Comments for the Delta Science ISB regarding Stressors

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Quantitative Models, Data and Professional Judgment

Quantitative models are needed to

- quantify the effects of various stressors on the Delta ecosystem and water supply,
- predict the effects of management actions on the ecosystem and water supply, and
- provide estimates of uncertainty about both of the above.

Many of the parameters of these models would be based on data collected in the Delta. These data would include (1) water variables (e.g., historical flows by time and location, salinity, clarity, quality), (2) aquatic life variables (e.g., fish, zooplankton, phytoplankton, vegetation, and benthic invertebrates data collected throughout the year over as many years as are available and reliable), (3) undesired invasive plant and animal species, and (4) contaminants and pollutants (which may be measured on soils in the Delta as well as upstream). Professional judgment and expert opinion are indeed essential and valuable, especially for factors deemed important but data-poor.

Features of the Quantitative Models

The scope and scale of the models could vary depending on the questions being asked. It is necessary to think big and longterm—what will the natural resources of the Delta, biota and water, and the urban, suburban and rural development and needs look like 20 years from now? 50 years from now? How will human population growth, diminishing non-renewable energy supplies (e.g., oil and natural gas), changes in ocean conditions, and changes in climate affect the Delta and the people of California? What would we like the Delta to look like and what can we do now to increase the chances of achieving our aims? At least one relatively large, in spatial and temporal scope, quantitative model is needed for these kinds of predictions.

Whatever the scope and scale of these quantitative models, certain features are essential.

1. Model outputs:
   (a) Include variables related to features of the Delta ecosystem and water supply that are important to stakeholders. These include forecasts of water supply at particular times of the year, water quality, fish abundances by time and area, and biodiversity measures. Note that this implies a spatial structure to the models.
   (b) Include measures of uncertainty or prediction error. That uncertainty is a function of natural environmental variation, sampling variation in the data, statistical error in model parameter estimates, and differences between the underlying structure of the model and the underlying structure of reality.
   (c) Are related, directly or indirectly, to variables that can be measured, or estimated, by statistically sound sampling and monitoring programs, so that predicted progress toward goals can be compared to observed progress.
2. Model processes and parameters:
   (a) Are, to the degree possible, estimated in a statistically sound way from historical data, e.g., fish survey and other forms of aquatic life survey data, water measurements (flow, temperature, salinity, clarity), pollutants and contaminants.

(b) Will have, as is feasible, mechanistic underpinnings that reflect current biological and hydrological science. Water dynamics need to be integrated with biology dynamics. For example, if the Delta Cross Channel (DCC) gates are opened at time t for duration δ when the Sacramento River flow at Freeport is F cfs, the probability of fish movement from region A to region B is $m_{A \to B,t}$ and the survival probability in region A is $S_{A,t}$.

3. Model inputs: Include management actions, directly or indirectly. For example, opening of DCC gates is an action that is translated into flow inputs. Another example, a change in the water chemistry of sewage effluent at some point source translates into changes in some water quality input variable.

4. Conceptual models guide formulation of the processes, and selection of model inputs and outputs. Professional judgment and expert opinions are particularly important at the conceptualization stage. Differing judgments and opinions translate into different conceptual models which translate into alternate quantitative models. These *competing* models can be evaluated by comparing their predictive power with new data sets, and future observations.

An Ongoing Effort

There is in a sense a huge backlog of data, particularly from years of fish surveys and water monitoring, that needs to be sorted, sifted, integrated and synthesized, i.e., "analyzed", to guide formulation and fitting of quantitative models. Once such models are produced there needs to be ongoing and carefully focused data collection (e.g., monitoring) to assess the quality of model predictions, to allow comparison between competing models, and to refine and improve models. Model development and usage will make clearer model weaknesses and gaps in our understanding of the dynamics of the Delta. These weaknesses and gaps in turn can guide and make more efficient future data gathering. This is a cyclic process in a true "adaptive management" sense—(1) state objectives and translate objectives into measurable quantities, (2) consider a range of actions and use models to predict the consequences, (3) make a decision and carry out an action, (4) collect data on the measurable quantities to see how close, or not, the outcomes were to objectives and to model predictions, (5) refine and update the models, (6) return to step (1)[1].

"Manhattan Project" Type Attention Merited

The importance of the Delta to the state of California, its people, its economy, its environmental quality, is such that an energetic, carefully focused and planned effort be made to produce quantitative models as described above. The complexities of the ecological and hydrological processes are such that no single person can construct such models. A team approach is required. This team would include individuals knowledgeable about the aquatic organisms (e.g., fish biologists, aquatic ecologists), about water flows, transport and other dynamics (e.g., hydrologists), about pollutants and contaminants (e.g., toxicologists, soil scientists), about population dynamics (e.g., quantitative ecologists, mathematicians), and about using data and software to formulate, fit and evaluate models (e.g., statisticians and computer scientists).

While it might sound like hyperbole, attention, and to some degree effort, at the level of the Manhattan Project are merited. The problems are complicated and the range of required expertise is broad. The lack of adequately useful, and adequately accurate, models for predicting the consequences of management actions, or inactions, impairs the ability to make decisions more likely to create and maintain a sustainable, healthy Delta. Billions of dollars and hours have been spent on data collection, engineering and habitat restoration projects, and adversarial activities (e.g., lawsuits). In contrast, the amount of money and time spent on careful, focused analysis of the collected data, and on the development of large scale integrated hydrological and ecological models useful for assessing management actions, is relatively miniscule. Devoting a small fraction of the time, money, and mental energy spent on non-data analysis and synthesis activities to focused data analysis and model development seems a wise decision in the long run.

[1] This is an approximate paraphrasing of the bare bones of Adaptive Management framework as defined in the Department of Interior Technical Guide by Williams, Szaro and Shapiro (2007, updated 2009).