BAY DELTA CONSERVATION PLAN

INDEPENDENT SCIENCE ADVISORS REPORT

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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:

[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.

POD Species

- Striped bass (*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.

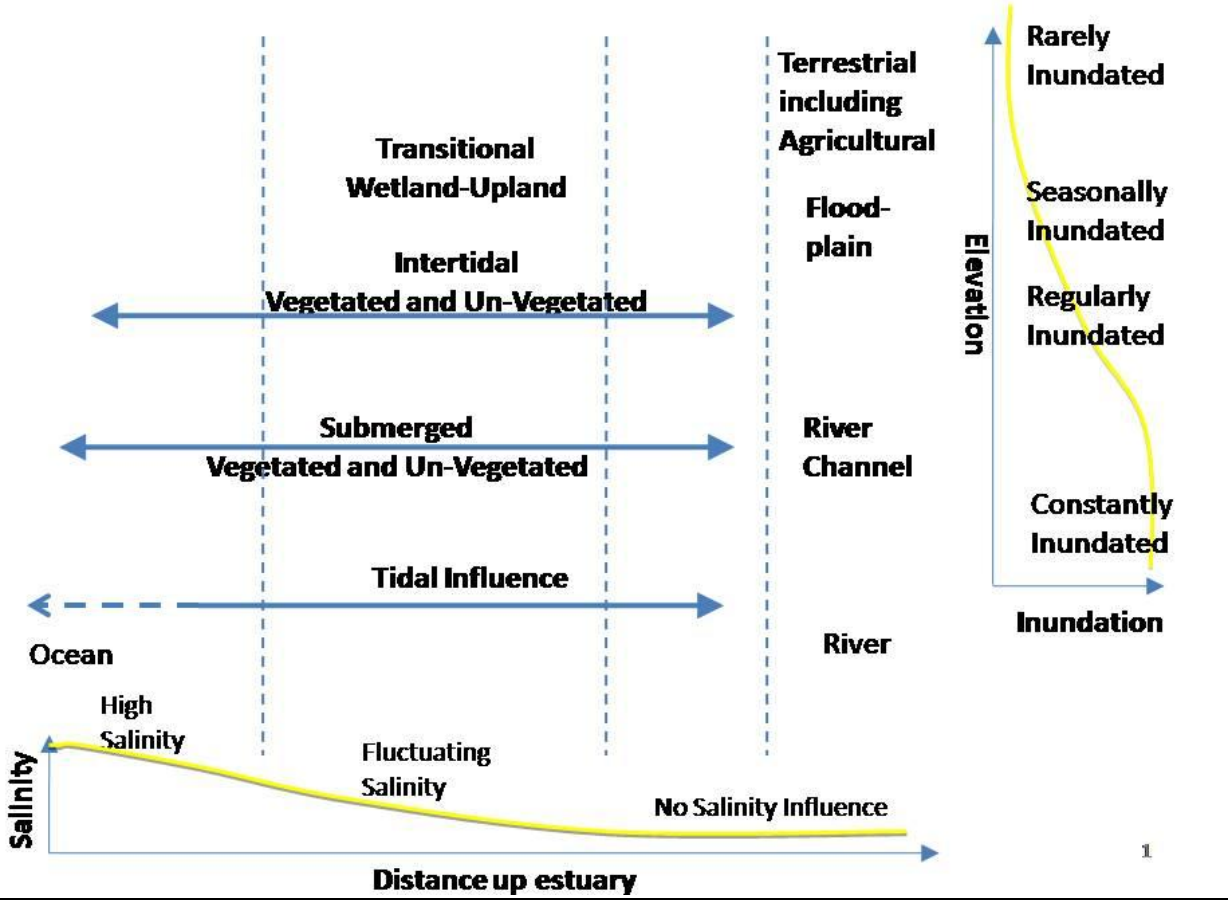

Figure 1. Horizontal and vertical gradients that control environmental conditions in the Delta.

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.

[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.

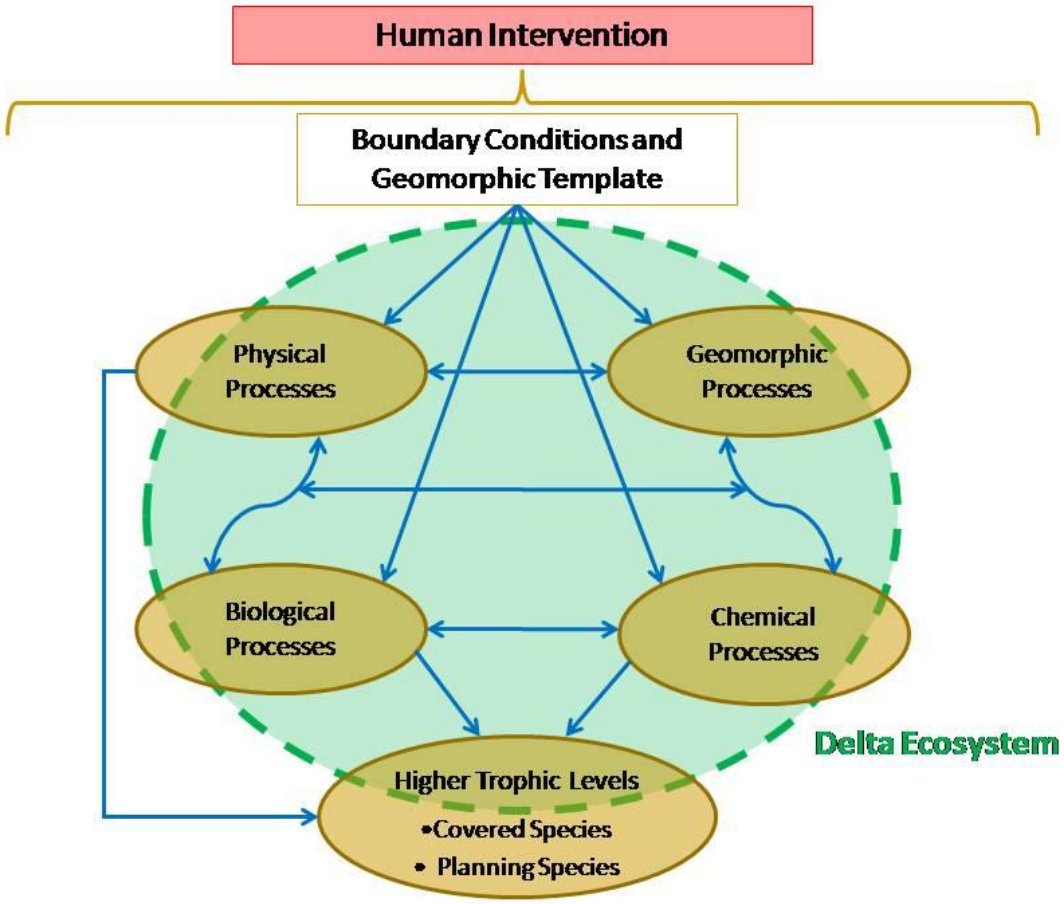

Figure 2 – Conceptual diagram of interactions among environmental processes that influence responses of higher trophic levels, including Covered Species, to changing conditions.

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.

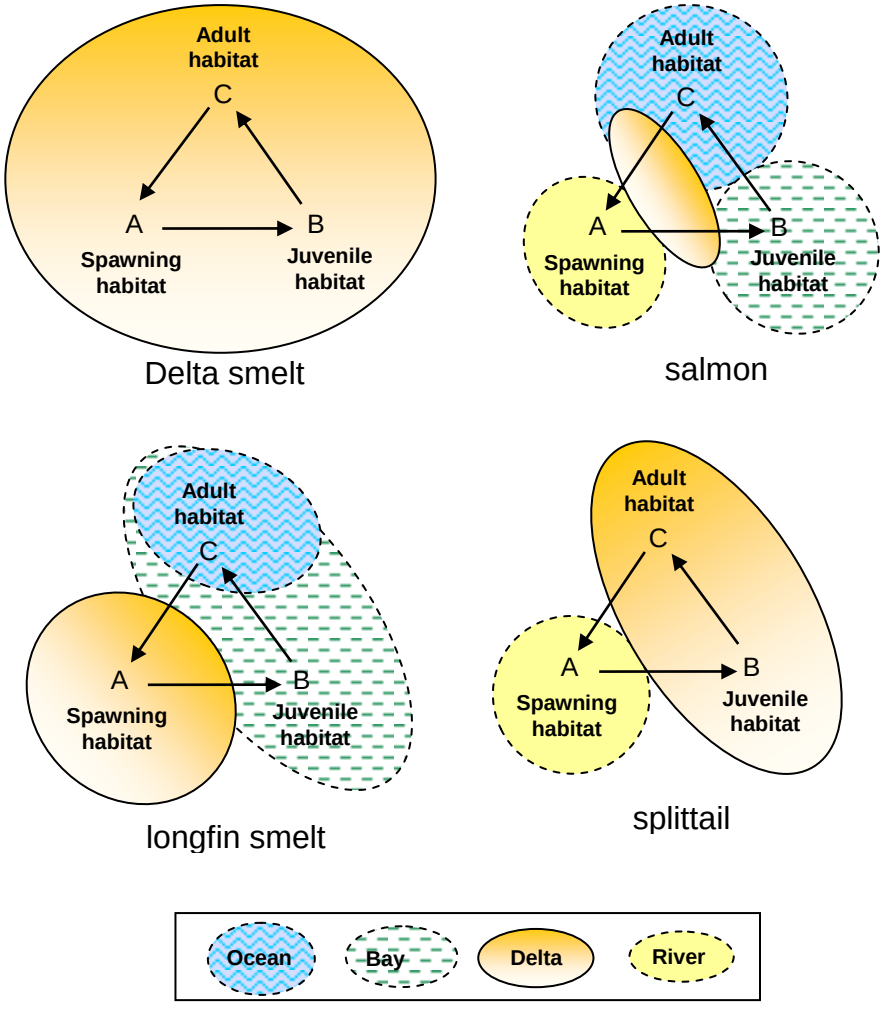

Figure 3. General pattern of use of the Delta by Covered Species over their life cycle. Arrows indicate migration among habitat types.

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.

7.0 LITERATURE CITED

Alpers CN, Eagles-Smith C, Foe C, Klasing S, Marvin-DiPasquale MC, Slotton DG, and Windham-Myers L. *In preparation*. Mercury Conceptual Model, Delta Regional Ecosystem Restoration Implementation Plan.

Atwater BF, Conard SG, Dowden JN, Hedel CW, Macdonald RL, and Savage W. 1979. History, landforms and vegetation of the estuary's tidal marshes. In: Conomos TJ, editor. San Francisco Bay: The urbanized estuary. Pacific Division, AAAS. p 347-385.

Bauer BO, Lorang MS, and Sherman J. 2002. Estimating boat-wake-induced levee erosion using sediment suspension measurements. Journal of Waterway Port Coastal and Ocean Engineering 128: 152-162.

Belluco E; Camuffo M; Ferrari S; Modenese L; Silvestri S; Marani A and Marani M. 2006. Mapping salt-marsh vegetation by multispectral and hyperspectral remote sensing. Remote Sensing of Environment 105: 54-67

Bennett WA. 2005. Critical assessment of the Delta smelt population in the San Francisco Estuary, California. San Francisco Estuary Watershed Science 3: Article 1.

Bennett, WA, Kimmerer WJ, and Burau JR. 2002. Plasticity in vertical migration by native and exotic estuarine fishes in a fluctuating low salinity zone. Limnology and Oceanography 47:1496-1507.

Bouley P and Kimmerer WJ. 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology Progress Series 324: 219-228.

Brandes PL and McLain JS. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In: Brown RL, editor. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179(2). Sacramento (CA): California Department of Fish and Game. p 39-136.

Brandes PL and White J. 2005. Environmental Water Account expenditures for Chinook salmon in Water Year 2005.

Brown LR and Michniuk D. 2007. Littoral fish assemblages of the alien-dominated Sacramento–San Joaquin Delta, California 1980–1983 and 2001–2003. Estuaries and Coasts. 30: 186-200.

Brown R, Greene S, Coulston P, and Barrow S. 1996. An evaluation of the effectiveness of fish salvage operations at the intake to the California Aqueduct, 1979-1993. *In* J. T. Hollibaugh (ed.), San Francisco Bay: The ecosystem. AAAS. p. 497-518.

Burau JR. *In preparation*. Hydrodynamic/Transport Conceptual Model, Delta Regional Ecosystem Restoration Implementation Plan.

Busch DE and Trexler JC. 2003. Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives. Island Press, Washington. p 425.

Byrd K and Kelly M. 2006. Salt marsh vegetation response to edaphic and topographic changes from upland sedimentation in a Pacific estuary. Wetlands 26: 813–829.

CALFED. 2000. Ecosystem Restoration Program Plan Strategic Plan for Ecosystem Restoration

California Regional Water Quality Control Board Agricultural Waiver Program. 2007 <http://www.waterboards.ca.gov/centralvalley/programs/irrigated_lands/index.html>.

Caswell H. 2000. Matrix Population Models: Construction, Analysis, and Interpretation, Second Edition. Sinauer Associates, Sunderland, MA.

Chatwin, PC. 1976. Some remarks on the maintenance of the salinity distribution in estuaries. Estuarine and Coastal Marine Science 4: 555-566.

Christiansen T, Wiberg PL, and Miiligan TG. 2000. Flow and sediment transport on a tidal salt marsh surface. Estuarine, Coastal, and Shelf Science 50: 315-331.

Cloern JE. 1999. The relative importance of light and nutrient limitation of phytoplankton growth: a simple index of coastal ecosystem sensitivity to nutrient enrichment. Aquatic Ecology 33: 3-16.

Cloern JE. 2007 Habitat connectivity and ecosystem productivity: implications from a simple model. American Naturalist 169: E21-E33.

Conaway CH, Ross JRM, Looker R, Mason RP, and Flegal AR. 2007. Decadal mercury trends in San Francisco Estuary sediments. Environmental Research 105: 53–66.

Connor MS, Davis JA, Leatherbarrow J, Greenfield BK, Gunther A, Hardin D, Mumley T, Oram JJ, and Werme C. 2007. The slow recovery of San Francisco Bay from the legacy of organochlorine pesticides. Environmental Research 105: 87-100.

Culberson SD, Foin TC, and Collins JN. 2004. The role of sedimentation in estuarine marsh development within the San Francisco Estuary, California, USA. Journal of Coastal Research (20)4: 970-979

Davis JA, Hetzel F, Oram JJ, and McKee LJ. 2007. Polychlorinated biphenyls (PCBs) in San Francisco Bay. Environmental Research 105: 67-86.

Feyrer F, Herbold B, Matern SA, and Moyle PB. 2003. Dietary shifts in a stressed fish assemblage: Consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67: 277 - 288.

Foe C and Knight A. 1985. The effect of phytoplankton and suspended sediment on the growth of *Corbicula fluminea* (Bivalvia). Hydrobiologia 127: 105-115.

Garrison BA. 1998. Bank Swallow (*Riparia riparia*). *In* The Riparian Bird Conservation Plan: a strategy for reversing the decline of riparian-associated birds in California. California Partners in Flight. <http://www.prbo.org/calpif/htmldocs/riparian_v-2.html>.

Gifford SM, Rollwagen-Bollens GC, and Bollens SM. *in press*. Mesozooplankton omnivory in the upper San Francisco Estuary. Marine Ecology Progress Series

Grimaldo LF. 2004. Diet and carbon sources supporting fishes from open-water, edge and SAV habitats in restored freshwater wetlands of the San Francisco Estuary. San Francisco State University MS Thesis.

Grimm V and Railsback SF. 2005. Individual-based Modeling and Ecology. Princeton University Press, Princeton, NJ.

Hand LH, Kuet SF, Lane MCG, Maund SJ, Warinton JS, and Hill IR. 2001. Influences of aquatic plants on the fate of the pyrethroid insecticide lambda-cyhalothrin in aquatic environments. Environmental Toxicology and Chemistry 20:1740-1745.

Harden-Jones FA. 1968. Fish Migration. Edward Arnold, London.

Herzog SK. 1996. Wintering Swainson's hawks in California's Sacramento-San Joaquin River Delta. The Condor 98:876-879.

Hoenicke R, Oros DR, Oram JJ, and Taberski KM. 2007. Adapting an ambient monitoring program to the challenge of managing emerging pollutants in the San Francisco Estuary. Environmental Research 105: 132-144.

Hollibaugh JT and Wong PS. 1996. Distribution and activity of bacterioplankton in San Francisco Bay. In: Hollibaugh JT, editor. San Francisco Bay: The Ecosystem. AAAS. p. 263-288.

Holling CS. 1978. Adaptive Environmental Assessment and Management. Chichester J. Wiley p. 377.

Howe AJ and MacFarlane RG. 2005. Vegetation-sediment-flow interactions in estuarine wetlands. In: Zerger A and Argent RM, editors. MODSIM 2005 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2005. p 332-338.

Jassby AD, Cloern JE, and Cole BE. 2002. Annual primary production: patterns and mechanisms of change in a nutrient-rich tidal estuary. Limnology and Oceanography 47: 698-712.

Jassby AD, Kimmerer WJ, Monismith SG, Armor C, Cloern JE, Powell TM, Schubel JR, and Vendlinski TJ. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 5: 272-289.

Jassby AD, Cloern JE, and Powell TM. 1993; Organic carbon sources and sinks in San Francisco Bay -variability induced by river flow. Marine Ecology Progress Series 95: 39-54.

Jassby AD and Van Nieuwenhuyse. 2005. Low dissolved oxygen in an estuarine channel (San Joaquin River, California): mechanisms and models based on long-term time series. San Francisco Estuary and Watershed Science 3: Article 2.

Kimmerer WJ. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science 2.

Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages. Marine Ecology Progress Series 243:39-55.

Kimmerer WJ. *In press*. Losses of Sacramento River Chinook salmon and Delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary Watershed Science

Kimmerer WJ and Nobriga ML. *In press.* Investigating particle transport and fate in the Sacramento-San Joaquin Delta using a particle tracking model. San Francisco Estuary and Watershed Science.

Knowles N and Cayan D. 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco Estuary. Geophysical Research Letters 29 : 1891.

Koch EW, Sanford LP, Chen SN,. Shafer DJ, and Smith JM. 2006. Waves in seagrass systems: review and technical recommendations. US Army Corps of Engineers Technical Report. Engineer Research and Development Center, ERDC TR-06-15. p 82.

Kuivila KM and Foe CG . 1995 Concentrations, transport and biological effects of dormant spray pesticides in the San Francisco Estuary, California. Environmental Toxicology and Chemistry. 14: 1141-1150.

Leonard LA and Reed DJ. 2002. Hydrodynamics and sediment transport through tidal marsh canopies. Journal of Coastal Research SI 36: 459-469.

Liermann M and Hilborn R. 2001. Depensation, evidence, models and implications. Fish and Fisheries 2:33-58.

Lightbody AF and Nepf HM. 2006. Prediction of velocity profiles and longitudinal dispersion in emergent salt marsh vegetation. Limnology and Oceanography 51: 218–228.

Lindley ST and Mohr MS. 2003. Modeling the effect of striped bass (*Morone saxatilis*) on the population viability of Sacramento River winter-run Chinook salmon (*Oncorhyncus tschawytscha*). U.S. Fishery Bulletin 101: 321-331.

Little EE and Finger SE. 1990. Swimming behavior as an indicator of sublethal toxicity in fish. Environmental Toxicology and Chemistry 9: 13-19.

Lopez CB, Cloern JE, Schraga TS, Little AJ, Lucas LV, Thompson JK, and Burau JR. 2006. Ecological values of shallow-water habitats: Implications for the restoration of disturbed ecosystems. Ecosystems 9: 422-440.

Lucas LV, Cloern JE, Thompson JK, and Monsen NE. 2002. Functional variability of habitats within the Sacramento-San Joaquin Delta: Restoration implications. Ecological Applications 12: 1528–1547.

Lucas LV, Koseff JR, Cloern JE, Monismith SG, and Thompson JK. 1999a. Processes governing phytoplankton blooms in estuaries. I: The local production-loss balance. Marine Ecology Progress Series 187: 1-15.

Lucas LV, Koseff JR, Cloern JE, Monismith SG, and Thompson JK. 1999b. Processes governing phytoplankton blooms in estuaries. II: The role of horizontal transport. Marine Ecology Progress Series 187: 17-30.

Lund J, Hanak E, Fleenor W, Howitt R, Mount J, and Moyle P. 2007. Envisioning Futures for the Sacramento-San Joaquin Delta. Public Policy Institutue of California. p 324.

Mahall BE and Park RB. 1976a. The ecotone between Spartina Foliosa Trin. and Salicornia Virginica L. in salt marshes of northern San Francisco Bay: I. Biomass and production. Journal of Ecology 64: 421-433.

Mahall BE and Park RB. 1976b. The ecotone between Spartina Foliosa Trin. and Salicornia Virginica L. in salt marshes of northern San Francisco Bay: II. Soil water and salinity. Journal of Ecology 64: 793-809.

Mahall BE and Park RB. 1976c. The ecotone between Spartina Foliosa Trin. and Salicornia Virginica L. in salt marshes of northern San Francisco Bay: II. Soil aeration and tidal immersion. Journal of Ecology 64: 811-819.

Marani-Belluco ME, Ferrari S, Silvestri S, D'Alpaos A, Lanzoni S, Feola A, and Rinaldo A. 2006. Analysis, synthesis and modelling of high-resolution observations of salt-marsh eco-geomorphological patterns in the Venice lagoon. Estuarine Coastal and Shelf Science 69: 414-426.

Margoluis RA and Salafsky NN. 1998. Measures of Success: Designing, Managing, and Monitoring Conservation and Development Projects. Island Press, Washington, D.C.

Mazda Y, Magi M, Ikeda Y, Kurokawa T, and Asano T. 2006. Wave reduction in a mangrove forest dominated by *Sonneratia* sp. Wetlands Ecology and Management 14: 365-378.

McElhany P, Ruckleshaus M, Ford M, Wainwright T, and Bjorkstedt E. 2000. Viable salmon populations and the recovery of evolutionary significant units. NOAA Technical Memorandum NMFS-NWAFSC-42. <ww.nwfsc.noaa.gov/publications/displayallinfo.cfm?docmetadataid=5561>.

Monismith SG, Kimmerer WJ, Burau JR, and Stacey MT. 2002: Structure and flow-induced variability of the subtidal salinity field in northern San Francisco Bay. Journal of Physcial Oceanography 32: 3003–3019.

Mount J, and Twiss R, 2005, Subsidence, sea level rise, and seismicity in the Sacramento – San Joaquin Delta: San Francisco Estuary and Watershed Science 3: Artincle 5.

Moyle PB. 2002. Inland Fishes of California. University of California Press, Berkeley, CA.

Moyle PB, Baxter RD, Sommer T, and Matern SA. 2004. Biology and population dynamics of Sacramento splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: A Review. San Francisco Estuary and Watershed Science 2: Article 4.

Moyle PB, Herbold B, Stevens DE, and Miller LW. 1992. Life history and status of Delta smelt in the Sacramento-San Joaquin estuary, California. Transactions of the American Fisheries Society 121: 67-77.

Müller-Solger AB, Jassby AD, and Müller-Navarra D. 2002. Nutritional quality of food resources for zooplankton (*Daphnia*) in a tidal freshwater system (Sacramento-San Joaquin River Delta). Limnology and Oceanography 47: 1468-1476.

Nepf HM. 2004. Vegetated flow dynamics. In S. Fagherazzi, M. Marani, and L. Blum [eds.], Ecogeomorphology of Tidal Marshes. Coastal Estuarine Studies Monograph Series 59: 137–164.

Nobriga M and Feyrer F. 2007. Shallow-water piscivore-prey dynamics in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 5: Artincle 4.

Oros DR, Collier RW, and Simoneit RT. 2007. The extent and significance of petroleum hydrocarbon contamination in Crater Lake, Oregon. Hydrobiologia, 574: 85-105.

Orsi J and Mecum W. 1986. Zooplankton distribution and abundance in the Sacramento-San Joaquin Delta in relation to certain environmental factors. Estuaries 9: 326-339.

Pearcy RW and Ustin SL. 1984. Effects of salinity on growth and photosynthesis of three California tidal march species. Oecologia 62: 68-73.

Phelps H. 1994. The Asiatic Clam (*Corbicula fluminea*) invasion and system-level ecological change in the Potomac River estuary Washington, DC. Estuaries 17: 614-621.

Presser TS and Luoma SN. 2006. Forecasting selenium discharges to the San Francisco Bay-Delta Estuary: ecological effects of a proposed San Luis Drain extension: U.S. Geological Survey Professional Paper 1646: 196. <http://pubs.usgs.gov/pp/p1646/>

Presser TS, Luoma SN, Wainwright-De La Cruz SE, Linville RG, Beckon WN. *In preparation.* Selenium Conceptual Model: Framework and Sub-Models-Delta Regional Ecosystem Restoration Implementation Plan.

Presser TS and Piper DZ. 1998. Mass balance approach to selenium cycling through the San Joaquin Valley, sources to river to bay. In: Frankenberger WT, Jr and Engberg RA, editors. Environmental Chemistry of Selenium: New York, New York, Marcel Dekker Inc. p 153-182.

Rahmstorf S. 2007. A semi-empirical approach to projecting sea-level rise. Science 315: 368-370.

Reed DJ. 2002. Understanding tidal marsh sedimentation in the Sacramento-San Joaquin Delta, California. Journal of Coastal Research SI 36: 605-611.

Reyes E, White ML, Martin JF, Kemp GP, and Day JW. 2000. Landscape modeling of coastal habitat change in the Mississippi Delta. Ecology 81: 2331-2349.

Rose KA, Cowan JH Jr, Winemiller KO, Myers RA, and Hilborn R. 2001. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries 2: 293-327.

Rojstaczer S and Deverel SJ. 1995. Land subsidence in drained histosols and highly organic mineral soils of California: Soil Science Society of America Journal 59: 1162-1167.

Rybczyk JM, Callaway JC, and Day Jr JW. 1998. A relative elevation model for a subsiding coastal forested wetland receiving wastewater effluent. Ecological Modelling 112: 23-44.

Sandahl JF, Baldwin DH, Jenkins JJ, and Scholz NL. 2004. Odor-evoked field potentials as indicators of sublethal neurotoxicity in juvenile coho salmon (*Oncorhynchus kisutch*) exposed to copper, chlorpyrifos, or esfenvalerate. Canadian Journal of Fisheries and Aquatic Sciences 61: 404-413.

Silvestri S, Marani M, and Marani A. 2003. Hyperspectral remote sensing of salt marsh vegetation, morphology and soil topography. Physics and Chemistry of the Earth 28: 15–25.

Sobczak WV, Cloern JE, Jassby AD, Cole BE, Schraga TS, and Arnsberg A. 2005. Detritus fuels ecosystem metabolism but not metazoan food webs in San Francisco Estuary's freshwater Delta. Estuaries 28: 124-137.

Sobczak WV, Cloern JE, Jassby AD. and Muller-Solger AB. 2002. Bioavailability of organic matter in a highly disturbed estuary: The role of detrital and algal resources. Proceedings of the National Academy of Sciences USA 99: 8101-8105.

Sommer T, Armor C, Baxter R, Breuer R, Brown L, Chotkowski M, Culberson S, Feyrer F, Gingras M, Herbold B, Kimmerer W, Mueller-Solger A, Nobriga M, and Souza K. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32: 270-277.

Stacey MT, Burau JR, and Monismith SG. 2001. Creation of residual flows in a partially stratified estuary. Journal of Geophysical Research 106: 17013-17037.

Technical Review Panel. 2005. Review of the biological opinion of the long-term Central Valley Project and State Water Project operations criteria and plan. Report prepared for Johnnie Moore, Lead Scientist of the California- Bay-Delta Authority. Sacramento, CA. http://198.31.87.66/pdf/workshops/OCAP_review_final_010606_v2.pdf [accessed Nov 15 2007]

Tsihrintzis VA and Madiedo EE. 2000. Hydraulic resistance determination in marsh wetlands. Water Resources Management 14: 285-309.

U.S. Fish and Wildlife Service. 2006. Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) 5-year review: Summary and evaluation. U.S. Fish and Wildlife Servce, Sacramento, CA. p 28. <http://www.fws.gov/sacramento/es/documents/VELB%205-year%20review.FINAL.pdf>

U.S. Fish and Wildlife Service. 1999. Draft recovery plan for the giant garter snake (*Thamnopsis gigas*). U.S. Fish and Wildlife Service, Portland, OR. p 129.

Ustin SL, Pearcy RW, and Bayer DE. 1982. Water relations in a San Francisco Bay salt marsh. Botanical Gazette 143: 368-373.

Vorosmarty CJ, Green P, Salisbury J, and Lammers RB. 2000. Global water resources: vulnerability from climate change and population growth. Science 289: 284-288.

Vosylien MZ, Sveceviius G, and Kazlauskien N. 2003. Toxic effects of ammonia on rainbow trout *Oncorhynchus mykiss* in all stages of development. In: Fish Physiology, Toxicology, and Water Quality. Proceedings of the 7th International Symposium, Tallinn, Estonia, May 12-15, 2003. EPA/600/R-04/049.

Walters C. 1986. Adaptative Management of Renewable Resource. New York; Macmillan Publishing. p 374.

Werner I, Deanovic LA, Connor V, de Vlaming V, Bailey HC and Hinton DE. 2000. Insecticide-caused toxicity to *Ceriodaphnia dubia* (Cladocera) in the Sacramento-San Joaquin River Delta, California, USA. Environmental Toxicology and Chemistry 19: 215–227

Weston DP; You J and Lydy MJ. 2004. Distribution and toxicity of sediment-associated pesticides in agriculture-dominated water bodies of California's Central Valley. Environmental Science and Technology 38: 2752-2759.

Wilkerson FP, Dugdale RC, Hogue VE, and Marchi A. 2006. Phytoplankton blooms and nitrogen productivity in San Francisco Bay. Estuaries and Coasts 29: 401-416.

Williams JG. 2006. Central Valley Salmon: A perspective on Chinook and Steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4: Article 2.

Winemiller KO and Rose KA. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49: 2196–2218.

Woodbridge B. 1998. Swainson's hawk (*Buteo swainsoni*). In: The Riparian Bird Conservation Plan: a strategy for reversing the decline of riparian-associated birds in California. California Partners in Flight. <http://www.prbo.org/calpif/htmldocs/riparian_v-2.html>

Woudneh MB and Oros DR. 2006a. Quantitative determination of pyrethroids, pyrethrins, and piperonyl butoxide in surface water by high-resolution gas chromatography/high-resolution mass spectrometry. Journal of Agriculture and Food Chemistry 54: 6957 -6962

Woudneh MB and Oros DR. 2006b. Pyrethroids, pyrethrins, and piperonyl butoxide in sediments by high-resolution gas chromatography/high-resolution mass spectrometry. Journal of Chromatography A 1135: 71-77

Yee D, Grieb T, Mills W, and Sedlak M, 2007. Synthesis of long-term nickel monitoring in San Francisco Bay. Environmental Research 105: 20-33.

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