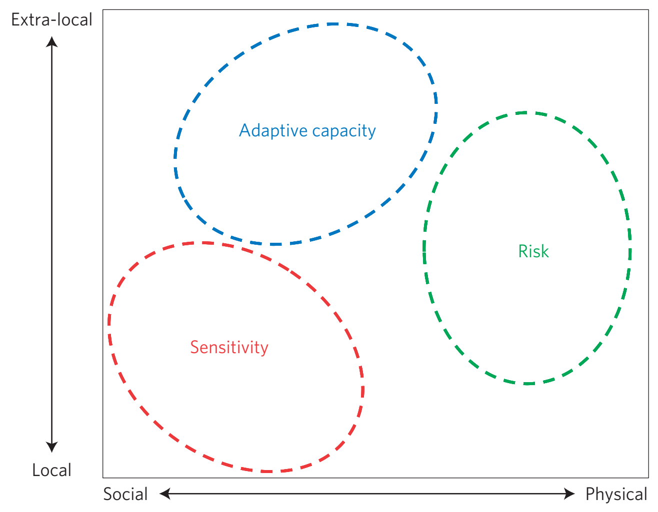

Figure 2 | Underlying dimensions of community MDS plots. Word clusters fall along a social to physical dimension (*x* axis) and a local to extra-local dimension (*y* axis) in all three communities. (To see the terms within the clusters and individual MDS plots for each community, see Supplementary Figs 7–9.)

In contrast, there is only one road connecting St Michaels to the rest of the Eastern Shore, so like the African American community in Crisfield, workshop participants in St Michaels regard roads as a possible external perturbation and therefore see them as similar to the words that connote risk.

Assessing local adaptive capacity and sensitivity

Crisfield's MDS plot also differed from the other two by having more terms in the cluster that correspond to adaptive capacity. Whereas the study communities in St Michaels and Dorchester County both include five terms in the adaptive capacity cluster, Crisfield includes nine. A key adaptive capacity term for Crisfield study participants is family members. Whereas workshop participants in St Michaels and Dorchester County thought primarily about concern for the well-being of family members during a climate event, resulting in the term's location in the sensitivity cluster, Crisfield residents had relied heavily on immediate and extended family members for assistance during and after Hurricane Sandy. Thus, in Crisfield, family members were not viewed as a community liability, but as a source of adaptive capacity.

The adaptive capacity cluster for Crisfield also includes God, knowledge and communication, which captures the importance of their deep faith, place-based knowledge, and social networks of communication during and after Hurricane Sandy. In contrast, workshop participants in Dorchester County grouped these words in the cluster corresponding to sensitivity, suggesting that community members perceive a relative lack of knowledge and access to government officials increases their sensitivity to climate change impacts. Furthermore, the location of God in the sensitivity cluster reflects their fear that their churches, all four of which are located near water bodies or tidal wetlands, will be lost to sea-level rise. Finally, in St Michaels, the terms God, knowledge and communication were grouped in a fourth, separate cluster. A possible ethnographic accounting for this result is that study participants in St Michaels perceived these terms to transcend the issue of climate change, with the result that they ended up being most similar only to each other using Johnson's hierarchical cluster analysis.

A final important overall finding from these three MDS plots is that in all communities sensitivities to flooding are thought about as local, whereas adaptive capacities are extra-local. Some of the workshop participants expressed feeling uncomfortable navigating the techno-bureaucratic world of policymaking and regulation, and thus felt that they were isolated from the resources and expertise that could otherwise help them to better adapt to flooding from sea-level rise. The social and political isolation experienced by these communities is not something that is readily captured by quantitative vulnerability indices, yet is nevertheless an important contributor to local-level vulnerability.

Notably, 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. Although race was not a term in the pile-sorting activity (see Methods), in 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 (see Additional Discussion of Results in Supplementary Information). Our ethnographic data further revealed that race can have differing impacts among seemingly similar communities; although race contributes to the vulnerability of all the study communities, it has impacted Crisfield to a greater degree. The advanced age of many in these communities also contributes to the difficulties they face in accessing resources for adaptation. Government and non-governmental agencies increasingly rely on online systems for dissemination of information and submission of applications for aid. Internet navigation is often more difficult for senior citizens, who have had less practice than those in younger generations. In addition, seniors may experience health problems that make it difficult for them to exert energy in reaching out to agencies that could otherwise enhance their adaptive capacity.

We have shown that systematically eliciting cultural knowledge about climate change and connecting it to a scientific framework of vulnerability can yield nuanced insights about local vulnerability. Although the qualitative methods we employed are relatively straightforward for identifying similarities and differences in the way communities group social–ecological factors related to climate change, interpretation of these results depended on consultation with community members. The results as presented here do not exactly reflect the understanding of vulnerability to sea-level rise of any one individual, but rather reveal each study community's shared implicit and explicit understanding of vulnerability that influences behaviour and decision-making.

We find that the ways in which social–ecological factors affect local vulnerability can differ considerably even among communities classified as having an equally high vulnerability as measured by quantitative indices. Although the revealed similarities are useful for suggesting adaptation needs at a more regional level, the differences revealed by the MDS plots allow us to better understand the unique local experiences of vulnerability. Specifically, the different roles that social–ecological factors play in different communities re-emphasize the need for adaptation strategies to be tailored to the local circumstances. Understanding these nuanced differences in local vulnerability is a crucial precursor for policymakers to develop climate adaptation plans that will be flexible enough to meet diverse local needs. The methods employed in this study can be beneficially used towards that goal because they allow for expeditious analysis of the ways in which both quantifiable and non-quantifiable dimensions of vulnerability relate and are actualized in the local setting.

Finally, our finding that these African American communities feel isolated from sources of adaptive capacity located mostly outside their communities points to the need for policymakers to proactively reach out to these communities and provide them with the information, training and access to resources from which they could greatly benefit. In essence, this result suggests that enhancing democratic processes and actively engaging underserved communities in grassroots efforts for adaptation planning is key for reducing vulnerability among those who are most vulnerable. Such insights cannot be gained from vulnerability indices alone; a comprehensive understanding of vulnerability requires methodological diversity and an integrative approach that includes perspectives from physical, natural and social sciences.

Methods

Methods and any associated references are available in the online version of the paper.

Received 9 June 2014; accepted 1 May 2015; published online 8 June 2015

References

1. IPCC *Climate Change 2007: Impacts, Adaptation and Vulnerability* (eds Parry, M. L. *et al.*) (Cambridge Univ. Press, 2007).
2. IPCC *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (eds Field, C. B. *et al.*) (Cambridge Univ. Press, 2014).
3. Samson, J., Berteaux, D., McGill, B. J. & Humphries, M. M. Geographic disparities and moral hazards in the predicted impacts of climate change on human populations. *Glob. Ecol. Biogeogr.* **20,** 532–544 (2011).
4. Brooks, N., Adger, W. N. & Kelly, P. M. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *J. Glob. Environ. Change* **15,** 151–163 (2005).
5. Adger, W. N. Vulnerability. *Global Environ. Change* **16,** 268–281 (2006).
6. Ahsan, M. N. & Warner, J. The socioeconomic vulnerability index: A pragmatic approach for assessing climate change led risks–A case study in the south-western coastal Bangladesh. *Int. J. Disaster Risk Reduct.* **8,** 32–49 (2014).
7. *Building Resilience in SIDS: The Environmental Vulnerability Index* (South Pacific Applied Geoscience Commission and United Nations Environment Programme, 2005).
8. Cardona, O. D. *Indicators of Disaster Risk and Risk Management: Summary Report* (Inter-American Development Bank, 2005).
9. Adger, W. N., Brooks, N., Bentham, G., Agnew, M. & Eriksen, S. *New Indicators of Vulnerability and Adaptive Capacity* (Tyndall Centre for Climate Change Research, 2004).
10. Lummen, N. & Yamada, F. Implementation of an integrated vulnerability and risk assessment model. *Nat. Hazards* **73,** 1085–1117 (2014).
11. Cutter, S. L., Boruff, B. J. & Shirley, W. L. Social vulnerability to environmental hazards. *Soc. Sci. Q.* **84,** 242–261 (2003).
12. Cutter, S. L. & Morath, D. P. in *Measuring Vulnerability to Natural Hazards: Toward Disaster Resilient Societies* (ed. Birkmann, J.) 304–321 (United Nations Univ. Press, 2013).
13. National Oceanic and Atmospheric Association *Social Vulnerability Index (SOVI)* (Digital Coast, Office for Coastal Management, 2014); http://coast.noaa.gov/digitalcoast/data/sovi
14. Eakin, H. & Luers, A. L. Assessing the vulnerability of social-environmental systems. *Annu. Rev. Environ. Res.* **31,** 365–394 (2006).
15. Birkmann, J. Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications. *Environ. Hazards* **7,** 20–31 (2007).
16. Cutter, S. L., Emrich, C. T., Webb, J. J. & Morath, D. *Social Vulnerability to Climate Variability Hazards: A Review of the Literature* (Univ. South Carolina, 2009).
17. Cutter, S. The vulnerability of science and the science of vulnerability. *Ann. Assoc. Am. Geogr.* **93,** 1–12 (2003).
18. Furman, C. *et al.* Social justice in climate services: Engaging African American farmers in the American South. *Clim. Risk Manage.* **2,** 11–25 (2014).
19. Roncoli, C., Crane, T. & Orlove, B. in *Anthropology and Climate Change: From Encounters to Actions* (eds Crate, S. A. & Nuttall, M.) 87–115 (Left Coast Press, 2009).
20. Fiske, S. J. *et al. Changing the Atmosphere. Anthropology and Climate Change. Report of the AAA Global Climate Change Task Force* (American Anthropological Association, 2014).
21. *Sea Level Variations in the United States 1854–2006*, Technical Report No. NOS CO-OPS 053 (NOAA National Ocean Service, 2009).
22. IPCC *Climate Change 2013: The Physical Science Basis* (eds Stocker, T. F. *et al.*) (Cambridge Univ. Press, 2013).
23. *NOAA's State of the Coast* (NOAA, 2012); http://stateofthecoast.noaa.gov
24. Titus, J. G. & Richman, C. Maps of lands vulnerable to sea level rise: Modeled elevations along the US Atlantic and Gulf coasts. *Clim. Res.* **18,** 205–228 (2001).
25. Titus, J. G. & Strange, E. M. *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1: Coastal Elevations and Sensitivity to Sea Level Rise* (US EPA, 2008).
26. Boesch, D. F. *et al. Updating Maryland's Sea-Level Rise Projections. Special Report of the Scientific and Technical Working Group to the Maryland Climate Change Commission* (Univ. Maryland Center for Environmental Science, 2013).
27. Krech, S. *Praise the Bridge that Carries you Over: The Life of Joseph L. Sutton* (G. K. Hall; Schenkman Pub. Co., 1981).
28. Paolisso, M. *et al.* Climate Change, Justice, and Adaptation among African American Communities in the Chesapeake Bay Region. *Weath. Clim. Soc.* **4,** 34–47 (2012).
29. Wennersten, J. R. *Maryland's Eastern Shore: A Journey in Time and Place* (Tidewater Publishers, 1992).
30. Anderson, H. in *Maryland Marine Notes* 1–3 (Maryland Sea Grant, 1998).
31. *Sea Level Rise and Coastal Flooding Impacts* (NOAA Digital Coast, 2014); http://coast.noaa.gov/slr
32. Bernard, H. R. *Research Methods in Anthropology: Qualitative and Quantitative Approaches* (AltaMira Press, 2006).
33. Kruskal, J. B. & Wish, M. *Multidimensional Scaling* (Sage University Paper Series on Quantitative Applications in the Social Sciences, Sage Publications, 1978).
34. Weller, S. C. & Romney, A. K. *Systematic Data Collection* (Sage Publications, 1988).
35. Shaffer, L. J. & Naiene, L. Why analyze mental models of local climate change? A case from Southern Mozambique. *Weath. Clim. Soc.* **3,** 223–237 (2011).
36. Johnson, S. C. Hierarchical clustering schemes. *Psychometrika* **32,** 241–254 (1967).
37. IPCC Summary for Policymakers *in Climate Change 2007: Impacts, Adaptation and Vulnerability* (eds Parry, M. L *et al.*) 7–22 (Cambridge Univ. Press, 2007).

Acknowledgements

This research was financially supported in part by a grant from the NOAA Climate and Societal Interactions–Coasts Program (NA110AR4310113). While conducting this research and writing this manuscript, C.D.M.H. was supported by an EPA STAR Fellowship (FP—91749201-0). The researchers would like to thank E. Douglas for her leadership on the NOAA project and the African American communities of St Michaels, Dorchester County and Crisfield for their participation in this study.

Author contributions

Both authors were involved in designing the research. C.D.M.H. conducted the fieldwork. Both authors carried out the analysis. C.D.M.H. wrote the text and made the figures. M.P. contributed to the text.

Additional information

Supplementary information is available in the online version of the paper. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence and requests for materials should be addressed to C.D.M.H.

Competing financial interests

The authors declare no competing financial interests.

NATURE CLIMATE CHANGE DOI: 10.1038/NCLIMATE2668

Methods

Identifying research communities. Our research objective during autumn of 2012 was to identify the location of environmental justice communities and to understand broadly how these communities may be vulnerable to climate change, particularly flooding from sea-level rise. In regard to climate change and its impacts, we define environmental justice communities as those that are less responsible for causing climate change yet face a greater level of vulnerability to its impacts. African Americans living in rural areas have the lowest carbon footprint of any other group in the United States, emitting 23% less than the national average[38]. Furthermore, a previous pilot project[28], conducted from 2009–2010, identified rural African American communities on Maryland's Eastern Shore as vulnerable to the impacts of climate change—particularly flooding from sea-level rise. The pilot project suggested that these communities have been centred around local United Methodist churches both historically and at present. An interview with an area United Methodist District Superintendent confirmed this connection. Thus, we began identifying potential study communities by mapping African American United Methodist churches using ArcGIS software[39]. A GIS layer from the Maryland Department Natural Resources[40] that shows areas likely to be inundated by different sea-level rise scenarios was used to approximate the church communities' relative risk to flooding from sea-level rise (Fig. 1).

Once identified, visits were made to many of these church communities along Maryland's Eastern Shore. Participant observation and informal interviews during these visits helped identify a variety of social and environmental vulnerability factors, including racial issues, economic struggles, demographic changes, cultural loss, proximity to coast, loss of land, and pollution. This initial data collection informed our selection of three African American communities (Dorchester County, Crisfield and St Michaels) for the remainder of our study.

Generating terms for pile sorting. To define these communities' cultural domain of climate change, we held a workshop in each of the three study communities. Before the workshop, we selected pile-sort terms from a free-listing exercise that was done at the United Methodist Churches in Smithville and Bellevue in 2009 and 2010. At that time, African American workshop participants were asked to list the words that came to mind when they thought of 'climate change'[28]. The two church groups came up with a total of 91 terms.

Owing to the great extent to which the Smithville and Bellevue congregations are similar to our current study congregations—many of the participants were involved in both studies, others are related to those in the first study or know their families well, and all study communities share similar social histories and economic struggles—using these previously elicited terms was justified. Additional steps were taken, however, to ensure the validity of the terms for pile sorting by current study communities. This entailed reducing the list of 91 terms, many of which were cognates, to 30 key terms (Tables 2 and 3) that captured the core cognitive subdomains that had been identified among our three study communities during seven months of ethnographic fieldwork. Specifically, terms were included in the final list of 30 if they: were relevant to the Eastern Shore of Maryland (for example, the terms 'flooding' and 'storms' met this criterion, whereas the terms 'volcanic ash' and 'genocide' did not); represented a more general concept as opposed to a more specific one (for example, the terms 'emergency' and 'illness' met this criterion, whereas the terms 'rescue vehicle' and 'doctors' did not); and/or were known to be of significance to our study communities based on the ethnographic work done for the seven months before the workshops (for example, the terms 'isolation' and 'ageing' were words that came up repeatedly in informal interviews, and thus met this criterion, whereas the terms 'criminal activity' and 'loss of habitat' never came up and thus did not meet this criterion). Finally, in a couple of cases a term was changed to a similar word that would be more easily understood by all participants. Specifically, the word 'illness' replaced the terms 'depression' and 'stress' and the word 'roads' replaced the term 'infrastructure.'

One term that was expected but which did not emerge among the 91 terms generated by Smithville and Bellevue congregations in 2009 and 2010 was race. Reflection after longer term involvement with these communities suggests that study participants were not comfortable bringing up the issue of race with Anglo American researchers during the preliminary workshops. (Later, as we built rapport with the African American church communities, study participants became more candid about the role that race plays in their vulnerability.)

Sampling strategy. Given the exploratory and ethnographic nature of the research, we used a purposive sampling strategy to produce a non-probabilistic sample of key informants within and across the study communities[41]. We began by identifying key informants in each of our study communities who were knowledgeable of the range of views and values on climate change within their community, and who were also capable of conveying that information to us and garnering the participation of other community members in our study. Working with these key informants and the African American churches in each community, we invited all African Americans within each community to participate in a community workshop. (The church is central to these African American communities, with most attending church regularly. Those few who do not attend regularly remain connected to the church through close ties to church-attending family and friends.) The number of participants at each community workshop varied (see below); however, comparison of the responses to questions at the workshops with those responses generated by interviews before and after the workshop indicates that we had sufficient attendance at all workshops to ensure community views were well-represented. Specifically, we conducted 46 interviews with 34 different African American community members (some community members were interviewed more than once to clarify responses) until ethnographic analysis of the content suggested that we had reached thematic saturation, with no significant new information appearing in the later interviews. The authors obtained subject consent and the study methods were approved by the University of Massachusetts-Boston Institutional Review Board.

Data collection. At the workshops, each participant was given an envelope that contained each of the 30 pile-sort terms on an individual slip of paper. Participants worked independently to sort their terms into piles in such a way that, while thinking about climate change, terms that were more similar would be in a pile together, whereas terms that were less similar would be in separate piles. Each individual has a different amount of knowledge about climate change and its relationship to their community—this is part of the heterogeneity within all communities—and no two individuals sorted the terms in exactly the same way. In total 65 individual pile sorts were conducted: 35 in Dorchester County, 12 in Crisfield, and 18 in St Michaels. Among our informants were 25 men and 40 women (11 men and 24 women in Dorchester County; 7 men and 5 women in Crisfield; 7 men and 11 women in St Michaels). The average age of our informants was 65 years (67 years in Dorchester County; 49 years in Crisfield; 71 years in St Michaels). For reasons of individual subject privacy, only aggregate data can be provided to readers if requested.

Cultural domain analysis. The pile-sort data produce a two-dimensional matrix of item-by-item proximities for each participant. The cells of the matrices contain a 1 or 0, indicating whether the individual paired the terms or not. These matrices can be aggregated. In aggregate, the cells indicate the percentage of times that each pair of terms was placed together in a pile by all informants. Whereas individual proximity data show the structure of a cognitive domain, aggregating the data shows the structure of a cultural domain (that is, shared cognitive information that forms a conceptual frame or model).

We used Anthropac 4.98 to calculate the aggregate proximity matrices from the pile-sort data[42]. We used multidimensional scaling (MDS) to visualize the patterns of relationships among the sorted terms. MDS arranges the terms in N dimensions such that the distance between the points corresponds as closely as possible to their similarity to each other as captured by pile sorting[33,43]. Visually, the closer two terms are in the spatial representation, the more similar workshop participants thought the words were, whereas terms that are farther apart are more dissimilar.

It takes $N-1$ dimensions to plot the terms perfectly; however, it is not possible to analyse a 29-dimension plot—2 dimensions is preferred. With fewer dimensions the algorithm has to make compromises on where to place terms in relation to others. The goodness of fit for items in an MDS plot is measured in terms of stress. A 30-object matrix scaled in 2 dimensions with a stress of 0.33 has a 1% chance of having no structure[44]. When plotted in 2 dimensions, all three of our MDS plots (Supplementary Figs 1–3) had a stress level less than 0.15 (0.149 in Dorchester County and Crisfield; 0.135 in St Michaels), indicating a good fit of the data and a low probability (less than 0.5%) that the structure is merely random.

Intercommunity variation was statistically assessed using quadratic assignment procedure to measure the similarity between community MDS plots. Quadratic assignment procedure computes the correlation between two square matrices and determines the likelihood that the observed correlation is larger than expected under random permutation[42].

Analysis of MDS plots includes both: identifying and evaluating the meaning associated with close clusters of terms; and explaining the hidden cognitive dimensions that underlie the overall distribution of the terms. Our analysis of the MDS plots and their meaning rests on two years of ethnographic study and more than 30 interviews with community members. When we began interpretation of the MDS plots, we did not apply the categories of risk, sensitivity and adaptive capacity. No mention of these categories or quantitative vulnerability indices was made to study participants. Rather, we used cluster analysis (described below) to mathematically define (that is, using systematic treatment of magnitudes as expressed by numbers) close clusters of words within each MDS plot to limit our own biases in our interpretation of the results. Cluster analysis alone, however, does not indicate what level of segregation (for example, three clusters versus six clusters of terms) is meaningful. Thus, interview and ethnographic data were crucial for choosing a level of clustering (in our case, three groups for Dorchester County and Crisfield, and four groups for St Michaels) that was consistent with the way interviewees discussed the relationships between terms in the MDS plots.

As we wanted to ensure that our analysis was primarily rooted in local cultural understandings of climate change, we did not conduct any cluster analyses until after we had discussed the results of the MDS plots (Supplementary Figs 1–3) with community members. We conducted 16 follow-up interviews with workshop participants (5 in Dorchester County, 6 in Crisfield, and 5 in St Michaels). Interviewees were selected to maximize the diversity of views and depth of community knowledge represented. Building off insights gained at the community workshops, interviews included ten questions to better understand community challenges and opportunities, both in relation to sea-level rise and more generally. We also specifically discussed the results of the MDS plots (Supplementary Figs 1–3) with community members. We began this part of the interview by ensuring that interviewees understood how to read the MDS plot (that is, that terms closer together in the plot had been put in the same pile more often by community members than terms that were far apart). We then asked a set of integrated open-ended questions that ranged from general to more specific. These interviews were audio-recorded, transcribed, and systematically coded using Atlas.ti 6.2. We used a hybrid coding approach, whereby we coded both deductively (using codes we developed before reviewing the transcripts) and inductively (creating new codes as important concepts emerged from the data). This approach allowed us to simultaneously evaluate the validity of the conceptual framework we had developed from the community workshops and previous ethnographic research while also remaining open to new concepts and understandings that could emerge from the data. To illustrate how our interview and ethnographic data were employed, we here present some examples of interview responses and how they helped to inform our MDS analysis. (To protect confidentiality, pseudonyms are given for interviewees.)

Identification of clusters. Discussions of the MDS plots often prompted interviewees to comment on the clusters they saw in the data (Supplementary Table 1). In these quotes interviewees not only identified words they viewed as belonging together, but also began to explain the relationship between certain terms. For example, in the second quote for the risk cluster (Supplementary Table 1), Ira Stone of Crisfield indicates the connections between certain terms—rising tides, water, floods, roads, shelters, erosion, melting ice, temperature, pollution and water—and also begins to define those terms in relation to the others by commenting on how they can cause loss of life or cause someone to become stranded. In other words, he is describing how these social–ecological factors impact the community.

Determining cluster meaning and organizational dimensions. As an interview progressed we transitioned from open-ended questions to clarifying questions designed to test our working hypotheses of the meaning behind clusters and the overall distribution of data. For example, following the identification of clusters by interviewees such as those quoted in Supplementary Table 1, we inquired what characteristics those clustered terms had in common and how they related to other clusters on the MDS plot. Many interviewees identified the terms we ultimately labelled as risk to be related to the environment. In contrast, they spoke of the terms we ultimately labelled as sensitivity to be characteristics of their local church community. They also described the terms that we ultimately labelled as adaptive capacity to be things that people need to respond to the rest of the terms, especially in an emergency.

These conversations not only helped to clarify the character of each cluster, but also revealed the organizational dimensions underlying the cultural model of climate change as represented by the MDS plots. Identifying the first dimension—social to physical—was relatively straightforward as participants repeatedly spoke in terms of the 'environment' at one side of the MDS plot and the 'community' or 'people' on the other side. The second dimension, which we ultimately defined as local to extra-local, was more difficult to identify. Interviewees used many different ways to talk about the difference between the terms at the top and bottom of their community MDS plot. The first theme that seemed to emerge was that of control. An interviewee in St Michaels described how the community could not control those terms that we ultimately identified as sensitivity. Others, when presented with this hypothesis, agreed; however an interviewee in Crisfield pointed out that the communities also lacked control over those things ultimately identified as adaptive capacity. This same individual went on to talk about the difference in familiarity the community had with different terms on the MDS plot. He explained that although the African American community in Crisfield was very familiar with the terms we ultimately characterized as sensitivity and many of the terms we ultimately characterized as risk, they had very little familiarity with those terms we identified as adaptive capacity. This conversation and others that followed with interviewees in Crisfield and the other communities ultimately led us to determine that, although important to our study participants, the concept of control did not fit as an underlying organizational dimension.

We ultimately identified the second dimension of the MDS plots as local to extra-local. Although this dimension was not discussed in precisely those terms by our informants, interview responses and ethnographic data supported the salience of spatial distance to our study communities. For example, conversations about communities' physical isolation, family members' outmigration, and the undesirability of permanent relocation were frequent and intense. When applied to the MDS data, the location of terms along the y axis made ethnographic sense in terms of the degree to which they were 'local' or 'extra-local.' Thus, the second dimension was identified.

Johnson's hierarchical clustering. Finally, we used Johnson's[36] hierarchical clustering schemes to mathematically identify clusters within the MDS plots (Supplementary Figs 4–6). This clustering method begins by assuming each item to be in an independent, singleton cluster, and then finds the two most similar and joins them together. We used average-link clustering, which considers the distance between two clusters to be the average distance from any member of one cluster to any member of the other cluster. This clustering algorithm is repeated until all terms are in one cluster, resulting in a collection of hierarchically nested partitions. Interview data was then used to corroborate and assist with the interpretation of these clusters (Supplementary Figs 7–9).

References

38. Congressional Black Caucus Foundation, Inc. *Climate Change and the African American Community* (Center for Policy Analysis and Research, 2004).
39. *ArcGIS Desktop: Release 10* (Environmental Systems Research Institute, 2011).
40. *SLRInd0_2 - Sea Level Rise Inundation Vulnerability 0–2 feet* (CGIS, 2007).
41. Guest, G. in *Handbook of Methods in Cultural Anthropology* (eds Bernard, H. R. & Gravlee, C. C.) 185–214 (Rowman & Littlefield, 2015).
42. Borgatti, S. P. *ANTHROPAC 4.0 Reference Manual* (Analytic Technologies, 1996).
43. Bernard, H. R., Ryan, G. W. & Borgatti, S. P. in *Networks, Resources and Economic Action: Ethnographic Case Studies in Honor of Hartmut Lang* (eds Greiner, C. & Kokot, W.) 189–215 (Dietrich Reimer Verlag, 2010).
44. Sturrock, K. & Rocha, J. A multidimensional scaling stress evaluation table. *Field Methods* **12,** 49–60 (2000).