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Are coastal managers ready for climate change? A case study from estuaries along the Pacific coast of the United States

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ABSTRACT

A key challenge for coastal resource managers is to plan and implement climate change adaptation strategies inlight of uncertainties and competing management priorities. In 2014, we held six workshops across estuaries along the Pacific coast of North America with over 150 participants to evaluate resource managers' perceived level of understanding of climate change science, where they obtain information, how they use this knowledge, and their preparedness for incorporating climate change into their management decisions. We found that most resource managers understood the types of climate change impacts likely to occur in their estuaries, but often lacked the scientific information to make decisions and plan effectively. Managers stated that time, money, and staff resources were the largest obstacles in their efforts. Managers identified that they learned most of their information from peers, scientific journals, and the Internet and indicated that sea-level rise was their greatest concern. There was, however, variation in managers' levels of readiness and perceived knowledge within and among workshop locations. The workshops revealed that some regions don't have the information they need or the planning capacity to effectively integrate climate change into their management, with eight out of fifteen site comparisons showing a significant difference between their level of preparedness ($F_{5,26} = 6.852$; $p = 0.0003$), and their willingness to formally plan ($F_{5,26} = 12.84$; $p = 0.000002$). We found that Urban estuaries were significantly different from Mixed Use and Rural estuaries, in having access to information and feeling more prepared to conduct climate change planning and implementation ($F_{2,29} = 17.34$; $p = 0.00001$). To facilitate climate change preparedness more comprehensive integration of science into management decisions is essential.

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1. Introduction

Global climate change is anticipated to have pronounced impacts on coastal ecosystems and their human communities, including key estuarine species that provide important ecological functions and services (Harley et al., 2006; Scavia et al., 2002). Coastal landscapes and estuaries lie at the interface between land and sea and will be affected by climate change through sea-level rise, changing storm frequency and severity, increased water temperature, changes in sedimentary processes, ocean acidification, and coastal eutrophication (IPCC, 2014). These changes are expected to threaten important natural resources and services such as fisheries production, migratory birds, marine mammals, invertebrates, and endangered species. Human infrastructure, coastal roads, sewage systems, and fresh water supplies are also likely to become increasingly vulnerable to climate change (Hunt and Watkiss, 2011; Klein and Nicholls, 1999). While these impacts are expected to be widespread across the world's coastlines, local and regional differences in the severity or timing of impacts make it challenging to plan for climate change, especially for natural

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resource managers.

Because the magnitude of specific climate change impacts may vary geographically, it is important to understand climate risk and coastal manager's needs and readiness at local and regional scales. Assessing risk and prioritizing management actions are often conducted using vulnerability or impact assessments (Fussel and Klein, 2006; Glick et al., 2011), which can be used to develop adaptation strategies and actions. One approach to preparing for and understanding vulnerability to climate change is the use of resilience and adaptation planning (Smit and Wandel, 2006; Turner et al., 2003). Walker et al. (2004) define "resilience" as the capacity of a system to adapt to change while retaining essentially the same function and structure. Undertaking effective steps to manage for coastal resilience - including preparing, planning, and implementing climate change adaptation strategies - is challenging given the complex physical and social landscape and the uncertainty surrounding the magnitude of change (Holling, 1973; Walker et al., 2004).

In this study, we compared knowledge of managers on; 1) how well natural resource managers understood climate science, 2) how they gained their knowledge, and 3) what additional learning opportunities might be most effective to improve climate readiness. We believe this information is imperative as governmental and non-governmental agencies, states and counties, and conservation groups develop methods, plans, coursework, and training opportunities to assist in managing for climate change across coastal ecosystems.

2. Methods

2.1. Workshop sites

To gather systemic data comparable along the coastline, we hosted six 1–2 day workshops and surveyed natural resource managers at sites in Washington, Oregon, and California, USA. These workshops were organized and facilitated between September and December 2014 to evaluate perceptions of climate change understanding and to identify knowledge gaps and science needs to help inform climate change adaptation planning in estuaries. Our facilitation team consisted of an interdisciplinary group of scientists currently evaluating the impacts of climate change on estuarine ecosystems along the United States Pacific Coast. Workshop participants were invited based on the recommendation of the local U.S. Department of the Interior, U.S. Fish and Wildlife Service National Wildlife Refuge (NWR) manager. These NWR managers were asked to reach out to their professional networks to invite collaborators and individuals who were involved in management decisions or planning in an official or unofficial capacity. The intention was that participants would be people who work with the NWR and surrounding lands and was not a random sample across all management sectors. Participants included individuals from non-governmental organizations, first nation tribes, regional, state, and federal natural resource managers, other decision-makers, and scientists. With most of these managers trained in either biology or the environmental sciences (geography, geology, wildlife, hydrology, etc.) we wanted to specifically assess the natural resource managers' and their partners' perceived levels of understanding of climate change and preparedness.

In this study, we defined a "natural resource manager" as a person who is responsible for managing any coastal natural resource, including biological systems, water quality, or land. At each workshop, our team presented Climate-Smart Conservation principles and practices (Hansen et al., 2010) and an overview of the current state of climate change science for their coastal zone. Workshop content was tailored to present site-specific research findings, including sea-level rise modeling results for local tidal marshes, coast-wide trends, and summaries of baseline physical data for the workshop sites. The site-specific modeling presented at the workshops was conducted by the workshop team between 2012 and 2014 and consisted of an assessment of the vulnerability of tidal marsh habitats along the Pacific coast based on 100 year projections (2010–2110) of sea-level rise scenarios (Takekawa et al., 2013; Thorne et al., 2015a,b,c, 2016).

We selected workshop study sites to represent a variety of geographic locations and range of management concerns, such as dense Urban landscape (U), Rural (R), and Mixed Use (M). All workshops sites had a focus on U.S. Fish & Wildlife Service refuges and biological management concerns: (1) Tijuana Slough NWR (U) - San Diego County, California, (2) San Pablo Bay NWR (U) - Napa, Solano and Sonoma counties, California, (3) Humboldt Bay NWR (M)- Humboldt County, California, (4) Siletz Bay NWR (R) - Lincoln County, Oregon, (5) Willapa Bay NWR (R) - Pacific County, Washington, and (6) Nisqually NWR (M) - Thurston and Pierce counties, Washington (Fig. 1).

2.2. Manager surveys

We conducted surveys to assess how well natural resource managers and their collaborators perceived climate science, how they gained their knowledge, and what additional learning opportunities might be most effective to improve climate readiness. First, we administered a pre-workshop web-based questionnaire to workshop participants using Survey Monkey (https://www.surveymonkey.com/), where we asked workshop participants to self-assess their perceived state of understanding about climate change impacts to their estuary, list the natural resources they manage, and state their information needs (Appendix A). We scored responses using nominal or ordinal scales and tabulated them.

Second, we administered a different post-workshop questionnaire in paper form at the end of each workshop to the workshop participants (Appendix B). We scored responses using nominal or ordinal scales and tabulated results. In both surveys, questions consisted of a mix of open-ended, multiple-choice (nominal), and ranked (ordinal) informational questions. In addition, to gain more information during the workshops, we conducted small group exercises (4–6 people) where participants were prompted to answer a set of questions using USGS photo-quad maps of their estuaries (Appendix C). These exercises were designed to facilitate participant interaction and identify key management resources and concerns and to evaluate what they thought would be impacted by climate change in the near- and long-term. The exercises were used to help find consensus within and across groups on important topics. Results from these exercises were presented to the larger group by a spokesperson from each map group at the end of the exercise.

Finally, to help summarize differences in workshop outcomes across the Urban, Rural, and Mixed Use estuaries, we interviewed all scientific staff individually (n = 9 individuals) who participated in the workshops (by presenting their science, leading discussions, coordinating the exercises, etc.). Scientific staff members were asked a specific set of questions to help facilitate conversation to provide feedback on the overall workshop experience, including impressions of participants' perceived level of understanding of the science, general knowledge, preparation to plan for climate change, and their science information needs (Appendix D). Interviews were done after all workshops were completed by an independent scientist (D. Elliott-Fisk) who did not attend the workshops. A score of 1–3 (1 = Yes, 2 = Moderate/Modest, 3 = No) was given to each person's answer for each question and then averaged across all

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