Using Cultural Consensus Analysis to Measure Diversity in Social–Ecological Knowledge for Inclusive Climate Adaptation Planning

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ABSTRACT: Climate adaptation is context specific, and inclusion of diverse forms of knowledge is crucial for developing resilient social–ecological systems. Emphasis on local inclusion is increasing, yet participatory approaches often fall short of facilitating meaningful engagement of diverse forms of knowledge. A central challenge is the lack of a comprehensive and comparative understanding of the social–ecological knowledge that various stakeholders use to inform adaptation decisions. We employed cultural consensus analysis to quantitatively measure and compare social–ecological knowledge within and across three stakeholder groups: government employees, researchers, and local residents in rural coastal Maryland. The results show that 1) local residents placed more emphasis on addressing socioeconomic and cultural changes than researchers and government employees, and 2) that the greatest variation in social–ecological knowledge was found among local residents. These insights yielded by cultural consensus analysis are beneficial for facilitating more inclusive adaptation planning for resilient social–ecological systems.

SIGNIFICANCE STATEMENT: We wanted to understand the degree to which knowledge on coastal climate resilience is shared within and across three groups—government employees, researchers, and local residents—in rural areas around the Chesapeake Bay. We found that local residents placed a greater emphasis on addressing socioeconomic and cultural changes than researchers and government employees, who focused more on environmental changes. We also show that local residents as a group had the greatest variation in social–ecological knowledge as compared with the other two stakeholder groups. These results not only point to the importance of including local residents in climate adaptation planning, but also highlight the need to ensure that the full diversity of local knowledge is represented in planning.

KEYWORDS: Social Science; Coastlines; North America; Adaptation; Decision making; Resilience; Vulnerability

1. Introduction

Adaptation to anthropogenic climate change poses difficult decision-making and management challenges because of the long time scales involved; the complex interconnectedness between socioeconomic, ecological, and climate conditions; and the uncertainties around future climate impacts and risks (Few et al. 2007; Jones et al. 2014). While scientific and technical information is crucial for good adaptation decision-making, it is rarely sufficient to guide adaptation planning on its own (Bell and Lederman 2003; Kettle et al. 2014). Rather, good adaptation decision-making requires a participatory process that integrates scientific assessment of risks with an understanding of how risks and adaptation options are framed, perceived, and understood by all relevant stakeholders (Johnson et al. 2017; Jones et al. 2014). This necessitates inclusion of nonscientific local knowledge that is anchored in particular contexts and is often accumulated over generations (Thornton and Scheer 2012).

Research has shown that local knowledge—the information, experience, insights, and values held by people situated in a particular place—can be integrated with scientific knowledge to promote place-based adaptation (Krupnik and Jolly 2002; Miller Hesed and Paolisso 2015; Orlove 2009; Orlove et al. 2010; Paolisso et al. 2019; Strauss 2009; Strauss and Orlove 2003; Van Dolah 2018). These studies reveal how local knowledge not only serves to contextualize and ground-truth scientific information (Thornton and Scheer 2012) but is also crucial for assessing whether a given adaptation strategy aligns with cultural values and equitably distributes costs and benefits (Adger et al. 2011, 2013). Furthermore, inclusion of diverse local knowledge, interests, and values is necessary for fostering community empowerment (Thornton and Scheer 2012) and developing trust within decision-making processes (Jones et al. 2014). In addition, meaningful engagement of local communities and knowledge is a key characteristic of resilient social–ecological systems (Berkes 2007; National Research Council 2006; Norris et al. 2008). Given these benefits, a number of international policy documents explicitly call for local participation in climate change adaptation decision-making (Least Developed Countries Expert Group 2002; Smit and Pilifosova 2001; United Nations Framework Convention on Climate Change 1992; Wilbanks 2003).

Despite this recognition of the importance of local knowledge, participatory approaches to adaptation decision-making have often fallen short of engaging and empowering local communities in meaningful ways (Agarwal et al. 2012; Ayers 2011; Klenk et al. 2017; Sherman and Ford 2014). A fundamental challenge is the absence of a comprehensive and comparative understanding of the diverse forms of implicit and explicit knowledge that individuals and groups draw upon to inform and

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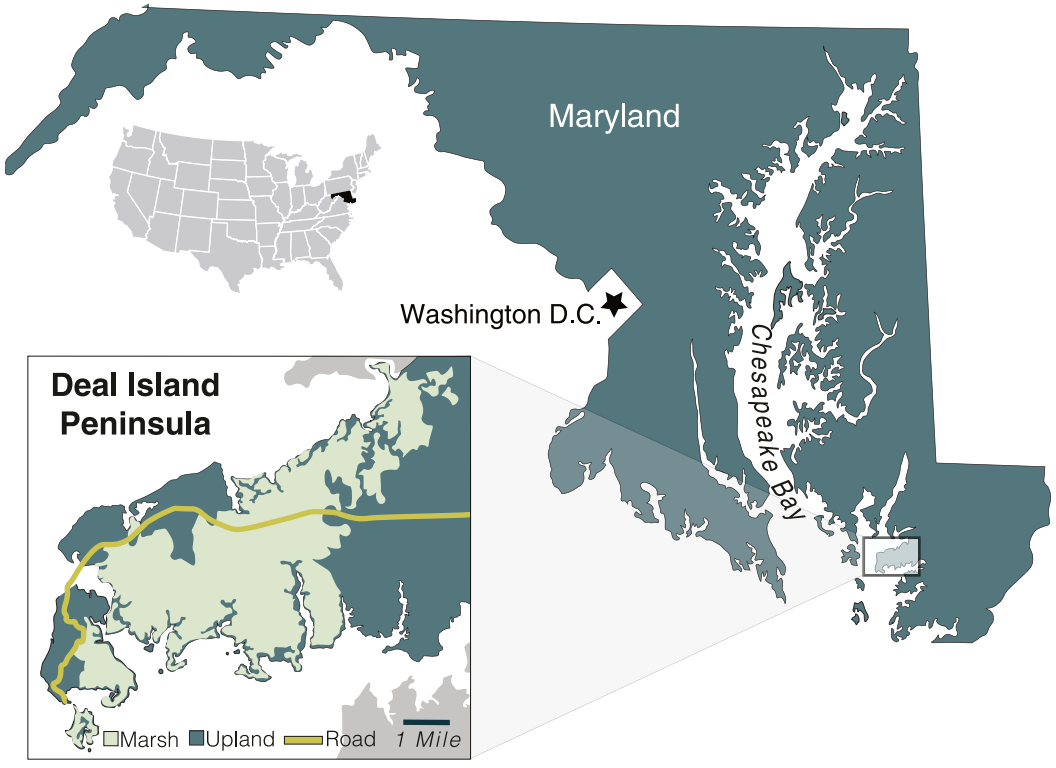

FIG. 1. Map of the Deal Island Peninsula.

guide their climate change adaptation decisions. Without a systematic approach for analyzing knowledge and the degree to which it varies within and across stakeholder groups, we cannot know to what extent knowledge differs or is shared among those assembled for participatory planning.

Cultural consensus is an underutilized theoretical and methodological approach for formally measuring the distribution of cultural knowledge and values, which have traditionally been studied with qualitative methods (Dengah 2013; Dressler 2018; Dressler et al. 2015, 2012; Gatewood 2012; Paolisso 2015; Romney et al. 1986). Cultural consensus theory and methods reveal the similarities and differences in knowledge within and across groups by producing quantitative indicators of consensus and modeling responses to specific knowledge statements or questions. Cultural consensus analysis (CCA) has been applied to explore patterns of shared knowledge on a variety of topics. For example, CCA was used to measure and compare perceptions of climate change among American Indian communities (Carothers et al. 2014), to study shared knowledge on HIV/AIDS prevention and treatment and its association with other variables (Copeland 2016), and to compare perceptions of the ideal Pentecostal lifestyle (Dengah 2013). The statistically derived quantitative outputs of cultural consensus are helpful for communicating with researchers and managers who are more comfortable with quantified information. At the same time, the quantitative outputs of CCA cannot be readily understood without interpretation informed by ethnographic research (Garro 2000). Thus, useful employment of cultural consensus requires bridging quantitative statistics and qualitative social sciences, making this approach a good fit for interdisciplinary or multistakeholder studies.

In this article, we use cultural consensus to systematically study the degree to which knowledge pertaining to coastal resilience is shared and distributed within and across stakeholder groups. We focus on a rural coastal area where exclusion of local knowledge in adaptation decision-making is especially problematic (Colgan 2004; Hales et al. 2014; Kapucu et al. 2013; Scavia et al. 2002). Throughout the paper, we refer to this local knowledge as "social–ecological knowledge" to highlight the importance of always recognizing the presence of the entangled and inseparable sociocultural components in ecological or environmental systems (see Berkes et al. 1998). Specifically, we compared the social–ecological knowledge of three stakeholder groups (county-, state-, and federal-level government employees, scientific researchers, and local residents) as it relates to the topic of coastal resilience.

2. Methods

a. Study location

Located in the Chesapeake Bay—the largest coastal estuary in the United States—the Deal Island Peninsula (DIP) comprises 26 mi^2 (67 km^2) of low-lying marsh, forest, and farmland on Maryland's lower Eastern Shore (Fig. 1). Just as climate change is affecting coastal areas around the world (Wong et al. 2014), DIP—with an average elevation of just 3 ft (0.9 m)–is also threatened by increased flooding and erosion

(Paolisso et al. 2019; Spanger-Siegfried et al. 2014). Over the twentieth century, sea level in this region rose about 30 cm (Titus and Strange 2008); however, there is a 66% probability that it will rise another 40–130 cm by the year 2100 as a result of climate change (Boesch et al. 2018). This would cause the shores to the east of the Chesapeake Bay to retreat by more than 5–10 km (Titus and Richman 2001). DIP residents face increasingly flooded roads, yards, and tidal ditches. Already some roads are impassable during intense rain events or extreme high tides, limiting residents' ability to leave or return to their homes and preventing emergency services, utilities, and school buses from reaching these areas. Some residents are also beginning to face the incremental transition of their once-dry yards to soggy, marshy ground. By 2050, DIP will face increasing rates of inundation under current sea level rise projections, with a significant portion of DIP underwater by 2100 (Glick 2008; Maryland Department of Natural Resources and ESRGC 2016; National Oceanic and Atmospheric Association 2014). Shoreline erosion is also a concern for many waterfront property owners. Some areas of DIP are experiencing rates of erosion that are upward of 8 ft (2.4 m) yr^{-1} (Maryland Department of Natural Resources 2008).

In addition to the impacts of climate change, DIP is affected by a shifting local economy and demography. DIP is home to six small communities that are dispersed across a series of interconnected, wetland-dominated islands. These communities have a proud watermen heritage; commercial fishing, crabbing, and oystering have been central to the local economy since the nineteenth century and continue to be important to the local communities both economically and culturally (Paolisso 2002; Van Dolah 2018; Warner 1977). However, the number of watermen is declining; while many watermen are reaching the age of retirement, high cost and other restrictions to entry discourage new individuals from joining the industry. Younger families are choosing to move elsewhere for more profitable economic opportunities rather than continue in the family waterman tradition. At the same time, DIP's rural beauty and affordable waterfront properties are drawing increasing numbers of second-home buyers and retirees (known locally as ''come-heres'').

b. *Participant recruitment*

This study built on ongoing participatory and collaborative work with the Deal Island Peninsula communities and therefore used a purposive sampling strategy to produce a nonprobabilistic sample of key informants within various stakeholder groups (Guest 2015). During autumn of 2015, we invited individuals who have been engaged with ongoing collaborative research on DIP since 2012 (Handwerker 2001, 2002; Johnson et al. 2018; Paolisso et al. 2019; Wainger et al. 2017) to participate in an Integrated Coastal Resilience Assessment (ICRA) that was carried out between 2016 and 2018 (Paolisso et al. 2019; Teodoro et al. 2021; Van Dolah 2018). We also recruited additional local and nonlocal actors who were recommended by the DIP stakeholder network to participate in the ICRA. Importantly, sampling for cultural consensus analysis need not be random, but rather requires the inclusion of individuals who are part of the group of interest and knowledgeable about a specific topic or domain of knowledge (Handwerker 2001, 2002). Participation was voluntary, and participants received no direct benefits.

Those that agreed to participate in the ICRA included researchers, government employees, and local residents. Researchers included both natural and social scientists from regional academic institutions. Local residents included two resident types locally referred to as born-heres and come-heres—that is, residents who were born in the area and residents who have relocated to DIP from elsewhere, respectively. Government employees included technical service providers, resource managers, planners, and decision-makers from county, state, and federal government agencies, as well as representatives from regional nongovernmental organizations that are working closely with government agencies to address regional coastal issues. These three stakeholder groups have strong cultural differences, at times mistrust and misunderstand each other, and have historically had little sustained interaction with each other. The ICRA brought them together using collaborative learning—an approach that aims not to change individual views, but rather to facilitate increased understanding of others' views (Feurt 2008). By participating in the ICRA, this diverse network of stakeholders engaged in a series of collaborative assessment activities including workshops, field assessments of stakeholder-selected areas of concern, and discussions to identify, characterize, and prioritize vulnerabilities and adaptation projects. Earlier interactions made it clear that both local and nonlocal stakeholders were interested in better understanding the benefits and limitations of particular restoration and adaptation activities prior to any decisions on actions and investments (Johnson et al. 2017).

c. *Developing the questionnaire*

The cultural consensus questionnaire was designed to help us understand the variability and distribution of knowledge and perspectives relevant to adaptation planning for coastal resilience on DIP. Questions were developed following long-standing interactions with the stakeholder network (Johnson et al. 2018; Paolisso et al. 2019; Wainger et al. 2017) and were informed specifically by (i) information gathered at workshops and other sites of discourse and interaction, and (ii) insights gathered from 28 in-depth semistructured interviews with various members of the stakeholder network with regard to perspectives on resilience and options for adaptation (Johnson 2016). Drawing on the work of Quinn (2005), we recorded, transcribed, and used text analysis software to manage and organize study participant's narratives and statements. From that information, we identified important themes and used verbatim statements from participants to craft survey questions that closely followed the language of those interviewed. If we thought that one stakeholder group might not understand the language of another stakeholder group, we added a bit more explanation text to the survey question. In total, we developed 34 agreement questions organized around the four subthemes of vulnerability, resilience, social–ecological adaptation, and climate change (see Table 3). Participants were asked to respond to the questions

TABLE 1. Descriptive statistics for samples for round 1, 2, and 3 and pooled. One asterisk indicates $p < 0.05$ and two asterisks indicate $p < 0.001$, comparing round 1, round 2, and round 3 with chi-square.

Variable	Round 1 ($n = 55$)	Round 2 ($n = 54$)	Round 3 ($n = 40$)	Pooled ($n = 149$)
Age ± std dev	49.9 ± 14.5[a]	71.5 ± 17.7	53.2 ± 12.6	51.8 ± 13.9
Stakeholder group				
% researchers	27.3	27.8	20.0	25.5
% government	36.4	31.5	30.0	32.9
% locals	36.4	40.7	50.0	41.6
Local participants*				
% born-heres	50.0	36.4	30.0	38.7
% come-heres	50.0	63.6	70.0	61.3
Gender				
% women	40.0	45.4	48.8	44.3
% men	60.0	54.6	51.3	55.7
Participation**				
% high	27.3	31.5	45.0	33.6
% medium	23.6	25.9	35.0	27.5
% low	49.1	42.6	20.0	38.3

[a] Missing age data for eight participants.

on a 4-point Likert scale (strongly agree, agree, disagree, or strongly disagree) (cf. Weller 2007; Paolisso 2015; Dressler 2018).

d. Data collection

ICRA participants were asked to complete the questionnaire at the beginning, middle, and end of the ICRA process. Data were collected electronically through Qualtrics, an online survey platform (Qualtrics, Provo, Utah). "Round 1" was collected from 30 January to 2 May 2016; "round 2" was collected from 6 March to 11 July 2017; and "round 3" was collected from 7 November 2017 to 24 January 2018.

A challenge of community-led, participatory research is that the focus of the project shifts over time to address issues that emerge as most relevant or interesting for the community. A reality of this participatory approach is that, as the topic of focus shifts, some participants become less engaged with the project, while others become more engaged. As a result, though it was our intention to survey all participants three times, some only completed the survey one or two times (Prell et al. 2021). Despite this shifting network of project participants, the sample demographics remained relatively stable across the three survey rounds. There was no significant difference between rounds in age, stakeholder group, or gender (Table 1). We did see, however, that the proportion of come-heres significantly increased over the course of the project. This reflects the project's shift in focus to particular sites near to where many come-heres live. This change in project focus occurred at the collaborative workshop on 1 November 2016, 4 months prior to the distribution of the round-2 survey. Over the course of the project, a total of 75 stakeholders were invited to complete the questionnaire in one or more rounds. The response rates were 69% ($n = 55$), 73% ($n = 54$), and 67% ($n = 40$), respectively.

e. Cultural consensus analysis

To measure the diversity of social–ecological knowledge on coastal resilience, we carried out CCA (Paolisso 2015; Weller 2007). CCA is a quantitative approach used by cognitive anthropologists to study patterns of shared knowledge on a particular cultural domain of interest, such as coastal resilience to climate change. The approach includes a set of theories, assumptions and methods that have been applied across a wide range of cultural domains (Dengah 2013; Dressler et al. 2012; Johnson and Griffith 2010; Kempton et al. 1995; Paolisso and Dery 2010). Knowledge on a given domain is heterogeneously distributed among individuals such that no one individual possesses the entire model, but some individuals have more cultural knowledge within a given domain than others. Factor analysis is used to determine variance patterns in responses to questions about a particular domain and quantifies the extent to which knowledge is shared. Cultural consensus is identified when there is a strong pattern of responses across questions and respondents. Importantly, the identification of cultural consensus does not mean that respondents all answered each question the same way, but rather that their responses have enough of a pattern to suggest that they were drawing upon a shared pool of broader explicit and implicit knowledge when answering the questions (Romney et al. 1986; Weller 2007). This pattern is captured by the amount of variance that loads on the first factor. In CCA, the first- and second-factor eigenvalues must have a ratio of at least 3:1 for cultural consensus to exist among respondents. The higher the eigenvalue ratio is, the greater is the consensus among respondents.

The cultural consensus model also calculates individual cultural competence scores—a quantitative measure of the degree to which individual responses correspond to those of the entire group. This is determined by correlating the response of each informant with the aggregated responses from all other informants (excluding that particular individual's responses from the aggregations) (Weller 2007). These cultural competence scores are then used to produce an answer key that models the "correct" answer to each statement by giving greater weight to the responses given by individuals with higher cultural competence and lesser weight to responses from those with lesser

TABLE 2. Cultural consensus overall and for each stakeholder group for round 1, 2, 3, and pooled samples.

Stakeholder group		Round 1	Round 2	Round 3	Pooled
Overall	Ratio of first and second eigenvalue	6.400	5.667	5.039	5.904
	Mean cultural competence ± std dev	0.748 ± 0.174	0.705 ± 0.271	0.721 ± 0.232	0.725 ± 0.230
	Range of cultural competence	0.20–0.97	From −0.67 to 0.96	From −0.04 to 0.98	From −0.68 to 0.97
Government employees	Ratio of first and second eigenvalue	13.285	6.712	8.319	10.037
	Mean cultural competence ± std dev	0.788 ± 0.094	0.749 ± 0.165	0.785 ± 0.092	0.773 ± 0.127
	Range of cultural competence	0.51–0.94	0.35–0.96	0.57–0.89	0.32–0.94
Researchers	Ratio of first and second eigenvalue	9.450	13.866	12.368	11.317
	Mean cultural competence ± std dev	0.838 ± 0.082	0.779 ± 0.148	0.833 ± 0.155	0.814 ± 0.132
	Range of cultural competence	0.65–0.93	0.43–0.97	0.47–0.96	0.41–0.95
Local residents	Ratio of first and second eigenvalue	4.169	4.799	3.552	4.258
	Mean cultural competence ± std dev	0.686 ± 0.199	0.638 ± 0.373	0.695 ± 0.235	0.674 ± 0.285
	Range of cultural competence	0.31–0.94	From −0.71 to 0.95	0.10–0.96	From −0.73 to 0.97

cultural competence. Correct answers ranged from 1 to 4 and were divided into equal bins such that a modeled answer from 1 up to 1.75 indicated "strongly agree," from 1.75 up to 2.5 indicated "agree," of 2.5 indicated "neither agree nor disagree," from greater than 2.5 up to and including 3.25 indicated "disagree," and from greater than 3.25 up to and including 4 indicated "strongly disagree."

We first conducted CCA on each of the three survey rounds separately using Anthropac 4.98 (Borgatti 1996). Noting that the level of consensus (the ratio of the first and second eigenvalues; see Table 2) and modeled responses were stable across the three survey rounds, we followed the methods of Dressler et al. (2015) by pooling survey responses across the three rounds and running CCA again in order to compare the cultural knowledge of stakeholder groups across the project overall. Importantly, because we are not interested in individual patterns of difference, but rather in cultural patterns—which by definition require analysis of autocorrelation among cases (see Handwerker 2005)—the independence of survey responses is not crucial to CCA. We focus our discussion on the results of the CCA of pooled survey responses in this paper.

f. Residual agreement analysis

The first factor explains only part of the variation in the correlation matrix; to explore whether additional patterns of shared knowledge exist among a subset of the respondents we look at the residual agreement, which is captured by the second factor (Dengah 2013; Dressler et al. 2015). We plotted each response by its first factor (the cultural competence measure that indicates agreement) and second factor (the residual measure) scores (Fig. 2). If subgroup variation exists beyond the consensus answer key, respondents will be meaningfully distributed along the axis of the second factor; otherwise, a cluster along the first factor with a random radiation from the cluster in a "fried egg" pattern (Caulkins and Hyatt 1999; Garro 1986) is expected. We saw that respondents were meaningfully distributed according to stakeholder groups along the axis of the second factor, indicating patterned residual agreement. A one-way ANOVA between subjects was also conducted to compare the residual measure among local residents, researchers, and government employees. We then ran CCA on each stakeholder group for each questionnaire round and pooled across all rounds to explore this pattern further. Similarly, a *t* test was run to compare the residual measure among two subgroups of local residents, and CCA was run on each subgroup. For the ANOVA and *t* tests, an average residual score was used for individuals who had taken the survey more than once.

g. Ethnographic research and CCA interpretation

Ethnography is an inductive approach that assists researchers in minimizing their own cultural biases while maximizing their ability to holistically understand a research problem. Through the use of both qualitative and quantitative methods, the ethnographer both observes and records information, which in turn is partially validated by the ethnographer's actual participation in relevant activities of the study group(s). The ethnographer skillfully tacks between subjective engagement and objective observation, all of which is recorded and analyzed using methods from both the humanities and social sciences. The goal is to produce a holistic understanding that includes multiple perspectives. More than any other research approach, ethnography is designed to span social and cultural boundaries to produce information for diverse stakeholders with the intent to identify differences and similarities.

As such, ethnography can lead to increased interdisciplinary exchange of information and increased integration of diverse stakeholders. Key methods of ethnographic data collection—such as interviews and participant observation (see Bernard 2006, 210–250, 368–370; Chapman and Berggren 2005, 149–154; Agar 1996, 137–139)—build rapport between researchers and study participants, encouraging individuals to speak more candidly about their hopes, concerns, and experiences. Furthermore, because ethnography often incorporates multiple scales of analysis, it can raise local-level concerns into conversation with global-level analysis and

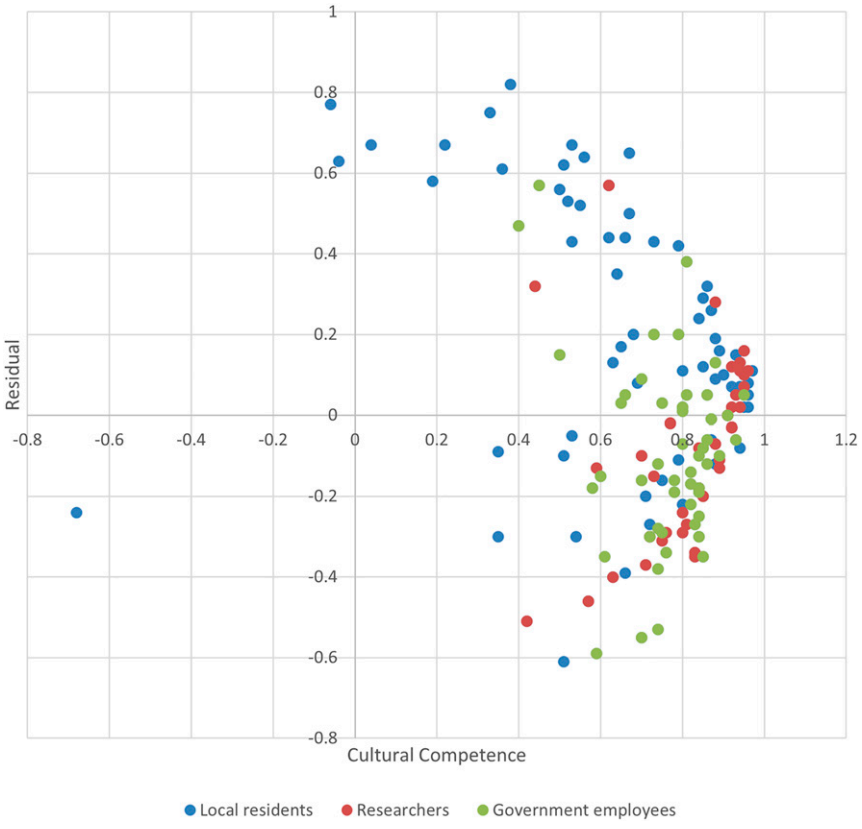

FIG. 2. Cultural competence vs residual scores by stakeholder group.

planning (Fiske et al. 2014, p. 19). Ethnographic fieldwork often requires more time; however, it ultimately yields more in-depth and holistic analyses than those generated by quantitative methods alone.

To interpret the results of CCA, we relied on the ongoing ethnographic research we have conducted in rural coastal communities on the Chesapeake Bay since 2012 (see Johnson et al. 2017; Miller Hesed 2016; Miller Hesed and Paolisso 2015; Miller Hesed et al. 2020; Paolisso et al. 2012; Van Dolah 2018; Van Dolah et al. 2020). This work has been recognized for its importance and value by two anthropology awards—the Washington Association of Professional Anthropologists (WAPA) Praxis Award (2019) and the Hackenberg Prize (2021)—and has included hundreds of hours of participant observation, more than 200 informal and semistructured interviews with study participants on the topics of resilience and adaptation to climate change, numerous collaborative and interactive workshops (see Johnson et al. 2018; Wainger et al. 2017), five surveys with nearly 300 respondents (see Paolisso et al. 2012; Miller Hesed and Paolisso 2015; Miller Hesed 2016; Van Dolah 2018; Paolisso et al. 2019; Miller Hesed et al. 2020), and systematic, qualitative, and quantitative analysis of patterns in knowledge, values, and practices related to climate change. This large body of data was instrumental in interpreting the reasons for different patterns in the distribution of cultural knowledge indicated by the results of the CCA.

3. Results and discussion

a. Shared social–ecological knowledge for coastal resilience

Our analyses show that we do have cultural consensus (i.e., shared social–ecological knowledge) in the responses to our survey questions on coastal resilience on DIP in each round and when responses are pooled across rounds (see "overall" row in Table 2). The mean competence scores overall for each round and for all rounds pooled together are relatively high, further supporting the finding that respondents share social–ecological knowledge about coastal resilience.

The modeled answers for the pooled survey responses (see Table 3) show that, as a group, participants agree or strongly agree with all but one statement. (The statement that participants disagreed with was written in the negative—that is, *absence* of local government offices and officials—so the response was the reverse of agree.) These modeled answers demonstrate that all participants share social–ecological knowledge in which environmental, scientific, socioeconomic, and cultural factors are understood as generally important to coastal resilience; however, this does not mean that all participants would necessarily prioritize the importance of these factors in the same way.

b. Patterned differences between stakeholder groups

Despite sharing overall social–ecological knowledge for coastal resilience, residual analysis revealed that participant responses still differed from each other in meaningful and

TABLE 3. Modeled answer key overall for pooled rounds. Answers are modeled from the responses of all participants (local residents, researchers, and government employees). Here, [1–1.75) = SA (strongly agree), [1.75–2.5) = A (agree), [2.5] = N (neither agree nor disagree), (2.5–3.25] = D (disagree), and (3.25–4] = SD (strongly disagree).

Statement	Answer
Vulnerability: Please identify your level of agreement with each condition as it contributes to vulnerability of communities and/or the environment in the DIP area	
1. Lack of understanding about how marshes change and the impacts of rising waters, erosion, and storms on marshes	1.68 SA
2. Lack of understanding on what can be done to restore marshes	1.52 SA
3. Lack of working relationships with researchers and government planners outside the community	1.84 A
4. Lack of understanding about the future impacts of climate change	1.70 SA
5. Lack of research and assistance to sustain local commercial fisheries	1.92 A
6. Lack of local employment opportunities outside of commercial fishing	1.51 SA
7. Lack of government representation and knowledge of government programs that can assist coastal communities	1.70 SA
8. Loss of traditional social networks that support people through changes and difficult times	1.90 A
9. Declining role of local churches and Christian practice in everyday life	2.33 A
10. Loss of heritage and cultural ways of life	1.89 A
Resilience: Please identify your level of agreement with each condition as it contributes to resilience in the face of community and environmental change in the DIP area	
11. Existing family networks and community support	1.48 SA
12. Faith and religion	1.84 A
13. Access to scientific research findings	1.80 A
14. Access to government agencies and officials	1.76 A
15. Traditional cultural practices of self-reliance and hard work	1.63 SA
16. A rich heritage to be shared and communicated to others	1.59 SA
17. Recent increase in ''come heres'' who bring new knowledge and skills	1.84 A
18. Increasing heritage activities	1.76 A
19. Absence of local government offices and officials	2.65 D
Social–ecological adaptation: Please identify your level of agreement with each statement as a priority for what research and government should help to do for the DIP area	
20. Restoration of Deal Island Peninsula marshes	1.44 SA
21. Protection of Deal Island Peninsula shorelines	1.34 SA
22. Assistance to communities and individuals in flood protection	1.40 SA
23. Preservation of community heritage and culture	1.52 SA
24. Sustain local fishery-dependent livelihoods	1.54 SA
25. Work with local churches to harness the power of beliefs and faith	1.99 A
26. Increase collaboration with Deal Island Peninsula residents and their civic organizations	1.37 SA
27. Create jobs and new economic opportunities for communities	1.49 SA
Climate change: Please identify your level of agreement with each statement regarding climate change	
28. The climate is changing in different ways from before due to the impacts of human activities	1.38 SA
29. Climate change is affecting the communities of the Deal Island Peninsula already	1.35 SA
30. Climate change is affecting the environment of the Deal Island Peninsula already	1.35 SA
31. The Deal Island Peninsula area will experience more storms and floods in the future due to climate change	1.39 SA
32. The resilience of Deal Island Peninsula communities will be reduced in the future due to climate change	1.66 SA
33. Climate change is a significant threat to the social and ecological system of the Deal Island Peninsula	1.42 SA
34. Building relationships with people and organizations that have an interest in the Deal Island Peninsula and can help communities cope with climate change	1.38 SA

systematic ways. Figure 2 shows that there is a distribution of respondents along the residual (vertical) axis and that local residents are mostly clumped above the x axis while researchers and government employees are mostly clumped near or below the x axis. To more formally test the distribution of stakeholders along the residual axis, a one-way ANOVA between subjects was conducted to compare the residual measure among local residents, researchers, and government employees. There was a significant difference between the three stakeholder groups [$F(2, 74) = 11.27$; $p < 0.00$] indicating that the pattern of residual agreement does indeed relate to variation between stakeholder groups.

Looking at the eigenvalue ratio ranges can be helpful to further understand stakeholder differences. We ran CCA on each group separately and found that the eigenvalue ratios for stakeholder groups varied somewhat, with local residents consistently yielding the lowest eigenvalue ratios (3.552–4.799) and government employees (6.712–13.285) and researchers (9.450–13.866) yielding notably higher eigenvalue ratios (Table 2). This suggests that there was a greater diversity of responses to the agreement statements among local residents than the other two stakeholder groups, which we explore further in the next section.

A number of factors help account for this pattern of diversity in social–ecological knowledge. The modeled answers for each

TABLE 4. Modeled answer key for each stakeholder group for pooled rounds. Here, L = local residents, R = researchers, and G = government employees; [1–1.75) = SA (strongly agree), [1.75–2.5) = A (agree), [2.5] = N (neither agree nor disagree), (2.5–3.25] = D (disagree), and (3.25–4] = SD (strongly disagree).

Statement	L	R	G
Vulnerability: Please identify your level of agreement with each condition as it contributes to vulnerability of communities and/or the environment in the DIP area			
1. Lack of understanding about how marshes change and the impacts of rising waters, erosion, and storms on marshes	1.64 SA	1.65 SA	1.75 A
2. Lack of understanding on what can be done to restore marshes	1.45 SA	1.49 SA	1.62 SA
3. Lack of working relationships with researchers and government planners outside the community	1.67 SA	1.68 SA	2.16 A
4. Lack of understanding about the future impacts of climate change	1.70 SA	1.91 A	1.58 SA
5. Lack of research and assistance to sustain local commercial fisheries	1.81 A	1.86 A	2.08 A
6. Lack of local employment opportunities outside of commercial fishing	1.34 SA	1.58 SA	1.65 SA
7. Lack of government representation and knowledge of government programs that can assist coastal communities	1.44 SA	1.72 SA	1.97 A
8. Loss of traditional social networks that support people through changes and difficult times	1.73 SA	1.76 A	2.23 A
9. Declining role of local churches and Christian practice in everyday life	1.95 A	2.39 A	2.72 D
10. Loss of heritage and cultural ways of life	1.74 SA	1.85 A	2.11 A
Resilience: Please identify your level of agreement with each condition as it contributes to resilience in the face of community and environmental change in the DIP area			
11. Existing family networks and community support	1.47 SA	1.28 SA	1.68 SA
12. Faith and religion	1.65 SA	1.79 A	2.03 A
13. Access to scientific research findings	1.83 A	1.59 SA	1.96 A
14. Access to government agencies and officials	1.83 A	1.60 SA	1.84 A
15. Traditional cultural practices of self-reliance and hard work	1.40 SA	1.70 SA	1.81 A
16. A rich heritage to be shared and communicated to others	1.46 SA	1.52 SA	1.81 A
17. Recent increase in ''come heres'' who bring new knowledge and skills	1.66 SA	1.89 A	2.00 A
18. Increasing heritage activities	1.70 SA	1.76 A	1.86 A
19. Absence of local government offices and officials	2.26 A	2.81 D	2.93 D
Social–ecological adaptation: Please identify your level of agreement with each statement as a priority for what research and government should help to do for the DIP area			
20. Restoration of Deal Island Peninsula marshes	1.39 SA	1.47 SA	1.49 SA
21. Protection of Deal Island Peninsula shorelines	1.19 SA	1.37 SA	1.46 SA
22. Assistance to communities and individuals in flood protection	1.29 SA	1.46 SA	1.45 SA
23. Preservation of community heritage and culture	1.37 SA	1.51 SA	1.72 SA
24. Sustain local fishery-dependent livelihoods	1.30 SA	1.61 SA	1.73 SA
25. Work with local churches to harness the power of beliefs and faith	1.72 SA	2.05 A	2.21 A
26. Increase collaboration with Deal Island Peninsula residents and their civic organizations	1.35 SA	1.30 SA	1.45 SA
27. Create jobs and new economic opportunities for communities	1.47 SA	1.49 SA	1.54 SA
Climate change: Please identify your level of agreement with each statement regarding climate change			
28. The climate is changing in different ways from before due to the impacts of human activities	1.85 A	1.04 SA	1.23 SA
29. Climate change is affecting the communities of the Deal Island Peninsula already	1.72 SA	1.16 SA	1.22 SA
30. Climate change is affecting the environment of the Deal Island Peninsula already	1.63 SA	1.20 SA	1.26 SA
31. The Deal Island Peninsula area will experience more storms and floods in the future due to climate change	1.82 A	1.10 SA	1.28 SA
32. The resilience of Deal Island Peninsula communities will be reduced in the future due to climate change	1.96 A	1.33 SA	1.71 SA
33. Climate change is a significant threat to the social and ecological system of the Deal Island Peninsula	1.80 A	1.13 SA	1.35 SA
34. Building relationships with people and organizations that have an interest in the Deal Island Peninsula and can help communities cope with climate change	1.64 SA	1.18 SA	1.32 SA

stakeholder group show that despite sharing social–ecological knowledge on coastal resilience, the stakeholder groups differed in their modeled answers for 20 statements (Table 4). Most of these differences are in the strength of agreement (i.e., agree vs strongly agree). We carefully reviewed each of these differences, drawing on our ethnographic understandings to determine whether or not they were meaningful. We found in each case that the difference in the strength of agreement corresponded to our ethnographic understanding of differing priorities among our stakeholder groups. In the following paragraphs we explain how differences in the strength of agreement in the modeled answers for each stakeholder group reflect nuanced variations in the otherwise shared social–ecological knowledge.

The local residents' stakeholder group varied the most from the other two groups, with different modeled answers for 11 of

the statements. Specifically, local residents more emphatically agreed (i.e., strongly agreed) that loss of traditional social networks and heritage contribute to vulnerability on DIP, that faith and religion, an increase in come-heres, and increasing heritage activities contribute to resilience, and that work with local churches should be a priority adaptation response. On the topic of climate change, while researchers and government employees strongly agreed with all statements, local residents merely agreed that the climate is changing due to the impacts of humans, that climate change significantly threatens DIP, and that the changing climate will cause more storms and floods and reduce resilience on DIP. On one statement local residents differed entirely; that is, while researchers and government employees disagreed that the absence of local government offices and officials contributes to resilience, local residents agreed. Local residents' agreement with this statement aligns with their value of self-reliance and cultural preference for self-sufficiency (Johnson 2016; Van Dolah 2018). While their familiarity and experiences with specific government agencies are primarily at the county and state levels, local residents' preference for "less government" in community cultural, social, and economic affairs applies generally to all government agencies (Johnson 2016; Van Dolah 2018).

The modeled answers for government employees differed for six of the statements, all within the subthemes of vulnerability and resilience (Table 4). Specifically, while local residents and researchers were more emphatic (i.e., strongly agreed) that lack of understanding about marshes, lack of working relationships with researchers and government employees, and lack of government representation and government programs contribute to the vulnerability of communities on DIP, government employees put less emphasis on the importance of these factors for vulnerability (i.e., merely agreed). Government employees also merely agreed that a rich heritage and traditional cultural practices of self-reliance and hard work contribute to resilience, while local residents and researchers strongly agreed. Government employees also differed in their response to the importance of the declining role of local churches and Christian practice in everyday life; while local residents and researchers agreed that this contributes to the vulnerability of DIP, government employees disagreed.

Researchers were unique in their modeled answers for only three statements, also in the subthemes of vulnerability and resilience. Specifically, they agreed (instead of strongly agreed) that lack of understanding about future impacts of climate change contributes to vulnerability and strongly agreed (rather than agreed) that access to scientific research findings and government agencies and officials contributes to resilience.

Overall, local residents place a greater emphasis on the importance of religion, local heritage, and self-determination, while placing less emphasis on climate change and its impacts on DIP. This finding matches well with our ethnographic understanding that DIP residents consider demographic, economic, and cultural changes an equal—if not greater—threat to their well-being and way of life than impacts from climate change (Johnson 2016; Van Dolah 2018). In addition, residents see their local characteristics to be a fundamental component of their ability to adapt (Johnson 2016; Van Dolah 2018). In contrast to this local perspective, the modeled government employees answer key deemphasizes the importance of religion and local heritage, while emphasizing climate change. Again, this fits with our ethnographic understanding of government employees who are enmeshed in scientific and technical climate change reports, with less familiarity with how climate change impacts and vulnerability are experienced at the local level (Miller Hesed and Ostergren 2017; Miller Hesed and Paolisso 2015). In general, researchers fell in the middle. This makes sense since this particular group of researchers spans the social and natural sciences (Johnson 2016; Johnson et al. 2018); while the social scientists in the group have done extensive research with DIP communities, natural scientists more often interact with natural resource managers in government agencies. Thus, as a whole, it makes sense that the modeled response of the researchers would fall in the middle.

While all stakeholders are drawing on shared social–ecological knowledge of climate resilience, taken together, these differences in the modeled answer keys reveal that stakeholder groups place differing levels of importance on various aspects of climate adaptation planning on DIP. This was expected and was one of the reasons that we used a collaborative learning approach to strengthen understanding and engagement between locals, government and nongovernmental organization representatives, and academics in planning climate adaptation on DIP (Johnson et al. 2017).

c. Diversity of knowledge among local residents

The relatively small eigenvalue ratios for local residents as compared with those for government employees, researchers, and even all stakeholders together (Table 2) indicates that a greater diversity of responses exists among local residents than within any other stakeholder group. Ethnographic observations suggested that this diversity of knowledge among local residents could at least be partly attributed to differences between local residents who identify as born-heres—those who were born on and continue to live on DIP—and come-heres—those who moved to DIP later in life. The difference between the residual scores (i.e., the second factor) for the 12 born-heres ($M = 0.366$; std dev = 0.277) and the residual scores for the 23 come-heres ($M = 0.150$; std dev = 0.327) was marginally significant, $t(33) = -1.95$, with $p = 0.059$. Ethnographic observations of these groups, however, supported further investigation of differences in their cultural knowledge. Specifically, some of the come-heres live full time on the peninsula, mostly as retirees, while others are part-time residents with vacation homes in the area. Many of these residents have purchased property along the shoreline for the scenic vistas and affordable waterfront, and as newcomers to DIP lack culturally embedded local environmental knowledge that born-heres draw upon in navigating environmental change (Van Dolah 2018). In contrast, most of the born-heres are from working watermen families with ancestral ties to the peninsula and tend to reside in the interior areas of the island—an adaptive strategy inherited from prior generations' experiences with flooding and storms

TABLE 5. Cultural consensus results for born-heres, come-heres, and all local residents together for survey rounds 1, 2, and 3, and all survey rounds pooled.

	Stakeholder group	Round 1	Round 2	Round 3	Pooled
Born-heres	Ratio of first and second eigenvalue	5.290	5.716	4.516	5.503
	Mean cultural competence ± std dev	0.750 ± 0.151	0.767 ± 0.127	0.714 ± 0.154	0.755 ± 0.131
	Range of cultural competence	0.43–0.94	0.55–0.93	0.47–0.98	0.45–0.92
Come-heres	Ratio of first and second eigenvalue	3.696	6.484	3.582	4.455
	Mean cultural competence ± std dev	0.627 ± 0.230	0.603 ± 0.453	0.691 ± 0.296	0.642 ± 0.356
	Range of cultural competence	0.27–1.00	From −0.68 to 0.97	0.02–0.99	From −0.72 to 0.99
Locals	Ratio of first and second eigenvalue	4.169	4.799	3.552	4.258
	Mean cultural competence ± std dev	0.686 ± 0.199	0.638 ± 0.373	0.695 ± 0.235	0.674 ± 0.285
	Range of cultural competence	0.31–0.94	From −0.71 to 0.95	0.10–0.96	−0.73–0.97

(Johnson 2016). When CCA were run on these two subgroups separately, the eigenvalue ratio of the first to second factors was higher for each subgroup than for all locals together (Table 5), indicating that variation in responses was patterned according to whether locals were come-heres or born-heres.

Comparison of the born-heres' and come-heres' modeled answers (Table 6) reveals areas in which these local subgroups differ. Notably, born-heres place a greater emphasis on factors internal and specific to the local community such as heritage and cultural ways of life and faith, religion, and the role of the church. We see this reflected in our ethnographic data; for example, born-heres wish to see more youth employment opportunities within the local communities (Johnson 2016), support policies and markets that would sustain local fisheries (Paolisso 2002), and share a strong faith in a God who will provide for all their spiritual as well as physical needs (Webster and Paolisso 2016). In contrast, come-heres emphasize scientific knowledge, strongly agreeing with the importance of access to scientific findings; understanding future climate impacts and how marshes are changing; and of the existence of working relationships with researchers and government employees outside the community, social networks to support people through difficult times, and an increase in come-heres with new knowledge and skills. Come-heres also strongly agree with all seven climate change statements, while born-heres merely agree. This aligns with our ethnographic understanding that born-heres have a mixed perspective on science and scientists, whose findings have led to overregulation of local fisheries (Paolisso 2002) and who undervalue the importance of faith and religion in responding to climate change (Miller Hesed et al. 2020; Van Dolah 2018).

Another key difference between born-heres and come-heres is their view of government presence on DIP. Born-heres more strongly agree with the statement that access to government agencies and officials contributes to resilience for the DIP area, as well as *disagree* with the statement that absence of local government offices and officials contributes to DIP resilience. These modeled answers for born-heres differ from those modeled for all local residents in aggregate (Table 6), which match the modeled answers for come-heres. Ethnographically, we see that local views about government involvement in local affairs are complicated. Born-heres strongly value self-reliance and independence (Van Dolah 2018), yet their engagement with government through the collaborative research carried out since 2012 may have increased their recognition that government involvement could help them to be more successful in responding to climate change. In contrast, come-heres, who tend to be retirees with more expensive properties, are concerned with sustaining the value of their waterfront property and may fear that government involvement could make it more costly for them to protect their property. For example, we have heard come-heres express concerns that new policies or regulations could increase flood insurance premiums or require more expensive methods of shoreline protection.

4. Conclusions

The results from CCA demonstrate that there are meaningful differences in what each stakeholder group understands to be most important for coastal resilience, even as these groups also share the social–ecological knowledge that many facets of their reality—including environmental, scientific, socioeconomic, and cultural factors—are relevant to coastal resilience on DIP. While government employees tended to emphasize environmental concerns and solutions, local residents put more emphasis on the importance of social, cultural, and economic resources in addressing their underlying vulnerability to coastal climate change impacts. We also found that, among our three stakeholder groups, local residents had the greatest variation in responses to the agreement questions, with come-heres aligning more closely with the views of government employees than born-heres.

These findings have several implications for participatory adaptation planning. First, the fact that all stakeholders shared social–ecological knowledge for coastal resilience is encouraging. Identifying this shared knowledge is beneficial for moving forward with further engagement, as rural communities, government employees, and researchers can sometimes mistrust each other's intentions or discount each other's knowledge (e.g., scientific or experiential knowledge) (Paolisso et al. 2019).

Second, our finding that government employees emphasized environmental aspects of coastal resilience (while local residents emphasized the importance of social, economic, and cultural factors) aligns with other studies (Crate and Nuttall 2009; Fiske et al. 2014; Marino 2015) that have found that

TABLE 6. Comparing pooled answer keys of born-heres (B), come-heres (C), and all local residents together (L). Here, [1–1.75) = SA (strongly agree), [1.75–2.5) = A (agree), [2.5] = N (neither agree nor disagree), (2.5–3.25] = D (disagree), and (3.25–4] = SD (strongly disagree).

Statement	B	C	L
Vulnerability: Please identify your level of agreement with each condition as it contributes to vulnerability of communities and/or the environment in the DIP area			
1. Lack of understanding about how marshes change and the impacts of rising waters, erosion, and storms on marshes	1.92 A	1.45 SA	1.64 SA
2. Lack of understanding on what can be done to restore marshes	1.58 SA	1.36 SA	1.45 SA
3. Lack of working relationships with researchers and government planners outside the community	2.05 A	1.42 SA	1.67 SA
4. Lack of understanding about the future impacts of climate change	2.08 A	1.41 SA	1.70 SA
5. Lack of research and assistance to sustain local commercial fisheries	2.09 A	1.60 SA	1.81 A
6. Lack of local employment opportunities outside of commercial fishing	1.33 SA	1.34 SA	1.34 SA
7. Lack of government representation and knowledge of government programs that can assist coastal communities	1.74 SA	1.22 SA	1.44 SA
8. Loss of traditional social networks that support people through changes and difficult times	1.81 A	1.67 SA	1.73 SA
9. Declining role of local churches and Christian practice in everyday life	1.89 A	2.00 A	1.95 A
10. Loss of heritage and cultural ways of life	1.61 SA	1.82 A	1.74 SA
Resilience: Please identify your level of agreement with each condition as it contributes to resilience in the face of community and environmental change in the DIP area			
11. Existing family networks and community support	1.46 SA	1.48 SA	1.47 SA
12. Faith and religion	1.30 SA	1.94 A	1.65 SA
13. Access to scientific research findings	1.94 A	1.74 SA	1.83 A
14. Access to government agencies and officials	1.73 SA	1.89 A	1.83 A
15. Traditional cultural practices of self-reliance and hard work	1.29 SA	1.49 SA	1.40 SA
16. A rich heritage to be shared and communicated to others	1.39 SA	1.51 SA	1.46 SA
17. Recent increase in ''come heres'' who bring new knowledge and skills	1.80 A	1.54 SA	1.66 SA
18. Increasing heritage activities	1.62 SA	1.74 SA	1.70 SA
19. Absence of local government offices and officials	2.67 D	1.96 A	2.26 A
Social–ecological adaptation: Please identify your level of agreement with each statement as a priority for what research a1nd government should help to do for the DIP area			
20. Restoration of Deal Island Peninsula marshes	1.39 SA	1.39 SA	1.39 SA
21. Protection of Deal Island Peninsula shorelines	1.30 SA	1.11 SA	1.19 SA
22. Assistance to communities and individuals in flood protection	1.52 SA	1.14 SA	1.29 SA
23. Preservation of community heritage and culture	1.37 SA	1.36 SA	1.37 SA
24. Sustain local fishery-dependent livelihoods	1.30 SA	1.30 SA	1.30 SA
25. Work with local churches to harness the power of beliefs and faith	1.55 SA	1.89 A	1.72 SA
26. Increase collaboration with Deal Island Peninsula residents and their civic organizations	1.53 SA	1.23 SA	1.35 SA
27. Create jobs and new economic opportunities for communities	1.73 SA	1.28 SA	1.47 SA
Climate change: Please identify your level of agreement with each statement regarding climate change			
28. The climate is changing in different ways from before due to the impacts of human activities	2.47 A	1.38 SA	1.85 A
29. Climate change is affecting the communities of the Deal Island Peninsula already	2.05 A	1.44 SA	1.72 SA
30. Climate change is affecting the environment of the Deal Island Peninsula already	1.96 A	1.36 SA	1.63 SA
31. The Deal Island Peninsula area will experience more storms and floods in the future due to climate change	2.27 A	1.47 SA	1.82 A
32. The resilience of Deal Island Peninsula communities will be reduced in the future due to climate change	2.31 A	1.69 SA	1.96 A
33. Climate change is a significant threat to the social and ecological system of the Deal Island Peninsula	2.28 A	1.42 SA	1.80 A
34. Building relationships with people and organizations that have an interest in the Deal Island Peninsula and can help communities cope with climate change	1.88 A	1.45 SA	1.64 SA

climate adaptation policies tend to focus on addressing climate change impacts, rather than addressing social and economic disparities that make communities vulnerable to those impacts to begin with. For example, it is not enough to raise everyone's heating, ventilation, and air conditioning units out of the flood zone without also addressing the larger issue of job loss, which leaves communities like those on DIP more socially vulnerable to storm or flooding impacts due to a loss of financial resources critically needed to respond and adapt to these events. Thus, adaptation efforts must be more holistic—to address both projected environmental impacts and socioeconomic and cultural circumstances—to effectively increase coastal resilience to climate change.

We also found that local residents had the greatest diversity in responses to the coastal resilience statements as compared with researchers and government employees. While

including local residents in adaptation planning and implementation has been emphasized (Least Developed Countries Expert Group 2002; Smit and Pilifosova 2001; United Nations Framework Convention on Climate Change 1992; Wilbanks 2003), there has been less discussion of how to identify who among the local residents should be included. Cultural consensus analysis quantitatively demonstrates that local residents' views are not homogenous. Specifically, we found that the views of come-heres aligned more closely with those of government employees than those of born-heres. Because come-heres tend to be retirees with more leisure time and greater financial wealth than born-heres, they are already positioned to have a greater impact on government coastal adaptation decision-making. Thus, it is even more important that decision-makers reach out to born-heres to make sure their concerns and priorities are also considered. Importantly, our findings do not suggest that born-heres are disinterested in climate change, but that they are more concerned with first addressing the socioeconomic challenges and maintaining their cultural resources as a way to promote resilience, than planning for environmental changes that have not yet begun impacting them on a daily basis (Paolisso 2002; Johnson 2016; Van Dolah 2018). This finding suggests that participatory adaptation processes must be intentional in engaging the full diversity of local knowledge to best address the various and interconnected local risks.

The importance of engaging local knowledge in adaptation decision-making is well established; however, relatively little attention has been given to the problem of ensuring that the full diversity of knowledge among local populations is included. Without deliberate inclusion of all local knowledge, adaptation decisions may end up supporting only some in the community. We have shown that a cultural consensus approach is useful for measuring the diversity of knowledge within and across stakeholder groups and can be particularly useful for identifying the diversity of social–ecological knowledge among local participants. This study demonstrates how methods for systematically comparing social–ecological knowledge can reveal areas of agreement and disagreement among and between stakeholder groups to facilitate more fair and effective engagement between decision-makers and local residents in climate adaptation planning and implementation.

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