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Understanding end-user adoption of an online climate resilience tool

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ABSTRACT

Increasingly, climate researchers are pressured to generate products and tools from their research that support informed decision-making for increased social and environmental resilience. Despite the goal of these tools to integrate climate science into decision-making, little follow-up study is conducted after climate resilience tools are released to understand their effectiveness or application. It is important as limited resources across federal, state, local, and private sectors are invested in the development of climate resilience tools to understand their efficacy at achieving their intended purpose(s). This study leveraged Gulf TREE, a climate resilience tool released in 2018, to assess diffusion and adoption by intended users for intended purposes. Strategic efforts to enhance Gulf TREE via stakeholder engagement during development and positive evaluations prior to tool release, suggested there would be a high rate of adoption across all potential end-users; however, an end-user's intention to use a tool does not guarantee implementation. To expand the body of knowledge around climate resilience tool development, diffusion, and adoption, the authors explored the following research objectives: 1) Assess if end-users are adopting Gulf TREE; 2) Assess if end-users are adopting Gulf TREE for the intended purpose of finding climate change resilience tools; 3) Assess if end-users from different stakeholder categories are adopting Gulf TREE similarly. The study successfully determined that the climate resilience tool, Gulf TREE, was being adopted for its intended purposes. There were not sufficient data for statistical comparisons of use between stakeholder categories; however, general trends provided some indication of different stakeholder types utilizing Gulf TREE with different frequencies and for different purposes. Further, the study identified variability among sectors for how Gulf TREE was integrated into their existing suite of tools, with federal government and Sea Grant stakeholders using Gulf TREE as their primary resource versus academia and non-profit who appeared to have alternatives on which they continued to rely. Finally, this study identified that usability and usefulness may not be good indicators of tool adoption. This study expands the limited peer-reviewed assessments of a climate resilience tool's use. Continuing to develop this body of knowledge will allow for a better understanding of what constitutes a successful or effective climate resilience tool, how to improve current and future climate resilience

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tools, and how to best utilize limited resources when attempting to integrate climate science into decision-making.

1. Introduction

Increasingly, climate researchers are pressured to generate products and tools from their research that support informed decision-making for increased social and environmental resilience. In the U.S., this push stems from a variety of sources and mechanisms, but the most prominent is from climate science funders (e.g., NOAA National Centers for Coastal Ocean Science, NSF Coastlines and People, NOAA RESTORE Science Program). Despite the goal of these tools to integrate climate science into decision-making, little follow-up study is conducted after climate resilience tools are released to understand their effectiveness or adoption (Ernst and Preston, 2020; Gardiner et al., 2019; Haße and Kind, 2019). When climate resilience tools are evaluated, it is commonly based on intended use, objective and subjective assessment of increased knowledge from utilizing the tool one time during a training or facilitated use, or subjective evaluation of the tool's usefulness by target end-users during or after a training or initial introduction (e.g., Fletcher et al., 2015; Stephens et al., 2015). These usability evaluations are crucial for tracking effectiveness; however, it does not capture if a tool is being adopted by the target users. Further, if use is evaluated, results are typically integrated into reports to funders or used internally by the development team. Rarely are these results shared publicly or published in peer-reviewed literature, thereby preventing the development of a robust body of knowledge that enables overarching analyses to understand if and how climate resilience tools are being utilized after they are developed.

As limited resources across federal, state, local, and private sectors are invested in the development of climate resilience tools; it is important to understand their efficacy at achieving their intended purpose(s). Evaluation of if and how climate resilience tools are applied will clarify if they are achieving their intended purpose(s), how they can better achieve their intended purpose(s), and if not being utilized for their intended purpose(s), if they are contributing in unintended ways to the understanding and application of climate science. For example, *Keeping Pace* (Collini et al., 2016) was designed to be a guide on how to select sea-level rise models. Informal evaluation conducted by the authors, specifically use inquiries at conferences, workshops, and one-on-one conversations, revealed that *Keeping Pace* was rarely utilized for that purpose; instead, it was being used to communicate the importance of model selection and key concepts within sea-level rise models. As a result, the authors developed an improved alternative, Gulf TREE. Additionally, advertisement and training on *Keeping Pace* shifted to reflect the application for which it was better suited, thus optimizing the limited resources available for encouraging use of *Keeping Pace*.

Gulf TREE, a search engine to help users select a climate resilience tool that best meets their needs, was released in 2018 in response to requests from stakeholders in the Gulf of Mexico (Gulf). Initial scoping of Gulf TREE was a result of feedback to the Northern Gulf of Mexico Sentinel Site Cooperative (Cooperative), the Gulf of Mexico Alliance (GOMA), and the Gulf of Mexico Climate and Resilience Community of Practice (CoP). All three organizations are comprised of Gulf stakeholders and partners attempting to utilize climate resilience tools. Prioritization exercises, evaluations, and formal and informal feedback solicitations revealed that the partners were overwhelmed by the numerous climate resilience tools available and needed guidance on selecting the most appropriate one (Collini, 2015; Collini et al., in review; GOMA, 2016; Mohrman, 2017).

Strategic efforts to enhance Gulf TREE via stakeholder engagement during development and positive end-user evaluations prior to tool release, suggested there would be a high rate of adoption across all potential end-users (Heming and Collini, 2018; NOAA Office for Coastal Management, 2015; Raub and Cotti-Rausch, 2019); however, intention to use a tool does not guarantee implementation (Rogers, 2003; Taylor and Todd, 1995). Prior to and throughout development, the team queried stakeholders on their needs around climate change resilience, climate resilience tools, and features to include in Gulf TREE. During workshops where intended end-users beta-tested Gulf TREE, 89 % of workshop participants (n = 67) indicated a strong intention to utilize Gulf TREE in their work (Heming and Collini, 2018). Additionally, during beta-testing, 73 % of users found relevant tools, indicating that Gulf TREE was effective (Heming and Collini, 2018). Though these positive results implied Gulf TREE would be used, it did not ensure that Gulf TREE was utilized after its release in 2018.

Given the nature of Gulf TREE – a tool that connects users to other tools – it is critical to clearly describe what is considered adoption, or use, of Gulf TREE. For the purposes of these analyses, the authors defined adoption as an end-user filtering the body of existing climate resilience tools to find a tool for a specific purpose, to better understand the available breadth of climate resilience tools, or to find additional information about a tool with which they were already familiar. Adoption of Gulf TREE is not predicated on the subsequent decision to adopt a tool found via Gulf TREE.

To expand the body of knowledge around climate resilience tool development, diffusion, and adoption, the authors explored the following research objectives:

1 Assess if end-users are adopting Gulf TREE.
2 Assess if end-users are adopting Gulf TREE for the intended purpose of finding climate change resilience tools.
3 Assess if end-users from different stakeholder categories are adopting Gulf TREE similarly.

2. Methods & materials

2.1. Google analytics

Google Analytics is the web-use tracking software utilized for Gulf TREE. It provides the number of visitors, number of visits, length of time a visitor spends on the site, which pages they visit, which pages are the most popular, and visitor's page navigation. The authors used analytics from March 1, 2018 (the week of Gulf TREE release) to February 28, 2019 to establish the number of visitors to the site. These data were further refined to estimate how many of the visitors to the Gulf TREE website may have adopted Gulf TREE for its intended purpose. The authors used the Google Analytics metric "Sessions" to approximate the number of times Gulf TREE was used based on visitor data. Sessions are defined as "…a group of user interactions with your website that take place within a given time frame" (Google, 2019b). The authors used the bounce rate to adjust the number of sessions. A bounced session, as defined by Google Analytics, "…is a single-page session" (Google, 2019a). While an end-user may learn about Gulf TREE without navigating beyond the home page, an end-user cannot use Gulf TREE for any of its intended purposes without interacting with more than one page; therefore, uses were estimated as the number of sessions with the bounces removed.

To estimate the total number of Gulf TREE end-users over the analysis period, this study employed a modified version of the Google Analytic metric "Users" (Google, 2019b). The authors modified the "Users" metric to more accurately estimate potential number of individuals who used Gulf TREE by using the bounce rate to remove individuals who came to the site but only interacted with one page. Google breaks Users data down by "New Visitor" and "Returning Visitor" and provides the

average bounce rate for each category. To integrate this number accurately, the number of visitors identified as a returning visitor were removed from the new visitors to ensure that a returning visitor was not also counted in the new visitor category. The resulting number was then further modified by removing the number of new visitors that "bounced" or did not visit more than one page (Eq 1).

$$\text{Adjusted New Visitors} = (\text{New Visitors} - \text{Returning Visitors}) * (100\ \% - \text{Bounce Rate}) \quad (1)$$

Then the number of visitors classified as returning visitors was adjusted based on bounce rate for returning visitors. This provided an estimated number of returning visitors that likely utilized Gulf TREE (Eq 2).

$$\text{Adjusted Returning Visitors} = \text{Returning Visitors} * (100\ \% - \text{Bounce Rate}) \quad (2)$$

A sum of the two adjusted numbers resulted in a representative estimate of Gulf TREE users.

2.2. Digital survey instrument

To complement the web-use tracking data, this study leveraged a digital survey instrument deployed approximately one year after Gulf TREE release to elucidate details regarding Gulf TREE use and performance. The authors used a sample of convenience coupled with a snowball distribution approach (Creswell, 2014; Vogt and Johnson, 2016). Initial distribution relied on the networks of GOMA, the Cooperative, and CoP. The survey invitation also included a request for the survey to be further distributed among the recipient's own networks. Additionally, a link posted at the top of Gulf TREE encouraged users to fill out the survey. The authors deployed the survey in spring 2019 and it remained open for four weeks. The authors sent reminders after two weeks, three weeks, and on the final day the survey was open. This distribution approach was free, allowed access to potential end-users with whom the surveyor did not have direct contact, and was relatively low effort for the authors, allowing for quick spread of the survey.

Questions from the survey used for this study focused on type and frequency of Gulf TREE use along with information that enabled comparisons between stakeholder categories. See full survey instrument in Supplementary Material (S1). Stakeholder category options in the survey were the same as those utilized during Gulf TREE development: academic, business/consultant, community member/concerned resident, county/local government, federal government, non-profit, Sea Grant, state government, other (Heming and Collini, 2018; Mohrman, 2017). In addition to asking users for what purpose they used Gulf TREE, the survey also asked how often they used Gulf TREE over other resources that had similar functions for finding a new tool or for finding a tool with which they were already familiar (Table 1). Each response was assigned an integer value from 0 "I have not needed…" to 5 "Always". All survey data were tabulated, summarized, and compared for trends across sectors.

Table 1
Response options to the survey question asking respondents how often they use Gulf TREE over other resources that had similar functions for finding a new tool or finding a tool with which they were already familiar.

Response Options
I have not needed to find a climate resilience tool/I have not needed to find information, including access, for a specific climate resilience tool
Never
Rarely
Sometimes
Often
Always

3. Results

3.1. Objective one and two – assess if end-users are using Gulf TREE, and if so, are using it for the intended purpose of finding climate resilience tools

Analysis of web analytics data from March 1, 2018 – February 28, 2019 indicated 1114 likely Gulf TREE users throughout the year with 1938 visits. Adjusted new visitors was 855 and adjusted returning visitors was 258. This results in an average of 1.7 sessions per user. When only looking at the sessions per user for returning users, the average sessions per user was 3.2 sessions per users. Additional metrics provided by Google Analytics indicated that the average pages per session were 4.6 and the average length of session was 4.3 min.

The digital survey instrument had 52 responses total in which respondents self-identified which sector they best represented (Fig. 1). Of the total respondents, 71.2 % (n = 37) were aware of Gulf TREE prior to receiving the survey and 26.9 % (n = 14) of total survey respondents had used Gulf TREE (Fig. 2). Respondents indicated they used Gulf TREE an estimated 43 times over the intervening year. This resulted in an average of three uses per user; almost twice as much as estimated using the web analytics.

The majority of purposes for using Gulf TREE identified by survey respondents were intended by the project designers (Table 2). Two additional purposes identified by respondents were "to present to a partner" and "shared with teachers as part of Climate Change workshop as a possible tool to explore with students."

3.2. Objective three – assess if end-users from different sectors are using Gulf TREE similarly

Of the 14 Gulf TREE users identified from the digital survey instrument, there was at least one representative in each stakeholder category except for concerned citizen (Fig. 2). This is to be expected, as concerned citizens are not target end-users for Gulf TREE. The number of users from each category ranged from one to three, preventing any statistical analyses; however, some trends could be identified. Local/county government respondents (n = 2) had 100 % agreement among different types of uses (Table 2). Both local/county government respondents had used Gulf TREE to increase understanding of available tools and to identify a tool for a specific purpose and they had not used Gulf TREE to learn more about a tool with which they were already familiar. Otherwise, there were a diversity of uses among different stakeholder categories for different purposes (Table 2).

When users responded to the question about how often they used Gulf TREE over other resources that had similar functions for finding a new tool or for finding a tool with which they were already familiar there was also some indication of trends (Table 3). Sea Grant and federal government agency respondents indicated they use Gulf TREE frequently over other similar resources for both categories. Non-profits and academics seem to have a wider variety of resources they utilize to find new tools and to gain information about already known tools.

4. Discussion

4.1. Tool use and its role in climate resilience tool evaluation

The results of this study indicate that Gulf TREE was used by the target end-users for the intended purposes. This is important to document as it demonstrates that the resources invested into Gulf TREE, a climate resilience tool, did achieve their goal. There were 1114 estimated users and 1938 uses with an average session length of 4.3 min and 4.6 pages per session from March 1, 2018 to February 28, 2019 based on Google Analytics. The average pages per session and length support the assumption of use as those rates align with observations of Gulf TREE use during beta-testing and subsequent trainings. During the trainings and beta-testing there were no explicit data collected on time or page

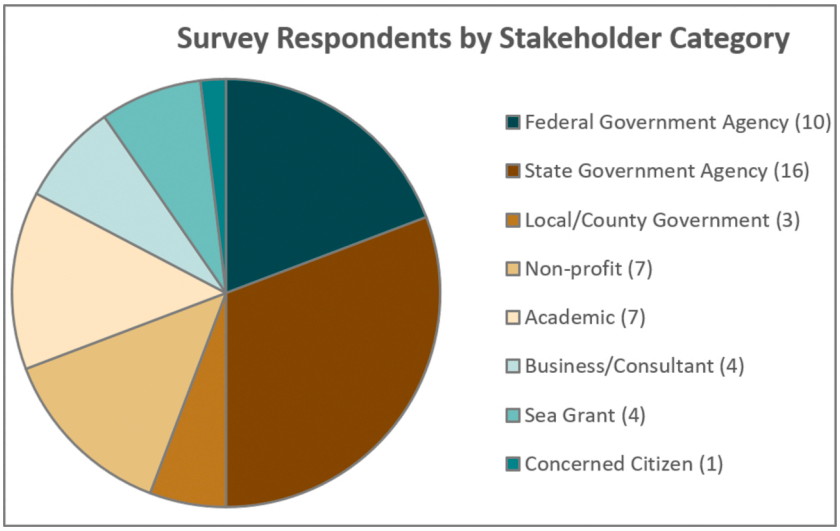

Fig. 1. Respondents to a survey inquiring about Gulf TREE adoption broken down by stakeholder category.

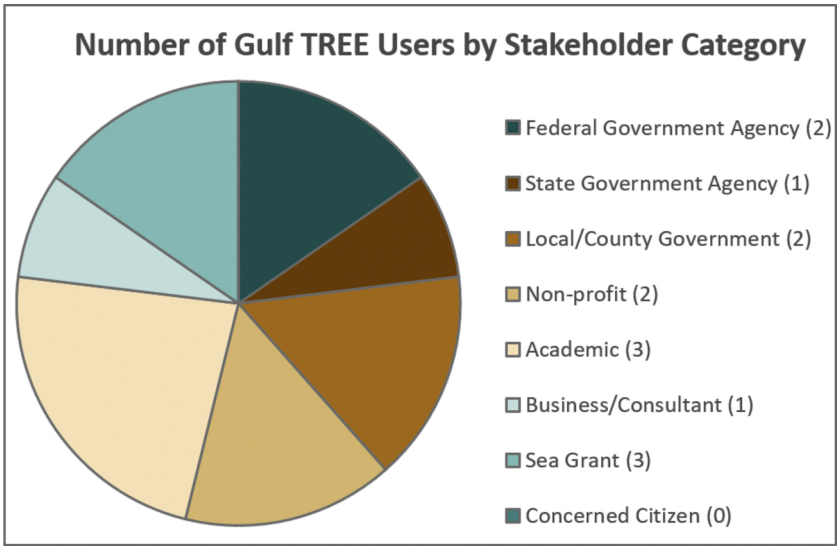

Fig. 2. Number of survey respondents to a digital survey that indicated they had adopted Gulf TREE broken down by stakeholder category.

Table 2
Purposes for which users adopted Gulf TREE as indicated by the survey.

Uses of Gulf TREE	Federal Gov. (n = 2)	State Gov. (n = 1)	County/Local Gov. (n = 2)	Non-profit (n = 2)	Academic (n = 3)	Business/ Consultant (n = 1)	Sea Grant (n = 3)	Total Number of Users	Percentage of Total Users
Understanding what tools are available	1	1	2	0	1	1	1	7	50%
Finding a tool for a specific purpose	0	0	2	1	1	0	2	6	43%
Gain more information on an already known tool	1	0	0	1	0	1	2	5	35%
Other purpose	0	0	0	1	1	0	0	2	14%

views; however, for basic uses trainees were given a max of 10 min to explore the tool and find solutions and generally many were done much sooner than 10 min even the first time using the tool. Further, four or five pages being viewed is an indication that individuals went to the home page, searched, and looked at two or more tool fact sheets, which reflects the use the authors observed during the beta-testing and subsequent trainings.

After Gulf TREE beta-test workshops, 73 % had success finding a relevant climate resilience tool and 89 % of participants indicated they would continue to use Gulf TREE, strong indicators of usability and usefulness. However, only 38 % of survey respondents who had heard of Gulf TREE had used it and only 44 % of respondents who participated in the beta-test workshop had subsequently used Gulf TREE. This supports conclusions from the existing literature on tool adoption that intended use is not a good indicator of adoption for climate resilience tools (Rogers, 2003; Taylor and Todd, 1995). The data also suggest that

Table 3
Respondents were asked how often they use Gulf TREE over other resources with similar functions. Numeric value is on a scale from 0 to 5, where 0 indicates that the respondent did not need to find climate resilience tools and 5 is that they always use Gulf TREE over other similar resources. Average response value provided for each stakeholder category by two intended uses of Gulf TREE.

Sector	Use to find a new tool	Use to find information on a known tool
Federal Government Agency	4	3.5
State Government Agency	3	3
Local/County Government	3	2
Non-profit	1.5	2
Academic	1.33	0.33
Business/Consultant	3	3
Sea Grant	4.33	4

usability, even when coupled with intention to adopt, is not a good proxy for assessing the likelihood that a climate resilience tool is being adopted. The authors stress that evaluation of tools must include assessment of adoption as most current peer-reviewed literature on evaluating climate resilience tool performance is focused on usability (Fünfgeld et al., 2019; Stephens et al., 2015).

Recently, a framework for evaluating climate resilience tools, the Knowledge Product Evaluation (KnoPE) framework, was released (Ernst and Preston, 2020). This framework outlines key aspects of decision-support tools that should be examined to holistically evaluate them and explicitly addresses the need to evaluate the use of climate resilience tools. Their framework was designed for tools that specifically support urban resilience in the face of climate variability and change, though the principles developed in KnoPE apply to broader types of climate resilience tools. KnoPE provides guidance on four dimensions – element overview, scalar assessment, resilience assessment, and use assessment. Use assessment "identifies whether and how [tools] are used… and any outcomes related to their use" (Ernst and Preston, 2020, p. 10). The first two components of the use dimension, whether and how tools are used, is what this study provided. KnoPE currently employs a quality over quantity approach; therefore, while it is positive that Gulf TREE was used and purposes for which it was used were identified, there are not data available for direct comparison to assess performance quantitatively.

Expanding on this point, when assessing use the authors recommend that it be a true measure of adoption or "real use" (Haße and Kind, 2019). Because the majority of the studies include some component of usability assessment, use is often solicited by the evaluators and/or additional facilitation and support is given to the users when using the tool. For example, when Fünfgeld et al. (2019) and Palutikof et al. (2019) were evaluating their tools, they solicited case studies through which tools were used and then users provided feedback. It is important to understand if without additional support climate resilience tools are being adopted through a target audience, particularly if this is how they were intended to be used. Ideally, enough data will be published that funders and tool developers will begin to have benchmarks to quantitatively assess performance. Currently, it is extremely difficult to draw comparisons because many of the existing studies that report quantitative indicators of use employed a variety of metrics such as percentage of communities who used their tool or unadjusted web analytics (Gardiner et al., 2019; Haße and Kind, 2019; Laudien et al., 2019; Palutikof et al., 2019). Further, it is difficult to draw comparisons across these studies as they span multiple countries, population sizes, and governance structure types all of which likely impact adoption as well (Holmes and Butler, 2021; Moser and Ekstrom, 2010; Raub and Cotti-Rausch, 2019). Continuing to build quantitative data on use will allow for development of benchmarks by which to evaluate adoption and determine if additional work is needed to refine or adapt the tool.

4.2. Modifying Google Analytics

Previous studies that used Google Analytics or other similar web tracking data as a measure of awareness or use (e.g., Gardiner et al., 2019; Laudien et al., 2019; Palutikof et al., 2019) did not discuss or apply any modifications to the analytics to better estimate use. In the case of this study, without this adaptation of the data there would have been an estimated 3218 uses and 1937 users. The authors propose a continued exploration of how to apply resources such as Google Analytics to determine if tools are being used. The approach used here, removing single-page or bounce sessions and users, is a more accurate representation of Gulf TREE use because a visitor to the website cannot use Gulf TREE for any of its intended purposes by only going to one page. Removing bounces is not a panacea; it does not a guarantee that all 1114 estimated users utilized Gulf TREE for one of its intended purposes and ad blocking software interferes with counts for Google Analytics. There are resources that can be explored for further enhancing the data provided by the base Google Analytics to better assess if visitors to a site are using the tool for the intended purpose(s). For example, there are software that can video a user's entire session and less robust software that can track if certain buttons on the website are clicked. Additionally, after the period of this study, Google Analytics began providing even more detailed breakdown of visitors and their exploration through a User Explorer. The authors suggest that this is another alternative for more refined assessments of use that could be easily employed to begin building a more robust body of knowledge around quantifying climate resilience tool use.

4.3. Implications of tool use frequency

In addition to the binary yes or no of having used Gulf TREE, this study assessed how often users are applying Gulf TREE. On average, users applied Gulf TREE three times a year based on the survey data, or 1.7 times based on the Google Analytics data. When Google Analytics data are limited to only users who used Gulf TREE more than once, this number jumps to three times per user. The difference between the survey and Google Analytics data could be due to more frequent users of Gulf TREE being more likely to answer the survey and/or the uncertainty associated with the Google Analytics estimates of the number of sessions and users, even after adjusted for bounce rate. Both sources of potential inaccuracy seem likely, indicating average use per Gulf TREE user is probably less than three times a year. Additionally, responses regarding how frequently users turned to Gulf TREE over other similar tools (Table 3) indicate that while adopters needed climate resilience tools more often than they used Gulf TREE, Gulf TREE was still an important resource for finding climate resilience tools.

4.4. Gulf TREE use across different stakeholder categories

The available data on how different stakeholders utilized Gulf TREE was limited ($1 \leq n \leq 3$); however, there were some identifiable trends. The data suggested that stakeholder category may not be a good indicator for which purposes an end-user may apply Gulf TREE (Table 2). The exception was the local/county government respondents ($n = 2$) who had 100 % agreement on using Gulf TREE for understanding the breadth of available tools and to find a tool for a specific purpose. Neither of them utilized Gulf TREE to find information on a tool with which they were already familiar. This could be because local/county government staff already have established pathways to known tools or it could be they did not have any known tools.

Additionally, there was variability between how different stakeholder categories integrated Gulf TREE into their existing process for finding climate resilience tools (Table 3). Users from the non-profit and academic sectors indicated that they rarely used Gulf TREE over other similar tools; therefore, it is possible that these stakeholders rely on a more diverse suite of approaches to find climate resilience tools.

However, federal government and Sea Grant users indicated Gulf TREE was an important resource for them, using it over other resources "Often". This could be an indication that Gulf TREE may not be as useful for some stakeholder categories as it is for others. Climate researchers seeking to develop decision-support tools should consider their target audiences' suite of existing tools carefully and determine if a new tool is warranted or if an existing tool could be refined with the new science.

4.5. Limitations

Key limitations of this research are the survey sample size and potential bias of the survey. The number of responses to the survey (n = 52) and the subsequently lower number of respondents who had adopted Gulf TREE (n = 14) prevented robust determination of trends among different stakeholder categories. Further research should be conducted to understand if the trends viewed between stakeholder categories were an artifact of the small sample size or were indicators of real trends. Leveraging existing networks to share the survey may have biased the sample to those who were already familiar with Gulf TREE. Further, those who already used Gulf TREE may have been more likely to respond to the survey. Additionally, the reminders likely only reached the first round of potential survey respondents that were directly contacted by the Cooperative, GOMA, and the CoP, which may have depressed response rate. It is also impossible to assess how many people saw the survey and did not fill it out so a response rate cannot be calculated. This method also lacked the ability to randomize or strategically sample from various subpopulations within the target end-user demographic. Finally, bias is likely introduced in this method as those who have greater connections to multiple individuals within the networks are more likely to recruit to the survey.

4.6. Key takeaways

A primary takeaway from the study is that Gulf TREE, a climate resilience tool, was adopted by users across multiple sectors; however, there were differences in how different users applied Gulf TREE both in purpose and in their overall climate resilience tool selection. There was variety within and across sectors for what purposes stakeholders used Gulf TREE. Additionally, Gulf TREE appears to not be as critical for nonprofits or academics, but be very useful for federal and Sea Grant users. This could be an indication of the diversity of approaches for finding tools available to some sectors over others.

Another takeaway is that this study contributed to the broader body of knowledge around quantifying climate resilience tool use. Gulf TREE was used an estimated 1938 times by over 1000 different users in its first year. It was estimated that adopters of Gulf TREE used it between two and three times over the course of the year. This was confirmed through an online user survey that demonstrated adoption across the different sectors and frequency of use.

Related, this study provides an example of how Google Analytics can be adjusted to better estimate use of an online climate resilience tool and makes several other suggestions for additional advancements. Continuing to enhance approaches for quantifying and confirming climate resilience tool use is a critical component of effectively and efficiently evaluating success of climate resilience tools.

Finally, highly ranked perceived usability, usefulness, and/or intention to use a tool do not guarantee tool adoption. Gulf TREE had high rates of intention to be used (89 %) and had high rates of frequency with which it provided the desired information (73 %) indicating usefulness and usability, yet only 38 % of potential users had adopted Gulf TREE.

4.7. Next steps

Additional research should include an understanding of how stakeholder engagement facilitated adoption of Gulf TREE and explore additional aspects of the adoption-decision process to better understand drivers of the observed adoption rates. Research indicates that tool use will be greater if stakeholders are engaged throughout the process (GAO, 2014; NOAA Office for Coastal Management, 2015; Raub and Cotti-Rausch, 2019) and Gulf TREE had a robust stakeholder engagement process (Collini et al., 2021; Heming and Collini, 2018; Mohrman, 2017). This positions it well for a study exploring the link between adoption and stakeholder engagement. Further, those findings could be linked back to the adoption-decision process as defined by Rogers (2003) to better understand how the progression from knowledge to adoption may be impacted by stakeholder engagement. Additionally, it is critical to understand any relationships that exist between the diffusion and adoption of climate resilience tools and socio-political issues around climate change. Not all communities are prioritizing climate change, which could potentially diminish the use of climate resilience tools. Further, addressing climate change frequently requires funding, expertise, and time outside of existing budgets and capacity (Fünfgeld et al., 2019; Moser and Ekstrom, 2010). For underserved and under resourced communities, this could also diminish the use of climate resilience tools. Finally, the political contention around climate change may also influence how climate resilience is being discussed and pursued (Moser and Ekstrom, 2010), which may also influence the rate of diffusion and adoption of climate resilience tools. Understanding these relationships will help professionals across the climate resilience spectrum better develop and disseminate climate resilience tools.

5. Conclusion

This study is a needed contribution to peer-reviewed literature quantifying a climate resilience tool's use and exploring mechanisms by which to accurately capture use. The study successfully determined that the climate resilience tool, Gulf TREE, was being adopted for its intended purposes. There were not sufficient data for statistical comparisons of use between stakeholder categories; however, general trends provided some indication of different stakeholder types utilizing Gulf TREE with different frequencies and for different purposes. Understanding that the tool was used and for its intended purposes provides valuable feedback for assessing if the resources spent developing the tool were well utilized. However, further research is needed to assess what, if any, role stakeholder engagement played in the adoption-decision process to understand the return on the time and money invested for the stakeholder engagement process. Additionally, it is impossible to assess if the number of uses of Gulf TREE over the intervening year or the adoption rate are relatively high or low without additional published data on other climate resilience tools. Continuing to develop this body of knowledge will allow for a better understanding of what constitutes a successful or effective climate resilience tool, how to improve current and future climate resilience tools, and how to best utilize limited resources when attempting to integrate climate science into decision-making.

CRediT authorship contribution statement

Renee C. Collini: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Visualization, Project administration, Funding acquisition. **Mikaela C. Heming:** Conceptualization, Methodology, Validation, Writing - original draft. **Christina F. Mohrman:** Conceptualization, Writing - review & editing. **Melissa T. Daigle:** Conceptualization, Writing - review & editing. **Casey A. Fulford:** Writing - review & editing. **Celina L. Gauthier Lowry:** Writing - review & editing. **Marian D. Hanisko:** Conceptualization, Writing - review & editing. **Steven Mikulencak:** Writing - review & editing. **Rhonda Price:** Writing - review & editing. **Tracie T. Sempier:** Conceptualization, Writing - review & editing. **Christine Shepard:** Writing - review & editing. **William V. Underwood:** Writing - review & editing. **Mark S. Woodrey:**

Conceptualization. **Marina D. Denny:** Conceptualization, Writing - review & editing. **Eric Sparks:** Conceptualization, Writing - review & editing.

Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2021.06.022.

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