Template for Review of Science Programs
3rd Draft – 12 February 2012. Includes edits and comments from EC, EH, JM, JL, JW, VR

Preliminary findings from DISB review of science programs that deal with habitat restoration in the Sacramento - San Joaquin Delta and Suisun Marsh

NOTE TO READERS:
This document synthesizes initial findings from the DISB's review of habitat restoration in the Delta and Suisun Marsh based on meetings conducted between August and December 2012. Because the review is still underway and additional meetings and interviews are planned, the views expressed in this document should be viewed as preliminary.

EXECUTIVE SUMMARY

The scale of habitat restoration envisioned for the Delta presents both formidable challenges and tremendous opportunities. Recognizing this, the Delta Independent Science Board (DISB) began its legislatively mandated review of the science supporting Delta decisions and activities by interviewing individuals from state and federal agencies, NGOs, and consulting firms who are actively engaged in habitat restoration projects in the Delta. These interviews were conducted from August 2012 through February 2013. This report summarizes DISB findings and recommendations based on those interviews.

Findings

1. One of the clearest impressions emerging from our review is the high level of dedication, enthusiasm, and knowledge of the staff most directly involved in restoration. This is particularly impressive given the formidable challenges of conducting habitat restoration in the Delta and the limited funding available to do it.
2. The goals of most projects we evaluated were clearly stated, but generally were stated as acreages to be converted without considering whether the area, condition, or location of habitat is suitable for creating new habitat for target organisms. There is an implicit assumption of "if we build it, they will come."
3. There is considerable ambiguity about restoration goals for the Delta as a whole. Restoration projects are being planned and implemented largely independently of one another and of their landscape context. Overall coordination seems to be lacking.
4. There is concern about the process by which habitat restoration activities are "credited" toward meeting the requirements of the Biological Opinions and the Bay Delta Conservation

Plan (BDCP). The crediting process should be clarified and guidelines established that are based on best available science.

5. All agencies report that climate change and sea-level rise are being considered in habitat restoration plans, although it is not clear how the potential effects will be incorporated into the actual restoration actions. In addition to sea-level rise, restoration projects need to consider how changes in temperature and hydrology resulting from climate change will influence the Delta.
6. Every agency and group talked about adaptive management and their intent to create an adaptive management plan for restoration projects. However, we saw no completed plans. Furthermore, 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 information among projects.
7. The entities involved in habitat restoration recognize that restoration of the Delta cannot be done piecemeal. Program and agency administrators meet, but the collaborations are not as deep-rooted as one might wish, although it was apparent to us that the intent to do this integration is clearly there.
8. The success or failure of restoration actions will be subject to decisions made on other components of Delta management, such as flow regulation or levee maintenance. These broader influences do not appear to figure prominently in most habitat restoration projects or plans.
9. Our findings and recommendations parallel those of National Research Council (NRC) panels, which we did not read carefully until late in our review. This concordance among independent science-review bodies reinforces the importance of the findings and the recommendations presented below.

Recommendations

1. Although the goals of individual restoration projects may be specific to the projects, the **goals should be integrated and coordinated among projects** to capitalize on potential synergies and complementarities among the various projects. Goals should be realistically attainable, clearly stated, and developed through a transparent process that includes scientists, managers, administrators, policy makers, regulators, and key stakeholders. Goals should be framed to extend beyond the requirements of regulatory compliance.

2. Individual **restoration projects should be planned and implemented in the context** of (a) broader environmental factors that may affect the restoration (e.g., the surrounding landscape, land uses, hydrologic flows); (b) complementarities and connectivity to other restoration projects; and (c) other management activities in the Delta (e.g., water diversions, levee improvement or abandonment).

3. **Restoration projects should be prioritized**, based on their potential and likely benefits, costs, feasibility, and linkages with other projects or management activities in the Delta. 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 current and proposed conditions and actions are a foundation of spatial planning and should be developed. This should begin with a map showing current and

planned habitat restoration projects that are coded by the form of habitat restoration proposed.

4. **Restoration projects should include change and uncertainty** in their design and implementation. Tools such as simulation or scenario modeling, or risk analysis, should be used to bracket a range of future possibilities and weigh different scenarios by their uncertainty, potential benefits, costs, and the repair costs of being wrong. The adoption of conceptual models is encouraged; for example, the DRERIP approach uses deterministic models of ecosystem components linked with cause-and-effect relationships of interacting variables. Threshold dynamics and the potential for irreversible change in key system attributes should be considered in planning and modeling efforts.

5. **Adaptive management should be part of every restoration plan and project**. In a dynamic environment, the ability to revise approaches as conditions change is a key to success. Whenever possible, the adaptive-management process should follow the nine-step procedure outlined in the Delta Plan. Sufficient resources (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.

6. **Monitoring the responses of key variables to habitat restoration actions should be included in every restoration plan and project**. 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. This will require dedicated and secure long-term funding.

7. **Restoration activities should be integrated and coordinated, and the scientific knowledge available to support these activities synthesized.** The integration and coordination should occur at multiple levels—monitoring, adaptive management, restoration planning, and implementation, and these activities should 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 people charged with representing their agencies. It is even more desirable that such coordinating bodies be independent, to provide objective, third-party assessments, and that they have the authority and resources to achieve real integration and coordination.

8. **Scientific activities and expertise should be integrated.** 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. To be successful in bringing the best available science to bear on issues in the Delta, the DSP requires more science staff and, particularly, more certain long-term funding.

9. We recommend that entities involved in habitat restoration consider ways to **"strategically network" habitat restoration projects in the Delta**. There may 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.

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INTRODUCTION

The 2009 Delta Reform Act states 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 that shall be scheduled to ensure that all Delta scientific research, monitoring, and assessment programs are reviewed at least once every four years." The Act further 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" that the DISB reviews (Water Code §85280 (a), parts (3) and (4)).

Habitat restoration is central to the current and long-term plans for enhancing the ecological integrity and functioning of the Delta while undertaking actions to ensure the availability of water from the Delta to water users in California, which are the co-equal goals of the 2009 Delta Reform Act. 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, 800 acres of low salinity habitat to benefit longfin smelt, and a number of related actions for salmonids (http://www.water.ca.gov/environmentalservices/frpa.cfm). Additionally, the Bay Delta Conservation Plan (BDCP) calls for more than 100,000 acres of habitat restoration in the Delta over a 50-year period, including floodplain, wetland and riparian habitats.

Given the scope and scale of present and proposed habitat restoration, and its potential effects on the ecological health and sustainability of the Delta, the Delta Independent Science Board (DISB) initiated a review of science in the Delta with a focus on science programs concerned with habitat restoration in the context of climate change. We initiated this review in summer 2012, after completing multiple reviews of the Delta Plan, considering flow criteria for the San Joaquin River and its tributaries, and addressing several other requests. We chose to review programs by thematic area because Delta science, like the human activities that need it, cuts across the boundaries of government agencies, universities, consultants, and interest groups. In our selection of habitat restoration as its first review theme, the DISB embarked on an overview of various 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.

APPROACHES

To evaluate the science currently used or anticipated 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, as well as those charged with, implementing the restoration plans (Table 1). We examined documents describing current and

[1] Although the term "Delta" refers to the Statutory Delta (e.g. Yolo Bypass up through Fremont Weir), we also consider habitat restoration efforts in Suisun Marsh.

planned restoration efforts, and attended many of the presentations at the 2012 Bay–Delta Science Conference. Several of us also drew on prior experience with habitat restoration in a variety of ecological settings.

Table 1. Entities and individuals that met with 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
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	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

In conducting our review, we developed questions on general areas of information requested from agencies and entities conducting restoration (Table 2).

Table 2. General areas 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?

FINDINGS

Instead of evaluating each current or planned restoration project separately, we summarize our general observations and findings with respect to several aspects of habitat restoration in the Delta. Overall, it is apparent that the habitat-restoration projects we heard described, most of which deal with restoration of tidal wetlands or the maintenance and upgrading of levees, are generally well-conceived and based on good science. However, we have many reservations about the slow pace of restoration activities, the piecemeal approaches used , and problems with permitting and crediting. We also have concerns about the role of adaptive management. While the importance of adaptive management was mentioned by most of our interviews and interactions, we did not observe any examples where it actually was being done. The agency administrators charged with planning and/or carrying out habitat restoration recognize the enormity of the task and the many challenges involved, and they also exhibit a dedication to conducting successful restoration programs and working with stakeholders to ensure that plans recognize and consider public concerns. We observed, however, that restoration projects seem independent of one another or, when projects are overlapping, tend to be poorly coordinated as part of a larger, integrated vision for habitat restoration with clearly defined and agreed-on goals and objectives.

Clear restoration goals

To be effective, restoration requires that the goals, objectives, and desired endpoints be clearly specified and agreed upon at the outset, even though these goals and objectives may later be modified based on new knowledge (as part of a larger adaptive management framework). Goals also should be ecologically realistic and feasible. Although the goals of most projects we evaluated were clearly stated, in many cases these goals were framed in terms of acreages to be converted to a particular vegetation or habitat type rather than advantages 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 lead to the failure of a project.

There was a general recognition that information on the historical Delta (Whipple et al. 2012) may be useful in defining a preliminary context for habitat restoration, but that the historical conditions can no longer be attained. 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, process and function, and the conditions to which species are adapted. Nonetheless, attempts to re-create historical conditions are likely to be misguided and ineffective, and none of the programs we reviewed had that as their goal. Moreover, human interventions may alter habitats in ways that render historical considerations counterproductive. As an alternative, the goals of "rehabilitation" (rather than restoration) of habitats should emphasize ecosystem functions and resilience (National Research Council 2012; Moyle et al., 2012). This may result in a system with a different composition and structure than that in the present or past. The difficulty here is in deriving operational ways to identify and assess "ecosystem functions" and "resilience."

In the regulatory context of BDCP, the goals of many habitat restoration projects are strongly influenced by the Endangered Species Act and associated Biological Opinions. As a result, meeting regulatory requirements may or may not be consistent with the goals of larger, integrated habitat restoration programs within the Delta. Thus, it is important to incorporate and integrate these projects into the broader scope of habitat restoration efforts.

We observed that there is considerable ambiguity about overall restoration goals for the Delta as an ecosystem. Should the goals be framed in terms of acres of a vegetation type, patterns of hydrologic flows, ecosystem function, resilience, recovery targets for threatened species, ecosystem services, or a compendium of these alternatives, depending on the specific project? Clearly, there is no single goal or target that applies to all projects and plans; yet, without a comprehensive consideration of how different goals inter-relate (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 restoring a population of a particular species rather than (or in addition to) restoring habitats to improve overall ecosystem health.

There is also concern among us about the process by which habitat restoration activities are "credited" towards meeting the requirements of the Biological Opinions and BDCP. Some agency representatives have suggested that crediting should happen in stages. For example, some of our interviewees suggested that 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 suggest that crediting should occur when the land acquisition for restoration occurs, and still others suggest that the needs of adaptation might dictate that credit vary with time. In this case, an initial credit is 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 best available 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.

Connectivity and landscapes

Restoration projects are being planned and implemented largely independently of one another and of their landscape context. Nothing happens in just one place, however; and to paraphrase John Donne, "no restoration project is an island, entire of itself". Restoration in aquatic systems is affected by events or management activities upstream that affects what happens downstream, including other restoration projects. Restoration of wetland habitats along waterways or levees is affected by the environment and land uses in the surrounding landscape. Connectivity among habitats to be restored depends on many factors, including the ability to acquire lands, navigate the permitting process, and secure funding for the restoration. The size and scale of projects is important as well. 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 model analysis of the consequences of where and how restoration is conducted in Suisun Marsh. Results indicate that the type of restoration performed alters the salinity observed throughout the Delta (John DeGeorge, RMA Modeling Team).

In marine ecosystems, Marine Protected Areas (MPAs) are often viewed to be best developed as networks (e.g., North American Marine Protected Areas Network; http://www.mpa.gov/nationalsystem/international/nampan/). "Strategic networking" of habitat restoration projects in the Delta, for example, might be considered by the agencies and entities involved. Beyond networking or linking together restoration sites and projects, there may 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 broader scale framework of restoration and adaptive management.

Future changes

Many changes are occurring in the Delta, today and in the future. These changes include changes in climate, hydrology, land use, economics, sea-level effects, potential levee failures, and public and political perceptions and agendas. Management of the Delta to attain the co-equal goals will require dealing with multiple uncertainties and changes. It is clear to the DISB that "Business as usual" is not an option. It is likely that some habitat restoration projects will not turn out as planned. Therefore, the need for strategic planning of restoration projects, with long-term risk considered from the outset, is important.

All agencies reported that climate change and sea-level rise were being considered in habitat restoration plans, although it is unclear based on their presentations and interviews how the potential effects will be incorporated into the 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. When models were described, the same ones seemed to be suggested as usable over and over again and it was unclear whether the models described had been subject to peer review (see below for more on modeling). Uncertainties in projections of regional climate changes and their effects means that restoration plans will need to incorporate flexibility to adapt as projections improve.

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

The dynamics of every ecosystem are at some point nonlinear, and the more complex the ecosystem the greater the array of nonlinearities. 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 (the Pelagic Organism Decline, POD, is an example), and perhaps regime shifts. 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. The recent analysis of the environmental history of the Delta (Whipple et al. 2012) indicates that this has already happened, and 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 included in restoration plans for the Delta, although several people seemed to be aware of the difficulties they might pose to planning activities. 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.

Adaptive management and monitoring

The many changes that the biological and physical environments of the Delta are undergoing now and the 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. 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 necessary to minimize this risk. Indeed, the inclusion of an adaptive management program is mandated in the 2009 Delta Reform Act.

Every agency and group that we interviewed talked about adaptive management, and every plan for the Delta presented addresses adaptive management, typically with an outline of how it will be implemented. It is not clear to us, however, that there is a unified perception of what the adaptive management process entails. Throughout our meetings and interactions, we found no examples of cases where adaptive management was actually being implemented or rigorously planned. While many of the parties we met with talked about developing adaptive management plans, we saw none in place. We only saw one example (one of the DRERIP models) where conceptual models had been developed, despite the fact that this is supposedly the first step in adaptive management. Moreover, and perhaps a critical omission, we also heard no mention of performance measures, an essential metric for use in monitoring the outcomes of restoration projects.

Monitoring is the lynchpin of adaptive management. Without long-term monitoring, targeted on key variables that can indicate the effectiveness of actions and/or reduce critical areas of uncertainty, adaptive management will not be possible. While the need for monitoring is recognized in most projects and plans, there is insufficient attention 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 among projects. Monitoring also requires reliable sources of long-term funding. We were told that some small projects did not have enough resources to conduct monitoring. Thus, adaptive management cannot be done in these cases. Other challenges associated with monitoring include developing ways to collect monitoring data in a common format and make them easily available, as well as synthesis of the results and inculcation of them into the ongoing planning process.

Because monitoring is essential to the adaptive management process, we have certain key recommendations that need to be emphasized. Coordination of ongoing monitoring activities and appropriate resources to execute monitoring programs at the appropriate spatial and temporal scales are critical for assessing the outcomes of habitat restoration projects. We further recommend that an objective and independent body be responsible for monitoring the outcomes and success of restoration projects, and that this body should be supported by a fund that is derived from a fixed-percentage allocation from each project.

Since 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. Because challenges and restoration goals differ among sites and projects, adaptive management will need to be specific in its applications, while at the same time being 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 require a range of sites and habitats that are scattered over a larger area or a series of larger areas. Adaptive management should be applied at these broader or larger scales as well. This will have to be done more with modeling, and less with field studies – although field data will also be important.

Modeling

To be effective, restoration activities at local sites must be connected to restoration goals and processes that occur at much broader geographic scales. Flows of water, nutrients, and supported species must be able to enter and leave restoration sites in ways that support the overall ecological goals for not just single sites but for the entire Delta. Substantial restorations also have potential to affect (for good or for ill) ecosystems in other parts of the Delta, such as by changing tidal ranges and flows and changing predation and food for migrating fishes.

Computer modeling is one way to explore, quantify, and integrate the broader effects of local restoration. For example, as marshlands are expanded in Suisun Marsh, Cache Slough, and San Francisco Bay, will the resulting dissipation in tidal energy reduce tidal ranges enough to reduce the effectiveness of these and other now-less-tidal marshes that result?

Broad-scale effects that mat affect local site restoration also should be examined. These broad-scale effects include sea-level rise, changes in delta diversion infrastructure locations and operations, and long-term abandonment of some Delta islands. Computer modeling is the best way to explore the implications of such changes on local and system-wide restoration efforts. At the local scale, computer modeling is also often useful for designing and implementing local restoration plans. Examples of incorporating this approach include examination and exploration of local scour, flow patterns, and resident times within restoration sites. If site conditions become problematic, it can be expensive to fix; therefore, computer modeling can help anticipate and reduce the number of expensive and time-consuming adjustments needed.

Computer modeling capability provides useful and timely insights, but is ever-evolving, expensive, and time-consuming to develop and this approach can result in counter-productive controversy under some circumstances. The development and management of modeling capability is currently highly decentralized, which has both advantages (in terms of entrepreneurship) and disadvantages (in terms of difficulties of 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. This will require substantial development of common digital terrain, 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 achieving such modeling capability. We also heard suggestions for development of a model library for use by Delta scientists and agencies involved in habitat restoration, and we fully endorse this suggestion.

Coordination and collaboration among public and private entities

All of the entities involved in managing the Delta ecosystem recognize that restoration of the Delta cannot be accomplished piecemeal. The NRC report (NRC 20112) 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. 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 take pride in these collaborations.

Nonetheless, 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, but real coordination involves collaboration and teamwork among the scientists and staff conducting the restorations at multiple locations.

The need for coordination and collaboration 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 on 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 both public and private entities, and landowners, is communication, and more specifically the sharing of data and information about restoration projects and their results. We acknowledge that it is difficult to share information among projects involving private lands if more open access to the information might affect land values, speculation, or other stakeholder activities. Confidentiality issues must be addressed if comprehensive adaptive management is to occur.

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.

Capabilities and capacity of state agencies

One of the clearest impressions emerging from our review is the high level of dedication, enthusiasm, and knowledge of the staff most directly involved in restoration. This is particularly impressive given the formidable challenges of conducting habitat restoration in the Delta and the limited funding available to do it. 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 get the work done 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. Additionally, the state does not receive the benefits of career development and training from resources that are invested, and there is no long-term investment in people to build the in-house expertise that is needed for the long time frame that is required of many restoration projects in the Delta. Although the same consultants are often used, which do provide 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.

On private sector roles

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, under agency supervision. NGOs are often taking a lead in restoration projects, such as The Nature Conservancy work on McCormack-Williamson Tract. At the most involved end of the spectrum, there are private firms that 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. 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 continue to 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.

Relation to the National Research Council reviews

The National Research Council of the National Academy of Sciences has conducted two reviews that are relevant to the present DISB review of habitat restoration in the Delta (NRC 2011, 2012). 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 in Table 3. 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.

Table 3. The following table extracts comments from two reports of the National Research Council of the National Academies (2011, 2012) that bear on the Delta Independent Science Board review of habitat restoration programs in the Delta.

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)

RECOMMENDATIONS

[*Note: these are some initial thoughts that need more attention; perhaps they can be made actionable by referring, as much as possible, to the entities that would carry them out.*]

1. Although the goals of individual restoration projects may be specific to the projects, the **goals should be integrated and coordinated among projects** to capitalize on potential synergies and complementarities among the various projects. Goals should be realistically attainable, clearly stated, and developed through a transparent process that includes scientists, managers, administrators, policy makers, regulators, and key stakeholders. Goals should be framed to extend beyond the requirements of regulatory compliance.

2. Individual **restoration projects should be planned and implemented in the context** of (a) broader environmental factors that may affect the restoration (e.g., the surrounding landscape, land uses, hydrologic flows); (b) complementarities and connectivity to other restoration projects; and (c) other management activities in the Delta (e.g., water diversions, levee improvement or abandonment).

3. **Restoration projects should be prioritized**, based on their potential and likely benefits, costs, feasibility, and linkages with other projects or management activities in the Delta. 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 current and proposed conditions and actions are a foundation of spatial planning and should be developed. This should begin with a map showing current and planned habitat restoration projects that are coded by the form of habitat restoration proposed.

4. **Restoration projects should include change and uncertainty** in their design and implementation. Tools such as simulation or scenario modeling, or risk analysis, should be used to bracket a range of future possibilities and weigh different scenarios by their uncertainty, potential benefits, costs, and the repair costs of being wrong. The adoption of conceptual models is encouraged; for example, the DRERIP approach uses deterministic models of ecosystem components linked with cause-and-effect relationships of interacting variables. Threshold dynamics and the potential for irreversible change in key system attributes should be considered in planning and modeling efforts.

5. **Adaptive management should be part of every restoration plan and project**. In a dynamic environment, the ability to revise approaches as conditions change is a key to success. Whenever possible, the adaptive-management process should follow the nine-step procedure outlined in the Delta Plan. Sufficient resources (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.

6. **Monitoring the responses of key variables to habitat restoration actions should be included in every restoration plan and project**. 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. This will require dedicated and secure long-term funding.

7. **Restoration activities should be integrated and coordinated, and the scientific knowledge available to support these activities synthesized.** The integration and coordination should occur at multiple levels—monitoring, adaptive management, restoration planning, and implementation, and these activities should 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 people charged with representing their agencies. It is even more desirable that such coordinating bodies be independent, to provide objective, third-party assessments, and that they have the authority and resources to achieve real integration and coordination.

8. **Scientific activities and expertise should be integrated.** 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. To be successful in bringing the best available science to bear on issues in the Delta, the DSP requires more science staff and, particularly, more certain long-term funding.

9. We recommend that entities involved in habitat restoration consider ways to **"strategically network" habitat restoration projects in the Delta**. There may 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.

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