PAPER

Vulnerability to Inundation and Climate Change Impacts in California: Coastal Managers' Attitudes and Perceptions

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ABSTRACT

Coastal California has witnessed persistent sea-level rise (10-20 cm) along its southern and central open ocean coastal sections and in San Francisco Bay over the past century. This paper aims to understand the perceptions of local coastal managers in California of current inundation-related risks, the added risks from climate change, and vulnerability to the growing coastal problems. We also explore the extent to which coastal managers are beginning to think about and tackle these increasing management challenges.

Survey results presented here suggest that inundation already creates critical management challenges in California, but other, non-inundation-related coastal problems also vie for managers' attention. Despite high awareness of global warming and moderately good understanding of potential impacts of climate change on coastal areas, currently pressing issues and limited staff time and resources constrain their ability to begin dealing with the growing risks from sea-level rise. The sobering conclusion is that California is inadequately preparing for the impacts of climate change on coastal areas at this time. Local government will need substantial support from state and federal agencies if the level of preparedness for climate change and other inundation-related risks is to be elevated in the future.

1. Introduction

In post-Katrina America, coastal flooding, inundation, and erosion from sea-level rise and extreme events first bring to mind images of the Gulf of Mexico coastline. But of course, these problems are far more common both historically and geographically, regularly affecting the Atlantic and Pacific (and increasingly the Arctic) coastlines of the United States (e.g., National Research Council, 1987, 1990a, 1990b; Dolan et al., 1990; Hanson and Lindh, 1993, 1996). Climate change and related sea-level rise (SLR) projections—even the more conservative ones based on thermal expansion and gradual ice melt—suggest that these historic trends will persist if not accelerate over coming decades and centuries (Church et al., 2001; Meehl et al., 2005; Wigley, 2005). However, if recent observations of rapid ice sheet decay, especially from Greenland (Krabill et al., 2004; Shepherd et al., 2004; Alley et al., 2005; Dowdeswell, 2006; Rignot and Kanagaratnam, 2006) become further substantiated, the possibility of dramatic rates of SLR can no longer be denied. Such rapid SLR (several feet per century) would result in catastrophic impacts for many U.S. and other low-lying coastal regions around the world from inundation, erosion, and land loss—impacts that are almost too daunting to consider for coastal managers.

As it is, eustatic sea-level rise, episodic flooding, and erosion are common along most of the U.S. coastline today. With the high degree of development in immediate shorefront areas, coastal managers already face daunting problems. Moreover, many coastal management decisions made today (e.g., installation of hard shoreline protection or other significant infrastructure, siting of development in coastal hazard areas or on the landward edges of wetlands) create legacies that will affect and possibly constrain management options in the future when sea levels are higher and coastal climates changed because of global warming. Based on the extant review of the scientific literature on climate change impacts on coastal regions (e.g., McLean et al., 2001), there is no plausible future scenario one can imagine that would alleviate these existing problems.

The goals of this paper are to understand (1) coastal managers' perceptions of current risks, (2) their appreciation of the added risks from climate change, (3) their perceived vulnerability to the growing coastal problems, and (4) the extent to which they have begun thinking about and tackling these increasing management challenges.

2. Sea-Level Rise and Inundation Risks along the California Coast

In this paper we focus on coastal California, which has witnessed persistent sea-level rise along its southern and central open ocean coastal sections and in San Francisco Bay and adjacent estuaries over at least the past century (e.g., California Coastal Commission, 2001). The state also episodically experiences severe acute flooding, coastal erosion, beach loss, and cliff retreat from winter storms, es-

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pecially during El Niño events (Flick and Cayan, 1984; Flick, 1998; Ryan et al., 1999; Storlazzi and Griggs, 2000; Moore and Griggs, 2002; Sallenger et al., 2002). Recent research suggests that historical sea-level rise along these stretches of the California coastline has ranged from 10 to 20 cm over the past century (based on available reliable tide gage records), a rate comparable to global estimates of eustatic SLR over the past century (Cayan et al., 2006). Over the past few years, the U.S. Geological Survey conducted assessments of physical vulnerability to future SLR along the Atlantic, Gulf, and Pacific coastlines, including that of the California (Hammar-Klose and Thieler, 2001; Thieler and Hammar-Klose, 2000). They developed a coastal vulnerability index (CVI) based on six factors:

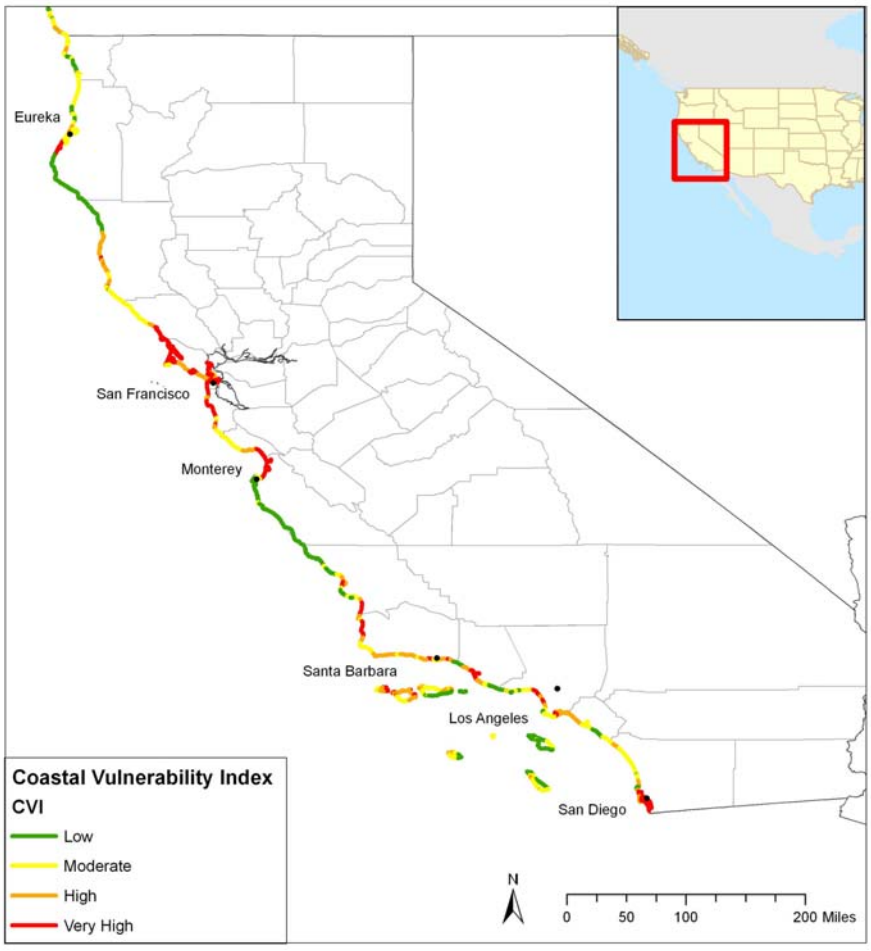
- tidal range,
- wave height,
- coastal slope,
- historical shoreline erosion rates,
- geomorphology, and
- historical rates of relative SLR.

These factors together determine the risk of inundation and erosion, and provide a reasonable approximation of areas likely to experience impacts from future SLR. Along soft coasts, also common along the California coast, the CVI tends to underestimate cliff retreat and thus the significance of higher sea levels for this process. The USGS recently completed a complementary assessment of the California shoreline, which compensates for this shortcoming of the SLR vulnerability assessment by better accounting for shoreline change and the importance of cliff retreat along this state's coast (Hapke et al., 2006). Importantly, the CVI does not incorporate projections of *future* SLR under different assumptions of climatic change and hence does not delineate the extent of areas likely to be inundated or eroded in the future. Rather, the CVI indicates past and current, i.e., experienced SLR impacts, and by extension suggests which coastal areas are more or less vulnerable to future SLR impacts. Areas of highest vulnerability to future SLR are those that are today's hotspots of coastal management problems related to flooding, levee stability, coastal erosion, cliff retreat and beach loss (Figure 1).[3] Recent research suggests that this simple conceptual extension from today into the future may be too conservative, especially on complex coastlines (Slott et al., 2006), but it can serve as a reasonable first approximation.

To assess what future rates of SLR the state of California can expect, Cayan et al. (2006) used the standard set of emissions scenarios underlying the forthcoming Intergovernmental Panel on Climate Change (IPCC) assessment (AR4, expected in early 2007) run on three different climate models (PCM, HadCM3, and GFDL). They conclude, "Relative to sea levels in 2000, by the 2070–2099 period, sea-level rise projections range from 11–54 cm (4.3–21 in) for simulations following the lower (B1) greenhouse gas (GHG) emissions scenario, from 14–61 cm (5.5–24 in) for the middle-upper (A2) emissions scenario, and from 17–72 cm (6.7–28 in) for the highest (A1fi) scenario" (Cayan et al., 2006, p.ix).

FIGURE 1

California's Physical Vulnerability to Sea-Level Rise



Source: Map based on data from Hammar-Klose and Thieler (2001)

[3] Again, it is important to recall that the CVI tends to underestimate cliff and shoreline retreat along soft coasts (see discussion in text). Moreover, the concept of "vulnerability" as used by Thieler and colleagues only captures the physical risk to which coastal areas are exposed. It does not encompass socioeconomic variables that would reflect a coastal community's sensitivity to these changes (e.g., are there any hard shoreline protection measures such as sea walls and levees to protect communities from their exposure to sea-level rise?). Nor does their index capture a community's resilience, i.e., its ability to deal with and bounce back from the impact of an inundation event).

They further illustrated through composite analysis of secular changes in sea level and variation in tides and wave climates that when the higher sea-level baseline coincides with storms, astronomical high tides, and/or ENSO events, resulting flooding and wave action increase "the potential for inundation of levees and other structures. There may also be increased risk of levee failure due to the hydraulics and geometry of these structures. Rising sea levels from climate change will increase the frequency and duration of extreme high water levels, causing historical coastal and San Francisco Bay/Delta structure design criteria to be exceeded" (Cayan et al., 2006, p.x).

3. Preparing for the Impacts of Sea-Level Rise

In recent years, California has emerged as a strong leader in assessing the risks of climate change on the state. Specifically, in June 2005, Governor Arnold Schwarzenegger issued Executive Order S-3-05, in which he not only set stringent emission reduction targets and asked for regular updates on the science of climate change and its impacts, but also for "report[s] on mitigation and adaptation plans to combat these impacts." In addition, California's Ocean Protection Council recently released its strategic plan (California Ocean Protection Council, 2006), which also calls for a better understanding of climate change impacts on coastal and marine areas and the development of appropriate response strategies. As part of a large effort to provide an initial science update to the Governor and California state assembly, we conducted a study of local and state coastal managers' preparedness for the impacts of climate change on coastal areas. Here we report selected results from that study, focusing on coastal managers' perceptions of current and future problems associated with SLR. Below we describe our data sources and methodology and then report our findings. In subsequent sections we discuss the implications of these findings for current and future coastal management as the risk of inundation increases with climate change.

3.1 Methods

Based on past research by the lead author (Moser, 2000, 2005, 2006), we did not try to assess coastal managers' perception of sea-level rise *per se*, but rather their perception of more immediate, clearly visible problems associated with sea-level rise, including coastal erosion, beach loss and cliff retreat, coastal flooding, and saltwater intrusion into coastal aquifers. These more immediate problems are at the core of many coastal managers' daily work and correspond well with the physical vulnerability index described above by Thieler and colleagues. It should also be noted that many of the problems associated with climate change and sea-level rise (all discussed in the findings section 3.2) are not independent. For example, coastal flooding affects water quality and habitats; saltwater intrusion and coastal erosion also alter habitats and ecosystem conditions.

To explore coastal managers' perception of inundation and sea-level rise related coastal problems, we employed a survey instrument to understand their current coastal management challenges and elicit perceptions and attitudes about global warming and related impacts on coastal areas. The population surveyed consisted of 299 local and county government employees along the state's open ocean and bay coasts who have some role in coastal management activities. The California Coastal Commission and Bay Conservation and Development Commission provided lists of contacts; additional names were identified through an extensive web search. We broadly defined "coastal management" to include any aspect of local management concerned with the safety, environmental protection, public infrastructure, and development of coastal cities and counties on land and in nearshore coastal waters. Table 1 lists the type and number of staff that responded to this survey (note that we approached additional types of local government officials but list only those who actually replied). Our goal was to obtain at least two or three individuals from each coastal county or municipality. In larger communities, we often identified a half dozen or more individuals.

The comprehensive, 18-page survey mailed in June 2006 inquired about respondents'

- community/county characteristics including degree of development and types of current coastal management challenges and strategies
- attitudes about global warming and possible consequences of global warming on coastal areas and management
- information currently used or needed to effectively carry out coastal management responsibilities
- basic demographic information (e.g., age, employment position, level of education attained, etc.

Survey questions included open-ended and multiple-choice informational questions, attitudinal questions using a Likert scale, as well as check-all and forced-choice questions. The main focus of this paper is questions relating to current management challenges, attitudes and perceptions regarding global warming, and whatever actions California local governments have taken to date to address climate change impacts. Other forthcoming papers will focus on other survey results.

Of the 299 surveys, 14 were returned blank or due to inadequate address; eight additional respondents considered their location non-coastal. The overall response rate was 46.1%, a rate we considered quite good. Maybe more importantly, the 135 usable responses represented about 89% of coastal cities and about 89% of coastal counties approached. We tabulated and analyzed the obtained data using simple statistical analyses. We could not conduct any meaningful correlation analysis comparing the physical vulnerability index with the human percep-

TABLE 1

Survey Respondents (numbers in top row and percentage in bottom row, n=135)

Planner	Permitting Officer	Publ. Works Engineer	Env. Specialist	Developm't Coordinator	Harbor etc. Manager	Water Res. Manager	Elected Official	Other*
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%

* emergency service managers, natural resources managers, multiple/mixed responsibilities, or not otherwise specified by respondent

tions from the survey (for more discussion on this issue see Section 5). However, the qualitative comparisons yielded interesting contextual insights that place managers' perceptions and concerns in perspective. We discuss these findings below.

3.2 Findings

3.2.1. Coastal Managers' Perceptions of Current Coastal Zone Management Challenges

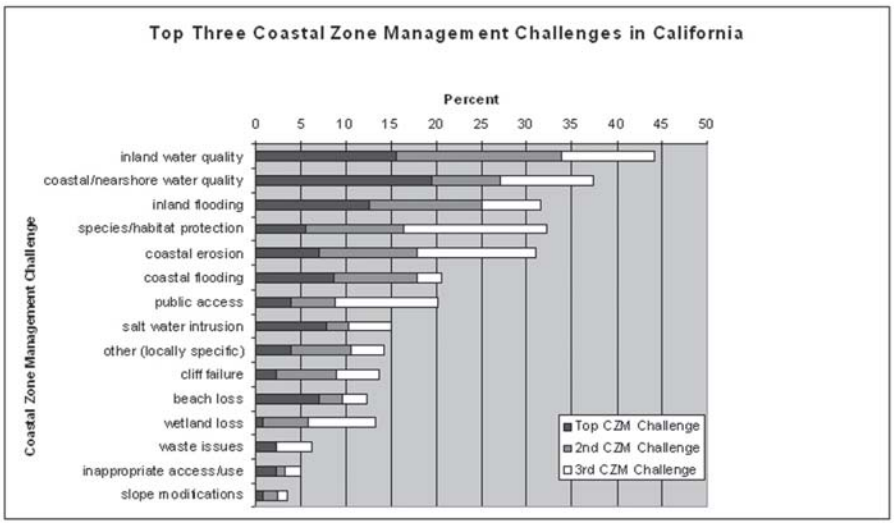
Key management challenges. We asked survey participants about the kinds of coastal management challenges their community or county currently faced. They first identified all relevant problems from a list of 14 given options and one write-in option, and then prioritized the top three challenges in their area (Figure 2).

Integrating these findings further, it is apparent that nearly a third of all respondents (32.7%) identified water quality issues (in coastal and nearshore areas as well as in local streams, estuaries, and inland areas) as one of the top three coastal zone management problems in California. Twenty percent of respondents identified shoreline change (including coastal erosion, beach loss, cliff failures/retreats and related nourishment questions) among the top three management challenges. Flooding in both shorefront and inland areas (related to extreme precipitation events) was mentioned by 17.7%, and species and habitat protection issues (including wetland loss concerns) followed closely with 14.6%.

We identified five coastal management challenges (coastal flooding, coastal erosion, beach loss, cliff failure, and saltwater intrusion) as most directly related to sea-level rise and inundation, and examined how many cities considered these as their top management challenges. In seven cities at least one respondent identified coastal flooding as the community's top coastal management challenge; coastal erosion was the top management challenge in six cities; cliff retreat in two; beach loss in five communities; and saltwater intrusion in another five. Of the 54 cities for which we had data on this question, 74% named at least one of these five problems among their top three management challenges.

FIGURE 2

The Top Three Coastal Zone Management Challenges in California Today



The results highlight how the most critical management challenges arise from the interaction of intense development in coastal areas with a dynamic shoreline, fragile ecosystems, and a variable coastal climate. For example, point and non-point source pollution from highly urbanized areas is washed into coastal streams and waters during extreme precipitation events, negatively affecting water quality. Ongoing sea-level rise and episodic coastal storms drive dynamic shoreline changes while homeowners and business are trying to stabilize the shorefront and/or maintain wide beaches for coastal recreation, tourism, and as buffer against natural forces. Both development and high recreational or economic usage of coastal areas disturb and/or constrain the ability of species and habitats to adapt to a rising sea level.

Severity of top coastal zone management challenge and perceived changes over time. Next, we asked survey participants to rate the severity of the coastal management challenge they had identified as their top concern on a scale from 1 (not serious at all) to 5 (very severe), with the midpoint indicating "moderate severity." We list the top ten management challenges according to their average severity score in Table 2. Note that the top management "challenge" is not necessarily "severe." In the survey, we did not define for the respondents what we meant by "challenge" or "severity." It is in principle conceivable to have a management challenge that raises difficult debates among concerned parties or is a policy priority, but is not necessarily physically severe or urgent. Thus, the average severity scores in

TABLE 2

California Coastal Managers' Perception of the Severity of the Top Coastal Zone Management Challenge.

Top CZM Challenge	Perceived Severity at Present[1]	Perceived Change in Severity in Past 5 Yrs[2]	Expected Change in Severity in Next 5 Yrs[2]
Public access	4.20	4.00	3.80
Saltwater intrusion	4.10	3.40	3.10
Spec./habitat protect.	4.00	3.57	3.86
Inland flooding	3.69	2.88	2.56
Cliff Failure	3.67	3.67	3.67
Coastal flooding	3.60	2.70	2.30
Coastal erosion	3.56	4.11	4.11
Water quality	3.37	3.63	2.89
Coastal water quality	3.32	3.48	2.76
Beach loss	3.11	4.00	3.00

[1] Scale: The top CZM problem currently is **1** – not serious at all; **2** – slightly problematic; **3** – moderate; **4** – severe; **5** – very severe

[2] Scale: The top CZM problem has/will have **1** – significantly decreased; **2** – decreased; **3** – not changed; **4** – increased; **5** – significantly increased

Table 2 do not necessarily correspond one to one with the management challenges prioritized above by California coastal managers.

The severity ratings give a more differentiated picture of today's coastal management challenges in California. Nearly nine out of ten (89.9%) management challenges that our survey respondents identified as their no.1 challenge fall into the moderate and severe categories. Interestingly, according to the average severity ratings, managers perceive the top three issues (public access issues, saltwater intrusion, and species or habitat protection) as distinctly worse than the remaining seven (note the jump in average ratings between the third and fourth currently most severe entries). Eight out of the ten pertain to the immediate shorefront and can—at least in part—be directly related to sea-level rise or storm-related inundation and to associated shoreline change processes. Public access, while a direct reflection of property rights and development patterns in the immediate shorefront, is also and will be further affected by an encroaching sea as unmitigated erosion, beach loss and cliff failures can reduce public access to beach areas. This example highlights again the interrelationships between coastal management challenges: the bottom seven issues listed in Table 2 all impact on public access and species/habitat protection while saltwater intrusion will be exacerbated by sea-level rise. In turn, saltwater intrusion and coastal flooding affect coastal water quality, and so on. As the pattern of expected changes over the next five years discussed in more detail below suggests, coastal managers do not seem to take these interrelationships (especially with the prospect of accelerating sea-level rise and other climatic changes) into full account in their assessment of current and future severity.

The survey further revealed that 55.6% of all respondents perceive their top management challenge to have gotten worse or significantly worse over the past five years. Managers view eight out of ten management challenges listed as having become aggravated to at least some degree over the past five years (Table 2). The greatest worsening is seen for coastal erosion, beach loss, and public access issues. The perceived improvement of essentially event-driven problems (inland and coastal flooding) may be related to fewer severe storm events in the most recent past (the 1-2 winters prior to the survey), and/or simply reflect that single events tend to diminish in importance in people's mind, especially if difficult, chronic problems concern them on an almost daily basis.

In terms of expected change, the total distribution of responses is bimodal, with 37.3% of respondents expecting at least some or significant improvement, and 41.3% expecting some or significant further deterioration regarding the management problem they considered the top challenge today. More specifically, respondents expected further worsening of coastal erosion, public access, and species and habitat protection, but seem more optimistic about flooding and water quality problems, both inland and in coastal and nearshore areas (Table 2).

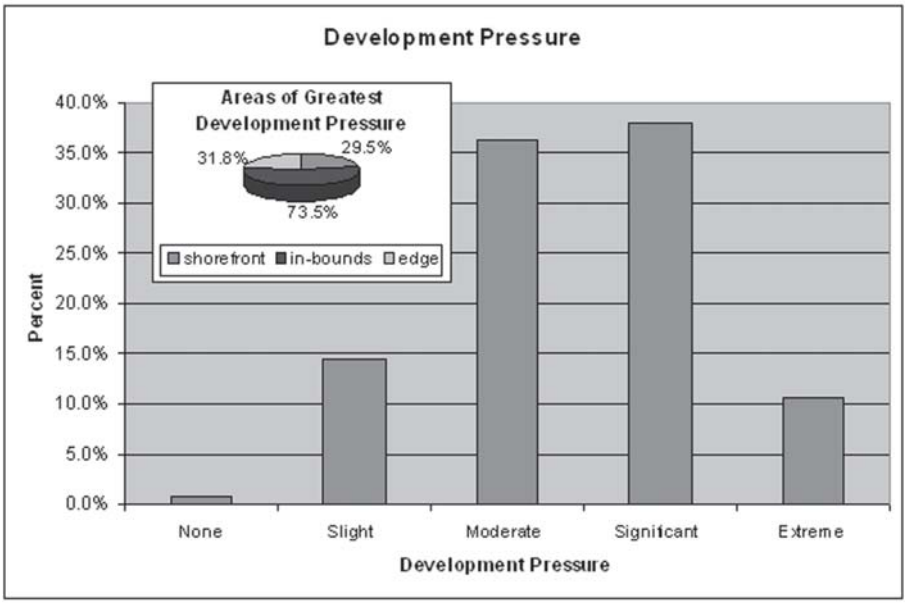
It is reasonable to suspect that these expectations of future problems are driven in no small part by the experience of current challenges, for example, in terms of perceived severity of the problem (detailed above), but also the respondents' views on ongoing development pressures, political contentiousness surrounding an issue, and efforts underway to alleviate these problems.

Indeed, when we asked respondents about development pressures in their communities and counties, the average development pressure on a scale from 1 (no development pressure) to 5 (extreme development pressure) was 3.4, with a majority of respondents experiencing moderate to significant development pressures (Figure 3). As may be expected given the already high degree of development along the immediate shorefront, communities now witness the greatest pressures inland from the shoreline, with some ongoing additional pressures from infilling and redevelopment along the shorefront and problems with sprawl at municipal boundaries (Figure 3, insert). As development continues, pressure on species and habitat and public access issues is likely to continue to increase – in short, an internally consistent influence on respondents' expectations about the future.

When we asked respondents to characterize the political atmosphere around the most challenging coastal management issue on a scale from 1 (highly contentious) to 4 (consensual), the average rating was 2.5 (moderately contentious). More specifically, however, our respondents rated the political atmosphere around two of the top three problems listed in

FIGURE 3

Perceived Development Pressures in California Coastal Cities and Counties



Note: We defined areas of greatest development pressure roughly as follows: "**shorefront**"—the immediate first one or two blocks along the water front; "**in-bounds**"—all areas away from the "shorefront" as defined above and away from the landward municipal boundaries; and "**edge**"—areas along the landward municipal boundaries.

Table 2 (public access issues and species/habitat protection) among the most contentious issues with average ratings of 1.80 and 1.86, respectively. Other issues from Table 2 considered politically contentious included beach loss (2.33), coastal erosion (2.44) and coastal water quality (2.52). While in-depth interviews with respondents would have to be done to reveal particular reasons behind their expectations of the future, it is reasonable to assume that these judgments of the political atmosphere also affect managers' perceptions of how coastal zone management challenges may change in the next few years.

Finally, to the extent environmental changes such as climate change are of sufficient concern to rise as high as or above other pressing concerns, expectations about the climatic or environmental future may also influence expectations of future severity of management challenges. We asked about concerns about global warming *after* inquiring about ongoing pressures so as not to influence respondents' views. We summarize our findings regarding awareness, attitudes, concerns, and knowledge about climate change in the next section.

3.2.2. Coastal Manager's Attitudes toward Global Warming and Coastal Impacts

Attitudes Toward and Knowledge about Global Warming. To assess survey participants' awareness and attitudes toward global warming, we asked them to indicate their level of agreement with various statements regarding global warming. California coastal managers exhibited very strong opinions. More than half (53.5%) strongly agreed with the statement, "Global warming is real and already happening now." Another 38.6% slightly agreed with this same statement. This attitude was also reflected in the 84.1% who agreed—either slightly or strongly—with the statement "Global warming is probably happening and we will start seeing impacts in the near future." The control statement, "Global warming is probably not happening now and will not cause problems in the future" had 95.1% respondents disagreeing.

Equally strong were respondents' levels of personal concern with global warming. Almost half (47.4%) said they were concerned personally and another 39.1% said they were very concerned about global warming. Only 3% were not concerned at all. For 72.9% of the respondents, this concern translated into thinking about what implications global warming might have for them personally and for their work.

When we asked managers to self-assess how well informed they feel about global warming and its implications, 18.8% said they felt well informed, 68.4% felt moderately well informed, with the remainder either not well or not at all informed or unable to judge. These responses were confirmed when we asked managers to indicate their estimate of the possibility that their area might experience certain impacts from global warming: the general pattern of responses was quite consistent with expert judgment. At least four out of five respondents thought there was a moderate to high possibility that global warming would produce changed rainfall patterns (93.8%), higher rates of sea-level rise (89.4%), more frequent storms (84.8%), higher ocean temperatures (84.4%), more flooding (82.2%), and higher air temperatures (82%), as well as higher-order impacts such as more algal blooms (87.9%), changes in water quality (84.4%), and other impacts on marine life (81.7%).

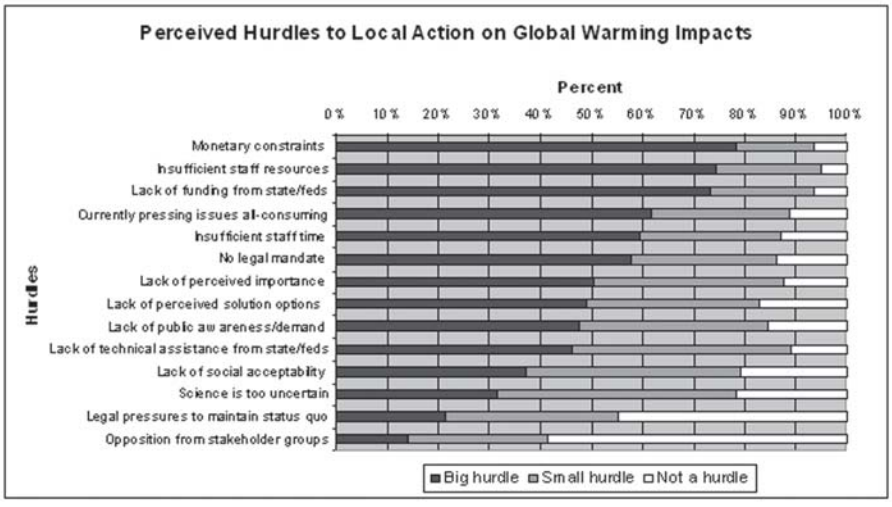
It is likely that if we had simply asked survey participants to write in the kinds of impacts they expected, we would have received fewer and less confident answers. Considering, however, that these respondents are not necessarily experts on global warming, the responses are overall internally consistent, and reflect a moderate level of understanding of climate change impacts. Clearly, the response pattern does not reflect general expert judgment of confidence in these impacts. For example, the somewhat surprising response rate for higher air temperatures vs. changes in rainfall patterns may have to do with the critical importance that rainfall has in much of California for water supply (especially in the form of snowfall over the Sierra Nevada). As a result, climate change news coverage in the state frequently focuses on water-related impacts, and thus may be higher on people's radar screens.

Local Government Response to Date to Global Warming. Interestingly, despite respondents saying they had considered what global warming could mean for them personally and in their work, very few expected their actual job responsibilities to change or had any opinion on that question. Similarly, when we asked respondents whether their local government had begun gathering any information about global warming impacts, half did not know. About 30% had consulted some government or external expert or convened public discussions in their communities on the issue.

When we asked whether local governments had formally developed any plans to deal with the potential impacts from global warming, responses were sobering. Two of the counties that responded to our survey (San Luis Obispo and Sonoma) said that they had

FIGURE 4

Perceived Hurdles to Local Action on Global Warming Impacts



such plans in place; however, neither plan considers coastal impacts. Four other counties are currently preparing such plans and will look at coastal impacts. Among the coastal cities that responded to our survey, only one currently has a plan in place to deal with the impacts of global warming (Berkeley), and six are in the process of developing such plans (Solana Beach, Goleta, San Francisco, Palo Alto, Alameda, and Arcata); at least five of them will consider coastal impacts. Importantly, close to 20% of respondents did not know whether their city or county had any such plan.

We then asked respondents to identify what hurdles prevented them from addressing the impacts of climate change. Their answers reveal important constraints on local action (Figure 4).

Managers overwhelmingly (78.2% of respondents) see monetary constraints at the local level as the leading hurdle to taking on global warming impacts, followed closely by insufficient staff resources to analyze and assess relevant information (74.4%), lack of funding from state and/or federal agencies to prepare a plan (73.4%), the view that currently pressing issues are all-consuming (61.6%), i.e., leaving little room to take on anything seemingly new, unfamiliar, or overwhelming. Concern about insufficient staff time (59.7%) confirmed this view. More than half of the respondents (57.7%) also viewed the lack of a legal mandate to take global warming impacts into account as a major hurdle.

4. Discussion

How representative are the findings presented here of all of coastal California? At first glance, one could argue that they capture the situation quite well. As mentioned above, we received surveys from 89% of all approached cities, and 89% of all contacted coastal counties. The types of communities represented include everything from metropolitan areas, to retirement communities, tourist towns, farming communities, working or recreational harbors, to mixed urban centers. Similarly, cities and counties varied in population size, adequately representing the range of communities of coastal California.

While coastal management—as broadly defined for this study—is spread out over numerous departments, commissions, boards, and services, our study focused primarily on "implementing staff" and to a lesser extent on elected officials or bodies. To the extent any plans were passed in those elected, policy-setting institutions and are now being put into action, department staff would know about them. Thus, we believe that our survey adequately captured the local government situation "on the ground," even though we received only very limited responses from elected officials.

After our initial survey mailing, we did receive a number of calls or emails from individuals who said they did not consider themselves "coastal," felt they could not speak for their entire local government, or were not experts on global warming. Reassurances about these matters (and clarification in subsequent reminder mailings) resulted in some answering the survey, others not. Based on previous in-depth interviews with state and local coastal managers in California and elsewhere, the results of the survey may be biased by the non-responders. The tendency to not respond may reflect similar insecurities as expressed by those who contacted us, indicate coastal management staff's lack of time, and may be stronger in cases where no action on climate change has been taken. Differently put, those who have something to tell are more likely to want to share it. If so, the results presented here may be overly optimistic. The degree of time, staff, and resources constraints overall may be felt even more acutely; the level of awareness, concern, and knowledge of global warming and coastal impacts is probably lower than captured here. Thus, the motivation to act may be lower and the perceived hurdles to taking action even higher than indicated by our survey. Thus, we cautiously view our findings as representative of those most engaged in coastal management today and those most aware and concerned about climate change, but probably as "too rosy" for coastal California as a whole.

One may also ask how transferable our findings are to other U.S. states. We are not aware of any other studies that have conducted broad surveys of local coastal management staff regarding their current challenges or anticipated future problems due to climate change. Thus, there is no comparable basis on which to judge transferability of findings. One study explored SLR response options and obstacles for local governments generically (Burby and Nelson, 1991). Another nationwide study nearly two decades ago tried to assess what policies states and local governments had actually put in place to deal with sea-level rise (Klarin and Hershman, 1989). A more detailed study of the few states and local entities they had identified as having begun to deal with these inundation-related risks revealed that Klarin and Hershman's assessment was slightly too optimistic (for further discussion see Moser, 2005): fewer states than they indicated had actually put specific sea-level rise response policies in place. Undoubtedly, additional states and communities have since begun to tackle this challenge, but we are not aware of a nationwide update of the Klarin and Hershman review. Moreover, states and particular localities will differ in what they perceive to be their most challenging management problems at present, as physical characteristics of the coast, regional climate variability, coastal development patterns and policy histories differ across the nation. However, 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 concerns and pressures, staff and funding constraints, as well as legal limits on managers' ability to address inundation risks and other climate change impacts. These were—less specific to the topic of this paper, yet geographically more comprehensive—confirmed by the independently arrived, yet almost identical findings of the two U.S. ocean commissions (U.S. Commission on Ocean Policy, 2004; Pew Oceans Commission, 2003). Both 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. Thus, we cautiously view our findings as having broad applicability outside California, even if a number of specifics—such as the

ranking of current management challenges, or the degree of awareness and understanding of global warming impacts—are likely to differ from location to location.

As for California survey participants' responses about current coastal management challenges (Section 3.2.1), we find them to be internally consistent with those about expectations about coastal management in the future. They also are internally consistent with expected changes related to global warming and why so little action has been taken to date to address coastal impacts of climate change. Being overwhelmed and understaffed with current problems, leaves little room to get informed about, much less begin addressing the growing risks related to climate change and sea-level rise. Such constraints do not even allow managers to find out that many of the expected impacts from global warming are not "new" and "extra" or "different" but mostly more severe versions of what they are already intimately familiar with. These internal consistencies give us further confidence that our results adequately capture the current perceptions of coastal managers regarding inundation-related risks.

The responses regarding current or future inundation-related management challenges did not meaningfully correspond to the objective physical vulnerability index (CVI, described above, with majority values assigned to city boundaries). We attribute this lack of significant correlation to a range of factors, including lack of awareness of the CVI among managers, variations in the degree of development of vulnerable coastal areas, other challenges competing for managers' top concern and attention, the objective and subjectively perceived severity of other management problems, as well as the fact that we included several management challenges in our survey that predominate in non-shorefront areas and/or are not just related to sea-level rise. This finding just highlights the fact that coastal managers (broadly defined) must address and balance their time commitment to more than shorefront (inundation-related) issues, i.e., they have broader responsibilities. At the same time, most coastal managers' job responsibilities do not expressly include attention to future risks, and in that sense are more narrowly focused than climate change risks may demand.

Clearly, not taking action with climate change impacts explicitly in mind does not mean coastal communities are entirely unprepared for climate change and inundation-related impacts. Based on state law and/or the local coastal management plans implementing these state regulations, numerous policies, regulations, planning guidelines, and informational approaches are in place now to address current coastal issues and these are certainly useful as coastal risks increase. However, as the projections of future climate change and related inundation risks discussed in the Introduction and Section 2 suggest, even more strictly implemented existing coastal management strategies may not be sufficient for dealing with the growing risks from climate change. In some instances, additional science (e.g., to translate increased rates of SLR into legally defensible setbacks) is necessary to inform future decision-making.

The sobering conclusion from both the very small number of local entities that have begun thinking about a future under climate change conditions and the perceived hurdles to begin doing so is that California is inadequately prepared and inadequately preparing for the impacts of climate change on coastal areas at this time. The results presented here (and more rich insights from the survey discussed in forthcoming papers) suggest that local government will need substantial support if the level of preparedness for climate change and related inundation-related risks in California is to be elevated in the future.

5. Summary and Conclusions

In this paper we aimed to understand (1) California coastal managers' perceptions of current management risks, (2) their understanding of the added risks from climate change, (3) their perceived vulnerability to the growing coastal problems, and (4) the extent to which they have begun thinking about and tackling these increasing management challenges.

Our survey respondents identified water quality, shoreline change, flooding, and species and habitat protection issues among their top management challenges at present. Perceived severity of the management challenges added public access to beach areas and saltwater intrusion in coastal aquifers and estuaries to this list of priorities. All will be worsened if—or rather when—expected impacts of climate change in coastal areas come to pass. Indeed, California's coastal managers expect such worsening, except for flooding—a perception that may be influenced by relatively fewer storm/flooding incidences and relatively greater concern for other chronically pressing issues. Despite these expectations, considerable concern about global warming in general and a moderate understanding of what climate change may bring to coastal communities in the future, California local governments have taken only very limited action to prepare for future coastal risks. In this paper we identified monetary constraints, limited staff resources and time, a sense of being overwhelmed with currently pressing issues and a lack of a legal mandate among the key reasons why these communities have not done more to date. The results also show that the challenge of addressing problems that may develop over decades is much greater than the challenge of addressing only "here and now" problems.

That we need to help local governments prepare for the impacts of climate change is an easy conclusion, but not one easily realized. Both federal and state budgets are under enormous pressures from competing priorities. California, more than most other states, has illustrated exemplary leadership on climate change, both in terms of support for state-specific research and for a variety of emissions reductions efforts. Its state-funded global change research program is now turning greater attention to adaptation questions. This type of research will be enormously helpful if it identifies adaptation options available at different levels of decision-making as well as the realistic constraints that need to be addressed to realize the state's substantial adaptive capacity (Luers and Moser, 2006).

The research results presented here reveal a number of ways in which federal agencies involved in coastal management (e.g., NOAA, EPA, U.S. Army Corps of Engineers) can complement these state-funded research efforts through a variety of funding mechanisms, such as federal research funds, planning grants (e.g., via Section 309 improvement grants),

conference support, or additional money for Sea Grant extension services. Similarly, California state agencies concerned with various aspects of coastal management (e.g., the California Coastal Commission, the San Francisco Bay Conservation and Development Commission, Department of Boating and Waterways, Coastal Conservancy, the state Environmental Protection Agency, State Parks, and so on) could not only make climate change and related inundation risks a higher priority in their own planning and operations but support and/or require local jurisdictions to include such considerations in projects that require state approval. The Bay Conservation and Development Commission, for example, regularly interacting with local governments around San Francisco Bay, has prominently raised climate change and sea-level rise to a top priority in its recent strategic management plan. Likewise, the California Coastal Commission in late 2006 launched a series of public workshops on global warming and its implications for areas under its jurisdiction. Such actions can help raise broader awareness and pave the way for local assistance.

Importantly, future coastal management efforts in California, if they are to assist local governments in preparing for the impacts of sea-level rise, inundation, and other climate change impacts must address the hurdles identified by local officials as major encumbrances. The results presented here suggest that legal mandates, and in particular funding mechanisms and additional staff resources to implement such mandates, e.g., to assess community vulnerabilities to various coastal impacts and identify response strategies, must play a prominent role in such state guidance and assistance. In addition, local coastal managers would benefit from regular doses of relevant and accessible information on the latest climate change science, especially that relevant to coastal areas. Such information also must highlight feasible management strategies to counter perceptions that "there are no viable response options." Maybe more important even than the written word are opportunities for coastal managers to learn from each other (e.g., in conferences and workshops), to learn what others in similar management situations are doing to address climate change and inundation risks, and how they are funding impacts/vulnerability assessments and response strategies.

Consistent with the priorities of California's Ocean and Coastal Protection Council's Strategic Plan, this research—through its exploration of managers' understanding and expectations of global warming impacts and their perceptions of action hurdles—also suggests that there is a need to improve not only managers' and the public's awareness, but maybe, more importantly, their deeper understanding of climate change impacts on coastal communities. Such awareness and understanding will—from the bottom up—support and create demand for greater local preparedness as climate change creates ever growing challenges from sea-level rise and storm-related inundation along this state's resource-rich and beautiful shoreline.

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