Appendix G

Independent Science Advisors Reports

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Appendix G-1

Bay Delta Conservation Plan Independent Science Advisors Report

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BAY DELTA CONSERVATION PLAN

INDEPENDENT SCIENCE ADVISORS REPORT

Lead Scientist:
Denise Reed, University of New Orleans

Independent Science Advisors:
Jim Anderson, University of Washington
Erica Fleishman, University of California Santa Barbara
David Freyberg, Stanford University
Wim Kimmerer, San Francisco State University
Kenneth Rose, Louisiana State University
Mark Stacey, University of California Berkeley
Susan Ustin, University of California Davis
Inge Werner, University of California Davis

Facilitation Team:
Bruce DiGennaro, The Essex Partnership, LLC
Wayne Spencer, Conservation Biology Institute

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EXECUTIVE SUMMARY

A group of nine scientists were convened in September 2007 to provide independent advice to the Bay Delta Conservation Plan (BDCP) Steering Committee. These scientists provided advice on the use of science in developing an effective Conservation Plan for the Sacramento-San Joaquin Delta in accordance with California's Natural Community Conservation Planning Act (NCCPA) and the BDCP Planning Agreement. Consistent with the requirements of the NCCPA, the Science Advisors' report includes a listing of principles for conservation planning, design, and management. The Report also includes a series of more specific recommendations regarding application of the existing knowledge base and the use of data and analyses for informing the BDCP. The following briefly summarizes key foundational principles and recommendations from the Report. These principles and recommendations should be considered as the overall conservation strategy and potential conservation measures are developed for the BDCP.

Principles for Conservation Planning

The Advisors developed sixteen principles that address overarching issues, fundamental aspects, of Delta ecosystem dynamics, and conservation approaches and analyses. These points should be considered during the development and implementation of the BDCP.

Overarching Principles

A. Changes in the estuarine ecosystem may be irreversible.

B. Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea-level rise) and unforeseen or rare events (e.g., the consequences of new species invasions).

C. The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin Rivers into the Pacific Ocean.

Delta Ecosystem Dynamics

D. The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics. The Delta cannot be managed as a homogeneous system.

E. Species that use the Delta have evolved life history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities.
F. Achieving desired ecosystem outcomes will require more than manipulation of Delta flow patterns alone.
G. Habitat should be defined from the perspective of a given species and is not synonymous with vegetation type, land (water) cover type, or land (water) use type.
H. Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem.
I. Land use is a key determinant of the spatial distribution and temporal dynamics of flow and contaminants which, in turn, can affect habitat quality.
J. Changes in one part of the Delta may have far-reaching effects in space and time.

Conservation Approaches and Analysis

K. Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred.
L. Adaptive management is essential to successful conservation.
M. Conservation measures to benefit one species may have negative effects on other species.
N. Data sources, analyses, and models should be documented and transparent so they can be understood and repeated.
O. Ecosystem responses, especially to changes in system configuration, can be predicted using a combination of statistical and process models. Statistical models document status, trends, and relationships between responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions.
P. There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change.

Plan Scope

The Advisors agree that the BDCP Planning Agreement has correctly identified the aquatic species to be covered assuming the current list of Covered Activities. However, the extent of the available information for each species varies considerably, suggesting that each species should be evaluated individually. The Advisors specifically caution against using guilds, communities of species, or other "groupings of convenience" for planning and analysis. Rather, the Advisors recommend an approach to planning that embraces the spatial and temporal environmental gradients that occur within the Delta and the influence of these gradients on Covered Species. The Advisors developed six recommendations regarding Plan Scope:

1. Seek further advice on the appropriate geographic scope as the nature of the Covered Activities and conservation strategies becomes more defined.
2. Consider the San Joaquin fall-run Chinook salmon as a Covered Species distinct from other Central Valley fall-run Chinook salmon.
3. Revisit the inclusion of Swainson's hawk, giant garter snake, bank swallow, and other listed taxa as Covered Species once the Covered Activities, including conservation strategies, are more fully identified.
4. Use planning species such as threadfin shad, striped bass, largemouth bass, Brazilian waterweed, overbite clam, and freshwater clam to assess effects of conservation strategies on a wider range of ecosystem components and dynamics than the Covered Species represent.
5. Examine how individual species respond to gradients in environmental conditions (and changes in those gradients) to inform assessment of the effects of conservation strategies, rather than using guilds, species communities, or other groupings of convenience.
6. Assess the sensitivity of conservation outcomes to anticipated changes in environmental gradients that will likely arise from sea-level rise, subsidence, climate-change induced alteration in the timing of runoff, human activities, and other processes over the time frame of the Plan and beyond.

Delta Ecosystem Dynamics

The Delta is a highly complex system of interacting physical, geomorphic, biological, and chemical processes, all of which are influenced by human activities both inside and outside the Delta. The Advisors consider several of these interactions particularly important for anticipating the response of the Covered Species to changes in environmental conditions, the Covered Activities, and other human influences. The report includes a set of tables that identify the most important processes influencing covered species, assess the current state of knowledge regarding those processes, outline key uncertainties, and assess the ability to predict how these processes operate within the system. The Advisors developed four recommendations concerning information needs, recognizing that a wide array of studies will be needed to support successful Plan implementation:

7. Routinely collect high resolution airborne imagery over the Delta, including lidar, hyperspectral or multispectral, and thermal, to detect and quantify spatial changes in miocrotopography, surface water temperature, surface turbidity, algal blooms, aquatic wetland and riparian plant species composition, and fractional cover.
8. Maintain current monitoring programs within the Delta and institute a comprehensive, long-term, Delta-wide monitoring program to provide data on contaminants in sediments, water, and aquatic organisms, including in-Delta diversions and return flows.
9. Refine and expand existing monitoring programs as Covered Activities and conservation actions are specified, and critical data needs can be identified.
10. Develop an integrated database of monitoring data (e.g., salinity, temperature, nutrients, contaminants) and relevant spatial data layers (e.g., topography, distributions of submerged, emergent, and floating aquatic plant species).

The report discusses population dynamics and process interactions at higher trophic levels. Understanding and forecasting population dynamics requires considering influences of key environmental variables on all life stages. In the case of the Covered Activities, understanding and forecasting population dynamics may also require considering the effects of environmental conditions outside the range of conditions that the species currently experience. The Advisors developed four recommendations for incorporating understanding of population dynamics into conservation planning:

11. Consider relationships between environmental conditions and the Covered Species in a life cycle context.
12. Pursue efforts to quantify the contribution of entrainment and other factors to stage-specific mortality rates of Covered Species in order to assess the population-level benefits of offsetting such losses.
13. Identify how anticipated changes in environmental conditions, including those associated with Covered Activities and climate change, propagate through populations of Covered Species, and consider how uncertainties regarding future environmental conditions potentially influence population response to Covered Activities.
14. Examine possible bottlenecks at other life stages, including those that occur outside the planning area, rather than only those at the life stage immediately affected by Covered

Activities or within the Delta. Bottlenecks at other life stages can modulate the population response to changes in environmental conditions within the Delta.

Methods of Analysis

Detailed consideration of analytical tools was beyond the Advisors' scope of work. However, the Advisors offered twelve recommendations concerning approaches for analyzing Delta hydrodynamics and species populations. The intent is not to provide a comprehensive evaluation of all available tools and models, but to provide recommendation on how analytical tools can be used to address conservation issues.

15. When potential conservation measures have been developed, convene a group of science advisors with experience in systems analysis, ecosystem restoration, population and food web dynamics, and other relevant disciplines to identify appropriate analytical tools and assessment techniques to support conservation planning and implementation in the Delta.
16. Use a hydrodynamic model that is based on fundamental physics and that accurately reproduces tidal flows in the system for analysis of Delta transport and dispersion, particularly for predictions of proposed management scenarios on hydrodynamics.
17. Use data that span as broad a range of hydrologic and operational conditions as possible to evaluate a model's performance and increase the probability that the model will have sufficient accuracy and precision for evaluating management scenarios.
18. Use models with appropriate dimensionality for the target of the analysis:
    a. Use a two-dimensional, depth-averaged analysis to predict transport of passive dissolved substances.
    b. Use a three-dimensional hydrodynamic model to account for both tidal dispersion processes and gravitational circulation associated with salinity intrusion into the Delta, or parameterize gravitational circulation based on local density forcing.
19. To allow integration of particle or organism behavior into Delta transport models:
    a. Develop a highly resolved three-dimensional hydrodynamic model to produce accurate projections of vertical and lateral variability in channels and junctions.
    b. Conduct drifter-tracking studies, especially around channel junctions, to evaluate model ability to predict particle trajectories.
20. Apply an array of tools to improve prediction of water temperature at various spatial and temporal scales:

a. Develop a correlative analysis of atmospheric conditions and water temperatures to assess large-scale variations in temperature,
b. Analyze river inputs and tidal dispersion to predict temperature at finer spatial and temporal resolution.
c. If prediction of fine-scale temperature variation between adjacent environments is desired, pursue observational and modeling studies into the effects of shallow, vegetated environments on local temperature dynamics, including the effects of shading along perimeter water.

21. Evaluate future sediment supply to the Delta from the watershed, and document sediment resuspension characteristics in the Delta, to support the development of an integrated hydrodynamic-sediment transport model to predict sediment concentrations and their variability
22. Develop spatially-explicit models of plankton dynamics, and institute monitoring to provide necessary input to these models, to improve prediction of Covered Species response to changing environmental conditions.
23. Develop statistical models that relate a) spatial and temporal distributions of environmental factors to life history stages of the Covered Species, b) fish movement to environmental factors that cue migration, c) net and tidal flows to migration, and d) abundances of the Covered Species at different life stages to relevant environmental variables.
24. When sufficient information is available and the questions to be addressed are tractable to model, develop and apply process models for covered species that are built upon the conceptual and statistical models. These process models can be used for predicting short-term, life stage-specific responses, and for predicting long-term responses of population dynamics.
25. Use hydrodynamic models of the Delta built on fundamental processes to analyze the potential consequences of different climate change scenarios (e.g., sea-level rise, timing and amount of runoff) on net and tidal flow patterns.
26. Develop and apply statistical and process models to examine the potential effects of increasing variability in salinity and water temperatures on ecosystem processes and Covered Species in the Delta.

Adaptive Management and Monitoring

Adaptive management is a systematic process for continually improving management policies and practices by learning formally from their outcomes. The Advisors think that adaptive management is perfectly suited to the BDCP, but implementing it will require a sincere, ongoing commitment to the principle and the process, and a decision-making process specifically designed to accommodate adaptive management. The Advisors developed three recommendations concerning adaptive management and monitoring:

27. Design a conservation plan based on adaptive management.
28. Identify and implement as soon as possible an administrative mechanism for the Plan to be modified in response to rapidly evolving information, data, and analyses.
29. Convene a group of science advisors to work with consultants, PREs, and implementing agencies to develop an appropriate adaptive management and monitoring strategy to support implementation of the BDCP.

1.0 INTRODUCTION

This report presents early advice and recommendations regarding the use of science in the development of the Bay Delta Conservation Plan (BDCP or Plan). The report was prepared by a multidisciplinary group of independent science advisors[1] (Science Advisors or Advisors) convened by the BDCP Steering Committee (Steering Committee) in accordance with the state of California's Natural Community Conservation Planning Act (NCCPA) and the BDCP Planning Agreement[2] (Agreement).

The advice and recommendations provided herein are based on current knowledge of the Bay Delta ecosystem and the current state of the BDCP planning process. Both the knowledge base and the planning process are evolving rapidly. Because it is early in the BDCP planning process, many of the details regarding the specific actions that the Plan will cover are undefined, as are the potential conservation measures that may be included in the Plan. Science and scientists will be able to inform management options more directly as more details emerge regarding the overall conservation strategy, including information on potential water management and conveyance actions. Additional scientific information from ongoing studies and analyses (e.g., those under the auspices of the Interagency Ecological Program, the Pelagic Organism Decline (POD) Management Team and the CALFED Science Program) should also be incorporated into the BDCP process as it becomes available. The Advisors strongly suggest establishing a mechanism for continued scientific engagement throughout the BDCP process.

1.1 Independent Scientific Input

The BDCP Planning Agreement calls for the use of the best available scientific information, including advice from well-qualified independent scientists, in preparation of the BDCP. In accordance with NCCPA requirements, the Agreement specifically seeks independent scientific advice on:

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[1] Science Advisors: Jim Anderson, Univ. Washington; Erica Fleishman, UC Santa Barbara; David Freyberg, Stanford Univ.; Wim Kimmerer, San Francisco State Univ.; Denise Reed, Univ. New Orleans; Kenneth Rose, Louisiana State Univ.; Mark Stacey, UC Berkeley; Susan Ustin, UC Davis; Inge Werner, UC Davis

[2] see http://resources.ca.gov/bdcp/docs/BDCP_Planning_Agreement_revised_9.13.2007.pdf

- Scientifically sound conservation strategies for species and natural communities proposed to be covered by the BDCP;
- Conservation actions that would address the needs of species, ecosystems, and ecological processes in the Planning Area proposed to be addressed by the BDCP;
- Management principles and conservation goals that can be used in developing a framework for the monitoring and adaptive management component of the BDCP; and
- Data gaps and uncertainties.

The Planning Agreement also notes that independent scientists may be asked to provide additional feedback, including reports, on key scientific issues during preparation of the BDCP.

A Facilitation Team was retained by the Steering Committee to assist in convening independent Science Advisors and establishing an overall process for engaging scientific input. In June 2007 the Facilitation Team developed a workplan for facilitating independent scientific input for the BDCP (Appendix A). The workplan recommends a series of topically based workshops designed to provide focused, timely advice.

In consultation with the Steering Committee, the Facilitation Team identified and convened a group of independent Science Advisors for an initial workshop focused on addressing the broad requirements of the NCCPA as reflected in the Planning Agreement (see above). The workshop was held September 12-14, 2007. The workshop was designed specifically to:

- Identify principles to inform regional conservation planning under the NCCPA;
- Assess the knowledge base available for planning (what is known and not known);
- Comment on the scope of the ecological and conservation goals and objectives of the BDCP;
- Identify critical ecological processes and scales of variability that the Plan should embrace.

To help focus the Science Advisors' input and to highlight the range of scientific issues that might be relevant to development of the BDCP, a list of topics and questions was developed with input from the Steering Committee (Appendix B). Specific questions were also submitted individually by Steering Committee members (Appendix C).

The Advisors were asked not to review or comment on the specific Conservation Strategy Options being considered by the Steering Committee at the time of the September 2007 Advisors' workshop. The Conservation Strategy Options Evaluation Report prepared by the Plan consultants was not completed until after the Science Advisors' workshop.

1.2 Report Scope and Organization

The contents of this report reflect the Advisors' review of existing information, results of the three-day Advisors' workshop, and subsequent discussions amongst the Advisors. The report addresses key requirements of the NCCPA, as noted in Section 1.1. However, due to the complexity of the scientific issues involved and the early state of the planning process, some topics are addressed in more detail than others. For example, the report provides a clear set of conservation planning principles to help guide Plan development. The report also addresses principles for adaptive management and monitoring, but at this early stage of planning it is not possible to provide detailed recommendations on these topics.

Following this introduction, the remainder of the report is organized to provide scientific input, advice, and recommendations on specific topics as follows:

- Section 2 – Principles for Conservation Planning in the Delta;
- Section 3 - Plan Scope;
- Section 4 – Delta Ecosystem Dynamics;
- Section 5 – Methods of Analyses; and
- Section 6 – Adaptive Management and Monitoring

Specific recommendations are imbedded within each of the respective report sections. To the extent possible, the Advisors provided concrete recommendations that address how specific principles and analytical approaches can be applied to conservation planning. The Advisors also comment on information needs given the scope of the Plan as currently understood.

The recommendations contained in this report are intended to apply broadly to conservation planning in the Delta, both in terms of approaches that could be employed to inform decision-making (e.g. methods of analysis) and in terms of more specific implementation actions (e.g. monitoring). In crafting these recommendations, the Advisors have not focused on legal issues related to who would be responsible for implementation. In some cases, the recommendations may go beyond the specific responsibilities of the BDCP and the Potentially Regulated Entities (PREs). For example, development of a comprehensive monitoring program for contaminants in the Delta (Recommendation R8) would involve regulatory issues and entities beyond the BDCP. Similarly, there are significant ongoing monitoring programs such as those under the purview of the Interagency Ecological Program (IEP). These will likely continue regardless of the BDCP and are beyond the direct scope of the Plan, but could be enhanced or augmented by the Plan. The Advisors do not intend to imply that all recommendations contained in the report should be pursued solely by the PREs as part of the BDCP. Instead, the recommendations represent actions that could support conservation of species and their habitats in the Delta.

The Advisors have not attempted to prioritize the recommendations contained in this report. The relative importance of various recommendations and appropriate sequencing depends on the specific goals and objectives of the Plan and nature of the Plan actions, both of which are still under development. Once the Plan objectives and proposed actions are more clearly defined and if requested by the Steering Committee, the Advisors can provide further guidance on prioritization of the recommendations.

2.0 PRINCIPLES FOR CONSERVATION PLANNING IN THE DELTA

The following principles reflect broad, fundamental concepts that the Science Advisors think are important to acknowledge and understand in developing an HCP/NCCP for the Delta. Although the principles are framed in the context of the BDCP, most if not all are relevant to any comprehensive management plan. As the overall conservation strategy and potential conservation actions are developed for the BDCP, they should be reviewed and evaluated in light of the principles outlined below. The principles are further referenced throughout the report to complement additional observations and recommendations regarding the scope of the Plan and the knowledge base for planning.

A. ***Changes in the estuarine ecosystem may be irreversible.*** Relatively permanent changes in structure or processes (e.g., species introductions, extinctions, and succession, changing climate, or human infrastructure) within the ecosystem may prevent the ecosystem from reverting to a former state when temporary influences (e.g., toxicants, diversions) are removed. Similarly, some ecosystem processes within the Delta result in progressive change and cannot be reversed. Therefore, the future state of the ecosystem is difficult, if not impossible, to predict. Accordingly, goals and objectives that target restoration to historic conditions may not be realistic. Indeed, it may not even be possible to quantify historic or baseline conditions. Because predictions of the outcome or success of management interventions are highly uncertain, a strategy of adaptive management[3] may increase the probability that conservation goals will be achieved (see Principle L).

B. ***Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea-level rise) and unforeseen or rare events (e.g., the consequences of new species invasions).*** Conservation strategies should take into account the probability of particular system responses to both foreseeable changes and inevitable rare and unpredictable events. Evaluation of mitigation or adaptive management strategies for Covered Species should include consideration of potential alternative future states (e.g., salinity intrusion further into the Delta or large numbers of deeply flooded islands) and incorporate management flexibility (both operational and institutional) that can account for and respond to changing conditions.

[3] For more on adaptive management see Busch, D.E. and J.C. Trexler, editors. 2003.

C. ***The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin Rivers into the Pacific Ocean.*** For example, high inter-annual variability in precipitation and river flows are, in part, due to climate patterns that span the entire Pacific Ocean. In addition, many animals that use the Delta do so for only part of their life cycles, spending other parts upstream in the rivers or as far away as northern Canada. Effective conservation strategies will require a system-wide approach that considers the Delta in its larger environmental context. Such strategies may consider implementing actions outside the planning area that would benefit species within the planning area.

D. ***The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics. The Delta cannot be managed as a homogeneous system***. Gradients in salinity, temperature, and turbidity establish a range of environments with boundaries that vary seasonally and among years. Variations in channel depth, vegetation density, and water velocity interact to create additional spatial and temporal variability. Potential spatial and temporal variation in the system response should be explicitly considered in development of potential conservation measures.

E. ***Species that use the Delta have evolved life history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities.*** Changes in geomorphology, tidal and freshwater flow, and chemical composition of the water may fundamentally alter the processes that maintain populations of animals and plants. Examples include cues for migration, feeding, and avoiding predation, all of which affect rates of survival. Conservation strategies that seek to reestablish or maintain conditions within known tolerances of the species and that acknowledge the inherent natural variability in these conditions will likely be more successful.

F. ***Achieving desired ecosystem outcomes will require more than manipulation of Delta flow patterns alone.*** Many important drivers of ecosystem dynamics are highly variable, unpredictable, and difficult to manipulate (for example, humans cannot convert a dry year into a wet year). Furthermore, a number of key ecosystem drivers are independent of freshwater flow patterns (e.g., species introductions). Achieving conservation goals will require that managers directly address drivers that are difficult to manipulate and not related to flow.

G. ***Habitat should be defined from the perspective of a given species and is not synonymous with vegetation type, land (water) cover type, or land (water) use type.*** The term 'habitat' refers to the space and time within which an organism lives and the abiotic and biotic resources in that space and time. Thus, habitat location and quality are dynamic in space and time. At any given time, a given species may be absent from high-quality habitat because of various external constraints that restrict its populations to locations of lower-quality habitat.

H. ***Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem.*** Water quality, including salinity, temperature, turbidity and contaminants, is influenced by inputs of substances from rivers, downstream sources, and local sources, estuarine physics and geomorphology, and water operations. The distribution of salinity determines the distribution of geochemical conditions and affects all estuarine species. Temperature and turbidity influence growth and reproductive rates, and contaminants can have a variety of negative effects. Water quality may affect Covered Species directly or indirectly through water quality effects on the estuarine food web that supports the Covered Species.

I. ***Land use is a key determinant of the spatial distribution and temporal dynamics of flow and contaminants which, in turn, can affect habitat quality.*** Chemicals enter the Delta from many land-use-related sources along many pathways, including atmospheric drift, rain, river flow, storm runoff during winter, return flow from irrigation during summer and fall and from seepage year round, point sources including municipal and industrial effluents, and direct application to surface waters (e.g., control of non-native aquatic plants). These patterns in distribution and timing of contaminants can influence habitat quality for species.Other effects of land use include significant alteration of high flow behavior from flood-damage mitigation, and alteration of local water inflow volumes and timing. Consequently, conservation planning must consider the role of current and future land use within and outside the Delta.

J. ***Changes in one part of the Delta may have far-reaching effects in space and time.*** Although specific actions may affect the entire Delta, the effects are not uniform in magnitude throughout the Delta. For example, changes in the physical structure of one part of the Delta, such as a levee failure or new barriers, can alter flow patterns that may affect how organisms migrate and therefore where they are abundant in or outside the Delta. Similarly, changes in flow and sediment transport determine how chemicals are partitioned among sediments, plants, and water, and where those chemicals will accumulate.

K. ***Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred***. Potential negative ecological impacts of management actions should be considered and designs should attempt to minimize these impacts before projects are implemented, rather than assuming that mitigation will be effective. For example, it is better to take actions that reduce take of fish at the pumps then to rely on salvage of entrained fish to minimize pumping effects. While habitat enhancement or restoration can theoretically benefit populations, these effects are difficult to quantify compared to direct mortality. Consequently, the measurable impact of habitat improvement on fish populations may be small, and the scale of restoration needed to achieve conservation goals through mitigation is likely very large. Moreover, the potential for success of large-scale restoration efforts is often uncertain.

L. ***Adaptive management is essential to successful conservation***. Uncertainty about the likely outcomes of conservation actions arises from a variety of causes that may be inherent in the system, due to substantial changes within the system, or related to incomplete monitoring or understanding. Therefore, conservation actions should be implemented in an adaptive management context. For the BDCP, like any other conservation plan, adaptive management involves the development of quantitative conservation objectives and quantitative triggers for changes in management. The objectives also should be achievable within a specified period of time, given the scope and constraints of the Plan.

Conservation actions should be based on well-supported hypotheses about their outcomes, given the potential irreversibility of changes to the state of the ecosystem. Information from monitoring of projects and system response must feed back to system models used to inform managers and those overseeing implementation[4].

M. Conservation measures to benefit one species may have negative effects on other species. Actions necessary to achieve objectives for different conservation targets may conflict (i.e., a given action simultaneously may benefit some species or ecological processes of conservation concern and have a negative influence on other species or processes) (Margoluis and Salafsky 1998). Conservation plans must recognize these potential conflicts, evaluate tradeoffs among conservation targets, and, to the extent possible, minimize negative effects.

N. Data sources, analyses, and models should be documented and transparent so they can be understood and repeated. Important environmental decisions may be informed by statistical analysis and modeling, both of which have multiple sources of uncertainty. Analysts can obtain different results by using different data or models. Comparison among alternative methods of analyses is an effective way to explore uncertainties. These comparisons require sufficient clarity about the differences among analyses. Clear documentation of data and analyses enables comparison of results derived from alternative methods. Documentation also helps to identify what is known and not known, and the major sources of uncertainty.

O. Ecosystem responses, especially to changes in system configuration, can be predicted using a combination of statistical and process models. Statistical models document status, trends, and relationships between responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions. Statistical models may allow us to characterize empirically how a system works. However, statistical models may not allow us to predict system responses, because they apply only within the range of conditions over which data have been collected. Process models rooted in underlying mechanisms provide a much stronger basis for predicting system responses to environmental change (i.e., extrapolating beyond

[4] For more on adaptive management see Busch, D.E. and J.C. Trexler, editors. 2003.

available data), although model calibration and validation of process models are more challenging than for statistical models.

P. ***There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change.*** Some of these uncertainties are reducible, often through additional data collection and scientific study, which can be important components of adaptive management. Other uncertainties are not reducible because they are rooted in inherent system variability. Uncertainty is unavoidable and methods for addressing uncertainty should be incorporated explicitly into decision-making.

3.0 PLAN SCOPE

The scope of an NCCP/HCP is defined by its geographic area and time horizon, and the actions, species, and communities to be covered. This report provides some preliminary observations and advice regarding each of these items based on available information. The Advisors recommend that the Steering Committee seek additional scientific input regarding the plan scope as new information becomes available, particularly as more specifics concerning the nature of the actions to be covered by the BDCP are developed.

3.1 Geographic Area

The Advisors emphasize that the Delta is embedded within a larger environmental context and cannot be managed as an isolated system (Principle C). The current boundary, as defined in the Planning Agreement, is the Statutory Delta[5]. Species and communities in the Planning Area are affected by actions and processes outside the Planning Area (e.g., upstream water diversions, spawning habitat for anadromous fish, contaminant inputs, precipitation patterns in the Sierra Nevada, sea level rise, and other aspects of climate change). Also, depending on the selected conservation strategies, some Covered Activities may occur outside the Statutory Delta. Some Covered Activities also may affect species and communities outside the Planning Area (e.g., by changing the quality of Delta outflow or increasing salinity in Suisun Bay).

The Advisors think it is premature to make firm recommendations regarding changes to the Planning Area (Recommendation R1). However, the Advisors note that alterations to the Planning Area may be necessary as planning progresses to reduce regulatory uncertainties and undesired consequences of Covered Activities..

R1. Seek further advice on the appropriate geographic scope as the nature of the Covered Activities and conservation measures becomes more defined.

[5] As defined by section 12220 of the California Water Code.

3.2 Time Horizon

For the purposes of this report, the Advisors assumed that the duration of the permit, and the time available to plan and implement Covered Activities, would be 50 years. Some actions to be permitted under the Plan will likely take many years to implement. The distribution of species and the distribution and quality of their habitat will change during that time (e.g., due to species introductions and climate change). Therefore, the Advisors recommend building contingencies into the Plan via an adaptive management program (see Section 6.0) that anticipates and can adjust to such changes to the degree feasible (Principles A and L).

3.3 Covered Species

The Advisors agree that the Planning Agreement has correctly identified the aquatic species to be covered assuming the current list of Covered Activities[6]. These species are Central Valley steelhead (*Oncorhynchus mykiss*), Central Valley Chinook salmon *(Oncorhynchus tshawytscha)* (spring run, winter run, and fall/late-fall runs), Delta smelt *(Hypomesus transpacificus)*, green sturgeon *(Acipenser medirostris)*, white sturgeon (*Acipenser transmontanus)*, splittail (*Pogonichthys macrolepidotus)* and longfin smelt (*Spirinchus thaleichthys)*. However, the Advisors suggest that the San Joaquin River fall-run Chinook salmon deserves consideration as a Covered Species, distinct from other Central Valley Chinook salmon, because the two taxa are exposed to significantly different environmental conditions in and upstream of the Delta (Recommendation R2).

> ***R2. Consider the San Joaquin fall-run Chinook salmon as a Covered Species distinct from other Central Valley fall-run Chinook salmon.***

The Planning Agreement also identified four additional species to consider for coverage (Recommendation R3). The Advisors agree that it is premature to make firm recommendations about coverage for these species until Covered Activities and conservation strategies, are specified. However, the Advisors offer the following preliminary thoughts about including these species.

[6] The Covered Activities are those described at the 3/23/07 BDCP Steering Committee meeting. See http://resources.ca.gov/bdcp/docs/03_23_2007__handout_Covered_Activities_List.pdf

R3. Revisit the inclusion of Swainson's hawk, giant garter snake, bank swallow, and other listed taxa as Covered Species once the Covered Activities and conservation strategies, are more fully identified.

- Swainson's hawk (*Buteo swainsonii*) – This species is listed as threatened under the California ESA. It nests within the Planning Area where large trees for nesting occur near extensive agricultural fields over which the species can forage (Woodbridge 1998). The Delta is also an important wintering area for the species (Herzog 1996). Swainson's hawk typically does not travel far to forage and is likely to nest only near foraging habitat. Nesting habitat probably will not be affected directly by the currently listed Covered Activities. However, coverage for the species should be considered more thoroughly if Covered Activities are likely to include flooding of islands or major changes in agricultural practices. Such activities could reduce the amount of foraging habitat for Swainson's hawk and result in abandonment of nesting territories within the Planning Area.
- Giant garter snake (*Thamnophis gigas*) – This aquatic snake is listed as threatened under the California and federal ESA. It is found in the northern and eastern Delta (with one recent record from the western Delta in the vicinity of Decker and Sherman Islands), associated with agricultural wetlands, irrigation canals, sloughs, ponds, low gradient streams, and other aquatic land use and land cover types with emergent vegetation (USFWS 1999); http://www.californiaherps.com/snakes/maps/tgigasmap.jpg). Covered Activities could potentially affect giant garter snakes, positively or negatively, via construction in occupied areas, changes in agricultural practices, or flooding of habitat.
- Bank swallow (*Riparia riparia*) – This species is listed as threatened under the California ESA. It is not known to nest within the Statutory Delta (Garrison 1998). It nests on vertical banks with soft soil or in cliffs, usually after flood waters recede and low water levels expose cut banks. If BDCP conveyance approaches or conservation measures cause direct or indirect changes to the structure of channel banks outside the current planning area, this species may be affected and coverage should be considered.
- Valley Elderberry longhorn beetle (*Desmocerus californicus dimorphus*) – This species has been recommended for delisting by the U.S. Fish and Wildlife Service due to positive effects of ongoing conservation actions and evidence of the existence of many more populations, over a much broader geographic range, than was known at the time of listing (USFWS 2006). Therefore, the Advisors suggest that the subspecies not be covered under the NCCP/HCP.

Given that regulatory assurance is a priority for the Potentially Regulated Entities (PREs), it is prudent to examine the potential effects of Covered Activities on the full range of species that are listed under federal and state endangered species acts, or are likely to be listed during the permit period. For example, plant and animal species associated with tidal marsh and riparian vegetation may be candidates for coverage by the Plan depending on the final array of Covered Activities.

3.4 Planning Species

In addition to species to be covered by incidental take authorizations, it may be useful for the Plan to consider other species as "planning species". Although planning species may not be listed and therefore do not require incidental take permits, considering the effects of the Plan on these species may assist in meeting ecosystem goals. Planning species might include species that have strong effects (positive or negative) on Covered Species or ecological processes. For example, a planning species might play a key role in food webs that include Covered Species. Participants in other NCCPs (e.g., San Diego Multiple Species Conservation Plan, Yuba-Sutter HCP/NCCP, and Santa Clara Valley HCP/NCCP) have identified non-listed species that they think should be considered as planning species.

The Advisors discussed whether to recommend planning species for the BDCP. In general, the Advisors do not advise designating species as planning species solely for economic, recreational, or aesthetic reasons. However, some non-listed species that may be affected by Covered Activities and conservation measures exert strong influences on the Bay-Delta ecosystem and on populations of Covered Species. Specifically, the Advisors have identified two groups of species as potentially useful planning species given the current list of Covered Activities: two non-native species of pelagic fish shown to be in decline (i.e., POD species, see Sommer et al. 2007) that are not included in the list of covered aquatic species, and four non-native invasive species that have altered the structure, composition, and function of the Delta ecosystem (Recommendation R4). These two categories are addressed further below.

<u>POD Species</u>

- <u>Striped bass</u> (*Morone saxatilis).* Striped bass is not native to the Delta, although its introduction was intentional. Its decline is of concern because it contributes to the total biomass of pelagic fishes in the ecosystem, and abundance indices for 2002-2005 included record lows for young striped bass (Sommer et al. 2007). The reason for this decline is unknown, although it is not due to low adult abundance (Sommer et al. 2007). The POD Management Team and collaborating scientists are analyzing trends and associations between abundance and environmental covariates.

- Threadfin shad (*Dorosoma petenense).* Like striped bass, threadfin shad is not native to the Delta and is of interest as a planning species primarily because of its previously high abundance (in some years it has been the most abundant fish in the Delta (Sommer et al. 2007)) and sharp drop in abundance in 2001, concurrent with the declines of other POD species.

Life histories of striped bass and threadfin shad are different from those of Delta smelt and longfin smelt (two other declining pelagic species covered by BDCP). This implies that their abundance and population dynamics may be responding to different drivers. Furthermore, adult striped bass consume other fish and may cause substantial mortality to young winter-run Chinook salmon (Lindley and Mohr 2003) and possibly other pelagic species. Considering striped bass and threadfin shad as planning species and exploring their potential response to conservation strategies may provide insight into the effect of conservation measures on diverse components of the ecosystem. Their inclusion as planning species does not imply that conservation actions should be developed to increase their abundance. Rather, considering how these species may respond to actions that are designed to benefit the Covered Species may provide information on the potential effects of plan implementation on a more diverse set of components of the Delta ecosystem.

Non-native species with ecosystem-level impacts

- Largemouth bass (*Micropterus salmoides).* Abundance of this species has increased in the Delta over the past few decades concurrently with the increase in submerged vegetation (Brown and Michniuk 2007). Largemouth bass have a much more limited distribution in the estuary than striped bass, but a higher per capita impact on small fishes in near-shore waters (Nobriga and Feyrer 2007). The effects of consumption of Covered Species by largemouth bass are unknown.
- Brazilian water weed (*Egeria densa*). This species increases water clarity by trapping fine sediments, and increases vegetation structure in littoral areas. This shifts the Delta waterways from turbid, pelagic conditions that favor native species of fish to clear, vegetated littoral conditions that favor introduced species such as largemouth bass (Brown and Michniuk 2007). Remote sensing studies from 2003 to 2006 showed that the range of Brazilian water weed has fluctuated from year to year and that previously occupied areas are

frequently recolonized, even where control methods have been applied. Submerged non-native vegetation covers about 10-12% of the waterways in the Delta. Approximately 80% of the submerged vegetation is Brazilian water weed (S. Ustin, unpublished).

- Overbite clam (*Corbula amurensis*). This species was introduced in 1986. Grazing by overbite clam is thought to have resulted in a substantial decline in phytoplankton and calanoid copepods, the primary prey of early life stages of pelagic fishes, in brackish waters of the Delta and Suisun Bay (Kimmerer 2002b).
- Freshwater clam (*Corbicula fluminea).* This species was introduced to the Delta in 1945, but understanding its effect on the ecosystem is hampered by the lack of ecological studies preceding its invasion. However, the introduction of freshwater clam has caused substantial changes to other estuarine ecosystems, including shifts from a phytoplankton base toward submerged aquatic vegetation (Phelps 1994). Freshwater clams are food limited in the Delta (Foe 1986) and they can control phytoplankton biomass in at least some locations in the Delta (Lucas et al. 2002, Jassby et al. 2002), which likely reduces the energy supply to some Covered Species.

The identification of these non-natives as planning species does not mean that conservation actions need to be developed for their benefit. Rather, because these species have caused substantial changes in ecosystem processes, assessing how the species respond to conservation actions designed to benefit the Covered Species may provide information on the potential effects of plan implementation on a more diverse set of components of the Delta ecosystem.

R4. Use planning species such as threadfin shad, striped bass, largemouth bass, Brazilian waterweed, overbite clam, and freshwater clam to assess effects of conservation measures on a wider range of ecosystem components and dynamics than the Covered Species represent.

3.5 Covered Communities

The Advisors caution against using guilds, communities of species, or other groupings of convenience for planning and analysis. Although species interact to form ecological communities, we often lack knowledge about the effects of a given species on the distribution or probability of persistence of another species. In addition, although sets of species often use some resources in common, each species has distinct resource requirements that should be accounted for individually. Although the Advisors acknowledge that the statutory language of the NCCPA focuses on communities, they do not think communities are defined clearly enough to be particularly useful for conservation planning within the Delta.

It will be more scientifically robust and effective to consider the presence of Covered Species relative to characteristic sets of ecological conditions than to correlate the presence of Covered Species with easily observed vegetation or substrate types (Recommendation R5). These sets of ecological conditions are defined by the way in which key environmental gradients interact across the Delta. Two of the most influential gradients within the Delta are (1) distance from the ocean which influences tidal exchange and salinity, and (2) elevation which influences inundation (Figure 1).

The interaction of tidal exchange and salinity produces four zones from ocean to rivers: (1) high salinity with tidal exchange, (2) fluctuating salinity with tidal exchange, (3) freshwater with tidal exchange, and (4) freshwater with no tidal exchange. The borders of these zones are dynamic and depend on Delta inflows, the range of oceanic tides (mainly spring vs. neap), and regional weather.

The elevation gradient produces four zones: (1) constantly inundated, (2) inundated and exposed on tidal time scales, (3) seasonally inundated, and (4) infrequently inundated. Although the elevations are fixed, at least on short time scales, the zones of inundation vary according to water levels, which depend on the interaction of river flows and the tide as well as atmospheric pressure and winds. Structures such as levees, barriers, and tidal gates modify gradual gradients of tidal exchange and salinity, creating abrupt shifts in environmental conditions (e.g., in elevation or salinity), and subsidence increases the degree of inundation during floods. These alterations can disrupt the transport and exchange of chemical and biological materials along these gradients.

R5. Examine how individual species respond to gradients in environmental conditions (and changes in those gradients) to inform assessment of the effects of conservation strategies, rather than using guilds, species communities, or other groupings of convenience.

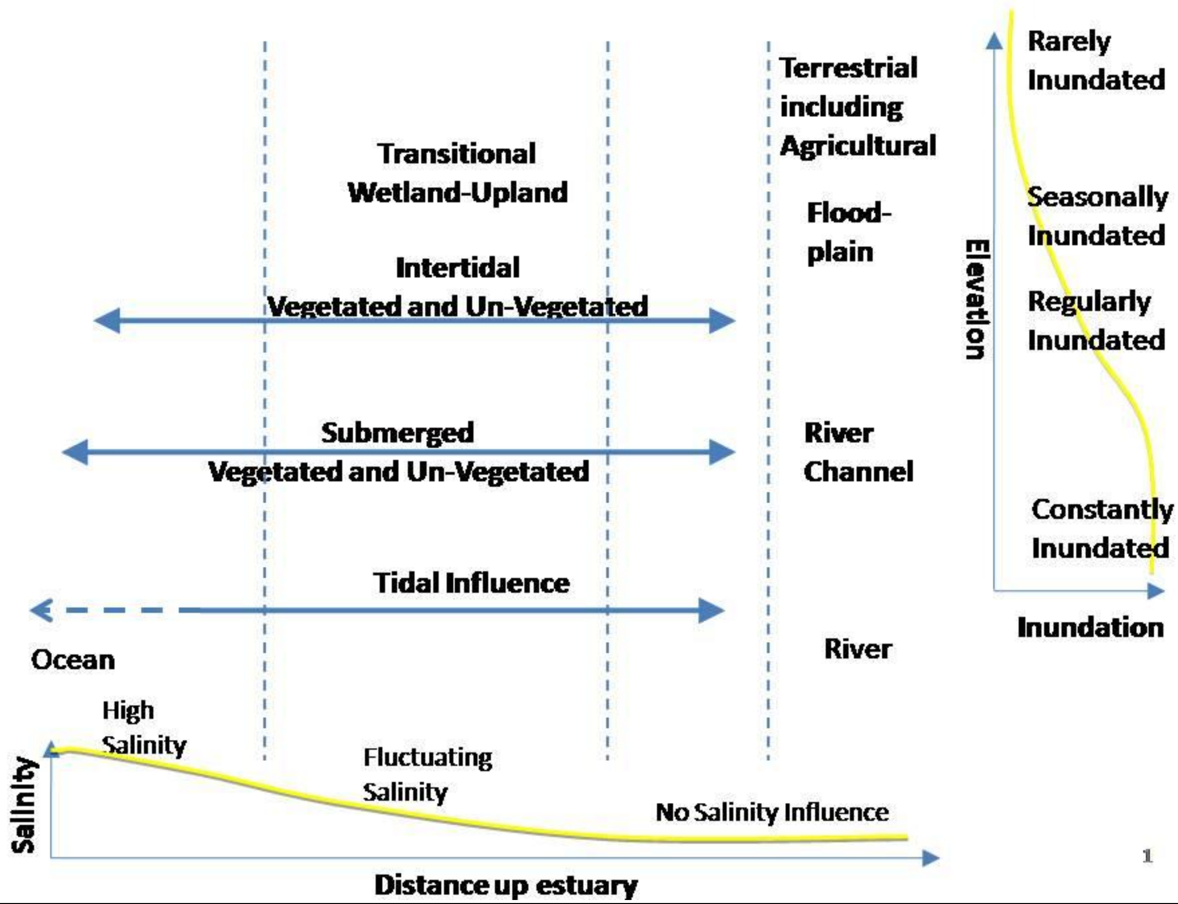

Figure 1. Horizontal and vertical gradients that control environmental conditions in the Delta.

Species disperse and are distributed across gradients of tidal exchange and salinity according to intraspecific and interspecific competition (especially in lower-stress environments) and the species' ability to exploit the range of environmental conditions (Byrd and Kelly 2006). As a result, different combinations of species occur in different areas at different times (Principle G). For example, inundation and salinity gradients affect the species richness, distributions, abundance, and biomass of tidal wetland plants (Mahall and Park 1976b, Atwater 1979).

Tidal exchange and salinity are interdependent. For example, soil salinity increases as wetland elevation increases to mean high high tide (MHHT), and then decreases further inland (Mahall and Park 1976b). Thus, spatial zonation in wetlands reflects a combination of biotic factors and physical and chemical factors, such as tidal regime, soil topographic features, and soil properties (Silvestri et. al. 2003, Belluco 2006, Mahall and Park 1976a, b, c).

Incorporating an understanding of environmental gradients in the Delta into conservation planning allows for consideration of changes to the drivers of those gradients. For example, sea-level rise will shift tidal gradients within the Delta and alter salinity penetration. Current estimates of global sea-level rise range from 9 cm[7] to more than 1 m[8] by 2100. Some scientists suggest conservation planning in the Delta should use sea-level rise estimates of 50-140 cm for the 21st century[9]. Similarly, increased temperature associated with climate change has already begun to alter runoff patterns in the system through a shift to an earlier peak in snowmelt (Knowles and Cayan 2002), which will influence environmental gradients within the estuary. Subsidence in the Delta and associated salinity penetration in the event of a levee failure have been identified as a potentially substantial influence on long-term salinity patterns (Mount and Twiss, 2005). Considering the influence of these anticipated changes on conservation measures is an essential element of planning (Recommendation R6).

Changes in the human environment should also be considered. This will likely take the form of increased urbanization around and within the Delta, and a shift in the pattern of demand for water from agriculture to municipal use. Increases in demand are expected to have at least as great an effect on water supplies globally as reductions in supply due to climate change (Vörösmarty et al. 2000). The same may be true at a regional level for water supplies in the Delta.

> ***R6. Assess the sensitivity of conservation outcomes to anticipated changes in environmental gradients that will likely arise from sea-level rise, subsidence, climate-change induced alteration in the timing of runoff, human activities, and other processes over the time frame of the Plan and beyond.***

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[7] Low range estimate from IPCC Fourth Assessment report (Low range estimate from IPCC Fourth Assessment). Note this does not include ice sheet melting and is based on the most optimistic emissions scenarios.

[8] Rahmstorf, S 2007 *A Semi-Empirical Approach to Projecting Sea-Level Rise* Science v. 315, pp. 368-370

[9] Memo from CALFED Independent Science Board to Lead Scientist, 6 September 2007. Located at http://www.calwater.ca.gov/science/isb/isb_archive_07.html August28-29, 2007 meeting.

4.0 DELTA ECOSYSTEM DYNAMICS

The Delta is a highly complex system of interacting physical, geomorphic, biological, and chemical processes, all of which are influenced by human activities both inside and outside the Delta. The Advisors consider certain of these interactions particularly important for anticipating the response of the Covered Species to future changes in environmental conditions, the Covered Activities, and other aspects of human use of the Delta. External influences (e.g., river inflows, diversions, tides) interact with the underlying physical structure of the system to influence physical, geomorphic, food web, and chemical processes. The interaction of these processes influences species population dynamics in a variety of ways (Figure 2). A process-based approach provides a basic framework for understanding system dynamics and for developing and evaluating conservation strategies (Principle O). Physical processes drive many aspects of the ecosystem both directly and indirectly (Principle F), (Figure 2).

This section is not intended to provide a detailed description of the all the physical, geomorphic, biotic, and chemical processes within the Delta. Rather, this section aims to

1. Identify the most important processes influencing Covered Species;
2. Assess the current state of knowledge regarding those processes;
3. Outline key uncertainties, and;
4. Assess the ability to predict how these processes operate within the system.

Understanding these processes, and acknowledging the limits of our understanding, is critical to the formulation of a conservation strategy. It is important to keep in mind that the system is neither static nor homogeneous (Principle D) so our understanding changes with time and new data.

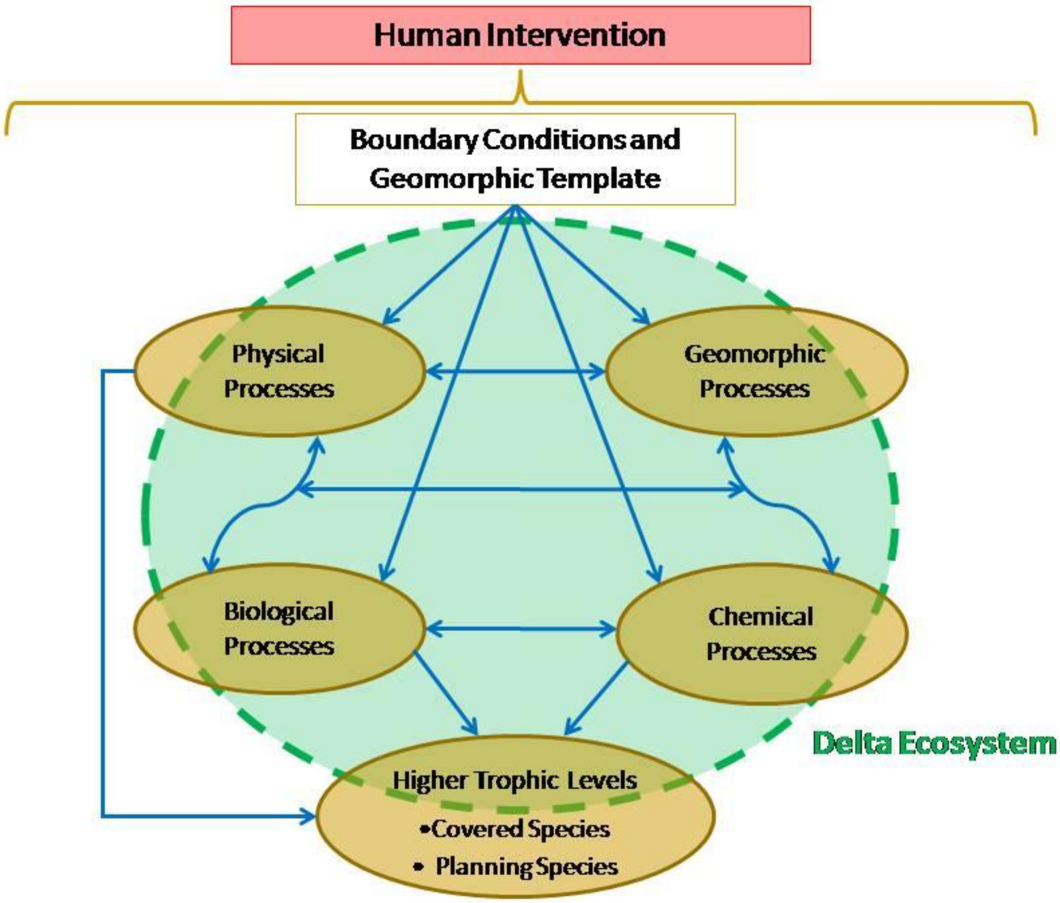

Figure 2 – Conceptual diagram of interactions among environmental processes that influence responses of higher trophic levels, including Covered Species, to changing conditions.

4.1 Process Interactions in the Delta

To understand the Delta ecosystem it is essential to consider the factors both internal and external to the Delta that drive the ecosystem (Principle C). At least 11 external processes or factors fundamentally influence the Delta ecosystem (Table 1). In addition to physical processes that are driven by external factors, some biological and chemical processes in the Delta are directly influenced from outside the Delta (e.g., harvest of salmon in the ocean, chemical applications) (Figure 2).

The Advisors have identified a number of critical processes that influence higher trophic levels, including the Covered Species (Tables 2-5). The roles of these processes in influencing different life stages of Covered Species are addressed in section 4.3 below. Interactions among these processes are frequently more important than any one process alone. Many interactions among processes are mediated by changes in dissolved constituents, (Principle H), including salts and nutrients. Inputs from upstream and from within the Delta alter the amount of these constituents, but their dynamics are often controlled by tidal dispersion (Table 5 and Principle I).

Water quality in the Delta influences higher trophic levels directly and indirectly via changing environmental conditions (Figure 1) and toxicity, and as a control on primary production and energy inputs to the food web (Table 4). Other important process interactions occur at a local scale. The Delta's aquatic food web is driven by phytoplankton and, to some extent, bacteria rather than by detrital organic matter (Table 4). However, aquatic plants, which are often the primary source of detritus, can influence turbidity through flow attenuation (Tables 1 and 2), which potentially increases phytoplankton growth. Aquatic plants may also absorb contaminants such as pyrethroid insecticides (Table 5).

Anticipating the ecosystem response to Covered Activities requires an understanding of these and other complex interactions among abiotic and biotic processes. The use of models to predict population dynamics of Covered Species is addressed in Section 4.4.3. However, forecasting changes in the process interactions described here and in Figure 2 is important for understanding the system level implications of Covered Activities. Many of these interactions are driven by physical processes. Because our ability to predict the physical dynamics of the system is effectively limited to the current system configuration (Table 2 and Section 4.4.2); predictions of how these process interactions will change in the future are highly uncertain.

4.2 Information Needs

Although monitoring programs have been implemented for some aspects of the Bay Delta system (e.g., hydrodynamics, salinity, fish densities and distribution), the ability to predict the response of any system component to the Covered Activities is limited in many instances by available data (Tables 1-5). To address the needs outlined in Tables 1-5, additional data that could be collected include detailed topography and bathymetry, wind stress and solar insolation, bed sediment character, and distribution and rates of clam grazing. This list is not intended to be comprehensive but serves to illustrate the range of data needs currently limiting conservation planning. The Advisors acknowledge efforts of groups such as CMARP (Comprehensive Monitoring and Research Program) in identifying a broader array of monitoring needs. It may be possible to monitor some parameters using recently developed techniques for the acquisition of detailed spatial data (e.g., remote sensing, towed samplers) and the Advisors encourage the evaluation and, if appropriate, implementation of these approaches (Recommendation R7). The influence of contaminants on the dynamics of plants and animals in the Delta is unclear. With the exception of mercury, which has been relatively well studied in the Delta and surrounding watersheds, and selenium, for which data are available upstream but not in the Delta, predictive ability related to effects of contaminants is fundamentally constrained by a lack of information (Recommendation R8).

Existing monitoring programs should be maintained (Recommendation R8), but as conservation options become more fully developed it is likely that additional data will need to be collected to support analysis of options; these analyses include model development and validation (Section 4.4). Development of detailed recommendations on monitoring to inform BDCP conservation actions requires more information on the nature of Covered Activities and more explicit conservation goals (Recommendation R9 and section 6.0). The effective and transparent use of existing and newly acquired data in conservation planning requires a database that can incorporate data collected over space and time (Recommendation R10). Such a database will be an important tool in Plan development. The database could inform the design of future research and monitoring activities, and assist in developing both hypotheses about relationships among ecosystem components and statistical and process models.

R7. Routinely collect high resolution airborne imagery over the Delta, including lidar, hyperspectral or multispectral, and thermal, to detect and quantify spatial changes in miocrotopography, surface water temperature, surface turbidity, algal blooms, and aquatic, wetland, and riparian plant species composition and fractional cover.

R8. Maintain current monitoring programs within the Delta and institute a comprehensive, long-term, Delta-wide monitoring program to provide data on contaminants in sediments, water, and aquatic organisms, including in-Delta diversions and return flows.

R9. Refine and expand existing monitoring programs as Covered Activities and Conservation Actions are specified and critical data needs can be identified.

R10. Develop an integrated database of monitoring data (e.g., salinity, temperature, nutrients, contaminants) and relevant spatial data layers (e.g., topography, distributions of submerged, emergent, and floating aquatic plant species).

Scientific studies will be necessary to explore the effects of Conservation Actions and other environmental changes on Covered Species. These studies will need to examine the fundamental interactions between physical, chemical, biogeomorphic and food web processes that influence the Covered Species. Targeted research can facilitate development of more successful statistical and process models, including models that support predictions of ecosystem response to changing Delta configurations and boundary conditions. More information on the Covered Activities and conservation strategies is essential before the Advisors can offer guidance on the array of scientific input that will be needed to support BDCP planning and implementation.

4.3 Population Dynamics and Process Interactions at Higher Trophic Levels

The discussion below focuses on fish because of their dominance on the list of Covered Species, but similar issues and recommendations would apply to any other covered and planning species. Organisms at higher trophic levels in the Delta are influenced by interactions among physical, chemical, biogeomorphic and food web processes (Figure 2).

Of relevance for evaluating alternative management and conservation actions is how the factors shown in Tables 1-5 affect the growth, mortality, reproduction, and movement of individual members of the Covered Species. The cumulative responses of individuals over life stages, space, and time influence the dynamics of populations. Population dynamics encompasses seasonal and interannual fluctuations in distribution and abundance, long-term trends in distribution and abundance, likelihood of persistence and recovery, and other phenomena. Understanding and forecasting population dynamics requires consideration of the dependence of all life stages on key environmental variables. Understanding and forecasting population changes due to Covered Activities may also require understanding how Covered Species respond to environmental conditions outside the range of conditions they currently experience

4.3.1 Life Cycles

To identify how environmental changes in the Delta may affect the Covered Species, first it is necessary to consider which portions of each species' life cycle occur within the Delta. For anadromous species such as salmon and steelhead the Delta serves as a migratory corridor for juveniles and adults, and a rearing area for some juveniles (Williams 2006). By contrast, one or more of the life stages of resident species of fishes occur within the Delta, Delta smelt spawn in the central and northern Delta. The juveniles move downstream into the brackish waters of the western Delta and Suisun Bay, and adults migrate back into the Delta to spawn (Bennett 2005, Moyle et al. 1992). Longfin smelt are thought to spawn in the Delta, while juveniles and sub-adults are found throughout the saline parts of the estuary, and adults may enter the near-shore areas of the ocean (Moyle 2002). Splittail spawn on floodplains in the Yolo and Sutter bypasses and along the Cosumnes River. Juvenile and adult splittail inhabit tidal freshwater and brackish water in the Delta (Moyle et al. 2004). Sturgeon, like salmon, are anadromous, but sturgeon tend to spend a greater proportion of their adult life stage throughout the estuary than do salmon (Moyle 2002). Thus, each Covered Species uses the Delta in a different way.

The Advisors suggest viewing each species' use of the Delta through a life cycle triangle that depicts the species' life cycle from birth to death as a closed migration path (Harden-Jones 1968) (Figure 3 and Recommendation R11). The path begins in the spawning habitat where adults produce offspring. The larval fish disperse to the juvenile habitat and eventually move to the adult habitat. The path is completed when the adults migrate back to the spawning habitat to reproduce. The population dynamics of a species are determined by the survival of fish over the migration path, the number of offspring produced by adults in the spawning habitat, and the number of times adults cycle between the adult and spawning habitats during their lifetime. The critical life history processes, or vital rates, include growth of individuals, mortality in each habitat, movement among habitats, and reproduction in the spawning habitat. These vital rates control the population dynamics of the species in the Delta. The set of vital rates across life stages dictates the rate at which an individual moves through its life cycle. Specific sets of vital rates, which have proven successful over evolutionary time, define the life history strategy of the species (Winemiller and Rose 1992).

R11. Consider relationships between environmental conditions and the Covered Species in a life cycle context.

4.3.2 Population Responses to Environmental Conditions

A major challenge for assessing how populations respond to environmental changes and management actions is to determine how the vital rates at different life stages may respond to the altered environmental conditions. Quantifying the effects of conservation measures on abundances at different life stages is difficult. Determining whether these effects are sufficient to offset uncertain management-induced mortality rates is even more difficult (Principle K). It is necessary to examine how hydrodynamics, salinity, temperature, food availability, contaminants, and other environmental variables directly and indirectly affect the rates of growth, reproduction, mortality, and movement. Of these processes, growth is usually the easiest to study in the field and in the laboratory. Reproduction is also generally quantifiable under current environmental conditions. Mortality is difficult to quantify and the sources and locations of mortality are notoriously difficult to identify (Recommendation R12). Even mortality at the south Delta export pumps, which are intensively monitored for fish entrainment, has some major unknowns such as mortality in the channels leading to the pumps (Kimmerer in press). Some of the unknowns related to entrainment mortality could be reduced through a program of research that might include studies of radio-tagged fish, predator removal studies, bioenergetic analysis of predators, sampling fish behind the louvers at the fish facilities, and studies of predator aggregation at release points[10]. Such a program should be built around a modeling component so results of individual studies could be compared and placed in a population context.

[10] See also the Summary of the June 22 -23, 2005 CALFED Science Program Predation Workshop at http://www.calwater.ca.gov/science/events/workshops/workshop_predation.html

R12. Pursue efforts to quantify the contribution of entrainment and other factors to stage-specific mortality rates of Covered Species to in order to assess the population-level benefits of offsetting such losses.

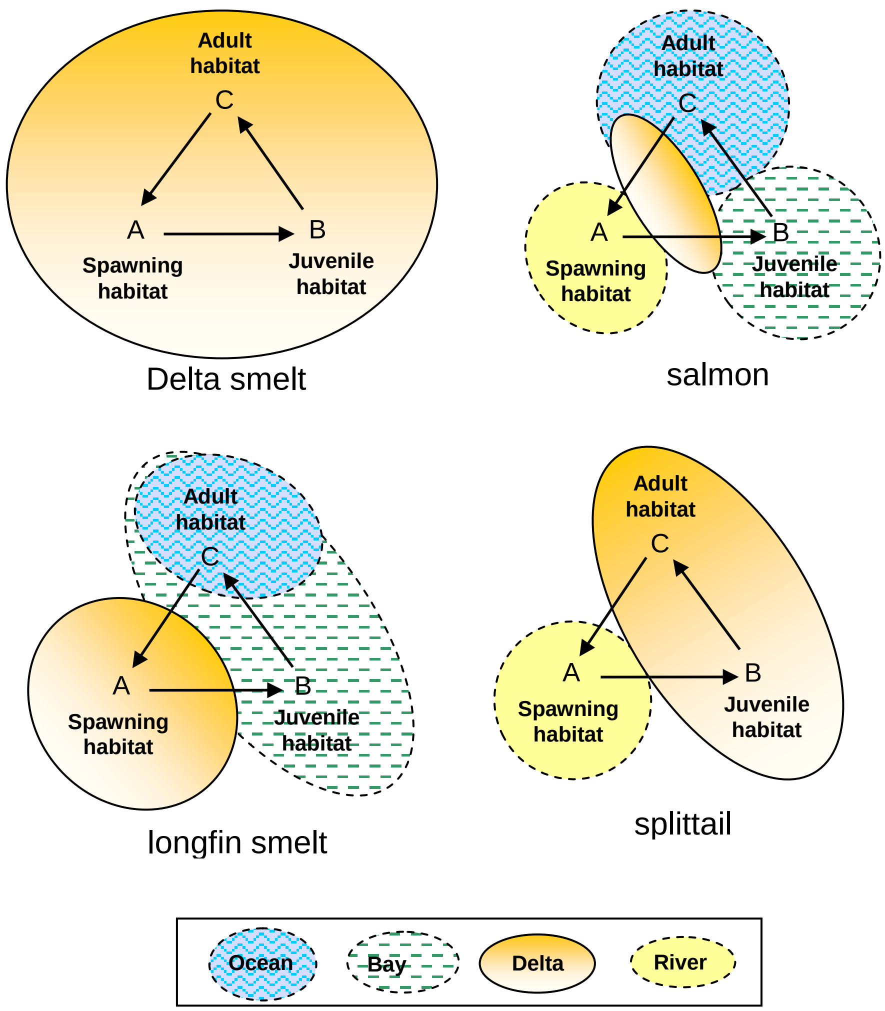

Figure 3. General pattern of use of the Delta by Covered Species over their life cycle. Arrows indicate migration among habitat types.

Determining how changes in environmental conditions may affect movement of the Covered Species is particularly important and challenging. Aquatic organisms in the Delta use various cues to move among habitats. Thus, effects of tidal and net flows on fish movement must be explicitly considered in analyses. Movement is important because vital rates, especially growth and mortality, depend on the timing and routes of movement through the Delta. For example, the central Delta is probably poorer habitat for salmon than the migration pathway along the Sacramento River (Brandes and McLain 2001). The vulnerability of many species to detrimental effects of the Delta pumps depends on their location within the Delta. Additionally, understanding how water operations and management actions affect fish exposure to salinity, temperature, and food is critical to understanding growth, movement, and mortality. Yet relatively little is known about how environmental cues affect fish behavior and movement. Even less is known about how alteration of these cues by management actions might affect movement, which, in turn, would affect the vital rates and population dynamics of species that use the Delta (Principle E).

Tables 1 through 5 describe factors that affect the vital rates at each life stage (Figure 3). These factors can influence habitat quantity and quality differently for each species by modifying the connections among habitats, pathways of movement, and the growth, survival, and reproduction of individuals as they move through their habitats.

- Table 1 describes the fundamental drivers of the Delta ecosystem, many of which can affect the vital rates of fish at different life stages, and most of which can be altered by human activities. The boundaries of the environment are defined by bathymetry, shorelines, and topography, which together determine the geographic extent of habitats for each species and the physical connections among habitats.
- Table 2 describes relevant physical processes and factors in the Delta, such as transport and mixing of water and dissolved and particulate constituents (including salts, sediments, and biota) and water temperature. These processes are particularly important because they affect both the physical transport of species and the temporal and spatial cues that the species use to navigate between specific habitats (Figure 3). For example, the hydraulic characteristics of the Delta Cross Channel determine the fraction of migrating juvenile salmon moving into the interior Delta. Throughout their life cycle, resident species rely on cues that initiate and direct their migrations. It is plausible that a species' ability to use the Delta may be the result of behavioral responses to hydraulic and chemical cues that have evolved over long time periods through natural selection. Individuals that moved in certain ways in response to specific cues had higher survival and reproductive success. For example, to avoid being flushed out of the estuary by the net river flow, many small organisms, including some larval fish, have evolved

behaviors that move them into water with higher velocities during the flood tide and lower velocities on the ebb tide. These behaviors may produce a net upstream movement to counteract losses due to the net river outflow (Bennett et al. 2002, Kimmerer et al. 2002). Changes in these cues due to management actions, or the ability to respond to such cues due to other environmental changes (e.g., contaminants - Little and Finger 1990, Sandahl et al. 2004), may alter movement patterns in ways that disrupt a how a species progresses through its life cycle (Figure 3).

- Table 3 identifies important biogeomorphic processes that determine the quality of the habitats for the different life stages of each species. For example, splittail attach their fertilized eggs to submerged aquatic vegetation on floodplains (Sommer et al. 1997). Therefore, the extent, structure, and composition of floodplain vegetation and the frequency and extent of flooding influence spawning success. Further, processes such as flow, wave energy, marsh accretion, and subsidence of Delta islands can indirectly affect spawning success through their effects on vegetation structure.
- Table 4 identifies critical processes in lower trophic levels of the food web that structure the habitat quality for fish, in particular through the effects of these processes on the growth rates of Covered Species within each of their habitat types. Growth rate, in turn, affects survival and reproduction because body size is a major determinant of the vulnerability of fish to predation and because maturity and fecundity are size-dependent (Rose et al. 2001). Critical processes that affect food web dynamics include the energy inputs in terms of primary organic material, the structuring of predator-prey communities, and the effects of non-native invasive species on the food web dynamics. For example, the western Delta and Suisun Bay, which provide habitat for juvenile to adult Delta smelt, contain invasive clams that consume Delta smelt prey and therefore can affect Delta smelt growth and survival. Food web processes can also affect the Covered Species by affecting their predators.
- Table 5 identifies contaminants that have the potential to affect the growth, survival, and reproduction of the Covered Species as they develop through their life cycle. The table considers current-use and legacy pesticides; mercury, selenium and other metals; polychlorinated biphenyls, and polyaromatic hydrocarbons. The table notes pathways by which the chemicals move through the habitats of Covered Species, their indirect effects on Covered Species via the food webs, and some direct effects on the Covered Species.

Together, Tables 1 through 5 describe the environment in which the Covered Species complete the portion of their life cycle that occurs within the Delta. Understanding how environmental factors affect the population dynamics of Covered Species is central to predicting how Covered Activities and conservation strategies may influence those species. Uncertainties regarding future changes in these environmental factors, and how cumulative uncertainties influence predictions of species response, must be considered in conservation planning (Recommendation R13).

R13. Identify how anticipated changes in environmental conditions, including those associated with Covered Activities and climate change, propagate through populations of Covered Species, and consider how uncertainties regarding future environmental conditions potentially influence population response to Covered Activities.

The complex life cycles (e.g., use of multiple habitats by different life stages) and the diversity of life history strategies (i.e., different collections of vital rates) of the Covered Species will complicate evaluation of management and conservation actions. There will likely be trade-offs among the species of concern (Principle M). The effects of management and conservation actions on population dynamics of Covered Species will be constrained by unknown bottlenecks (i.e., constraints on life stage survival and reproduction from environmental and other factors) within and outside of the Delta (Recommendation R14).

More-detailed descriptions of how to consider limiting stages or bottlenecks in a population's life history can be found in McElhany et al. (2000) and the OCAP review (Technical Review Panel 2005). These two papers addressed the concept of viable salmonid populations. The papers described four parameters that are central in evaluating population status, and ultimately, population viability: abundance, population growth rate, population spatial structure, and diversity (life history and genetic). For anadromous fish species that use the Delta as a migration corridor, improvement in water quality or other environmental conditions in the Delta may not have proportional responses at the population level. In general, anadromous fish in the San Joaquin River appear to be more sensitive to conditions in the Delta during migration than fish in the Sacramento River (Technical Review Panel 2005). Under the best passage conditions, the Delta will have limited negative impacts on survival and reproduction of anadromous fish. However, if physical and hydraulic configurations act to block migration, divert fish into the pumps, or extend migration time, then the effects of management actions in the Delta could be negative and significant. In neither case is it obvious how the populations will respond to within-Delta actions because of the potentially large effects of conditions outside of the Delta.

R14. Examine possible bottlenecks at other life stages, including those that occur outside the planning area, rather than only those at the life stage immediately affected by Covered Activities or within the Delta. Bottlenecks at other life stages can modulate the population response to changes in environmental conditions within the Delta.

Table 1- Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem				
Critical Process/ Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**
Riverine inflows	Riverine inflows are a key driver of the hydrodynamics of flow and transport (scalar, biotic) in the Delta channel system. Characteristics include daily flows and concentrations of dissolved constituents such as organic matter, nutrients, and contaminants, as well as particulate organic matter, sediment, and biota. Time scales range from minutes (flood flows) to seasons to decades and longer. Periodic and aperiodic variability is strongly coupled to climate and weather. Trends are strongly driven by climate change and human alteration of the catchment, including systems that affect upstream water resources (e.g., dams and reservoirs, diversions, return flows, levees).	Inputs of constituents from the watershed are strongly dependent on riverine inflows at all times. Current understanding at the level of fundamental processes is high. Data are available only for a few specific locations.	Understanding of variability (including extreme events) and the influence of climate is moderate.	Variability is very high, limiting predictability. Modeling tools exist, but application at relevant scales is limited by computing capacity, and especially by limited availability of characterization data. Hydrologic models are calibrated to existing conditions, which constrains applicability under changed conditions. Confounded by non-physical elements of upstream operations, e.g., operating rules and emergency actions

Table 1- Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Tides	Mixing in the Delta is largely driven by tidal flows (Burau *in press*). Net flows in western Delta channels are modest relative to tidal flows, except during flood periods (Burau *in press*).	Tides in the San Francisco Estuary have principal periods at ~12.4 and 25 hours and 2 weeks, but many other tidal periods are present, and tides are modified by non-periodic oscillations in water level in the ocean due to wind set-up and atmospheric pressure fluctuations. Existing network of tide gages at the Golden Gate and around the estuary provides high-frequency traces of water-surface elevation.		High predictive ability for the astronomical tides through tide tables. Moderate predictive ability for non-periodic modifications because the controlling processes are not predictable over time scales longer than hours to days. Tides may be modestly affected by sea level rise, which is moderately predictable.
Sea level	Mean sea level defines the base level of the seaward boundary of the estuary and thus is a critical driver for tidal processes in the estuary including the Delta. Sea level is predicted to rise over the time scales of an NCCP/HCP. Some recommend planning for a rise of 50-140 cm by 2100[9]. A rise of this magnitude will cause inundation in some low-lying areas and can alter thermal and salinity regimes, pumping heads, wave regimes.	Mechanisms leading to changes in mean sea level and non-periodic modification of the periodic tide are well understood. Substantial, long-term historic data are available at a number of locations near and within the Bay-Delta system.	Prediction of rates and extents of change.	Sea level rise is a near certainty and has been observed. The rate of sea level rise is only moderately predictable over the period of the NCCP/HCP because of inherent stochasticity in climate, incomplete data, and dependence on future human behavior and policy decisions.

Table 1- Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Water exports	Large volumes of water are diverted from the freshwater Delta by large state and federal pumps in the southern Delta. This water supplies farms and cities throughout central and southern California, some in the San Joaquin basin and some outside. Fish facilities associated with the pumping plants extract fish from the water and return them to the estuary, but these facilities are not very efficient, and there is considerable concern over the number of fish killed and the potential population-level consequences[11] .	Export flows are set by operators, and water is released from reservoirs in the Sacramento basin to meet export needs and salinity or other standards in the estuary. The quantity exported is well known, but the impacts to fish are only beginning to be quantified.		High for flow.
In-Delta Diversions	Substantial volumes of water are diverted from channels and ground water within the Delta. Diversions influence in-Delta flows[12] and may remove substances and organisms from the Delta.	The nature of most surface-water diversions is well-understood. The quantity and timing of diversion flows is estimated from cropping patterns and weather, which is a crude estimate. Estimates are unavailable for actual diversion volumes. Coupling between surface water and ground water is well understood, but has received relatively little attention in the specific context of the Delta.	Ground water diversions and their impacts on surface waters.	Moderate predictive ability on time scales of months, since magnitude and timing are dependent on weather, water law, population growth, land use, etc.

[11] Brown et al. 1996, Kimmerer in press.
[12] Kimmerer and Nobriga in press

Table 1- Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem				
Critical Process/ Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**
Return flows	Some of the water extracted and used within the Delta may return to the Delta (e.g., wastewater treatment plant (WWTP) discharges, island drainage, ground water seepage to channels)	High level of understanding for the underlying physical processes, although return flows have received relatively little study. Data are available for WWTP discharges. Few data are available for return flows via ground water seepage or island pumping.	Quantity of return flows. Ground water seepage or island pumping.	Moderate predictive ability for large-scale exports and point return flows (e.g., WWTPs) due to unpredictability of future patterns of weather, climate, population growth, land-use change, etc. Moderate predictive ability for distributed return flows in a bulk, temporal sense, (e.g., as a fraction of diversions), but low for specific return flows due to variability in subsurface properties, vegetation patterns, etc.
Weather	Solar radiation, air temperature, relative humidity, wind speed and direction drive a number of important processes and conditions e.g. water temperature, precipitation, snowmelt, evaporation/transpiration, water waves and set-up, and demands for water diversion and export (especially for irrigation).	High level of understanding of basic processes at local spatial scales. Moderate for variability (including extreme events) and climate drivers, and for conditions over large spatial extents at shorter time scales. Data are limited to specific measurement locations; but improved remote sensing instruments show promise.	Connections between climate change and local weather changes.	Low to moderate predictive ability. Weather forecasting remains constrained by stochasticity (limits predictability over long time scales).

Table 1- Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Land use	Land use plays a significant role in determining the magnitude, rates, and trends in many other Delta system drivers. Especially critical are land use changes that can alter the hydrologic response of catchments to precipitation, demand for water, return flows, and constituents in inflows and return flows.	Moderate level of understanding for the mechanisms connecting land use changes to changes in hydrologic response. Aggregated data sets of land use are available across a wide range of relevant scales. Substantial local land use data are available, but dispersed and inconsistent, making aggregation difficult. Remote sensing and GIS tools are increasing in use and improving in capacity and ease of use.		Low to moderate predictive ability due to dependence on population growth, policy decisions, etc.
Levees/barriers/ gates	Barriers within the Delta can significantly affect flow, transport, and mixing. Levees influence channel flow geometry, friction, and channel-island exchange. Levee failure causes a rapid change in physical configuration of the Delta and a short-term intrusion of saline water into the Delta .	Physical processes are well-understood but friction parameters are not well known. Moderate knowledge of levee geometry and local data on structures. Data on the condition of levees are limited but growing		Moderate predictive ability. Non-catastrophic performance predictable with available tools. Prediction of catastrophic performance limited by lack of detailed spatial data and dependence on the stochasticity of weather, climate, and earthquakes.

Table 1- Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Bathymetry	Water depth and distribution is a fundamental influence on hydrodynamics. Complex bathymetry at channel junctions and bends is an important influence on tidal dispersion. Shallow water limits the height of wind waves and water depth determines their interaction with the bottom, which can stir up sediment.	The positions of most Delta channels are fixed but cross- sections and bed forms are dynamic. USGS recently compiled a 10 m grid of depth from 9 km inland of Mare Island and 10 km from Sacramento south to Mossdale[13]. Many surveys used to provide bathymetric data are decades old.	Detail around junctions and bends. Bed forms and their movement[14]. Inconsistent survey-to-survey accuracy limits accuracy of USGS grid. Major change possible with levee failure.	Small changes in bathymetry are influenced by sediment inflows. Bedload is a small fraction of total sediment inputs from the Sacramento River but poorly documented. Levee failure is the most significant likely future change (unless new dredging of navigation channels occurs).
Shorelines	Slope, sediment characteristics, and exposure to wave action influence colonization by plants and use by aquatic animals. Fetch, or the distance over which wind waves are produced, determines wave height for a given wind speed and thus is an important influence on erosion of shorelines.	General typology of bank forms and characteristics are well established (few natural shorelines remain). Limited studies of bank erosion by boat wakes[15].	Detailed mapping of shoreline type and characteristics	Most Delta shorelines are managed. Major changes associated with levee failure and responses.

[13] http://sfbay.wr.usgs.gov/sediment/delta/index.html
[14] Sand dunes > 3m high have been documented in Three Mile Slough (Dinehart, USGS)
[15] Bauer et al. 2002

Table 1- Assessment of Knowledge Base, Uncertainty and Predictive Ability for Important Drivers of the Delta Ecosystem

Critical Process/ Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability
Topography	Fundamental control on inundation regimes (see Section 3.5).	Recent Light Detection and Ranging (LIDAR) surveys will provide the best synoptic data. Subsidence rates of up to 4 cm/yr have been documented in peat soils[16]. Peat has been eliminated in some parts of delta; subsidence continues in the central, western and northern Delta. Peat strata are thickest in the western Delta.	Effect of alterations in land use on subsidence. Consequences of levee failure.	Low predictive ability for land use effects.

[16] Rojstaczer and Deverel 1995

Table 2 – Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes					
Critical Process or Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Hydrodynamics	Hydrodynamics in the Delta are driven by tides, freshwater flows, water exports and local diversions, and atmospheric forcing.	The geometry of the Delta is highly altered from its historical structure of dendritic sloughs. Today, the Delta consists of a network of interconnected channels that extend around Delta Island, leading to circular flow paths that are distinctively different from the branching structure of the historical Delta. Hydrodynamics in the Delta are governed by a combination of tidal motions and net, river-derived flow. Net flow transports water and its dissolved and particulate constituents, and tidal exchange mixes and transports water and constituents. Tidal exchange becomes increasingly important moving from east to west, and as river flow decreases. The complex phasing of tidal flows at the intersections of channels can determine transport. A critical parameter is the ratio of tidal excursion to channel length: where this parameter is large, the flow environment will be highly dispersive and the hydrodynamics of the junctions will be control transport. Where this parameter is small, as in the eastern Delta which is more under the influence of river flow, transport is largely driven by the net flow. When salt penetrates into the western Delta, stratification and density-driven net flows (e.g., gravitational circulation) may have important effects on salt transport and mixing.	Temporal and spatial details become progressively more difficult to predict at smaller scales.	Variable predictive ability. In general, the ability to predict physical characteristics in the Delta, including hydrodynamics and transport of constituents (salinity, temperature, turbidity and particles), increases with increasing spatial and temporal scale.	Exports, reservoir releases, configuration, barriers, dredging in channels (see Table 1).

Table 2 – Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes					
Critical Process or Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Transport of dissolved constituents (Eulerian transport)	The transport and dispersion of water constituents (salinity, temperature, suspended sediment and contaminants) are dominated by the interaction of tidal hydrodynamics with the complex geometry of the Delta	Much of the Delta is strongly tidally dispersive, but becomes increasingly advective towards its northern, eastern, and southern boundaries. Increases and decreases in freshwater flows and exports shift the boundaries between "advective" and "dispersive" environments. Large-scale dispersion in the Delta is largely determined by flow interactions with a number of local features. Most common of these are channel junctions, which split the flow and separate water parcels rapidly and broadly. Open tracts of water (Franks Tract, e.g.) alter the transport pathways through the Delta, and their influence may vary seasonally.	A quantitative measure of Delta-scale dispersion is not readily available. The vertical variation of flows, particularly in junctions, is not well resolved.	Dispersion in the Delta can be well modeled with a highly resolved two-dimensional model as long as the hydrodynamics are accurately represented. Most hydrodynamic models of the Delta are well-calibrated to current conditions (geometry, range of flows, etc.); their performance under scenarios of large-scale change would be uncertain.	

Table 2 – Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes					
Critical Process or Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Transport of particles (Lagrangian transport)	Lagrangian transport applies to any constituent for which history is important. Examples would include the dynamics of reacting contaminants or individual-based modeling of biota.	Particle transport in the Delta is governed by the same hydrodynamics as for dissolved constituents, but the resolution required is much finer (i.e., the scale of the particle under consideration). If the velocity distribution and turbulent coefficients were known exactly, transport of particles could be easily calculated. In channels, the lateral and vertical velocity structures are reasonably well understood, with possible limitations in the cases of strong curvature or large bedforms (e.g., sand waves). Particle transport is very complex in junctions between channels of different tidal phase, depth, and density of water, and can be very difficult to resolve.	There is a severe lack of Lagrangian data in the Delta so that it is nearly impossible to even assess our ability to accurately predict transport. Some data have been collected at Sherman Lake and the DCC (both drifter studies) and Mildred Island (dye releases). The lack of detailed descriptions of transport and mixing in channel junctions is probably the most substantial limitation in the scientific understanding of transport in the Delta.	Predictability requires a highly-resolved three-dimensional model of water velocities, mixing coefficients, and particle characteristics. This is especially true for junctions where flows are particularly complex.	
Salinity	Salinity transport is largely governed by tidal dispersion and gravitational flow, which in turn occurs due to salinity variations.	Down-estuary the response of salinity to Delta outflows is well-established (X2 relationships.[17]) Within the Delta itself, the importance of tidal dispersion processes means that X2-type relationships are unlikely to hold. Movement of the salinity field into the Delta creates new dispersion mechanisms due to density forcing in the complex channel network.	Quantitative measures of tidal dispersion in the Delta are limited. In the case of a large event like a levee failure, prediction of salinity intrusion into the Delta becomes more difficult and would likely require a three-dimensional approach.	The prediction of salinity movement into the Delta is difficult because of uncertainties associated with Delta dispersion, and because density stratification and gravitational circulation are themselves difficult to predict	

[17] Jassby et al. 1995; Monismith et al. 2002

Table 2 – Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Temperature	Temperature variation is dominated by exchanges with the atmosphere through heating and cooling by solar insolation and surface heat fluxes. Tidal dispersion mixes oceanic temperatures and river temperatures.	Temperature in the Delta is governed locally by a heat balance between inputs from solar radiation and convection, and losses to convection and evaporation. This balance is influenced by the temperature of water flowing in from the rivers, and by exchange with the ocean. Therefore, the statistical relationships between water temperature and air temperature vary spatially throughout the Delta. Although much of the variability in water temperature in the Delta can be explained by variability in air temperature [18], the influences of flow, exchange, and temperatures in the rivers and down-estuary are also important. For example, recent analysis [19] of historical water and air temperature records indicate that at stations near temporary barriers in the South Delta, the correlation between water temperature and air temperature changes when the barriers are in place.	Local variations in forcing due to, for example, shading, sheltering from wind, and channel morphology, will create local variations in temperature. Data to drive analysis at these small scales are not available.	Predictability depends on scale, but data requirements for atmospheric forcing (e.g., insolation, convection, evaporation) could be large. A three-dimensional modeling approach may be required due to the vertical structure created by heating/cooling at the air-water interface	

[18] Kimmerer 2004
[19] Stacey and Wagner *unpublished*

Table 2 – Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Physical Processes					
Critical Process or Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Turbidity	Sediment dynamics are strongly governed by hydrodynamics, but complicated by the supply of sediment and the interaction of the particles with the bed through deposition and resuspension.	Sediment supply from the rivers depends strongly on river flow, but may be lower than historical values because of trapping behind dams. While in suspension, sediment is subjected to transport by the tidal currents in the same way as dissolved constituents. Particles move into or drop out of suspension depending on the bed stresses created by the tidal flows (in the channels) and wind waves (in the shallows). The size distribution and composition of the particles can also change due to flocculation in low-salinity water and the aggregation of particles due to 'sticky' biological films. The interaction of flows with the bed are strongly modulated by the presence of submerged vegetation (notably the Brazilian waterweed, see below). The reduction in turbulence due to vegetation allows particles to drop out of suspension, clarifying the water in areas of extensive vegetation.	Threshold for resuspension uncertain due to two factors: 1) Determining the hydrodynamic bed stress, and; 2) Determining threshold values of the bed stress for resuspension and deposition.	Prediction of bed stresses is difficult due to: 1) Importance of wind waves in shallows; 2) Bed forms; 3) Bed movement, and; 4) Effects of vegetation on bed stresses.	

Table 3 – Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Biogeomorphic Processes

Critical Processes/Factors	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Attenuation of flow and waves by vegetation	The presence of emergent and submerged vegetation impedes flow and reduces wave energy, resulting in decreased turbidity, reduced bed stress, and sediment deposition. Tidal pumping in the Delta is influenced by extensive SAV[20].	Direct effects of vegetation on flow and waves have been studied in a few cases[21] and only recently in the Delta[22] . The drag created by submerged vegetation directs the primary flow paths over the top of the vegetation. Vertical exchange across the top of the canopy by turbulence produced in the resulting shear layer dominates the exchange between the open water and vegetated regions of the Delta. Field and laboratory studies show the importance of turbulence and drag around stems and through foliage are important[23]. Studies of wave attenuations how non-linearities associated with depth of inundation and length scale of vegetation[24].	Characterization of buoyancy and flexibility of the vegetation in response to inundation and flow. Small-scale vegetation-flow interactions and how they produce turbulence.	Application of analytical theory is limited by the lack of detailed knowledge of vegetation characteristics[25]	Control measures for Brazilian water weed limit its influence but must be repeated continually.

[20] SAV (submerged aquatic vegetation).
[21] For example, Leonard and Reed 2002; Howe et al. 2005; Chrstiansen et al. 2000; Tsihrintzis 2002.
[22] Sereno *unpublished*
[23] For summary see Tsihrintzis 2002.
[24] For example Koch et al. 2006; Mazda et al. 2006
[25] Analytical theory has been well developed by Nepf and co-workers among others (e.g., Nepf 2004) and has been field tested with relatively rigid vegetation (Lightbody and Nepf 2006). However, this has not yet been fully applied to flexible and buoyant SAV like Brazilian water weed.

Table 3 – Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Biogeomorphic Processes

Critical Processes/Factors	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Marsh vertical accretion	The vertical accretion of tidal marshes in the Delta allows them to keep pace with sea-level rise.	Accretion is controlled by mineral sediment deposition and soil organic matter accumulation. Limited studies within the Delta of contemporary accretion dynamics show sediment supply is greatest close to the Sacramento River, and organic accumulation is relatively constant across the Delta[26]. The response of vegetation to salinity changes associated with sea-level rise is driven by complex interactions between soil salinity and inundation[27]. Studies in Suisun Marsh show low sediment input to high marshes and accretion dominated by organic accumulation[28].	Rates of net belowground production (production less decomposition) in tidal fresh and low-salinity brackish marshes in the Delta and its sensitivity to changes in inundation and salinity. The response of vegetation, especially in more brackish areas, to changes in timing of freshwater inflows[29].	Available models for vertical accretion[30] require local data on soil characteristics, which themselves are highly variable, so models have not yet been applied in the Delta. Most models of vegetation response to changes in salinity and inundation are empirical[31] and cannot be applied in the Delta.	Changes in salinity and nutrient inputs influence vegetative growth and organic accumulation. Influence of increased atmospheric CO_2 on plant productivity.

[26] Reed, 2002

[27] Few plant species tolerate salinities approaching 0.5 seawater strength, although even higher salinities and hypersaline conditions occur seasonally on the marsh plain due to salts in tidal waters and evapotranspiration concentrating salts in the root zone. Strong seasonal variation in salinity is important for controlling the distribution of some brackish marsh species, with low winter and early spring salinity promoting the canopy development stage and tolerance of higher salinities in late summer when annual expansive growth is complete.

[28] Culberson et a l. 2004

[29] Vegetative growth of most salt marsh species, with the exception of the hypersaline *Salicornia virginica*, generally begins with mild late winter temperatures in February and March and peaks in late spring when salinities begin to rise (Ustin et al. 1982; Pearcy and Ustin 1984).

[30] For example Rybzyck et al. 1998

[31] For example Reyes et al. 2000

Table 3 – Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Biogeomorphic Processes

Critical Processes/Factors	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Subsidence reversal	High rates of subsidence on Delta islands used for agriculture are of concern due to the increasing potential for levee failure. Subsidence reversal by converting land use to permanent shallow flooding has been proposed to limit oxidation of existing peat and promote the accumulation of new organic material.	An experimental study has been underway at Twitchell Island since 1997. Unpublished results show average vertical elevation change of approximately 4cm/yr in managed tule/cattail stands. Field studies of tidal marshes show lower rates of accumulation. Preliminary findings from Twitchell Island experiment show variations in vertical change with hydrology.	‘Optimal’ hydrology not yet determined. Effect on wildlife of large-scale change from agriculture to tule/cattail stands.	Predictions of the effectiveness of subsidence reversal techniques will require mechanistic understanding of the processes.	Requires continued intervention.

Table 4- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Food web Processes

Critical Process or Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Energy Inputs (unvegetated open water)	Inputs of energy (as organic matter or sunlight) provide the basis for all biological activity in an estuarine ecosystem. Declines in the production of organic matter in the Delta and Suisun Bay are likely responsible for declines in some aquatic organisms, including some covered species.	Principal source of organic matter available to Delta open-water food web is phytoplankton (microscopic algae) [32], but in brackish water the foodweb depends largely on bacteria, implying a subsidy of phytoplankton-derived organic matter from freshwater or marine water. Phytoplankton growth is limited by light, which greatly reduces the probability of eutrophication (excessive growth of phytoplankton)[33] Phytoplankton abundance and production in the Delta have declined substantially in recent decades.[34] The decline in brackish water is probably due to grazing by the overbite clam, but the cause of an earlier decline in freshwater has not been identified. Accumulation of phytoplankton depends on conditions for growth and losses to clam grazing and to transport in the water, so areas of sluggish circulation with few clams (e.g., southern Delta) have high phytoplankton biomass. Water exports remove about 18% of annual phytoplankton production in the Delta, but this loss was a relatively small component of the mass balance of phytoplankton.[35]. Studies in Suisun Bay show phytoplankton growth can be suppressed by high concentrations of ammonium at high light levels.[36] The blue-green alga *Microcystis* has formed blooms in recent years that may be causing problems in the food web.	Spatial distribution and abundance of clams. Resolution of the role of ammonium. Importance of *Microcystis* blooms in producing toxins and disrupting foraging by animals	Moderate	Human control over phytoplankton of the Delta is extremely limited. Ammonium inputs from sewage treatment plants could have some negative influence. Changes in hydrodynamics (especially residence time) could be important. These changes could be overwhelmed by the effect of clam grazing.

[32] Jassby et al. 1993; Sobczaket al. 2005; Sobczak et al. 2002.
[33] Cloern 1999; Lopez et al. 2006; Lucas et al. 1999a; Lucas et al. 1999b.
[34] Jassby et al. 2002.
[35] Ibid.
[36] Wilkerson et al. 2006.

Table 4- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Food web Processes					
Critical Process or Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Foodweb Dynamics (unvegetated open water)	Declines in estuarine fish may be linked to changes in the abundance of their prey (mostly zooplankton).	There is a fundamental difference in how planktonic and benthic (bottom-dwelling) animals respond to changes in salinity. Plankton do not experience rapid changes in salinity because they move with the water. Benthic organisms are more subject to variable salinity since they stay in place on the bottom. Zooplankton include small forms (rotifers and the larvae of copepods) and larger zooplankton, mainly cladocerans in the freshwater Delta and copepods in brackish water [37]. Mysid shrimp are less abundant than in the past – many fish species now feed more on introduced amphipods (some associated with waterweed beds) than on mysids [38]. Zooplankton feed mainly on phytoplankton in freshwater and on ciliates in brackish water; the ciliates are part of a microbial foodweb based on both phytoplankton and bacteria.[39] Species composition of zooplankton has changed especially since the invasion of the overbite clam. Plankton populations have responded to changes in abundance of major predators (e.g., decline in northern anchovy) and new invasions (e.g., *Limnoithona tetraspina* in 1993). Zooplankton, freshwater clams, and juvenile Delta smelt experience food limitation.	There is no monitoring program for ciliates, bacteria, and other microbes. Abundance of clams (especially the freshwater clam) is not adequately monitored because of their great spatial variability in abundance. Extent of consumption of zooplankton by freshwater clams is unknown. Salinity response of clams is unknown. Importance of hydrodynamic connections including losses to export pumping and local diversions, and changing hydrology and salinity distributions.	Low	There are few opportunities to manipulate or control food web dynamics. It might be possible to control clam distributions by manipulating salinity, but this must be thoroughly investigated before it is attempted in the Delta.

[37] Orsi and Mecum. 1986.
[38] Feyrer et al. 2003; Nobriga 2007
[39] Zooplankton in the freshwater Delta consume mainly phytoplankton (Müller-Solger et al. 2002). However, in brackish regions they feed mostly on single-celled ciliates (Bouley and Kimmerer 2006). Gifford et al. *in press*; Hollibaugh and Wong (1996); Sobczak et al. (2005); Sobczak et al. (2002) suggest a subsidy of phytoplankton-derived organic matter to the Low-Salinity Zone, possibly from the freshwater Delta, and a foodweb based on bacteria more than phytoplankton.

Table 4- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Food web Processes					
Critical Process or Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Foodweb Dynamics (vegetated water bodies)	The foodwebs associated with submerged vegetation (mainly Brazilian waterweed) support some species of fish, although these may be fishes that prey upon covered species.	Fishes of vegetated margins are supported by a different foodweb from fishes in the open water [40]. This little studied foodweb is based mainly on algae that live on the vegetation rather than the vegetation itself. Fishes primarily prey on amphipods (crustaceans).	Degree of interaction with open-water foodwebs. Energy balance and overall productivity	Moderate; presumably these foodwebs occur wherever there is submerged vegetation.	Removal of waterweeds would also remove the associated food webs but the impact on open-water food webs is unknown.
Species introductions	Introduced species believed to have had an important impact on the Delta ecosystem include many fish species, Brazilian waterweed and water hyacinth, and the freshwater and overbite clams. The only invasion event whose effect was observed through monitoring and analysis was that of the overbite clam.	Species introduction s can cause rapid changes in the ecosystem such as the decline in phytoplankton and some zooplankton resulting from the introduction of the overbite clam. These changes are not generally predictable because of the multiple foodweb relationships that change when a non-native species becomes established, and because only some non-native species have such profound effects on the ecosystem	Nature of future invasions.	Future introductions are likely to produce large, and largely unpredictable, changes to the estuarine ecosystem.	Changes resulting from invasions could counteract the benefits of restoration or other management actions meant to support covered species.

[40] Grimaldo 2004

Table 5- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants					
Critical Process/Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Pesticides in current use	Winter storm runoff and irrigation return water can contain fertilizer, current-use pesticides, and other chemicals. Organophosphate insecticides are gradually being replaced by pyrethroid insecticides. Large amounts of herbicides are being applied.	Insecticides, in particular organophosphates (e.g. chlorpyrifos, diazinon), have been present at acutely toxic concentrations in tributaries and the Delta[41] Pyrethroids at toxic concentrations have been found in sediment samples from water bodies draining agricultural areas in the Central Valley[42] Dissolved pyrethroid concentrations toxic to aquatic life have been found in water samples from Central Valley agricultural drains and creeks[43] Aquatic plants have been shown to absorb pyrethroids, and microbial assemblages living on the plants may enhance pyrethroid degradation[44].	Geographic and temporal distribution of contaminants within the Delta. Effects of structural changes (wetlands, floodplains) on contaminant dynamics. Contaminant effects on Delta species in the context of their habitats – direct and indirect, lethal and sub-lethal (e.g., on behavior, growth, reproduction). Effects of multiple stressors, e.g. contaminants, high temperature, food limitation, or disease[45]	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Input could be controlled by changes in use and pesticide control methods. Half-lives are relatively short, so existing contaminants would degrade within months-years.

[41] Kuivila and Foe 1995; Werner et al. 2000; California Regional Water Quality Control Board Agricultural Waiver Program 2007
[42] Weston et al. 2004; California Regional Water Quality Control Board Agricultural Waiver Program 2007
[43] Bacey et al. 2005; Woudneh and Oros 2006 a, b
[44] Hand et al. 2001
[45] This uncertainty applies to all contaminant groups described in Table 5.

Table 5- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants

Critical Process/Factor	Description and Importance	Current State of Knowledge	Key Uncertainties	Predictive Ability	Human Intervention/External Factors
Legacy pesticides	Residues of legacy pesticides, primarily organochlorine (OC) pesticides including DDTs, chlordanes, and dieldrin, remain high	In San Francisco Bay, pesticides and their breakdown products occur at concentrations high enough to contribute to advisories against the consumption of sport fish from the Bay[46] Legacy pesticides continue to enter the Bay from the Central Valley, from dredging and disposal, and other sources. DDT and other OC pesticides have been detected in agricultural irrigation ditches and drainage canals of the Delta region[47].	Geographic and temporal distribution of contaminants within the Delta. Effects of structural changes (wetlands, floodplains) on contaminant dynamics. Information on bioaccumulation of contaminants in wildlife and the extent and effects of maternal transfer to offspring. Understanding of the toxic effects of legacy pesticides, singly and in combination, on Delta species.	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Legacy contaminants are persistent and difficult to remove. Other than mechanically removing contaminated sediments, human control is extremely limited. May contribute to advisories against consumption of fish due to high bioaccumulation potential.
Mercury	The Delta, and many of its tributaries, are on the State Water Quality Control Board's 303 (d) list of impaired water bodies because of mercury contamination.	Measured at potentially toxic concentrations, and associated with detrimental effects in some waterbirds in the Bay area[48] . Methylmercury is the most bioavailable and toxic form of mercury. Methylation occurs in wetlands, but rates of production vary widely, and some wetlands even appear to reduce methylmercury concentrations.[49]	Geographic and temporal distribution of mercury within the Delta. Effects of structural changes (wetlands, floodplains) on mercury dynamics. Information on bioaccumulation of mercury in wildlife and the extent and effects of maternal transfer to offspring. Understanding of the toxic effects of mercury, alone or in combination with other contaminants, on Delta species.	Possibly the best understood contaminant in the system[29]. Understanding of the effect of wetlands on biochemical fate of mercury is important for predictability.	Mercury sources are difficult to control. May contribute to advisories against consumption of fish due to high bioaccumulation potential.

[46] Connor et al. 2007
[47] California Regional Water Quality Control Board Agricultural Waiver Program 2007
[48] Conaway et al. 2007 and cited references therein
[49] Alpers et al. *in preparation*

Table 5- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants					
Critical Process/Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Selenium	Selenium is a reproductive toxicant. Selenium in agricultural drainages in the western San Joaquin Valley remains a threat because drainage problems are unresolved. Other sources are refineries (reduced after 1995) and wastewater treatment plants (minor source).	Loading through the San Luis Drain was reported to have caused massive bird deformities and local extirpation of most fish species at the Kesterson Refuge[50]. Loading of selenium to the San Joaquin River from approximately 100,000 acres of the western San Joaquin Valley was authorized in 1995.[51] Selenate, the form of selenium is most common in agricultural drainage, and can be converted to selenite in oxygen-poor environments, such as wetlands and organic-rich, stagnant waters. Selenite is bioaccumulated much more readily than selenate.[52].	Monitoring of the San Joaquin River near Vernalis is minimal and therefore effects of selenium in the Delta are extrapolated with some uncertainty. No monitoring of selenium downstream of Vernalis takes place in the Delta. Selenium inputs in drains, sloughs, and rivers are variable because of biological removal. [53] Information on bioaccumulation of contaminants in wildlife and the extent and effects of maternal transfer to offspring. Understanding of the toxic effects of Se, alone or in combination with other contaminants, on Delta species.	Low	Source control methods to reduce selenium concentration in irrigation return flows are under development.

[50] Presser and Luoma 2006
[51] Presser et al. 2007
[52] In the San Francisco Bay-Delta, Se concentrations in white sturgeon are just above the monitoring threshold of 5.9 µg/g. While these concentrations are below the current USEPA standard of 7.9 µg/g, there is substantial scientific evidence indicating that this standard is not protective enough and more stringent standards for the Bay-Delta are being considered.
[53] Presser and Piper 1998

Table 5- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants					
Critical Process/Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Other Heavy Metals	Dissolved copper concentrations are high in the low-salinity zone (copper is bound to organic molecules in higher-salinity waters, making it less available to biota) Nickel has been identified as an important water pollutant[54] Tri-butyl tin (used in antifoulant paints) is very stable and highly toxic to non-target invertebrate organisms.	Little is known about heavy metal concentration in the Delta.	Geographic and temporal distribution of contaminants within the Delta. Understanding of the effects of structural (habitat for covered species) changes (wetlands, floodplains) on contaminant dynamics. Understanding of the toxic effects of heavy metals, singly and in combination, on Delta species.	Low.	Input could be controlled in some cases (direct application, storm water runoff control).

[54] Yee et al. 2007

Table 5- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants					
Critical Process/Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Polychlorinated biphenyls (PCBs)	PCBs are industrial legacy contaminants, very persistent, and bioaccumulation potential in aquatic organisms is high.	PCB concentrations in some San Francisco Bay sport fish today are more than ten times higher than the threshold of concern for human health[55]. PCB contamination is generally associated with industrial areas along shorelines and urban runoff in local watersheds. PCB concentrations in the estuary may be high enough to adversely affect wildlife.	Although reports[56] suggest that significant PCB loads enter San Francisco Bay through Delta outflow, no monitoring data are available for the Delta. Understanding of the toxic effects of PCBs, singly and in mixture, on Delta species. Information on bioaccumulation of contaminants in wildlife and the extent and effects of maternal transfer to offspring.	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Legacy contaminants are persistent and difficult to remove. Other than mechanically removing contaminated sediments, human control is extremely limited. May contribute to advisories against eating fish due to high bioaccumulation potential.

[55] Davis et al. 2007 and cited references therein
[56] Davis et al. 2007

Table 5- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants					
Critical Process/Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Polycyclic aromatic hydrocarbons (PAHs)	Polycyclic aromatic hydrocarbons (PAHs) are generated by the incomplete combustion of organic matter and enter the aquatic environment through atmospheric deposition or stormwater runoff from roads, urban areas, and industrial areas. Another potential source is creosote, which has been used to impregnate wood products such as pier pilings.	Stormwater runoff from urban and industrialized areas and inflow from tributaries (including the Delta) are the major sources of PAHs in San Francisco Bay. Relatively low PAH concentrations were observed in the Sacramento/San Joaquin Rivers and the Delta during the 1993-2001 monitoring period [57].	Geographic and temporal distribution of contaminants within the Delta. Understanding of other toxic effects of these contaminants, singly and cumulative, on Delta species.	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Could be controlled in part by reducing the input of stormwater runoff.

[57] Oros et al. 2007

Table 5- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants					
Critical Process/Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Emerging Pollutants	A growing number of organic compounds, including flame retardants, pesticides, plasticizers, water repellents, fragrances, pharmaceuticals, and personal care product ingredients can mimic the actions of natural hormones. Endocrine disrupting chemicals (EDCs) can interfere with the hormonal systems in humans and wildlife, and act at extremely low concentrations resulting in negative effects on reproduction and development. Exposure of fish populations to low concentrations of such compounds can have dramatic effects.	High concentrations of flame retardants (polybrominated diphenyl ethers, PBDE) have been found in freshwater clam tissue from the Sacramento and San Joaquin River[58] . Tissue concentrations of PBDE in striped bass and halibut significantly increased in 1997 and 2003. PBDE was also found in least tern (*Sternula antillarum*) and California clapper rail (*Rallus longirostris obsoletus*) eggs.	Distribution and effects of endocrine disruptors on reproduction of Delta species.	Low due to lack of information on environmental concentrations and toxic effects, especially chronic effects.	Better wastewater treatment methodology (enhanced treatment) will potentially lead to breakdown or elimination of these compounds from WWTP effluents, but some chemicals may become more toxic due to chlorination.

[58] Hoenicke et al. 2007

Table 5- Assessment of Knowledge Base, Uncertainty, Predictive Ability and Role of External Factors for Important Chemical Processes and Contaminants					
Critical Process/Factor	**Description and Importance**	**Current State of Knowledge**	**Key Uncertainties**	**Predictive Ability**	**Human Intervention/External Factors**
Nutrients	Un-ionized ammonia (NH_3) can be toxic to fish[59]. Ammonia contributes to the depletion of oxygen in the Stockton Deep Water Ship Channel[60] and creates a barrier to fish passage.	NH_3 has reached concentrations that could be toxic to sensitive fish species such as salmon[61].	Information on sensitivity of Delta fish species to ammonia.	Moderate. Ammonia concentrations have been monitored for decades at some sites in the Delta.	Better wastewater treatment methodology (enhanced treatment) will reduce ammonia load released into Delta

[59] Note that this is a different chemical form from ammonium (the ionized form), discussed under foodweb assessment, above. The two forms are in equilibrium and the relative proportion of ammonia increases as pH and temperature increase.
[60] Jassby and Van Nieuwenhuyse 2005
[61] Vosylien et al. 2003

5.0 ANALYTICAL METHODS

Predicting the effects of Covered Activities and conservation strategies on Covered Species and communities is one of the most important tasks for most HCP/NCCPs. At a minimum, the BDCP should analyze individual and cumulative effects of the Covered Activities on populations of Covered Species. This requires assessing effects of the Covered Activities on the various physical, chemical, and biotic processes and gradients influencing population dynamics (Section 4.3). The Plan should also explicitly disclose and address uncertainties about these predictions and should address how foreseeable changes in the system (e.g., sea-level rise and other consequences of climate change, changing salinities) are likely to affect species and ecosystem processes over at least the 50-year permit duration. The scale of the area influencing the Delta (Principle C), the inherent variability in ecosystem processes (Principle D), and the need to address both conservation measures and other foreseen changes in the system (Principle B) means that analyses in support of BDCP planning and implementation must embrace a wide range of processes and uncertainties (Tables 1-5).

Detailed consideration of uncertainties requires more information on Covered Activities and conservation strategies than is currently available. In addition, detailed consideration of analytical tools was beyond the scope this group of advisors was convened to address. In this section, the Advisors offer some initial recommendations concerning appropriate approaches to analyze Delta hydrodynamics and population dynamics of Covered Species. The intent here is not to provide a comprehensive evaluation of all available tools and models. The Advisors recognize the urgent need for in-depth consideration of analytical tools and assessment techniques, beyond that provided here, to support BDCP planning and implementation (Recommendation R15).

R15. When potential Covered Activities and conservation strategies have been developed, convene a group of science advisors with experience in systems analysis, ecosystem restoration, modeling, population and food web dynamics, and other relevant disciplines to identify appropriate analytical tools and assessment techniques to support conservation planning and implementation in the Delta.

5.1 Hydrodynamic Analyses

The Sacramento-San Joaquin Delta is an unusual hydrodynamic environment due to strong tidally driven flows in a channel network. The interaction of tidal flows with this geometry creates a highly dispersive environment, in which the phasing of flows in intersecting channels strongly determines dispersion throughout the system. While the net flows affect transport over large spatial and temporal scales, the dispersion of salt, temperature, phytoplankton, and other constituents is much more strongly influenced by tidal-timescale flows. As a result, any hydrodynamic model that is used to predict transport and dispersion in the Delta must accurately predict the tidal flows, including the phasing of flows in intersecting channels (Recommendation R16). Transport models may be based on fundamental physics, or may use empirically determined dispersion coefficients. Because these coefficients are not based on fundamental processes, they will have limited utility in forecasting future conditions, especially changes involving large-scale alterations in the configuration of the Delta (Recommendation R17).

R16. Use a hydrodynamic model that is based on fundamental physics and that accurately reproduces tidal flows in the system for analysis of Delta transport and dispersion, and particularly for prediction of the effects of proposed management scenarios on hydrodynamics.

R17. Use data that span as broad a range of hydrologic and operational conditions as possible to evaluate a model's performance and increase the probability that the model will have sufficient accuracy and precision for evaluating management scenarios.

The appropriate dimensionality of a model will depend on the target of the analysis. For many dissolved substances, a depth-averaged (two-dimensional) tidal model that can accurately reproduce the tidal flows, including the phasing in junctions, is likely to be sufficiently accurate (Recommendation R18). This is because much of the Delta is relatively shallow and unstratified, resulting in limited vertical variability in the concentrations of dissolved substances. To examine the distribution of dissolved substances, it is not critical to resolve the vertical structure of the flows. Instead, computational effort would be better focused on quantifying temporal variability on the tidal time scale and the horizontal variability of flows in intersecting channels and junctions.

Resolving vertical structure of flows is more relevant for constituents that produce density stratification (salinity and temperature), settle through the water column (sediment), or have their own behavior (fish). In each of these cases, a higher dimensional model may be required. For example, one would expect the initial dispersion of salt into the Delta from Suisun Bay resulting from a levee failure to be dominated by tidal dispersion processes (the phasing and interaction of tidal flows). This aspect of the salt intrusion would be well represented by a depth-averaged tidal model. Once the salt field enters the Delta, however, the density gradients that are created lead to further intrusion. The resulting gravitational circulation brings saline waters upstream in the deep portions of the Delta (e.g., San Joaquin and Sacramento channels) and moves relatively fresh water downstream at the surface. This exchange flow will not be well represented in a depth-averaged model (Recommendation R18). One alternative is simply to pursue a three-dimensional model, which would require significant computational effort. Another alternative is to parameterize the effects of exchange flow through a supplemental along-channel dispersion coefficient (Chatwin 1976) that includes a threshold based on the local salinity gradient (Stacey et al. 2001).

R18. Use models with appropriate dimensionality for the target of the analysis:

- ***a. Use a two-dimensional, depth-averaged analysis to predict transport of passive dissolved substances.***
- ***b. Use a three-dimensional hydrodynamic model to account for both tidal dispersion processes and gravitational circulation associated with salinity intrusion into the Delta, or parameterize gravitational circulation based on local density forcing.***

The integration of particle (or organism) behavior into transport analysis requires refinement of hydrodynamic models of the Delta. As with the other transport analyses, the tidally driven flows, including the phasing of flows in intersecting channels and the resulting flow structures that arise in channel junctions, must be accurately predicted. At the same time, many species have limited ability to swim relative to tidal currents, but they are capable of vertical and lateral migrations that allow them to selectively sample tidal streamlines (see Section 4.3). As a result, a hydrodynamic model must accurately resolve the vertical and lateral structure of both the mean flows and the turbulent motions (Recommendation R19). Developing such a model will require additional data collection and hydrodynamic analysis to establish the lateral and vertical structure of flows in channel junctions. Lagrangian particle trajectories should also be studied in the field (Recommendation R19) and used to evaluate the model's ability to project particle paths, particularly flow paths through junctions.

R19 . To allow integration of particle or organism behavior into Delta transport models

a. Develop a highly resolved three-dimensional hydrodynamic model to produce accurate projections of vertical and lateral variability in channels and junctions.

b. Conduct drifter-tracking studies, especially around channel junctions, to evaluate model ability to predict particle trajectories.

Water temperature affects all vital rates of aquatic organisms, and in some cases (Delta smelt, salmon) adverse effects of high temperature have been demonstrated (Bennett, 2005; Brandies and McLean, 2001). Nevertheless, there is no model of temperature in the Delta that could be used to analyze the effects on biota. Whereas salinity in the Delta is a result of intrusion from the Bay, temperature variation in the Delta is largely forced at a local level by atmospheric heating and cooling (Kimmerer 2004). The influence local atmospheric forcing, however, varies across the Delta because of river inflows and mixing with the lower estuary. The mixing of these adjacent waters alters the correlation between atmospheric conditions and Delta water temperatures. Depending on the spatial and temporal scales of interest, a correlative analysis of atmospheric conditions and water temperatures may be sufficient for predictions of water temperature. However, refining the spatial and temporal details of water temperatures within the Delta requires inclusion of tidal dispersion processes in the analysis (Recommendation R20). At a smaller scale, temperature gradients will develop between Delta channels and shallow environments and between open and vegetated regions. Current understanding of these finer scale variations is limited by uncertainties in how shallow vegetated environments affect temperature and the exchange between shallow vegetated locations and adjacent regions. If the analysis requires data on fine-scale temperature variation between adjacent environments, observational and modeling studies of the effects of shallow, vegetated environments on the local temperature dynamics, including the effects of shading along perimeter waters, will be needed (Recommendations R9 and R20).

R20. Apply an array of tools to improve prediction of water temperature at various spatial and temporal scales:

a. Develop a correlative analysis of atmospheric conditions and water temperatures to assess large-scale variations in temperature.

b. Analyze river inputs and tidal dispersion to predict temperature at finer spatial and temporal resolution.

c. If prediction of fine-scale temperature variation between adjacent environments is desired, pursue observational and modeling studies into the effects of shallow, vegetated environments on local temperature dynamics, including the effects of shading along perimeter water.

Suspended sediments have a variety of important effects on biota, and concentrations of sediments are changing (Table 2). Sediment movement must be modeled at the tidal time scale because particles are deposited and resuspended at short time scales. Tidal dispersion redistributes sediments that enter the estuary from the watershed. To predict future concentrations of suspended sediments, future sediment supply must first be evaluated through an analysis of land use in the watersheds, hydrologic forcing, and reservoir operations. Additionally, short time-scale bed stresses (due to tidal flows and wind waves) and the effects of these bed stresses on sediment resuspension define the key uncertainties in predictive modeling of dynamics of suspended sediment (Recommendation R21). Studies of sediment particle characteristics in the Delta and associated resuspension characteristics are needed to reduce these uncertainties. Once such studies are complete, an integrated hydrodynamic-sediment transport model of the Delta can be developed to predict sediment concentrations and their variability.

R21. Evaluate future sediment supply to the Delta from the watershed, and document sediment resuspension characteristics in the Delta, to support the development of an integrated hydrodynamic-sediment transport model to predict sediment concentrations and their variability

5.2 Approaches to Assessing Population-Level Responses

It is challenging to describe the dynamics of species throughout their life cycles with sufficient accuracy and precision to allow for predictions of the effects of alternative managements actions on population dynamics. We recommend that analyses be performed on a population level for pragmatic reasons (e.g., data availability, tractability) but viewed in an ecosystem context (i.e., analyze populations but think ecosystem). The analysis of effects of environmental changes in the Delta on Covered Species depends on the development and application of a variety of predictive models. These models depend on accurate and somewhat mechanistic descriptions of environmental influences (Figure 2). Hydrodynamics strongly affects biological interactions and the distribution of salinity, temperature, turbidity, and vegetative cover that influence Covered

Species both directly and indirectly (Section 5.1). For example, turbidity (Table 2) has a direct influence on at least some of the Covered Species. Delta smelt will not feed in clear water (J. Lindberg, UC Davis, pers. comm.), and the abundances of Delta smelt, threadfin shad, and young striped bass in autumn increase as turbidity increases (Feyrer et al. 2007). Presumably these species can forage more efficiently where turbid water provides some protection from predators. Turbidity also has a direct negative influence on phytoplankton production, so these energy inputs to the food web (Table 4) may increase as the water becomes clearer.

During their juvenile life stages in the Delta, the Covered Species feed mainly on zooplankton, epibenthic crustaceans (e.g., mysids and amphipods), and insects. Analyses of Covered Species currently treat their food sources as a static input. However, the abundance of zooplankton and epibenthic crustaceans is highly dynamic. Models and analyses of Covered Species could be improved, and the range of applicability of the models and analyses increased, by including some dynamic aspects of their food supplies (Recommendation R22).

R22. Develop spatially-explicit models of plankton dynamics, and institute monitoring to provide necessary input to these models, to improve prediction of Covered Species responses to changing environmental and food web conditions.

The Advisors suggest that the evaluation of the potential effects of Covered Activities on populations use a step-wise approach involving both qualitative and quantitative models. While the analyses should be at the population level, the analyses must be set in an ecosystem context. The qualitative models (conceptual models, such as those being developed by POD and DRERIP) provide a common framework for discussion, for evaluating expert opinion, and for general planning and research on Delta processes. Quantitative models, including both statistical (e.g., regression) and process (population dynamics) models, are valuable for exploring the possible effects of current and future management actions.

The Advisors suggest using a stepwise approach based on the life cycles of the Covered Species (Recommendation R11). Evaluations might begin with analyses of how potential changes in environmental conditions caused by management actions (e.g., flow, salinity, temperature, turbidity, vegetation) would affect each of the vital rates of the life stage(s) known or thought to be *directly* affected by those actions. The next step would examine if and how the environmental changes could directly affect the vital rates of *other life stages*. In addition, analyses should examine how direct effects of Covered Activities on one life stage may indirectly affect other life stages. By examining effects of management actions on the vital rates of each life stage of the species of interest, and then iterating through all of the life stages, one obtains information not only on responses of key life stages but also on responses at the population level. Availability of data varies among the Covered Species; for some species, such as winter run Chinook salmon and Delta smelt, data are likely sufficient to estimate population level responses. For the less well studied species, analyses may be limited to the response of the directly affected life stage.

Together, qualitative and quantitative models provide a framework for clearly stating assumptions of analyses and allowing others to easily understand and evaluate the analyses (Principle N). Qualitative (e.g., conceptual) models describe important process-response relationships but do not quantify them. Quantitative models are more valuable for understanding specific interactions between the Covered Species and their environment. Quantitative population models include both statistical and process models. Statistical and process models are distinguished based on how they represent the relationship between populations and environmental variables. Statistical models can quantify correlations between environmental variables and the abundance, vital rates, and spatial distributions of populations at different life stages. Statistical models often have weak predictive power, especially for forecasting the responses of populations to environmental conditions that the species have not experienced during the period of data collection.

Process models relate the rate of change in abundance (rather than abundance itself) to environmental and other explanatory variables via mathematical equations (often differential or difference equations). Process models attempt to represent how growth, mortality, reproduction, and movement (i.e., vital rates) are affected by environmental conditions. Process models can also integrate these vital rates across life stages to predict population-level responses, such as annual biomass, biomass production, long-term abundance, resilience (ability of a population to return to baseline after a perturbation), or persistence. Moreover, because they represent how changes in the environment may affect vital rates, process models can also be used to explore how alternative future states of the Delta might affect the population dynamics of the Covered Species. With such models, it is possible to explore the impacts of climate change scenarios, other major environmental changes, and the increasing demands on the Delta ecosystem and its resources. Process models also provide a platform for evaluation of the responses of populations to simultaneous changes in multiple environmental factors. The combined effects of these factors at the population level are often not obvious from the effects of individual factors on different life stages.

Process models are more difficult to validate than statistical models because process models do not have an evaluation criterion like a significance test. In addition, process models must be used cautiously because they include a large number of parameters, not all of the relevant mechanisms may be represented. Development of a comprehensive conservation and management plan will require the complementary use of statistical models and multiple types of process models.

An important step in linking the factors described in Tables 1-5 to population dynamics of the Covered Species is to correlate the spatial and temporal distributions of the environmental drivers with the life history stages of the species (Recommendation R23). For example, because salmon use the Delta as a migratory corridor, it is important to understand how the Delta affects juvenile migration (Figure 3). Vital rates of resident species such as Delta smelt are affected by movement of the species between the juvenile and adult habitats. Accordingly, statistical models can relate the movement of resident and anadromous fish to the environmental factors that cue migrations and flows at the tidal time scale that affect the migrations.

Statistical modeling should also be used to identify correlations between abundance and vital rates at different life stages and environmental variables (Tables 1-5). Although such correlations do not indicate causation, identifying relationships is valuable for developing the process models and prioritizing further analyses and data collection (Recommendation R24). For example, a relationship between Delta water exports and the survival of juvenile salmon passing through the Delta relative to those passing through the lower Sacramento River implicates water exports as a factor in the survival of a key life stage in the salmon life cycle (Brandes and White 2005). Quantifying how vital rates at each life stage are directly affected by Covered Activities, and applying statistical and process modeling to accumulate these effects over the life cycle, is critical to quantifying how the activities will affect the population dynamics of Covered Species.

An extensive database of monitoring information for the Delta is available, and Plan development should take advantage of the reviews and analyses that were performed for the biological opinions (BO), OCAP, the Environmental Water Account (EWA), and the POD. The OCAP review (Technical Review Panel 2005) dealt with the life cycle approach for salmon. The EWA analyses and panel suggestions are relevant given that EWA also was faced with quantifying how changes in water availability (albeit at a smaller scale than may be anticipated under BDCP) might affect the population dynamics of Delta smelt and other species. The POD effort concentrates on understanding the general decline of four species, which including two of the Covered Species. Note, however, that results of analyses conducted for other programs, while helpful, may not be sufficient for evaluating management and conservation actions proposed for the BDCP. Additional analyses tailored to the specific issues related to the BDCP will likely be needed.

R23. Develop statistical models that relate a) spatial and temporal distributions of environmental factors to life stages of the Covered Species, b) fish movement to environmental factors that cue migration, c) net and tidal flows to migration, and d) abundances of the Covered Species at different life stages to relevant environmental variables.

The Advisors emphasize that there are no shortcuts to understanding and realistically evaluating the effects of management and conservation actions on Delta species. Well-informed conceptual models are the foundation. Conceptual models are strengthened with statistical analyses that identify relationships among the species and biotic and abiotic properties of the species' critical habitats inside the Delta and, when relevant, outside the Delta (Figure 3). Finally, the accumulated conceptual and statistical information provides the basis for developing scientifically-sound process-based models of population dynamics (Recommendation R24). Some of the past efforts at process modeling for species in the Delta have tried to simply link correlative relationships across life stages. This rarely results in a process model with any predictive power, and is not recommended. Process-based population models with a long history of development and use, and based on well-known mathematics (e.g., matrix, projection, individual-based), are available for developing scientifically sound models of population dynamics (Caswell, 2000; Grimm and Railsback, 2005). The process models use the information from the statistical analyses, but are not simply a set of linked statistical relationships.

R24. When sufficient information is available and the questions to be addressed are tractable to model, develop and apply process models for Covered Species that are built upon the conceptual and statistical models. These process models can be used for predicting short-term, life stage-specific responses and, in some cases, for predicting long-term responses of population dynamics.

5.3 Cautionary Notes

Models for higher trophic levels are difficult to parameterize and validate because they require a diverse set of information both for their development and to evaluate the effects of many possible predictor variables over different temporal and spatial scales. Species at higher trophic levels also tend to have relatively complex life cycles and live for multiple years. As a result, models for higher trophic levels that truly address population responses must generate long-term predictions that span multiple generations in order to estimate the full effects of responses to environmental change and management actions. The Advisors suggest, as an initial step, the development of a series of process-based models that focus on separate life stages. This approach differs from statistical modeling, as it requires more extensive decisions about temporal, biological, and spatial scale. Before a model can be developed, for example, analysts must specify the time step and the duration of the simulations, the level of biological detail needed (e.g., total abundance, age-classes, individuals), how each of the vital rates will be represented (e.g., assign growth rates or simulate foraging), and the spatial resolution (size of cells). The extent and resolution of a model should reflect the questions it is being used to address.

It is important to consider the potential influence of density dependence on each of the key vital-rate processes. Density dependence usually is assumed to be compensatory (a negative feedback) because as abundance increases, resources become limiting, resulting in changes in the key processes that act to reduce net population growth rate and reduce population size (Rose et al. 2001). However, depensatory density dependence (or Allee effects) is a positive feedback on abundance and thus destabilizes population size. Depensatory density dependence operates when abundance becomes so low that mortality increases or reproduction decreases, thereby decreasing abundance even further (Liermann and Hilborn 2001). It is not clear whether the Covered Species exhibit depensatory density dependence, but because depensatory density dependence increases the probability of extinction of small populations, the possibility should be considered.

Models of higher trophic levels should be developed with great care and scrutiny to increase the probability that acceptable accuracy is obtained in their forecasts. Confidence intervals around model predictions must be quantified. Models will need to represent the environment of the Covered Species at the temporal and spatial scales that affect the vital rates of those species.

As a final cautionary note, the Advisors emphasize that no model, however carefully developed, will describe a sufficiently complete set of mechanisms to allow accurate and reliable prediction of future system states. This situation arises because of lack of knowledge of some key processes or variables, and because a large number of complex processes must be represented simply. Models are, by definition, simplifications of the real system. For example, models of Delta smelt must represent both their prey and their predators with relatively simple relationships based on available data. However, the population dynamics of prey and predators are neither simple nor well understood. Thus, while some aspects of the smelt population could be quite accurately represented in a model, (weight at age), the factors affecting those dynamics (e.g., salinity) might themselves vary in ways not represented in the model. Therefore, the process of developing a model should be seen as iterative, with scientific investigations applied to resolve uncertainties as the model is refined.

5.4 Exploring Future System States

The Advisors caution that models used to predict system responses must explain a considerable amount of the variation in the data used to construct the model. Further, the data used for calibrating the model must represent a broad range of antecedent conditions, including hydrologic and operational variability, in order to increase the ability of the model to assess future conditions. If predictions encompass new locations or time periods in which values of independent or response variables exceed the values used to build the model, the model forecasts need to be evaluated with great care

While a number of uncertainties currently limit our ability to predict all of the changes in critical processes and factors in the Delta ecosystem (Principle P), sufficient data and adequate tools exist to explore some of the anticipated changes. For example, the consequences of climate change in the Delta include sea level rise and a shift toward earlier peak runoff of precipitation. The Advisors recognize that existing process-based hydrodynamic models are of limited application if the structure of the Delta is altered (e.g., by levee failures or major siphons) or manipulated (e.g., by additional gates and barriers), but these models should be used to provide insight into the potential effects of climate change under the current Delta geometry (Recommendation R25).

R25. Use hydrodynamic models of the Delta built on fundamental processes to analyze the potential consequences of different future climate change scenarios (e.g., sea-level rise, timing and amount of runoff) on net and tidal flow patterns.

A subset of future conditions potentially can be examined with existing models. In some cases, however, the use of existing models in a predictive context may be misleading. For example, the ecological theory that spatial and temporal variability is important for maintaining the species richness of ecosystems has been extended to suggest that native species would benefit from increased variability in the Delta (Lund et al. 2007). Our ability to examine whether this concept indeed applies to the Delta is limited because, among other reasons, most data on the system have been collected during a period of reduced variability compared to historical conditions (Recommendation R26). Importantly, there is no one perfect model for use in conservation planning. Instead, planning can sometimes be better informed by results from several different models that address the same issue. However, in all cases data analyses and models should be fully documented and accessible (Principle N).

R26. Develop and apply statistical and process models to examine the potential effects of increasing variability in salinity and water temperatures on ecosystem processes and Covered Species in the Delta.

6.0 ADAPTIVE MANAGEMENT AND MONITORING

The BDCP must be developed despite great uncertainty about the outcomes of the selected management actions. These uncertainties arise because of lack of knowledge about the current state of the ecosystem, inherent variability, and the likelihood that the future state of the system will differ from the current state as a result of deliberate and unplanned events. Several approaches can be taken in the face of such uncertainty to increase the probability that conservation objectives will be achieved. First, analyses can be conducted to attempt to minimize the uncertainty about a particular course of action,. Exclusive of other measures, such an approach is unlikely to succeed because of the magnitude of the uncertainties discussed above. Second, an initial course of action can be taken with plans to revisit the action in the future and alter it if necessary. This approach is preferable to the first, but it fails to maximize application of the information that can be gained from the response of the system to the actions taken; this approach is essentially static, and passive. An improvement on these approaches is to investigate and learn systematically from the course of action taken using adaptive management, a formal process designed to reduce uncertainties and identify significant negative consequences as they arise (Holling 1978, Walters 1986). An adaptive management approach was formally incorporated into the Strategic Plan for the CALFED Ecosystem Restoration Program (CALFED, 2000) but adaptive management was never fully implemented. The Advisors recommend that conservation planning for the BDCP be founded on adaptive management as described here (Recommendation R27).

R27. Design a conservation plan based on adaptive management.

Adaptive management is a systematic process for continually improving management policies and practices by learning formally from their outcomes. First, conceptual models are developed to describe current understanding of the system and how a given action is expected to affect the system. These conceptual models are then developed into quantitative models that may be used, with some degree of uncertainty, to predict system responses. Management actions are designed to include collection of data needed to detect responses to the actions and to other variables that influence the system. Perhaps most crucially, a feedback loop is established by which monitoring data, model outputs, and other information are periodically assessed, the success of the action is evaluated, and, if appropriate, alternative actions are implemented.

Adaptive management is most powerful when an action can be implemented as a formal experiment with replicates and controls. However, active adaptive management is rarely possible for a large system under severe constraints. Passive adaptive management, in which the response of the system to a manipulative action is observed, is much less powerful because it is difficult to separate the effects of the action from other simultaneous environmental changes. Nevertheless, even passive adaptive management is a great improvement over less rigorous processes that fail to examine the effects of management actions.

Adaptive management has been criticized because of institutional impediments to implementation. One of the most challenging aspects of adaptive management is ensuring that information from monitoring of projects and system response is used to refine system models. Data must flow to managers and others overseeing implementation. The information needs of managers, in turn, must be used to guide collection of data. The process of adaptive management requires institutional mechanisms that provide for revisiting objectives and models over time as more is learned about the species and processes being targeted for conservation (Recommendation R28).

> ***R28. Identify and implement as soon as possible an administrative mechanism for the Plan to be modified in response to rapidly evolving information, data, and analyses.***

The Advisors think that adaptive management is well suited to the BDCP, but implementing adaptive management will require a sincere, ongoing commitment to the principle and the process, and a decision-making process specifically designed to accommodate adaptive management. A formal adaptive management program cannot be designed until conservation measures are more fully defined. However, the Advisors recognize the potential value of implementing the BDCP as an adaptive management program, and reiterate their advice that adaptive management be incorporated as early as possible in planning (Principle L). Accordingly, the Advisors recommend that the Steering Committee seek further input on the development of an adaptive management approach for BDCP planning and implementation (Recommendation R29).

> ***R29. Convene a group of science advisors to work with consultants, PREs, and implementing agencies to develop an adaptive management and monitoring strategy to support implementation of the BDCP.***

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APPENDIX A:

Workplan for Facilitating Independent Scientific Input

Science Advisory Process
Bay Delta Conservation Plan

1. Introduction and Purpose

The State of California's Natural Community Conservation Plan (NCCP) Act mandates a process for the inclusion of independent scientific input to ensure that each NCCP is informed with best available science. Regional Habitat Conservation Plans (HCP) developed under the federal Endangered Species Act are often guided by similar input. To meet this mandate for the Bay Delta Conservation Plan (BDCP), a group of independent scientists will be convened to identify and evaluate scientific information and provide objective insight and expert opinion pertaining to species, ecological communities, and habitats addressed by the plan. The role of the Science Advisory Group is to establish science-based conservation and natural resource management principles and standards that will be used to guide BDCP preparation.

This document outlines procedures for engaging independent scientific input for the BDCP, consistent with the requirements of the NCCP Act and guidance developed by the California Department of Fish and Game (August, 2002). Topics addressed include:

1. Communication protocols and ground rules for engaging independent scientific input;
2. A workplan for obtaining meaningful scientific input in a timely fashion;
3. Processes for selecting advisors, framing relevant conservation science questions, and developing work products; and
4. Guidelines for avoiding conflicts of interest.

Bruce DiGennaro (The Essex Partnership) and Dr. Wayne Spencer (Conservation Biology Institute) will collectively serve as the Facilitation Team for the BDCP independent science advisory process. This document is based on the Scope of Work adopted by the BDCP Steering Committee on May 4, 2007, the experience of other NCCP science advisory processes, and the NCCPA and guidance noted above.

2. Ground Rules for Engagement and Communication Protocols

The Facilitation Team will act as a neutral intermediary between the Steering Committee and the Science Advisors. In this capacity, the Facilitation Team will work with both the Steering Committee and the Science Advisors (coordinating closely with the Lead Scientist) to facilitate communications and maintain the integrity and independence of the process.

Communication between the Steering Committee and Science Advisers shall be channeled through the Facilitator. Questions from stakeholder groups or the public will be channeled through the Steering Committee to the Facilitator, who will forward appropriate questions to Science Advisors. The Facilitation Team will recommend which questions or other input are appropriate for the advisors to address. If there is not consensus among Steering Committee members based on the recommendations of the Facilitation Team, the Facilitation Team will make a decision in consultation with the Lead Scientist based on the input received and their collective experience.

The Lead Scientist, other Science Advisors, and the Steering Committee may communicate directly in meetings during the information gathering, field trip, and workshop phases of the science advisory process, and in briefings following submittal of the Science Advisor products to the Steering Committee. Steering Committee members will not contact the Lead Scientist or other Science advisors individually concerning BDCP matters. Similarly, Science Advisors (including the Lead Scientist) will not communicate with the Steering Committee or its representatives during their deliberative process except through the Facilitator.

Science Advisors (including the Lead Scientist) will be free to directly contact other members of the scientific community during the information gathering phase of the process for the purposes of obtaining existing data or other materials needed to inform their deliberations. To encourage informative deliberations, and for allow for transparency and recording of information sources, Science Advisors shall track their contacts with other scientists regarding BDCP matters, explicitly report the use of any such unpublished information in the science advisory reports. and provide the Facilitation Team with a summary of their interactions.

The Facilitation Team will ensure that all Science Advisors understand their roles pursuant to the NCCP Act. Science advisor recommendations are advisory only and not binding on the Steering Committee, member agencies, or consultants involved in NCCP/HCP preparation. Recommendations from the Science Advisors will be made available to the public after distribution to the Steering Committee.

Communications regarding the Science Advisors should be directed to the Steering Committee Chair or her designee or to Bruce DiGennaro (bruce@essexpartnership.com, 401-709-2449) as the designated points of contact for the Steering Committee and Facilitation Team respectively.

3. Workplan

The Facilitation Team proposes a workplan for engaging science advisors in the BDCP process that is tailored to meet the specific needs of the BDCP while providing focused and timely advice consistent with the requirements of the NCCP Act. The proposed workplan is described in Attachment 1 and shown graphically in Figure 1. The workplan includes topically focused interactions with the Steering Committee to facilitate input, as well as discrete deliverables designed to advance the planning process.

4. Process for Selecting Advisors

The Facilitation Team will be responsible for engaging Science Advisors, after appropriate input from the BDCP Steering Committee and Lead Scientist. Key steps in identifying and selecting Science Advisor shall include:

1. Development and review of Areas of Expertise
2. Nomination of potential Science Advisors
3. Selection and contact of Science Advisors

The BDCP Steering Committee, with input from the Facilitation Team and Lead Scientist, will create a "long-list" of science advisor candidates that possess appropriate expertise and qualities and that fit into the identified Areas of Expertise. The Facilitation Team will work with Steering Committee and the Lead Scientist to identify any potential conflicts of interest and to develop a "short list" of candidates based on expertise, experience, proven ability to work well with groups, and ability to contribute useful information on schedule. Using the short list, the Facilitation Team and the Lead Scientist will make initial contact with candidates to determine their interest and availability to serve. Once the Facilitation Team has assessed advisor interest, they will formally invite the science advisors into the process on behalf of the Steering Committee.

To the degree feasible, the Science Advisors will be balanced in terms of the following factors, keeping in mind that adequate coverage of key areas of expertise is the primary criterion:

- local, regional, and national perspectives
- species-specific expertise vs. more holistic ecosystem and conservation planning viewpoints
- previous independent science advisory experience

Final recommendations regarding the selection of advisors shall be made by the Facilitation Team. If there is not consensus among Steering Committee members, the Facilitation Team will make a final decision to ensure that there is no actual or perceived influence by the Steering Committee, consultants, Lead Scientist or other parties concerning the final composition of the group. The Facilitation Team can replace or supplement the initial group of advisors if need arises during the process. The Facilitation Team will establish appropriate agreements and arrangements for honoraria with individual advisors. The timeframe for selecting advisors is outlined in Attachment 1 (Proposed Workplan).

5. Process for Identifying Issues and Developing Questions

To help focus the Science Advisor's input, and to ensure the full range of pertinent scientific issues are addressed, an initial list of science questions will be developed by the Facilitation Team, in consultation with the Lead Scientist and the Steering Committee. The initial list of science questions will be provided to the Steering Committee for review and comment. Advisors may identify additional questions to address during their deliberations.

The Facilitation Team, in consultation with the Lead Scientist, will be responsible for channeling pertinent questions from the Steering Committee to the Science Advisors and communicating answers back to the Steering Committee, or ensuring that they are incorporated into the Science Advisors' work products. Questions to the Science Advisors will be addressed only if they are directly relevant to NCCP/HCP conservation goals and objectives. The Science Advisors will not make value judgments about policies, procedures, laws, economic costs, or societal values. However, it is appropriate for them to objectively address scientific implications of how policy decisions might affect biological resources, such as covered species populations or habitats, as well as how scientific information will be used.

6. Development of Work Products

The Facilitation Team will be responsible for coordinating development of Science Advisor work products. The Facilitation Team will work with the Science Advisors, including the Lead Scientist, to identify writing assignments and track completion of those assignments. The Facilitation Team will work with the Lead Scientist to compile and edit material from the Advisors to ensure that their products are understandable to a broad audience and meet the requirements of the NCCP Act. The Facilitation Team will also ensure that the products reflect the consensus of advisors wherever possible, or to clarify any areas of disagreement or scientific uncertainty that remain.

A draft Guidance Report will be prepared following the science advisor workshops. The draft will be distributed to the Steering Committee for review and comment prior to being finalized for public release. The purpose of this review is to identify any factual errors or portions of the report that may require additional clarification, and not to influence the substance of the report. In no case shall the Facilitation Team allow for the Steering Committee or any other parties to influence the nature of the scientific recommendations in the report, which must substantially reflect the consensus recommendations of the Independent Science Advisors. The Facilitation Team, in consultation with the Lead Scientist, will review comments provided by the Steering Committee and work with Science Advisors to make appropriate adjustments and produce a final Guidance Report.

7. Conflict of Interest

Individuals currently under contract to member agencies of the Steering Committee for work related to the BDCP will be precluded from serving as Science Advisors. At the outset of the process, all selected Science Advisors will be required to disclose for the record any activities they are, or have been, engaged in within the past three years in the Delta, including research projects, as well as any financial affiliations they may have with members of the Steering Committee. Service as a BDCP Science Advisor shall not preclude the pursuit of future grants or research related to the Delta.

ATTACHMENT 1
PROPOSED WORKPLAN FOR INDEPENDENT SCIENCE INPUT

The following outlines a proposed workplan for obtaining independent, timely, focused science input for the BDCP process. The workplan is organized over time as described below and shown graphically in Figure 1.

Initial Planning (by End of June 2007)
Initial planning for science advisor engagement. Specific tasks will include the following:
(a) the selection of advisors;
(b) initial written guidance for the scientific input process and
(c) framing science questions.

Deliverables:

- Guidelines for Scientific Input
- Identification and selection of Science Advisors
- Science Questions

Steering Committee Engagement:

- Meeting #1 – June 1, 2007; Review proposed plan and solicit input on areas of expertise and potential science advisors.
- Meeting #2 – June 15, 2007; Discuss science questions.

Initial Engagement (by September 2007)

The Science Advisors will be convened to participate in topically focused workshops. The exact number and focus of each workshop will be determined based on discussions with the Steering Committee and the Lead Scientist regarding the development of Science Questions (which will be used to frame the advisor discussions). Potential topics may include broad principles for guiding preparation of the Conservation Plan, as required by the NCCP Act. The exact timing of the workshops will be influenced by the availability of the selected Science Advisors.

Deliverables:

- Workshop Summaries
- Draft Guidance Report(s) containing Science Advisor observations and recommendations
- Final Guidance Report(s)

Steering Committee Engagement:

- Meeting #3 – TBD: Review initial workshop observations and recommendations
- Meeting #4 – TBD; Meet with Lead Scientist to discuss Guidance Report(s)

Later Engagement (2008)

Recognizing that additional science input on specific issues such as adaptive management and monitoring may be needed once a conservation strategy has been selected, the Facilitation Team recommends that the Steering Committee commit to a second engagement of Science Advisors in 2008. This additional independent scientific input could be used to advance discussion on specific elements of the selected conservation strategy (e.g., management and monitoring principles) as the well as the design of potential near-term conservation actions while longer-term investment strategies mature. The second engagement would also allow for advice regarding new information that may emerge after the initial engagement.

Deliverables:

- Input on specific issues or plan elements

Steering Committee Engagement:

- Meeting #5 – TBD: Review additional observations and recommendations
- Meeting #6 – TBD; Meet with Lead Scientist to discuss input

APPENDIX B:

Topics and Issues to be Discussed by Independent Science Advisors

BDCP INDEPENDENT SCIENCE ADVISORY WORKSHOP
SEPETEMBER 12-14, 2007
RYDE HOTEL

WORKSHOP TOPICS AND ISSUES TO BE DISCUSSED

The following major topics, and issues listed under each topic, are intended to help frame the advisors' discussions and not to rigidly dictate the scope of the discussions nor form the outline of the advisors' report. There is necessarily broad overlap and intertwining of issues amongst the major topic areas, and we have purposely structured the workshop to allow advisors to circle back to refine their input on particular topics or issues after moving on to other topic areas (in case discussion on a particular topic stimulates new thoughts on a topic already addressed).

Note also that the list of issues under each topic is not necessarily comprehensive. Additional issues are likely to arise before and during advisors' discussions and will be addressed as appropriate. We encourage Steering Committee members to continue submitting additional topics or issues to the Facilitation Team.

Conservation Principles

Charge: Formulate scientific principles for guiding ecosystem restoration and conservation of species and natural communities in the study area.

Issues to Consider:

a. The current, highly altered nature of the system
b. Invasive species
c. Flows and transport pathways
d. Water qualities
e. Future climate regimes
f. Physical and/or biological characteristics
g. Natural processes and self-sustaining outcomes
h. Ecological gradients (e.g., water depths, salinity, temperature regimes, substrate types)

Plan Scope

Charge: Identify natural communities, species, and processes that should be addressed to help achieve the plan's goals.

Issues to Consider:

a. The list of natural communities to be addressed by the plan
b. The list of species intended for coverage under state and federal take permits
c. Additional "planning" species, which may lack special protection status but may serve as useful indicators for other species, communities, or processes of interest
d. Effective ways of grouping species to assist in developing and assessing conservation strategies (e.g., species guilds, resident vs. anadromous species, species sharing limiting factors)

e. Physical and ecological processes to be addressed by the plan
f. The plan's geographic scope and how to address effects that extend beyond geographic boundaries
g. The temporal scope of the plan and how to address short vs. long-term effects

Knowledge Base for Planning

Charge: Review existing information and assess it's adequacy as a scientific foundation for conservation planning.

Issues to Consider:

a. Gaps in existing information that create uncertainties for planning, analyzing, managing, and monitoring
b. Additional data sources or literature that should be considered during planning and analysis
c. Methods for addressing data gaps and dealing with uncertainties
d. Physical or biological process models that might inform development of conservation strategies, (e.g., models of population dynamics, community dynamics, or nutrient or water flows)
e. Sufficiency of available data (including accuracy and precision) for use in models identified above
f. The need to expressly and specifically identify and document the implications of scientific uncertainties on the recommendations of the science advisors

Critical Processes

Charge: Identify critical physical and ecological processes for restoring and conserving species and natural communities, and methods for assessing, conserving, restoring, and monitoring such processes.

Issues to Consider:

a. Historic ecological processes that maintained ecosystem and species viability
b. Current state of those processes
c. Future desired states for those processes
d. Methods for achieving future desired states
e. Examples of processes to address:
   - Nutrient flows
   - Water flows
   - Population dynamics
   - Disturbance cycles
   - Ecological migration
   - Exotic species invasions
   - Harvest
   - Population genetics
   - Climate change

External Factors

Charge: Identify external factors or processes, not under direct influence of BDCP participants, that might affect BDCP covered resources, and how can these externalitices be addressed by BDCP analyses and actions.

Issues to Consider:

a. Climate change (e.g., how might it affect this ecosystem and the target species, and how can these effects be addressed by the plan?)
b. Current and future land uses in the vicinity of the Bay Delta, or beyond plan boundaries, that may directly or indirectly affect the success of BDCP conservation strategies
c. Other existing or ongoing regional conservation plans in the vicinity of the Bay Delta.

The following index table provides a summary of where within the Independent Science Advisors Report specific issues and topics are discussed.

Conservation Principles	
Charge: Identify scientific principles for guiding ecosystem restoration and conservation of covered species and communities in the study area. Response Summary: Sixteen principles were formulated reflecting broad, fundamental concepts deemed important to acknowledge and understand in the process of developing an HCP / NCCP for the Delta.	
Specific Issues:	Report Section Reference
Current altered state of the system	Section 2 (Principles – A, B, & E)
Invasive species	Section 2 (Principles – A, B, F & P)
Flows and transport pathways	Section 2 (Principles – D, C, F, H, I, & J)
Climate change	Section 2 (Principles - B & P)
Physical characteristics	Section 2 (Principles – A, B, C, D, G, I, & J)
Biological characteristics	Section 2 (Principles – C, E, K, & M)
Natural processes / Sustainable outcomes	Section 2 (Principles – A, B, D, E, F, G, J, K, L, & O)
Ecological gradients	Section 2 (Principles – C, D, E, G, H, & I)

Plan Scope	
Charge: Identify natural communities, species, and processes that should be addressed to help achieve the plan's goals. Response Summary: The report provides preliminary observations and advice regarding geographic and temporal scope of the plan, covered species, communities, processes, and conservation strategies based on currently available information. The Advisors recommend seeking further advice on these topics as the Covered Activities become more defined.	
Specific Issues:	Report Section Reference
List natural communities to be addressed by plan	Section 3.5
List species intended for coverage under state and federal permits	Section 3.3
Identify additional "planning species"	Section 3.4
Identify effective ways of grouping species, communities, or processes of interest to assist in developing and assessing conservation strategies	Section 3.5
Identify physical and ecological processes to be addressed by the plan	Section 4.0
Geographic scope of the plan	Section 3.1
Temporal scope of plan	Section 3.2

Knowledge Base for Planning	
Charge: Review existing information and assess its adequacy as a scientific foundation for conservation planning. Response Summary: The Advisors have made observations on the current state of knowledge, its limitations, and made several recommendations for addressing data gaps and refining predictive ability. These observations are generally summarized in Section 4 and its associated tables.	
Issues:	Report Section Reference
Gaps in existing information that create uncertainties	Section 2 (Principles – N & P) Section 4.2 Tables 1-5
Additional data sources of literature that should be considered during planning and analysis	Tables 1-5 Section 4.3 Section 5
Methods for addressing data gaps and dealing with uncertainties	Section 2 (Principles – N, O, & P) Section 4.2 & 4.3 Section 5
Physical or biological process models that might inform development of conservation strategies	Section 2 (Principle - O) Section 5
Sufficiency of available data for use in models	Section 2 (Principles – N, O, & P) Tables 1-5
The need to expressly and specifically identify and document the implications of scientific uncertainties on the recommendations of the advisors	Section 2 (Principles – L, N, & P) Tables 1-5 Section 5

Critical Processes	
Charge: Identify critical physical and ecological processes for restoring and conserving species and natural communities, and methods for assessing, conserving, restoring, and monitoring such processes. Response Summary: The Advisors identified certain process interactions considered to be particularly important for understanding the response of Covered Species to changing conditions. Boundary conditions (e.g. river inflows, diversions, tides) combine with the geomorphic template (the physical structure of the system) to influence physical, geomorphic, foodweb, and chemical processes, which in turn act on each other and influence species population dynamics in a variety of ways.	
Issues:	Report Section Reference
Historic ecological processes that maintained ecosystem and species viability	Section 2 (Principles – A, B, D, & E) Section 4.1
Current and future desired states[62] of ecological processes	Section 2 (Principles – A & B) Tables 1-5
Methods for achieving future desired states	Section 2 (Principles – K & L) Section 4,2 & 4.3 Section 5
Example processes to address:	
Nutrient flows	Tables 1, 4 & 5
Water flows	Tables 1 & 2
Population dynamics	Section 4.3
Disturbance cycles	Section 2 (Principles – D & E)
Ecological migration	Section 2 (Principles – C, D, E, G, & H) Section 4.3
Exotic species invasions	Section 2 (Principles – A, B, C, D, & G) Section 3.4 Table 4
Harvest[63]	Section 2 (Principle C)
Population genetics	Section 2 (Principles – C & E) Section 4.3
Climate change	Section 2 (Principles – B & P) Section 3.5 Tables 1, 2, &3 Section 5.4

[62] The Advisors did not evaluate specific future Delta conditions or conservation strategies.
[63] The Advisors focused on ways in which harvest can be considered in studies of population dynamics rather than its specific role

External Factors	
Charge: Identify external factors or processes, not under direct influence of BDCP participants, that might affect BDCP covered resources, and how these externalities can be addressed by BDCP analyses and actions. Response Summary: The Delta is part of a larger river-estuarine system that is affected by both rivers and tides as well as by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin rivers into the Pacific Ocean.	
Issues:	Report Section Reference
Climate Change	Section 2 (Principles – C & H) Table 1 Section 3.5 Section 5.4
Current and future uses in the vicinity of the Bay Delta or beyond plan boundaries that might affect BDCP conservation strategies	Section 2 (Principles I & M) Table 1 Table 5
Other existing or ongoing regional conservation plans in the vicinity of the Bay Delta[64]	

[64] The Advisors did not specifically examine other plans. However, they did draw on work from POD, DRERIP and IEP in their deliberations.

APPENDIX C:

Additional Questions Submitted to the Independent Science Advisors from the Steering Committee

The following table lists additional questions provided to the Independent Science Advisors by Steering Committee before the September 2007 Advisors Workshop and provides references for where within the Advisor's report these questions are generally discussed. Because many of these questions are very specific, requiring detailed investigations beyond the scope of the Advisor's initial charge, the Advisors did not attempt to specifically answer each question. However, the questions were used to better understand the interests of the Steering Committee and to help frame the overall discussion of the Advisors. In the course of developing Principles for Conservation Planning and other general guidance, the Advisors did touch upon several of the fundamental issues underlying many of the specific questions posed, as noted in the index table below.

Questions Provided by Non-Governmental Organizations	
Question	Report Section Reference
Understanding that ecosystems are dynamic and past conditions cannot be duplicated, how can information about historical conditions in the Bay-Delta estuary and historical relationships between Bay-Delta habitat conditions and biological resources best be used to guide development of the conservation strategy?	Section 2 (Principles - A & E)
Flows have been the most obvious driver of ecological conditions in the Bay-Delta estuary. Is it possible to protect and restore covered species without significantly improving flow conditions in this system?	Section 2 (Principle F)
The degree to which most previous management actions protect Bay-Delta ecological resources have been implemented has been very small in scale when measured against the degree of human alteration of the Bay-Delta estuary's habitats, hydrology, etc. To what extent should the consideration of the magnitude of potential management changes[65] in habitat, hydrology and other ecological conditions help both in generating meaningful data and in securing significant improvement in estuarine functions?	Section 4.3 Section 5 Section 6
Is there any quantitative basis for concluding that factors other than flow and exports are affecting covered species at the population level?	Section 2 (Principle F) Section 4.3

[65] The Advisors did not consider specific management strategies.

Questions Provided by Potentially Regulated Entities	
Question	Report Section Reference
Do biological evaluation criteria developed to help screen conservation strategy options adequately address the range of issues adversely affecting the covered species?	The Advisors did not examine the criteria.
What are the factors influencing the populations of covered species and their relative importance?	Tables 1-5 Section 4
Can a more variable Delta hydrologic regime (variation between freshwater outflow and saltwater inflow) be detrimental or beneficial to covered species?	Section 2 (Principles – F & M) Section 3.5 Section 4.3 Section 5.4
Has climate change affected the necessary conditions for native species in the Delta that are at the southern most extent of their range? How would climate change affect the covered species in the future under each of the climate change scenarios described in DWR's report, *Progress on Incorporating Climate Change in to Management of California's Water Resources* (July 2006)[66]. Under the projected effects of climate change is there a time in the future when the Delta will no longer be suitable habitat for one or more covered species?	Section 2 (Principles – A, B, E, & P) Section 3.5
Has reduced turbidity affected the necessary conditions for native species in the Delta? Can the effects of reduced turbidity be addressed by the conservation strategy options?	Section 2 (Principles – A & E) Section 5.2 Table 2
Please review the Delta smelt/*eurytemora* co-occurrence analysis by BJ Miller Does food supply (zooplankton density and geographic distribution) appear to be a major determinant of smelt population? How can food supply be considered in the conservation strategy?	Section 4.1 (Table 4)
Would a more variable Delta hydrologic regime be detrimental or beneficial to non-native species such as the zebra or quagga mussels?	Section 2 (Principle D) Section 3.5 Section 5.4
Will replacing riprap-lined levees with riparian vegetation have a substantial positive effect on the population of covered species? Should this be included as part of our conservation strategy options? For which species?	Section 2 (Principle G) Section 3.5 Section 5.1

[66] The Advisors did not consider the implications of specific climate change scenarios

Does increasing shallow water habitat improve populations for covered species?	Section 2 (Principle G) Section 3.5
Is it possible to create refugia for foundational species of the Delta ecosystem such as *eurytemora*?	This specific question was not addressed.
Is it environmentally beneficial to covered species be able to move large Delta water diversion points based on the location of habitat needs of the Delta's native species?	Section 2 (Principle M) Section 4.3
What conclusions are supported by the data on the effect of unscreened in-delta diversions on covered species:	The Advisors did not specifically examine these data.
A. Can screening in-Delta diversions improve conditions for the Delta's native pelagic and anadromous fish?	Section 2 (Principle G) Section 4.3.2
B. How does the #/AF of entrainment due to in-Delta diversions compare to entrainment caused by exports?	Section 4.3.2
Is there sufficient data to determine if toxic events in the north Delta, and municipal and agricultural wastewater discharges throughout the Delta have affected the viability of zooplankton, pelagic, and anadromous species in the Delta? Should toxics and wastewater discharge control program for areas in and immediately adjacent to the Delta be included in the conservation strategy options?	Section 4.1 Table 5
What effects do upstream diversions on the San Joaquin River tributaries have on the covered species?	Section 2 (Principle C) Table 1
Is it possible to achieve recovery of the Delta smelt by addressing only the effects of pumping at the SWP and CVP pumping plants?	Section 2 (Principle F)
Given the uncertainty of some of the science surrounding the covered species and the associated Delta ecosystem what strategies can be incorporated into the conservation plan to address known data gaps? What uncertainties do you feel are most important to consider when developing specific conservation measures or adaptive management protocols?	Section 4.1 Tables 1-5 Section 6

Appendix G-2

Bay Delta Conservation Plan Independent Science Advisors
Report Concerning Non-Aquatic Resources

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Bay Delta Conservation Plan

Independent Science Advisors Report Concerning Non-Aquatic Resources

Prepared For
Bay Delta Conservation Plan Steering Committee

Prepared By

Wayne Spencer (Facilitator)
Peggy Fiedler
Geoffrey Geupel
Marcel Holyoak
Patrick Kelly
Glenn Wylie

November 2008

Table of Contents

1 Introduction

This report summarizes recommendations from a group of independent science advisors (ISA) concerning the treatment of non-aquatic species and communities by the Bay Delta Conservation Plan (BDCP). The intent of the ISA process is to ensure that the plan has access to the best available science. Our recommendations are not binding, and are not intended to either question or promote particular plan goals or policies, but are intended to help inform the planning process. Attachment A provides brief biographies of the advisors.

Contents of this report reflect discussion among the science advisors at a workshop held on September 30, 2008 (Attachment B) and their review of various draft plan documents (Attachment C). A previous ISA workshop and report (Reed et al. 2007) focused on the aquatic species and communities that have been the BDCP's highest priorities. This second workshop and report, by a different set of science advisors, focuses on non-aquatic species and communities that could be affected by plan actions.

2 Covered Species

This section provides information concerning what non-aquatic species may be affected by BDCP implementation, either positively or negatively. The intent is <u>not</u> to recommend which species should or should not be covered by regulatory take authorizations or permits under endangered species regulations. It is up to the potentially regulated entities (PREs) to decide which species they wish to obtain permit coverage for, whether under Endangered Species Act Section 10 and the NCCP Act or under other regulations (e.g., Section 7 of the ESA or Section 2081 of the Fish & Game Code). Moreover, it is up to the fish and wildlife agencies to determine for which species permit coverage is ultimately warranted, under what regulations, and with what terms and conditions. We offer the following scientific information and advice to be considered as BDCP participants make decisions about species coverage and conservation actions.

2.1 Species Selection Process

The advisors generally concur with the evaluation criteria and process that was used to identify potentially covered species by the consulting team (Attachment C, Document #3). However, we have some questions and concerns about how the four evaluation criteria (listing status, occurrence in planning area, potential to be affected, and information sufficiency) were applied, and we suggest reconsidering the evaluation of certain species.

First, the advisors were unclear how the original list of 111 species that SAIC evaluated for coverage was derived, and are concerned that some at-risk species or subspecies that may occur in or near the planning area were not evaluated. For example, several birds that are California Species of Special Concern (SSC) (Shuford and Gardali 2008) are known or potentially occur in the planning area, but were apparently not evaluated, such as the Modesto song sparrow (*Melospiza melodia mailliardi*) and yellow warbler (*Dendrocia petechia*).

Listing Status. For some species, advisors question how the determination was made that they were unlikely to be listed, in light of myriad uncertainties and considering the proposed 50-year permit duration. We believe it is prudent to err on the side of caution in making such determinations, because an unexpected listing can be disruptive to plan implementation[1]. In particular, the advisors note that there is an inherent circularity in the logic to not cover some SSC on grounds they are unlikely to be listed. Inclusion on the California SSC list indicates that a species meets some or all criteria for California Threatened or Endangered status, and that highlighting this at-risk status may help prevent the need to list the species by encouraging conservation and recovery actions for it (Shuford and Gardali 2008). The advisors therefore recommend treating SSC as if they are likely to be listed. If the planning area is important to viability of an SSC, the plan should evaluate whether implementation may adversely affect it and therefore warrant coverage.

Occurrence in Plan Area. The advisors note that survey coverage in the plan area is sparse for many species, and that it is difficult to assume absence on the basis of existing data, such as CNDDB records. This is particularly true for plants and invertebrates. Some species occurring in the vicinity of the Bay Delta have been found outside their known geographic ranges after being listed and could occur in the plan area. We also note that species ranges are dynamic, and that shifts in response to climate change and other factors are being documented for numerous taxa in California and throughout the world (Moritz et al 2008, Parmesan 2006, Root et al. 2003). We therefore recommend carefully considering the potential for species to occur within the plan area over the proposed 50-year permit duration.

We understand that some plan actions may occur outside the planning area (the statutory boundary of the Delta) but that only species occurring inside the boundary were evaluated. We recommend identifying all at-risk species that may be affected by the plan (i.e., listed, SSC, or CNPS list species), whether inside or outside the plan boundary (e.g., by an around-Delta conveyance or by restoration actions in Suisun Marsh). We recognize that permits for BDCP effects on some species may be obtained via other regulatory means than BDCP take authorizations (e.g., project-specific Section 7 or 2081 authorizations), but it seems wise to anticipate the full range of potential effects to inform such decisions as early as possible.

Potential to be Affected by Plan Actions. The advisors also feel it is prudent to err on the side of caution when considering the potential for species to be affected by plan actions, whether positively or negatively, because the nature and extent of the plan's covered actions and conservation measures are not yet fully defined. For example, we understand that the consultants only considered an eastern alignment in determining whether species may be adversely affected by an around-Delta conveyance. It appears from maps and other information we reviewed that additional species could be adversely affected by other alignments, especially a western alignment. Until the conveyance alignments and other plan measures are more fully developed,

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[1] For example, during development of the San Diego Multiple Species Conservation Plan (MSCP) the Quino checkerspot butterfly (*Euphydryas editha quino*) was considered unlikely to be listed and was not covered. The butterfly was listed as Endangered one year after MSCP approval, triggering project delays and a costly plan amendment.

we recommend keeping an inclusive list of potentially affected species, and winnowing the list as decisions are made and uncertainties resolved.

Advisors question the assumption that siphoning aqueducts under tidal channels, streams, and sloughs can completely avoid impacts on riparian habitat or other floodplain habitats. While the impacts of siphons may be lower than alternative conveyance solutions, based on observations of existing siphons elsewhere in the Central Valley, advisors are uncertain whether all direct and indirect impacts associated with construction and maintenance of siphons can be completely avoided. We recommend not relying on this assumption in considering species for coverage until facility design is sufficiently advanced to remove such uncertainties.

Restoration actions intended to benefit aquatic species may positively or negatively affect habitat for or populations of terrestrial species. For example, restoration of tidal marshes in lowland portions of the plan area could flood habitats currently occupied by covered terrestrial plant and animal species, while increasing habitat potential for marsh species.

Even if plan actions do not directly affect habitats or populations of certain terrestrial species, they have potential to constrain conservation or recovery actions for these species by other plans. For instance the Antioch Dunes represent a rare sand dune habitat that supports a number of rare, endemic plants and animals, such as the federally endangered Contra Costa wallflower (*Erysimum capitatum* ssp. *angustatum*), Antioch Dunes evening primrose (*Oenothera deltoides* ssp. *howelli*), and Lange's metalmark butterfly (*Apodemia mormo langei*). We agree that this community and its endemic species are not likely to be directly affected by BDCP actions. However, due to the extreme rarity and conservation importance of this community, we recommend analyzing whether any covered actions might constrain the possibility of future habitat restoration within this very limited geographic area by other entities, or whether BDCP conservation actions could contribute to recovery of these species.

Sufficiency of Information. The advisors were unclear about how this determination was made for each species, given uncertainties about the distribution of many species in the plan area and the preliminary nature of the covered actions and conservation measures. We assume that the determination focused on whether scientific understanding is sufficient to determine how covered actions and conservation measures might affect each species, provided the species is present in affected areas. We understand the rationale that there must be sufficient scientific understanding about how covered actions and conservation measures may affect a species to determine whether that species should ultimately be covered by take authorizations. However, where there is not sufficient information to make such a determination at this time, we believe it is prudent to keep the species on a comprehensive species list as the plan develops, in case sufficient information becomes available to make the assessment, rather than to remove such "uncertain" species from the list prematurely.

The explanation for this criterion (Attachment C, Document #3, Page 8) states, "A guide for this criterion is if the species is covered or proposed for coverage under other HCPs and NCCPs, which indicates a confidence that sufficient information is available to cover the species." We point out that the nature of BDCP covered actions and conservation measures differs considerably from that of most other HCPs and NCCPs, which usually involve trading off habitat losses due to development, primarily in upland areas, with conservation and management of habitat preserves in other locations. In contrast, BDCP actions will likely result in complex and widespread changes in hydrodynamics, water qualities, etc., as well as potentially widespread habitat restoration projects, especially of wetland communities. Such actions may affect covered species in ways not addressed by other HCPs and NCCPs in the region. Moreover, how these changes may interact with climate change and other factors to influence habitat and populations of covered species is highly uncertain. We believe that where existing scientific information is not currently sufficient to determine plan effects on species, those species should be retained on the list of potentially covered species until sufficient information becomes available to determine that the plan is unlikely to have effects on them (e.g., until covered actions are more fully defined and more comprehensive surveys can be performed). These uncertainties about plan effects on diverse species reemphasize the critical importance of a solid adaptive management and monitoring program for the BDCP.

2.2 Potential Covered Species Additions

Based on the above review of the species selection criteria, we believe the following species should be considered (or reconsidered) for coverage, because they are listed or have potential to be listed as Threatened or Endangered and they could be affected by plan actions. These include some species not addressed in the consultants' evaluation, and others that were evaluated but determined unlikely to require coverage due to one or more of the evaluation criteria. For example, they include several SSC that we believe should be treated as likely to be listed, for reasons explained above. Finally, they include some species about which the consultants were uncertain for one or more of the evaluation criteria.

- **Riparian woodrat** (*Neotoma fuscipes riparia*[2]). The consultants' evaluation was uncertain about this federally endangered species' occurrence in the plan area and likelihood of being affected. Surveys are being performed for the species in appropriate habitats within the BDCP area, and we recommend awaiting results of those surveys before determining whether to pursue coverage. Before 2003 riparian woodrats were thought to survive only at Caswell Memorial State Park and a few other areas along the lower Stanislaus River. However, the species was found in 2003 at the San Joaquin River National Wildlife Refuge, just south of the planning area, and it may be more widely distributed than previously thought. Ongoing riparian habitat restoration efforts at the San Joaquin River NWR and elsewhere will likely lead to population and range expansion. In addition to loss of habitat, riparian woodrats are threatened by fires and floods, as evidenced by population reductions in San Joaquin River NWR following a wildfire there in 2004 and major flooding in 2006. Riparian woodrats are expected to respond favorably to riparian habitat restoration programs.
- **Northern harrier** (*Circus cyaneus*) has been a California Bird SSC since 1978 (Shuford and Gardali 2008). Recent declines throughout the Central valley have been attributed to habitat loss, intensified agricultural practices, and increases in nonnative predators (cats, dogs, and eastern red foxes). Harriers are known to breed regularly at the Cosumnes Reserve and were found in 69 widely scattered blocks in the Sacramento County Breeding Bird Atlas. The

[2] Taxonomic revision will likely result from studies that are presently ongoing by Marjorie Matocq at University of Nevada, Reno (P. Kelly).

nests of this ground-nesting species are highly vulnerable to disturbance from humans, dogs, livestock, and agricultural activities during the breeding season. Conservation measures, such as restoring wetland habitats in what are currently uplands, could adversely affect a small number of harriers. Further information on occupancy, persistence, and ideally nesting success in protected areas is needed.

- **Lesser sandhill crane** (*Grus canadensis canadensis*). This recent addition to the California bird SSC list (Shuford and Gardali 2008) winters in large numbers within the Delta (Christmas Bird Count data). Like the greater sandhill crane (which was included as potentially covered in the consultant's evaluation) the greatest threats to the species are changes in agricultural practices and habitat loss. Management actions, such as promoting late (February) discing of grain crops, managing grasslands with cattle, providing shallow wetlands, and preventing collision with power lines, will benefit both the lesser sandhill crane and the greater sandhill crane.
- **Least Bell's vireo** (*Vireo belli pusillus*) was not evaluated by the consultants, presumably because it has not been found in the plan area since before the species was listed as Endangered in the 1980s. Least Bell's vireo was restricted to a few small populations in southern California at the time of listing, but it has since been increasing in population and expanding northward within its historic range in the Central Valley. In recent years least Bell's vireos have nested as far north as Gilroy (Santa Clara County) and San Joaquin River National Wildlife Refuge (Merced County). Experts consider it likely to re-occupy riparian habitats in the BDCP area in the near future.
- **Yellow warbler** (*Dendroica petechia*) was not evaluated by the consultants. A California SSC since 1978 (Shuford and Gardali 2008) this species has declined significantly as a breeding bird throughout the state and in the Central Valley and may be close to extirpation (Heath 2008). Extensive surveys in the Bay Delta and San Joaquin valley in the late 1900s failed to locate breeding populations. Possible breeding records in Contra Costa County and a new expanding population on the San Joaquin River NWR (Hospital Creek) suggests high potential for this species to return to the delta in healthy numbers. An early seral-stage, riparian-dependent species, restoration programs that restore ecosystem processes (e.g., natural flood events), a mosaic of riparian habitat, and healthy understory will benefit this easily monitored species (Riparian Habitat Joint Venture 2004).
- **Modesto song sparrow** (*Melospiza melodia*, "Modesto" Population) was not evaluated by the consultants. This resident California bird was considered a valid subspecies (*M. m. mailliardi)* until 2001 (Patten 2001), and may be again under additional taxonomic research (Gardali 2008). Regardless of whether the "Modesto population" of the song sparrow is ultimately determined to be a valid subspecies, it is a California SSC that is endemic to the Sacramento Valley (Gardali 2008). The Bay-Delta is one of two areas with the highest population densities. Major loss (> 90%) of its preferred wetland and riparian habitat has led to a significant reduction in range and abundance. While it can be locally abundant along riparian corridors or small wetlands it is rare along irrigation canals, levees, and in mature riparian habitat. The protection and restoration of wetlands and dynamic riparian systems with understory and habitat mosaics will aid in this species' recovery.
- **Western pond turtle** (*Clemmys marmorata*). The western pond turtle is a California state SSC. The turtle's habitat includes freshwater sloughs and marshes in the Delta (Zeiner et al.

1988-1990). Salt-water intrusion brought about by reducing freshwater flows into the Delta could have a negative effect on local populations.

- **California tiger salamander** (*Ambystoma californiense*) is a federally threatened species with recent sightings in the vernal pool habitats on the western edge of the project area. This area is included in designated Critical Habitat for the species (U.S. Fish and Wildlife Service 2004), and actions there, such as construction of a western around-Delta conveyance, have the potential to adversely affect the species. The consultants' evaluation was uncertain about the potential for plan actions to affect the species, presumably because covered actions are not yet fully defined.

- **California red-legged frog** (*Rana aurora draytonii*) is federally Threatened and a California SSC that is known to occur in the plan area. The consultant's evaluation concluded that plan actions were unlikely to affect the species. The advisors are unclear how this determination was made given that locations of covered actions and conservation measures have not yet been fully defined and that surveys sometimes find this species in unexpected locations. Red-legged frog could be adversely affected if covered actions occurred in or near occupied or potential habitat. We recommend including this as a potentially covered species pending further analysis as covered actions and conservation measures are better defined.

- **California black walnut** (*Juglans hindsii*) was considered by the consultants' evaluation to be unlikely to become listed. However, this California endemic is a CNPS list 1B.1 species (seriously endangered in California) and has a Natural Heritage Rank of G1/S1.1. It is known to hybridize with other species of walnuts. Although it has been widely planted and used for root stock, natural occurrences are limited, and only one confirmed natural stand appeared viable as of 2003 (http://cnps.web.aplus.net/cgi-bin/inv/inventory.cgi). We recommend considering covered status for this species if natural populations occur in the plan area that could be positively or negatively affected by covered actions.

- **Bristly sedge** (*Carex comosa*) is found along the margins of marshes, swamps, and in wet meadows. The consultants' evaluation was uncertain about this species' potential to be listed. We share this uncertainty, and believe there is a small potential for it to be listed in the next 50 years. We therefore agree with the consultants "undetermined" finding and suggest keeping this species on the list until uncertainty is reduced.

- **Various plant species** found in vernal pools, swales, or flats that could be adversely affected by plan actions, especially in combination with climate change, or have the potential to benefit from the plan's conservation actions. The consultant's evaluation determined that these species were unlikely to be affected by covered actions, or they were uncertain about the potential for effects. We are also uncertain about potential plan effects on these species, given that plan actions aren't yet fully described, and believe they should be retained until uncertainties are resolved.
    - Bogg's Lake hedge-hyssop (*Gratiola heterosepala*)
    - San Joaquin Valley Orcutt grass (*Orcuttia inaequalis*)
    - Heartscale (*Atriplex cordulata*)
    - Brittlescale (*Atriplex depressa*)
    - Vernal pool smallscale (*Atriplex persistens*)

  - Round-leafed filaree (*Erodium macrophyllum*)
  - Fragrant fritillary (*Fritillaria liliacea*)
  - Lesser saltscale (*Atriplex minuscule*)

We agree with the consultant's evaluation that the following species, which are associated with the extremely rare Antioch Dune community, are unlikely to be directly affected by the covered actions or conservation measures currently under consideration. However, as explained earlier, we recommend evaluating whether BDCP implementation could contribute to the recovery of these species or whether BDCP implementation might indirectly constrain potential conservation and recovery actions for these species by other entities.

- Delta green ground beetle (*Elaphrus viridis*)
- Lange's metalmark butterfly (*Apodemia mormo langei*)
- Antioch Dunes evening primrose (*Oenothera deltoides* ssp. *howelli*)
- Contra Costa wallflower (*Erysimum capitatum* spp. *angustatum)*

2.3 Potential Covered Species Deletions

The consultants' draft evaluation concluded that the following species should be considered for coverage, or stated that this conclusion was "undetermined." The advisors believe that these species are unlikely to require coverage, and they could be deleted from the list.

- **Snowy plover** (*Charadrias alexandrinus*, interior population). Since 1945 there are only three breeding records for this species in the Central Valley (all in Yolo County). Its extremely rare occurrence and preference for agricultural evaporation ponds and alkali playas in the Valley suggest that BDCP is unlikely to affect this species and that the delta is not an area in which to focus conservation efforts for it.
- **Coast horned lizard** (*Phrynosoma coronatum*) does not likely inhabit the plan area (Stebbens 2003) or areas likely to be affected by around-Delta conveyances.
- **Caper-fruited tropidocarpum** (*Tropidocarpum capparideum).* This species was believed to be extinct for several decades, but was rediscovered in Monterey County at Fort Hunter Liggett in 2000-2001. It primarily occupied valley grasslands, with some documented locations within the plan area. However, it has not been re-located in the plan area in recent years and is presumed extirpated.

2.4 Planning Species

The advisors are concerned that the plan focuses so strongly on species for which regulatory coverage is being sought (e.g., listed threatened and endangered species) that it might not adequately account for ecological processes and community interactions that are essential to all species in the area, including covered species. Some conservation plans identify additional "planning species" for which regulatory coverage may not be necessary, but that can serve as indicators of ecological conditions or processes in covered communities. Indicator species can be effective monitoring tools in adaptive management plans, especially where intensive monitoring of covered species is infeasible. We recommend considering whether some additional planning species should be evaluated in the plan and included in the monitoring program to help meet BDCP goals.

One approach for identifying useful planning species is to identify groups of species whose vulnerability can be attributed to a common threat or stressor, such as loss of habitat area or alteration of a natural disturbance regime. For each group, one or more species are selected that are both highly sensitive to the threat category and relatively easy to monitor. Such species can thus serve as indicators for that group. We recommend that the plan identify what threat categories are most appropriate for non-aquatic communities in the BDCP area, systematically evaluate whether the proposed list of covered species already has sufficient indicator species for each threat category and each community type, and then supplement the covered species list as necessary to fill any gaps in this matrix with additional planning species.

One example system for identifying threat categories that has been applied in previous conservation plans is based on Lambeck (1997) who identified four groups of species. We suggest adjusting this general approach to the BDCP issues and area to identify planning species that may help attain plan goals and objectives. The following groups could be modified or supplemented with others, as appropriate for this purpose.

- *Area-limited species* have large home ranges, occur at low densities, or otherwise require large areas to maintain viable populations. Examples include large mammals (especially carnivores) and large raptors, such as northern harrier. Although this category has proved useful in design of large-scale, terrestrial reserve systems, the advisors do not necessarily recommend selecting large, wide-ranging terrestrial species as good planning species for BDCP. However, it may be useful to identify species that require relatively large habitat patches or habitat mosaics as indicators of successful habitat restoration efforts, if covered species do not already meet this need for all communities.

- *Dispersal-limited species* are limited in their dispersal capacity, sensitive to particular movement barriers such as highways or canals, or are vulnerable to mortality when trying to move through a human-dominated landscape. Examples include salamanders, turtles, large snakes, flightless insects, and large-seeded herbaceous plants. The advisors believe that some of the potentially covered species may adequately cover this category for most communities (e.g., California tiger salamander, Valley elderberry longhorn beetle).

- *Resource-limited species* require specific resources or habitats that are very rare or at least occasionally in short supply. Classic examples include nectarivores, cavity-nesting birds, cliff-nesting birds, vernal pool species, or burrow-dwelling animals. The advisors recommend considering whether there are resource specialists in the planning area that could serve as useful indicators for rare ecological communities or resources that may not be adequately addressed by covered species. For example, tree swallows and possibly spotted sandpipers are good indicators of healthy floodplain environments, diverse aquatic insect communities, and fish breeding habitat (gravel bars).

- *Process-limited species* are sensitive to details of the disturbance regime (e.g., the frequency, severity, or seasonality of floods or fires) or other manifestations of natural processes, such as hydroperiod, salinity gradients, or fire-return intervals. Examples include riparian plants like sycamore and elderberry that establish following floods, or vernal pool species which require seasonal flooding, such as Contra Costa goldfields (*Lasthenia conjugens*). Early seral species such as song sparrows and yellow warblers are good indicators of ecosystem processes such as periodic flooding (Chase and Geupel 2005).

To this list of four categories, we suggest adding one for invasive species that serve as indicators of where management intervention is required. For example, wetland margins are often highly invaded by non-native species like Lepidium; and black rats (*Rattus rattus)* seem ubiquitous in riparian habitat in the Central Valley. Rats are nest predators of birds, including the Modesto song sparrow (Hammond 2008), and unpublished data from the Endangered Species Recovery Program suggests that woodrat reproductive success is lower in areas with high *Rattus* densities (P. Kelly).

3 Covered Communities

Due to the BDCP's focus on conserving imperiled fish species, the plan currently includes three "covered communities" and seven "other communities." [3] We recommend considering whether the plan should add more covered communities, in recognition of the interdependences among ecological communities within a broader ecosystem context. We point out that (1) many of the potentially covered species are found in the "other communities" rather than in the covered communities; (2) some of the rarest communities in the plan area are disproportionately vital to imperiled species, such as inland dune scrub and seasonal wetlands; and (3) community types are interdependent in complex ways and should not be treated in isolation of one another. For instance, changes in water level, flooding period, or nutrient deposition from flooding in certain habitats will likely impact adjacent habitats and associated covered species. Moreover, many covered species require resources from multiple community types (e.g., amphibians that require wetlands and uplands). Even if all communities in the plan area are not treated as "covered communities," the advisors at least recommend describing and assessing all communities within the plan area with a comparable level of detail and care, and describing community interdependencies in an ecosystem context. We expand on this in our review of the Existing Ecological Conditions chapter in Section 4.1.

We further recommend that analysis and documentation of plan effects recognize the finer vegetation types or habitat conditions that exist within these broadly defined natural community types[4]. The plan documents we reviewed (e.g., Attachment C, Document #2) appropriately recognize these finer distinctions by providing cross-walk tables of the various plant associations and alliances (Hickson and Keeler-Wolf 2007, Sawyer and Keeler-Wolf 1995) within each natural community type. We recommend continuing to recognize these finer distinctions, especially where they are important to assessing plan effects on covered species. For example, the category "natural seasonal wetlands" includes diverse types of seasonal wetlands, from vernal pools to alkali flats, which differ tremendously in ecological conditions and in the suite of covered species each supports.

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[3] BDCP Planning Agreement: Attachment C, Document #1.

[4] Community types were defined based on the CALFED Bay-Delta Program Ecosystem Restoration Program Volume 1 and Multiple Species Conservation Strategy (CALFED 2000), which defined 18 "broad" natural communities, while recognizing that there are finer habitat types and vegetation communities within each of these.

The Antioch Dunes represents a unique ecosystem of critical conservation concern that lies entirely within the project area. The dunes once extended along a two-mile reach of the southern shore of the San Joaquin River immediately east of the town of Antioch (Powell 1983) and totaled approximately 190 acres. This unique, isolated ecological community supports a diversity of rare and endemic species of plants and insects. For example, the Antioch Dunes are the type locality for 27 insect species, including eight that are endemic to the Dunes, and four that are considered extinct (Bettleheim 2005). Today, only 55 acres of remnant aeolian dunes are protected within the Antioch Dunes National Wildlife Refuge, although an additional 12 acres of dunes are found on the adjacent Pacific Gas & Electric property. A comprehensive conservation plan was issued by the U.S. Fish & Wildlife Service in 2002, but few if any of the management needs have been fully addressed. The Antioch Dunes National Wildlife Refuge was identified as a potential area for habitat restoration under the Ecological Restoration Program of CALFED (1999).

As discussed earlier, we recognize that the Antioch Dunes community is unlikely to be directly impacted by BDCP covered actions, but in light of the extreme rarity of this community and its associated species, we recommend assessing whether BDCP actions may in any way constrain restoration and recovery actions within this community, or whether BDCP conservation actions could contribute to recovery actions (e.g., by including restored dune habitats as a possible component of BDCP restoration plans in appropriate locations).

Communities need to be considered not just in isolation but as interdependent communities of species that affect one another within mosaics and across gradients. This is important in assessing effects of covered activities and designing conservation measures (e.g., locating restoration areas). The goal should be to recreate and maintain natural transitions between communities along gradients (such as elevation, salinity, and moisture gradients) rather than creating isolated habitat types with “hard edges.” For example, the unnaturally abrupt transitions from marsh vegetation to uplands that are created by dikes around marshlands provide no safe haven for rails and other species during flood events, subjecting them to high predation rates. Naturally connected and transitioning communities along elevation and moisture gradients will (1) benefit the covered fish species, (2) provide more natural habitat mosaics to support terrestrial and wetland species, and (3) create more sustainable conditions during climate change and sea-level rise.

Each community type has a characteristic set of species (of all kinds, not just plants). The advisors urge more consideration of the sets of species in each community and how they interact. As discussed in Section 2.4, it would be valuable to identify species that are indicators of particular communities. It may also be useful to identify common species associations or guilds typical of particular habitat types, plant assemblages, or limiting resources. Such species groups can provide useful indicators of biological integrity within ecological communities, which can be useful in adaptive management and monitoring.

4 Draft Plan Documents

In general, the advisors were impressed with the quality of documents and maps we reviewed. The following general comments are intended to improve what already appear to be thoroughly researched and thoughtfully prepared information products.

4.1 Existing Ecological Conditions

We recommend that the existing ecological conditions chapter begin with a broader treatment of the Bay-Delta ecosystem, natural communities, and processes, including those important to non-aquatic species. All communities in the study area should be described to a similar level of detail as the three covered communities. Currently, the three covered communities are treated fully, with detailed depictions of physical conditions, vegetation, fish and wildlife, non-native species, ecosystem processes, environmental gradients, and future conditions under a changing climate. However, the seven "other communities" have briefer descriptions of only the physical conditions, vegetation, fish, and wildlife, and these are more cursory than those for covered communities.

Section 2.3.2 on existing ecosystem processes does a good job of describing the broad suite of physical, chemical, and biological processes occurring within the project area. Likewise section 2.3.3 describes well the physical processes, and 2.3.4 describes the covered communities. What is missing is an integration of community types to describe how they are arranged or interconnected in spatial mosaics, and how these mosaics work to provide ecosystem services and support covered species. For example, it would be useful to characterize patterns of adjacency and intergradation among different community types and whether the boundaries between communities are (1) natural vs. artificial (e.g., separated by dikes, roads, or ditches), or (2) gradual vs. abrupt (e.g., transitioning along natural gradients or having sharp, discrete edges). How different habitat types interact both physically and through the movement of organisms across habitat boundaries or gradients is important to understanding likely affects of plan actions and other changes on covered species. Physical interaction is likely through the interdependence of water levels in adjacent (undiked) habitats and fluxes of sediments and nutrients. In the absence of additional species-specific information, the adjacency of habitats is expected to provide a measure of the flux of organisms across habitat boundaries, and barriers of various kinds (dikes, roads, railroads, etc.) may hinder the movement of certain species. Conservation measures should strive to create habitat mosaics with natural transitions between adjacent communities along gradients. Such mosaics will be more robust in the face of changes in hydrology and sea-level rise by allowing species, communities, and processes to adjust gradually over space and time. We expand on these concepts in Section 5.

4.2 Species Accounts

The draft species accounts that we reviewed were generally well researched, organized, and accurate. We recommend producing similar accounts for all potentially covered species, with perhaps shorter accounts for those species that were considered but not retained on the potentially covered list.

Below is a sampling of minor improvements that the advisors recommend for particular species. In Section 4.4 we provide additional information sources that should be consulted and referenced in the species accounts.

- Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*). It is important to note that, although this species has been proposed for delisting by the U.S Fish & Wildlife Service, it is still officially listed and should continue being treated as such. The delisting process is not yet final, and even once it is finalized, there will still be a required monitoring period of 5 years.
- The riparian brush rabbit account should be updated with the latest information developed by the Endangered Species Recovery Program (ESRP) at California State University – Stanislaus[5]. Note that the accounts currently available on the ESRP website are not particularly current, as results of recent and ongoing research are not yet incorporated. Surveys are being conducted within the BDCP plan area, the results of which should be used to update the account.
- An account should be prepared for the riparian woodrat using the latest information from ongoing surveys and research by ESRP[4]. As with the riparian brush rabbit, please note that the species account on the ESRP website is not particularly current. For example, recent unpublished data suggest that woodrat reproductive success is lower in areas with high black rat densities than in areas where black rats are systematically removed (P. Kelly). Riparian woodrats were first captured by ESRP in the San Joaquin River National Wildlife Refuge on March 26, 2003. Although they are captured periodically there, they are not abundant, especially since a wildfire in 2004 and major flooding in 2006. Woodrats usually build stick houses (also called nests, dens, or middens) on the ground, making them susceptible to flooding. However, they can also den arboreally in stick nests and cavities, which makes them somewhat less vulnerable to flooding than riparian brush rabbit populations. Fires may therefore be a more serious threat to riparian woodrats than flooding. As with the riparian brush rabbit, surveys are being conducted within the BDCP plan area over the next two years, the results of which should be used to update species information.

4.3 Species Habitat Models

We reviewed preliminary draft maps prepared by the consultants for a selection of covered species, to assess the general modeling approach they are using to predict habitat distribution for covered species. The approach has been to use available GIS layers (especially land cover types) and known or assumed habitat associations to depict the potential distribution of each species in the plan area.[6] This approach is fine when the relationships between species occurrence and mapped land-cover types (or other discretely mapped GIS polygons) are well established and reliable. However, errors of omission and commission are common, and their extent or frequency is difficult to assess. Overlaying available occurrence records onto these maps offers some additional information and a rough indication of model accuracy. However, when

[5] Please contact Pat Kelly at pkelly@esrp.csustan.edu for more information.
[6] The term "models" is somewhat misleading because the maps are more like compilations of information and expert opinion rather than being based on any graphical or mathematical algorithm.

occurrence records are sparse or spatially biased, for instance when based on ad-hoc reporting of occurrences to CNDDB, they are not in themselves reliable indicators of model accuracy.

A more thorough approach to habitat modeling would be to use niche models to statistically quantify the relationship between occurrence (or abundance) and habitat conditions (e.g., Guisan and Thuiller 2005, Elith et al. 2006), although we recognize that species occurrence records are too sparse for most covered species to build reliable statistical models. Regardless of the method used, all distribution maps must be applied and interpreted with great caution due to uncertainties.

Furthermore there is a need to consider more fully the likely distribution of habitat 50 years into the future based on climate change predictions. Habitat models can be coupled with climate envelope models to forecast changes in species ranges under different climate change models (e.g., Loarie et al. 2008).

4.4 Information Sources

We recommend considering the following information sources to bolster the scientific foundations of the plan and plan documents.

- California Riparian Habitat Restoration Handbook (Griggs 2008). This recent publication is based on years of experience designing, implementing, and monitoring riparian and riverine habitats in California, and serves as a practical "how-to" guide for planners and practitioners.
- California Bird Species of Special Concern (Shuford and Gardali 2008).
- California Mammal Species of Special Concern.[7]
- Contra Costa County Breeding Bird Atlas (http://www.flyingemu.com/ccosta/).
- State Wildlife Action Plan (Bunn et al. 2005).
- Antioch Dunes National Wildlife Refuge Comprehensive Conservation Plan (USFWS 2002).
- The most recent publications and model results concerning climate change effects on species ranges and phenologies that pertain to the study area and species. For example, Loarie et al. (2008) assessed likely effects of climate change on California's flora, and predicted that about 2/3 of our endemic plant species will experience >80% range contractions over the next century, with major disassociation of current plant communities likely. Hijmans and Graham (2006) discuss the accuracy of predictions from widely used climate-envelope models, and Green et al. (2008) showed that such models are able to retroactively predict range shifts for bird species.
- ClimateWizard is a climate change modeling and analysis "toolbox" that should be ready for public use in the near future. It may be useful for investigating how climate change may

[7] Unfortunately, the most current version of this document has been under review for several years now and is not yet available. We recommend checking on the status with the California Department of Fish and Game. See also: http://www.dfg.ca.gov/wildlife/species/ssc/mammals.html

affect covered species and communities in the BDCP area. See http://faculty.washington.edu/girvetz/ClimateWizard/index.html for more information.

- PRBO Conservation Sciences has created predictive models of species distribution for 19 different bird species using a machine-learning algorithm called Maxent (Phillips et al. 2006, http://www.cs.princeton.edu/~schapire/maxent/). The models predict distributions based on species occurrence locations and GIS-based environmental data layers. This approach can significantly improve predictive ability over simple habitat suitability index (HSI) or wildlife habitat relationship (WHR) models, which are often based on broad-scale habitat associations that are not necessarily applicable throughout a species' range. CADC (http://www.prbo.org/cadc/) provides links to maps for 19 species of land birds the Central Valley that includes the delta region, including California Bird SSC and California Partners in Fight (http://www.prbo.org/cms/258) focal species. For more information on modeling methods: see http://data.prbo.org/cadc/tools/lip/background.php.

5 Conservation Measures

Based on our review of information provided by the consultants, the advisors offer some recommendations about how conservation measures under consideration to benefit aquatic communities and species may affect terrestrial communities and species, along with some additional recommendations for conservation actions specific to the terrestrial resources. Our discussions focused primarily on the following pragmatic questions:

- What potential positive or negative effects might the proposed conservation measures (Attachment 3, Documents 4-8) have on non-aquatic species and communities? How can potential negative effects be avoided, minimized, or mitigated, and how can potential positive effects be enhanced?
- How can restoration of floodplain, intertidal marsh, channel margin, and riparian vegetation designed to benefit covered fish species be implemented or refined to also benefit non-aquatic species?
- Is establishing appropriate hydrologic conditions sufficient to provide for the natural establishment of native woody riparian vegetation ("passive restoration") or is more active restoration, such as planting trees and shrubs, necessary?
- Will native species and communities naturally shift ranges in response to changes in hydrological regimes (e.g., upslope shifting of intertidal plants) or colonize restored habitats, or is more active intervention necessary (e.g., transplantation or reintroduction)?
- What additional conservation actions should be considered to benefit covered non-aquatic species, beyond those conservation measures already being considered to benefit aquatic species?
- Are there specific locations in the planning area that are essential to sustaining populations of covered terrestrial species, or "hotspots" where numerous species coexist, and that therefore should be focal areas or avoidance areas for conservation measures?

Based on these discussions, we have organized recommendations for BDCP conservation measures into the following sections on conservation design principles, recommended analyses, locations of conservation concern, restoration recommendations, and species-specific conservation actions.

5.1 Conservation Design Principles

We recommend the following general principles be considered during the selection, design, and implementation of conservation measures:

- Plan conservation measures hierarchically, working from ecosystem to community to species-level considerations. Do not plan conservation measures for specific covered species or communities in isolation, without considering their relationships with other species and communities in the broader ecosystem.
- Design reserve or management areas to achieve mosaics of community types within areas large enough to support the most area-dependent covered (or planning) species and desired ecological services, and to accommodate future shifts due to climate change (e.g., sea-level rise, changing runoff patterns, shifting climate "envelopes").
- Strive for representation of all community types in habitat mosaics well distributed across the Delta, but considering site-specific conditions. Where possible, maintain or create "soft edges" or natural transitions along environmental gradients, as opposed to abrupt transitions or "hard edges" between community types.
- Bigger is better for habitat conservation and restoration sites, but don't ignore small areas that support rare communities or species. For example, small areas of seasonal wetlands, inland dunes, or alkali flats support disproportionate numbers of imperiled species.
- Seek to preserve and enhance natural heterogeneity in elevation, water depth, flooding frequency, nutrient conditions, vegetation types, and adjacency of different habitat types within and among the conserved, restored, or maintained habitat mosaics.[8]
- Enhance and preserve habitat connectivity where possible to maximize potential for natural range shifts, population expansions, escape from disturbance events (fires, floods), and maintenance of ecological processes, and to avoid isolating small populations of those species having limited dispersal abilities.
- Strive to create self-sustaining systems, but recognize that some communities and species may need active or perpetual management. For example, some invasive, nonnative species may require prolonged control efforts to sustain covered species or communities that they adversely affect.

5.2 Recommended Analyses

We recommend the following analyses be performed prior to finalizing the plan's conservation design, to assess likely effects of proposed covered activities and conservation measures on non-aquatic resources, and to inform how best to design and locate covered activities and conservation measures.

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[8] A variety of observational studies demonstrate that species diversity is higher in heterogeneous habitats than in homogeneous habitats (Harman 1972; Abele 1974; Pollock et al. 1998; Williams et al. 2002).

- Do an overlay analysis for covered actions (e.g., facilities, conveyance alignments) and conservation measures (e.g., potential wetland restoration sites) with known and potential locations of covered species and communities. This should include an assessment of how changing hydrological regimes (water depth, flows, flooding, etc.) overlay onto existing ecological communities and species. Assess how the combination of changes will affect the conservation design principles discussed in section 5.1 (e.g., community representation, habitat patch size, environmental heterogeneity, natural gradients, maintenance of rare communities, and adjacency and connectivity of existing community types within mosaics). Pay particular attention to the potential for rare communities, such as seasonal wetlands and inland dune scrub, to be impacted. This should include consideration both of direct effects (e.g., flooding of rare upland habitats for wetland restoration) as well as potential indirect effects (e.g., constraining options for restoration efforts that could be carried out by other entities or under other plans).
- Assess for each covered species whether natural range shifts or colonization into restored habitat is likely to occur with changing conditions (e.g., hydrological and sea-level changes, restoration actions), or whether translocation/transplantation is required. For species not likely to shift naturally, prioritize avoidance of occupied areas and consider translocation/transplantation plans as part of the adaptive management program.
- Assess the distribution of "hard" vs. "soft" edges and determine where restoration actions can be used to soften edges. For example, determine where covered wetland or transitional plants are located at unnaturally sharp transitions to other physical conditions or habitat types that may constrain their ability to shift range over time in response to climate change and rising water levels. This analysis can inform where restoration actions could be prioritized to sustain ecological shifts due to water-level changes (including grading to create gradual elevation gradients and revegetation to create wetland-upland vegetation gradients).
- Use climate envelope models coupled with habitat models (Loarie et al. 2008, Hijmans and Graham 2006, Green et al. 2008) to identify potential effects on covered species over a 50-year horizon. This could inform where offsite conservation actions may be more effective in hedging against climate change for some covered species.

5.3 Locations of Special Concern

The advisors discussed whether there are certain geographic locations in the BDCP plan area that are of particular importance to at-risk species or communities, or to maintaining critical ecological processes. The following are a few key locations where impacts should be avoided or where additional conservation, restoration, and management may be beneficial. We realize that these locations and their importance are likely already well known to BDCP participants, but felt their importance was worthy of emphasis.

- **Staten Island** is a critical wintering area for sandhill cranes and other birds, due in large part to wildlife-friendly agricultural practices.
- **Franks Tract State Recreation Area**. In addition to its importance to aquatic resources, the marshes of Frank's Tract are a hotspot of bird diversity and support a variety of rare and imperiled species, including California black rail, yellow warbler, yellow-breasted chat, and song sparrow.

- Occupied areas for riparian brush rabbits, including **Stewart Tract**, and near Lathrop. Occupied areas should be better defined by surveys currently underway by ESRP.
- **Antioch Dunes** represent a small remnant of a very rare ecological community that supports numerous endemic and imperiled species (see Sections 2 and 3). Remaining dunes have become isolated by urban development, limiting potential for restoring or expanding habitat.

5.4 Restoration Recommendations

- Recognize that restoration is a process, not a one-time action. We recommend following the restoration process designed by River Partners (Griggs 2008) for riparian and riverine restoration projects.
- Passive riparian restoration (just restoring semi-natural flooding regimes) is unlikely to be effective due to invasive weeds and insufficient colonization by dispersal-limited species. Some planting of woody vegetation, including both understory and overstory plants is recommended (Riparian Habitat Joint Venture 2004). Also, follow-up management to control invasives may be needed for up to 10 years post restoration to ensure success, and translocation may be necessary for some species.
- Given that water level changes will occur (due to conveyance changes, restoration efforts, and climate change), design and engineer plan facilities and structures in a manner that allows for control of water flows and depths to maintain diverse ecological conditions and particular species' needs. We recommend assigning a BDCP Work Group or Technical Team to evaluate the range of conditions desired to support the diverse requirements of covered species, communities, and processes in the plan area (terrestrial as well as aquatic). Recognize that optimizing how these metrics can best be manipulated to sustain covered species should be a focus of the systematic adaptive management and monitoring program.
- All else being equal, locate habitat restoration areas near existing habitat areas to expand or connect similar habitats, and to facilitate population expansions for covered species. For example, consult The Nature Conservancy's Cosumnes Watershed Plan and prioritize adjacent or nearby restoration sites. On the other hand, distributing restoration sites across the plan area will capture broader gradients in ecological conditions and may help spread the risk of restoration failures, maximize habitat diversity, and deal with uncertainties due to climate change and other dynamics.
- For floodplain restoration, consider leaving breached levees at least partially in place to provide physical habitat diversity and serve as refugia for species during floods ("bunny mounds"). Such physical features provide for habitat heterogeneity and increased bird diversity (Riparian Habitat Joint Venture 2004). However, it is important that old levees or other elevated areas be vegetated or revegetated with natural, local, plant palettes to provide escape cover during flood events as well as year-round habitat for diverse covered species.
- Also for floodplain and marsh restoration, meandering and dendritic channels are better than straight, undivided, and unbraided channels. Where floodplain areas are to be graded to create proper depths and drainage, consider leaving some permanent aquatic habitat (slightly deeper ponds or channels) to provide habitat for giant garter snakes, so long as these are configured to prevent fish stranding.

- Strive to create natural combinations of habitat types in mosaics that transition along physical gradients, rather than restoring single community types in isolation. For example, where tidal emergent marsh restoration is planned, also restore adjacent transitional and upland vegetation communities moving up the elevation gradient. This establishes the natural mosaic of habitat conditions required by many species, increases biological diversity and foodweb complexity for covered species (including fish), and will help accommodate ecological shifts due to changing climate and water levels.
- Use restoration to increase the rarest habitat types, if feasible. Seasonal wetlands (vernal pools) stand out as a rare habitat type that may be affected by project actions. Although vernal pool creation is controversial as a mitigation action, there may be opportunities for enhancing or restoring existing or former vernal pool areas in appropriate locations. If adverse impacts to vernal pools and associated species are unavoidable, offsite conservation of intact vernal pool systems may be preferable to attempting to create or restore vernal pools within the plan area. Inland dune scrub is also extremely rare. Although we do not anticipate direct negative plan effects on inland dune communities, BDCP actions have potential to create opportunities for restoring dune communities in some locations, perhaps to be implemented by other entities or plans.
- Use restoration to create "soft edges" between habitat types along ecological gradients. For example, many populations of potentially covered plant species occupy narrow bands of conditions along the elevation-tidal gradient, and many are currently up against "hard edges" (i.e., sharp transitions to other physical conditions or habitat types) due to dikes, levees, or other artificial features. This provides little or no opportunity for these populations to shift ranges with changing water levels or hydrological regimes. Where possible, restoration should be used to soften such edges via grading and/or revegetation to create opportunities for gradual range shifts and other adjustments to changing conditions.

5.5 Species-specific Conservation Actions

The advisors do not recommend relying on species-specific mitigation actions or structures (e.g., artificial burrows, nest boxes, nesting islands, "bunny mounds," created pools) as *primary* conservation tools. Conservation, maintenance, and restoration of intact habitat mosaics and ecological communities must be primary. However, the following specific mitigation actions should be considered as supplements to conservation and management of diverse habitats to enhance habitat value, particularly where covered species face specific life-requisite shortcomings despite habitat conservation and restoration:

- **Artificial burrows** are sometimes used by nesting burrowing owls, but have not been shown to increase owl populations in the long term. It is better to maintain natural burrow conditions and healthy prey populations (e.g., no ground squirrel control programs or insecticide use). Artificial burrows may be beneficial in certain situations where natural burrows are limiting as a supplemental mitigation measure.
- "**Bunny mounds**," or areas of ground elevated above the highest expected flood levels, are important in floodplain habitats to allow for escape by riparian brush rabbits and other species. These can be expensive to create from scratch, especially if fill has to be transported from other sites, but high mounds that are vegetated with brushy cover can contribute significantly to sustaining individuals and populations during floods, and create habitat

heterogeneity that also benefits diverse communities of birds and other taxa. Look for opportunities to get "free bunny mounds" such as, by leaving portions of the old levee as elevated ground when breaching levees for floodplain restoration. These should be revegetated with appropriate trees and shrubs, if necessary.

- **Nesting islands.** Creating or leaving some higher ground within subtidal and intertidal restoration areas can provide nesting islands for some shorebirds as part of an overall heterogeneity strategy.
- **Brown-headed cowbird trapping** (following guidelines of the North American Cowbird Advisory Council http://cowbird.lscf.ucsb.edu/) can benefit populations of songbirds that are adversely affected by nest parasitism by this species, such as least Bell's vireo and yellow warbler.
- **Contaminant control**, including control of herbicides, rodenticides, and light pollution may be an important management measure in conservation areas.
- **Vegetation management** on levees. We do not recommend burning, mowing, or herbicide use to control vegetation on levees.
- **Feral cat control** may be necessary in conservation areas or other areas important to covered species. Restrictions on maintaining feral or free-roaming cat populations should be enforced throughout the plan area.

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Attachment A – Advisor Biographies

Dr. Peggy L. Fiedler, Senior Botanist & Co-Director, Ecosystem Science and Natural Resources Management Services, WSP Environment & Energy, LLC. Dr. Fiedler has 30 years of experience in field research and teaching in conservation biology, ecology and evolutionary biology, and waters/wetlands ecosystem restoration. Her current interests are focused on designing plant community types in mega-diverse floras for ecosystem restoration, applying population viability models and metapopulation theory to the reintroduction of rare plant species, understanding demographic patterns of rare plants (including hybrid taxa) and improving monitoring protocol in waters/wetland ecosystem restoration.

Geoffrey R. Geupel, Director, Terrestrial Ecology Division, PRBO Conservation Science, Petaluma, CA. Geoff has over 28 years of experience in ornithological monitoring and conservation research in California. Recent publications and presentations have helped define bird monitoring protocols now used throughout North America. He has taught numerous technical workshops on bird monitoring and currently oversees more than 20 projects that use bird data to evaluate conservation actions. Current areas of interest include breeding and population biology, demographic monitoring, bird response to habitat restoration and management, and developing measurable populations metrics for conservation planning. He is currently Co-chair of California Partners in Flight and is formally involved with five of the six habitat joint ventures in the state.

Dr. Marcel Holyoak, Professor, Environmental Science and Policy, University of California at Davis. Dr. Holyoak is broadly trained as a population and community ecologist, with interests in conservation, biostatistics, and theoretical ecology. Much of his recent work addresses the responses of individual species and ecological communities to habitat fragmentation. His research group has conducted most of the work on the federally threatened Valley Elderberry Longhorn Beetle that has been performed in the last decade. He has a PhD. from the University of London (Imperial College) in ecology and biostatistics from 1992, and a BSc. in biology from the same university in 1989. He is acting Editor-in-Chief of a top-ranked ecology journal, *Ecology Letters*, and will become the new editor for this journal in January 2009.

Dr. Patrick A. Kelly, **Coordinator and Director of Endangered Species Recovery Program (ESRP) and Professor of Zoology, California State University, Stanislaus**. Dr. Kelly's main research interests are in mammalian ecology and conservation, and his current research focuses on the conservation and recovery of endangered mammals in California, including the riparian brush rabbit and riparian woodrat. He joined ESRP as Assistant Director in July 1993 and became Director in January 1996. Pat received a B.Sc. from University College Galway, Ireland, in 1981, and a Ph.D. from the University of California, Berkeley, in 1990.

Dr. Wayne Spencer, Senior Conservation Biologist, Conservation Biology Institute, San Diego, CA. Dr. Spencer is a conservation biologist and wildlife ecologist with expertise in conservation planning and endangered species recovery. He has worked on various regional NCCPs and HCPs in California as a consulting biologist, science advisor, and science facilitator. His research focuses primarily on rare and endangered mammal species, including the Pacific fisher, Stephens' kangaroo rat, and Pacific pocket mouse. He is also a Research Associate with the San Diego Natural History Museum. He served as the Facilitator for this BDCP Non-aquatic resources workshop and report.

Dr. Glenn Wylie, **Research Wildlife Biologist, USGS Western Ecological Research Center, Dixon, CA**. Dr. Wylie is a wildlife biologist specializing in wetland ecology as is concerns migratory birds and listed species in California. In the last 10 years he has been researching the distribution, abundance, and ecological requirements of giant garter snakes. Dr. Wylie was a science advisor for the Recovery Team for giant garter snakes and has advised habitat conservation planning for the city of Sacramento. He is currently advising Solano County in developing a habitat recovery plan as well as participating in the Yuba/Sutter and Yolo County efforts in habitat conservation planning.

Attachment B – Workshop Agenda

AGENDA
Bay-Delta Conservation Plan
Independent Science Advisors' Workshop
Concerning Non-aquatic Resources

30 September 2008

Hawthorn Suites Hotel, Crocker Room
321 Bercut Road, Sacramento. 916-441-1200
(Exit Richards Blvd East off of I-5, take first left at Bercut)

0900 – 1030 Orientation Session (Science Advisors and Consultant Team)

0900 – 0915	Welcome, introductions, and logistics
0915 – 0930	Overview of science advisory process and workshop goals (Wayne Spencer)
0930 – 1000	Overview of BDCP conservation approach and issues (Pete Rawlings, John Gerlach, and Jim Estep)
1000 – 1030	Q & A session and open discussion
1030 – 1045	Break

1045 – 1600 Advisors Only Session

1045 – 1130	Review of proposed covered species list and process
1130 – 1200	Review of existing conditions documents (Existing Ecological Conditions, stressors summaries, species accounts, distribution maps, habitat measures)
1200 – 1300	Working lunch (provided) – continued discussion of existing conditions documents and maps
1300 – 1400	Principles for addressing data gaps and uncertainties
1400 – 1500	Principles for conservation, restoration, and management of species, communities, and ecological processes
1500 – 1515	Break
1515 – 1600	Outline report and writing assignments
1600	Adjourn

Attachment C – Documents Reviewed By Advisors

Advisors reviewed the following documents in preparing this report. All documents (accept Document 1, BDCP Planning Agreement) are unpublished Draft reports, memoranda, chapters, or handouts prepared by SAIC.

1. October 6, 2006. Planning Agreement regarding the Bay Delta Conservation Plan.
2. March 7, 2008. Draft existing ecological conditions chapter and covered species accounts (on CD).
3. May 22, 2008. Proposed covered species selection process and potential species for coverage under BDCP.
4. September 5, 2008. Steering Committee Handout 1. Summary table: Other Stressors Working Group recommended conservation measures for consideration by the BDCP Steering Committee.
5. September 5, 2008. Steering Committee Handout 2. Other Stressors Working Group recommended conservation measures for consideration by the BDCP Steering Committee.
6. September 5, 2008. Steering Committee Handout 3. Summary table: Draft other stressors conservation measures by working biological objectives.
7. September 19, 2008. Steering Committee Handout 1. Restoration Program Technical Team recommended conservation measures for consideration by the BDCP Steering Committee.
8. September 19, 2008. Steering Committee Handout 2. Summary table: Draft habitat restoration conservation measures by working biological objective.
9. September 19, 2008. Draft plant species accounts and associated distribution maps for the following species:
    - Alkali milk-vetch
    - Delta button celery
    - Delta mudwort
    - Delta tule pea
    - Heckard’s peppergrass
    - Legenere
    - Mason’s lilaeopsis
    - San Joaquin spearscale
    - Soft bird’s beak
    - Suisun Marsh aster
10. September 19, 2008 Draft animal species accounts and associated distribution maps for the following species:
    - California black rail
    - California clapper rail
    - Conservancy fairy shrimp
    - Giant garter snake
    - Greater sandhill crane

- Longhorn fairy shrimp
- Riparian brush rabbit
- Salt marsh harvest mouse
- Suisun shrew
- Swainson's hawk
- Tri-colored blackbird
- Valley elderberry longhorn beetle
- Vernal pool fairy shrimp
- Vernal pool tadpole shrimp
- Western burrowing owl
- Western spadefoot toad
- Yellow-breasted chat

11. September 30, 2008. Poster-sized maps and PDFs of the following plan maps:

- BDCP natural communities
- Elevation-based restoration suitability categories
- Aerial imagery of the planning area
- DWR agricultural classes
- BDCP conveyance route options

Appendix G-3

Bay Delta Conservation Plan Independent Science Advisors' Report on Adaptive Management

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BAY DELTA CONSERVATION PLAN

INDEPENDENT SCIENCE ADVISORS' REPORT

ON

ADAPTIVE MANAGEMENT

Prepared for
BDCP Steering Committee

Prepared by

Independent Science Advisors:
Cliff Dahm, CALFED Science Program
Tom Dunne, University of California Santa Barbara
Wim Kimmerer, San Francisco State University
Denise Reed, University of New Orleans
Elizabeth Soderstrom, American Rivers
Wayne Spencer, Conservation Biology Institute
Susan Ustin, University of California Davis
John Wiens, PRBO Conservation Science
Inge Werner, University of California Davis

Science Facilitator:
Bruce DiGennaro

February 2009

Table of Contents

Executive Summary

This report summarizes recommendations from a group of independent scientists (Advisors; Appendix A) convened in December 2008 (Appendix B) concerning incorporation of adaptive management into the Bay Delta Conservation Plan (BDCP). The report includes a general review of pertinent BDCP documents and a recommended framework for incorporating adaptive management into the planning, design, and implementation of the BDCP.

Comments on BDCP Documents

It is clear from documents reviewed by Advisors (Appendix C) that efforts to develop an Adaptive Management Program (AMP) for BDCP are in their early stages. The documents show progress toward defining the elements of an AMP but lack several elements essential to effective adaptive management. The incomplete state of the documents made it difficult to evaluate the plan's scientific foundations, and many statements in the documents suggest a need to more fully assimilate and apply existing knowledge about the Delta to the development of conservation measures and the AMP.

The Advisors offer the following general comments and recommendations:

Existing Knowledge and Peer Review - Far more is known about the Bay-Delta ecosystem than is suggested by the BDCP documents we reviewed. The extensive knowledge base about the Delta should be fully exploited in selecting and designing BDCP actions. The omission of critical knowledge about the functioning of the Bay-Delta ecosystem also indicates the need for more development of the conservation plan itself. **We strongly recommend that technical documents that form the basis of the BDCP be reviewed by independent technical experts to ensure the credibility of the program and a sound foundation for conservation actions.**

Goals and Objectives - We agree that goals and objectives should be placed within a hierarchy of ecosystems, communities, and species. However, most objectives stated in the documents, and the conservation measures meant to address them, apply only to the species level. **We recommend developing explicit community and ecosystem objectives to reflect the hierarchical approach described in BDCP documents.**

Modeling - Models are extremely valuable for formalizing the link between objectives and proposed conservation measures to clarify how and why each conservation measure is expected to contribute to objectives. This key element of adaptive management is largely missing from BDCP documents we reviewed. **We recommend more extensive and explicit use of models to formalize knowledge about the system and to select, design, and predict outcomes of conservation measures to be implemented and monitored.**

Feedback – Formal processes for devising actions to maximize learning, and for assimilating new knowledge to provide the feedback that is key to adaptive management, were not discussed in the documents. **We recommend that greater attention be given to the learning value of actions, and to establishing a formal process by which new knowledge is used to alter actions or revise goals or objectives.**

Integration - The documents reviewed by the Advisors did not link the various conservation measures together as a package, and there was little sense of synergy or potential conflict among these clearly related actions. **We recommend the development of models to show clearly how various actions relate and how interactions will be integrated across multiple conservation measures and the entire adaptive management process.**

Guidance for a Robust Adaptive Management Program

Effective adaptive management includes several key steps, some of which are not included in the documents we reviewed. Adaptive management does far more than simply adjust actions as new information becomes available (which is merely common sense). It is a more comprehensive process of deciding how to choose initial actions in the face of uncertainty and systematically learning and evaluating how the manipulated system responds to those activities so that changes can be made as events unfold. Key missing elements of adaptive management in BDCP documents include (1) the formal setting of goals *based on problems to be addressed*, (2) the establishment of objectives (as distinct from goals), and (3) the use of conceptual or simulation models to bring the knowledge base to bear on the problems to be solved and predict outcomes of conservation actions. In addition, (4) monitoring must be more clearly and formally designed to establish criteria to evaluate effectiveness, and (5) monitoring results must be analyzed and assimilated to provide the information necessary for the feedback critical to adaptive management. Most critical are the succeeding steps (6) of capturing and interpreting information from monitoring and other sources to evaluate how the actions are working, what they are accomplishing, and how the knowledge base is changing. These critical steps require substantial investment in time, people, and resources.

We suggest that particular attention be paid to the following:

The Adaptive Management Approach - The form of adaptive management to apply (active vs. passive)[1] to a given conservation measure depends on the scope of the measure and its degree of reversibility. In the design phase, it is important to recognize where an adaptive management strategy resides on the active-to-passive spectrum.

Knowledge Base - The knowledge base comprises the scientific understanding of a system; it should be used to identify likely influences of conservation measures on the ecosystem and the degree of confidence in those influences. It provides the context for establishing goals and objectives, the information base for models, and the foundation for selecting, designing, and monitoring conservation measures.

Assessment and Synthesis - Assessment is critical to making monitoring useful. In the adaptive management framework, monitoring provides a quantitative basis for analysis, synthesis, and evaluation of knowledge to support management decisions.

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[1] Active adaptive management is experimental, involving manipulations intended to achieve conservation goals but also to improve knowledge. Passive adaptive management is not experimental, but is nevertheless approached from a scientific perspective to improve knowledge and adapt strategies during project implementation.

Continual Assimilation of Knowledge and Decision Making - The weakest aspect of most adaptive management plans is in the sequence of steps required to link the knowledge gained from implementation and other sources to decisions about whether to continue, modify, or stop actions, refine objectives, or alter monitoring. This step must be much more fully developed than was evident in the BDCP documents we reviewed. Responsibility for this step should be assigned to a highly skilled agent (person, team, office) having the right mix of policy and technical expertise. This investment is critical to making adaptive management effectively support the BDCP.

1 Introduction

This report presents recommendations from a multidisciplinary group of independent science advisors concerning the use of adaptive management in the development and implementation of the Bay Delta Conservation Plan (BDCP). The advice and recommendations are intended not to question or promote particular plan goals or policies, but to provide guidance for incorporating adaptive management into the BDCP.

The group of nine advisors (Appendix A) was convened by the BDCP Steering Committee at a facilitated workshop held on December 17-19, 2008 (Appendix B). Prior to the workshop, advisors were provided with several draft BDCP documents for review (Appendix C). Comments in this report are based on the documents we reviewed and brief discussions with representatives of the BDCP planning team, who presented overviews of the emerging plan and important unresolved issues during two open sessions at the workshop.

Because the draft documents provided to us were in an early stage of development and did not describe a comprehensive Adaptive Management Program (AMP), we did not evaluate them in detail as a finished plan. Rather, we focused our effort on providing guidance for structuring an AMP for the BDCP that would support effective application of existing and evolving scientific understanding to BDCP decisions both before and during its implementation.

Section 2 articulates eight principles that we suggest be used as a foundation for the BDCP AMP. Section 3 incorporates these fundamental principles into an adaptive management framework tailored specifically to the BDCP and describes key elements of that framework. Appendix D provides two detailed examples of how draft BDCP conservation measures could be revised to better reflect the suggested framework.

2 Principles for Adaptive Management

The following principles for effective adaptive management emerged from our deliberations and are integral to our proposed adaptive management framework (see Section 3):

1. The scope and degree of reversibility of each proposed action (i.e., conservation measure) determines the form of adaptive management that can be applied (e.g., “active” or experimental adaptive management versus “passive” adaptive management).
2. The knowledge base about the ecosystem is key to decisions about what to do and what to monitor, and includes all relevant information, not just that derived from monitoring and analysis within the context of BDCP.
3. Program goals should relate directly to the problems being addressed and provide the intent behind the conservation measures; objectives should correspond to measurable, predicted outcomes.

4. Models should be used to formalize the knowledge base, develop expectations of future conditions and conservation outcomes that can be tested by monitoring and analysis, assess the likelihood of various outcomes, and identify tradeoffs among conservation measures.
5. Monitoring should be targeted at specific mechanisms thought to underlie the conservation measures, and must be integrated with an explicitly funded program for assessing the resulting data.
6. Prioritization and sequencing of conservation measures should be assessed at multiple steps in the adaptive management cycle.
7. Specifically targeted institutional arrangements are required to establish effective feedback mechanisms to inform decisions about whether to retain, modify, or replace conservation measures.
8. A dedicated, highly skilled agent (person, team, office) is essential to assimilate knowledge from monitoring and technical studies and make recommendations to senior decision makers regarding programmatic changes.

In the following section we expand on these principles and provide details of the proposed adaptive management framework.

3 Framework for Adaptive Management

Figure 1 presents a framework for incorporating adaptive management into the planning, design, and implementation of the BDCP. The framework is based on previously developed adaptive management frameworks, but has been refined to make key aspects of the process more explicit and to tailor the approach to the needs of the BDCP. The framework is specifically intended to improve the approach described in the draft BDCP documents and to avoid shortcomings of many previous AMPs. **We recommend adopting this refined framework to guide BDCP planning and implementation.**

In the following sections we detail elements of this adaptive management framework, while expanding on the principles presented in Section 2. Appendix D provides two detailed examples of how elements of the proposed BDCP Conservation Measures might correspond to the elements of the diagram and be guided by the proposed framework and principles.

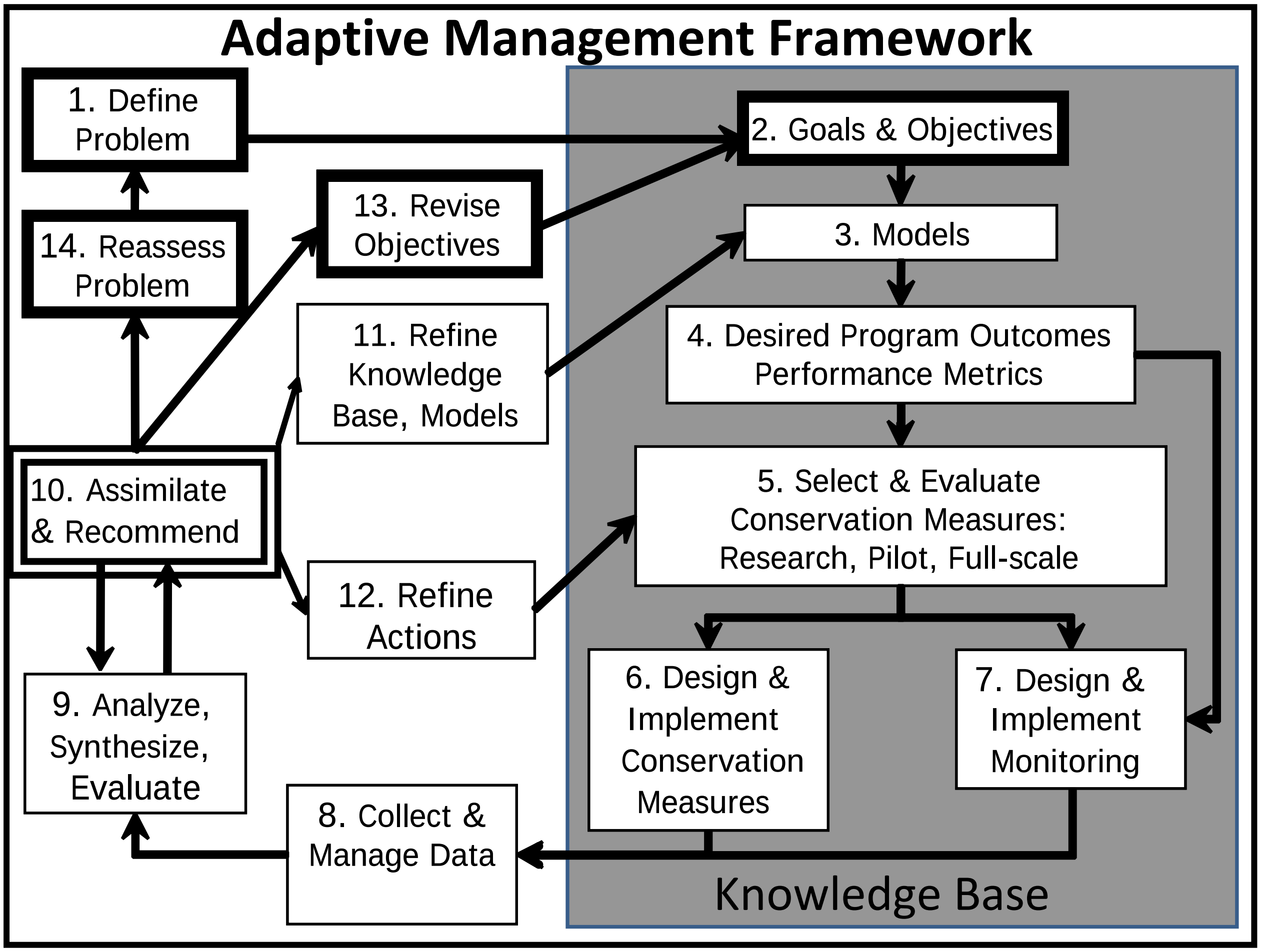

Figure 1. *A recommended AMP framework for BDCP showing the flow of information and responsibilities of different entities.* The large shaded box underlying the right side of the figure represents the knowledge base for defining goals and objectives, designing predictive models, predicting outcomes, identifying performance metrics, and designing and implementing conservation measures and monitoring actions. Boxes framed with thin lines represent tasks performed by technical staff, such as scientists, land and water managers, and other analysts. Boxes framed with bold lines represent tasks performed by senior decision makers (i.e. policy makers and program managers who control program objectives and funding). The box framed with double lines (Box 10) represents a key step that is missing from most AMPs: Assimilate and Recommend. This task requires a body of skillful "polymaths" who understand both the technical and policy implications of the information passed along by technical staff (who analyze, synthesize, and evaluate monitoring and other data; Boxes 8 and 9). The task represented by Box 10 is to assimilate this diverse information, understand its consequences, and formulate recommendations to both the senior decision makers and the technical staff, such as revising plan objectives or conservation measures.

3.1 Form of Adaptive Management (Principle 1)

The literature on adaptive management defines two broad categories: active and passive. Active adaptive management is experimental, involving manipulations intended to achieve conservation goals but also to improve knowledge. Passive adaptive management refers to actions that are not experimental, but that are nevertheless approached from a scientific perspective in order to improve knowledge and adapt strategies during project implementation.

The form of adaptive management applied to a given conservation measure depends on the scope of the measure and its degree of reversibility. At one extreme, there is only one Delta, ruling out simultaneous replication of actions that broadly affect the system. In addition, some conservation measures, such as major investment in an around-Delta conveyance, are unlikely to be reversed, so temporal replication is also impossible. In such circumstances, monitoring of processes and of system responses to natural and managed events form the basis for learning, as is the case in various non-experimental sciences. At the other extreme, there are many opportunities for experimental manipulation to achieve goals while simultaneously learning. For example, gates on Delta tidal channels could be operated on a schedule intended to produce contrasts with predictable and testable consequences. It is crucial to recognize that passive adaptive management differs from active only in the use of experimental manipulations and the consequently greater power to detect the influence of the manipulations. Otherwise, these two forms of adaptive management proceed according to identical principles and processes, as outlined in Figure 1. Note also that research aimed at particular sources of uncertainty can be part of an adaptive management program (Box 5 in Figure 1).

3.2 Applying the Knowledge Base (Principle 2)

The knowledge base (large gray box in Figure 1) is key to decisions about what conservation measures might be implemented and what responses to monitor. It forms the foundation for all steps from formulation of goals and objectives (Box 2) to the selection, design, and implementation of conservation measures and monitoring (Boxes 6 and 7). The knowledge base comprises the scientific understanding of the system and is used to identify likely influences of conservation measures on the ecosystem. It also includes knowledge of the feasibility, costs, and probable external implications of projects for the broader society and economy of the region. The knowledge base provides the context for establishing goals and objectives, the source of information for models used to project conservation outcomes, and the basis for believing that an action will have a certain outcome. The knowledge base is continually updated as new information becomes available and as adaptive management proceeds.

Far more is known about the Bay-Delta ecosystem than is suggested by BDCP documents we reviewed, which strongly emphasized (1) uncertainties about the system, (2) a central role for hypothesis testing, and (3) the role of monitoring data in reducing uncertainties. We certainly do not discount the importance of these issues, but point out that the extensive knowledge base about the Delta and the planning context should be fully exploited in selecting and designing BDCP actions. Enough is known about the Bay-Delta ecosystem, or can be inferred from studies of other systems, to conclude that:

1. Certain outcomes can be predicted with confidence[2].
2. Most scientific knowledge about the Delta has been derived by approaches other than hypothesis testing (e.g., analysis of monitoring data, modeling, and parameter estimation).
3. Not all pertinent knowledge comes from regular monitoring; knowledge may also stem from short, targeted field campaigns and observations in single natural events that cannot be replicated.
4. Monitoring adds no knowledge without a dedicated process for data management and analysis.

A thorough understanding of the knowledge base is essential for modeling, monitoring, and other actions to be efficiently focused on reducing key uncertainties.

For this plan to incorporate "best available scientific information" requires that the components of the overall knowledge base used for each step in the process be synthesized and referenced. The information in the knowledge base should be used according to a hierarchy that emphasizes peer-reviewed science and other formal evaluations. Published papers should be given the greatest weight (especially highly influential or often-cited, and therefore highly scrutinized and replicated papers), followed by unpublished papers, technical reports, newsletter articles, and presentations or personal communications from experts. Review or summary articles can be used in lieu of extensive lists of publications. Personal communications should be cited with the name and affiliation of the person and the date of the communication. Local knowledge of experts or stakeholders is also an important component of the knowledge base, even if not published, but such knowledge should be recorded explicitly so that it can be reviewed.

Although peer review is the gold standard of scientific publication, it may not always provide assurances as to the quality of the data or the accuracy of statistical analyses, since reviewers rarely have time to replicate reported analyses or examine raw data. Therefore studies used as a basis for significant decisions should be thoroughly checked and analyses replicated if possible.

Data used in analyses must have undergone a quality assurance check. Generally this is done routinely for widely-used data, such as daily flows, salinity, and fish abundance indices. Documents using the knowledge base should promote transparency by explaining clearly what we know and how we know it, with full citations to the sources of information (e.g., papers, data sets, websites, personal communications with affiliation) and ensuring that these are readily available (e.g., posting technical reports on websites).

The incomplete state of the draft BDCP documents we reviewed made evaluation of scientific content of the plan difficult. However, many statements in these documents suggest an incomplete knowledge of the Delta among the project team. For example:

- Literature citations were sometimes inaccurate (e.g., Handout #5 lines 41-45: "highly productive" and similar statements are not true and not stated in the reference).

[2] For example, field studies in the California Bay-Delta and elsewhere indicate that restoring intertidal marsh will increase carbon input to estuarine food webs for well-understood biogeochemical reasons, although monitoring and research would be essential to show the magnitude of this input and its long-term fate.

- Inappropriate citations were used (e.g., the use of Kimmerer 2004 to support a statement about tidal marshes and sea-level rise on page 2-43 of the March 2008 Draft Existing Ecological Conditions Chapter and Covered Species Accounts).
- Often the most recent published findings were not used (e.g., Feyrer et al., 2007).
- Unpublished data and presentations appear to be given equal weight to published findings (e.g., Handout #5 page 28 line 33).
- Several statements fail to reflect the current state of knowledge or provide little substantive foundation, for example, in handout #4 page 14:
    - Lines 41-42: "These zooplankton can reduce phytoplankton to very low concentrations, resulting in a clear water state" is poorly supported by the citations provided. In fact, published work indicates that phytoplankton biomass in the Delta is rarely if ever limited by zooplankton (Kimmerer 2004).
    - Line 35: "Additionally, the statistical analyses used in this paper may be questionable" should be amplified and supported by reference to specific work.

Note that these and several other examples in Appendix D are presented only to illustrate a broad and pervasive problem identified by the Advisors in the documents that were provided. **We recommend that the technical documents that form the basis of the BDCP plan and conservation actions be reviewed by independent technical experts to ensure the credibility of the program and a sound foundation for conservation actions.**

3.3 Problem Statement Leads to Goals and Objectives (Principle 3)

A clear problem statement should link directly to program goals, which in turn are linked to specific objectives. The BDCP documents we reviewed generally failed to distinguish among these elements. The CALFED Ecosystem Restoration Program (ERP) Strategic Plan defines goals and objectives for ecosystem restoration, which BDCP planners might find helpful.

The problem statement specifies the issue or concern that proposed conservation measures are intended to solve or mitigate. If the problem is not stated clearly, the linkages to everything else in the adaptive management framework will be weak or inconsistent, compromising the entire approach.

Goals are broad, general intentions or visions for some aspect of the system. Goals propose broad solutions and encapsulate desired future conditions. For example, a central problem statement for BDCP is that some native fishes are in danger of extinction. One goal therefore is to restore the abundance of those species (ERP Goal 1). However, declines in each species may be linked to broader, systemic problems. Therefore, additional goals call for rehabilitation of natural processes (Goal 2) and habitats (Goal 4), and reductions in the rate of introduction of new species (Goal 5) and in contaminant effects (Goal 6). The last two goals are included regardless of whether a quantitative link can be made to the abundance of a particular species, because it is widely believed that accomplishing these goals is highly likely to favor several species and other societal preferences.

Objectives are specific, often quantitative, statements of outcomes that reflect the goals that the program is expected to achieve. Some objectives can be stated as quantitative targets for species or locations in a hierarchical arrangement (see Figure 4-2 of the CALFED ERP Strategic Plan). However, given uncertainties, it is not yet possible to develop quantitative conservation objectives for many species, communities, or processes, so many objectives must be stated in qualitative form. Nevertheless, as information accumulates, objectives can be refined and made progressively more quantitative. This step need not always await monitoring data, because predictive models applied within the context of the knowledge base can also assist in developing quantitative objectives (Box 3 in Figure 1).

Note that objectives for different species or communities may conflict or require tradeoffs (for example, altering flows to benefit one species may harm another). Such conflicts should not preclude development of objectives for each species or community. Rather, it would be beneficial to explicitly articulate such competing objectives and thereby highlight tradeoffs implicit in planning and management decisions.

We strongly recommend that the problem, goals and objectives, and the linkages among them, be clearly articulated steps in the process. The Advisors agreed with the approach of placing goals and objectives within the hierarchical scaling framework of ecosystems, communities, and species that was included in the draft BDCP Goals and Objectives documents. Careful consideration of program objectives within this context may help identify possible undesirable interactions and minimize conflicts among objectives that might occur if developed independently at the species level. In fact, most examples of objectives in the draft BDCP documents address individual species, with less attention to community and ecosystem level objectives. Thus, they fail to address the array of potential conflicts among objectives. Although the advisors encourage the continued inclusion of these species-specific objectives in the plan, **we recommend development of explicit community and ecosystem objectives to reflect the hierarchical approach described in the BDCP documents.**

3.4 Use of Models (Principle 4)

Models (Box 3) are used to formalize and apply the knowledge base, develop expectations, assess the likelihood of success, and identify tradeoffs. In particular, models should be used to formalize the link between objectives and proposed conservation measures to make clear how and why each conservation measure is expected to contribute to objectives. This key element of adaptive management is missing from the BDCP documents we reviewed, except for mention of hydrodynamic and particle tracking models. The use of models would make more explicit the relative potential benefits of different conservation measures and how they may interact (conflicts, tradeoffs, or synergies). Our impression on reviewing the BDCP documents is that this formal analytical step was skipped in jumping directly from objectives to potential conservation measures.

The types of models used in adaptive management should include at least conceptual, statistical, and process models. Conceptual models are used to make clear the expected links between actions and outcomes, the roles of other factors, the degree of confidence in the outcomes, and potential tradeoffs (e.g., among species or alternative conservation measures). The roles of conceptual models are described in Chapter 3 and Appendix B of the ERP Strategic Plan and the uses of conceptual diagrams (as components of conceptual models) are explained at http://ian.umces.edu/pdfs/stc_2008_conceptualdiagrams.pdf. A formalized approach to the development of conceptual models has been developed under the auspices of the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) and should be used to guide the development of any additional conceptual models needed for the BDCP. Statistical models may allow us to characterize empirically how a system works. However, statistical models may not allow us to predict all system responses, because they apply only within the range of conditions over which data have been collected.

Process models rooted in underlying mechanisms provide a much stronger basis for predicting system responses to environmental change (i.e., extrapolating beyond available data), although model calibration and validation of process models are more challenging than for statistical models[3]. Process models should be used increasingly as the knowledge base becomes more diversified and complex. Process models (e.g., population models, particle tracking models) express the mechanisms responsible for the relationships in conceptual models as mathematical equations and can incorporate uncertainty and system variability. Process models are especially useful in analyzing complex actions and developing plans for irreversible changes to the system (e.g., an around-delta conveyance). Given the expense and potential for unforeseen consequences of large-scale permanent changes to the system, process model simulations offer a relatively inexpensive way of anticipating problems and developing operational criteria or other design elements to minimize problems.

Process models also provide a powerful tool for refining reversible actions. For example, BDCP action FLOO1.1 (Yolo Bypass) includes a reference to varying operations to "adaptively manage" floodplain conditions and extensive monitoring to track changes. Such post-hoc monitoring will likely have low power to detect effects given background variability. Enough is known about this system to develop process models to forecast the magnitude of effects of these manipulations and maximize the value of the manipulation and the monitoring. Modeling will allow calculations of the monitoring effort needed to detect effects and comparisons between expectations and observations during the manipulations.

3.5 Desired Program Outcomes and Performance Metrics (Principle 5)

A key component of our proposed adaptive management framework is definition of measurable outcomes and associated performance metrics (Box 4 in Figure 1) that are directly related to the programmatic objectives via models (Box 3 and Section 3.4). These measurable outcomes and performance metrics are critical for several reasons. First, they document desires and expectations about how the system could function in the future following implementation of conservation measures. Second, they are used to track progress toward meeting the objectives. Third, they help define the monitoring essential to the evaluation of any chosen conservation measure. Measurable outcomes can be predicted using models (see Section 3.4). Each outcome should have at least one associated performance metric, a target for successful achievement of

[3] See BDCP Independent Science Advisors Report, November 2007 for a more detailed description of the potential application of statistical and process models to BDCP issues.

that outcome, a monitoring program designed to identify progress toward that target, and decision points for amending actions if acceptable progress is not being made.

3.6 Select and Evaluate Conservation Measures (Principles 2 and 4)

The specific actions to be taken as part of an adaptive management program (i.e., conservation measures) should be selected and evaluated based on a comprehensive and formal application of the knowledge base and models, with full consideration of possible interactions among the actions. At this step in the process (Box 5) critical decisions are made about which conservation measures to implement, as well as whether each measure is to be implemented as a full-scale action, as a pilot study, or as a research program. This decision regarding the nature or level of each action depends on each action's physical and temporal scale, the degree of confidence in its benefits, and the consequences of being wrong:

- A full-scale action is taken to solve a large-scale problem when (1) the action is considered highly likely to achieve or contribute to one or more key objectives, (2) the benefits are believed to outweigh potential detriments, and (3) there is little additional benefit to performing pilot studies or research before implementing the action.
- A pilot action is taken if there is good reason to think that the action will have an effect, but there are uncertainties that can be resolved only through manipulation of the ecosystem.
- Research is considered a conservation measure if it is directed at resolving specific issues key to implementation of the Plan.

The DRERIP scientific evaluation process initiated by the ERP Science Board includes an approach for evaluating conservation measures using conceptual models. Where available, process models may be more suitable for this task.

It is also important to consider the interactions among various conservation measures. The documents reviewed by the Advisors did not clearly link the various conservation measures together as a package, and there was little sense of synergy or potential conflict among the actions. Yet, many of the actions are clearly linked or represent different aspects of the same manipulation. For example, design of an around-Delta conveyance would perforce include operational requirements on inflows and outflows, cross-channel gate operations, south Delta flows, X2, and other flow-related aspects of the system. Thus, most if not all of the conservation measures would be influenced by, or result from, the new operational criteria. Likewise, changes in outflow (WAOP9) are acknowledged as the principal cause of changes in salinity in Suisun Bay and the western Delta (WAOP10), yet they are presented as if they were separate. It is confusing and inaccurate to present these conservation measures as independent actions. This also results in excessive repetition and impedes comprehension of the documents.

3.7 Prioritization and Sequencing of Conservation Measures (Principle 6)

As part of developing goals, objectives, and outcomes, attention should be given to determining the priority and sequencing of conservation measures. *Priority* indicates the relative importance or urgency of a conservation measure, while *sequencing* indicates the order in which the measures are implemented. It is unlikely that funds and other resources necessary for implementing all conservation measures will be immediately available when the plan is finalized and implementation begins. Even though priority and sequencing may be determined by financial or political considerations, the decision-makers should be provided with an assessment of the consequences of their choices that has been developed using the knowledge base.

Prioritization should involve the allocation of conservation measures to categories (e.g., High, Medium, or Low Priority) rather than ranking all measures relative to one another. This categorization should be based on consensus criteria that consider the scale and breadth of the expected outcomes relative to the objectives. For example, measures contributing to more than one objective should generally receive a higher priority ranking than those contributing to only one. In addition, measures *essential* to achieving an objective should receive a higher priority than measures that may further an objective but are not essential.

Sequencing criteria could include (1) ease of implementation, (2) interdependence of measures, (3) feasibility of near-term implementation, (4) availability of funding, (5) uncertainty of measure implementation and outcomes, and (6) the potential for synergies among measures.

3.8 Design and Implement Conservation Measures and Monitoring (Principles 5 and 6)

Once conservation measures have been evaluated and selected (Box 5) they must be designed, analyzed, implemented, and constructed (Box 6). By “design” we mean to clearly describe the actions to be undertaken, including exactly what will be done, where, on what schedule, how, by whom, with what anticipated results, and with what accompanying monitoring actions. In cases where the measure is being implemented as part of an adaptive management experiment, the design need not adhere to formalisms of strict experimental design. It should focus on achieving the desired conservation outcomes but should also consider how monitoring will be conducted and how data will be managed and analyzed to assess the relative performance of the experimental units. The design should carefully consider the pertinent knowledge base, including results of any relevant research, pilot studies, or full-scale studies performed in the previous step (Box 5).

The monitoring plan for a conservation measure is designed and implemented in parallel with the conservation measure itself (Boxes 6 and 7) to generate data useful in comparing system performance to expected outcomes. The National Research Council (1990) defines three classes or purposes of monitoring: *compliance, model verification,* and *trend*. Building on this concept, the Advisors identified four types of monitoring that seem appropriate within our proposed adaptive management framework:

1. *Compliance* monitoring is built into permit requirements and focuses on whether the conservation measures are being implemented as planned.
2. *Performance* monitoring identifies whether individual conservation measures are achieving their expected outcomes or targets.
3. *Mechanistic* monitoring demonstrates whether the mechanisms thought to link conservation measures to desired outcomes are working as predicted.

4. *System-level* monitoring is used to identify the degree of success of the entire program (i.e., the cumulative effects of numerous conservation measures) relative to ultimate desired outcomes as described in the BDCP documents. This requires a sustained, long-term commitment to monitoring of critical features of the whole system, rather than the response of a single measure in the vicinity of a single locality.

Current monitoring practice is usually limited to compliance and system-level monitoring, with some performance monitoring. However, the outcomes of most conservation measures are likely to be influenced by external factors that are uncontrolled or unobserved. Mechanistic monitoring is therefore essential to understand whether changes at the system level are a result of one or more conservation measures or are due to external factors beyond the control of BDCP. Thus, mechanistic monitoring is crucial to adaptive management because it allows effects of the conservation measures, acting through the proposed mechanisms, to be distinguished from other effects.

Table 3X[4] lists a series of hypotheses associated with each conservation measure and monitoring target. Framing the monitoring targets as hypotheses makes clear the links to mechanistic monitoring. In order to be useful, however, scientific hypotheses should be stated in ways that allow them to be tested. For example, the first hypothesis in the table, "Increase production of organic carbon in support of food production within the Delta" is not stated as a hypothesis, and contains two concepts that should be separate if they are to be tested. This could be restated as: (1) The production of labile organic carbon will increase during the additional periods of flooding; and (2) The production of zooplankton (i.e., food for fish) in the estuarine foodweb will increase during periods of flooding. Note that some hypotheses lend themselves to formal tests, whereas others are more suited to parameter estimates (e.g., in the above example, the quantitative increases in carbon production and zooplankton production). Also note that hypotheses may not apply to all monitoring targets, particularly compliance and system-level monitoring.

Much of the trend monitoring and some of the other types of monitoring for aquatic species are already being conducted by the Interagency Ecological Program (IEP) and other agencies. BDCP should capitalize on these ongoing efforts to the fullest extent possible. However, these other monitoring programs may be altered or discontinued by the controlling agency; therefore, BDCP should coordinate with those agencies to ensure continuity of monitoring required specifically for evaluating the performance of the BDCP.

3.9 Collect, Manage, Analyze, Synthesize, and Evaluate Data (Principle 7)

Assessment is crucial to making monitoring useful. Much of the current monitoring in the Bay-Delta produces data that are under-analyzed and therefore under-used. The purpose of monitoring in the adaptive management framework is to provide a quantitative basis for analysis, synthesis, and evaluation. These activities are essential steps in the feedback to management decisions that are hallmarks of adaptive management.

[4] This was a draft summary table titled "Conservation Measure Effectiveness Monitoring and Potential Adaptive Management Responses" provided to advisors in December 2008.

Monitoring data must be made readily available online as soon as quality-control analyses have been completed. This has not always been the case with Bay-Delta monitoring programs, but it is essential for ease of access and transparency. Data management is also critical to allow analyses, synthesis, and evaluation. Data management must include the metadata required to identify how the data were collected, the methods used, any calculations employed, time and date, and site locations and characteristics. Effective data management is designed before data collection begins and is integral in the budgeting of successful monitoring frameworks.

Figure 1 highlights the expectation that the consequences of any conservation measure will be monitored and assessed to improve understanding of whether and how the measure is having the desired effects. No data should be collected under BDCP without a specific plan for analysis and synthesis by a particular person or group, with an adequate budget expressly allocated for data analysis and synthesis. This budget should be at least 10% of the cost of the monitoring, based on the Advisors' collective experience. The synthesis should provide answers to the questions implicit in the design of performance metrics: how have things changed, have they changed in expected ways, and what might have caused deviations from the expected trajectory? Note that expectations, generated by conceptual or simulation models, are essential to this effort. Although expectations often will not be met, they provide a basis for evaluating the data and trends. The results of these analyses should be published in technical, peer-reviewed reports to ensure both a degree of external review and easy access.

3.10 Translating Information into Action (Principles 7 & 8)

The weakest aspect of most adaptive management plans is in the sequence of steps required to link the knowledge gained from the implementation of conservation and monitoring actions (Boxes 3 through 9) to the governance actions of sustaining, refining, or replacing program goals and objectives or judging an action to be complete and successful (bold boxes in Figure 1). However, adaptive management plans rarely define the process and the responsibility for assimilating this information into the governance of the conservation plan. In the absence of this step, the adaptive management plan cannot really be adaptive. Information from technical reports is often captured and transmitted to decision-makers in irregularly scheduled exercises, such as ad hoc white papers and through conferences to brief managers or policy-makers. Such processes are inefficient and ineffective as a means of informing decision-makers, and lack the transparency needed in adaptive management.

To assimilate information and formulate recommendations (Box 10) requires both policy and technical expertise. This step is fundamental to the successful integration of accumulating knowledge and information into plan policies, such as revising goals and objectives, refining analytical models, or allocating funding. This step also is a key responsibility that is generally lacking from AMPs, a flaw that undermines successful implementation of adaptive management. The link between the technical step of "Analyze, Synthesize, Evaluate" and the decision-making step of "Assimilate and Recommend" requires regular interaction and exchange of information between technical staff and decision makers.

Box 10 in Figure 1 therefore highlights the need for some highly skilled agent (person, team, office) to be assigned the responsibility for continually assimilating scientific information generated by investigations *both within and external to the adaptive management program* and transforming it into knowledge of the kind required for management actions. Boxes 11 through 14 indicate that such actions may include (1) refining a particular conservation measure, (2) refining the knowledge base and models of system behavior that are extracted from the knowledge base, (3) revising objectives of an entire conservation measure, and (4) reassessing whether the original target problem is solved, transformed, or still a problem. This last action may also be affected by external events such as changing societal preferences, newly recognized environmental threats, or other changed or unforeseen circumstances.

The actions of the agent represented by Box 10 need to be carried out continually but on a range of time scales. For example, individual components of the knowledge base might be refined gradually and annually, whereas particular conservation measures might be refined only after a few years of project implementation. The entire problem might be re-assessed or re-visited once in a decade. The key principle, however, is that *the process of transferring and transforming the results of technical analyses into knowledge to support decisions cannot be taken for granted in the hope that it will occur in the absence of a body specifically charged with making it happen*. This function requires remarkably skillful people, who are truly inter-disciplinary ("polymaths"). Whatever their training, these individuals (or team of individuals) need to be comfortable with a wide range of technical information, as well as understand the functioning of government, law, economics, and the management of large projects.

Although this component of the adaptive management process is not well-developed in the field of environmental and resource management, examples of it are widespread in other, well-capitalized areas of human affairs. For example, the medical and biotechnology industries support highly trained personnel to monitor the myriad scientific results relevant to that field and to convey that information into forms that support the goal of the industry to deliver products and make a profit. This is the foundation of evidence-based medicine (Elstein 2004). Military Departments support links to the scientific community (e.g., Army Research Office, Office of Naval Research, Strategic Environmental Research and Development Program) to assimilate their useful results and recommend support for relevant studies. In government, the Congressional Budget Office, Government Accountability Office, and the Office of Science and Technology Policy all employ people who can assimilate disparate technical information into forms required for government decision-making.

Investment in some entity with the specific role of assimilating knowledge from the technical studies and making recommendation for changes is an essential component of large, complex environmental management projects. **We strongly recommend that BDCP put considerable thought and investment into institutionalizing an entity that is specifically tasked with assimilating knowledge and recommending adaptive changes to goals, objectives, models, conservation measures, and monitoring, as illustrated in Box 10 of Figure 1.** We consider this investment critical to the success of BDCP and to making adaptive management an integral part of the plan.

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Appendix A – Advisor Biographies

Cliff Dahm, Ph.D., Lead Scientist, CALFED Science Program, Sacramento, and Professor, Department of Biology, University of New Mexico. Dr. Dahm is an ecosystem ecologist with expertise in restoration ecology, biogeochemistry, microbial ecology, hydrology, climatology and aquatic ecology. He is presently on loan to the US Geological Survey to serve as lead scientist for the CALFED Science Program from the University of New Mexico (UNM), where he is a professor in the Department of Biology. He emphasizes interdisciplinary approaches required for understanding aquatic ecosystems. He has served as interim director for the Sevilleta Long-Term Ecological Research (LTER) Program at the Sevilleta National Wildlife Refuge in central New Mexico, director for the Freshwater Sciences Interdisciplinary Doctoral Program at UNM and is currently a member of the Science Steering Group for the Global Water Budget Program of the U.S. Global Change Research Program. He has served as a program director for the Division of Environmental Biology of the National Science Foundation and was awarded the NSF's Director's Award for Program Management Excellence. He has worked on adaptive management protocols in Florida and Queensland, Australia. Dr. Dahm received a B.S. in Chemistry from Boise State University, an M.A. in Chemical Oceanography from Oregon State University, and a Ph.D. in aquatic ecology and oceanography from Oregon State University.

Tom Dunne, Ph.D., Professor of Environmental Science & Management and of Earth Sciences, University of California Santa Barbara. Dr. Dunne conducts field and theoretical research in fluvial geomorphology and in the application of hydrology, sediment transport, and geomorphology to landscape management and hazard analysis. He has worked on hydrology and geomorphology in many parts of the world, including New England, Northern Canada, Kenya, the Pacific Northwest, and the Andean and lowland parts of the Amazon River Basin. His current work concentrates on sediment transport and river channel evolution in gravel-bed rivers of the Sacramento and San Joaquin basins, including the relationship between physical and biological processes in a restored reach of the Merced River. He has served on many National Research Council Committees, the CALFED Ecosystem Restoration Program, the CALFED Independent Science Board, as well as the Adaptive Management Forum of the US Fish and Wildlife Service. Dr. Dunne received his Ph.D. in Geography from The Johns Hopkins University.

Wim Kimmerer, Ph.D., Research Professor of Biology, Romberg Tiburon Center for Environmental Studies, San Francisco State University. Dr. Kimmerer's research focuses on the San Francisco Estuary, emphasizing effects of human activities on the estuarine ecosystem. Research topics include zooplankton ecology, effects of introduced species and variable freshwater flow, population dynamics of fish such as salmon, striped bass, and the threatened delta smelt, simulation modeling of populations, and analysis of the extensive monitoring database from the estuary. Dr. Kimmerer is chair of the Interagency Ecological Program's Estuarine Ecology Team, and has assisted the IEP with long-range planning and design of monitoring programs. He was a member of the CALFED Ecosystem Restoration Program Core Team, developing a strategic plan for the program, and the Ecosystem Restoration Program Science Board, providing guidance on the application of adaptive management in the program. He is also serving as a science advisor to the CALFED Science Program, and has participated on numerous review panels on key issues in the Delta. Dr. Kimmerer received his Ph.D. in biological oceanography from the University of Hawaii.

Denise Reed, Ph.D., Professor, Department of Earth and Environmental Sciences, and Interim Director, Pontchartrain Institute for Environmental Sciences, University of New Orleans. Dr. Reed's research interests include coastal marsh response to sea-level rise, the contributions of fine sediments and organic material to marsh soil development, and how these are affected by human alterations to marsh hydrology. She has worked on coastal issues on the Atlantic, Pacific, and Gulf coasts of the US, as well as other parts of the world, and has published the results in numerous papers and reports. She is involved in restoration planning both in Louisiana and in California, and in scientifically evaluating the results of restoration projects. Dr. Reed has served on numerous boards and panels concerning the effects of human alterations on coastal environments and the role of science in guiding ecosystem restoration, including the Chief of Engineers Environmental Advisory Board, a number of National Research Council Committees, and the Ecosystems Sciences and Management Working Group of the NOAA Science Advisory Board. She received her B.A. and Ph.D. from the University of Cambridge in England and has worked in coastal Louisiana for over 20 years.

Elizabeth Soderstrom, PhD., Senior Director of Conservation for American Rivers. Previously, Dr. Soderstrom was the Senior Director for Sierra and International Rivers at the Natural Heritage Institute, during which time; she managed the Sharing Water Project on the Okavango River in Southern Africa, launched the Mountain Meadows Initiative, and applied adaptive management principles to river restoration as a Switzer Leadership Fellow. She also assisted both the CALFED Science Program and the Sierra Nevada Conservancy in developing and using performance measures. Dr. Soderstrom has also served as an International Engineering and Diplomacy Fellow with the American Association for the Advancement of Science at USAID's Center for the Environment in Washington, DC, and at USAID's Regional Center for Southern Africa based in Gaborone, Botswana. In these positions, she implemented the International Coral Reef Initiative, was an advisor and representative to the Ramsar Convention on Wetlands of International Importance, and the Convention on Biodiversity, and researched and designed a role for United States assistance in the management of international rivers in southern Africa. Dr. Soderstrom received a B.A. in English Literature, and a B.S. and M.S. in Biological Sciences from Stanford University, and a Ph.D. from the University of California, Berkeley.

Wayne Spencer, Ph.D., Senior Conservation Biologist, Conservation Biology Institute, San Diego. Dr. Spencer is a conservation biologist and wildlife ecologist with expertise in conservation planning and endangered species recovery. He has worked on various regional NCCPs and HCPs in California as a consulting biologist, science advisor, and science facilitator. His research focuses on rare and endangered mammal species, including the endangered Stephens' kangaroo rat, Pacific pocket mouse, and Pacific fisher. He has also worked extensively on approaches to designing landscape-level reserve systems and maintaining ecological connectivity. He is a Research Associate with the San Diego Natural History Museum and a science advisor to numerous conservation NGOs. He received his B.S. in Biology and Wildlife Management at the University of Wisconsin, Stevens Point, his M.S. in

Wildland Resource Science at UC Berkeley, and his Ph.D. in Ecology and Evolutionary Biology at the University of Arizona.

Inge Werner, Ph.D., Associate Adjunct Professor and Director of the Aquatic Toxicology Laboratory, University of California at Davis, School of Veterinary Medicine. Dr. Werner's research focuses on the molecular, biochemical and physiological responses of fish and aquatic invertebrates to anthropogenic environmental stressors, and interpreting these in an ecological context. Her work includes aquatic monitoring programs to assess pollutant impacts in California's Sacramento-San Joaquin watershed and delta, studies on the impact and efficacy of alternative pest control methods in orchard and field agriculture, and the effects of elevated temperature, pesticides and heavy metals on aquatic organisms. She has worked on various zooplankton, amphipod and clam species, as well as native fishes including Chinook salmon, steelhead trout, delta smelt, and green sturgeon. Dr. Werner has an M.S. in Limnology from the University of Freiburg, Germany, and a Ph.D. in Zoology with specialization in aquatic toxicology from the University of Mainz, Germany.

Susan Ustin, Ph.D., Professor of Environmental Resource Science, Department of Land, Air, and Water Resources, University of California Davis. Dr. Ustin is an ecosystem ecologist with 25 years experience in environmental applications of remote sensing. Her current research involves working at a variety of scales from leaf level radiative transfer modeling to quantify landscape biogeochemistry to global mapping of wildfire occurrence. She has extensive experience in developing methods of analysis for hyperspectral imaging data, focusing on detection of environmental stresses and degradation. She has worked on many projects in the San Francisco estuary and delta, starting with her dissertation research and most recently mapping invasive aquatic plants in the delta region. She received a B.S. and M.S. in Biological Sciences from California State University Hayward and a Ph.D. in Botany from the University of California Davis in 1983 in the area of plant physiological ecology with work on physiological responses to salinity and drought stress in wetland plant species in the California Delta.

John Wiens, Ph.D., Chief Conservation Science Officer, PRBO Conservation Science, Petaluma. John Wiens grew up in Oklahoma as an avid birdwatcher. Following degrees from the University of Oklahoma and the University of Wisconsin-Madison (M.S., Ph.D.), he joined the faculty of Oregon State University and, subsequently, the University of New Mexico and Colorado State University, where he was a Professor of Ecology and University Distinguished Professor. His work has emphasized landscape ecology and the ecology of birds, leading to over 200 scientific papers and 7 books. John left academia in 2002 to join The Nature Conservancy as Lead Scientist, with the challenge of putting years of classroom teaching and research into conservation practice in the real world. In 2008, he joined PRBO Conservation Science as Chief Conservation Science Officer. His aim is to build on the long-standing work of PRBO on bird populations to address conservation in a rapidly changing world – "conservation futures." Climate change is affecting species distributions, economic globalization is altering land uses, and demands for the goods and services provided by nature are changing how people relate to nature. John is working with PRBO staff and partners to develop guidance for assessing the impacts of these changes and how management practices can help natural systems adapt.

Appendix B – Workshop Agenda

DECEMBER 17-19, 2008

<u>Wednesday - December 17, 2008</u>

1. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – Steamboat Rm.** **12:00 – 1:30**
   (Advisors Only)
   - *Advisors meet to review charge*

2. **<u>OPEN SESSION</u> – Embassy Suites Sacramento – Steamboat Rm.** **2:00 – 4:00**
   (Steering Committee and Public welcome)
   - *Introduce advisors*
   - *Background presentations by SAIC and others*
   - *Steering Committee representatives interact with advisors*

3. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – Steamboat Rm.** **4:00 – 5:00**
   (Advisors Only)
   - *Organize Review*
   - *Homework assignments*

<u>Thursday - December 18, 2008</u>

1. **<u>CLOSED SESSION</u> - Embassy Suites Sacramento – John Sutter Rm.** **8:00 – 12:00**
   (Advisors Only)
   - *Discuss program strengths and weaknesses*
   - *Discuss successful elements from other programs*
   - *Craft initial recommendations*

   Lunch **12:00 – 1:30**

2. **<u>OPEN SESSION</u> – Resources Building – Rm. 1131** **2:00 – 3:30**
   (Steering Committee and Public welcome)
   - *Present initial findings and recommendations*
   - *Discuss findings with Steering Committee representatives*

3. **<u>CLOSED SESSION</u> – Resources Building – Rm. 1131** **3:30 – 5:00**
   (Advisors Only)
   - *Refine recommendations*
   - *Work on findings memorandum.*

<u>Friday - December 19, 2008</u>

<u>CLOSED SESSION</u> - Embassy Suites Sacramento – John Sutter Rm. **8:00 – 12:00**
(Advisors Only)
- *Finalize language for findings memorandum*

Adjourn **12:00**

Appendix C – Documents Reviewed By Advisors

Adaptive Management Section, Chapter 3, Conservation Strategy; Draft. December 2, 2008. BDCP Steering Committee Meeting, Handout #6, December 5, 2008.

An Overview of the Conservation Strategy for the Bay Delta Conservation Plan. December 12, 2008.

Annotated BDCP HCP/NCCP Document Outline. Bay Delta Conservation Plan Steering Committee Meeting, Handout #6, November 21, 2008.

Bay Delta Conservation Plan Independent Science Advisors Report, Independent Science Advisors (Reed et al.), November 16, 2007.

Bay Delta Conservation Plan Independent Science Advisors Report Concerning Non-Aquatic Resources. Independent Science Advisors (Spencer et al.), November 2008.

BDCP HCP/NCCP Biological Goals and Objectives; Working Draft. BDCP Goals and Objectives Working Group, Technical Meeting. December 11, 2008.

Biological Goals and Objectives: Hierarchical Relationships. Goals and Objectives Working Group meeting. November 21, 2008.

Chapter 2 Existing Ecological Conditions. Science Applications International Corporation, March 7, 2008.

Designing Monitoring Programs in an Adaptive Management Context for Regional Multiple Species Conservation Plans. USGS, 2004.

Draft Water Operations Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #5, October 31, 2008.

Examples Demonstrating Relationships Among Goals and Objectives, Viability Attributes, Monitoring, and Adaptive Management For Selected Species. Bay Delta Conservation Plan Steering Committee Meeting, Handout #11, November 21, 2008.

Guidance for the NCCP Independent Science Advisory Process, California Department of Fish and Game, August 2002.

Monitoring and Adaptive Management Sections for Selected Conservation Measures; Draft. Science Applications International Corporation, December 12, 2008.

Section 3.3 Approach to Conservation: Overview of Key Conservation Measures and their Integration; *Working Draft.* Bay Delta Conservation Plan Steering Committee Meeting, Handout #5, November 21, 2008.

Table 1. Proposed Conservation Measures Contributing to Improving Viable Salmonid Population (VSP) Parameters for the Sacramento River Winter-Run ESU. Science Applications International Corporation, December 5, 2008.

Table 3.X. Conservation Measure Effectiveness Monitoring and Potential Adaptive Management Responses. Science Applications International Corporation, December 5, 2008.

Third Draft Habitat Restoration Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #3, October 31, 2008.

Third Draft Other Stressors Conservation Measures. Bay Delta Conservation Plan Steering Committee Meeting, Handout #4, October 31, 2008.

Appendix D.

Examples of Recommended Adaptive Management Framework Applied to Two Proposed Conservation Measures

The Advisors selected two examples of BDCP proposed conservation measures to illustrate how our proposed Adaptive Management Framework would apply to them and to developing additional conservation measures. These examples illustrate the need for goals and objectives to be articulated clearly and that the existing knowledge base must be integrated into models (conceptual or otherwise) to identify expected outcomes. This will connect goals and objectives, expected outcomes, performance metrics, and monitoring in a logical manner. We also point out inaccuracies or gaps in how these examples are presented in the draft BDCP documents. We recommend that these examples be used to improve the development, analysis, and presentation of conservation measures for the BDCP.

Other Stressors Example

Conservation measure TOC01 is to "Reduce the Load of Ammonia in Effluent Discharged from the Sacramento Regional County Sanitation District into the Sacramento River…If Warranted Based on Research." [5]

Knowledge Base

The knowledge base is currently provided in the form of a rationale in draft BDCP documents. Although information from a few key scientific publications is cited, the rationale does not provide a satisfactory summary of the knowledge base with respect to ammonia/ammonium and effects on different trophic levels of the Delta, as well as secondary effects due to trophic interactions. The information provided is also not well substantiated. Ammonia and ammonium are some of the best-characterized contaminants in this system, and information on concentrations producing toxic effects for fish and other species is relatively abundant. The BDCP documents should explain in a more specific manner why ammonia and ammonium are of concern in the Lower Sacramento River. Examples of available information that should be included are data on total ammonia/ammonium concentrations collected by Sacramento Regional County Sanitation District (SRCSD), California Department of Water Resources, and the Interagency Ecological Program toxicity information reviewed in US EPA (1999), as well as many scientific papers in the peer-reviewed literature. Results from Teh et al. (2008) are misquoted, as no conclusive evidence was found to support the statement that ammonium caused the observed reduction in survival of prey species (copepods) for delta smelt and longfin smelt.

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[5] This goal is inaccurately worded, and this inaccuracy is perpetuated throughout BDCP documents. The terms ammonia and ammonium refer to two chemical species that are in equilibrium in water (un-ionized ammonia and ionized ammonium). Chemical tests usually measure both ammonia and ammonium (NH_3, NH_4^+), while the toxicity is primarily, but not completely, attributable to the un-ionized form. Ammonia concentration is not directly measured but can be calculated if temperature and pH are known.

Goals and Objectives

This conservation measure is essentially a research and monitoring program, but no clear goals or objectives are provided, and the title of the conservation measure is inconsistent with the performance measure or measures of success, which are focused on adverse effects on fish (see below). For example, a clear goal statement would be:

Minimize or eliminate direct and indirect toxic effects of ammonia and ammonium from Sacramento Regional County Sanitation District (SRCSD) effluent on covered species.

Objective statements could then be:

1. Reduce the load of ammonia and ammonium in SRCSD effluent to levels which will not cause adverse indirect or direct effects to covered species in the Lower Sacramento River.
2. Reduce the load of ammonia and ammonium in SRCSD effluent to ….mg/L (quantitative threshold).
3. Reduce the load of ammonia and ammonium in SRCSD effluent to minimize or eliminate risk of indirect and direct ammonia/ammonium toxicity to covered species in the Lower Sacramento River.

This would lead directly to specifications of performance metrics and potential research goals, such as monitoring total ammonia/ammonium concentrations as well as pH and water temperature downstream of the outfall in areas where fish habitat and elevated concentrations coincide (Objective 2; relatively easy), reducing ammonia/ammonium to "safe" concentrations of ammonia/ammonium for covered fish species and their prey (Objectives 1 and 3) and identifying performance metrics for monitoring adverse effects on Delta species at different trophic levels (more difficult).

This conservation measure is stated as contingent upon ongoing or planned research. The BDCP documents should explain specifically what the goals of this research are, and what outcomes will warrant the implementation of the full-scale conservation measure.

Tradeoffs are not explicitly addressed, but should be. For example, it is possible that a reduction in nutrient input due to an increased level of treatment could affect primary productivity or phytoplankton community composition downstream of the treatment plant. It is important to discuss different levels of wastewater treatment (nitrification or coupled nitrification and denitrification to achieve removal as nitrogen gas) and their expected outcomes. This should be discussed in the context of studies by Dugdale et al. (e.g., 2007; ammonium inhibition of diatom growth), Jassby et al. (2002; 2008; nutrient loading and dynamics), and Lehman et al. (2005, 2008; *Microcystis aeruginosa*), as well as related publications and ongoing studies referred to in the "Rationale."

Models

Models should capture and formalize the knowledge base. A conceptual model could provide the framework for the conservation measure and inform selection of performance metrics, but sufficient data already exist to create a more quantitative model. For example, information on the oxidation of ammonia and ammonium in municipal wastewater treatment effluent after upgrading to tertiary treatment (nitrification only) is readily available from the Stockton Wastewater Treatment Plant, which recently switched from secondary to tertiary treatment. Information on total ammonia/ammonium concentrations in the Lower Sacramento River is also available (DWR, SRCSD, Interagency Ecological Program (IEP) Pelagic Organism Decline (POD)). There also is a relatively large body of information on the acute and chronic toxic effects of ammonia and ammonium on fish and some aquatic invertebrates, and US EPA water quality criteria exist (US EPA, 1999).

Desired Program Outcomes and Performance Metrics

Contingent upon the goals and objectives, it is important to clearly state the desired outcomes of the conservation measure: While it is relatively easy to define desired outcomes and performance metrics if the goal is to "reduce the load of effluent-related ammonia and ammonium…," it is more difficult to define these if the goal is to "reduce adverse direct or indirect effects on covered fish species." The latter requires information on acute, chronic, and sublethal effects of ammonia and ammonium on covered fish species and their prey under current conditions and conditions projected under reduced loading. It also requires seasonal assessment of ammonia and ammonium loads under variable pH and temperature and the hydrodynamic transport and fate of the ammonia and ammonium downstream in the Sacramento River and within the Delta.

Select and Evaluate Conservation Measures

The choice about whether to implement a conservation measure as a full-scale action, as a pilot study, or as a research program depends on its physical and temporal scale, the degree of confidence in its benefits, and the consequences of being wrong (see Section 3.6). A full-scale action is taken to solve a problem when the action is considered highly likely to achieve or contribute to one or more key objectives, and there is little additional benefit to performing pilot studies or research before implementing the full-scale action. Clearly, this is not the case here. At present, the actual conservation measure TOC01 provided in the BDCP document consists of a research program to "evaluate the need and, if demonstrated to be necessary to protect covered fish species, reduce the levels of SRCSD effluent-derived ammonia and ammonium entering the Delta." The "need" is defined by the goal "to protect covered fish species." The full-scale action would be to improve the SRCSD wastewater treatment process to reduce ammonia and ammonium in the effluent. To realize this measure, the plan calls for monitoring total ammonia/ammonium concentrations in the river, and for performing studies to provide conclusive evidence of whether or not the discharge of ammonia and ammonium in effluent from the SRCSD Wastewater Treatment Plant has substantial adverse direct or indirect effects on covered fish species.

It would facilitate evaluation and future adaptive management decisions if the development of this conservation measure was described in detail, provided clear information on goals and objectives, specified research objectives, and detailed why presently available data are insufficient to implement a full-scale action.

Design and Implement Conservation Measures

As stated above and in Section 3.6, the actions to be undertaken under this conservation measure should be described in greater detail. What are the specific research goals and hypotheses, and what is monitoring expected to show? How is risk to covered species defined? Provide details of the design to be used in determining what levels of ammonium and ammonia have adverse direct or indirect effects on covered fish species, and how often these levels are exceeded. Specific information gaps that lead to uncertainties should be addressed clearly. What actions will be taken to reduce uncertainties? Text in Lines 16-18 of the draft plan describes neither uncertainties nor risks. Identify alternative strategies if identified partner entities choose not to collaborate on the conservation measure.

Collect, Manage, Synthesize, and Evaluate Data

Performance metrics should provide useful information to evaluate the success of the conservation measure and should be directly related to the objectives. For example, data collection and management planning should address the questions of how and where will monitoring be conducted, what sorts of inputs may be required to model the system, and how will results be analyzed? As an important example, monitoring of total ammonia/ammonium should involve simultaneous pH and temperature measurements so levels of un-ionized ammonia can be calculated. The spatial and temporal scope of data collection also needs to be considered as impacts to foodwebs and covered species are evaluated. A well designed data collection and management plan will facilitate effective synthesis and evaluation of the resulting data as the BDCP is implemented.

Remaining Components of the Adaptive Management Framework

The full-scale action to reduce the ammonia/ammonium load in the Lower Sacramento River by improving treatment technology at SRCSD would be costly and largely irreversible. This conservation measure makes the full-scale action contingent upon the significant risk of direct or indirect toxic effects on covered fish species due to effluent-derived ammonia/ammonium. Establishing the “need” for the full-scale action, or refining the conservation measure to achieve this goal, requires in-depth scientific knowledge of ecotoxicological principles and risk assessment strategies. Highly skilled individuals are needed to successfully include results provided by research in adaptive management decisions.

Riparian Restoration Example

The stated conservation measure is to "restore between XX and XX acres of riparian forest and scrub communities as a component of restored floodplain, freshwater intertidal marsh, and channel margin habitats."[6]

Knowledge Base

The benefits to covered species of restoring riparian forest and scrub are presumably supported by previous science and applied management, but little of this background knowledge is apparent in the plan documentation. Only two citations are provided to support elements of the rationale for the conservation measure.

While it is not necessary to provide complete documentation of all of the knowledge that underlies development of the plan, the knowledge base should be developed sufficiently to provide a clear and transparent foundation and justification for the proposed plan.

Goals and Objectives

Goal NACO1 is to "Protect, enhance, and restore tidal perennial aquatic, tidal freshwater emergent, brackish freshwater emergent, floodplain, and valley riparian communities to provide habitat and ecosystem functions to increase the natural production (reproduction, growth, and survival), abundance, and distribution of covered species."

This goal is too broad and includes implicit assumptions that may not be warranted. The first part is about plant communities, the second about unspecified habitat, the third about functions of unspecified parts of the ecosystem, and the fourth is about population processes of unspecified species. Moreover, this goal includes five habitat types and production, abundance, and distribution characteristics for each habitat type. This makes it impossible to define clear metrics for each of these important Delta habitats. This goal should be broken into parts that logically hang together. Again, the ERP Strategic Plan provides guidance on this. More carefully stated, this might read as four goals, each having a discussion of why these goals have been selected:

1. Protect, enhance, and restore tidal perennial aquatic, tidal freshwater emergent, brackish freshwater emergent, floodplain, and valley riparian plant communities.
2. Protect or restore functional habitat types.
3. Restore and enhance ecosystem functions such as….
4. Increase the natural production, abundance, and distribution of covered species.

Objective NACO1.5 is to "Restore at least XX acres of riparian forest and scrub within the Delta to provide habitat and ecological functions in support of covered species."

This is a clearly stated and measurable objective, although it is not clear what variables or processes qualify as "ecological functions." The objective should lead to specific outcomes that

[6] The documents we reviewed did not supply acreages, but explained these would be determined in the future.

can be evaluated to determine whether the goal (as expressed in this objective) is being achieved. What does "support" mean operationally?

Models

There is no indication in the documentation we received that modeling of any sort has been used to assemble and synthesize the knowledge base about the dynamics and controlling factors of riparian forest and scrub communities and their linkages to various habitats in the Delta. Such models might be used, for example, to determine *how* restoration of riparian forest and scrub will actually provide habitat and "ecological functions" to covered species. Is XX acres a sufficient amount of forest or scrub to provide habitat to which covered species (species differ in the amount of habitat needed to support functioning populations)? One might use existing information on breeding birds in riparian habitats, for example, to model how restoration at different levels might affect reproduction, growth, or survival of different species. Spatial optimization models might be employed to assess the consequences of different spatial arrangements of riparian forest and scrub restoration within different areas of the Delta, and to explore tradeoffs among different approaches to riparian restoration. At a minimum, the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) conceptual models could be used to be more explicit about the relationships between the covered species and riparian forest and scrub.

Desired Program Outcomes and Performance Metrics

Expected outcomes are scattered through the description of Riparian Habitat Restoration conservation measures. For example:

- "At floodplain restoration sites that function hydrologically as flood bypasses (e.g., the Yolo Bypass), riparian vegetation is expected to establish along margins of existing and created drains and channels and other locations with suitable hydrology."
- "Levees constructed and maintained by other entities that incorporate "green" levee components would also increase the extent of riparian habitat … by allowing for the establishment and growth of riparian vegetation on levee surfaces."
- "Restoring riparian forest and riparian scrub habitats is expected to … increase the extent of valley elderberry longhorn beetle habitat and nesting habitat for Swainson's hawk and yellow-breasted chat; … increase … instream cover … through contributions of instream woody material; … increase production and export of terrestrial invertebrates into the aquatic ecosystem; and … increase cover for rearing juvenile salmonids and Sacramento splittail."

In general, these outcomes are framed in ways that enable conservation measures to be developed and measurements designed to assess progress in meeting the goal and objectives. Thinking about outcomes could be broadened to include other benefits, such as the potential role of riparian vegetation in flood abatement, water retention or in carbon sequestration. In general, outcomes could be more broadly considered in the context of ecosystem services.

Metrics to measure progress toward realizing these outcomes are not provided; this section is still in preparation.

Select and Evaluate Conservation Measures

Presumably the evaluation and selection among several potential conservation measures has already occurred, although this measure is sufficiently broad that it likely includes several alternatives. It would facilitate adaptive management if the conservation measures were developed in greater detail, to indicate how restoration is to be accomplished, where restoration will be targeted, what factors will be considered in determining whether, when, where, and how to undertake restoration, and the like. For example, the approach embraces a "build it and they will come" philosophy – e.g., "riparian habitat would be allowed to naturally establish in floodplain habitat areas that are restored…"[7] A more proactive approach to ensuring that the desired type of riparian habitat becomes established may be more effective. This additional level of detail will be needed before this measure can be evaluated using the DRERIP tools.[8]

The possibilities of conducting preliminary research or pilot studies to evaluate whether the conservation measures are likely to produce the expected outcomes in a cost-effective and timely manner are not considered; this may be an outcome of the recent scientific evaluation using the DRERIP tools. Pilot projects can be invaluable tools for generating public support for restoration actions and for the design of larger-scale projects (e.g., Toth et al. 1998).

Design and Implement Conservation Measures

Details of the design(s) to be used in restoring riparian habitat are not provided; it may not be the intent of this plan to include such details, but they will be needed in order to design effective monitoring programs.

Design and Implement Monitoring

The BDCP documents indicated that monitoring will be conducted to assess the use of restored habitats by covered species, factors that govern the establishment and growth of native riparian vegetation, the need to control non-native invasive species, and the ability of restored habitat to provide unspecified "desired ecosystem and covered species benefits."

Monitoring must be adequate to determine whether the expected and desired outcomes are being met. This requires a monitoring plan be developed that describes what will be monitored, at what spatial and temporal intervals, by what methods, and how the data will be used to assess performance.

Remaining Components of the Adaptive Management Framework

The report mentions using adaptive management to (1) improve the design and management of restored areas to provide for the successful establishment, growth, and benefits of restored riparian habitats, and (2) evaluate the need for control of non-native invasive species or the use of riparian plantings to improve success. These are appropriate adaptive management responses.

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[7] Although the report acknowledges that this approach could allow the establishment of non-native invasive species, it does not fully address the implications of this issue.

[8] The BDCP independent science advisory report concerning non-aquatic resources (November 2008) also noted that simply restoring semi-natural hydrological regimes in floodplains won't restore natural riparian conditions, that restoration is a process rather than a one-time action, and that there is a useful knowledge base for guiding restoration actions that should be fully integrated into restoration planning, implementation, and monitoring.

The application of adaptive management to riparian habitat restoration, however, would be enhanced by considering the potential management responses to various outcomes *as part of the conservation plan*. The use of models to explore likely scenarios would help managers anticipate and plan for adaptive management actions as the effects of the conservation measures undertaken become evident through focused monitoring.

Literature Cited in Appendix D

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Appendix G-4

Bay-Delta Conservation Plan Delta Science Program Panel
Review of the "Logic Chain" Approach

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BAY-DELTA CONSERVATION PLAN

DELTA SCIENCE PROGRAM PANEL

REVIEW OF THE "LOGIC CHAIN" APPROACH

Prepared for
BDCP Steering Committee

Prepared by
Cliff Dahm, Delta Science Program
Denise Reed, University of New Orleans
Elizabeth Soderstrom, American Rivers
John Wiens, PRBO Conservation Science (Chair)

19 March 2010

Background

The Bay-Delta Conservation Plan (BDCP) is being prepared through collaboration among several government, non-government, and private-sector entities. The goal of BDCP is to identify actions that will contribute to the recovery and protection of endangered and sensitive species and their habitats in the Sacramento-San Joaquin Delta of California while maintaining or improving water supplies to a diversity of users. To this end, a "logic chain" has been proposed as a framework for linking recovery goals for covered fish species with BDCP goals, objectives, conservation measures, monitoring, and adaptive management.

The review panel convened by the Delta Science Program met in Sacramento on March 2-4, 2010, to evaluate this approach. In this review, we drew heavily from the following documents: Logic Chain Status Report, Chapters 3.3 and 3.4 of the draft BDCP, SAIC Draft Effectiveness Monitoring for Conservation Measures document, Summary Report of the DRERIP Evaluations of BDCP Draft Conservation Measures, Independent Science Advisors' Report on Adaptive Management, and examples of logic chains provided by American Rivers and The Bay Institute.

The Charge

The charge to the review team had three elements. The first was to address whether the logic chain framework is a useful tool for refinement of BDCP goals and objectives. The second was an assessment of the logic chain framework with a focus on determining if the internal logic was sound and if there were critical gaps. The third element was to recommend next steps for populating key logic chains and to consider where additional science was needed in the BDCP process. This report addresses these three elements of the charge to the review team.

Recommendations

Adequacy of the logic chain framework

- The general logic-chain approach should continue to be developed and then applied, as it has the potential to clearly articulate and link goals, objectives, actions, and outcomes.
- The logic chain should be first applied to the covered fish species.
- The revisions to the logic chain structure developed by the review panel should be incorporated, as appropriate, to reduce areas of ambiguity and refine the logic chain.

Assessment of the logic chain framework

- BDCP should distinguish between order-of-magnitude approximations of BDCP goals and objectives that are acceptable in the early planning phase and the more detailed descriptions that will be necessary as the plan is finalized and ready for implementation.
- The projected outcomes should be framed as testable hypotheses linked to specific conservation measures and evaluated against actual outcomes. Outcomes must be quantified, with specified and measurable parameters and appropriate metrics. The analytical methodology to be employed should also be specified. It is important to know with clarity whether a conservation measure is working as intended.
- Use metrics to evaluate the success of outcomes that clearly link to biological functions; consider the judicious use of surrogate metrics. For example, accurate quantification of rare and endangered fish species may not be possible but overall community structure that characterizes native and non-native groups could serve as a surrogate measure.
- Constraints to implementation of the conservation measures (e.g., financial, environmental, logistical) should be considered as part of the planning process rather than as factors to be included only when one comes to implementing conservation measures. This will ensure that expectations about implementation are commonly understood. For example, budgetary requirements to make the necessary monitoring measurements and analyze the resulting data should be developed as soon as possible so that this information can be used in the prioritization of conservation measures.
- The potential impacts of system dynamics, variation, and change (especially those associated with climate variability, climate change, and sea-level rise) on the effectiveness of conservation measures should be explicitly addressed in the logic chain. A steady-state equilibrium, in which the system varies around some stable long-term state (i.e., stationarity), cannot be assumed.
- The adaptive management framework should be developed in greater detail, recognizing that analysis is *not* the endpoint of adaptive management. Adaptive management

approaches should be incorporated into the body of the logic chain rather than relegated to something that is done at the end, after measures have been implemented.

<u>Next steps and science needs</u>

- Rather than developing all logic chains at the same pace, logic chains should be developed in detail for 2-3 species and then evaluated as a proof of concept. These logic chains should be for species for which understanding is high (e.g., splittail). A user-friendly version of the logic chain that describes the approach and its uses in readily understandable terms should be developed now.

- The upper section of the logic chain (problem, recovery/species goals, and recovery/species objectives) should be developed and populated by the responsible regulatory and permitting agencies. This needs to be done immediately, because the application of logic chains to BDCP goals and objectives and the evaluation of hypotheses that feed into adaptive management depend on a clear statement of the problem to be addressed and well-defined recovery/species goals and objectives.

- The middle section of the logic chain (BDCP goals and BDCP objectives) should be developed through collaborative efforts. A limited number of experts from the permitting agencies, non-governmental organizations, and the potentially regulated entities should participate in developing this section of the logic chains.

- A science expert workshop should be convened to populate the lower part of the logic chain, focusing on the conservation measures, outcomes, monitoring, metrics, and the form of an adaptive management process once the upper and middle sections of the logic chains have been completed.

- Simulation models and scenario analysis should be used to explore the potential consequences and cost-effectiveness of conservation measures as part of the planning process, before measures are actually implemented.

- The formalisms of other approaches such as cost-benefit analysis, return-on-investment, or ecological risk analysis should be used to help set priorities and evaluate outcomes. Such tools should be used to inform decision making and negotiations, to consider tradeoffs, and to establish priorities among conservation measures.

General Comments

Before dealing with the details of the logic-chain, we offer several general comments as broad guidance for further development of the approach. First, our ability to recover or manage covered species depends on a clear understanding of what factors are limiting or creating stress to populations. These are the factors that must be removed or mitigated by the conservation measures. Such factors may be identified in recovery plans or may require additional information obtained from the scientific literature and/or expert opinion, and should be refined through the adaptive management process.

Second, there is an underlying (but unstated) assumption of stationarity that runs through the logic chain approach, the draft BDCP documents, and recovery plans. This assumption leads to the expectation that there is a stable "baseline" condition for the Bay-Delta ecosystem and the populations it supports. Given the massive changes in this ecosystem over the past century, this is almost certainly not true now. The potential effects of climate change on sea level, tidal fluxes, Sierra snowfall, and the timing of freshwater runoff make it even less likely to hold in the future. The logic chain and BDCP should explicitly incorporate non-stationary dynamics into the framework.

Third, it is important to incorporate study designs, monitoring protocols, and metrics as part of the logic chain. In particular, consideration of the statistical power required for detecting the effects of conservation measures, coupled with a determination of acceptable levels of response of covered species or other targets to conservation measures, may help to determine the feasibility or priority of particular measures.

Fourth, although it is important to have a clear and logical structure for developing hypotheses about the consequences of conservation measures and the efficacy of these measures in addressing BDCP goals and objectives, the framework should not be so highly structured and prescriptive that it constrains thought or resists the exercising of dynamic adaptive management. The Bay-Delta ecosystem is complex. The responses of covered species to conservation measures will always be clouded by uncertainty – did a species respond to a measure or to something else? Dealing with such uncertainties requires flexibility in planning and implementation.

Evaluation of the Logic Chain

In order to understand the logic and function of the logic chain, the review team chose to delve into the logic chain example for the Delta Smelt (Appendix 2). We reviewed and assessed this example from top to bottom; here are our observations and comments, utilizing the terminology of the example provided.

<u>Problem statement, goals and objectives</u>

The problem statement, goals, and objectives need to match or encompass those in the recovery plan(s). Broad statements for the species/populations as a whole are acceptable at this level.

<u>Conceptual models</u>

This part of the logic chain only references *conceptual* models. Various types of models -- conceptual, statistical, process, simulation, etc. – can be used to identify factors that limit the population as a whole, and different models and types of models consider factors such as population dynamics, hydrology, predation, or habitat availability. These models (or perhaps a nested set of increasingly more specific models) can be used to identify what limiting factors or stressors (if any) occur within the planning area and, therefore, would be addressed by BDCP actions. In addition, when these models are used, they relate to what has caused the problem, as articulated in the problem statement.

Hypotheses

The “hypotheses” (which as stated in the logic chain are actually assumptions rather than hypotheses) can better be characterized as specific “BDCP goals” with each goal statement articulating how a limiting factor might be addressed *within the BDCP planning area*. One goal statement for each limiting factor (e.g., increase food in the pelagic zone by 15 percent to improve sub-adult survival) specifying season and location would be necessary.

The limiting factors framed as goals do not need to be directly tested as formal hypotheses. The process relies on the models (above) or the wider knowledge base to identify the limiting factors and assumes that alleviating those factors will in fact address the problem.

Desired change

To link with the goal statements described above, the “desired change” category would be logically called “BDCP objectives.” The level of quantification of the objectives depends on whether they will be used to develop prioritizations in the early planning phase (in which case they can be order-of-magnitude approximations) or if they are part of the finalized plan. If the latter, the objectives would need to be the so-called “SMART objectives” that are specific, measurable, achievable, relevant and time-based.

In some cases, the terminology “thresholds of change” has been used instead of “desired change,” suggesting that there is a lower threshold of detectability of an effect or an upper threshold beyond which additional changes have no additional beneficial effects. These levels define an envelope of effects or change that is either detectable or relevant. We find the use of this terminology confusing and, in some instances, inaccurate. It needs to be clear whether this is something to be achieved (like a target) or exceeded (like a minimum acceptable achievement).

Conservation Measures

The conservation measures are the BDCP conservation measures or actions. They relate directly to the BDCP goal and objective statements and reduce the limiting factors within the BDCP planning area. Linking proposed conservation measures to BDCP goals and objectives will help to show gaps, such as objectives for which no appropriate measure exists.

Once the conservation measures have been described, a clear prioritization process would be useful, as not all measures will be logistically, financially, or politically feasible. Such prioritization could be based on an evaluation of cost effectiveness of measures relative to their outcomes and the linkages between implementation, analysis, and adaptive management. Negative consequences and the timing of actions (sequencing) would also need to be considered.

Outcomes

The projected outcomes currently are not framed as quantitative, testable hypotheses. It is at this level of the logic chain where such hypothesis testing should occur. Stated as such, these hypotheses would drive the analytical approaches for evaluating the hypotheses and the form and structure of monitoring (i.e., gathering the information to evaluate or test the hypotheses).

The monitoring design (or experimental design) may vary among different conservation measures or be applied in different ways to different places for the same conservation measure (i.e., a real experiment). It will be critical to determine what level of measurement, monitoring, and analysis would be considered not too little (to demonstrate an effect), nor not too much (a huge investment in limited resources), but just right (the Goldilocks approach). Costing of the analytical methods and monitoring would be a consideration in the prioritization of conservation measures mentioned above. The monitoring structure will in turn lead to the selection of appropriate metrics and consideration of such key attributes as spatial and temporal resolution, statistical power, analytical framework to employ, and best representation and visualization of results.

Analysis

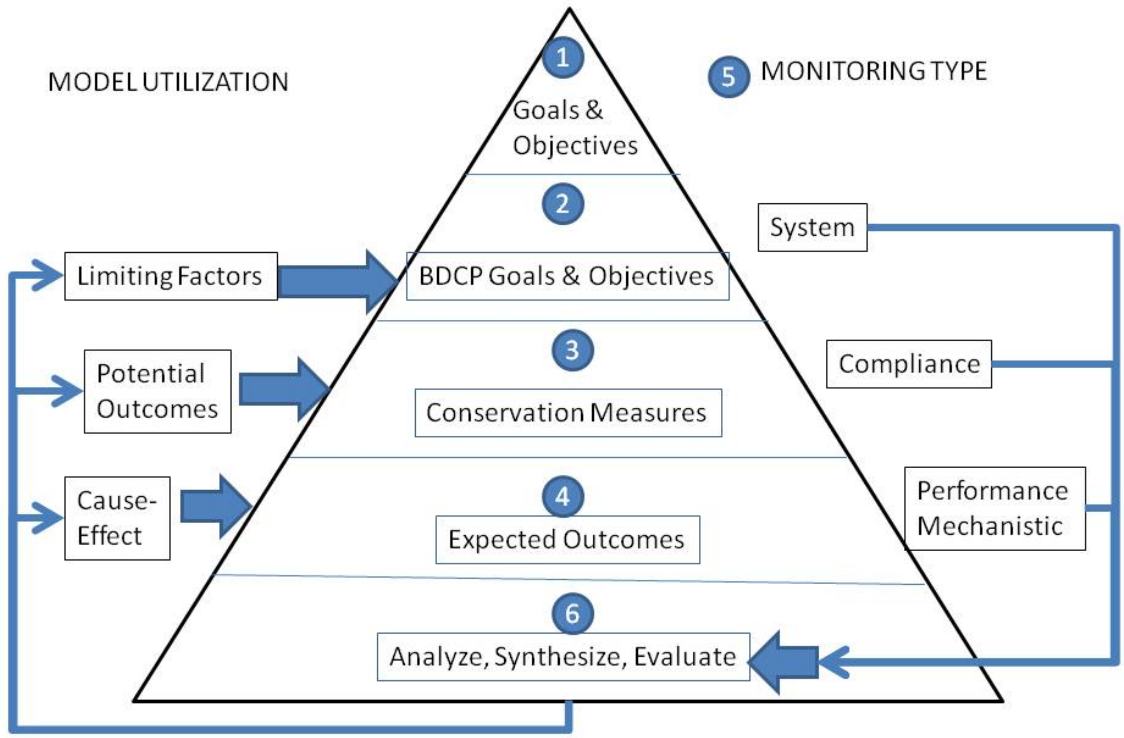
The analysis box in the Delta smelt logic chain provided would benefit from being more detailed and expanded to include the adaptive management loop. Adaptive management is not the same thing as the hypothesis testing that is included as part of the logic chain. Implementation of conservation measures leads to actual outcomes that must be monitored and analyzed. The comparison of projected outcomes (the hypotheses) with the actual outcomes is the focus of analysis. These results then feed into the adaptive management loop and back into other components of the logic chain (see next section). This is also where the system metrics may come in - how do the outcomes relate back not only to the specific objectives (e.g., food supply), but to the broader objectives (e.g., population growth, survival).

The adaptive management phase involves not only the analytical element, but the synthesis/interpretation component – what does analysis comparing projected and actual outcomes mean in terms of the objectives, identification of limiting factors, goals, or problem statement? To be effective, adaptive management needs to be part of the process, not an add-on at the end or a post-facto component once the actions have been taken. The details of adaptive management are missing from the logic chain.

There are two aspects of the hypothesis testing/analysis/interpretation components that must be distinguished: (1) the “virtual,” in which the analysis is conducted as a sophisticated conceptual or analytical modeling exercise, to explore the *anticipated* consequences of a conservation measure and the adaptive management loop; and (2) the “real,” in which the conservation measure has been implemented and we are looking at what *actually* results.

An Alternative Approach

Although there is much of value in the logic-chain approach, our evaluation and comments suggest that there is room for improvement, especially to clarify some of the logical relationships in the logic chain. We offer here an alternative approach that incorporates elements of the logic chain. The following diagram traces the main elements of this approach; the following comments are keyed to the numbered sections in the diagram.



1. At the top of triangle are the recovery/species goals and objectives. Because the BDCP needs to contribute to recovery of the covered species, there must be a clear link to the needs of those species. This is best defined by existing recovery plans for the species. If a recovery plan is not available, the responsible agencies should provide guidance on appropriate goals and objectives for the species as a whole.

2. The contribution to recovery made by BDCP is not predefined. Expert opinion and conceptual models of the species can be used to identify limiting factors/stressors for the species; BDCP should further select those limiting factors/stressors that can be addressed by the potentially regulated entities (PREs) and that occur within the planning area. From this subset of limiting factors, BDCP can then identify more specific goals and objectives that are within its scope and that are scaled by the level of effort envisioned for the Plan.

3. Conservation Measures must be identified that have the capacity to achieve the BDCP goals and objectives. Candidate measures can be screened using simple models (e.g., conceptual, statistical) to assess potential outcomes, both positive and negative. After

screening an initial list of conservation measures, some BDCP goals and objectives may appear unlikely to be addressed; additional conservation measures should then be developed and/or the BDCP goals and objectives should be revisited to ensure that their scale and scope generally match with the level of effort envisioned for the Plan.

4. Once the types and overall scale of the conservation measures have been determined, they can be further developed to the ‘project level’ and more specific expected outcomes identified. At this level of specificity, models of all types can be used to apply cause-effect relationships and find outcomes that achieve BDCP goals and objectives (and identify any potential negative outcomes). Where cause-effect relationships are weak or there is disagreement over the nature or magnitude of outcomes, testable hypotheses can be developed linking the action to the outcome and projects designed to test the hypotheses. The analytical framework for testing these hypotheses (and the necessary mechanistic monitoring) should be developed at this stage, prior to implementation of the projects.

5. Monitoring informs all of these steps. System-level monitoring informs whether goals and objectives for BDCP and the species are being achieved. Compliance monitoring ensures that measures (e.g., actual Old and Middle River (OMR) flows, elevation of grade or fill, water quality standards) are being implemented as expected. Performance monitoring is used to tell whether a conservation measure is achieving the expected outcomes, and mechanistic monitoring provides diagnostic information on why the expected outcomes are or are not being achieved. These types of monitoring are described in the Independent Advisors’ Report on Adaptive Management.

6. Once projects have been implemented and monitoring data are available, the key adaptive management step of Analyze, Synthesize and Evaluate must be conducted to: a) assess performance; b) inform adjustments to implemented projects and future actions; c) incorporate information as part of the knowledge base and; d) utilize information in models for future use in the planning process. This is the essence of adaptive management.

Linking Conservation Measures to Outcomes: Issues of Study Design, Quantification, Metrics, and Monitoring

Specific conservation measures provide the opportunity to develop clear hypotheses that predict outcomes, require rigorous quantification, and lead to well-designed studies with defined metrics and monitoring approaches. Conservation measures exert themselves at a variety of spatial scales. For example, reduction in a specific stressor might produce a response at the scale of the entire Delta while a habitat restoration project will impact a specific location. Study designs must necessarily consider the spatial component of the conservation measures and monitor appropriate response variables to the action. Study designs also must consider appropriate analytical frameworks for comparing responses to the actions. Will evaluation of the conservation measure be compared to a long-term trend, a control site, or a change in trajectory within a specific location? Scientists should be engaged to address the challenges of designing studies that effectively evaluate whether implemented conservation measures are yielding desired outcomes. This is an area where scientific expertise should be focused rather than on identifying overarching goals and objectives.

Well-designed studies linked to specific conservation measures are critical for developing the larger integrated monitoring framework. Finite resources will be available to evaluate the effectiveness of conservation measures agreed upon through BDCP. The sooner that study designs with designated metrics and monitoring locations are developed for each conservation measure to be implemented, the more readily can decisions be made on the best package of metrics to deploy, the locations for these measurements, and the analytical framework for data analyses. These decisions are integral to application of adaptive management, communication of outcomes from specific conservation measures, and informing decision-makers on management actions. These steps must be carried out within the context of the overall planning effort and not left until later.

The Role of Adaptive Management

In a system as complex as the Bay-Delta, involving multiple constituencies and numerous projects that entail huge investments, it is essential to avoid costly mistakes. The focus of the logic-chain approach on defining meaningful goals and objectives for BDCP is an important part of a successful planning process. It is also an essential element of adaptive management, which itself must be a core part of BDCP. Much has been made of adaptive management and its role in effective conservation and management. *Real* adaptive management, however, is rarely undertaken. In particular, the part of the process that involves assessment and synthesis of information gained after actions have been taken is often neglected or short-circuited, and the critical phase of linking that knowledge to decisions about whether to continue, modify, or stop actions, refine objectives, or alter monitoring efforts is usually missing. The report of Independent Science Advisors on Adaptive Management to the BDCP Steering Committee provides detailed guidance that should be incorporated into any logic-chain approach in BDCP.

Several aspects of adaptive management merit particular attention in relation to the logic-chain approach. First, adaptive management must begin with a clear definition of the problem to be addressed and the goals and objectives to be met. The hierarchical structure of logic plans helps to bring clarity to these statements of goals and objectives. Second, models can play a valuable role in adaptive management. Many of the conservation measures being proposed for the Bay-Delta are large and expensive; simulation or scenario models can be used to explore the likely outcomes of these measures before actually implementing the measures, and this information can be used in an adaptive-management framework to adjust goals, objectives, hypotheses, or measures as appropriate. Third, the adaptive-management phases of assessment, synthesis, translation, and communication must be integral parts of either model-based or actual implementations of adaptive management. Little is accomplished by producing model output or monitoring following the implementation of conservation measures if the resulting information does not make its way, in a carefully evaluated and readily comprehensible form, into the decision-making process.

Prioritization and Sequencing

The successful development of quantifiable objectives for BDCP will provide added benefits by allowing the expected outcomes of individual conservation measures to be compared to one another and used with other data to prioritize and sequence implementation. Measures with more significant outcomes and a broader range of species to benefit will be identified. Together with cost information (including the potential for negative outcomes), this information can be used by BDCP to develop a prioritized list of conservation measures, with the order of implementation being dependent upon decision criteria such as risk tolerance, availability of funds, cost relative to expected benefit, water requirements, and ease of implementation. For example, an implementation plan could sequence high-priority projects based on costs and reliability of benefits to seek to achieve early successes at minimal cost. Well-developed decision-support tools, such as ecological risk assessment or return-on-investment analysis, should be incorporated into the prioritization process.

APPENDIX 1

Specific Questions to the Panel and Panel Responses

The charge to the Review Panel included several specific questions. Here are our answers; the main body of the report describes our responses, evaluations, and suggestions in greater detail.

Purpose

- Does the framework reflect the recommendations made in February 2009 by the BDCP Independent Science Advisors' Report on Adaptive Management? *No*
- Can the framework adequately serve as a basis for refining the BDCP goals and objectives and developing an adaptive management plan? *Yes, if developed fully*
- Is the logic framework clearly defined and described? *Only partially*
- Is it internally consistent? *It is not consistent in how hypothesis testing is being employed*
- Is it clear for what purpose and how the framework might be used? *Yes, although greater clarity in linking BDCP goals and objectives to conservation measures and outcomes would be an improvement*

Approach

- Are the linkages between elements of the framework clear? *Yes*
- Is the relationship between recovery plan goals and BDCP goals and objectives clear? *No*
- What level of detail is necessary for the goals and objectives and for the framework in general? *Recovery/species goals and objectives can be stated qualitatively if sufficient detail is not available; BDCP objectives can be stated qualitatively or with order-of-magnitude approximations in the early planning stages, but with greater quantification as the plan is finalized for implementation; expected outcomes to conservation measures should be stated in sufficient quantitative detail to permit measurement, analysis, and testing of hypotheses.*
- Is the current use of conceptual models and hypotheses clear and helpful? *Only partially; currently the hypotheses are in the wrong place in the logic chain.* If not, how might this be changed or refined? *We have offered a refinement of the logic chain approach that improves clarity*
- What are the next steps regarding populating the logic chain? *General goals and objectives should be defined and populated by the appropriate regulatory agencies; it should be an immediate priority to develop clearer, more concise language and to find consensus on goals and objectives within the BDCP steering committee*
- What, if any, future role/need is there for additional scientific input? *The hypotheses linking conservation measures to projected outcomes, the design of studies to assess these linkages, and the framework for implementing adaptive management would benefit from additional scientific input*

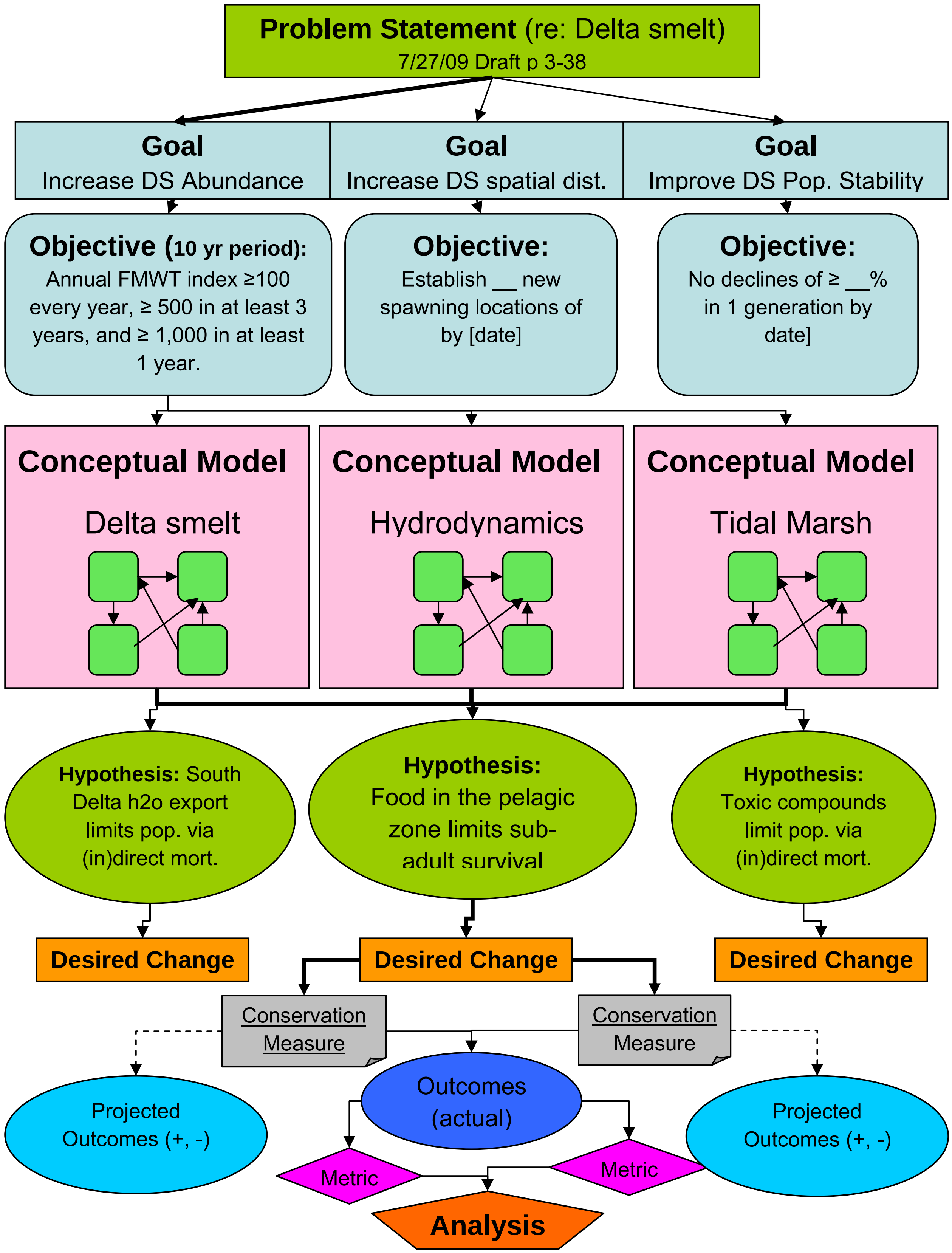
Feasibility

- Is the framework approach feasible to implement? *Yes, if done so in a focused manner*

- If not, what can be done to streamline or phase the approach? *Conduct a complete logic chain assessment for 2-3 species as proof of concept*

APPENDIX 2

The Current Version of the Logic Chain for Delta Smelt
(Appendix B of the Logic Chain provided by American Rivers and The Bay Institute)


Problem Statement (re: Delta smelt)
7/27/09 Draft p 3-38
Goal
Increase DS Abundance
Goal
Increase DS spatial dist.
Goal
Improve DS Pop. Stability
Objective (10 yr period):
Annual FMWT index ≥100 every year, ≥ 500 in at least 3 years, and ≥ 1,000 in at least 1 year.
Objective:
Establish __ new spawning locations of by [date]
Objective:
No declines of ≥ __% in 1 generation by date]
Conceptual Model
Delta smelt
Conceptual Model
Hydrodynamics
Conceptual Model
Tidal Marsh
Hypothesis: South Delta h2o export limits pop. via (in)direct mort.
Hypothesis: Food in the pelagic zone limits sub-adult survival
Hypothesis: Toxic compounds limit pop. via (in)direct mort.
Desired Change
Desired Change
Desired Change
Conservation Measure
Conservation Measure
Projected Outcomes (+, -)
Outcomes (actual)
Projected Outcomes (+, -)
Metric
Metric
Analysis

Appendix G-5

Bay-Delta Conservation Plan Delta Science Program Panel
Second Review of the "Logic Chain" Approach

BAY-DELTA CONSERVATION PLAN

DELTA SCIENCE PROGRAM PANEL
SECOND REVIEW OF THE "LOGIC CHAIN" APPROACH

Prepared for
BDCP Steering Committee

by
Denise Reed, University of New Orleans
Kurt D. Fausch, Colorado State University
Gary D. Grossman, University of Georgia
Kenneth A. Rose, Louisiana State University

23 August 2010
Revised 6 September 2010

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Summary Findings and Recommendations

Panel findings and recommendations are summarized below according to the three primary goals of the logic chain approach.

Develop reasonably achievable BDCP objectives and conservation measures that contribute to broader species recovery goals.
The logic chain structure could be simplified to reduce the number of objective statements and to focus BDCP objectives. Recommended changes to the logic chain structure are shown in Figure 2. Specific findings and recommendations include:

- The identification of "BDCP" goals and objectives, versus global goals and objectives, is very important. The structure of the upper portion of the logic chains needs to be agreed upon for the logic chains to be effective.
- Identify stressors prior to the development of BDCP objectives. BDCP objectives should be linked to specific stressors, and stressors to both BDCP and global goals.
- Explicitly identify stressors that are outside of BDCP's management zone in the logic chains.
- Whenever possible, focus BDCP objectives on measures of individual and population-level performance, such as habitat-specific estimates of growth and survivorship, quantitative estimates of abundance, and quantitative measures of movement and/or distribution.
- Consider developing logic chains for selected key community and ecosystem properties to capture outcomes associated with certain conservation measures that are not obvious from piece-wise presentation among species-specific logic chains.
- Include estimates of magnitude and certainty to facilitate prioritization of conservation measures and to aid in future adaptive management. Estimates of both the magnitude of effects and their associated certainty can be done in narrative form with supporting documentation.
- Retain flexibility to tailor logic chains for each species, recognizing the trade-off between consistency and uniqueness. For example, although the four Viable Salmonid Population (VSP) characteristics should be important in conserving most fish populations, a simpler structure may provide more biologically realistic logic chains for species like delta and longfin smelt.
- Consider a workshop with technical experts for each species, with the goal of preparing a simpler "influence diagram".
- Adjust the format and presentation of the chains to make them more readable.
- Minimize "insider" information and poorly-defined jargon in the logic chains. Terms like "productivity", as used in the logic chains, are generic terms, and not sufficiently specific to ensure clear goals or objectives.

Describe possible metrics designed to monitor and evaluate the effectiveness of implementing the BDCP conservation measures.

- Great care should be used when populating the compliance and performance monitoring boxes in the logic chain. Three levels need to be considered separately: 1) the level that addresses the Global Goal, 2) the "covered activity" level, and 3) compliance monitoring, which measures implementation of the planned conservation measure.
- Although the Panel sees a distinction between annual abundance indices and BDCP performance metrics, the Panel strongly recommends that the BDCP performance metrics be related to fish vital rates (reproduction, growth, mortality).
- Contribute funding to creating and maintaining a repository of data, similar to the National Science Foundation's Long-Term Ecological Research site network.
- Identify the key unknown biological attributes of covered species, and commit to long-term sampling and focused studies on fundamental biology and ecology of species to be paired with that centered on solving immediate problems related to water management.

Link implementation of conservation measures, through monitoring and evaluation, to the adaptive management program.

- Clearly identify the management goals that can be addressed via adaptive management (sensu Walters 1986) in the draft Plan (i.e., by November), those that can be addressed during the subsequent refinement phase (prior to the formal permit issuance), and those that can only be addressed during implementation.
- A programmatic approach to research should be developed for early adoption, even prior to permitting, and the post-permitting adaptive management approach must be described and finalized as soon as possible, so that conservation measures and post-implementation monitoring can be refined and developed using that research.
- Consider an objective process for developing an implementation plan that acknowledges: (1) the certainty of achieving expected outcomes; (2) that not all measures can be implemented immediately; (3) that not all will achieve their ultimate outcomes immediately, and (4) that some are contingent on the success of others (perhaps using optimization or other approaches as suggested by the first Logic Chain Panel) to provide more realistic expectations of how the system might change as a result of the Plan.
- Consider using a formal decision support system (one that allows for incomplete information, generalized relationships, uncertainties etc.) to identify high priority measures and those for early implementation.
- Develop an adaptive management plan in sufficient detail for the November Draft Plan so it is clear to all participants which procedures will be used to revise BDCP objectives and how additional information, especially reduced uncertainty, will be incorporated into the Plan during implementation (i.e., revisiting the logic chains).
- Comprehensively articulate conservation outcomes based on the logic chains, including their spatial distribution, at decadal intervals to provide a realistic expectation of the changes expected as a result of plan implementation.

1. Background

The Bay Delta Conservation Plan (BDCP) is being prepared through a collaboration of state, federal, and local water agencies, private enterprise, state and federal fish agencies, environmental organizations, and other interested parties to obtain permits under federal and state endangered species acts. The plan will identify a set of conservation measures that will provide for changes in conveyance and operations of the State and federal water projects, operations of Mirant power generation, reductions of other stressors, and habitat restoration actions to contribute to the recovery of endangered and sensitive species and their habitats in California's Sacramento-San Joaquin Delta. The goal of the BDCP is to provide for both species and habitat protection and improved water supplies.

The logic chain approach has been developed by the BDCP Steering Committee to provide a framework and planning tool for:

1. Developing reasonably achievable BDCP objectives and conservation measures that contribute to the broader (global) species recovery goals;
2. Describing possible metrics designed to monitor and evaluate the effectiveness of implementing the BDCP conservation measures; and
3. Linking implementation of conservation measures, through monitoring and evaluation, to the adaptive management program.

An earlier version of the Logic Chain approach was reviewed in March 2010 by a panel convened by the Delta Science Program (Dahm et al., 2010). This second Review Panel was also convened by the Delta Science Program on August 4 and 5, 2010 and was supported by Delta Science Program staff, including Cliff Dahm and Elizabeth Soderstrom, and BDCP support contractors including Bruce DiGennaro of the Essex Partnership, Wayne Spencer of the Conservation Biology Institute and Kateri Harrison of Swale Consulting. The agenda for the second review meeting is included as Attachment 1.

2. The Charge

This Review Panel was charged with focusing on:

1. Assessing populated logic chains to evaluate internal logic, measurability, linkages between plan components, and consistency in approach;
2. Recommending alternative strategies or metrics for identifying progress towards meeting goals and objectives or alternative ways of framing goals and objectives such that they are practicable; and
3. Offering advice on constructing an integrated monitoring and evaluation program linked to the logic chains.

Other topics suggested by the BDCP and included in the charge to the Panel were:

4. Discussion and review of metrics and how they provide a context for design of measureable, practicable BDCP Objectives and Stressor Sub-objectives.
5. Discussion of current and potential future monitoring within this system to create a context for objectives that will be measureable and practicable that will support adaptive management in the future.

The Panel members were asked to review four logic chains: longfin smelt (*Spirinchus thaleichthys*), winter-run Chinook salmon (*Oncorhynchus tshawytscha*), and white and green sturgeon (*Acipenser transmontanus* and *A. medirostris*). The Panel focused their efforts on reviewing the longfin smelt and Chinook salmon logic chains because these were the most complete. Although no members of the Panel currently conducts research specifically on any of these species, several have previous experience working in these environments and with estuarine species, and so represent an experienced group of fish biologists and natural resource scientists. Therefore, the Panel reasoned that the logic chain architecture and presentation should be clear and apparent to them, with minimal additional information required and the comments and recommendations provided in this report are based on that reasoning. This report includes some general observations on progress since the previous logic chain review panel and provides some recommendations on logic chain structure, content and use within the BDCP planning process. Key comments and recommendation are shown in bold italics in the text.

3. Progress to Date

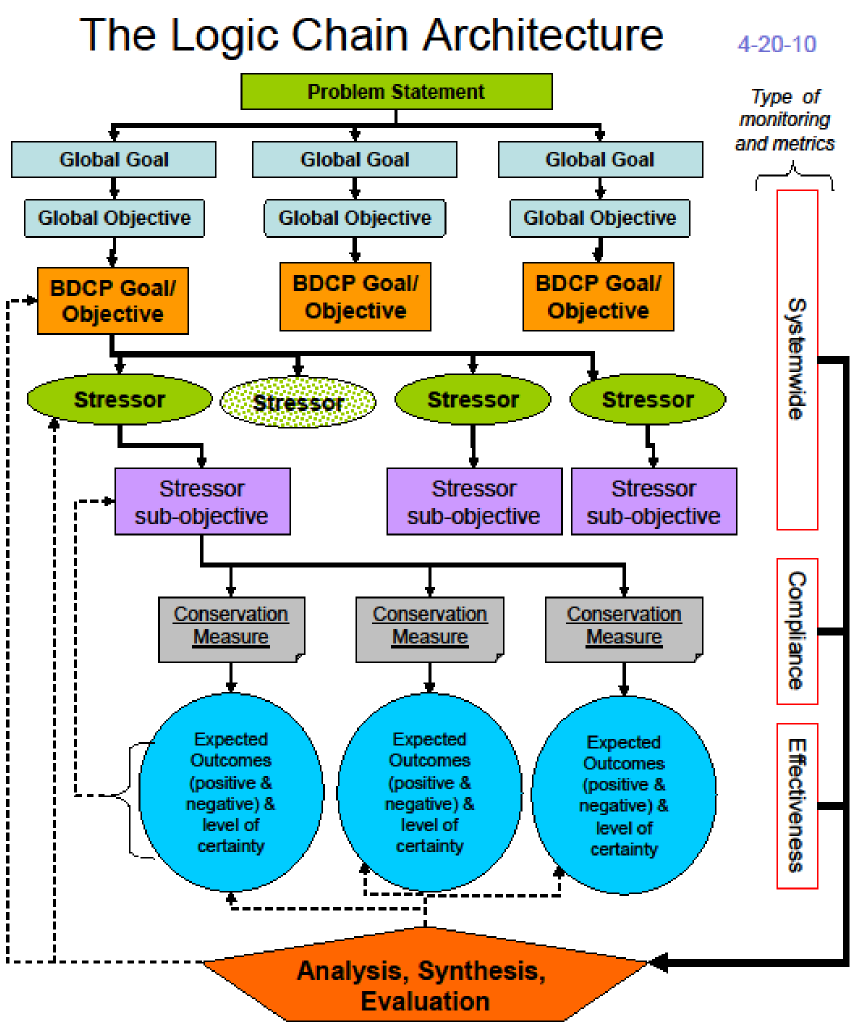
The Panel was impressed with the tremendous amount of work and detail that went into development of the two example logic chains. Conceptually, the logic chain approach will aid in identifying how conservation measures influence the key stressors affecting fish populations in the Delta as well as those affecting the ecosystem as a whole. The Panel appreciated that the logic chain structure enables the chains to capture many of the potential factors affecting the species involved. The two examples reviewed in detail by the Panel (longfin smelt; winter run Chinook salmon) seemed to be relatively complete in terms of accounting for possible stressors, and how conservation measures fit into the overall Bay Delta Conservation Plan. The example logic chains were well thought-out and documented, given the data available.

The Panel also noted that the BDCP team was responsive to the earlier review of the logic chain approach (Dahm et al., 2010). In particular, the two examples and the presentations made by the BDCP team members reflected steps 1-3 proposed in the earlier review. These recommendations were: detailed preparation of logic chains for 2-3 species, development of upper portion of the logic chain (additional comments on this aspect are provided below), and collaborative development of the middle portion of the logic chain. The Panel notes that other comments in the earlier report also were considered, such as the use of metrics that were clearly linked to biological functions for evaluating conservation measures and the inclusion of, and distinction between, compliance and performance monitoring. The use of the conceptual models from the DRERIP evaluation as one of the building blocks for the logic chains, at least at this stage of their development, is endorsed by the Panel.

4. Logic Chain Structure

The Panel recommends several changes to the original logic chain structure (Figure 1) which are described below and in Figure 2. In order to clearly illustrate our suggested revisions, we prepared a hypothetical (and overly simplified) logic chain for longfin smelt (Figure 3) that includes one possible conservation measure.

Figure 1. Logic Chain Structure presented to the Review Panel

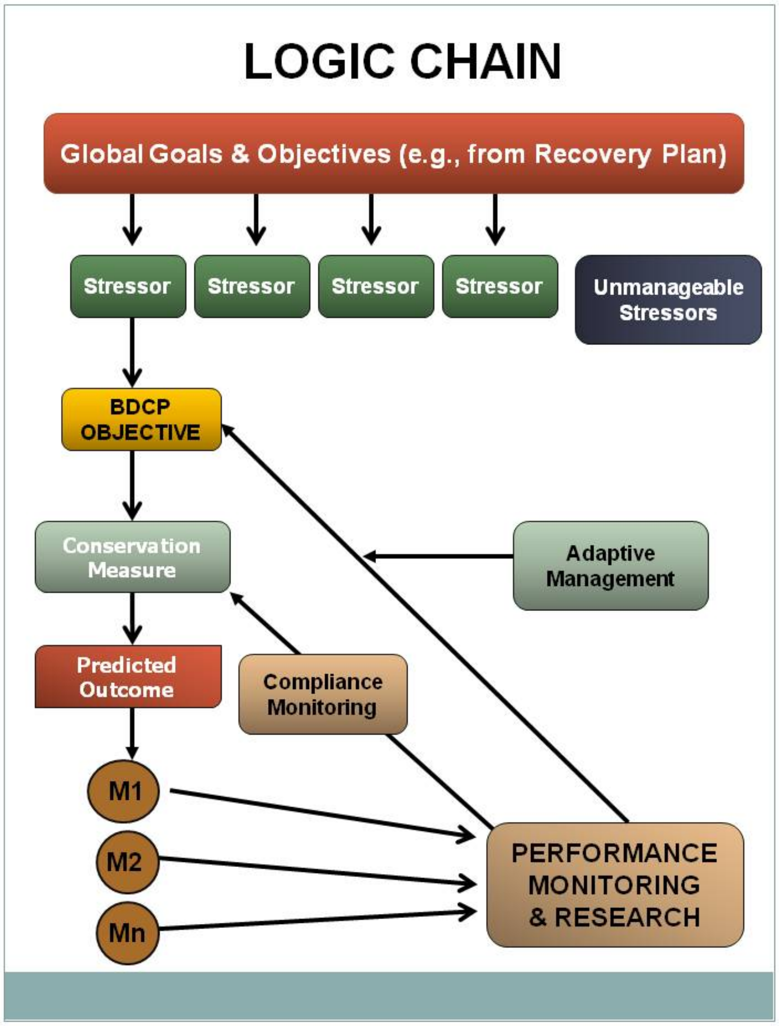


Schematic of the Logic Chain architecture for one species. One stressor (dappled green) is outside of the BDCP purview; thus it has no associated BDCP goal. In this example, stressors and steps below this level refer to one of the BDCP objectives; other BDCP objectives would be developed simultaneously. Similarly, for illustration purposes, only one stressor sub-objective is developed here. Dashed lines refer to different types of evaluations (based on monitoring data) that will be used to adaptively manage within the conservation strategy.

4.1 Goals, Objectives and Stressors

The structure of the upper portion of the logic chains needs to be agreed upon or else the logic chains will be ineffective. The Panel recognizes the importance of all parties agreeing upon a clear statement of goals and objectives and identifying the role of BDCP in achieving them. As presented to the Panel, the logic chains included a problem statement as well as both global goals and objectives and BDCP goals/objectives (Figure 1); this resulted in difficulties in identifying

Figure 2. Proposed Revised Logic Chain Structure. See text for explanation. M1, M2 and Mn refer to an indeterminate number of metrics developed for use in monitoring of the conservation measure and predicted outcomes.



the scale at which conservation measures were to be evaluated (i.e., the global context or a BDCP context). It also appeared to the Panel that the BDCP team was having difficulty resolving some of the wording of the goals and objectives – a very important element of the logic chain approach in that it sets expectations regarding the scope of BDCP 'responsibilities' for meeting the conservation outcomes. The responsibility for species recovery is determined by the ESA, and how recovery is measured is determined by the US Fish and Wildlife Service (USFWS) and NOAA Fisheries. How is the global goal for recovery of endangered species (set by the agencies) linked to the BDCP goals? These links need to be made explicit.

The Panel endorses the recommendation of the previous logic chain review panel (Dahm et al., 2010) concerning the placement of the stressors within the logic chains, and expands on that earlier recommendation here. In the logic chains, BCDP objectives should be linked to specific stressors, and stressors to global goals. For example, for the stressor of "insufficient flow through the Yolo Bypass", the conservation measure would be to increase flows and the BDCP objective(s) could be to increase survival and successful migration of juvenile Chinook salmon, and increase juvenile foraging habitat for sturgeon.

It is important to recognize within the logic chain structure that BDCP will not address all of the stressors identified by the recovery plans. Those not addressed can be grouped together in the logic chain and identified as "unmanageable stressors." It should be clearly stated whether they are unmanageable because BDCP has not identified any appropriate conservation measures, because they are simply not influenced by any management actions under the auspices of BDCP (e.g., they are associated with ocean, or upstream factors), or they are not under management control (e.g., droughts).

To address these issues the Panel recommends the following changes to the upper sections of logic chain structure:

- ***Distinguish between Global goals and objectives set by agencies and "BDCP" goals and objectives.***
- ***Stressors linked to the global goals and objectives should be considered prior to the identification of BDCP objectives.***
- ***Stressors not potentially influenced by BDCP should be explicitly listed in the logic chains.***

The Panel's recommended structure reduces four levels (Problem, Global Goal, Global Objective and BDCP Goal and Objectives) to two levels (Figure 2). The problem in general will be described elsewhere in the Plan and Global Goals and Objectives should be derived from existing recovery plans or provided by resource agencies.

4.2 Monitoring Metrics

The Panel discussed at length compliance and performance metrics for monitoring. It was not clear that the monitoring approach within the logic chains focused on vital demographic rates and population-related parameters that are directly related to rates of population change. The global goals and objectives will relate to the recovery of the species, which the Panel assumes will be assessed by the agencies and that will include some sort of annual abundance index. Compliance and performance metrics would be the responsibility of BDCP. Compliance monitoring is designed to confirm that the conservation measure was achieved, whereas performance monitoring is designed to evaluate how well the expected outcomes of the conservation measure are being achieved[1]. It is critical to utilize performance metrics that reflect the spatial and temporal scales of the specific conservation measure and its expected local biological effect. This not only allows for the success of the conservation measure to be evaluated as part of adaptive management, but also provides information on possible causes of changes in the abundance indices when such changes are detected. However, the Panel does recognize that, in some cases, performance metrics can be based on the annual abundance indices if that is appropriate for evaluation of the effects of a specific conservation measure. Ultimately, local performance measures must be considered in the context of trends in abundance indices to assess the population-level effects of the conservation measure.

Within the revised logic chain structure, multiple monitoring metrics are shown related to each conservation measure and its expected outcome. This performance monitoring can then be used within an adaptive management framework to evaluate BDCP objectives (Figure 2). The revised structure also specifically notes the need for compliance monitoring to determine that conservation measures were implemented as expected. In addition to these clarifications within the logic chain, the Panel recommends that:

- ***Whenever possible, objectives of the chains should focus on measures of individual and population-level performance, such as habitat-specific estimates of growth and survivorship, quantitative estimates of abundance, and quantitative measures of movement and/or distribution.***
- ***The BDCP performance metrics must relate to fish vital demographic rates.***

[1] See Science Advisors Report on Adaptive Management (Dahm et al., 2009) for more on different types of monitoring.

4.3 Explicit Treatment of Uncertainty

The logic chains appeared to take a static approach to ecosystem processes, and did not explicitly consider uncertainty. Yet everyone recognizes that conditions in the Delta are not at equilibrium. The logic chains will likely need to consider variation in physical and biological factors for wet, dry, and "average" years. The concept of tailoring performance metrics to the water year type adjusted for flow variation seems promising. The example logic chains presented to the Panel do not include estimates of either the magnitude or uncertainty associated with a given conservation measure and its expected outcome. Some information on magnitude and uncertainty was presented in the logic chains provided to the Panel as part of the DRERIP evaluations, but it was unclear how this information was to be incorporated into the BDCP logic chains.

The Panel recommends that:

- ***Given the 50-year projected life of the BDCP, issues like climate change and continued invasion by non-native species need to be considered.***
- ***Magnitude and uncertainty estimates should be included to facilitate prioritization of conservation measures and aid in future adaptive management. Estimates of both magnitude of effects and their associated uncertainty can be done in narrative form with supporting documentation.***

4.4 Focus of Logic Chains

The current logic chains are species - based, which is appropriate given that the species involved have different life histories and ecological requirements; however, this separation can only result in successful management when the ecosystem context of the species is explicitly recognized. In addition, there may be both positive and negative effects at the community and ecosystem levels associated with certain conservation measures that are not obvious from piece-wise presentation among species-specific logic chains. This could be achieved by including the community and ecosystem aspects in each species logic chain but broader implications could be lost.

The Panel recommends that:

- ***In addition to covered species, the BDCP Steering Committee should consider developing logic chains that focus on key community or ecosystem properties.***

4.5 Example of Revised Structure

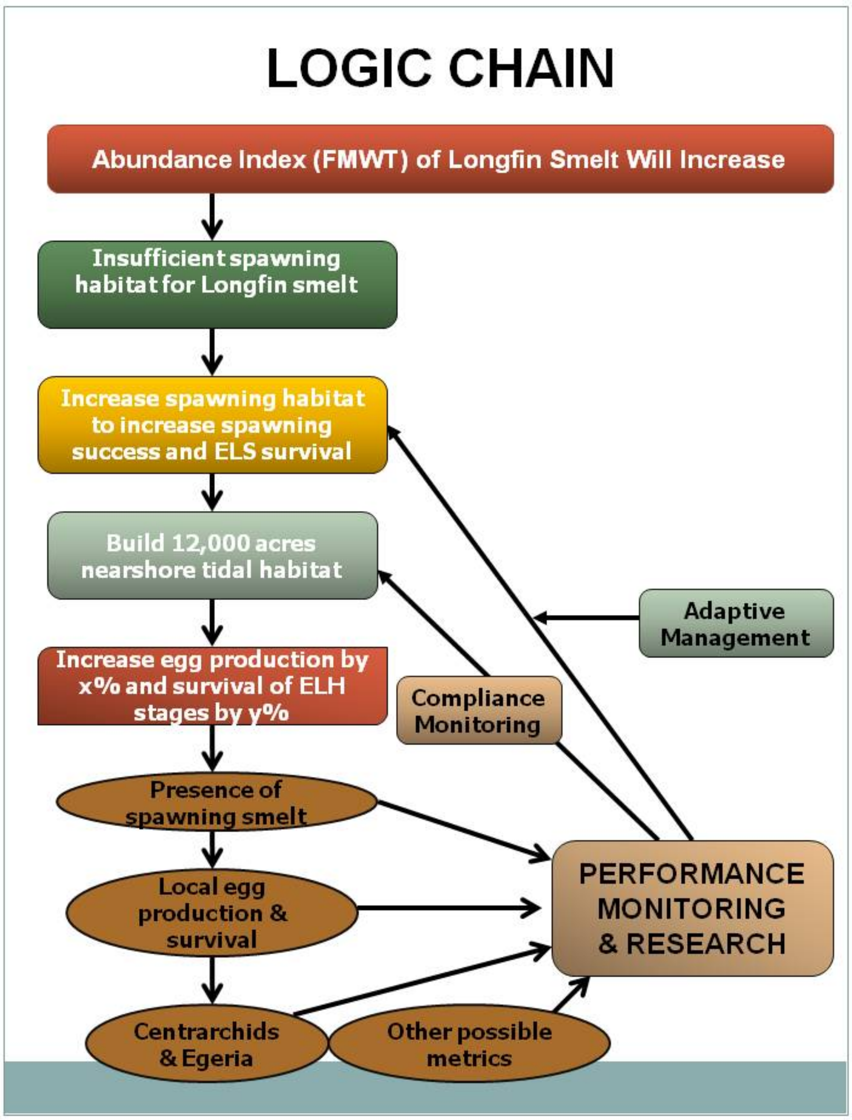
To illustrate the different levels in the revised structure and the linkages among them, the Panel outlined an example application for one line in the chain (i.e., one stressor, one BDCP objectives, one conservation measure for that objective, etc.). This is shown in Figure 3. A completed logic chain would have multiple branches from each stressor, objective, conservation measure and outcome. This example does not include uncertainties as recommended above. These could be identified on the diagram using a color coded key or in supporting narrative.

In our example logic chain (Figure 3), the global goal is to increase the Fall Mid-Water Trawl index and a stressor is insufficient spawning habitat for longfin smelt, and underneath this in the chain is a potential BCPD objective of creating nearshore tidal habitat. The conservation measure deemed to meet that objective was to build 12,000 acres of nearshore tidal habitat to increase spawning, overall egg production and survival of early life stages. Compliance monitoring would involve measuring how many acres were built. Performance monitoring would measure the presence of spawning smelt (i.e., smelt did use the new habitat), quantifying local egg production and survival (i.e., the new habitat is suitable for spawning), and determining whether the new habitat also resulted in increases in invasive competitors and predators such as centrachids and *Egeria* (i.e., were there negative consequences?).

5. Logic Chain Content, Format and Knowledge Base

After evaluating the general structure of the logic chains, the Panel examined the information required to populate (i.e., assign information) and interpret the logic chain. These comments and recommendations pertain to how the information is presented, its sources and how knowledge should be organized to support development and evolution of the logic chains.

Figure 3. Outline Example of Revised Logic Chain Structure for longfin smelt. Refer to text for additional explanation.



5.1 Logic Chain Content

Although the four characteristics that form the basis of the viable salmonid populations (VSP) approach are important in conserving most fish populations, a simpler structure, where some characteristics are combined or down - weighted in importance, would aid in creating more biologically realistic logic chains for species like the two smelts. There may also be other aspects of the logic chains that require a tradeoff between consistency and uniqueness among species. The Panel suggests that greater flexibility be used so that the logic chains can be tailored to each species. The use of the VSP (McElhany et al. 2000) as a framework for the logic chains is good, but may not be ideal for all species. The four parameters highlighted in the VSP are population size, population growth rate, spatial structure, and life history and genetic diversity. The VSP approach is useful because it focuses on the intersection of spatial and temporal scales around which managers make water resource decisions, and over which fish populations and metapopulations carry out their life cycles (e.g., Fausch et al. 2002; Fausch 2010). However, the use of the VSP framework for all species may result in forcing a salmonid-based framework on species for which it is inappropriate. For example, what is known about life-history diversity for Delta smelt, and how important is it?

Terms like "productivity", as used in the Logic Chains, are generic terms, and not sufficiently specific to ensure clear goals or objectives. Clear terms are needed for clear communication. The term productivity allows users to conjure up their own specific meaning. It becomes clear on further reading that the goals really involve vital demographic rates (e.g., reproduction, survival, and growth). The term "production" has a specific meaning in fish population biology. This term refers to the total increase in biomass (fish tissue) within the fish population during a time interval, including that lost through mortality (Chapman 1978). In practical terms, it is the product of the mean biomass in the population times its growth rate, usually measured at rather frequent intervals, especially during the season that fish are growing rapidly. Thus, the units of production are g/m^2/year of tissue produced. Avoid vaguely defined terms and define what is meant.

Great care should be used when populating the compliance and performance monitoring boxes in the logic chain. Three levels needs to be considered separately: 1) the level that addresses the Global Goal, such as measuring adult sturgeon returning to spawning areas or the FMWT index for smelt, 2) the "covered activity" level (e.g., Yolo Bypass), to assess how a specific conservation measure action at a local-to-regional scale affects appropriate abiotic and biotic variables, and 3) compliance monitoring, which measures that the conservation measure was implemented as planned. Dealing with the specifics of the monitoring will have a great influence on the adaptive management and evaluation of the BDCP. The revised logic chain tries to emphasize this by delineating measurements at these three levels. Often, measurements for the first level are used by the USFWS and NOAA-Fisheries to monitor the status of the species. At the second level, although physico-chemical variables can be used as performance metrics, variables that directly relate to fish processes and vital rates must also be included.

In most cases, measuring vital demographic rates as part of performance monitoring is possible, though technically and analytically challenging. For example, for the Yolo Bypass, Chinook salmon smolt output downstream, and adult salmon and sturgeon passage upstream, could be explicitly measured. For smolts, capture-recapture methods (i.e., marking and recapturing individuals) focused explicitly on estimating abundance and survival (where appropriate), and the uncertainty in these parameters (i.e., confidence intervals), have been available for more than two decades (see Burnham et al. 1987; White and Burnham 1999), but application of these methods requires trained field biologists, often large field sampling programs, and biometricians with expertise in analyses of these data (for an example with spotted owl management, see Burnham et al. 1996).

5.2 Logic Chain Format

The logic chain should provide a mechanism by which biologists and decision makers can easily grasp the information, while retaining supporting documents that provide the details about all possible stressors and conservation measures. One solution would be a workshop with technical experts for each species, with the goal of preparing a simpler "influence diagram". In their deliberations, the Panel worked with the example logic chains, and found the extensive and complicated supporting materials challenging to both read and understand. This certainly is a consequence of trying to abstract the critical features from a complex and variable system. Nonetheless, the massive tables of goals, objectives, stressors, conservation measures, and expected outcomes hamper understanding and indentifying key issues for each species, and hence make it difficult for general users to prioritize conservation measures. For example, for winter-run Chinook salmon, restoration of floodplain rearing habitat in the Yolo Bypass is likely a key conservation measure which, if addressed, might have the largest positive effect that could contribute to recovery. Such information needs to be readily identified by logic chain users. This problem could be addressed by the development of a simpler 'influence diagram" (a term borrowed from decision theory, such as use of Bayesian Belief Networks; see Jensen 1996; Marcot et al. 2006) for each chain. The diagram could include: 1) the *key* factors that influence habitat, growth, and survival of the target species at the most important life stages, 2) the *key* stressors that reduce these physical and biological attributes, 3) the options for altering these factors, and 4) how these coalesce to influence the key population performance measures (e.g., persistence of the species or stock). Peterson et al. (2008) provide an example application in a much more circumscribed system.

The Panel suggests adjusting the format of the logic chains themselves to make them more readable. The Logic Chain tables presented to the panel used a vertical format in which the reader attempted to work linearly from top to bottom within a "stressor" column, but soon was faced with Expected Outcomes and Risk Factors that did not seem to belong in the column. For example, in the winter-run Chinook salmon table, Stressor 3 addresses Predators and Invasive/non-native species, with a Sub-objective of reducing predation on juveniles by a given percentage by a certain date from Sacramento to Rio Vista. However, the next item working down the table (an Expected Outcome) states "Removal of old structures was not evaluated by DRERIP", which initially the panel did not understand. Likewise, the metric under the next

Expected Outcome down (OCSM13-P4: Reduce predation) includes two statements "Change in biovolume of *Egeria densa* relative to control areas (#20)," and "Change in areal coverage of water hyacinth relative to control areas (#21)". Overall, it was not clear why old structures, *Egeria densa*, or water hyacinth would influence predation, nor was it very clear that Risk Factors encompassed the idea that various conservation measures might have unanticipated negative effects that would cause problems elsewhere. Although it is possible that some of these things are explained elsewhere in material that the Panel did not read, it would be wise to clarify them more for new users.

The Panel recommends minimizing "insider" information and poorly-defined jargon in the logic chains. If the logic chains are expected to present important information in a way that is accessible to the many parties interested in BDCP, it would seem wise to use simpler and more direct statements that the average biologist or policy maker can understand, rather than codes and terms that are familiar only to BDCP personnel (e.g., OCSM13-P4, or Metric #20). Likewise, one could clearly label Risk Factors as Possible Negative Effects of conservation measures, or something similar. However, it is certainly advisable to hyperlink these simpler statements to documents where codes and details used by BDCP from past analyses and plans are found.

5.3 Knowledge Base for Logic Chain Development

Funds need to be targeted to create and maintain such a repository of data, similar to the National Science Foundation's Long-Term Ecological Research site network. The credibility and usefulness of the logic chains are dependent on the quality of the information used to populate them. There is apparently no centralized repository of data and analysis for species covered by the BDCP, and much is unpublished. This prevents reanalysis of past data, and synthesis of new and past data into useful models. The Panel was struck by the realization that data are often in the hands only of the original investigators, multiple versions of the same dataset exist, and data are susceptible to either physical loss (computer crashes, media deterioration) or retirements (the investigator leaves or dies, and much information and interpretation is lost). Given that these data are all that we have from the expenditure of millions of dollars of research and monitoring over many years, this modest investment in standardizing and protecting that irreplaceable knowledge seems self-evident. Although we acknowledge the need for publication by the primary collectors of the data, a central repository will facilitate subsequent analyses by a variety of scientists that will result in the quickest assessment of the biological processes being described.

The Panel recommends that technical experts identify the key unknown biological attributes of covered species, and a concerted effort be made to provide stable funding to address these knowledge gaps. These studies will require long-term efforts, with adequate funding, but will reap long-term rewards. Availability of information for some species and stressors is limited, and this will ultimately limit the usefulness of the logic chains. The logic chains are only as strong as their weakest link and presently that link is basic life history information for many Delta species. Examination of the example logic chains highlighted how information-limited we are for some species and stressors. The Panel was struck by the lack of key biological information for some of the covered species and life stages. Key information such as movement patterns and residence times in various habitats (river vs. delta, north delta vs. south delta) for key life stages in a species life cycle, population structure, habitat-specific growth and survivorship rates, diets over the life cycle, and identification of spawning habitat, are essential to populate the logic chains, yet also are missing or weakly known. This is a common problem, and requires a commitment to long-term sampling and focused studies on fundamental biology and ecology of species to be paired with that centered on solving immediate problems related to water management (e.g., survival through pumps and screens).

6. Applying the Logic Chains in the BDCP

The Panel recognizes that the logic chains can provide a useful tool for organizing current ideas and formulating a comprehensive restoration plan to address BDCP goals and objectives. The approach provides more than just a better articulation of the existing goals – it links actions to those goals and lays out expected outcomes. However, to be used as a key building block for the Plan, it is important that the narrative is scientifically credible and that both potential positive and negative outcomes are considered.

To effectively use the logic chains to build the plan, it will be essential to clearly lay out linkages among logic chains, effects analysis, implementation plan, monitoring and research components, and adaptive management. It is clear to the Panel, and those who briefed them, that there need to be feedbacks between the logic chains and the effects analysis. The effects analysis will become a new and important set of data for the Plan, and the process of incorporation of those data in the decision processes and logic chains needs to be described explicitly.

The Panel recommends that BDCP clearly identify the issues raised by the logic chains that can be addressed in the draft Plan (i.e., by November), or addressed during the subsequent refinement phase (e.g., the following year as the Plan is finalized and prior to the formal permit application), and that can only be addressed during implementation. A programmatic approach to research should be developed for early adoption, even prior to permitting, and the post-permitting adaptive management approach must be described and finalized as soon as possible, so that conservation measures and post-implementation monitoring can be refined and developed using that research.

The Steering Committee should consider using a formal decision support system (one that allows for incomplete information, generalized relationships, uncertainties etc) to identify high priority measures and those for early implementation. The panel believes that BDCP will be most successful if an objective process for implementation is developed that acknowledges: 1) the uncertainty of achieving expected outcomes, 2) that not all measures can be implemented immediately, 3) that not all measures will achieve their ultimate outcomes immediately, and 4) that some are contingent on the success of others (perhaps using optimization or other approaches as suggested by the first Logic Chain Panel) to provide more realistic expectations of how the system might change as a result of the implementation of the Plan. Conceptually, developing the BDCP calls for optimization of solutions for multiple objectives, subject to various constraints. Formal optimization, or at least the thinking underlying optimization, can be applied to subsets of measures and specific spatial regions. The Panel recognized that, unless the intent is to implement every conservation measure currently under consideration, some means of discriminating among conservation measures, in terms of their expected outcomes and the certainty of achieving those outcomes, is needed. Such a structured decision process could also consider issues such as cost, feasibility of implementation, and effectiveness in alleviating stressors. At present, the procedures for making decisions are, at the least, unclear. Transparency is especially important due to the complexity of the issues being addressed and the short time frames within which the Plan is being developed. Although it is unlikely that a formal decision support system could be applied prior to the issuance of the Draft Plan in November 2010, the Draft Plan should include consideration of how such an approach will be used during plan refinement (i.e., post-November 2010).

An adaptive management plan should be developed in sufficient detail for the November Draft Plan so it is clear to all participants which procedures will be used to revise BDCP objectives and how additional information, especially reduced uncertainty, will be incorporated into the Plan during implementation (i.e., revisiting the logic chains). During the Panel meeting there were frequent references to the adaptive management component of the BDCP effort. The nature of the adaptive management plan being proposed by the Steering Committee and how it would be implemented was not clear to the Panel, based on the materials provided. Formal adaptive management, as outlined in Kendall (2001Walters (1986), Stankey et al. (2005), and Nichols et al. (2009), would require clear agreement on the objective to be optimized, and would require specific expertise in decision analysis to apply. As it stands now, adaptive management comes after the Plan has been developed and during implementation, and the Panel is concerned that 'punting' too many difficult issues that far into the future into an undefined process called adaptive management can undermine the credibility of the Plan. Issues deferred to the adaptive management phase should be those which require specific monitoring data, research, and analyses. The more decisions which are left for adaptive management to address, the more important it is that a robust adaptive management plan, in terms of thinking, coordination and funding, be developed.

The Panel recommends a comprehensive articulation of BDCP conservation outcomes based on the logic chains, including their spatial distribution, at decadal intervals to identify targeted outcomes and provide flexibility for changing environmental conditions. Creating appropriate expectations will be important for BDCP. The success of BDCP relies on good science, effective implementation, rigorous monitoring, strong adaptive management, and transparency, and judging the success of the BDCP will be how the results measure up to expectations. On one hand, it is important to emphasize the importance of the positives of the BDCP process. On the other hand, it is also important to ensure that everyone understands what can realistically be achieved and over what time and space scales.

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Attachment 1

Logic Chain Review Panel
August 4-5, 2010
Delta Stewardship Council Office, Bay Room
650 Capitol Mall, 5th Floor
Sacramento, CA 95814
AGENDA

Wednesday August 4th

1. **Advisory Panel meets and reviews charge** (panel only) **8:00 – 8:30**
2. **Presentation on BDCP logic chains, metrics and monitoring** **8:30 – 10:30**
   a. Overview and Context (15 min)
      Laura King Moon, Wayne Spencer
   b. Logic Chains (1 hr)
      Dave Harlow (winter run chinook salmon, longfin smelt)
      Josh Israel (green and white sturgeon)
   c. Metrics and Monitoring (15 min)
      Cliff Dahm

   d. Example Monitoring Framework (30 min)
      Ted Sommer (Yolo Bypass)
      Chris Enright (Suisun Marsh)

3. **Questions and Discussion** **10:30 - 11:30**
   Lunch Break **11:30 –12:30**
4. **Advisory Panel further reviews materials, begins to draft recommendations, and formulates questions** **12:30 – 5:30**

Thursday, August 5th

1. **Advisory Panel meets with BDCP Team with further questions** **8:00 – 10:00**
2. **Advisory Panel refines recommendations** **10:00 – 12:00**
   Lunch Break **12:00 – 1:00**
3. **Advisory Panel Reports out to BDCP Team and takes comments** **1:00 – 4:30**
4. **Advisory Panel discusses next steps and writing assignments** **4:30 – 5:00**