

Indicators and Indices of Drought in Southeastern Coastal Ecosystems

Award Number: NA130AR4310173

Final Report

09/01/2013 - 08/31/2017

Project Overview

While many drought indices and indicators exist (focusing on, for example, agriculture or reservoir management), coastal ecological resources receive little attention. This project seeks to improve understanding of coastal resources that are adapted to or dependent upon particular spatial and temporal patterns of precipitation, salinity, or streamflow to determine stress caused by drought.

Contributions to NIDIS

This project is intended to support the National Integrated Drought Information (NIDIS) Coastal Carolinas Drought Early Warning System (DEWS) program. It addresses questions and needs identified by DEWS stakeholders and partners for 1) improved understanding of the unique vulnerabilities and impacts of drought in coastal areas and 2) new tools, information, and other resources that will help managers and decision makers integrate drought- and coastal resource management activities.¹

The research findings and resources produced through this project will also contribute to and inform Coastal Carolinas DEWS priorities and activities as outlined in the [2017-2018 Strategic Plan](#). These include Priority 3 (“Improve Coastal Drought Monitoring and Use of Drought Indicators and Indices”) and Priority 2 (“Improve Drought Early Warning Outreach and Communication Capacity”).

In addition, the focus on ecological drought and effects on coastal conditions and resources is somewhat unique among the DEWS regions and programs. The methods and findings described here may be transferrable to other DEWS or NIDS activities.

Project Team Members

Daniel Tufford, PI (through February 2017), University of South Carolina

Kirsten Lackstrom, PI (beginning March 2017), University of South Carolina

Lauren Rouen, University of South Carolina

David Chalcraft, East Carolina University (sub-award for Phase 1 of the project)

Casey Nolan, East Carolina University (sub-award for Phase 1 of the project)

Personnel Changes during the Award

Daniel Tufford was the original PI for this project, which began in September 2013. Tufford retired from the University of South Carolina in 2016. Lackstrom, a PI with the Carolinas Integrated Sciences &

¹ The Coastal Carolinas DEWS scoping workshop (2012) and strategic planning meeting (June 2016) final reports provide additional details. Information is available at the [Coastal Carolinas DEWS](#) page on drought.gov.

Assessments (CISA) team, assumed project management responsibilities in 2017. Lauren Rouen was hired in fall 2016 to assist with the activities described in this report.

Project Products and Deliverables

The resources and products developed through this project are available on the CISA [website](#).² The full list of deliverables, including presentations, begins on page 8 of this document. Major contributions include the following:

- Nolan, C. B., D. L. Tufford, and D. R. Chalcraft. 2016. Needs Assessment of Coastal Land Managers for Drought Onset Indicators in the Southeastern United States. *Journal of Coastal Research* 32, Issue 5: pp. 1016 – 1024.
- Lackstrom, K. and L. Rouen. 2017. Ecological Responses to Drought in the Coastal Carolinas and Georgia: Research Review.
- Carolinas Integrated Sciences & Assessments (CISA). 2017. Inventory of Salinity Datasets for Use with the Coastal Salinity Index. (spreadsheet)
- Carolinas Integrated Sciences & Assessments (CISA). 2017. Inventory of Ecological Response Datasets and Monitoring Programs for Use with the Coastal Salinity Index. (spreadsheet)

Summary of Work

Phase 1: Needs Assessment

In the first phase of the project, a needs assessment was conducted through 30 structured interviews with coastal resource managers along the Carolinas' coast. The interviews identified use of, and needs for, specific drought indices and indicators to effectively understand and monitor drought in coastal ecosystems. Research findings were published in the *Journal of Coastal Research* (Nolan et al., 2016).

Key findings and results include:

- *83% of interviewees indicated a need for early drought detection, but a lack of awareness of current drought indicators.* All interviewees who indicated a need for an early warning drought indicator also emphasized the need for indicator parameters that reflected freshwater availability and impacts on ecological resources.
- *50% of interviewees agreed that drought indicators should be specifically focused on specific kinds of habitats, although 90% of interviewees thought that a single index could be useful for multiple habitats that have broad similarities.* More specifically, freshwater wetlands, especially those with organic soils, were identified as the habitat most sensitive to drought impacts. Variables related to freshwater availability and salinity measures were identified as the most useful for early drought warning and identification of potential impacts.
- *86% of interviewees reported a lack of resources to collect needed data for a drought indicator.* Specific concerns included, practical constraints (e.g., staff time), broad spatial gaps in data that limit extrapolation, and the extent to which an indicator was relevant among neighboring habitat types.

² http://cisa.sc.edu/projects_salinity.html

Suggestions by interviewees to overcome these constraints include coordinated data collection among managers of similar habitats, a focus on ecological variables most common across habitats (e.g., soil salinity), and selection of input parameters that coincide with other management plans in order to increase relevance and, in turn, regular use of the indicator.

Phase 2: Ecological Responses to Drought

The second component of this project involved efforts to better understand and characterize ecological drought in coastal systems and advance the use and application of the Coastal Salinity Index (CSI). Development of the CSI is a central activity of the Coastal Carolinas DEWS program. The CSI provides a way to characterize drought and wet conditions by monitoring salinities in fresh and saltwater ecosystems. The tool is intended to improve understanding of the effects of changing salinities on coastal ecosystem conditions and resources and on freshwater availability for ecological needs.

In collaboration with DEWS partner Paul Conrads, U.S. Geological Survey (USGS) South Atlantic Water Science Center, the project team conducted four specific activities. Summary information about each activity is provided below.

- 1) Identify, collect, and prioritize salinity datasets for calculating the CSI
- 2) Identify, collect, and document ecological response datasets
- 3) Collect and review existing information about drought and salinity effects on coastal ecological resources
- 4) Engage with project stakeholders and partners

Inventory of Salinity Datasets

Rouen worked with USGS and Coastal Carolinas DEWS partners to identify and obtain salinity datasets in North Carolina and South Carolina. The objective was to develop criteria and prioritize salinity datasets that could be used by USGS to calculate the CSI for different locations. Available as a downloadable spreadsheet, the final inventory of salinity datasets includes information such as data source, location, frequency of data collection, period of record, and other details. These monitoring sites are operated by agencies such as USGS, the National Estuarine Research Reserve System (NERRS), and the National Park Service (NPS). Priority datasets have been identified and include those with active data collection, a long period of record, and potential opportunities to compare with ecological response datasets (Figure 1). USGS began the work to calculate the CSI for South Carolina sites in spring 2017; this work is expected to be complete by early 2018. The CSI calculations can then be compared with ecological response variables to assess linkages between ecological indicators and salinity levels as expressed by the CSI. Conrads is working with USGS colleagues to identify applications of the CSI in other Southeast locations. Using the same prioritization criteria as for the Carolinas, Rouen identified additional salinity datasets that could be used to calculate the CSI across the region (Figure 2).

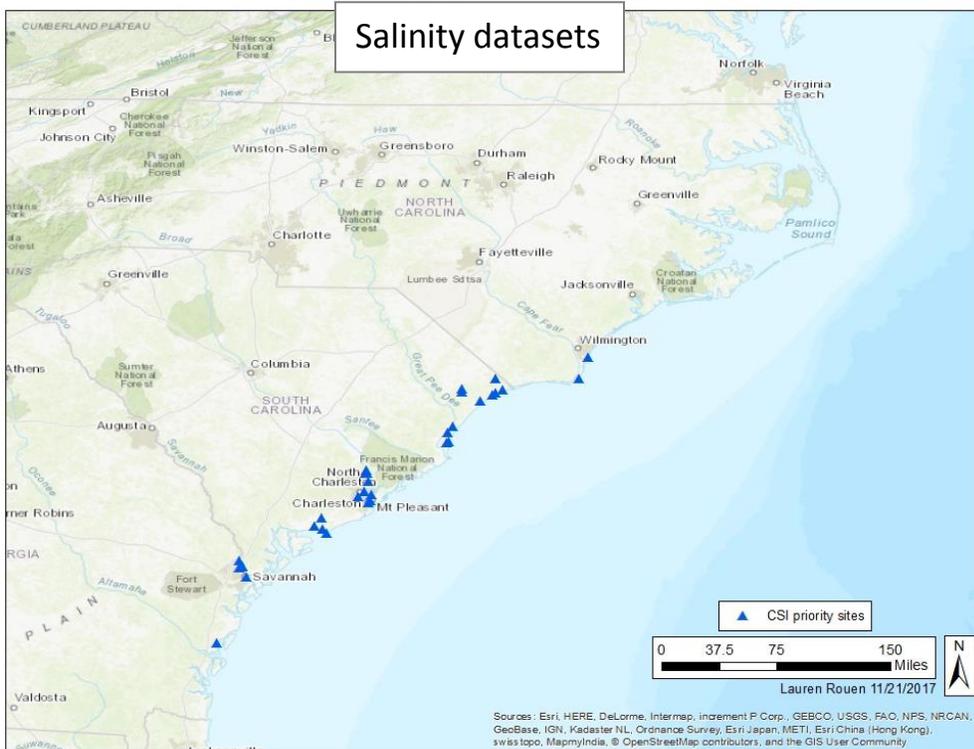


Figure 1. Locations of salinity datasets (North Carolina, South Carolina, Georgia)

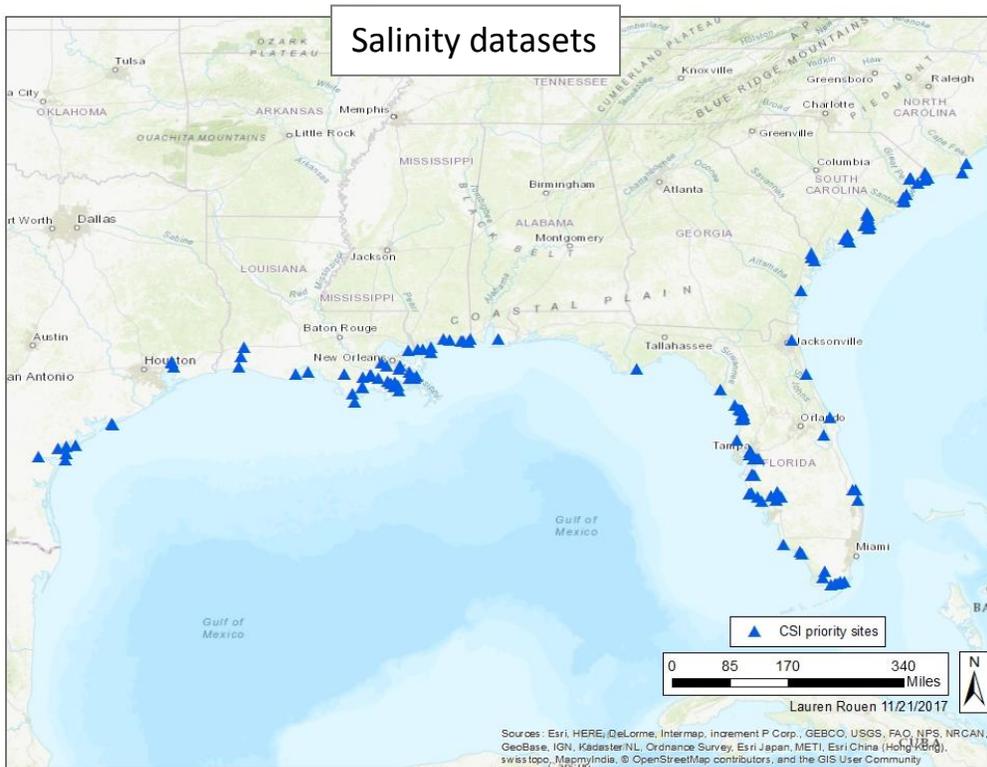


Figure 2. Locations of salinity datasets (entire Southeast region)

Inventory of Ecological Response Datasets

The purpose of this activity was to identify and collect ecological response datasets that can be used to assess the linkages between ecological variables and salinity levels as expressed by the CSI. Rouen first worked with USGS and Coastal Carolinas DEWS partners to identify and obtain water quality and ecological responses datasets in North Carolina and South Carolina. Additional datasets were identified through the research review activity (described below). A downloadable spreadsheet contains the inventory of datasets with details such as location, period of record, frequency of data collection, and where the data are available online. Figure 3 shows the locations of datasets that have been identified and included in the inventory. The datasets include tree ring chronologies, litter fall, pore water salinity, water quality parameters, inshore fisheries and crustacean surveys, blue crab landings, and groundwater conductivity.

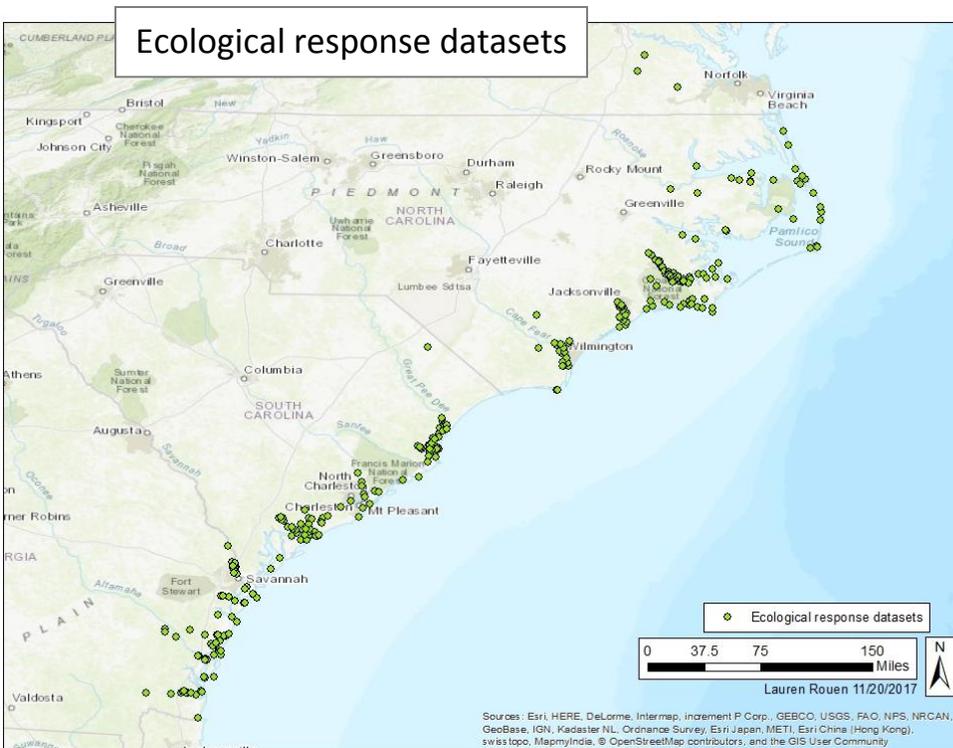


Figure 3. Locations of ecological response datasets, for potential use with the CSI

Ecological Responses to Drought in the Coastal Carolinas and Georgia: Research Review

Lackstrom and Rouen conducted a literature review to identify research and other efforts investigating “coastal drought” and/or the relationships between salinity and ecological response in the estuarine and coastal areas of South Carolina, North Carolina, and Georgia. While Georgia was not in the original study area, the similarities between coastal areas of South Carolina and Georgia made it practical to include this portion of the coast. The literature review was also used to help identify salinity and ecological response datasets that can be used to further develop and apply the CSI (see above).

Engagement with project stakeholders and partners

The project team initiated many activities to engage with Coastal Carolinas DEWS and CSI stakeholders. These activities are intended to facilitate coordination with a variety of organizations during the application of the CSI and associated research activities (i.e., assess the linkages between salinity and environmental response.) The overarching aim is to ensure that the two projects (CSI and this project) are responsive to resource management questions and needs.

The CSI Working Group

In fall 2016 Lackstrom and Conrads established the “CSI Working Group” to provide feedback on the development of the CSI and recommendations for its use by resource managers and researchers. Members represent agencies and organizations with responsibilities and interests pertaining to drought monitoring and resource management, including: the ACE Basin NERR, CISA, Clemson University, the Department of Interior Southeast Climate Science Center, the National Park Service, the North Carolina Water Resources Research Institute, the North Inlet-Winyah Bay NERR, South Carolina Department of Natural Resources (SC DNR), South Carolina Sea Grant Consortium, the Southeast Coastal Ocean Observing Regional Association (SECOORA), the State Climate Offices of North Carolina and South Carolina, The Nature Conservancy, University of South Carolina, and USGS.

Three CSI working group webinars have been conducted (December 2016, April 2017, September 2017) thus far. (CISA plans to continue these webinars and group discussions on a quarterly basis.) During these discussions, working group members have contributed their expertise on a wide range of topics. This includes information about available salinity and ecological datasets and updates on other regional activities (e.g., water quality monitoring) and concerns (e.g., species-specific impacts) that may be pertinent to drought (and high salinity) monitoring. The working group has provided feedback on the interpretation and usability of the CSI plots, a draft “CSI User’s Guide,” and preliminary analyses to compare the CSI with environmental response variables.

Exploring CSI-Ecological Linkages

In 2017 Lackstrom, Rouen, and Conrads conducted a series of one-on-one meetings with staff scientists, division managers, and researchers from SC DNR, the ACE Basin and North-Inlet and Winyah Bay NERRs, Clemson University, and University of South Carolina to discuss data availability, specific research and management questions, and opportunities for ongoing collaboration on this project. Several researchers have either shared their data with the project team or used the currently available CSI calculations to investigate CSI-ecological response linkages. Initial explorations have been conducted using water quality, tree ring, and fisheries data.

Presentations

Team members have presented at and participated in several regional conferences and meetings to share information about project progress and connect with existing and potential partners. These are listed in the “Products and Deliverables” section of this document (page 8).

Communications and Outreach

CISA staff created a project [webpage](#). It includes links to resources and publications produced through this project, as well as information about the Coastal Salinity Index and links to USGS resources.

Rouen and Lackstrom are adapting Information gathered through the research review for a “Coastal Drought Story Map.” The aim is to develop a Coastal Carolinas DEWS communications product that can be disseminated to a wide range of audiences. While improvements will be made after additional stakeholder feedback, the story map is currently available for viewing at

<http://uscgeography.maps.arcgis.com/apps/MapSeries/index.html?appid=783ed9a679034785aecc62f04991c4a5>.

Products and Deliverables

Journal Article

C. B. Nolan, D. L. Tufford, and D. R. Chalcraft. 2016. Needs Assessment of Coastal Land Managers for Drought Onset Indicators in the Southeastern United States. *Journal of Coastal Research* 32, Issue 5: pp. 1016 – 1024. <https://doi.org/10.2112/JCOASTRES-D-15-00182.1>

Project Reports and Resources

Lackstrom, K. and L. Rouen. 2017. Ecological Response to Drought in the Coastal Carolinas and Georgia: Research Review.

Carolinas Integrated Sciences & Assessments (CISA). 2017. Inventory of Salinity Datasets for Use with the Coastal Salinity Index. (spreadsheet)

Carolinas Integrated Sciences & Assessments (CISA). 2017. Inventory of Ecological Response Datasets and Monitoring Programs for Use with the Coastal Salinity Index. (spreadsheet)

Engagements with Project Stakeholders and Partners

CSI Working Group Webinars

December 12, 2016

April 11, 2017

September 26, 2017

Presentations (listed in reverse chronological order)

2017 Rouen, L. and P. Conrads. Using the Coastal Salinity Index for Monitoring Drought in the Carolinas. 2017 Georgia Water Resources Conference, April 19-20, Athens, GA.

Rouen, L. and P. Conrads. Using the Coastal Salinity Index for Monitoring Drought in the Carolinas. North Carolina Water Resources Research Institute Annual Conference, March 15-16, Raleigh, NC.

2016 Lackstrom, K. Coastal and wetland ecosystems: overview of drought indicators, impacts, and management issues. 2016 DOI Southeast Climate Science Center Workshop: Ecological Drought – Impacts, Resistance, and Recovery. November 16-17, Raleigh, NC.

Conrads, P. How Drought Uniquely Affects the Coast. Organized Session (presentations listed below). American Water Resources Association, 2016 Annual Water Resources Conference, November 13-17, Orlando, FL.

- Conrads, P. Development of a Coastal Drought Index Using Salinity Data
- Conrads, P. Linking Coastal Drought to Ecological Response
- Lackstrom, K., K. Dow, A. Farris, B. Haywood, D. Chalcraft, C. Nolan, D. Tufford. Drought and Coastal Ecosystems: An Assessment of Decision Maker Needs for Information

- 2015** Nolan, C. Ecological Indicators of Drought in Coastal Ecosystems. Cape Fear Arch Conservation Collaborative Quarterly Meeting, November 10, Ocean Isle Beach, NC.
- Nolan, C., D. Tufford, and D. Chalcraft. Needs Assessment of Coastal Land Managers for Drought Indicators in the Southeastern U.S. North Carolina Water Resources Research Institute Annual Conference, March 18-19, Raleigh, NC.
- 2014** Lackstrom, K., A. Brennan, P. Conrads, L. Darby, K. Dow, D. Tufford. 2014. Drought and Coastal Ecosystems: Identifying Impacts and Opportunities to Inform Management. South Carolina Water Resources Conference, October 15-16, Columbia, SC.
- Darby, L, K. Dow, K. Lackstrom, A. Brennan, D. Tufford, P. Conrads, M. Childress, R. Boyles, D. Chalcraft. 2014. Expanding on successful activities to enhance drought information for the coastal Carolinas. AMS 21st Conference on Applied Climatology, June 9-13, Westminster, CO.
- Tufford, D. Connecting Ecological Linkages to the USGS Real-Time Salinity Drought Index. NIDIS Coastal Drought Monitoring Knowledge Assessment Workshop: USGS Real-Time Salinity Drought Index, January 7, Charleston, SC.

Posters (listed in reverse chronological order)

- 2016** Conrads, P., D. Tufford, L. Darby. Critical Aspects of the Coastal Drought Index: Length of Salinity Data Record and Ecological Response Data. 2016 South Carolina Water Resources Conference, October 12-13, Columbia, SC.
- 2015** Brennan, A., K. Lackstrom, R. Boyles, D. Chalcraft, M. Childress, P. Conrads, K. Dow, C. Konrad, and D. Tufford. Developing a Drought Early Warning Information System for Coastal Ecosystems in the Carolinas. North Carolina Water Resources Research Institute Annual Conference, March 18-19, Raleigh, NC.
- Brennan, A., K. Lackstrom, R. Boyles, D. Chalcraft, M. Childress, P. Conrads, K. Dow, C. Konrad, and D. Tufford. Developing a Drought Early Warning System for Coastal Ecosystems in the Carolinas. Interagency Conference on Research on the Watersheds, March 2-5, North Charleston, SC.