BAMS Article

Demystifying Drought

Strategies to Enhance the Communication of a Complex Hazard

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ABSTRACT: Drought is a complex phenomenon that is difficult to characterize and monitor. Accurate and timely communication is necessary to ensure that affected sectors and the public can respond and manage associated risks and impacts. To that end, myriad drought indicators, indices, and other tools have been developed and made available, but understanding and using this information can be a challenge for end users who are unfamiliar with the information or presentation or for decision-makers with expertise in areas outside of climate and drought. This article highlights a project that aimed to improve the usability and dissemination of drought information for North Carolina (NC) audiences by addressing specific needs for a better understanding of how drought is monitored, the climatic and environmental conditions that can cause or worsen drought, and the impacts occurring in NC's different sectors and subregions. Conducted to support NC's official, statewide drought monitoring process, the project's methods and results have utility for other geographies and contexts. The project team designed an iterative process to engage users in the development, evaluation, refinement, and distribution of new resources. Featured products include the Weekly Drought Update infographic, which explains the factors used to determine NC's drought status, and the Short-Range Outlook infographic, a synthesis of National Weather Service forecasts. Effective strategies included using stakeholders' preferred and existing channels to disseminate products, emphasizing impacts relevant to different user groups (such as agriculture, forestry, and water resources) rather than indices, and employing concise narratives and visualizations to translate technical and scientific information.

KEYWORDS: Social Science; Drought; Climate services; Communications/decision making

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Providing accurate and timely information about drought conditions is important to ensure that affected sectors, communities, and the public can respond to and manage risks and impacts. This can be challenging since drought evolves on varying time scales, can occur over geographically confined or expansive spatial scales, and can have both natural and human causes. Furthermore, individual experiences with the same event can differ considerably by locale and sector (AghaKouchak et al. 2015; Giordano and Vurro 2010; Van Loon et al. 2016a,b; Weitkamp et al. 2020). Researchers and climate service providers have addressed needs for drought information through divergent approaches, each of which brings its own strengths and challenges. We highlight three here.

First, scientists have developed myriad quantitative drought indices to characterize the aspects (e.g., precipitation, temperature, soil moisture, vegetation stress, hydrology) that are most meaningful for specific research and/or management questions (Mishra and Singh 2010; Svoboda and Fuchs 2016). However, "more" information does not necessarily equate to "useful" information. Having multiple quantitative indicators is often of limited utility because they are inconsistent across different spatial and temporal scales, difficult to compare, limited in their ability to depict onset and recovery, and consequently challenging to convey in public communications (Steinemann et al. 2015). Additionally, organizations with monitoring and response duties typically need more than quantitative indicators and may also rely on historical experiences and impact reports, as no single indicator can capture all drought aspects at a single time point or for a particular place (Finnessey et al. 2016; Fontaine et al. 2014; Mizzell and Lakshmi 2003; Steinemann and Cavalcanti 2006).

Second, recognizing that decision-makers are most likely to understand and use information tailored to their contexts, significant work has been devoted to identifying users' needs and developing tools for their decisions and applications, particularly in the agriculture (e.g., Prokopy et al. 2017), fire management (e.g., McEvoy et al. 2019), and water management (e.g., Steinemann et al. 2015) sectors. While this specialized nature of drought information provision is undoubtedly useful for decision-makers working in those fields, information and products developed for one purpose may be difficult for nonexperts or those working in other contexts to access, interpret, and utilize (Bachmair et al. 2016; Hao and Singh 2015; Purdy et al. 2019).

Third, to facilitate more comprehensive and consistent monitoring and understanding of drought events, composite drought indices integrate multiple variables or indicators into a single tool. The U.S. Drought Monitor (USDM) exemplifies such a product and a unique approach to drought monitoring (Hao et al. 2017; Svoboda et al. 2002). Rotating authors use percentile rankings of various indicators, local and regional guidance, and converging lines of evidence to create the weekly map and designate drought severity levels for all 50 states, Puerto Rico, the U.S. Virgin Islands, and U.S.-affiliated Pacific Islands (Rippey et al. 2021; Svoboda et al. 2002). The USDM provides a timely and convenient format, integrates a wide range of drought information to show the "big picture," and enhances public awareness of drought (Rippey et al. 2021; Steinemann 2014). On the other hand, perceived shortcomings echo broader critiques of composite indicators that aim to reduce complexity in depicting drought status (Bachmair et al. 2016; Hao and Singh 2015). Ambiguity about which information is emphasized in creating a given week's USDM map, and its accuracy in depicting on-the-ground conditions, contributes to questions about the map's relevance for local-level assessments and decisions (Ferguson et al. 2016; Hao and Singh 2015; Steinemann 2014; Steinemann et al. 2015).

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Together, these three approaches illustrate the balancing act scientists and monitoring groups face in providing and using drought information (Bachmair et al. 2016; Clifford et al. 2020). Multiple indicators are needed to capture drought's complexities, but they can be difficult to navigate and apply (Steinemann et al. 2015). Composite indicators (e.g., the USDM) aim to provide information for everyone, but they often fail to capture nuances in drought conditions and impacts that resonate with local users' contexts. Demands for highly customized products for all potential users and applications place impractical expectations on information providers who may lack resources or capacity to perform such work (Clifford et al. 2020; Guido et al. 2020).

We report on an applied research project devoted to addressing these challenges and improving drought communication in North Carolina (NC). A collaboration between the State Climate Office of North Carolina (SCONC) and the National Oceanic and Atmospheric Administration's (NOAA's) Carolinas Integrated Sciences and Assessments (CISA) program, the project aimed to produce and deliver understandable and relevant drought information to NC decision-makers in accessible formats and distribution channels. Information producers and users alike participated in the development, evaluation, and dissemination of new drought communications prototypes. We documented the characteristics and factors that contributed to the usefulness and usability of drought information for a variety of user groups, focusing on product content, design and format, and delivery methods. This article presents project-specific findings and broader insights that can be applied to other drought communication efforts.

Project overview

The North Carolina context. Located in the southeastern United States, NC's annual average precipitation ranges from 1,000 to 1,400 mm yr^{-1} (40–55 in. yr^{-1}). Precipitation is generally balanced year-round with no pronounced wet or dry seasons. It is driven primarily by synoptic-scale frontal activity in the fall and winter, localized convective showers and thunderstorms in the spring and summer, and tropical storms in the late summer and early fall. Despite this generally humid subtropical climate, NC's climatological history includes numerous instances of drought, from flash droughts (Ford and Labosier 2017; Schubert et al. 2021) to multiyear events with far-reaching impacts (Weaver 2005). Many of these droughts are in the recent memory of the state's inhabitants. For example, the state experienced its drought of record in 2007–09. At its peak in December 2007, the USDM classified more than 66% of the state as in exceptional drought (D4) (National Drought Mitigation Center 2021). In 2016, the state experienced simultaneous hydrologic extremes as Hurricane Matthew's rains led to widespread flooding in the eastern half of the state while an intense, drought-exacerbated wildfire season occurred in the state's mountainous west (Ward and Davis 2016).

The NC Drought Management Advisory Council (DMAC) is the state's primary drought monitoring body. Formed initially as an ad hoc committee to assess statewide droughts in the 1990s, the state of North Carolina officially established the council in 2003 following a severe, multiyear drought at the turn of the century. NC General Statute 143-355.1 details the DMAC's primary responsibilities to include improving coordination between agencies, facilitating the management and mitigation of drought impacts, and providing consistent and accurate information to the USDM, state agencies, and the public. Members participate in a volunteer capacity (Table 1), and their monitoring methods align with the USDM's "convergence of evidence" approach (Svoboda et al. 2002). They meet regularly via teleconference to review indicators and other objective drought measures, assess local conditions, recommend drought designations to the week's USDM author, and issue county-level drought advisories through the DMAC website.[1] Except for rare cases,

[1] www.ncdrought.org

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the North Carolina drought map shown on the DMAC website and the USDM map are identical (Davis and Ward 2017).

Despite this proactive approach to monitoring, communicating about drought to non–drought experts and public audiences presents a challenge to the DMAC, its member organizations, and other information providers serving the state. Especially during droughts, the DMAC receives questions ranging from, "Why is (or isn't) my area in drought?" to "How was this map created?" to "When will the drought end?" revealing that existing products and methods of communication, such as the NC drought map, inadequately address the variety of users' concerns and questions.

Table 1. Membership of the North Carolina (NC) Drought Management Advisory Council (DMAC), organized by sector.

Agriculture
NC Cooperative Extension Service
Forestry
NC Forest Service
Water resources
NC Department of Environmental Quality, Division of Water Resources (DMAC Chair)
Cube Hydro
Duke Energy
Tennessee Valley Authority
U.S. Army Corps of Engineers
U.S. Geological Survey
Weather and climate
National Weather Service
State Climate Office of NC
Other
NC Department of Public Safety
NC Utilities Commission
NC Wildlife Resources Commission
National Drought Mitigation Center
South Carolina Department of Natural Resources, State Climatology Office
Virginia Department of Environmental Quality

Project design and methods. The goal of this project was to support NC's official, statewide drought monitoring process by developing new products to enhance information sharing and understanding of drought by diverse audiences. Drawing from research pertaining to climate services (e.g., Vogel et al. 2017), coproduction (e.g., Meadow et al. 2015), and user-centered design (e.g., Zulkafli et al. 2017), we applied best practices to design the project, engage participants, and evaluate various factors that contribute to products' usability and usefulness. We engaged individuals and groups who wear multiple hats; that is, they monitor drought, make drought-related decisions, and are responsible for communicating about drought. Participants included DMAC members and representatives from key sectors (agriculture, forestry, water resources) affected by drought. More than 475 individuals engaged in this project (appendix). Since many participants provided feedback on multiple occasions (e.g., participated in both a webinar and a later conference workshop), this count does not represent unique individuals. All activities were carried out with approval from NC State University's Institutional Review Board.

The project consisted of several interrelated components (Fig. 1). We began with a needs assessment to collect information about our target sectors' drought-related decisions, information needs, and communication preferences. Respondents indicated that they use and value many existing resources, namely, the USDM; temperature, precipitation, and soil moisture data; hydrological data (streamflow, lake levels); and NOAA forecast products. We also affirmed overall needs for improved awareness of available products and how drought is monitored, particularly the process to develop the weekly NC drought map. We created many new resources (e.g., fact sheets, a story map) and collaborated with the NC Department of Environmental Quality (DEQ) to update the DMAC website. The remainder of this paper features two products: the Weekly Drought Update (WDU; Fig. 2) and the Short-Range Outlook (SRO; Fig. 3).

We created the first WDU and SRO prototypes in January 2019, choosing an infographic-style design to meet user preferences for clear, concise information (Carr et al. 2016; Grainger et al. 2020). The WDU provides the reasoning behind the NC drought map

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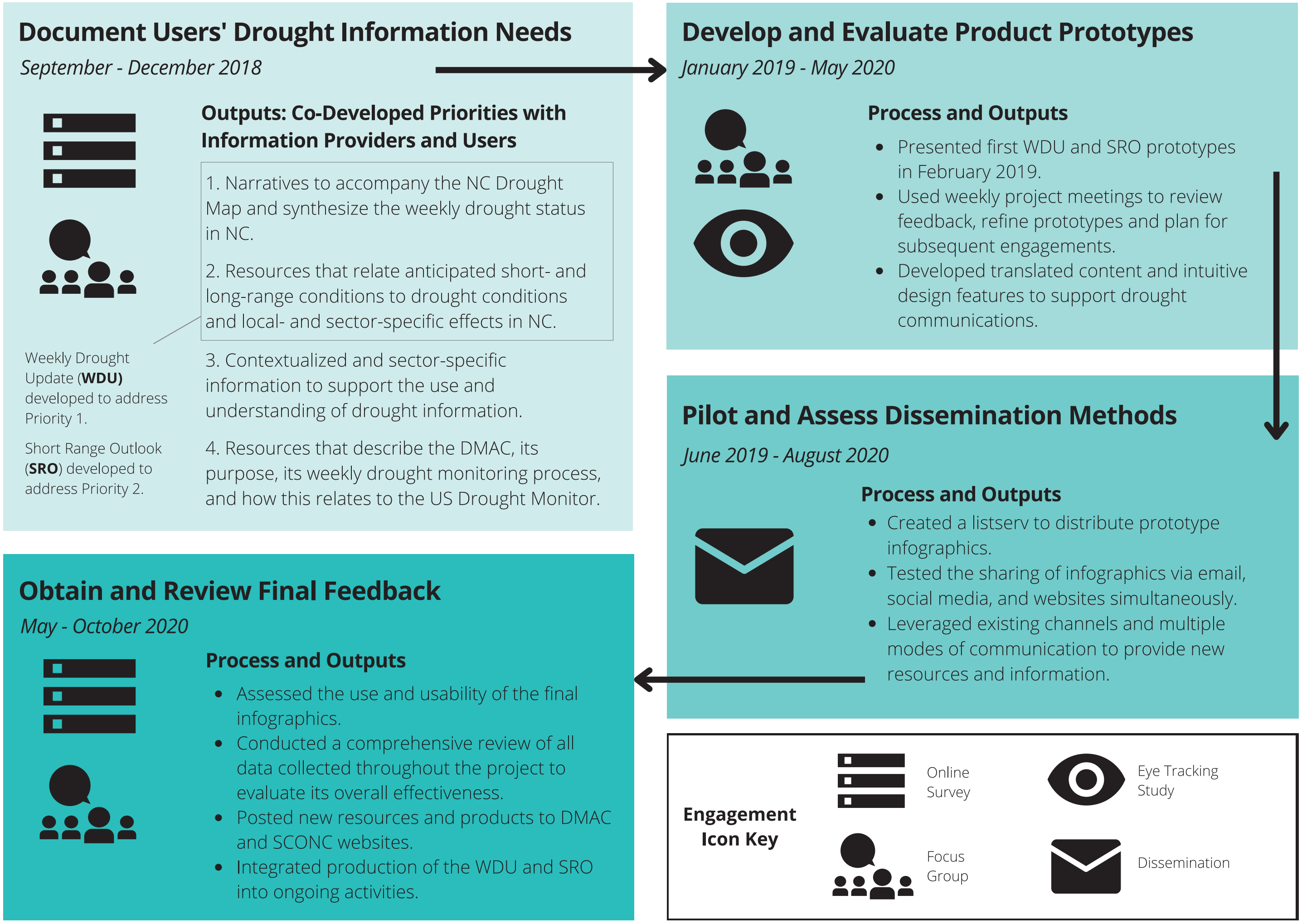

Fig. 1. Project components and timeline.

designations, such as why changes do or do not occur from week to week. As a DMAC member, the SCONC participates in weekly calls and provides drought and other climate data to inform the monitoring process. SCONC staff develop the WDU content based on the data and information shared and discussed by the DMAC while determining drought designations. The WDU is released on Thursdays, to coincide with the publication of the USDM.

The SRO conveys short- to medium-range forecast information and potential effects on drought conditions (e.g., formation, intensification, amelioration) and is issued monthly. SCONC staff develop the SRO content by synthesizing forecasts and area forecast discussions provided by the National Weather Service (NWS) offices covering NC, the Weather Prediction Center, the National Hurricane Center, the Climate Prediction Center (CPC), and computer model guidance. Each infographic has three panels that follow the time period conventions used by the CPC: *week 1* (the next 7 days from the outlook issue date), *week 2* (days 8–14 after the issuance date), and the combined *weeks 3–4* (days 15–28).

We engaged with users until May 2020 to improve these infographics using multiple methods. Focus groups featured interactive discussions and activities to elicit feedback on the understandability and relevance of the content as well as formatting and design elements. To supplement qualitative feedback from focus groups, we held two eye-tracking usability studies, using an experimental design to examine which product features attracted users' attention and facilitated comprehension (Fabrikant et al. 2010; Padilla et al. 2018; Vanderplas et al. 2020). In June 2019, we created a listserv to pilot the dissemination of the WDU and SRO prototypes and invited DMAC members and focus group attendees to register.

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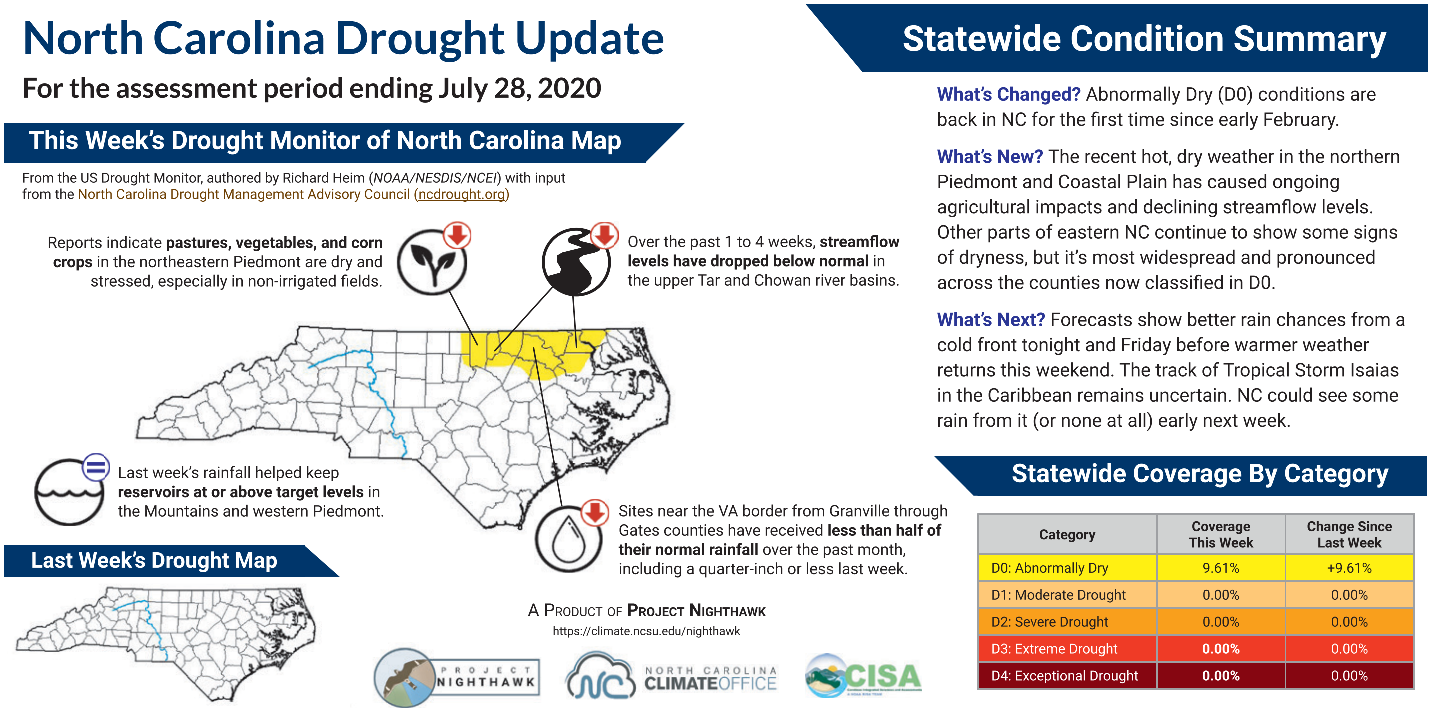

Fig. 2. Example Weekly Drought Update infographic.

In May 2020, we surveyed all listserv recipients to obtain feedback on the final prototypes' content and formatting, preferred methods of receiving and sharing the products, and if and for what purposes they had used the provided information.

To wrap up, we reviewed all quantitative and qualitative data collected throughout the project (i.e., survey responses, eye-tracking study results, focus group discussion notes, participant correspondence) to assess the overall effectiveness of the processes we employed as well as the elements that contributed to relevant and actionable information for users (McNie 2013). Reports available on the project website provide details about the project design, evaluation methods and results, and other activities and outcomes (Ward et al. 2019, 2020).[2]

[2] https://climate.ncsu.edu/research/drought_comm/

Strategies for enhancing drought communications

The challenge of this project was to develop and deliver products with relevant and actionable drought information to our target audiences, while acknowledging that one-size-fits-all approaches are generally ineffective. Unlike recent literature examining risk communications for hazards such as hurricanes (Millet et al. 2020), floods (Percival et al. 2020), or sea level rise (Moon et al. 2020), we found limited research specific to drought communications and messaging for multiple audiences. Here we discuss the best practices we followed to meet user needs for relevant, clearly written and visualized, and efficiently disseminated drought information, with references to analogous work.

Know your audiences. Being purposeful about when and how we engaged decision-makers was integral to the project's success. We relied on iterative and participatory processes to engage users and to ensure that we, as information producers, understood their contexts, needs, and preferences and could then apply that knowledge as we created new resources (Dilling and Lemos 2011; McNie 2013). Methods to facilitate this work included providing space for direct interactions between information providers and users (Alexander and Dessai 2019), collaborating with the target information users in the design of prototypes to promote learning

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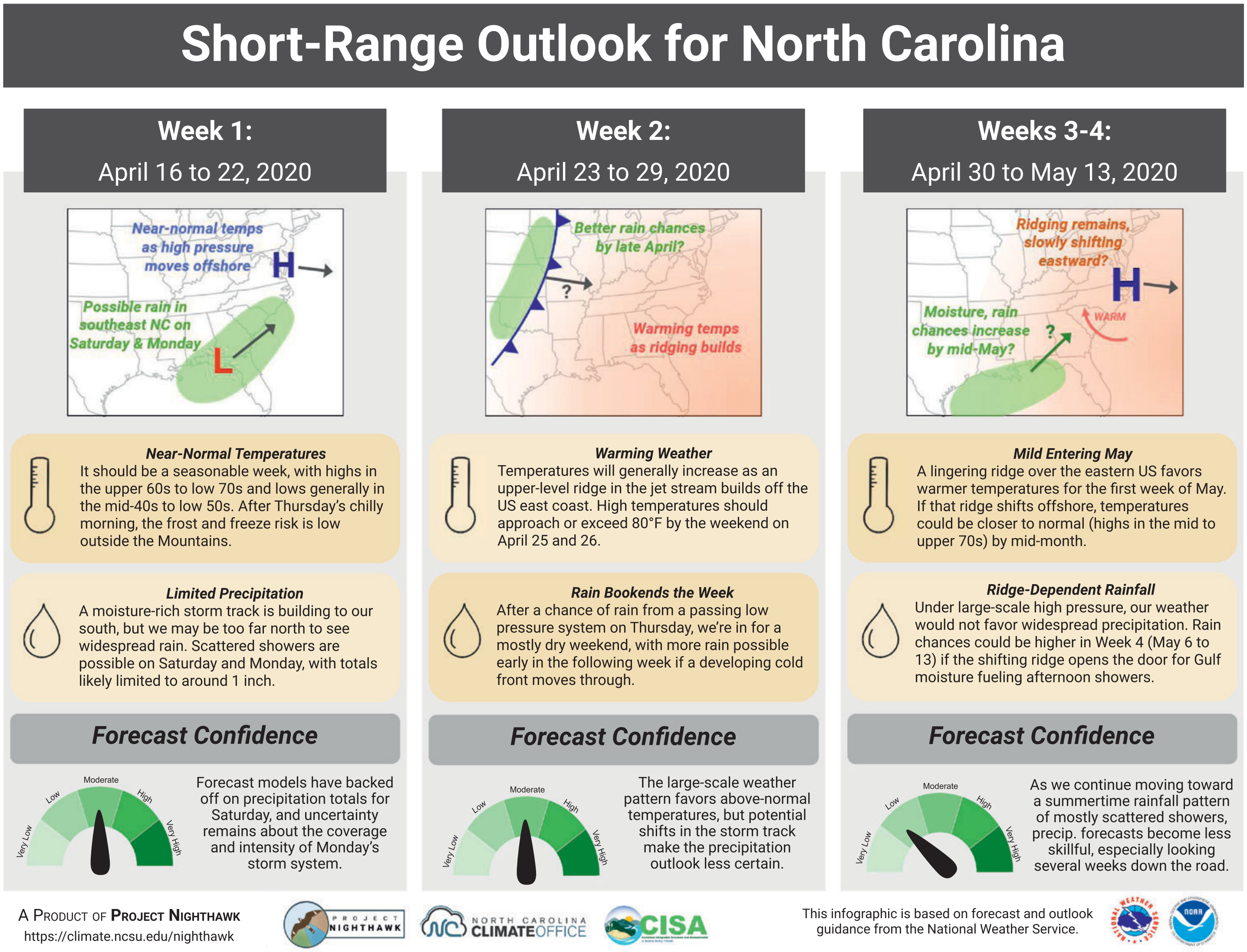

Fig. 3. Example Short-Range Outlook infographic.

and inquiry (Purdy et al. 2019), and assessing the utility of information for users' actual decisions and contexts (Grainger et al. 2020).

Beginning with our initial needs assessment and reinforced with data collected during subsequent activities, we identified unique and varied decision points, time scales, and context needed by each group with whom we engaged. Our NC-specific findings are best illustrated as a set of distributed communication chains that convene through the DMAC's weekly process (Fig. 4). Different organizations provide input into their own, the DMAC's, and the USDM's drought monitoring processes; use drought information in sector-specific ways; and then translate and contextualize drought information to their constituents. The forestry sector exemplifies this dispersed drought information network. The NC Forest Service (NCFS), a DMAC member, uses multiple indicators to monitor fire conditions and activity internally and provides that information as an input to the DMAC process. NCFS also communicates about drought-related fire conditions to the public and through the Fire Environment Committee (FEC), whose members represent a range of entities with roles in fire response and management, including the NCFS, NC State Parks, The Nature Conservancy, and the NWS. Individual FEC members, in turn, communicate drought information to supervisors, colleagues, and constituents in their organizations.

Delineating sector-specific decision contexts helped us to unpack sectoral differences, but rather than viewing these differences as insurmountable, we sought to identify shared interests

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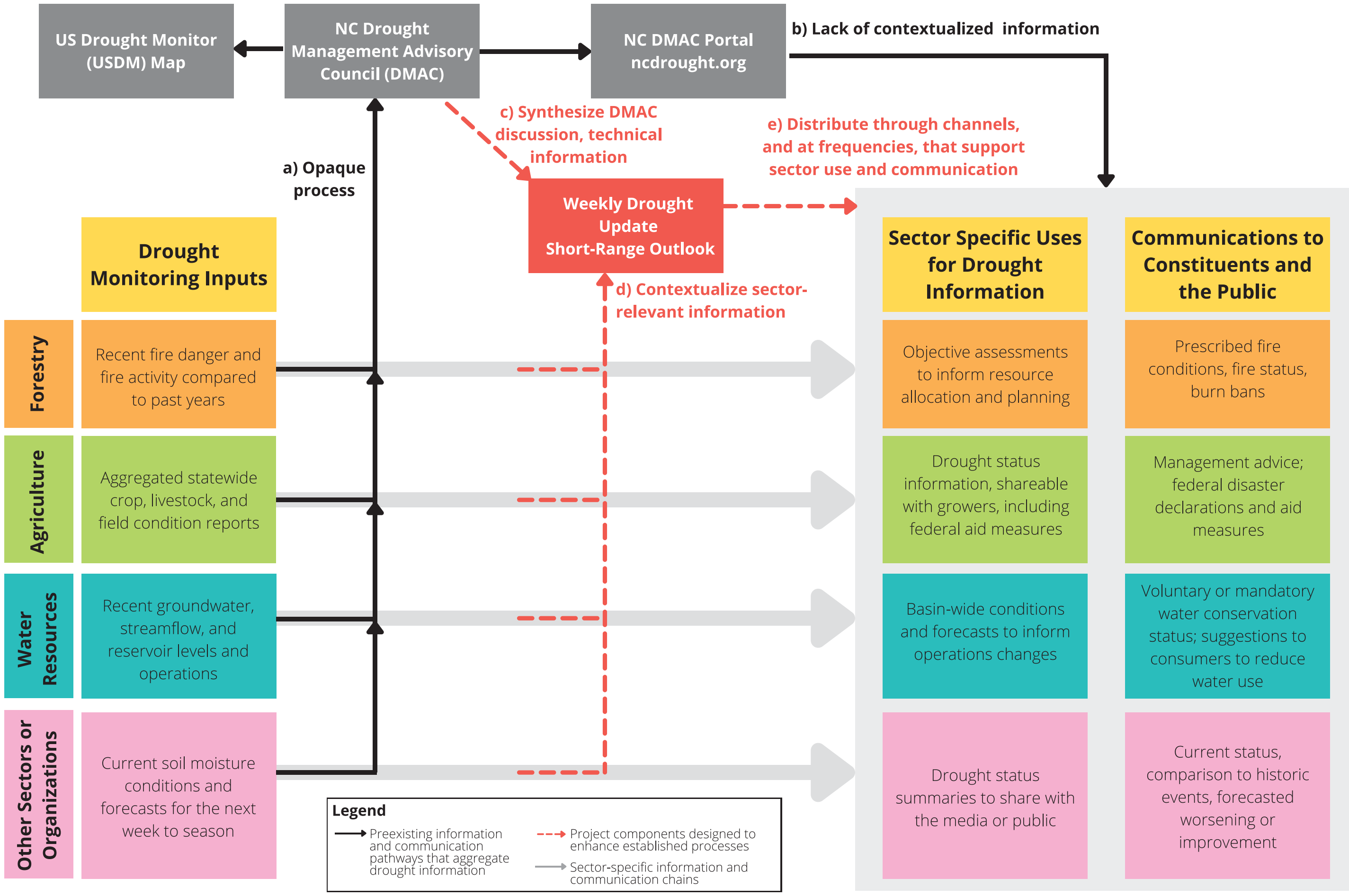

Fig. 4. The network of drought communication chains in North Carolina. The solid gray and black arrows illustrate the pathways through which drought information is provided, aggregated, used, and communicated by the project's target sectors. Shortcomings of existing processes are noted at two stages: (a) how the DMAC determines drought status, and which specific inputs are considered, is unclear to external audiences. (b) As stand-alone products, the NC DMAC portal and weekly drought map lack sufficient context to help users understand and apply the information. The dashed red arrows indicate how the Weekly Drought Update and Short-Range Outlook infographics supplement them by (c) translating the technical information discussed by the DMAC, (d) providing climate and impacts information that is meaningful to users, and (e) leveraging trusted and used distribution channels.

and information needs on which to focus new products. By understanding this existing network, we were able to design the WDU and SRO to address communication shortcomings expressed by all sectors and to fit their various decision contexts. For example, agriculture and forestry sector participants use and share drought information year-round as part of routine planning and situational awareness. Water utilities likewise continually monitor conditions to inform operations, but they might only disseminate drought-related information to their customers if their water system is experiencing a water shortage. Common to all the audiences with whom we engaged was the need for regularly provided, up-to-date drought information for operational time frames and decisions (i.e., days to weeks). Project participants appreciated that the infographics provided a routine perspective on statewide conditions and filled a gap for plain language information that helped them educate and enlighten others (findings consistent with VanDyke et al. 2021; Wall et al. 2017).

Keep it simple. Feedback collected throughout the project indicated that the WDU and SRO helped users understand drought conditions and the factors that contribute to drought status, and that these products were easier to comprehend than other information sources typically

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used. Here we highlight how we applied science translation and product design best practices and user input to refine the products.

First, we recognized a need to convey information in accessible ways for nonexperts. A tension often exists between information users who want simple, concise (but informative and meaningful) drought messages and information providers (e.g., DMAC members) who struggle to communicate very complex, technical, and nuanced concepts to the variety of audiences who are interested in or need drought information. This tension is reinforced by project participants' prior experiences during times of drought, which suggested a lack of understanding has diminished trust in and the perceived accuracy of drought products. We also expected that our target user groups (e.g., extension agents, fire managers, water resource managers) would further synthesize or explain information in the WDU and SRO to other audiences. Our engagements revealed that not all users are themselves drought experts, and they may need assistance with translating drought information.

We grounded the infographics' development in communications and design literature. We used nontechnical, jargon-free, and concise language and broadly understood, rather than scientific, terms (Meloncon and Warner 2017; Venhuizen et al. 2019). Obtaining regularly solicited guidance from users ensured that information was understandable, correctly translated, and provided sufficient detail to meet their decision-making needs. Users emphasized the need to avoid overtranslating or compromising the nuance of the original data or information. Retaining connections to the originators of information helped to build trust in these products, such as citing forecast (SRO) and impact (WDU) information sources.[3]

We found that contextualizing information in terms of users' personal experiences and reference points enhanced participants' drought understanding. Contextualized formats also have the advantage of facilitating more attention to and engagement with that information for decision-making (Marx et al. 2007). For example, the WDU presents the current week's USDM map along with three to four short, impact-based narratives describing conditions that shaped the weekly assessment. These narratives can be quantitative, such as recent precipitation deficits or streamflow and groundwater percentiles; qualitative, such as crop reports from agricultural extension agents; and either geographically specific, such as impacts in one particular county; or broad, such as overall conditions across part or all of the state. The SRO compares forecasted temperatures to normal temperature values for a given time of year.

Second, project participants consistently indicated preferences for less text and more easy-to-interpret visual elements when reviewing the infographic prototypes. They generally preferred versions that contained icons in addition to text to versions that contained only text. Visual attention and cognitive processing are influenced by viewers' personal knowledge of and experiences with the topic, familiarity with the format in which the information is presented, and other factors such as color blindness, the cultural meanings of colors, and end users' numeracy and spatial reasoning skills (Gerst et al. 2020; Harold et al. 2016).

Many of our efforts to refine the infographics thus focused on finding an appropriate balance between text and graphical elements. For instance, using data collected through numerous engagements, we modified the WDU design to eliminate unnecessary and distracting elements and facilitate users' information processing (Grainger et al. 2020; Harold et al. 2016). Changes include replacing a yellow notepad graphic with a neutral background, replacing large blocks of bulleted text with smaller sections organized with headings, and using boldface font to emphasize key points. An initial WDU version also contained a streamflow map that was difficult to read and potentially confusing since it used a different color scale than the drought

[3] Additional details about the making of the infographics are available in separate "How It's Made" infographics. The key elements of the WDU are described here: https://climate.ncsu.edu/wp-content/uploads/2020/10/DroughtUpdate_About.pdf. The methods and data sources used to develop the SRO are explained here: https://climate.ncsu.edu/wp-content/uploads/2020/10/SROutlook_About.pdf.

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map. In this case, users preferred short text descriptions of technical information, signified by intuitive icons, over having additional maps to interpret. The SRO went through a similar process. To help viewers navigate through the key points, the final version compartmentalizes text and visual elements, standardizes the order in which elements appear for each week, and visually separates the different time periods with whitespace.

Finally, we recognized the need to effectively communicate forecast confidence and uncertainty, a need which is well documented in the literature (Gerst et al. 2020; Morss et al. 2008). Complex information (e.g., CPC probabilistic forecasts) requires translation of numerical data to text-based information, such as above, below, or near normal. However, this translation retains a risk of misinterpretation since it relies upon an understanding of the nuances of normal conditions for a given indicator and time of year. Instinctively, users will draw from their own biases and heuristics to apply information and may not interpret the presented information as intended by the provider (Morss et al. 2008; Wernstedt et al. 2019). Clear explanations of why uncertainty exists have been found to facilitate understanding of and trust in the communication (van der Bles et al. 2019).

Recognizing that probabilistic guidance can be prone to misinterpretation (Gigerenzer et al. 2005), our depiction of the SRO's forecast confidence went through several iterations. The final SRO uses three distinct features to communicate drought-relevant forecast information. First, a map highlights key weather features likely to affect NC (e.g., cold fronts, tropical systems). Second, short text summaries describe expected temperature and precipitation patterns, including any events that could initiate or worsen drought conditions and impacts (e.g., heat waves, low humidity). Third, each period includes a measure of the forecast confidence. We initially used a five-point numeric scale that users indicated was difficult to interpret and apply. Subsequent feedback combined with guidance from related literature (e.g., Carr et al. 2018) yielded the final version which uses a metered confidence scale that ranges from "very low" to "very high" along with a short text-based summary to communicate forecast confidence and uncertainty.

Provide climate context. Throughout this project, participants indicated an overall need for information to improve their understanding of contemporary drought events—their origins, progression, and termination. Many of the commonly asked questions regarding local conditions (Why is, or is not, an area in drought?) and what to expect in the future (When will the drought end?) stemmed from the lack of informational resources that placed drought into a broader weather and climate context and which could be used to inform near-real-time and short-term decisions.

We found that a combination of time scales helped users to understand the reasoning behind changes to the current map and how forecasted conditions may affect drought status. Climatologies, past events, analogs, and drought causes were considered comparatively less useful, though not necessarily not useful, by our project's participants. The USDM and NC drought map, as stand-alone products, are retrospective: they reflect the most recent week's conditions and past weather patterns and processes. Participants indicated an overall desire for more forward-looking information, such as current and short-term forecasts (i.e., over the next 1–7 days), particularly when experiencing a drought or dry conditions. For these reasons, we designed the WDU to show an evolution of conditions from the previous week using an inset map, a table showing the percentage change in drought status, and text-based sections titled "What's Changed" and "What's New" (Fig. 2). The "What's Next" section describes expected weather patterns through the next seven days, but we avoided speculating on specific changes to drought status and impacts. The SRO product focuses completely on what users might expect over the upcoming 4-week period.

Another theme that emerged from our user engagements were simultaneous desires for local information and an ability to see the "bigger picture," but with added context. Participants tended to favor seeing local geographic units that align with the scales on which they work,

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for example, river basins for water resources participants and counties for agriculture and forestry sector participants. Similar findings from this research area suggest that users tend to prefer geographic specificity over broader-scale information that lack local applicability (Dilling and Lemos 2011; Mase and Prokopy 2014; Moon et al. 2020). However, our participants also indicated that staying attuned to conditions in neighboring areas and across the state were useful for monitoring conditions elsewhere that might move toward, or otherwise affect, their specific locale or unit of interest. Providing the regional context is therefore an important component of the WDU and SRO infographics (Dow et al. 2009). The WDU includes a statewide map with county lines, icons that highlight specific locations and/or impacts, and a table showing the statewide coverage of each drought category. The SRO exhibits a regional map to emphasize larger-scale climate and weather patterns, with text that highlights local conditions.

We additionally employed the WDU as an educational tool to proactively answer users' anticipated questions about changing conditions and seasonal patterns. The WDU for 21 July 2020, explains how to differentiate between normal summer variability weather, abnormal dryness, and emerging drought (Fig. 5). While not following the typical WDU format, project participants indicated that knowing why the drought map appears blank is just as useful for their own monitoring and awareness as when the map shows drought. During the span of the project, we also used the WDU to educate users about flash drought, ameliorating effects of hurricanes or "drought busters," and how drought and seasonal changes affect reservoir management. The decision to include this type of educational information was based on our understanding of users' (lack of) familiarity with how a given event or action may affect drought status and whether the infographics could serve as mechanism to inform or elucidate.

Employ existing networks. To improve the exchange and use of drought information, new resources should consider not only how users and sectors fit into the drought monitoring process, but also how and when they access information and share it with colleagues and constituents. Centralized clearing houses or web portals are often the default method of drought information dissemination, but these can have limited utility when created under

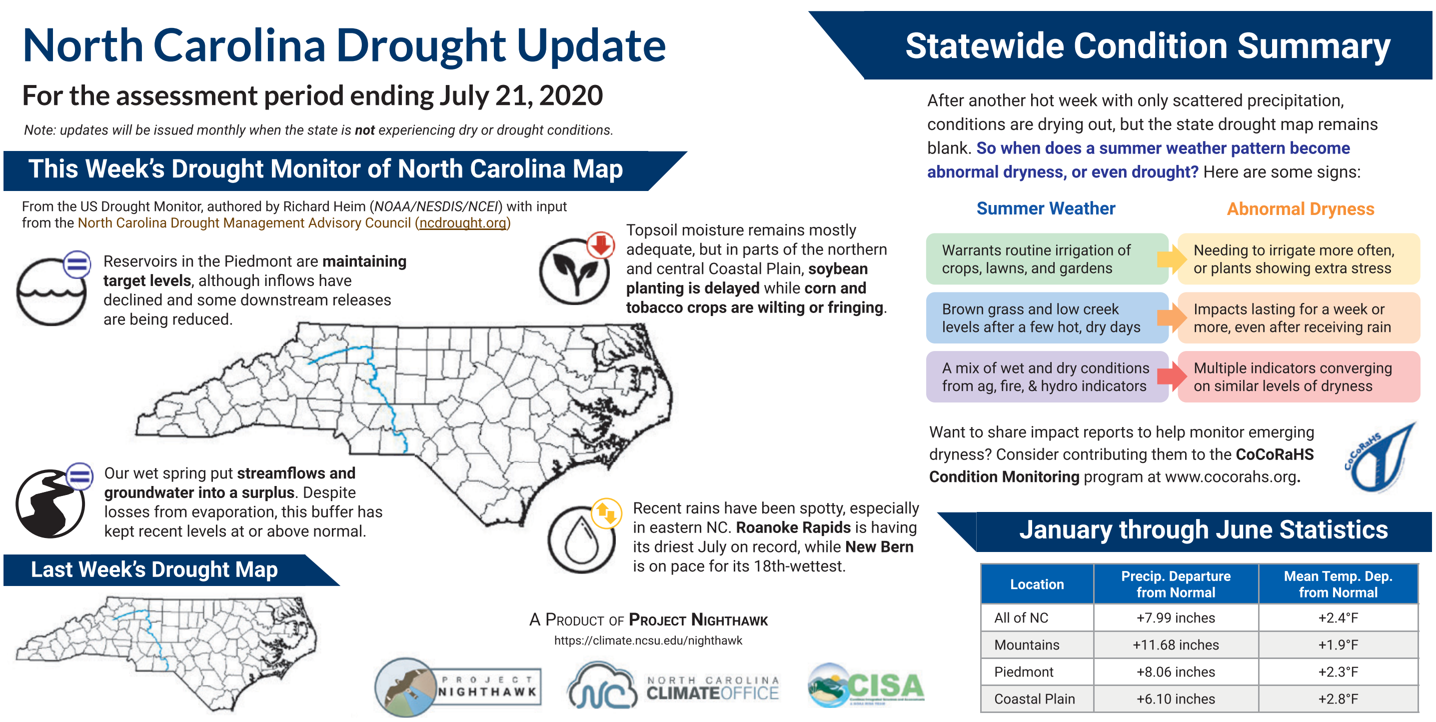

Fig. 5. Weekly Drought Update infographic from 21 Jul 2020. This infographic was issued to educate users why dry summer conditions may not warrant a drought designation on the NC drought map.

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the assumption of homogenous user needs and expertise and with little user feedback (Cash et al. 2006; Percival et al. 2020; Stegmaier et al. 2020; Swart et al. 2017). Though we developed a stand-alone page on the SCONC website to share project details and news, we maintained a focus on proactively disseminating new products via our target users' preferred channels rather than creating totally new mechanisms. Due to the distributed nature of the drought communications network, we aimed to reduce barriers to discoverability and accessibility by embedding our outputs in existing processes and relying on trusted messengers, such as cooperative extension and colleagues, to facilitate drought information exchange, methods consistent with Brugger and Crimmins (2015) and Colston et al. (2019). Participants receiving the infographics through our pilot listserv reported forwarding these to higher-level decision-makers, colleagues, and constituents, thereby extending the products' reach (e.g., as found by VanDyke et al. 2021).

Project participants indicated overall preferences for combinations of web-based and "pushed" information. We learned early in the project that the DMAC website was considered a trusted and go-to source for state- and county-level drought status information, and therefore the most logical place to post the infographics. Participants consistently rated short emails and text message alerts as useful and desired ways for receiving products, which is why we chose to share the WDU and SRO products via an email listserv. Having products in easily digestible formats (e.g., factsheets, infographics, animated maps or graphics) and available as both images and PDFs facilitate their (re)distribution, via email or social media. We posted infographics to the SCONC's Twitter account but were also aware of participants' mixed social media preferences. Some suggested they only use social media for personal communications, while others considered social media a valuable professional outlet for sharing information with their constituents, their broader organizational networks, and the public.

Though all the sectors we engaged with provided, used, and disseminated drought information, their practices varied. We found that water utilities and NWS offices generally prefer Twitter to disseminate information, while extension agents typically use Facebook to connect to colleagues and constituents. Individuals in the agriculture and forestry sectors indicated that they did, or were likely to, share the WDU and SRO directly with their colleagues and constituents. In contrast, water resources managers, especially utilities with communications staff, suggested they would use these infographics for their own situational awareness, but they preferred to use their own water system's branding and design their own messaging to motivate customers' behaviors (i.e., water conservation) during drought [consistent with findings by Liang et al. (2018)].

Building drought communications capacity

This project has helped to demystify drought for NC decision-makers by developing new, readily accessible resources to enhance understanding of how drought is monitored, the climatic and environmental conditions that can cause or worsen drought, and the impacts occurring in NC's different sectors and subregions. Despite the first and second wettest years on record in NC intersecting with the project's span, the state experienced several short-lived droughts during this period that allowed us to evaluate the infographics' effectiveness in providing timely and actionable information. During these times, participants reported using the infographics to communicate to and educate their constituents, colleagues, and supervisors about drought conditions. While not as prevalent, users reported consulting the infographics to monitor changing conditions and to inform decisions related to prescribed burns, fire response, and crop management. Importantly, as suggested by Crimmins and McClaran (2016) and VanDyke et al. (2021), products achieved our goal of augmenting, not replacing, other resources that decision-makers utilized. For example, one water resource manager reported, "I consult the outlook [SRO] every month. One thing I like about it is that you provide an indication of forecast confidence. I feel

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like your outlook, combined with the NWS 3-month outlook and the 3-day QPF [quantitative precipitation forecast], gives me the best crystal ball available."

This project demonstrated that drought communications can move beyond portals and products that lack context, and we hope the insights and templates generated through this project can be applied in other settings. However, we also recognize the challenges associated with directly adopting a project or product from another place. First, every state approaches drought monitoring a bit differently, and the processes to assess local conditions, contribute to the USDM, make drought declarations, and lead response and planning varies by state (Fontaine et al. 2014; Fu et al. 2013). For example, in contrast to the NC DMAC, which meets weekly, the South Carolina (SC) Drought Response Committee (DRC) convenes only when drought conditions exist or conditions are returning to normal (Altman et al. 2017). The DRC and USDM have separate processes. The DRC consists of governor-appointed members from across the state and represents different stakeholder groups. The DRC uses seven main indicators to assess drought, one of which is the USDM, and makes drought declarations at the county level to protect and conserve water resources. The SC Department of Natural Resources (DNR), the agency lead for the DRC, recently adapted the WDU infographic to explain the conditions that drive SC's drought status on the USDM map for SC to DRC members, stakeholders, and the public. The SC DNR's adoption of the WDU was partly possible due to increased capacity due to the establishment of a new water resources climatologist position. This position leads the effort to monitor SC conditions and provide weekly input to the USDM and then disseminate that information to the DRC and other groups. However, this type of position is not standard across federal, state, or local entities, which leads us to a second challenge: finding a balance between information provision that is decision relevant and contextualized but that does not put a huge burden on agency staff (Clifford et al. 2020).

Research to assess usable and useful information often focuses on users and neglects providers' capacities and capabilities (Guido et al. 2020). Translating scientific data into more accessible formats, engaging with information users, and designing effective participatory activities require financial support, appropriate skills and expertise, and time (Guido et al. 2013, 2020). We were able to implement this project by obtaining external funding, leveraging other funded activities, harnessing the existing collaborative environment in which the DMAC operates, and employing our collective translation skills, based on years of climate extension work. Most organizations involved in drought monitoring and communications often do so on a voluntary basis and may lack the resources to take on substantial new tasks, something we found with many DMAC members. To that end, we sought opportunities to make the products long-lasting and sustainable by integrating them into existing routines and activities. Due to its role on the DMAC, SCONC staff can easily update the WDU based on each week's conversation and currently publishes these on Thursday mornings to coincide with the latest USDM release. They are available through a listserv and posted on the DMAC website. In conjunction with other work funded by the NCFS, the SCONC continues to issue the SRO through a listserv.

We also acknowledge that while social media platforms can be valuable tools to enhance awareness, connect different user groups, and inform decision-making (Tang et al. 2015), they are less effective in promoting in-depth discussions and follow-up (Knudson and Guido 2019). The SCONC has subsequently integrated lessons learned from this project into its climate education efforts with cooperative extension and other audiences. Workshops and trainings provide opportunities to continue the drought dialogue and support mutual learning between the SCONC and their constituents who look to them for drought-related information and expertise (Goodrich et al. 2020; Knudson and Guido 2019). Finally, through the project we identified a need for an online tool that enables water utilities to create and view a simple summary of hydrological and water supply conditions for their area(s) of interest (e.g., watershed, political jurisdictions). While such a tool was outside this project's scope,

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we leveraged established and emerging partnerships to pilot a "Water Supply Dashboard" with the Internet of Water, NC DEQ, and the Triangle Water Supply Partnership.[4] Through the new products and processes fostered through this project, we met needs for information that bridges divides between information types (e.g., past, current, future; local, regional, national) and organizations and interests that are often siloed in their approach to drought communications. By focusing on process and partnerships, as well as the products themselves, this project has contributed to more proactive drought communications for a wide range of user groups and uses.

[4] The Water Supply Dashboard will enable users to discover real-time water supply information and help water resource managers monitor and communicate water supply status and risk reduction measures to their staff, boards, and customers. As this project evolves, more information will be available on the Internet of Water website: https://internetofwater.org.

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Data availability statement. Due to privacy and ethical concerns, supporting data from user feedback cannot be made openly available.

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Appendix: Project engagements and participation

Table A1 contains a summary of user engagements and participants during different phases of the project. We included fully and partially completed surveys when analyzing the initial online survey responses (Groves et al. 2009). Invitees were encouraged to forward the survey link to colleagues, so the actual number of recipients may be higher than indicated here. To avoid overengaging participants, we brought the project *to* them whenever possible and employed a variety of data collection methods (e.g., Prokopy et al. 2017).

Table A1. Summary of all project engagements. An asterisk designates stakeholder events where focus groups and eye-tracking studies were conducted.

Document users' drought information needs and prioritize prototypes ideas (September–December 2018)		
Online surveys	Agriculture and forestry	Water resources
Invitees	Cooperative extension agents	Water utilities serving populations > 5,000
Opened/sent	100/316 (31%)	40/183 (22%)
Completed	52 (16% of invitees)	22 (12% of invitees)
Partially completed	48 (15% of invitees)	18 (10% of invitees)
Webinars	DMAC members and key representatives from the target sectors	
	14 participants	17 participants
Develop and evaluate product prototypes (January 2019–May 2020)		
Focus groups (in person and via webinar)	9 events, 132 participants NC DMAC *DMAC Annual Meeting Agriculture *Weather + Climate Workshops (2; SCONC trainings for Extension) *NC Association of County Agricultural Agents State Meeting Forestry *Fire Environment Committee Meeting Water resources *NC Water Resources Research Institute Annual Conference Webinar with water utilities *Catawba-Wateree Drought Management Advisory Group Meeting *Triangle Water Supply Partnership Quarterly Meeting	
Eye-tracking studies	2 events, 45 participants *NC Cooperative Extension Annual Conference *NC Water Resources Research Institute Annual Conference	
Pilot and assess dissemination methods (June 2019–August 2020)		
Infographic distribution list	79 participants DMAC members, Cooperative Extension agents, Fire Environment Committee, water utility managers and staff	
Obtain final feedback (May–October 2020)		
Online survey	74 invited from the infographic distribution list, 26 responses (35%)	
Focus groups (via webinar)	3 events, 49 participants *Fire Environment Committee Meeting Webinar with National Weather Service offices *DMAC Annual Meeting	

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