Habitat Restoration in the Sacramento-San Joaquin Delta and Suisun Marsh:

A Review of Science Programs

Delta Independent Science Board

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Delta
Stewardship
Council

Habitat restoration in the Sacramento-San Joaquin Delta and Suisun Marsh

SUMMARY

Current plans call for the restoration of tens of thousands of acres of mainly intertidal habitat in the Sacramento-San Joaquin Delta and Suisun Marsh. Restoration on this scale presents both formidable challenges and tremendous opportunities. As part of its legislatively mandated oversight of Delta science programs, the Delta Independent Science Board reviewed these habitat restoration efforts. We held discussions with individuals from state and federal agencies, NGOs, consulting firms, and universities. We were impressed by their dedication, enthusiasm, and knowledge, as well as by the scientific and institutional challenges they face.

Our findings and observations about the restoration efforts are grouped under a series of criteria for a successful restoration program. In such a program: the goals are clearly articulated; the design incorporates spatial and temporal context, adaptive management and flexibility, and monitoring; modeling is used in design and evaluation; planning and implementation are coordinated among projects; the necessary scientific expertise is available; and stakeholders are involved early and often.

Our findings and recommendations agree with those reached independently by National Research Council (NRC) panels. For convenience, as in the Delta Plan, we use "the Delta" to encompass both the statutory Delta and Suisun Marsh.

Findings and observations

1. Clear restoration goals
The goals of most projects we evaluated were clearly stated, although there was less clarity about the targets or desired outcomes of the restoration efforts. However, we found considerable ambiguity about overall restoration goals for the Delta as an ecosystem. Moreover, we found that several projects were planned within the regulatory context of the Bay Delta Conservation Plan, so the goals were strongly influenced by the Endangered Species Act and associated Biological Opinions. Therefore, meeting regulatory requirements might or might not be consistent with the goals of larger, integrated habitat restoration programs within the Delta. No single goal or target applies to all projects and plans, but without consideration of the interrelation or conflict of different goals the overall health of Delta ecosystems may not be improved. Few of the projects reviewed incorporate operational and realistic performance measures that would allow progress toward goals to be measured.

2. Geographic context

Many of the individuals we interviewed recognize that restoration at one location in an aquatic system is affected by events or management activities elsewhere, including other restoration projects. Nevertheless, many restoration projects in the Delta are being planned and implemented largely independently of one another and their landscape context. There has been little progress toward strategic networking that links habitat restoration projects or clusters projects according to shared suites of environmental characteristics (e.g., operational landscape units). For instance, no comprehensive tabulation of Delta restoration projects is currently available to the public.

3. Extended timescale

We found widespread awareness that modifications of climate, hydrology, land use, economics, sea level, and the spread of invasive species affect the design, implementation, and outcomes of restoration projects, both today and in the future. Therefore, it is important to have strategic planning of restoration projects that incorporates long-term risks. It is unclear how these potential effects are being incorporated into actual restoration actions in the Delta. Although some progress has been made toward developing models to evaluate complex, nonlinear responses of the Delta ecosystem to changing environmental conditions, few projects consider how these factors relate to restoration activities.

4. Adaptive management

Restoration planners and practitioners are grappling with uncertainty from ongoing and projected changes in Delta environments. The changes make it difficult to predict the outcomes of specific habitat-restoration activities. Few of the projects reviewed incorporate the adaptive management that this situation requires. We found no consensus about what the adaptive management process entails and no examples of cases where adaptive management was actually being implemented, rigorously planned, or broadly coordinated among sites.

5. Monitoring

Few of the projects reviewed are structured for long-term monitoring in support of adaptive management. Although the need for monitoring and for comprehensive, shared data-management systems to assemble the information generated by monitoring are recognized in most projects and plans, much trial and error may be involved in selecting and updating the best targets for monitoring, determining the appropriate frequency or duration of monitoring, or developing methods and data management that will enable sharing and synthesis of findings among projects. Long-term funding for monitoring seems to be lacking and some projects lack resources to conduct any post-project monitoring at all.

6. Modeling

Models can be powerful tools in assessing how restoration actions taken in one area might affect other areas, addressing uncertainties, or analyzing risks related to costs and benefits of restoration actions. Although several presentations included models to evaluate flows of water, nutrients, sediment, and planktonic organisms, these models were not being used to assess the potential outcomes of restoration activities or to connect restoration activities at local sites to restoration goals and processes for the Delta as a whole. Conceptual modeling at the design stage, combined with simulation or scenario modeling before and after implementation, can be effective approaches.

7. Coordination of planning and implementation
Although many individual restoration projects are underway or planned, the projects are not integrated in a way that would capitalize on the synergies and complementarities among projects and avoid situations in which the actions of one project may conflict with the goals of another. A greater degree of coordination among project administrators, scientists, planners, and implementers is needed.

8. Scientific expertise
Habitat restoration rests on a solid foundation of information and experience from multiple scientific disciplines. While most projects we reviewed included strong scientific components, it was not obvious that the scientific needs of a project were always identified in the planning stage and measures taken to ensure that the necessary expertise would be available. Observational research and modeling studies can help to identify and prioritize gaps in scientific knowledge. The need for scientific experts to spend time in the field to observe unexpected responses to restoration that may require monitoring and to provide the data and insights that are essential for adaptive management was not widely recognized.

9. Stakeholders
Habitat restorations affect and are affected by an array of individuals and interests that extends well beyond an individual project. In many instances, those who are planning, implementing, and overseeing a restoration recognize the importance of continuing communication with those who are affected by restoration (e.g. landowners).

Recommendations

Based on these findings, we offer several recommendations for improving and enhancing habitat restoration in the Delta. While many of those working on habitat restoration in the Delta are putting some of these recommendations into practice, broader adoption would do much to improve the implementation of restoration and its outcomes.

1. **Coordinate and integrate the planning and implementation of habitat-restoration projects to capitalize on synergies and complementarities among projects.**
    - Communicate clearly stated and realistic goals so that related projects can be linked at the outset.
    - Recognize and incorporate conceptual and spatial connectivity and the complementarities among projects into planning.
    - Include the potential impacts of other management activities in the Delta, such as water diversions and levee alterations, in the design of restoration projects.

2. **Include considerations of climate change and environmental uncertainty in the design and implementation of restoration projects.**
    - Consider the effects of climate change, sea-level rise, land-use change, and other environmental changes in planning and modeling efforts.
    - Incorporate adaptive management into every restoration plan and project.

- Include explicit designs for monitoring the responses of key variables to restoration actions in restoration plans and guarantee adequate, long-term funding for these programs.

3. **Prioritize restoration projects.**
    - Consider multiple criteria (e.g., benefits, costs, feasibility, opportunities) in determining which restoration projects should be done, and when they should be done.
    - Link restoration projects together in strategic networks, based on shared goals, timing, location, and actions, to maximize both financial and ecological returns on investments.

4. **Coordinate and integrate science to inform and guide restoration actions, adaptive management, and prioritization.**
    - Coordinate scientific research with restoration planning, and synthesize and communicate the findings to those responsible for planning and implementation.
    - Provide adequate long-term funding and independent oversight for monitoring programs.
    - Enhance collaboration among scientists in different organizations.
    - Use conceptual modeling, simulation or scenario modeling, and risk analysis to assess uncertainties and the potential costs and benefits of restoration actions.
    - Coordinate the broad design and implementation of restoration activities and the use of science to support these activities, either by an independent body or a rigorous peer review process that can provide objective, third-party assessments.
    - Develop a comprehensive map and accompanying database to show where habitat restoration activities are being conducted or planned in the Delta, accompanied by essential information on these projects.
    - Identify and prioritize research needs for habitat restoration. This could be accomplished through meetings, workshops, and symposia.

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INTRODUCTION

This review of habitat restoration activities in the Delta is mandated in the 2009 Delta Reform Act, which stipulates that the Delta Independent Science Board (DISB) "…shall provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs…." The Act requires DISB to provide the Delta Stewardship Council with "a report on the results of each review" and to include "recommendations for any changes in the programs" (Water Code §85280 (a), parts (3) and (4)).

Given the many programs that bring science to bear on adaptive management of the Delta, reviewing each individually would be a formidable undertaking. More to the point, this would artificially fragment our assessments of efforts that address the same issues. Delta science, like the human activities that need it, cuts across the boundaries of water and habitat projects and the many government agencies, universities, consultants, and interest groups involved. Accordingly, we chose to review programs by thematic areas. Because of the scope and scale of present and proposed habitat restoration and its potential effects on the ecological health and sustainability of the Delta, we selected habitat restoration as the first review theme. We reviewed how science is incorporated into habitat restoration activities—past, ongoing, and planned, as well as in riverine, wetland, and riparian habitats—with an emphasis on how restorations will be managed adaptively in the face of climate change. We initiated this review in summer 2012 and compiled information through February 2013.

The coequal goals articulated in the Delta Reform Act require "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem" (Water Code §85054). Habitat restoration is central to meeting these goals. The Fish Restoration Program Agreement (FRPA), for example, is focused on restoring 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh[1] to benefit delta smelt (*Hypomesus transpacificus*), 800 acres of low-salinity habitat to benefit longfin smelt (*Spirinchus thaleichthys*), and a number of related actions to benefit salmonids (*Oncorhynchus* spp.) (http://www.water.ca.gov/environmentalservices/frpa.cfm). Additionally, the most recent draft of the Bay Delta Conservation Plan (BDCP) calls for more than 100,000 acres of floodplain, wetland, riparian, and terrestrial habitat restoration in the Delta over a 50-year period (see http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/BDCP_Effects_Analysis_-_Appendix_5_E_Habitat_Restoration.sflb.ashx). The overall extent, locations, and status of current and currently proposed habitat restoration projects are summarized in Appendix 3.

APPROACH

To evaluate the science currently used, anticipated, or needed to support habitat-restoration efforts and climate-change considerations in the Delta, we met with, listened to, and interviewed representatives from many of the entities involved in or charged with implementing

[1] Although technically the term "Delta" refers only to the Statutory Delta, we include habitat restoration efforts in Suisun Marsh because they affect and are affected by restoration actions in the Delta and because Suisun Marsh is included in the Delta Plan and BDCP.

the restoration plans (Table 1). In conducting our review, we developed questions and requested information from agencies and entities conducting restoration (Appendix 1). We examined documents describing current and planned restoration efforts, and attended many presentations at the 2012 Bay–Delta Science Conference that emphasized habitat restoration. Our review also drew on our prior experiences with habitat restoration in a variety of ecological settings, both within and outside of the Delta.

Table 1. Entities and individuals who addressed the DISB during its review of habitat restoration.

Federal agencies	National Marine Fisheries Service	Jeff McLain
	U.S. Army Corps of Engineers	Mike Dietl
	U.S. Bureau of Reclamation	Sue Fry
	U.S. Fish and Wildlife Service	Mike Chotkowski
	U.S. Geological Survey	Jon Burau, Dan Cayan, Mike Dettinger, Jacob Fleck, Noah Knowles, Lisa Lucas, Lacy Smith, Dave Schoellhamer, Jan Thompson, Isa Woo, and Scott Wright
State agencies	Department of Fish and Wildlife	Sarah Estrella
	Department of Fish and Wildlife	Carl Wilcox
	Department of Water Resources	Randy Mager
	Department of Water Resources	Dennis McEwan
	Department of Water Resources	Katie Shulte-Joung
	Department of Water Resources, Division of Environmental Services	Dean Messer
	Department of Water Resources, FloodSAFE Environmental Stewardship and Statewide Resources Office	Gail Newton
	Sacramento-San Joaquin Delta Conservancy	Campbell Ingram
Consultants	CBEC	Chris Bowles
	ESA	Michelle Orr
	RMA	John DeGeorge
	Westervelt Ecological Services	Greg Sutter

	Wetlands and Water Resources, Inc.	Stuart Siegel
	Wildlands	Cindy Tambini
Nonprofit organizations	San Francisco Estuary Institute (SFEI)	Robin Grossinger, Letitia Grenier
	Solano Land Trust	Ben Wallace
	The Nature Conservancy (TNC)	Jaymee Marty
Water district	Metropolitan Water District of Southern California	Curt Schmutte
Other organizations	State and Federal Contractors Water Agency (SFCWA)	Byron Buck
	U.C. Davis	Robyn Suddeth, Carson Jeffres, Richard Howitt, Nathan Burley, and William Fleenor

A FRAMEWORK

Reviews are best accomplished when there is a frame of reference for what a successful or "ideal" project or program should include. Based on the literature on ecological restoration (e.g., Perrow and Davy 2002; Society for Ecological Restoration International [SER] 2004, 2005[2]) and our interviews, discussions, and experiences, we suggest that successful habitat restoration projects in the Delta will include the following attributes:

1. *Goals are clearly articulated*. To be effective, habitat restoration requires that the goals, objectives, and desired endpoints be clearly specified and agreed upon at the outset. Goals should be realistic and feasible. Goals should be accompanied by well-defined, operational performance (i.e., outcome) measures. Periodic independent review of large restoration projects can assist in maintaining a focus on goals and avoid unplanned departure from the intended mission of the project.

2. *Spatial context is part of the design.* Individual restoration projects, regardless of their size, are not isolated from the surrounding aquatic and terrestrial landscape, or from restoration or management actions undertaken elsewhere. Nothing happens in just one place; to paraphrase John Donne, "no restoration project is an island, entire of itself."

3. *Temporal context is part of the design.* Environments vary, and these variations are projected to increase in frequency and magnitude as well as change directionally as a result of the combined effects of climate change and land-use change. While future changes are difficult to predict, models can be effective tools to investigate anticipated change.

[2] SER (2005) includes a useful listing of 51 guidelines for restoration projects.

4. *Adaptive management and flexibility are part of the design.* As a result of environmental changes and unanticipated responses to management actions, a restoration project may not go as planned. Consequently, habitat restoration must be conducted in the framework of adaptive management, and implementation designs must incorporate a capacity to change as changing conditions demand.

5. *Monitoring is part of the design.* Monitoring is the lynchpin of adaptive management. Long-term monitoring targeted on key variables that can indicate the effectiveness of actions or reduce critical areas of uncertainty is critical to evaluating progress toward goals. Because monitoring generates data, which must be analyzed to be useful, data management and analysis should be incorporated into a project plan.

6**.** *Modeling is essential in design and evaluation.* Restoration activities at local sites must be connected to restoration goals and processes that occur at much broader geographic scales. Flows of water, nutrients, sediment, and planktonic organisms must be understood at the system scale. Life-cycle models provide a means to link life stages of organisms and their ecology across habitats. Models can help to assess how restoration actions taken in one area might affect other areas. Modeling is particularly appropriate to assess restoration actions under various climate-change scenarios.

7. *Planning and implementation are coordinated among projects.* In many cases, individual restoration projects are part of a broader array of restoration efforts in a landscape or region. To capitalize on the synergies and complementarities among projects, and to avoid situations in which the actions of one project may conflict with the goals of another project, coordination among project administrators, scientists, planners, and implementers is essential.

8. *The necessary scientific expertise is available.* Habitat restoration is based on a solid foundation of information and experience from multiple scientific disciplines. The science needs of a project should be identified in the planning stage and measures taken to ensure that the necessary expertise will be available.

9. *Stakeholders are involved early and often.* Habitat restorations affect and are affected by an array of individuals and interests that extend well beyond an individual project. There should be regular communication between those who are affected by restoration (e.g., landowners) and those who are implementing and overseeing the restoration. Communication should occur before initiating a restoration project as well as throughout and following restoration activities.

FINDINGS AND OBSERVATIONS

Most of the habitat-restoration projects described to us deal with restoration of tidal wetlands or the maintenance and upgrading of levees. In general, these projects are well-conceived. The agency and NGO staff most directly involved in restoration show a high level of dedication, enthusiasm, and knowledge. This is particularly impressive given the formidable challenges of conducting habitat restoration in the Delta and the limited funding available to do it. There is clearly a desire to do habitat restoration that works, and the importance of strong scientific foundation for the projects is widely recognized. Agency administrators charged with planning and/or carrying out habitat restoration recognize the enormity of the task and the many challenges involved. They also show a dedication to conducting successful restoration programs and working with stakeholders to ensure that plans recognize and consider public concerns.

However, we have reservations about the slow pace of restoration activities, the piecemeal approaches, and problems with permitting and crediting that deter implementation and achievement of goals. We also have concerns about the role of adaptive management in the restoration plans and in defining the science that is needed to support adaptive management. Restoration projects seem to be largely independent of one another and often lack an integrated vision with clearly defined and shared goals and objectives. Consequently, the science supporting the projects is often fragmented rather than being coordinated and integrated among projects.

In the following sections, we describe in greater detail the findings of our review and some additional observations, organized according to the attributes of successful restoration projects outlined above.

1. Clear restoration goals

"Goals are the ideal states and conditions that an ecological restoration effort attempts to achieve" (SER 2005). Goals are an integral part of a strategic plan, whether it is for an individual project or area or for a broader region or program (e.g., the Delta Plan, BDCP). The goals of most projects we evaluated were clearly stated, although there was less clarity about the targets or desired outcomes of the restoration efforts. We found considerable ambiguity about overall restoration goals for the Delta as an ecosystem. For example, should the goals be framed in terms of acres of a vegetation type; patterns of hydrologic flows; ecosystem function and resilience; recovery targets for threatened species and ecosystem services; or a compendium of these alternatives, depending on the specific project? In many projects, the goals were framed in terms of acreages to be converted to a particular vegetation or habitat type, rather than benefits of the habitat created. A focus solely on the amount of habitat restored without considering whether the area, condition, or location of habitat is suitable for target organisms may be inefficient and ineffective, and in some cases compromise a project. Some (e.g., National Research Council [NRC] 2012, Moyle et al. 2012) have proposed that the goals of habitat restoration should emphasize enhancing ecosystem functions and resilience. The difficulty in using this approach is in deriving operational ways to identify and assess "ecosystem functions" and "resilience." There was a general recognition that the conditions that characterized the historical Delta (Whipple et al. 2012) can no longer be attained, and none of the programs we reviewed had that as its goal. Nonetheless, historical ecology can provide a tool for using the past to understand the foundations of the present landscape and to assess its future potential for restoration by considering landscape patterns, processes, and functions and the conditions to which species are adapted (Wiens et al. 2012).

Goals are also influenced by policy and regulations. We found that several projects were planned within the regulatory context of BDCP, so the goals were strongly influenced by the Endangered Species Act and associated Biological Opinions. As a result, meeting regulatory requirements might or might not be consistent with the goals of larger, integrated habitat restoration programs within the Delta.

While not directly related to the science of restoration, we are also concerned about the process by which habitat restoration activities are "credited" toward meeting the requirements of the Biological Opinions and BDCP. Some agency representatives suggested that crediting should happen in stages—credits could be applied in increments as project proponents demonstrate success. This is a reasonable argument but implementation could be problematic in some cases because restored habitats need to develop characteristic geomorphic features, which may take time to become established. Alternatively, others suggested that crediting should occur when the land acquisition for restoration occurs, and still others suggested that the needs of project adaptation or modification might dictate that credit vary with time. In this case, an initial credit would be given to reward the initial restoration effort but with credit decreasing (or discounted) over time so that a continuous stream of resources is available for adaptive management. In any case, there is a need to clarify the crediting process and to establish guidelines that are based on science. Considerable experience on crediting exists within the Interagency Review Team that evaluates mitigation banks, although this experience does not appear to have been consulted as the Fish Agency Strategy Team (FAST) process is being developed.

Although no single goal or target applies to all projects and plans, without a broader consideration of how different goals interrelate (or conflict), the goals for individual projects may be achieved without improving the overall health of Delta ecosystems. Restoration priorities among projects might differ, for example, if the broad restoration goal for the Delta is to restore a population of a particular species rather than (or in addition to) restoring habitats to improve overall ecosystem health, or if the goals are determined by regulations or credit allocations rather than ecological considerations. The differences are important, for they may dictate differences in the science and monitoring that are required to judge progress toward meeting goals and in how science is applied in adaptive management (or, indeed, whether adaptive management is part of the plan).

Goals go hand-in-glove with performance measures. We found that few projects incorporated operational and realistic performance measures. Although tabulating the number of acres of tidal wetland restored may be easy, for example, it does not provide an adequate measure of the contribution of such restoration to enhancing the functioning of Delta ecosystems. Without performance measures, there is no rigorous and objective way to tell whether progress is being made toward goals. While the specifics of performance measures must be closely aligned with specific goals, stating goals without accompanying performance measures is incomplete. Some general benchmarks for gauging the success of projects in recovering ecosystem integrity, health, and the potential for long-term sustainability are provided by the Society for Ecological Restoration (SER 2005). Although not all of these attributes may apply to habitat restoration in the Delta, they may provide some guidance in formulating performance measures. (Performance measures are also discussed under Finding 4, Adaptive Management.)

2. Geographic context is of critical importance

Nothing happens in just one place. Restoration at one location in an aquatic system is affected by events or management activities upstream, including other restoration projects. Restoration of wetland habitats along waterways or levees is affected by the environment and land uses in the surrounding landscape. The discipline of landscape ecology is replete with concepts, theories, analyses, and examples showing how processes and dynamics in one area of habitat (such as a restoration project) are influenced by the composition of the broader landscape mosaic and the patterns of connections among landscape elements (e.g., Hobbs 2002, Bissonette and Storch 2003, Wiens and Moss 2005, Lindenmayer et al. 2008).

We found, however, that restoration projects in the Delta are being planned and implemented largely independently of one another and of their landscape context. Several people pointed out that achieving connectivity among habitats to be restored in the Delta is constrained by many factors, including the ability to acquire lands, complete the permitting process, and secure funding for restoration. Project size and scale are important as well. Nonetheless, the long-term success or failure of restoration projects may rest on how well the linkages and connectivity are incorporated into the planning and implementation of individual projects. One striking example of the interdependence of restoration projects is provided by a modeling analysis of the consequences of where and how restoration is conducted in Suisun Marsh. Results indicate that the type of restoration can alter salinity and tidal fluctuations in many other parts of the Delta (John DeGeorge, RMA Modeling Team, personal communication).

In marine ecosystems, Marine Protected Areas (MPAs) are often viewed to be best developed as networks of complementary areas, in which the whole of the network has greater ecological benefits than the sum of its parts (e.g., North American Marine Protected Areas Network; http://www.mpa.gov/nationalsystem/international/nampan/). Such "strategic networking" could be considered to link habitat restoration projects in the Delta. Beyond networking restoration sites and projects, there may also be value in clustering projects together according to shared suites of environmental characteristics, such as the "operational landscape units" developed by the San Francisco Estuary Institute (Whipple et al. 2012). Clearly, the planning and implementation of individual restoration projects should occur within a landscape framework over multiple scales. The analyses of Whipple et al. (2012), for example, indicate that historical factors and current dynamics differ fundamentally among different parts of the Delta. The science underpinning restoration efforts must recognize these differences, which may affect the design, implementation, and long-term success of restoration projects.

3. An extended timescale must be considered

Many changes are occurring in the Delta. Modifications of climate, hydrology, land use, economics, sea level, and the spread of invasive species, as well as potential levee failures, will affect the design, implementation, and outcomes of restoration projects today and in the future. All are affected by changing public and political perceptions and agendas. Management of the Delta to attain the co-equal goals will require dealing with these changes and the multiple uncertainties they produce.

It is clear to the DISB that a "business as usual" approach will not be viable. Unanticipated environmental changes will lead some (perhaps many) habitat restoration projects to not turn out as planned. Therefore, it is important to consider strategic planning of restoration projects that incorporates long-term risks now, rather than at sometime in the future.

All agencies reported that climate change and sea-level rise were being considered in their habitat restoration plans, although it is unclear based on their presentations and interviews how these potential effects will be incorporated into actual restoration actions. Overall, when climate change was being considered, sea level rise was the primary focus. Little attention was given to climate change effects on altered hydrology and temperature. Agencies indicated that they are mandated to include climate change considerations, although few specific details were provided.

Uncertainties in projections of regional climate changes and their effects means that restoration plans will need to incorporate flexibility to adapt as projections improve. This is particularly important given the coarseness of resolution of current models of climate change and sea-level rise, which renders their application to specific sites and projects problematic. As the science of climate change progresses, new insights (e.g., the effects of "atmospheric rivers" on precipitation regimes that affect the Delta; Dettinger 2011) are being incorporated into climate-change models, while the spatial resolution of modeling and projections are rapidly improving. As they become available, new projections should be communicated to those planning and implementing restoration projects as quickly as possible. To be effective, restoration plans must incorporate approaches and alternatives that are resilient and adaptable to both anticipated and unintended changes associated with climate change and sea-level rise.

There is a major need for science to evaluate complex, nonlinear responses (e.g., Scheffer 2009) of the Delta ecosystem to changing environmental conditions and how these affect, and are affected by, restoration activities. The dynamics of every ecosystem are, at some level, nonlinear, and the more complex the ecosystem the greater the array of nonlinearities (Gunderson and Holling 2002). As a result, nonlinearities, discontinuities, and threshold responses must be considered and anticipated in designing habitat restoration programs. In practical terms, this means that, as the Delta undergoes changes, it will be beset by discontinuities and thresholds (e.g., the Pelagic Organism Decline and regime shifts; Chapter 6 in Lund et al. 2010). In some cases the system may change in composition, structure, and/or function in ways that make it virtually impossible to return to a former condition, as visualized in state-and-transition models (Bestelmeyer 2006, Bestelmeyer et al. 2011). The analysis of the environmental history of the Delta (Whipple et al. 2012) indicates that this has already happened, perhaps several times. With climate change and other future environmental shifts, thresholds will be encountered more often. These thresholds will confound habitat restoration programs that are based on assumptions of a continuation of current conditions and processes and of linearity (NRC 2012). Unfortunately, we noted few indications that nonlinear, threshold dynamics are being considered in restoration planning for the Delta, although several people seemed to be aware of the difficulties such nonlinear responses might pose for implemented restoration plans. Attention should be given to developing ways of incorporating contingencies for threshold changes in ecosystem dynamics into the design of restoration projects, perhaps through a dedicated activity sponsored by the Delta Science Program. Both projects and restoration programs should be prepared for surprises.

Because climate change will influence both water supply reliability and ecosystem structure and function, trade-offs and priorities in water allocations must also be considered, especially during dry years (NRC 2012). Secure funding and institutional capability will need to be established to respond to such changes.

4. Adaptive management is essential to habitat restoration

The many ongoing changes in the Delta's biological and physical environment and the anticipated prospects of increased changes, extreme events, and thresholds in the future will increase uncertainty, making it difficult to predict the outcomes of specific habitat-restoration activities. In fact, the inclusion of an adaptive management program is mandated in the 2009 Delta Reform Act. Consequently, habitat restoration must be conducted in the framework of adaptive management. To do this requires that effective strategic planning of restoration projects be conducted at the outset. Some restorations may not be readily amenable to adaptation. Therefore, effective planning before implementation will be needed to minimize this risk.

The importance of adaptive management was mentioned during most of our interviews and interactions, and every plan for the Delta presented addressed adaptive management, typically with a general outline of how it will be implemented. However, we found no clear instances in which it actually was being done in a formal sense. Two examples, however, illustrate progress toward implementing adaptive management in the Delta. The first is a comprehensive adaptive management plan for the Dutch Slough Restoration Project in eastern Contra Costa County (Cain 2008). The plan is framed in terms of testable hypotheses about restoration outcomes. The plan's broad goal is to attempt to learn lessons to apply to tidal-wetland restorations elsewhere in the Delta. Delays in other aspects of the Dutch Slough project have held up the plan's implementation. The second example is a plan that makes abundant use of conceptual models, developed under the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) (DiGennaro et al. 2012, Presser and Luoma 2013).

It is not clear to us that there is a unified perception of what adaptive management entails. Moreover, we only saw one example (one of the DRERIP models) where conceptual models had been developed (DiGennaro et al. 2012), despite the fact that conceptual modeling is supposedly the first step in adaptive management. We also heard no mention of performance measures, which are essential for monitoring the outcomes of restoration projects. This is a critical omission. However, performance measures do figure prominently in the Dutch Slough adaptive management plan cited above. They also receive careful attention in a conservation strategy for the Central Valley (Ecosystem Restoration Program, 2011). These, however, appear to be the exception rather than the norm.

Finally, there is an issue with the application of adaptive management to habitat restoration in the Delta that is not generally recognized or acknowledged. Conditions in the Delta will change quickly in the future, requiring that adaptive management be nimble. However, the nine-step adaptive management process envisioned in the Delta Plan (or any other adaptive management design) includes multiple points at which information must be gathered, data analyzed and synthesized, and decisions made. Collectively, these will make adaptive management a slow process (which may be why it has so rarely been done), limiting its capacity to make adjustments quickly. Consideration should be given to how the adaptive management process can be streamlined, without sacrificing its scientific rigor.

5. Effective monitoring is key to the application of adaptive management

Monitoring is the lynchpin of adaptive management. Without long-term monitoring, targeted on key variables that indicate the effectiveness of actions and/or reduce critical areas of uncertainty, formal adaptive management will not be possible. While the need for monitoring is recognized in most projects and plans, insufficient attention is given to selection of the best targets for monitoring, the appropriate frequency or duration of monitoring, or the use of methods and data management that will enable sharing and synthesis of findings among projects. Monitoring also requires reliable sources of long-term funding. We were told that some small projects lacked sufficient resources for monitoring, which prevents formal adaptive management. Other monitoring challenges include developing ways to collect monitoring data in a common format and make them easily available for analysis, inclusion in modeling research, and synthesis of results and their inclusion into the ongoing planning process.

Because there have been so few ongoing and effective monitoring programs and evaluations of restoration efforts in the Delta, it is difficult to determine the success of past programs. Challenges and restoration goals differ among sites and projects. Therefore, adaptive management will need to be specific in its applications, while at the same time be broadly coordinated among sites. Clearly, there is no one-size-fits-all rule that will apply to specific adaptive management and restoration programs. At the same time, however, adaptive management must extend beyond site-scale monitoring, experimentation, and learning. Most of the species of concern in the Delta require a range of sites and habitat types that are scattered over a large area. Adaptive management should be applied at these broader scales as well. The need to scale-up interpretations of site-specific monitoring to broader areas and habitats may best be done through modeling, although field data and observations (e.g., Sagarin and Pauchard 2012) are of critical importance in validating and using the models.

6. Modeling benefits restoration projects

To increase benefits, restoration activities at local sites must be scaled up and connected to restoration goals and processes occurring at much broader geographic scales. Flows of water, nutrients, and supported species must be able to enter and leave restoration sites to support overall ecological goals, not just at single sites, but for the entire Delta. Some large restorations may also affect (for either good or ill) ecological structure and function in other parts of the Delta, for example by changing tidal ranges and flows or changing predation levels and food for migrating fishes. As marshlands are restored and expanded in Suisun Marsh, Cache Slough, and San Francisco Bay, the resulting dissipation in tidal energy may reduce tidal ranges enough to reduce the effectiveness of marshes in these and other regions. Such complex, connected processes are best addressed by modeling research.

Broad-scale effects that may influence local site restoration also should be examined. These broad-scale effects include sea-level rise, changes in Delta diversion-infrastructure locations and operations, long-term abandonment of some Delta islands, or breeching of major levees. Computer modeling is the best way to explore the implications of such changes on local and system-wide restoration efforts. At the local scale, modeling is also often important for designing and implementing restoration plans. Examples of incorporating this approach at local scales include examination and exploration of local scour, flow patterns, and water resident-times within restoration sites. If site conditions change, adjustments may be expensive. Simulation modeling and exploration can help to anticipate and reduce the number of expensive and time-consuming adjustments needed in implemented restoration projects.

Modeling provides useful and timely insights, but it is ever-evolving, expensive, and time-consuming to develop. The CASCADE and CASCADEII models, for example, are powerful and detailed, and they have the potential to help restorationists assess how actions in one area might affect other areas under differing climate-change scenarios (Cloern et al. 2011). Their potential usefulness is compromised to an extent by the need for both supercomputing capacity and the expertise to run the models. We note that such highly sophisticated models could serve to test the effectiveness of simpler models that might be more readily used in the design and planning of restoration projects, or in the adaptive management process.

The development and management of modeling capability in the Delta remains highly decentralized, which has both advantages (e.g., entrepreneurship) and disadvantages (e.g., difficulties in model comparisons). More effort should be brought to bear in developing, testing, and disseminating more advanced 3-D modeling capabilities suitable for conditions in a changing Delta. Meeting this challenge will require substantial development of common digital geomorphic, bathymetric, hydrologic, and water-quality data sets. A consortium of state, federal, and local agencies, involving consulting firms with substantial relevant expertise, will be important to achieve such modeling capability. We also heard suggestions for development of a model library for use by Delta scientists and agencies involved in habitat restoration; we fully endorse this suggestion.

7. Planning and implementation are coordinated among projects

All of the entities involved in managing the Delta ecosystem recognize that habitat restoration for the Delta cannot be accomplished by fragmented efforts. The NRC report (NRC 2012) calls for scientific integration and notes that more than coordination is needed for the Delta. Program and agency administrators do talk with each other and, although the collaborations could be strengthened, the intent to cooperate is clearly there. Certainly, there is a recognition that entities must work together to achieve the co-equal goals required in the legislation of the Delta Reform Act. The intent to collaborate is illustrated by the Ecosystem Restoration Program, which formally began in 2000 and involves the California Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service (Ecosystem Restoration Program 2011). Collaborative efforts also produced DRERIP models (DiGennaro et al. 2012) and the Dutch Slough adaptive-management plan (Cain 2008). The latter effort involved collaboration of federal, state, university, and private-sector scientists. In addition, field staff in some programs (notably, DWR's Floodsafe Environmental Stewardship Statewide Resources Office, FESSRO) are working across program boundaries in a true interdisciplinary fashion, and clearly take pride in these collaborations. At a broader level, the Interagency Ecological Program (IEP) illustrates the potential benefits of long-term, multi-agency collaboration.

We noted that the lack of linkages among projects is exacerbated by the overall lack of coordination among the multiple entities involved in planning, conducting, monitoring, or regulating the restoration. Sharing of plans at an administrative level is commendable. However, real coordination involves collaboration and teamwork among the scientists and staff conducting the restorations at multiple locations.

The need for integration extends beyond the scope of habitat restoration projects and planning. The success (or failure) of restoration actions, individually and collectively, will be subject to decisions made by other components of Delta management. For example, decisions on flow regulation will affect both the establishment and permanence of wetland and floodplain vegetation, and the value of such habitats to fish and wildlife. Decisions on how levees are managed and prioritized for strengthening or abandonment also will determine the long-term fate of many restoration projects (NRC 2012). We did not find that these broader influences figured prominently in most habitat restoration projects or plans.

One impediment to collaboration among public and private entities and landowners is communication; more specifically, the sharing of data and information about restoration projects and their results. We recognize that it is difficult to share information among projects involving private lands if opening access to the information might affect land values, speculation, or other stakeholder activities. Confidentiality issues must be addressed if the science and monitoring required to support comprehensive adaptive management are to occur.

The lack of any broadly available or comprehensive Delta-wide maps showing current and planned restoration activities in the Delta is symptomatic of the difficulties of coordinating and integrating restoration efforts. An accurate and comprehensive set of maps showing what is being done where, and by whom, is essential if there is to be real coordination of restoration efforts across the Delta and the many entities involved in habitat restoration. Such maps are also necessary to link restoration projects with other management activities in the Delta that may influence the effectiveness of the restoration. A general map of current and proposed areas for habitat restoration in the Delta, developed by the Delta Science Program in collaboration with the California Department of Water Resources and the Sacramento–San Joaquin Delta Conservancy, is provided in Appendix 3 along with a discussion of the status of Delta restoration projects.

Information about where habitat restoration is being planned or implemented is the foundation for making intelligent decisions about how to prioritize restoration projects. Not everything that is needed can be done, and some projects should be done before others. Prioritization of restoration projects cannot be done unless the disparate projects are integrated and a database is created to enable planners to accomplish this integration. The Ecosystem Restoration Program (2011) provides an example of one attempt to prioritize areas for restoration, and the Delta Plan and BDCP indicate broadly defined areas for priority restoration projects. Decisions about what to do, and when and where to do it, is a major challenge in integrating restoration activities in the Delta; such decisions cannot be made in a piecemeal fashion.

We also detected some tension between the science, management, stakeholder, and regulatory communities. To be effective, all of these communities must overcome past history and work together. Adaptive management, for example, will require that regulatory entities be responsive, particularly in expediting the permitting process and having the flexibility to allow changes in permit specifications as changing environmental conditions warrant.

8. The necessary scientific expertise is available

Habitat restoration relies on a solid foundation of information and experience from multiple scientific disciplines. The scientific needs of a project should be identified in the planning stage and measures taken to ensure that the necessary expertise will be available. Collaboration and organizational conditions should be developed to facilitate new understandings of the system of interest and to translate knowledge into management actions and decision systems.

State Agencies

One of the clearest impressions emerging from our review is the high level of dedication, enthusiasm, and knowledge of the staff of state agencies most directly involved in restoration in the Delta. This is particularly impressive given the formidable challenges of conducting habitat restoration in the Delta with limited funding. Nonetheless, levels of science staffing in the entities responsible for habitat restoration are inadequate, and work is frequently contracted to external consultants. There are advantages to this: consultants often complete work in a timely fashion; mobilize more people and resources; and leave for other projects when a contract ends, which is advantageous when specific expertise is needed for only a short time. But contracting consultants is often more expensive than hiring state employees, at least in the short term. Perhaps more importantly, over the long term, the state does not receive the benefits of establishing substantial technical and management expertise and leadership in-house, which is needed for the multi-decadal timeframe required of many restoration projects. Although the same consultants are often used, providing some continuity and long-term familiarity with the system, there is a need to assess when consultants are the best choice for using resources wisely and serving the long-term needs of science in the Delta, and when long-term investment in state agencies is a better option.

Private Sector Involvement

In the presentations made to us, it became clear that there are important roles for private firms in the development of effective restoration projects. There is a spectrum of degrees of involvement. At one end, private contractors are employed by government restoration projects for construction, maintenance, or aiding with general or specific elements of design and analysis. Private firms and NGOs are also often employed to take substantial charge of some restoration sites, typically under agency supervision. NGOs are often taking a lead in restoration projects, such as The Nature Conservancy's work on the McCormack-Williamson Tract. At the most involved end of the spectrum, several private firms identify, purchase, develop, and then sell shares of restoration projects for regulatory or mitigation credits. To date, these efforts have been limited to a few hundred acres in the Delta.

In some cases, private firms also bring strong science and technical expertise that is needed for monitoring and evaluation, as well as the follow-up analyses needed for an agency to conduct adaptive management. The availability of this expertise should be assessed when a restoration project is being developed.

It is apparent to us that much of the best and most nimble wetland restoration expertise in California resides in private firms. The consultants currently working in the Delta have both a long history of involvement in the Delta and an in-depth knowledge of its ecosystems. They provide continuity in Delta habitat restoration. Given the enormity of restoration efforts anticipated in the coming years, it is important to find ways to make the best use of NGOs and private firms in restoration activities, while bolstering the science staffing of the state agencies involved in the Delta.

University Research

University research has been central to understanding many of the issues that affect habitat restoration. It has also contributed to the training of the agency staff and policy makers who are responsible for the monitoring and assessment programs and for the design and funding decisions that will make restoration happen. Some research, such as the studies forecasting how climate change may affect the Delta, results from initiatives that are independent of the Delta but are key to supporting ecosystem restoration in the Delta. Earlier funding programs, such as the CALFED science program and the current Delta Science Program, have focused some university research efforts with proposal solicitations targeting research issues that were key to reducing uncertainty about restoration prospects and outcomes. Many restoration initiatives integrate university-based researchers in their efforts (e.g., fish friendly farming in the Yolo Bypass).

The organization and scope of university-based science provides tremendous opportunities for restoration efforts and adaptive management in the Delta, but efforts must be made to facilitate interaction between the scientists and managers. In the past, successful efforts to integrate research science into ecosystem restoration and water management decision-making processes involved some shift in the knowledge or actions of agency staff, stakeholders, and/or research scientists (Taylor and Short 2009, Suding 2011). While research scientists are often concerned with understanding how a system operates, management scientists are concerned with getting a system to work (Taylor and Short 2009). When these goals overlap or when one side finds a way to operate in the context of the other side, it is easier to apply the knowledge or agree on how to proceed. Efforts should also be made to attract talented investigators, leverage research initiatives, and spark new investigations of key topics that will improve ecosystem restoration in the Delta.

Sustaining Field Knowledge

As ecosystems change, new factors, such as an invasive species and the species they threaten, can become critical to monitor while some of the processes and factors that have heretofore been monitored may become less critical. Observers in the field, typically scientists but also managers and others such as trained citizen-science groups, often are the ones who discover new phenomena of ecological importance. Discovering new phenomena usually requires a solid understanding of what has been there in the past as well as appropriate time being spent in the field. Sustaining such field expertise and providing a mechanism for new observations to be recorded and to lead to new understanding is a critical part of adaptive management and monitoring. It should be encouraged.

9. Stakeholders are involved early and often

Habitat restorations affect and are affected by an array of individuals and interests that extends well beyond an individual project. Considering and assessing probable impacts of restoration and restoration activities on stakeholders should be a component of plans and design of projects. Those who are affected by restoration (e.g., landowners) should be in continuing communication with those who are implementing and overseeing the restoration. In the individual restoration projects that were described to us, there appears to be good involvement of stakeholders, at least in the early phases of projects. In large-scale projects such as BDCP, stakeholder involvement will be essential for success at every stage of the project (i.e., planning, implementation, monitoring) and will be of critical importance for adaptive management to be successful.

RECOMMENDATIONS

Habitat restoration is essential for rebuilding the ecological functions and integrity of Delta ecosystems. It is also a key element of plans for future water management in the Delta. Habitat restoration is also expensive and demanding. It is important that it be done right.

While the findings we have summarized above contain some specific recommendations, we offer here several general recommendations to strengthen individual restoration projects, produce greater cohesion among restoration efforts over the Delta as a whole, and solidify the scientific foundation of restoration plans and activities. Our findings and recommendations parallel those reached independently by the National Research Council (NRC) panels (Appendix 2). This concordance among independent science-review bodies reinforces the recommendations presented below.

1. Coordinate and integrate the planning and implementation of habitat-restoration projects to capitalize on synergies and complementarities among projects.

- *Communicate clearly stated and realistic goals so that related projects can be linked together at the outset*. Develop goals through a transparent process that includes scientists, managers, administrators, policy makers, regulators, and key stakeholders. Frame goals to extend beyond the requirements of regulatory compliance.
- *Recognize and incorporate conceptual and spatial connectivity and the complementarities among projects into planning*. Projects with similar goals or in similar environmental settings or that require similar restoration actions can benefit by sharing plans and experiences. Spatial connectivity among projects (e.g., tidal wetland restorations) can enhance the value of the individual projects.
- *Include the potential impacts of other management activities in the Delta, such as water diversions or levee alterations, in the design of restoration projects*. The Delta is an extensively interconnected system in which actions or events in one location can have

cascading effects on the results of restoration elsewhere. Broad coordination of management of water flows, land uses, infrastructure, water quality, and wildlife is needed to ensure that actions do not conflict with one another.

2. Consider climate change and environmental uncertainty in the design and implementation of restoration projects.

- *Consider the effects of climate change, sea-level rise, land-use change, and other environmental changes in planning and modeling efforts.* These effects will be felt, with varying impacts, everywhere in the Delta. In some cases, threshold dynamics and the potential for irreversible change in key system attributes will add to uncertainties.
- *Incorporate adaptive management into every restoration plan and project*. In a dynamic environment, the ability to revise approaches as conditions change is a key to success. When possible, the adaptive-management process should follow the nine-step procedure outlined in the Delta Plan. Sufficient personnel and funding should be provided to ensure that science-based adaptive management can actually be carried out over appropriate time spans. Steps should be taken to bridge the science-policy communications gap so that the scientific information can be incorporated into policy and management decisions. Permitting and regulatory procedures should be revised to allow previously approved actions to be changed as changing environmental conditions warrant.
- *Include explicit designs for monitoring the responses of key variables to restoration actions in restoration plans and guarantee adequate long-term funding for these programs*. Successful monitoring requires that performance measures be developed at the onset of a project and a monitoring program be designed around the established performance measures. Monitoring targets should be chosen to provide the most accurate and useful information related to the specific goals of the restoration, and monitoring should be designed to assess both short-term and long-term effects of the restoration. The potential for establishing a trust fund to support monitoring, funded through a surcharge on restoration projects, should be explored.

3. Prioritize restoration projects.

- *Consider multiple criteria (e.g., benefits, costs, feasibility, opportunities) in determining which restoration projects should be done, and when they should be done*. For example, a comparison of potential restoration sites with potentially vulnerable levee locations could indicate where restoration efforts might be secure or insecure in the future. Multi-layer mappings of both current and proposed restoration projects and actions and accompanying databases and data-management systems are a foundation of spatial planning and need to be developed. This should begin with development of maps showing current and planned habitat restoration projects that are coded by the form of habitat restoration proposed
- *Link restoration projects together in strategic networks, based on shared goals, timing, location, and actions, to maximize both financial and ecological returns on investments*. For example, projects might be clustered together according to shared suites of environmental characteristics, such as the “operational landscape units” developed by the San Francisco Estuary Institute.

4. Coordinate and integrate science to inform and guide restoration actions, adaptive management, and prioritization.

- *Coordinate scientific research with restoration planning, and synthesize and communicate the findings to those responsible for planning and implementation*. The integration and coordination should occur at multiple levels—monitoring, adaptive management, restoration planning, and implementation--and these activities need to be done among projects, not just individually. Various multiagency steering or coordinating groups have been proposed. Such groups must include scientists and stakeholders as well as individuals charged with representing their agencies.
- *Provide adequate long-term funding and independent oversight for monitoring programs.* Monitoring is essential to the adaptive management process. Moreover, the coordination of ongoing monitoring activities and the availability of sufficient resources to execute monitoring programs at the appropriate spatial and temporal scales are critical for assessing the outcomes of habitat restoration projects. An objective and independent body should be responsible for reviewing the outcomes and success of restoration projects. Although it is unclear how this body would be funded, one possibility is that this body could be supported by a fund that is derived from a fixed-percentage allocation from each project.
- *Enhance collaboration among scientists in different organizations*. Although the various entities dealing with the co-equal goals collectively have considerable scientific expertise, institutional barriers and agendas make it difficult to fully capitalize on this expertise. Efforts should be made to foster greater collaboration and communication among scientists in different organizations. The Delta Science Program (DSP) sponsors several activities with this aim. DSP activities could serve this purpose but may need to be expanded.
- *Use conceptual modeling, simulation or scenario modeling, and risk analysis to assess uncertainties and the potential costs and benefits of restoration actions*. Modeling should be prominent in all stages of habitat restoration, ranging from planning and design to analysis of ecosystem responses that may lead to adaptive changes in management. For example, the DRERIP approach at the design stage uses deterministic, conceptual models of ecosystem components linked with cause-and-effect relationships of interacting variables. The potential effects of climate change on restored habitats are best investigated by modeling approaches that use monitoring data collected before and after implementation of the restoration project.
- *Coordinate the broad design and implementation of restoration activities and the use of science to support these activities, either by an independent body or a rigorous peer review process that can provide objective, third-party assessments*. To be effective, this body should have the authority and resources to achieve real integration and coordination.
- *Develop a comprehensive map and accompanying database to show where habitat restoration activities are being conducted or planned in the Delta, accompanied by essential information on these projects.* This effort is currently being coordinated by the Delta Conservancy and should be encouraged.
- *Identify and prioritize research needs for habitat restoration.* Habitat restoration in the Delta and Suisun Marsh can both require and promote understanding of underlying

physical and biological processes. Meetings, workshops, and symposia should involve representatives of agencies, universities, and consultants. The Delta Science Program is an appropriate organization to organize this.

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APPENDICES

Appendix 1. General areas covered for information gathering about habitat restoration and climate change in the Delta

1. Current and planned restoration efforts

- Describe your current and planned habitat restoration efforts in the Delta
- How does scientific research inform these actions?
- How are these efforts likely to be affected by climate change, sea-level rise, or other environmental changes? (i.e. are the current and planned activities likely to be effective in 10-20 years, given the rapid pace of environmental change?)
- How are modeling, monitoring, and adaptive management incorporated into current and planned habitat restoration efforts, and are these designed to facilitate adaptation to climate change?

2. Collaboration, communication, and synthesis

- How are your habitat restoration activities shared or coordinated with other public agencies or private organizations?
- How are the potential effects of climate change being incorporated into collaborative efforts?
- How are the results of the work used to inform adaptive management and decision-making?
- How are the results communicated to multiple stakeholder groups and the general public?

3. Policy and Decisions

- How are priorities established about what to restore, where, and when?
- How are models or decision-support tools used to set priorities?
- What policies drive or constrain the restoration work?
- Are current policies or decision processes appropriate for habitat restoration in a rapidly changing environment? If not, what policies or processes are needed?

Appendix 2. Similarities between the DISB and the National Research Council reviews

The National Research Council of the National Academy of Sciences conducted two reviews that are relevant to the present DISB review of habitat restoration in the Delta (NRC 2011, 2012). In order to conduct an independent analysis, we did not examine the NRC reports carefully until we were near the conclusion of our review and had drafted some initial findings and recommendations. On reading the NRC reports, it became apparent that there are a great many parallels and similarities between their observations, findings, and recommendations and ours. We summarize these parallels by quoting from the NRC reports below. The convergences in conclusions between the two independent review panels make a strong statement and add to the urgency of heeding the conclusions and recommendations of each group.

Issue	NRC comments
Unclear goals	"A systematic and comprehensive restoration plan needs a clearly stated strategic view of what each major scientific component of the plan is intended to accomplish and how this will be done." (2011:6) "Only when the goals are made specific and operational will the trade-offs required become apparent, and the trade-offs will require policy judgments about priorities, acceptable risks, and acceptable costs. Such judgments should be informed by science." (2012:43) "experience in the delta and in other ecosystems highlights the importance of clear, well-articulated goals and of a workable governance system … While no plan, however well thought out and developed, will be fully realized, without an effective plan, rehabilitation efforts are doomed." (2012:179)
Restoration and management targets	"Delta restoration programs will need to balance consideration of an ecosystem approach with the ESA's emphasis on individual species." (2012:11) "Given the diverse set of organisms and processes that constitute the bay-delta ecosystem, the ultimate success of any approach targeted only to particular species seems doubtful. In contrast, broad ecosystem approaches, recognizing substantial uncertainty, are needed …" (2012:132) We should "focus on management that promotes diverse, resilient ecosystems that sustain most desired species and that provide the greatest suite of ecosystem services." (2012:179) "support for better understanding of the processes that link flows, habitat structure, and habitat characteristics such as salinity, turbidity, and

	temperature should remain a high priority." (2012:134)
Future changes	"restoration of ecosystems to a historical baseline is no longer possible in many areas. (2012:41) "delta planning must envision a system that may be very different from what exists today, both physically and functionally." (2012:153) "Restoration projects should be designed with flexibility to accommodate potential changes in hydrology due to levee failure." (2012:177) "Future planning should include the development of a climate change-based risk model and analysis that incorporates data on the actual changes in delta conditions as well as alternative future climate scenarios and their probability." (2012:181) "An approach that does not consider alternative futures may fail to achieve the anticipated benefits leading to the further degradation of the bay-delta ecosystem." (2012:172) "ecological changes in response to engineering changes will not necessarily be linear." (2012:135)
Adaptive management and monitoring	"A more uncertain and variable water future will require water planning and management for the delta that is anticipatory as well as adaptive." (2012:39) "long-term changes in the food web due to invasions or nutrient inputs or climate change might alter the influence of flow on the ecosystem; thus, continued monitoring is essential." (2012:132) "Early detection through monitoring is useful to prepare for likely changes to the ecosystem." (2012:134)
Integration and leadership	"the lack of explicitly integrated comprehensive environmental and water planning and management results in decision making that is inadequate to meet the delta's and state's diverse needs, including environmental and ecological conditions in the delta [and] has hindered the conduct of science and its usefulness in decision making." (2012:12) "Achievement of a scientifically, technically, and socially supportable plan requires the individual and collective consideration of 'significant environmental factors,' a quantified effects analysis, and goal-based adaptive management programs that provide a platform for future investments in water-supply and restoration activities. These all require clear-headed decision making and leadership that are difficult to come by if governance of the plan or water management as a whole remains fragmented." (2012: 197)

	The "lack of a leadership model is a major contributor to the controversies, litigation, disagreements, and continuing lack of consensus." (2012:200)

Appendix 3. Status of Delta habitat restoration

Previous compilations

Progress toward habitat restoration in the Delta was reported in two posters at the 2012 Bay-Delta Science Conference. One presented map output from a preliminary "GIS database of current and planned restoration projects" (Davis Fadtke et al. 2012). The poster abstract states that project areas are being categorized by habitat type and project status where possible. The authors are affiliated with the Sacramento-San Joaquin Delta Conservancy, Wetlands and Water Resources, Inc., and the California Department of Water Resources.

The second poster, by staff of the California Department of Fish and Wildlife, summarized efforts under the Ecosystem Restoration Program (Garcia et al. 2012). The Program is being implemented in collaboration with the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration. The abstract stated that the program has "acquired or restored over 82,000 acres of habitat Program-wide and is currently managing over 70 projects ranging from research to full-scale implementation."

Map in this report

The habitat-project map in this report (Appendix Fig. 1) is derived from the unpublished GIS database announced by Davis Fadtke and colleagues (2012). The map depicts dozens of areas where habitat protection, enhancement, or restoration are planned. The status of these efforts varies; in some cases the land is being acquired, while in others the projects are underway or have been completed. The efforts date from one or more years between 1994 and 2012.

The database, originally compiled by staff of the California Department of Water Resources, is now being managed by the Sacramento-San Joaquin Delta Conservancy. The map itself was compiled by Katie Morrice of the Delta Science Program with guidance from Kristal Davis Fadtke of the Delta Conservancy and Anitra Pawley of the Department of Water Resources.

Maps and acreages in draft plans

Areas in which habitat restoration is deemed important in the current version of the Delta Plan are also shown in Figure 1 of this report. In the plan's November 2012 draft, pages 144 and 147 describe these “Priority Habitat Restoration Areas” and Figure 4-6 of the draft plan shows them on a map (http://deltacouncil.ca.gov/delta-plan/current-draft-of-delta-plan). The legend in Figure 1 of this report, prepared by the Delta Science Program, states that the Priority Habitat Restoration Areas contain sites that may prove suitable for habitat restoration. As a supporting reference, the Plan cites a report of the Ecosystem Restoration Program that provides a verbal description of 11 priority areas for habitat restoration in the Sacramento–San Joaquin Delta and the Suisun Marsh (Ecosystem Restoration Program 2011, p. 76-81)

The Delta Plan's priority areas for habitat restoration largely overlap with what the Bay Delta Conservation Plan calls “Restoration Opportunity Areas.” The latter are depicted in the

March 14, 2013 draft of BDCP chapter 3, where they can be found at small scale in Figure 3.2 (parts 2-12) and at large scale in Figure 3.4 (parts 6-16) (BDCP_+Chapter 3+-+Conservation+Strategy+-+Figures+3-14-13.pdf at http://baydeltaconservationplan.com/Library/RecentDocuments.aspx).

A BDCP fact sheet on habitat restoration, also posted March 14, 2013, proposes 145,000 acres of habitat restoration and habitat protection. The main categories are designated tidal habitat (65,000 acres), cultivated lands (45,420 acres), grassland habitat (10,000 acres), new floodplain (10,000 acres), managed wetlands (6,500 acres), and riparian habitat (5,000 acres). A smoothed graph in the fact sheet projects completion of all this acreage in the first 40 years of BDCP implementation (BDCP+Restoring+the+Delta+Ecosystem+Fact+Sheet+3-14-13.pdf at http://baydeltaconservationplan.com/Library/RecentDocuments.aspx).

Inventories not yet public

The database announced by Davis Fadtke and colleagues (2012) is not yet available publicly. The database is being updated by the Delta Conservancy with contributions from the Department of Water Resources. The compilers face challenges in accurately describing project goals (for instance, are new habitats being created, or are existing habitats being preserved), in reporting project status (which projects are truly complete, and which may have gone no further than land acquisition), and in estimating habitat areas (some of the riparian projects have been measured in linear units, while others measure acreages of entire properties that are noticeably larger than the project areas within them). Consequently, beyond the map summary in Figure 1, the DISB was unable to use the preliminary database in preparing this report. We were unable to obtain even a round-number sum of the project areas depicted in Figure 1 for comparison with modern and historical acreages of natural habitats or with the restored acreage envisioned under the Bay Delta Conservation Plan.

An ideal database would likely tabulate project goals, habitat types, dates for the start and completion of project phases, monitoring efforts before and after restoration, performance measures, and roles of adaptive management. Such information would help users to track recent progress toward habitat restoration and to compare it with the 40-year restoration rates envisioned for BDCP.

References

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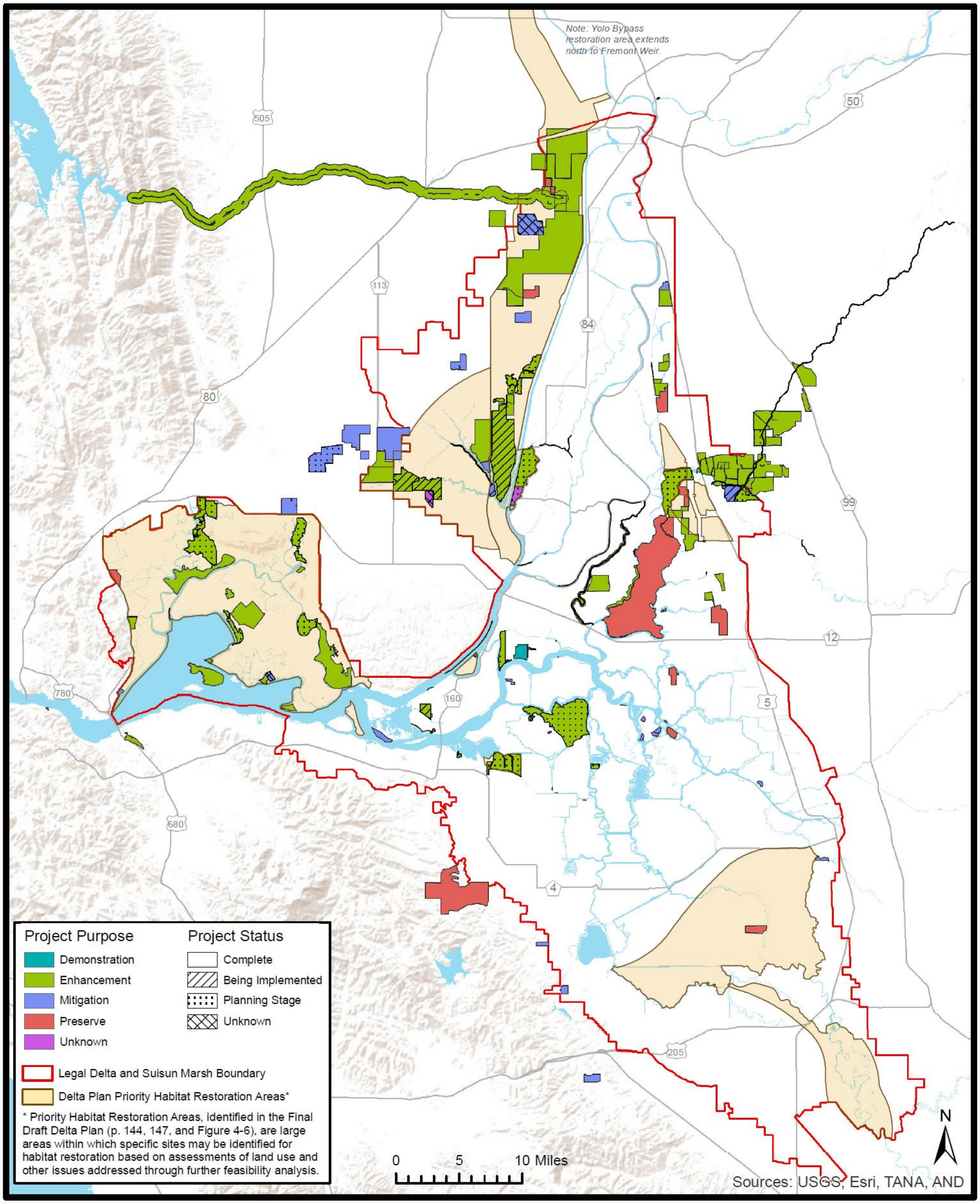

Appendix Figure 1. Habitat projects in the Sacramento–San Joaquin Delta. Map prepared in April 2013 by Delta Science Program. Habitat projects include protected areas and projects that have or are planned to have a habitat enhancement or restoration component. Data were collected from 1994 through 2012 and compiled in 2011 and 2012 by the California Department of Water Resources and the Sacramento–San Joaquin Delta Conservancy. *Disclaimer: This map is intended for informational uses and was created from an evolving database. Accuracy has not been verified. Boundaries may represent properties and not actual projects.*