Coastal Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ucmg20

Utilizing an End-User Driven Process to Identify and Address Climate-Resilience Tool Needs in the U.S. Gulf of Mexico

Renee C. Collini, Mikaela C. Heming, Christina Mohrman, Melissa T. Daigle, Casey A. Fulford, Celina L. Gauthier Lowry, Marian D. Hanisko, Steven Mikulencak, Rhonda Price, Kristin R. Ransom, Tracie T. Sempier, Christine Shepard, William V. Underwood, Mark S. Woodrey, Marina D. Denny & Eric Sparks

To cite this article: Renee C. Collini, Mikaela C. Heming, Christina Mohrman, Melissa T. Daigle, Casey A. Fulford, Celina L. Gauthier Lowry, Marian D. Hanisko, Steven Mikulencak, Rhonda Price, Kristin R. Ransom, Tracie T. Sempier, Christine Shepard, William V. Underwood, Mark S. Woodrey, Marina D. Denny & Eric Sparks (2022) Utilizing an End-User Driven Process to Identify and Address Climate-Resilience Tool Needs in the U.S. Gulf of Mexico, Coastal Management, 50:2, 197-214, DOI: 10.1080/08920753.2022.2022975

To link to this article: https://doi.org/10.1080/08920753.2022.2022975

© 2022 The Author(s). Published with license by Taylor & Francis Group, LLC

Published online: 24 Jan 2022.

Submit your article to this journal

Article views: 718

View related articles

View Crossmark data

Citing articles: 1 View citing articles

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=ucmg20

COASTAL MANAGEMENT
2022, VOL. 50, NO. 2, 197–214
https://doi.org/10.1080/08920753.2022.2022975

Taylor & Francis
Taylor & Francis Group

OPEN ACCESS Check for updates

Utilizing an End-User Driven Process to Identify and Address Climate-Resilience Tool Needs in the U.S. Gulf of Mexico

Renee C. Collini[a,b,c], Mikaela C. Heming[a,b], Christina Mohrman[d], Melissa T. Daigle[e], Casey A. Fulford[f], Celina L. Gauthier Lowry[g], Marian D. Hanisko[h], Steven Mikulencak[g], Rhonda Price[i], Kristin R. Ransom[h], Tracie T. Sempier[b], Christine Shepard, William V. Underwood[k], Mark S. Woodrey[c], Marina D. Denny[a] and Eric Sparks[b,c]

[a]School of Human Sciences, Mississippi State University, Starkville, Mississippi, USA; [b]Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Mississippi, USA; [c]Coastal Research and Extension Center, Mississippi State University, Biloxi, Mississippi, USA; [d]Gulf of Mexico Alliance, Ocean Springs, Mississippi, USA; [e]Louisiana Sea Grant Law & Policy Program, Louisiana State University, Baton Rouge, Louisiana, USA; [f]Alabama Association of Conservation Districts, Montgomery, Alabama, USA; [g]Texas A&M AgriLife Extension Service, Houston, Texas, USA; [h]Office for Coastal Management, National Oceanic and Atmospheric Administration, Stennis, Mississippi, USA; [i]Coastal Restoration & Resiliency, Mississippi Department of Marine Resources, Biloxi, Mississippi, USA; [j]Gulf Program, The Nature Conservancy, St. Petersburg, Florida, USA; [k]Coastal Section, State Lands Division, Alabama Department of Conservation and Natural Resources, Spanish Fort, AL, USA; [l]Department of Wildlife, Fisheries, and Aquaculture, Mississippi State University, Mississippi, USA

ABSTRACT

Many tools have been generated in recent decades to support decision-makers in understanding and acting on climate science, causing stakeholders in the Gulf of Mexico (Gulf) to repeatedly express the need for guidance when selecting climate resilience tools. The Climate and Resilience Community of Practice (CoP), Gulf of Mexico Alliance (GOMA), and the Northern Gulf of Mexico Sentinel Site Cooperative (Cooperative) developed and implemented an end-user driven process for tool creation. Research has suggested that integrating target end-users throughout tool development improves the probability a tool will be utilized, yet there is little practical guidance available on how to successfully design and implement an end-user driven tool development process. In this study, an end-user driven process and results from implementing the process during tool development are presented. Challenges, successful approaches, and lessons learned to support future tool development, especially for tools focused on sharing climate science are identified. Guidance is provided on needed expertise, timelines for engagement with target end-users, and methods on how to solicit, analyze, and assimilate end-user needs, perspectives, and priorities into a final product.

KEYWORDS

Climate change; decision-support tools; end-users; tool development; co-development

CONTACT Renee Collini r.collini@msstate.edu School of Human Sciences, Mississippi State University, Starkville, MS, USA.

© 2022 Taylor & Francis Group, LLC

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (http://creativecommons.org/licenses/by-nc-nd/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way.

Introduction

Increasingly, coastal decision-makers across local, state, and federal levels are considering climate hazards when managing built and natural environments (California Environmental Protection Agency et al. 2019; Fish and Wildlife Service 2017; Landrieu and Hebert 2017; NERRS Science Collaborative Program 2018; Sonnenfeld 2019; Southeast Florida Regional Climate Change Compact 2010). Many resources, often dubbed "tools," have been generated in recent decades to support decision-makers in understanding and acting on climate science. While designed to help coastal stewards make more informed decisions, the tools available are so numerous and complex they leave many individuals feeling overwhelmed and unable to find what they need (Gulf of Mexico Alliance 2016; Kidwell et al. 2015; Raub and Cotti-Rausch 2019; Rew PC 2020). Further, these end-users are rarely integrated into the tool development process, resulting in the creation of a multitude of tools that do not fit their needs (Raub and Cotti-Rausch 2019).

Despite the repeated calls to involve stakeholders when developing tools (General Services Administration 2016; Raub and Cotti-Rausch 2019), there is little practical guidance available to researchers, tool developers, or extension and outreach professionals on how to successfully design and implement an end-user driven tool development process. An end-user driven process is an iterative process between the developer and the intended end-users focused on maximizing usability from the perspective of the user (Brancheau and Wetherbe 1990; Dayton 2004; Maniatopoulos et al. 2015; Raub and Cotti-Rausch 2019; Rogers 2003). Research has suggested that integrating target end-users throughout tool development improves crucial factors that potential users consider when deciding whether to use a new tool (Crawford et al. 2002; Dayton 2004; General Services Administration 2016; Raub and Cotti-Rausch 2019). The three most important factors when an end-user decides to use a new tool are perceived relative advantage, compatibility, and complexity (Dayton 2004; Rogers 2003), all of which may be directly and indirectly improved by a well-executed end-user driven process. These processes require transdisciplinary collaborations to ensure that communication science, technology adoption science, and physical sciences are all being effectively integrated. Further, they require an understanding of and relationships with the specific networks, communities, and individuals that make up the target end-users.

Here we describe the end-user driven process we developed, which was built upon the experiences, capacity, and processes of three boundary organizations in the Gulf of Mexico, the Northern Gulf of Mexico Sentinel Site Cooperative (Cooperative), Gulf of Mexico Climate and Resilience Community of Practice (CoP), and the Gulf of Mexico Alliance (GOMA). Their end-user driven process is predicated on identifying and meeting the needs of the intended end-users through an intentionally iterative, representative, and adaptive process. We argue that this kind of process is especially important when dealing with particularly complicated or wicked problems such as climate change (Levin et al. 2012). Issues specific to these problems around perception, common understanding, and unique socio-political needs are captured throughout the development of the tool to reduce potential barriers around perceived complexity, relative advantage, and compatibility. The proposed process was tested in the development of a tool to effectively address Gulf stewards' climate resilience tool needs.

Results of this test are presented, and we identify challenges, successful approaches, and lessons learned to support future tool development, especially for tools focused on sharing climate science.

It should be noted that similar to tool development, it has been increasingly recommended to involve stakeholders when conducting climate change research. Co-production has proven successful at participants viewing the resulting science as being more credible, accessible, and more often applied (Arnott, Neuenfeldt, and Lemos 2020; Cooke et al. 2021). However, the co-development process outlined here is separate from co-production of knowledge. A climate resilience tool is a resource to convey or apply knowledge whereas co-production is focused on creating new knowledge or gaining a new, shared understanding (Campbell et al. 2016; Cooke et al. 2021). While some phases may overlap, researchers and tool developers should understand the differences between co-production of knowledge and the co-development of tools prior to applying an approach for stakeholder engagement.

Materials and methods

This section is structured in two parts. The first subsection is a description of how the end-user driven development process was generated and by whom. The next section is a description of the six-phased end-user driven development process. Methods for Phases One-Five of the six-phased process are presented here. It should be noted that Phase Six, *evaluate use and efficacy,* is consistently under-resourced in project budgets/timelines and is the least often studied and implemented phase.

Generating the end-user development process

We convened a team of experts in technology adoption, communication, extension and outreach best practices, and local needs including targeted end-users. Many of our team members were from the Cooperative, GOMA, and CoP. Boundary organizations, like the Cooperative, GOMA, and CoP, are organizations that operate at the interface of decision-making and research (Gulf of Mexico Alliance 2016; Gustafsson and Lidskog 2018; Kidwell et al. 2015) and are well suited to support an end-user driven process because they span a multitude of disciplines from physical to social sciences and include coastal stewards for the built and natural environments. Target end-users in this case included a state natural resource manager, extension specialists that focus on resilience, and a municipal planner. The team's recommendations were used to develop a methodological approach for identifying and addressing stakeholder needs when considering and developing a new climate resilience tool. These experts generated recommendations through in-person meetings, conference calls, and proposal development. Recommendations were synthesized into a multi-phase, end-user driven approach (Figure 1).

End-user driven process development description

The team of experts identified that an intentional effort to build and maintain trust between the tool developers and end-users is a critical aspect of the process across

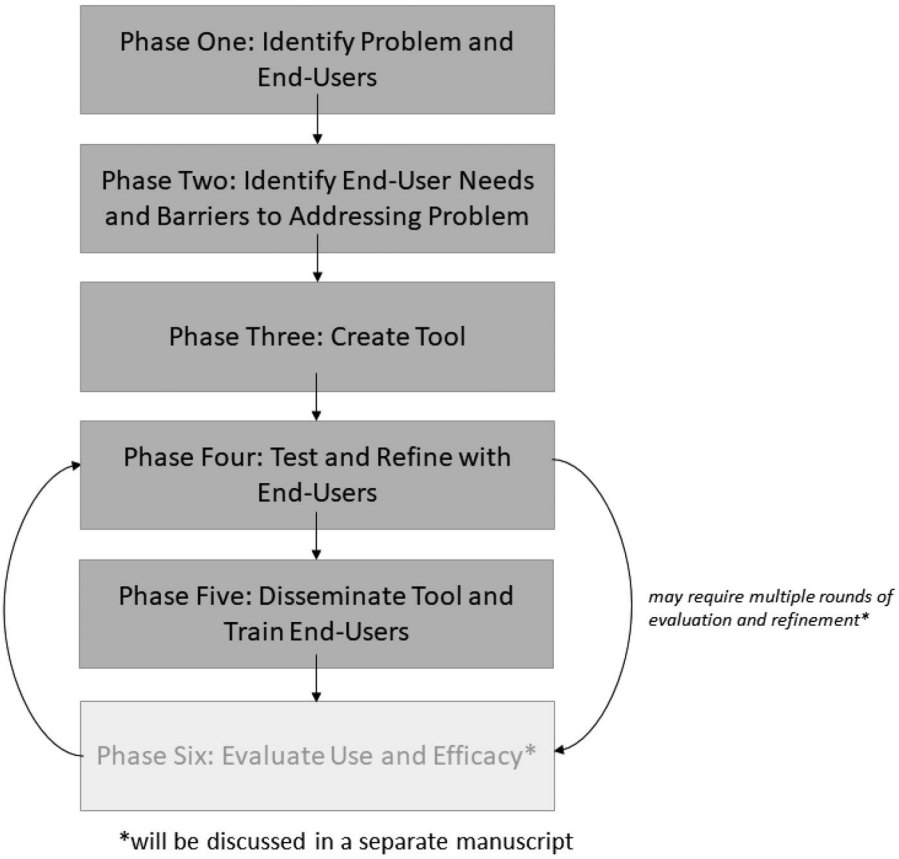

Figure 1. Multi-phased, end-user driven process developed to support tool development.

all phases. Trust is built through open communication and honest two-way dialogue. Utilizing an end-user driven process requires significant investment from the end-users on the front-end of the process with a delayed return on investment. All involved parties need to be cognizant of this fact and ensure that at each step end-users are given an opportunity to express and feel validated in their opinions and have the intended application of their feedback clearly communicated. Further, by leveraging resources outside of peer-reviewed literature such as reports, unpublished qualitative data, workshop notes, meeting proceedings, etc. repetitive demands on end-users' time can be minimized. In the following descriptions of each phase, techniques, approaches, and best practices are identified to facilitate the development of this trust.

Phase One, *identify problem and end-users*, occurs prior to any funding or tool idea development. This phase can be both formal and informal, utilizing common techniques employed during needs assessments (e.g., Balaswamy and Dabelko 2002; Kinzie et al. 2002; Mayfield, Wingenbach, and Chalmers 2005; Rossi, Lipsey, and Henry 2019). The needs assessment should be focused on a specific end-user group or groups and utilized to assess what condition/issue the end-users would like changed. The needs assessment should include preliminary exploration of existing efforts, if any, to reach the desired condition and why they are not effective. The resulting information can

be used to determine the best course of action to address the need. This is the point at which development of a new tool or enhancement of an existing tool may be indicated; however, a new tool should not be considered unless end-users confirm the likelihood of the tool to move the end-users from the current condition to the desired condition. Stewards across the built and natural environment have clearly expressed they are suffering from tool and information overload (Gulf of Mexico Alliance 2016; Kidwell et al. 2015; Mohrman 2017; Raub and Cotti-Rausch 2019); therefore, generating additional tools should be a explicitly indicated and necessary step. Further, it is strongly urged to assess if an already used tool would be suitable for enhancement or could be adapted to meet the end-users needs to reduce duplication and further over proliferation of tools. If it is determined a new tool is necessary, only then proceed with tool development. The Phases outlined below can also be used to modify an existing tool.

Identifying end-users is equally as critical as assessing the needs. It is not possible to move forward into Phase Two without understanding the intended users of a new or updated tool. End-users can vary widely depending on the identified needs and the type of tool to be developed. Examples of end-users can include but are certainly not limited to municipal staff (e.g., planners, emergency management, GIS analysts), state and federal staff (e.g., natural resource managers, policy-makers), elected officials, utility authorities, extension and outreach professionals, non-profits, and residents. Working with boundary organizations is a highly recommended approach for appropriately identifying and building bridges to end-users, which is critical in Phase Two. However, depending on the end-user, the needs, and the potential tool, boundary organizations are only one pathway to identifying end-users. It is critical that tool developers know who they are building a tool for before they begin.

Phase Two, *identify end-user needs and barriers to addressing the problem*, has three distinct elements: design, implementation, and data analysis. These elements work together to ensure the data collected support development of a tool that meets end-user needs. The design element of Phase Two is identifying a strategic process that will comprehensively capture end-user needs and barriers. The strategy needs to account for technology adoption theory by ensuring that data collected will identify ways to enhance perceived relative advantage, compatibility, trialability, and observability and reduce perceived complexity (Dayton 2004; Rogers 2003). Phase Two design should also integrate social science recommendations about how to engage with stakeholders (e.g., NOAA 2007, 2015), which data collection techniques to use (NOAA Office for Coastal Management 2016a; Table 1), and how to structure the information, engagement materials, and messaging (e.g., Akerlof, Covi, and Rohring 2017; Bales, Sweetland, and Volmert 2015; DeLorme, Stephens, and Hagen 2018; National Academies of Science, Engineering, and and Medicine 2017; Neilson 2018; NOAA 2007, 2016b). Phase Two requires the greatest amount of input from end-users with the least amount of observable benefit in the short-term; therefore, it is essential that techniques utilized in design make the end-users feel validated and valued. Related, it is also important in the design to include communication of how the data will be utilized.

The implementation and data analysis of Phase Two requires expertise and sufficient time to effectively and meaningfully execute the design. Implementation should include appropriate time for advertising, utilizing a variety of techniques specifically

Table 1. Common facilitation techniques. Common facilitation techniques used to elicit feedback from meeting participants. Adapted in part from: NOAA Office for Coastal Management. 2016. Planning and Facilitating Collaborative Meetings. 76 pp.

Facilitation Technique	Description	Purpose
Flip Charting	Comments are captured on a pad and posted on an easel that can be viewed by all participants.	Allows participants to see and hear each other's input and creates a record for future review. Also allows participants to recognize they have been heard and clarify misunderstandings.
Brainstorming: Small and Large Group Discussion	Participants share their ideas in small groups of 5-10 people or with all meeting participants.	Gather perceptions and ideas on specific topics. All participants have equal status.
Brainstorming: Roving Flip Charts	Questions are posted on easels around the room. Participants move from one chart to the next in small groups and input is recorded on flip charts by a facilitator. Participants rotate until they have visited all charts.	Gather perceptions and ideas on specific topics, generating as many ideas as possible and building on contributions of different participants. All participants have equal status.
Multi-Voting (Sticky Dot Voting)	A list of alternatives are posted for everyone to see and participants are given stickers (sticky dots) to place next to their preferred option(s).	Prioritizes a list of options, with all participants providing input.
Likert Scale	A question is posed with a rating scale of responses, including a neutral midpoint (e.g., strongly agree, agree, neutral, disagree, strongly disagree).	Measures how participants feel about a specific topic.
Evaluation: Large Group Discussion	Participants share their ideas in response to a short list of questions posed by the facilitator.	Gather feedback after activities (e.g., after a presentation or results of multi-voting) or at the end of a meeting. Encourages engagement and promotes buy-in from participants by providing an opportunity for comments.
Evaluation: Anonymous Survey	Participants complete a list of questions about meeting format, content, and experience.	Allows participants to provide feedback on their experience. Allows facilitators the opportunity to collect feedback, evaluate participant understanding of key concepts, and improve content for future meetings.

designed to best reach target end-users. Successfully reaching target end-users requires familiarity with the end-users and benefits from having someone on the team that has established relationships with the target end-users. One approach for this is to include target end-users on the team that is developing the tool. Implementation and data analysis should be conducted by individuals with expertise in facilitation and/or social science data collection and analysis. It is essential that the collected data are analyzed and transformed into actionable information that can be utilized during tool development. If the data collected from end-users are not utilized, it will reduce the probability the tool will meet end-user needs and it could damage relationships with end-users, further reducing the probability the tool will be utilized or that future feedback will be provided (Fletcher et al. 2015; NOAA Office for Coastal Management 2015; Raub and Cotti-Rausch 2019; Sayce et al. 2013).

Phase Three, *create tool*, is very dependent on the type of tool being developed and could include updating or enhancing an existing tool instead of creating a new tool. Opportunities for end-users to participate during tool creation will further enhance the benefits from an end-user driven process and can ultimately save money and time

on making changes during Phase Four. Phase Three is also when the expertise of extension and outreach professionals is critical. Their ability to apply social science techniques in the communication and application of physical sciences will be needed to cross-walk between the tool developers, end-users, and scientists. Differing terminology and expectations will need to be synergized among different stakeholders, requiring an understanding of the science being integrated into the tool and the limitations/capabilities of the tool. Without this cross-walk there could be mismatches during tool development that may generate barriers to tool use.

Phase Four, *test and refine with end-users*, should also be an in-depth process collecting qualitative and quantitative data. Closely following the methodology of Phase Two, Phase Four consists of the same three elements of approach design, implementation, and data analysis that have the same considerations. The difference with Phase Four is an additional element – tool refinement. After the data have been analyzed, it is critical that resources and time be allotted to make recommended changes based on the end-user experiences and feedback. As discussed earlier, without follow-through on the end-user recommendations, tool developers risk jeopardizing relationships and reduce the probability the tool will be utilized. Additionally, as with the design element in Phase Two, design of Phase Four includes communication of how end-user feedback in Phases Two and Three contributed to the current tool and how input from Phase Four will be utilized (i.e., describe the tool refinement element).

Phase Five, *disseminate tool and train end-users*, is an ongoing, iterative process reliant on continued resources after the tool is refined and is an essential aspect of tool use. The adage "if you build it they will come" has been proven unfounded regarding tools (Raub and Cotti-Rausch 2019); therefore, ensuring there is time to advertise and train end-users on the tool's function and purpose is critical. Advertising should consider Rogers' Theory of Diffusion on the importance of both common source (e.g., mass media) and inter-personal sources (e.g., colleagues) to the diffusion of new technology throughout a community (Rogers 2003). Additionally, training potential end-users will help reduce barriers to tool use such as perceived complexity, minimal relative advantage, and minimal compatibility.

Results

To meet the needs of end-users with a wide range of climate challenges and technical capacities, a flexible, adaptable platform, Gulf TREE, was developed over the course of three years (mid 2015 – early 2018) using the six-phased end-user driven development process (Table 2). The following section is structured by Phase of development including how it was applied and what information was gained at each Phase.

Phase one – identify problem and end-users

Phase One was accomplished through standing networks and engagement opportunities with the Cooperative, GOMA, and CoP. Methods employed were informal evaluations of existing tools and resources via networking conversations and large-group discussions and informal needs assessments at Cooperative, GOMA, and CoP annual meetings

Table 2. Application of end-user driven process. End-user driven process phases used in the development of Gulf TREE.

End-User Driven Process Phases	Methods Used in the Development of Gulf TREE
Phase One: Identify Problem and End-Users	Cooperative, GOMA, and CoP partner discussions, formal and informal surveys, and feedback on existing products.
Phase Two: Identify End-User Needs and Barriers to Addressing Problem	Designed and implemented workshops to collect data on needs and barriers. Analyzed data to inform resource creation.
Phase Three: Create Resource	Gulf TREE website development by Project Team. Alpha testing with end-users.
Phase Four: Test and Refine with End-Users	Designed and implemented workshops to collect data on resource. Beta testing with end-users. Analysis of end-user feedback and improvements to resource.
Phase Five: Disseminate Resource and Train End-Users	Workshops, trainings, and presentations to socialize Gulf TREE resource and encourage its use.
Phase Six: Evaluate Use and Efficacy	End-User Survey

and during subgroup conference calls. The data collected at the various annual meetings was synthesized, summarized, and prioritized by the CoP Tools Working Group. Working within these boundary organizations, we were able to leverage existing relationships and opportunities to quickly and efficiently identify the needs of end-users.

Our primary end-users were coastal decision-makers at the federal, regional, state, and local level across the built and natural environment. Secondary end-users (coastal researchers, tool developers, and outreach and extension professionals) were also considered in development of the tool as they frequently support the primary end-users when addressing climate issues. The end-users identified a need for guidance when navigating the myriad of available tools and resources around climate resilience to enhance tool selection. When existing resources to support the selection of climate resilience tools were informally evaluated the most prominent gap between those resources and stakeholder needs was a lack of guidance on how to narrow down the available field of climate resilience tools. A list or inventory, even with the additional information on the capabilities and functionality of the tools and models, still required the user to understand the majority of the metadata, including the implications of those metadata for a tool's suitability to the user's needs (Rew PC 2020; Sempier and Swann 2018). Without this guidance, climate resilience tools in the Gulf were improperly or infrequently used. After completion of the tool evaluation and the subsequent needs assessment, a Project Team that included target end-users was established. We worked together to identify fiscal resources to support an end-user driven solution for the problem. A multitude of potential solutions such as on-call-tech support and additional training were considered by end-users on the Project Team as insufficient. The best option was deemed a comprehensive, online, interactive tool that could provide guidance on climate resilience tool selection in real-time.

Phase two – identify end-user needs and barriers to addressing problem

Data collection for Phases Two and Four (*test and refine with end-users*), occurred during two separate rounds of workshops across the Gulf. The workshops were designed and implemented by experienced extension and outreach professionals trained in social

science techniques. Extensive effort was expended to ensure there was representation across all intended end-user sectors at the workshops. Workshop locations spanned the entirety of the Gulf of Mexico to capture regional differences in climate needs and were hosted in collaboration with partners local to each area. Workshops were advertised through existing email listservs, newsletters, webinars, and meetings. For local government staff (e.g., planners, environmental managers, public works, utility employees, etc.), a commonly underrepresented demographic at workshops, direct emails and calls were utilized to further encourage participation. When possible, these invitations were extended from trusted sources on the Project Team.

A variety of methods were employed during the workshops to gather honest and comprehensive input from end-users. Methods to collect data during Phase Two and Phase Four workshops data ranged from facilitated small-group discussions, Likert-scale rating, sticky dot prioritization, large-group discussions, roving small-group discussions, and worksheets (Heming and Collini 2018; Mohrman 2017; Table 1). Additional facilitation strategies such as priming and demonstrations were used to ensure robust data collection (NOAA Office for Coastal Management 2016a; Table 1). For example, Phase Two workshops began by priming the participants to consider their own climate issues, how they might employ climate resilience tools, and factors critical to resilience tool selection. This portion of the workshop was essential to ensure that participants were able to reflect on their own experiences and be able to accurately frame responses to the questions and discussions. Evaluations were also conducted at the close of each workshop to assess the approaches and to evaluate perceptions and effectiveness of the content delivered.

The workshops from Phases Two and Four had representation from across national, state, and local organizations from the built and natural environment. One hundred thirty-two participants from 69 organizations participated in the workshops, with 45 participants attending both workshops. Additionally, evaluation of both workshops demonstrated that 91% of participants agreed or strongly agreed it was a good use of their time, 90% felt it increased their understanding of the project, 55% felt it increased their understanding of climate resilience tools, and 81% planned to use the information and the final tool in development in their future work. In-depth reports summarizing the workshops and their results can be found online (Heming and Collini 2018; Mohrman 2017).

Phase Two workshops were designed to gain an understanding of end-user needs regarding climate change resilience, climate resilience tools, and factors important to tool selection. The goal of the new tool, as framed by the end-users, was to help them narrow the available climate resilience tools to those that will best meet their needs – a "tool for tools." The information collected at the Phase Two workshops provided data on the specific climate issues the end-users were addressing. Further, data were collected on non-climate related issues that are important when selecting climate resilience tools, ranging from comfort with climate terminology through available funding and time resources (Mohrman 2017). Analyses for Phases Two and Four also utilized similar qualitative and quantitative analysis techniques. Quantitative analysis techniques included descriptive statistics for Likert data and prioritization efforts and qualitative analyses included standard coding and sorting of flipchart notes and discussion notes (Heming and Collini 2018; Mohrman 2017). Data from Phase Two

workshops were further synthesized into recommendations and specific actions to be integrated into Phase Three.

The resulting features recommended during Phase Two for the online tool spanned both function and content. Some features were already anticipated to be part of the tool, such as narrowing questions, elements for transparency (e.g., a list of all tools), tool factsheets and other tool-specific outputs, identifying when tools have case studies and help features (tutorials on how to use the tool, help boxes), and multi-platform compatibility (desktop, tablet, smartphone). Features the Project Team had not considered included: ranked tool recommendations, social features (e.g., tool ratings, user forums, ways to contact other users and the developers), log-in feature to save searches, specific navigation features to move through the tool, and ability to see progress throughout the search.

Phase three – create tool

Phase Three integrated information from Phases One and Two to develop an online tool to support end-users attempting to identify an appropriate climate resilience tool for their needs. The tool, dubbed Gulf TREE, was developed in collaboration with a web-design firm and volunteer alpha-testers who were identified during Phase Two workshops. The firm was selected specifically because of their experience and willingness to integrate and adapt to end-user needs and responses. The alpha-testers were engaged at all major decision points around esthetics and functionality. Additionally, a full-time Project Coordinator cross-walked terminology between different sectors of end-users, tool developers, and web designers to ensure clear communication and use of language. A functioning, but not finalized version of Gulf TREE was utilized for the Phase Four workshops.

Gulf TREE's primary function is to narrow the available climate resilience tools through the application of filters. As filters are added, tools that do not meet the criteria of that filter are removed from the list of potential tools for the user. The beta version of Gulf TREE included features specifically requested by stakeholders whenever possible and additional features based on feedback regarding end-user comfort with climate resilience tool concepts. Features added to Gulf TREE as a result of requests by workshop participants included the ability to rate and leave comments on tools and an ability to track progress through the guided search. To improve users' comfort with climate resilience tool concepts while using Gulf TREE, standard terminology was utilized throughout and a glossary was generated, any available tool documentation or tutorials were included in the factsheets, and users were connected to each other through the ability to rate tools and leave comments. Not all end-user suggestions were within the scope of the project mission or budget; therefore, data collected during Phase Two and discussion with target end-users on the Project Team were utilized to identify what features and concepts were critical to include.

Phase four – test and refine with end-users

Phase Four workshops were designed to evaluate a beta-version of the tool and identify how it could be improved. Beta-testing was intentionally scheduled late enough in

development that the online tool's purpose and functionality was clear, but still early enough in development that time and funding remained to allow adaptation based on end-user feedback. Key information obtained during the workshop was identification and prioritization of participants' likes, dislikes, and what they felt was missing from the tool. Additional information was solicited around specific language choices, the functionality, and other details about the tool (Heming and Collini 2018). Phase Four data were manually sorted, coded, and counted to transfer data from three data collection methods (worksheets, multi-voting, & brainstorming) into one interoperable database. An inductive coding approach was applied, and two Project Team members independently reviewed the data to ensure agreement of common themes and priorities. The feedback database built from the Phase Four analysis was narrowed into specific changes for Gulf TREE to enhance usability, relative benefit, and compatibility. The feedback was narrowed by using a basic multi-criteria decision approach based on cost, available resources (e.g., funding, time, expertise), and stakeholder prioritization (Heming 2018).

During Phase Four workshops, end-users identified features and aspects of the online tool to keep, features to change, and missing features. Prioritized features to keep were focused around ease of use, clarity of language and information communication, the large breadth of tools that are up-to date and relevant to climate change, and the variety of filter options addressing multiple climate issues on the coast. Participants prioritized opportunities for improvement that focused on both functionality (e.g., specific navigation requests, layout) and content (e.g., label presentation, specific language choices). Our data collection methods enabled in-depth discussion around particularly complex challenges or issues. The multi-criteria decision approach used to transform these data into an executable plan resulted in 14 distinct changes made to Gulf TREE to enhance usability, benefit, and compatibility (Table 3).

Positive views around functionality and potential benefit to end-users were indicators that Gulf TREE would be utilized among targeted end-users. A majority of the respondents were matched with a climate tool (73%, n = 78) and of those respondents matched with a tool, 44% added additional unsolicited details specifying that their match appeared relevant. Further, when queried if they intended to use Gulf TREE in the future, 89% of respondents agreed or strongly agreed and 90% of respondents intended to contact others about Gulf TREE.

Phase five – disseminate tool and train end-users

After completion of Phase Four, Gulf TREE was widely advertised through the Cooperative, GOMA, and CoP networks coupled with webinars, trainings, and presentations at professional meetings, symposia, and conferences for the different target end-users. The Project Team included 13 individuals representing 12 different organizations who within the first year after tool release conducted webinars, trainings, and presentations to increase awareness of Gulf TREE. Efforts included 25 in-person presentations to over 600 people, five tool expos, six webinars to more than 200 people, and continuous social media, newsletter, and website postings and communications.

Table 3. Changes made to Gulf TREE during phase four. These describe the issues and solutions identified by end-users and prioritized as those to be undertaken using a basic multi-criteria decision approach.

Issue	Solution
Relevant matches are not reachable in Guided or Filtered search when there are no exact matches	Show relevant matches when there are no exact matches and when there are
All slider-format questions are difficult to use (i.e., Level of Effort, Level of Expertise, and Cost)	Have different points on the slider self-select the ones that are 'included' and make more obvious with bolded words and highlighted path along the slider
More information (e.g., Cost) should be on the Tool Landing Page	Add a 'Free', '$', '$$', etc. ranking on each Tool Box in the top-right corner
Users want to be able to leave, or 'bail out', of the Guided Search without completing the search and immediately go to their results	Make the Tool Counter (bottom-left corner of searches) into a 'bail out button' that takes users directly to search results
There is confusion about the difference between 'Exact' and 'Relevant' tool matches on the Tool Landing Page	Add definition to 'Relevant' matches on the Tool Landing Page
The Guided Search and Filtered Search language (with the two side-bar buttons) was confusing	Change 'Help me Search' to 'Guide my Search on Homepage; Change 'Guide my search' to 'Guide new search' on Tool Landing Page; Change 'Top Filters' and 'More Filters' to 'Change Top Filters' and 'Change More Filters'
There is no ability to save or print a list of the search filters applied (not the results)	Add a print page that pulls up a list of active filters
No flexibility in search bar for a tool – users need to type it in exactly in order for it to pop up	Change search bar capabilities so that it can search entire term; required internal list of potential terms for tool searches
Cost is not listed on the Tool Factsheets	Add cost as a category on the Tool Factsheets
The geographic scope / location question is disorganized and hard to use	Add a type-able search bar to search each state's counties/parishes (total of 5 search bars)
Outputs are not listed on the Tool Factsheets	Add outputs as a bulleted list on the Tool Factsheets
Bug in 'Limitations' or 'Target Audience' heading on Tool Factsheets for Firefox browser	Fix bug so that the header (e.g., 'Limitations' or 'Target Audience' stays with the column
Users cannot easily access the glossary while using the search functionality	Add a type-able search box for the glossary terms
Additional functionality is needed to access the Results from the Filtered Search page	Add a 'Results' button under 'Top Filters' and 'More Filters' on the Tool Landing Page and Filtered Search page

Discussion

Developing Gulf TREE through an end-user driven process generated many successes that improve the likelihood that Gulf TREE will be used regularly by Gulf stewards. Roger's Theory of Diffusion identifies that perceived ease of use, compatibility, and applicability are primary predictors of technology use (Dayton 2004; Rogers 2003). By clearly defining the primary end-users and working with the end-users to identify their needs before and during tool development, all three of Roger's attributes (ease of use, compatibility, and applicability) were addressed. Activities in Phases One, Two, Three, and Four enabled integration of key considerations for content and functionality that enhanced ease of use and compatibility. Additionally, applicability of Gulf TREE for the end-users is greater because end-users expanded the scope of the tools included and the information provided about the tools (Heming and Collini 2018). Further, Phase Four provided an opportunity for potential end-users to become more familiar with Gulf TREE, increasing perceived applicability and adaptability. This is reflected in the responses of the workshop participants where 89% of them intended to utilize Gulf TREE. Existing literature also supports the idea that end-user participation before

and during tool development lowers the barriers to application (Haße and Kind 2019; Maniatopoulos et al. 2015; Voinov et al. 2016).

An important follow-up study that should be conducted is to explore Gulf TREE use and perceptions of ease of use, applicability, and compatibility among Gulf TREE target end-users after Gulf TREE was released. These data would provide insight on how intended use and the improvements to Gulf TREE translated to adoption after release.

Best practices

A key best-practice was having a robust analysis approach to transform end-user feedback into action. In each round of workshops, data were collected at seven different locations utilizing a variety of techniques which generated complexity during data processing. It was important to have a transparent, repeatable approach to ensure objective characterization of end-user perceptions and needs. This was particularly critical after the second round of workshops (Phase Four) when qualitative feedback was adapted for quantitative decision-making. We adapted a basic multi-criteria decision approach based on cost, available resources, and stakeholder prioritization to consider return on investment for each potential action and determine the path forward that provided the most benefit to end-users (Heming 2018). This approach was successful at providing a transparent and repeatable process driven by end-user feedback. We highly recommend that such an approach be utilized for others faced with similar decisions.

A second best practice was building in enough time to account for the longer timetable of end-user driven processes. While lending itself to positive outcomes, the end-user driven process requires significantly more time than a traditional top-down approach. Utilizing the end-user driven approach for Gulf TREE required three years. We estimate using a traditional top-down approach would have taken between 18 months to two years. Significant time was given to collecting data from end-users, analyzing the information, and allowing time to integrate the data into the tool. Additional time was also required for the iterative nature of developing tools with end-users (Phase Three) through multiple rounds of review and revision.

Another best practice was conducting Phase Four when there were still sufficient resources and time to make substantial changes to the beta version of Gulf TREE. Conducting the Phase Four work when we did, significantly improved our ability to modify Gulf TREE in response to end-user feedback.

Lessons learned

It is important to consider the many potential sources of influence on tool development that could conflict with or confuse end-user feedback. The most common influences come from those involved directly in the development including the Project Team and hired consultants (e.g., web developers). Influences that may come from the hired consultants include limited skillsets, bias, and/or intention to adapt/mimic an already existing product. The Project Team may also unintentionally bias the process through underestimating necessary time and budget, unconscious biases, or administrative policies. For

example, often it is standing policy when hiring a consultant to hire the lowest bid; however, this often leads to the above issues of limited skillsets and/or intention to adapt an existing product to save on cost. Fidelity to the end-user driven process outlined here (e.g., adherence to social science standards for minimizing biases, adequate budget and timelines, expertise among project leadership to ensure end-user feedback is prioritized) minimized competition with end-user needs during tool development.

Another lesson learned was that though significant resources were available to develop Gulf TREE, there were still time and fiscal limitations. There will never be enough time or money to make all the changes requested by end-users; therefore, it is critical that data collection throughout the end-user driven process enable a thorough understanding of what needs are most critical and that this limitation is communicated to end-users. For example, in the Phase Two and Four workshops a combination of qualitative (e.g., small and large group brainstorming) and quantitative (e.g., prioritization exercises) data collection approaches enabled robust analyses. Additionally, working with practitioners trained in social science methods ensured that the data collected provided a comprehensive understanding of end-user needs and perspectives. Further, the funding was one-time grant funding without resources for long-term maintenance of the site, which could limit the long-term functionality of the tool. Agreements were developed between the three partner organizations for basic website hosting and continual content updates, which will extend the benefits of Gulf TREE. However, any major issues that arise including technology incompatibilities over time are not within the scope of these groups and could lead to reduced or cessation of function. This is a significant limitation and one that should be considered and addressed for future tools.

Implications for coastal management

The results of this work provide clear guidance for a variety of audiences associated with coastal management, including coastal stewards of the built and natural environment (e.g., planners, natural resource managers), boundary organizations, and funders. Significant investment in engaging the end-users led to positive outcomes for intended use. Given the limitations in support after the release of tools, funders should consider investing in maintenance and operations of existing tools in which significant investments have already been made to ensure compatibility, relative benefit, and ease of use among target end-users. This avoids duplication in the creation of new tools that provide similar services and allow for existing tools in which end-users have already invested time and money to be enhanced to support additional functions.

By following this approach, overzealous tool proliferation could also be avoided. Funders requiring end-user driven tool-development processes and/or not having tool development as a mandatory outcome could reduce the overwhelm of tools being developed. Additionally, boundary organizations could find in Phases One or Two tools that are already being used that could simply be modified or enhanced to meet the needs of the end-users. Thoughtful and strategic tool development will reduce waste on tool development that is not producing the desired outcomes.

Finally, stakeholders such as land managers and city planners can also use this information as a litmus test when agreeing to participate in a tool-development process. Target end-users of a tool can determine if in the proposed outline if there is sufficient

time and funding that their input will result in meaningful impact on the proposed tool. This will arm the end-users with information and provide rationale to ask for the process they would like or to not expend their valuable time on activities that have a low probability of a usable and useful outcome.

Conclusions

Using an end-user driven process when developing tools can significantly improve usability, applicability, and compatibility (Crawford et al. 2002; Dayton 2004; Lee 2004; Raub and Cotti-Rausch 2019). Successfully employing an end-user driven process requires an intentional, comprehensive approach such as the one described here (Brancheau and Wetherbe 1990; General Services Administration 2016; Maniatopoulos et al. 2015; Raub and Cotti-Rausch 2019; Whitehouse 1999), more resources than a traditional top-down approach, and a team with a diverse set of skills including representation of the target end-users. This approach was tested in development of Gulf TREE, a climate resilience tool for Gulf coastal stewards. Results of this approach indicate positive perceptions of usability, compatibility, and applicability of the final product with high intent of end-users to utilize Gulf TREE. Additional research needs include follow-up studies on Gulf TREE use and end-user perceptions of Gulf TREE among those that did not participate in the development process.

The end-user driven process outlined above serves as a model for tool developers to integrate stakeholders and end-users into tool development addressing a gap left by recommendations to employ these approaches in existing literature (General Services Administration 2016; Raub and Cotti-Rausch 2019). Though designed for tool development, this process can be adapted when developing a wide variety of resource types for end-users. We provide clear guidance on needed expertise, timelines for engagement with target end-users, and methods on how to solicit, analyze, and assimilate end-user needs, perspectives, and priorities into the final product.

Acknowledgements

We would like to thank the many, many stakeholders across the Gulf of Mexico who gave their time, expertise, and valuable suggestions to improve this tool. We would also like to thank Nicole Love who joined our team briefly to ensure this work would move forward. We would also like to thank the reviewers for their contributions to enhancing the clarity and impact of this work. This work was supported by the EPA Gulf of Mexico Program under Grant MX-00D44016 and Mississippi-Alabama Sea Grant Consortium under Grant A/O-40.

Declaration of interest statement

There have been no financial interest or benefit that has arisen from applications of this work.

ORCID

Renee C. Collini http://orcid.org/0000-0003-4287-5879
Tracie T. Sempier http://orcid.org/0000-0002-0934-4171
Eric Sparks http://orcid.org/0000-0003-1102-2478

References

Akerlof, K., M. Covi, and E. Rohring. 2017. Communicating sea level rise. In *Oxford research encyclopedia of climate change*, 1–50. doi: 10.1093/acrefore/9780190228620.013.417.

Arnott, J. C., R. J. Neuenfeldt, and M. C. Lemos. 2020. Co-producing science for sustainability: Can funding change knowledge use? *Global Environmental Change* 60:101979. doi: 10.1016/j.gloenvcha.2019.101979.

Balaswamy, S., and H. Dabelko. 2002. Using a stakeholder participatory model in a community-wide service needs assessment of elderly residents: A case study. *Journal of Community Practice* 10 (1):55–70. https://rampages.us/pis3/wp-content/uploads/sites/28151/2018/06/participatory-needs-assessment.pdf. doi: 10.1300/J125v10n01_04.

Bales, S. N., J. Sweetland, and A. Volmert. 2015. , How to Talk About Oceans and Climate Change: *A FrameWorks Message Memo*. Washington, DC:. FrameWorks Institute.

Brancheau, J. C., and J. C. Wetherbe. 1990. The adoption of spreadsheet software: Testing innovation diffusion theory in the context of end-user computing. *Information Systems Research* 1 (2):115–43. doi: 10.1287/isre.1.2.115.

California Environmental Protection Agency, California Natural Resources Agency, California Department of Food and Agriculture, California Air Resources Board, & California Strategic Growth Council. 2019. *January 2019 Draft California 2030 Nautral and Working Lands Climate Change Implementation Plan*, 89. https://ww2.arb.ca.gov/sites/default/files/2020-10/draft-nwl-ip-040419.pdf

Campbell, H., D. Vanderhoven, P. Chatterton, A. Dyson, A. Irvine, R. Lupton, R. Pain, W. Shaffi, S. Slatcher, M. Webber, et al. 2016. *Knowledge that matters: Realising the potential of co-production*. N8/ESRC Research Programme. N8 Research Partnership, 70. https://eprints.whiterose.ac.uk/99657/1/Final%20Report%20-%20Co-Production%20-%20%202016-01-20.pdf

Cooke, S. J., V. M. Nguyen, J. M. Chapman, A. J. Reid, S. J. Landsman, N. Young, S. G. Hinch, S. Schott, N. E. Mandrak, and C. A. D. Semeniuk. 2021. Knowledge co-production: A pathway to effective fisheries management, conservation, and governance. *Fisheries* 46 (2):89–97. doi: 10.1002/fsh.10512.

Crawford, M. J., D. Rutter, C. Manley, T. Weaver, K. Bhui, N. Fulop, and P. Tyrer. 2002. Systematic review of involving patients in the planning and development of healthcare. *British Medical Journal* 325 (7375):1263.

Dayton, D. 2004. A model of user-centered technology adoption. *Technical Communication* 51 (2):207–33.

DeLorme, D. E., S. H. Stephens, and S. C. Hagen. 2018. Transdisciplinary sea level rise risk communication and outreach strategies from stakeholder focus groups. *Journal of Environmental Studies and Sciences* 8 (1):13–21. doi: 10.1007/s13412-017-0443-8.

Fish and Wildlife Service. 2017. *Fish and wildlife service sustainability: Chapter 1 Implementing sustainable practices*. https://www.fws.gov/policy/565fw1.pdf

Fletcher, P. J., M. Spranger, J. C. Hendee, Y. Li, M. Clark, and G. A. Kiker. 2015. Decision tools for coral reef managers: Using participatory decision support to integrate potential climate impacts and informed decision making. *Global Ecology and Conservation* 4:491–504. Technology Adoption Folder. doi: 10.1016/j.gecco.2015.09.003.

General Services Administration. 2016. *Climate data user study/results*, 38. Washington DC.

Gulf of Mexico Alliance. 2016. *Governors' Action Plan III*. Ocean Springs, MS

Gustafsson, K. M., and Lidskog, R. 2015. Boundary organizations and environmental governance: Performance, institutional design, and conceptual development. *Climate Risk Management*. 19:1–11. https://www.sciencedirect.com/science/article/pii/S2212096317300049

Haße, C., and C. Kind. 2019. Updating an existing online adaptation support tool: Insights from an evaluation. *Climatic Change* 153 (4):559–67. doi: 10.1007/s10584-018-2166-6.

Heming, M. 2018. *Obtaining, understanding, and using stakeholder feedback* [Oral Presentation]. Alabama-Mississippi Bays and Bayous Symposium, Mobile, AL, November.

Heming, M., and R. C. Collini. 2018. *Beta-testing workshop feedback on a new climate tool decision-support search engine for the Gulf of Mexico*, 41.

Kidwell, D., M. Hanisko, L. Rounds, M. Woodrey, W. Gray, R. Collini, and J. Harper. 2015. *Northern Gulf of Mexico Sentinel Site Cooperative Implementation Plan 2013–2018*. http://masgc.org/assets/uploads/publications/1137/ngom_ssc_implentation_plan_updated_final.pdf

Kinzie, M. B., W. F. Cohn, M. F. Julian, and W. A. Knaus. 2002. A user-centered model for web site design: Needs assessment, user interface design, and rapid prototyping. *Journal of the American Medical Informatics Association* 9 (4):320–30. doi: 10.1197/jamia.M0822.

Landrieu, M. J., and J. P. Hebert. 2017. *Climate action for a resilient New Orleans*. City of New Orleans.

Lee, T.-T. 2004. Nurses' adoption of technology: Application of Rogers' innovation-diffusion model. *Applied Nursing Research : ANR* 17 (4):231–8. doi: 10.1016/j.apnr.2004.09.001.

Levin, K., Cashore, B, Bernstein, s, and Auld, G. 2012. Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Science*. 45:123–152. https://link.springer.com/article/10.1007/s11077-012-9151-0

Maniatopoulos, G., R. Procter, S. Llewellyn, G. Harvey, and A. Boyd. 2015. Moving beyond local practice: Reconfiguring the adoption of a breast cancer diagnostic technology. *Social Science & Medicine (1982)* 131:98–106. doi: 10.1016/j.socscimed.2015.02.036.

Mayfield, C. A., G. J. Wingenbach, and D. R. Chalmers. 2005. Assessing stakeholder needs: Delphi meets the Internet. *Journal of Extension* 43 (3)https://archives.joe.org/joe/2005june/iw1.php.

Mohrman, C. 2017. *Feedback on climate tool use and needs from users across the Gulf of Mexico*. http://masgc.org/assets/uploads/documents/FinalDraft-WorkshopSynthesis.pdf

National Academies of Science, Engineering, and Medicine. 2017. *Communicating science effectively: A research agenda*. Washington DC: The National Academies Press. doi: 10.17226/23674.

Neilson, A. 2018. Considering the importance of metaphors for marine conservation. *Marine Policy* 97:239–43. doi: 10.1016/j.marpol.2018.03.019.

NERRS Science Collaborative Program. 2018. *Summary of reserve management needs*. National Estuarine Research Reserve Science Collaborative. http://nerrssciencecollaborative.org/media/files/Reserve_Management_Needs_Oct2019.pdf

NOAA Office for Coastal Management. 2007. *Introduction to survey design & delivery*. Training Materials. https://coast.noaa.gov/digitalcoast/training/survey-design.html

NOAA Office for Coastal Management. 2015. *Introduction to stakeholder participation*. NOAA Office for Coastal Management. https://coast.noaa.gov/digitalcoast/training/stakeholder.html

NOAA Office for Coastal Management. 2016a. *Planning and facilitating collaborative meetings*. https://coast.noaa.gov/data/digitalcoast/pdf/planning-and-facilitating-collaborative-meetings.pdf

NOAA Office for Coastal Management. 2016b. *Risk communication basics*. https://coast.noaa.gov/digitalcoast/training/risk-communication-guidebook.html

Raub, K. B., and B. E. Cotti-Rausch. 2019. Helping communities adapt and plan for coastal hazards: Coastal zone management program recommendations for national tool developers. *Coastal Management* 47 (3):253–16. doi: 10.1080/08920753.2019.1596674.

Rew PC, R. P. C. 2020. *Second Resilience Ecosystem Workshop (REW2): Meeting Summary and Action Items*, 30. https://static1.squarespace.com/static/5c9d2a9a840b16db131e2eea/t/5ee92d9a4a75271dedaea3fe/1592339867400/REW2_Summary_June2020.pdf

Rogers, E. M. 2003. *Diffusion of innovations*. 5th ed. New York, NY: Free Press.

Rossi, P. H., M. W. Lipsey, and G. T. Henry. 2019. *Evaluation: A systematic approach*. 8th ed. Thousand Oaks, CA: SAGE Publications Inc.

Sayce, K., C. Shuman, D. Connor, A. Reisewitz, E. Pope, M. Miller-Henson, E. Poncelet, D. Monié, and B. Owens. 2013. Beyond traditional stakeholder engagement: Public participation roles in California's statewide marine protected area planning process. *Ocean & Coastal Management* 74:57–66. doi: 10.1016/j.ocecoaman.2012.06.012.

Sempier, T., and Swann, L. 2018. Resilient Gulf Communities: Technical services and information (Mississippi-Alabama Sea Grant Publication MASGP-18-043; Resilient Gulf Communities, p. 4). Mississippi-Alabama Sea Grant Consortium. https://gulfofmexicoalliance.org/wpcontent/uploads/2020/07/GOMA-Tech-Services-FINAL.pdf

Sonnenfeld, S. 2019. Climate emergency resolution advances. *New Haven Independent*, August 2. https://www.newhavenindependent.org/index.php/archives/entry/climate_emergency/

Southeast Florida Regional Climate Change Compact. 2010. https://southeastfloridaclimatecompact.org/

Voinov, A., N. Kolagani, M. K. McCall, P. D. Glynn, M. E. Kragt, F. O. Ostermann, S. A. Pierce, and P. Ramu. 2016. Modelling with stakeholders—Next generation. *Environmental Modelling & Software* 77:196–220. doi: 10.1016/j.envsoft.2015.11.016.

Whitehouse, R. 1999. The uniqueness of individual perception. In *Information design*, Ed. Robert Jacobson, 103–29. Cambridge, MA: MIT Publishing.