Dear DISB colleagues,

Attached is the most recent draft of the Habitat Restoration report prepared by Liz, Vince, and John. Input for this revision came from Brian, Dick, Jay, and Ed. This draft is for discussion during our conference call on Wednesday. We have left some comments that passed among the three of us to help you understand some of the issues that we believe should be addressed by the complete DISB. This is a major reorganization of the previous draft.

There are several issues to consider:

1. Are additional references needed?

2. We have noted some places where examples would be helpful.

3. Perhaps most important, should we have a list of priority research projects, with an example prepared by Brian, as has been suggested? If we are to include this section, other priorities will need to be added. If you feel that this section should be included and have strong feelings about what a research priority in terms of what is needed for habitat restoration in the Delta, please provide your suggestions during the call (and we may ask you to write that one up for us). Also, please consider whether they should be shortened to a paragraph or two as John suggested in his comments.

We look forward to your input on this draft during the conference call.

Liz, Vince & John

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Template for Review of Science Programs
3rd Draft – 12 February 2013. Includes edits and comments from EC, EH, JM, JL, JW, VR
4th Draft – 23 February 2013. EC, JW
5th Draft—28 February 2013 JW,VR
6th Draft – 3 March 2013 EC, VR
7th draft—24 March 2013 JW,VR, EC

8th draft—25 March to DISB

DISB review of science programs that include habitat restoration in the Sacramento-San Joaquin Delta and Suisun Marsh

SUMMARY

The scale of habitat restoration envisioned for the Sacramento-San Joaquin 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, consulting firms, and universities who are actively engaged in habitat restoration or planning in the Delta. These interviews were conducted from August 2012 through February 2013. This report summarizes DISB findings and recommendations based on those interviews and discussions among the DISB. Our findings and recommendations parallel those reached independently by the National Research Council (NRC) panels. This concordance among independent science-review bodies reinforces the findings and recommendations presented below.

We have organized our report in terms of what we believe are the key elements of a successful restoration program: (1) Goals are clearly articulated, (2) Spatial context is part of the design, (3) Temporal context is part of the design, (4) Adaptive management and flexibility are part of the design, (5) Monitoring is part of the design, (6) Modeling should be used as a tool as appropriate. (7) Planning and implementation are coordinated among projects, (8) The necessary scientific expertise is available, and (9) Stakeholders are involved early and often.

Findings

One of the clearest impressions from our review is the high level of dedication, enthusiasm, and knowledge of the agency and NGO staff most directly involved in restoration. This is particularly impressive given the formidable challenges of habitat restoration in the Delta and the modest funding available to do it. In terms of key elements needed for habitat restoration to be successful in the Delta, we recommend the following:

1. Clearer restoration goals needed

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. Because goals go hand-in-glove with performance measures, the low proportion of projects that incorporated operational and realistic performance measures is problematic.

2. Geographic context must be considered
Restoration at one location in an aquatic system is affected by external events or management activities, including other restoration projects. Many restoration projects in the Delta are being planned and implemented largely independently of one another and of their landscape context. Strategic networking to link habitat restoration projects and clustering projects according to shared suites of environmental characteristics (e.g. operational landscape units) should be considered.

3. Extended timescale must be considered
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 will be incorporated into actual restoration actions in the Delta. There is a major need for science to evaluate complex, nonlinear responses of the Delta ecosystem to changing environmental conditions and how these relate to restoration activities. 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.

4. There is a need for adaptive management
The present and future changes in the biological and physical environments increase uncertainty, making it difficult to predict the outcomes of specific habitat-restoration activities. Therefore, effective planning before implementation and use of adaptive management (as mandated in the 2009 Delta Reform Act) are necessary to minimize this risk. Unfortunately, we found no unified perception of what the adaptive management process entails and no examples of cases where adaptive management was actually being implemented or rigorously planned., Adaptive management will need to be specific in its applications, while at the same time be broadly coordinated among sites.

5. Monitoring
Without long-term monitoring targeted at key variables, formal adaptive management will not be possible. Although the need for monitoring is recognized in most projects and plans, insufficient attention is given to selection and updating 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. Long-term funding for monitoring seems to be lacking and some small projects lacked sufficient resources to conduct post-project monitoring, which prevents formal adaptive management.

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6. Modeling should be used as a tool when appropriate.
To meet the co-equal goals for the Delta as a whole, 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 and juvenile species must be understood at the Delta-scale. Models have the potential to help those involved in restoration to assess how actions in one area might affect other areas. Tools such as conceptual modeling, simulation or scenario modeling, or risk analysis should be used to assess uncertainties and the potential costs and benefits of restoration actions.

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 rests 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. Gaps in scientific knowledge should be identified and prioritized and addressed through research and modeling studies. Scientific experts need time in the field to observe possible emergent properties that may need monitoring as well as time to stay abreast of the literature. Restoration successes and failures in other systems should inform restoration projects in the Delta.

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. Those who are affected by restoration (e.g. landowners) should be in continuing communication with those who are implementing and overseeing the restoration.

Recommendations
Based on these findings, we offer several recommendations for improving and enhancing habitat restoration in the Delta.

1. The planning and implementation of habitat-restoration projects should be coordinated and integrated to capitalize on synergies and complementarities among projects. This requires that:

- Clearly stated and realistic goals be communicated and shared so that related projects can be linked together at the outset;
- Complementarities, and both conceptual and spatial connectivity, among projects should be recognized and incorporated into planning; and
- The potential impacts of other management activities in the Delta, such as water diversions or levee alterations, should be included in the design of restoration projects.

2. Restoration projects should include considerations of climate change and environmental uncertainty in their design and implementation. To do this will require that:

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- Adaptive management be part of every restoration plan and project; and
- Explicit designs for monitoring responses to restoration actions are included in restoration plans and the viability of these programs supported by adequate, long-term funding.

3. Restoration projects should be prioritized.

- An overall coordination or integration effort should establish restoration priorities.
- Multiple criteria (e.g., benefits, costs, feasibility, opportunity) should be considered in determining which and when restoration projects should be done; and
- Restoration projects should be linked together in strategic networks, based on shared goals, timing, location, and actions to maximize both financial and ecological returns on investments.

4. The science to inform and guide restoration actions, adaptive management, and prioritization should be coordinated and integrated.

- Scientific research should be coordinated with restoration planning and the findings synthesized and communicated for planning and implementation;
- Monitoring programs require adequate long-term funding and independent oversight;
- Collaboration among scientists in different organizations should be enhanced;
- Conceptual modeling, simulation or scenario modeling, and risk analysis should be used to assess uncertainties and the potential costs and benefits of restoration actions; and
- The design and implementation of restoration activities and the use of science to support these activities should be coordinated by an independent body that can provide objective, third-party assessments.

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MAIN REPORT: DISB review of science programs that include habitat restoration in the Sacramento-San Joaquin Delta and Suisun Marsh

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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 large number of 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 government agencies, universities, consultants, and interest groups. 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 and locations of current and currently proposed habitat restorations are shown in Figure 1.

Comment [J1]: This is the link to what's available on the web, which is more than a year old. Can we provide something more recent?

Comment [v2]: Figure 1 is the map. In the legend we should give the sources and any potential caveats about it.

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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 the restoration plans (Table 1). In conducting our review, we developed questions and requested

[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.

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 a partial listing of individuals interviewed by 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, Mike Dettinger Noah Knowles, Lisa Lucas, Lacy Smith, Jan Thompson and Isa Woo
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

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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 believe that successful habitat restoration projects in the Delta can be characterized by 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 ecologically 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 for anticipating change.

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

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

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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 should be used as a tool when appropriate.* 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 and juvenile species must be understood at the system-scale. Models have the potential to help those involved in restoration to assess how actions in one area might affect other areas. Models may also be useful in assessing 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 scientific 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 extends well beyond an individual project. Those who are affected by restoration (e.g. landowners) should be in continuing communication with those who are implementing and overseeing the restoration.

FINDINGS

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 exhibit 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.

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. Agency administrators charged with planning and/or carrying out habitat restoration recognize

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the enormity of the task and the many challenges involved, and they also show a dedication to conducting successful restoration programs and working with stakeholders to ensure that plans recognize and consider public concerns. However, 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, 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. However, 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 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 information on 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 their 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.

Comment [J3]: This is one place in which an example would help. Lauren or others to provide?

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

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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.

Comment [J4]: Several have suggested that this section on credits is overly detailed and has little to do with science, while others have argued for keeping it. We should decide this during the conference call.

Although there is no single goal or target that applies to all projects and plans, without a comprehensive 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 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) (Appendix 4). Although not all of these attributes may apply to habitat restoration in the Delta, they may provide some guidance in formulating performance measures.

Comment [v5]: This has not been prepared in Tabular format because we wanted to see if the DISB feels it is necessary and should be included.

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

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secure funding for the 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 model 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 is 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 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

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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 projections is 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 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. 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 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. 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 necessary to minimize this risk

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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 examples where it actually was being done in any formal sense. It is not clear to us, either, that there is a unified perception of what the adaptive management process entails. Moreover, 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. We also heard no mention of performance measures, which are essential for monitoring the outcomes of restoration projects. This is a critical omission.

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 to conduct monitoring, which prevents formal adaptive management. 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 their inculcation 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. This approach may have to 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 studies offer benefits to restoration projects.

Comment [v6]: Jay has provided numerous references that can be added if needed.

To be effective in contributing to the co-equal goals for the Delta as a whole, 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, not just for single sites, but for the entire Delta. Some large restorations may also affect (for either good or for ill) ecosystems in other parts of the Delta, such as by changing tidal ranges and flows or changing predation and food for migrating fishes. For example, 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.

Broad-scale effects that may affect 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, computer modeling is also often useful for designing and implementing restoration plans. Examples of incorporating this approach include examination and exploration of local scour, flow patterns, and water resident-times within restoration sites. If site conditions become problematic, adjustments may be expensive. Computer modeling can help to anticipate and reduce the number of expensive and time-consuming adjustments needed.

Computer modeling capability 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 various climate-change scenarios. Their potential usefulness is compromised, however, by the need for supercomputing capacity and the expertise to run the models. 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 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 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 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.

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. 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.

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

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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 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 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 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.

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.

Comment [RN7]: Do we want to recognize managerial expertise or citizens' experiential knowledge? By emphasizing the separate disciplines, are we promoting them rather than interdisciplinary scientists and managers with "professional" training? Adaptive management is at the science-management interface, while disciplines are a phenomenon of academe.

Might this sentence better refer to "teams of scientists with both broad and deep training."

Stage 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

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needed for the multi-decadal time frame that is required of many restoration projects in the Delta. 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 work on the 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.

In some cases, private firms also bring strong science and technical expertise that is needed for conducting monitoring and evaluation, as well as the follow-up analyses that are needed for an agency to conduct adaptive management. The availability of this expertise should be included 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.

University Research

Another finding from our review is the value of university research to restoration efforts in the Delta. 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, result from initiatives that are independent of the Delta problem, but are key to supporting ecosystem restoration in the Delta. Funding programs such as the CALFED science program and Delta Science Program have focused some university research efforts with PSPs 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 opportunity 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,

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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, for example an invasive species and the species it threatens to drive out, 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, most 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 the monitoring process.

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. 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 introduced 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 the adaptive management process to be successful.

Comment [EC8]: This section is still not well-developed in terms of our findings about the Delta. We should discuss this further during the conference call.

RECOMMENDATIONS

Habitat restoration is an essential ingredient of rebuilding the ecological functioning 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.

The findings we have summarized above lead us to offer several recommendations that we believe will 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 above and recommendations parallel those reached independently by the National Research Council (NRC) panels (Appendices 2 and 3). This concordance among independent science-review bodies reinforces the findings and recommendations presented below.

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1. The planning and implementation of habitat-restoration projects should be coordinated and integrated to capitalize on potential synergies and complementarities among projects.

- *Clearly stated and realistic goals should be communicated and shared so that related projects can be linked together at the outset*. Goals should be 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.
- *Complementarities, and both conceptual and spatial connectivity, among projects should be recognized and incorporated 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.
- *The potential impacts of other management activities in the Delta, such as water diversions or levee alterations, should be included 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 effects 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. Restoration projects should include considerations of environmental change and uncertainty in their design and implementation. The effects of climate change, sea-level rise, land-use change, and other environmental changes 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. These factors should be considered in planning and modeling efforts.

- *Adaptive management must 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. 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.
- *Explicit designs for monitoring the responses of key variables to restoration actions should be included in restoration plans and supported by adequate, long-term funding*. 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.

3. Restoration projects should be prioritized.

- *Multiple criteria (e.g., benefits, costs, feasibility, opportunity) should be considered in determining which when restoration projects should be done*. For example, a comparison of potential restoration sites with potentially vulnerable levee locations could indicate

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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 could begin with a map showing current and planned habitat restoration projects that are coded by the form of habitat restoration proposed (e.g., Figure 1).

- *Restoration projects should be linked 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. The science to inform and guide restoration actions, adaptive management, and prioritization should be coordinated and integrated.

- *Scientific research should be coordinated with restoration planning and the findings synthesized and communicated 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 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.
- *Monitoring programs require adequate long-term funding and independent oversight.* Monitoring is essential to the adaptive management process and coordination of ongoing monitoring activities and availability of appropriate 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 monitoring the outcomes and success of restoration projects. This body should be supported by a fund that is derived from a fixed-percentage allocation from each project.
- *Collaboration among scientists in different organizations should be enhanced*. 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.
- *Tools such as conceptual modeling, simulation or scenario modeling, or risk analysis should be used to assess uncertainties and the potential costs and benefits of restoration actions.* For example, the DRERIP approach uses deterministic models of ecosystem components linked with cause-and-effect relationships of interacting variables.
- *The design and implementation of restoration activities and the use of science to support these activities should be coordinated by an independent body that can provide objective, third-party assessments*. To be effective, this body should have the authority and resources to achieve real integration and coordination.

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RESEARCH NEEDS

Habitat restoration in **the Delta and Suisun Marsh can both require and promote understanding of underlying physical and biol**ogical processes. Below we offer a few examples of current uncertainties and opportunities in restoration science.

1. Marsh accretion and sea-level rise

The San Francisco Bay estuary and its tributaries are subject to many climate-induced changes (Cloern et al., 2011), and these include the drowning of the tidal marshes. Sea level is likely to rise between 40 and 170 cm in central California by 2100, and the rate is expected to increase as the century wears on (Committee on Sea Level Rise in California, Oregon, and Washington, 2012). Restoration scientists and managers have questioned whether tidal marshes, both existing and restored, will be able to keep up with submergence (Orr et al., 2003)

Tidal marshes and tidal swamps aggrade by trapping sediment that tides bring in and by retaining organic matter that the wetland plants produce on site (Nyman et al., 2006; Mudd et al., 2009; Kirwan et al., 2010; McKee, 2011). The retained organic matter includes roots and rhizomes that the plants inject into wetland soils (Davey et al., 2011).

On many coasts, vertical accretion has allowed tidal wetlands to keep pace with slow sea-level rise of recent millenniums. In the classic example of a salt marsh in Massachusetts (Mudge, 1862), the marsh accreted about 3 m in the past 3,000 years, for an average rate of about 0.1 cm/yr (Donnelly, 2006). Higher rates of tidal-marsh accretion have been reported from the San Francisco Bay estuary, but little is known about their applicability to future conditions in the Delta and Suisun Marsh.

In the regions adjacent to southern San Francisco Bay, twentieth-century salt marshes endured 1-2 cm/yr of submergence that was occasioned by land subsidence from 20th-century ground-water withdrawal (Patrick and DeLaune, 1990; Watson, 2004). The submergence was fast enough, however, for plant communities to shift landward at cordgrass (*Spartina*), formerly limited to the low parts of a marsh, spread into a pickleweed (*Sarcocornia*) high marsh in the late 1950s or early 1960s (Harvey, 1966; Atwater et al., 1979, p. 359, 361).

At San Pablo and Suisun Bays, tidal marshes probably built up apace with sea-level rise in the past 50-100 years (Callaway et al., 2012). The vertical accretion rates, estimated from depths to nuclear-test fallout that peaked in 1963, were in the range 0.1-0.9 cm/yr. The rates were found to increase with frequency of tidal inundation; low marsh accreted more rapidly than high marsh.

Rates of vertical marsh accretion in the Sacramento - San Joaquin Delta averaged about 0.1 cm/yr across the past 2,000-6,000 years (Drexler et al., 2009; Drexler, 2011). These rates were likely limited, however, by relative sea-level rise during those millenniums; the ability of the marshes to keep up with submergence at projected 21st-century rates is unknown. In the central Delta, where tidal-marsh peat probably averages about 90 percent organic matter by volume, marsh accretion before A.D. 1850 depended far less on inorganic sedimentation than on accumulation of plant matter (Atwater and Belknap, 1980, p. 99). Sparse estimates of accretion rates in today's Delta marshes are as high as 1.8 cm/yr (Orr et al., 2003). Estimates derived from sediment-rich marshes may understate the potential for maintaining Delta marshes by organic accretion (Schoellhamer et al., 2012).

Comment [v9]: There seemed to be a general acknowledgement that this should be added. How much detail we want to go in to for each was not clear. Brian has added an example, and we hope that other topics can be developed. However, as written the research question is not clear (to me).

Comment [J10]: I think it might be worthwhile to highlight several (5-6) areas of research potential, with perhaps one paragraph and 4-5 key references for each. This should be an appendix to the main report, since it's less of a review of what's being done or planned and more some suggestions that came to our minds on the basis of our review.

Comment [EC11]: I agree with John's suggestion. I would like to see ~5 research needs areas highlighted in this section with each 1-2 paragraphs in length inclusive of key references. This section should be discussed during our conference call.

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APPENDICES

Appendix 1. 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?

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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 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. This 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

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	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)

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

Appendix 3. Attributes (i.e., outcomes or performance measures) of a successful restoration project. From SER (2004).

Comment [J12]: If we decide to keep this is should be redone as a Word table.

Comment [EC13]: I'd like to hear from other members of DISB before we convert this information to a Word table.

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Section 3:

Attributes of Restored Ecosystems

This section addresses the question of what is meant by "recovery" in ecological restoration. An ecosystem has recovered - and is restored - when it contains sufficient biotic and abiotic resources to continue its development without further assistance or subsidy. It will sustain itself structurally and functionally. It will demonstrate resilience to normal ranges of environmental stress and disturbance. It will interact with contiguous ecosystems in terms of biotic and abiotic flows and cultural interactions.

The nine attributes listed below provide a basis for determining when restoration has been accomplished. The full expression of all of these attributes is not essential to demonstrate restoration. Instead, it is only necessary for these attributes to demonstrate an appropriate trajectory of ecosystem development towards the intended goals or reference. Some attributes are readily measured. Others must be assessed indirectly, including most ecosystem functions, which cannot be ascertained without research efforts that exceed the capabilities and budgets of most restoration projects.

1. The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure.

2. The restored ecosystem consists of indigenous species to the greatest practicable extent. In restored cultural ecosystems, allowances can be made for exotic domesticated species and for non-invasive ruderal and segetal species that presumably co-evolved with them. Ruderals are plants that colonize disturbed sites, whereas segetals typically grow intermixed with crop species.

3. All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or, if they are not, the missing groups have the potential to colonize by natural means.

4. The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory.

5. The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent.

6. The restored ecosystem is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges.

7. Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible.

8. The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem.

9. The restored ecosystem is self-sustaining to the same degree as its reference ecosystem, and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure and functioning may change as part of normal ecosystem development, and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change.

Other attributes gain relevance and should be added to this list if they are identified as goals of the restoration project. For example, one of the goals of restoration might be to provide specified natural goods and services for social benefit in a sustainable manner. In this respect, the restored ecosystem serves as natural capital for the accrual of these goods and services. Another goal might be for the restored ecosystem to provide habitat for rare species or to harbor a diverse genepool for selected species. Other possible goals of restoration might include the provision of aesthetic amenities or the accommodation of activities of social consequence, such as the strengthening of a community through the participation of individuals in a restoration project.

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