Drought and Coastal Ecosystems: Identifying Impacts and Opportunities to Inform Management

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ABSTRACT. The National Integrated Drought Information System (NIDIS) is in the process of developing drought early warning systems in areas of the U.S. where the development and coordination of drought information is needed. In summer 2012, NIDIS launched a pilot program in North and South Carolina, addressing the uniqueness of drought impacts on coastal ecosystems. The topic of coastal drought has not been studied comprehensively by the drought community nor well-integrated into monitoring and management processes. To help inform the NIDIS-Carolinas program, approximately 40 interviews with fishermen, outdoor recreation business owners, and land managers in the Beaufort County (SC) and Carteret County (NC) areas were conducted to document and assess local-level experiences with drought and decision makers' needs for drought information and resources in the coastal Carolinas. Interviewees' drought concerns center on water quality conditions, particularly salinity levels and fluctuations, and the availability of freshwater to meet the needs of coastal animals, plants, and habitats. Fluctuating salinity levels affect the movement, location, and abundance of many aquatic species, thereby affecting their accessibility to fishers. On managed lands, drought conditions increase fire risks and make impoundments unsuitable for waterfowl and fish, thereby affecting conservation objectives and limiting recreational use of those areas. Interviewees do not regularly use formal sources of drought information but consider a range of locale-specific information related to weather (precipitation, temperature), salinity, wind, tides, and other environmental conditions in making decisions. Interviewees indicated interest in baseline data regarding "normal" and extreme hydroclimate conditions, development of indicators of ecological drought, and integration of drought information with other coastal and ecological monitoring efforts. Findings from these interviews will inform subsequent projects in the development of a drought early warning system for the coastal Carolinas.

INTRODUCTION

Drought is often described and measured according to the typology introduced by Wilhite and Glantz (1985):

- Meteorological: a deficiency in precipitation over an extended period of time
- Agricultural: inadequate soil moisture to support crop growth
- Hydrological: deficiency in surface or subsurface hydrology or water supply
- Socioeconomic: insufficient water to meet the supply and demand for human use

These categories, however, do not capture conditions that are increasingly recognized as "ecological drought." No definitive definition of ecological drought exists, but the term generally refers to a water deficiency causing stress to plants, animals, and ecosystems (Lake 2003, 2011). Furthermore, existing drought monitoring management focuses primarily on agricultural impacts, fire risks, and maintaining water supplies for municipal and industrial use, energy production, and navigation. While these are important impacts to monitor and mitigate, our understanding of the full range of drought impacts (e.g. impacts to environmental resources, public health, water quality, tourism and recreation) remains limited (Lackstrom et al. 2013; Thomas et al. 2013).

Coastal ecosystems in the Carolinas provide important environmental, social, economic, and cultural services to the Carolinas. They offer habitat for commercial and recreational fisheries and migratory birds, opportunities for jobs and recreation, protection from flooding and storms, and water quality benefits (Burkett and Davidson 2012; SC Ocean Report 2012). Coastal resources can be adversely affected by drought (see Gilbert et al. 2012), but many of the ecological and socioeconomic impacts have not been comprehensively studied by the drought community or well-integrated into existing drought planning and response processes. This paper reports on a project designed to 1) document and assess the impacts of drought on local-level decision makers and

communities and 2) identify what drought information and tools would be most useful to end-users in the coastal Carolinas.

PROJECT DESCRIPTION

The project was conducted by the Carolinas Integrated Sciences & Assessments (CISA) team to support the National Integrated Drought Information System (NIDIS) Regional Drought Early Warning System (DEWS) pilot in the Carolinas. One aim of the NIDIS DEWS program is to improve drought early warning, monitoring, and management systems on national, regional, state, and local levels.[i] The NIDIS-Carolinas pilot program specifically focuses on coastal ecosystems. At a 2012 scoping workshop in Wilmington, NC, stakeholders from across the coastal Carolinas identified drought-related needs and priorities for the region. Project priorities include evaluating drought indicators and indices appropriate for coastal ecosystems, communicating drought information to coastal decision makers, and improving the reporting and collection of drought impacts data (Brennan et al. 2012).

As a first step towards better understanding of coastal drought impacts, the research team conducted interviews with coastal decision makers in the Beaufort County, SC, and Carteret County, NC, areas. These two counties were selected as residents in each are closely connected to the coastal environment. The estuarine, inshore, and offshore environments support both commercial and recreational fishing, important activities for the local and state economies. These regions also include conservation areas and other land resources which are used for habitat and wildlife protection, as well as recreation. Furthermore, these communities have faced several droughts in the past 15 years. Two major statewide droughts (2007-2008, 1998-2002), and more recent moderate drought conditions (2010-2013) have occurred during this time period.

METHODS

Semi-structured interviews with coastal decision makers were used to obtain information about their experiences with on-the-ground drought impacts, tools and strategies to respond to drought, other stressors that affect their (or their organization's) capacity to cope with drought conditions, and their drought information use and needs. 48 individuals participated in interviews. They represented small business (commercial fishing, recreational fishing, outdoor recreation) and resource management interests (wildlife refuges, conservation land, forests, fisheries) and were evenly distributed across the two states. Interviews were conducted primarily by phone and in-person when possible. South Carolina interviews took place between March and June 2013. North Carolina interviews took place between October and November, 2013. Interviews lasted approximately 45-60 minutes, were recorded with permission of the interviewees, and transcribed. The research team used QSR NVivo, a qualitative analysis software program, to code and analyze the transcripts.

The coding and analysis focused on examining interviewees':

- observations of ecological drought and the responses of the affected biota (Lake 2003)
- socioeconomic impacts, i.e. the effects of drought on their activities, decisions, and livelihoods
- other stressors (climate, biological, and human) which interact with drought to exacerbate impacts or affect decision making
- use of, and needs for, drought information and resources to cope with future drought impacts.

Key themes related to ecological drought in coastal habitats, and the impacts experienced by four different respondent groups (commercial fishing, recreational fishing, refuge and land management, and outdoor recreation), are highlighted in the results section.

RESULTS

What is Coastal Drought? An Overall Perspective

Although drought is the primary focus of this project, interviewees discussed drought and drought impacts in the context of a wide range of climatic, environmental, and human stressors that affect coastal ecosystems. Coastal drought, as articulated by interviewees, primarily involves 1) changes to water quality conditions, particularly increasing salinity levels and fluctuations, and 2) changes in the availability and timing of freshwater to support animals, plants, and habitats. Drought conditions are produced not only by a lack of rainfall in the coastal region itself, but also by a lack of freshwater inflow from upstream and interactions with tidal regimes (Gilbert et al. 2012). Recent events have included both intense seasonal droughts and extended (multi-season or multi-year) droughts. Interviewees discussed the importance of local geography and micro-climates, additional weather and climate sensitivities (e.g. water and air temperature, sea level rise, severe storms and flooding events), and other environmental stressors that, when combined with drought, can negatively affect already stressed species and habitats. For example, it is suspected that black gill disease is more likely to affect shrimp during drought conditions. Refuge managers reported concerns about the invasive

species *Phragmites* which grows well in drought conditions and crowds out preferred vegetation. Many interviewees also voiced concerns about human stressors on the coastal environment. While the direct connections to drought impacts are not clear, the perception is that habitat loss and degradation due to increased development, upstream water management, and pollution and contaminants in coastal waters exacerbates the adverse effects of drought.

Drought Impacts: The Fishing Perspective

Higher-than-normal salinity levels and/or fluctuating salinity zones during drought conditions can alter the suitability of habitat for species with salinity preferences. Fish and crustacean species that prefer brackish water and typically reside in estuary areas may move upstream due to rising salinity levels caused by reduced freshwater inflow. At the same time, saltwater species were observed in estuarine and upstream environments. With greater numbers of individuals crowded into a shrinking habitat, several interviewees expressed concerns about the resulting competition for food and longer-term impacts on species that rely on particular salinities during different stages of their life cycle. Blue crabs and shrimp, as well as several finfish species (striped bass, red drum, and Southern flounder), were identified as the most sensitive species to these conditions.

Fluctuating salinity levels, which affect the movement and location of many aquatic species, consequently affects their accessibility to fishers. In this study, crabbers and shrimpers were most impacted by these fluctuations. The lack of accessibility of these species is often compounded by other factors. For example, regulations limit the areas where commercial crabbing is permitted, and during drought conditions crabs move upstream past the permitted areas. Shrimpers discussed how intense and shorter-term (seasonal) drought can contribute to less-than-optimal conditions for shrimp growth. The timing and amount of rainfall, in addition to salinity and temperature, affect the seasonal movement of shrimp and their availability to shrimpers.

In general, fishermen are accustomed to working under variable and adverse conditions, and interviewees discussed a number of strategies they use to cope. Some commercial fishermen with the capacity to do so travelled to different areas or changed equipment to catch their preferred species. Others reported diversifying the types of fish they caught, diversifying business practices (e.g. selling at farmer's markets, entering the wholesale or retail market), or pursuing work outside the fishery. Despite the availability of these different response options, the commercial fishing sector faces a multitude of stressors, and interviewees' responses to drought were considered in terms of, and often limited by, this broader context. As small businesses, commercial fishermen already face higher operating costs, competition from imports, and variable prices for their product. Fishery management plans, rules, and regulations also influence fishing decisions and activities. Any additional expenses or new activities to cope with drought must be considered alongside these other constraints.

Representatives of the recreational fishing businesses primarily work as fishing guides or outfitters, although the individuals interviewed for this study each specialized in a particular angling niche. Some concentrate exclusively on nearshore or offshore waters, while others focus on a particular species of fish or type of fishing (e.g. fly fishing). Similar to commercial fishers, those who target nearshore and estuarine-dependent species were most affected by salinity fluctuations, habitat changes, and the subsequent movement and location of the targeted fish. Changes to bait fish populations, such as menhaden, also affected some interviewees. Fishing guides are generally mobile and report being able to adapt quickly to altered fishing conditions. Coping responses include moving to new areas, if they had appropriate equipment and travel costs were not prohibitive, or targeting different species that were not as affected by drought conditions. Extended droughts, however, can have longer-lasting impacts on the abundance and overall health of sport fisheries by affecting the recruitment of juveniles and loss of suitable nursery habitat. During extreme and multi-year events, several interviewees observed declines in some sport fisheries and fishing activities, which resulted in business losses as clientele moved to areas with more favorable fishing conditions.

Drought Impacts: The Land Management and Recreation Perspectives

Interviewees working in wildlife refuges and managed lands (e.g. conservation parcels, forests) discussed ecological drought in terms of a lack of freshwater. Wildlife refuge impoundments require freshwater for migrating waterfowl, the vegetation that support the waterfowl, and sometimes fish. Drought (in conjunction with warm temperatures) can lead to high evaporation rates and loss of water volume in the ponds themselves and in the water sources used for flooding the impoundments in the fall. Such conditions also affect other birds that use these sites for nesting. A lack of freshwater inputs has also affected the soils and vegetation more broadly. Interviewees reported observing stressed and dying trees (bald cypress, pines), the expansion of salt mash species (e.g. *Spartina alterniflora*) into freshwater marsh areas, and changes to entire vegetation and plant communities due to shifts in soil salinity and fresh (to brackish) waters.

Resource management activities are directly affected by drought. For example, refuge managers monitor and

maintain waterfowl impoundments through complex systems of diversions, dikes, canals, and gates. The control of water levels and discharge, to optimize the growth of submerged aquatic vegetation and water conditions for migrating waterfowl, can be difficult to manage when there is not enough water or when there is too much saltwater. Management can be complicated by having to balance the demands of multiple stakeholders, including conservation interests, hunters, fishers, and owners of private land adjacent to the impoundment area.

Drought can lead to the drying of peat soils and build-up of fire fuel. During drought conditions fire managers may not be able to conduct prescribed burns, thereby increasing the vulnerability of coastal habitats to possible catastrophic fires. While monitoring drought conditions are important for fire management on a daily- to seasonal basis, interviewees are also concerned about the impacts of longer-term drought which, in combination with policies that have contributed to fire suppression, may increase the overall risks of ecosystems and human communities to fire.

Drought impacts on managed land and water areas can limit recreational opportunities and activities. For example, refuge managers cancelled hunting events due to de-watered waterfowl impoundments and curtailed fishing events where aquatic habitat conditions could not support normal fish-stocking activities due to drought. On the other hand, outdoor recreation businesses such as guided kayak and eco-tours expressed the fewest concerns about the impacts of ecological drought. Like the recreational fishing group, this group is adaptable and mobile. They can guide their clients to a variety of local habitats and destinations or look for different types of wildlife. Reported impacts were primarily related to the inconvenience of finding alternative tour locations, particularly if certain species of interest (e.g. Rocky Shoal Spider Lilies) had failed to thrive in areas with increased salinity. When drought affected environmental aesthetics, guides relocated or refocused activities. In some cases, relocation brought additional expense, due to fuel costs or access fees, and some acknowledged that alternatives did not always meet customers' expectations.

Drought Information Use and Needs

In general, interviewees reported that they do not regularly use or refer to formal sources of drought information, such as the U.S. Drought Monitor or drought designations issued by state drought committees. Due to the nature of their work, individuals involved in fishing and recreation businesses report using information related to the weather and tide conditions but typically rely on their own personal knowledge and expertise regarding the local environment to make day-to-day and week-to-week decisions about travel, destination, and effort. Broader economic (e.g. operating costs, competition), regulatory (e.g. gear or access restrictions), and environmental (e.g. overfishing threats) factors play the predominant role in longer-term planning, particularly for fishing-oriented businesses. Land and refuge managers use a variety of locale-specific weather, hydrologic, salinity, and environmental data, but only fire managers reported use of drought-specific information (e.g. the Keetch-Byram Drought Index) to monitor fire potential. While most of the organizations represented in this study do use external sources of water, weather, and climate information (primarily from federal agencies), many have site-level data collection and monitoring systems and rely on that information to make management and planning decisions.

There were mixed messages in terms of needs for drought information. Fishers, in particular, voiced skepticism about the accuracy and applicability of drought forecasts or outlooks, particularly given the multitude of factors that affect fishing conditions and the environments in which they work. Of the different groups who participated in this study, only refuge and other resource managers expressed needs related to drought-specific information. Several project participants suggested that improving understanding of baseline conditions and previous drought events would be beneficial. Interviewees raised questions about "normal" precipitation and average frequency of drought events in the coastal Carolinas, expected duration or length of time of drought recovery, and rates of groundwater or aquifer recharge following a drought event. In addition, while most participants indicated having observed or experienced impacts that they attributed, in part, to drought over the past 10-15 years, there was also considerable uncertainty regarding drought as the exact cause or the degree of such effects. Consequently, information about how specific species or ecosystems respond to extreme hydroclimate events (drought and flooding) and the thresholds at which severe impacts occur is needed. This is especially the case for several species of anadromous fish, crabs, shrimp, and types of vegetation (e.g. marsh grasses, tree species). Improved understanding of the immediate and long-term impacts on populations and communities, and how extreme events influence various life stages of species of concern (e.g. class years, larval vs. adult), would aid in management processes seeking to monitor and mitigate those impacts.

DISCUSSION

This project reveals several issues to consider in the ongoing effort to develop a drought early warning system for the coastal Carolinas. While commonly used indices incorporate data such as rainfall, streamflow, soil

moisture, groundwater levels, and snow pack, such indices were developed for upland areas and may not be appropriate indices for characterizing coastal drought, particularly when monitoring the ecological and socioeconomic dimensions of drought impacts. It was clear from the interviewees that while drought is a significant concern, it is not a stand-alone issue. Rather, it is one of many stressors they face when making business or resource management decisions. As coastal decision makers are interested in the full-range of hydroclimate extremes, i.e. too little or too much rainfall, drought information will need to be integrated into a larger network of information. In light of the disparate concerns and impacts regarding coastal drought that emerged through this research, coordinated efforts between researchers and managers to integrate existing and new information with other coastal and ecological monitoring efforts will likely increase the utility and relevance of that information for decisions. Findings from this study will help to inform ongoing work and collaborations as part of the NIDIS-Carolinas DEWS Pilot Program. Specific projects will develop: an 'Atlas of Hydroclimate Extremes' for the Carolinas, a coastal drought index that depicts the freshwater-saltwater interface, ecological drought indicators for coastal areas, a coastal zone fire risk assessment, and a decision-support tool to forecast blue crab landings in South Carolina.

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[i] Information about the NIDIS Regional DEWS Program is available at http://drought.gov/drought/content/regional-programs.