ADAPTIVE MANAGEMENT/CONCEPTUAL MODELING

Restoring and managing the Bay-Delta ecosystem requires a flexible management framework that can generate, incorporate, and respond to new information and changing Bay-Delta conditions. Adaptive management provides such flexibility and opportunities for enhancing our understanding of the ecosystem. Within an adaptive management framework, natural systems are managed in such a way as to ensure their recovery and improvement while simultaneously increasing our understanding of how they function. In this manner, future management actions can be revised or refined in light of the lessons learned from previous restoration and management actions.

The key to successful adaptive management is learning from all restoration and management actions. Learning allows resource managers and the public to evaluate and update the problems, objectives, and models used to direct restoration actions. Subsequent restoration actions can then be revised or redesigned to be more effective or instructive. In an adaptive management process, learning must be continuous so that ecological restoration continuously evolves as the ecosystem responds to management actions and to unforeseen events, and as management actions are revised in light of new information.

To facilitate learning, adaptive management emphasizes the use of the scientific method to maximize the information value of restoration and management actions. Resource managers explicitly state hypotheses about ecosystem structure and function based upon the best available information, and then they design restoration actions to test these hypotheses. In this respect, adaptive management treats all management interventions as experiments.

In adaptive management, treating interventions as experiments includes:

- making management decisions based on the best available analyses and modeling of the system;
- being clear about what management intervention is expected to achieve in terms of restoring ecological structure and function and the implications for species conservation;
- designing management intervention to help distinguish among alternative hypotheses about ecosystem behavior, where practical and compatible with the long-term goals of the program;
- monitoring the effects of management intervention and communicating the results widely so that progress relative to expectations can be evaluated, adjustments made, and learning achieved.

Furthermore, integrating individual projects into the evolving adaptive management program involves: 1) having clear goals and objectives for management that take into account constraints and opportunities inherent in the system to be managed; 2) using models to explore the consequences of a range of management policy and program options in relation to contrasting hypotheses about system behavior and uncertainty; and 3) identifying implementable findings that sustain or improve the production of desired ecosystem services while, at the same time, generating new kinds of information about ecosystem function.

The first step of an adaptive management process requires clearly defining a problem or set of problems affecting ecosystem health. Defining a problem usually requires determining the geographic bounds of the problem; the ecological processes, habitats, species, or interactions affected by the problem; and the time that the problem affects the ecosystem.

Many resource managers, scientists, and stakeholders interested in the restoration and management of the Bay-Delta ecosystem have implicit beliefs about how the ecosystem functions, how it has been altered or degraded, and how various actions might improve conditions in the system. That is, they have simplified mental illustrations about the most critical cause-and-effect pathways. Conceptual modeling is the process of articulating these implicit models to make them explicit.

Conceptual models can provide several benefits. The knowledge and hypotheses about ecosystem structure and function summarized in conceptual models can lead directly to potential restoration actions. They can highlight key uncertainties where research or adaptive probing might be necessary. Alternative, competing conceptual models can illustrate areas of uncertainty, paving the way for suitably-scaled experimental manipulations designed to both restore the system (according to more widely accepted models) and explore it (to test the models). Conceptual models can also help to define monitoring needs, and they can also provide a basis for quantitative modeling.

There is no recipe for developing conceptual models, nor is there a template for what they should look like. There is no unique set of conceptual models that provides a basis for ecosystem restoration and that can be determined deductively. Conceptual models should be designed for a particular purpose and should contain only those elements relevant to solving a particular problem, including alternative explanations that might yield alternative solutions.

As a feature of a submitted proposal, the applicant should present a conceptual model that describes the causal interconnections among key ecosystem components. The model can be presented graphically or as a narrative, and should demonstrate how physical and biotic system components respond to anticipated stressors or limiting factors. The model should indicate the pathways by which the system accommodates natural disturbances and how the system exhibits resilience to disturbance by illustrating the adaptable bounds of variation.

There are circumstances under which only large scale experiments can resolve system uncertainties. In such circumstances, simulation modeling would be necessary to allow explicit exploration of the main pathways of causal interaction and feedback processes, as well as to provide preliminary predictions of the consequences of different management actions.

Simulation modeling could indicate that pilot experiments are unlikely to provide useful information for designing or implementing large scale manipulations or indicate that only a delta-wide experiment is possible. For example, only a large scale flow experiment will reveal whether a certain species can be recovered by changing flow conditions. At least some modeling would be a necessary prerequisite to undertaking a such large scale experiment. Such experiments will usually be costly and would require a rather convincing argument about their potential value before being launched. Correspondingly, the amount of pre-program modeling should be proportional to the size and scope of the proposed management action.

Proposals that elucidate limiting/controlling environmental factors will be favored in the review process. Proponents should explicitly link the proposed action or study to key native populations, species, or communities. Proponents should identify those biotic attributes that are of particular interest, explain why they are important, and why they are expected to be limiting in the context of the proposed work. Even if the proposed work focuses on physical or chemical components of the ecosystem, relations between those components and valued biotic components must be clarified, and the importance of understanding those relations should be articulated.

The success of restoration efforts is ultimately tied to population and community responses of the native biota. The appropriateness of any given management action can be assessed on the basis of how favorably the biota respond. However, many different factors may control responses under different environmental conditions, and those factors most limiting to the distribution and abundance populations and communities are usually unknown. Effective ecosystem restoration requires a clear understanding of how ecological processes (and their interactions) constrain populations and communities, including knowledge of when and where particular factors are (or are not) limiting. This knowledge can come from empirical relations, simulation models, or selected experiments. Focused research could include studies of the basic life histories of species, spatial and temporal dynamics of communities, or other aspects that help understand limits to distribution and abundance of biota.

Although the proposal does not require that the research agenda be framed as falsifiable null hypotheses, the applicant should clearly indicate how data gathered will produce results that differentiate among alternative explanations for ecosystem phenomena observed. An explicit experimental framework should be presented that unambiguously articulates research goals and application of results.