FINAL PROJECT MEMO – CLIMATE CHANGE ADAPTATION FOR COASTAL NATIONAL WILDLIFE REFUGES

1. ADMINISTRATIVE:

Principal Investigators:
Mitch Eaton, U.S. Geological Survey, Southeast Climate Adaptation Science Center, meaton@usgs.gov
Jennifer Costanza, Department of Forestry and Environmental Resources, NCSU, jkcostan@ncsu.edu
Fred Johnson, U.S. Geological Survey Wetland and Aquatic Research Center, fjohnson@usgs.gov
Julien Martin, U.S. Geological Survey Wetland and Aquatic Research Center, jmartin@usgs.gov
Laura Taylor, Center for Environmental and Resource Economic Policy and Department of Agricultural and Resource Economics, NCSU, laura.taylor@gatech.edu
Zachary Brown, Center for Environmental and Resource Economic Policy and Department of Agricultural and Resource Economics, NCSU, zsbrown2@ncsu.edu

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2. PUBLIC SUMMARY:

Coastal ecosystems in the eastern U.S. have been severely altered by local processes associated with human development, including drainage of coastal wetlands, hydrologic alterations affecting sediment supply, and land-use change, and by global-scale ecological changes including sea-level rise and other effects associated with climate change. Together, these forces are degrading the capacity of ecological and social systems to respond to disturbance. The goal of this project was to foster active engagement with stakeholders; develop a comprehensive problem definition that expressed local values, knowledge, and perceptions; and encourage building of effective networks and trust across organizations and individuals in South Carolina's Lowcountry. To address global change impacts at a regional level, we established the Cape Romain Partnership for Coastal Conservation to include representation from federal and state resource agencies, local conservation NGOs and organizations representing underserved community interests. Research topics, originating from discussions with Partnership members, focused on quantifying key drivers of change including localized sea-level rise (SLR) predictions, estimates of hurricane inundation as amplified by SLR, urban growth trends and forecasts, and impacts on management. Additional research included efforts to inform coastal planning through the development of models for understanding salinity dynamics, land-use change and its effects on flooding, ecosystem services, and forest management, and the impacts of uncertainty and risk on long-term investments in land protection.

Emphasizing broad stakeholder engagement as a means for successful adaptation planning, our interactions with Lowcountry planners and residents revealed a complex relationship between society and the environment, with sense of place, cultural heritage, and quality of life being important considerations for adaptation planning. With guidance provided by a bridging organization, community-based governance of the commons, in which broad stakeholder participation and power sharing are key elements, is essential for adapting this social-environmental system to the forces of global change.

3. TECHNICAL SUMMARY:

The goals and objectives of this project evolved over the course of its implementation. Original project goals, in line with a traditional U.S. Geological Survey (USGS) role of science support, focused on: 1) delivering actionable, state-of-the-art science products to assist refuge planning, 2) developing future scenarios to serve as a basis for communication among diverse stakeholders, and 3) fostering understanding and collaborative decision making among these local stakeholders such that effective adaptation planning can continue beyond the duration of this project. Specific annual objectives for the work with Cape Romain National Wildlife Refuge (NWR) included: 1) engaging stakeholders to understand perceptions of climate change, imagined futures on the landscape, and their interest in planning for the future; 2) documenting impacts associated with land use and climate change and developing future scenarios; 3) evaluating the location, provision of, and changes to ecosystem services in the region; 4) applying economic methods to quantify the value of ecosystem services used by society under current and potential future conditions; and 5) developing methods and approaches to work collaboratively with stakeholders over the life of the project. Although the primary goals and objectives remained relevant over the course of the project, their relative emphases evolved to reflect our growing recognition of the long-term benefits of providing partners with a robust *process* for productive engagement and collaborative learning into the future relative to the potentially shorter-term benefits of specific scientific *products*.

Beginning with the conclusion of the earlier phase of this project (Understanding Conservation Management Decisions in the Face of Sea-Level Rise Along the U.S. Atlantic Coast, 2014), the U.S. Fish & Wildlife Service (USFWS) – USGS partnership had established that the spatial and temporal scale of global change processes were mismatched with the capabilities of a single refuge to exert any influence over such large-scale drivers, either through policy changes or resource management actions. Therefore, the refuge would have to partner with other entities, organizations and decision makers in the region to have any hopes of responding to anticipated changes and continuing to achieve its mission. We recognized from the outset that in order to carry out a successful project, we would have to balance scientific assessment of physical drivers and their impact on landscapes and resources with thoughtful stakeholder engagement inclusive of a diversity of local values and levels of preparedness. Our intent was to serve as 'honest brokers' and co-develop with partners a fully collaborative process in which all stakeholders are continuously engaged in diagnosing the problem, specifying objectives, developing appropriate adaptation strategies, and considering the effects of unknown futures. Accepting that the complex nature of this social-ecological adaptation problem limited the usefulness of a traditional decision-analytic approach, we explored alternative methods for engagement, collaborative learning and decision making.

We facilitated a series of exercises to familiarize partners with scenario planning for communicating the opportunities and threats arising under alternative, plausible futures. Focusing on quantitative trends for three primary drivers with high impact and high uncertainty, including manifestations of climate change, social-political shifts at a global level, and forces of local value and power structures, we developed narratives for four alternative scenarios to be used in later strategic planning. This exercise underscored the complex relationship between the temporo-spatial scale of the production of ecological services and the institutional scale at which they are managed. Conditional on each scenario, we then used a SWOT analysis to lead the partners through an assessment of the relevant (**s)**trengths and (w)eaknesses of the Partnership to address (t)hreats and (o)pportunities when attempting to meet conservation and societal objectives. Based on this approach, the group developed sets of prioritized strategies to consider in the context of a given scenario.

In addition to engagement tools and communication strategies, we developed or applied a number of models and other science products in support of this project. We provided a summary examination of the forces of global change in South Carolina's Lowcountry, including sea-level rise projections, past frequency and intensity of tropical storms, patterns of erosion of coastal barrier islands, and population growth and urbanization forecasts. To support decisions for designing future conservation areas for protecting valued resources, we evaluated the anticipated changes in coastal habitats as a function of sea-level rise and expected patterns of urban growth and developed two parcel-selection models that incorporated projections of SLR on habitat changes and development threats. One of these approaches borrowed concepts from economic theory to consider conservation strategies as investment decisions in a volatile market (i.e., under climate change) and explicitly framed a reserve design as a tradeoff between expected habitat outcomes and the risks of future conditions differing from those expected. This model (Eaton et al. 2019) was recently published in the journal *Ecological Applications* and an extension of the work (Sierra-Altamiranda et al. 2020) was recently published in *Ecological Modelling*. To predict the impacts of climate change and management of freshwater flows on coastal habitats and processes, we built models of salinity dynamics and the performance of oyster reef restoration efforts (Yurek et al. 2020) to help inform coastal planning. These models can support restoration decisions by evaluating site locations for enhanced shoreline protection and/or fisheries production benefits. We developed a conceptual state-and-transition model for pine savanna and woodland fire management dynamics (Figure 1) and simulated alternative urban growth scenarios on increasing pine savanna and woodland extent by 2070. Simulations assumed that proximity to urban development constrained the ability for managers to implement prescribed fire. Scenarios also varied in the extent to which restoring long-unburned versus maintaining frequently-burned sites were prioritized. We found that prioritizing prescribed burning for restoring long-unburned sites and those closer to development led to greater areas of frequently-burned pine savannas and woodlands across the landscape as a whole, even when the projected rate of urban growth was high (Costanza, *in prep*). Lastly, we developed a spatially-explicit economic model to predict feedback dynamics between land value, land-use change, and effects on ecosystem service provision (Villegas 2019). This model can be used to explore the effects of zoning policies and incentives on urban growth and ecosystem services. In support of this model, we have compiled a comprehensive database from published literature that provides estimates of the value of coastal wetland ecosystem functions and services.

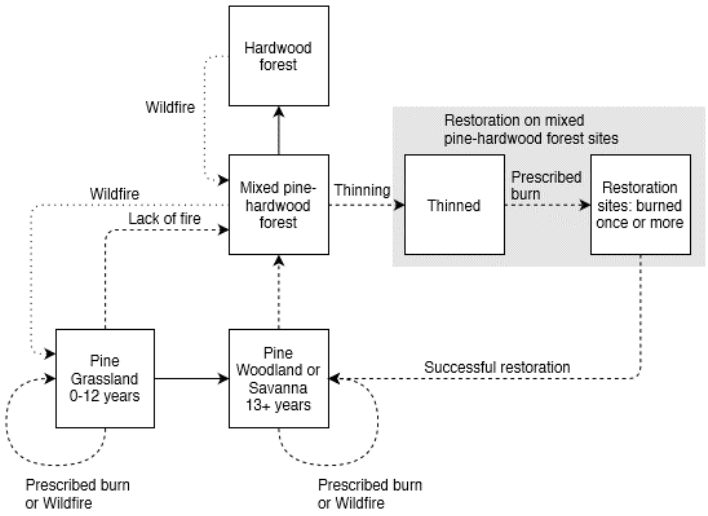

Figure 1. Conceptual state-and-transition model for pine savanna and woodland dynamics including management strategies. Solid arrows indicate succession, while dashed arrows represent management actions or probabilistic events. When this model was used in simulations, proximity to urban or residential land uses interacted with the time since the last burn on a site to constrain burning. In other words, the longer a site had gone without being burned, the more development constrained burning.

4. PURPOSE AND OBJECTIVES:

The original objectives identified at the outset of this project (Phase I) were focused on a narrow community of decision-makers – resource managers of coastal National Wildlife Refuges. These refuges are recognized as having an important role in sustaining natural resources, preserving ecosystem services and in helping socio-ecological systems respond and adapt to global-change processes (especially sea-level rise and changing land use). Traditional objectives of the NWR System are to: (1) maximize protection and recovery of threatened and endangered species; (2) maximize habitat for and protect populations of migratory birds and at-risk species in decline; (3) meet waterfowl goals of the North American Waterfowl Management Plan (NAWMP); and (4) maximize opportunities for the public to connect with nature. We began to address these objectives by considering two scales of adaptation strategies: 1) considering the efficient allocation of finite staff-time and budgets for managing existing programs and resources to minimize loss when achieving a refuge's mission under its current structure and 2) recognizing declines in social and ecological values produced by the existing refuge configuration over the long-term and developing a strategy for when and where to acquire or protect new areas in order to sustain refuge objectives and the public good as the system evolves over time.

One important outcome of Phase I was recognition of a fifth objective, that of maximizing the longevity of an individual refuge to continue providing its valuable conservation, education and recreational services into the future. The decision on whether or not to maintain the existence of a refuge, however, does not ultimately belong to the refuge itself. National and regional funding allocations, including the possibility of closing or relegating refuges into 'custodial status,' with limited management, staffing and visitor access, are made by other decision makers. Nevertheless, a refuge does have the ability to allocate local resources to activities that will engender greater public and political support for allowing it to continue meeting its intendent mission. Refuge staff identified several conditions within their powers to implement that are essential for maintaining public benefits provided by the refuge, including development of broad partnerships, ongoing public support and political will to encourage sufficient operational resources (i.e., budgets), the expansion of a conservation land base, and the ability to effectively manage the protection of this land base. Phase II of this project recognized the relative importance of this fifth objective (to maximize refuge longevity) and the additional complexity it would create for guiding long-term adaptation planning. Identifying a landscape-scale objective such as this also provided the opportunity to expand our thinking to consider the value provided by refuges in the context of a broader set of societal benefits.

Our goal for the current phase of this research program evolved to identify potential ways in which local conservation interests beyond those of the NWR System could participate in a social process of collaborative adaptation planning. Ultimately, we hoped to explore how that process might be broadened and enhanced to include a more diverse set of stakeholders (i.e., those other than conservation interests). Although the project ended before we could expand activities explored with conservation partners to this broader set of proposed stakeholders, we believe we left the Partnership for Coastal Protection with the tools and understanding to engage with other local interests and maintain collaborative learning and innovation for global change adaptation strategies.

See additional details regarding the evolution of objectives and stakeholders in Section 3.

5. ORGANIZATION AND APPROACH:

Project activities were organized around two primary themes: 1) stakeholder engagement to develop a process of collaborative learning for adaptation solutions, and 2) independent research to provide relevant and requested information and to support adaptation strategies.

Engagement activities* included:

1) A 2014 structured decision-making workshop was held at the National Conservation Training Center, West Virginia, convening refuge managers and project leaders from four refuge complexes on the Atlantic coast to develop decision prototypes for a case study of sea-level rise planning and adaptation at Cape Romain NWR (Nilius et al. 2014).
2) A follow-up workshop was held the next year at Cape Romain NWR to bring together project team members and Cape Romain NWR staff to discuss models of human behavioral change and to develop preliminary stakeholder engagement and communication strategies.
3) We conducted a review of local media reports on climate and other changes in the Lowcountry to develop a sense of understanding of issues being discussed, in what way, and by whom over the course of the previous two years. The review contributed to shaping an understanding of local contextualization of human behavior and preparedness for adaptation ("stages of change"), concepts we believed were important when developing a communications strategy. We relied on models of human behavior developed by the social sciences to comprehend how social processes and culture shape our perceptions and how we process information for behavioral change.
4) In 2016, the project team and staff from Cape Romain NWR interviewed potential partners in the greater Charleston, South Carolina, area to assess interest in collaboration, with a goal of introducing our intentions, learn what others are doing in the region, and identify areas of overlap, mutual interest, potential value-added, and topics of potential conflict. Details on the organizations and individuals we met with are provided in other project documents (e.g., Eaton et al. 2020).
5) In early 2017, we held a scenario planning workshop in Awendaw, South Carolina, with members of the partnership that formed based on the previous engagement. This workshop was designed to co-develop with stakeholders alternative narrative descriptions of plausible futures that may unfold for the Lowcountry region. This exercise was intended to provide a comprehensible mechanism for exploring the complexities of uncertain futures, guide collective learning and robust adaptation planning, and serve as a tool for communicating impacts and shared values with a diversity of stakeholders.
6) A second Awendaw workshop was held in late 2017, to apply the previously-created scenarios in the development of strategic actions that might help mitigate the effects of global change on the Lowcountry. We used another participatory planning method – a SWOT analysis – to assess regional Strengths, Weaknesses, Opportunities, and Threats from both an internal (i.e., within individual organization) and external (i.e., among organizations across the Partnership) perspective when developing adaptation strategies.

Activities around primary research, modeling and collection of relevant information* included:

1) Summarizing drivers of change in coastal South Carolina, including
    a. Providing historical trends in sea-level rise (SLR) in the Charleston region.
    b. Commissioning a tailored climatological study of the region to project local SLR probabilities on a decadal scale to 2080 and evaluating possible impacts to coastal habitats (Horton & Bader, 2014).
    c. Background and trends in the records of storms and storm surge.
    d. Developing a model to assess the effects of an interaction between storms and possible future sea levels.
    e. Summarizing the trends of barrier island dynamics including a review of localized sediment transport and the impacts of SLR on erosion of islands and coastal marshes.
    f. Past trends in population growth and projections of urbanization and land-use change in coastal South Carolina counties.

2) Developing models to support reserve design decisions as an adaptation strategy for habitat loss under projected sea levels and urbanization-drive land-use change (Eaton et al. 2019, Altamiranda et al. 2020).
3) Modeling coastal salinity and water temperature, including a quantitative analysis of the relationship between water flow, temperature and salinity.
4) Predicting long-term dynamics of oyster reef restoration efforts under climate uncertainty and variable management policies (Yurek et al. 2020).
5) Integrating econometric land use models with ecosystem services models to guide coastal management and planning for flood control (Villegas 2019).
6) Simulating the effects of alternative prescribed fire management priorities on longleaf pine ecosystem dynamics in the Francis Marion National Forest. This project examines whether stated conservation goals of increasing the area and old-growth characteristics of longleaf pine savannas and woodlands over time in the Francis Marion National Forest can be met given competing management scenarios to prioritize maintaining frequently-burned sites and restoration of long-unburned sites. Progress towards either objective is affected by uncertainty of urban growth futures and whether sites near projected urban growth are prioritized for burning over other sites (Costanza *in prep*.).

*Details of non-referenced activities can be found in Eaton et al. 2020.

6. PROJECT RESULTS:

Quantitative results stemming from this project are described in publications on the reserve-design algorithms (Bonneau et al. 2018, Eaton et al. 2019, Sierra-Altamiranda et al. 2020), oyster reef dynamics modeling (Yurek et al. 2020), sea-level rise projections (Horton & Bader, 2014), and econometric modeling of land-use change and changes to ecosystem service production (Villegas, 2019).

An additional publication on the results of simulating alternative prescribed fire management priorities is in preparation (Costanza *in prep.*). Results suggested that the total amount of fire-maintained pine savannas and woodlands increased by 2070 over circa 2017 levels regardless of where burning was placed in the National Forest. The amount of increase depended on whether burning was used for maintaining frequently-burned sites or restoring long-unburned sites, as well as whether sites closer to development were prioritized over those distant from infrastructure. These results will be summarized in a resulting peer-reviewed publication.

Scenario planning activities suggested that cultural values and provisioning services are a primary concern, even among conservation interests which traditionally prioritize biodiversity. This exercise also revealed strong place-based attachment. Regarding highly influential drivers of change in the region, sea-level rise and population growth were considered the most certain, while economic opportunity, climate variability, and politics were considered the least certain. In addition to climate change, participants identified global socio-political shifts and disruptions as an important contributor to changes and the trajectory of the socio-environmental conditions in the Lowcountry. A third axis of future scenarios identified by participants as influential revolved around local values and power structures, with social identity and resilience, community mobilization of resources and institutional hierarchies all able to mitigate or exacerbate the effects of other change drivers on the local environmental and social outcomes. Four plausible future scenarios were developed by two teams based on different possible outcomes along each axis of the three major drivers.

Scenarios were later used to assess partner organizations' strengths and weaknesses in confronting future opportunities and threats (SWOT) represented by a given scenario, with a focus on sustaining the supply of

ecological goods and services to the region. Organizational strengths included partnership capacity, legal authority, public support, natural resource expertise, resources (especially the conservation land base), and outreach capacity. Weaknesses included communication/marketing, internal alignment (i.e., consistent goals and priorities within an organization), institutional inertia, limited funding and staff, and shifting political priorities. Strengths and weaknesses varied among federal and state agencies and NGOs, reinforcing that collaborative partnerships can leverage greater capacity and effectiveness. Important external threats included unchecked growth and development, impacts to human health and well-being, and extreme weather impacts to valued ecological goods and services. The most commonly identified opportunities included the attraction of strong culture and lifestyle in the Lowcountry, high levels of social cohesion, demand for ecological goods and services, and opportunities for expanding partnership development. We elicited importance scores for SWOT factors and then developed potential strategies for each pairwise combination of strengths/weaknesses and threats/opportunities. Higher-scored combinations reflected those strategies deemed more important to address either highly influential factors or those with significant uncertainty (and, therefore, risk); these included stakeholder engagement and outreach to communicate benefits of protected areas for providing ecosystem services, partnership development and increase in the conservation community's awareness of its collective expertise, and expanding effective alignments.

As part of ongoing work to quantify the value of ecosystem services, we compiled data from 47 published studies covering 14 U.S. states and one Canadian province (1974 to 2017) providing estimates of the value of at least one coastal wetland ecosystem function. In more than one-third of these studies, estimation was based on regression models and economic methods (e.g., nonmarket valuation) to assess the value of ecosystem functions and services. We classified studies into seven categories based on the primary ecological functions and services provided by ecosystems: flood control and storm buffering, recreational fishing, wildlife habitat, commercial fishing and hunting, water quality improvements, amenity, and preservation services. All estimates were converted to 2010 U.S. dollars. Estimates range widely across studies and categories. For example, the estimated average wildlife habitat value is \$15 ha^{-1} $year^{-1}$ and ranges from \$5 to \$31 across studies. The estimated average preservation value varies widely between different locations from \$28 to \$54,970 ha^{-1} $year^{-1}$. Based on 11 studies, the average estimated value of flood control is \$5,308 ha^{-1} $year^{-1}$ while the median value is \$1,106 ha^{-1} $year^{-1}$ and the average value of recreational fishing is \$1,496 ha^{-1} $year^{-1}$. Because the sample size of case studies is relatively small, further analysis will be necessary to refine study characteristics in order to improve estimates of specified ecosystem functions and services.

7. ANALYSIS AND FINDINGS:

Key insights from early planning workshops suggested that engendering social and political support for conservation ends will be most effective if the objectives of broad stakeholder interests are considered when quantifying the value of the refuge mission and outcomes. This understanding presented an opportunity to reframe the metrics used for appraising and scaling the value of the refuge to better match the decision context of stakeholders throughout the Lowcountry landscape. From our research, interactions with project partners and other stakeholders, and an extensive literature review, we came away with several propositions for further engagement with individuals and organizations with some degree of interest in adaptation to an uncertain future that will eventually emerge in South Carolina's Lowcountry; these propositions are transferable to other regions defined by diverse values and experiencing large-scale drivers of change. A central theme of these propositions is the growing understanding among some academics and practitioners that practical solutions to 'wicked' problems will ultimately be generated by local actors behaving in accordance with their own particular perception of the social-ecological landscape. This view is a fundamental shift from many traditional conservation and climate change planning perspectives, which tend to be positivistic, strategic, and hierarchical.

Although we do not provide detailed description of the lessons learned by undertaking this project, we list these propositions below and invite the interested reader to explore further details discussed in Eaton et al. (2020), and Johnson, Eaton, Mikels-Carrasco & Case (2020).

1. Effective adaptation may rely more on bottom-up governance than centralized governments. There is increasing interest in commons governance, referring to the broader processes by which institutions, organizations, and individuals make conservation decisions, being more community-based, in which broad stakeholder participation and power sharing are key elements.
2. Conservation is integral to a broader set of governance issues, which include social, economic, and cultural values. Management of the commons now recognizes that the social-ecological system, with all its complexities, is the fundamental unit of analysis and that social systems provide rich opportunities for identifying solutions but are often resistant to change and constrain possibilities.
3. Approach land protection in a way that is consistent with the preservation of a region's cultural heritage and the importance of private property rights. Fee-simple purchases of land by the federal government may not be strongly supported by local communities. Other options, including state-level land conservation and encouragement of 'working landscapes,' which accommodate traditional, land-based livelihoods like forestry, agriculture, and commercial fisheries, could help sustain the flow of ecological goods and services that support quality of life.
4. Engage stakeholders using a model of human behavior to better understand the diverse ways in which individuals and organizations perceive the social-ecological systems in which they are embedded. Doing so may facilitate more effective engagement and communication strategies.
5. Engage in a mode of coproduction of knowledge and meaning. This approach can include the interaction of science and governance, whereby science information must be understood and integrated with appreciation of the local context and the perception of this information within the social system. The second form of coproduction is one in which experts and users collaborate to develop a shared body of useful knowledge.
6. Use coproduction and methods of engagement, such as scenario planning and analyses of organizational strengths and weaknesses, to build the adaptive capacity to prepare in advance for environmental stressors or adjust as stressors affect change in the human-environmental system.

8. CONCLUSIONS AND RECOMMENDATIONS:

A draft Cape Romain NWR Comprehensive Conservation Plan (U.S. Fish and Wildlife Service 2010a) emphasizes the protection and acquisition of fish and wildlife habitat in partnership with Francis Marion National Forest. The current project sought to develop decision-making tools to support this effort, but ultimately focused more on governance and collective decision-making within the larger social-ecological system that is the Lowcountry. This focus on process over product differs from the strategic guidance on climate change provided by the NWR system, which emphasizes training employees in climate-change adaptation, providing technical assistance (U.S. Fish and Wildlife Service 2010b), educating the public about climate change, protecting infrastructure, and using energy wisely.

We believe the despair and sense of isolation that can arise from a refuge-centric strategy can be overcome in part by engaging local conservation interests and, perhaps more importantly, those who depend on the ecological goods and services that support quality of life throughout the Lowcountry. Given the more immediate demands on their time and attention, this approach is likely to be unfamiliar for some refuge staff (Johnson et al. 2015). Fortunately for Cape Romain NWR, there is a diverse, active, and vibrant conservation community in the Lowcountry. Many opportunities for engagement exist and, if acted upon, will help to minimize the 'problem of fit' and enhance the capacity for collective action.

The recognition that social and ecological systems are coupled is an increasingly familiar perspective for governance of common-pool resources, such that the issues and problems of one cannot be addressed without considering the consequences for the other. Additionally, a central theme emerging from our research is the importance of place attachment, which generates social cohesion and facilitates problem solving. These ideas have important implications for when, where, and how stakeholders are engaged to address the rapid changes being experienced by the Lowcountry. As proposed by several disciplines within the social sciences, how we view, understand, and experience the world can vary greatly among individuals. These differences are not trivial, such that a linear process of decision making – in which consensus on objectives can be reached, or even that all interests are prepared to come to the table – can resolve. In the end, complex conservation problems can only be solved by society at large. Acceptable solutions will only arise when there is a respect for the pluralities of experience and meaning that stakeholders bring with them to the decision-making process.

9. MANAGEMENT APPLICATIONS AND PRODUCTS:

Decision analysis methods used, tools developed, and expected outcomes of study findings are discussed in other sections of this report and, more specifically, in the published products listed at the end. Project partnering organizations and agencies included:

- Cape Romain National Wildlife Refuge
- South Carolina Department of Natural Resources
- The Nature Conservancy of South Carolina
- NOAA Office for Coastal Management
- Center for Heirs Property
- Lowcountry Land Trust
- Francis Marion National Forest
- South Carolina Sea Grant Consortium
- Conservation Programs, South Carolina Aquarium

Individuals from each organization participated as active Partnership members and asked to contribute their own organization's objectives in order to specify partnership goals, leverage unique strengths, and develop joint strategies for collaborative problem solving. In addition, Cape Romain NWR staff provided GIS and other informational and logistical support. The U.S. Forest Service has more recently aided these efforts by developing a StoryMap communication tool to highlight key messages from this project.

Stakeholder Quotes:

"*As a planning, organization, community organization, and network tool it is a powerful scenario planner. I'm still working on my understanding of its practical approach as a land manager and how we are guided by our process plans and how it could be integrated into decisions we make [but t]his is applicable to so many coastal low-gradient geographies like ours. This has opened my limited understanding of how to model such a multivariate situation...*" Andrew Gude, Lower Suwannee & Cedar Keys NWRs

"*A ground level, grass roots approach to dealing with this situation as suggested in the draft report could be beneficial. However, the first step is honoring or respecting each parties mission and purpose. As the report points out there must also be a strong desire by everyone involved to focus on the long-term needs and responses to dealing with sea level rise/climate change related problems. Far too often only short-term solutions are offered. I think the report correctly addresses the need to think long term regarding these issues.*" Scott Lanier, Alligator River NWR

"*Scenario planning could help reach broader audiences. For example, there are certainly people who think they are not affected by climate change. However, scenario planning could expose these people to the challenges, possibilities or opportunities associated with climate change/sea level rise response.*" Scott Lanier, Alligator River NWR

"*Integrating science into the strategic growth of the refuge system in the face of climate change through the process described holds promise that we can come up with defensible, marketable and implementable strategies for acquiring interest in lands (and maybe waters) to advance conservation of natural resources.*" Mike Bryant, Coastal North Carolina NWR Complex (former)

"*While continuing to manage the habitat they have on Refuges, my long-term view is there must [be] a dynamic land protection plan that identifies and acquires interest in undeveloped land at higher elevations west & north of the current Refuge lands for the purpose of wildlife conservation.*" Mike Bryant, Coastal North Carolina NWR Complex (former)

"*…when I think of USGS I think of a stellar group of scientists who have carried us from a state of near desperation, to one of hope and anticipation. It has been our good fortune.*" Raye Nilius, South Carolina Lowcountry NWR Complex (former)

"*The recognition of social and cultural aspects of trying to counter the impacts of SLR is a sound approach. It is generally not used as much as it should be in my experience but if done well it can lead to lasting change and support that is not achievable any other way. If the local community and especially our closest partners are not engaged failure is inevitable.*" Jon Andrew, former Southeast Region Refuge Chief

10. OUTREACH:

Presentations

Eaton, MJ. 2016. Ecosystem services, trade-offs and uncertainty. A Community of Ecosystem Services (ACES) Conference. Jacksonville, FL.

Eaton, M, S Yurek, J Martin, FA Johnson, H Charkhgard, C Kwon, Z Haider. 2018. Reserve design under climate uncertainty. International Statistical Ecology Conference, University of St. Andrews, St. Andrews, Scotland.

Eaton, MJ, FA Johnson. 2019. Global Change Adaptation Planning for National Wildlife Refuges. National Adaptation Forum annual meeting. Madison WI.

Eaton, MJ. 2019. Principles of decision science: Risk management for decision making under uncertainty. Presentation to staff from multiple departments in Alberta Environment & Parks.

Haider, Z, MJ Eaton, S Yurek, J Martin, FA Johnson, B Udell, H Charkhgard, C Kwon. 2019. Modern Portfolio Theory to formalize diversification as an explicit strategy for managing risk in climate-driven reserve design [abs.], Informs Annual Meeting. Seattle, Wash. http://meetings2.informs.org/wordpress/seattle2019/

Johnson, FA, MJ Eaton, BK Williams. 2016. Decision Analysis through the lens of Resilience Thinking. Ecological Society of America. Ft. Lauderdale, FL.

Johnson, FA, MJ Eaton. 2016. Addressing wicked problems associated with global change. Dept. of the Interior, Southeast Climate Science Center, Five-Year Review, Raleigh, NC.

Johnson, FA, MJ Eaton, J Martin. 2017. Navigating the science-policy boundary in natural resource management. Greater Everglades Ecosystem Restoration, annual conference. Coral Springs, FL.

Martin, J, S Yurek, MJ Eaton. 2019. Decision analysis for coastal restoration. US Geological Survey. St. Petersburg Coastal and Marine Science Center.

Villegas, L. 2019. Integrating econometric models of land use change with models of ecosystem services and landscape simulations to guide coastal management and planning for flood control. 13th Annual Meeting of The Environment for Development (EfD). Bogota, Columbia (https://efdinitiative.org/news/events/13th-annual-meeting-efd-colombia).

Yurek, S, MJ Eaton, J Martin. 2018. Predicting long term performance and risk of oyster reef restorations under deep uncertainty in climate and management policy. Nat'l Conference on Ecosystem Restoration. New Orleans, LA.

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Websites

Martin, J., Johnson, F.A., Yurek, S., and Eaton, M.J., 2019. Climate change adaptation for coastal national wildlife refuges: U.S. Geological Survey, Wetland and Aquatic Research Center.

Southeast Climate Adaptation Science Center. Informing Conservation Management Decision-Making at Coastal National Wildlife Refuges.

Southeast Climate Adaptation Science Center. Climate Change Adaptation for Coastal National Wildlife Refuges.

Francis Marion National Forest StoryMap. Highlights of the major activities, outcomes and lessons of this project from the perspective of adaptation and land-use planning by Francis Marion NF.

Media releases

E&E News (Cape Romain Maritime Boneyard). Chelsea Harvey

Resulting peer-reviewed articles and reports

Bonneau, M, R Sabbadin, FA Johnson, B Stith. 2018. Dynamic minimum set problem for reserve design: Heuristic solutions for large problems. *PLOS One* (External URL)

Costanza, JK. Simulating the effects of urban growth and time since fire on effectiveness of prescribed burning in pine savannas and woodlands. *In preparation*.

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