Marine Policy 118 (2020) 103987

Contents lists available at ScienceDirect

Marine Policy

journal homepage: http://www.elsevier.com/locate/marpol

Stakeholder-defined scientific needs for coastal resilience decisions in the Northeast U.S.

Grace D. Molino [a,*,1], Melissa A. Kenney [b,2], Ariana E. Sutton-Grier [b,c]

[a] Brown University, Department of Earth, Environmental and Planetary Sciences, Providence, RI 02912, United States
[b] Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20740, United States
[c] National Ocean Service, National Occeanic and Atmospheric Administration, Silver Spring, MD 20910, United States

ARTICLE INFO

Keywords:
Climate change
Natural infrastructure
Societal impacts
Document analysis
Extreme events
Useable science

ABSTRACT

Over the past decade, coastal communities and ecosystems in the Northeast United States have begun to face acute and chronic impacts of climate change. Extreme events such as Superstorm Sandy caused stakeholders in this region to examine what information is needed to implement adaptation and mitigation plans to prepare for the next major storm. The objective of this study was to determine research needs identified by stakeholders in the Northeast needed for decision-support and policy creation so that scientists can target future research efforts to fill gaps. Modeled after document analysis methods in Dilling et al. (2014), this study examines documents sourced from local and regional organizations in both the public and private sectors to determine gaps in information necessary for climate resilience planning. Stakeholders throughout the Northeast expressed a need for solution-based research, in particular natural and nature-based solutions such as wetlands. Additionally, there was a need to better understand the economic impacts of climate change on key industries in the region as well as cost-benefit analyses of different adaptation options. It was also determined that government organizations, such as Sea Grant, play a crucial role in supporting stakeholder needs assessments both in terms of funding and providing necessary expertise. This study provides a baseline of stakeholder-expressed research needs in the Northeast to start the conversation between communities and researchers interested in conducting useable science.

1. Introduction

Coastal communities and ecosystems are facing a number of threats due to climate change and other environmental stressors [1,2]. Sea level rise, for example, is one of the greatest threats as it is leading to increased storm surges as well as nuisance or "blue sky" flooding that is unrelated to major storm events [3–5]. Coastal communities are interested in increasing their resilience to these threats so that they are better prepared to manage them, mitigate the impacts, and bounce back from disasters more quickly.

Traditionally, the ways that coastal communities could decrease flood and erosion risk was via gray or built infrastructure such as seawalls, dikes, and levees, but there is growing interest in using both natural coastal ecosystems and hybrid (which combines natural and built components) solutions to increase resilience [6,7]. "Natural infrastructure" refers to the use of healthy coastal ecosystems, including marshes, mangroves, coral and oyster reefs, and beaches and dunes, to provide wave attenuation and erosion risk reduction [8–14]. However, when using natural and hybrid solutions for coastal resilience, the project needs to be designed for each specific community; there is no "one size fits all solution" [6]. This can make determining what the potential options are and choosing a resilience approach very complicated and challenging for coastal communities.

Additionally, there can be a mismatch between the information available to communities and the decisions they are trying to make including coastal resilience policies and land use planning. To best help communities with resilience decision making, scientists need guidance on how to target their research to answer stakeholder-relevant questions. However, despite the calls for use-inspired science that better supports decision-maker needs [15–18], there is a gap between the

* Corresponding author.
E-mail address: gdmolino@gmail.com (G.D. Molino).
[1] Boston University, Department of Earth and Environment, 685 Commonwealth Avenue, Boston, MA 02215 United States.
[2] Institute on the Environment, University of Minnesota, St. Paul, MN 55108, United States.

https://doi.org/10.1016/j.marpol.2020.103987
Received 19 September 2019; Received in revised form 7 February 2020; Accepted 16 April 2020
Available online 30 April 2020
0308-597X/© 2020 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

science that is produced and the science that is used [19].

To bridge the information usability gap, consideration of knowledge and scientific needs defined by stakeholder communities, adopting co-production models, and effective translation are all critical when moving research into action [19,20]. Additionally, such research should consider stakeholder values for coastal resilience decisions [21] and information needs should be intertwined to improve project decision-making and evaluation.

NOAA defines "stakeholders" generally as "those who have an interest in or are affected by a decision [22]. To more specifically fit the goals of this study, the term "stakeholder" will refer to an individual, group, or organization who has an interest which may be affected by coastal climate impacts or has to make decisions on how to manage such impacts. Interests can include, but are not limited to, business, personal, monetary, or cultural. Specific examples from this study include New Jersey residents, the City of Boston, the New England Power Generators Association, and The Nature Conservancy.

Though explicit involvement of stakeholders through co-produced science is ideal [20], in some cases, direct stakeholder involvement may not be feasible or stakeholder needs may be well-articulated through previous engagement efforts [23]. Thus, to minimize stakeholder fatigue, it is useful to understand the stakeholder needs already articulated and documented.

Using a document analysis approach [24], this study focused on identifying, categorizing, and synthesizing research priorities expressed in non-journal publications by the coastal stakeholder community in the Northeast United States. This study modifies a stakeholder needs assessment of climate and water impacts, used in Dilling et al. (2014) [25], to assess coastal resilience stakeholder needs in the Northeast U.S. to support coastal resilience policies and decisions, a topic and region which had not been analyzed previously. Adopting this formal approach allowed us to identify research themes and priority areas identified by stakeholders which can inform the research decisions of the scientific community, the targeted end-user of the study results. This enables scientists to design their research to fully consider decision contexts, improved scientific translation products or engagements, and use-inspired research study designs that explicitly address stakeholder needs. While all needs of stakeholders determined by this study will be discussed at least briefly, the majority of the analysis will focus on research needs with the intention of informing scientists and other researchers interested in refining their own research to increase its impact and its use in coastal resilience decisions.

The following section details the approach and methods used to answer these questions. The results section reviews the identified stakeholder needs, which can be broken down into four areas: (1) physical impacts of climate change, (2) mitigating and adapting to climate change, (3) human health and response to climate change, and (4) areas of improvement beyond research. Finally, the implications of these needs are discussed in the context of policy and decision-making in a region which has already begun to feel the impacts of climate change.

Notably, this is the first study that the authors are aware of which establishes a baseline of stakeholder needs to adapt to coastal climate impacts in the Northeast U.S. Researchers and organizations interested in community engagement and use-inspire research may use this study as a starting point for conversations with stakeholders to reduce stakeholder fatigue, to focus future stakeholder engagements, and to develop collaborative research studies or translate scientific findings for use in decisions.

2. Methods

The primary goal of this study was to determine the scientific research needed to support coastal community resilience efforts in the Northeastern U.S. Document analysis, a technique commonly used in social science, was used to unobtrusively understand the published perspectives of stakeholders in the region [24,26,27]. This method capitalizes on already available documents produced by the target sector and does not require additional interviews. The approach does have the constraint that it is limited to available documents which are typically produced by only a subset of stakeholders and therefore may represent an incomplete perspective. This method has, however, been used previously to identify stakeholder needs related to climate change [25, 28–30]. Such approaches are important for minimizing stakeholder fatigue by formalizing the process of understanding stated information needs, which allows additional engagements to focus on ideation [25].

All documents considered for this study were identified through an extensive web-based search and snowball sampling through our personal Federal, state, and local coastal resilience community networks. Documents were selected for inclusion in the study if, after reading, they met four criteria: (1) geographic region, (2) topical relation to coastal resilience, (3) stated expression of stakeholder needs, and (4) date of publication.

First, documents were selected if they focused on the geographic Northeast United States as defined by the 3rd National Climate Assessment (NCA) [2], excluding West Virginia and Vermont as they do not have a coastline and their watersheds do not contribute significantly to Northeast coastal waters (Fig. 1). The scale of focus for each document could be local, state, or regional as long as it pertained to an area contained within the Northeast region.

Second, the documents had to discuss coastal resilience, in the broadest sense of the term. This study uses the definition provided by the 3rd NCA, "an ecological, human, or physical system's ability to persist in the face of disturbance or change and continue to perform certain functions" [2]. Issues impacting coastal resilience were considered anything which would affect the natural, built, social, and economic functions of communities within the coastal Northeast.

Third, documents also had to include scientific needs as defined by the stakeholders themselves. Communities have a unique perspective on what information is needed to understand and to make decisions about how to adapt to climate change but may not be able to find, synthesize, translate, or produce the scientific information needed to inform or to evaluate these decisions. Documents were included if it was determined that stakeholders significantly contributed to the process. Viewpoints of local, state, regional, and national organizations within the Northeast were considered, this includes documents from both public and private sectors.

Finally, documents published between 2009 and 2017 were included in this study. This timeframe was selected because this represented "recent" stakeholder assessments of research needs and captured the window of time both before and after the 2012 Superstorm Sandy event which had a significant impact on coastal communities and sparked increased attention and action towards coastal preparedness and climate adaptation actions in the Northeast.

Fifty (50) documents were ultimately selected for use in this study (see Supplementary Materials for a complete list). Forty of the 50 documents focused on local or state-level stakeholder needs, with exactly four documents associated with each state to avoid biasing regional needs. The remaining 10 documents were published by regional organizations that encompassed two or more states in the Northeast. These documents were mostly gray literature that was freely available online including state climate assessments, workshop proceedings, reports, action plans, and white papers. Peer-reviewed journal articles were not included because stakeholders' research perspectives are not commonly published in the peer-reviewed literature. To begin the analysis, each document was classified based on location, year of publication, and authorship. Documents were classified for authorship by government, private organizations, academic organizations, or "multiple" which refers to collaboration between several different types of organizations that fall into the previous categories. An author was any party which was acknowledged to have contributed significantly to the creation of the document via authorship or acknowledgement. Ninety-four authors were identified as most documents received contributions from more

Fig. 1. Map of Northeast states, as defined by the 3rd National Climate Assessment (2014), that were included in the stakeholder needs analysis. Gray states were included in the analysis; the other states were not included because they do not have any coastline, nor a watershed that contributes significantly to Northeast coastal waters.

than one individual or organization.

Coding and analysis of needs were based on a modified coding schema developed by Dilling et al., 2014 [25], which was additionally used for a cross-regional analysis in Dilling et al., 2015 [28]. In this context, 'coding' refers to the process of highlighting a section of the document where needs are stated and designating it to a more general category of needs that it falls under. Once documents were selected and classified, as described above, they were imported into NVivo, a qualitative analysis software, to enable consistent coding and analysis of emerging patterns [31]. The documents were then reread and deductively coded using six major stakeholder needs categories, termed "nodes" in NVivo: (1) Research Topics, (2) Monitoring and Data Collection, (3) Social Issues, (4) Coordination, Collaboration, and Communication, (5) Policies, Programs, and Law, and (6) Infrastructure (Fig. 2). Nodes 1–5 were based on the coding schema developed by Dilling et al., 2014 [25] which was adapted by adding more detailed sub-node codes specific to coastal areas. Node 6, "Infrastructure," was added inductively during this process because within the documents, coastal communities repeatedly expressed a need for more information about the vulnerability of current infrastructure as well as use of natural infrastructure as a solution. This process of inductively modifying the hierarchy of nodes and sub-nodes during document analysis applies a common approach of qualitative analysis research in which data collection design remains adaptable until a significant portion of research is complete [32]. A few needs were so specific a sub-sub-node was created to capture a greater level of detail that would be helpful for guiding future research. No assessment was made to determine degree of actual need for any of the coded items; each was considered equally valid during analysis.

After coding was completed, sub-nodes which had been coded in 50% or more of the documents were analyzed and four major themes of research needs emerged: (1) physical impacts of climate change, (2) mitigating and adapting to climate change, (3) human health and response to climate change, and (4) areas of improvement beyond research. These themes were based on similarities in the information and data needs coded in the document and were not necessarily grouped based on the overarching node under which the need was coded.

The second round of analysis relaxed the constraint for consideration of a sub-node in the analysis to a 20% threshold; this threshold captured more specific sub-nodes that were important research needs but were

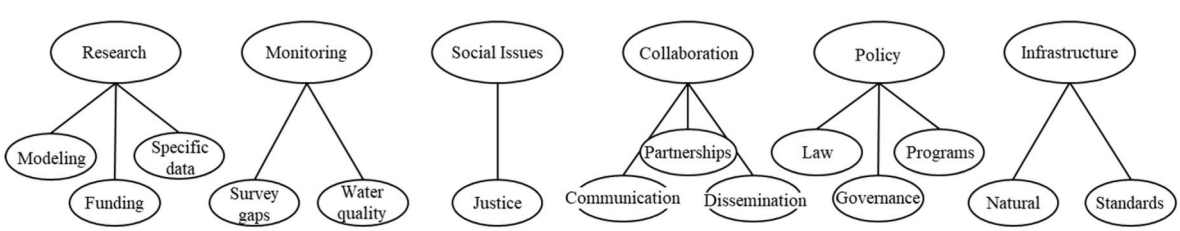

Fig. 2. Final coding schema of nodes and first tier of sub-nodes used to identify stakeholder needs to support coastal resilience decisions. Category names were shortened for this graphic; content of each was not changed. For complete coding schema see Supplementary Materials.

not included under a more frequently coded for sub-node. For example, "sustainable shorelines" was coded in 14 of the 50 documents but was included because this sub-node represented an infrastructure option for which information was requested and was not always included in documents discussing more generally natural and nature-based features.

Finally, each subsection of the Results, calls out specific examples of research needs from sub-sub-nodes that may have been explicitly mentioned in only a few documents due to their specific application but should still be considered; for example, oyster reefs only came up a few times but are still discussed under natural and nature-based solutions given their relevance as a key habitat restoration option.

3. Results

3.1. Overview of the document dataset

The final dataset contained 50 documents that met the decision criteria. The documents represent a nine-year time span from 2009 to mid-2017. The majority of documents (37) were published after Superstorm Sandy. Two major spikes in the prevalence of source publication date can be seen during 2013 and 2015 (Fig. 3). The increase in documents published during 2013 is attributed to a response to Superstorm Sandy which hit in late 2012. A number of organizations commissioned reports to study the effects of the storm on coastal communities and what is needed to prepare for extreme events. The high number of documents published in 2015 is because 2015 was the midway point or endpoint of several five-year studies. For example, the Mid-Atlantic Regional Council on the Ocean (MARCO) was founded in 2009 and began research projects which spanned five years from 2010 to 2015.

Table 1 shows that more than half of the authors (i.e., largest category of authors) coded for in the documents were from government organizations, with a heavy emphasis at the state-level. Notably, half of the states in the Northeast region had documents produced by their respective Sea Grant programs. Authors coded as "private" were associated with both nonprofits and businesses; 20% of the authors were coded as such. The third largest segment of authors was "multiple", referring to authorship that was collaborative between several types of organizations, which made up 15% of all the authors. These authors were typically representatives from state-level councils or regional bodies such as Delaware's Sea Level Rise Advisory Committee and the Long Island Sound Study. These collaborative organizations were usually comprised of government workers and officials, university researchers, and private businesspeople. Rarely did documents directly attribute significant contribution to citizens from the communities acting in a stakeholder capacity. Authors coded as "academic" was the smallest segment (11%); this is due in part to the method of document selection which focused on non-journal literature sources.

Table 1
a) Authors attributed to one or more documents in the study, separated by sector of author; b) funding sources for one or more papers, separated by sector of funding source; c) documents with identified funding sources, separated by sector of funding source.

Sector	Number of authors
a)	
Government	51
Private	19
Multiple	14
Academic	10
Total	94
Sector b)	Number of funding sources
Government	11
Private	9
Total	20
Sector c)	Number of documents funded
Government	20
Private	10
Total	30

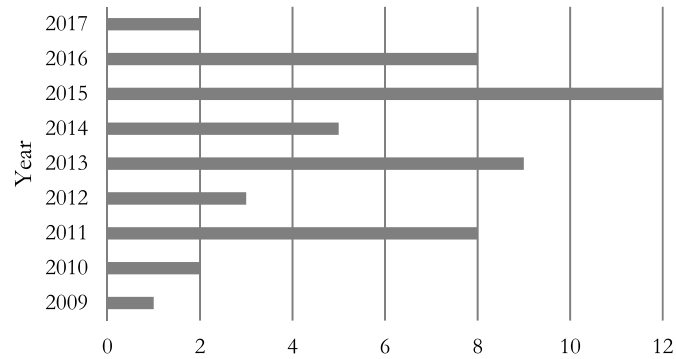

Fig. 3. Number of coastal resilience documents published between 2009 through mid-2017. Superstorm Sandy occurred in late 2012; 74% of the total documents were published after this event.

Documents were also coded for funding sources, when data were available. Eleven government agencies and programs funded 20 of the 50 documents. The top government agency funder, and top funder overall, was NOAA (7 of 50). All other funding sources were categorized as being from private organizations: nine NGOs funded 10 documents (Table 1).

Documents pre-Superstorm Sandy tended to be climate adaptation plans put out by state and local governments. These documents were broad, focusing on climate-related issues throughout the state, usually with a coastal section. However, after 2012, the documents focused more specifically on coastal issues, regardless of whether Superstorm Sandy was explicitly mentioned in the document or not. It is clear that Superstorm Sandy was a major motivator and a turning point for coastal states. After Superstorm Sandy, the focus of documents produced shifted from general awareness and climate adaptation planning to more detailed climate impact preparedness, especially focused on the next major hurricane or storm, for coastal communities. Reports from states not directly impacted by Superstorm Sandy still cited the storm as a reason for a needs assessment to minimize the risk of significant damage on their communities.

The needs identified by stakeholders have been separated into four overarching research areas (1) physical impacts of climate change, (2) mitigating and adapting to climate change, (3) human health and response to climate change, and (4) areas of improvement beyond research. This structure is intended to highlight key research needs to guide individual scientists and organizations interested in studying or funding projects that fall under a certain area. Physical impacts of climate change contain research needs focused on identifying and assessing the vulnerability of coastal locations and populations to climate impacts. Mitigating and adapting to climate change research needs included more studies on natural and nature-based features, alternative energy, and economically valuable species which are adapted to suit the changing climate. Research needs regarding human health and response to climate change include an assessment of the cost of climate impacts on coastal infrastructure and industries as well as the economic value adaptation options provide in risk reduction. Finally, while not the focus of this study, the fourth section summarizes the major areas of improvement needed beyond research including communication and collaboration, climate education, and data availability.

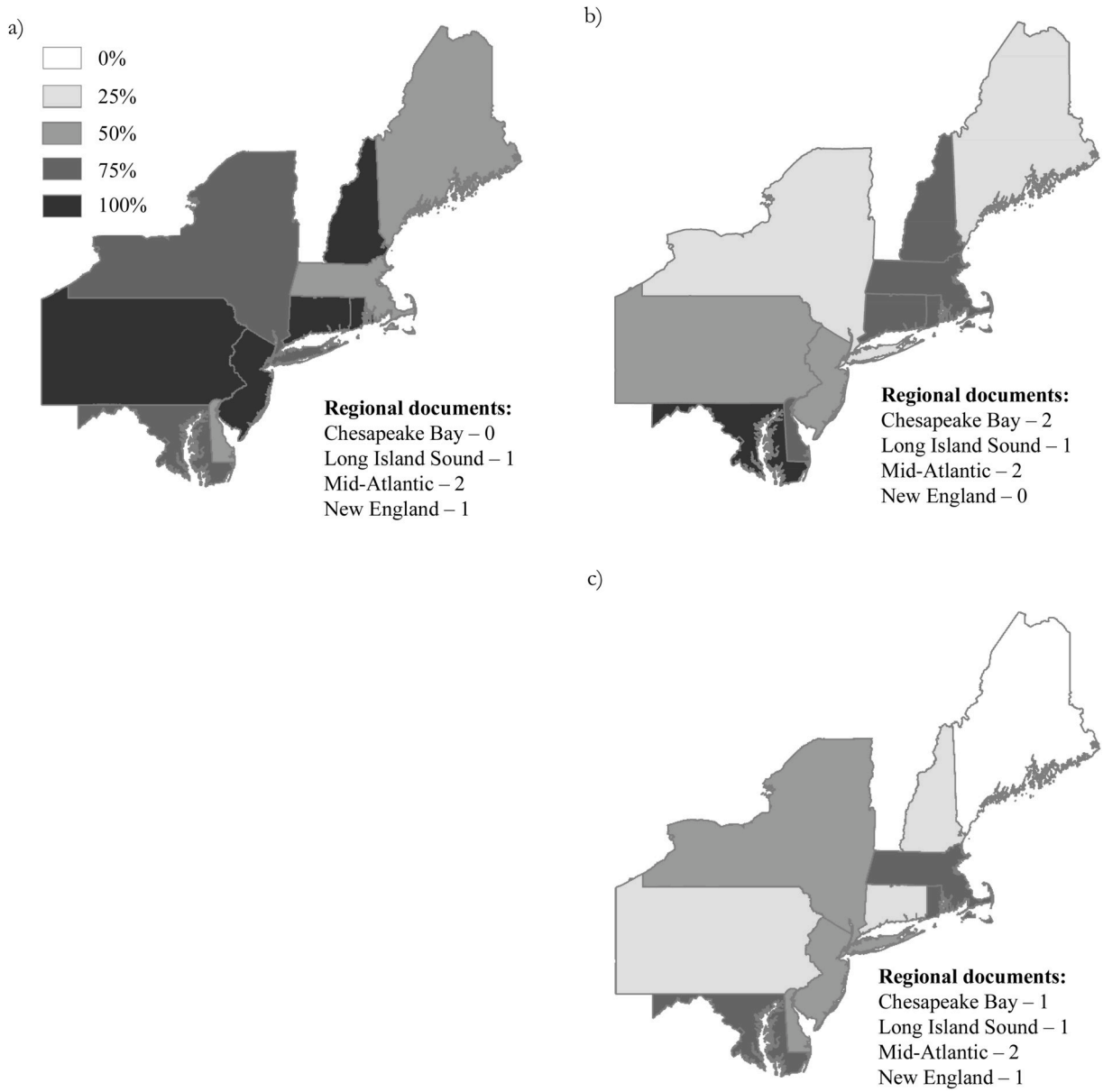

Fig. 4. Maps representing three key themes of research needs across the Northeast region. Colors represent what percentage of documents associated with each state mention each need. a) Overall, thirty-six documents called for research locating vulnerable infrastructure and adaptation options; b) thirty documents mentioned a need for more research on natural and nature-based features; c) twenty-three documents requested more information on the economic impacts of climate change and the cost/benefits of adapting or not.

3.2. Research on physical impacts of climate change

3.2.1. Location and vulnerability of infrastructure

Climate impacts on coastal infrastructure and the resulting land use changes were the most widely identified research needs (Fig. 4a). These documents highlighted that research is needed to both determine the location of vulnerable coastal infrastructure and then to explore land management practices which can reduce risk from climate impacts. The flood vulnerability assessments specifically identified include household properties, municipal water systems, wastewater, hazardous waste, and transportation infrastructure. In the Northeast region, flood risk assessments pertain to both chronic conditions such as sea level rise as well as acute, extreme events such as storm surge and high precipitation. Of particular interest to stakeholders was understanding impacts and risks to evacuation or emergency routes during storm events or other local disasters (Docs. 8, 35, 37, 38). Eight documents also addressed the need to identify areas of cultural and historical significance, both on land and below water; for example, “identify and focus research efforts on historical, archaeological, and ethnographically significant sites that are most vulnerable to sea level rise and climate change” (Doc. 9).

The documents additionally discussed several management options, such as updating design standards, for infrastructure in an area deemed at risk of flooding. Another option discussed was to set back infrastructure out of areas vulnerable to flooding (Docs. 9, 11, 24, 38); including research for “when and where to fortify existing buildings and when to move, demolish-recycle, or abandon vulnerable structures” (Doc. 9). Beyond coastal retreat, nine documents discussed the importance of establishing “buffer zones” around riparian floodplains and wetlands as another means of protecting infrastructure, and three documents stated the need to allow for inland upslope migration for buffers around wetlands (Docs. 23, 24, 40). Overall, stakeholders acknowledged that current and future climate conditions threaten their coastline: they need to know where the threats are the greatest and how best to design infrastructure to withstand these impacts or otherwise retreat inland.

3.2.2. Flood trends and mapping

Nineteen of the documents acknowledged the need for research on flood trends, both storm-induced and nuisance. Stakeholders in six documents stated a gap in historic and current decision-relevant information necessary to "improve analysis of coastal and riverine flood risks resulting from a combination of storm surge, sea level rise, and extreme precipitation events in coastal areas (Doc 24)" (Doc. 5, 32, 34, 35, 37, 43). Additionally, there was a need for predictions of future flooding given different sea level rise scenarios; the term "future" is clearly emphasized as current maps show outdated information that does not incorporate recent climate predictions. Notably, it is critical to determine "a higher vertical flood elevation and expanded corresponding horizontal floodplain… to address current and future flood risk for new construction" (Doc. 24). Coastal stakeholders also expressed a need to improve the information available regarding bathymetric features and geologic processes along shorelines, both of which impact flood patterns.

Standard map and flood data formats to enable easy use by communities would greatly aid in the use of the information available (Docs. 8, 14, 36, 49). The desired features, in addition to flood mapping, include private and public infrastructure and evacuation routes. Four documents called for an update to Federal Emergency Management Agency (FEMA) maps to better inform stakeholders of the risk that their property faces (Docs. 9, 10, 22, 32). Stakeholders also expressed a need to map what infrastructure, including private and commercial buildings and roads, is located in the updated flood zones. States that were impacted by Superstorm Sandy explicitly stated the need to assess the vulnerability of emergency evacuation routes for coastal communities. This information was highlighted as critical to community planning and decision-making efforts, especially for coastal locations with high flood risk.

3.3. Research on mitigating and adapting to climate impacts

3.3.1. Natural and nature-based solutions

Stakeholders in all 10 states in the region overwhelmingly suggested that natural and nature-based approaches should be considered as a key component of resilience planning (Fig. 4b); coastal wetlands were the most frequently mentioned solution (for examples see Docs. 1, 5, 25, 32). However, to more easily and rapidly implement natural and nature-based approaches, additional research is needed.

First, improved understanding of the flood reduction and wave attenuation properties of different vegetation types are needed to assess potential exposure reduction provided by nature-based solutions such as wetlands (Docs. 1, 5, 36). Second, to better assess the benefits of natural and nature-based solutions versus those of built infrastructure, ecosystem service research, especially that which is predictive of changes in these services given climate change and other stressors, would be particularly useful. Third, seven documents requested improved predictive models and land use data to predict where marshes will migrate as sea level rises; maps of current wetland habitat combined with projections of future wetlands can support wetland migration and land management decisions. Fourth, research is desired on effective implementation of living shoreline techniques, such as oyster reefs and eelgrass beds (Docs. 1, 26, 32). Fifth, once green infrastructure approaches have been implemented, stakeholders also identified a significant research need for "monitoring of the effectiveness of living shoreline and resilience projects, including pursuing approaches to quantify and characterize the impacts of projects" (Doc. 31).

In sum, all the states expressed a need to better understand natural and nature-based coastal protection in order to facilitate the consideration or implementation of these coastal resilience alternatives instead of, or in addition to, traditional built infrastructure. Thus, the research needs focused primarily on better understanding how to design and build effective projects and the need to monitor projects once they are completed to assess effectiveness, particularly in the case of major storm events.

3.3.2. Adaptation of management practices to climate change

3.3.2.1. Ecosystems. Further research into ecosystem-based management was stated in 27 of the documents. First, to aid in conservation and restoration efforts, it would be useful to spatially identify ecologically important habitats which may have keystone or endangered species. Second, understanding how climate change currently impacts these ecosystems as well as modeling future impact would also improve management efforts. Third, five documents explicitly cited the need for "long-term monitoring" of key ecosystems (Docs. 4, 9, 15, 33, 39). Ecosystem monitoring was particularly important to stakeholders for understanding how climate change may impact marine resources given the importance of several culturally and economically valuable fish and shellfish species in the region. For examples, documents from Massachusetts and New Jersey stressed the need to understand the risks facing their respective fisheries (Docs. 4, 26); Maryland and Maine stakeholders expressed concern for the future of their iconic blue crab and scallop industries, respectively (Docs. 19, 10). Northeast stakeholders stated there are "major gaps in our understanding of the responses of marine life and habitat to climate change" (Doc. 29). Stakeholders were also concerned about the impact of climate change on agriculturally important species. Documents representing seven of the ten states highlighted the need for locally/regionally specific information on the impacts of climate change on agricultural production. Identification of crop species "better able to accommodate shifting climate conditions" (Doc. 9) so agricultural services can adapt and survive in the coming century is of great importance to stakeholders (Docs. 6, 9, 17, 23). Of interest are crop species well adapted to hotter conditions (Doc. 17, 33), sea level rise (Doc. 6), and reduced water quality from salinity (Docs. 25).

3.3.2.2. Stormwater. Research aimed at improving stormwater management was discussed in documents representing 90% of the states in this study. Improved management included identification of vulnerable locations, investigation of strategies to combat flooding, and understanding the impacts of increased runoff on natural and built infrastructure. Models of stormwater flows are needed to determine areas of potential inundation and changes to flow patterns resulting from sea level rise (Docs. 6, 8). Five documents additionally expressed the need to identify strategies to increase infiltration in drainage basins and recharge reservoir opportunities (Docs. 17, 24, 38, 40, 41). Notably, several documents explicitly called for an evaluation of green infrastructure for stormwater management and treatment (Docs. 15, 20, 36); for example, one stated that it is essential to improve methods of control of "agricultural, urban, and stormwater runoff to prevent ocean and freshwater contamination, as well as enrichment of nutrients in aquatic areas that offer ideal growth medium for harmful algal blooms" (Doc. 9). Finally, identifying pollution sources and monitoring surrounding water quality was viewed as a necessary investment to better understand the impact of runoff on ecosystems (for examples see Docs. 9, 15, 28). As climate change continues to impact ecological and water management systems, it is critical for stakeholders to identify vulnerabilities and then adapt management practices to reflect these changes, so the system services are maintained.

3.3.3. Greenhouse gas reduction and alternative energy approaches

Twelve documents discussed strategies for increasing energy efficiency and reducing greenhouse gas emissions at local and state levels. Communities are interested in exploring the potential for localized energy solutions (Docs. 9, 12, 27, 33). For example, one document stated, "The City should pursue community energy solutions, such as district energy systems or microgrids, that increase energy reliability and decrease greenhouse gas emissions" (Doc.12). Alternative energy

solutions proposed focused on the installation of solar and offshore wind farms. Three documents identified the need for studies of marine seafloor bathymetry and ecosystems to select infrastructure locations which maximize energy production while minimizing harm on marine ecosystems (Docs. 5, 9, 11). Additionally, three documents recommended further work evaluating wetland and forest carbon sequestration methods (Docs. 5, 9, 36). Improved understanding of the potential impacts of climate change on energy infrastructure and carbon sequestration strategies is also needed to increase the likelihood of success (Docs. 9, 33). The emphasis on energy and climate mitigation highlighted the aim for integrated strategies to increase community resilience.

3.4. Research on human health and response to climate change

3.4.1. Costs of climate change and benefits of adaptation

Stakeholders across the region expressed interest in better assessing the costs and benefits of climate change impacts on coastal property and industries, and resilient infrastructure solutions. Four documents stated the need for research examining the economic value of protection provided by wetlands (Docs. 5, 15, 40, 45). Additionally, four other documents called for comparisons of the costs and benefits of natural and nature-based features, such as wetlands, versus built or gray infrastructure to increase coastal resiliency (Docs. 5, 6, 20, 39). There was also acknowledgement by stakeholders that a better understanding of the "relationships between coastal communities and of the local economic benefits of recreational activities" (Doc. 29) was needed to improve assessments of climate impacts, such as sea level rise, on the local economy. Furthermore, stakeholders suggested a need for more information regarding socioeconomic factors motivating individuals and communities to take adaptive actions. Twenty-four documents mentioned economic incentives as an important tactic that should be used to motivate stakeholders to act towards increasing coastal resilience, but only two documents explicitly stated a need for research to support successful incentive programs (Docs. 9, 45). Combined, these documents point to an important research gap - the need for more information on the economic value of coastal ecosystems and nature-based options, in particular to quantify the risk reduction provided by different solutions to better compare infrastructure investment choices.

3.4.2. Climate-induced health risks

Based on this analysis of stakeholder needs and local issues presented in the documents, there was concern expressed about how climate change will impact human health risks, such as food-borne, vector-borne, and water-borne illnesses, as well as air quality impacts. Seven documents expressed a need for monitoring vectors and pathogens to understand potential risks at local and state levels. For air quality, further analysis was requested to better understand how changes in air quality impact the health of populations at local and state levels (Docs. 9, 17). There were also questions as to the capabilities of health services to accommodate both a rise in climate-related illnesses as well as physical climate impacts, such as sea level change, which can impact health care facilities that are vulnerable to flooding (Docs. 9, 25).

3.5. Areas of improvement beyond research

Although not a focus of this study, there are several widely stated needs of stakeholders that extend beyond data and information. One almost ubiquitous suggestion (41 documents) was the need for improved communication. Communication includes both a one-way flow of resilience-relevant information from agencies to coastal communities as well as a two-way flow through dialogue to understand local needs. To facilitate climate resilience planning, there must be a "common understanding of vulnerabilities and the successes and barriers related to implementing adaptation measures" (Doc. 2). There was also a clear need for improved emergency communication before, during, and post-extreme events to aid with evacuations, conveying current conditions, and recovery efforts (Docs. 21, 24, 25, 26, 27, 38, 44). Another widely agreed upon need (42 documents) was for better coordination between multiple levels of government agencies, as well as between the government and coastal community partners. Seven documents, written by organizations responsible for multi-state bodies of water or watersheds (e.g., Chesapeake Bay Program and Long Island Sound Study), additionally emphasized a need for coordination of regional activities between states. Coasts by nature cross political boundaries making them "areas with competing interests, stakeholders, and multiple jurisdictions" that require strong coordination and communication efforts (Doc. 9).

Climate education was stated as a need in 42 documents. This involves informing the general public as to the impacts of climate change and the potential mitigation options available to them. Basic training of employees in sectors that will be affected by climate change, such as agriculture, water utilities, and healthcare, on how to manage the impacts is another key part of this need. Documents representing 9 of the 10 states in this study also expressed a need for better data availability and dissemination. Datasets need to be readily available and consolidated into a central location for decision-makers to access. Having an informed public and data which can be utilized easily will aid in creating climate resilient communities prepared to tackle the impacts of climate change.

4. Discussion and conclusion

Natural disasters often drive stakeholders to assess their needs to improve coastal resilience efforts. Not surprisingly, in the Northeast U.S. post-Superstorm Sandy there was a substantial increase in the number of documents produced detailing these efforts (Fig. 3). This is likely because communities recognized their own lack of preparedness for major events and wanted to determine areas of improvement before the next big storm.

Highlighted here are several key scientific research needs stated under the overarching research areas that would aid coastal communities in their resilience planning and decision making. Although these only represent three areas of research needs out of all the ones identified in the study, they are the most cited throughout the entire region under each overarching research area. Organizations and agencies interested in researching or funding studies with wide-reaching implications can look here for ideas and evidence for how to design their work to aid coastal communities.

One of the most important research needs identified was the need for research on climate impacts to coastal infrastructure and the resulting changes in land use. Thirty-six of the 50 documents discussed this need (Fig. 4a); stakeholders specifically called for the identification of existing built infrastructure, such as homes and roads which are vulnerable to flooding, so that they can begin to adapt through creating updated building standards or setbacks. They also requested similar information about coastal ecosystems, desiring an analysis of where critical habitats are most in danger of disappearing, in order to prioritize conservation efforts.

A second major research area reported in all states in the study region called for a need to better understand the benefits of natural and nature-based approaches in combating climate impacts, in particular, the use of wetlands for flood protection (Fig. 4b). Further research about the current location of these systems, projected inland migration, as well as how well they work in different geographic, ecological, and bathymetric contexts, is a priority information need to advance more natural and nature-based projects [6].

Third, there was widespread interest across the region in improving understanding of the economic impacts of climate change (Fig. 4c). Tourism, agriculture, and aquaculture are important and in certain cases, iconic, industries in this area. Stakeholders would benefit from more information about the impact of climate change on coastal

recreational activities, better projections about the future of different fisheries, and ways to minimize these negative impacts. Additionally, information on heat-resistant crops and other climate-resilient strategies would help farmers adapt practices given climate change. These data would benefit all these coastal industries so that they can continue to play an important role in the regional coastal economy.

Related, coastal communities desired cost-benefit analyses of adaptation strategies (Fig. 4c). Stakeholders are interested in the economic value of protection offered by different natural solutions. For example, a separate study which focused specifically on the costs and benefits of natural and nature-based defenses, states a need for better estimates of maintenance costs and the value of additional services, such as carbon sequestration, of different defense options [13]. Stakeholders recognize that infrastructure along the coast in many cases is already vulnerable to sea level rise and flooding from extreme events; cost-benefit analyses such as these allow communities to weigh the options of fortifying existing structures versus infrastructure abandonment or setbacks when making crucial management decisions. This has prompted discussions about organized retreat which is a particularly fascinating finding because it demonstrated that there was regional interest in considering retreat even though retreat received sporadic support from homeowners after Superstorm Sandy [33].

In addition, there are three major themes that are not specifically science research needs but the understanding of which is central to assisting coastal communities. First, there is a crucial role for government funding and authorship in many of these stakeholder participatory efforts, thus the role of government is key to ensuring the needs of stakeholders are heard. Second, communities are looking to solution-driven research to support mitigation efforts, particularly natural infrastructure. And third, there is a lack of specific social science research needs being asked for by stakeholders despite a widespread call for this type of research by organizations both in and outside this study.

The first major finding from this analysis is the important role that government agencies and affiliate programs play in coastal resilience planning. One major role played by the government was funding these stakeholder needs assessments; of the 50 documents analyzed, government agencies funded a third of the documents with acknowledged funding sources (Table 1). NOAA was by far the largest funder with seven documents funded directly by offices of NOAA, and two documents funded by state Sea Grant programs which receive federal funding from NOAA. Another important role of government agencies was that agency employees helped write or produce the majority of these documents. There was a total of 94 authors contributing to 50 documents, over 50% of the authors were from government agencies (Table 1). Of these, the largest contribution came from 8 state Sea Grant programs either as a main author or as part of a broader coalition. Both NOAA and Sea Grant programs are clearly important supporters of state development of coastal resilience plans and projects and without their support (financially and via expertise), communities would have a more difficult time developing such assessments. Future research should include an evaluation of research needs suggested by government agencies themselves, such as the Army Corp of Engineers, which meet both the "stakeholder" definition as well as that of an end-user. The North Atlantic Coastal Climate Assessment is a comprehensive starting point [34] and suggests that some research priorities include improved research and collection of pre- and post-storm data and better design guidance for natural and nature-based features.

A second key finding is that stakeholders across the region expressed interest in solution-driven research to aid mitigation plans, of which natural infrastructure is a quintessential example. This suggests there is a strong interest in implementing more projects using these approaches instead of the traditional gray/built approaches that are typical of coastal resilience efforts. This may be because communities recognize the multiple benefits provided by natural and nature-based approaches that include being more resilient to major storms [35], being more cost-effective to build [7], and supporting other ecosystem functions such as habitat [36] and carbon sequestration [37]. This call for more information on natural and nature-based solution-driven research approaches highlights a change in the ways communities are thinking about how to increase resilience as compared to a decade or two ago when natural and nature-based features were not a part of the conversation and in most cases only more traditional built approaches were considered.

Third, it appears that there is a fundamental, critical gap in the information needs identified; while documents called for the support and integration of social science information, there was minimal call for social science research needs themselves beyond economics to support many of the critical decisions regarding coastal retreat or other alternative resilience strategies. The stated natural science, engineering, and economic needs were numerous and very specific, whereas other social science needs beyond economics were rarely mentioned and when they were, they were too general to help guide future research projects. Of the 50 documents, two broadly called for better understanding of the social and socio-economic impacts of climate change (Docs. 3, 19) and two requested information on the social response to sea level rise (Docs. 6, 24). More specifically, documents asked for research on social factors which might influence the decision to implement natural infrastructure projects (Docs. 5, 45) and the human relationship to several bodies of water (Docs. 29, 32). However, other social science dimensions, such as the historical and cultural connections people have with particular locations and the equity of certain adaptation strategies, were not identified as research needs. These types of social factors are crucial to ensure the success of certain adaptation measures, such as coastal retreat and relocation from rising sea level, yet are often not incorporated into traditional cost-benefit analysis. For example, Dorchester County, Maryland, USA is predicted to lose over half of its land to SLR by 2100 [38]; for families that have lived on the same land for generations, the decision to leave is not as simple as cost and cannot easily be monetized. The 4th National Climate Assessment points to the importance of including these human dimensions in coastal decision making, in particular, the inclusion of social science and societal factors to understand the cultural and social aspects of resilience, mitigation, and retreat [39]. One possible explanation for this gap is a dearth of social scientists contributing to the reports analyzed; social science expertise was not amongst the disciplines typically included. Another explanation is that communities may not be able to express social science needs as clearly as they might biophysical needs or think about social science needs as part of scientific information needs. Greater social science literacy amongst experts crossing disciplines would allow for greater specificity in the translation between needs articulated by stakeholders and incorporation into impact, planning, and adaptation reports.

It is useful to note that our study found some similar results to the climate resilience stakeholder needs assessment conducted by Dilling et al. (2015) [28], which focused on needs pertaining to water decisions in three U.S. regions: the Carolinas, the Great Lakes, and the Intermountain West. In both our study and Dilling et al. (2015) [28], improved collaboration and communication were both common areas of need. Similar to the Northeast, stakeholders in the Carolinas and Great Lakes regions expressed the need for collaboration between states which share coasts and/or watersheds given the inter-jurisdictional nature of these resources. Additionally, there already exists a significant amount of relevant information about the impacts of climate change; however, this needs to be better translated into useable formats for stakeholders to incorporate it into decision-making.

A major difference was the emphasis on improved emergency management communication before, during, and after extreme events, which was a focus in the Northeast region but not the other three regions. This result is likely because, in the Western regions of Intermountain West and Great Lakes, there is a focus on chronic, longer-term water issues related to precipitation patterns and not episodic, extreme events like hurricanes and Nor'easters faced by the Northeast. Interestingly, the discussion of using natural infrastructure to mitigate

flooding impacts due to climate change was unique to Northeastern states despite the fact that wetlands can have important disaster risk reduction benefits both along coastal and inland areas [40]. This is possibly due to the spotlight on sea level rise in coastal communities. Despite these differences, it is clear that a common framework of stakeholder needs exists across regional boundaries. Efforts to tackle adaptation needs would be furthered by bringing stakeholders from across regions together to discuss shared research needs and solutions.

Future work would benefit from in-person interviews of key stakeholder groups throughout the region as well as workshops and surveys to directly capture the current needs of a wider group. This would ensure that a greater diversity of voices is heard, especially those that may not have been captured in these documents such as socially vulnerable communities. However, as far as the authors are aware, this is the first study to complete a comprehensive analysis of stakeholder needs to manage coastal climate impacts in the Northeast U.S. The results provide guidance on the research needs of coastal communities to support their decision-making. The hope is that this study will improve the involvement and funding efforts by key players as well as begin to bridge the gap between communities and researchers to start a dialogue aimed at generating use-inspired science and improved coastal resiliency planning.

Declaration of competing interest

None.

CRediT authorship contribution statement

Grace D. Molino: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Melissa A. Kenney:** Conceptualization, Methodology, Resources, Writing - review & editing, Supervision. **Ariana E. Sutton-Grier:** Conceptualization, Resources, Writing - review & editing, Supervision.

Acknowledgments

G.D. Molino was partially supported by the Earth Science Systems Interdisciplinary Center at the University of Maryland and NOAA National Ocean Service, Ernest F. Hollings Undergraduate Scholarship. M. A. Kenney and A.E. Sutton-Grier were partially supported by the National Oceanic and Atmospheric Administration (NOAA) Grant NA14NES4320003 (Cooperative Institute for Climate and Satellites – CICS) at the University of Maryland /ESSIC. M.A. Kenney received partial support from Maryland Sea Grant under award NA18OAR4170070 Subaward R/CL-2 from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpol.2020.103987.

References

[1] P.A. Sandifer, A.E. Sutton-Grier, Connecting stressors, ocean ecosystem services, and human health, Nat. Resour. Forum 38 (2014) 157–167, https://doi.org/10.1111/1477-8947.12047.
[2] J.M. Melillo, T, T.C. Richmond, G.W. Yohe, Climate Change Impacts in the United States, The Third National Climate Assessment, 2014, https://doi.org/10.7930/j0z31WJ2.
[3] W.V. Sweet, J. Park, From the extreme to the mean: acceleration and tipping points of coastal inundation from sea level rise, Earth's Futur 2 (2014) 579–600, https://doi.org/10.1002/2014EF000272.
[4] H.R. Moftakhari, A. Aghakouchak, B.F. Sanders, R.A. Matthew, Earth's Future Special Section: Cumulative Hazard: the Case of Nuisance Flooding Earth' S Future, Earth's Futur, 2017, pp. 214–223, https://doi.org/10.1002/eft2.186.
[5] E.B. Barbier, A global strategy for protecting vulnerable coastal populations, Science 80 (345) (2014) 1250–1251, https://doi.org/10.1126/science.1254629.
[6] A.E. Sutton-Grier, K. Wowk, H. Bamford, Future of our coasts: the potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems, Environ. Sci. Pol. 51 (2015) 137–148, https://doi.org/10.1016/j.envsci.2015.04.006.
[7] A.E. Sutton-Grier, R.K. Gittman, K.K. Arkema, R.O. Bennett, J. Benoit, S. Blitch, K. A. Burks-copes, A. Colden, A. Dausman, B.M. DeAngelis, A.R. Hughes, S. B. Scyphers, J.H. Grabowski, Investing in natural and nature-based infrastructure: building better along our coasts, Sustainability 10 (2018) 1–11, https://doi.org/10.3390/su10020523.
[8] C.C. Shepard, C.M. Crain, M.W. Beck, The protective role of coastal marshes: a systematic review and meta-analysis, PloS One 6 (2011), https://doi.org/10.1371/journal.pone.0027374.
[9] F. Ferrario, M.W. Beck, C.D. Storlazzi, F. Micheli, C.C. Shepard, L. Airoldi, The effectiveness of coral reefs for coastal hazard risk reduction and adaptation, Nat. Commun. 5 (2014) 1–9, https://doi.org/10.1038/ncomms4794.
[10] K.B. Gedan, M.L. Kirwan, E. Wolanski, E.B. Barbier, B.R. Silliman, The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm, Climatic Change 106 (2011) 7–29, https://doi.org/10.1007/s10584-010-0003-7.
[11] E.B. Barbier, I.Y. Georgiou, B. Enchelmeyer, D.J. Reed, The value of wetlands in protecting southeast Louisiana from hurricane storm surges, PloS One 8 (2013) 1–6, https://doi.org/10.1371/journal.pone.0058715.
[12] G. Guannel, K. Arkema, P. Ruggiero, G. Verutes, The power of three: coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience, PloS One 11 (2016) 1–22, https://doi.org/10.1371/journal.pone.0158094.
[13] S. Narayan, M.W. Beck, B.G. Reguero, I.J. Losada, B. Van Wesenbeeck, N. Pontee, J.N. Sanchirico, J.C. Ingram, G.M. Lange, K.A. Burks-Copes, The effectiveness, costs and coastal protection benefits of natural and nature-based defences, PloS One 11 (2016) 1–17, https://doi.org/10.1371/journal.pone.0154735.
[14] K.K. Arkema, G. Guannel, G. Verutes, S.A. Wood, A. Guerry, M. Ruckelshaus, P. Kareiva, M. Lacayo, J.M. Silver, Coastal habitats shield people and property from sea-level rise and storms, Nat. Clim. Change 3 (2013) 913–918, https://doi.org/10.1038/nclimate1944.
[15] J. Lubchenco, Entering the century of the environment: a new social contract for science, Science 279 (1998) 491.
[16] T.U. Wall, E. McNie, G.M. Garfin, Use-inspired science: making science useable by and useful to decision makers, Front. Ecol. Environ. 15 (2017) 551–559, https://doi.org/10.1002/fee.1735.
[17] J.M. Sullivan, E.B. Cerny-Chipman, A.A. Rosenberg, J. Lubchenco, Bridging the science-policy interface: adaptive solutions in the anthropocene, in: Conserv. Anthr. Ocean Interdiscip. Sci. Support Nat. People, Academic Press, 2017, pp. 3–22, https://doi.org/10.1016/B978-0-12-805375-1.00001-5.
[18] R. Moss, P.L. Scarlett, M.A. Kenney, H. Kunreuther, R. Lempert, J. Manning, B. K. Williams, J.W. Boyd, E.T. Cloyd, L. Kaatz, L. Patton, Decisions support: connecting science, risk perception, and decisions, in: Clim. Chang. Impacts United States Third Natl. Clim. Assess., U.S. Global Change Research Program, 2014, pp. 620–647, https://doi.org/10.7930/J0H12ZXG.On.
[19] M. Carmen-Lemos, C.J. Kirchhoff, V. Ramprasad, Narrowing the climate information usability gap, Nat. Clim. Change 2 (2012) 789–794, https://doi.org/10.1038/nclimate1614.
[20] A.M. Meadow, D.B. Ferguson, Z. Guido, A. Horangic, G. Owen, T. Wall, Moving toward the deliberate coproduction of climate science knowledge, Weather. Clim. Soc. 7 (2015) 179–191, https://doi.org/10.1175/WCAS-D-14-00050.1.
[21] E.M. Hamin, Y. Abunnasr, M.R. Dilthey, P.K. Judge, M.A. Kenney, P. Kirshen, T. C. Sheahan, D.J. DeGroot, R.L. Ryan, B.G. McAdoo, L. Nurse, J.A. Buxton, A. E. Sutton-Grier, E.A. Albright, M.A. Marin, R. Fricke, Pathways to coastal resiliency: the adaptive gradients framework, Sustainability 10 (2018), https://doi.org/10.3390/su10082629.
[22] Office for Coastal Management (NOAA), Introduction to Stakeholder Participation, 2015. https://coast.noaa.gov/data/digitalcoast/pdf/stakeholder-participation.pdf.
[23] L. Dilling, M. Carmen-Lemos, Creating useable science: opportunities and constraints for climate knowledge use and their implications for science policy, Global Environ. Change 21 (2011) 680–689, https://doi.org/10.1016/j.gloenvcha.2010.11.006.
[24] J. Saldaña, The Coding Manual for Qualitative Researchers, third ed., SAGE, 2015.
[25] L. Dilling, J. Berggren, What do stakeholders need to manage for climate change and variability? A document-based analysis from three mountain states in the Western USA, Reg. Environ. Change 15 (2014) 657–667, https://doi.org/10.1007/s10113-014-0668-y.
[26] R.K. Yin, Case Study Research: Design and Methods, third ed., Sage Publications, Inc., 2003.
[27] G.A. Bowen, Document analysis as a qualitative research method, Qual. Res. J. 9 (2009) 27–40, https://doi.org/10.3316/QRJ0902027.
[28] L. Dilling, K. Lackstrom, B. Haywood, K. Dow, M. Carmen-Lemos, J. Berggren, S. Kalafatis, What stakeholder needs tell us about enabling adaptive capacity: the intersection of context and information provision across regions in the United States, weather, Clim. Soc. 7 (2015) 5–17, https://doi.org/10.1175/WCAS-D-14-00001.1.
[29] R. Bierbaum, J.B. Smith, A. Lee, M. Blair, L. Carter, F.S.C. Iii, P. Fleming, S. Ruffo, M. Stults, A comprehensive review of climate adaptation in the United States: more than before, but less than needed, Mitig. Adapt. Strategies Glob. Change 18 (2013) 361–406, https://doi.org/10.1007/s11027-012-9423-1.
[30] K. Frank, I. Chen, Y. Lee, S. Kalafatis, T. Chen, Y. Lo, M.C. Lemos, Network location and policy-oriented Behavior : an analysis of two-mode networks of coauthored

documents concerning climate change in the great Lakes region * ,†, Pol. Stud. J. 40 (2012) 492–515.
[31] Qsr International, NVivo 11 Pro for Windows: Getting Started Guide, (n.d.) 1–49. doi:10.15713/ins.mmj.3.
[32] L. Bickman, D.J. Rog (Eds.), Handbook of Applied Social Research Methods, Sage Publications, Inc., 1998.
[33] R. Freudenberg, E. Calvin, L. Tolkoff, D. Brawley, Buy-In for Buyouts: the Case for Managed Retreat from Flood Zones, 2016. Cambridge.
[34] US Army Corp of Engineers, North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk, 2015. https://www.army.mil/e2/c/downloads/379567.pdf.
[35] R.K. Gittman, A.M. Popowich, J.F. Bruno, C.H. Peterson, Marshes with and without sills protect estuarine shorelines from erosion better than bulkheads during a Category 1 hurricane, Ocean Coast Manag. 102 (2014) 94–102, https://doi.org/10.1016/j.ocecoaman.2014.09.016.
[36] R.K. Gittman, C.H. Peterson, C.A. Currin, F.J. Fordie, M.F. Piehler, J.F. Bruno, Living shorelines can enhance the nursery role of threatened estuarine habitats, Ecol. Appl. 26 (2016) 249–263, https://doi.org/10.1890/14-0716.
[37] J.L. Davis, C.A. Currin, C.O. Brien, C. Raffenburg, A. Davis, Living shorelines: coastal resilience with a blue carbon benefit, PloS One (2015) 1–18, https://doi.org/10.1371/journal.pone.0142595.
[38] T. Horton, S. Cannon-Brown, D. Harp, High Tide in Dorchester, Bay Journal Films, 2017. USA, https://vimeo.com/252911985.
[39] E. Flemming, J. Payne, W. Sweet, M. Craghan, J. Haines, J.F. Hart, H. Stiller, A. E. Sutton-Grier, Coastal effects, in: D.R. Reidmiller, C.W. Avery, D.R. Easterling, K. E. Kunkel, K.L. Lewis, T.K. Maycock, B.C. Stewart (Eds.), Impacts, Risks, Adapt. United States Fourth Natl. Clim. Assess., Volume II, U.S. Global Change Research Program, Washington, DC, USA, 2018, pp. 322–352, https://doi.org/10.7930/NCA4.2018.CH8.
[40] J. Endter-Wada, K.M. Kettenring, A.E. Sutton-Grier, Sustaining wetlands to mitigate disasters and protect people, Front. Ecol. Environ. 16 (2018) 431, https://doi.org/10.1002/fee.1959.