The Science Enterprise Workshop: Supporting and Implementing Collaborative Science

Executive Summary
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Co-hosted by U.S. Geological Survey and the Delta Stewardship Council

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Preface

The 2016 Science Enterprise Workshop brought together over 200 scientists, policy makers, and managers for three intensive days of discussion on management, communication, and funding of applied science in support of decision-making. The workshop was conducted at a critical time for the Delta, as many of the management agencies have made marked efforts to shift toward increased program coordination and increased stakeholder integration into science. The workshop was intended to provide responses to a persistent line of questioning from those working within the California Bay-Delta system: How can we make science more useable and on-point for management decisions, rather than just useful? How can we better fund and support critical science investigations? How can we be better organized and efficient, and what governance structures works best to inform decision-making? And importantly for policymakers, how do we draw more attention to the California Bay-Delta and create better recognition of the estuary's importance?

The workshop was designed to bring in experts working around the country in large and complex ecosystems to provide relevant examples of how their own systems addressed these "wicked problems", and what tools and resources were critical to success. What we found was that the California Bay-Delta is not unique in most ways: programs for other major ecosystems face similar challenges across a wide variety of issues. The dialogue at the workshop reflected the richness of these experiences and wealth of practical approaches, both effective and less-effective, that have been tried in various regions.

The top-line message from the workshop was clear: coordinating disparate science activities that address complex regional resource issues is inherently difficult, but careful attention to issues and practices can improve the ability of science enterprises to support and inform decision-making. A year and a half later, we are finding that the recommendations and core concepts presented at the workshop remain fresh and relevant to ongoing discussions around how the California Bay-Delta science enterprise can be improved.

The basic recommendations included here were reported out shortly after the workshop to the Delta Plan Interagency Implementation Committee (DPIIC). Originally, these recommendations were derived through discussion at the workshop, via a post-workshop meeting of scientists and policymakers, through efforts of the Delta Stewardship Council and Science Program staff and colleagues at the U.S. Geological Survey (USGS), and via review and discussion among the workshop organizing committee. There is more detail here based on a more careful review of the workshop proceedings report, and feedback in the months after the workshop.

No distillation of the workshop can capture the full breadth of the discussions that occurred, nor did we strive for consensus at the workshop. Dialogue in the regional and expert panel sessions at the

workshop extended well beyond the topics we originally defined in the program. It should be recognized that there is likely disagreement as to what is most important, and that important ideas that are not mentioned here may lie dormant in the advance briefing paper and workshop proceeding report until they are brought forth in the future. This summary, however, does reflect considerable input from many parties and hopefully captures the major "lessons learned."

One of the greatest successes from the workshop, in our minds, is that the community of scientists, managers, and policy makers alike have been engaged since the workshop in serious discussions about what it means to build and work across organizational lines to coordinate a science community serving all parties in the California Bay-Delta. Where possible, we have attempted to capture examples of where real progress is being made on the recommendations listed in this report. Although not exhaustive, we see these examples as evidence of progress and a positive indicator of continuing momentum. While this workshop was not the first, and likely will not be the last of its kind, we are encouraged that the experience has substantially enhanced prospects for increased collaboration.

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Introduction

The Science Enterprise Workshop, held November 1- 2, 2016, in Davis, California, brought together scientists and science-policy experts from across the country to share information about how collaborative science is funded, managed, and communicated in several high-profile and complex ecosystems – the California Bay-Delta, Chesapeake Bay, Coastal Louisiana, Great Lakes, Greater Everglades Ecosystem, and Puget Sound. At the workshop, participants had the opportunity to hear from a wide range of experts highlighting how different regions have developed science management mechanisms to support managers who are working on improving the long-term health and viability of some of the nation's high-profile ecosystems.

This workshop offered an opportunity to learn from other systems, all of which have particular strengths and weaknesses that can provide insight for the California Bay-Delta. It was designed as a comparative review to identify important lessons from other systems, helping managers and policymakers to:

- Avoid mistakes or "reinventing the wheel" in efforts to better coordinate and integrate science, including approaches to deal with social, biological, chemical, and physical aspects of complexity;
- Better understand governance and management systems that have been set up in other large, complex ecosystems facing multiple stresses and diverse stakeholder interests to jointly conduct science and manage resources;
- Identify practical means by which science programs allocate financial and intellectual resources and ensure the relevance of ongoing lines of research and monitoring;
- Hear expert's perspectives on what makes science "legitimate" to stakeholders and the public, and on the limitations of traditional approaches to applied science; and
- Enhance networking among programs and experts, and contribute to the body of knowledge on natural resource management of major regional systems.

Science Enterprise is not interchangeable with "science program." Instead, it refers to the collection of science programs and activities that exist to serve managers and stakeholders in a regional system. The elements of an enterprise range from in-house programs within single agencies or other organizations to large-scale collaborative science programs funded by governments, to academic research that may operate independently of management and stakeholder entities. Science enterprises can vary greatly in the degree to which resources are concentrated in collaborative programs and produce publicly-available results. The differences among regional systems can reflect historical factors, depth and persistence of conflict regarding resource issues, governmental guidance and engagement, the range of agencies and interests involved, and other factors.

There were several key concepts that were discussed throughout the Workshop, including:

- **Useful versus Useable Science**: This key concept draws the distinction between the perceptions of scientists who conduct research to answer questions important to resource managers and the perceptions of managers. While all useable science is useful, the converse is not true. Useable science "directly reflects expressed constituent needs, should be understandable to users, should be available at the times and places it is needed, and should be accessible through the media available to the user community"[1].
- **Cooperation, Coordination, Collaboration**: This key concept draws the distinction between three terms that are often used interchangeably, but with recognizable differences, in order of increasing joint commitment:
    - Cooperation –involves sharing information and sometimes resources while each party pursues its own goals;
    - Coordination –involves sharing information and resources, with the parties pursuing a common interest or objective. The interest or objective, however, is defined independently by each party; and
    - Collaboration –involves sharing information and resources and modifying activities based on a common interest or objective that they jointly define.
- **Co-production:** This key concept – while more commonly used in other systems but not the California Bay-Delta – denotes the participation of managers or stakeholders in the design, execution, and interpretation of scientific studies. The term has come into use as the practice of integrating science consumers into the process of science production. Co-production may be implemented as a transparency measure or as a form of actual collaboration (see above).
- **Relevance, credibility, and legitimacy:** This key concept is often used when describing three features commonly thought to be essential for science to play a role in policy and management decisions[2]. Credibility (technical trustworthiness) and relevance (close alignment of research to management information needs) are straightforward. Legitimacy is the belief that the scientific process is being applied impartially and without partisan bias or prejudice. Legitimacy can be the most difficult, and important, of the three factors to foster in situations where science is being used to inform contentious resource management decisions. An effective science-policy interface generally acts to increase legitimacy[3].

[1] (Lemos, MC and BJ Morehouse, "The co-production of science and policy in integrated climate assessments", Global Env Change 15 (2005), 57-68).

[2] (Sarkki, S. et al. "Balancing credibility, relevance and legitimacy: A critical assessment of trade-offs in science-policy interfaces" Science and Public Policy 41(2) 2014, pp. 194-206; Heink, U. et al. "Conceptualizing credibility, relevance and legitimacy for evaluating the effectiveness of science-policy interfaces: Challenges and opportunities" Science and Public Policy 42(5) 2015, pp. 676-689)

[3] (Posner SM, E McKenzie, and TH Ricketts "Policy impacts of ecosystem services knowledge", Proceedings of the Nat'l Acad. of Sciences 113(7) 2016, pp. 1760-1765)

The Workshop program started with a comparison of the systems, where experts from each region presented an overview and history of regional program development; major resource management issues; current science enterprise structure; funding for science; important tools for implementing science; and communications and co-production. A common framework for discussion allowed for more direct comparisons across systems.

The Workshop program also featured comparative discussions on common challenges and opportunities that often arise in the management of science enterprises. Regional experts were joined by social scientists, legal experts, and economists on panel presentations to discuss decision-making and key topics related to: science strategies in large multi-agency or multi-entity programs; governance and adaptive management; funding and resource allocation; and legitimacy, co-production, and communication. There was also considerable discussion around some key concepts and distinctions, such as between "useable" and "useful" science; the different but related concepts of coordination, collaboration, and coproduction as means of cooperating in science; and the essential roles of credibility, relevance, and legitimacy in creating science that is valued by managers.

The Workshop was documented in multiple ways. First, an advance briefing paper was prepared in consultation with the regional representatives who spoke about their systems. Second, a detailed workshop proceedings report was compiled after the event to document the presentations, panels, and audience questions. A video record was also prepared. All of these documents are available online at http://deltacouncil.ca.gov/sci-enterprise or https://mavensnotebook.com/science-enterprise-workshop/. We encourage interested parties to read the Workshop proceedings report in full, it contains a wealth of commentary on the experiences of specific regional systems, beyond what we can present here.

Workshop Outcomes

On November 14, 2016, DPIIC met to discuss the results from the Workshop, held only 10 days prior, and still fresh in everyone's mind. A wealth of information had been exchanged at the Workshop, where participants engaged in thoughtful discussion of how to address some of the most challenging aspects of ecosystem science and management here in the California Bay-Delta, as well as in other systems across the country. We identified common themes throughout the presentations and panel discussions that were relevant across all of the systems, not just the California Bay-Delta. We presented a set of **general recommendations** that effective science enterprises require:

- Clear communication on the importance of scientific findings
- Clear leadership and decision-making structure with responsibility at the highest level
- Integrated modeling and forecasting to support decision-making
- Integration of social sciences with natural sciences and engineering
- Independent review processes to ensure credible, legitimate, and relevant science
- Competitive funding mechanisms to attract the best and the brightest
- Willingness to do adaptive management

In addition, we presented a set of **specific recommendations** for the California Bay-Delta science enterprise to improve the science enterprise within our region, that is, to further:

- Analyze the implications of ongoing sea-level rise and climate change; and
- Improve connections of science and management across San Francisco Bay, the Delta, and the upper watershed.

The DPIIC members, which include representatives from seventeen State and federal agencies that work in the California Bay-Delta, discussed the set of recommendations and endorsed them as guiding principles.

General Recommendations

What follows is a discussion of the general recommendations that effective science enterprises seek to establish. We have divided the general recommendations into three main categories: 1) Effective leadership; 2) Efficient use of available funds; and 3) Scientific credibility, legitimacy, and value to decision-makers. These recommendations were drawn from both the comparative presentations of the systems and from the topical panel discussions. We have summarized the recommendations and organized them under main headings to provide additional context and guidance.

1) Effective Leadership

Fostering of clear and effective leadership and leadership relationships was the strongest of the recommendations from the workshop. Each of the regional systems had distinct and different governance structures and management protocols, but everyone who addressed leadership agreed on the need for active leadership and well-defined decision-making systems. For example, the Florida Everglades program has a governance structure that clearly defines roles for a federally-led Task Force, state agencies, Tribes, and local governments and stakeholders. Many participants spoke about the importance of incorporating stakeholder participation in decision-making, and using social science to create depth and breadth of understanding where engineering and natural sciences stop. A key lesson learned was that different entities with different roles and interests have differing perceptions of and tolerance for risk, so the ability to communicate across organizational boundaries about scientific uncertainty and risk was identified as important skill of effective leaders.

Recommendation: Ensure clearly defined leadership and decision-making structures with active engagement at the highest level.

Clear science leadership and management leadership are both critical to success. Overall performance is usually higher in programs with leadership that engages at all levels of government and works effectively with relevant budget and legislative cycles. In addition to leadership, a clear organizational structure that identifies roles and responsibilities of decision makers, managers, scientists, and stakeholders is needed. It is essential that this structure provides mechanisms for a policy-neutral role for science. The structure also should embrace meaningful stakeholder engagement, as this will help assure relevance and increase the legitimacy of the scientific information developed locally for use in resource management decisions.

Recommendation: Adopt real adaptive management.

Adaptive Management (AM) is widely embraced in formal management plans and is a critical process for linking scientific insights to management decisions. However, authentic adaptive management is infrequently implemented and often fails when, as is often the case, decision stakes are high. A usual cause is unwillingness or inability of agencies and stakeholders to agree to implement changes to existing resource management policies. The economic implications of such decisions can be high, underscoring the importance that scientific information developed within AM programs to support resource decisions have the credibility and legitimacy to be widely accepted as dispositive.

The concept of uncertainty plays a key role in adaptive management. Scientists need to understand how uncertainty is understood by managers and be able to communicate scientific uncertainty in understandable and useable ways. So too, decision-makers must be able to understand and apply statements of scientific uncertainty in the context of management or policy. A good deal depends on the fostering of effective communication among scientists and managers. Leadership and entrepreneurial spirit are widely regarded as critical qualities in science managers who support successful AM efforts. Scientists' familiarity with agency and stakeholder cultures, interests, and individual personalities are also helpful to ensuring that science provides effective, trustworthy support in adaptively managed projects.

> Panelist Richard Roos-Collins noted that "the only constant in life is change" – and he pointed to how Dr. Garrett Hardin deals with uncertainty in his work on the Tragedy of the Commons. Those who propose change, will face skeptics and opponents who talk about the risk of change – and what the skeptics and opponents do not do is acknowledge the risks and consequences of doing nothing. Dr. Hardin says, "But we can never do nothing. That which we have done for thousands of years is also action. It also produces evils. Once we are aware that the status quo is action, we can then compare its discoverable advantages and disadvantages with the predicted advantages and disadvantages of the proposed reform, discounting as best we can for our lack of experience."

Recommendation: Integrate social science with natural science and engineering to understand the full scope of management issues.

The historical focus on the natural sciences in regional resource management has obscured the fact that resource management is fundamentally a human enterprise, with human dimensions always present. It is critical to understand social factors affecting management and the conduct of science itself – critical where management addresses both environmental and resource management goals (which is nearly everywhere). For example, economic insights into resource management will help with identification of science and management priorities. Multiple panelists opined that resource management science efforts benefit from incorporating social science perspectives. Social scientists study people, their institutions, their politics, their economics, and the approaches they use to make decisions. These are important factors to understand and should be a component of science enterprises that exist to inform resource management.

2) Efficient Use of Available Funds

While different systems face varying challenges in terms of available funds for science, in all cases funds must be used efficiently and effectively to maximize the value of scientific information that informs decision making. This requires identifying critical scientific uncertainties that relate to decision making and linking these uncertainties to focused scientific efforts, from monitoring to research and synthesis. Whether those decisions are driven by regulation, litigation, or master planning, efficient and effective use of resources will enhance public confidence and support for science. For example, experts from Coastal Louisiana had several examples of how to ensure efficient use of funding. Following the Deepwater Horizon catastrophe, federal legislation created the Gulf Coast Ecosystem Restoration Council[4] to oversee restoration, monitoring and research in areas affected by the spill. To ensure that science investments were aligned with the best researchers and facilities available and that funds were spent efficiently, GCERC developed Centers of Excellence to administer competitive grant programs for research and monitoring. In addition, they identified land-loss as one of the most compelling (and vexing) management issues only after soliciting broad input in development of a master plan for the region. Through the use of integrated modeling they were able to develop tools that inform priorities for decision-making on infrastructure projects to protect and replenish the shoreline.

Recommendation: Use competitive funding mechanisms to attract the brightest and best.

Regional science enterprises benefit from the work of local agency, academic, and stakeholder scientists. All of the regional science enterprises discussed at the workshop have communities that include dozens to hundreds of experienced scientists and engineers engaged in studies and ongoing monitoring. However, as some of the workshop panel participants highlighted, “sometimes the scientists you need are not the ones that you have.” Competitive funding mechanisms that attract exceptionally capable scientists from inside and outside the region, and even outside the nation, are invaluable for filling holes in local expertise and to ensure that the best available scientists can be put to work on the most pressing problems. Competition helps keep local programs vital, and helps minimize an “endowment” mentality among scientists affiliated with local agencies and institutions. As experience in multiple regional systems shows, with careful attention to detail competitive mechanisms can be effectively tailored to include criteria that ensure good fit of non-agency scientists to projects serving management needs. They can also be tailored to expand the role of academics, NGOs, consultants, and others that may make important contributions to the body of scientific knowledge of a region.

Recommendation: Increase the use of integrated modeling and forecasting to support decision-making.

The development of transparent, credible models linking physical and biological dynamics is important to assuring informed decision making. Models help to synthesize the information that is gathered, identify data gaps, deduce causal relationships and interactions among physical, chemical, and biological variables in an ecosystem, and predict system responses to adaptive management actions. Workshop

[4] GCERC, https://www.restorethegulf.gov/

participants argued that forecasting is one of the most valuable approaches to management-support science. Done carefully, forecasting approaches provide predictions of future states and organized information about the uncertainty of the predictions and possible alternative outcomes. The forecasting approach also enforces a focus on future events, which is almost always more valued by managers and stakeholders than the pursuit of increasingly precise explanations of the past. In addition, the use of open-source software and application of data standards in collection, management, and the public release of the data are important components of transparency, credibility, usefulness, and longevity of integrated modeling.

3) Science Credibility, Legitimacy, and Value to Decision-makers

Scientific information will only have value for decision makers if it is relevant, credible, and legitimate. While relevancy is more straightforward to address given general agreement on critical issues, addressing credibility and legitimacy can be challenging given the broad range of perspectives and the historical lack of trust amongst some players involved in science and policy issues. For example, the South Florida Ecosystem Restoration Task Force coordinates stakeholder participation in a variety of venues, like the Water Resources Advisory Commission. The South Florida Ecosystem Restoration Working Group meets every three months to discuss science programming and coordination jointly among agencies and stakeholders. The integration of agency managers and stakeholders in these groups ensures that agencies hear and respond to stakeholder perspectives, and allows stakeholders to participate in the framing and prioritization of science that may affect their interests. The importance of this sort of stakeholder engagement as a tool to foster legitimacy and social capital cannot be overstated.

Recommendation: Improve communication and discussion of scientific findings.

Participants recommended that strong efforts be made to improve communication, and commented on a variety of communication issues. Clear communication helps assure stakeholder and public engagement and understanding and is crucial to effective application of science to decision making. It is an essential part of making science useable or actionable as opposed to merely useful or interesting. Science is communicated not just in peer-reviewed articles but via dialogue in multiple channels and fora. While peer-reviewed scientific publications are critical products that form the foundation of scientific knowledge, participants emphasized that managers usually prefer derivative presentations that link key findings to management issues and decisions. A broadly functioning science-policy interface consisting of people and organizations that serve as science- and management-fluent and policy-neutral conduits between scientists and managers is essential. Reliable intermediaries – either impartial scientists with good communication skills, or trustworthy policy-makers with a penchant for science – can be critical to communicating findings and informing decisions. For example, understanding how scientists and managers differently use “uncertainty” and being able to effectively discuss scientific uncertainty with both groups is critical. Besides good communications among managers, stakeholders, and scientists, participants recommended supplementary communications strategies reaching out to other interested audiences through public awareness campaigns, school-aged education, direct public outreach, and the like.

Recommendation: Independent review processes help make research more credible, relevant, legitimate, and efficient.

In controversial resource management environments, rigorous fundamental scientific practices can be extremely valuable as a safeguard of stakeholder and public confidence. Independent review, in which carefully vetted external experts provide trusted and policy neutral advice on the quality of scientific work and on its interpretation, is a cornerstone of modern science. While independent review is not a panacea, it is a useful quality control measure that increases the legitimacy and credibility of new findings. It takes many forms, from independent advisory bodies, purpose-created review panels, to "over-the-shoulder" and ordinary publication review processes. Panel experts at the workshop encouraged the use of review processes that also address the value and efficiency of science activities rather than merely technical merit. Rigorous audits or other third-party review of programs to transparently evaluate whether they efficiently serve the purposes for which they are intended can be very valuable to managers and governing bodies. Long-term monitoring programs are especially important subjects for value and efficiency review because of their expense, indefinite commitment, and the tendency of local constituencies to resist even well-motivated proposals for change. The Florida Everglades program was pointed out as a good example of a major program that is regularly reviewed – in this case by a dedicated National Academy of Sciences panel.

Lessons Learned and Progress in the Bay-Delta

Workshop experts and participants made two key recommendations specific to the California Bay-Delta. There recommendations are reflective and inclusive of the broader set of recommendations for systems, but highlight two areas where we can make progress overall. They were as follows:

Recommendation: Do not neglect the implications of climate change, including sea-level rise.

State and federal management agencies are obligated by law or policy to consider the effects of climate change in project planning. Participants in the workshop noted that climate change has more fraught implications in the Bay-Delta compared to some other systems. California has unusually variable hydrology, and the current long-term projections of higher temperatures, higher sea level, and more precipitation falling in severe storms implicate not only water management, but also natural hazards management and restoration planning. It was suggested that Bay-Delta scientists give especially careful consideration to the potential effects of climate change in analyses intended to inform planning for the future.

Recommendation: Improve connection of science and management across San Francisco Bay, the Delta, and the upper watershed.

Several workshop participants commented on the apparent segregation of San Francisco Bay from the Delta in management and science fora. Differences in leading management issues is a major driver of the division: water quality management is of great importance in the Bay, while water supply and diversion policies are a great challenge in Delta management. Participants recommended that practical steps be taken to increase voluntary cooperation and coordination between Bay and Delta science

communities, to help foster more efficient environmental monitoring regimes and better informed science priorities.

At the November 2016 DPIIC meeting we identified several possible next steps to advance both the general and specific recommendations in the California Bay-Delta system. These included getting started on some key "early" initiatives, including:

- To develop a proposal for improved integrated modeling focused on forecasting and management decisions (e.g., climate change, sea-level rise, and ecohydrology);
- To develop a joint funding strategy including a new competitive research grants program to attract the best and the brightest and to better integrate social sciences with natural sciences and engineering;
- To develop near-term actions to improve science management and communications across the Bay, Delta, and watershed.

In addition, we identified the need to complete the reporting of the workshop (by issuing this report), and further define a suite of recommended actions and best practices for improvements to Bay-Delta science, management, funding, and communication, including but not limited to:

- Development of a communication and public education plan for California Bay-Delta science, including identifying "champions" that can help support these initiatives.
- Formal review of science governance and management structure; to recommend improvements to better identify leadership, formalize organizational structure, and improve decision-making ability (through a 3rd party audit).
- Development of additional proposals for how to better integrate social sciences with natural sciences and engineering; and additional tools needed to understand and communicate risks from climate change and sea-level rise.

Overall, we recommended that the DPIIC work cooperatively to implement these recommendations and other voluntary actions aimed at achieving the vision of achieving One Delta, One Science. We recommended that we continue to use DPIIC workgroups to track progress on current initiatives, and advise on where lessons learned and best practices can enhance recent and ongoing efforts, such as the 2017-2021 Science Action Agenda, adaptive management frameworks for water supply and ecosystem restoration, Delta Independent Science Board review of the Monitoring Enterprise, and implementation of AB 1755 for data management.

Over the past year and half, the Delta Stewardship Council has made considerable progress on implementing these recommended actions. For example, we have issued a request for qualifications for preparation of a Climate Change Vulnerability Assessment and Adaptation Strategy for the Sacramento-San Joaquin Delta and Suisun Marsh. This work will provide critical support to the Council in improving the understanding of projected climate change risks and potential adaptation strategies, as well as a robust process to incorporate stakeholder input and advice from a technical advisory committee, and a public awareness communication plan. This effort will incorporate lessons learned from the San Francisco Bay Conservation and Development Commission (BCDC) Adapting to Rising Tides (ART) program.

We have also made considerable progress on implementing an approach to improving integrated modeling. The Delta Science Program formed an integrated modeling steering committee, with members from state, federal and private sectors. Many of the participants have been meeting informally for years to discuss improvements and practice standards – but now are organized with a formal committee charge. In addition the DSP has issued a request for proposals that will further support the effort with private sector efforts. The progress from this group continues to be reported out at semiannual DPIIC meetings.

There is a longer list of ongoing efforts by many parties that have been inspired by or drawn from the workshop. At the risk of underselling the lasting influence of this dialogue, we will simply say that progress is being made on many fronts. We hope to continue the conversation about how the science enterprise spanning the California Bay-Delta can continue to evolve.