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Review

A synthesis of thresholds for focal species along the U.S. Atlantic and Gulf Coasts: A review of research and applications

Emily J. Powell [a, *], Megan C. Tyrrell [a, 1], Andrew Milliken [a, 2], John M. Tirpak [b], Michelle D. Staudinger [c]

[a] DOI North Atlantic Landscape Conservation Cooperative, 300 Westgate Center Dr., Hadley, MA, 01035, USA
[b] Gulf Restoration Program, U.S. Fish and Wildlife Service, 700 Cajundome Boulevard, Lafayette, LA, 70506, USA
[c] DOI Northeast Climate Science Center, University of Massachusetts Amherst, 611 North Pleasant Street, Amherst, MA, 01003-9297, USA

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ABSTRACT

The impacts from climate change are increasing the possibility of vulnerable coastal species and habitats crossing critical thresholds that could spur rapid and possibly irreversible changes. For species of high conservation concern, improved knowledge of quantitative thresholds could greatly improve management. To meet this need, we synthesized information pertaining to biological responses as tipping points to sea level rise (SLR) and coastal storms for 45 fish, wildlife, and plant species along the U.S. Atlantic and Gulf Coasts and Caribbean through a literature review and expert elicitation. Although these species were selected based on their ecological, economic, and cultural importance, just over half (56%, n = 25) have quantitative threshold data currently available that can be used to assess the effects of SLR and storms during some aspect of their life history. Birds, reptiles, and plants represent the best studied coastal species. Thirteen of the species (29%) are projected to lose at least 50% of their population or habitat (e.g., foraging, nesting, spawning, or resting habitat) in some areas with a 0.5 m or greater rise in sea levels by 2100. Two species (a bird and reptile) may gain habitat from projected SLR and be resilient to future impacts. Numeric thresholds were not available for the remaining 20 species we searched for. Coastal fishes, mammals, and amphibians were among the groups representing a major information gap in this field of research. In addition, quantitative threshold responses to coastal storms were scarce for all taxa. While vulnerability assessments and qualitative research related to the impacts of SLR and storms on coastal species and habitats are increasing, work that incorporates quantitative thresholds as response and impact metrics remains limited. Additional monitoring, modeling, and research that provides multiple quantitative thresholds across species' life stages and/or latitudinal gradients is ideal to support robust coastal management and decision-making across spatio-temporal scales in the face of climate change.

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* Corresponding author.
E-mail addresses: emily_powell@fws.gov (E.J. Powell), megan.tyrrell@state.ma.us (M.C. Tyrrell), andrew_milliken@fws.gov (A. Milliken), john_tirpak@fws.gov (J.M. Tirpak), mstaudinger@usgs.gov (M.D. Staudinger).
[1] Current address: Waquoit Bay National Estuarine Research Reserve, 149 Waquoit Hwy, East Falmouth, MA, 02536, USA.
[2] Current address: Lake Champlain Fish and Wildlife Conservation Office and Western New England Complex, U.S. Fish and Wildlife Service, 11 Lincoln Street, Essex Junction, VT, 05452, USA.

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1. Introduction

Coastal ecological and human communities are increasingly vulnerable to the impacts of a changing climate. Rising sea levels and coastal storms are changing physical landscapes, disrupting natural systems, and pushing some wildlife populations to the brink of irreversible change. The U.S. Atlantic and Gulf Coasts and Caribbean are regions that are particularly vulnerable to the impacts of coastal storms and rising sea levels (Melillo et al., 2014; Dalton and Jonescomps, 2010). The Northeast coast is among the most developed in the world (Horton et al., 2014), and the Southeast is home to vital infrastructure and some of the fastest-growing coastal metropolitan areas in the country (Carter et al., 2014; RPA, 2013; Entergy, 2010). Gulf Coast communities are already incurring substantial losses from relative sea level rise (SLR) and hurricanes on the order of billions of dollars annually (Carter et al., 2014; Entergy, 2010). The destruction from Hurricanes Katrina and Sandy across the Gulf Coast and Northeast megaregions, respectively, has made coastal resilience a national priority.

The resilience of human and ecological communities to climate change is inherently linked. Coastal habitats that provide vital nesting, resting, and feeding areas for threatened birds and other wildlife also provide societal benefits through ecosystem services. For example, beaches, mangroves, marshes, shellfish beds, and barrier islands offer increased flood protection and storm defenses, carbon sequestration, erosion control, natural water filtration, recreation, and increased quality of life, among other benefits. The value that U.S. coastal wetlands alone provide in protection against coastal storms has been estimated at $23.2 billion per year (in 2008 dollars) (Costanza et al., 2008). Ensuring the integrity and proper functioning of these ecosystems will enhance both the ecological and societal resilience of our coasts.

1.1. The need for ecological threshold information

The need for identifying ecological thresholds related to climate change impacts is well documented (e.g., Needelman et al., 2012; NRC, 2010; CCSP, 2009a; Burkett et al., 2005), but large gaps remain in understanding what tipping points are, as well as when and where they will occur. In 2009, the U.S. Global Change Research Program (USGCRP) released a 'state of knowledge' report on the scientific understanding of thresholds for ecosystems in response to climate change, which found that the capacity to predict and manage threshold crossings that could trigger large-scale, abrupt changes in ecosystems and/or the services they provide was limited (CCSP, 2009a).

Threshold data provide information about critical tipping points beyond which a population is no longer viable or management options are no longer available. We adopted the Intergovernmental Panel on Climate Change's (IPCC, 2014) definition of ecological threshold for a species as any abrupt or nonlinear change or disruption to a species' population, productivity, reproduction, or habitat in response to a threat. For our thresholds assessment, we focused on SLR and coastal storms as the focal climate change related threats. While we use the term 'threshold' frequently, tipping point, ecosystem shift, and abrupt or nonlinear change are interchangeable with this term.

Natural resource managers and conservation scientists need quantitative data to most effectively manage natural resources and prepare for the consequences of crossing tipping points. Moreover, methods for assessing a species' vulnerability to climate change, defined as a function of a system's sensitivity and exposure to climate change as well as its capacity to adapt to those changes (IPCC, 2007), often rely, at least partly, on qualitative data and expert judgment (e.g., Hare et al., 2016; Watson et al., 2015b). Threshold data provide truly quantitative values about how a species will likely respond to a particular threat, thereby generating greater confidence in species rankings and vulnerability assessments.

Further, future storms and accelerating rates of SLR are expected to exacerbate and compound other climate change threats, such as changing precipitation regimes (Osland et al., 2016), and non-climatic threats like urbanization and pollution. Such compound effects could lead to a species reaching a critical threshold level more quickly. Of particular concern is the potential for a keystone species' threshold response to cascade and impact other species, leading to "wholesale ecosystem collapse" (NRC, 2013). For example, the absence of sea otter populations in coastal waters of the North Pacific resulted in abundant sea urchin populations and loss of kelp forests that had indirect effects on dozens of other coastal species (Soulé et al., 2003). Generating more information on thresholds for keystone species is a priority if resource managers are to be prepared for the possibility of abrupt, irreversible system changes (CCSP, 2009a).

The impacts of climate change on species and habitats will be largely determined by their adaptive capacity, which includes the ability of a species or population to cope with climatic change through a combination of phenotypic plasticity, dispersal ability, and genetic diversity (Beever et al., 2016). Thus, there are inherent factors that contribute to a species' fundamental adaptive capacity as well as extrinsic factors that constrain or affect its ability to endure myriad threats (e.g., climate change, land use change, pollution, etc.); management also plays an important role to mitigate extrinsic effects and ensure species-level adaptive capacity is