Cooperative Ecological Investigations in the San Francisco Estuary: Science for a Changing State

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California is a state of change. Ongoing changes include its exceptional climatic and hydrological variability and the phenomenal growth of its human population since it became a state in 1850, from less than one million people to thirty-eight million today and fifty million projected by 2050. To sustain this growth, California has been and continues to be "terraformed" into a novel landscape. This rapid, transformational change can be viewed as a grand experiment with uncertain outcomes. But this experiment was not conceived in a scientific way; for much of California's statehood the relative likelihood of different potential outcomes was seldom evaluated before transformational actions took place, and actual outcomes were rarely tracked systematically and comprehensively. Science began to play a larger role when unintended and undesirable outcomes became more clearly visible. Individual government agencies started employing scientists to evaluate changes of interest to their agency's mission and how to best manage them. But it still took several decades before the realization took hold that these changes could neither be controlled nor understood one at a time. In the San Francisco Estuary (Bay-Delta), this realization eventually led to the long-term scientific cooperation of originally four and now nine State and Federal agencies in the Interagency Ecological Program (IEP). The IEP has been conducting cooperative ecological investigations in the Bay-Delta since 1970 and has provided consistent and comprehensive long-term data and information about changes in fish, flows, habitats, and many other important management targets and indicators of change. Perhaps even more importantly, the IEP has functioned as a stimulating, unbureaucratic "science space" for scientists from different agencies, universities and elsewhere to connect, exchange ideas, and work together to address scientific questions relevant to their own and other agencies and institutions. This interdisciplinary science collaboration that started with the IEP has since been expanded with the help of the Delta Science Program and others. Because of these efforts, we now know a lot not just about how the Bay-Delta has changed, but also about why it changed and how it might change in the future – more than ever before, we understand many of the complex connections between our actions, other drivers, and ecological outcomes. We also have a highly connected, vibrant science community adept at converting scientific data into usable knowledge. The challenge now is to better support and connect scientists with managers and policymakers so we can turn what started as an inadvertent grand terraforming experiment into a sustainable, adaptive management scheme for a changing state and world.

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Six things the Delta Science Community has learned in the past two years

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During the Town Hall meeting held during the 2012 Delta Science Conference, Directors of Agencies and leading scientists explored the challenges of integrating science and policy in several key areas. Some of the challenges expressed included how collaborative science could be achieved when one forum attempts to foster open collaborative science and another program is embroiled in litigation with many of the participants common to both activities. The complexity of the Bay-Delta was also discussed and the critical need to quantify uncertainty, the sensitivity of scientific projections to assumptions, and a continuing commitment to understanding the risks associated with management actions. The importance of viewing the Bay-Delta as a system where decisions made in one part of the state influence other regions were also used as examples to highlight the complexity of the system and the linkages that must be understood. During the past two years these issues have been addressed in multiple venues including several that are featured in the Delta Science Conference 2014, including the Collaborative Adaptive Management Team, the Inter-Agency Ecological Program and the preparation of the Delta Science Plan. The latter was completed in December 2013 and considered more than 1,000 comments received from over 100 organizations.

This presentation highlights some of the lessons learned during the past two years of collaborative science. The presentation will consider processes, emerging technologies, some examples of new discoveries as well as continuing critical barriers to knowledge discovery.

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Making Science Actionable

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Many of the world's large estuarine ecosystems are severely stressed due to population growth, water quality and quantity problems, vulnerability to flood and drought, and the loss of native species and cultural resources. Consequences of climate change and accelerated sea level rise further increase uncertainties about the future. The availability of information and improved communication of scientific and engineering issues is raising the level of dialogue at the science-policy interface. However, severe challenges persist since scientific discovery does not occur on the same timeframe as management actions, policy decisions or at the pace sometimes expected by elected officials. Common challenges include the need to make decisions in the face of considerable uncertainty, ensuring research results are actionable and preventing science being used by special interests to delay or obsfucate decisions.

The major societal challenges facing the California Bay-Delta system require innovations in governance, policy, and ways of implementing management strategies. Transformative change is very difficult to achieve with history in other systems showing that these transformations are difficult to achieve, with benefits only being widely recognized years or decades into the future. The innovators are sometimes heavily criticized and attacked professionally at the time of change.

Understanding the magnitude of water challenges facing California and the Bay-Delta system, the California State Legislature passed the landmark legislation in 2009 (CA Water Code SS 85054) that established "*Coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem*". The legislation also stated that "*The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place*." Further, the State of California and Federal Agencies have stated that management decisions should be based on the best-available science. This presentation describes the challenges of integrating policy, management and scientific research and progress and the importance of supporting public servants tasked with major management decisions as well as supporting the science that inform these difficult decisions.

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Habitat Quality: A Fish's Perspective

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One of the fundamental challenges in ecology is to predict species distributions in an environment and to evaluate the consequences of that distribution to survival, reproductive success and overall production. Understanding habitat quality is at the very core of our ability to predict a species' persistence in an ecosystem. How do we define the habitat quality that an ecosystem affords a particular species? Is there a way to look at a habitat and quantitatively evaluate and, indeed, map the habitat quality and quantity for a given species? Moreover, how well can a species exploit that prevailing habitat?

Habitat quality must be defined from the perspective of an individual species or life stage of a species since the physiological and behavioral requirements differ across species. Habitat quality must also be a function of both abiotic and biotic factors that prevail in a particular ecosystem. But, how do we weigh biological and abiotic characteristics of the environment in a meaningful way from the fish's perspective? Fish Growth Rate Potential (GRP) is used as an example of a quantitative, species-specific measure of fish habitat quality. GRP is the expected growth rate of a fish of given size if placed in a specified volume of water with known physical and biological conditions. This bioenergetics metric is not only a robust and integrative measure but it is also a nonlinear response to the combined physical and biological habitat. Illustrative examples will be drawn from hypoxic areas in the Chesapeake Bay, Northern Gulf of Mexico and the Great Lakes.

A new concept is introduced as a measure of the ability of the fish to use the habitat quality it is afforded. The purposeful separation of habitat quality potential and habitat use provides an innovative way to address habitat issues and might provide new insights and lines of research for the Bay Delta.

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