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Key lessons for incorporating natural infrastructure into regional climate adaptation planning

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ABSTRACT

Sea-level rise, potential changes in the intensity and frequency of storms, and consequent shoreline erosion and flooding will have increasing impacts on the economy and culture of coastal regions. A growing body of evidence suggests that coastal ecosystems—natural infrastructure—can play an important role in reducing the vulnerability of people and property to these impacts. To effectively inform climate adaptation planning, experts often struggle to develop relevant local and regional information at a scale that is appropriate for decision-making. In addition, institutional capacity and resource constraints often limit planners' ability to incorporate innovative, scientifically based approaches into planning. In this paper, we detail our collaborative process in two coastal California counties to account for the role of natural infrastructure in climate adaptation planning. We used an interdisciplinary team of scientists, economists, engineers, and law and policy experts and planners, and an iterative engagement process to (1) identify natural infrastructure that is geographically relevant to local jurisdictional planning units, (2) refine data and models to reflect regional processes, and (3) develop metrics likely to resonate within the local decision contexts. Using an open source decision-support tool, we demonstrated that protecting existing natural infrastructure—including coastal dunes and wetlands—could reduce the vulnerability of water resource-related structures, coastal populations, and farmland most exposed to coastal flooding and erosion. This information formed part of the rationale for priority climate adaptation projects the county governments are now pursuing. Our collaborative and iterative approach, as well as replicable use of an open source decision-support tool, facilitated inclusion of relevant natural infrastructure information into regional climate adaptation planning processes and products. This approach can be applied in diverse coastal climate adaptation planning contexts to locate and characterize the degree to which specific natural habitats can reduce vulnerability to sea-level rise and storms.

1. Introduction

Sea-level rise and extreme storm events will have significant consequences for the economy and culture of coastal regions through gradual inundation, and increased frequency of flooding and rates of erosion (Heberger et al., 2009; Griggs and Haddad, 2011; National Research Council, 2012). Sea-level rise also could lead to loss of coastal wetlands, dunes, and beaches, particularly if the shoreward migration of these natural habitats is blocked by development (Griggs, 2005; Kraus and Mcdougal, 2013; Berry et al., 2013). Prevailing responses to the risk of coastal flooding and erosion are engineered approaches (hereafter referred to as 'built'

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infrastructure such as levees and seawalls, in contrast to 'natural' infrastructure such as dunes and coastal wetland). However, seawalls can be costly; in California capital costs for new seawalls average approximately $7 000 per linear foot and yearly maintenance costs average approximately 3% of construction costs (Heberger et al., 2009; King et al., 2010; ESA PWA et al., 2012). Further, built infrastructure may only address one part of a multidimensional problem. For example, built infrastructure designed to prevent future inundation may have indirect effects, such as loss of recreational beaches or fish nursery habitat due to seawall construction, and ultimately fail to address the long-term needs of human communities (Caldwell and Segall, 2007; Turner et al., 2010; Adger et al., 2011).

Natural infrastructure can play an important role in mitigating risks to coastal communities from climate change impacts. These habitats can protect communities from erosion and flooding by dissipating wave energy and stabilizing the shoreline (Millennium Ecosystem Assessment, 2005; Barbier et al., 2008; Everard et al., 2010; Gedan et al., 2010; Shepard et al., 2011; Pinsky et al., 2013) and in some cases can do so cost-effectively in comparison to built infrastructure approaches (ECA, 2009; Jones et al., 2012; Lowe et al., 2013; Lowe et al. (2013) estimated marsh restoration costs in the San Francisco Bay in California at approximately $10 000/acre). Unlike built infrastructure, natural infrastructure has the capacity to migrate upslope as sea level changes and even slow the relative rate of sea-level rise by accumulating sediments that allow the coastline to keep pace with rising waters (Reed, 1995; McKee et al., 2007; Kirwan and Temmerman, 2009; Gedan et al., 2010). In addition to coastal protection, natural infrastructure can provide multiple benefits to many different sectors of the community, including provision of fishery habitat, water quality regulation, and recreation values (Zedler and Kercher, 2005; Barbier et al., 2008; Everard et al., 2010).

A critical challenge lies in introducing feasible natural infrastructure strategies to decision-makers and planners at the regional and local scale. To include natural infrastructure in coastal planning, decision-makers seek to understand where and when habitats (alone, or in combination with built infrastructure) can provide adequate coastal flooding and erosion risk reduction. Scientists and other disciplinary experts can provide practical guidance and evidence to support planners and decision-makers in selecting this relatively under-utilized approach to climate preparedness, particularly where built infrastructure approaches might be more familiar and override other less-familiar options (Hart et al., 2012). Here we report on the engagement process and outcomes from a unique collaboration between an interdisciplinary academic team and county-level planners in California. This collaboration was designed to overcome the challenges associated with co-production of practical and transferable information for integrating natural infrastructure into regional climate adaptation planning in coastal California.

California is an ideal state in which to explore the role of natural infrastructure in climate adaptation planning because a) the effects of climate change, including sea-level rise, are already apparent (Caldwell et al., 2013); b) the existing policy framework—including the California Climate Change Adaptation Planning Guide (CNRA, 2012) and Integrated Regional Water Management plan requirements (CDWR 2011)—encourages adaptation planning; c) intact natural habitats still provide coastal protection from sea-level rise and storms as well as provide co-benefits such as improved fisheries habitat and recreational opportunities; and d) existing laws expressly protect these coastal habitats (California Coastal Act, 1976; California Endangered Species Act, 1984; Caldwell and Segall, 2007; Farber, 2008; Eichenberg et al., 2010; Peloso and Caldwell, 2011). However, it remains difficult to translate scientific information in a way that enables integration of natural infrastructure into climate adaptation plans for several reasons. First, these approaches are new and relatively untested compared to the more established practices that rely solely on built infrastructure (Hart et al., 2012; Rayner, 2005). Second, even with new knowledge and tools that help assess climate risk and potential contribution of natural infrastructure to coastal protection (Everard et al., 2010; Shepard et al., 2011; Pinsky et al., 2013; Jones et al., 2012; Arkema et al., 2013), there is a gap in how to translate and apply this information in practice at the regional and local level to real decision contexts.

Cash et al. (2003) proposed a framework for improving the effectiveness of translating scientific information into action that includes three key attributes that can be applied to the climate adaptation context: saliency, credibility, and legitimacy (Moser and Ekstrom, 2010; Lemos et al., 2012). Saliency refers to the responsiveness of the information to the policy context. Credibility refers to the perceived quality and validity of the information. Legitimacy refers to the perceived fairness of the process of producing the information (Cash et al., 2003). These three attributes are more likely present if there is iterative communication between scientists and planners that facilitates information flow and understanding (Cash et al., 2003). In addition, joint production of information using "boundary objects"— an interface that translates between the scientific and planning languages including decision-support tools or collaborative products such as maps, models or reports (Guston 2001; Clark et al., 2010)—can increase the presence of these three attributes. This interface increases saliency of the scientific information by engaging end-users early in the process, the credibility by incorporating multiple types of expertise in the process, and the legitimacy by providing increased access to the information production process (Cash et al., 2003; White et al., 2010; Guston, 2001).

We developed an interdisciplinary collaboration between planners and academic scientists, economists, engineers, spatial analysts, and law and policy experts focused on producing management-relevant science that can serve as evidence and guidance for translating and applying natural infrastructure approaches in integrated watershed planning conducted in the state of California. Our unique team used an iterative communication approach to facilitate translation of scientific information. We also used an open source decision-support tool as a "boundary object" to facilitate communication across groups, communicate scientific information using management-relevant metrics and scales, visualize analyses and outputs, and clarify goals in a format that is relevant to climate adaptation planning needs (Cash et al., 2003; White et al., 2010; Ekstrom et al., 2011). Utilizing a free, open-source tool also maximizes the replicability and transferability of our approach, allowing others to use the approach and tool tailored to local conditions, using local data, and embedded within local decision-making.

In this paper, we first provide background on the integrated water management planning process in California and regionally specific information on the Monterey Bay area, including habitats that provide coastal protection services and regional and state policy context. We then describe our collaborative approach to co-producing regionally relevant information on where protection of natural infrastructure could reduce vulnerability of people, farmland, and water-resources related structures in the Monterey Bay area and how that information is used in an integrated watershed planning context.

2. Integrated Regional Water Management planning in California

In 2002, the State of California implemented an Integrated Regional Water Management (IRWM) planning process to