# PREPARING FOR THE IMPACTS OF CLIMATE CHANGE IN CALIFORNIA: OPPORTUNITIES AND CONSTRAINTS FOR ADAPTATION

WHITE PAPER

*A Report From:*
**California Climate Change Center**

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Arnold Schwarzenegger, *Governor*

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# Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

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- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

**The California Climate Change Center (CCCC)** is sponsored by the PIER program and coordinated by its Energy-Related Environmental Research area. The Center is managed by the California Energy Commission, Scripps Institution of Oceanography at the University of California at San Diego, and the University of California at Berkeley. The Scripps Institution of Oceanography conducts and administers research on climate change detection, analysis, and modeling; and the University of California at Berkeley conducts and administers research on economic analyses and policy issues. The Center also supports the Global Climate Change Grant Program, which offers competitive solicitations for climate research.

**The California Climate Change Center Report Series** details ongoing Center-sponsored research. As interim project results, these reports receive minimal editing, and the information contained in these reports may change; authors should be contacted for the most recent project results. By providing ready access to this timely research, the Center seeks to inform the public and expand dissemination of climate change information; thereby leveraging collaborative efforts and increasing the benefits of this research to California's citizens, environment, and economy.

For more information on the PIER Program, please visit the Energy Commission's website www.energy.ca.gov/pier/ or contact the Energy Commission at (916) 654-5164.

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# Abstract

In response to Executive Order S-3-05, this paper examines California's opportunities and constraints for managing the impacts of climate change. It reviews the extant literature on adaptation and provides examples from selected sectors in California to illuminate the constraints and, in some cases, limits to the ability to adapt to climate change. Based on these insights, recommendations are made for how government, research, and civil society can help California most effectively prepare for climate change impacts. The key findings are:

**Key Finding #1:** California's response to climate change is not a simple choice between mitigating greenhouse gas emissions and adapting to the impacts of climate change. Adaptation and mitigation are necessary complementary strategies for managing climate change. The state must determine the portfolio of solutions that will best minimize potential risks and maximize potential benefits.

**Key Finding #2:** 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 further challenge the state's ability to cope with climate-related stresses.

**Key Finding #3:** Adaptation is being addressed by the international community and largely ignored within the U.S. A deeper discussion is needed about the costs and challenges of adaptation in California and elsewhere in the U.S.

**Key Finding #4:** To enhance Californians' preparedness for climate variability and change, decision-makers in the private and public sectors require greater *awareness* of the risks they face, increased capacity to *analyze* such information and use it in decision-making, and the ability to remove any institutional, financial, political, and other barriers in the way of turning good intentions into *actions*.

**Key Finding #5:** Many opportunities exist to enhance California's adaptive capacity and resilience in the face of change, even in the absence of perfect foresight about future climatic changes. In fact, California's adaptive capacity—the *ability* to adapt—is significant. However, implementing that capacity into real adaptive actions on the ground is actually quite difficult and requires special attention and long-term commitment at all levels of government, across climate-sensitive industries, and throughout society.

**Key Finding #6**: The ability to cope and adapt is differentiated across population, economic sectors, and regions within the state. The state has an opportunity to ensure and enhance "environmental justice" while fostering California's adaptive capacity to climate change and other interactive stressors.

## 1.0 Motivation and Overview of This Report

Governor Arnold Schwarzenegger's Executive Order S-3-05 of June 1, 2005, called for specific emission reductions and a periodic update on the state of climate change science and the emerging understanding of potential impacts on climate-sensitive sectors such as the state's water supply, public health, agriculture, coastal areas, and forestry. In addition, the executive order requested that future impact assessments include a "report on mitigation and adaptation plans to combat these impacts." This report is a preliminary effort to respond to that request. It examines California's capacity to deal with the existing climate variability and assesses opportunities and constraints in preparing for potential future impacts of climate change.

The request for plans to cope with and adapt to the unfolding impacts of climate change opens up a critical opportunity to expand the much-needed discussion on how society should manage the changes ahead. The growing focus on adaptation is thus welcome and timely.

Climate policy has often been presented as a choice between mitigation and adaptation (Tol 2005; Smit et al. 1999; Tol et al. 1998; NAS 1992), where *mitigation* refers to reducing the accumulation of greenhouse gases in the atmosphere and *adaptation* refers to adjusting to the impacts of a warming world through reducing vulnerability and enhancing ecosystems', sectors', and society's resilience in the face of change (see Textbox 1).

**Textbox 1: Definition of Key Concepts and Terms**

**Mitigation**—The reduction of heat-trapping greenhouse gas emissions into the atmosphere.

**Adaptation**—The range of adjustments of the environment or those taken by individuals, organizations, communities, or other entities to deal with the potential or experienced impacts of climate change.

**Vulnerability**—The extent to which a natural or social system is susceptible to sustained damage from weather extremes, climate variability, and change (and other interactive stressors).

**Adaptive Capacity**—The ability of a system to anticipate and adapt to the potential or experienced impacts of climate change. Sometimes equated with and other times distinguished from **Coping Capacity**—the ability of a system to deal with the impacts of present-day weather extremes or climate variability.

**Resilience**—The ability of a system to absorb and rebound from the impacts from weather extremes, climate variability, or change and to continue functioning.

This perception of mitigation and adaptation as alternative or "substitute" responses to global warming evolved in part as a result of the belief that climate change was primarily a problem of the future with impacts resulting from slow, gradual, and highly uncertain processes (Figure 1). This dichotomous paradigm is currently being replaced in the policy and research communities by a perspective that views them instead as complementary. Research efforts focus on delineating how mitigation and adaptation efforts can be employed synergistically, or at least

implemented in a way that they do not counteract each other or produce negative ancillary effects and costly trade-offs (Klein et al. 2005; Tol 2005; Wilbanks 2005; Wilbanks et al. 2003; Kane and Shogren 2000).

Figure 1 (a) depicts mitigation and adaptation as an either/or choice, where the reduction of impacts can be achieved either through mitigation or through adaptation. This framing is now recognized as misleading because mitigation of current emissions will have no effect on near-term impacts that result from the time-delayed changes in climate resulting from past emissions. Figure 1 (b) represents the more accurate understanding that coping and adaptation are needed to deal with the unavoidable impacts in the near term, while mitigation is needed to prevent further, more severe impacts in the future.

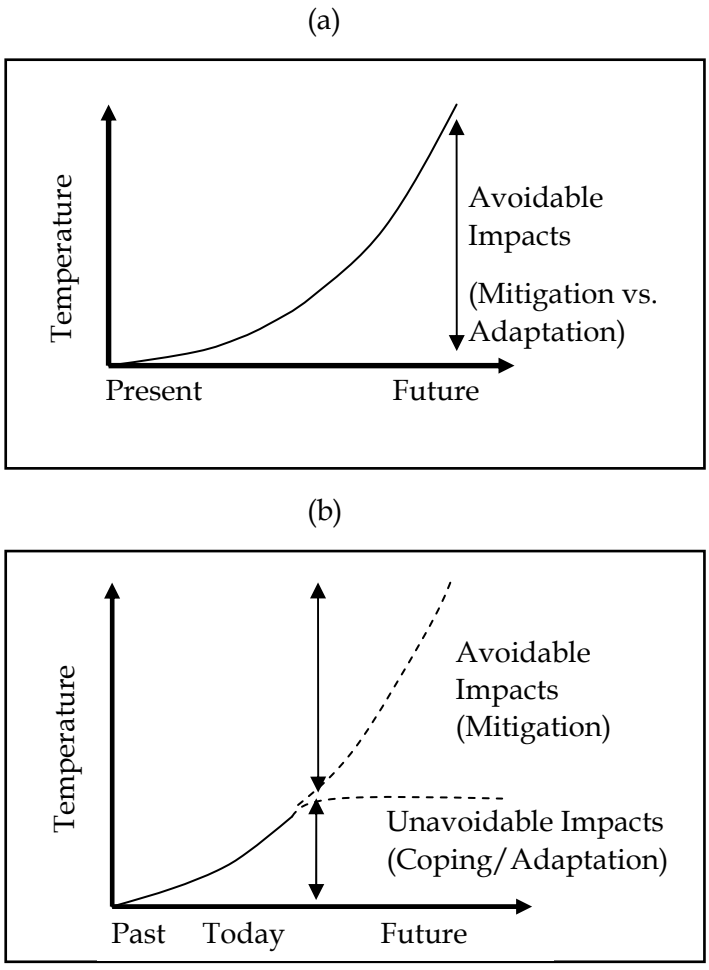



**Figure 1: Alternative framings of societal response options to climate change**

California's response to climate change is thus not a simple choice between mitigating greenhouse gas emissions and adapting to the impacts of climate change. Adaptation— while it is not the ultimate solution—is a necessity because climate change is demonstrably underway, the first impacts are already being observed, and further impacts over the next 30 years are unavoidable due to the emissions already released into the atmosphere and the time lag in the climate system. At the same time, the state's long-term ability to cope with climate impacts depends on the pace and magnitude of global climate change. These facts make adaptation and mitigation necessary complementary strategies to deal with climate change, and the state must determine the portfolio of solutions that can best minimize potential risks and maximize potential benefits.

**Key Finding #1:** California's response to climate change is not a simple choice between mitigating greenhouse gas emissions and adapting to the impacts of climate change. Adaptation and mitigation are necessary complementary strategies for managing climate change. The state must determine the portfolio of solutions that will best minimize its potential risks and maximize its potential benefits.

This report does not focus on mitigation but begins to examine the many opportunities for enhancing California's adaptive capacity and resilience in the face of change. It highlights the ways in which the ability to cope and adapt is differentiated across populations, economic sectors, and regions within the state. The state has the opportunity, and some would argue the responsibility, to focus its attention and resources in ways that ensure and enhance "environmental justice" while fostering California's adaptive capacity to climate change and other interactive stressors.

This paper offers a summary of the insights from the extant literature on adaptation and provides examples from selected sectors in California to illuminate the opportunities and constraints—and in some cases, limits—to the ability to adapt to climate change. Examples are drawn primarily from water, coastal, and fire management sectors based on the authors' expertise. Future work should examine these and other sectors more thoroughly.

Section 2 argues that it is necessary to pay critical attention to preparedness and the ability to adapt to climate change now. Opportunities for and constraints on adaptation, including the differential ability to cope with climate change across the state, are discussed in Section 3. The paper concludes with recommendations for government, research, and civil society.

## 2.0 A Critical Time to Look at Adaptation

### 2.1 Present-Day Vulnerabilities and Unavoidable Impacts in the Near Term

In times of disaster the vulnerabilities of society are revealed. In recent years, the western United States has experienced extended droughts, putting significant strain on the region's and California's water management systems and imposing severe restrictions on agriculture. Similarly, the El Niños of 1987, 1992, and 1997 are still "marker events" in the memory of many Californians for the havoc they created along the state's coastline. These events not only strained the emergency response capabilities and caused significant economic damage to private and public property, but also exposed the risky implications of past management, planning, and development decisions.

While none of these events can be attributed to human-induced global warming, their devastating impacts raise serious questions about society's vulnerability to, and its ability, willingness, and preparedness to cope with, climate variability and change.[1]

As local, regional, and international communities work toward slowing the rate of warming through the reduction of greenhouse gas emissions, global climate continues to change in response to the emissions already released to the atmosphere from human activities in the past. It is now evident that even if actions could be taken immediately to dramatically curtail the global emissions of greenhouse gases, the inertia of the Earth's climate system is such that 0.5°C (0.9°F) or more of additional warming would still occur (Hansen et al. 2005; Meehl et al. 2005; Wigley 2005). This suggests that a global, concerted effort is needed to curtail emissions and thus slow down human-induced global warming. At the same time, society has to increasingly focus on enhancing its capacity to cope with the already-occurring and unavoidable impacts that we will experience over the next few decades, no matter what emission-reducing steps will be taken.

Empirical observation and scientific analyses of historical trends in climatic and ecological indicators in California are consistent with global trends and with the early impacts expected from global warming: temperatures are increasing, precipitation patterns are changing, plants and animal species are responding already to these climate changes (Table 1). These early impacts and trends in California and elsewhere in the U.S. and the world (for additional examples see CEC 2005; Parmesan and Galbraith 2004; Smith and Galbraith 2003) serve to underscore the need for the state to begin examining its ability to adapt to climate variability and change.

1. The term "climate variability and change" is used in this report as it is commonly used in the adaptation literature (even if that usage is not precise from a physical science perspective). It includes phenomena at various temporal and spatial scales such as individual weather extremes; seasonal, interannual, and multi-decadal climate variability; and long-term climate change.

**Table 1: Selected trends in indicators of climate change and observed impacts in California**

| Indicator | Region | Trend | Number of Years Observed | Reference |
|---|---|---|---|---|
| Winter temperature | Statewide | 0.6° C (1.1°F) increase per decade between 1950–1997 | 47 | Mote et al. 2005 |
| Snow pack | High-elevation Sierra Nevada | 20%–80% increase (1997 relative to 1950) | 47 | Mote et al. 2005 |
| Snow pack | Low-elevation Sierra Nevada | 20%–80% decrease (1997 relative to 1950) | 47 | Mote et al. 2005 |
| Glaciated area | Lyell Glacier, Sierra Nevada | 30%–70% decrease (since 1883) | 120 | Basagic and Fountain 2005 |
| Spring stream flow pulse | Statewide | 10–30 days earlier (1948–2002) | 54 | Stewart et al. 2005 |
| Lilac bloom date | Western U.S. | 7.5 days earlier (1957–1994) | 38 | Cayan et al. 2001 |
| Honeysuckle bloom date | Western U.S. | 10 days earlier (1957–1994) | 27 | Cayan et al. 2001 |
| Species composition in rocky intertidal communities | Southern Monterey Bay | 0.79°C (~1°F) warming of near-shore ocean temps (since 1931–1933), southern species increasing, native northern species declining | 60 | Sagarin et al. 1999 |
| Edith's Checkerspot Butterfly | Statewide | Northward and upward shifts in species range (observation period: ~1962 to 1992–1996) | 30+ | Parmesan 1996 |
| Sachem Skipper Butterfly | Statewide | Northward range expansion (observation period: 1965–1999) | 35 | Crozier 2003 |
| Total annual number of fish species | Southern California | Decline of cold-water species, increase of warm-water species (observation period: 1960–1995) | 25 | Holbrook et al. 1997 |

Studies that project future climate and its impacts on California and the western United States suggest that even modest climate warming will exacerbate these already-observed changes. For example, the most recent projections for California indicate continued warming in the state over the 21st century but the rate of warming depends on the amount of greenhouse gas emissions

(Hayhoe et al. 2004). Of particular concern are potential impacts on California's water supply, human health, coastal areas, and natural (unmanaged) ecosystems, as well as on agriculture, forestry (including related fire management), and the energy sector, which are highly sensitive to changes in temperature and water availability.[2]

In addition to the expected changes in average temperature and precipitation, changes in climate variability are also of significant concern. In fact, changes in climatic extremes have already been observed (e.g., more extreme rainfall and heat events; see Karl and Knight 1998) and—while scientifically more uncertain than changes in average temperature—numerous studies expect variability to increase further in the future (IPCC 2001b; Easterling et al. 2000). Changes in regionally important interannual climate variability related to the El Niño—Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO), for example, which can produce major strains in climate-sensitive sectors, remain the subject of debate in the scientific community at this time, but would be critically important to California.

In summary, human-induced climate change is underway, early impacts are already evident, further impacts over the next few decades are unavoidable, and projections of future change suggest growing challenges from global warming to California. The state therefore must confront the need to adapt while recognizing and addressing the constraints or limits on adaptation over the long term.

## 2.2 The Risk of Major Climate Shifts and Abrupt Changes in the Future

The estimates of societal benefits of expending scarce resources today to mitigate uncertain future climate change depend considerably on the assumptions about the sensitivity of the climate system to greenhouse gas emissions, i.e., on the estimated warming resulting from a doubling (compared to pre-industrial levels) of carbon dioxide ($CO_2$) concentrations in the atmosphere. While the consensus estimate of mean climate sensitivity remains on the order of 2°C–3°C (3.6°F–5.4°F) (Kerr 2004), it is now recognized that the distribution of this uncertain quantity may have greater weight in its upper tail than previously assumed (Andronova and Schlesinger 2001; Allen and Ingram 2002; Gregory et al. 2002; Knutti et al. 2002; Webster et al. 2003; Stainforth et al. 2005). This heavier emphasis on the upper end of the probability distribution implies an increased likelihood that the upper bound of the change in global mean temperature from a doubling of atmospheric $CO_2$ concentration may be considerably higher than previously estimated. This also entails an upward revision of the upper bound on estimated potential damages. In other words, society's gamble to *not* invest in mitigation, and/or to *not* invest in avoiding potentially more severe climate change, is now believed to be a worse bet than previously thought.

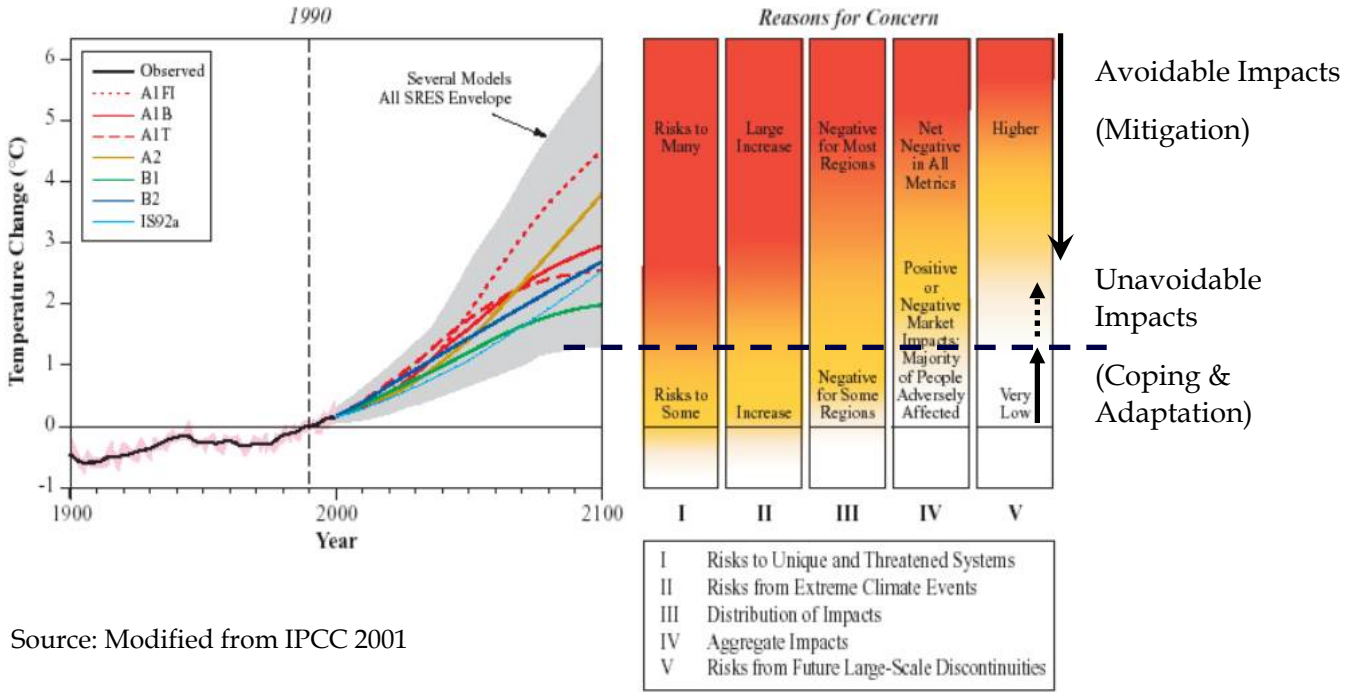
Furthermore, although there remains much uncertainty around the specific impacts of climate change, it is important to remember that embedded in this uncertainty is the possibility of

2. For updated impact assessments on these sectors and extensive reviews of the relevant literature, see the companion PIER white papers prepared for Energy Commission/CalEPA by other research teams for the Governor's Scenarios Report.

catastrophic change (Schneider and Azar 2001; Mastrandrea and Schneider 2004; Schneider 2004). In fact, the complex dynamics of the climate system imply that significant changes should be expected in the long term as a result of gradual changes: Paleo-climatic evidence demonstrates that very rapid shifts in the climate regime have occurred in the past, and it is now recognized that such "nonlinearities" might recur as a result of anthropogenic greenhouse gas emissions (e.g., NAS 2002; Overpeck et al. 2005). The potential collapse of the North Atlantic Thermohaline Circulation is perhaps the best-known example, but the rapid melting of the Greenland ice sheet and other possibilities of abrupt climate change abound.

Figure 2 highlights the urgency of both emissions abatement and adaptation by illustrating the growing severity and potential nonlinearity of impacts from rising temperatures.

Due to the long residence time of heat-trapping greenhouse gases in the atmosphere and the long time lags in the climate (and related complex Earth) systems, some impacts from past emissions can not be avoided. Adaptation to these impacts is an unavoidable necessity. For the same reason (time lags), and because of unpredictable but imaginable surprise responses of the climate system to large and rapid greenhouse gas forcing, mitigation must begin now to avoid "dangerous interference in the climate system," i.e., major and widespread aggregate ecological and socioeconomic impacts and the possibility of large-scale discontinuities.




Source: Modified from IPCC 2001

**Figure 2: Managing impacts of climate change through mitigation and adaptation**

**Key Finding #2:** 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.

### 2.3 The Missing Debate about "Adaptation in the Real World"

Although adaptation has increasingly gained attention in the international global environmental change research and policy communities (see, e.g., summaries of the research in IPCC 2001b, or the adaptation-related goals in the UN Framework Convention on Climate Change, United Nations 1992), U.S. public discourse of the need and options for, and possible constraints on, adapting to climate change remains limited. The limited discussion by the American public is in large part due to the fact that climate policy is dominated by two groups.

On one side, there are those who continue to deny and actively question the reality of climate change. They further believe that even if climate change were to become a problem in the future, Americans would be able to adapt and that therefore there is no need to take action now either to prepare or to mitigate (see, e.g., the discussion in Kates 1997). The view that the United States can cope with whatever climate change may bring has remained largely unquestioned to date, maybe in part because of a confusion between *adaptive capacity* in a general sense (e.g., as indicated by a high GDP or average per capita income) and the *realization of that capacity* in real action in specific places.

More recently, some have tried to substantiate the idea that human systems have almost unlimited capacity to adapt to change[3] but not the financial resources to invest in major mitigation efforts (e.g., Goklany 2000, 2005). These typically very coarse-scale economic assessments compare the relative benefits of expending resources on economy-wide mitigation versus adaptation in a small number of selected sectors, arguing that spending money on economic development and adaptation should be the exclusive response to climate change, especially in the near term. These assessments do not examine the full range of costs economy-wide, nor do they explore the implementation challenges of adaptation "on the ground." Moreover, they only focus on human systems, not the natural environment on which humans depend. Ecological impact assessments have reiterated repeatedly that natural and unmanaged species and ecosystems are unlikely to be able to adapt as global warming accelerates (e.g., IPCC 2001b; Schneider and Root 2002) or to provide indefinitely the wealth of ecosystem services that support life and human well-being as stresses on ecosystems continue to increase (e.g., Millennium Ecosystem Assessment 2005).

3. This belief is being challenged increasingly in the scientific literature through theoretical and empirical studies (e.g., Moser 2005; Tompkins and Adger 2005).

Another important reason for the limited public debate about adaptation has been the influence of those, including in the environmental advocacy community, who would rather avoid talking about adaptation because of a concern that it would distract from the need for mitigation, or because doing so would be perceived as defeatist (e.g., Burton 1994). In addition, because of the close linkage between poverty and economic marginality on the one hand and the limited ability to cope with weather extremes, climate variability, and change on the other, the scientific community has focused most of its attention on questions of adaptation on the poorest and most vulnerable in developing countries. This, too, is beginning to change (e.g., CBCF 2004). The combination of all these reasons may help explain why the media have been largely silent on the topic of adaptation as well. Thus, adaptation has not yet emerged in California and in the United States more generally as a legitimate and needed subject for public and policy debate, leaving Americans ill-prepared for the complex challenges already existing today and waiting ahead.

**Key Finding #3:** Adaptation is being addressed by the international community and largely ignored within the U.S. A deeper discussion is needed about the costs and challenges of adaptation in California and elsewhere in the U.S.

## 3.0 Opportunities and Constraints in Adapting to Climate Variability and Change

If the need for adaptation is taken seriously at the local, state, national, and international levels, questions arise as to what can be done and through which institutional mechanisms we should prepare for the unavoidable and uncertain future impacts, how that can be done most cost-effectively, and how it should be done to minimize the negative social and environmental side effects. Answers need to be found in the context of not just climate variability and change, but multiple stressors (Section 3.1).

Fortunately, as will be illustrated with examples below, many opportunities exist to decrease society's vulnerability to current weather extremes and climate variability; for example, by making coastal and floodplain development more storm resistant, improving warning systems for heat extremes, and so on (for additional discussion and examples see Section 3.2). Such measures will go a considerable way toward increasing society's resilience in the face of change. A growing body of research shows that proactive measures to address climate change impacts prove more cost-effective and efficient than reactive (i.e., post-impact or post-disaster) measures (e.g., Schneider et al. 2000; Easterling et al. 2004). With conscious planning, such measures can be realized in the course of numerous short-term operational and longer-term strategic planning and management decisions (Paavola and Adger 2002).

For example, so-called no-regrets (albeit not necessarily cost-free) measures and policies include actions that are already justified by current climatic conditions but may have even greater value when changes in climate are considered, or actions that can be justified as protection against future climate change impacts but which already produce environmental and social benefits today. For example, improved water conservation measures can alleviate water shortages in dry years under current climate; however, water conservation will prove even more valuable as climate change increases pressures on California's water system by diminishing supply and increasing demand (for additional examples see Wilkinson 2002).

Alternatively, "low-regrets" strategies are those that—in the course of regular infrastructure upgrading and maintenance such as replacement of sewage pipes or long-term development planning and siting—can incorporate "safety buffers," for example, to account for potentially more extreme runoff or higher sea levels without incurring huge additional costs at the time of the upgrade. In cases where present-day weather extremes and climate variability cause damages, additional opportunities exist during the recovery period to rebuild in ways that are informed by the possibility of future climate change. This paper explores a range of such no- or low-regrets options in Sections 3.3).

It would be wrong to assume, however, that just because many opportunities for preparedness and adaptation exist, that they will all be taken or smoothly implemented. In fact, if one views adaptation to climate (past and current climate variability and change) as an ongoing part of the human-environment relationship (Burton et al. 1993; Lamb 1982), and acknowledges the multi-billion dollar impacts that weather- and climate events have on society worldwide today, then this point becomes painfully evident. Adaptation—whether planned or unplanned, or undertaken in the private or public sector—is imperfect (i.e., measures are not always perfectly timed, efficiently implemented, or wholly adopted because of a variety of constraints and barriers as discussed in Section 3.4). Moreover, what may appear as the most reasonable pathway to adaptation may sometimes be completely avoided or can generate social injustices

and negative ecological ancillary effects (Section 3.5). Thus significant efforts need to be made to improve forward thinking and to prevent maladaptations (e.g., Schneider et al. 2000; West and Dowlatabadi 1998). Clearly, as illustrated by this study's case examples, effective adaptation takes time and committed staff and resources.

Finally, there are limits to adaptation, especially in addressing the threats of abrupt climate changes or in dealing with those to natural, unmanaged species and ecosystems, which may or may not be able to keep up with the increasingly rapid and severe climate change expected in future decades. These constraints and limitations illustrate why reliance on adaptation alone is misplaced and why mitigation must remain an indispensable part of the response portfolio required to reduce the threats from unanticipated or rapid climatic changes.

## 3.1 Climate in the Context of Multiple Other Stressors

The effects of climate variability and change are not experienced in isolation. For example, while a drought may cause severe challenges to agricultural production, other forces such as population pressures, price fluctuations, market competition, and technological innovation interact to determine how severely farmers may experience the drought and their options for responding to it. Other natural and social systems may be subject to stresses such as economic downturns, degradation in air and water quality, urbanization, or disease. For example, population growth and increasing development in the wildland-urban interface are believed to be increasing the risk of wildfires in many regions (Cova 2005; Fried et al. 2004). Climate change is expected to exacerbate these problems by increasing the severity and frequency of fire hazards (Fried et al. 2005; Lenihan et al. 2003; Brown et al. 2005). As a result, because climate pressures cannot be substantially minimized over the short term, there is increased incentive to reduce non-climatic pressures as a way to decrease vulnerability to climatic extremes. In the case of wildfire management, this might include creating zoning laws that limit development in high-risk regions (Cova 2005).

These examples illustrate a growing recognition in the scientific literature of the importance of viewing climate change within the context of multiple interacting stresses (e.g., IPCC 2001b; Turner et al. 2003; O'Brien et al. 2004; O'Brien and Leichenko 2000, 2003). Climate change adds to these pressures and will likely exacerbate many existing ecosystem and resource management concerns as well as health and economic risks (e.g., Smith and Galbraith 2003). Thus, programs that set out to enhance society's capacity to cope with climate variability and change must recognize that climate is just one of many challenges that communities, industry, resource managers, and regional planners must manage. In fact, in many cases, climate risks might rank low on the list of concerns or may not be a conscious element in management at all—as this study's empirical work with California's coastal and fire managers illustrated. Changes in population, economic development, federal and state policies, technology, and social values may be more important determinants of water supply or coastal management than climate-related stresses over the next few decades (see also IPCC 1996; Fredrick and Gleick 1999). Although even in the short term, climate is likely to aggravate conditions, the multi-stressor context highlights the need to integrate, or "mainstream," climate risk into ongoing decision and management processes.

Integrated resource management approaches provide a useful framework from which to build capacity to cope with current climate variability and to adapt to climate change within the context of multiple stresses. For example, integrated water resources management approaches have shown promise for balancing multiple and changing demands for water and other resources (IPCC 2001b). Such integrated water resource management plans seek "to ensure the coordinated development and management of water, land, and related resources by maximizing economic and social welfare without compromising the sustainability of vital ecosystems" (Agenda 21, 1992).[4] It is encouraging to note that California's Water Plan calls for the creation of incentives to support integrated water resource management (CA Draft Water Plan 2005). The following sections explore additional opportunities to enhance coping and adaptive capacity in the state.

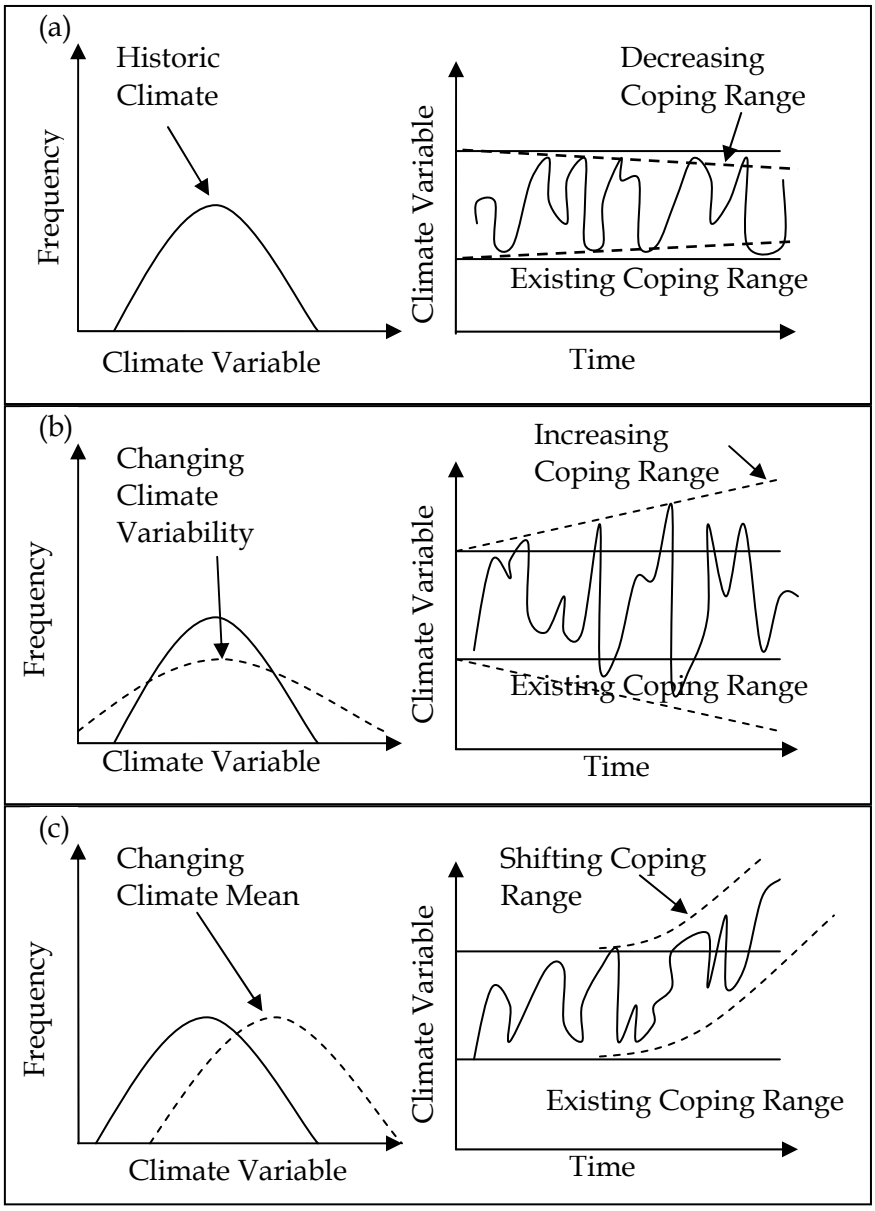
### 3.2 Building Coping Capacity to Deal with Current Climate Variability

California society and state economy have evolved over time to live with and take advantage of the state's diverse climatic zones and environmental conditions. The economies of the warm coastal regions of Southern Californian thrive on beach-going residents and tourists. In the moderate climatic region of the Napa Valley, the climate-sensitive wine industry has grown as the foundation of the local economy. And in the snow-rich Sierra Nevada, an important part of the economy has evolved around the climate-sensitive ski industry. Each of these regions has developed strategies to cope with climatic conditions that deviate from the mean, such as weather that is unusually hot, cold, wet, or dry. For example, in extremely hot years, vineyards in the Napa Valley often harvest early so as to avoid over-ripening (Cahill, personal communication). In unusually dry years, the ski resorts in the Sierra rely on snow-making equipment. However, each sector's ability to cope is often confined within a certain range of climatic conditions. This range is referred to as the "coping range" (Smit and Pilifosova 2003), as illustrated in Figure 3.

The panels on the left of Figure 3 illustrate the frequency distribution of a given climate variable such as temperature, precipitation, or drought. The panels on the right represent the coping range and variability of the climate variable over time. Solid lines represent existing conditions and dashed lines represent changing conditions.

To cope with its historical climate and climate variability, California has constructed reservoirs, built levees, and developed information networks and hazard warning and emergency response systems. The water rights system in the state—established after settlement—may not have been designed with historical climate averages and variability in mind, but has functioned reasonably well within those climatic parameters. These structural, institutional, financial, and legal mechanisms along with social capital and cultural norms all contribute to a society's "coping capacity" or "coping range" (e.g., Adger 2003; Brooks et al. 2005; Haddad 2005; Pelling and High 2005; Tompkins and Adger 2005).

4. Agenda 21, agreed upon at the Rio Earth Summit in 1992, called on all countries to introduce national strategies for sustainable development. See http://www.un.org/esa/sustdev/documents/agenda21/english/Agenda21.pdf.




Source: Graphic representation based on Smit and Pilifosova 2003; Burton et al. 1993

**Figure 3: Changing coping ranges**

Many of these customary coping strategies could be enhanced to widen the range of climate conditions that Californians can deal with without major harm. For example, heat/health watch and warning systems, cool-off spaces, and wider penetration of air conditioning in all homes and public buildings could help residents deal more effectively with heat waves (Kalkstein 2003). At the same time, increased use of air conditioning would increase energy demand during the hottest period of the year, increase the urban heat island effect, and—depending on the energy source—could actually increase greenhouse gas emissions.

However, a number of the coping strategies historically employed are coming under increasing pressure from multiple non-climatic stresses that may make them less effective over time. For example, water storage capacity behind dams is declining as that storage space fills up with sediment, and levees in the Sacramento–San Joaquin region will protect the land behind them less effectively from future coastal storms as average sea level rises. The result is that certain regions, sectors, and populations are becoming more vulnerable to climate variability and change.

To reduce these growing vulnerabilities, California will need to make adjustments to maintain or even strengthen current coping capacity. Sections 3.3 and 3.4 draw from the growing literature on coping with, and adapting to, climatic change to develop a framework that can help California identify and implement proactive strategies to build its resilience to climate variability and change by strengthening coping capacity and preparing for change (Textbox 2).

**Key Finding #4:** To enhance Californians' preparedness for climate variability and change, decision-makers in the private and public sectors require greater *awareness* of the risks they face, increased capacity to *analyze* such information and use it in decision-making, and the ability to remove any institutional, financial, political, and other barriers in the way of turning good intentions into *actions*.

**Textbox 2: Awareness—Analysis—Action: The AAA of Adaptation**

To enhance society's preparedness for climate variability and change, decision-makers—be they in the private or the public sector—first need to become aware of the potential impacts and risks, and how these risks may affect them personally and collectively, or their specific business or management responsibilities. This *awareness* needs to be coupled with a fuller understanding and the capacity to *analyze* such information. This can provide the necessary motivation and willingness to act. Moreover, decision-makers need to have the ability to use this understanding in decision-making, i.e., to translate their awareness and concern into concrete *actions*. Typically, the latter step involves removing institutional and other barriers that can prevent realization of well-intended policies and plans.

A decision-maker with the motivation and political will to act on climate variability and change may be able to translate such intent directly into a decision and action, or he or she may be in a position to design policy or guidance which then is implemented by others (this is frequently the case in the public sector where policies at the federal or state level must be implemented at the local level). At each level, awareness, analytic capacity, and the ability to act must be met in order for implementation to actually occur.

The United Kingdom Climate Impacts Group (UKCIP) has provided guidance to local authorities to prepare for climate change (UKCIP 2003), which in many ways follows this awareness-analysis-action approach. As outlined by Brooks et al. (2004), UKCIP encourages local authorities to ask the following questions (here grouped into the AAA framework):

**Awareness**

- Do you know how climate change could impact your area?

**Analysis**

- Can you identify and assess the risks from climate change to your services?

**Action**

- Do your current policies, strategies, and plans include provisions for the impacts of climate change?
- Are developments with a lifetime of more than 20 years required to factor in climate change?
- Does your Emergency Planning Service take into account climate change?
- Are you addressing climate change in your local community strategy or community plan?
- Have you briefed your elected members on any key risks arising from climate variability and long-term climate change?

A similar assessment by California's private industry managers and public administrators would provide a helpful baseline from which to build institutional capacity.

For example, an initial survey of wildfire managers in Southern California indicates a moderate level of awareness of climate change as an issue, but little knowledge of specific analyses of the implications climate change might have on the intensity and frequency of California wildfires (Figure 4). While many officials interviewed believed that more analysis should be done to understand the potential effects of climate change on wildfire, many also acknowledge that wildfire management is currently challenged with more urgent issues such as development pressures, financial constraints, and interagency coordination.

**Textbox 3: Survey of Wildfire Specialists**

The need to actively promote awareness, analysis, and action is illustrated by an initial survey of wildfire managers in Southern California. This survey indicated a moderate level of awareness of climate change as an issue, but little knowledge of specific analyses on the implications climate change might have on the intensity and frequency of California wildfires (Figure 4). While many officials interviewed believed that more analysis should be done to understand the potential effects of climate change on wildfire, many also acknowledged that wildfire management is currently challenged with more pressing issues such as development pressures, financial constraints, and interagency coordination.

The results presented here are from a formal survey of 45 wildfire specialists from San Diego, San Bernardino, Riverside, and Los Angeles Counties. Individuals were asked to rank the level of awareness in their organization of climate change, the level of relevant analysis that has been conducted regarding climate change impacts on wildfires, and the level of action taken to address climate change in their department. Individuals were also asked if they thought additional analysis of the local implications of climate and wildfire was needed and if they thought additional actions were needed to prepare for wildfires in light of the changing climate.

It is important to note that preparing for climate variability may or may not suffice to deal with climate change, depending on the nature of the future climate regime and associated environmental and social conditions. For example, a sustained program of brush clearance around development will help mitigate fire risk now and in the future, but the frequency and spatial extent of clearance operations may need to be adjusted based on vegetation changes, drought frequencies, and future development patterns. Thus, plans to deal with climate variability need to be assessed on a regular basis to make further adjustments on an "as needed" basis.

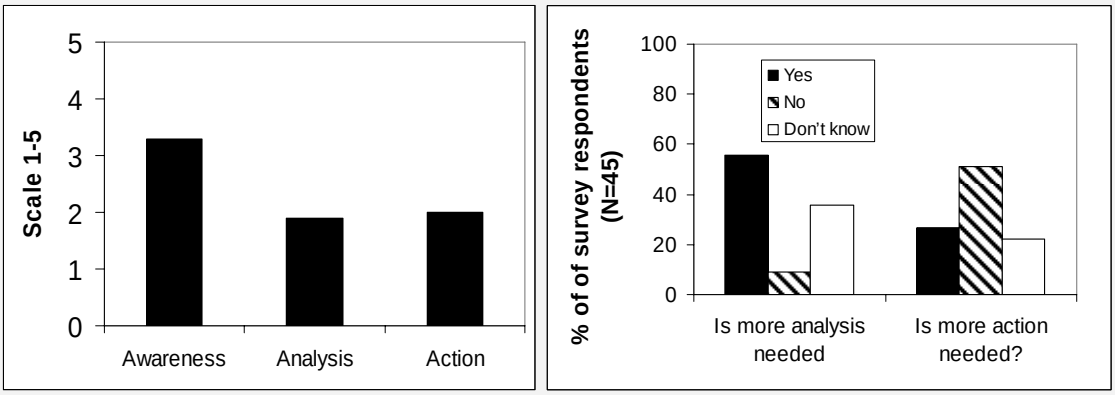



**Figure 4: Preliminary assessment of fire managers' awareness and actions related to climate change in Southern California**

### 3.3 Building Adaptive Capacity and Resilience in Light of Climate Change

Building adaptive capacity essentially means broadening the range of options for proactively or reactively reducing society's vulnerability and increasing resilience to climate change.

Building resilience to climate change over the medium term will require more than reducing vulnerability and increasing capacity to cope with current climate variability. Human-induced changes in the climate system will likely be experienced in several ways: environmental and societal impacts can be stimulated by (1) *gradual changes* in average meteorological variables such as temperature and precipitation, (2) *more frequent and/or more intense climatic extremes*, and (3) climatic or other environmental and societal changes that amount to a "*regime shift*," i.e., changes that are so large or different in nature that society has no relevant historical experience or institutional mechanisms for handling them.[5]

All three types of changes—if sufficiently large—can move society outside its experienced coping range (see Figure 3 above). For example, water resource management in California currently depends heavily on snow melt for its water supply. However, over the next few decades, spring snow pack in the Sierra Nevada is expected to decline by 30%-40% (Hayhoe et al. 2004; see also Mote et al. 2005; Dettinger et al. 2004; Kiparski and Gleick 2003, 2004; Stewart et al. 2004; Miller et al. 2003; Kim et al. 2002). Adjusting to such substantial loss in surface water storage in a sustainable manner will require considerable forward-looking investment and planning.

Over the last decade, the global change research community has focused on understanding the causal structure of vulnerability and identifying strategies to enhance resilience of communities within the context of climate variability and change (Turner et al. 2003; Handmer et al. 1999; IPCC 2001b). *Vulnerability*, defined by Working Group II of the IPCC (2001a) as the extent to which a natural or social system is susceptible to damage from climate change (see Textbox 1), is often characterized as a function of the system's *sensitivity* and *exposure* to changes in climate and its *capacity to adjust or absorb* the impacts created by a given change in climate. Thus, reducing vulnerability or enhancing resilience to climatic stress requires actions that either reduce a system's sensitivity and exposure or enhance its capacity to respond more quickly and recover more effectively from the effects of climate and interactive stressors.

A growing body of literature offers insight into how specific regions or populations cope with climatic extremes, the conditions that promote or constrain the capacity to cope, and the relative effectiveness of specific coping strategies (e.g., Bohle et al. 1994; Kelly and Adger 2000; Adger et al. 2005; Smit et al. 2001). This literature builds on the theoretical frameworks of three distinct areas of study—food security, risk and hazard management, and ecological resilience—to identify general and specific determinants of adaptive or coping capacity (Brooks et al. 2005). Below, this paper briefly reviews a number of these strategies and mechanisms for enhancing adaptive capacity to climate change (drawing on Tompkins and Adger 2005; Brooks et al. 2005; Easterling et al. 2004; Folke et al. 2002; Klein and Tol 1997; Lambin 2005). It gives a general overview of the basic points of intervention and provide examples from climate-sensitive sectors in California.

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5. One could imagine a case, for example, where climate changes are not particularly severe, but society's ability to cope has drastically diminished – e.g., a substantial decline of the health care system, a collapse of the insurance industry, or a significant reduction in federal disaster aid. Such non-climatic changes, too, could produce a "regime shift" with a much diminished coping range when faced with the impacts of climate change.

### 3.3.1 Possible strategies

A number of strategies—enacted at different levels of government or by various actors in the private sector—can facilitate preparation for, and adaptation to, the unavoidable impacts from climate changes over the next few decades. Many of these strategies will not solely address climate risks, but serve multiple environmental, social, or economic goals. They include, but are not limited to, the areas discussed below.

#### 3.3.1.1 Enabling the development and application of technologies

The availability of technologies is a critical component of enhanced response capacity in many climate-sensitive sectors (Tompkins and Adger 2005). One example is human health. California currently does not have any heat warning systems (Kalkstein 2003; Sheridan and Kalkstein 1998). A number of technological and institutional advances could enhance the state's ability to deal with the projected increase in heat extremes (Hayhoe et al. 2004), including greater forecasting capability of heat waves and extremes spreading such information in a timely fashion to Californians in affected regions (especially to the most vulnerable populations such as the elderly, the young, and the infirm), communicating in languages other than English, alerting health care providers, mobilizing relevant response systems, and ensuring adequate supplies of clean electricity to power air conditioners.

#### 3.3.1.2 Enhancing institutional flexibility

As climate changes, patterns of extreme events are shifting in yet-difficult-to-predict ways. This uncertainty is aggravated by the incomplete understanding of how social and ecological systems will respond to climate variability and change. Furthermore, even when individuals have the knowledge and inclination to change, organizational and institutional barriers can often prevent the implementation of many needed changes (Lach et al. 2005). As a result, a critical component of climate change adaptation must be increasing institutional flexibility so that planners and managers are able to deal with uncertainty and expect surprise more readily (Bazerman and Watkins 2004; Brooks 1986; Gallopin 2002; Glantz et al. 1998; Janssen 2002; Kates 1985; Kates and Clark 1996).

Greater institutional flexibility can enhance the capacity to manage uncertainty and respond to surprise (Gleick et al. 2002; Easterling et al. 2004; Berkes and Jolly 2001; Fredrick and Gleick 1999). For example, water markets may be an important proactive coping response as they may increase flexibility of water allocation to accommodate a wider range of climate conditions (Kiparski and Gleick 2004). However, while water markets provide opportunities, clear market guidelines must be provided to ensure equitable access, protect the environment, and ensure transparency (Gleick et al. 2002). Deliberate attempts to assess and learn from management "experiments" (adaptive management) will be facilitated by flexible institutional mechanisms and as such can also be critical for promoting social learning (Gunderson 1999).

#### 3.3.1.3 Providing financial resources

Financial resources to deal with the impacts of climate change are strained at the federal, state, and local levels. National and state-level debts, competing demands and priorities, and unfunded mandates are just some of the reasons why many managers and policy-makers resist taking on yet another issue, especially one as big as climate change. It is precisely for this reason

that *proactive* climate change management—shown to be more cost-effective than *reactive* measures—should be promoted more forcefully.

Financial incentives from federal or state sources to assess community preparedness, for example, have proven important mechanisms to mobilizing action (e.g., Moser 2005). While sometimes challenging to realize, communities have found creative financing mechanisms (e.g., bonds) to invest in activities that have longer returns, but help protect or enhance their assets. For example, gradual land-use changes can lead to habitat fragmentation that can limit some species' ability to migrate and adapt to climate change (Parmesan and Galbraith 2004). However, land-use and management policies that focus on preserving migration corridors may reduce the risk of extinction of certain populations in fragmented landscapes (Ricketts 2001; Parmesan and Galbraith 2004; Fried et al. 2005) while preserving a highly attractive landscape mosaic that raises the value of adjoining real estate.

#### 3.3.1.4 Changing cultural norms

Cultural norms deeply affect the values, beliefs, expectations, and behaviors of individuals and whole societies. In present-day American society, for example, the right to private property—as codified in the Constitution—is a closely defended cultural value. Many coastal management conflicts, for example, focus on the right of the public (e.g., to the beach, safety) vs. the rights of the individual (e.g., to protection of private property, privacy). These heated conflicts are frequently carried out in the courts, but public forums in which to discuss their implications for long-term coastal management in light of climate change risks are still missing. Nearly a half-century of awareness-raising efforts around the environmental impacts of human activities has affected values, beliefs, and in some cases public policies and individual behaviors. Thus, littering is now generally viewed as "bad," recycling as "good." Similar social norms are only beginning to emerge around climate-relevant behavior.

These examples simply hint at the complex ways in which deeply anchored cultural norms enable or constrain possibilities for responding to climate change. Typically, such norms change only slowly, over the course of generations, but their impact can be profound. They are most easily influenced at a young age through parental, informal, and formal education. As suggested by the frequently cited example of teaching children about recycling, even an intervention directed at the younger generation will influence the thinking and behavior of adults in indirect ways. Such pathways and opportunities may be useful avenues for efforts to facilitate individual behavioral adaptations.

Many debates over the adequacy of scientific knowledge and scientific uncertainties hide underlying differences over values and beliefs. Providing public forums to discuss desirable futures could help redirect such debates to the necessary deeper dialogues over differences in worldviews and norms that guide behaviors and policy decisions.

#### 3.3.1.5 Building social capital

Social capital—loosely defined as informal networks of trustful relationships within an organization, community, or society—is viewed increasingly as a critical determinant of adaptive capacity, even if it is difficult to measure (e.g., Pelling and High 2005; Adger 2003). Communities with greater social capital tend, for example, to more quickly and readily share critical information that might enable them to respond to climate signals, identify relevant

resources, mobilize people, and so on. As the coastal managers interviewed for this study suggested, such information exchange (e.g., across state agencies) has much improved over the past few years, but still heavily depends on individuals. Thus, any efforts that could help develop information and tools that would facilitate information exchange, support adaptive management, foster smooth decision processes, and reward forward-looking planning capabilities would build social capital in the state.

#### 3.3.1.6 Improving science–practice interactions

Adequately and effectively preparing for climate change requires the best available scientific and other information because of and despite the fact that many adaptation decisions will have to be made in the face of persistent uncertainty. More frequent interactions between the science and the policy-making and management communities will facilitate the insertion of such information into decision-making. Frequently still, such science-practice linkages are ad hoc and of inconsistent quality (Vogel et al. forthcoming). Thus, while California is among those states in the union with exceptional scientific capacity, the state may consider providing incentives and more effective mechanisms to establish better science–practice interactions to support and enhance the exchange between providers and users of information.

The Regional Integrated Sciences and Assessments (RISA) centers of the National Oceanographic and Atmospheric Administration have taken impressive steps to improve science-practice interactions. For example, the regional Climate Assessment for the Southwest United States (CLIMAS) is a multiyear project designed to evaluate the vulnerability of the Southwest to climate variability through multiple methods and disciplinary approaches. CLIMAS has used a series of workshops, interviews, and surveys with local experts, decision-makers, and different private-sector groups (e.g., ranchers, water users and managers, forest fire managers) to establish a scientific research agenda corresponding to the specific information needs of these stakeholders. Through these interactions, CLIMAS has formalized communication channels with various stakeholders groups and tailored scientific output to meet local decision-making needs (Bales et al. 2004). CLIMAS researchers argue that the participatory structure of the project is essential for ensuring that the outputs can be and are applied toward the reduction of regional vulnerability to climatic extremes (Lemos and Morehouse 2005).[6]

Improvement in the science–practice interaction are achieved most effectively if approached from both sides. Currently, many resource managers do not use climatic information for their day-to-day responsibilities. Others do use information about current weather and climate but are not required to look toward the future and consider the possibility of a different climate in decisions that will have long-term impacts. In some cases institutional constraints may present barriers to regularly integrating climate information into long-term planning of weather-

5. Note that California, too, hosts a RISA center at Scripps Oceanographic Institution under the guidance of Dr. Dan Cayan. The center currently lacks the human resources and social scientific expertise to conduct outreach similar to that undertaken by CLIMAS (Cayan 2005). This suggests that improvement of science-practice interaction requires committed staff, resources, training, and relevant expertise.

sensitive resources or activities because different people within an organization have responsibility for short-term, tactical planning (weather and current climate) vs. long-term, strategic planning (climate change). Their professional responsibilities may not formally require the use of climate information or long-term planning. For example, coastal managers in California must consider historical sea-level rise when calculating setback distances from the oceanfront, but are not presently required to calculate such setbacks under the assumption of a faster rate of sea-level rise (Textbox 4).

**Textbox 4: Information Needs of California Coastal Managers**

The 1,100 miles (1,770 km) of California coastline are one of the state's major attractors for development, economic activity, tourism, and recreation, and also critically at risk from the combined impacts of climate change. Sea-level rise, changing coastal storms, rainfall and runoff patterns into the coastal ocean, increases in coastal water temperatures, species shifts, and higher temperatures will combine to create unique challenges for coastal managers.

For this preliminary study, key federal, state, and regional governmental decision-makers involved in California coastal management were interviewed to qualitatively explore the state's coping and adaptive capacity. A particular focus was managers' information needs should they begin taking climate change and projections of a higher sea level into account. The study is ongoing and will be complemented with a survey of local-level decision-makers. (A full report of this case study will be prepared separately.)

Responsibilities for coastal management are spread over multiple institutions, including federal and state agencies, state commissions, regional councils, and local government. The latter is principally responsible for implementing laws and development plans. Policy- and decision-makers at federal, state, regional, and local levels are concerned with:

- Development, planning, and supporting diverse economic activity in the coastal zone
- Siting and appropriate construction of homes, businesses, and related infrastructure
- Protection of coastal development and residents from natural hazards such as floods, erosion, cliff failures, earthquakes and tsunamis, fires, etc., including prediction, preparedness, warning, disaster response, and recovery-related responsibilities
- Provision of water, energy, and other infrastructure to coastal dwellers
- Protection of water resources and quality in coastal inland waters and in the coastal ocean
- Provision of recreation areas (e.g., beaches, state parks, and access to open space)
- Protection of habitat and species (e.g., dunes, wetlands, and associated plants and animals, several of them threatened or endangered)

This diversity of responsibilities and underlying goals points to the diversity of needs and the range of opportunities—as well as the potential for conflict—involved in enhancing California's coping/adaptive capacity in the coastal zone.

Moreover, the cross-scale collaboration and integration of management efforts can be challenging. Currently, coastal managers are not required to consider future climate in their planning or management decisions. They typically don't have the time, staff, or financial resources to examine potential impacts of climate change on their management responsibilities. Some are highly knowledgeable about climate change while others are unaware or only marginally knowledgeable about the potential for harm that climate change could bring to coastal California. Most do not use weather-, climate-, or sea level–related information in their decision-making today. Thus, the biggest hurdle to overcome is for coastal managers to consider climate change in their management activities at all.

At the same time, it should not be assumed that awareness or the availability of information alone will solve the management challenges faced in coastal California. (Similar findings have been made in other regions and sectors; see Changnon et al. 1995; Golnaraghi 1997; Pulwarty and Redmond 1997; Callahan et al. 1999; Ray 2003; Cash 2003; Rayner et al. 2002; Jacobs 2002.) The capacity to assess and analyze available information and use it in decision-making and the ability to overcome any institutional, organizational, financial, or political barriers to action are often as or even more important.

To the extent information and awareness are limiting factors, science can play a critical role in filling such information gaps and raising managers' awareness and understanding of climate change risks. More specifically, this study revealed the following information-related needs:

**Specific management-related information needs**

- Translation of projected sea-level rise and changes in coastal ocean and wave climate into shoreline retreat, beach erosion, and bluff retreat rates (this would help determine setback distances from the shoreline or edge of the bluff), expressed for several planning- or project-relevant timeframes (20–25, 50, 75 years)
- Information about potential changes in future coastal storm frequency
- More reliable forecasting of El Niño events, and any changes in the frequency or severity of such events (as they strongly influence the variability in storm frequency), and how these changes would affect the shoreline retreat rates
- Remapping of flood zones under different sea-level rise projections; this would affect siting and construction standard decisions in floodplains and emergency and evacuation plans (improvement of California floodplain maps is already underway under the auspices of the American Technology Council and could be enhanced through consideration of climate change–related changes)
- Information about potential changes in runoff and near-shore coastal and estuarine water temperatures, and exploration of the implications of such changes for water quality, water availability, and aquatic ecology

**Information management and accessibility needs**

- Exchange of information among all coastal states and coastal communities about their responses to climate change–related impacts and risks

- Better collaboration and exchange of relevant information among all involved agencies (at federal, state, and local levels) within California
- Inventory and integration of existing (and additionally developed) information into common formats, e.g., geographic information systems
- Accessibility of integrated databases at various levels of spatial aggregation/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)
- Adequate funding of ongoing monitoring of critical, management-relevant variables

Priority should be given to making information accessible at the level where managers make ultimate decisions.

**Information needs about uncertainty**

- Uncertainty ranges around projections to indicate scientific confidence
- Distinction between more and less likely impacts (e.g., “at-least” sea-level rise vs. “maybe-as-much-as” sea-level rise)
- Scientific basis for uncertainty buffers (e.g., additional setbacks, extra capacity for storm water runoff)

Interviewees suggested, however, that uncertainty per se is not the critical challenge in determining possible responses. Needed instead is a broader debate about the acceptability of individual vs. public risks and how the responsibility in case of impact should be shared.

**Trusted sources of information**

Interviewees suggested that such information must come from trusted sources, but differed in their preferences regarding who should produce it. They expressed underlying concerns over which institution would be most trusted, scientifically credible, and least “political” from the perspective of the information users. Suggested information providers (in no particular order of preference) included:

- Federal Emergency Management Agency (FEMA)
- National Oceanic and Atmospheric Administration (NOAA)
- United States Geological Survey (USGS)
- Scripps Institution of Oceanography (SIO)
- California’s Ocean Protection Council

Ideally, the needed information would not just be “made available”—even in a timely fashion and accessible language and formats—but be conveyed in frequently repeated training sessions to coastal managers who are not yet concerned with climate change. These trainings would help make abstract climate change and generic impacts more “imaginable” through local or regional examples and case studies, and examine the technical, institutional, economic, and social aspects of potential management options.

### 3.3.2 Mainstreaming adaptation into everyday management

*Mainstreaming* adaptation means using or creating mechanisms that allow decision-makers to integrate future climate risks into all relevant ongoing policy interventions, planning, and management. Increasing adaptive capacity involves proactive steps that consider anticipated future risks in current day-to-day decision-making and management, especially where these decisions have long-lived impacts. Such actions would increase the likelihood that infrastructure and other long-term investments will remain robust even under changed climatic and environmental conditions. In fact, they could stimulate innovation and economic growth (e.g., Kabat et al. 2005). For example, coastal land-use planning and decisions over where to site development today requires consideration of how higher sea levels, increased erosion, and potentially increased flooding may affect buildings and infrastructure over the next 70 years. This timeframe would cover the typical life span of new construction. Failing to consider these long-term implications may create difficult-to-manage flooding and erosion hazards, eliminate the possibility for coastal wetlands to migrate inland, and place enormous investments at costly risk.

A related example is hazard management and emergency preparedness. Such plans require periodic update for other reasons than climate change (e.g., population growth, land use change, or infrastructure maintenance). Plan reviews offer the opportunity to reassess whether relevant environmental hazard management and response systems in the state are able to cope with the likely increase in frequency and intensity of extreme climate-related events. Hazard management ranges from preparedness, monitoring, and warning prior to a hazardous event, to disaster response during an extreme event, to risk-sharing mechanisms such as insurance, to the recovery and rebuilding after the disaster. Such hazard management plans need to be specific to the hazard and to the location of where such events might be expected, and must consider future climate projections. For example, preparing adequately for extreme heat events and their potential human health impacts is different under varying climatic projections and over different regions such as large urban areas in northern or southern California versus rural areas in the Central Valley. Relying on historical experience of hazardous events— as is currently common practice—is unlikely to suffice as climate change alters typical frequencies and intensities of extreme events. Future hazard management must thus incorporate climate change in risk calculations. Yet using regularly scheduled or episodically arising opportunities to update and upgrade policies and plans appears to be the "path of least resistance" to enhance California's readiness for climate change. The question is: will it be done?

## 3.4 Constraints on Coping and Adaptive Capacity

Proactive measures to building resilience to climate-related stresses are likely to be more effective if they are designed from a fuller understanding of current coping capacities and what factors limit them. TheAwareness-Analysis-Action framework (see Textbox 2) can provide a systematic way to examine the constraints that could limit the realization of California's significant coping and adaptive capacity.

### 3.4.1 Lack of awareness

As the preliminary findings from the studies of California fire and coastal managers suggest (Textboxes 3 and 4), many of those who would be in charge of implementing adaptation

policies and decisions, especially at the local level, are currently unaware of or unconcerned about climate change, or do not feel that it is their responsibility to address potential impacts in their spheres of responsibility. Both the understanding and the motivation to address climate change were low in many cases.

This finding has to be viewed in the context of a generally still rather low level of active awareness and sophisticated understanding of climate change in the U.S. population (FrameWorks Institute 2001), and also very common "cognitive illusions" or biases against absorbing and understanding uncertain information (Nicholls 1999). These biases tend to make people misjudge the accurate levels of risk, dismiss unfamiliar and insufficiently communicated risks, and believe overconfidently that they are not vulnerable to them.

Moreover, resource managers face countless pressing ongoing and near-term concerns, which for good reason absorb most if not all of their available time, attention, and resources. However, enhancing their ability to manage climate variability today can assist in building resilience for further climate change tomorrow. Thus, by enhancing managers' awareness of future threats and promoting their understanding of how preparedness for future climate change can be built into today's management responsibilities, the ability to cope with current and future climate variability and change can be enhanced. However, significant educational effort is needed along with incentives, staff, and financial resources to motivate resource managers to engage the topic in their day-to-day lives. Because the science of climate change impacts changes rapidly and the problem is long term in nature, it will be difficult to maintain staff knowledge and capacity at high levels. This is made even more difficult by competing and distracting demands on managers' attention, the difficulty of maintaining motivation to act on any long-term problem, high staff turnover, the expected wave of retirements in the near future from many state agencies (McIntosh 2005) which eliminates significant stores of institutional memory, and budget-imposed constraints on hiring, retaining, and training new staff to replace retiring personnel.

### 3.4.2 Insufficient ability to analyze climate-relevant information and use it in decision-making

The ability to understand climate change (impacts) information and link it effectively to management responsibilities and decision processes is a challenge in each of the sectors this project has begun to examine. In part, this linkage is hindered by the fact that scientific output does not easily or directly match the information needs that could inform management decisions (see the need for improved science–practice interactions discussed in Section 3.3.1.6). In part, this is because decision-making varies considerably in the sophistication of tools and information used at present. For example, while sea-level rise projections are valuable as a general indicator to raise awareness of future coastal risks in a general sense, permitting officers who determine setback distances to site new buildings need to know how these projections translate—together with possible changes in storm activity—into future coastal erosion rates. Emergency managers need to know how such future changes affect evacuation needs and routes and would rather look at maps indicating changes in 100- and 500-year flooding risks than at a graphic of average sea-level projections.

As suggested in Textbox 3, many managers would appreciate not just more information, however potentially useful. Several mentioned trainings in how to use such information as an important capacity building strategy for California.

Again, enhancing managers' ability to analyze and use climate-relevant information in their decision-making requires long-term commitment as it involves training and institutional capacity building, including building sustained or even institutionally formalized science–decision-maker interactions or positioning well-trained experts in state and local agencies. Furthermore, managers who have been trained to use climate information must have the professional and institutional latitude to stay abreast of the trends in relevant climate science and climate impacts research.

### 3.4.3 Constraints on action

The constraints on action are basically the opposites of the same factors that—in theory—enhance coping and adaptive capacity: lack of financial resources; technical or technological constraints; institutional constraints and inflexibilities; cultural norms that predispose individuals, communities, or entire societies to short-sighted and maladaptive responses; constraints arising from imbalances in political power or other positioning and delaying tactics; and—importantly—lack of social acceptability of different adaptation options. While the first few factors frequently constrain the motivation to act, the latter few appear to be the ultimate lynchpins of implementation. Even cursory insights from the history of hazard management (most recently illustrated by the devastating impacts from Hurricane Katrina in the Gulf Coast region; see Weichselgartner and Obersteiner 2002; Glantz 2005), or from a review of the implementation of so-called lessons learned after major El Niño events along the U.S. west coast and around the globe (Glantz 2001), strongly suggest that society fails again and again at taking these hard-won lessons to heart and subsequently acting on them.

The empirical research for this report suggests that state policy-makers should be highly skeptical and carefully aware of the practical limitations that decision-makers at all levels face in preparing for the impacts of climate change. Coastal zone managers interviewed for this study, for example, repeatedly mentioned harsh and persistent, and frequently litigious, struggles between interest groups over questions of shoreline protection and development—struggles that absorb crucial financial and staff resources, create political stalemates, and produce a climate of conflict in which long-term visions for the coast would be very difficult to discuss. Moreover, even if coastal communities could resolve legal, technological, and related aesthetic and social acceptability challenges, the question would still remain who—at the federal, state, and local level—could or should pay for shoreline protection and its long-term maintenance.

Likewise, water managers in California are still caught in an arcane system of water rights allocations, and face challenging trade-offs between water supply and flood management—in each case affecting wide areas, critical infrastructure, and important economic sectors.

Large-scale economic and demographic forces drive sprawl and development patterns at the urban-wildland interface, thus creating challenges and legacies for fire managers which are beyond their local ability to control (see Collins 2005). They literally, and other resource managers figuratively, repeatedly speak of being able to focus only on "putting the next fire out" rather than taking the long-term view.

These examples merely begin to shed light in purely qualitative terms on the real-life constraints that make implementation of adaptation options in California not only difficult and conflict-ridden, but quite likely also slow and inefficient, thereby possibly missing cost-effective windows of opportunities when they open. Strong leadership and dedicated commitment for the long haul will be required to overcome or at least lower these hurdles. Importantly, policy-makers at the state and local levels must be aware that California's capacity to cope and adapt is uneven at present, as is the ability to realize that existing potential.

**Key Finding #5:** Many opportunities exist to enhance California's adaptive capacity and resilience in the face of change, even in the absence of perfect foresight about future climatic changes. In fact, California's adaptive capacity—the *ability* to adapt—is significant. However, implementing that capacity into real adaptive actions on the ground is actually quite difficult and requires special attention and long-term commitment at all levels of government, across climate-sensitive industries, and throughout society.

### 3.5 The Differential Ability to Cope and Adapt: Environmental Justice and Climate Change

It is broadly understood that the effects of climate change will not be equally distributed across sectors, populations, and regions (e.g., Tol et al. 2004; IPCC 2001b; Baer et al. 2000; Munasinghe 2000). For example, vulnerability to health effects associated with climate change varies depending on a range of socioeconomic factors including wealth and age (Epstein 1994; Kalkstein 1998; Ebi et al. 2005). Agriculture is another example where large distributional effects are expected (Parry et al. 1999; Easterling 1997). While national assessments of the projected impacts on agriculture and forestry as a whole show little or no change, regional analyses indicate that there will be winners and losers (e.g., O'Brien and Leichenko 2003; CBCF 2004). The most vulnerable regions and communities are those most exposed and sensitive to the effects of climate variability and change and least able to cope with or adapt to these impacts (e.g., Tol et al. 2004; Smit et al. 2001).

Of particular concern are the potential social equity implications of climate change (e.g., Tol et al. 2004; Brown 2003; Paavola and Adger 2002; Byrne et al. 1998). Many studies have demonstrated that the poor and people of color in the U.S. and across the globe already face greater health and environmental risks than the society at large (e.g., CBCF 2004; Sagar and Banuri 1999; Williams 1999). For example, Kalkstein and Greene (1997) found that residents within inner cities in the United States, which are disproportionately populated by low-income inhabitants, face a greater risk of heat-related mortality than non–inner city residents. Similarly, McGeehin and Mirabelli (2001) found that the probability of heat-related mortality was twice as high for African Americans as for whites in U.S. urban areas. The increased susceptibility to heat stress in certain populations may be partly attributed to the well-documented differential access to health care resources across racial and socioeconomic classes (Collins et al. 2003; Collins et al. 2002; Doty and Ives 2002), but also to greater exposure (e.g., farm workers unable to escape the heat). For example, African Americans, Hispanics, and Asians are among the populations with the lowest health insurance coverage in the U.S. (Bulatao and Anderson 2004).

Without appropriate actions, climate change will likely aggravate existing inequities within California society and the rest of the United States (CBCF 2004). More research needs to focus on identifying the populations, sectors, and regions within California most vulnerable to climate variability and change. In particular, analysis should focus on the distributional affects across socioeconomic and racial groups. In addition, specific attention must be paid to addressing the needs of already-disadvantaged populations.

**Key Finding #6:** The ability to cope and adapt is differentiated across population, economic sectors, and regions within the state. The state has an opportunity to ensure and enhance "environmental justice" while fostering California's adaptive capacity to climate change and other interactive stressors.

## 4.0 Conclusions and Recommendations

Developing and implementing a plan to effectively manage climate change will require a broad discussion on the needed societal response that involves all levels of government, the private sector, and civic society. Such a discussion should—at a minimum—address the following questions:

- What level of climate change (or risk of change) is society willing to accept (thus also raising questions about the extent of greenhouse gas mitigation)?
- What goals should adaptation achieve, e.g., preserving the status quo, actively managing change toward new conditions, promoting deeper societal changes required for sustainability?
- What is an acceptable level of individual vs. public risk and how should the responsibility in case of impact be shared?
- What are the social justice, environmental, economic, and other trade-offs associated with allocation of scarce resources as more systems come under growing pressure from climate and other stresses?

To fulfill the mandate contained in Governor Schwarzenegger's Executive Order S-3-05 to report on mitigation and adaptation plans to combat climate change impacts, it is necessary to begin with an understanding of the fundamental processes that enhance or constrain the state's ability to cope with, and adapt to, climate change. Many of these factors will be determined by drivers emanating from outside of California—such as global market forces or national framework policies. At the same time, the state has a tremendous and critical influence on regional and local capacity to deal with the unavoidable impacts and to assess opportunities and constraints in preparing for potential future impacts of climate change. As an economically vibrant, technologically innovative, and frequently courageous political pioneer state, California may have a greater capacity than some to face the challenges from climate change.

At the same time, California is also highly exposed and many of its ecosystems and economic sectors are critically sensitive to higher temperatures and changing precipitation patterns, while the obstacles in the way of enhancing its resilience are nothing short of formidable. A concerted focus on further researching, quantifying, and addressing these constraints is clearly needed. More specifically, actions are recommended at three levels, each discussed in greater detail in the sections below.

### 4.1 Government and Policy Actions

Government at both the state and federal levels can play a crucial role in stimulating and facilitating lower levels of government (regional and local institutions, which often are the implementing arms of government) and the private sector by providing incentives to begin exploring the growing risks from climate change, the response options, and ways to implement them. While higher levels of government can stimulate action elsewhere, the challenge of seamlessly coordinating and integrating federal, state and local policy actions across scales cannot be overstated and needs to be carefully and consciously addressed. Toward these ends, the state could:

- Fund state- or location-specific climate vulnerability assessments that identify the most important climate risks for a particular area or population and characterize the region's ability to manage to the projected changes
- Establish mechanisms that increase lower-level governmental accountability vis-à-vis state-set climate-related and other environmental goals (e.g., no net loss of particular habitats, implementation of planning goals or building standards)
- Initiate (and provide adequate funding and staff to arrange) public forums to discuss climate change risks and response options; forums could be agency-specific or location-specific, for the private sector, public officials, or the general public
- Promote integrated resource management that promotes incorporating climate risks among other multiple and interacting stressors
- Review and update hazard plans in a manner that incorporates a changing climate in risk calculations
- Provide financial incentives, initiate institutional changes (including a review and revision of agency mandates, job descriptions, and staff capacity), or even pursue legislative mechanisms to mandate climate-conscious planning and management
- Lead by example in all efforts under state jurisdiction that involve natural resource management and planning; implement such efforts under an "adaptive management" paradigm to learn from those management strategies and improve and adjust them over time

### 4.2 Future Research Directions

State and federal agencies can also enhance the adaptive capacity by building the necessary knowledge base for adaptation. A considerable body of research has been developed across the country and elsewhere. The state could draw and build on this existing research, support research that applies the insights from elsewhere to the state, and fill gaps in understanding. Specifically, in view of the discussions in this report, the state could support and encourage additional research in the following areas to help meet future adaptation needs:

- Encourage research that uses a vulnerability approach to help identify the risks of climate change within the context of multiple stressors
- Encourage collaborative and participatory research that seeks to expand the knowledge of resource managers regarding climate and weather risks, and how risks affect coping/adaptation options
- Encourage research that identifies critical thresholds in climate-sensitive sectors; for example, species-specific thresholds of landscape connectivity would help in the design of protected areas that would afford species habitat protection as environmental conditions change
- Encourage research into the socioeconomically and racially differentiated vulnerabilities to, and capacities to deal with, the impacts of climate change
- Encourage research into the feasibility of adaptation options against the backdrop of climatic, economic, technological, institutional, social, legal, ecological, or other

constraints and stressors; as well as research on how to overcome the obstacles or minimize these constraints

- Encourage further sector-specific empirical research into resource managers' specific information needs: how they process information about climatic risks, identify and assess coping strategies, and choose whether, when, and how to employ them
- Respond to these identified information needs of different decision-makers by providing information that is directly relevant and easily accessible to different stakeholders' decisions

### 4.3 A Role for Civil Society in Fostering Public Dialogue on Adaptation

To date, the American public "debate" over climate change has largely focused on the need for mitigation. Civil society has a significant role to play in preparing for change by expanding the public discussion to also include the need for adaptation.

Recognizing the state of the science about climate change, the debate over the two sides of societal response to climate change needs to be reframed as one of complementary necessities. Without such an informed public conversation about coping and adaptation, proactive steps and strategies will not be explored or supported, much less implemented. This would leave society to cope in inefficient and probably more costly ways as further impacts manifest in the future. Uncertainties about future climate thus imply no delay in this self-reflection and examination at all, but instead suggest a profound governmental and civic responsibility for initiating public dialogue and working toward the well-being of all members of society.

Civic actors may take the following specific steps, among others:

- Scientists can play a bigger role in educating the interested public as well as local, regional, and state decision-makers about the need for adaptation, thus stimulating public discussion of the potential options and constraints on coping and adaptation
- Environmental advocacy groups can begin examining how climate change may impact their interests and goals and help identify win-win solutions
- Private sector businesses can identify their exposure and risks in light of climate change, and begin identifying measures that help reduce their vulnerabilities over the short, medium, and longer term

Preparing for and adapting to the impacts of climate change will take committed, ongoing, and collaborative effort from government, the private sector, the research community, and civil society. While the challenges are large, California has a history of leading the nation in terms of policy and forward-looking management approaches. The state has an opportunity once again to advance the debate and lead by example.

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