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# More than information: what coastal managers need to plan for climate change

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ABSTRACT

Climate change and sea-level rise (SLR) increasingly threaten the world's coastlines, managers at local, regional, state, and federal levels will need to plan and implement adaptation measures to cope with these impacts in order to continue to protect the economic, social, and environmental security of the state and of local communities.

In this paper, we explore the information needs of California coastal managers as they begin confronting the growing risks from climate change. Through this case study we examine the challenges managers face presently, what information they use to perform their responsibilities, what additional information and other knowledge resources they may need to begin planning for climate change. We place our study into the broader context of the study of how science can best support policy-makers and resource managers as they begin to plan and prepare for adaptation to climate change.

Based on extensive interview and survey research in the state, we find that managers prefer certain types of information and information sources and would benefit from various learning opportunities (in addition to that information) to make better use of available global change information. Coastal managers are concerned about climate change and willing to address it in their work, but require financial and technical assistance from other agencies at the state and federal level to do so. The study illustrates the strong need for boundary organizations to serve various intermediary functions between science and practice, especially in the context of adaptation to global climate change impacts.



## 1. Introduction

All over the world, local managers and planners, public works officials, local and state elected officials, and community development specialists are at the forefront of making decisions that impact the social, political, and economic well-being of their local communities. Specific information and knowledge about the social, economic, and environmental conditions of a community are needed to make decisions that enhance the community's development and well-being while minimizing potentially adverse social and environmental impacts. This holds particularly true now as decision-makers in coastal regions and communities worldwide must begin managing their jurisdictions to adapt to a rapidly changing climate and accelerating sea-level rise (Church et al., 2001; McLean et al., 2001; Nicholls et al., 2007). What information could best support coastal managers in confronting the growing risks from climate change?

In this paper we try to answer this question by examining information needs of coastal managers in the U.S. state of California, and by implication in the United States and other coastal countries more broadly. While the specific institu-

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tional and informational contexts for coastal management differ by place, many of the challenges of effectively connecting science to practice persist across locales. We thus place our study into the broader context of how scientific knowledge, information, and resources can best support the daily decisions of practitioners that work along ocean coasts as they prepare for the impacts related to climate change. The specific purpose of this project was to better understand what specific information and knowledge resources California coastal managers need to begin planning and preparing for adaptation to climate change in their day-to-day management responsibilities. To understand managers' information needs, this study also tried to determine how coastal managers perceive present and future changes caused by climate variability and change and sea-level rise. We also attempt to gain a better understanding of what coastal managers already know about climate change, what type(s) of information they draw upon to assess the risks, and what additional information they would need in order to incorporate climate change into their management decisions.

### 1.1. *Why California? Why state and local decision-makers?*

California shares with many coastal regions its major attraction for residential and commercial development, economic activity, tourism, and recreation. These highly developed coastal areas – built on or abutting diverse morphology that ranges from narrow sandy pocket beaches (and some wider, artificially replenished ones) to steep rugged cliffs and the wide flat wetland areas of the San Francisco Bay – are vulnerable to the effects of climate variability and change and sea-level rise (Griggs et al., 2005; Bromirski et al., 2002; duVair et al., 2002; Storlazzi and Griggs, 2000; Ryan et al., 1999; Flick, 1998). ''Today's climate variability and weather extremes already pose significant risks to California's citizens, economy, and environment. They reveal the state's vulnerability and existing challenges in dealing with the vagaries of climate. Continued climate changes and the risk of abrupt or surprising shifts in climate will likely further challenge the state's ability to cope with climate-related stresses in the future'' (Luers and Moser, 2006). Indeed, the most recent climate change projections for the state project accelerated sea-level rise (SLR), greater potential for storm damage, and expensive economic impacts of a possible levee system failure (Cayan et al., 2006; Vicuña et al., 2006). These challenges, however, are not unique but are faced by managers in coastal regions across the world.

Under the U.S. federal Coastal Zone Management Act of 1972, as amended, and other relevant national laws, federal agencies have important roles to play in dealing with such coastal hazards. However, state and local coastal managers will be at the front lines of preparing for climate change impacts, planning ahead, and adapting to the impacts as they unfold. Generally speaking, coastal management at the state and local level involves balancing the needs and desires of a multiplicity of stakeholders and resource users, which places preparing for the impacts of climate change into a challenging context.

As it is, state and local coastal managers have their hands full with current problems related to protection of habitat and species, public safety in the face of natural hazards, access to coastal areas, provision of recreational areas, supply and protection of water, energy, and other infrastructure; and the siting and appropriate construction of development (Luers and Moser, 2006). These challenges leave them with little extra capacity to become knowledgeable about climate change or begin developing long-term adaptation strategies. Additional obstacles to addressing climate change include economic constraints, insufficient expertise and personnel to address pertinent issues, and lack of information (Moser and Tribbia, 2006/2007).

In this paper, we explore coastal managers' information use and needs to begin to address climate change in their management decisions.[1] We also examine how the science–coastal management interactions could be improved to increase the likelihood that global change-related information effectively informs state and local decision-making.

### 1.2. *The science–practice disconnect*

Researchers vie to construct as precise an understanding of coastal and climatic processes as possible to characterize the physical risks that may threaten coastal areas. Indeed, research on climate change impacts on coastal areas projects accelerating sea-level rise, changing coastal storms, changing rainfall and runoff patterns into the coastal ocean, increases in coastal water temperature, species and habitat shifts, higher air and water temperatures, increasing flooding, coastal erosion and cliff retreat are expected to continue and exacerbate in the future (Rahmstorf, 2007; Nicholls et al., 2007; Meehl et al., 2005; Wigley, 2005; Church et al., 2001; McLean et al., 2001). To assure coastal states and communities are beginning to prepare, mitigate, and adapt adequately to the impacts of climate change, this information should (ideally) percolate from scientists to the managers who need it most. And while we rely on ''the expectation that [environmental] science can help inform human decisions about societal change'', many management decisions continue to be made without scientific input (Sarewitz and Pielke, 2007).

Clearly, a disconnect remains at the intersection between science and decision-making, i.e., between the information and knowledge produced by scientists and the information and knowledge applied by decision-makers. There are many reasons why scientific information and knowledge is not always used in environmental policy and management. Scientists and researchers are often driven to publish results in scientific and professional journals that may only have a limited audience base. In addition, scientists have little incentive to deliver information to non-scientists. Many do not engage in research with the underlying purpose to communicate findings to anyone outside their area of expertise (e.g., The Royal Society, 2006; Kyvik, 2005; Willems, 2003). Scientists also frequently simply assume that their information and knowledge is reliable and useful without necessarily checking this assumption against reality (e.g.,

[1] This paper stems from a larger effort to provide California policy-makers with a scientific assessment of the state's preparedness for climate change (pursuant Executive Order S-3-05 issued by Governor Arnold Schwarzenegger in June 2005).

Sarewitz and Pielke, 2007; Morss et al., 2005; Jacobs et al., 2005). On the other hand, decision-makers are preoccupied with the responsibilities of their jobs and tend not to have the time or inclination to search for information from scientific sources, even if it may be relevant to their work. Besides time constraints, the non-familiar, technical jargon common in many scientific reports can form tremendous hurdles for non-experts to overcome (e.g., Dabelko, 2005). In addition, science may not hold the overriding priority over other inputs in decision-making. As McNie (2007, p. 17) summarizes the situation in her extensive review of the pertinent literature, "scientists... may simply be producing too much of the wrong kind of information [while] users may have specific information needs that go unmet."

### 1.3. *Information needs and boundary organizations*

The described science–practice disconnect persists in the face of the near-ubiquitous argument that "more and better" information is needed in order to improve decision-making. Managers are thought to need greater amounts of higher quality information to take climate change impacts into account in planning and management decisions. Some suggest that improvements in science (e.g., better understanding, greater precision, accuracy, and resolution) will, in turn, improve decisions about both the management of our resources and about science policy itself (Myatt et al., 2003; Gregory and McDaniels, 2005; Sarewitz and Pielke, 2007) and that information shortages contribute to fallacies in decision-making, because "people do not have enough information or knowledge to make informed decisions on many aspects concerning [coastal] flooding and defence" (Myatt et al., 2003, p. 284).

However, this traditional approach to providing scientific information to decision-making, i.e., getting the science right and only then giving it to decision-makers has been found to not always be effective (Cash et al., 2006; Wilbanks and Stern, 2002). Many environmental policy initiatives fall short of expectations because experts simply believe that "better science will lead to better decisions" without fully understanding the decision situation and institutional context within which scientific information could be used (e.g., French and Geldermann, 2005; Rayner et al., 2005), or what a decision-maker could really use. In the typical "loading dock" approach (Cash et al., 2006), the primary emphasis of information production is "on the opinions of scientists and other technically trained participants" rather than the potential users framing science-related policies (Gregory and McDaniels, 2005, p. 189).

If "better information" or "more information" is not sufficient, and maybe not even as significant to decision-making as previously thought, but information – well integrated into the decision process – appears necessary, then what process can help create or ensure a better science–practice match? Many researchers have suggested that certain intermediary organizations – the so-called *boundary organizations* – can help improve the end-to-end process of knowledge co-production and application by enabling scientists and decision-makers to increase mutual understanding of capacities and needs while remaining within their respective professional boundaries (e.g., Mitchell et al., 2006; Cash et al., 2003, 2006; Cash, 2001; Guston, 2001; Gieryn, 1999; Schön, 1995; Daft, 1989). Such boundary organizations "involve the participation of actors from both sides of the boundary, as well as professionals who serve a mediating role in the co-production of knowledge that can be used by multiple audiences" (Guston, 2001, p. 401). Importantly, the notion of knowledge co-production (e.g., Jasanoff, 2004; Miller, 2001), which can be facilitated through boundary organizations, points to the importance of not just creating a better fit of scientific information into decision processes, but of 'end to end' and iterative systems of information flow (e.g., Agrawala et al., 2001; Lemos and Morehouse, 2005).

Boundary organizations have the overall dual purpose of protecting but also transcending the divide between science and practice (e.g., protection from the politicization of science, transcending for improved information flow). To do so they perform four critical functions, which help manage and maintain the relationship between information producers and users (Cash et al., 2003). The first is a *convening* function: bringing stakeholder parties together for face-to-face contact to foster trust-building and mutual understanding, which is the foundation of effective information production, transfer and ultimate use (Wilbanks and Stern, 2002). The second function of boundary organizations – *translation* – assures that information and resources are comprehensible for co-operating individuals and organizations (see also Sarewitz and Pielke, 2007). The third function of boundary organizations is to facilitate *collaboration* so that co-operating groups can be brought together for frank and transparent dialogue to make possible effective working relationships that co-produce relevant and scientifically credible, applied knowledge. The final function that boundary organizations sometimes play is *mediation* to assure that various interests of stakeholders, information producers and users are fairly represented (e.g., O'Riordan and Cameron, 1994).

The foregoing discussion establishes three key arguments underlying our paper. First, scientific information can, and some would argue should, inform decision-making, especially for long-term problems such as global change. Second, information *per se* often does not adequately inform decision-making because of a persistent science–practice disconnect. And third, intermediary or boundary organizations (or less formal arrangements of science–practice interactions) can play important roles in bridging that disconnect and facilitate the production of useful information as well as foster the actual use of such information in decision-making. In our research, we thus explore the following questions: What are decision-makers' information needs regarding global climate change and related adaptation decisions? How well and by whom are they getting these information needs met already? What more do managers need? What other knowledge resources (besides *just* information) would help coastal managers prepare for and adapt to climate change?

Below we describe our research methodology and data sources; next we report our findings. Subsequently we explore the implications of these findings for current and future science and decision-making related to the risks of climate change and sea-level rise, and discuss the transferability of our findings beyond California. In Section 5, we make several

**Table 1 – Survey respondents (numbers in top row and percentage in bottom row, $N = 135$)**

| Planner | Permitting officer | Public works engineer | Env. specialist | Development coordinator | Harbor etc. manager | Water Res. manager | Elected official | Other[a] |
|---|---|---|---|---|---|---|---|---|
| 50 | 13 | 24 | 5 | 9 | 3 | 3 | 1 | 24 |
| 37.9% | 9.8% | 18.2% | 3.8% | 6.8% | 2.3% | 2.3% | 0.8% | 18.2% |

*Source*: Moser and Tribbia (2006/2007, p. 6).
[a] Emergency service managers, natural resources managers, multiple/mixed responsibilities, or not otherwise specified by respondent.

recommendations on how scientists and practitioners can improve their interaction and communication in order to increase the nation's preparedness for the impacts of climate change in coastal areas.

## 2. Research methods

Our research proceeded in two stages. In the first phase, we interviewed government staff from various levels involved in California coastal management to determine their information use and needs. We elicited insights into how California is currently dealing with challenges in the coastal zone, how these issues may be affected by global warming in the future, and whether the state has begun to prepare for climate change impacts on coastal ocean and resources. The 18 semi-structured interviews with key informants typically lasted 60–90 min. Interviewees included regional, state, and federal coastal zone managers[2] and interview questions explored:

- current coastal management challenges and management responsibilities of interviewees,
- levels of awareness and understanding of climate change impacts on coastal zones,
- information use and constraints that affect coastal decision-making,
- historic actions taken by coastal managers to cope with adverse coastal conditions and perceived changes in the state's coping capacity,
- information needs related to climate change impacts,
- other perceived barriers to California's ability to adapt to climate change.

Interviews were transcribed and qualitatively analyzed. In this paper we mainly report on the commonalities and notable differences in information needs, pragmatic suggestions for improving information supply and use, and informational and other critical barriers to begin preparing for climate change at this time.

Building on the insights gained from the interviews, in the second phase of this study we explored parallel questions with local coastal managers. To do so we employed a survey 18-page, 40-question, pre-tested mail survey instrument to understand their current coastal management challenges, elicited perceptions and attitudes about global warming and related impacts on coastal areas, as well as information needs and potential barriers to managing current and future coastal challenges.

For this study, we define "coastal management" as all management occupations concerned with the safety, environmental protection, public infrastructure, and development of coastal areas, on land and in nearshore coastal waters (see also Moser and Tribbia, 2006/2007). Therefore, the type of staff we contacted included planners, permitting officers, public works engineers, community development coordinators, harbor, parks or beach managers, environmental specialists, water resources managers, emergency managers, and to a lesser extent elected officials. We surveyed 299 municipal and county government employees in these management resorts. Table 1 lists the number and types of respondents (Moser and Tribbia, 2006/2007).[3]

Survey questions consist of open-ended and multiple-choice informational questions, attitudinal questions based on a Likert scale, check-all and forced-choice questions. Out of the 299 mailed surveys, 14 were returned blank or due to inadequate address and eight additional respondents considered their location non-coastal. The overall response rate was 46.1%; and the 135 usable responses represented about 89% of coastal cities and about 89% of coastal counties approached. These statistics indicate a reasonably good response rate and very good representation of coastal communities in California.

The data from the survey were analyzed using simple statistical analyses and compared with the qualitative insights from the interviews. The findings are discussed in the section below.

## 3. Findings

To provide some case-specific context to the discussion of coastal managers' information needs, we asked them what

[2] Interviewees are staff from regional institutions such as the San Diego Association of Governments (SANDAG) and the Beach Erosion Authority for Clean Oceans and Nourishment (BEACON); state government staff from the San Francisco Bay Conservation and Development Commission (BCDC) and Coastal Commission, State Parks, Resource Agency, State Office of Emergency Services, Department of Boating and Waterways, Water Resources Control Board; as well as federal staff from the U.S. Army Corps of Engineers, National Oceanic and Atmospheric Administration (NOAA), Federal Emergency Management Agency (FEMA), and the National Parks Service.

[3] Survey respondents were identified through extensive web searches and with the help from the California Coastal Commission and Bay Conservation and Development Commission. We attempted to obtain responses from at least two or three individuals from each coastal county or city, but we were often able to identify six or more individuals from communities with larger government staff.

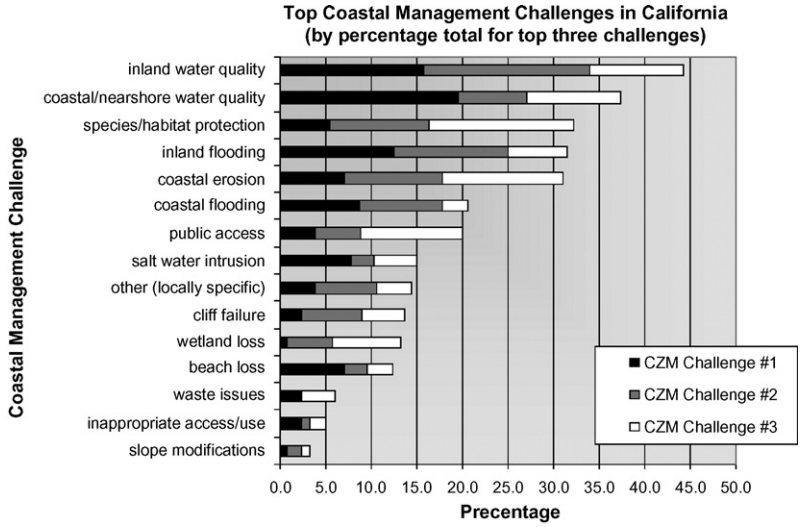


**Fig. 1 – Top coastal management challenges in California as identified by survey respondents. *Source*: Adapted from Moser and Tribbia (2006/2007, p. 7).**

they considered the top three coastal management challenges. Fig. 1 illustrates the challenges faced by survey respondents in California today, clearly a common set in many coastal regions. Interviewees from higher levels of governance confirmed these views citing challenges like coastal erosion, beach protection and nourishment, and public access, to name but the most frequently mentioned. It is notable that eight of the top 15 challenges mentioned by survey respondents (namely coastal/nearshore water quality, inland water quality, inland flooding, coastal flooding, salt water intrusion, coastal erosion, beach loss, species/habitat protection, and public access) can directly or indirectly be related to climate variability and sea-level rise. This suggests that coastal managers are already dealing with many of the problems expected to worsen as sea-level rise accelerates due to global warming.

### 3.1. *Information currently used in coastal management*

We first asked managers what types of information they generally use in their daily work; results are shown in Fig. 2 (by general category). Not surprisingly, given the types of management challenges faced, and the population of respondents, the most frequently used type of information is about environmental features: 87.1% use land-use information, 60.6% draw on some kind of information about habitats, and 55.3% use information about endangered species. The next most frequently used category of information is weather, climate or hydrology-related, including issues such as flood risk (used by 71.2%), water quality (59.8%), and climate and weather (43.9%). Leading socioeconomic information include population data (used by 55.3% of respondents) and property tax information (46.2%). Additionally, managers

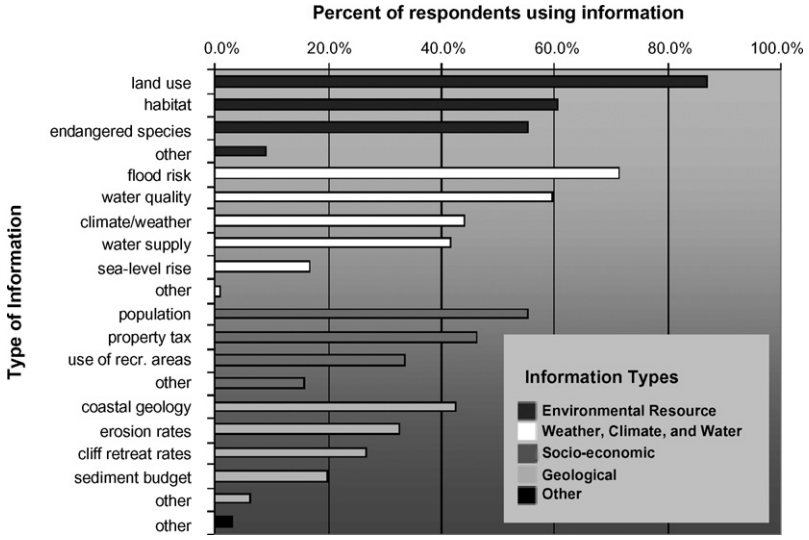


**Fig. 2 – What sources of information do coastal mangers use?**

use some types of geologic information, including about coastal geology (42.4%), erosion rates (32.6%) and cliff retreat rates (26.5%).

From our interviewees we learned of similar information use, reflecting interviewee's management resorts and job responsibilities. With only one or two exceptions, none currently use projections of *future* climate variability and change, or projections of sea-level rise under different climate scenarios in their planning and management decisions today (the sea-level rise information typically used is simply an extension of past SLR trends into the foreseeable future). Beach loss or cliff retreat information is similarly based on historic rates and does not account for likely future acceleration.

### 3.2. Problems with and suggested improvements for currently available information

Interviewees frequently mentioned information they would like to use but do *not* have. Several mentioned the declining or general lack of funding for ongoing monitoring of current environmental conditions. For them, this problem loomed larger than the lack of information about future conditions (i.e., climate change and its impacts). Interviewees pointed to difficulties in access to available information rather than the complete lack of information as a big problem. As one federal agency interviewee stated, ''the more information and the better access we have to it, I think, that will help our decision-making process.'' To summarize, interviewees identified various information management needs and specific ways to make available information more accessible and user-friendly, including:

- Better collaboration and exchange of relevant information among all agencies (at federal, state, and local levels) in coastal management.
- Inventory and integration of existing (and additionally developed) information into common formats, e.g., geographic information systems.
- Development of an integrated database accessible by managers at different levels of governance; data ideally would be aggregated or disaggregated to various levels of spatial resolution (e.g., state, local, watershed/littoral cell levels) and for different temporal resolutions (e.g., calculation of erosion over a variety of specified time increments of 10, 20, 50 years).
- Regular exchange of information among coastal states, and among coastal communities about their management responses to climate change-related impacts and risks (Luers and Moser, 2006, pp. 21–23).

As one state official aptly summed it up, ''There are so many pieces; we need a basic structure to integrate the information that we do have. Then we can find out what else we need to know. I don't have enough information at my fingertips to even say what doesn't exist.''

### 3.3. Information sources commonly consulted by coastal managers

We also inquired about the sources of information managers typically consult to determine which channels they commonly turn to. Using customary information channels can help lower the hurdles for managers to become aware of available information and to use it.

We first asked how interviewees keep up with developments in climate change in general, most mentioned newspapers as their first and primary source. Several interviewees expressed appreciation for the easily accessible information about climate change available through newspapers and popular media sources like *The New Yorker*, the *Los Angeles Times*, and others. While we did not ask this same question of survey respondents, their moderate level of understanding of climate change impacts on their region clearly reflected the attention given to particular topics in local media (see Moser and Tribbia, 2006/2007).

Table 2 lists results on more specific information sources. It illustrates, for example, that more than 70% of respondents either never or only rarely use the typical outlets for scientific information (primarily peer-reviewed scientific journals). By contrast, scientists write rarely in practitioners' professional or trade journals, which nearly 80% of the surveyed managers consult occasionally, frequently, or all the time. Interesting also, is the relatively low use of local experts (38.9% never or rarely consult one), while another 37.2% draws on local expertise occasionally. In our interviews, this somewhat surprising finding was confirmed especially among the officials from regional institutions. While plenty of interesting information on global warming can be found via the Internet, and – due to its easy accessibility – many planners and managers use this source, quality assurance can be difficult to assess for non-experts and local specificity may not be

**Table 2 – Information sources consulted by California coastal managers (by frequency of use)[a]**

| | Scientific journals (%) | Prof. journals (%) | Colleague in-house (%) | Prof. listserve (%) | State agency staff (%) | Colleague in other community (%) | Conference or meetings (%) | Local experts (%) | Internet (%) | Other (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Do not use | 35.1 | 7.0 | 4.4 | 24.1 | 5.1 | 2.6 | 2.5 | 11.6 | 2.5 | 94.1 |
| Rarely | 35.1 | 13.9 | 7.1 | 23.1 | 23.7 | 15.4 | 11.6 | 27.3 | 4.9 | 0.8 |
| Occasionally | 22.5 | 40.0 | 15.0 | 25.0 | 34.7 | 47.9 | 54.5 | 37.2 | 18.9 | 1.7 |
| Frequently | 7.2 | 28.7 | 39.8 | 22.2 | 26.3 | 23.9 | 24.0 | 14.9 | 41.8 | 2.5 |
| All the time | 0.0 | 10.4 | 33.6 | 5.6 | 10.2 | 10.3 | 7.4 | 9.1 | 32.0 | 0.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

[a] N varies between 108 and 122 because not all survey respondents answered, and not all answered this question for all categories.

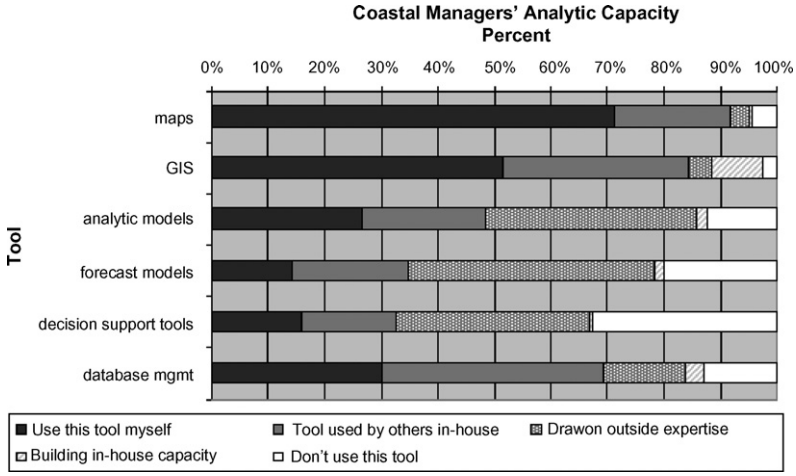


**Fig. 3 – Coastal managers' analytic capacity and use of information processing tools.**

obtained from this source. Professional listserves, by contrast, where more specific management-relevant information could be exchanged show an even spread (in terms of frequency of use) across each category.

The other notable, albeit not surprising finding is the high-frequency use of interpersonal communication channels: much information is obtained from colleagues in-house or in similar positions in other local communities, from state agencies, and at conferences and in meetings. Especially the latter two point to opportunities for information transfer that could be far better exploited than they are at present, e.g., to showcase relevant research, educate about global warming, and bring together scientists and practitioners to begin the effective co-production of decision-relevant knowledge resources.

Next, we inquired about the tools managers commonly use in their management duties to display, analyze, and/or transform available technical information into useful management-relevant information. We termed managers' ability to do so their *analytic capacity*. Fig. 3 illustrates coastal managers' analytic capacity and the types of tools they use in their daily work.

The findings suggest (and are qualitatively confirmed in interviews) that managers most commonly use standard tools such as maps (71.3%) and, increasingly, geographic information systems (51.6%). If respondents do not use these tools themselves, typically a colleague nearby does. The in-house capacity to use more sophisticated tools such as analytic or forecasting models and decision support tools (not specified in our survey, so up to respondents' interpretation) drops significantly, at the same time that communities draw more frequently on outside expertise if they want to use these tools.[4] In other words, local communities would have to spend money to increase their analytic capacity via consultants to process available information through such tools. In economically challenging times for municipal budgets this may be a rather vulnerable form of analytic capacity. We note that a sizable proportion of survey respondents indicated that they do not need or use some of these more sophisticated tools in their work. If managers were to be expected to process complex information and use sophisticated tools, a significant amount of local capacity building would thus be necessary. These findings suggest that complex scientific information – if it is to be easily accessible and useful to state and local managers – should be presented in highly processed form, and/or in the formats (e.g., in graphic displays, or for use in commonly used GIS platforms or spreadsheet software) managers are well versed using already.

### 3.4. *Information gathered and desired about global warming*

We next asked coastal managers what type of information their community had already gathered to date on the potential impacts from global warming and related climate changes. Fewer than 5% of the respondents had hired a consultant to gather climate change information and another 6% had contacted a local expert; less than 10% had convened a working group among their colleagues to pull together such information; slightly fewer had contacted state agency experts; and just over 8% had initiated some public discussion in their communities. Maybe more tellingly, 60% of respondents did not know whether any information had been gathered yet on global warming impacts in their community. When we asked them to identify which issues had served as big hurdles to planning ahead, 74.4% cited *insufficient staff resources to analyze and assess relevant information*; another 59.9% mentioned *insufficient staff time to even begin getting informed about climate change and gather relevant information*, and 46.2% mentioned *lack of technical assistance from state or federal agencies*. Moser and Tribbia (2006/2007) discuss in more detail what actions local communities in California have or have not taken to date

[4] Note, we do not claim that local communities should be able to use such tools, although complex decisions about climate change impacts and response options may be aided by analytic, forecasting, and decision support tools. We simply observe that local communities currently have lower capacity in-house in the use of these potentially useful tools, and if they decided to use them would either have to build such capacity or hire outside assistance.

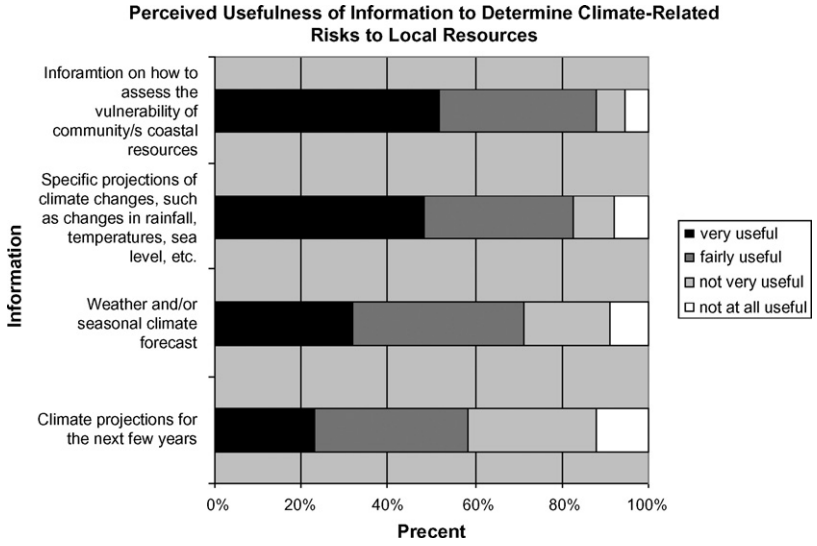


**Fig. 4 – Types of information coastal managers want to assess global warming.**

to prepare for global warming, including the role of other perceived obstacles to action.

We asked survey respondents to rate the usefulness of the following different types of information (whether or not managers currently use them in their job) for determining the risks to local coastal resources from 'very useful' to 'not useful at all': weather and/or seasonal climate forecasts, climate projections for the next few years, information on how to assess the vulnerability of their community's coastal resources, and (locally or regionally) specific projections of climate changes such as changes in rainfall, temperatures, sea-level, etc. (Fig. 4).

The results suggest that from a manager's perspective, help with determining what is most at risk is the highest priority (51.6% rate such assistance as very useful and another 36.5% as useful). While this may not be surprising when one considers managers' key responsibilities and concerns, what is surprising is that they do not have, do not know of, or do not find vulnerability assessment tools currently available sufficient, and maybe that scientists have not made them more accessible or user-friendly to practitioners.

Survey respondents indicated that they would find locally or regionally specific projections of particular changes in climate also very useful (48%) or at least useful (34.6%). While sizeable numbers of local officials would find almost all weather and climate information helpful, reflecting maybe their generic interest, the considerable interest in locally specific projections of climate change variables points to the irresolvable time lag between science's ability to generate considerable concern about this global problem and its slower-to-mature ability to deliver credible, reliable, and locally specific information that could inform local action. Interestingly, however, survey respondents did not consider the uncertainties in climate change science a significant obstacle to taking action on the issue (31.4% considered it a big, 47.1% a small, and 21.5% no hurdle at all).

From our interviews we gleaned additional insights regarding what types of information about climate change and related impacts coastal managers would find useful. Most frequently mentioned were:

- Translation of SLR height predictions into shoreline retreat, beach erosion, and bluff retreat rates, presented for planning-relevant time horizons, such as 5, 10, or 25 years.
- Wave and climate data that could be included in bluff retreat models.
- Better understanding of the linkage between climate change, SLR and wave climatology, i.e., their effects on storm frequency and intensity.
- Beach profile surveys that help better predict climate change impacts on shoreline change.
- Better understanding of littoral sand budgets and beach profile response to long-term SLR.
- Probabilistic climate change projections ("most likely scenario" or "at least" sea-level rise) with measurable indicators of change over 5, 10, 20-year, and to a lesser extent over longer time frames.
- Remapping of flood zones under different sea-level rise projections.
- More reliable forecasting of El Niño events, and any changes in the frequency or severity of such events under climate change, including impacts on shoreline retreat rates.
- Information about potential changes in runoff, pollutant loads, salinity, and near-shore coastal and estuarine water temperatures, and exploration of the implications of such changes for water quality, water availability, and aquatic ecology.

Climate change projections, especially when downscaled to the local level, carry considerable levels of uncertainty. We thus asked interviewees what they would want to know about these uncertainties, and how important scientific uncertainty was with regard to their willingness to use scientific information. Clearly, planners in particular are commonly confronted with high levels of environmental and social uncertainty, which makes planning over longer timeframes

**Table 3 – Perceived usefulness of opportunities to learn more about global warming and to improve understanding and use of technical information**

| | Hands-on training (%) | User manuals (%) | Conferences (%) | Better college training (%) | Web-based clearinghouse (%) | Dedicated listserves (%) | In-house sharing (%) | Other (%) |
|---|---|---|---|---|---|---|---|---|
| Not useful at all | 2.4 | 4.9 | 1.6 | 1.6 | 0.0 | 2.5 | 9.8 | 0.0 |
| Somewhat useful | 25.2 | 34.4 | 42.3 | 38.2 | 31.7 | 41.8 | 39.3 | 0.8 |
| Very useful | 47.2 | 45.1 | 40.7 | 43.9 | 47.2 | 33.6 | 29.5 | 0.0 |
| Extremely useful | 24.4 | 13.9 | 13.8 | 9.8 | 18.7 | 15.6 | 10.7 | 0.8 |
| Do not know | 0.8 | 1.6 | 1.6 | 6.5 | 2.4 | 6.6 | 10.7 | 98.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

$N = 123$ respondents.

especially challenging but not necessarily new or unique (e.g., Abbott, 2005; Christensen, 1999). In fact, interviewees suggested that few things they deal with are ever certain, so they do not have that expectation (a finding consistent with the opinions of survey respondents described above) that climate change information would be, and have their ways to discount information accordingly. As one interviewee acknowledged, they simply take information that is less certain ''with a grain of salt.'' Managers would want the following types of information, however, if it could be produced credibly:

- Uncertainty ranges around climate change (impact) projections as an indication of scientific confidence.
- Well founded distinctions between more and less likely impacts (e.g., ''at-least'' sea-level rise vs. ''maybe-as-much-as'' sea-level rise).
- A better scientific basis for uncertainty buffers (e.g., additional setbacks, extra capacity for storm water runoff).
- Basic understanding of the reasons for the uncertainty (e.g., lack of data, lack of complexity in the models, unpredictability of future state of the world, insufficient understanding of natural processes).

Importantly, both from the interviews and the survey responses, it is clear that scientific information, even if uncertain, needs to be translated into management-relevant variables or metrics. While ''sea-level rise'' or ''changes in storm frequency or intensity'' are generically interesting and important causal drivers behind shoreline change, a permitting officer deals in erosion and cliff retreat rates to determine setbacks; a planner needs cumulative projections for planning relevant time horizons not of 100 but 20–30 years; a water quality manager is interested in what does or does not run off into the coastal ocean. In some instances, science is only now improving its capacity to the point where it can make defensible, reliable regional climate change projections; in other instances, the additional work of translating climate projections into management-relevant variables has yet to be undertaken.

### 3.5. *Learning opportunities to facilitate understanding and use of global change information*

Merely providing previously missing or replacing imprecise data or knowledge (often in the form of new study results, reports, or data bases) will not necessarily ensure that information is useful or that it will be used, nor does it guarantees improved decision outcomes. We thus asked our survey respondents to select from a number of opportunities that might be helpful to learn more about climate change and to learn to better use such information (Table 3).

The two opportunities that the coastal managers found potentially most useful were hands-on training (with 71.6% judging them very or extremely useful), and web-based clearinghouses (with 65.9% judging them very or extremely useful), followed by user manuals (59%) and conferences (54.5%). These findings point to important capacity building needs that the state or federal agencies or other boundary organizations could fill.

### 3.6. *Trusted information sources and knowledge providers*

In our interviews, we also inquired from whom managers seek information, and – if they could obtain more information about global warming – which sources they would most trust. This question relates to the common finding in the science policy literature that trust in the information and its source is an important predictor for whether or not information enters into policy- and decision-making (e.g., Mitchell et al., 2006). The interviewed managers indicated various sources of climate change information which they would trust, including: the United States Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), the National Oceanic and Atmospheric Administration (NOAA), Scripps Institution of Oceanography (SIO), and California's Ocean Protection Council. Interviewees viewed other sources as more problematic (e.g., regulatory agencies, some state agencies), and yet others were not mentioned at all, in particular other academic sources aside from Scripps.

The latter finding is particular noteworthy: the most credible source of climate change expertise, amply available in the state, is the academic cohort of universities and research laboratories. Both the interview and survey results suggest this resource appears to be largely untapped, at least directly, by coastal managers at the local level and by state-level mission agencies.[5] These, of course, are the primary players that will have to develop and implement plans for

[5] As mentioned above, much scientific information on climate change is also available via the Internet, a source that managers tap frequently, but for the purposes of decision-making, the information available on the web may have critical limitations (see text above for additional discussion).

adaptation to climate change, yet their needs for information are not yet met directly by the available experts. One might argue that maybe these information needs are met indirectly by state agencies, university extension services, or via the web. Several lines of argument, however, suggest this is not the case. First, the state of local managers' understanding of climate change is only modest and does not reflect expert education of the likelihood of impacts (see Moser and Tribbia, 2006/2007). Second, staff from several key state agencies that we interviewed stated that they have no or very little and infrequent interaction with scientists on climate change. Moreover, the state's two Sea Grant college programs (coastal extension service), the state's Climate Change Center (with campuses at Scripps and UC-Berkeley), and the state's Regional Integrated Sciences and Assessment (RISA) Program at Scripps were not mentioned or unknown to our interviewees. Only 21% of those who responded to the survey mentioned that they occasionally or frequently consult with local experts. Of these, only nine (of the 29 responses) specified they consulted with universities in the state. These institutions, important potential boundary organizations in the state, could, but currently do not, play a significant role in reaching out to coastal managers.

Additionally, interviewees indicated that they would be interested in having opportunities (e.g., briefings from scientists, regular meetings with colleagues, or participation in working groups) to help exchange and understand information, and discuss the management implications of global warming. One interviewee, painting a rather elaborate and hopeful vision of entraining coastal managers on climate change, stated the following:

> ''a delivery of information in a forum that focuses on coastal zone managers and you pay their travel to come to this forum; you spend two or three days briefing them on the science; you provide them some tools to communicate what the issues are; you provide them mitigation tools and examples of policy options that are applicable; and you plant the seed. Then you hope that you have enough time that those seeds grow into actual governmental actions and mitigations.''

In short, interviewees and survey respondents expressed a desire for more than just information. With concerns about global warming high, and a considerable readiness to act (Moser and Tribbia, 2006/2007), California coastal managers now need interactive forms of learning, forums for discussing this information, and praxis-oriented case examples to explore and learn about management options for adaptation.

## 4. Discussion

The above discussion highlights the many dimensions of information needs and use in day-to-day coastal management in California. Against a backdrop of already pressing management challenges, coastal managers have very specific information needs, most of which are not about future problems but about the current conditions, and many of which are already not entirely met. Lack of resources, staff, and time present major hurdles for them to even get informed about how global warming may affect the problems they deal with on a daily basis.

The majority of coastal managers at any level of governance does not presently use information about projected climate change in their planning or decision-making, though awareness and concern are high (Moser and Tribbia, 2006/2007). If these managers were to begin planning for climate change, relevant information would have to be presented and explained in understandable language and offered in accessible format. It would also have to more closely relate to the management functions and management-relevant metrics decision-makers carry out and use. Managers also want some indication of confidence in the scientific projections, but not only a probability or narrowing of range of future conditions, but also explanations of associated uncertainty.

Moreover, our study illustrates that managers have preferred types of information and information sources and would benefit from a number of different learning opportunities to be able to interpret and appropriately use global change information. To date, coastal managers insufficiently benefit from the available scientific information on coastal impacts of climate variability and change and sea-level rise, as it exists in largely untapped scientific journals, few experts are ever consulted, and relevant research institutions are not yet linked into the ''management on the ground.'' Moreover, coastal managers are interested in the topic and would be willing to address climate change impacts in their work, but they require financial and technical assistance from other agencies at the state and federal level or from one or more boundary organizations that can play the intermediary role of co-producing knowledge resources between science and management.

Clearly, coastal managers already deal with the kinds of problems today that climate change is likely to worsen in the future (Fig. 1 above). They also use various types of information (e.g., climatic and geologic) that, if appropriately augmented with climate change information, could be easily integrated into existing information processing and management procedures. The additional information would be integrated most easily, if it were provided in formats and on platforms that managers already commonly use. More complex information or sophisticated presentation would require additional training and capacity building, as well as supplementary resources, and managers expressed a desire to learn in this fashion. In reality, however, top-level leadership and support, if not formal expectation, may well be required for busy coastal managers to attend and actively participate in yet more meetings, workshops, trainings, or conferences.

Maybe more importantly, managers from local, regional, state, and federal agencies indicate that they need more than just information. Enabling managers to access, understand, process, and use information requires a comprehensive approach to integrating and facilitating science knowledge into practical management. One approach to accomplish this may be through informal interactions between scientists and managers, maintained over years of relationship- and trust-building, mutual learning and increasing alignment of

scientific inquiry and practical use.[6] This approach, however, is haphazard and depends on the personal interest, good will, and skill of the participating scientists and practitioners alone.

Another approach to support managers in learning, understanding, and using scientific knowledge in their daily work is through institutionalized forms of interaction between information producers and users. We suggest that boundary organizations constitute such an institutionalized form of interaction that could aid the exchange and interaction process and thus ultimately help coastal managers address climate change in their work. The potential benefits are manifold. Maybe the primary function such intermediary individuals or institutions could pursue at this time would be the translation function (described above), i.e., to make the state of the science accessible to coastal managers and help them more fully understand what climate change and SLR could mean for their local communities (or for state-led management efforts). They could also help inform managers what tools and options are available to address the unfolding impacts through existing planning exercises or management procedures and institutions. As one interviewee suggested "climate change and global warming are not on top of [managers'] priority list because they do not know how to go about dealing with it in their own jobs." Boundary organizations could help unpack scientific jargon and relate the information in the professional language and perspectives of managers. Thus the mounting scientific evidence of climate change and impacts on coastal areas would become more understandable, accessible and salient to state and local managers who will see what is at stake, and what the connections are between their current activities and the longer-term challenges. Such facilitated communication could then serve as a starting point to produce a next iteration of use-inspired yet credible scientific information, with greater legitimacy because it accounts for stakeholders' perspectives and needs (Cash et al., 2006; Guston, 2001; Clark et al., 2002).

According to a recent National Research Council study (Brewer and Stern, 2005, p. 26), forums are needed in which participants "integrate analysis with broadly based deliberative processes involving the range of parties interested in or affected by the decisions." Boundary organizations could serve these convening and facilitating functions by providing the forums in which scientists, managers, and concerned stakeholders could engage in deliberation. Interviewees and survey respondents agreed that education about and discussion of global warming issues related to coastal management could be facilitated by convening experts and managers in workshops, in inter- and intra-agency working groups, improvements to and integration of existing information and knowledge resources, provision of training programs, and so on. Because scientists do not typically offer such services, and managers are busy dealing with their day to day responsibilities, boundary organizations could provide precisely these convening, translating, and facilitating services, and thereby help improve coastal managers' efficacy in preparing for climate change.

Finally, as standing institutions, boundary organizations could facilitate ongoing active and collaborative participation of scientists and coastal zone practitioners in the actual production of knowledge. Ultimately, this could enhance buy-in from both sides and facilitate trust-building, which increases the chances that information is actually being used in decision-making. Yaffee and Wondolleck (2000, p. 25), for example, suggest, "collaborative processes [among public, scientific, and governmental participants] ... are achieving ecological results while also improving community-level communication and cooperation." Through such co-production of relevant information, knowledge, and training resources, managers and scientists would better understand their respective needs and capacities, and – over time – meet information needs with use-inspired knowledge (Stokes, 1997). More specifically, scientific knowledge of coastal processes will evolve because the potential use and application of this knowledge by coastal managers will steer the direction of scientific investigation. Such opportunities may work most effectively if state and federal resources provided sustained financial support.

Indeed, interviewees and survey respondents emphasized that dealing with climate change in coastal management would be enormously facilitated through adequate funding, technical support, directive and leadership from "on high" and more political pressure from "below." In short, there will be a true information need, and a need to better link science to policy, when there is a real demand for action. To meet this need through appropriate supply from the science side, academic institutions must set appropriate incentives for, and provide commensurate training to, scientists interested in engaging with practitioners. Again, the matching of need and supply will be easier through ongoing institutionalized interactions between information producers and users (Sarewitz and Pielke, 2007; Vogel et al., 2007).

In our research, we did not discover any institution that currently plays such boundary-spanning functions between science and coastal managers in California, but in other states and regions they may exist. While California is exemplary in its leadership on greenhouse gas emission reductions, its efforts to prepare for and adapt to the impacts of climate change lag somewhat behind. At the same time there is still no widespread public recognition that adaptation is now an inevitable complement to mitigation of climate change (Pielke et al., 2007). It is quite possible that top-level leadership as well as public pressure and demand for action from below are required to build the necessary pressure on local and state governments to begin taking the need for adaptation more seriously.

Are these findings from California transferable to the situations of coastal managers in other states and countries? We are not aware of any other studies that have conducted in-depth interviews and broad complementary surveys of coastal management staff regarding their current challenges or anticipated information needs regarding climate change, though various studies conducted in the United Kingdom (Van Koningsveld et al., 2005), the Netherlands (Van Koningsveld, 2003; Van Koningsveld and Mulder, 2003/2004), and the

[6] The literature documents many examples in other resource management areas that have demonstrated the need for such trustful scientist–practitioner relationships (e.g., Cash et al., 2006; Cash, 2001; Dabelko, 2005; Jacobs et al., 2005; McNie, 2007; Morss et al., 2005; Rayner et al., 2005; Vogel et al., 2007).

European Union (Van Koningsveld et al., 2005) note a similar disjuncture between science and coastal management.

Moreover, several in-depth studies by Moser (2000, 2005, 2006) of state and local coastal management of sea-level rise and coastal erosion in Maine, Hawai'i, North and South Carolina, New York, Texas, Oregon and Washington reveal very similar coastal management challenges, concerns and pressures, staff and funding constraints, informational limitations, and challenges in the science–practice interaction. The two U.S. ocean commissions (U.S. Commission on Ocean Policy, 2004; Pew Oceans Commission, 2003) also identified funding and staffing constraints, lack of coordination in coastal governance across sectors and levels of decision-making, lack of scientific input in decision-making, and shortsighted pro-development policies as undermining the effectiveness of integrated, forward-looking coastal management today. Finally, the specific needs identified here for coastal managers are generally confirmed in the social study of science literature (see the adaptation-specific paper by Vogel et al., 2007; as well as the comprehensive literature review by McNie, 2007). Thus, we cautiously view our findings as broadly applicable outside California, the U.S. and even beyond the coastal sector, even if the specifics are likely to differ from location to location.

## 5. Conclusions

Climate change and related impacts to coastal areas can be classified as a "creeping environmental problem" (Glantz, 1998), punctuated by occasional extreme storm or flooding events, which together threaten the world's coastline. Glantz (1998) argues that, "graduated societal responses to slowly compounding environmental changes may not resolve the problem. Dealing with such problems requires getting ahead of them." Based on the findings in this case study, we argue that coastal managers may be better able to deal with the impacts from climate change if they began preparing for them now. Improving the transfer and uptake of relevant scientific information and knowledge resources, especially with the help of intermediary boundary organizations, would help managers to "get ahead" of these emerging and worsening problems.

California, maybe more so than many other U.S. states (or even other countries), is in the enviable position of having several highly promising resources available to draw on:

- World renown expertise in local universities and research laboratories on climate change and its impacts, as well as strong academic expertise on coastal hazards.
- A considerable number of highly concerned and willing-to-act coastal managers.
- Several institutions that could play boundary-spanning roles and
- Strong political leadership on global warming.

What is missing is an institution devoted to bringing them together on the question of adaptation to climate change. The National Sea Grant College Program with its state chapters may be one such institution to play this role. It is "dedicated to enhancing the understanding, conservation, and sustainable use of the nation's coastal and marine resources" supported by efforts from scientists and engineers at public and private universities (California Sea Grant, n.d.). The state's extension service[7] does not mention "climate change" or "global warming" as a focal point or even a marginal consideration in achieving these goals. Nationally, attention to and fiscal support in the Sea Grant Program for outreach on climate change and coastal impacts has varied considerably over the past decade, but attention to climate change impacts is resurging at the federal level at present.

Other institutions in California, such as the state's RISA program (see http://meteora.ucsd.edu/cap/) or others, could also step into this boundary-spanning role. While future research may explore the precise shape and roles such a boundary organization could play, how the science–practice relationship could be improved, and what novel opportunities could be created to incorporate climate change science into outreach efforts, these existing institutions could dedicate some resources and effort now toward meeting the growing information and learning needs of coastal managers to help them prepare for climate change.

In conclusion, in this paper we gave a case illustration of the oft-observed science–practice disconnect in the context of coastal zone management and adaptation to the emerging and future impacts of climate change and sea-level rise. California, as we discussed above, is far from being a singular case—neither in its exposure to the threats from sea-level rise, nor in its dearth of attention to climate change adaptation in practical day-to-day management at the state and local level to date. Since this study was undertaken, the state's legislature has begun to address the needs for a legal mandate and financial resources to support local managers in planning for climate change impacts (Assembly Bill 1066). The U.S. Commerce Department's NOAA also has recognized local managers' information and training needs and is beginning to address them through various programs. But these are still the early days. It is our hope that case studies such as ours can help California and other states identify what the greatest information needs on a particular issue are, how best to deliver on them, and how to institutionalize ongoing scientific support for practical management in effective ways.

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[7] See http://www-csgc.ucsd.edu/CSGCWhatWeDo.html for more detailed information on the California Sea Grant College Program. It is the largest of 30 programs within the Nation Sea Grant network and has a Coastal Community Development Program that concentrates on "community planning and growth management in coastal areas" and providing "services to coastal communities to aid in efforts to protect their environmental amenities, strengthen their economies and improve their quality of life . . . by providing the enhanced science-based support needed to balance environmental, social and economic considerations" (National Sea Grant, no date).

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