IMPROVING ADAPTIVE MANAGEMENT IN THE SACRAMENTO-SAN JOAQUIN DELTA

A Report from the

Delta Independent Science Board

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Summary

Adaptive management is a science-based, structured approach to environmental management. It aids decision-making in the face of uncertainty about outcomes by emphasizing the acquisition and use of new knowledge, experience, and stakeholder input in management of natural resources under changing conditions.

The Delta Reform Act of 2009 calls for adaptive management of efforts to make water supplies more reliable and ecosystems healthier. It is often talked about, but as a comprehensive, science-based process, adaptive management is little used in the Delta. This is not a unique situation; many environmental management programs around the world have encountered difficulties in managing natural resources adaptively.

The Delta Independent Science Board (Delta ISB) reviewed how adaptive management is perceived and used in the Delta and how it might be applied more efficiently and effectively. This report identifies impediments to adaptive management in the Delta and makes recommendations for incorporating adaptive approaches to improve management of the Delta and its resources.

Impediments

Adaptive management is commonly depicted as a cycle that proceeds from planning, through doing, to evaluating outcomes and then modifying plans and actions as needed. Monitoring and analysis are essential to adaptive management, but the cycle can grind to a halt when findings must be interpreted and communicated to the decision-makers who must decide whether modifications are needed.

Several additional factors contribute to the meager use of adaptive management in the Delta:

- Managers and decision-makers may be averse to taking the risks inherent in adaptive management, especially if the underlying science is inconclusive.
- Adaptive management can be ponderously slow, failing to keep up with rapid changes and the urgency of management decisions.
- Multiple regulations and permit requirements may restrict management flexibility.
- Adaptive management and monitoring require sufficient and dependable funding.
- Monitoring and associated costs may be greater than the perceived benefits of adaptive management, making it difficult to maintain long-term interest.

- The benefits of adaptive management are often not immediately apparent, so there may be few incentives for supporting the approach.

Recommendations

To overcome these challenges, structured adaptive management will need to become second nature in managing the Delta's water, habitats, and wildlife. This will entail a unified understanding of what adaptive management is and what it is not; what it requires in resources; what it needs in organizational, operational, and regulatory flexibility; and when it is appropriate to use and when it is not. To become fully integrated into Delta management, adaptive management will require *collaboration* among agencies, managers, scientists, engineers, and stakeholders, and *commitments* by those who control resources and make decisions.

The following recommendations aim to move adaptive management from a topic of conversation to a common and useful aspect of management programs and actions for the Delta.

1. **Convene a workshop or review panel to determine how to coordinate and assist adaptive management in the Delta.** The Delta Stewardship Council should assemble an appropriate mix of experts, agency leaders, resource managers, practitioners, scientists, stakeholders, and regulators to consider the composition and roles of a coordinating team that will advance adaptive management in the Delta and implement the recommendations of this report.

2. **Support adaptive management with funding that is dependable and flexible.** Adaptive management in the Delta will not become a reality unless the paucity and unpredictability of funding for the process are remedied. Radically different and more effective ways to fund adaptive management are needed.

3. **Design and support monitoring**. Design monitoring protocols to fit the needs of management. Set the timing of measurements to correspond with the dynamics of important ecosystem processes. Monitoring should be conducted in coordination with a data-management system to make the information readily accessible for analysis and sharing.

4. **Integrate science and regulations to enhance flexibility.** Rigid regulations and permitting requirements inhibit the flexibility required to change directions quickly when it becomes apparent that management outcomes are not as planned.

Regulatory and permitting agencies should develop innovative ways to incorporate flexibility into regulations and permits..

5. **Develop a framework for setting decision points or thresholds that will trigger a management response.** The most vexing issue in adaptive management is determining when conditions should trigger a formal re-evaluation or change in practices. To counter reluctance to change which may delay adaptive responses (especially if the system is changing slowly), such decision points should be included in adaptive-management plans at the outset.

6. **Use restoration sites to test adaptive-management and monitoring protocols.** Adaptive management should be part of habitat-restoration projects envisioned in California EcoRestore, so that these projects can act as learning laboratories for improving adaptive management.

7. **Capitalize on unplanned experiments.** Unexpected events (e.g., extreme droughts, large floods, levee breaks) or necessarily quick management decisions (e.g., construction of salinity barriers, cold-water releases from dams) provide opportunities to learn and test adaptive management. Capitalizing on these opportunities requires having contingency plans, monitoring protocols, and modeling capability in place and identifying funds and staff that can be shifted to respond.

8. **Recognize when and where adaptive management is not appropriate.** Adaptive management is not a panacea to be used in all situations. Sometimes, adaptive management may be inappropriate or need to be greatly streamlined. In other situations, sufficient support from federal, state, and local agencies may be lacking. In these circumstances, attempts to implement adaptive management may not be effective, and substantial changes in expectations and a refocusing of adaptive management attention and even legislation may be needed. Decisions about whether or how to use adaptive management should be made thoughtfully, after careful consideration of the alternatives.

We believe that with greater legal and regulatory flexibility, along with firmer expectations and support, adaptive management can improve the performance, reduce long-term costs, and increase scientific confidence in Delta management activities. But the Delta is changing, ever more rapidly. Climate change, sea-level rise, increased frequency and severity of extreme events, new invasive species, economic globalization, social and demographic shifts, and politics will create fundamental changes in the Delta and increase uncertainty. Stewardship of the Delta and its way of life will require new

approaches—helping species move to new locations, accepting some non-native species as part of the new nature, restoring landscapes rather than bits of habitat, balancing the needs of people and the environment, and coming to grips with the inevitability that some species will be lost.

The Delta can become a model of enlightened management. Adaptive management is an important part, but fresh thinking and new approaches will be needed, founded on a new state of mind about people, resources, and the environment. Business as usual will only continue the current trend toward environmental degradation.

> *"There will always be uncertainties that surround any action. Difficult political choices will be necessary. Adaptive management is the preferred approach to implementing management actions in the face of uncertainty. Regular monitoring and evaluation of the Delta's response to management is the best way to detect unexpected outcomes and adjust management actions to deal with uncertainties."*
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> --- Luoma et al. (2015: 17)

I. Background and Structure of This Report

The Sacramento-San Joaquin Delta is one of the most studied estuaries in the world. It is also highly variable and changing, which creates considerable uncertainty about the outcomes of current and proposed management practices. Consequently, management of the Delta must be flexible and adaptive. Science is central to this effort.

The Sacramento-San Joaquin Delta Reform Act of 2009 (SBX7 1) directed the Delta Stewardship Council to develop a Delta Plan to serve as the blueprint for achieving the coequal goals of (1) providing a more reliable water supply for California and (2) protecting, restoring, and enhancing the Delta ecosystem. The Act stipulated that the Plan "include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions" (Water Code section 85308(f)). The Delta Plan further stated that "Ecosystem restoration and water management covered actions[1] must include adequate provisions, appropriate to the scope of the covered action, to assure continued implementation of adaptive management …" (Delta Plan G P1; 23 CCR section 5002(b)(4)). In other words, an adaptive management strategy is *required* for most significant ecosystem restoration and water-management projects in the Delta. Additionally, in establishing the Delta Independent Science Board (hereafter, Delta ISB or "we"), the Act further required that the Delta ISB "provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews…" (Water Code section 85280(a)(3)).

[1] Covered action means a plan, program, or project as defined pursuant to Section 21065 of the Public Resources Code that meets all of the following conditions: (1) Will occur, in whole or in part, within the boundaries of the Delta or Suisun Marsh; (2) Will be carried out, approved, or funded by the state or a local public agency; (3) Is covered by one or more provisions of the Delta Plan; and (4) Will have a significant impact on achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta. (California Water Code section 85057.5).

This report summarizes a Delta ISB review of how adaptive management is currently being conducted in the Delta. We also offer our perspectives and recommendations on how adaptive management can be incorporated into programs more effectively to become an integral part of managing land, water, and other natural resources in the Delta. We are scarcely the first to advocate the use of science-based adaptive management in the Delta. In *The State of Bay-Delta Science, 2008,* Healey (2008) emphasized the value of adaptive management in addressing complex, "wicked problems." In 2009, the Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management[2] reviewed adaptive management in the Delta. Their findings and recommendations remain pertinent.

We emphasize at the outset that many agency staff, practitioners, and decision-makers in the Delta recognize the importance of adaptive management and appreciate the value of basing management practices and decisions on a solid foundation of science, data, knowledge, and experience. Many individuals and programs would like to manage their activities adaptively, yet they find it difficult to do so. Accordingly, in this report we consider how adaptive management is perceived and used in the Delta and how its application might be made more efficient and effective. Several efforts are already underway to develop systematic approaches to adaptive management in the Delta under the auspices of the Delta Science Program (DSP), the Collaborative Science and Adaptive Management Program (CSAMP), and the Collaborative Adaptive Management Team (CAMT). These activities may provide a foundation for building a more comprehensive and effective framework for adaptive management.

Unlike other reviews that the Delta ISB has undertaken, our focus here is on the process of adaptive management itself, rather than on the specifics of the science that supports adaptive management in the Delta. There already exists a large body of scientific understanding and knowledge that provides a basis for adaptive management, and it clearly identifies the science needs, especially in monitoring and modeling, for effective application of this approach.

The Review Process

Our assessment of adaptive management in the Delta is based on the results of a questionnaire (Appendix C) distributed to several agencies, in-person interviews with individuals directly involved in managing the Delta and its resources, a review of pertinent scientific and management literature, and comments from the public on a draft

[2] http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Independent_Science_Advisors_Report_on_Adaptive_Management_-_Final_2-1-09.sflb.ashx.

report. Respondents to the questionnaire and individuals interviewed are listed in Appendix D. The responses to our questions were thoughtful, detailed, and candid, and we much appreciate the willingness of many people to help us understand how and why adaptive management seems to be such a hard thing to do in the Delta.

We used this approach because so little is documented about how adaptive management is actually done in the Delta. Moreover, we felt that evaluating impressions and perceptions of adaptive management by the professionals doing management in the Delta may reveal needs and solutions to adaptive-management implementation and challenges. Public comments also provided new information and prompted additional thought about some topics.

The raw materials for this report are the responses, comments, and insights provided by the individuals and groups we consulted. Throughout this report we indicate direct, verbatim quotes from questionnaire respondents or interviewees (without naming them) in *italics*.

The Sections

To provide context, we begin with a brief background on adaptive management: what it is, when it may be most useful, and what factors have limited its applications. Additional background on adaptive management may be found in the cited references and suggested readings listed in Appendix A.

We then describe how adaptive management is perceived by the interviewees. We follow with a more detailed treatment of how adaptive management is or is not implemented in the Delta, organized by the nine steps of the process described in the Delta Plan. We then comment on factors that seem to constrain or impede the application of adaptive management in the Delta. After this, we take a broader view of adaptive management: how it might be streamlined; how it can be more responsive to changes in the physical, ecological, and social environments; and what "best available science" really means in the context of adaptive management. We conclude by suggesting a path forward, offering recommendations for what is needed to make adaptive management more achievable and effective in the Delta, proposing some immediate actions, and offering some brief concluding comments.

II. Some Context

What is adaptive management?

"Most substantive environmental management decisions are iterative. There are precious few that will not be reviewed at some point in the future, and for which learning about key uncertainties is not a key priority" (Gregory et al. 2012: 254). This statement captures the essence of adaptive management. "Adaptive management" was first articulated as a science-based approach to resource management by C.S. "Buzz" Holling and Carl Walters in the 1970s and 1980s (Holling 1978, Walters 1986). Since then, it has been incorporated into statutes at local to international levels. It is now the approach advocated by many agencies and organizations to deal with complex environmental-management problems. The words "adaptive management" are used effortlessly by politicians, bureaucrats, administrators, managers, and scientists, all presuming that they are talking about the same thing. We have found that this is not the case.

So we begin with definitions. The Delta Reform Act defines adaptive management as: "a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project[3] to achieve specified objectives" (Water Code section 85052). More simply, adaptive management can be thought of as a structured approach to management and decision-making that accumulates and incorporates knowledge to reduce uncertainty (Gregory et al. 2012).

Adaptive management is a proactive approach to taking risks, anticipating that plans may often not turn out as intended, having a backup plan(s), and continuing to monitor and evaluate progress toward goals. It provides a pathway for undertaking actions when knowledge about a system is incomplete and for modifying the approach as knowledge is gained and uncertainty is reduced. In short, management involves making decisions; adaptive management focuses attention on how the decisions are made using available knowledge and learning over time.

There is nothing mystical about adaptive management; in a sense, it is something we all do often. We may have planned a schedule but, unexpectedly, the bus is late or an appointment cancelled. Based on our experience and evaluation of options, we modify our schedule as new circumstances arise and carry on. Finding that the grocer is out of our favorite pasta, we substitute or plan something else for dinner. If our vacation plan calls for visiting a museum that is closed for renovation, we improvise. The success of

[3] There is some ambiguity about the term "project," which may refer formally to a defined activity, usually with designated funding and a defined start and end date, or more informally to a general area of ongoing activities. We use "project" in the former sense and "management action" or "action" for the latter. "Program" is a broader level that may include several projects.

evidence-based medicine is based on accumulated experience, learning, and continuing evaluation of outcomes. Surgeons in an operating room rely on this knowledge to adapt when something unexpected happens; therapeutic protocols such as chemotherapy are based on similar evidence and experience. Engineered structures often change from initial designs as construction occurs and users modify their requirements and expectations.

Adaptive adjustments such as these are expressed on a continuum, from the *ad hoc* adaptations we make almost automatically, to the more systematic knowledge-based decisions of a surgeon, to the structured decision-making process called for in the Delta Reform Act. The power of adaptive management in managing environmental resources increases as we move toward the structured, science-based end of this continuum.

In its management applications, adaptive management is the antithesis of dogged implementation of previously planned management actions even after it becomes apparent that they are not having the desired effects.[4] In contrast, adaptive management fosters flexibility in management actions, but it does so through an explicit, structured process. It entails having clearly stated goals, identifying alternative management practices or objectives, framing hypotheses about cause and effect, systematically monitoring outcomes, learning from these outcomes, sharing information with key players and decision-makers, and being flexible enough to adjust management practices and decisions in light of what is learned. It involves planning ahead for surprises, doing the monitoring and analyses to see what's coming, and having a Plan B (and then Plans C, D, …) ready and waiting to implement. Computer models often are used in adaptive-management to integrate available knowledge and, as learning occurs, to provide synthesis and a means of developing and exploring promising management actions before they are attempted as field experiments or pilot projects.

Adaptive management is most powerful in reducing uncertainty when management actions are thought of as experiments. By using a design that includes appropriate controls, monitoring, and replication, the factors that produced the observed outcomes can be disentangled from a variety of potentially confounding factors. As a result, one can have a good idea of *why* a management action did or did not work as expected. For example, restoration of the Tijuana Estuary in southern California involved partitioning the area into a series of modules that could be subjected to different, replicated experimental treatments (e.g., planting of different combinations of marsh plants). The results could then be used to adjust subsequent restoration efforts (Zedler and Callaway 2003). Williams and Brown (2014) describe four case studies of successful

[4] What might be described as the "Damn the torpedoes, full speed ahead" approach to management, often the easiest approach for institutions and programs, and for managers nearing retirement age.

adaptive management, and the South Bay Salt Pond Restoration Project described in Box 1 (page 17) provides an example closer to home.

However, in many cases only a single action can be undertaken at a single place and time, and replication is not possible. Therefore, the best one can do is to monitor the previous and subsequent states of the system being managed. Adaptive management may still be used in such situations if the basic requirements noted above—setting goals, monitoring, learning, and flexible decision-making—are met. It may be useful to use existing data and knowledge to conduct a "what if" thought experiment in developing possible scenarios and outcomes, perhaps using computer simulation modeling. Experience has shown that experiments don't have to be conducted in the field to be informative.

When is adaptive management most useful?

The Delta Reform Act requires the use of adaptive management for science-based management of the Delta and its resources. Conducting comprehensive adaptive management, however, can be demanding, expensive, time-consuming, and politically sensitive. Adaptive management should not be undertaken if there is no opportunity to apply what is learned, if there is little uncertainty about what actions to take or their outcomes, or if there is little agreement among parties about goals and objectives (Gregory et al. 2006, Williams and Brown 2012, 2014). Adaptive management is most likely to be useful and effective when:

1. There is considerable uncertainty, making it difficult to predict with confidence the outcomes of management actions but actions must nonetheless be taken (i.e., waiting for better knowledge is not an option);
2. The system is complex and nonlinear, which means that many direct and indirect pathways can affect outcomes, identifying cause(s) and effect(s) is difficult, and the system being managed may veer in unexpected directions in response to management actions and other factors;
3. The system is changing rapidly, which means that the conditions when the desired outcomes are expected may differ from those when the management actions are first applied;
4. There is potential to learn (and reduce uncertainty) by observing and recording what happens in response to management actions;
5. Costs, benefits, and risks can be assessed and balanced quantitatively;
6. There are technical and institutional means to incorporate what is learned to improve management practices;

7. The management actions do not have irreversible long-term effects on the system and management is flexible. In contrast, if an action results in a permanent or long-term alteration of the system (e.g., construction or removal of a dam, installation of a large pumping station, filling a wetland, or extinction of a species), the flexibility to adapt is foreclosed; and
8. Stakeholder and institutional support is sufficient and flexible enough and stakeholders and decision-makers buy into the process.

The upshot is that adaptive management is more useful in some situations than in others, and sometimes it may be inappropriate or not feasible. We return to consider such situations in Section VII.

Some Examples

Despite the incorporation of adaptive management into the guidelines for many governmental agencies and the hundreds of papers and books written on the subject, actual examples of successful adaptive management are surprisingly (and distressingly) rare. For example, of the 1,336 published papers dealing with adaptive management and biological systems reviewed by Westgate et al. (2013), fewer than 5% explicitly claimed to do adaptive management, and of these less than a dozen actually met their strict criteria for adaptive management.

Several management or restoration projects show both the promise and the difficulty of conducting adaptive management in large, complex ecosystems. For example, ecological restoration in San Diego Bay provides a model of many of the elements of effective adaptive management (Zedler and Callaway 2003). Restoration was prompted by the need to mitigate damages from highway and flood-channel construction and to provide habitat for endangered species. The work entailed close collaboration of scientists with state and federal agencies. Frequent meetings helped to ensure that information was shared among all parties. Restoration actions, standards, and eventually the design of the mitigation program itself were adjusted based on the results of ecosystem monitoring.

In other cases, the goals are long-term and the process is still underway. The Delta Plan used restoration of the Kissimmee River in Florida as an example of adaptive management (see Dahm et al. 1995). Although this project involves planning, design, monitoring, and evaluation, it is not structured as an experiment. In contrast, the Glen Canyon Dam Adaptive Management Program adopted an explicit experimental approach, using controlled flows from dam releases to assess options for restoring sand-bar habitat below the dam and protecting endangered fish in Grand Canyon. The Program includes

both management and technical working groups; the Grand Canyon Monitoring and Research Center (USGS) provides science support to monitor and assess ecological responses to the experimental flows (National Research Council 2004, Melis et al. 2005). Restoration of the Everglades is also often cited as an example of adaptive management of a complex ecosystem (see Gunderson and Light 2006; National Research Council 2004, 2014; Convertino et al. 2013). Doremus et al. (2011) and LoSchiavo et al. (2013) provide summaries of what has been learned so far. Because there are close parallels between restoration efforts in the Everglades and adaptive-management challenges in the Delta, we include a synopsis from Doremus et al. (2011) as Appendix B.

The Rio Condor Project in Chile illustrates both the potential and possible reasons for failure of planning for adaptive management. In 1993, The Trillium Corporation purchased some 272,000 hectares of forested land in Tierra del Fuego. The intent was to integrate sustainable production of valuable forest products on a grand scale with conservation and ecotourism; Lindenmayer and Franklin (2002) provide details on the early history of the project. After extensive design and planning (and navigating several legal and bureaucratic challenges), the Rio Condor project was implemented in 1999. The design incorporated extensive monitoring and scientific research to support a rigorous adaptive-management process that included experimental testing of both forest-management and conservation-practice hypotheses, with periodic evaluation by outside experts. With a background like this, what could go wrong?

The answer, as is most often the case, was funding. Trillium had underestimated costs and overestimated returns, and defaulted on the loans to purchase the lands in 2002. So much for the adaptive-management plan! Goldman Sachs then stepped in to acquire the defaulted loans, donating the area to the Wildlife Conservation Society in 2004. Renamed Karukinka Natural Park, it now serves multiple conservation functions, including assessing carbon benefits, protecting populations of guanaco (*Lama guanicoe*) and several endangered species, and promoting ecotourism.[5] Although the outcome differed from the initial plan, the effort succeeded in meeting the different, adaptively revised, objectives.

What factors limit the use of adaptive management?

Why are there so few examples of successful adaptive management? As in the Rio Condor example, the funding needed to support the phases of adaptive management

[5] http://www.wcs.org/saving-wild-places/latin-america-and-the-caribbean/karukinka-landscape-chile.aspx

is often not secure.. But there are numerous other barriers (see Gregory et al., 2006, Lund and Moyle, 2013, Williams and Brown, 2014, and page C-4 in the Delta Plan).

1. Understanding complex systems requires multiple disciplines that are typically housed in different agencies and have different responsibilities, different priorities, and different approaches; transcending these boundaries is difficult;
2. Uncertainty about the response of complex systems to multiple factors often leads to a hesitancy to move forward on adaptive management once a management decision is made;
3. Mechanisms and approaches for designing and implementing large-scale ecosystem experiments are not well-developed;
4. Support for adaptive management and its goals may shift with the political winds, creating administrative uncertainty that inhibits implementation;
5. Managers are often risk-averse, and consequently are reluctant to take actions that might not work as planned and could be regarded as "failures";
6. Key stakeholders have not been involved in the planning and design of a management action, do not understand the underlying rationale, have different interests and priorities, and consequently do not buy into the process;
7. Regulations (e.g., restrictions under the Endangered Species Act) may limit experiments or data gathering (although such activities may be undertaken if they are included in the authorized actions; that is, they are planned in advance);
8. The need to obtain multiple permits from multiple entities to conduct complex adaptive management can cause delays, during which time the system changes, requiring adjustment of plans or goals, which may then require additional permitting;
9. Human resources (i.e., expertise, time) needed to plan, implement, monitor, or evaluate the actions and outcomes are not available; and
10. Communication among all parties, especially among scientists, managers, decision-makers, and stakeholders, is not accorded a high priority.

Another example—the South Bay Salt Pond Restoration Project in San Francisco Bay (Box 1)—illustrates how these factors can be addressed in planning and implementing adaptive management. In general, however, these barriers impede implementation of adaptive management; unless they can be resolved, adaptive management will continue to be a fine-sounding aspiration that is rarely realized. We offer further comments on the major impediments to implementing adaptive management in the Delta in Section VI.

Box 1. Adaptive Management in the South Bay Salt Ponds Restoration Project[6]

[put in box]

In 2003, state and federal agencies acquired 6,110 ha of solar evaporation salt ponds at the south end of San Francisco Bay from Cargill, Inc. The South Bay Salt Pond Restoration Project (the Project) was soon established to restore and enhance wetlands while providing wildlife-oriented recreation and flood management. Adaptive management is a central element of the project.[7] This itself is unsurprising; proposing adaptive management is now *de rigueur* for almost any large environmental project. What is noteworthy is that adaptive management is actually being used effectively in managing this large and complex restoration project. There are lessons in this for overcoming impediments to implementing adaptive management in the Delta.

Several features of adaptive management in the Project stand out, particularly against the backdrop of the narrative elsewhere in our report:

1. Adaptive management was incorporated into Project planning from the beginning and figured prominently in the Project EIS/EIR;
2. Management of the Project is explicitly collaborative, involving the California State Coastal Conservancy, the U.S. Fish and Wildlife Service, the California Department of Fish and Wildlife, local flood control and water agencies, and non-profit organizations. Communication among these entities, and with scientists, managers, and stakeholders, is a regular activity;
3. Project participants identified key uncertainties (all of which incorporate the overarching uncertainty of climate change) early in the planning. Specific studies have been designed and conducted to address these key uncertainties as restoration actions have been implemented;
4. Models and experiments have been used to test hypotheses and reduce uncertainties, in some cases leading to changes in restoration and management practices[8];
5. Monitoring has been, and continues to be, used to assess both ecological responses (e.g., bird use of managed and unmanaged ponds) and compliance (e.g., water quality); the results have been used to inform management decisions; and
6. Each restoration target has a management trigger for action if the system is not meeting specified expectations; if this happens, a list of potential actions is already in place to guide adaptive responses.

[6] Thanks to Laura Valoppi (USGS) for providing this example.

[7] http://www.southbayrestoration.org/pdf_files/SBSP_EIR_Final/Appendix%20D%20Final%20AMP.pdf

[8] http://www.southbayrestoration.org/science/adaptive_management_in_action.html

Incorporating adaptive management into plans is only part of the challenge. To implement adaptive management requires addressing the impediments noted in Section VI. How has this been done in the South Bay Salt Pond Restoration Project?

1. Aversion to taking risks. The restoration actions are phased over 50 years, so some risks can be taken in the early stages because there is time to make corrections in later phases;
2. Typical slowness. The Project Lead Scientist can quickly relay preliminary scientific findings to the management team and management changes to researchers without waiting for work tor reports o be published. Topic-specific work groups of researchers and managers discuss the latest data and management challenges;
3. Regulatory requirements and delays. To anticipate potential regulatory or permitting hurdles, Project participants meet annually with regulators to apprise them of results from the current year's actions and discuss management actions planned for the coming year;
4. Perceptions about monitoring. By building an adaptive-management process into the Project at the outset, the importance of monitoring has been made clear; monitoring is designed to address specific management questions, reinforcing its relevance;
5. Communication gap. The Project Lead Scientist is part of the management team and the point person for explaining the results of scientific studies (appropriately translated) and Project progress to diverse audiences;
6. Insufficient and undependable funding. The Project is not immune to funding challenges; researchers and managers work together to obtain grants and other funding. The multi-agency management of the Project facilitates these efforts; and
7. Accelerating pace of environmental change. Pre-restoration studies provide a baseline for gauging future change, and restoration sites are compared with reference sites to separate the effects of environmental change from restoration actions. A BACI (before-after-control-impact) design is used whenever possible, with strong statistical study designs. Models project that sea-level rise will accelerate after mid-century; in anticipation, managers have begun to bring in clean fill and reuse dredged sediments in the restoration design and are trying to increase conversion of ponds to marsh.

[box ends here]

III. General Responses

To get a sense of how respondents to the questionnaire viewed adaptive management, we initially presented a series of statements to be rated on a scale of 1 (strongly disagree) to 5 (strongly agree). These statements were modified from a nationwide survey of adaptive management reported by Benson and Stone (2013). The results are tabulated in Appendix E and are summarized here.

Respondents generally agreed that adaptive management requires a high degree of collaboration, that conceptual models should include social, political, and economic factors as well as ecological factors, and that it is important to communicate the results to stakeholders. However, there was less agreement on whether baseline information about the Delta is usually gathered or conceptual models are usually built before action is undertaken; the degree to which results from monitoring and assessment are used in decision-making; and whether adaptive management leads to changes in management and actions. There was still greater variation in responses to other questionnaire statements—some agreed, others disagreed about whether their agency did or did not use adaptive management; whether the agency's management was flexible enough to do adaptive management; whether laws and regulations did or did not restrict management options; and whether laws and regulations could be changed to make adaptive management more successful.

The strongest, most uniform response we received, however, was disagreement with the statement that "Monitoring is adequately funded to support adaptive management." This concern emerges often in this report and is considered it further in Section VI.

IV. Perceptions of Adaptive Management: How is it Useful?

If adaptive management is not perceived to be useful, then it will not become a common practice, even in situations that cry out for an adaptive-management approach. Several individuals questioned whether adaptive management really yields any benefits beyond those of normal, non-adaptive management. For example, one respondent wondered whether "*the results of adaptive management are worth the effort*" and another asked, "*Does the cost and effort to implement adaptive management take resources away from implementing the actual project?*"

Most of the people we surveyed, however, saw value in at least some elements of the process, if not in the entire process itself. They recognized the potential for adaptive management to promote discussion among parties with opposing views, clarifying the

problem to be solved, and articulating the decisions that need to be made. For example, adaptive management can help to identify areas and sources of uncertainty and target where additional research or knowledge is needed. In this way, the process emphasizes the importance of an "*upfront investment in knowledge*" to increase the likelihood that the actions will yield the desired results and prompt discussion of how this knowledge can inform decisions. Moreover, by developing hypotheses of how and why a system might respond to management actions, the process can help to determine "*What does one do at a fork in the road?*" The conceptual framework or model developed as part of adaptive management can focus thinking about an action and its possible outcomes and ensure that scientific guidance is part of the process. Moreover, this approach can help to identify why things might not have worked as planned and provide the basis for a more mechanistic understanding of the issues of concern. By using this approach, costs to the public from misdirected actions may actually be reduced.

Adaptive management also can provide insights into causes of ecological changes and system linkages beyond the object(s) of management interest, such as whether there is a need to examine other stressors and connectivity pathways. In practical terms, it can be used to determine which disciplines or agencies need to be involved to address a problem or to engage in collaborative work on a project. Consequently, it can help to avoid mistakes that might result from a failure to consider a full range of system dynamics and mechanisms. Finally, some respondents felt that adaptive management can facilitate communication by transmitting scientific knowledge about a system and its performance to managers and policy makers.

These and other responses demonstrate broad recognition among Delta scientists and managers that adaptive management can aid in identifying knowledge gaps and sources of uncertainty; using knowledge about the Delta to consider alternative courses of action; fostering clarity and transparency in developing management plans and making decisions; understanding and anticipating how a system may respond to management actions; identifying both direct and indirect consequences of those actions; engaging multiple parties in discussions and planning; and fostering communication among scientists, managers, and decision-makers.

At a conceptual level, then, most people who responded to the questionnaire or interviews believe they have a general understanding of what adaptive management is and how it can benefit management. The real questions are whether this understanding translates into actually *doing* adaptive management in the Delta and, if not, what factors impede the implementation of adaptive management?

V. Implementation of Adaptive Management: How is it Being Done?

One questionnaire respondent stated that "*We include actions to conduct studies and monitoring to resolve uncertainties and to verify assumptions made in establishing standards, limits, or performance measures, and also consider opportunities to revisit and revise decisions, pathways, and milestones based on new information or unforeseen circumstances*." This report would be unnecessary if this process were widespread in the Delta. But it isn't. Adaptive management in the Delta is frequently talked about, is often claimed to be used, but is rarely implemented as a rigorous, science-based process that incorporates structured decision-making, triggers for actions, and stakeholder involvement.

Results from a survey by the Delta Science Program illustrate this point. In 2011, when the implications of the Delta Reform Act were just beginning to become apparent, the Program surveyed state and federal agencies and several non-governmental organizations on whether they were including adaptive management in their programs.[9] Of the 46 programs surveyed, 7 had no response as to whether they used adaptive management, 10 indicated that they did not use it, 8 said they planned to use it sometime in the future, and 21 claimed to use it in some form. The latter responses, however, included such things as managing program administration to respond to change, using data to make decisions, reviewing programs for performance, or adjusting programs on the basis of experience. In other words, almost anything that might lead to change in a program was regarded as adaptive management.

It is apparent from the 2011 report and our recent surveys and interviews that an understanding of what "adaptive management" is varies substantially and is very much in the eye of the beholder. Different agencies and programs often perceive adaptive management in multiple ways and modify their definition and approach to suit their purposes. One interviewee observed that "*there is no agreement about what adaptive management is, but everyone thinks they are doing it.*" Consequently, actions such as adjusting releases of cold water from dams to foster movement, survival, or migrations of salmon, flooding agricultural fields in autumn to provide habitat for migratory shorebirds and waterfowl, or reducing water exports at pumping stations to prevent entrapment of smelt and other fish may be adaptive management to some people but routine management decisions to others. These are examples of adjusting actions to fit

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9 http://www.deltacouncil.ca.gov/sites/default/files/documents/files/DISB_on_the_DSP_January_2012_v2.pdf

circumstances—managing adaptively—and they are often based on past experience. But they are not the sort of structured decision-making embodied in the description of adaptive management in the Delta Plan. Although these actions may be appropriate in fulfilling particular management needs, the implication that these might be a structured, adaptive-management approach is not justified. Divergence of approaches and interpretations may impede the communication and collaboration needed for effective adaptive management of the Delta.

To clarify and standardize how adaptive management should be structured, the Delta Plan describes a cyclic, nine-step process (Fig. 1). Many versions of the adaptive-management cycle exist in the literature, embodying anywhere from three to more than a dozen steps, with some depicting a circular sequence and others a web of interacting processes (see, for example, Healey, 2008, Murphy and Weiland, 2014, and Williams and Brown, 2014). However, all are founded on science and all involve the same basic activities: *Plan* (identify the problem and design the management approach(es)); *Do* (implement the management action(s) and monitor the results); and *Evaluate and respond* (analyze and synthesize the results, communicate the findings to appropriate parties, and make any necessary adjustments). In fact, a distinguishing feature of structured adaptive management is the importance of the initial planning phase, which is fully as important as implementation and evaluation. As Murphy and Weiland (2014: 206) observed, "Adaptive management requires a demanding upfront approach that emphasizes the production, critical assessment, and appropriate interpretation of scientific information throughout the adaptive-management process."

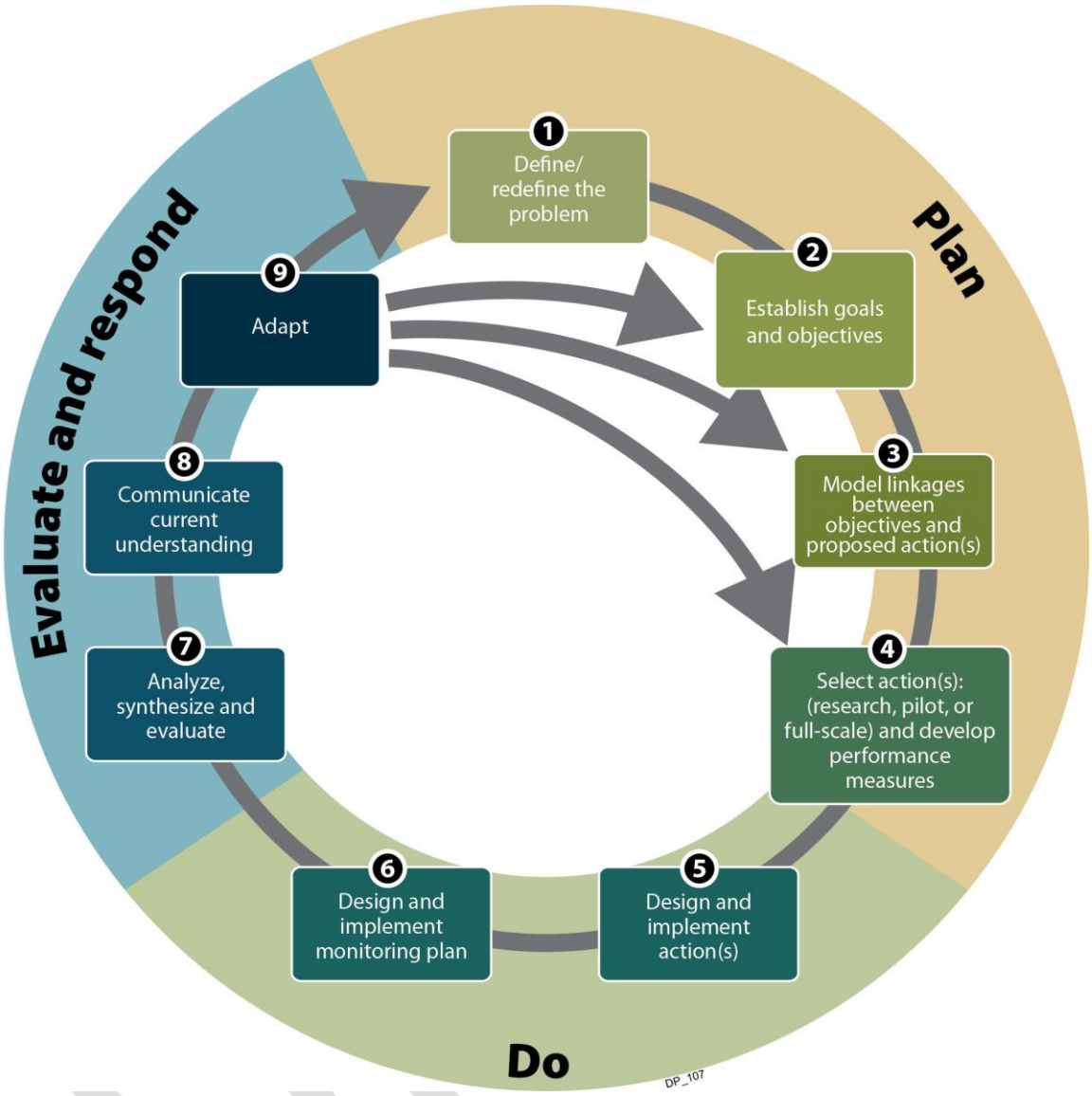

Figure 1. The nine-step framework for adaptive management depicted in the Delta Plan. Boxes represent steps in the process, and the circular arrow represents the general sequence of steps. The additional arrows indicate possible next steps to address the problem or revise the selected action based on what has been learned.

To assess perceptions about the nine-step approach, we asked questionnaire respondents and interviewees to comment on how the nine steps are expressed in practice; the discussions and implications for management in the Delta are summarized for each step below.

Define/redefine the problem

It is hard to imagine that a management action would be planned or undertaken without knowing the problem to be addressed. Disagreements and uncertainties are worsened if the problem is not clearly defined. While it is not always necessary that everyone involved in a project sees the problem in the same way, such differences should be openly discussed before a project begins. And while defining the problem is the starting point for effective management,, simply defining the problem is not enough. Major underlying causes should be identified and ideally framed as testable hypotheses.

Everyone we interviewed considered that their work begins with a clear understanding of the problem. A clear definition of the problem can indicate at the outset the array of collaborators needed to address the problem and can establish the baseline conditions for management against which progress (or at least change) can be measured. Often, however, the problem is defined by entities other than those designing and doing the management. As one respondent observed, "*We are typically told what the 'problem' is by other agencies. Our job is to figure out how to fix the problem.*" In at least some cases, the problem statement is accompanied by an identification of key uncertainties, which helps define knowledge gaps that need to be filled. Appropriately, the problems are defined by perceived management, political, or societal needs rather than scientific needs. The role of science, after all, is to help address the specified problem in a rigorous way, so that "*the science should be relevant to the problem*."

Overall, our impression is that the various agencies and programs do a good job, individually, of framing the problem (even if it is not "their" problem), in many cases setting the stage for subsequent steps in adaptive management. Sometimes there is clear coordination and collaboration among agencies or entities to address a common problem, although this is not as prevalent as it should be.

Establish goals and objectives

Clear goals and objectives are essential to adaptive management; as Yogi Berra once observed, "If you don't know where you are going, you'll end up someplace else." Differing values and priorities among stakeholders can stymie clearly stated management

objectives (as the did for the Everglades Adaptive Management Program; National Research Council 2004). Clear goals and objectives reduce reliance on subjective feelings that "things just aren't right" or "this isn't working" and management can move forward.

Most problems are considered in terms of outcomes; managers "*look first at the outcomes and then ask what is needed to ensure getting there*." The desired outcomes, in turn, dictate what performance measures will be used to determine the "success" of a program (and thus the need to adaptively manage). When the goals and objectives are set by administrative or regulatory criteria (e.g., meeting water-quality standards or permit specifications), as is often the case, the targets or outcomes of actions are clearly specified but the mechanistic understanding of causes needed to conduct adaptive management (*why* did the actions produce the observed outcomes) may remain elusive. Some programs and agencies are able to identify ecologically sensitive performance measures (e.g., juvenile fish migration survival rates, spawning density, dissolved oxygen), but obtaining detailed information on such measures is often difficult. As one respondent commented, "*Performance measures have generally been established in federal ESA biological opinions or State water rights decisions and are often too broad, too difficult, and too costly to measure.*"

This statement highlights the challenge faced by scientists, managers, and decision-makers in the Delta. It is important to frame clear goals and objectives that are relevant to the State's coequal goals of managing for both water reliability and Delta ecosystems. However, if progress toward meeting those goals and objectives cannot be assessed because the outcomes are difficult to measure (e.g., juvenile fish survival) or the indicators are not directly related to the goals (e.g., salinity at some locations), it will be difficult to determine whether it is appropriate to stay the course of action or adaptively change practices.

Overall, all of the people we interviewed felt that their programs and agencies have a clear sense of their goals and objectives, even though they often struggle with meeting objectives that are not their own and are under constraints that limit their ability to measure progress toward meeting those objectives.

Model linkages between objectives and proposed action(s)

The third step in the adaptive-management process in Figure 1 entails modeling. To model, or even to think about how proposed actions might address a problem to attain goals and objectives, requires knowledge—information about what is to be managed, how it may respond to actions, and what factors or contingencies might affect outcomes.

Much of this information can be gleaned from what has been learned in other current or past projects, whether in the Delta or elsewhere. Adaptive management relies on both conceptual and quantitative models. Modeling without such background knowledge may end up being detached from reality and less likely to produce practical guidance.

How is modeling used to support management in the Delta? These responses are typical of what we heard: "*We use conceptual models to guide our understanding of the complex nature of ecological systems and to help identify data gaps*" and "*We ultimately decide which models to use based on the state of the science, availability of appropriate models and modeling expertise, cost/benefit of modeling versus not modeling an action, and project budget.*" There is also a general recognition of the need to develop quantitative modeling expertise and tools to implement adaptive management and balance long-term benefits against short-term costs. Even when quantitative models are used, however, there is often little follow-up and no adjustment of models based on new information. Developing quantitative models that capture the complexity of Delta systems requires staff well-versed in systems thinking, data analysis and management, and modeling. Such staff are difficult to attract and retain and "*are often pulled off to address immediate needs*."

While most respondents use conceptual models and recognize at least the desirability of more quantitative systems models, others question the value of modeling in addressing problems in the Delta. There is a perception among some that even conceptual modeling may not be needed to conduct adaptive management, particularly when the ecological or physical processes are well known: "*we need to ask what a model can tell us that we don't already know that will add value to management.*" As one respondent put it, "*we model to exhaustion, modeling begets more modeling.*" Another noted that "*having models is great, but not at the expense of delaying action*."

Thus, while many individuals and entities working in the Delta embrace (albeit sometimes reluctantly) the role of modeling and its value in organizing thinking, identifying critical uncertainties, and communicating options to decision-makers, others prefer to base their actions instead on experience, expert opinion, or intuition. Although sophisticated quantitative modeling is not necessary in all situations, we believe that conducting adaptive management in a complex, multivariate system must at a minimum entail the development of a comprehensive conceptual model, organized in relation to the overall problem being addressed, the goals and objectives, the uncertainties involved, and the desired or anticipated outcomes. In developing guidance for ecosystem restoration for the Army Corps of Engineers, for example, Fischenich et al. (2012) suggested that conceptual models for adaptive management should (1) identify causes of degradation (i.e., the problem); (2) indicate how causal factors influence key system components; (3)

indicate how management can reduce stresses or restore the system (i.e., meet the objectives); (4) incorporate hypotheses to be tested; and (5) indicate what needs to be monitored, why, and over what time frame. This guidance could be applied to many projects in the Delta.

As complexity, the need for quantitative predictability, and/or the risk of unintended consequences of actions increase, more sophisticated models may be needed. Because such models are demanding of expertise, time, and money, they should be developed in a collaborative framework. The collaborative development of CALSIM by the US Bureau of Reclamation and the California Department of Water Resources is a good example. More recently (May 2015), the Delta Science Program and UC Davis Center for Watershed Sciences conducted a workshop on "Integrated Modeling for Adaptive Management of Estuarine Systems"[10] that brought together people from multiple disciplines and organizations. Models may play an important role in fostering inter-agency collaboration, which in turn may reveal insights or knowledge gaps apparent to one agency but not to others.

Overall, we found that while there is broad acceptance of the value of conceptual models, there are differences in perceptions of the usefulness or applicability of quantitative modeling. Moreover, neither of these types of models is routinely adjusted as new information becomes available.

Select action(s): (research, pilot, or full-scale) and develop performance measures

Adaptive management often identifies alternative actions that might be undertaken to address a problem. Models may help to select among these actions, but uncertainty may remain about which actions will produce the desired outcomes. When the actions are expensive, difficult to change, or have the potential to produce unwanted side effects, additional research or a small-scale pilot study may be appropriate before undertaking full action. One respondent indicated, "*if outcomes are fairly uncertain and time sensitivity is not an issue, then a small scale implementation (pilot) study is generally conducted before a larger scale project is undertaken*." This generally involves consultations among multiple agencies and stakeholders. Some programs use decision-support tools (e.g., Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Action Evaluation Procedure and Decision Support Tool[11]) to help determine what actions may be most appropriate in a particular situation. Others view conducting a

[10] http://deltacouncil.ca.gov/enewsletter/stories/july-2015/may-integrated-modeling-workshop-brought-together-international

[11] http://www.dfg.ca.gov/erp/scientific_evaluation.asp

pilot study before full-scale action as an alternative to implementing adaptive management after the action is taken—an approach that could be described as "plan, do a pilot study, and then forge ahead and don't look back."

Understandably, people in agencies with management responsibilities in the Delta feel "*the curse of the immediate,*" the push to take action without the luxury of first getting more information to increase the likelihood of long-term success. Despite this, some programs are committed to conducting pilot studies (and perhaps even more research) when the situation warrants and when they can justify (and fund) it. In practice, "*the lack of funding and staff resources for science is the primary limiting factor for targeted research and pilot studies*."

Clearly, information and knowledge can be obtained in many ways, and additional research involving an experiment or hypothesis test isn't always necessary for adaptive management. One interviewee noted that "*management decisions are typically made in response to regulatory requirements and to short-term crisis situations, so they are often made without considering targeted research or adaptive management*." There is a perception that "*there is a tradeoff between implementing actions and conducting the science to evaluate the actions,*" Research may be necessary in some situations involving critical knowledge gaps or uncertainties, but several respondents questioned whether the adaptive-management framework is simply another way for scientists to justify doing more research. Thus, "*there should be a very clear division between adaptive management and scientific research*," or, more bluntly, adaptive management "*will make projects more costly, complicated, and promote further implementation delays. In the end, less gets done, [we] go to more meetings, the resources continue to suffer, while the scientists wait for irrefutable answers*." Another respondent cautioned, "*Adaptive management should focus on finding out if the broad project objectives are being met, not with discovering answers to detailed scientific questions*."

There is disagreement about whether adaptive management should routinely involve new scientific research, or whether it should be based on existing knowledge, with research needs identified as knowledge gaps become apparent in the process of implementing adaptive management. There is no single answer to this perceived dichotomy. In either case, there is a risk that the research may become arduous and inappropriate for aiding timely management decisions. The level of science and research required should be scaled to what needs to be understood to inform management actions, to the costs (in terms of time, money, and staff) of doing the research, and to the likelihood that the research will significantly reduce uncertainties and enhance knowledge. While the research also may contribute to fundamental ("basic") scientific

knowledge, the primary focus should be on producing mechanistic knowledge related to the problem.

Overall, then, there seems to be considerable angst about including additional scientific research under the banner of adaptive management, even though everyone seems to agree that science is central to improving Delta management and is an important way to fill knowledge gaps and reduce uncertainties.

Design and implement action(s)

The first stage of the "Do" phase of the adaptive-management process is designing actions. All of the programs we considered included the design of management actions, often in considerable detail, although not always in the sequence outlined by the previous four adaptive-management stages.

Differences in goals and objectives among projects often lead to divergences in design. Still, most programs and agencies implement actions more or less as they were designed, to achieve stated goals and objectives. Once initiated, management usually sticks to the original design unless it is overwhelmingly clear that something is amiss—the system is responding negatively, the environment has changed in unanticipated ways, or external forces such as funding or administrative support have changed. Knowing when circumstances should prompt a re-evaluation or change in actions is one of the most challenging aspects of adaptive management.

Overall, we find that management actions are usually carefully planned and documented (not the least because permitting often requires it).

Design and implement monitoring plan

To be most effective, the planning and design of actions should be developed in tandem with the plan and design of monitoring—management plans and monitoring design should be closely coordinated. This is especially important when the management is structured adaptively as an experiment or is designed to test hypotheses. Linking monitoring with the design of management actions also will help to ensure that the monitoring is targeted, informative, and cost-effective rather than broad-based and unfocused. One reviewer of the Draft Report summarized it this way: *"Under an adaptive management regime, monitoring must be purpose oriented, address explicit objectives, be capable of detecting salient environmental changes, and provide quantitative results that can inform management responses."*

Unfortunately, monitoring details "*are often worked out as the project proceeds and funding becomes available.*" Insufficient up-front attention to the design of monitoring protocols can lead to ineffective monitoring or monitoring of the wrong things. If an action is designed to address regulatory needs, for example, the monitoring protocols are generally not designed to answer scientific questions that would improve project management or the design of future projects. Consequently, although the monitoring design may tell one whether management actions have complied with regulations or permit requirements, "*this monitoring data is typically useless to answer any questions.*" Even when the emphasis is on monitoring ecosystem performance, the focus tends to be on outcome measurements rather than mechanistic understanding of why actions succeeded or failed.

Monitoring and data management are also inseparable. As Lindenmayer and Franklin (2002) observed, "monitoring is necessary to generate the empirical data that are the definitive measure of the degree to which a management program is achieving its objectives." Some respondents and interviewees reported that their data are assembled in data banks or data-management systems that are available to others, although this was more often than not a work in progress. In other situations, however, "*database linkages outside individual projects are generally not worked out very well or at all*." The management of Delta data is a topic of active consideration by the Delta Science Program ("Enhancing the Vision for Managing California's Environmental Information"[12]).

Overall, programs often seem to find it difficult to maintain ongoing monitoring while implementing actions, much less after the actions have been completed. Relating monitoring to management actions remains a major impediment to implementing adaptive management in the Delta.

Analyze, synthesize, and evaluate

Several respondents indicated that the analysis of the results of an action is often done "*within a year or two*" of project completion or occasionally during implementation of the actions if conditions warrant. Where the actions are undertaken in a regulatory setting or have permitting conditions attached, however, there may be built-in checkpoints or triggers for assessing status. For example, "*when adaptive management triggers are met, we respond accordingly, with varying degrees of effort, detail, and adequacy*." In other words, mid-project assessments are generally done to comply with

[12] http://deltacouncil.ca.gov/docs/enhancing-vision-managing-california-s-environmental-information-final

reporting timelines and permit requirements rather than to assess whether the system is responding to management as hoped. Other respondents or interviewees said that "*the most common project evaluation is a qualitative assessment of whether a project has been implemented as designed*" or "*on the ground observations and assessment of habitat conditions and consideration of changes in environmental conditions are continually analyzed, but likely not well documented.*"

There seems to be a general pattern related to analysis, synthesis, and evaluation. If management actions are related to a multi-agency effort (the Interagency Ecological Program (IEP) was frequently mentioned), then prompt, ongoing, and thorough analyses may be conducted, as was the case for the Pelagic Organism Decline (POD), the Management, Analysis, and Synthesis Team (MAST), or the Fall Low-Salinity studies. More often, the burden (and it is often perceived in this way) of analysis and synthesis falls within a program or agency, and it may be delayed or not done at all unless there are specific requirements and appropriately trained and well-led staff to do so. It is important to emphasize that this is *not* a result of a disregard for the importance of analysis and synthesis or a lack of intent to do so; rather, it reflects the incessant, multiple distracting demands that are made on programs, staff, and agencies that are understaffed or lack the expertise to conduct basic data analyses. The difficulty is exacerbated when monitoring is inadequate or piecemeal, not targeted on the most appropriate variables, or the data are not managed in a way that facilitates insightful analysis.

In short, this phase is where the adaptive-management process, when it is actually undertaken, most often begins to break down. Failure to conduct the necessary analysis, synthesis, and evaluation of the results of management actions, particularly while the actions are underway (and thus potentially amenable to adaptive adjustment), is a major barrier to achieving adaptive management. To some degree, this situation is created by the imperative to move ahead on other actions once one project nears completion. This, in turn, reflects the perception that a project is "completed" when the action is done; as a result, analysis, synthesis, and evaluation are regarded as add-ons to be done as time and resources permit. Although it is clear that some (perhaps many) programs and agencies *want* to do the analysis, synthesis, and evaluation needed to gauge the effectiveness of their actions (and thus follow through with adaptive management), even the best intentions may be overwhelmed by the immediacy of management challenges in the Delta. Ecosystem-level, performance-based analysis and synthesis is especially important for creating an integrated system of actions over time, rather than planning opportunistic actions that tend to occur today without regard for future plans or changes.

Without timely analysis, synthesis, and communication, little is learned, at least in a way that can be incorporated into adaptive management. Moreover, the same mistakes

may be repeated in the next project. This problem relates back to monitoring issues and the lack of secure funding, which we discuss later in this report.

Communicate current understanding

If the scientific findings and knowledge gained in the previous steps of the adaptive-management process are not translated into clear and understandable language, managers and decision-makers will probably not use the information to respond adaptively.

Everyone we surveyed recognized the importance of communicating the results of their actions to decision-makers, other agencies, stakeholders, and to the public. In some cases there is frequent communication among managers and agency staff about habitat and management conditions for a specific project. Scientific findings are generally reported in conferences and briefings, some of which are directed toward the public. Translation of the science, however, "*is often not done until managers/decision-makers identify a specific question(s) they need answered*" and often the communication is to upper-level administrators about budgets rather than assessing what has or hasn't worked or coupling the communications with informative and up-to-date performance measures. One respondent noted "*the information that drives management decisions seems to be more based in local politics and whose land is being sought after for what purposes or with specific conflicts between parties that could result in lawsuits*" and another felt that "*there has not seemed to be an interest in what science-based actions might be assisting in the recovery of specific animal populations as marker of progress to species recovery as it relates to water/flood/land management decisions*."

Tailoring communication to facilitate adaptive management isn't easy. The audience interested in most projects, especially in the Delta, is diverse, with different interests, priorities, and knowledge. Managers and decision-makers have many responsibilities, so the challenges are to distill the results of all the previous phases of the adaptive management process and to determine how much information, of what sort, is needed to inform decisions. Lengthy reports or scientific papers are ineffective or are too often and too easily ignored.[13] The Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management (2009) recognized the need for individuals skilled in both communication and science to translate scientific findings for managers and decision-makers, a finding we strongly agree with.

[13] In contrast, the webpage of the South Bay Salt Pond Restoration Project is a good example of how to communicate succinctly. See http://www.southbayrestoration.org/science/adaptive_management_in_action.html

Overall, while effective and broad communication is seen as essential for adaptive management and for overall management of resources in the Delta, there is an unfilled need for an organizational structure that accommodates science communications to prepare informative briefings and understandable outreach materials as important results become available. Moreover, communication must be multi-way, with decision-makers, stakeholders, and all participants in adaptive management informing as well as being informed by others. Without broad communication of the appropriate information, the next step in the adaptive-management cycle may not occur and the process will not be successful. Consequently, attention should be given to communication when an adaptive-management plan is first being formulated, not when everything else has been done.

Adapt

In a broad sense, all of the previous steps in the adaptive-management process are about learning. The challenge, and the point of this step, is to put that learning into practice. As Hilborn (1992) noted, "if you cannot respond to what you have learned, you really have not learned at all." And responding involves making decisions.

In our interviews with agency representatives, the questions of who makes the decisions and how they do it came up repeatedly. In some programs, the process is adaptive but informal. If the results are desirable, then the actions continue and the techniques are applied elsewhere; if not desirable, the practices are assessed and changes may occur. Evaluating what outcome is or is not desirable should be related to the initial goals and objectives, although who deems what is a desirable outcome at the end of a project may not be the same person as the one who initially framed the goals and objectives, which may have been done years earlier. Moreover, as conditions change, what looks undesirable now may look more desirable as time passes (or vice versa). One respondent mentioned that "*we need tools to assist programs to conduct that critical but usually missing link in the cycle: adapt and then re-evaluate and change program goals and objectives*." In some instances, determining whether change is necessary may be based on the use of models to inform decision-making, although this may be slow because the data needed to run the models are insufficient. In this case, best professional judgment, stakeholder input, or external peer review may be an appropriate substitute.

The trickiest part of the adaptive-management process may be determining when the mismatch between the results of management actions and the original goals and expectations of a project is great enough to warrant changing the actions, models used, goals and objectives, or even restating the initial problem (Fig. 1). It may also be the most important part of the process. As Fischman and Ruhl (2015: 5) observe, "failure to specify actions triggered by thresholds can lead to dead ends in what should be the

continuing adaptive iteration cycle".[14] This may be especially problematic in a complex system such as the Delta, where outcomes often do not match expectations. When this happens it may indicate that the system was not understood (and modeled) as well as initially thought. Adapting may involve more than a slight change in management practices.

These two aspects of the "adapt" phase of adaptive management—who makes the decisions about whether to continue or to change management actions, and how much departure from expected outcomes should trigger a change in practices—often do not receive sufficient attention. The first is usually determined by who's in charge, which is usually tied to the administrative or organizational structure for conducting a project. The second depends on whether the mismatch between desired and realized outcomes has exceeded a threshold of acceptability, which is determined by such things as the cost and feasibility of making a change, the suitability of alternatives, the priorities of stakeholders and interest groups, and a multitude of other factors. Both the decision-making and the determination of trigger points are situation-specific. Nonetheless, it is important to know something about both issues as one goes through the steps in the adaptive-management cycle, because this will affect how plans are formulated, what data are gathered, and how the findings are translated into useful information. Misidentifying who makes decisions or being either premature or tardy in responding to triggers can easily derail the adaptive-management process. This is why some have suggested that the adaptive-management cycle should actually begin at the point where the decision-making and authority lie. Unless there is some focus on the decision-making process and authority, the entire process may stall when the time comes to adapt management practices or adjust goals and objectives. An open and transparent decision-making process can help avoid this outcome.

Overall, it is our impression that decisions about whether to continue or change management approaches and actions are often based on some level of monitoring and analysis, combined with experience and professional judgment, current management needs, and the political (and funding) climate. The process varies tremendously among and within agencies, however, and it is often informal rather than systematic. Unfortunately, there is a tendency to regard any process that might result in change as adaptive management, which may be why so many think they are doing it.

[14] Fischman and Ruhl use the example of how the Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) employed adaptive management in their proposals to comply with court mandates for management of listed fish in the Delta. NMFS included specific criteria to trigger revision of water operations to avoid jeopardy, whereas the FWS approach failed to provide precise, enforceable criteria. The NMFS approach was upheld, whereas the FWS plan was remanded.

VI. Why is Adaptive Management Not More Common in the Delta?: Constraints and Impediments

In Section II we listed some factors that generally impede applications of adaptive management. Several of these apply especially to management in the Delta and were mentioned frequently by questionnaire respondents and interviewees. To make adaptive management common for the Delta, these impediments must be effectively addressed.

Aversion to taking risks

Adaptive management maneuvers through uncertainty and unknowns by progressively crafting a better understanding and quantification of the problem. These uncertainties entail risk, with a probability of failing to achieve goals and objectives. Failure is an anathema to the results-driven and political context of any management agency. A manager or decision-maker must manage the risks of investing in projects with uncertain results, even when the stakes are high. Explaining such risks to administrators, politicians, or the public may be difficult. Perhaps these constraints and anxieties encourage managers to believe that it is better to err on the side of caution and be conservative in modifying original actions.

While this characterization does not describe the approach of all programs, managers, and agencies working in the Delta, it may not be too far off the mark for some. As one respondent observed, "*Agencies and agency staff are risk averse. They would rather not act, if there is a possibility that they may make the wrong decision, and having it attributed to them*." To implement adaptive management, however, managers must not be penalized for trying approaches that later turn out to be ineffective or even to fail.

The tendency of managers, decision-makers, policy specialists, and engineers to be risk-averse or to strive to maximize certainty in their decisions contrasts with the culture of science, in which uncertainty and risk are the *sine qua non.* To a scientist, doing an experiment or conducting a study in which the results were certain and there were no risks of surprises would be unexciting and pointless. This difference in perspectives may contribute to some of the communication difficulties between scientists and managers.

The curse of the immediate

The combination of an aversion to risk and the frequent need to make immediate decisions creates a conundrum that can compromise the use of adaptive management in

the Delta. Conducting comprehensive adaptive management will often be ponderously slow. Once the problem, goals, and objectives have been defined (which itself can be slow and contentious if multiple parties and interests are involved), doing the planning, modeling, designing, and permitting can easily take years before all is set to implement an action. Litigation can add more delays, and risk-avoidance by managers or decision-makers can further delay action. The system being managed may itself also respond slowly to management actions So it is little wonder that carrying the adaptive-management process to full term is rare.

Even if steps can be taken to reduce some delays, the orderly, sequential process of adaptive management is susceptible to being repeatedly sidetracked in the environmental, political, social, and fiscal setting of the Delta. Crises arise often, derailing long-range planning or continued monitoring. Staff assigned to data analysis, modeling, or monitoring may be shifted to address more immediate concerns, so knowledge to inform adaptive management may be obtained in fits and starts. As one respondent put it, "*the need to make decisions outpaces information flow*." Put simply, the pace of adaptive management does not match the pace of events and management decisions in the Delta. Faced with this temporal mismatch, it may often be tempting to move ahead with an action while assuring that adaptive management will be implemented later if it turns out to be needed. While some actions may need to be taken quickly (such as constructing a salinity barrier under extreme drought conditions), this need not preclude the careful thought and planning that underlie the first phases of adaptive management (see Section VII).

Regulations impede flexibility

Management of a system as complex as the Delta, with multiple local, state, and federal agencies involved in decisions about water and the environment, is suffused with an array of regulations and permit requirements. These regulations and requirements reflect a desire and need to establish order, certainty, and stability; they set standards and limits, and prescribe the legal and operational domain within which management must operate. In contrast, the targets of management—smelt or salmon, water quality, incoming flows, demands on water exports, salinity intrusion, and the like—are anything but orderly, certain, and stable. The targets are assumed to be stationary, but in fact they are constantly moving. The flexibility needed to deal with changing conditions or to implement the "adaptive" part of adaptive management may be precluded by regulations. Listing of species under the Endangered Species Act, for example, places restrictions on experiments or pilot studies that might improve management and leads to a focus on single species rather than the larger ecosystem.

Obtaining permits for projects can be an arduous process that delays even well-planned projects. For example, one of the most ambitious habitat-restoration projects in the Delta, the Dutch Slough Tidal Marsh Restoration Project,[15] must obtain permits from multiple state and federal agencies to initiate restoration activities. This process has taken years and remains incomplete. Even emergency actions face permitting delays. The proposal to construct an emergency drought barrier on the West False River to prevent tidal intrusion and a loss of water quality during the drought in 2015[16] likewise required multiple permits from multiple agencies. Construction went ahead after Governor Jerry Brown issued an Executive Order exempting the project from requirements of the California Environmental Quality Act (CEQA) and other state requirements and an emergency authorization was granted by the Division Commander of the Corps of Engineers.

Once permits have been issued for management actions, it may become difficult to change directions in mid-project, even if new knowledge indicates that change is needed. The need to modify permits or obtain new ones may bring a project to a halt, particularly if litigation is involved.

Monitoring is difficult to maintain

Science is the lynchpin of adaptive management and should be the foundation of monitoring. Without monitoring the right things, at the right times, and at the right places, there is little way to know whether management actions are on track and whether they are moving toward the desired goal or toward an alternative outcome. As Lindenmayer and Franklin (2002) noted, "it is impossible to systematically assess whether management goals are being achieved without adequate monitoring, which in turn, ensures that the effectiveness of policies, legal obligations, and social commitments… can be assessed." In short, without proper monitoring there is no way to manage adaptively. Monitoring is the "nerve center" of adaptive management (Fischman and Ruhl 2015).

Monitoring needs to occur before and during a project, not delayed until after the project is completed or when it is too late to make changes. Because the outcomes of actions are frequently not immediately apparent, however, monitoring also may need to be continued for some time after project completion to gauge the effectiveness of management actions. All of this emphasizes the importance of a continuing, long-term commitment to monitoring if adaptive management is to deliver on its potential.

[15] http://water.ca.gov/floodsafe/fessro/environmental/dee/dutchslough/index.cfm
[16] http://www.water.ca.gov/waterconditions/emergencybarriers.cfm

However, developing the needed long-term vision and commitment in the crisis-driven setting of the Delta is challenging. As one respondent noted, "*Unless there are legal or regulatory mandates to do monitoring, it is often the first thing to go when money gets tight.*" Others suggested "*monitoring is typically [of] discrete elements for a short duration to meet regulatory requirements*" and "*not designed to answer science questions*." More generally, "*Adaptive management science efforts are not funded. They get added to a project and other resources and staff are depleted to meet the new requirements*."

There is also a perception that the level of monitoring required by adaptive management is excessive and may not add value commensurate with its costs. Such monitoring "*takes away from other resource management obligations and needs*." For example, "*Monitoring for a 300-acre restoration project far exceeds the costs of doing the restoration, so one can't blend implementation with monitoring or the project becomes too expensive.*" This may be particularly true if the monitoring must generate sufficient statistical power to detect responses to management actions in the complex and variable environment of the Delta. The success of the Interagency Ecological Program in catalyzing continuing, long-term monitoring of aquatic resources in the Delta and in developing standardized monitoring protocols to evaluate the effects of tidal wetland restoration shows that it can be done, but it requires dedicated and stable funding.

Incentives are lacking

In the business world, profits provide a compelling incentive for using adaptive management. Incentives are less obvious for applying adaptive management to environmental or natural-resource institutions. Consequently, some may wonder why bother—what is to be gained by undertaking an arduous and expensive process? There is a "stick" for doing adaptive management—the requirements of the Delta Reform Act and the Delta Plan—but what is the "carrot"? Using adaptive management should increase cost-effectiveness in the long run, identify and reduce uncertainties, or identify and adjust for mistakes more promptly. These benefits may all be true, but because adaptive management has so rarely been fully implemented there is little supporting evidence. If managers and program leaders are to embrace adaptive management (as we believe they should), there needs to be something more than comforting assertions to answer, "What's in it for me?" This question would be easier to answer if there were more examples of successful adaptive management in the Delta (and elsewhere) and if costs and benefits were clearly detailed.

Adequate long-term funding is unreliable

Without exception, the individuals and agencies we canvassed identified the lack of reliable, long-term funding as the greatest single impediment to adaptive management and monitoring in the Delta. Thus, "*little to no money is available or designated for developing and implementing monitoring to determine outcomes*." Or, "… *funding occurs for those programs mandated by law*"; otherwise, "*details of adaptive management and monitoring are often worked out as the project proceeds and the funding becomes available.*" Or, "*There is insufficient funding to conduct the science and collaboration necessary for evaluating actions and developing a response*." Or, "*Funding for monitoring of habitat enhancement after construction is not typically a priority or directive of fund sources*."

The difficulty of funding adaptive management indicates that it is often not as high a priority as it should be. Even if funding is available to support the adaptive management that programs or agencies want to do, however, the funds often come in ebbs and flows that render the funding inefficient or ineffective. "*Support comes in pulses that put a premium on showing progress, rather than deliberate, long-term projects.*" Bond funding, such as that from the recent Proposition 1, may provide money to do things, but not to follow up and determine the outcomes. General Fund allocations for adaptive management and monitoring are difficult to obtain. And there is a perception among some that these activities are thinly disguised ways to fund scientific research that does not address real problems.

Adaptive management is often viewed as an unfunded mandate. We believe that people and programs generally want to, and try to, practice adaptive management, but without dedicated and reliable funding they are reluctant to do so at the expense of existing projects and programs. But adaptive management cannot be done effectively in fits and starts or as an add-on when resources are available. If adaptive management is to be done, it must be built on a mechanism to follow through. It requires an underlying commitment to long-term stewardship of the Delta and its resources. It should be a high priority, the default practice ("Plan A") for most projects and management actions.

VII. Standing Back and Looking Forward: Broadening the Perspective on Adaptive Management

So far, we have focused on the details of the adaptive-management process and how it is used and perceived by those working in the Delta, relying heavily on their own words. Now we take a broader view, offering some thoughts prompted by those comments and responses. We hope that these thoughts will provide some guidance for

making adaptive management more user-friendly, and thus more widely used in dealing with resource issues in the Delta.

Adaptive management may not always be appropriate

Adaptive management should be the default approach to management actions in the Delta. It is also mandated by the Delta Reform Act and the Delta Plan. But adaptive management is not an inflexible, one-size-fits-all process appropriate for every situation; it couldn't be, given the variety of resource-management problems it is intended to address (Gregory et al. 2012). Adaptive management should not be forced upon a project that is unsuited for it, either because the actions do not warrant it or the institutional or stakeholder support is lacking. In the *Department of Interior Applications Guide for Adaptive Management*, Williams and Brown (2012) suggest that adaptive management is appropriate to situations in which both uncertainty and controllability are high and when the approach may reduce uncertainty by controlling (i.e., adapting) the actions that are taken (Fig. 2). Key determinants of adaptive management are its appropriateness, feasibility, and likelihood of success; a decision tree can help evaluate whether and when a situation might meet these criteria (Rist et al. 2013),

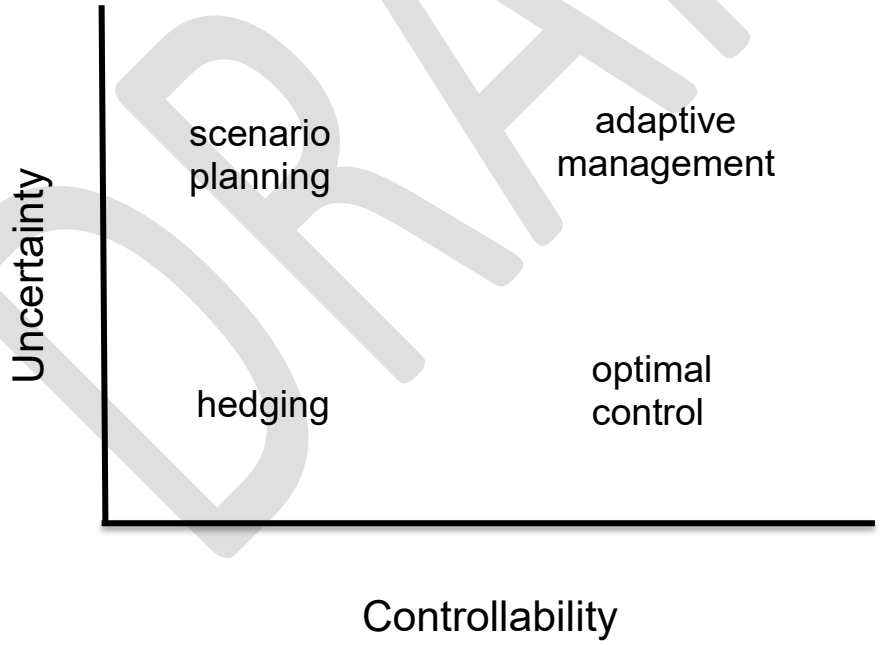

Figure 2. Approaches to making natural-resource decisions. The appropriate approach depends on the influence decisions can have on system behavior and the uncertainty of management impacts (after Williams et al. 2007).[17]

[17] http://www.usgs.gov/sdc/doc/DOI-%20Adaptive%20ManagementTechGuide.pdf

Funding is usually the most important factor influencing the decision to use adaptive management. It may make little sense to initiate an elaborate and expensive adaptive-management process if the money is not available to do it properly. However, for high-priority management actions in which the stakes, costs, and economic impacts are high, rigorous adaptive management may be essential. Here the value in investing in upfront knowledge acquisition may justify the expense, especially if an action, once started, cannot easily be changed. Such situations call for comprehensive adaptive management, and the nine-step process shown in Figure 1 provides clear guidance.

In many situations, however, the nine-step process might better be seen as aspirational rather than prescriptive. Can the adaptive-management process be streamlined to require fewer resources and move more quickly, and in doing so have less potential to disrupt a program? Steps 1 (defining the problem), 2 (establishing goals), 4 (selecting action(s)), and 5 (designing and implementing actions) are the core components of any management activity, whether adaptive or not. It is important that they be done thoughtfully, based on knowledge and experience, with an eye toward flexibility. Step 3 (modeling) is often considered a barrier, but this depends on the kind and level of modeling required. It should not take much time or effort to assemble enough of what is known about a system to develop a reasonable conceptual model, which can quickly reveal unrecognized linkages and critical knowledge gaps and can suggest alternative actions. The impediments to such modeling are more institutional than intrinsic to the modeling process.

Likewise, step 6 (monitoring) needn't involve assessing all components of a system with rigorous and demanding procedures. A good conceptual model may help to identify reliable indicators of system responses to management actions, and planning ahead to think about the circumstances that might lead to a change in management could help to determine where, when, and with what level of detail the targets should be monitored. Finally, steps 7 through 9 (analyze, communicate, and adapt) can be adjusted to the complexity and quantitative level of the information gathered and what changes, if any, are suggested and may need to be justified. The "synthesize and evaluate" part of step 7, especially, requires careful, focused thought and discussion among project participants (including stakeholders).

Streamlining the adaptive-management process is not acceptable to some. Fischman and Ruhl (2015) disparage what they call "AM-lite," in which clear objectives are lacking, the iterative process is not followed, monitoring is inconsistent, and defined trigger points for actions are missing. Although such approaches have been presented as adaptive management, courts have recognized that they are not (Fischman and Ruhl 2015). We suggest that a more judicious lightening of the process may sometimes be

appropriate, while remaining true to the spirit and intent of rigorous adaptive management.

Some have countered suggestions that adaptive management be simplified and made more user-friendly in appropriate situations by proposing that the process be made even more rigorous and demanding. Convertino et al. (2013), for example, advocate "enhanced adaptive management," in which the structured process we have described is integrated with decision analysis, scenario analysis, and environmental modeling. The approach explicitly evaluates alternative strategies, calculated the cost-benefit payoffs associated with each, and quantified stakeholder preferences in determining priorities among the strategies. Others (e.g., Gregory et al. 2012) argue that adaptive management is a weaker subset of formalized structured decision making, which is a more complex, scientifically robust, and demanding approach. It would be productive to explore these more formal analysis alternatives for some major management issues in the Delta.

The bottom line is that there are ways to manage adaptively, whether or not one does comprehensive adaptive management following the steps of Figure 1. The key is to understand the value and advantages of the process and to look ahead rather than reacting too quickly, avoiding all risk, or clinging to an existing approach that isn't working. Conducting adaptive management requires patience, persistence, and commitment (Williams and Johnson 1995), but it also benefits from thoughtful assessment of how much of the process is just right for the circumstances and objectives. A step in the structured approach to adaptive management (e.g., Fig. 1) should not be omitted simply because it is difficult or expensive, but neither should it be carried out with a level of detail and rigor (and difficulty and expense) that is not warranted by the effects the results will have on decision making.

Conditions change

Looking ahead is important not just so one can gauge the effectiveness of an action and make changes before it is too late, but also because the Delta, like the rest of California and most of the world, is undergoing massive change. All coastal areas will be affected by sea-level rise, and models of future climate change predict higher temperatures and altered rainfall and snowfall patterns, with changed hydrologic flows in the Delta. New non-native species will continue to arrive. Regulatory requirements and the economic values of land and water will continue to change. Consequently, even the most thoughtfully planned and carefully designed management actions may no longer be appropriate by the time they are completed, or even by the time they are implemented given protracted planning and permitting. If the system changes rapidly and unpredictably, an action may not produce the desired outcomes or it may be difficult to

determine whether a change in the system is due to the action itself or to changes in other factors. Although some people question whether the rapidity of these environmental changes precludes the effective use of adaptive management, others suggest that adaptive management is the best approach to deal with rapid changes because of its management flexibility, which is an essential element of decision-making in a changing world.

Adaptive management also provides a way to formally anticipate and prepare for changes through modeling and monitoring. Some plans for tidal wetland restoration, for example, are incorporating projections of sea-level rise, hydrology, and sedimentation to target actions at appropriate tidal elevations for future conditions (see Box 1). It may be useful to develop "anticipatory adaptive management," in which the management actions are designed for future conditions, when the actions will be completed and the outcomes are expected, rather than for the conditions existing at the time the actions are planned or initially implemented. Vleig and Zandvoort (2013) describe such an approach to adaptive management in the Rhine-Meuse Delta of the Netherlands and compare it with the approach outlined for the Sacramento-San Joaquin Delta in the Delta Plan.

Another consequence of environmental change impinges on how or whether adaptive management is implemented. If change is great enough or rapid enough, it may overwhelm any inherent resilience of a system and push it over a threshold or tipping point. Once a threshold is passed, the system may be so altered that it functions differently, rendering it difficult or impossible to return to a former condition even with intense management (Moyle and Bennett 2008). In such cases, the dynamics of the system may have been fundamentally altered, changing cause-effect relationships. Consequently, the previous understanding of the system, on which management relies, may no longer apply—the rules of the game have changed. The problem with thresholds, of course, is that you generally don't know they are there until you've passed them, when it may be too late to do much about it. In a complex ecosystem that has undergone massive alteration, such as the Delta, some thresholds have already have been passed; the Pelagic Organism Decline may be such a situation. We found little evidence that much thought has been given to the complications posed by such thresholds. Clearly, however, the likelihood of thresholds heightens the need to incorporate flexibility and adaptability into planning and management.

The bottom line is that future changes should always be considered in planning management actions, even though (as Yogi Berra also said), "It's tough to make predictions, especially about the future." Nonetheless, future changes will determine the effectiveness of management whether or not the approach is adaptive, whether or not there are legal or regulatory requirements to consider the future, and whether or not the approach is explicitly anticipatory.

"Best available science" may not always be essential

The use of "best available science" is a common requirement for management actions in an uncertain environment. It is explicitly mandated in the Delta Reform Act and is discussed at some length in the Delta Plan. Best available science "requires scientists to use the best information and data to assist management and policy decisions" (Delta Plan, page C-1). In essence, it is the gold standard for applied science.

We do not question the importance of using current and well-tested scientific knowledge to support management or the desirability of aspiring to the criteria established for best available science (Delta Plan, Table C-1). Indeed, management actions in the Delta should always have a strong foundation of scientific knowledge. However, it may be worthwhile to reflect on whether best available science is always the most appropriate or productive goal for implementing science-based management in the Delta. We have several comments.

First, what we believe is really intended is to bring the best available *knowledge* to bear on an issue or used to support a proposed action. Science often provides the most credible and reliable information, but it is not the only source of knowledge about the Delta. The learning that is the aim of adaptive management involves increasing the quality and quantity of knowledge on a particular issue, not just adding more science to the mix. Admittedly, "best available knowledge" doesn't have the same cachet as "best available science," but it may more accurately capture what is really being sought.

Second, the emphasis on "best" and the criteria used to define it appropriately sets a high bar. It may be set so high, in fact, that actions may sometimes be delayed while the search goes on for better data, better analyses, or additional scientific publications, all in the interests of meeting the goal of "best." There are already excuses available for delaying actions (especially controversial ones); aiming for "best" should not be one of them. On the other hand, some suggest that what is really meant is best *readily available* science. Framing it this way can help to avoid such delays, but what is "readily available" depends on how hard one looks. In some cases, depending on readily available science may promote taking actions with knowledge that is woefully incomplete. Conceptual models may help to reveal dangerous inadequacies in the knowledge base.

Third, adaptive management involves a succession of steps that build on what is sufficient to take action—further reduction in uncertainty often is not needed to move ahead. In fact, it is often necessary to initiate a management action when the available knowledge is just "good enough," rather than being the "best available" (or even "best

readily available"). The same criteria used to identify "best available" science might also be used, in a somewhat more relaxed form, to define what is "good enough" science. Essentially, thinking of the science as "good enough" allows a manager or decision-maker flexibility in considering the additional costs, risks, uncertainties, effort, and potential benefits of attaining "best available." However, using a "good enough" standard should *not* be an excuse for weakening the role of science in informing management and policy. Any standard, whether it be "best available," "best readily available," or "good enough," must be scientifically defensible and rigorous and, more importantly, can be implemented in a complex physical, biological, social, and regulatory environment. Formal risk analysis can help to resolve such issues.

All of this may be quibbling about words. Words matter, however. "Best available science" implies (correctly or not) that scientific certainty is as good as currently possible. Science that is just "good enough" doesn't sound nearly so rigorous, but it may be appropriate when combined with sound adaptive management.

VIII. Overall Findings

Most practitioners and managers in the Delta have a general understanding of what adaptive management is and what it entails. However, the term is perceived in different ways and is often regarded as any process that might lead to changes in actions. We find little evidence that the actual process is being fully implemented. Instead, adaptive management, the organized research needed to fill knowledge gaps and reduce uncertainty, and the essential monitoring needed to successfully implement it are often regarded as add-ons or obligations that divert attention from needed projects.

Despite the successful application of adaptive management in a variety of fields, ranging from engineering to medicine, there are several reasons for the struggle to implement it fully in the Delta. It is easy to blame a lack of funding and human resources, and certainly funding to undertake adaptive management (including the monitoring) is sporadic and inadequate and expertise is in high demand and difficult to attract and retain. But increased funding or staffing, by themselves, would not ensure that adaptive management would be fully implemented. To do so will require a change in the culture of management in the Delta. Managers and decision-makers must become more willing to take risks. *Not* managing adaptively entails the risk that, by following a traditional approach, better options are ignored. Risks of action (or inaction) should be weighed against benefits by using conceptual or quantitative modeling or informed judgment. Agencies must become more actively engaged in collaborations with one another and be willing to share staff and resources as the challenges require. Adaptive management must be recognized as a high priority, as dictated by the Delta Reform Act and the Delta Plan.

It must become an integral part of management plans and actions. As Luoma et al. (2015: 17) recently observed, effective adaptive management requires "collaboration, communication, and transparency among all interest groups as well as a willingness to overcome the institutional barriers to collaborative decision-making." The cost savings from sharing staff skilled in data management, analysis, and modeling may be particularly great. Perhaps most importantly, adaptive management requires greater flexibility—flexibility in decision-making, in regulations and permitting, and in planning for future changes.

These changes will not be easy or achieved quickly. However, the following suggestions and recommendations will help move adaptive management toward a more effective and integrated approach to managing the Delta, its water, and its ecosystems.

IX. A Way Forward: Improving Adaptive Management in the Delta

Science, management, and policy in the Delta are in a state of flux, brought on by the proposal to build new water-conveyance facilities; the heightened imperilment of several species at risk of extinction; the continuing entry of new, non-native species into the Delta; imminent changes in hydrology and sea-level rise due to climate change; the specter of increased salinity intrusion into the Delta; the vulnerability of aging levees; and increasing conflicts over who gets available water—all of which are exacerbated by the ongoing drought. This cauldron of change provides an unusual window of opportunity—and an imperative—to develop a more thoughtful and effective approach to achieving the goals highlighted in the 2009 Delta Reform Act for the future of the Delta. The Delta Plan and Delta Science Plan provide frameworks for capitalizing on this opportunity, and the theme of "One Delta, One Science" offers a way to bring coherence to the science currently fragmented among agencies and disciplines. This fragmentation thwarts effective adaptive management (Lund and Moyle 2013). A more holistic and integrated approach to science-based adaptive management in the Delta is needed to face both current and future challenges.

Despite legislated mandates to use adaptive management, this will not happen spontaneously. To become fully integrated into Delta management, adaptive management will require *collaboration* among agencies, managers, scientists, engineers, and stakeholders, and *commitments* by those who control resources and make decisions.

Advancing "collaboration" and "commitments" from aspirations to become the foundation for a widely used process of adaptive management in the Delta will require leadership from an organized body, an "adaptive management team." Such an adaptive

management team should be dedicated to promoting and coordinating adaptive management in the Delta and providing guidance and support in its applications. Among its functions, such a team could:

1. Provide leadership in aligning adaptive management with the needs and context of management actions;
2. Consider how anticipated changes in future conditions can be incorporated into adaptive-management plans and actions;
3. Identify potential synergies among agencies, support adaptive governance, and foster management flexibility;
4. Advise the Delta Stewardship Council and regulatory agencies on compliance issues and the appropriateness of adaptive management for proposed actions;
5. Encourage a greater emphasis on whole ecosystems and functioning landscapes; and
6. Assemble, synthesize, and communicate information about adaptive management.

Creating a body to coordinate adaptive-management activities is not a new idea. Similar suggestions have been made before. In the context of the CALFED program, for example, Zedler and Callaway (2003) proposed developing an adaptive management team that "meets annually, identifies priority research needs, prioritizes sites where adaptive restoration might take place, reviews research results, and recommends future actions." Lund and Moyle (2013) suggested that adaptive management in the Delta should be overseen by a "Delta Director" and a small interagency committee, with parallel structures for geographic subregions of the Delta., The Delta Science Plan developed by the Delta Science Program in 2013 recommended the creation of several "adaptive management liaison" positions to provide advice to their counterparts engaged in adaptive management in agencies and organizations; and convening an annual "adaptive-management forum" to share lessons learned and provide training in adaptive management. These efforts are now underway. In addition, the Collaborative Science and Adaptive Management Program (CSAMP, composed of agency directors, regional directors, and general managers) and the Collaborative Adaptive Management Team (CAMT, which includes senior scientists and high-level managers) focus on the effects of the State Water Project (SWP) and Central Valley Project (CVP) on listed species, particularly smelt and salmon. However, neither of these groups considers the broader issues of management of the species themselves, the ecosystems they occupy, or the Delta as a whole. The recirculated draft RDEIR/SDEIS for California WaterFix proposes formation of a Collaborative Science and Adaptive Management Program that would build on CSAMP and CAMT and focus primarily on the design and operation of

water-conveyance facilities, associated water-quality and ecosystem-protection requirements, and mitigation measures such as habitat restoration.

All of these efforts are designed to move adaptive management more into the mainstream of Delta activities, all are based on some version of a structured approach to adaptive management such as we have described, and all are in their early stages. They provide encouraging foundations on which to build a more comprehensive and coordinated approach to adaptive management in the Delta. To do this, however, several concerns and issues that were raised by interviewees and reviewers of our draft report must be addressed:

1. Can a coordinating body for adaptive management be effective without legal or financial authority? To confer authority, it may be appropriate for the resource agencies to lead in establishing governance and funding structures for adaptive management.
2. Can such a body be effective if it is not independent of the agencies charged with implementing (and funding) adaptive management? Adaptive management might best be coordinated through the Delta Stewardship Council, the Delta Science Program, or some body not directly involved in management activities.
3. Can management and policy agencies cede leadership of adaptive management to a coordinating body? Strong, independent leadership will be required to foster the mutual trust and respect needed to enable multiple parties to design and conduct coordinated adaptive management and navigate the tangled web of Delta interests.
4. Would it be better to promote adaptive management through a single body that considers overall management of the Delta, through more targeted teams focused on specific topics (e.g., habitat restoration, water flows) or geographical areas, or by some combination of the two? A single body well versed in the application of adaptive management could develop a broad perspective on management challenges in the Delta through the variety of projects that they deal with, although they would need to rely on specific expertise to evaluate individual projects. A targeted team approach has reverse advantages and disadvantages.
5. How should a body coordinating adaptive management be composed? Should it include agency representatives, practitioners with direct experience in managing resources, regulators, external scientists, and/or stakeholders? What sort of expertise and experience would best provide the envisioned functions? Should team members be full-time or part-time on assignment from their normal job?
6. How can such a body act as a facilitator of adaptive management, rather than being viewed as yet one more bureaucratic layer that is a hurdle to be avoided? Overcoming preconceptions about the role and responsibilities of such a body will be a major challenge

None of these concerns presents an insurmountable barrier to formation of a comprehensive approach to organizing adaptive management in the Delta. We believe that adaptive management is most likely to take hold and become commonplace in the Delta if there is some coordinating body. The devil, however, is always in the details. The above questions, and others, must be answered if such a body, however structured, is to be successful.

X. Recommendations

Fundamental changes are needed in how adaptive management is organized and managed in the Delta. This should begin with a unified understanding of adaptive management: what it is and what it is not; what it requires in resources; what it needs in organizational, operational, and regulatory flexibility; and when it is appropriate and when it is not. Implementing the following recommendations will help to advance adaptive management in the Delta.

1. **Convene a workshop to determine how to coordinate and assist adaptive management in the Delta.** The Delta Stewardship Council should assemble an appropriate mix of experts, agency leaders, resource managers, practitioners, scientists, stakeholders, and regulators to consider the concepts developed in this report; assess how best to resolve the above questions and concerns; recommend what sort of coordinating and/or governing body will be best suited to advance adaptive management in the Delta; evaluate how this body should relate to other ongoing and developing adaptive-management programs; ensure buy-in by the management, policy, and scientific communities; and consider how to implement the other recommendations of this report. Among its responsibilities, this body should also periodically assess how agencies are adopting and using adaptive management. Through these reviews, lessons can be passed on to other agencies and impediments discussed as problems arise.

2. **Support adaptive management with dependable and flexible funding .** Adaptive management in the Delta will not become a reality unless the paucity and unpredictability of funding to support the process are remedied. Radically different and more effective approaches to funding adaptive management are needed. Project budgets should include a line-item allocation at a fixed proportion (10-20%) to support Delta adaptive management, above and beyond the funds required for monitoring. These funds should *not* be transferred from other existing activities into a bin labeled “Adaptive Management” (i.e., not “robbing Peter to pay Paul”). Other avenues of dedicated funding for adaptive management should

be explored as part of the deliberations of the group proposed in Recommendation 1. Establishing an endowment to support adaptive management as well as the long-term needs of stewardship of Delta resources is one possibility.

3. **Design and support monitoring**. Designing monitoring protocols to fit the magnitude of management actions and the timing of important ecosystem processes will make the value of adaptive management more readily apparent. In addition, developing an institutionalized regional approach to monitoring may help to coordinate actions among projects and facilitate the collection, analysis, and synthesis of data that are compatible across projects. Monitoring programs should include an integrated data-management system. The development of comprehensive monitoring programs and protocols should draw from the experience of the Interagency Ecological Program, the Delta Regional Monitoring Program, and approaches developed elsewhere.

4. **Integrate science and regulations to enhance flexibility.** Rigid regulations and permitting requirements inhibit the flexibility required to change directions quickly when it becomes apparent that management outcomes are not as planned. Innovative ways to incorporate sufficient flexibility into regulations and permits to allow adaptive management should be developed with regulatory and permitting agencies. Approaches such as pre-authorization of adaptive actions, allowing variations around regulatory criteria, or focusing on performance objectives and flexible outcomes rather than set compliance targets may help.

5. **Develop a framework for setting decision points or thresholds that will trigger a management response.** The most vexing component of adaptive management is determining when conditions should trigger a re-evaluation or change in practices. In the absence of designated decision points, reluctance to change may delay adaptive responses, especially if the system is changing slowly. Such decision points should be part of adaptive-management plans from the outset.

6. **Use restoration sites to test adaptive-management and monitoring protocols.** Adaptive management should be part of the design of habitat-restoration projects envisioned in California EcoRestore, so that these projects can act as learning laboratories and develop practices that can be applied elsewhere in the Delta.

7. **Capitalize on unplanned experiments.** Unexpected events (e.g., extreme droughts, large floods, levee breaks) or necessarily quick management decisions (e.g., construction of salinity barriers, cold-water releases from dams) provide

opportunities to learn and test adaptive management. Capitalizing on these opportunities requires having contingency plans, monitoring protocols, and modeling capability in place and identifying funds and staff that can be shifted to respond. The RAPID grant program of the National Science Foundation may provide a useful model.

8. **Recognize when and where adaptive management is not appropriate.** Adaptive management is not a panacea to be used in all situations. Sometimes, adaptive management may be inappropriate or need to be greatly streamlined. In other situations, sufficient support from federal, state, and local agencies may be lacking. In these circumstances, attempts to implement adaptive management may not be effective, and substantial changes in expectations and a refocusing of adaptive management attention and even legislation may be needed. Decisions about whether or how to use adaptive management should be made thoughtfully, after careful consideration of the alternatives, with the guidance of an adaptive-management coordinating body as proposed in Recommendation 1.

XI. What Next?

It will not be easy to implement these recommendations. In our view, however, it is essential to do so if adaptive management is to become an integral part of management of the Delta and its resources. Making this happen will require leadership in science and policy, most immediately from the Delta Stewardship Council and Delta Science Program, but including other programs and agencies. The key words, once again, are *collaboration* and *commitments*.

The work of the Delta ISB in fostering wider and more nimble application of adaptive management to Delta management should not end with this report. We envision continuing Delta ISB involvement in several follow-up activities:

1. Work with the Delta Stewardship Council and others as they deliberate how best to implement Recommendation 1.
2. Meet with the individuals and programs who provided the material for our review to discuss our findings, how to address the impediments, and how to progress from words and plans to adaptive actions. These discussions will provide additional input to the deliberations of Recommendation 1.
3. Present and discuss these findings and recommendations to multiple audiences (e.g., Bay-Delta Science Conference, a perspective paper in *San Francisco Estuary and Watershed Science*).

4. Assist the Delta Science Program, the Delta Conservancy, CAMT, the Public Policy Institute of California, and others in organizing an Adaptive Management Forum, including local and invited experts and multi-perspective panels, to focus on the science that is needed to do adaptive management in a system as complex as the Delta. Individuals involved in other large projects, such as the Everglades or Glen Canyon Dam, will be included.
5. Work with the Delta Science Program to track progress on the implementation of adaptive management and the recommendations presented in this report.
6. The most compelling way to counter perceptions that adaptive management is too expensive or does not yield real benefits may be to document costs and benefits of programs where the process has been applied. An economic analysis of the return-on-investment of adaptive management**,** coordinated through the Delta Science Program, should be considered.

XII. Afterword

In *The State of Bay-Delta Science, 2008,* Kimmerer et al. (2008: 93) concluded, "Although it is tempting to call yet again for adaptive management, previous such calls have not been very successful. Instead, we recommend that scientific investigations and ways of thinking be incorporated further into the management process." We concur enthusiastically with the plea to put more science into management in the Delta, but we feel that it is too soon to give up on the prospect of making adaptive management a widespread and successful enterprise in the Delta. The potential benefits of adaptive management, if used judiciously and effectively, are great. We hope that the perspectives, comments, and recommendations in this report will help to move adaptive management in the Delta from talk to action.

We must temper this optimism, however, with a dose of realism. The Delta is changing ever more rapidly. Climate change, sea-level rise, increased frequency and severity of extreme events, new invasive species, economic globalization, social and demographic shifts, and politics will create fundamental changes in the Delta and increase uncertainty. Managing with more flexibility, a greater willingness to take risks, more latitude in permitting and regulations, enhanced collaboration and communication, and more nimble decision-making will help. But stewardship of the Delta and its way of life will require more. Management recipes of the past (including structured approaches to adaptive management) may no longer suffice. The novel ecosystems of the future will require novel approaches—helping species move to new locations, accepting some non-native species as part of the new nature, restoring landscapes rather than bits of habitat, balancing the needs of people and the environment, and coming to grips with the inevitability that some species will be lost.

The Delta can become a model of enlightened management. The conceptual and logical framework of adaptive management can help California prepare for this changed world. But fresh thinking and new approaches will be needed, founded on a new state of mind about people, resources, and the environment. Business as usual will only continue the current trend toward environmental bankruptcy.

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Appendix B. Adaptive Management in the Everglades. From Doremus et al. (2011).

The Everglades: Without Clear Goals, Adaptive Management Goes Nowhere

The Comprehensive Everglades Restoration Plan (CERP) illustrates one instance where adaptive management has failed primarily because it was mandated by Congress in an inappropriate context. The CERP was adopted in 2002 in an effort to restore the ecological functioning of the Florida Everglades.[2] Congress intended "to restore, preserve, and protect the South Florida ecosystem while providing for other water-related needs of the region, including water supply and flood protection."[3] The $8 billion cost of the restoration plan was to be shared equally by the federal government, through the Army Corps of Engineers, and the non-federal sponsor, the South Florida Water Management District (SFWMD).

Heavy emphasis has been placed on satisfying stakeholders' economic interests rather than the environmental mandates, and this imbalance places a chokehold on experimentation, learning, and adaptation. In response to stakeholders' demands, the CERP devotes a great deal of attention to the use of ever more heroic engineering techniques to expand water supplies and ensure flood control for South Florida's exploding population. Meanwhile, it gives low priority to the improvement of necessary sheet water flows—the primary ecological hallmark of the Everglades. As a result, the CERP remains in a planning mode, rather than an adaptive implementation mode. In a 2007 review, the Government Accountability Office observed that no CERP projects had been completed and that the only progress that had been made involved a few, select CERP-related pilot projects designed to understand nutrient removal in abandoned agricultural fields.[4]

Why has such a well-funded attempt at adaptive management faltered? One factor is the articulated goal of the CERP, which strives to have it all: ecosystem restoration as well as uninterrupted water supply and flood protection. As in other cases where private economic stakes are high, regulated entities and other stakeholders want certainty and stability. If scientists cannot predict outcomes with a great degree of certainty, experimentation in many instances, if not most, simply will not take place. As a result, the Everglades plan is stuck on modeling and data collection rather than learning through active experimentation and resolving uncertainties in favor of ecological resilience.

A second factor is the basic congressional directive for all Corps' decision-making, which gives the agency discretion to proceed with a project whenever benefits "to whomsoever they accrue" exceed costs.[5] These grants of broad discretion free the Corps to establish priorities based on politics instead of principled reasoning and evidence. As a result, the American public has been saddled with hundreds of questionable dams, levees, and other structures justified only by dubious cost-benefit analyses. In a study of Mississippi River management in 2004, the National Research Council issued a sweeping indictment of the misguided methodology used by the Corps to justify replacing locks and dams on the upper river.[6] The CERP appears to suffer from similar flaws.

Appendix C. The Adaptive-Management Questionnaire

DELTA INDEPENDENT SCIENCE BOARD

REVIEW OF ADAPTIVE MANAGEMENT IN THE DELTA

The Delta Reform Act of 2009 charges the Delta Independent Science Board (DISB) with providing "oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs "such that" all Delta scientific research, monitoring, and assessment programs are reviewed at least once every four years" (§85280 (a)(3)). Rather than reviewing individual programs one-by-one, we are conducting reviews based on broad thematic areas. This questionnaire is the first stage of our review of how adaptive management is being thought about, planned, and implemented in the Delta and how science can best support those efforts.

We intend that our review go beyond oversight to be constructive and helpful. To probe more deeply into the responses to this questionnaire, we will follow up with in-person interviews with some respondents. After preparing a report on our findings, we will engage in further discussions to help selected programs advance their adaptive management planning and actions and adjust the focus of future reviews.

Designing and implementing adaptive management isn't easy, and it is done much less often than it is talked about. By thinking about the following questions and then providing brief responses, you'll help us suggest whether, when and how adaptive management should be used, how it can be improved, and how science can best aid this process. The questionnaire is in three parts. **Please provide links to or copies of documents that you think would help us better understand how you are thinking about, planning, and/or implementing adaptive management.**

It would be most helpful if you could return the completed questionnaire to **Martina Koller (martina.koller@deltacouncil.ca.gov)** or **Lauren Hastings (lauren.hastings@deltacouncil.ca.gov)** by **November 20**.

I. A QUICK SURVEY

We'd like to develop a quantitative understanding of how adaptive management is used in Delta programs (after all, we're scientists). **Please assign a value from 1 (strongly disagree) to (5 strongly agree) to each of the following statements regarding your**

agency, division, or program ("entity") and current or planned programs. (You'll have the opportunity to say more in the sections that follow.)

I'm responding for (name of entity) _____. The entity is an agency, division, program, or other (specify) [**check one**]

1. My entity uses adaptive management as an organizing framework for its activities.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

2. In my entity's experience, adaptive management efforts often require collaborations among multiple agencies and stakeholders.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

3. My entity's broad management plans (e.g., resource management plans) include the flexibility necessary to engage in adaptive management.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

4. Laws and other administrative and regulatory requirements often constrain our entity's efforts to engage in adaptive management.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

If so, can you list any specific legal requirements that you believe hamper or facilitate adaptive management?

5. Changes could be made in existing legal requirements to make adaptive management more successful.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

If so, can you suggest specific changes to existing legal requirements that would facilitate adaptive management?

6. We usually build a conceptual model of the management action before implementing the action.

1 ☐ **2** ☐ **3** ☐ **4** ☐ **5** ☐ [**Check one**]

7. Conceptual models should include both human and ecological systems.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

8. We gather baseline information and/or data about the relevant system(s) before management actions are implemented.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

9. Monitoring is adequately funded to support adaptive management.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

10. Monitoring and assessment results are integrated into adaptive management decision-making.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

11. It is important to communicate the results of adaptive management experiments to stakeholders.

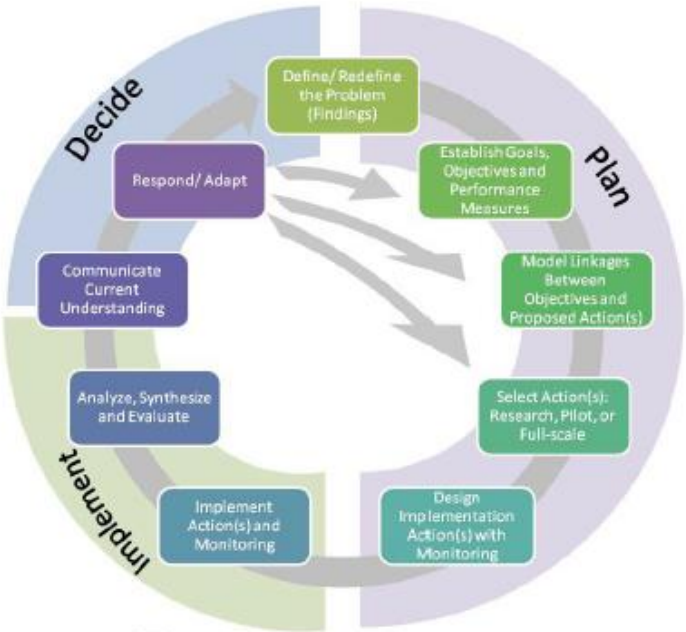
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

12. In my entity's experience, when adaptive management experiments tell us something new, management actions are changed to reflect what is learned.

1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ [Check one]

II. THE ADAPTIVE MANAGEMENT PROCESS

In the Delta Plan and the Delta Science Plan, adaptive management is visualized as a nine-step process. The figure illustrates how these steps are linked in sequence, and provides a useful framework for describing how you are thinking about, planning, or implementing adaptive management.



The following sections relate to each step of this adaptive management process. **Please briefly describe (a few sentences or short paragraph will suffice) how or whether each step is conducted or being planned in your program(s), along with any comments you'd like to share with us.** *The*

questions for each are there to help you think about the step; please feel free to address those questions or respond in any other way that suits you.

Step 1: Define the problem. Adaptive management depends on a clear understanding of the problem to be addressed through some combination of science, management, and policy. Click here to enter text.

Step 2: Establish goals, objectives, and performance measures. Goals and objectives provide specific guides or targets for adaptive management, and performance measures indicate whether actions are working well. How are performance measures identified and employed? What are some common performance measures for your projects? Click here to enter text.

Step 3: Model linkages between objectives and proposed action(s). Developing models helps define the structure and relationships of the system being managed. Models may be conceptual, analytical, simulation (of varying complexities), and involve probabilistic risks or scenarios. How are you using models, of which type(s)? How do you decide what kind of modeling is needed or justified, or how detailed it should be? Click here to enter text.

Step 4: Select actions: Research, pilot, or full-scale: Depending on the situation, the state of existing knowledge of the system, the uncertainties and risks of undertaking a planned action, its costs, and other factors, additional research (literature, modeling, field observations or experiments) may be needed before implementation, or it may be useful to conduct a pilot study. What is done in your program, and how are decisions made about what to do? What steps are taken to assemble and make accessible a knowledge base for the project or problem? How is targeted research incorporated into adaptive management? Click here to enter text.

Step 5: Design implementation action(s) with monitoring: Are details of adaptive management and monitoring in place *before* a project is started. Click here to enter text.

Step 6: Implement action(s) and monitoring. Monitoring generates lots of data. How are data managed? Are data bases linked with other data bases outside the project? Click here to enter text.

Step 7: Analyze, synthesize, and evaluate. When is analysis done after or during implementation? What kinds of project evaluation are common? Click here to enter text.

Step 8: Communicate current understanding. Communication of analysis results and synthesis of scientific data usually requires translation into readily understandable messages for managers and decision-makers. When is this done, how, and by whom? Click here to enter text.

Step 9: Respond/Adapt: How are decisions made about whether to change goals and objectives, revise or conduct more modeling, or conduct additional research or take different actions to achieve the objectives? Click here to enter text.

III. SOME SPECIFIC QUESTIONS

Here are a few additional questions that we'd like you to think about and tell us what you think, especially the last question.

1. How should one decide when adaptive management is needed or appropriate and when it is not? What criteria should be used to make this decision? Click here to enter text.

2. How have linkages among projects or actions and their effects been considered in your planning (or how should they be considered)? Click here to enter text.

3. What mechanisms exist for bringing scientists, managers, and stakeholders together throughout the adaptive management process? Click here to enter text.

4. What is the role of independent peer review, and in what phases of the process is it best applied?
   Click here to enter text.

5. How are your adaptive management science efforts funded (or how should they be funded)? What staff support is needed, with what sorts of expertise? Click here to enter text.

6. What legal, regulatory, or administrative barriers to doing effective adaptive management have (or will) you encountered? Click here to enter text.

7. Given the uncertainties that prompt adaptive management, there is a real likelihood of being wrong or mistaken. How do you deal with that possibility? Click here to enter text.

8. How are you incorporating anticipated future conditions (e.g., climate change, sea-level rise, land-use change) into adaptive management? Click here to enter text.

9. Do you have suggestions for making adaptive management work more effectively?
Click here to enter text.

10. What question(s) should we have asked but didn't (your answer would be helpful)?
Click here to enter text.

Appendix D. Agencies and Individuals Consulted for this Report

Agencies responding to the questionnaire

- California Department of Fish and Wildlife – Ecosystem Restoration Program
- California Department of Water Resources – FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO)
- Central Valley Regional Water Quality Control Board
- San Francisco Bay Regional Water Quality Control Board
- Suisun Resource Conservation District
- U.S. Bureau of Reclamation, Bay-Delta Office

Individuals interviewed personally

- Dan Castleberry, U.S. Fish & Wildlife Service
- Joshua Collins, San Francisco Estuary Institute
- Val Conner, Collaborative Adaptive Management Team
- Steve Culberson, U.S. Fish & Wildlife Service
- Ted Frink, California Department of Water Resources – FESSRO
- Les Grober, California State Water Resources Control Board
- Bruce Herbold, Environmental Protection Agency (retired)
- Campbell Ingram, Delta Conservancy
- Gail Newton, California Department of Water Resources – FESSRO
- Kim Webb, U.S. Fish & Wildlife Service
- Carl Wilcox, California Department of Fish and Wildlife
- Leo Winternitz, Collaborative Adaptive Management Team

Appendix E. Responses to Questionnaire Statements about Adaptive Management (1 = strongly disagree, 5 = strongly agree)

The statements:

1. My entity uses adaptive management as an organizing framework for its activities.
2. In my entity's experience, adaptive management efforts often require collaborations among multiple agencies and stakeholders.
3. My entity's broad management plans (e.g., resource management plans) include the flexibility necessary to engage in adaptive management.
4. Laws and other administrative and regulatory requirements often constrain our entity's efforts to engage in adaptive management.
5. Changes could be made in existing legal requirements to make adaptive management more successful.
6. We usually build a conceptual model of the management action before implementing the action.
7. Conceptual models should include both human and ecological systems.
8. We gather baseline information and/or data about the relevant system(s) before management actions are implemented.
9. Monitoring is adequately funded to support adaptive management.
10. Monitoring and assessment results are integrated into adaptive management decision-making.
11. It is important to communicate the results of adaptive management experiments to stakeholders.
12. In my entity's experience, when adaptive management experiments tell us something new, management actions are changed to reflect what is learned.

The responses:

	Respondent							
Question	Agency A	Agency B	Agency C	Agency D	Agency E	Agency F	Mean	Range
1	4	5	4	2	3	2	3.3	2 to 5
2	5	4	4	5	4	5	4.5	4 to 5
3	4	5	4	2	3	4	3.6	2 to 5
4	3	2	4	5	4	4	3.6	2 to 5
5	2	3	3	5	2	3	3	2 to 5
6	3	4	4	2	4	2	3.2	2 to 4
7	5	5	4	5	5	5	4.8	4 to 5
8	5	4	4	3	3	4	3.8	3 to 5
9	2	2	2	3	2	1	2	1 to 3
10	3	4	3	3	3	3	3.2	3 to 4
11	5	5	4	5	5	5	4.8	4 to 5
12	3	4	3	4	3	4	3.5	3 to 4