Citizen Science Condition Monitoring

Phase 2:
January 2016 through December 2017

Final Report | May 2018

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A NOAA RISA TEAM

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NIDIS

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Photo: Amanda Farris

Executive Summary

The Citizen Science Condition Monitoring project was created and piloted in the Carolinas by the Carolinas Integrated Sciences & Assessments (CISA) team. The program, which originally launched in September 2013, was designed to address drought impact monitoring needs identified for the Carolinas, inform broader efforts to develop more effective approaches to drought impacts monitoring, and facilitate the integration of impacts information into decision making. The idea for the project was borne out of stakeholder needs for more on-the-ground information about the societal and environmental impacts of drought. The project team utilized existing tools developed by the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network to pilot a new method of drought impacts reporting. Unlike drought impact reports, which are often submitted only once drought conditions become severe, condition monitoring seeks to document the evolution of impacts over time by asking volunteers to submit reports weekly to document changing conditions. This process provides more information about the onset, intensification, and recovery of drought impacts in contrast to more traditional, "one off", drought impacts reporting.

Phase 2 of the program (January 2016 – December 2017), outlined in this report, integrated feedback from observers and decision makers solicited during Phase 1 (September 2013 – December 2015) in order to enhance the reporting process and develop tools to improve access to information in the reports. New tools and resources developed during Phase 2 comprise a revised report form which incorporates a seven category condition monitoring scale bar, a web map to display observer reports, and updated communications and training materials. These resources were launched to the national network of CoCoRaHS observers, expanding the pilot from the Carolinas to a national program, although CISA's evaluation efforts focused only on the Carolinas.

Key Components of the Carolinas Condition Monitoring Pilot Project

The evaluation of the CoCoRaHS Citizen Science Condition Monitoring program addressed a national-level need for more systematic evaluation of the various tools and methods deployed to collect and communicate drought impacts information. The project evaluation entailed analysis of report content, obtaining feedback from citizen scientists, and surveys with drought decision makers and users of the reports.

- **Report content analysis** assessed the types of information included in reports as well as comparing observer scale bar selections with other, objective drought indices. This analysis revealed that observer scale bar selections generally reflect prevailing meteorological

conditions. Report content varies widely amongst observers providing a detailed picture of the multiple types of conditions occurring in different geographies and under ever-changing conditions.

- The CISA team requested **feedback from the observers** themselves, to understand what was needed to support a successful network of citizen scientists. CoCoRaHS observers are a dedicated group of volunteers who seek to provide relevant and useful information to the decision makers who rely on the reports to better understand how precipitation affects the local environment and community. Ensuring that volunteers are aware of how the information is used by decision makers is a key motivation for continued participation.
- **Decision makers** considered the citizen scientists to be credible and reliable sources of information. Their reports supply information about local conditions that existing monitoring networks and objective drought indicators do not necessarily provide. Feedback solicited from drought decision makers provided information about how the reports can be incorporated into regular drought monitoring as well as other types of decisions, such as frost/freeze warnings and burn bans.

Contributions to a Drought Early Warning System (DEWS)

As a key activity of the National Integrated Drought Information System (NIDIS) Coastal Carolinas DEWS program, one objective of the Citizen Science Condition Monitoring project was to provide usable and reliable drought information on an ongoing basis for drought monitoring and decision making. Project results indicate that a national network of citizen scientists, knowledgeable about their local communities and environment, can play an important role in an early warning system.

- Condition monitoring reports provide information about changing conditions, where drought is emerging, intensifying, or receding. Drought impact reports, in contrast, often focus on the adverse effects and consequences of the most severe or extreme drought.
- Condition monitoring reports contribute to the “convergence of information” used by U.S. Drought Monitor authors to determine drought designations. Citizen scientists’ place-based knowledge allows observers to provide contextual information about environmental and societal impacts of drought that objective indices do not.
- Regular communications and dissemination of educational materials, through networks such as CoCoRaHS, can help to increase public awareness of drought and its impacts.
- The decision making context and processes will shape how, and the extent to which, condition monitoring reports are considered in drought monitoring and response processes. Having staff capacity and regular (weekly) monitoring processes, such as those undertaken by the U.S. Drought Monitor and North Carolina Drought Management Advisory Council, facilitated the reports’ use and utility.

Recommendations

Based on findings and lessons learned from the project, the CISA team makes the following recommendations to support the continued success of a national condition monitoring program. Supporting key components of the program such as volunteer retention, consistency in reporting, and continued refinement of reporting guidance will ensure that the information provided by volunteers is relevant and useful for drought early warning.

- **Continue to support outreach with volunteers and decision makers**. Engagement with both citizen science volunteers and decision makers was critical for supporting their participation and should be continued to facilitate ongoing success of the national program.
- **Invest in technological improvements**. Condition monitoring participation would likely increase if a mobile phone app were available. Project participants also noted that web map enhancements and having a systematic process to collect and review photos would be useful for drought monitoring.
- **Develop regional guidance**. Drought in the Carolinas looks different than drought in other parts of the country. Condition monitoring guidance should reflect regional climates and geographies.
- **Explore new ways to assess report content**. Condition monitoring reports contain a wealth of information about local conditions and the effects of weather events. Additional analyses could examine how to more effectively access and use information for drought monitoring as well as signs of fire weather, frost/freeze occurrences, and other extreme events.
- **Support and encourage partnerships**. Partners from CoCoRaHS, the National Drought Mitigation Center, and the State Climate Office of North Carolina were instrumental in developing and evaluating the new tools and resources introduced through this project. These partnerships were pivotal in encouraging decision makers to consider the information in drought monitoring efforts.


Photo: Christopher Lumpp

Introduction

Identifying and assessing drought impacts are important for understanding and addressing drought vulnerabilities. While such information is a critical component of a comprehensive Drought Early Warning System (DEWS), the collection of drought impact information is typically not well-integrated into existing drought monitoring and management activities).[1, 2]

The Carolinas Integrated Sciences & Assessments (CISA) designed the **Citizen Science Condition Monitoring** project in response to needs and priorities identified by stakeholders at the NIDIS Carolinas Drought Early Warning System: Supporting Coastal Ecosystem Management Scoping Workshop (2012). Workshop participants suggested many potential benefits of improving drought impacts reporting, to include building public awareness of drought conditions and impacts, advancing understanding of the linkages between drought and on-the-ground conditions, and capturing more information about drought onset, intensification, and recovery. *A key priority was to assess ways in which drought impacts might be monitored through a citizen science effort.*

Initiated in 2013 as part of the National Integrated Drought Information System (NIDIS) Coastal Carolinas Drought Early Warning System (DEWS), the **Citizen Science Condition Monitoring** project built on existing tools developed by the Community Collaborative Rain, Hail and Snow (CoCoRaHS) network. CISA recruited citizen scientists in the Carolinas to participate in condition monitoring, asking volunteers to submit weekly status reports about the condition of ecosystems and communities in their area. The focus on regular reporting, in contrast to intermittent drought impact reports, is intended to create a baseline for comparison of change through time and to improve understanding of different stages of drought.

The project was conducted in two "phases." **Phase 1** took place from September 2013-December 2015 and demonstrated that the information provided by citizen scientists was relevant and had potential value for drought monitoring. A separate report documents Phase 1 activities and findings.

Phase 2 took place from January 2016-December 2017, building on recommendations and findings from Phase 1. Phase 2 activities focused on developing and testing new tools to streamline the processes of submitting and accessing condition monitoring reports. While originally conceived as a "pilot" project

[1] Hayes, M. M. Svoboda, N. Wall, and M. Widhalm. 2011. The Lincoln Declaration on Drought Indices: Universal Meteorological Drought Index Recommended. Bulletin of the American Meteorological Society 92: 485-488.
[2] Lackstrom, K., A. Brennan, D. Ferguson, M. Crimmins, L. Darby, K. Dow, K. Ingram, A. Meadow, H. Reges, M. Shafer, and K. Smith. 2013. *The Missing Piece: Drought Impacts Monitoring*. Workshop report produced by the Carolinas Integrated Sciences & Assessments program and the Climate Assessment for the Southwest.

for the Carolinas, the project expanded to a national effort due to positive feedback from project partners, citizen scientists, and drought decision makers.

This report specifically focuses on "Phase 2" (January 2016-December 2017) of the Carolinas pilot project. Individual sections describe the different components of the Carolinas pilot project: volunteer engagement, analysis of condition monitoring reports, and feedback from users of the condition monitoring tools and information. Each component included activities to assess how a citizen science effort can most effectively contribute to the monitoring and understanding of drought impacts. The report also discusses the expansion of the project to a national effort, condition monitoring contributions to drought early warning, and recommendations to further enhance and support the condition monitoring approach on the national level.

Key Features of the Project

1. The project leveraged well-established networks and tools, namely the Community Collaborative Rain, Hail and Snow (CoCoRaHS) Network and the National Drought Mitigation Center (NDMC) Drought Impact Reporter.

The CoCoRaHS Network, established in 1998, is a network of approximately 20,000 volunteer observers who record daily precipitation data throughout the U.S., Puerto Rico, the U.S. Virgin Islands, and Canada. CoCoRaHS is a trusted, high-quality source of precipitation data and is used for a wide range of climate monitoring and research applications. It often supplements data acquired through other monitoring networks, such as the National Weather Service Cooperative Observer Program, or fills in data gaps for areas not covered by those networks (Reges et al., 2016).[3] In addition to daily precipitation observations, CoCoRaHS volunteers have the option to provide supplemental reports regarding hail, severe weather, snow, and drought conditions. Drought impact reports, and subsequently condition monitoring reports, are ingested in the NDMC Drought Impact Reporter, and are accessible through both the CoCoRaHS and Drought Impact Reporter websites.

2. The project used a "condition monitoring" approach to drought impact reporting.

Typically drought impacts data is collected on an intermittent basis, or provided as "one-off" reports, only when dry conditions have reached a more severe level. In contrast, condition monitoring asks volunteers to submit regular status reports about the condition of their local ecosystem and community. Consistent reporting is intended to create a baseline for comparison of change over time and to improve understanding of drought onset, intensification, and recovery.

[3] Reges, H., N. Doesken, J. Turner, N. Newman, A. Bergantino, and Z. Schwalbe, 2016: CoCoRaHS: The evolution and accomplishments of a volunteer rain gauge network. *Bulletin of the American Meteorological Society* 97: 1831–1846, https://doi.org/10.1175/BAMS-D-14-00213.1.

3. The project addressed a national-level need for more systematic efforts that evaluate the various tools and methods being deployed to collect and communicate drought impacts information.

A major project goal was to assess the effectiveness and suitability of the CoCoRaHS citizen science network as a tool to expand drought impacts reporting and monitoring. CISA developed and implemented evaluation methods and activities around three major themes as part of the overall pilot project design in the Carolinas. The Phase 1 and Phase 2 final reports focus on the findings from these efforts.

a) *What practices and approaches are best for engaging citizen scientists around drought issues and building their capacity to participate in drought monitoring?*

   CISA regularly communicated with volunteers throughout the project to provide educational and training materials and to encourage and sustain participation. Communications also indicated to volunteers how their information was utilized by decision makers, a key motivation for many participants. For both Phase 1 and 2, CISA disseminated a series of three online feedback surveys (six total) to Carolinas volunteers to assess the effectiveness of those outreach efforts. Survey results informed ongoing efforts to engage citizen scientists in condition monitoring.

b) *What types of information can volunteers provide in their condition monitoring reports?*

   The CISA team analyzed condition monitoring report content to assess how information provided by citizen scientists could improve understanding of local drought impacts and sensitivities and how the condition monitoring approach could be used to identify signs of drought onset, severity, and recovery.

c) *How can the information provided add value to drought monitoring and decision making?*

   Interviews with drought decision makers provided feedback regarding how the citizen scientists' reports could be used in drought monitoring and decision making and enhance drought early warning and response activities.

4. The project relied on partnerships and ongoing outreach for a sustainable, drought impacts information system.

CISA regularly consulted and worked with national-, state-, and local-level partners such as the CoCoRaHS Network, the National Drought Mitigation Center (NDMC), the North Carolina and South Carolina State Climate Offices, and citizen science volunteers to implement and evaluate the project. Regular communications ensured that the Carolinas condition monitoring project was complementary and not duplicative of other efforts and that lessons learned in other places were incorporated into the Carolinas pilot. Ongoing involvement by CoCoRaHS and NDMC representatives enabled the pilot project to transition to a national effort.

Forty-one drought decision makers provided invaluable feedback over the course of the entire project (Phase 1 and Phase 2). They represented the U.S. Drought Monitor, National Weather Service Offices, drought response committees, and other organizations with responsibilities for monitoring and responding to drought. Their willingness to experiment with and integrate citizen scientists' reports into

drought decision making processes demonstrated how localized, on-the-ground information can be used in drought monitoring.

Volunteer engagement was an integral part of the project design due to its reliance on citizen science volunteers to provide information about their observations of local environmental conditions and drought impacts. Overall, 330 citizen science volunteers in North Carolina and South Carolina submitted condition monitoring reports as part of the Carolinas pilot. Over 1,900 CoCoRaHS observers in North Carolina and South Carolina received regular project newsletters, as well as other drought-related information and educational materials, as part of this project.

Although CISA never actively recruited observers in Georgia, 95 CoCoRaHS observers from Georgia participated in condition monitoring over the course of the study period. During Phase 1 when communications were directly solely to observers in the Carolinas, the 11 Georgia observers who submitted reports likely learned about the opportunity from their regional CoCoRaHS coordinators who helped CISA share information with their volunteers about condition monitoring and recruit participants for Phase 1. These coordinators are based in the National Weather Service forecast offices with county warning areas that extend into Georgia. After the launch of condition monitoring resources to the national network of CoCoRaHS observers, more Georgia observers who learned about the program through national CoCoRaHS communications submitted reports.

Carolinas CoCoRaHS Condition Monitoring Pilot Project Participation

	Phase 1 (Sept 2013 – Dec 2015)	Phase 2 (Jan 2016 – Dec 2017)	Total
Carolinas CoCoRaHS Observers	68	303	371 (54 observers participated in both Phase 1 and Phase 2)
Reports Submitted	1,572	3,165	4,737
Observer Feedback Surveys	3	3	6
Decision Maker Feedback Providers	17	35	41 (11 decision makers provided feedback in both Phase 1 and Phase 2)

Table 1: Carolinas CoCoRaHS Condition Monitoring Project Participation

Phase 1 Recap: September 2013 – December 2015

CISA recruited citizen science groups such as Master Naturalists, Master Gardeners, and CoCoRaHS observers to participate in condition monitoring. CISA asked volunteers to submit weekly status reports about the condition of ecosystems and communities in their area using tools developed by the CoCoRaHS network. To accommodate the project, CoCoRaHS worked with CISA to modify the existing "Drought Impact Report Form" on their website. Using this existing resource provided a fairly easy and efficient way for project volunteers to submit their reports. In addition, this arrangement provided an online repository for the reports. CISA team members, and other potential users, could then view and access the reports through either the CoCoRaHS or NDMC National Drought Impact Reporter websites.

From September 2013 to December 2015, 68 project volunteers provided 1,572 condition monitoring reports. The CISA team coded and analyzed these reports using NVivo, a qualitative analysis software package. CISA used this information to develop maps, graphs, and charts to summarize and visualize the report content for interviews with decision makers responsible for drought monitoring and decision making. CISA conducted interviews with representatives from the U.S. Drought Monitor, State Climate Offices, National Weather Service forecast offices, and state drought response committees to obtain feedback on how their organizations could use the information provided by citizen scientists. Interviewees indicated that the reports were relevant for drought monitoring. However, they also noted that the open-ended nature of the reports made them difficult and time-consuming to access and use. Positive feedback about condition monitoring as an improvement to previously established methods of drought impacts reporting motivated the project's continuation.

Phase 2: January 2016 – December 2017

Based on the positive feedback from citizen science observers, project partners, and decision makers, CISA began **Phase 2** planning in fall 2015. Informed by the needs and suggestions identified in **Phase 1**, new activities focused on streamlining the reporting process and improving the communication and visualization of the reports.

Phase 2 included four major project and corresponding evaluation activities:

1. **Develop new tools to streamline the processes of submitting and accessing condition monitoring reports (October 2015 – September 2017)**

   CoCoRaHS transitioned the original "Drought Impact Report Form" to a "Condition Monitoring Report Form" by removing unused parts of the form and adding a condition monitoring scale bar. CISA developed a web map to spatially display the condition monitoring reports.

2. **Continue communications and outreach with condition monitoring volunteers (January 2016 – December 2017)**

   This included monthly newsletters, quarterly conference calls, and a series of three online feedback surveys circulated to project volunteers over the course of Phase 2.

3. **Analyze condition monitoring reports (November 2017 – March 2018)**

   The State Climate Office of North Carolina studied observer scale bar selections to look for correlations with other, objective, drought indices, namely the Standardized Precipitation Index and the Standardized Precipitation Evapotranspiration Index. Observer case studies further explore how variations in scale bar selections differed across geographies and observer reports. Content analysis was based on observers' self-selected report categories.

4. **Engage with condition monitoring information users (January 2017 – December 2017)**

   Over the course of Phase 2, CISA provided information about the availability of condition monitoring reports to various drought decision makers, requesting that they review the information provided in the reports to determine if it was helpful to inform drought designations or other related decisions. Feedback interviews at the end of Phase 2 assessed if and how the information was used.

Transitioning to a National Program

The CISA team worked with CoCoRaHS headquarters throughout Phase 2 to implement condition monitoring for all CoCoRaHS observers nationally, building on the successful pilot project in the Carolinas. As revisions were made to the reporting process and new tools were developed to access the reports, CISA collaborated with CoCoRaHS partners at Colorado State University and the National Drought Mitigation Center (NDMC) to ensure that materials developed for Phase 2 of the Carolinas pilot were also appropriate to transfer to the national network of CoCoRaHS observers. This included the revised report form and condition monitoring scale bar, scale bar summary data charts, the web map, and recruitment and training materials, including an animation. CoCoRaHS launched the new report form and scale bar to its national network in October 2016 and launched the national web map, scale bar summary data charts, and training animation in September 2017.

This report describes the development of these new materials. However, the evaluation efforts described were solely conducted with respect to the Carolinas pilot program.

"How dry I am. There continues to be a need for rain. For the month of November, we had rain on 9 days for 2.02". This compares to 4 days and.72" in 2016. Lake level continues to drop, now at 409.16'. With warm temperatures, bird activity is low but the yard and garden continue to go dormant. There is very little lake activity."

Scale Bar Selection: Moderately Dry ~ Caswell County, NC, December 3, 2017

"Conditions in the Graniteville/Aiken, South Carolina area have not changed this past week. Received 0.17 inches of light rain on 04APR18. Air Quality sensor readings remain in the MODERATE range due to pine pollen. Soil temperatures have rebounded to the lower 60's. Evapotranspiration evaporative rates have ranged between 0.13 to 0.20 this past week. I had to bring in the ET gauge on the morning of 05APR18 due to freeze warnings issued. (Low Temp 30F). Irrigation of my lawns continues. Today's forecast (07APR18) for rain and thunderstorms are promising. I will report tomorrow (08APR18) if changing conditions are observed."

Scale Bar Selection: Moderately Dry ~ Aiken County, SC, April 7, 2018

Timeline

The timeline below provides a summary of activities conducted over the course of the entire condition monitoring project, from initial scoping to final analysis. There was some overlap between Phase 1 and Phase 2 activities as new tools and resources were developed beginning in 2015 to implement Phase 2 activities.

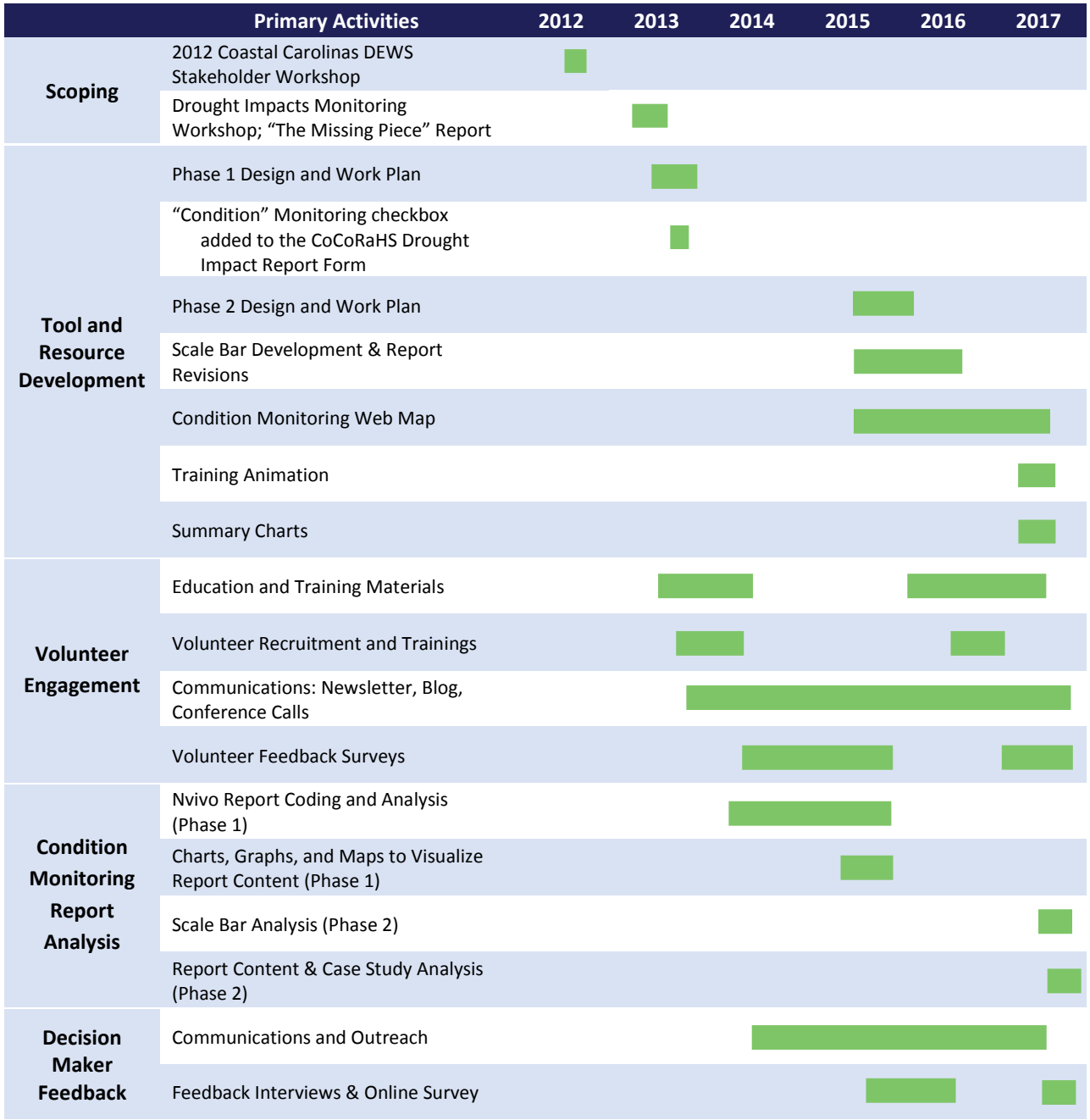


Figure 1: CoCoRaHS Citizen Science Condition Monitoring Project Timeline


Photo: Amanda Farris

New Tools for Condition Monitoring

The primary objective of Phase 2 was to develop, implement, and evaluate two enhancements to the project: 1) a condition monitoring scale bar and 2) the condition monitoring web map. These tools are intended to streamline the processes of submitting and accessing condition monitoring reports. CISA developed these tools based on feedback from Phase 1 of the project and in consultation with CoCoRaHS, the NDMC, drought decision makers, and CoCoRaHS observers.

Condition Monitoring Scale Bar

Submitting raw text reports produces rich data, but there are inherent drawbacks. The open-ended report format produces inconsistency in what is reported in terms of content, as well as spatial and temporal characteristics of the data. More importantly, it is very difficult and time consuming to process report text into a summarized form for end users. Open-ended reports are valuable, but Phase 1 interviewees noted a need for close-ended questions in addition to the text reports to provide more structure and comparability between different reports. The idea for a condition monitoring scale bar was proposed to meet this need.

Beginning in summer 2015, CISA graduate student David Eckhardt conducted research and outreach with decision makers and CoCoRaHS observers to develop the scale bar and prototype web map as a master's project in the University of South Carolina, Department of Geography. Summary information is provided in the February 2017 project progress report; more detailed information is available in Eckhardt's final master's project paper.[4]

In order to provide a standardized drought metric and enhance condition monitoring reporting, Eckhardt developed the Condition Monitoring Scale Bar using a seven category Likert scale format (Figure 2). This scale bar design limits cognitive load and the Likert scale protocol is well established. Striking a balance between decision maker utility and observer usability is important. The final iteration of the scale bar achieves this balance. The construction of the scale bar categories, and accompanying guidance, was based upon USDM categories.

[4] Eckhardt, D. 2015. Improving Citizen Science Condition Monitoring Reporting: Condition Monitoring Scale Bar. Master's Project Paper, Department of Geography University of South Carolina, Columbia, SC.

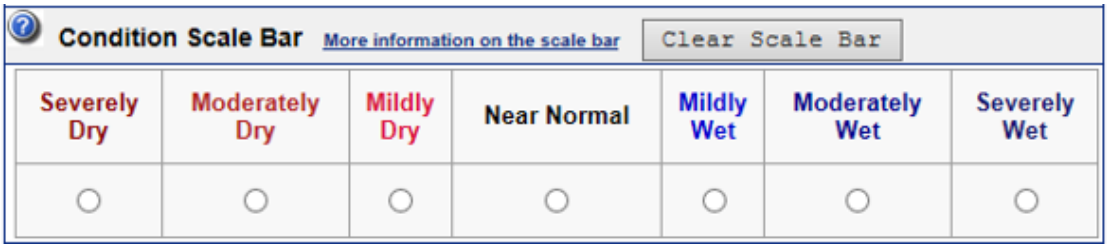


Figure 2: Final iteration of the Condition Monitoring Scale Bar

Scale Bar Guidance

During the conceptual development stage for the scale bar it became clear that citizen scientists would need guidance on making scale bar selections. Clear definitions as to what constitutes each category of dry and wet conditions are necessary in order to obtain consistent responses from observers. This sentiment was independently echoed by some drought decision makers in feedback interviews as well. Citizen science research also states that projects should develop protocols for citizen participation. Protocols can guide citizen scientists in their data collection efforts and help to ensure data quality and potential use of the data.[5]

CISA, with CoCoRaHS and NDMC input, created guidance for each dry, wet, and neutral category for the scale bar, producing seven descriptions of likely conditions. The guidance is a composite of the "Possible Impacts" categories used in the U.S. Drought Monitor Drought Severity Classification table and information derived from qualitative coding of Condition Monitoring reports during Phase 1 of the condition monitoring pilot project. Guidance for Mildly Dry is written to match D0 (Abnormally Dry), the least severe USDM category. Moderately Dry is tied to the possible impacts list for D1 (Moderate Drought), and Severely Dry is associated primarily with D2 (Severe Drought) but extends description to include the possibility of impacts listed under D3 (Extreme Drought) and D4 (Exceptional Drought).

Condition Monitoring Report Form

CISA, CoCoRaHS, and NDMC also collaborated to make modifications to the online report form, converting it from a "Drought Impact Report Form" to a "Condition Monitoring Report Form" (Figure 3). This change reflects a growing need and recognition for a more systematic approach to the monitoring of local conditions and the effects of drought at different stages.[6, 7]

Specific modifications included changes to the "Report Date" and "Report Categories" sections of the form and removal of the request for monetary impact amounts. Instead of requesting that observers include both a start and end date, the form was updated to only include a report submission date. This was intended to reduce confusion about when a report period might start or end for an observer. The

[5] Bonney, R., J. L. Shirk, T. B. Phillips, A. Wiggins, H. L. Ballard, A. J. Miller-Rushing, and J. K. Parrish. 2014. Next Steps for Citizen Science. *Science* 343: 1436-1437.
[6] Ferguson, D. B., A. Masayesva, A. M. Meadow, and M. A. Crimmins. 2016. Gauges to Range Conditions: Collaborative Development of a Drought Information System to Support Local Decision-Making. *Weather, Climate and Society* 8: 345-359.
[7] Meadow, A. M., M. A. Crimmins, and D. B. Ferguson. 2013. Field of Dreams, or Dream Team?: Assessing Two Models For Drought Impact Reporting in the Semiarid Southwest. *Bulletin of the American Meteorological Society*. doi: 10.1175/BAMS-D-11-00168.1.

General Awareness report category was added to allow observers to make a selection about the content of their report if they were not submitting information about specific impacts related to the other report categories (e.g., agriculture, tourism and recreation, water supply and quality, etc.). Finally, the request for monetary impacts was removed from the form. This information was rarely entered on the Drought Impact Report form, primarily because observers were unclear about what to submit. Figure 3 below shows the original Drought Impact Report form (top) in comparison to the modified Condition Monitoring Report form (bottom).

CoCoRaHS officially replaced the Drought Impact Report Form with the Condition Monitoring Report Form on Monday, October 10, 2016. As of April 13, 2018, 22,948 condition monitoring reports have been submitted by 3,297 CoCoRaHS volunteers across all 50 states, Puerto Rico, and the Bahamas.

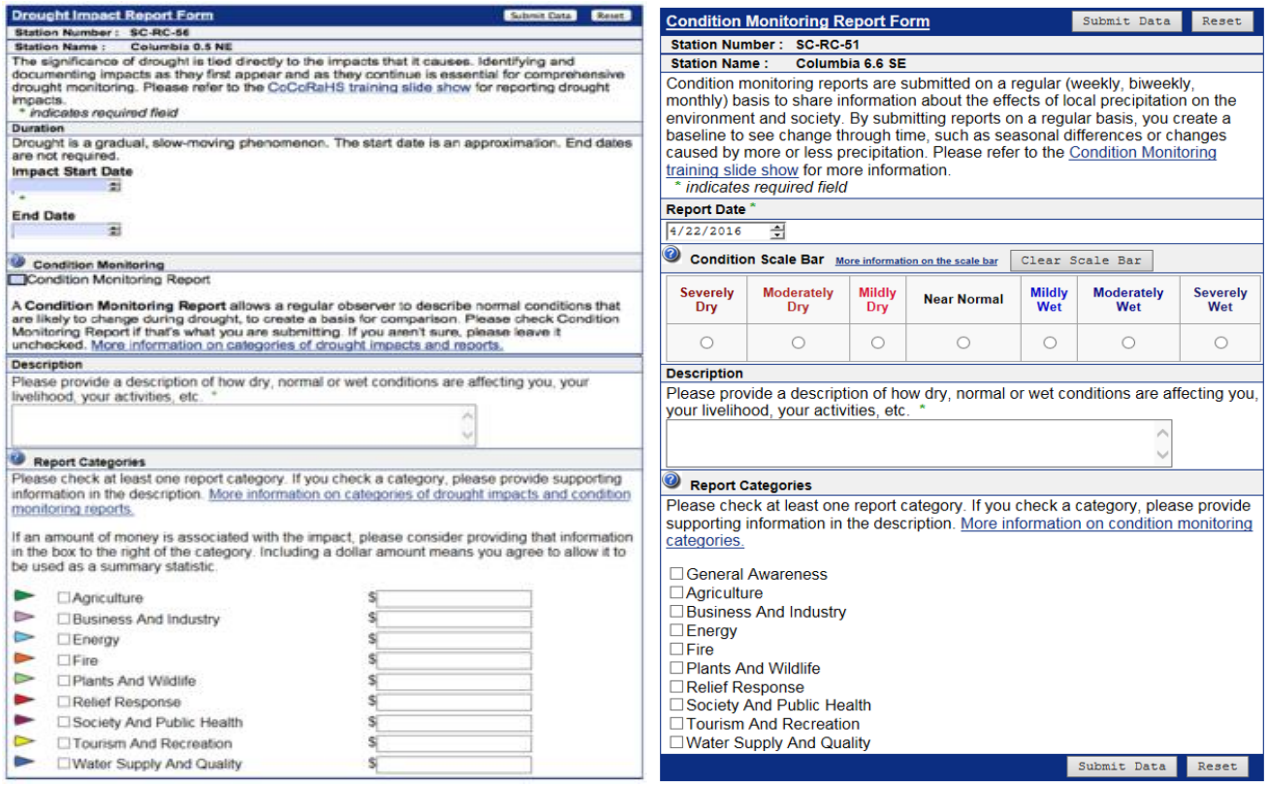


Figure 3: CoCoRaHS Drought Impact Report Form (left) converted to Condition Monitoring Report Form (right)

Condition Monitoring Web Map

Interviews with decision makers who regularly monitor drought conditions, such as US Drought Monitor authors, provided the impetus for the web map. Interviewees indicated that a streamlined and efficient way to access the condition monitoring reports would potentially enhance their use of reports for monitoring and decision making.

Carolinas Web Map Version 1.0

CISA began development of the Condition Monitoring Web Map in September 2015. Version 1.0 (Figure 4) was completed and made publicly available from the CISA website in April 2016. The web map allowed users to view the location of each observer's report and click the location to access the full qualitative report. Additional base layers that could be toggled on and off are intended to help contextualize observer reports. These layers included climate divisions, ecological regions, watersheds, and the US Drought Monitor map.

After this initial release of the web map, the State Climate Office of North Carolina (SCONC) began using the map to access condition monitoring reports and share information about drought impacts on weekly calls with the NC Drought Management Advisory Council (DMAC). These reports helped council members delineate drought designations on the NC drought monitor map.

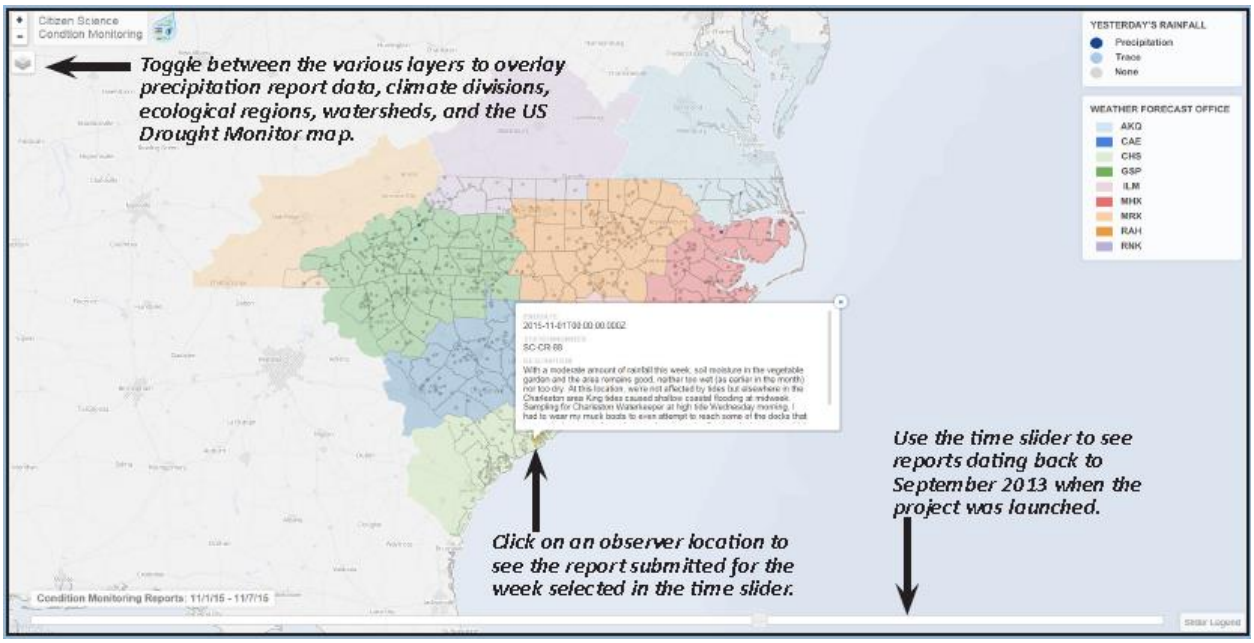


Figure 4: The Carolinas Condition Monitoring Web Map, Version 1.0

Carolinas Web Map Version 2.0

Refinements to the web map were made from June 2016 to January 2017; version 2.0 (Figure 6) was launched in January 2017. Web map 2.0 allowed users enhanced access to condition monitoring reports and provided spatial context for the information provided by citizen scientists. Improvements to the web map were made in the following areas: mobile first design, quicker site performance, increased report legibility, searchable report content, improved symbology, additional basemaps, and data downloading.

A collapsible sidebar was added to allow users to scroll through observer reports. Users can scroll through reports to find information of interest. The report location is highlighted on the map when a user hovers over a report in the sidebar. Reports can also be filtered in the sidebar by searching for specific keywords or category type in the search bar at the top of the column. Additionally, the pop up used in the map to display the report was improved to make the content more legible.

In the original version of web map 2.0, report locations were shown as a cluster in the symbology on the map. Feedback from users indicated that, even if observer locations were very close and the individual symbology overlapped on the screen, users would prefer to see the individual report locations represented. Therefore, a symbology was developed to denote the observers scale bar selection to represent their location (Version 2.1, Figure 6). Dry scale bar categories are represented by increasingly darker shades of red and as an inverted triangle. Wet scale bar categories are represented as triangles of increasingly darker shades of blue. The triangle and inverted triangle were used to help distinguish between wet or dry conditions for color blind individuals. The near normal scale bar selection is represented by a gray circle.

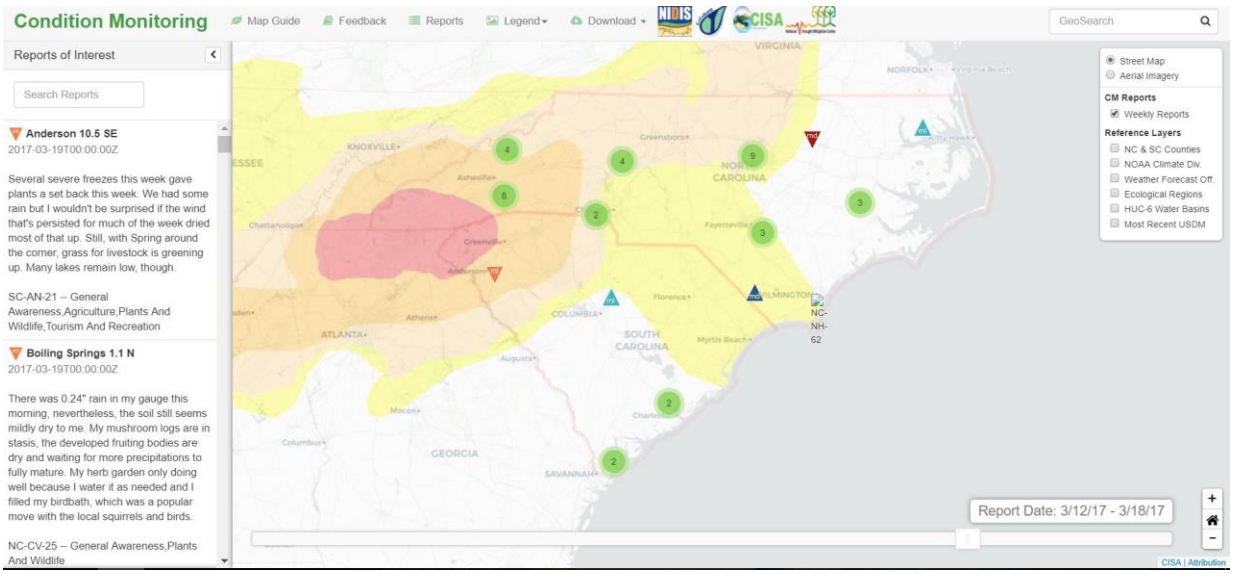


Figure 5: The Carolinas Condition Monitoring Web Map, Version 2.0

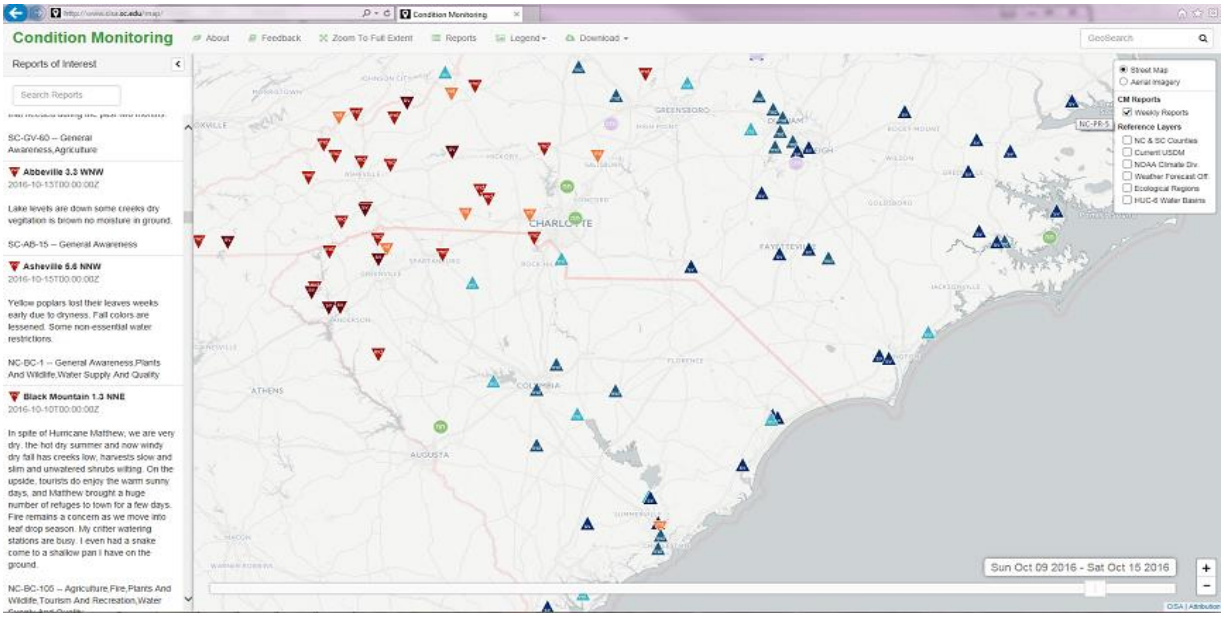


Figure 6: The Carolinas Condition Monitoring Web Map, Version 2.1

The National Condition Monitoring Web Map

CISA initiated discussions with CoCoRaHS and NIDIS about expanding the Condition Monitoring Web Map, initially only available to the Carolinas, to a national map in January 2017. CoCoRaHS provided IT support to CISA to help maintain the Carolinas web map such as ensuring that the data feed of condition monitoring reports continued uninterrupted, answering technical questions, and discussing how new features might be incorporated into the national version of the map. CoCoRaHS also provided IT support to CISA to develop a national condition monitoring web map to include code development and database management. The national web map was integrated into the CoCoRaHS website and launched in September 2017 (Figure 7).

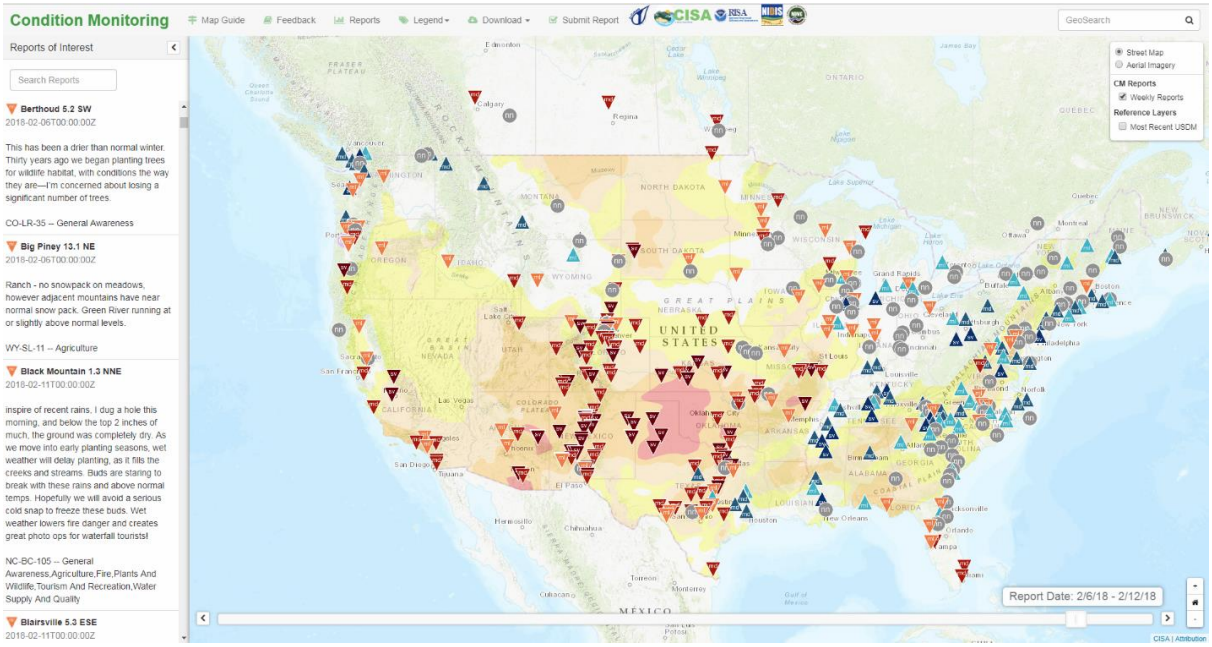


Figure 7: National Condition Monitoring Web Map

Condition Monitoring: From the Carolinas to a National Effort

As the Carolinas pilot project progressed, new tools and resources for the Carolinas would not have been possible without CoCoRaHS involvement and collaboration.[8] The CoCoRaHS team supported the change from "drought impact reporting" to "condition monitoring" for its entire network of observers. As described above, CoCoRaHS and CISA collaborated to modify the report form and develop the National Condition Monitoring Web Map.

October 10, 2016: CoCoRaHS released the condition monitoring report form to its network of approximately 20,000 volunteers. Through April 2018, over 23,000 reports have been submitted from observers across the United States.

September 11, 2017: CoCoRaHS launched the national web map and training animation. Between December 1, 2017 and April 15, 2018 (the date range for which CoCoRaHS has website user data), the map has recorded 3,096 views.

To accompany these new tools, CISA and the CoCoRaHS teams modified existing Carolinas-specific observer training materials for a national audience (see CoCoRaHS Condition Monitoring resource page), with the intent to encourage more CoCoRaHS observers to contribute to the program. Materials include general information sheets, reporting instructions, online training slideshows, and frequently asked questions.

These materials incorporate lessons learned and feedback from interactions with observers participating in the Carolinas pilot program. For example, guidance for observers with respect to report content and timing has also been refined over the life of the project to make the reports most useful. One such addition has been the recommendation to submit reports on Saturday or Sunday so that reports are available at the beginning of each week for review by US Drought Monitor authors and members of the NC Drought Management Advisory Council (DMAC) as they work to develop the weekly USDM map.

To accompany the national web map launch CoCoRaHS, CISA, and other partners developed a training animation and summary charts to support the condition monitoring effort. These resources were released in September 2017, with the launch of the national web map.

[8] Additional funding from NIDIS was provided through UCAR to CoCoRaHS and Noah Besser to support the national launch of the condition monitoring program.

Training Animation

CISA collaborated with animator Noah Besser and CoCoRaHS to develop a condition monitoring animation to help citizen scientists understand the reporting process and what their efforts can produce. The animation includes information describing condition monitoring, who uses the reports, how to submit reports, and what types of information to include. CISA developed the first draft of the storyline and narration script and provided feedback on the draft storyboard. After the initial round of revisions, CISA worked with CoCoRaHS to obtain feedback on the draft animation from CoCoRaHS volunteers, the target audience for the animation. Their feedback was incorporated into the final version of the animation.

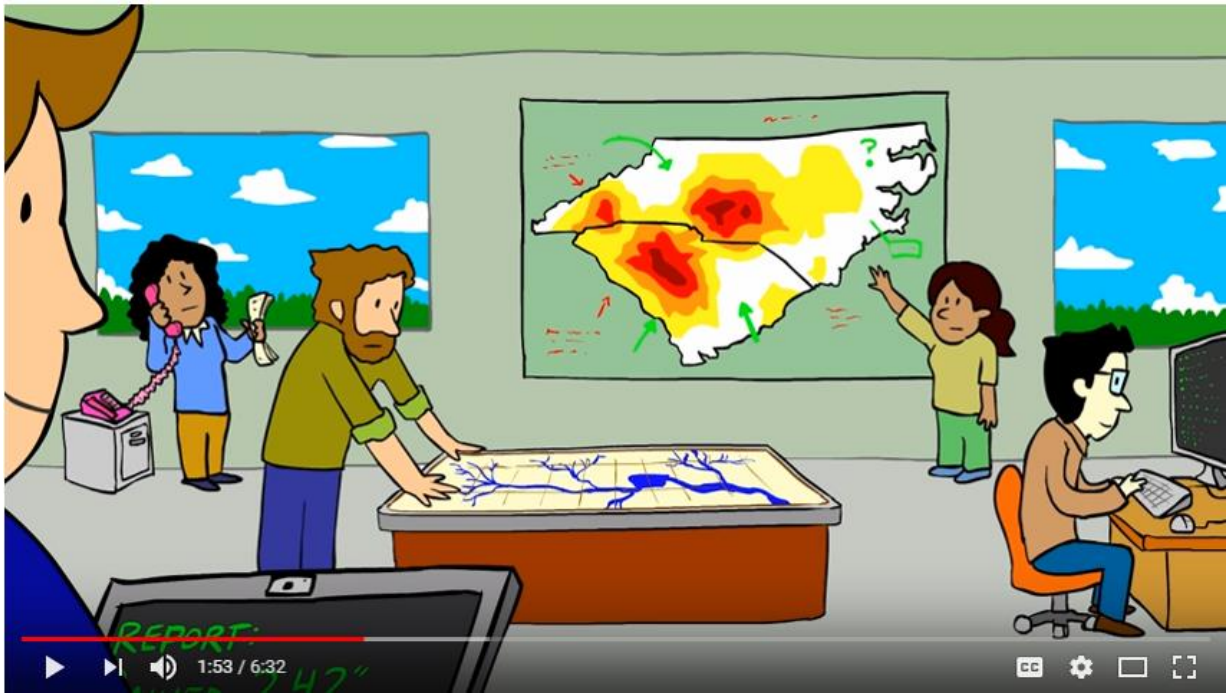


Figure 8: The CoCoRaHS Condition Monitoring Training Animation

Summary Charts

CoCoRaHS created a new webpage to provide summary charts which display information provided in condition monitoring reports to document changing on-the-ground conditions over time. The summary charts provide an overview of the data displayed on the national web map using observers' scale bar selections. By providing a weekly count of wet, dry, and near normal reports, at quick glance a user can see change over time in the information submitted by volunteers. Another chart depicts counts for which condition monitoring categories (Agriculture, Energy, etc.) were checked in the reports. Users can view data at the national, state, county, or station number level, beginning from October 2016 (when the condition monitoring report form was released nationally).

National Communications, Outreach, and Dissemination Plan

CISA and CoCoRaHS followed a strategic dissemination plan to ensure that information about these new resources was circulated to all CoCoRaHS observers, as well as potential users of condition monitoring reports. Information was circulated through the networks of CISA, CoCoRaHS, the National Drought Mitigation Center, other NIDIS DEWS programs with which the project team engages, and state and regional CoCoRaHS coordinators.

While CISA continued to issue targeted communications for the Carolinas, CoCoRaHS sent e-mail announcements directly to all CoCoRaHS observers. They also utilized the CoCoRaHS Message of the Day that appears after an observer submits a daily precipitation report to further promote the condition monitoring report form. A monthly e-mail written by Nolan Doesken, National Director of CoCoRaHS, continues to remind observers to submit their condition monitoring reports. Materials were also promoted through the NIDIS newsletters and other opportunities as they arose.


Photo: Julie Sohm

Condition Monitoring in the Carolinas: Volunteer Engagement and Participation

Observer guidance and communications and outreach efforts are very important for observer retention in all citizen science efforts (Dickinson et al., 2012). CISA worked to ensure high volunteer retention rates for the Carolinas pilot through distribution of materials such as a monthly newsletter and quarterly observer conference calls. As CISA and CoCoRaHS launched the new report form (October 2016), CISA communicated to Carolinas observers about the form modifications in advance of the change, primarily through the monthly Carolinas newsletter and a webinar.

Volunteer Recruitment: Utilizing an Existing Network of Observers

In summer and fall 2016, the CISA project team worked with the state climate offices and regional CoCoRaHS coordinators to disseminate information about Phase 2 and recruit participants from the existing network of CoCoRaHS observers in the Carolinas. CISA also conducted outreach to existing condition monitoring volunteers to encourage continued participation, using their experience with the project to solicit feedback during the development of the scale bar and revisions to the condition monitoring report form.

Phase 2 participation primarily relied on the existing network of Carolinas observers, although efforts were made to recruit participants from other citizen science initiatives and groups who monitor and manage environmental resources, particularly those in coastal areas who might be able to contribute to the Coastal Carolinas DEWS program. This included presentations to the Master Gardeners of Florence, SC, in November 2016, and at the Waccamaw Conference in Myrtle Beach, SC, in February 2017.

Communications and Outreach to Support Volunteer Retention

Following citizen science and volunteer engagement best practices, the team regularly communicated with volunteers through the monthly newsletter, the Cuckoo for CoCoRaHS in the Carolinas blog, the project webpage, volunteer conference calls, and presentations (in-person and via webinar).

Newsletter content drew from lessons learned in citizen science engagement, reiterating to participants the value of their contributions and how the information they provide is used. CISA team members solicited feedback for newsletter content from volunteers to show responsiveness to volunteer information needs. Project correspondence also provided information about other citizen science efforts and educational opportunities.

CISA distributed the monthly newsletter to all NC and SC CoCoRaHS observers, not just condition monitoring reporters, thereby encouraging new condition monitoring reporters as they learned more about the program each month. State CoCoRaHS coordinators were pleased to have this regular correspondence to share with volunteers noting a lack of time and resources in their own offices to provide this resource. The newsletter consistently included a "Climate Update for the Carolinas" with information about any recent significant weather events and the current US Drought Monitor map. The newsletter also included a "Star of the Month" condition monitoring reporter to highlight high quality reports from a different observer each month. Graduate students interviewed the "Star of the Month" to provide additional context and perspective. According to survey responses, observers selected as "Star of the Month" identified this as a key incentive to continued participation and increased their confidence in reporting. After the national program was launched, observers from other parts of the country were also included in this newsletter feature, in order to better connect the broader network of volunteers.

Other newsletter articles provided updates on the research efforts of the CISA team, information about a variety of different citizen science projects, ideas for report content such as monitoring for seasonal changes, interviews with drought decision makers about how they use condition monitoring reports, and seasonally relevant articles. For example, the December 2015/January 2016 newsletter featured a sports climatology with information about potential weather conditions for the upcoming football playoff season. Observers have reported using newsletter articles to learn about more citizen science opportunities such as the National Weather Service cooperative observer program and National Field Photos Weekends.

In addition, the team held quarterly conference calls with observers to disseminate information, deliver trainings, receive feedback, and provide a forum for discussion between observers, team members, and practitioners. End-users of the CoCoRaHS Condition Monitoring Reports such as the North Carolina State Climate Office or the local National Weather Service office often attended the calls as well. Observers expressed that these opportunities for communication helped them improve their personal data gathering and reporting.

The content of the Cuckoo for CoCoRaHS in the Carolinas blog posts coincided closely with the types of information and resources provided in the newsletter. However, blog readership was much lower. Additionally, feedback through volunteer surveys indicated that the blog was not a widely accessed resource. Therefore, CISA's communication efforts primarily focused on the newsletter and observer conference calls during Phase 2.

Volunteer Participation

Figure 9 below shows Carolinas condition monitoring observer locations and the number of reports submitted by each observer. Because communications and outreach in Phase 2 was circulated to all observers in the Carolinas, not just those who were directly recruited by CISA to participate, the number of participating observers and reports submitted in Phase 2 substantially increased.

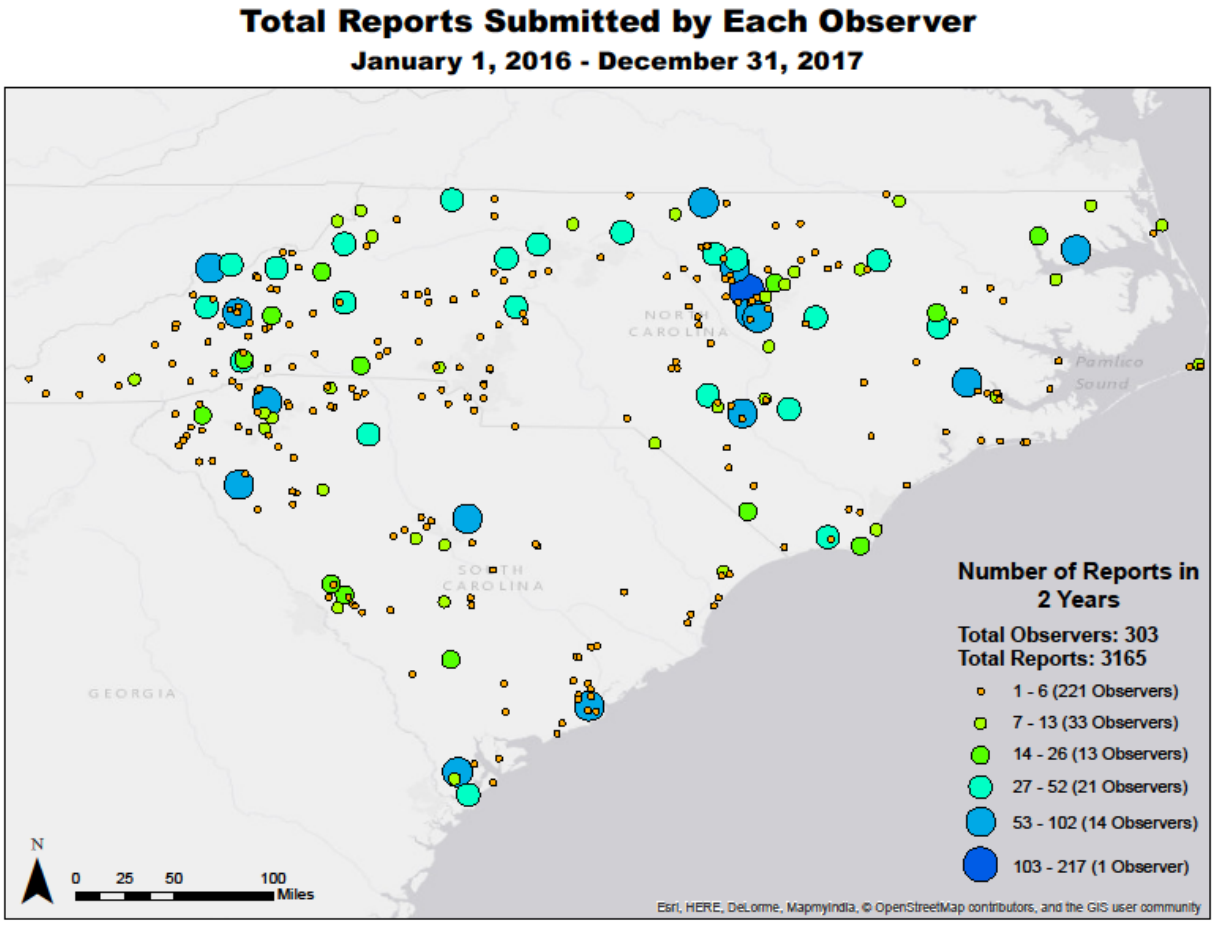


Figure 9: Total Reports Submitted by Carolinas Observers during Phase 2

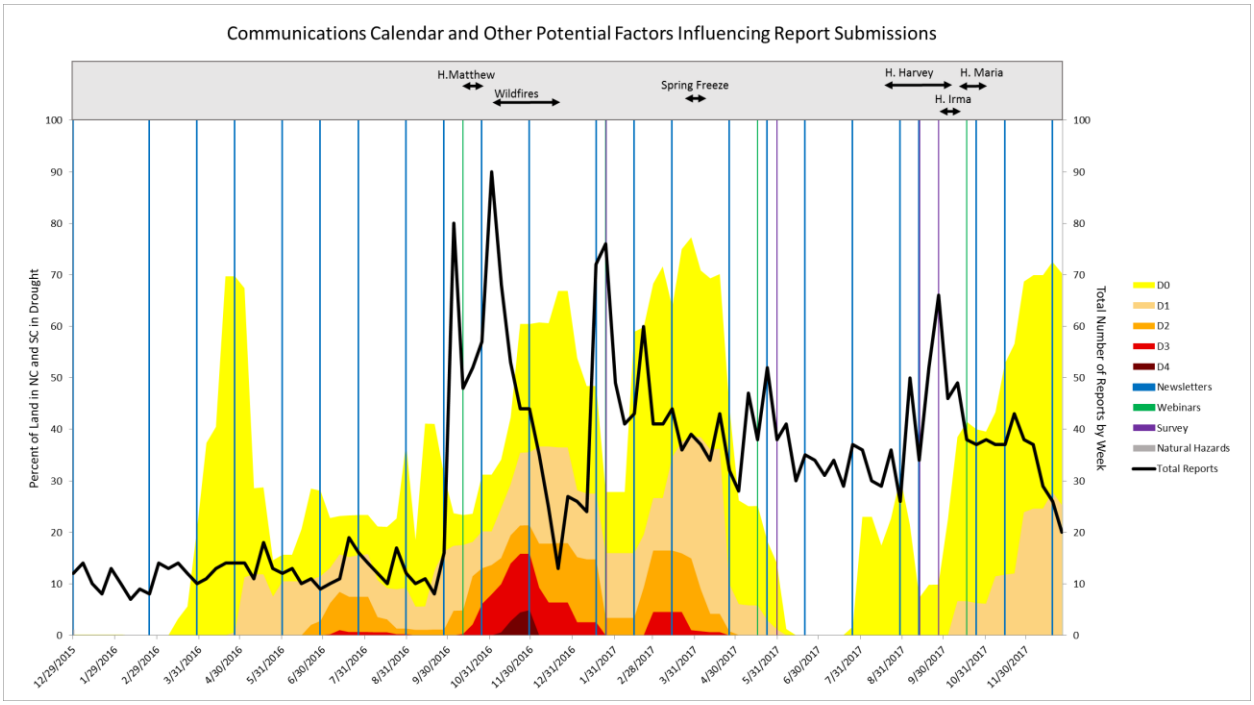


Figure 10: The number of condition monitoring reports submitted during Phase 2 (black line) overlaid with 1) US Drought Monitor drought designations in NC and SC, 2) extreme weather events that occurred, and 3) communication dissemination dates

Figure 10 above depicts the number of condition monitoring reports (represented by the black line) submitted during the Phase 2 study period in conjunction with factors which may have influenced the number of submitted reports. These factors include the severity of drought conditions in the Carolinas at any given time, extreme events which occurred during the study period, and the dissemination dates for communications and outreach materials (e.g., newsletter, webinars, feedback surveys).

The reporting trends suggest that communications by both CISA and CoCoRaHS helped to boost participation in condition monitoring. Feedback surveys also seemed to trigger spikes in condition monitoring. Over the course of the year during which three online feedback surveys were circulated to Carolinas observers, the number of respondents indicating that they did not submit condition monitoring reports because they were unaware of the program declined.

Drought conditions during the Phase 2 study period did not appear to contribute to a significant increase in the number of reports submitted. For example, there was a decline in the number of reports submitted between October and November 2016 despite worsening drought conditions. There was, however, a spike in reporting in January 2017. This more likely corresponded to the observer feedback survey and monthly newsletter that were circulated to Carolinas observers, reminding them to report. These communications materials seemed to be a greater driving force for participation in the earlier months of the study period.

Extreme events (other than drought) appeared to contribute to an increase in report submissions as well. For instance, Hurricane Matthew, which made landfall in the Carolinas in September 2016, led to major impacts along the coastline and throughout the Southeast as coastal residents evacuated to inland communities. An increase in report submissions motivated by these impacts was evident as observers documented their experiences during these events.

"As a result of Hurricane Matthew, the water from the marsh along the Ashley River covered my neighbor's backyard for the first time. It lifted the bottom step of my deck off its footing. It has never been this high, even last October [2015] did not reach this level."

Charleston County, SC, October 9, 2016

"No direct impact on me, but numerous people in the southeast portion of the state are severely impacted by the aftermath of Hurricane Matthew. Roads are blocked, farmers' fields are inundated, homes are under water, and beaches are eroded. Has the water supply been impacted by agricultural runoff? Testing stations are inaccessible due to flooding."

Brunswick County, NC, October 15, 2016

Volunteer Feedback Surveys

CISA disseminated three online surveys for project volunteers in the Carolinas to obtain feedback during Phase 2. More specific questions asked for feedback regarding the new tools developed for Phase 2 (i.e., condition monitoring scale bar and web map), motivations for participation, and the training and communications materials provided by CISA.

CISA circulated surveys to all CoCoRaHS observers in the Carolinas who submitted a precipitation report since October 2016 (Table 2), to correspond with the launch of the new condition monitoring report form on the CoCoRaHS website. To support the evaluation process during Phase 2, CoCoRaHS gave administrative access to CISA in order for the research team to have access to contact information for all observers in the Carolinas. This allowed CISA to request feedback from more observers than in Phase 1 of the project, during which only those observers with whom CISA had direct contact through trainings received surveys. Consequently only 85 participants received feedback surveys in Phase 1, while all Carolinas CoCoRaHS observers who reported precipitation data received surveys in 2017 (see Table 2).[9] The number of survey recipients varied over the study period due to new volunteers joining CoCoRaHS (CISA added these observers to the survey distribution list) or when observers unsubscribed from the CISA email distribution list.

Survey Circulation Date	Survey Recipients	Responses
January 26, 2017	1,877	800 (43%)
May 26, 2017	2,026	638 (31%)
September 25, 2017	1,997	320 (16%)

Table 2: Phase 2 Volunteer Feedback Survey Distribution and Responses

[9] Note: Not all survey respondents answered all questions. Figures 11-14 indicate the number of respondents who answered the specific questions discussed in the report.

Feedback on Participation

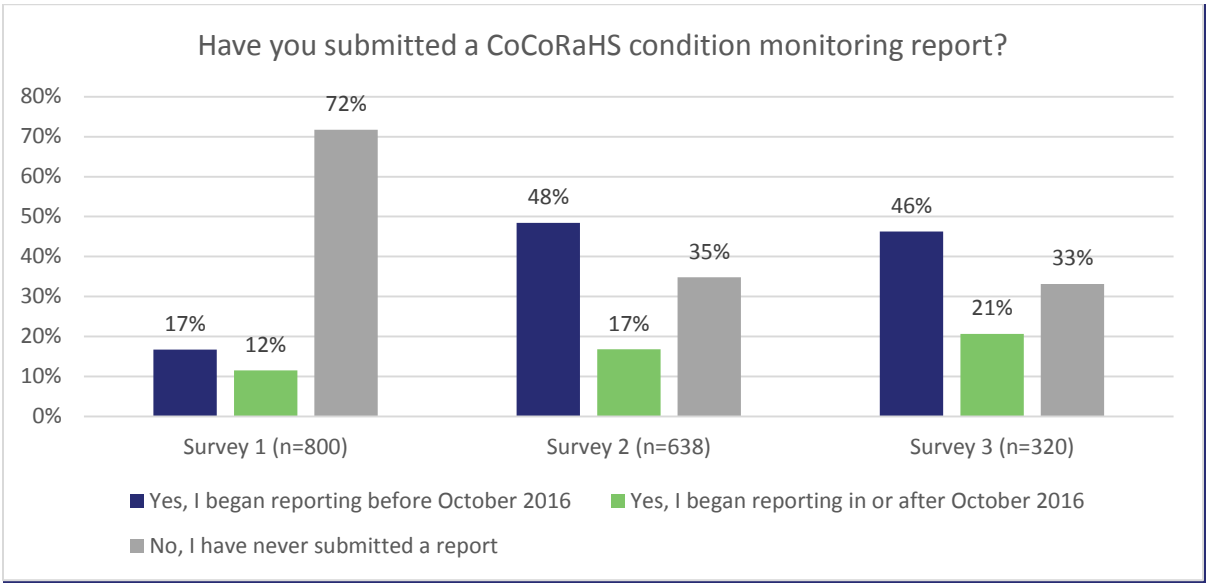


Figure 11: Carolinas CoCoRaHS observer participation in condition monitoring

All three surveys inquired about CoCoRaHS observers' participation in condition monitoring reporting (Figure 11). The reasons for not participating appeared to shift over the survey period (Figure 12). In Survey 1, most respondents (51%) listed they were unaware of the reports, while others (19%) were only interested in submitting precipitation data. Over the next two surveys, the number of respondents unaware of the program dropped (17%), but those interested in submitting only precipitation data increased (41%). From written comments, respondents who did not submit had a variety of reasons that echoed through all 3 surveys. Feedback included perceptions that the process was complicated and time consuming, the observer's location was not interesting enough or helpful, and personal issues, such as frequent travel.

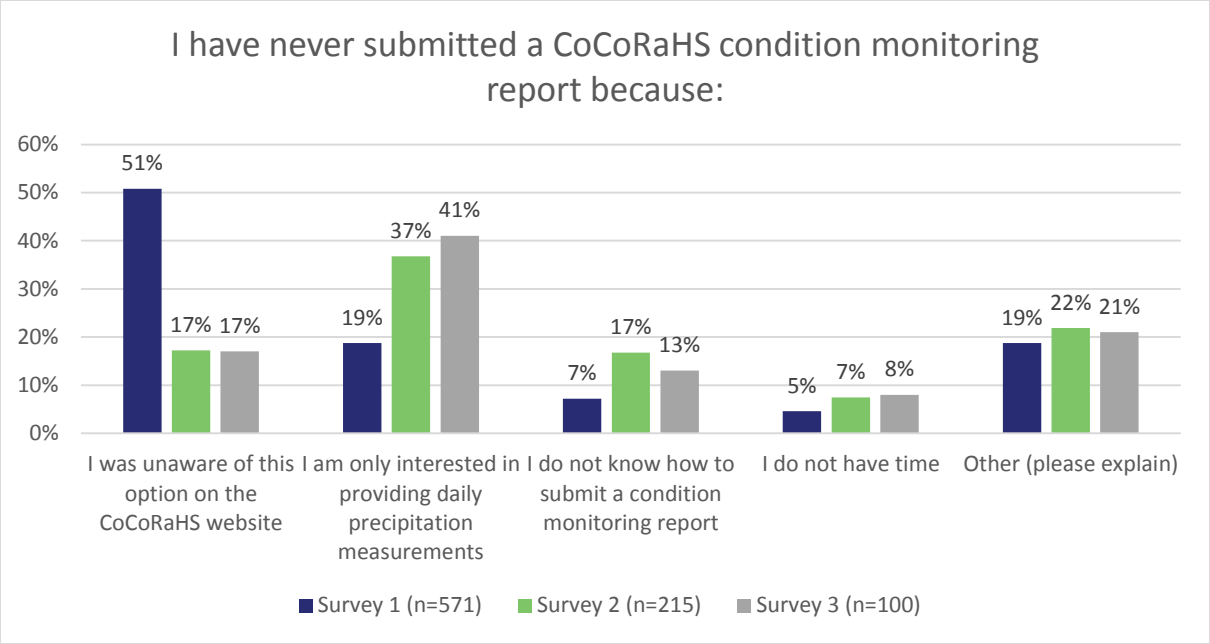


Figure 12: Reasons Carolinas CoCoRaHS volunteers did not submit condition monitoring reports

Survey 1: Feedback on Trainings, Scale Bar, and Web Map

The first survey asked for feedback on the scale bar, trainings, and the Carolinas-based web map. Approximately half of the respondents found the scale bar made reporting easier (47%). Deciding which category of the scale bar to select was easy or somewhat easy for most respondents (64%). Respondents selected categories by referencing data from their own reports (62%), comparing the conditions to normal precipitation amounts for the area (31%), or comparing conditions to the previous week (30%). Observer trainings were attended or viewed online by half of those surveyed, and the majority found them to be useful. The survey asked for web map feedback but a majority of respondents were not utilizing it at that time (58%). Most were unaware of the web map (71%), perhaps due to its recent release to the public. However, those who had viewed the web map found it useful and liked to be able to view and read other condition monitoring reports in conjunction with the US Drought Monitor Map.

Survey 2: Feedback on Reporting Frequency and Communications Materials

The second survey queried about the frequency of reporting, respondents' confidence in reporting, and the effectiveness of communication materials. Most respondents (71%) reported with the same frequency since beginning condition monitoring. Respondents who report consistently credited their participation to the complementary nature of monitoring with their interest in weather and the environment (79%). The map on page 27 (Figure 9) represents observer locations and indicates the number of reports submitted over the Phase 2 study period. Those who reported more consistently are represented by the larger circles, indicating a higher number of reports submitted. Other factors that motivated reporting include a sense of contributing to scientific knowledge, how well condition monitoring fits with an observer's skills, and resources provided by CoCoRaHS (Figure 13).

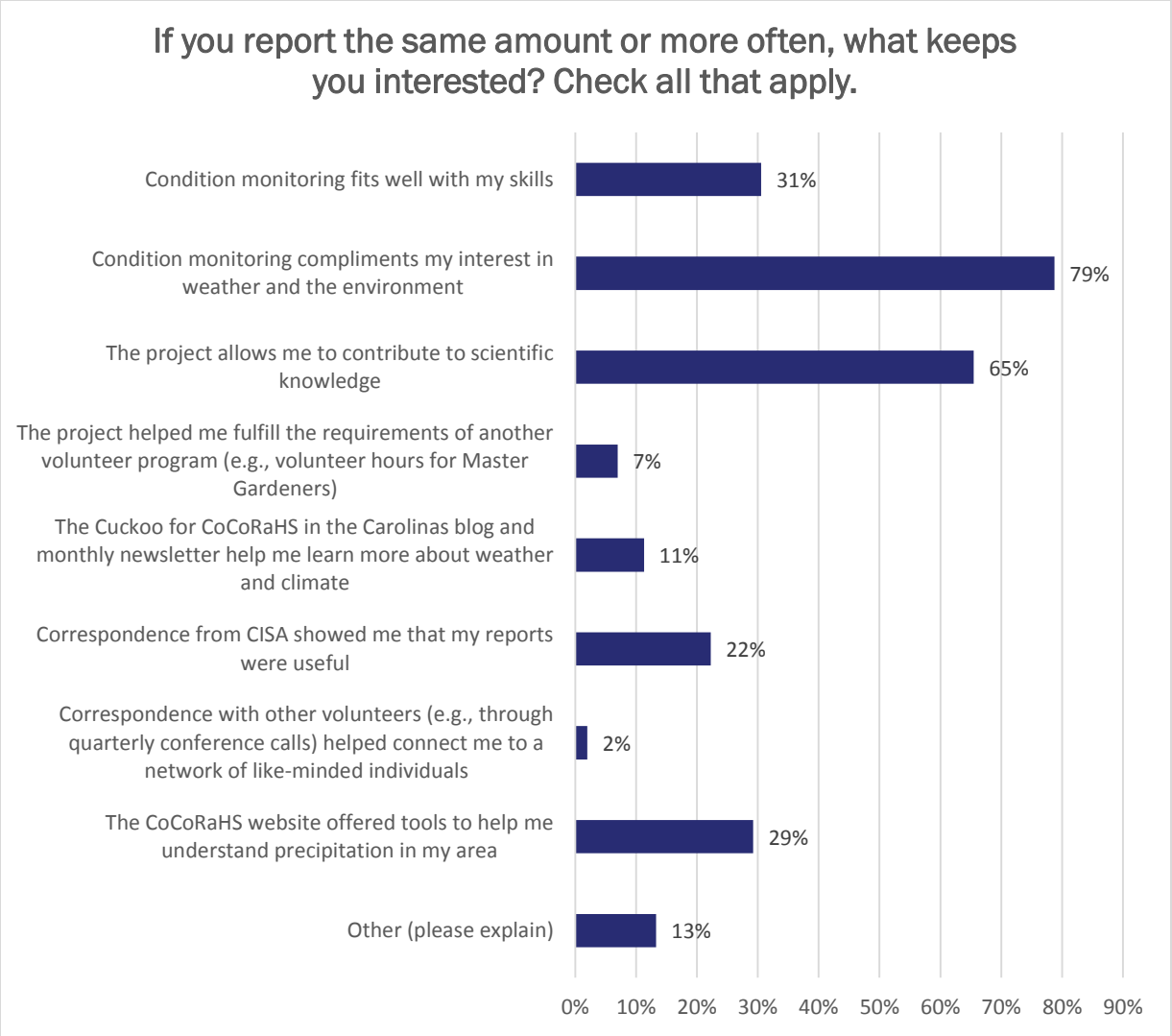


Figure 13: Motivations for conditioned participation in condition monitoring, n=301

Those who reported less frequently attributed this to a variety of reasons including forgetting to report, not feeling the need to report normal conditions, and travel. Most respondents were very confident (59%) in reporting conditions in their area, while very few were not confident (2%).

Survey respondents read the CISA and CoCoRaHS monthly newsletter (58%) more than the Cuckoo for CoCoRaHS in the Carolinas blog (21%). The most important information gleaned from these communications included the knowledge of how reports are being used, what information to provide in the condition monitoring reports, and current weather and climate conditions in the Carolinas.

Survey 3: Feedback on Learning, General Impressions, and Demographic Information

The final survey asked CoCoRaHS observers about their frequency of reporting, impressions of condition monitoring, and demographic information. Over 70% of respondents reported with the same frequency as when they first began reporting, with 20% reporting less often or not at all. When asked to rate

several statements about their experiences with condition monitoring, most respondents felt that they had learned more about the effects of precipitation on the local environment, contributed to scientific knowledge, and taught others about weather. While some respondents indicated that monitoring required more effort than they expected, they also believed it was useful to themselves and the scientific community, convenient, and they planned to continue reporting (Figure 14).

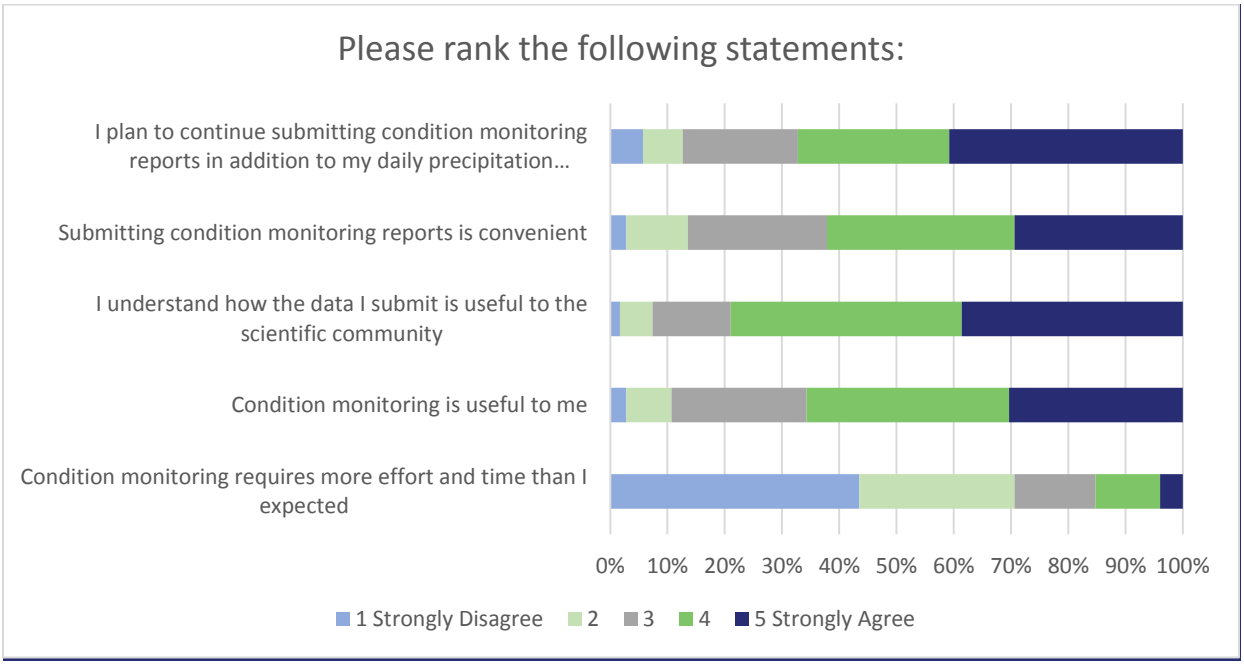


Figure 14: Carolinas' observers' perceptions about the CoCoRaHS Condition Monitoring program, n=178

More observers who responded to the survey reside in North Carolina (66%) than South Carolina (32%). There were more male (69%) observers than female. While there were several races represented, including African American, Hispanic, and mixed heritage, the majority of responders were white (88%) and over the age of 60 (74%). The age of observers corresponds with the majority being retired (64%). The majority of respondents (68%) were also graduates of college with a bachelor's degree or higher level of education.

Key Findings

Overall, volunteer participation in condition monitoring increased during Phase 2. CoCoRaHS volunteers who did not participate gave various reasons including the time commitment it required, disinterest, and perceived difficulty in participating. Volunteer communications including the newsletter, quarterly conference calls, and trainings raised awareness about the program. Improvements to the program during Phase 2, such as the development of the scale bar, made reporting easier for some volunteers. Ultimately volunteers appreciated knowing they contributed to scientific knowledge. Knowing that their reports were useful for decision makers was a key motivation for continued participation.


Photo: Amanda Farris

Condition Monitoring in the Carolinas: Report Content and Analysis

Feedback from drought decision makers indicates that condition monitoring reports provide valuable, useful information, particularly regarding changing conditions caused by weather patterns or seasonal change. Nevertheless, actual drought impacts information provided by CoCoRaHS observers is less-frequently used than objective drought indices and condition monitoring scale bar selections are primarily used for visual guidance on the web map to determine which reports to read.

It is common for new datasets, particularly those based on subjective assessments, to be met with a healthy amount of skepticism by decision makers. Even as CoCoRaHS reports have become integrated into more drought monitoring efforts, questions about their accuracy and reliability remain. Researchers at the State Climate Office of North Carolina (SCONC) addressed these questions through several types of report content analysis to determine if observer scale bar selections are comparable to objective drought indices and to assess what types of information are provided in observers' qualitative descriptions of local conditions.

During Phase 1, the content of 1,572 observer reports was coded using NVivo qualitative software. This information was used to develop charts and graphs to share with decision makers during the feedback process. This methodology required extensive amounts of time for report coding and analysis. Therefore, during Phase 2, new resources including the condition monitoring scale bar, summary report charts, and data download features were used to modify this analysis process.

The following sections describe the various types of analysis conducted by the SCONC. Results are included in the sections below while broader discussion points are included in the "Contributions to a Drought Early Warning System" and "Recommendations for the Future of Condition Monitoring" sections.

Overview of Condition Monitoring Reports

The period of analysis spans from October 2016, when the scale bar selection became an option on the condition monitoring report form, to December 2017, the end of Phase 2 of the Carolinas pilot project.

The team obtained the CoCoRaHS condition monitoring reports via the following URL query to CoCoRaHS's download service: http://data.cocorahs.org/cocorahs/export/ExportConditionMonitoringReports.aspx?format=geojson&startdate=10/01/2016&enddate=12/31/2017.

Reports were subset to only those that contained scale bar selections from observers in North and South Carolina, plus one observer in Georgia (site GA-MI-5) who had been actively involved since the start of the pilot project. These steps resulted in 2,709 reports submitted by 298 unique observers in the study area for the October 2016 – December 2017 period (Figure 15). All subsequent analyses refer to these 2,709 reports.

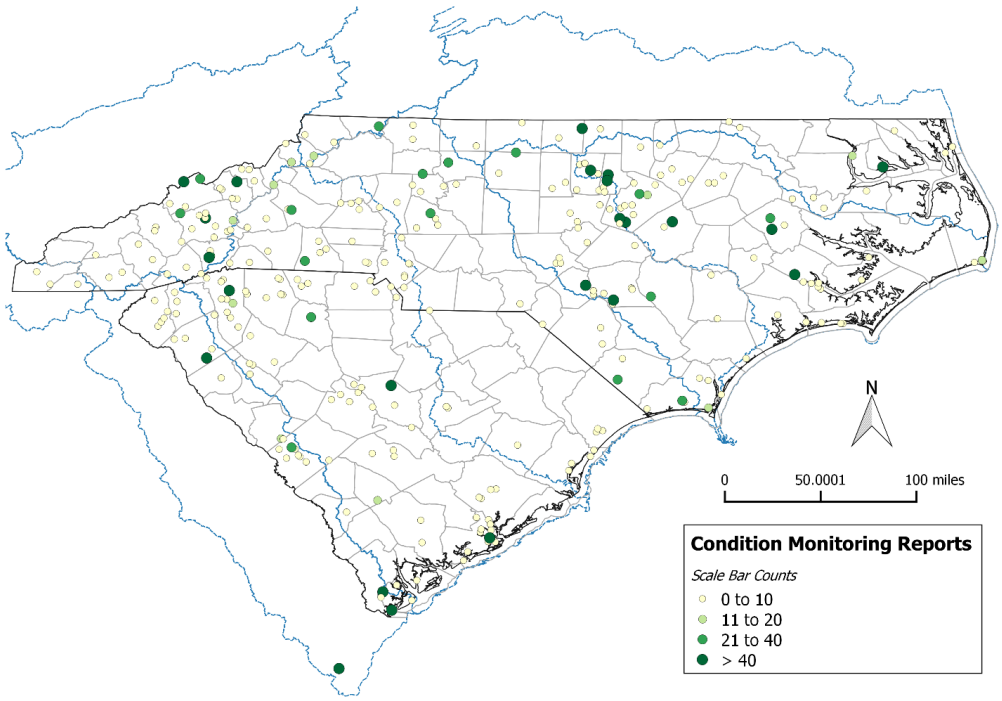


Figure 15: Reporters who submitted scale bar values with their condition monitoring reports during Phase 2 (October 2016 - December 2017)

Scale Bar Analysis

Pearson's correlation coefficients were calculated between scale bar selections and drought index values to get a sense of the time scale on which observers based their scale bar selections. Scale bar selections recoded to numbers facilitated comparison to objective drought indices (Figure 16).

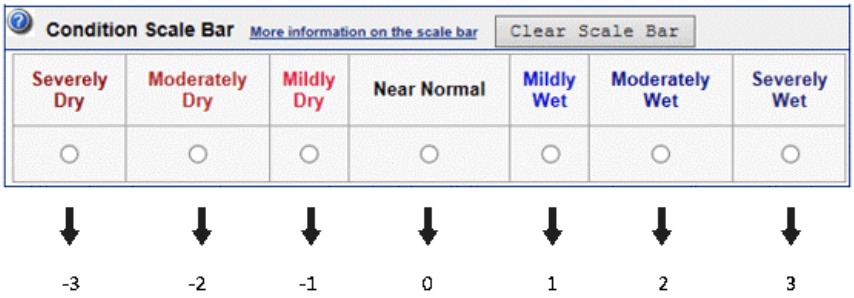


Figure 16: Scale bar selections from the CoCoRaHS condition monitoring report form recoded to numerical scores ranging from -3 to +3 for subsequent analysis

The Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) are two frequently-used indices for drought monitoring. The SCONC generates updated-daily SPI and SPEI for the contiguous United States using a combination of National Weather Service (NWS) Advanced Hydrologic Prediction Service (AHPS) quantitative precipitation estimates and PRISM (Parameter-Elevation Regressions on Independent Slopes Model) daily temperature estimates (used for SPEI only). These drought index grids have a spatial resolution of approximately 4.6 km. Both SPI and SPEI are normally-distributed with a mean of 0 and a standard deviation of 1, with positive values indicating wet conditions and negative values indicating dry conditions. SPI and SPEI values are continuous but SCONC rounds values to two decimal points for storage; additionally, the drought index values are theoretically unbounded, but they generally fall within +/-3.

SCONC obtained 1, 2, 3, 6, 9, and 12 month SPI and SPEI values[10] for grid cells closest to each CoCoRaHS observer's latitude/longitude coordinates and for corresponding condition monitoring report dates. All analyses used MATLAB (version R2017a) custom scripts and functions.

Though SPI and SPEI are continuous variables and the recoded scale bar values can only take on one of seven possible integer values, the Pearson correlation coefficient still provides insight into which timescale (short or long) observers likely use in their reports. **Correlations indicate that the most agreement is with short term** (1-month) time scale, with the **strength of the correlation decreasing with duration** (Table 3). The strength of the correlation with scale bar selections is roughly equivalent for SPI and SPEI. While SPEI does include a temperature component and SPI only uses precipitation, the two indices are strongly correlated in most instances (correlations for the study period were greater than 0.9 for all durations).

Pearson correlation coefficients suggest that more observers may be basing their scale bar selections on short-term conditions. Short-term SPI and SPEI values only explain approximately 50% of the variance in

[10] 1-, 2-, and 3-month SPI time scales assume "30-day months," Therefore, the 1-month is a 30 day SPI, 2-month is 60 days, and 3-month is 90 days. The 6, 9, and 12-month time scales, in contrast, are actually based on calendar days.

scale bar selections. Possible interpretations are that either the observers or the indices are not capturing all the factors that contribute to on-the-ground wet or dry conditions. Alternatively, **observers may be paying attention to different factors, such as secondary or tertiary drought impacts, that cannot be captured with these weather-data-driven drought indices.**

Drought Index Duration	Pearson Correlation Coefficient	
	SPI to Scale Bar	SPEI to Scale Bar
1	0.51	0.55
2	0.43	0.45
3	0.39	0.39
6	0.34	0.34
9	0.38	0.38
12	0.29	0.29

Table 3: Correlations between drought index values and scale bar selections are strongest for the 1-month time scale and decrease with longer timescales. Correlations for all timescales were statistically significant (α=0.05).

To further examine the relationship between scale bar selections and information that can be obtained from an objective drought index, an analysis of variance (ANOVA) was carried out between scale bar selections and 1-month SPEI. ANOVA is a test to determine whether groups' means are significantly different. For the purposes of this analysis, the groups corresponded to the different scale bar categories, and the dependent variable is the 1-month SPEI, chosen because it had the strongest correlation with scale bar selections. The ANOVA results indicated significant differences in group means ($F=197.88$, $p=1.69e-209$; Figure 17). The group means were additionally compared for each combination of categories; results indicated that, for all combinations, the mean of the 1-month SPEIs were significantly different, suggesting that the prevailing meteorological moisture conditions (wet vs. dry) are captured by the scale bar selections.

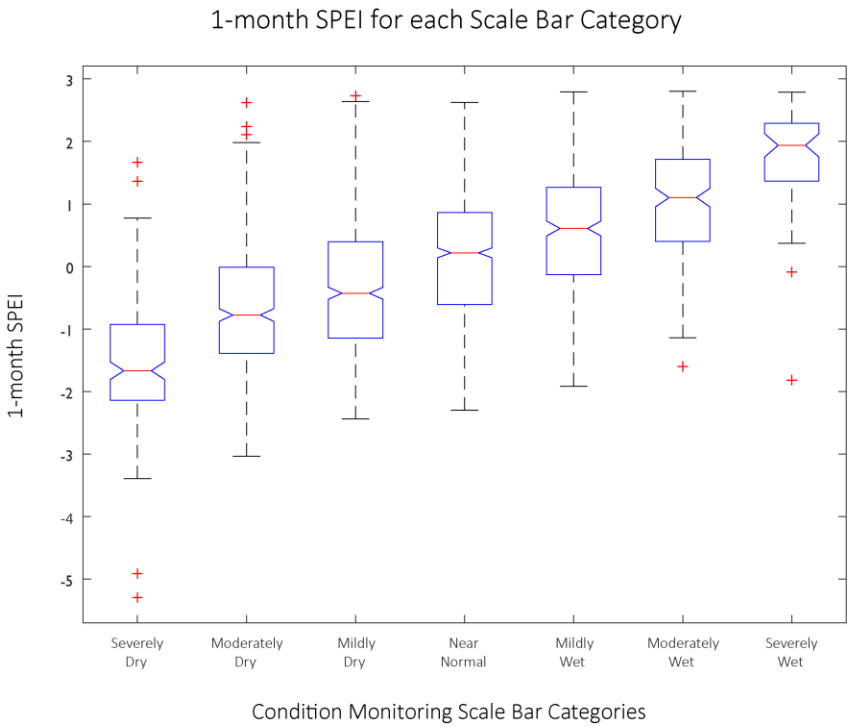


Figure 17: Boxplots reveal that 1-month SPEI values correspond with scale bar categories, with drier categories having lower SPEIs, and wetter categories higher SPEIs

While there are statistically significant differences between group means, boxplots (Figure 17) reveal instances when the 1-month SPEI and scale bar selections disagree on the prevailing moisture conditions (i.e., one suggests conditions are dry while the other suggests conditions are wet). This is particularly evident for drier scale bar selections. Numerous possible explanations exist for these discrepancies.

Recent precipitation may result in a positive (wet) 1-month SPEI value, but an observer may continue to see impacts from long-term dryness, leading to the selection of a dry category. In this hypothetical instance both sources of information are correct. Alternatively, observers may be basing their reports and scale bar selections on information that is more loosely linked to the impacts from raw precipitation amounts, such as wildlife activity or water use restrictions. Furthermore, occasional biases in the AHPS precipitation estimates can result in inaccurate SPEI values.

All, none, or some combination of these may be present. Such nuances are difficult to explore with quantitative data for the whole dataset, but a closer look at the reports and scale bar selections of individual observers could provide insight into what information is used to make scale bar selections and how this is similar to, or different from, information provided by objective drought indices.

Condition Monitoring Report Content

Condition monitoring reporters can choose from ten possible categories to tag the information contained in their weekly report. These categories correspond to the impact categories in the National Drought Impacts Reporter. The process of coding condition monitoring report content during Phase 1 of the project was very time and resource intensive. For Phase 2 of the project, the research team relied on self-selected report categories to analyze the types of information included in volunteers' reports.

Categorical Breakdowns

Figure 18 shows the proportions of categories submitted by all 298 observers. The most frequently checked category was "General Awareness" (2155), followed by "Plants and Wildlife" (1366), "Agriculture" (907), and "Water Supply & Quality" (683).

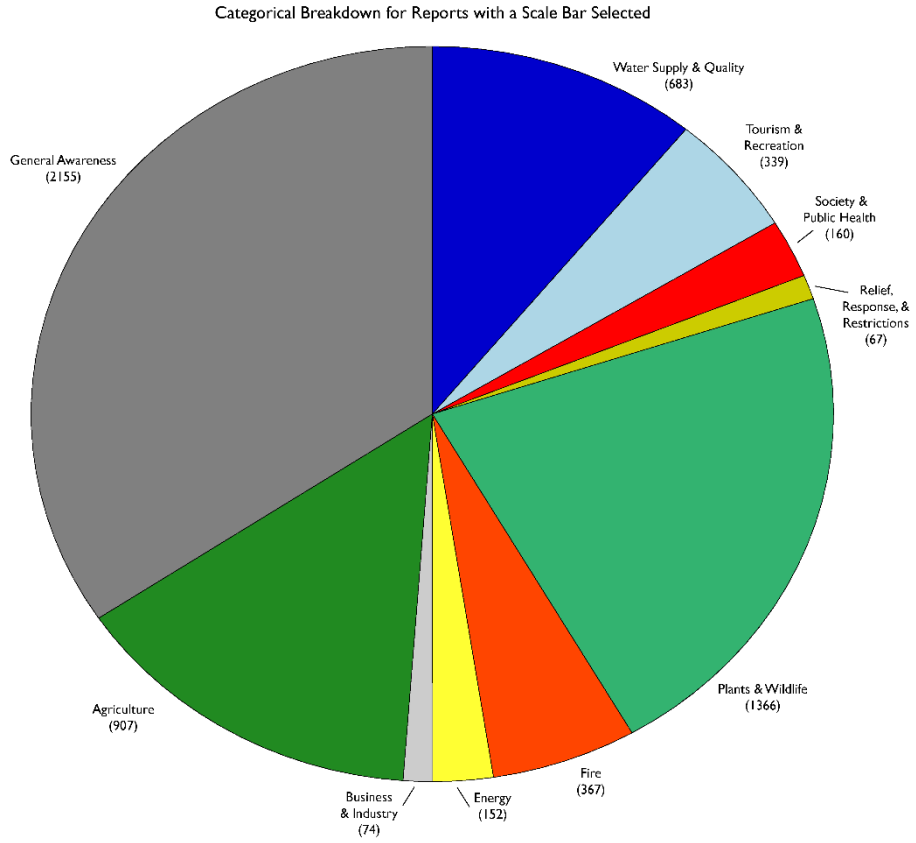


Figure 18: Breakdown of report categories selected by all 298 Carolinas observers.

Word Frequency

A word cloud (Figure 19) generated from all reports in the study period reveals that the most commonly-used words in condition monitoring reports include "rain" (1936 times), "week" (1570 times), "water" (1305 times), and "dry" (1078 times). These words suggest observers, as a whole, are basing the qualitative portions of their reports on recent conditions, with recent weather and precipitation featured prominently.

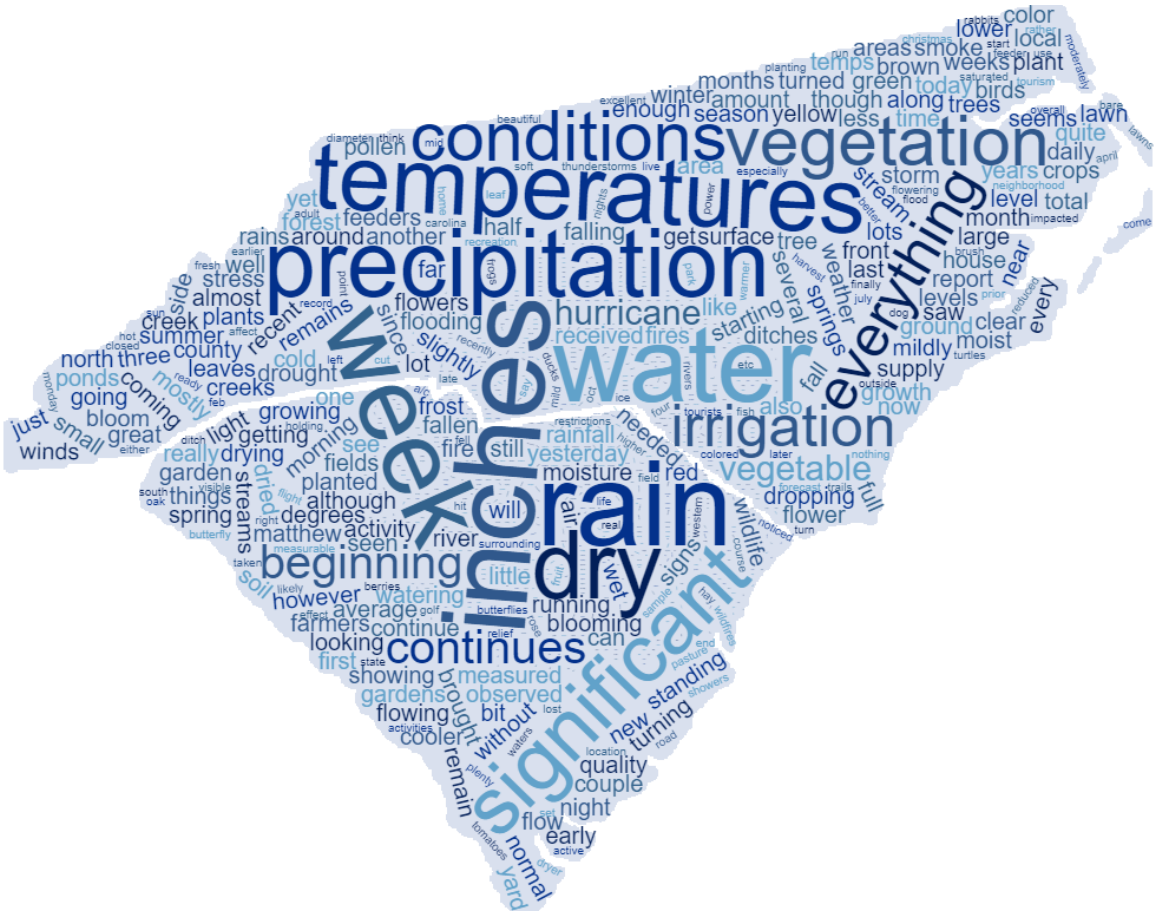


Figure 19: Word cloud generated from all 2,709 study period reports

Figure 19 was generated using the online word cloud creator at www.wordclouds.com. This tool determines word counts from a given input text file (in this case, a file containing 2,709 condition monitoring reports). Words that appear more frequently in the text appear larger in the generated word cloud. Not all words used in reports were able to be displayed in the graphic, but the most frequently-used words are present.

Minor modifications were made to the narrative reports prior to generating this word cloud. These modifications include converting all capital letters to lower case letters and replacing instances of double quotations as a unit for inch with the word "inches." Similarly, there were several instances where the phrase "t" was used to refer to the word "trace" (as in a trace amount of precipitation); in these instances, "t" was replaced with the word "trace." Finally, symbols "@" and "°" were replaced with "at" and "degree," respectively. Preliminary exploration revealed several instances of words that appeared in different tenses or pluralities, such as "rain," "rains," "rained," and "raining." However, due to the number of unique words (~2.500) and the absence of an existing, accessible routine to group these, the research team decided *not* account for any of these. More sophisticated analyses, such as those using MATLABs' text analytics package, could account for these subtleties and reveal additional detail about report content.

Observer Case Studies

While the information from all observers in the study period provides useful insight into the agreement between scale bar selections and objective drought information, it is too broad to capture the distinctions between the types of information that may inform an individual observer's reports and scale bar selections. Six observers (3 in NC and 3 in SC) were identified for a more in-depth case study analysis (Figure 20). These observers were selected by the project team based on a combination of knowledge of observers and observer report statistics (number and frequency).

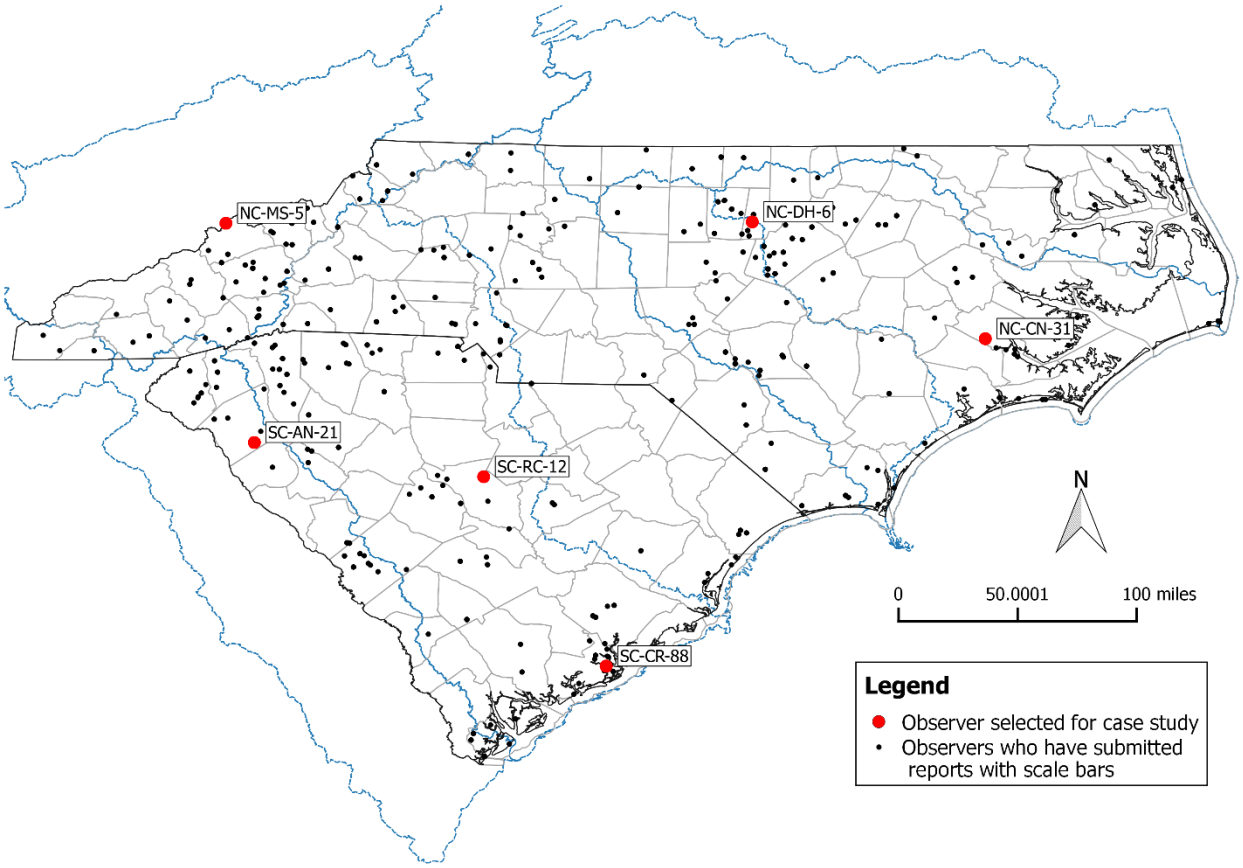


Figure 20: Observers selected for case study are marked with red dots on the map above.

Pearson correlation coefficients were calculated between the time series of scale bar selections and objective drought indices for the six case study observers (Table 4). The time scale(s) with the strongest correlation are inconsistent across observers, which may indicate that some observers base their reports on shorter-term conditions (NC-CN-31), while others may be reporting on conditions that reflect mid-term (NC-MS-5) or longer-term (SC-RC-88) conditions. Additionally, some observers' scale bar selections are strongly correlated with multiple drought index timescales (e.g. NC-DH-6). Rather than suggesting observers are "all over the place," in-depth analyses of individual observers (see Appendix) indicate that drought index patterns were, by chance, similar at multiple time scales during the study period, observers' reports were based on multiple indicators that respond at different time scales, or/and the indicators examined differ from observer to observer. This last point is supported observer categorical

selections (Figure 21). Some observers consistently report on one or two categories (e.g. NC-DH-6, SC-RC-12, SC-CR-88) while others seem to base their reports on a broader range of indicators (e.g. NC-CN-31, NC-MS-5, SC-AN-21).

Closer examination of category selections and narratives written by observers suggest, overall, that the scale bar selections are based on more information than what is presented by SPI or SPEI. In other words, they consider more than just precipitation and/or temperature. For example, NC-CN-31 frequently reports on a range of conditions that occurred over the preceding week, such as bird activity, gardening, and health impacts. It is evident from the narrative reports that observations refer to the most recent week and are sometimes compared to the preceding week. It is therefore not surprising that drought indices at the 1-month time scale have the strongest correlations with NC-CN-31's scale bar selections. That said, less than 50% of the variance in this observer's scale bar selections can be explained by these 1-month drought indices. Many of the conditions reported by this observer occur on different timescales; for example, changes in wildlife activity beyond what is expected of seasonal (e.g., migratory) patterns may be tied to longer accumulations of dry or wet conditions whereas plant stress can occur after just a few days without precipitation. More detailed examination of each case study observer can be found in the text below.

Pearson Correlation Coefficient between Scale Bar selections and:												
	NC-MS-5		NC-CN-31		NC-DH-6		SC-CR-88		SC-AN-21		SC-RC-12	
Drought Index Duration	SPI	SPEI	SPI	SPEI	SPI	SPEI	SPI	SPEI	SPI	SPEI	SPI	SPEI
1	0.50	0.55	0.42	0.47	0.63	0.58	0.34	0.37	0.46	0.53	0.58	0.59
2	0.68	0.69	0.16	0.13	0.44	0.40	0.28	0.27	0.66	0.74	0.57	0.53
3	0.63	0.64	0.18	0.14	0.37	0.34	0.40	0.35	0.78	0.83	0.49	0.47
6	0.60	0.55	0.03	0.07	0.25	0.19	0.45	0.42	0.83	0.81	0.64	0.54
9	0.43	0.39	0.02	0.03	0.49	0.45	0.46	0.44	0.80	0.78	0.61	0.45
12	0.27	0.23	0.07	0.05	0.61	0.61	0.56	0.54	0.49	0.53	0.26	0.13

Table 4: Pearson correlation coefficients between case study observers' scale bar selections and drought indices (SPI and SPEI)

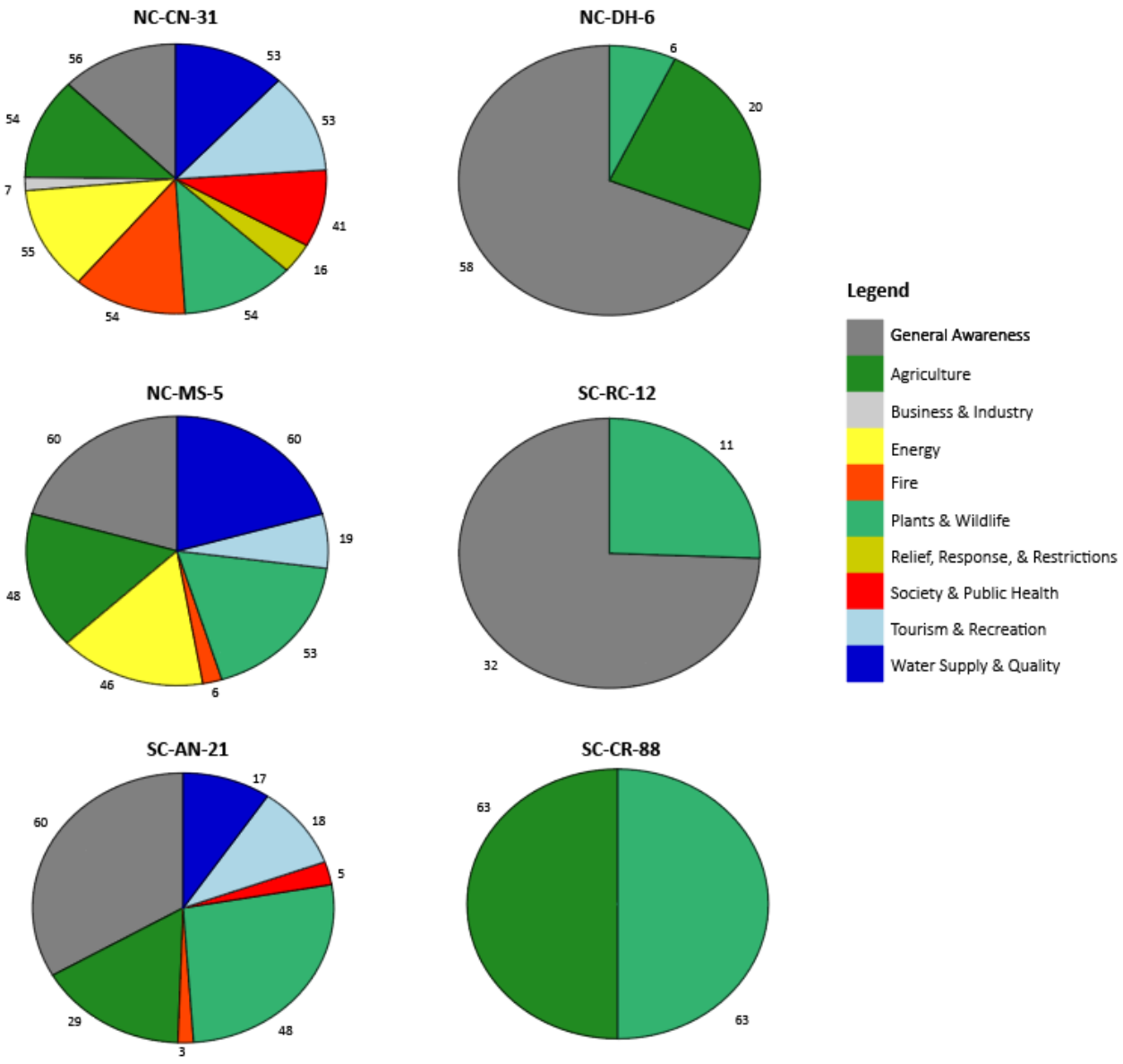


Figure 21: Case study observers' categorical report content selections

Case Study: NC-MS-5

NC-MS-5 is in Madison County, North Carolina. Comparison of observer scale bar selections to SPI and SPEI reveal the highest correlations occur at the 2-month timescale (Table 4). Analysis of the written narratives reveals the word "rain" is mentioned most frequently (86 times). Since the drought indexes used are based on precipitation (and SPI is *only* based on precipitation), it is not surprising that the scale bars chosen by this observer are strongly correlated with drought indexes. NC-MS-5 frequently reports on the same specific moisture indicators: a spring, microhydro, and the quality and quantity of drinking water produced. These, while strongly dependent on precipitation amounts, exhibit a lagged relationship to precipitation. It might take several weeks for the influence of no precipitation to be felt in the amount of water flowing from a spring, for example. This could be why a 2-month timescale has the strongest correlation and why other timescales (1, 3, and 6) are also strongly correlated. The categories "General Awareness and "Water Supply & Quality" were selected for every report submitted by this observer (60 times, Figure 21). A word cloud generated from this observer's written reports (left) shows the prevalence of water-related conditions, such as "spring," "quality," "quantity" (frequently in reference to the quality and quantity of drinking water), and "microhydro."

Case Study: NC-CN-31

NC-CN-31 is located in eastern North Carolina in Craven County. For the study period, Craven County never experienced drought conditions, and was designated as being in abnormally dry conditions as determined by the US Drought Monitor for a brief, ~1-month period that coincided with the end of the study period. Additionally, just prior to and at the start of the study period, Hurricane Matthew brought rainfall and subsequent flooding to portions of eastern North Carolina. The most commonly used word in this observer's reports is "week" (130 instances), and, unlike many observers who report on a single indicator each week, NC-CN-31 often provides a summary of a variety of conditions, broken down by categories, for the surrounding area. These can be seen in the pie charts of the observer's category selections (Figure 21), as well as in the word cloud (left), where words such as "week," "water," "plants" and "blooming," "fire" and "wildfire," "energy," and "agriculture" feature prominently. Because these observations take into account much more than rainfall or precipitation, it makes sense that the scale bar selections may not agree as strongly with precipitation or temperature-based objective drought indexes (Table 4).

Case Study: NC-DH-6

NC-DH-6 is located in the Piedmont of North Carolina in Durham County, a more-urban region of the state. NC-DH-6 only has three categorical selections: “General Awareness” followed by “Agriculture” and “Plants & Wildlife” (Figure 21). Examination of the narrative reports reflects these categories, with words like “soil” and “growth” frequently used in reference to recent conditions, along with words such as “week,” (“rain,” and “normal” (word cloud on left). The narrative reports frequently mention the current week’s precipitation amounts in relation to what is typical for that time of year or in comparison to previous years. Interestingly, the 1-month and 12-month timescales have the strongest correlation between this observer’s scale bar selections and objective drought indices (Table 4). Visual examination of time series (not shown) reveal that scale bar selections often changed from one week to the next, though there was an overall pattern of wetter conditions at the start, mildly dry to near normal in late 2016 and early 2017, a return to wetter conditions in mid-2017, followed by a general trend to drier conditions in late 2017. Like the scale bar selections, the 1-month SPI and SPEI, which respond to short-term precipitation patterns, show more pronounced changes from one week to the next. While both the 1-month and the 12-month drought indices also follow the same general pattern as the scale bar selections, it is dampened in the 1-month compared to the 12-month.

Case Study: SC-CR-88

SC-CR-88 is located in Charleston County, along the coast of South Carolina. Sixty-three reports with scale bar selections were submitted during the study period, and both “Plants & Wildlife” and “Agriculture” categories were selected for every one of these (Figure 21). The most commonly mentioned words in their narrative reports reflect this: “vegetable,” “garden,” “supplemental” (as in supplemental watering), “plants,” and “watering” (word cloud on left) The word cloud also reveals few instances of words that do not refer to agriculture, plants, or precipitation. Each of these indicators are typically thought of as responding to moisture on the short-term (i.e. meteorological or agricultural drought, which have timescales of up to 3 months). Because there is such a strong emphasis on agriculture and rainfall, it is surprising that the 12-month timescale of drought indices exhibit the highest correlations with SC-CR-88 scale bar values (Table 4).

Case Study: SC-AN-21

SC-AN-21 is located in western South Carolina. The reporting categories for the study period are “General Awareness” (selected 60 times), followed by “Plants & Wildlife,” “Agriculture,” “Tourism & Recreation,” and “Water Supply & Quality” (Figure 21) Analysis of word frequencies used in the written reports reveal that “week” is the most common word (105 times) followed by “rain,” both indicative of the observer looking at conditions over the past week (word cloud on left). These are, interestingly, followed in frequency by the word “still,” mentioned 54 times. In the reports, “still” is frequently (though not always) used as a reference to time. Examples include “Hummingbirds are still here” (October 1, 2017), or “My brother-in-law is still giving supplemental feed to his livestock because the winter grass isn't sufficient to carry the load and lake levels are still very low but at least we're starting to fill the rain bucket back up,” (January 8, 2017). The reference to ongoing or continuing conditions is one possible explanation for why the scale bar selections for SC-AN-21 correlate strongest with objective indices at the 3- to 6-month timescales, instead of the 1-month time scale, even though there are frequent references to indicators that are typically thought of as having short (<=1 month) time scales (Table 4).

Case Study: SC-RC-12

SC-RC-12 is located in central South Carolina in Richland County. This observer submitted 37 reports with an average of 10.02 days between reports. Reports frequently reference the number of days since the most recent rainfall and impacts to plants (word cloud on left). These are reflected in the observer’s categorical selections of “General Awareness” and “Plants & Wildlife” (Figure 21). Scale bar values are generally strongly correlated with SPI and SPEI at timescales of 1 to 9 months (Table 4). For this study period, different timescales of SPI and SPEI were strongly correlated, which could partly explain this pattern.


Photo: Christopher Lumpp

Condition Monitoring in the Carolinas: Decision Maker Feedback

Over the course of the pilot study, CISA engaged with drought decision makers to promote the use of condition monitoring reports and assess their usefulness for decision makers. The objectives and methods for doing so remained generally consistent over both Phase 1 and Phase 2. Feedback from decision makers sought to assess how the information provided in condition monitoring reports could be used to support drought monitoring, planning, and preparedness activities as well as decision maker perceptions about the credibility and reliability of citizen scientists as information providers. During Phase 2, CISA also solicited feedback about the web map, to determine if this new tool increased accessibility of condition monitoring reports and incorporation into different types of decision making.

Methods

CISA research staff conducted telephone interviews with 13 decision makers. 18 additional decision makers completed an online feedback survey which contained the same questions posed to telephone interviewees. The online survey option was offered to make participation as easy as possible for decision makers. The interview format did allow for follow up questions and some additional information that might not have been gleaned from online survey responses only. A copy of the feedback survey is available in Appendix D:

Phase 2 Decision Maker Feedback		
Telephone interviewees	13	1 telephone interview included 2 interviewees
Online survey respondents	18	1 survey was jointly completed by 3 people
Incomplete surveys	7	No names provided for follow up
Total	38	

Feedback interviews were conducted in November 2017, approximately one year after the scale bar and revised condition monitoring report form were released to CoCoRaHS volunteers.

Interviewees represented a cross-section of the diversity of interests and approaches to drought management. They are involved in drought monitoring and assessment at local, state, and national scales. and work for a variety of agencies and organizations including state-level drought management committees, CoCoRaHS, NC and SC state climate offices, the National Drought Mitigation Center, the National Drought Impacts Reporter, National Weather Service forecast offices throughout the Carolinas,

Soil and Water Conservation Districts, the US Department of Agriculture, and the US Drought Monitor. A master list of interviewees is included in Appendix F.

Decision Makers Use Condition Monitoring Reports to Identify Changing Conditions

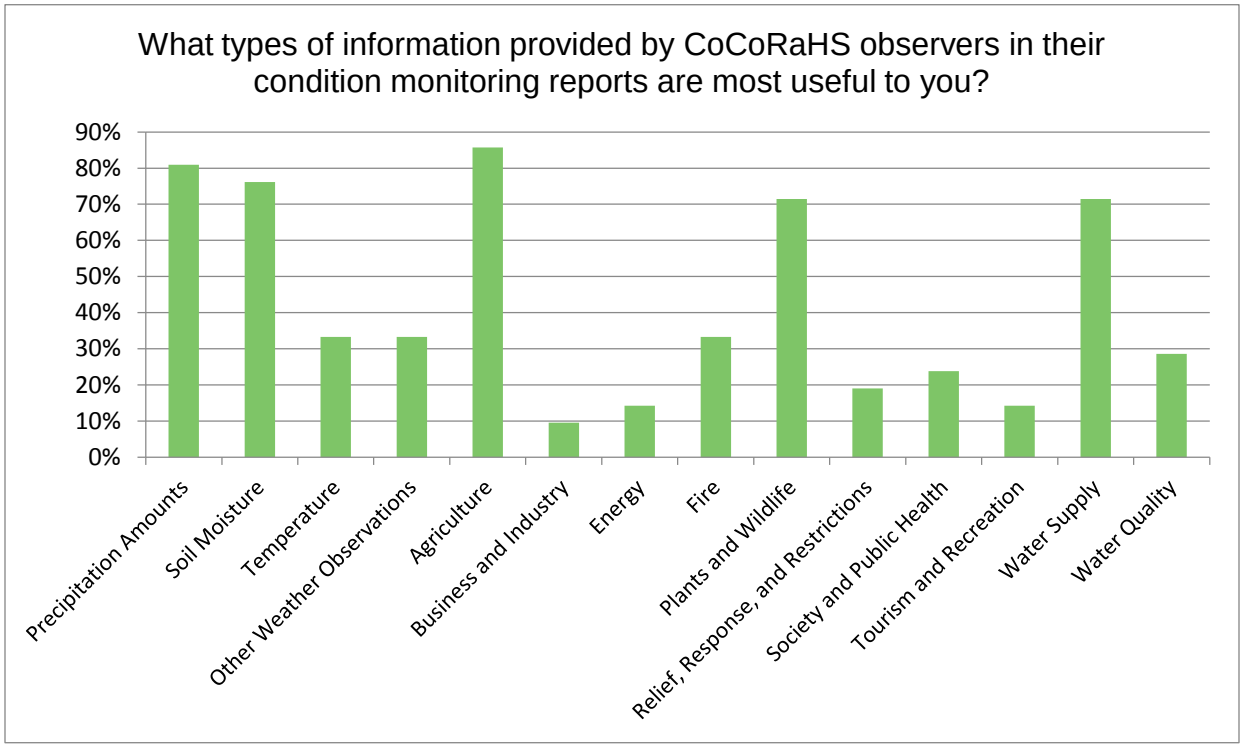


Figure 22: Types of Condition Monitoring Report Information Most Useful to Decision Makers

Decision makers found a wide range of condition monitoring report information useful for their respective decision making processes (Figure 22). For several categories, such as agriculture and water supply, drought committee members and US Drought Monitor authors utilize a variety of other indices to monitor these sectors. However, respondents noted that condition monitoring reports can help to fill gaps at times of the year when these indices are less informative. For instance, agricultural impacts are limited during the winter when there are fewer crop types to monitor. Information about impacts to other types of unmanaged plant species, as provided by CoCoRaHS observers, can help to fill this information gap.

Contextual information in the reports, such as recent weather conditions (e.g., windy, temperature, or the amount of precipitation received over the last week) also helps decision makers better understand how various factors contribute to local conditions.

"When I looked at it from my perspective of doing a national product and wanting to know what was going on in the different sectors, that's where I saw the main utility for me. It wasn't just agriculture product or water or energy or tourism or any of those categories. It wasn't just focused on that but the wide breadth of information because sometimes those are the areas that aren't as represented."

~ US Drought Monitor author

Ninety three percent (93%) of respondents indicated that condition monitoring reports add value to other sources of information. For instance, one respondent noted that observations such as whether, or how much, a reporter waters his/her vegetable garden is a clear indication of how recent precipitation, or a lack thereof, affects local conditions in real time. In such an instance, observers are recognizing that weather conditions are contributing to some type of impact.

Condition Monitoring Informs More than Just Drought-Related Decisions

Condition monitoring was initially designed to support drought decision making. Survey responses indicate that the reports have proven useful for better understanding how on-the-ground conditions have been affected by recent precipitation, or a lack thereof. Additionally, the broad range of agencies and organizations which were notified about the availability of the reports make many different types of decisions based on weather and climate. Through the interview process, CISA learned that the information in condition monitoring reports has proven useful for more than just drought monitoring.

National Weather Service (NWS) representatives noted that reports about extreme cold events helped to support decisions to issue winter weather and frost/freeze warnings. NWS representatives responsible for fire weather forecasts conveyed the utility of information provided in the reports for informing potential fire risk in an area. NWS interviewees also indicated that information about soil moisture levels, which are often included in the reports, could inform flood warnings if antecedent conditions might suggest a lack of infiltration for a heavy rain event.

Over the course of the study period, several extreme weather events occurred in the Carolinas including wildfires in the fall of 2016, hurricanes that tracked up the East Coast, and a late freeze that caused severe crop damage in spring 2017. Observers shared information in their reports about the extent of impacts in their region. One respondent also noted that his perception was that observers tended to pay more attention to local conditions when extreme events are occurring in other parts of the country. For instance, the California wildfires may have prompted observers to consider how dry conditions were at that time in the Carolinas.

Decision Maker Perceive Observers to be Credible and Reliable

Interviewees and survey respondents were asked about their perceptions of the credibility and reliability of condition monitoring observers in order to better understand how this might influence the use of condition monitoring reports. Credibility refers to whether or not observers provide information that can be trusted to better understand on-the-ground conditions. Reliability refers to whether or not condition monitoring reports serve as a consistent resource for this information. These questions were included in the feedback survey to better understand how decision makers perceive information submitted by citizen scientists and whether or not they consider it a legitimate data source to inform their decisions.

Sixty-eight percent (68%) of respondents indicated that they find observers to be both credible and reliable sources of on-the-ground information. The remaining respondents indicated that observers were either credible or reliable (16% each), but not both.

> *"CoCoRaHS observers are credible and reliable because they have a clear interest in citizen science and commit time out of their busy lives to report this valuable on-the-ground information. Many also appear to be quite knowledgeable about a variety of different topics, including nature, tourism, hydrology, agriculture, and botany."*
>
> *~ Southeast Regional Climate Center representative*

Decision makers also ranked which observer characteristics were most important in order to be considered credible and reliable. Respondents ranked consistency in submitting condition monitoring reports as the number one characteristic of an observer whose reports the decision maker would reference.

Interviewees perceived consistent reporters as having a better understanding of on-the-ground conditions, being more in-tune with smaller shifts, and reporting smaller changes each week knowing that they could add up to big changes over time.

Respondents also ranked the location of an observer as an important characteristic. Follow up discussion with telephone interviewees provided additional insight into this question. Most often the respondent's ranking order was determined by the type of decision to be made. For instance, NC DMAC committee members and US Drought Monitor authors noted that reports from observers who are located in areas where map lines are being drawn help determine appropriate delineations for drought severity on the map. Many of these interviewees ranked observer location as a more important characteristic.

Consistency in daily precipitation measurements and providing the most relevant types of information to the decision maker were also considered important characteristics.

Contributions to a Drought Early Warning System

A drought early warning system is a comprehensive system that collects and integrates information on the key indicators of drought in order to make usable, reliable, and timely drought forecasts and assessments of drought, including assessments of the severity of drought conditions and impacts. An early warning system also communicates drought forecasts, drought conditions, and drought impacts on an ongoing basis to decision makers at the federal, regional, state, tribal, and local levels of government, the private sector, and the public.[11] CISA's Citizen Science Condition Monitoring project was intended to support drought early warning by providing this "usable, reliable, and timely" information through an extensive national network of citizen scientists, who are knowledgeable about their local communities and environment. This place-based knowledge allows observers to provide contextual information about environmental and societal impacts of drought that other, objective indices do not. The data collection method for condition monitoring reports is intended to provide this information such that drought onset, intensification, and recovery are documented over time, recording the evolution of drought-induced impacts.

Condition Monitoring for Drought Early Warning

Decision maker survey respondents indicated that information in condition monitoring reports about changing seasons or conditions (becoming either wetter or drier) was most useful to them. The condition monitoring process was designed with this need in mind, as the process of drought impacts reporting often did not capture some of the early signs of drought or lingering impacts.

[11] https://www.drought.gov/drought/what-nidis

> *"Condition monitoring reports are most important for onset and recovery and seasonal transition. These are the most difficult conditions to convey on the map."*
>
> *~ US Drought Monitor author*

The majority of interviewees cited indicators of changing conditions (e.g., soil moisture, watering the garden more/less, water levels) as the more useful types of information. This type of information helped decision makers determine where drought conditions might be emerging or receding, providing the detail necessary to know where to draw the lines on a drought status map. Actual drought impacts information was referenced less often by decision makers.

Observer scale bar selections are used as visual guidance for which reports to read. For example, if several observers select "Mildly Dry" in an area that is not currently designated as being in abnormally dry or drought conditions, these reports may receive additional scrutiny. This scrutiny has the potential to translate into early warning of emerging drought conditions, particularly when other drought information is either not yet available or does not yet reflect the same level of dryness. Because the purpose is to capture the "baseline," condition monitoring reports – both the written portion and the scale bar selections – inform the drought monitoring and decision making process in a way that reports of solely drought impacts do not. As noted in the scale bar analysis section, the scale bar comparisons with objective drought indices suggest the assessments by these citizen scientists *do* reflect prevailing meteorological conditions, particularly, but not exclusively, at shorter timescales (e.g. 1-month).

Examination of the reports and scale bar selections of the six case study observers compared with contemporary, objective drought information revealed a complex web of observations and interpretations used by observers in preparing their reports. While data that can be captured with traditional means, such as precipitation, is frequently cited, so are other, less-measurable impacts, such as phenological or wildlife responses to changing moisture conditions. Typically, the information found in the reports from a single observer are chronological, building off previously-shared information and unfolding in a narrative-like fashion that conveys how conditions are evolving to a variety of factors – not all directly a result of precipitation amounts. Additionally, based on the information presented in reports and the selected scale bar values, the breadth and depth of information varies from one citizen scientist to the other. For decision makers, these observer-to-observer variations allow for a more detailed picture of the multiple types of conditions that are occurring simultaneously, and perhaps even at the same location.

Contributions to the US Drought Monitor Map

Over the course of the study period questions have been raised about whether or not there is potential for CoCoRaHS condition monitoring reports to exaggerate drought conditions in a particular area which might lead to a more severe drought designation for an area. This might happen, for instance, if more observers than normal submit reports in an area experiencing drier than normal conditions, drawing attention to that location on the map. In particular, US Drought Monitor (USDM) authors are aware of

this potential issue because of the ways in which the USDM is used to support other types of decisions, such as aid provided to ranchers through the livestock forest production program.

USDM authors addressed this concern directly in the telephone interviews. They described the "convergence of information" that they rely upon each week to delineate the lines on the map. They noted that a heavy influx of reports noting dry conditions in an area would raise red flags, leading them to investigate further and possibly contacting other drought decision makers in those areas for additional information.

A built-in screening process exists for CoCoRaHS observers who submit condition monitoring reports. Unlike the NDMC Drought Impacts Reporter, which is an open tool for anyone who wants to submit a report, condition monitoring through CoCoRaHS is limited to observers who sign up as CoCoRaHS volunteers and use a designated user name and password to access the online reporting forms. This, to some extent, is a limiting factor in how many reports might be submitted through CoCoRaHS in a particular area.

There are opportunities to capitalize on how this reporting system is set up. CoCoRaHS condition monitoring could be used as a way to encourage those who raise concerns about whether or not substantiated on-the-ground information is incorporated into USDM drought designations become condition monitoring reporters. By establishing themselves as consistent, detailed reporters, these stakeholders can earn a voice in the decision making process.

Decision Making Processes

In both North Carolina and South Carolina, the state drought committee structure and decision making processes are established by state legislation. However, the two committees function quite differently. These differences have been informative in assessing how committee function plays a role in the utility of condition monitoring reports for drought monitoring.

The North Carolina Drought Management Advisory Council (DMAC) meets via conference call each Tuesday. Agencies that provide different indicator information (e.g., the state climate office, NC Forestry Commission, US Geological Survey) as well as public and private sector representatives (e.g., water utilities, energy providers) participate in the calls to discuss and designate the drought status throughout the state. The DMAC passes this on to the US Drought Monitor map author to be considered for the national map each week.

> *"The SC State Climate Office utilizes the reports for identifying and validating weather impacts especially for drought. Often as we deliberate the drought status for some areas we have a limited amount of rainfall data and impact data so information provided in the reports proves to be beneficial. Ideally there would be more observers in each region providing reports for cross-reference."*
>
> *~ SC State Climatologist*

In contrast, the South Carolina Drought Response Committee (DRC) convenes only when drought conditions develop, worsen, or improve. The committee consists of a similar make-up of representatives as the NC DMAC. The SC DRC also considers a range of indicator and impacts information. However, the drought designations are state specific and there is not a formal process for consistently providing information to the US Drought Monitor.

The difference in committee structure and responsibilities was a contributing factor to differences in how condition monitoring reports were used in each state. In North Carolina, the DMAC committee member from the state climate office reviewed the condition monitoring reports weekly in order to share relevant information with other committee members during the weekly call. In South Carolina, the committee met only 16 times over the project study period (Phases 1 and 2). CISA team members who participated in the SC DRC calls learned that, although condition monitoring report information was mentioned during the meetings, report content had very little impact on the designations determined by the committee. In her survey responses, Hope Mizzell, the SC State Climatologist and Drought Response Program coordinator, noted that more consistency from reporters would validate the condition monitoring reports and allow for additional consideration by the SC DRC.

Volunteer Engagement

CISA's experience in recruiting observers for the project revealed that utilizing an existing network of observers was more successful than recruiting new CoCoRaHS volunteers, despite targeting volunteer groups with related interests such as Master Naturalists and Master Gardeners. CoCoRaHS volunteers are inherently an engaged group that is both interested in and knowledgeable about monitor weather and related impacts.

On the other hand, there are drawbacks to using CoCoRaHS as the primary platform to collect condition monitoring reports. Condition monitoring is not a 'stand-alone' activity through CoCoRaHS. Participants are asked to purchase the standard 4" CoCoRaHS rain gauge, register through CoCoRaHS, and submit daily precipitation reports in addition to condition monitoring reports. This may pose challenges to some potential observers for several reasons. The cost of the gauge may be prohibitive or an interested individual may not live in a place where a rain gauge can properly be installed (e.g., in an apartment complex).

Additionally, observers need clear guidance on how to participate. Some volunteers noted that they were less inclined to continue reporting because they were unsure whether or not the information they included in their reports was relevant for any type of decision making need. Guidelines about when to submit reports and suggestions for the types of information to include were developed as these lessons surfaced. However, more guidance would likely prove helpful.

During the feedback process, decision makers were asked whether or not they would consider requesting information directly from observers. For instance, if a particular area had not received any precipitation for a period of time, would it be appropriate to send a request for reports directly to observers in that area? Or, if decision makers needed more information about a particular impact (e.g., water levels) or sector (e.g., agriculture), would they be willing to ask directly? There were mixed responses to this question. Some decision makers felt that it could make the reports more useful. Others felt that it might lead an observer to over emphasize a less serious impact had they not been asked to

pay attention to something specifically rather than letting their own judgement discern whether or not to report. One decision maker noted that it may be asking too much of observers, who are already giving their time freely to provide the information. Making additional request may insinuate that more is expected of them than their initial commitment.

Interestingly, both decision makers and observers addressed concerns about the subjective nature of the report content throughout the feedback process. Observers expressed concern that their information would not be perceived as useful because it is based on each observer's subjective experience(s). Decision makers noted that they too see the information as being subjective. However, they also look to these observers as experts in terms of what varying degrees of wetness or dryness look like in their own backyards. For this reason, decision makers find the reports useful in better understanding what on-the-ground conditions are like (Figure 23).

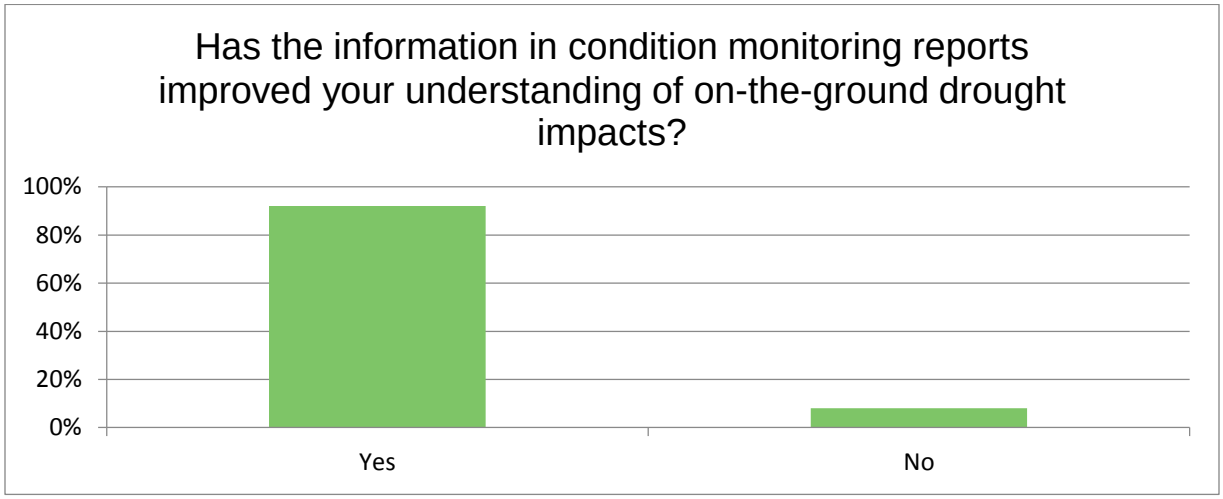
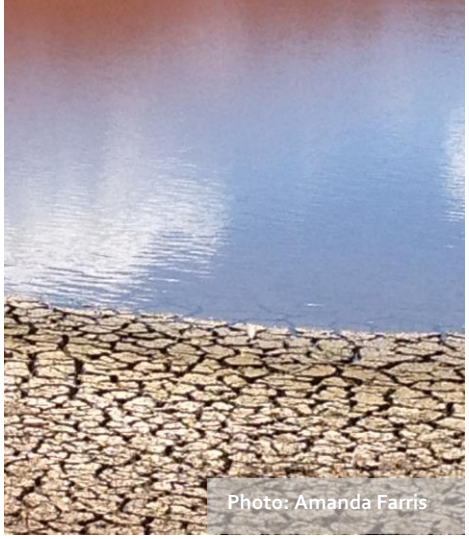


Figure 23: Ninety two percent (92%) of decision maker survey respondents indicated that condition monitoring report have improved their understanding of on-the-ground impacts.



Recommendations for the Future of Condition Monitoring

Throughout the four and a half year condition monitoring pilot project, CISA has learned many lessons about what contributes to the success of the program. Many of the ideas and feedback from observers and decision makers have been incorporated into the program to enhance the utility of condition monitoring reports for drought monitoring and to facilitate the process of submitting reports for volunteers. Despite the success to date, the program could be further supported or improved to ensure that it grows into a reliable network of observers and information users. The following are suggestions from the project team which could help to guide future development of the national program.

Provide Additional Support for Volunteer Engagement

Overall, CISA found that the volunteer engagement portion of this project has been integral to its success. In feedback surveys, observers repeatedly indicated that regular communications, education and training materials, and opportunities to engage with other volunteers through quarterly conference calls helped to empower them and foster their sense of community. The engagement process was also key to providing information to volunteers about how their information was utilized by decision makers, a key motivation for many participants.

Continuous volunteer training, communications, and engagement are necessary elements for the success of the national program. Despite the success of the program to date, the majority of CoCoRaHS observers do not regularly submit condition monitoring reports. Outreach efforts will help to recruit new volunteers to increase the coverage of reporting around the country. An annual contest between states, similar to the CoCoRaHS March Madness recruitment competition, could also help motivate participation. Continuous training and reminders to participate are necessary in order to maintain consistency in reporting, a key factor in the usefulness of reports for decision makers. Continued training also helps to refine observers' reporting capabilities and provides an opportunity to foster the network of participants and their sense of community belonging.

One suggestion would be to test a "train the trainer" model with regional CoCoRaHS coordinators. By providing additional training to coordinators who recruit volunteers in their areas, the more nuanced elements of the program can be conveyed through a network of coordinators, rather than solely relying on CoCoRaHS headquarters to be the only source of information for observers. Henry Reges, National Coordinator for CoCoRaHS, has been conducting some training during his routine visits to National Weather Service forecast offices around the country. However, feedback from these coordinators indicates that time constraints often limit their capacity to relay the information to observers in their area. Developing regionally tailored materials for these coordinators to pass on to their observers directly could help alleviate some of this burden.

Decision makers also emphasized the importance of having volunteers in rural areas, where other types of monitoring stations are not located. This is a challenge not only for condition monitoring but the CoCoRaHS program as a whole. Identifying ways in which residents in these areas could be targeted for recruitment could help to build out a more comprehensive network of reporters.

As noted above, consistency is key in giving legitimacy to reporters over time. Consistent reporting is likely to improve the skills of the observer as well as creating a reliable source of on-the-ground information for decision makers. One interviewee suggested designating "super reporters" who are the most consistent. This could help decision makers easily identify particular reporters so they are more confident in the information they review. Gaining recognition as a "super reporter" would likely also be a motivating factor for an observer, to remain as consistent as possible in their report submission. Similarly to the annual precipitation measurement recognition for CoCoRaHS observers who submit each day for 365 days, these "super reporters" could also be recognized to help validate the effort for observers. The precipitation measurement certificates are awarded in October at the end of each water year. Distributing condition monitoring "super reporter" certificates in the spring could serve as a reminder to report as the drier months of the year approach.

Demographics

Outreach and communications must be tailored to groups outside those who are typical citizen scientists or volunteers: Demographic questions were posed in the third feedback survey. The predominant profile of observers is a retired (64%) white (88%) male (69%) over the age of 60 (74%), with a Bachelor's degree or higher (68%). This profile is consistent with many other citizen science volunteer groups.

However, there are many different types of societal impacts not captured by this section of the population. Developing tailored training, communications, and outreach materials can help to encourage participation by other groups. Additionally, providing explicit information about how their contributions benefit their communities directly may also compel more participation.

Engage Decision Makers

Outreach to a variety of different types of decision makers who could utilize the information will also be important to ensure the success of the program. As CISA learned through the feedback process, the information in condition monitoring reports can be used for a wide range of decisions, not only drought monitoring. Ensuring that decision makers who could potentially benefit from the information, particularly National Weather Service forecast offices, will create a greater demand for condition monitoring reports and would also likely identify even more uses for the information.

CISA's evaluation also revealed that certain decision making processes through which drought conditions are monitored on a weekly basis (i.e., US Drought Monitor map publication, NC Drought Management Advisory Council weekly meetings) are more conducive to the use of information in condition monitoring reports. Identifying states with other drought monitoring processes where condition monitoring report information might be integrated would allow further evaluation to determine how the information can be used.

Invest in Technological Improvements

Mobile Phone App

In the volunteer feedback surveys, many volunteers noted that not having the ability to submit a condition monitoring report via the CoCoRaHS mobile phone app limited their participation. Additionally, the Message of the Day, which appears after a precipitation measurement is submitted through the desktop version of the website, is not available on the mobile app. The Message of the Day is used consistently as a reminder to submit condition monitoring reports. As a first step, adding the Message of the Day to the mobile app could help increase participation.

CoCoRaHS currently relies on volunteer efforts in the development of its mobile applications. Providing funding for the improvement of their app is likely to increase participation. This may also help to engage other demographics in the reporting process, who are more likely to utilize their mobile phones rather than a desktop or laptop computer to participate in a volunteer effort.

Photo Submissions

Over the course of the Carolinas pilot program, CISA has collected photographs from observers through direct e-mail. These have been passed along to decision makers for whom the information is likely to be most relevant. One observer in particular in Nash County, NC regularly submits a series of photographs via e-mail. CISA passes these photos onto Rebecca Ward, Extension Climatologist for the State Climate Office of North Carolina and member of the NC Drought Management Advisory Council. Rebecca has noted that, because the Nash County observer submits photos of water levels or plant growth (i.e., wilting or dying vegetation) in the same areas, the photos can be compared over time to determine the severity of wetness or dryness in the area.

Seventy nine percent (79%) of decision maker survey respondents indicated that photos would help to document or support information provided in condition monitoring reports. Several interviewees suggested that photo documentation of changing water levels would be especially helpful. Although, there were also several comments that photos would need to be submitted regularly in order to be useful. Those who were unsure if this would be helpful (21%) noted concern for requesting additional items from observers and that reviewing lots of photos along with the reports may be too burdensome.

The CoCoRaHS team has also expressed concerns in accepting photos from all volunteers because of additional technological requirements. These responses and suggestions are reflective of the Field Photo Weekends model that the Southern Climate Impacts Planning Program (SCIPP) has developed. Therefore, it may be beneficial to investigate ways in which this program can continue to be supported and promoted to ensure that photos are utilized by decision makers as a measure of on-the-ground conditions and change over time.

Web Map Improvements

Feedback about the national web map was very positive from both observers and decision makers. Both groups find the map to be relatively easy to navigate. Decision makers noted that it is very useful in identifying areas that might need more investigation based on the severity of dryness represented by the observer's scale bar selection on the map.

There were a few specific suggestions from decision makers to improve the utility of the national web map. These included:

- Adding a weekly precipitation layer similar to the US Drought Monitor map layer, that could be toggled on and off
- Creating a filter that would only display reports from observers who submit consistently (i.e., "super reporters")
- Adding a search field for specific dates, especially as more and more reports are added over time
- Adding a filter for only wet or dry reports, rather than having all reports displayed

Develop Regional Guidance for Condition Monitoring

Decision makers and CoCoRaHS-condition monitoring observers provided feedback on the guidance for the seven scale bar categories (severely wet to severely dry). Both agreed that the guidance is beneficial for observers to better understand what and how to report. It also helps decision makers understand what level of wetness or dryness an observer is seeing based on the guidance given for each category.

However, specific issues arose during feedback discussions such as how to account for variation in regional differences in dry or drought conditions. For example, what is defined as dry would be very different in Arizona versus South Carolina. Moreover, even within the Carolinas, the definition of what is dry can vary greatly from the coastal to mountain regions. Seasonal changes can also have a significant impact. How to account for temporal aspects in the guidance, which the category descriptions are currently lacking, was also raised. As the condition monitoring program expands nationally, addressing this need for regionally specific guidance for the scale bar categories should be considered.

The National Drought Mitigation Center is conducting research to better understand regional drought impacts based on information submitted to the National Drought Impacts Reporter. This work has potential to be very informative for regional scale bar guidance. Other DEWS, RISAs, or national programs which are doing applied climate work at the regional level would also make logical partners to help develop guidance.

Conduct More In-Depth Analysis of Report Content

The 22,000+ condition monitoring reports which have been submitted to CoCoRaHS since October 2016 make up a rich database. The results of the scale bar selection analysis indicate that observers' selected values reflect prevailing meteorological conditions, as indicated by SPI and SPEI. Furthermore, the types of information contained in the reports of the six case study observers reveal agreements between the types of observations shared, the categories selected, and the time scale of the objective drought index

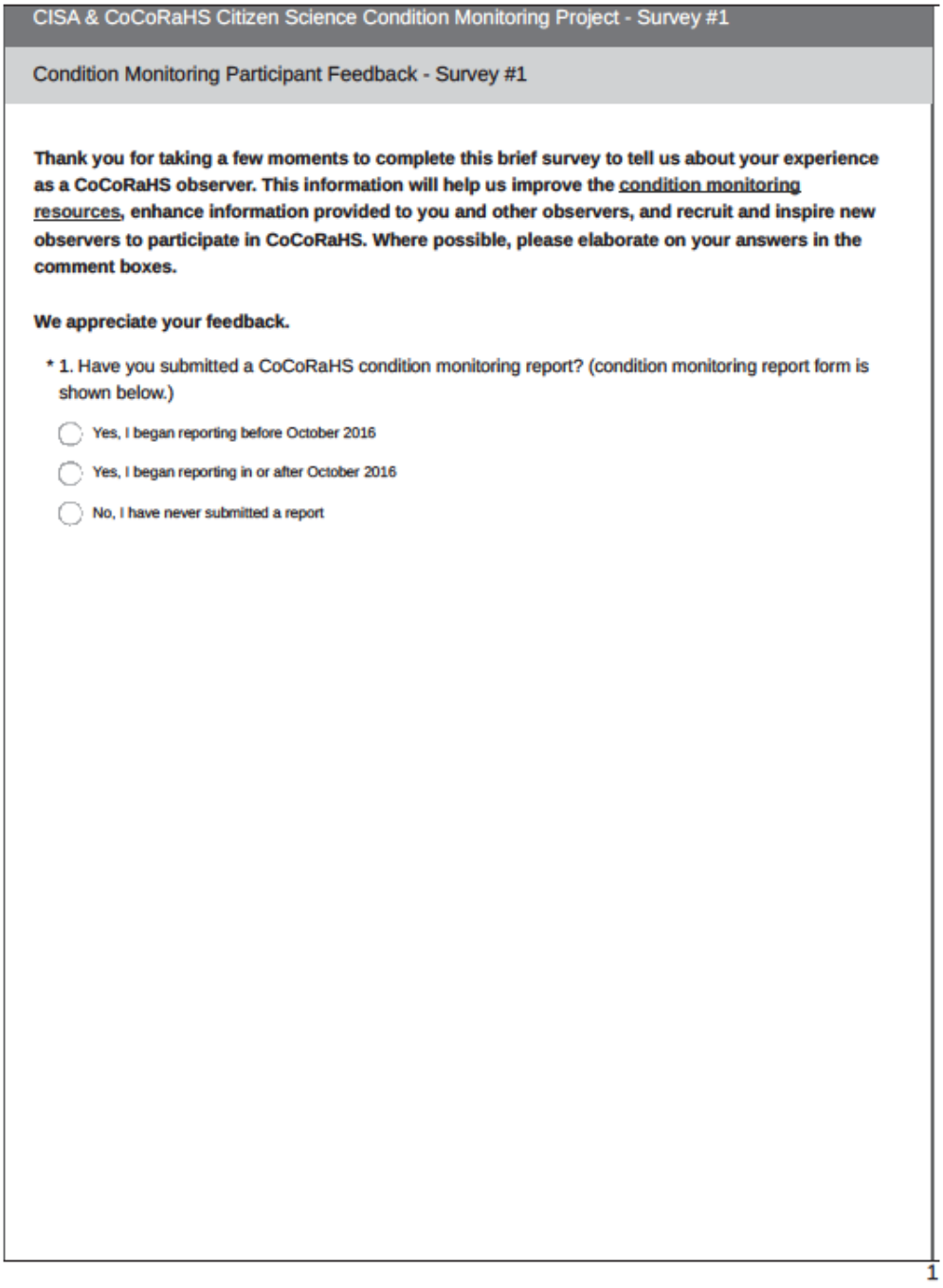
with the strongest correlation. Additional analyses could provide greater context for the reports that could ultimately lead to better drought early warning.

For the current assessment, minimal text analysis was performed on the reports to capture word counts. More sophisticated analysis of word pairs, such as mentions of “low soil moisture” versus “high soil moisture” could help quantify the degree of association between the types of information frequently tagged for each scale bar category. This could, in turn, add confidence to the accuracy of the reports. Connecting this information with comparisons to objective drought index values may additionally provide guidance on potential drought impacts in areas without on-the-ground information. This analysis conducted at other regional scales, along with other efforts to better understand the degree of impacts at different levels of drought severity as described above, could also help to inform the development of regional scale bar guidance, to better train observers in scale bar selections that accurately represent regionally-specific levels of drought.

In Conclusion

Providing additional support to continue engagement with volunteers and report users as well as investing in the iterative improvement of reporting guidance and technologies will help to ensure that the CoCoRaHS condition monitoring program continues to thrive and evolve.

Appendix A:
Volunteer Feedback Survey #1



CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #1

Condition Monitoring Participant Feedback - Survey #1

Thank you for taking a few moments to complete this brief survey to tell us about your experience as a CoCoRaHS observer. This information will help us improve the condition monitoring resources, enhance information provided to you and other observers, and recruit and inspire new observers to participate in CoCoRaHS. Where possible, please elaborate on your answers in the comment boxes.

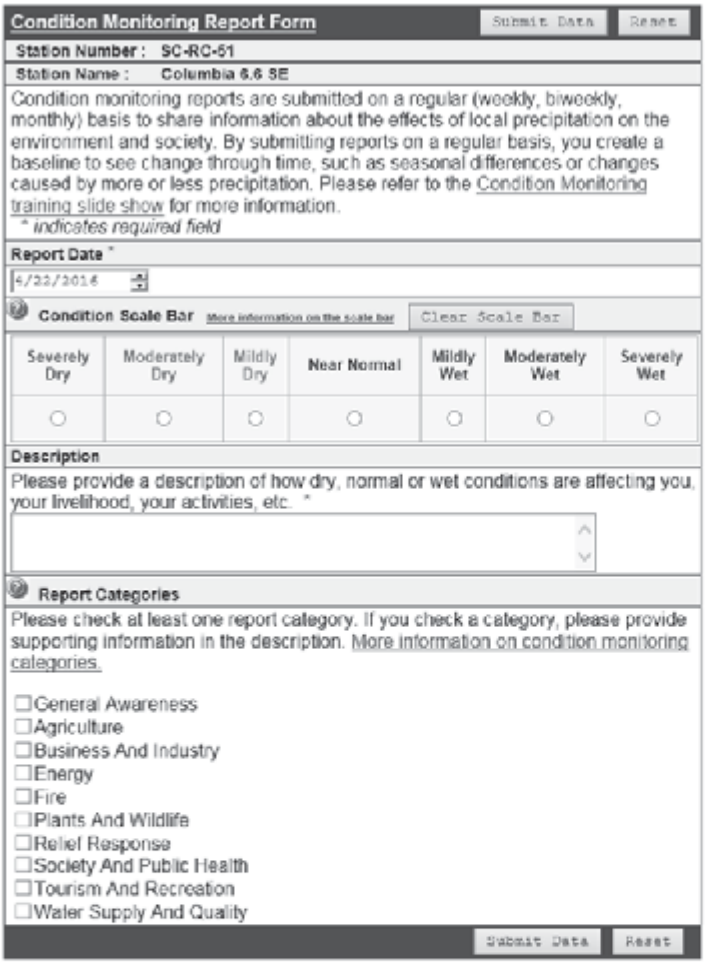
We appreciate your feedback.

* 1. Have you submitted a CoCoRaHS condition monitoring report? (condition monitoring report form is shown below.)

- ◯ Yes, I began reporting before October 2016
- ◯ Yes, I began reporting in or after October 2016
- ◯ No, I have never submitted a report

1

Condition Monitoring Report Form



Condition Monitoring Report Form

Submit Data | Reset

Station Number : SC-RC-51

Station Name : Columbia 6.6 SE

Condition monitoring reports are submitted on a regular (weekly, biweekly, monthly) basis to share information about the effects of local precipitation on the environment and society. By submitting reports on a regular basis, you create a baseline to see change through time, such as seasonal differences or changes caused by more or less precipitation. Please refer to the Condition Monitoring training slide show for more information.

* *indicates required field*

Report Date *

4/22/2016

Condition Scale Bar More information on the scale bar | Clear Scale Bar

Severely Dry	Moderately Dry	Mildly Dry	Near Normal	Mildly Wet	Moderately Wet	Severely Wet
○	○	○	○	○	○	○

Description

Please provide a description of how dry, normal or wet conditions are affecting you, your livelihood, your activities, etc. *

Report Categories

Please check at least one report category. If you check a category, please provide supporting information in the description. More information on condition monitoring categories.

- ☐ General Awareness
- ☐ Agriculture
- ☐ Business And Industry
- ☐ Energy
- ☐ Fire
- ☐ Plants And Wildlife
- ☐ Relief Response
- ☐ Society And Public Health
- ☐ Tourism And Recreation
- ☐ Water Supply And Quality

Submit Data | Reset

2

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #1

Condition Monitoring Participant Feedback

* 2. I have never submitted a CoCoRaHS condition monitoring report because

- ◯ I was unaware of this option on the CoCoRaHS website
- ◯ I am only interested in providing daily precipitation measurements
- ◯ I do not know how to submit a condition monitoring report
- ◯ I do not have time
- ◯ Other (please explain)

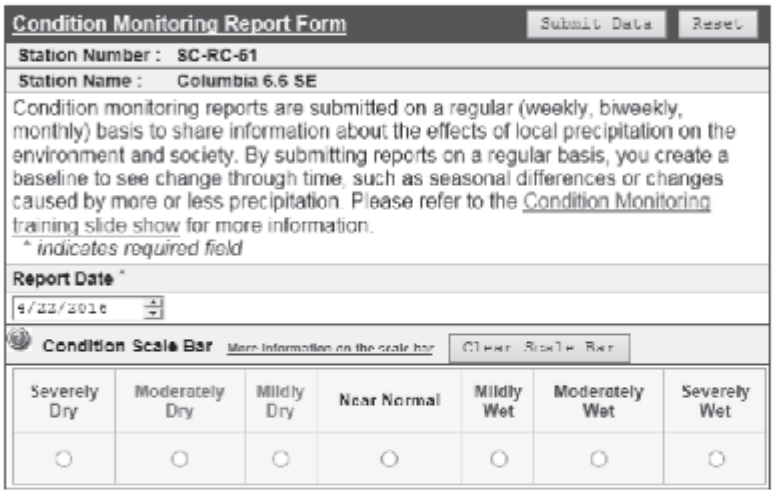
3

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #1

Condition Monitoring Participant Feedback

The Condition Monitoring Scale Bar was added to the online CoCoRaHS report form in October 2016, when the national Condition Monitoring Report Form was launched. The Scale Bar offers fast reporting of local conditions, ranging from from severely wet to severely dry.

Condition Monitoring Scale Bar



* 3. The addition of the condition monitoring scale bar

- ◯ Makes reporting easier
- ◯ Does not significantly change the reporting process
- ◯ Makes reporting more difficult

Please explain

4

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #1

Condition Monitoring Participant Feedback

* 4. How often do you submit condition monitoring reports?

- ◯ Weekly
- ◯ Monthly
- ◯ Less than once per month

* 5. On a scale of 1 to 5, how easy is it to decide which Condition Monitoring Scale Bar category to choose?

Difficult to decide		Somewhat easy		Easy to decide
1	2	3	4	5
◯	◯	◯	◯	◯

Please explain

* 6. How do you determine which scale bar category to select? (Choose all that apply)

- ☐ I look at normal precipitation for my area and compare it to precipitation we have received recently. (For example, I utilize the PRISM data on the CoCoRaHS website or I compare my current precipitation records to my previous records for the same time of year).
- ☐ I make a decision based on the information I include in my description of conditions, such as soil moisture levels, current condition of plants, vegetables, etc.
- ☐ I look at my previous weeks' selection to determine if there has been any significant change in conditions.

Other (please specify)

* 7. On a scale of 1 to 5, how helpful is thescale bar guidance in deciding which Condition Monitoring Scale Bar category to choose?

Not helpful		Somewhat helpful		Very helpful
1	2	3	4	5
◯	◯	◯	◯	◯

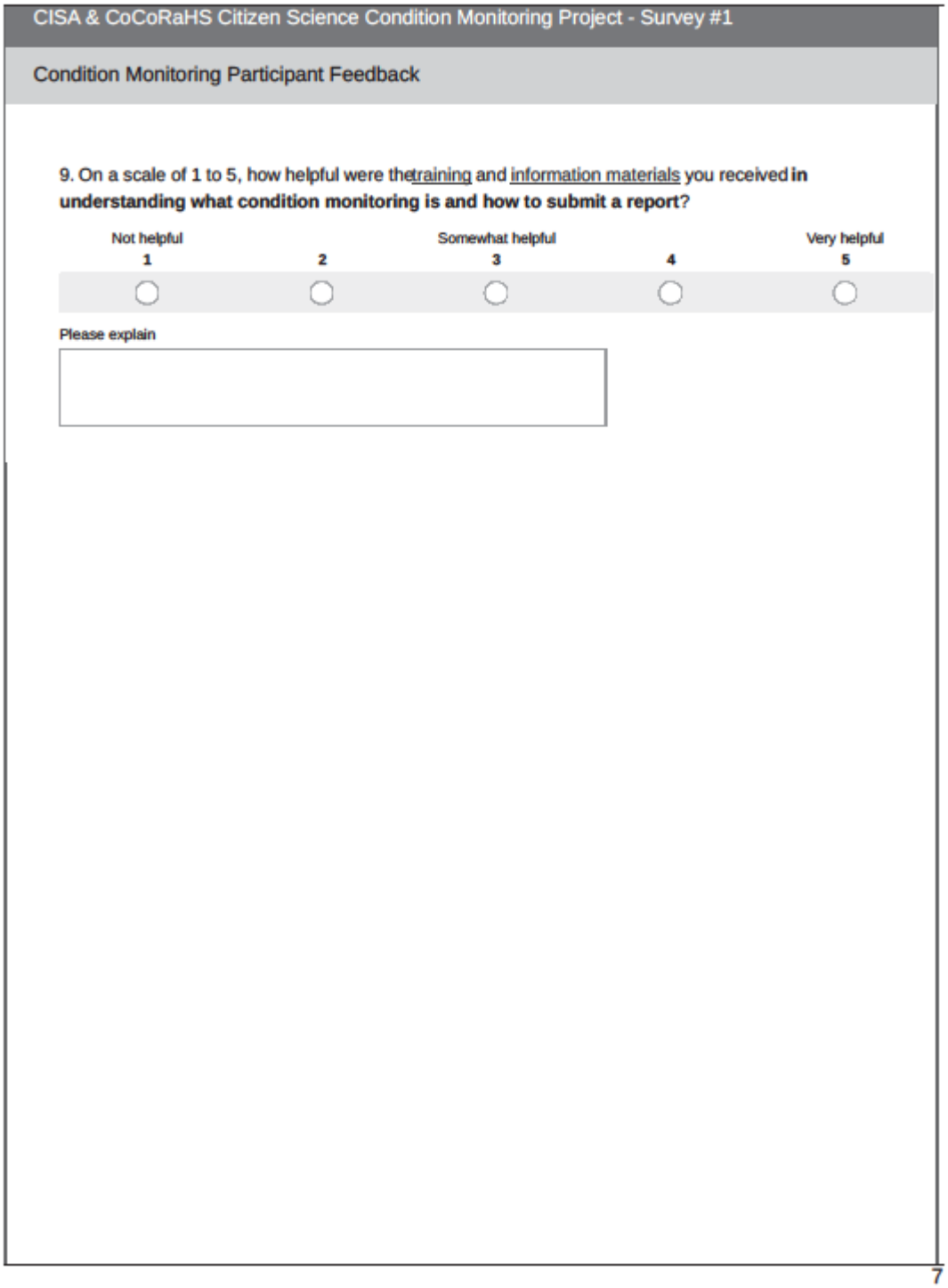
Please explain

5

8. Did you attend a training webinar to learn more about CoCoRaHS condition monitoring? (Check all that apply)

- [ ] Yes, I attended a webinar training in October 2016
- [ ] Yes, I attended a webinar training on January 25, 2017
- [ ] I have viewed online training materials on the CISA website (www.cisa.sc.edu/CoCoRaHS.html)
- [ ] I have viewed online training materials on the CoCoRaHS website (www.cocorahs.org/Content.aspx?page=condition)
- [ ] I did not attend a webinar and have not viewed any online training materials

6



CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #1

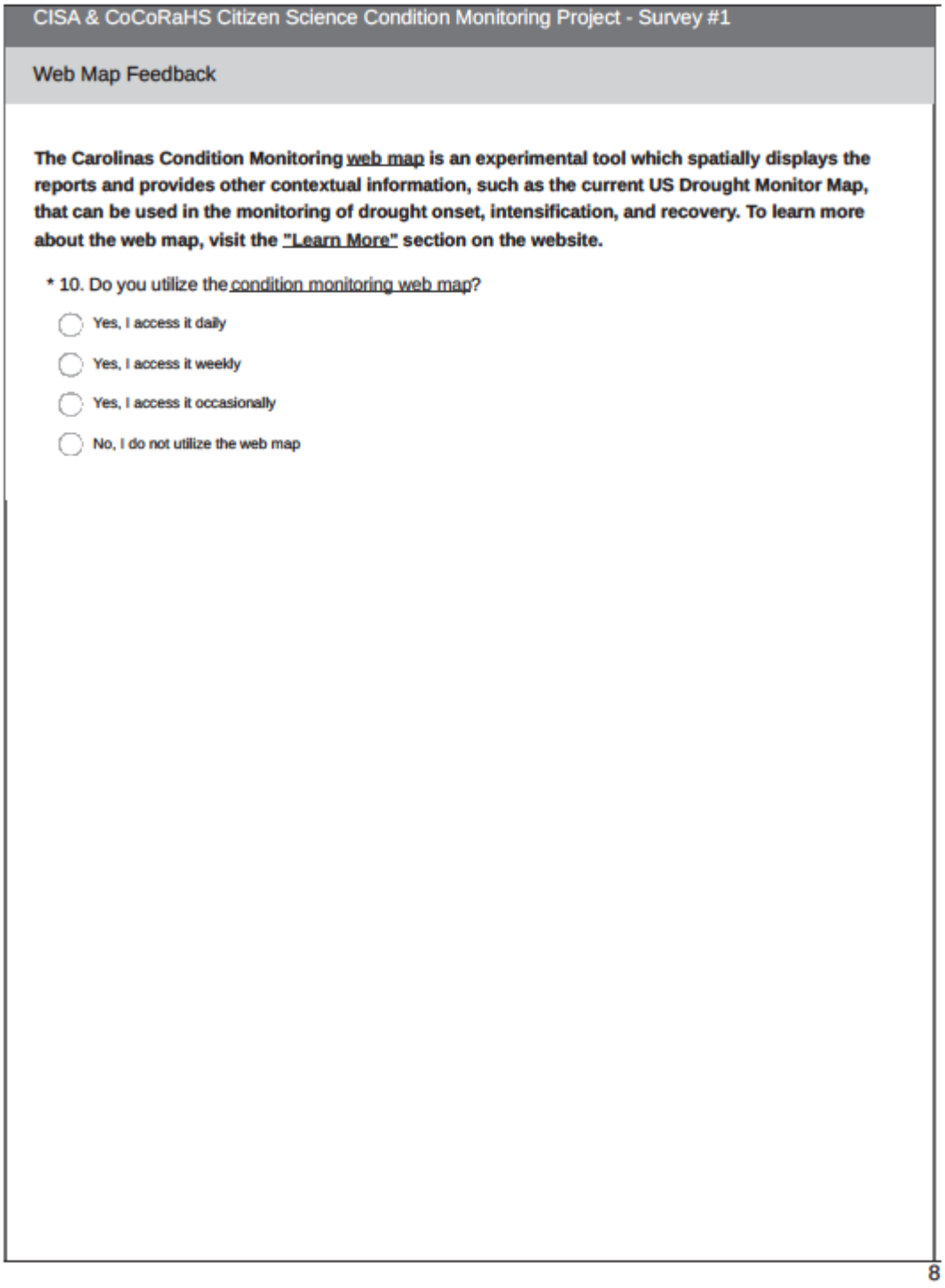
Condition Monitoring Participant Feedback

9. On a scale of 1 to 5, how helpful were the training and information materials you received **in understanding what condition monitoring is and how to submit a report?**

Not helpful		Somewhat helpful		Very helpful
1	2	3	4	5
○	○	○	○	○

Please explain

7



CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #1

Web Map Feedback

The Carolinas Condition Monitoring web map is an experimental tool which spatially displays the reports and provides other contextual information, such as the current US Drought Monitor Map, that can be used in the monitoring of drought onset, intensification, and recovery. To learn more about the web map, visit the "Learn More" section on the website.

* 10. Do you utilize the condition monitoring web map?

- ◯ Yes, I access it daily
- ◯ Yes, I access it weekly
- ◯ Yes, I access it occasionally
- ◯ No, I do not utilize the web map

8

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #1

Web Map Participant Feedback

* 11. Why do you utilize the web map? (Choose all that apply)

- [ ] I like to read other condition monitoring reports
- [ ] It is easier to access reports on the web map than on the CoCoRaHS website
- [ ] It is easier to access reports on the web map than on through the National Drought Impact Reporter
- [ ] It is easier to view reports in locations I am interested in because I can locate them on the map
- [ ] I can view the reports in conjunction with the US Drought Monitor map
- [ ] Other (Please explain)

* 12. On a scale of 1 to 5, how easy is it to use the condition monitoring web map?

Difficult to use		Somewhat easy		Easy to use
1	2	3	4	5
○	○	○	○	○

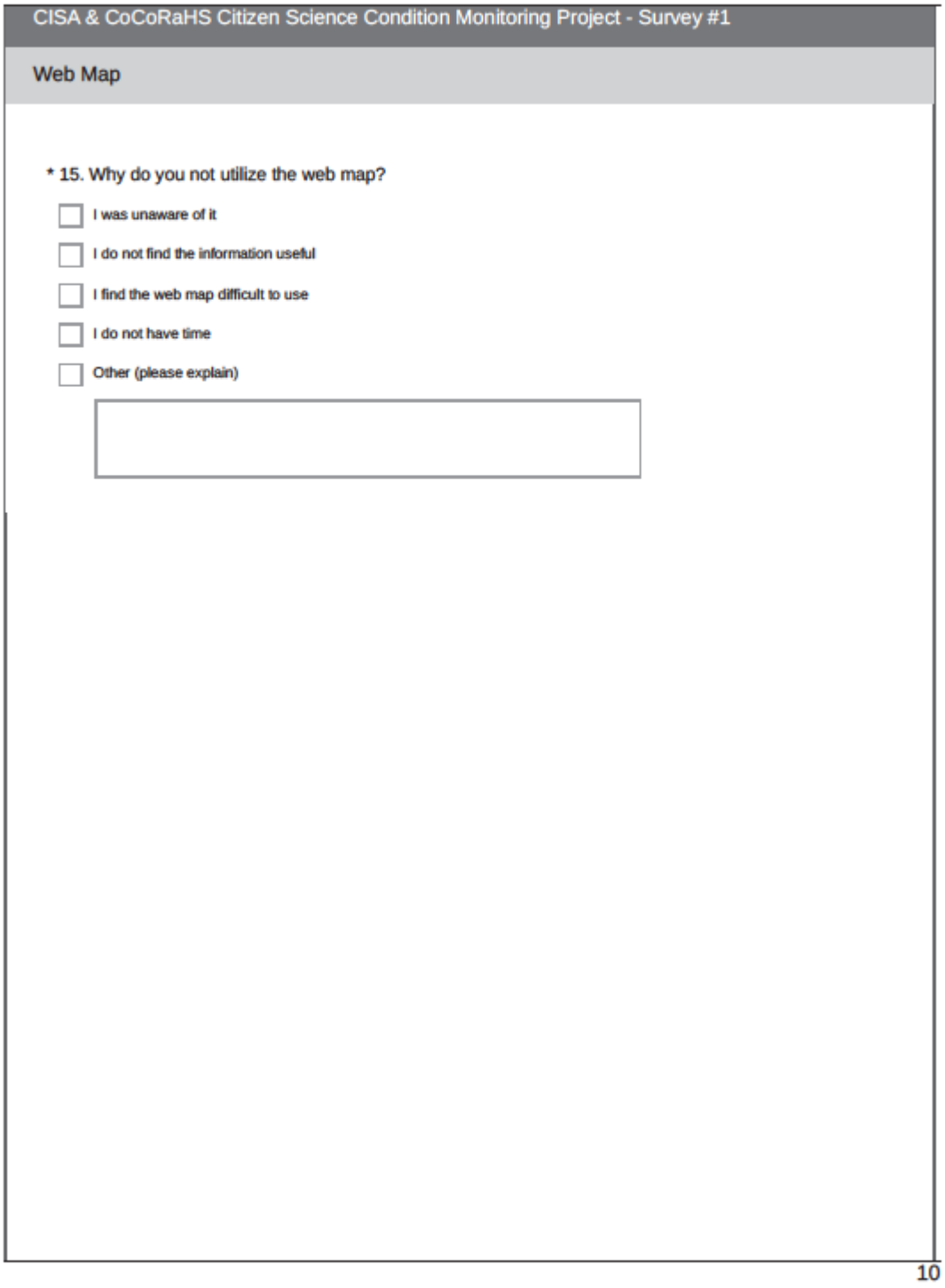
Please explain

* 13. Does the web map provide information that is useful to you?

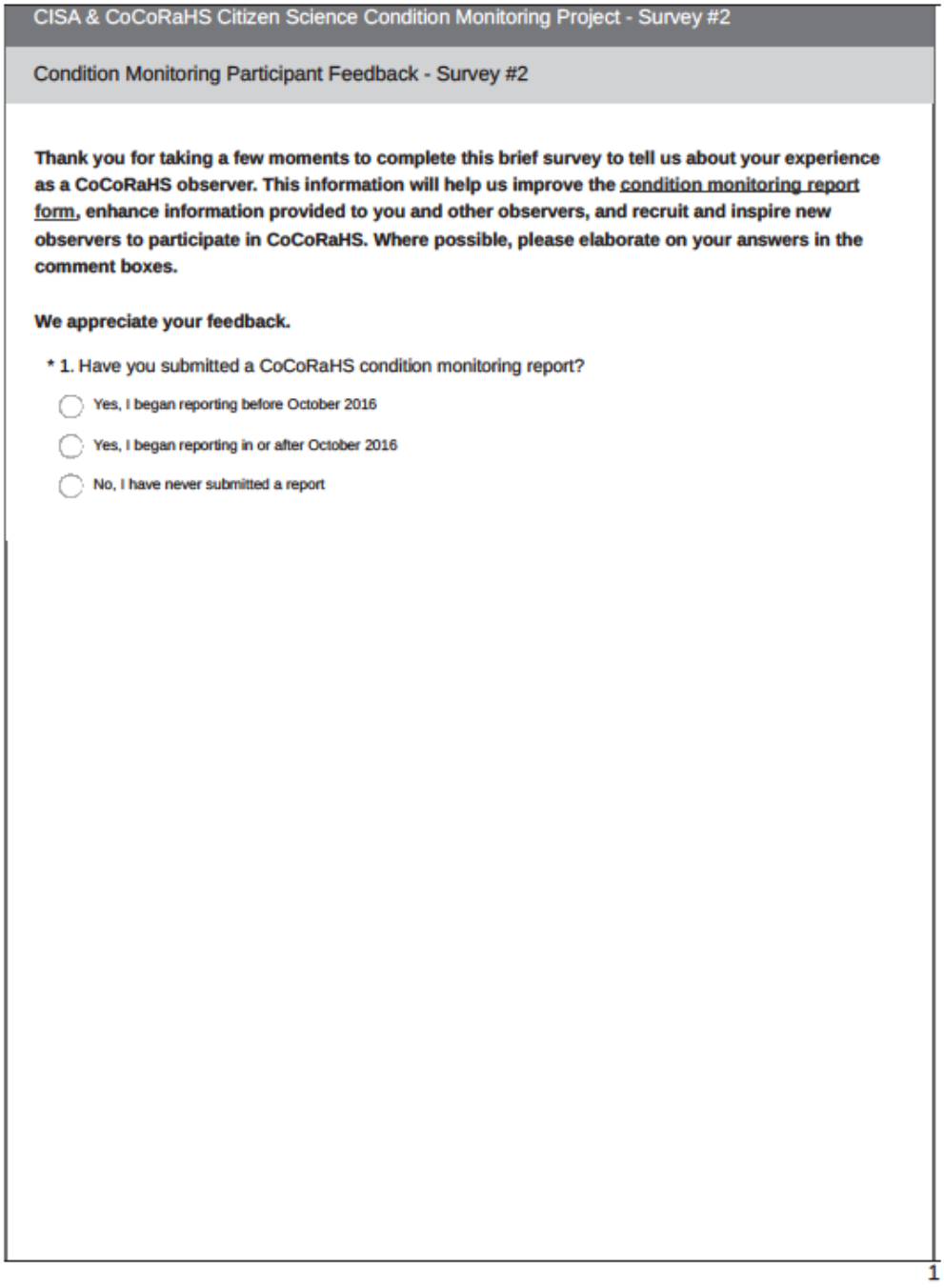
- ○ No, there is no useful information for me
- ○ I found the information interesting, but not necessarily useful
- ○ Yes, the web map provides information that is useful to me

14. If you answered yes to the question "Does the web map provide information that is useful to you," please explain how you use the information.

9


CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #1
Web Map
* 15. Why do you not utilize the web map?
I was unaware of it
I do not find the information useful
I find the web map difficult to use
I do not have time
Other (please explain)
10

Appendix B:
Volunteer Feedback Survey #2



CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #2

Condition Monitoring Participant Feedback - Survey #2

Thank you for taking a few moments to complete this brief survey to tell us about your experience as a CoCoRaHS observer. This information will help us improve the condition monitoring report form, enhance information provided to you and other observers, and recruit and inspire new observers to participate in CoCoRaHS. Where possible, please elaborate on your answers in the comment boxes.

We appreciate your feedback.

* 1. Have you submitted a CoCoRaHS condition monitoring report?

- Yes, I began reporting before October 2016
- Yes, I began reporting in or after October 2016
- No, I have never submitted a report

1

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #2

Condition Monitoring Participant Feedback

* 2. I have never submitted a CoCoRaHS condition monitoring report because

- ◯ I was unaware of this option on the CoCoRaHS website
- ◯ I am only interested in providing daily precipitation measurements
- ◯ I do not know how to submit a condition monitoring report
- ◯ I do not have time
- ◯ Other (please explain)

2

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #2

Condition Monitoring Participant Feedback

* 3. How has the frequency of your reporting changed since you first started condition monitoring?

- ◯ I report the same amount
- ◯ I report more often
- ◯ I report less often
- ◯ I no longer submit condition monitoring reports

3

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #2

Condition Monitoring Participant Feedback

* 4. If you report less frequently or no longer submit condition monitoring reports, please indicate why. Please check all that apply.

- [ ] Reporting takes more time than I expected
- [ ] I am not interested in reporting
- [ ] I forget to report
- [ ] I have health and/or mobility issues
- [ ] I frequently travel away from home
- [ ] I find it difficult to submit reports through the CoCoRaHS website
- [ ] I need more training to be confident in my reporting skills
- [ ] Other (please explain)

4

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #2

Condition Monitoring Participant Feedback

* 5. If you report the same amount or more often, what keeps you interested? Please check all that apply.

- [ ] Condition monitoring fits well with my skills
- [ ] Condition monitoring compliments my interest in weather and the environment
- [ ] The project allows me to contribute to scientific knowledge
- [ ] The project helped me fulfill the requirements of another volunteer program (e.g., volunteer hours for Master Gardeners)
- [ ] The Cuckoo for CoCoRaHS in the Carolinas blog and monthly newsletter help me learn more about weather and climate
- [ ] Correspondence from CISA showed me that my reports were useful
- [ ] Correspondence with other volunteers (e.g., through quarterly conference calls) helped connect me to a network of like-minded individuals
- [ ] The CoCoRaHS website offered tools to help me understand precipitation in my area
- [ ] Other (please explain)

5

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #2

Condition Monitoring Participant Feedback

* 6. Do you read the following regularly?

	Yes	No
Cuckoo for CoCoRaHs in the Carolinas blog	◯	◯
CISA and CoCoRaHS monthly newsletter	◯	◯

* 7. Do you find the information provided in the blog and/or newsletter helpful for the following: (Check all that apply)

- ☐ Knowing what information to provide for condition monitoring reports
- ☐ Knowing about current weather and climate conditions in the Carolinas
- ☐ Learning about additional information sources that are of interest to you
- ☐ Understanding how your reports are used
- ☐ Understanding how the information you submit to CoCoRaHS can benefit you
- ☐ Learning from examples of other reports (i.e., Observer of the Month)
- ☐ Other (please explain)

* 8. On a scale of 1 to 5, how confident are you in reporting conditions in your area?

1 Not Confident	2	3 Somewhat Confident	4	5 Very Confident
◯	◯	◯	◯	◯

Please explain

6

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #2

Condition Monitoring Participant Feedback

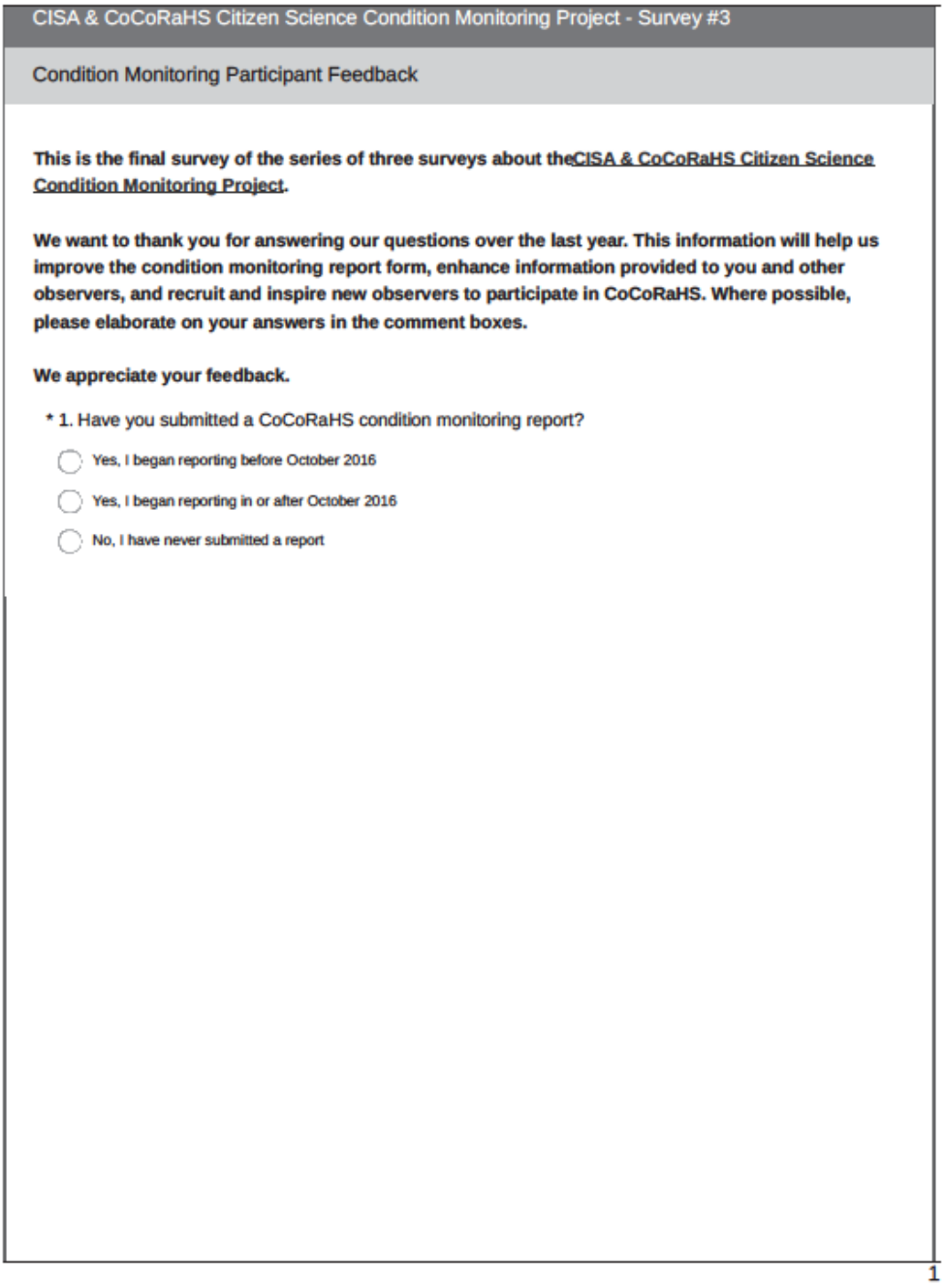
Thank you for taking the time to share your feedback with us. If you are interested in learning more about the CoCoRaHS Condition Monitoring Project, check out these resources:

- CoCoRaHS Condition Monitoring Resource Page
- CISA Condition Monitoring Project Page
- Condition Monitoring Web Map

Condition monitoring allows you to share information about how the rain, snow, sleet, or hail you have measured has affected your local environment and community. These reports provide valuable contextual information for the many people who use your precipitation measurements. Consider submitting a condition monitoring report this week!

7

Appendix C:
Volunteer Feedback Survey #3



CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #3

Condition Monitoring Participant Feedback

This is the final survey of the series of three surveys about the CISA & CoCoRaHS Citizen Science Condition Monitoring Project.

We want to thank you for answering our questions over the last year. This information will help us improve the condition monitoring report form, enhance information provided to you and other observers, and recruit and inspire new observers to participate in CoCoRaHS. Where possible, please elaborate on your answers in the comment boxes.

We appreciate your feedback.

* 1. Have you submitted a CoCoRaHS condition monitoring report?

- ◯ Yes, I began reporting before October 2016
- ◯ Yes, I began reporting in or after October 2016
- ◯ No, I have never submitted a report

1

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #3

Condition Monitoring Participant Feedback

* 2. I have never submitted a CoCoRaHS condition monitoring report because

- ◯ I was unaware of this option on the CoCoRaHS website
- ◯ I am only interested in providing daily precipitation measurements
- ◯ I do not know how to submit a condition monitoring report
- ◯ I do not have time
- ◯ Other (please explain)

2

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #3

Condition Monitoring Participant Feedback

* 3. How has the frequency of your reporting changed since you first started condition monitoring?

- ◯ I report the same amount
- ◯ I report more often
- ◯ I report less often
- ◯ I no longer submit condition monitoring reports

3

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #3

Condition Monitoring Participant Feedback

* 4. Please rank the following statements about learning from 1 to 5 with **1** being strongly disagree and **5** being strongly agree

	1 Strongly Disagree	2	3	4	5 Strongly Agree
As a condition monitoring reporter, I have learned more about how precipitation affects the local environment	○	○	○	○	○
Condition monitoring helps me keep track of the environment to inform other things I do (e.g., gardening)	○	○	○	○	○
Condition monitoring has helped me to contribute to scientific knowledge	○	○	○	○	○
Participation helped me meet the requirements of another volunteer program (e.g., volunteer hours)	○	○	○	○	○
I have used condition monitoring to teach others about local weather	○	○	○	○	○
I have used condition monitoring as an opportunity to connect with family and friends	○	○	○	○	○

4

* 5. Please rank the following statements about logistics from 1 to 5 with **1** being strongly disagree and **5** being strongly disagree

	1 Strongly Disagree	2	3	4	5 Strongly Agree
Condition monitoring requires more effort and time than I expected	○	○	○	○	○
Condition monitoring is useful to me	○	○	○	○	○
I understand how the data I submit is useful to the scientific community	○	○	○	○	○
Submitting condition monitoring reports is convenient	○	○	○	○	○
I plan to continue submitting condition monitoring reports in addition to my daily precipitation measurements	○	○	○	○	○

6. Please share any final thoughts, suggestions, or ideas to make Condition Monitoring even more successful.

5

CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #3

Optional Demographic Information

7. Do you participate in any other citizen science programs? Please check all that apply

- [ ] Master Naturalists
- [ ] Master Gardeners
- [ ] Other (please specify)

8. In which state do you currently reside?

- ◯ North Carolina
- ◯ South Carolina
- ◯ Other (please specify)

9. Sex

- ◯ Male
- ◯ Female
- ◯ Prefer not to answer

6

10. Which best describes your race?

- ◯ American Indian or Alaskan Native
- ◯ African American
- ◯ Asian/Pacific Islander
- ◯ Hispanic or Latino
- ◯ Mixed Heritage
- ◯ White
- ◯ Prefer not to answer
- ◯ Other (please specify)

11. What is your age group?

- ◯ 20-30
- ◯ 31-40
- ◯ 41-50
- ◯ 51-60
- ◯ 61-70
- ◯ 71-80
- ◯ 81 or older
- ◯ Prefer not to answer

7

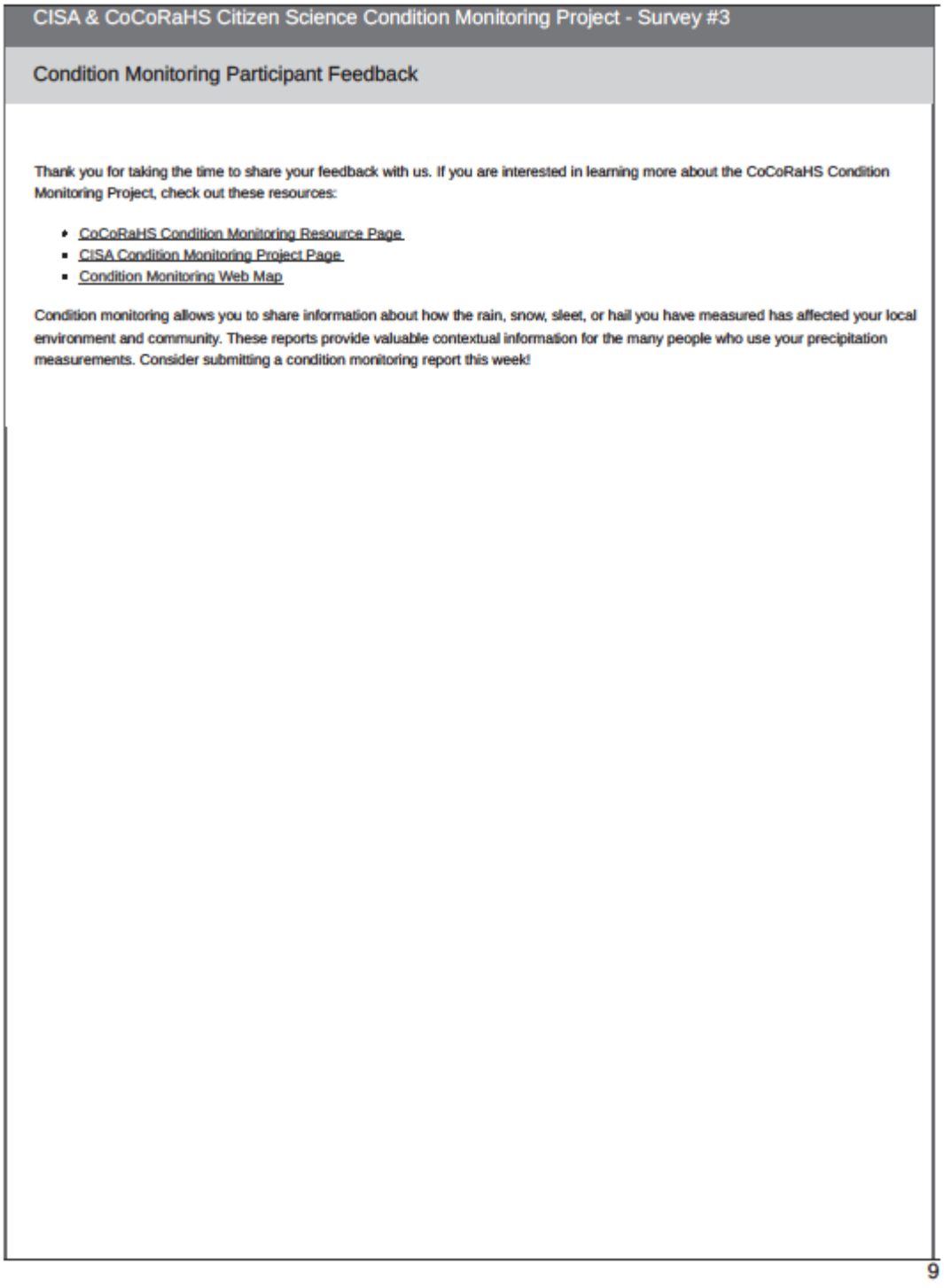
12. Please check the box(es) that is/are most applicable to your employment status. (Please check all that apply)

- ◯ Full-time
- ◯ Part-time
- ◯ Homemaker
- ◯ Caregiver
- ◯ Self-employed
- ◯ Retired
- ◯ Unemployed
- ◯ Student
- ◯ Other (please specify)

13. What is your highest level of education?

- ◯ 8th grade or less
- ◯ Some high school, no diploma
- ◯ High school diploma or GED
- ◯ Trade/technical/vocational training
- ◯ Some college credit, no degree
- ◯ Associate degree
- ◯ Professional degree
- ◯ Bachelor's degree
- ◯ Master's degree
- ◯ Doctoral degree

8



CISA & CoCoRaHS Citizen Science Condition Monitoring Project - Survey #3

Condition Monitoring Participant Feedback

Thank you for taking the time to share your feedback with us. If you are interested in learning more about the CoCoRaHS Condition Monitoring Project, check out these resources:

- CoCoRaHS Condition Monitoring Resource Page
- CISA Condition Monitoring Project Page
- Condition Monitoring Web Map

Condition monitoring allows you to share information about how the rain, snow, sleet, or hail you have measured has affected your local environment and community. These reports provide valuable contextual information for the many people who use your precipitation measurements. Consider submitting a condition monitoring report this week!

9

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Appendix D:
Phase 2 Decision Maker Feedback Survey

Condition Monitoring Feedback Survey

Survey Introduction

Thank you for taking the time to provide feedback about the CoCoRaHS Condition Monitoring program.

The program first began as a pilot project led by the Carolinas Integrated Sciences & Assessments (CISA) with support from the National Integrated Drought Information System (NIDIS) in 2013. The "condition monitoring" approach involves working with CoCoRaHS citizen scientists to submit regular status reports about the condition of their local environment and community. One of the goals of this project is to assess if and how this information is useful for drought monitoring and drought-related decisions.

Throughout the project, we have worked with CoCoRaHS leadership to refine the report form used by CoCoRaHS observers, create training materials, and develop tools such as the Web Map (below) to improve access to report information and to make Condition Monitoring a meaningful contribution to drought impacts monitoring and reporting.

Your feedback will help guide recommendations for continued program support and refinements.

CoCoRaHS Condition Monitoring Report Web Map

1

Condition Monitoring Feedback Survey

Accessing Condition Monitoring Reports

* 1. Please tell us how you may or may not have accessed and used CoCoRaHS condition monitoring reports.

- ◯ I have read through condition monitoring reports and HAVE USED them for drought monitoring, public communications, drought decisions, or other drought-related activities.
- ◯ I have read through condition monitoring reports but HAVE NOT USED the information in any capacity.
- ◯ I have NEITHER accessed condition monitoring reports NOR used them in any capacity.

2

Condition Monitoring Feedback Survey

Utilization of CoCoRaHS Condition Monitoring reports

* 2. Please let us know specifically how you have used condition monitoring reports (i.e., to provide information to a drought committee, to inform drought designations, to provide information to the general public such as through news media).

3. What types of information provided by CoCoRaHS observers in their condition monitoring reports are most useful to you?

- ☐ Precipitation Amounts
- ☐ Soil Moisture
- ☐ Temperature
- ☐ Other Weather Observations
- ☐ Agriculture
- ☐ Business and Industry
- ☐ Energy
- ☐ Fire
- ☐ Plants and Wildlife
- ☐ Relief, Response, and Restrictions
- ☐ Society and Public Health
- ☐ Tourism and Recreation
- ☐ Water Supply
- ☐ Water Quality

Please provide any recommendations of other types of information observers could provide that would make the reports more relevant and/or useful to you.

3

Condition Monitoring Feedback Survey

For Those Who Do Not Use Condition Monitoring Reports

* 4. Why have you not used CoCoRaHS Condition Monitoring reports? (Please check all that apply.)

- [ ] I am only interested in using objective indicators for my drought-related decision making.
- [ ] The type of information provided in the reports is not useful for my decisions.
- [ ] The geographic scale of information provided in the reports is not useful for my decisions.
- [ ] I already have too many other sources of information to sort through.
- [ ] Other

Other (please explain)

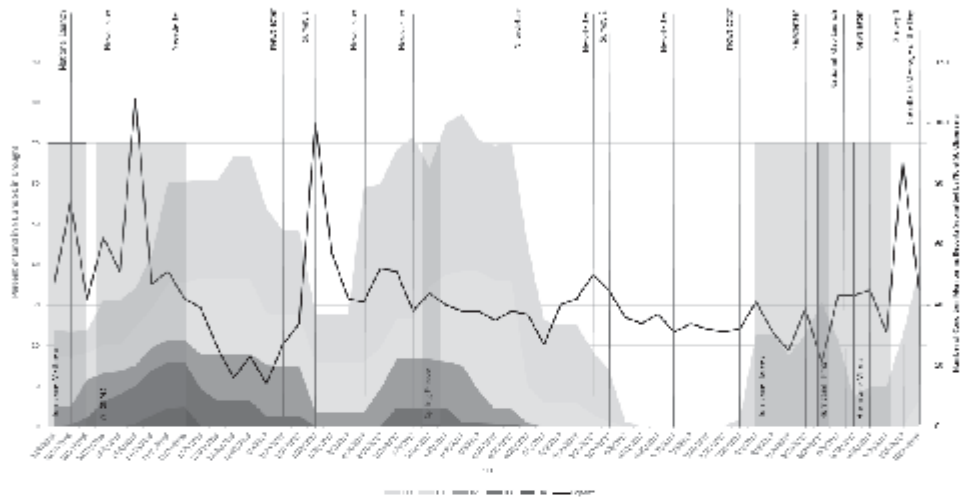
5. Do you have any recommendations for the types of information CoCoRaHS observers could provide that might make Condition Monitoring reports relevant and/or useful for your decision making needs?

4

Condition Monitoring Feedback Survey

Accessing Condition Monitoring Reports

Potential Factors Influencing Carolinas Condition Monitoring Report Submissions



The above timeline shows the number of submitted reports per week (solid black line) and includes several layers of information which may, or may not, have influenced the number of condition monitoring reports submitted by Carolinas CoCoRaHS observers including:

1) drought conditions in the Carolinas
2) extreme events impacting the region
3) communications and outreach materials circulated to observers during the study period (e.g., CoCoRaHS message of the day, newsletters, observer feedback surveys)

6. Do you access Condition Monitoring reports regularly, when prompted by weather and climate events, or both? Please check all that apply.

- [ ] When there are dry or drought conditions in my area of interest
- [ ] When there are other extreme weather events in my area
- [ ] Weekly, regardless of drought conditions
- [ ] Monthly, regardless of drought conditions
- [ ] Seasonally/Quarterly, regardless of drought conditions
- [ ] Other (please describe)

5

7. How do you prefer to access condition monitoring reports? Please rank the following options. Check "N/A" if you do not use a particular option listed here.

⠿	Online web map	☐ N/A
⠿	Report list on the CoCoRaHS website	☐ N/A
⠿	National Drought Impacts Reporter	☐ N/A

8. Why do you prefer to access condition monitoring reports in the format you selected as your 1st choice? Please check all that apply.

- ☐ This format is the one I am most accustomed to using.
- ☐ I was only aware of this option for accessing the reports.
- ☐ I find the information in this format to be the most useful.
- ☐ I find the information in this format to be the easiest to use.

Other (please specify)

6

Condition Monitoring Feedback Survey

Review of Background Materials

We have compiled several informational materials for your reference as you proceed through the rest of the survey. These include:

1) A map of observer locations and number of reports submitted
2) An analysis of condition monitoring scale bar selections in comparison to other, objective drought indices
3) Six individual observer case studies

These materials are available on the CISA website (see Project Feedback Background Materials links in the right column of the page). Links to the individual resources are also included in questions where we ask for specific feedback about the project.

7

Condition Monitoring Feedback Survey

Condition Monitoring Report Content

Please reference the Observer Case Studies when answering the questions on this page.

9. Has the information in condition monitoring reports *improved your understanding of on-the-ground drought impacts*?

- ◯ Yes
- ◯ No

Please provide any additional information you would like to share.

10. Has the information in condition monitoring reports *improved your understanding of the onset, intensification, and recovery of drought conditions*?

- ◯ Yes
- ◯ No

Please provide any additional information you would like to share.

11. Based on the condition monitoring reports you have reviewed, do you generally consider the information collected by CoCoRaHS observers:

- ◯ Credible - They provide information that can be trusted to better understand on-the-ground conditions
- ◯ Reliable - They serve as a consistent resource for on-the-ground impacts information
- ◯ Both
- ◯ Neither

8

12. Please rank the following observer characteristics in order of importance for why you might choose to read his/her condition monitoring reports.

- The observer submits condition monitoring reports consistently (weekly to monthly)
- The observer submits precipitation measurements daily
- The observer's condition monitoring reports provides the information I need about specific types of impacts (e.g., agriculture, water supply, soil moisture)
- The observer is located in an area where I need more information about on-the-ground conditions

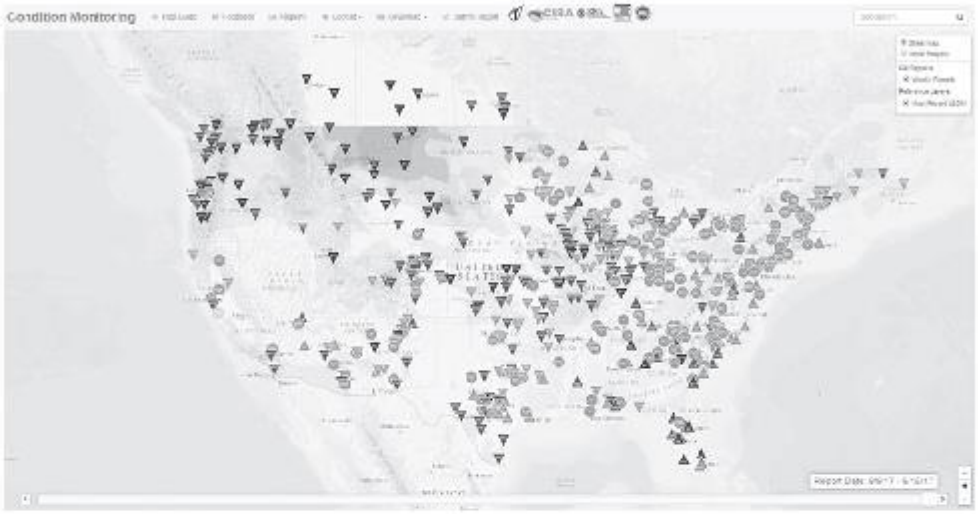
13. Please share any additional thoughts you have about the credibility and reliability of CoCoRaHS observers as a source for drought impacts information.

9

Condition Monitoring Feedback Survey

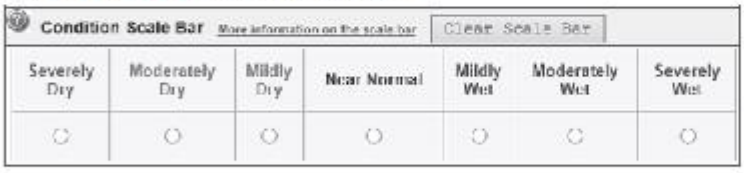
Web Map Review

CoCoRaHS Condition Monitoring Web Map



The CoCoRaHS Condition Monitoring Web Map was developed in order to improve access and usability of reports. The map spatially displays the reports and provides the current US Drought Monitor Map for the selected week. More information about all of the various map functions is available on the Map Guide.

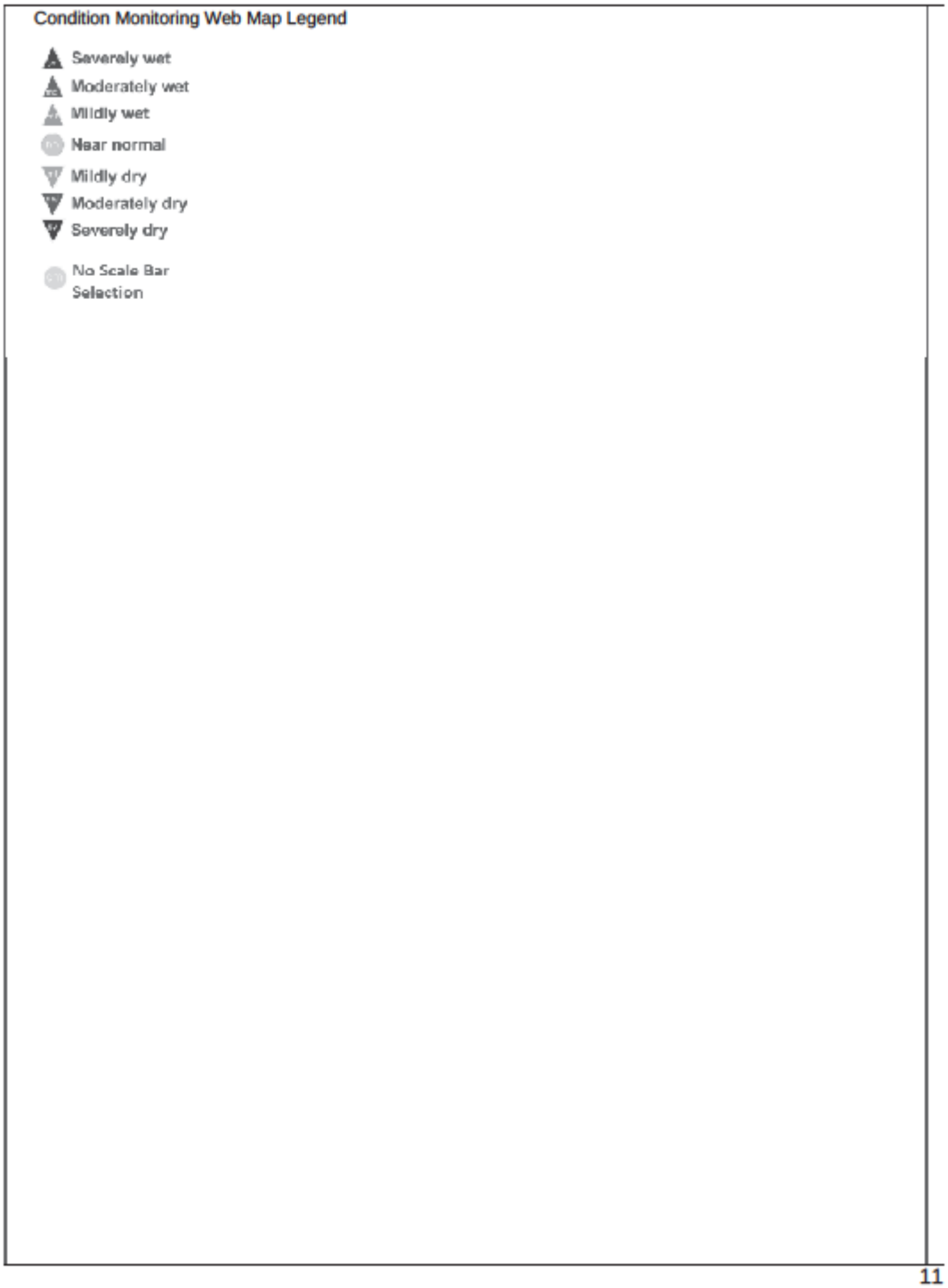
Condition Monitoring Report Form Scale Bar



As part of the new CoCoRaHS Condition Monitoring Report Form, observers are asked to select one of seven categories that best matches their observations of local conditions. Scale bar selections correspond to the symbols on the web map. Scale bar selections are also used to generate the summary report charts to help see changing conditions over time.

The seven scale bar categories from the condition monitoring report form are translated to the icons below on the web map in order to visualize wet, normal, and dry scale bar selections for each observer's condition monitoring report.

10


Condition Monitoring Web Map Legend
Severely wet
Moderately wet
Mildly wet
Near normal
Mildly dry
Moderately dry
Severely dry
No Scale Bar
Selection
11

Condition Monitoring Feedback Survey

Web Map and Scale Bar Feedback

14. Are there ways in which the web map could be improved that would enhance the accessibility and usefulness of the information (e.g., added map layers for additional contextual information)?

15. How would you describe your impressions of the condition monitoring scale bar? Check all that apply. You can reference the Condition Monitoring Scale Bar Analysis for additional information.

- [ ] Scale bar selections add value to CoCoRaHS Condition Monitoring reports.
- [ ] Scale bar selections make it easier to assess which reports to read based on a quick visualization of reported conditions (e.g., web map symbol).
- [ ] Scale bar selections are consistent with other objective indicators I use.

Please provide any additional comments you would like to share.

12

Condition Monitoring Feedback Survey

For Those Who Have Not Viewed or Accessed Condition Monitoring Reports

* 16. Why have you not viewed or accessed CoCoRaHS Condition Monitoring reports?

- [ ] I was unaware of the availability of Condition Monitoring reports.
- [ ] I am only interested in using objective indicators for my drought-related decision making.
- [ ] I already have too many other sources of information to sort through.
- [ ] Other

Other (please specify)

17. Do you have any recommendations for the types of information CoCoRaHS observers could provide that might make Condition Monitoring reports relevant and/or useful for your decision making needs?

13

Condition Monitoring Feedback Survey

Other Sources for Drought Impacts Information

18. Do you use any of the following sources for drought impacts information? Please check all that apply.

- [ ] Extension Agents
- [ ] National Drought Impacts Reporter
- [ ] National Weather Service
- [ ] Regional Climate Center
- [ ] River Forecast Centers
- [ ] Other (please specify)
- [ ] State Agency Information
- [ ] State Climate Office
- [ ] US Army Corps of Engineers
- [ ] USDA Agricultural Impacts Reports
- [ ] US Forest Service

19. If you use other drought impacts information sources, do CoCoRaHS Condition Monitoring reports provide added value to support your decisions?

- ( ) Yes
- ( ) No

Please explain

14

Condition Monitoring Feedback Survey

Condition Monitoring Program Design and Structure

20. It is very important for observers to know how their information is used, to encourage continued participation in the CoCoRaHS volunteer network. Would you be willing to specifically request certain types of information that might be useful to you through CoCoRaHS, providing examples of how the information would be used?

- ◯ Yes
- ◯ No
- ◯ Unsure

Please provide any additional comments you would like to share.

21. Would images from observers help to document or support information provided in CoCoRaHS Condition Monitoring reports?

- ◯ Yes
- ◯ No
- ◯ Unsure

Please provide any additional comments.

15

Condition Monitoring Feedback Survey

Final Questions

Thank you for taking the time to provide feedback about the CoCoRaHS Condition Monitoring program. We have just a few more questions about you to finish up the survey.

22. Please select which of the following applies to you in your current position and for your current work responsibilities. Check all that apply.

- [ ] CoCoRaHS Volunteer Coordinator
- [ ] Drought Researcher
- [ ] Extension Agent
- [ ] Media (television, newspaper, etc.)
- [ ] National Weather Service Affiliate
- [ ] Regional Climate Center Affiliate
- [ ] State Climate Office Staff
- [ ] State Drought Committee Member
- [ ] Soil and Water Conservation District Agent
- [ ] US Drought Monitor Map Author
- [ ] US Drought Monitor Map Contributor

Other (please specify)

23. Do you have any recommendations for other people or organizations with whom we should share this project information?

24. Would you be willing to discuss your responses in a follow up phone conversation if the CISA team has specific questions for you?

- ◯ Yes
- ◯ No

16

25. Please provide your contact information so that we can confirm who has completed the survey.

Name	
Organization	
Job Title	
State/Province	
Email Address	
Phone Number	

Thanks again for taking the time to provide feedback about the CoCoRaHS condition monitoring project. We will use your feedback in the final report for the Carolinas condition monitoring pilot project. We will share the final report with all survey respondents as well.

17

Appendix E:
Decision Makers Who Provided Carolinas Pilot Project Feedback

Name	Organization	Title	Feedback Provided Via
Klaus Albertin	NC Division of Water Resources / NC Drought Management Advisory Council	NC DMAC Chair	Phone Interview
Heather Aldridge	State Climate Office of North Carolina	Assistant State Climatologist, NC State CoCoRaHS Coordinator	Online Survey
Phil Badgett	NWS Weather Forecast Office Raleigh, NC	Meteorologist, NC Central Regional CoCoRaHS Coordinator	Phone Interview
Brian Fuchs	National Drought Mitigation Center / US Drought Monitor	Climatologist	Phone Interview
Todd Hamill	Southeast River Forecast Center	Service Coordination Hydrologist	Online Survey
Scott Harder	SC Department of Natural Resources	Senior Hydrologist; Land, Water, & Conservation Division	Phone Interview
Richard Heim	NOAA National Center for Environmental Information / US Drought Monitor	Meteorologist	Online Survey
Blair Holloway	NWS Weather Forecast Office Charleston, SC	Meteorologist	Online Survey
Kevin Kalbaugh	NC Emergency Management / NC Drought Management Advisory Council	Meteorologist/Planner	Online Survey
Eric Luebehusen	USDA World Agricultural Outlook Board / US Drought Monitor	Meteorologist	Phone Interview
Jordan McLeod	Southeast Regional Climate Center	Regional Climatologist	Online Survey
Hope Mizzell	South Carolina State Climate Office	SC State Climatologist	Online Survey
Barbara O'Connell	York County Soil & Water Conservation District	District Coordinator, York County CoCoRaHS Coordinator	Online Survey
Debra Owen	NC Division of Water Resources / NC Drought Management Advisory Council	Biologist	Online Survey
Julie Packett	NWS Weather Forecast Office Charleston, SC	Meteorologist, SC Southeast Regional CoCoRaHS Coordinator	Online Survey

Name	Organization	Title	Feedback Provided Via
Josh Palmer	NWS Weather Forecast Office Greenville-Spartanburg, SC	Service Hydrologist	Phone Interview
Linwood Peele	NC Division of Water Resources / NC Drought Management Advisory Council	Water Supply Planning Supervisor	Phone Interview
Bard Rippey	USDA World Agricultural Outlook Board / US Drought Monitor	Meteorologist	Phone Interview
William Schmitz	Southeast Regional Climate Center	Service Climatologist/Meteorologist	Online Survey
Eric Seymour	Wakefield, VA NWS Weather Forecast Office	Service Hydrologist	Online Survey
Anita Silverman	NWS Weather Forecast Office Blacksburg, VA	Meteorologist, NC Northwest Regional CoCoRaHS Coordinator	Phone Interview
David Simeral	Western Regional Climate Center / US Drought Monitor	Climatologist	Online Survey
Chris Stachelski	NWS Eastern Region Headquarters	Regional Observation Program Leader/Climate Services Program Manager	Phone Interview
Vann Stancil	NC Wildlife Resources Commission / NC Drought Management Advisory Council	Research Coordinator	Online Survey
Jeffrey Taylor	NWS Weather Forecast Office Greenville-Spartanburg, SC	Meteorologist, NC Western/SC Upstate Regional CoCoRaHS Coordinator	Phone Interview
Emily Timte	NWS Weather Forecast Office Charleston, SC	Meteorologist, SC Southeast Region CoCoRaHS Coordinator	Online Survey
Leonard Vaughn	NWS Weather Forecast Office Columbia, SC	Meteorologist, SC Midlands Regional CoCoRaHS Coordinator	Online Survey
Rebecca Ward	State Climate Office of North Carolina / NC Drought Management Advisory Council	Extension Climatologist	Online Survey
Curtis Weaver	USGS South Atlantic Water Science Center / NC Drought Management Advisory Council	Hydrologist	Phone Interview
Nat Wilson	NC Division of Water Resources / NC Drought Management Advisory Council	Environmental Supervisor	Online Survey
Mike Yoder	NC Cooperative Extension / NC Drought Management Advisory Council	Assoc. Director & State Program Leader, 4-H/Farm & Conservation Services	Phone Interview