San Francisco Bay Joint Venture
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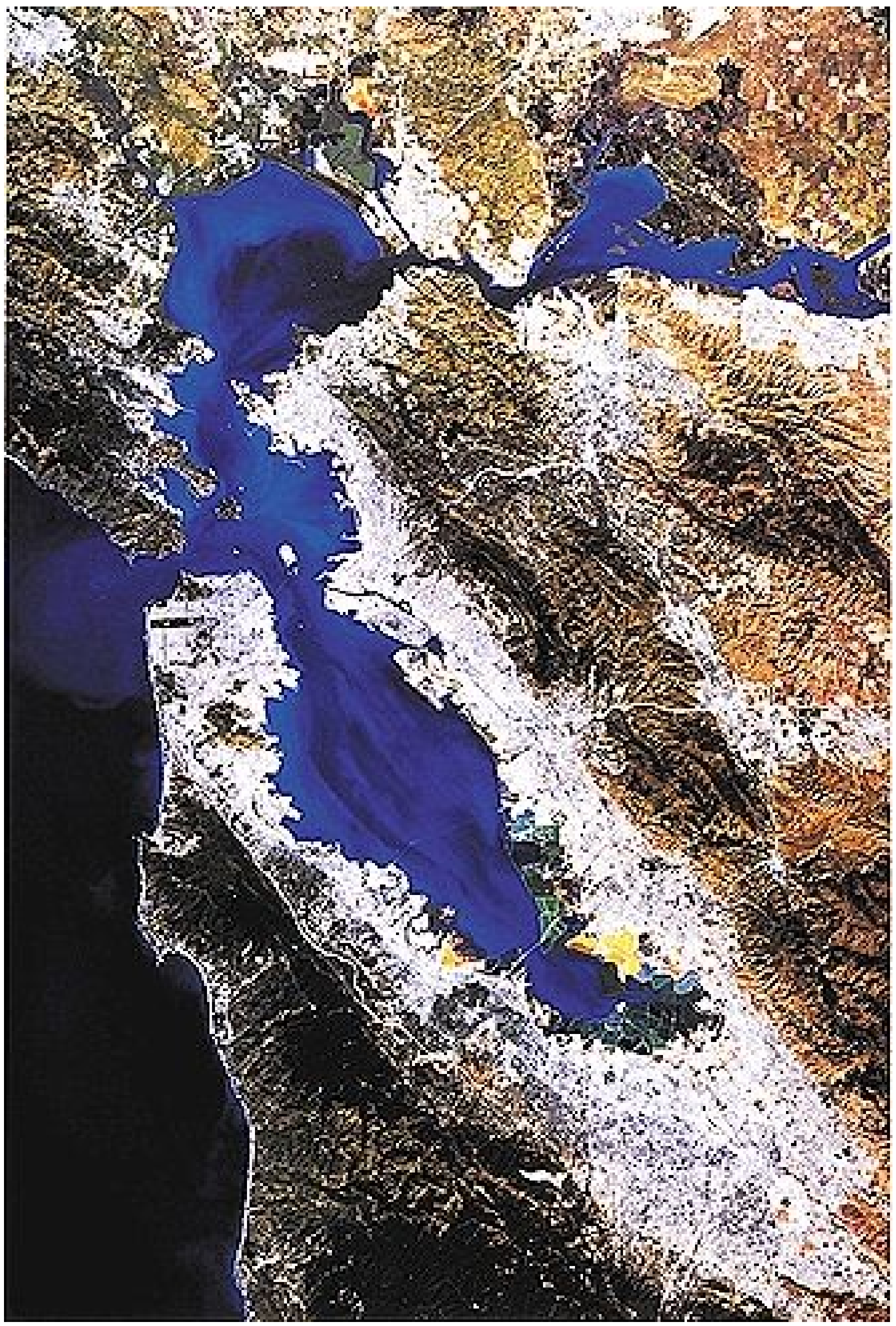
WETLAND RESTORATION AND PROJECTED IMPACTS FROM CLIMATE CHANGE

RECOMMENDATIONS FOR AND BY PARTNERS OF THE SAN FRANCISCO BAY JOINT VENTURE



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Purpose

The purpose of this document is to provide partners of the San Francisco Bay Joint Venture (SFBJV) with recommendations for the planning and implementing of wetland restoration efforts in an era of climate change. The information and recommendations are focused on the geographic region of the San Francisco Bay Joint Venture, and include wetland habitats*, as well as the species that rely on these habitats. It is not intended to encompass the entire scope of potential issues associated with global warming or climate change on a state, continental or global

scale. This is a 'living' document which will continue to evolve and change in accordance with the emerging nature of climate change and its projected impacts.

The role of the Joint Venture will largely be to:

- ***coordinate SFBJV partner efforts and stay updated on the activities and research relating to climate change predictions and projected impacts to San Francisco Bay Area wetland habitats and associated species***
- ***facilitate and promote partner programs related to climate change***
- ***help secure funding for the research, monitoring and modeling that will need to be undertaken***

** Wetland habitats which are identified for protection in the Implementation Strategy, Restoring the Estuary (2001) of the SFBJV include: bay habitats:: tidal marshes, tidal flats, lagoons, beaches, salt ponds and subtidal habitats, seasonal wetlands, diked and associated grasslands, and creeks and lake, which include riparian zones.*

Introduction

Climate scientists and the broader community finally agree the Earth's climate is changing and that this is a mounting concern for all of us. For those in the Bay Area wetland restoration community, projected impacts of climate change include an estimated sea level rise of 26-55 inches by 2100, shifts in salinity content and fresh water flows, notable rises in temperature and an increase in the severity of storms. These factors must be considered when planning and implementing sustainable and functioning wetland habitat restoration.

As we approach the end of the first decade of the 21st century, we are faced with more questions than answers, questions that can only be answered with scientific research and time. They include:

What do these projected impacts mean for wetland habitats and our efforts to restore and protect them?

How will the distribution of habitats and species shift as they migrate in response to sea level rise and temperature increases?

How will climate change projections influence the way we design and prioritize projects?

What research is needed to address existing data gaps and how will it get funded?

What is being done to address climate change projections within the JV partnership?

We can not let uncertainty become an excuse for inaction. This document is a preliminary attempt to address these questions, and provide recommendations for our partners and associates working to restore wetland habitats in the SF Bay Area.

Overview of Climate Change and Potential Impacts to Wetlands

Predicting the future of ecosystems in the context of global climate change is difficult at best. While climate change models have generated a wide range of projections, there is consensus that some ecosystems, particularly tidal wetlands, will be impacted more than others. Several factors make tidal wetlands sensitive to climate change. First, the rise in average global temperatures will influence the timing and degree of snow fall and ice melt, shifting temporal runoff patterns in watersheds supplied predominantly by mountain snowpack. Second, rates of sea-level rise are almost certain to increase over the next several decades. Sea-level rise will push sea water farther up into estuaries, increasing salinities in tidal ecosystems. Increases in sea level alone will account for losses of up to 22% of the world's remaining tidal wetlands. Moreover, the combination of sea level rise with reclamation and development infrastructure in coastal regions may result in the loss of up to 70% of coastal wetlands (Nicholls et al., 1999; Najjar et al., 2000; but see Hughes et al. 2000). Tidal marshes are likely to be particularly vulnerable to climate change impacts through these shifts in salinity and inundation patterns (Callaway, et al, 2007).

As wetland restoration planners, managers, scientists, funders, and conservationists, Joint Venture partners need to stay abreast of the emerging data on climate change in order to make informed decisions about the design and implementation of future wetland restoration projects. If the projections are accurate, the Bay Area will experience significant impacts from climate change. Management decisions and plans made now can minimize impacts to wildlife and help wetland habitats adapt with more resilience. We need to work together to address these issues if we hope to protect our communities, our natural environment and biodiversity and reduce the negative impacts from these projected changes.

CLIMATE CHANGE AND IMPACTS OF CONCERN IN THE SF BAY AREA

The consequences of climate change are not surprisingly projected to be substantial in California and to have far-reaching impacts to many ecosystems. Wetlands – coastal, riparian, seasonal, or tidal – all stand to suffer some of the greatest and most immediate and observable impacts. To summarize, the projected changes of greatest concern are: sea level rise, salinity shifts, temperature increases, hydrological changes (timing, quantity and quality) and an increase in the severity of storms. On their own, each carries with it specific implications, but also of concern is the cumulative effect of any combination of these factors.

For a region like the San Francisco Bay-Delta estuary, less snow and earlier melting of the Sierra snow pack will result in higher floodwaters during winter and an earlier spring but lower flows during late spring and summer. These changes will amplify seasonal and spatial shifts in estuarine salinity patterns, impacting wetland plant establishment, productivity, and reproduction. In addition, tidal marshes will have to accumulate substantial sediment to counteract sea-level rise or they will be subjected to longer periods of tidal inundation. The overall influence of climate change, therefore, is a combination of changes in inundation and salinity regimes, with impacts on plant communities and the ecological function of tidal marshes (Callaway et al. 2007).

The San Francisco Estuary is a resource of global importance and a cornerstone to the identity of the Bay-Delta region. Accordingly, investment in its ecological recovery through marsh restoration is both appropriate and wise (Callaway, et al. 2007). Developing and implementing a regional climate change strategy will be expensive and difficult. Yet the Bay Area has the potential to lead the nation in addressing the impacts of climate change due to the following factors:

- With so much expensive development on low-lying land along the Bay shoreline, we can't afford to postpone dealing with the problem;
- We're a wealthy region that can afford to pay for innovative strategies;
- We are home to many innovative institutions and people with the knowledge and expertise to address the challenges presented by climate change;

- We have a history of identifying solutions to problems ahead of the curve;
- Our region has a tradition of being willing to challenge the status quo.

A half century ago, the people of the Bay Area came to the conclusion that continuing with business as usual would destroy San Francisco Bay and we found the conviction and the political leadership to save the Bay. Once again we face the prospect of losing some of our most precious natural resources if we continue with the status quo.

WETLAND HABITATS AND RESPONSES

What do these projected impacts mean for wetland habitats and restoration efforts in the nine bay area counties identified for protection in the Implementation Strategy of the SFBJV? This section provides a brief overview of what may happen to some of these habitats, among them - tidal marshes, mudflats, subtidal habitats, riparian corridors and uplands - as a result of specific, projected changes.

Bay Wetlands, the Shoreline and associated habitats

Bay wetlands face several threats. To respond to sea level rise, wetlands must either rise in place, or transgress up the shoreline. Many Bay wetlands lie in front of hardened shorelines, which inhibit transgression. Sediment levels in the Bay appear to be decreasing from historic levels, meaning there may not be sufficient sediment available to allow the wetlands to rise in place.

One of the principal impacts of sea level rise on tidal marshes will come through storm events and storm surge. While current modeling does not allow us to predict whether storms will become more intense, weather patterns already suggest the likelihood of increasing storm severity. Furthermore, we can predict that with sea level rise the associated storm surge will be higher and more intense even if storms are of a similar strength. Consequently the region could experience a "100-year storm surge" every ten years. This will accelerate erosion of Bay marshes and shoreline.

Tidal Marshes and Mudflats

The predicted range of sea level rise for California, up to 72 cm by 2100 (Cayan et al. 2008), has the potential to inundate significant areas of current tidal marsh and mudflat habitats, with dramatic effects on overall habitat availability. The extent to which existing marshes and mudflats can "keep up" with sea level rise depends on sediment availability and other factors that influence marsh accretion rates . Given the extensive urbanization of uplands surrounding San Francisco Bay, the opportunities for landward marsh retreat are quite limited.

Perhaps equally important to tidal wetland systems as sea level rise, is the projected change in the salinity gradient associated with changes in the timing and flow of runoff from the Sierra Nevada. A reduction in freshwater inputs to the Bay is projected to shift the salinity gradient eastward during the spring and summer and may be exacerbated by potential changes in the management of Sacramento / San Joaquin Delta resources. Given the relatively low plant species diversity and productivity of high salinity marshes compared to fresh and brackish marshes , this salinity increase may reduce plant diversity even more and threaten several of the locally uncommon and rare plants that are associated with fresh-brackish marshes in particular .

As sea level rises and habitats shift upslope, mudflats should be the last to disappear, as plants are excluded from areas of high inundation. Thus, these habitats may be less immediately threatened than vegetated marshes. However, in many parts of the Bay, especially in the South and Central Bay, mudflats directly abut levees and seawalls. With no room for landward migration, these mudflats may be lost to sea level rise. Galbraith et al. projected that more than 60% of intertidal mudflats in the South Bay could be lost by 2100. However, the distribution of mudflats may also be affected by changes in salinity, particularly in the North Bay, where conditions are expected to become more saline. Because fewer plant species can tolerate the combination of high salinity and tidal inundation, an increase in salinity may partially compensate for the loss of mudflats to sea level rise, except if those mudflats are invaded by *S. alterniflora*, in which case they become generally inaccessible to foraging shorebirds .

Riparian Ecosystems and Changes in Hydrology

As a result of climate change, riparian ecosystems will face changes that increases in air and surface water temperatures, alterations in the magnitude and seasonality of precipitation and runoff, and shifts in reproductive phenology and distribution of plants and animals (Meyer et al. 22 1999, Barnett et al. 2005, Parmesan 2007, Rosenzweig et al. 2008). Riparian ecosystems are naturally resilient, provide habitat connectivity, link aquatic and terrestrial ecosystems, and create thermal refugia for wildlife. These characteristics make riparian restoration an important and pressing component of ecological adaptation to climate change.

Restoration practitioners should consider how restoration practices can be modified to accelerate and enhance the capacity of riparian ecosystems to adapt to climate change. Such modifications may include restoring private lands, engaging in water management decisions, widening transition zones, and putting the emerging field of restoration genetics into practice. Despite numerous challenges, the potential for riparian restoration to enhance ecosystem resistance, resilience, and response to climate change makes it imperative that we continue to restore riparian ecosystems and develop the science that supports this work.

Subtidal Habitats

Sea level rise will likely increase the overall depth of the subtidal habitat. Existing shallow subtidal habitats will likely be deeper, thus excluding shallow water habitat and biota from these areas while creating new shallow water habitat in areas that are inundated. As a result, sea level rise may reduce light attenuation for existing submergent aquatic vegetation (SAV) and shift the location of productive vegetative areas. The area of tidal influence is also likely to travel further up rivers and creeks and further into the Delta. Increased salinity levels may exclude certain SAV and aquatic invertebrates from specific parts of the Bay while increasing habitat for others. An increase in the severity of storms may increase the subtidal disturbance of sediments (the benthos would likely dig out). Increased turbidity from such storms in the spring may reduce SAV survival and growth. Restoration of eelgrass beds should consider models of sea level and salinity rise. Increased turbidity in the water may also impact invertebrates in the shallow water habitat. Deeper water areas of the Bay may likely become less turbid with the decrease in sediment supply and increased depths buffering wave action.

Upland Habitats and temperature rise

Areas adjacent to wetlands - upland habitats - are part of the same ecosystem and play an integral role in the health of wetlands. Uplands maintain continuity in the natural hydrologic cycle, influence the flow of sediment and nutrients through watersheds, preserve crucial shade (temperature control) areas particularly along riparian corridors, and provide habitat linkages among wetland habitats.

Anticipated changes in precipitation and evaporation resulting from a temperature increase, and longer dry season will likely cause direct plant mortality from drying, vegetation shifts and rearrange species distributions. Fire threats and increased intensity will further advance vegetation shifts. Species will undoubtedly move at varying rates, resulting in the rearrangement of current vegetations associations and potentially adding to the spread of invasive species. Because the Bay Area has a large variability in topography, climate and rainfall, as well as a thick fog belt along the coast, plants and animals will have a better chance of migrating in various directions in response to the changing climate provided that a large connected network of well managed conservation lands exists.

Projected Impacts to Plants and Wildlife

Wetland ecosystems in balance provide invaluable services to humans such as flood control, drinking water, and filtration of pollutants. They also provide critical habitat for an incredible range of wildlife species and plant life that have adapted to these systems over a much longer period of time than the changes from global warming are likely to occur. This places the ability of these species to adapt and survive in question. What will happen to the hundreds of thousands of migrating waterfowl and shorebirds that have come to rely on Bay Area habitats for their fueling stations and nesting grounds? What will be the distribution of habitats and species as they move in response to sea level rise?

Species distribution shifts

Initial impacts are likely to be caused by the salinity changes resulting from altered flow regimes, with even relatively small salinity changes potentially causing shifts in dominant vegetation. Although tidal marsh restoration projects in general will be adversely affected by increasing salinity, tidal freshwater marshes will be the most vulnerable (Callaway, et al. 2007). The combined effects of increased inundation and increased salinity will lead to shifts in tidal habitats, with threats greatest for higher elevation (high marsh) and low salinity (fresh-brackish) systems, which are likely to be "squeezed" at the diked and developed margins of the Bay-Delta. These broad-scale shifts may also be accompanied by changes in community composition and ecosystem function, as plant and animal distributions shift in different directions, resulting in the "tearing apart" of existing communities and the potential creation of novel species assemblages . Furthermore, as community composition changes, there may be more room for non-native plant species to invade tidal wetland systems . For example, smooth cordgrass (*Spartina alterniflora*), which has been a particularly aggressive invader in the South Bay, has a higher range of salinity and inundation tolerance than its native counterpart, Pacific cordgrass (S. *foliosa*) . Changes in these habitats will require adaptations in animal response especially in finding suitable habitat for nesting marsh birds (tidal marshes) and feeding, or fuel for migratory and wintering shorebirds (mudflats).

Tidal marsh bird responses

Due to the harsh environment created by high salinity and frequent inundation, tidal marshes have low avian species diversity but contain a high proportion of endemic subspecies, specially adapted to tolerate those harsh environments . Species such as the federally-listed California Clapper Rail (*Rallus longirostris obsoletus)*, which rely on high salinity pickleweed (*Sar-*

cocornia pacifica) marshes, may actually benefit from an increase in this habitat type. The tidal marsh song sparrow (*Melospiza melodia, samuelis, M.m. pusillula, M.m. maxillaris*), already adapted to extreme conditions, may be more resilient to increases in salinity and inundation, but this depends upon how plant and other bird species respond. For example, if marshes are invaded by *S. alterniflora*, song sparrows may face increased competition and predation threats from marsh wrens (*Cistothorus palustris*), which appear to prefer *S. alterniflora* for nesting (Nordby, et al., 2008).

Sea level rise is likely to pose a larger threat to tidal marsh birds than increasing salinity. Sea level rise may reduce both the amount and quality of tidal marsh habitat. If sediment accretion rates are not high enough the area covered by marsh habitat will decrease. Such a loss of habitat could threaten population viability for some species, especially (sub)species of concern that already have low population numbers . Furthermore, Tidal Marsh Song Sparrows and Salt Marsh Common Yellowthroats (*Geothlypis trichas sinuosa*) have been observed to have lower densities in smaller, more fragmented marshes , potentially due to increased predation rates.

In addition to habitat loss and fragmentation caused by an increase in mean sea level, extreme high tide events, especially when accompanied by storm conditions, may affect tidal marsh breeding birds directly by flooding their nests. For song sparrows, which generally nest in low-lying *S. pacifica* or gumplant (*Grindelia stricta*), high tide and storm-related flooding has been demonstrated to be a major source (up to 25%) of nestling mortality . This may be exacerbated in Spartina-invaded marshes, which can serve as "ecological traps," luring song sparrows to nest at lower elevations (Nordby et al., 2008). Furthermore, several species, including the California Black Rail (*Laterallus jamaicensis coturniculus*) and California Clapper Rail (*Rallus longirostris obsoletus)*, are known to depend on the presence of refugia from predators at high tide , which may be reduced or eliminated with a combination of sea level rise and increased storm frequency.

Waterfowl and fish eating birds responses

Diving ducks are the most numerous type of waterfowl in San Francisco Bay and what the Bay is renowned for among waterfowl enthusiasts. Scaup (greater – *Aythya marila* and lesser *A. affinis*) are the most abundant ducks on San Francisco Bay, numbering from 90,000-140,000 in the winter (Accurso 1992); through the course of the winter, they total 36-68 percent of the total Bay waterfowl population. (*Aythya valisineria*), common goldeneye (*Bucephala clangula)* , redhead *(Aythya americana)*, and ring-necked ducks *(Aythya collaris)* . Ruddy ducks *(Oxyura jamaicensis)* and bufflehead *(Bucephala albeola)* are smaller diving ducks that use manaed marshes, salt ponds and the open Bay. The surf scoter *(Melanitta perspicillata)* is by far the most abundant species of sea duck in the Bay, and the second most abundant waterfowl species overall; ranging from 43,000-61,000 (Accurso 1992). Ecologically similar species include white-winged and black scoter*(Melanitta fusca)* and black scoter (*Melanitta nigra*), but they are far less abundant.

The projected climate change impact sea level rise will have little impact on foraging energetics, but reduction in light attenuation could reduce important SAV beds. A risein salinity could also reduce SAV and mollusk prey. Summer/fall temperatureincreases may result in declines in dissolved oxygen and death of benthos in stagnant bays. A reduced spring runoff period with higher flows may change the invertebrate community composition or alter phenology of the spring migration. Potential increase in storm severity could decrease SAV growth and survival with increased turbidity, while invertebrate benthos may be scoured away or buried in disturbed sediments. Disturbed sediment may remobilize absorbed contaminants making them more bioavailable for accumulation into diving duck food webs.

What this means for Wetland Restoration Managers & Planners

Conservation biologists and others face a number of challenges regarding climate change over the next several decades, both in predicting and documenting its patterns as well as in dealing with its effects. Currently, the most reliable projections from climatic models are for global-scale temperature changes. Ecological impact assessments need to be done on a regional scale (Root and Schneider).

Research is a necessary component of effective adaptation. It provides information for resource managers, planners, and policy makers to make informed decisions and policies. To meet these needs, it is important to perform research at various geographic scales covering different time periods. Region-wide studies are important to identify large-scale trends as well as local areas that are particularly vulnerable to climate change impacts. Furthermore, local pilot projects can test the efficacy of climate change adaptation strategies for the Bay. Monitoring of the existing Bay ecosystem can identify vulnerability and verify models of future climate change. Modeling is required to forecast the magnitude and timing of global and regional impacts of climate change and to understand the response of different, interacting parts of the Bay ecosystem.

Collaboration across disciplines is necessary to plan adequate and comprehensive conservation responses to climate change. Within the Joint Venture community, there are many approaches to and concerns about the projected impacts from climate change. Agencies, land managers, funders, scientists, project managers and advocacy partners will need to develop strategies for tackling this emerging issue in the context of agency organizational priorities, with informed science. The SFBJV may indeed be able to offer a forum for this kind of coordination and sharing of information. How this will be accomplished and the resources for coordination have yet to be identified. In the meantime, two Joint Venture agency partners offer perspectives on how climate change predictions are impacting the planning process for managing and implementing wetland restorations.

Adaptive Management as a Model for Managing in an Uncertain and Changing Climate

Mendel Stewart, USFWS

In the spring of 2008, the Blue Ribbon Panel of the California Resources Agency advised the Governor to issue an executive order to all state agencies recommending that they plan for a 55 inch rise in sea level by 2100. While this is primarily intended as a planning tool for State agencies, it is based on predictions found in the International Panel Climate Change Fourth Assessment Report and has critical implications regarding the need for consistency in our actions.

In 2007, the Department of the Interior established a task force composed of three subcommittees -- Science, Law and Policy and Land and Water. The Land and Water Subcommittee specifically dealt with cataloging the types of impacts relevant to Interior managed lands and waters. The subcommittee evaluated current and prospective options for addressing the effects of climate change and to examine the Department's role in carbon sequestration. From this effort a variety of key themes were developed, some of which are transferable to the San Francisco Bay-Delta Estuary and our efforts to enhance, restore and manage Bay-Delta ecosystems.

The recently published Department of the Interior Adaptive Management Technical Guide suggests that adaptive management is most useful in situations in which there is a high level of uncertainty about the natural environment and the consequences of management decisions, but where there is also a high level of controllability of our actions. In the Bay-Delta, these two conditions will be present in many of the situations faced by resource managers in a world with a rapidly changing climate.

Adaptive management is a structured decision making process that explicitly builds uncertainty and the opportunity to obtain additional scientific information into the decision process. As climate predictions improve over time, and as human and ecological responses are observed and measured, adaptive management allows management responses in an iterative decision making process (Figure 1). Through adaptive management, decisions can also be prioritized based on comparisons of the expected impact of various responses. Management actions can be taken and the results of those actions used to develop future management actions. In addition, resource managers can compare the expected results of taking immediate actions to the results of delayed responses, which will help to prioritize alternatives based on their associated costs and benefits.

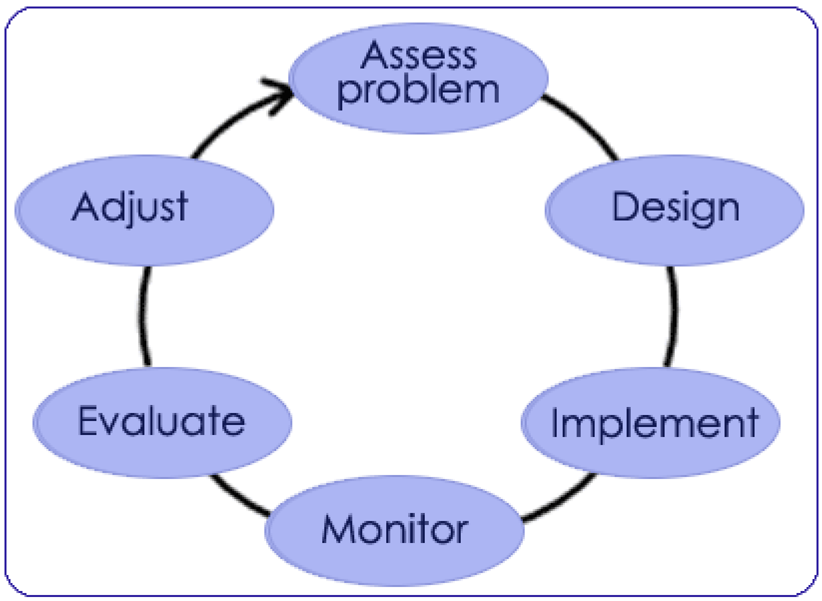

Figure 1: Adaptive Management Process

Revising Land, Resource, and Species Management Plans to Reflect Climate Change Effect

Revision of management plans to reflect the effects of predicted climate conditions will be necessary. This is true for most of the significant planning documents for the Bay-Delta including the Baylands Ecosystem Habitat Goals Report. For example, most resource management actions on National Wildlife Refuges are controlled by management plans created through coordination with partners, stakeholders, and refuge managers. In order to incorporate climate change considerations into day-to-day operations, resource managers need to revise and operate under management plans that reflect climate change projections based on the best available science. Included in this theme are endangered species status determinations, recovery plans, and other endangered species management actions.

Timely Local and Regional Data and Modeling

Resource managers must be able to acquire the research, data, and modeling needed to inform their decisions effectively in the new paradigm of managing for climate change. The two common concerns about the existing systems for acquiring research and modeling are scale and timeliness. Most of the climate data and ecological models available make predictions at the global and continental scales. Data associated with both climate predictions and the implications those predictions have for specific resources at the regional and management-unit level, will be critical for implementing new resource protection strategies.

The adaptive management process demands timely predictions, decisions, and feedback on the results of management decisions. While local feedback monitoring can normally be done within local budgets or with assistance of regional partnerships, the research, predictive capabilities, and model development that will be needed in the future are well beyond the budgets and other resource bases of most agencies and organizations of the Bay-Delta.

Resource managers will need a more effective mechanism to identify and acquire needed research, data collection, and model development support in a timely manner. There is a need to identify funding mechanisms in addition to finding ways to streamline field research needs and the decisions on when and where research is conducted around the bay in the face of a changing climate.

Species Inventory and Monitoring

Managing for climate change requires a thorough understanding of what species and habitats make up the ecological landscape of the Bay-Delta Estuary. Without an inventory of species and natural communities to establish a current baseline, we cannot begin to predict the ecosystem response to changing climate, or to develop actions to deal with those responses. Adaptive management requires monitoring to determine the success of individual management actions in order to learn from them and adjust the course for subsequent actions. Cooperative partnerships improve cost effectiveness and overall efficacy of monitoring actions and should be increased to fully realize the potential.

Risk-informed decision making and robust strategies

Thomas Kendall, US Army Corps of Engineers (USACE)

Climate change and variability add another level of uncertainty to wetland restoration and management. While much of the research of climate scientists is geared toward improving predictions about what is likely to happen, the element of uncertainty can not be completely eliminated. Therefore, planners must practice a form of risk-informed decision making.

Many planners are looking for a 'most likely future climate' downscaled from General Circulation Models, while others want to assign probability distributions to a range of future scenarios in order to use standard tools of optimization. Both methods may lead to brittle solutions that could fail if the future turns out differently (Olsen 2008). An alternative method under consideration by water resource planning agencies like the US Army Corps of Engineers, is for planners to recommend more robust strategies which do better under a range of possible futures. A robust decision making strategy would make use of adaptive management to monitor conditions over time in order to continuously update plans, designs and operations.

While current Corps of Engineers guidance is limited on climate change, the Corps does have some guidance specifically on sea level rise in its Planning Guidance Notebook (ER 1105-2-100, USACE, 2000). The guidance in part states: *Feasibility studies should consider which designs are most appropriate for a range of possible future rates of (sea level) rise. Designs that would be appropriate for the entire range of uncertainty should receive preference over those that would be optimal for a particular rate of rise but unsuccessful for other possible outcomes.* The exact meaning of 'receive preference' along with which future climate and sea level scenarios to include in restoration planning are the subject of several climate change task forces within the Corps of Engineers and other agencies. The current upper limit in use by the Corps is 1.5 m of eustatic rise by the year 2100.

The Hamilton-Bel Marin Keys wetland restoration project is one example of how sea level rise considerations have been included over the typical 50-year horizon used in the planning process by the Corps of Engineers. Consensus was reached on a mix of habitat types (project outputs) that include a relatively high component of seasonal (vs. tidal) wetlands early in the project life and later (after a moderate amount of sea level rise) transition to a greater percentage of tidal wetlands. Since grading for this project will occur over a period of many years as material becomes available from nearby dredging projects, there will be further opportunity to adjust the final elevations as new data on sea level trends become available.

Another important consideration in the Hamilton project is the potential risk of tidal flooding to adjacent communities currently protected by levees along the upland perimeter of the site. In order for these properties to remain protected throughout the project life, sufficient land interests must be kept available along the perimeter in case it becomes necessary to increase levee heights and footprints as sea level rises.

Current policies may not always favor full Federal support of plans that conservatively address climate change or have a large adaptive management element, and often the plan that can enjoy full Federal participation (i.e. maximum Federal funds) will be adopted. If and when project outputs are theoretically optimized at a lower level of Federal investment than what is desired by a consensus of stakeholders, a non-Federal sponsor may need to step in and fund the difference between the 'optimal' Federal and desired plan. Additional investments for adaptive management often fall into this category. This practice is in large part due to the way agencies like the Corps apply the Economic and Environmental Principles and Guidelines (P&G) for Water and Related Land Resources Implementation Studies (USWRC 1983). Recent legislation has directed an update of the P&G. This update could very well provide for an improved ability to recommend full Federal participation in climate change sensitive projects with resiliency features linked to adaptive management and monitoring.

Recommendations

PLANNING FOR THE FUTURE (adapted from Sierra Nevada Alliance toolkit)

We need to act now to protect the unique attributes of wetlands in the Bay area and consider the impacts of climate change in all of our restoration planning, design and projects. In order to do this we need to:

- Educate ourselves about the impacts of climate change,
- Identify a range of potential future change through modeling,
- Use adaptive management strategies,
- Monitor and track changes in weather, habitat and species distribution, subsidence, hydrology, sediment accretion rates
- Promote the resilience of wetland ecosystems and minimize non-climate stressors,
- Prioritize projects that will succeed under multiple scenarios,
- Integrate and coordinate partner strategies and efforts;

RECOMMENDED ACTIONS

Audience	Recommendations

Scientists	• Assess the applicability of existing climate change models and needs for future development of regional conservation and bird conservation models • Determine the kinds and quality of biological models needed to predict the effects of climate change on priority bird populations in SF Bay habitats • Identify bird species of greatest conservation need and areas most at risk because of global climate change • Insure that Baylands, Uplands and Subtidal goals reports add a section on climate change • Determine the sequestration rates of wetland habitats in Bay Area • Develop indicators and thresholds to gauge progress of climate change and assess the actual vs projected impacts
Public Lands Managers	• Complete large wetland restoration projects to serve as buffers to tidal flooding as well as sea level rise • Identify and deliver a pilot project/s that include remediation for climate change impacts • Incorporate climate change models into restoration plans • Prevent or reduce additional stressors that reduce the ability of the wetland ecosystem to respond • Utilize adaptive management to keep pace with the impacts of climate change • Restore riparian habitat and promote water and watershed management practices that will maintain the ecological integrity of riparian ecosystems
Private Land Managers	• Prevent or reduce additional stressors that reduce the ability of the wetland ecosystem to respond • Restore riparian habitat and promote water and watershed management practices that will maintain the ecological integrity of riparian ecosystems
Planners	• Complete large wetland restoration projects to serve as buffers to tidal flooding as well as sea level rise • Update sediment management plan for bay to maximize availability of sediment to build marshes • Work with best available science to develop a design criteria used to prioritize projects • Acquire or protect adjacent upland buffers to allow wetlands to move creating transitional zones when possible • Reduce development in low-lying areas, behind levees, or adjacent to the bay/coast and prevent or reduce other stressors that reduce the ability of the wetland ecosystem to respond • Identify and support projects that facilitate connectivity to marshes and wetlands prior to and as they are impacted by sea level rise • Support planning and implementation of shoreline pilot projects to buffer and protect habitats in the face of sea level rise • Customize restoration remedies to specific wetland habitat types
Conservation Groups	• Complete large wetland restoration projects to serve as buffers to tidal surges as well as sea level rise • Acquire or protect adjacent upland buffers to allow wetlands to migrate landwards • Provide decision support tools for improving habitat delivery programs (such as Farm Bill conservation programs, and the North American Wetlands Conservation Act)

	• Work with best available science to develop a design criteria used to prioritize projects • Insure that Baylands, Uplands and Subtidal goals reports add a section on climate change • Encourage JV partners to participate in county General Plan updates and support policies that promote wetlands protection and restoration • Carry out shoreline pilot projects to buffer and protect habitats in the face of sea level rise • Acquire or protect seasonal and perennial wetland habitat upstream
Policy/Decision Makers	• Develop a legislative strategy to address projected climate change impacts • Provide agencies with the authority for planning and land use regulation
Funders	• Fund projects that plan for and address sea level rise in their design • Fund research needed to determine future impacts and resolve existing data gaps • Fund planning and implementation of shoreline pilot projects to buffer and protect habitats in the face of sea level rise
JV Management Board	• Prioritize projects that incorporate applicable and available climate change models in restoration planning • Work with best available science to develop a design criteria used to prioritize projects • Encourage JV partners to participate in county General Plan updates and support policies that promote wetlands protection and restoration • Provide coordination services to JV partners through forums for Scientists to inform planners of their research findings, and for managers to inform scientists of their questions and management decisions.
Working Committees: Outreach	• Develop an "in-reach" plan to insure that all JV partners are aware of the white paper recommendations • Develop wetland messages for our target audiences as per outreach strategy and campaign to promote them in response to climate change and public perception
Restoration Strategy/Technical Committee Creeks Committee	• Work with JV partners to guide project managers and permitting agencies on biological planning, restoration design, research, monitoring and evaluation • Incorporate prioritization criteria recommendations in applicable and available climate change models • Prepare and/or disseminate recommended best management practices
Legislative	• Generate policy and legislative recommendations that incorporate climate change • Review and consider for adoption partner policies that address climate change • Promote policy recommendations with appropriate JV partners and decision makers positioned to effect legislative and policy actions

Outstanding Questions (October 2008)

- Resilience of the Bay relies on sediment rates, will they accrete fast enough?
- Will existing environmental protection laws keep pace with anticipated changes?
- As a habitat Joint Venture, how much of a watershed prespective do we need to adopt?
- What thresholds will we identify as markers of change?
- Can we establish an early warning system for changes with appropriate responses?

Existing Efforts and Perceived Needs

THE SF BAY JOINT VENTURE PARTNERSHIP and beyond

ORGANIZATION	ACTION
EXISTING EFFORTS	
AUDUBON CALIFORNIA	• Developing climate change models for forecasting the direct effects of climate change on bird distribution in California • Determining utility of predictions for San Francisco Bay
BAY CONSERVATION DEVELOPMENT COMMISSION (BCDC), UNITED STATES GEOLOGICAL SURVEY (USGS) and SCRIPPS RESEARCH INSTITUTE	• Updating inundation models for the Bay to include better elevation data, as well as tidal and storm surge data.
BCDC	• Preparing a background report that discusses various scenarios of impacts • Will revise existing Bay Plan policies • Offering a workshop with Bay Area experts on sediment data • Developing a regional climate change strategy which currently exists as a proposal for public review (Oct 2008) at: http://www.bcdc.ca.gov/planning/climate_change/SLR_strategy.pdf)
BCDC with ENVIRONMENTAL PROTECTION AGENCY (EPA), PHILIP WILLIAMS and ASSOCIATES (PWA), SAN FRANCISCO ESTUARY INSTITUTE (SFEI)	• Corte Madera watershed case study to determine sediments in the system, look at flood control practices, and use dredge materials and sandy berms as buffers
BCDC, EPA and ESTUARY PROJECT	• Analyzing non-sea level rise impacts of climate change on the estuary and wetlands to identify habitat shifts
BCDC, PACIFIC INSTITUTE & DUTCH consulting team	• Learning lessons from the innovations and approach of the Dutch
DUCKS UNLIMITED & USGS	• Assessing conductivity of wetland restorations in relation to sea level rise and potential habitat changes • Coordinating with SFBJV partners, Pacific Coast Joint Venture and Central Valley Joint Venture
EAST BAY REGIONAL PARKS with PWA	• Conducting a study at Hayward Regional Shoreline to determine the potential effect of sea level rise on shoreline levees and adjacent wetlands
PACIFIC INSTITUTE & PWA with funding from OCEAN PROTECTION COUNCIL (OPC)	• Assessing economic value of all human-built and habitat areas that could be inundated or eroded by sea level rise and estimating the costs of impacts and adaptation

Key Partners

FEDERAL AGENCIES	**EPA** **NOAA** **USACE** **USFWS** **USGS** **SFEP**
BUSINESSES	**PACIFIC GAS & ELECTRIC**
STATE AGENCIES	**BCDC** **CA RESOURCES AGENCY** **DFG** **DWR** **SCC** **WILDLIFE CONSERVATION BOARD**
NON-GOVERNMENT ORGANIZATIONS	**AUDUBON CALIFORNIA** **BAY AREA OPEN SPACE COUNCIL** **DUCKS UNLIMITED** **PRBO CONSERVATION SCIENCE** **THE NATURE CONSERVANCY**
UNIVERSITIES	**STANFORD UNIVERSITY** **SAN JOSE STATE** **UC BERKELEY** **UCSF**
INDEPENDENT CONTRACTORS	**PWA** **WETLANDS and WATER RESOURCES**

REFERENCES

Basham, M.P., Mewaldt, L.R., 1987. Salt water tolerance and the distribution of South San Francisco Bay Song Sparrows. Condor 89, 697-709

Bay Conservation and Development Commission (BCDC). October 2008. Climate Change Research Needs for the San Francisco Bay coastal sector. Staff Report

Callaway, J.C., Josselyn, M.N., 1992. The introduction and spread of smooth cordgrass (*Spartina alterniflora*) in South San Francisco Bay. Estuaries 15, 218-226

Callaway, J., Parker, T., Vasey, M. Schile, L. 2007. Emerging issues for the restoration of tidal marsh ecosystems in the context of predicted climate change. Madroño 54, 234-248

Chmura G., Shimon, A., Cahoon, D. Lynch, J. 2003. Global carbon sequestration in tidal, saline wetland soils

Evans, P.R., 1986. Use of the herbicide 'Dalapon' for control of Spartina encroaching on intertidal mudflats: beneficial effects on shorebirds. Colonial Waterbirds 9, 171-17

Evens, J., Page, G.W., 1986. Predation on black rails during high tides in salt marshes. Condor 88, 107-109

Fujii, R., Bergamaschi, B., Siegel, S. 2008. USGS Research Proposal CO2 Farming

Galbraith, H., Jones, R., Park, R., Clough, J., Herrod-Julius, S., Harrington, B., Page, G., 2002. Global climate change and sea level rise: potential losses of intertidal habitat for shorebirds. Waterbirds 25, 173-18

Goss-Custard, J.D., Moser, M.E., 1988. Rates of change in the numbers of Dunlin, *Calidris alpina*, wintering in British estuaries in relation to the spread of Spartina Anglica. J Appl Ecol 25, 95-109.

Greenberg, R., Droege, S., 1990. Adaptations to tidal marshes in breeding populations of the swamp sparrow. Condor 92, 393-404

Greenberg, R., Maldonado, J., Droege, S., McDonald, M.V., 2006. Tidal marshes: a global perspective on the evolution and conservation of their terrestrial vertebrates. Bioscience 56, 675-685

Hellman, J.J., Byers, J.E., Bierwagen, B.G., Dukes, J.S., 2008. Five potential consequences of climate Cchange for Invasive Species. Conserv Biol 22, 534-543

Hopkins, D., Parker, V., 1984. A study of the seed bank of a salt marsh in Northern San Francisco Bay. Am J Bot 71, 348-355

Hughes, L., 2000. Biological consequences of global warming: is the change already apparent? Trends in Ecology and Evolution 15, 56-61.

Johnston, R.F., 1956. Population structure in salt marsh Song Sparrows Part II: Density, age structure, and maintenance. Condor 58, 254-274

Knowles, N., Cayan, D.R., 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. Geophysical Research Letters 29, 1-4

Najjar, R.G., Walker, H.A., Anderson, P.J., Barron, E.J., Bord, R.J., Gibson, J.R., Kennedy, V.S., Knight, C.G., Megonigal, J.P., O'Connor, R.E., Polsky, C.D., Psuty, N.P., Richards, B.A., Sorenson, L.G., Steele, E.M., Swanson, R.S., 2000. The potential impacts of climate change on the mid-Atlantic coastal region. Clim Res 14, 219-233.Nicholls et al. 1999, Najjar et al. 2000, but see Hughes 2004.

Nicholls, R.J., Hoozemans, F.M.J., Marchand, M., 1999. Increasing flood risk and wetland losses due to sea-level rise: regional and global analyses. Global Environmental Change 9, S69-S87.

Nordby, J. Cohen. A. Beissinger, S., 2008. Effects of a habitat-altering invader on nesting sparrows: an ecological trap? Bio Invasions.

Odum, W.E., 1988. Comparative ecology of tidal fresh-water and salt marshes. Annu Rev Ecol Syst 19, 147-176

Olsen, J.R. 2008, "Planning Approaches for Climate Change," Institute for Water Resources (IWR) Working Paper, IWR, Alexandria, VA

Orr, M., Crooks, S., Williams., P.B., 2003. Will restored tidal marshes be sustainable? San Francisco Estuary and Watershed Science. 1, Article 5

Parmesan, C., 1996. Climate and species' range. Nature 382, 765-766.

Root, T. Schneider, S. 2006. Conservation and climate change: the challenges ahead. Conservation Biol 20. 706-708.

Sanderson, E.W., Ustin, S.L., Foin, T.C., 2000. The influence of tidal channels on the distribution of salt marsh plant species in Petaluma Marsh, CA, USA. Plant Ecol 146, 29-41

Seavy, N. E., T. Gardali, G.H. Golet, F.T. Griggs, C.A. Howell, T.R. Kelsey, S. Small, J.H. Viers, J.F. Weigand. In review

2008. Why climate change makes riparian restoration more important than ever Ecological Restoration.

Shuford, W.D., Gardali, T., 2008. California Bird Species of SpecialConcern: A ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California

Sierra Nevada Alliance. 2007. Sierra Climate Change Toolkit Second Edition http://www.sierranevadaalliance.org/publications/db/pics/1133215571_14593.f_pdf.pdf

Spautz, H., Nur, N., Stralberg, D., Chan, Y., 2006. Multiple-scale habitat relationships of tidal marsh breeding birds in the San Francisco Bay estuary. Stud Avian Biol 32, 247-269

Sweeney, K. Climate Change, California and Public Lands

Trulio, L., Callaway, J., Crooks, S. 2007. White Paper on Carbon Sequestration and Tidal Salt Marsh Restoration http://www.aviso.oceanobs.com/fileadmin/documents/OSTST/2007/domingues.pdf

U.S. Army Corps of Engineers (USACE), 2000. Planning Guidance Notebook, ER 1105-2-100, available at http://www.usace.army.mil/publications/eng-regs/er1105-2-100/

U.S. Water Resources Council (USWRC), 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.

Williams, J.W., Jackson, S.T., 2007. Novel climates, no-analog communities, andecological surprises. Frontiers in Ecology and the Environment 5, 475-482

INTERNET SITES/RESOURCES

ASSOCIATION OF STATE WETLAND MANAGERS

http://www.aswm.org/science/climate_change/climate_change.htm

BCDC - http://www.bcdc.ca.gov/planning/climate_change/SLR_strategy.pdf
http://www.bcdc.ca.gov/planning/climate_change/climate_research.pdf

CALIFORNIA CLIMATE CHANGE PORTAL-http://www.climatechange.ca.gov/

CLIMATE READY ESTUARIES – www.epa.gov/climatereadyestuaries

CONSERVATION FUND- http://www.conservationfund.org/?article=3127

CREEC NETWORK – http://wwwstatic.kern.org/gems/creec/Fall2008CREECConnections.pdf

DUCKS UNLIMITED-
http://www.ducks.org/Conservation/EcoAssets/1306/CarbonSequestration.html

NRDC - www.nrdc.org/globalWarming/boosting/contents.asp

PRELIMINARY REVIEW OF ADAPTATION OPTIONS FOR CLIMATE-SENSITIVE ECOSYSTEMS AND RESOURCES - www.climatescience.gov

SEA LEVEL AFFECTING MARSH MODEL - http://www.spea.indiana.edu/wetlandsandclimatechange/

SF BAY DELTA

http://groups.google.com/group/sf-sea-level-rise/topics?hl=en

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