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The U.S. Climate Resilience Toolkit: evidence of progress

Edward P. Gardiner[1] · **David D. Herring**[2] · **James F. Fox**[3]

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Abstract The U.S. Climate Resilience Toolkit (toolkit.climate.gov) is a federal website, launched in 2014, designed for state and local decision makers to bolster capacity for resilience to climate-related hazards. We document the development, conceptual foundation, and evolution of this toolkit to illustrate how to put data and tools into context for decision makers, namely by framing climate resilience within risk management, focusing on end users' stories, and engaging directly with users. As this is the first effort to bring together multiple federal agencies' tools, data, and case studies into a decision support platform, most attention has been given to framing climate adaptation and resilience. To that end, we introduce the Steps to Resilience, which incorporate risk management and decision making for climate-related hazards. The site structure and content support that framework. We introduce a five-part "Quality of Relationship" metric that helps our team define and measure success via the website and via engagement with end-users. Our results provide avenues for developers of similar toolkits to meaningfully present climate science to adaptation professionals and the decision makers they serve.

1 Introduction

U.S. Federal agencies have focused since the 1991 Global Change Research Act upon documenting sources and impacts of climate variability and change on local and national assets and populations. Thus, there is increasing awareness at local and regional levels about the need to improve resilience to climate-related hazards. The National Research Council has

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✉ Edward P. Gardiner
ned.gardiner@noaa.gov

[1] Collabralink Technologies, Inc. contractor to Climate Program Office, National Oceanic and Atmospheric Administration, Asheville, NC, USA

[2] Climate Program Office, National Oceanic and Atmospheric Administration, Asheville, NC, USA

[3] UNC Asheville's NEMAC, Asheville, NC, USA

recommended that U.S. Federal agencies provide climate adaptation decision support (2009). They further suggested focusing first and foremost on end-user needs and investing in processes and relationships between those users and information providers.

According to many adaptation specialists and scientists, the best way to prepare for potential future impacts of climate change is to build resilience to present-day climate-related hazards (Mimura et al. 2014). Often, this preparation can pay for itself in saved future costs of recovery after a disaster. Municipal planning that prevents climate-related disasters can bring a benefit-to-cost ratio between 4 and 15 (Healy and Malhotra 2009; Seiger et al. 2017). Despite continued work to understand impacts from climate-related hazards, less effort has focused on translating scientific assessments into actionable information for the individuals, businesses, and communities who have resources or responsibility to respond to shifting probabilities and impacts of climate-related hazards.

Many adaptation professionals in the USA are seeking better coordination among federal partners and interoperability among the tools and data they provide. In November 2014, the National Oceanic and Atmospheric Administration launched the U.S. Climate Resilience Toolkit (CRT; toolkit.climate.gov) and its companion geobrowser, the Climate Explorer, on behalf of the U.S. Global Change Research Program in order to provide that coordination, address the broadening awareness of climate impacts, and translate scientific resources for decision makers bearing the responsibility for those impacts. The website integrates and translates federal resources so end-users of climate information may access and understand the diversity of federal information about climate-related hazards. The CRT targets decision makers such as municipal planners, utility and resource managers, policy leaders, and business owners who want to make their assets (including human populations, natural resources, and infrastructure) resilient to those types of hazards. The goal of the CRT is to improve people's ability to understand and manage climate-related risks and opportunities and to help them make their communities and businesses more resilient to extreme events.

No effort by the U.S. Federal Government on behalf of diverse departments and agencies has previously sought to integrate science assessments, adaptation tools, and practical guidance about adaptation to climate-related hazards. This paper synthesizes the design, implementation, and application of the CRT in order to establish a baseline from which future assessments of this and other toolkits might be measured. First, we outline the planning framework used within the site and engagements that employ the toolkit. Second, we describe the structure and contents of the site itself. Third, we describe efforts to engage with our audience and account for our efficacy through a five-part quality of relationship. The CRT team evolved its content and design based upon evidence gathered from engagement with the site's audience (see Gardiner et al., this volume). Citing those interactions, here we present evidence of progress toward helping decision makers adapt to climate variability and change in the U.S.A. By framing climate resilience, focusing on end users' stories, and engaging directly with new users, we have developed lessons and opportunities for developers of similar toolkits in other nations or regions.

2 Steps to resilience

Prior to launching the CRT website, state and local government decision-makers requested that information be organized around a framework focused on improving resilience to climate-related hazards (Nelson et al. 2007; Hubbard 2009), so we authored one that we call the Steps to Resilience (StR). Resilience ("the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation"; IPCC 2014) emerged from ecosystem ecology (Hollings 1973) but has since become widely adopted in the theory and practice of adaptation related to climate hazards in both biophysical and social-political systems (Nelson et al. 2007; Pike et al. 2010; Wardekker et al. 2010). These two literatures, namely global environmental change and complex human-natural systems, are typically distinct (Nelson et al. 2007). The StR framework is not a specific recipe or process and may be applied across these diverse domains. Rather, it provides the semantic connectivity needed to link important concepts and to bridge otherwise divergent workflows within physical and social sciences. Encapsulating complex problems in simple language is essential to balancing the tension between simplicity and complexity in risk management (Preston and Kay 2010; Jones and Preston 2011).

Each step can be undertaken in a wide variety of ways and in an iterative fashion, but the sequence does capture the critical decisions that must ultimately be made sequentially to move from problem to solution (Explore Hazards, Assess Vulnerability and Risks, Investigate Options, Prioritizing and Plan, and finally Take Action) so that people from diverse professions may participate and understand their respective roles. Rather than prescribe specific methods and procedures, the StR provides diverse stakeholders a framework within which decision support takes place, i.e., defining a problem, quantifying objectives, identifying alternatives, and choosing the best one (Clemen 1997). This framework fits within the eight-step process of Willows and Connell (2003), later adopted by Bierbaum et al. (2014) in the third U.S. National Climate Assessment. The StR incorporates risk management, such as the ISO 31000 standards for risk management planning (International Organization for Standardization et al. 2015). We incorporate guidance from non-governmental organizations and foundations. The Kresge Foundation (2015) emphasizes the Ask-Analyze-Act trifecta. Snover et al. (2007) provided Five Milestones which lump some of our steps and separate others. These are a few of the processes and methods that are compatible with the StR framework. The toolkit website (https://toolkit.climate.gov/#steps) provides a checklist of questions to answer before moving from one step to the next. The following five sections provide the logic underlying the language used on the website.

2.1 Explore hazards

This first step in the StR is most effective when it yields a complete inventory of assets and the hazards they face. Federal data are essential for directing attention toward broad patterns that require detailed study to understand hazards at state, regional, or local levels. Meteorological, geological, or human-caused events become hazards when they threaten or impact humans, natural resources, or assets that people value. The CRT focuses on climate-related hazards such as inland flooding that follows extreme precipitation, rain-on-snow events, early onset snowmelt, and prolonged wet periods (Walsh et al. 2014). Other climate-related hazards include storm surge, nuisance flooding (Sweet et al. 2014), or heat waves (Sarofim et al. 2016). Additional hazards may be *indirectly* related to meteorological conditions, for example if arsonists set forest fires during drought conditions knowing their efforts are more likely to be successful under these climatic conditions (Prestemon and Butry 2010).

2.2 Assess Vulnerability and Risks

The StR accommodates a diverse array of applications. We use the framework and definitions the Government of Australia adopted in their climate change risk evaluation (Allen Consulting

Group 2005) (Fig. 1). Because climate resilience applies to complex human-natural systems (Liu et al. 2007), each resilience team must evaluate diverse assets (each with unique sensitivities), potential impacts, and adaptive capacities in order to evaluate and rank vulnerabilities to hazards. Both vulnerability and risk may be applied in biophysical (White 1974; Tuner et al. 2003) or social (Pike et al. 2010; Wardekker et al. 2010) systems (Tonmoy et al. 2014) and can include both qualitative and quantitative (Schröter et al. 2004) approaches.

The concept of potential impact must especially include diverse methods of valuation. For example, the economic impact of replacing or rebuilding is a straightforward analysis, but public perceptions of space, access to culturally significant landscape features, or ecosystem services all convey value.

Adaptive capacity is a moderating influence on vulnerability (Mimura et al. 2014; Jones et al. 2014; Fig. 1) and can often be altered or managed, so we focus toolkit users on this concept. Vulnerability analyses include spatially explicit models of ecosystem services, transportation and highway planning (FHWA 2012), wildlife management (Glick et al. 2011), and municipal planning (Snover et al. 2007). Each of these domains has its own focal time scales over which hazards are likely to occur and over which adaptive capacity may be measured (Füssel 2007). A system or asset with more adaptive capacity may be more resilient, even in the face of greater exposure, than a system or asset with less adaptive capacity. This is one way of understanding why impoverished communities may be disproportionately vulnerable to climate-related hazards, even within landscapes they share with more affluent communities. Within natural resources, wildlife, and conservation sciences, adaptive capacity often refers to the intrinsic capacity of a system to absorb or respond to change while maintaining ecosystem services (Glick et al. 2011). Regeneration of forest structure over an 80-year time horizon may be sufficient adaptive capacity for landscape managers, but city park managers may require new planting to quickly restore a desired function in a park setting. Within human systems, adaptive capacity refers to actions people can take to address

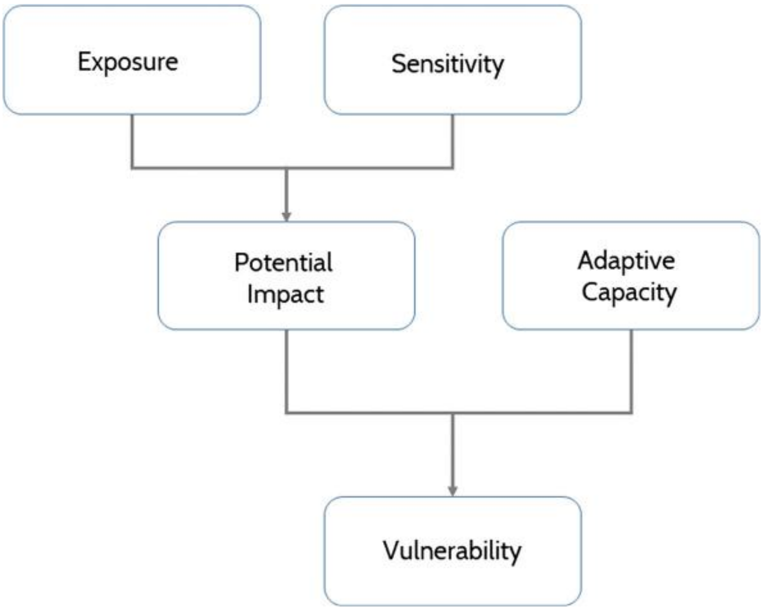

Fig. 1 Vulnerability is a function of many factors, including non-economic values (adapted from Schröter et al. 2004)

disturbances, such as rebuilding damaged property. Evaluating vulnerability across diverse assets and populations clearly involves ranking valuations with distinct metrics and drivers.

"Risk" is the product of both the magnitude of a possible consequence and the probability of that consequence being realized (Fig. 2). A team may formally quantify all of the risks to its assets or develop a qualitative ranking of a set of possibilities. The decision-making team must agree about the relative rank of possible impacts and probabilities of those eventualities in order to focus their efforts in subsequent steps. For instance, a region that may experience a rare but sustained drought that threatens its only drinking water supply could possibly rank this risk of greater concern than a frequently experienced flooding condition within a floodplain where there are no structures present.

2.3 Investigate options

The most pressing vulnerabilities and risks require options for adaptation. Case studies can be used to benchmark success in addressing specific hazards to assets or populations (Grannis et al. 2014). The CRT, like many online toolkits, includes more than 140 case studies for all U.S. regions and sectors. The CRT's case studies all use data, expertise, methods, or other resources from federal agencies. We know of no other database of these federal or federally funded case studies. Other websites and toolkits provide case studies from the private sector and non-profit organizations. Within the United States, the Climate Adaptation Knowledge Exchange (cakex.org) presents a sizeable library of examples; the Georgetown Climate Center (adaptationclearinghouse.org) focuses on adaptation plans and legal options for addressing climate adaptation challenges. By evaluating what others have done and focusing especially on the assets that are at greatest risk, the goal here is to reduce an overwhelming multiplicity of possible approaches into a manageable number.

2.4 Prioritize and Plan

The project management team will determine a set of criteria with which to compare every option being considered. These criteria may include financial costs, environmental or social impacts, esthetics, or other value systems. By ranking the responsiveness of each option relative to these criteria, it becomes possible to gauge the overall feasibility of each action being considered. Ranking

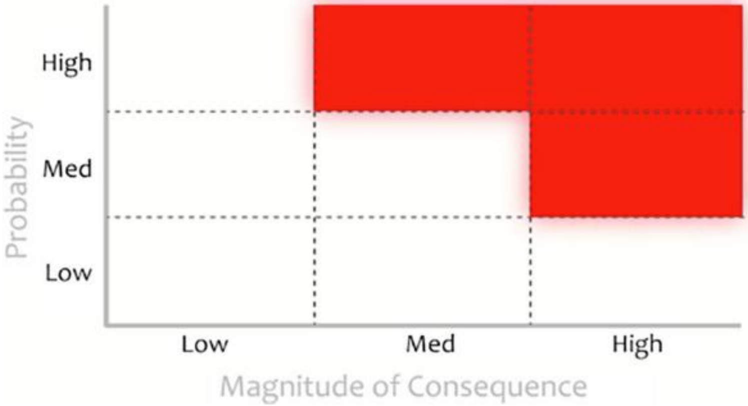

Fig. 2 Risk is a product of the magnitude of a consequence, perceived or quantified, and its probability of occurring

projects with respect to agreed-upon criteria also raises the possibility of considering co-benefits of sets of actions that complement one another. Identifying co-benefits can generate investment by asset managers who would otherwise work independently. Planners in the City of Baltimore, Maryland linked proposed climate resilience actions to their hazard mitigation plan (Baja et al. 2013). The Baltimore team used risk frameworks developed by FEMA and ICLEI (Snover et al. 2007). Baltimore's plan highlights a best practice: find and exploit co-benefits to build support and capacity for distinct management options. Park managers, police, and housing authorities may see benefit in acquiring public parks where today there exist residential or industrial land uses in floodplains. Understanding the co-benefits for each group, such a strategy may be more likely to succeed than if pursued by any one manager acting individually.

2.5 Take action

We encourage project teams to document their progress and share their findings. First and foremost, the team will be able to revise plans to redress any shortcomings as the project moves forward. Second, the documentation will improve the likelihood of success of future efforts that have the same objectives and methods. The CRT team documents case studies so that decision makers facing similar challenges may learn from their peer group using language common to their domain of expertise. Embedding resilience-building within business processes normalizes and broadens adoption of these concepts.

3 Building the toolkit

3.1 Site structure and contents

The site comprises the StR (already described), Case Studies, Tools, Expertise, Regions, and Topics (See Fig. 3). Prior to building the toolkit, we deployed card sorting (Coxon 1999) via

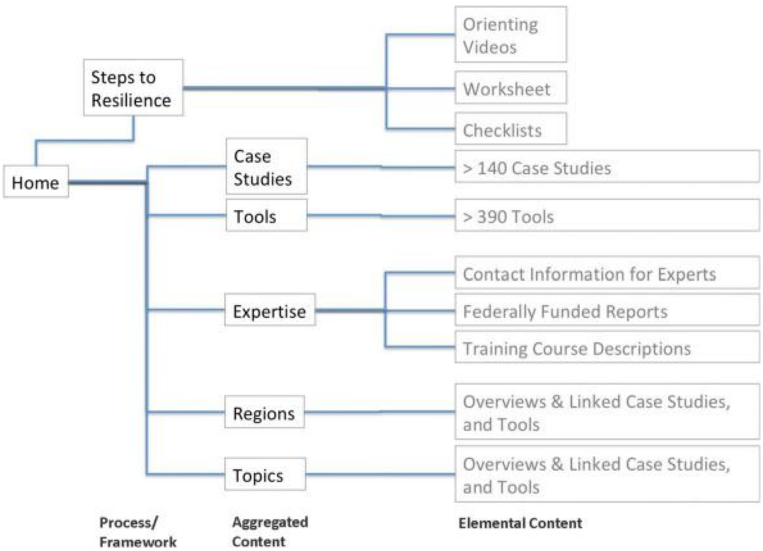

Fig. 3 Site structure for the U.S. Climate Resilience Toolkit

Optimal Workshop's online tool (optimalworkshop.com) using names and brief descriptions of the individual content items to be published. State and local government decision makers (n = 19) sorted these descriptions into groups, giving insight into how users prefer to categorize information. The majority ($n = 10$) had been in their profession for over 10 years while only three had been in their job for less than 5 years. Respondents showed roughly equal interest in all of the topics (Built Environment, Coasts, Ecosystems, Energy, Food, Health, Marine, Transportation, Tribal Nations, and Water) presented to them. Water resources were of primary interest, touching on the job roles of 14 of the 19 respondents. All of the content types that the editorial team planned to deploy were arrayed into a list, and respondents were asked to arrange those content types into self-similar groups. The overwhelming majority of potential users categorized content into groups corresponding to the sections listed above and which are described in more detail below.

The CRT team maintains a standard set of metadata and guidelines for documenting case studies in order to link each case study to specific climate hazards, regions, topics, and the particular Step to Resilience that each case study addresses. Prior to launching the CRT website, NOAA's Climate.gov highlighted individuals and communities undertaking resilience-building activities, including examples from operations management, emergency response and recovery, and long-term planning in Colorado, Florida, Georgia, Louisiana, Maryland, Missouri, New Jersey, and South Carolina. These case studies illustrate how federal data and tools proved useful in framing local impacts of climate change.

Case studies also typify the motivations that frequently accompany the application of science into action (Dilling et al. 2017). First, after experiencing a hazardous event, individuals, communities, or businesses are likely to address their vulnerabilities and risks. Second, perception of risk may motivate action. Third, there may be a "climate champion" who is highly motivated to drive hazard planning and responses. Fourth, external incentives such as federal funding can motivate individuals and groups into action. Within the theory of social diffusion (Rogers 1983), the business owners and educators featured in CRT case studies are early adopters and thought leaders who provide essential exemplars of best practices so that communities of practice or social norms may evolve in response to the recognition and adoption of new information that advances that communities' needs and interests.

There are ten topics with information gleaned from the U.S. National Climate Assessment (Melillo et al. 2014) and other peer-reviewed sources originating from federal science agencies. These sections provide context about climate threats and adaptation best practices, all linked to relevant case studies and tools. Subject matter experts from throughout the U.S. Federal Government contribute to the writing and review of these pages (see acknowledgements on website, toolkit.climate.gov), thus ensuring ongoing relationships between subject matter experts and end users.

A catalog of over 400 tools provides access to federally produced analysis, evaluation, and context-providing resources for adaptation planners. Each tool comes from a federal science agency or a funded partner and is included upon recommendation from the same curatorial oversight group that approves topical summaries. All tools are annotated with metadata so that the tools, topics, and case studies pages may be interlinked.

The CRT provides a bespoke data visualization mapping and graphing tool called the Climate Explorer. Google Analytics and conversations with our target audience revealed that people most often begin a search for tools and information with a particular location in mind. Informal interactions at early stakeholder engagements revealed most CRT users want data-based answers to questions that are specific to their place(s) and timeframe(s) of interest rather than raw climate data (see Gardiner et al. in this volume). A vocal minority of CRT users value interactive web-based data visualization tools, but they also want easy access to the raw data behind the tools so they can do their own analyses. These users require metadata and documentation about the data's sources, methods of collection and processing, margin of error, etc. Each of these insights guided the evolution of the "Climate Explorer" and the "Climate by Location" widget. Code for both is open-source. Federal partners and end users requested that the Climate Explorer include downscaled Global Circulation Model data from the Coupled Model Intercomparison Project version 5 (Taylor et al. 2012). To meet this need, the U.S. Global Change Research Program (USGCRP) assembled a team of scientists and science communications specialists from the Federal Government, academia, and the private sector who spent nearly a year assembling appropriate data, visualized map layers, and software for accessing and visualizing these resources in an intuitive way.

To help professionals develop expertise for using climate information, the CRT catalogs online and in-person training modules and opportunities which have been developed using federal funds. One example is the NOAA Digital Coast Online Tools Training Curriculum, portions of which have been certified by the American Planning Association. In 2014, The Association of Climate Change Officers (ACCO, accoonline.org), a non-profit, climate credential-providing organization, approached the CRT team to develop curriculum material that could be used to ensure that newly trained professional climate experts would receive current, vetted information about climate science and its application within the private sector. Through consultation and review with a panel of experts, the CRT team developed course modules focused on climate science, climate variability and change, vulnerability assessment, and leveraging climate data and tools for decision-making. These modules are used routinely within ACCO's in-person and online training. A third example of training includes the NOAA National Weather Service's Climate Variability and Change Virtual Course. Sometimes training requires too great an investment of time to help overcome a specific hurdle. To get people beyond barriers to entering into climate resilience building, the site's Expertise section also includes major climate reports and an interactive map with locations and websites where people in the USA may identify and reach out to federal scientists and their funded partners to request help or guidance.

The Regions section of the website was added in 2017 in response to requests by collaborators and website users. This section focuses attention on distinct geographies, including summaries of major climate influences and concerns and the partnerships among subject matter experts that can support resilience-building efforts. As with all sections of the website, access to tools, case studies, and relevant topical summaries are available within each regional section.

3.2 Semantic search and ontology

The CRT team developed a structured metadata tagging scheme for all content within the site. A study commissioned by NASA, NOAA, and the Office of Science and Technology Policy (unpublished data; climate-data-user-study.18f.gov/#report) revealed that climate resilience data, tools, reports, and other resources should be linked through metadata schema so that search engines and web harvesting tools may collate information across diverse domains. We have tagged all content using terms taken from climate and adaptation literature. As a result, readers of the CRT may search and cross-reference material from within the website and beyond. There is "no wrong door" to find content because content links to other sections based on shared attributes within the metadata scheme. For instance, tools that address sea level rise are linked to and from the "Coasts" and "Coastal Inundation" section and sub-section, respectively. Further, case studies involving sea level rise are linked to and from those tools and topics. The structured metadata scheme enables searches across both federal and non-federal websites using a bespoke tool embedded within the CRT's search functionality and based on semantic web technology (weblyzard.com). The CRT team provides a list of terms to the search tool which in turn builds a database of pages that cite those terms. The search algorithm uses the CRT's metadata schema as its basis, so content can be linked within and outside of the toolkit website.

4 Engagement, feedback, and evidence of progress

The CRT team uses five metrics to evaluate the "Quality of Relationship" between site developers and users. First, we seek to grow an audience of people who are aware of the site's contents. Second, we seek the trust of our audience by establishing that its resources are authoritative. Third, we want to know if users are satisfied with the CRT's contents and functionality—i.e., does the site meet their need for tools and/or information? Fourth, we assess users' perceptions of the CRT's usability (i.e., do they feel the site is easy to navigate and use?), and we want to know if they actually use tools and information in it. Fifth, we want our audience to know their questions and feedback matter to us, and that we will carefully consider and respond to their needs through website modifications or by hosting webinars or in-person training opportunities. Below, we present evidence of progress toward these objectives by reviewing the evolution of content and feedback over a 3-year period, 2014–2017.

The growth in visitorship suggests we are meeting the goals of our first metric. The site went live in November 2014 (the beginning of Fiscal Year 2015, FY15). In its first year, we established a baseline of 32,696 visits per month and set a goal to grow the visit rate by 10% per year. During FY16, actual site visits grew by 72% (Fig. 4). From October 2017 through July 2017, the average monthly visit rate was 98,885, a 76% increase over the FY16 average monthly visit rate. Among communities of people who are actively increasing resilience to

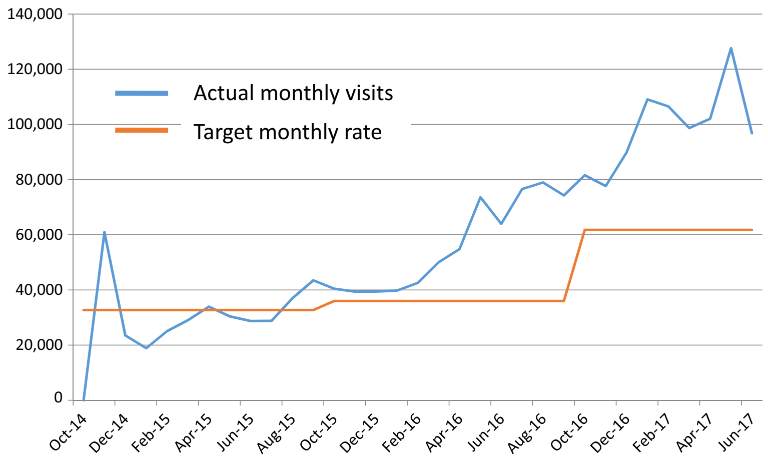

Fig. 4 Number of visits per month to the U.S. Climate Resilience Toolkit through time from its inception

climate stressors, there appears to be widespread recognition of the existence and availability of the U.S. Climate Resilience Toolkit as an online resource. Google Analytics tells us that about 34% of our visits are by “return visitors”—people who have previously visited the site.

To address our second two goals (building trust and measuring satisfaction), we maintain direct contact with our audience. We convene events, translate information, and mediate interactions among experts and toolkit users (sensu Cash et al. 2006). Our team hosts and participates in webinars, public speaking, and formal education through workshops so that we can interact directly with decision makers, thereby learning how to best position climate adaptation resources for people in distinct business sectors and geographies. Live conversations and events also provide an opportunity to evaluate the efficacy, utility, and authority of offerings within the website.

Some of our engagements span multiple events. For example, the Resilience AmeriCorps VISTA program, managed by the Corporation for National and Community Service, recruited and trained volunteers to improve resilience across a spectrum of societal, planning, and management issues within low-income communities across the USA. Members of the CRT team spoke at annual resilience training academies held in 2016 and 2017 for two sets of VISTA volunteers at the beginning of their 1-year terms of service. After Resilience AmeriCorps VISTA team members had been placed and established within communities, the CRT hosted online training for both sets of recruits, focusing attention on the unique requirements of climate resilience-building across diverse communities and applications. Volunteers learned about the StR, the website, and its resources. Attendees were given optional exercises to conduct on their own. Participants developed conceptual models (Fig. 5) about their own communities in Pittsburgh, Long Island, New York City, Phoenix, and New Orleans. Each reported that the conceptual models helped their colleagues grasp why climate information was important for addressing systemic issues in their host communities. Other volunteers

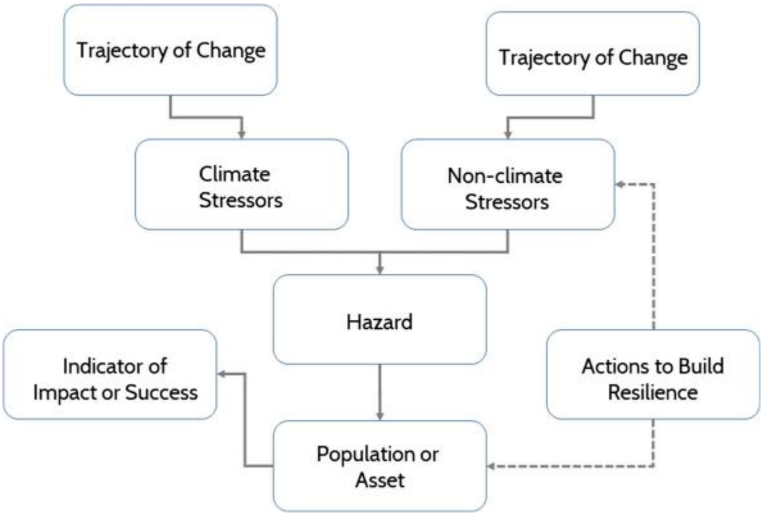

Fig. 5 Conceptual model of trajectory of change, stressors, hazards, assets, actions, and indicators pertinent to climate resilience. Since building resilience occurs outside of the realm of mitigating greenhouse gas concentration and other drivers of climate change, typically the actions for building resilience focus on non-climate stressors (e.g., environmental engineering) and safeguarding people or assets. Measures of success or failure are essential for managing resilience projects

worked through the StR using a planning workbook that is available through the toolkit. One such participant reported she needed more context about the distinctions between terms listed within Step 2, "Assess Vulnerability and Risks". This feedback sparked more attention to defining these terms in subsequent webinars. Other volunteers reported on their use of tools. A volunteer in New Orleans, for instance, was able to use the EPA Stormwater Calculator to focus officials and homeowners on properties' exposure to flooding. We hosted one-on-one information sharing sessions with VISTA members in Pittsburgh, Pennsylvania, and Norfolk, Virginia to deeply explore their concerns and challenges. Adoption of these techniques is evidence of our fourth metric regarding usability.

Active engagement between users and information providers has boosted the perception of trust, authority, and utility of the CRT's contents, thus enhancing our second and third Quality of Relationship metrics. The CRT hosts webinars about successful projects that leverage government programs such as the Community Rating System, which provides flood insurance rate relief to communities based on their capacity to increase resilience. The toolkit's central StR framework was refined through workshops conducted by UNC-Asheville's National Environmental Modeling and Analysis Center (NEMAC) among communities in the south-eastern United States (Asheville, North Carolina; Atlanta, Georgia; Fayetteville, Arkansas; Knoxville, Tennessee; Miami, Florida; Nashville, Tennessee; Orlando, Florida; Raleigh, North Carolina; Charleston, South Carolina, and Huntsville, Alabama). These workshops were conducted in partnership with the Southeast Sustainability Directors Network between 2014 and 2015. Representatives from each city continue to provide feedback on the StR framework. The StR are therefore both evidence of the CRT team's responsiveness to its audience and an outcome of true "co-production of knowledge" (Lemos and Morehouse 2005).

The toolkit includes notifications about funding so that organizations can seek and obtain support for their activities. The funders themselves also contribute content to the website so that potential fund recipients get insight into past activities by fund recipients. Subject matter experts work actively with content producers, thus improving the credibility and reliability of site contents. These are all aspects of our third Quality of Relationship metric regarding usability. Cash et al. (2003) suggest salience, credibility, and legitimacy are the essential elements of usability and reliability within the broader field of sustainability.

According to feedback following some of our engagements, direct interaction with the CRT team is one of the most valued resources we have offered our users (Gardiner et al., this volume), so we are prioritizing a sustained engagement plan for our audience. Decision makers and asset managers value opportunities to learn about actions that others have taken to build resilience, what tools and methods were used, and whether their peers were successful. They also want opportunities to engage with experts who can help them articulate and answer questions, find and use relevant tools and data products, and guide and inform their decision-making process. In-person events that feature experts addressing specific topics and specific regional issues are essential for helping people apply CRT resources, thereby meeting our third Quality of Relationship metric. In order to serve professionals the resilience information they require, we foster collaborations in distinct geographic regions and about specific topics as new ideas emerge. This was one of the recommendations made by the consultants 18F, who analyzed a broad set of government initiatives (climate-data-user-study.18f.gov) focused on climate data and tools.

We use qualitative information from our engagements to gauge whether our audience feels their opinions are considered in the ongoing development of the website. Feedback from users reveals a split between a majority who want a simple interface and an active minority who want more complexity and utility at a local level. Since the earliest design phases of the CRT, we have struggled with how to balance the complexities of our target users' needs for tools and information with the enormity of data, tools, and information that are available across the federal government and its grantees. The majority of our audience is satisfied with introductory information and frameworks that help them work with the very complex domain of climate resilience-building. Developing conceptual models (Fig. 5) and employing the StR, for example, facilitates the process of building teams with shared priorities. An active and vocal minority of toolkit users want prescriptive tools that provide site-specific guidance about design criteria and return intervals for specific classes of events. Our Climate Explorer increasingly serves these individuals' requests, but providing detailed information often entails either co-producing that knowledge or finding appropriate consultants who can serve them directly. Thus, we actively seek to serve both segments of our audience based on their preferences.

5 Conclusion

The CRT is not a "loading dock" for information (Cash et al. 2006). Our StR framework stemmed from a blend of literature review and real-world consultations with communities using climate information to analyze and understand their exposure and risks due to climate-related hazards. Targeted user feedback (captured through interviews, card sorting, and case studies) informed the structure, style, components, and format of the CRT. Our bespoke visualization and data access tool, the Climate Explorer, continues to evolve based on user feedback. We have focused on training and engagement in order to test our assumptions and refine our approach to serving user needs. The Regions section of the site emerged after users at live engagements requested this networking capability. We are innovating the use of semantic web technology while simultaneously improving a systematic metadata schema that links content throughout the website. We see evidence (Fig. 4) that U.S. audiences are finding and using content on the CRT. We formally evaluate and have evidence of progress toward continually improving the "Quality of Relationship" that we have with our target audience. Audience engagement provides mutual benefits for users and developers of the CRT and serves as a replicable model for other toolkit developers. The early results from this project establish a baseline from which future studies may evaluate expected increases in salience, credibility, and legitimacy of this platform (Cash et al. 2003). We intend to continue to reach those goals by maintaining relationships between climate experts and adaptation professionals.

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