Ecosystem Restoration Program

Conservation Strategy for Stage 2 Implementation

Sacramento-San Joaquin Delta Ecological Management Zone

July 21, 2010

Implementing Agencies:
California Department of Fish & Game
United States Fish & Wildlife Service
NOAA's National Marine Fisheries Service

FOREWORD

The Ecosystem Restoration Program (ERP) Conservation Strategy for Stage 2 Implementation Sacramento-San Joaquin Delta Ecological Management Zone (EMZ) addresses the statutory Sacramento-San Joaquin Delta (Water Code §12220 et seq.) – as described in ERPP Volume II (CALFED 2000b) and accompanying ERP Maps (CALFED 2000h). ERP also prepared Conservation Strategies for the Sacramento River, and San Joaquin River Regions, the primary sources of water for the Sacramento-San Joaquin Delta**.** Together these documents provide a comprehensive ecosystem Conservation Strategy for the Central Valley and the San Francisco Bay/Sacramento-San Joaquin Delta Estuary to guide ERP and other planning efforts.

As part of the CALFED Record of Decision (ROD), CALFED program implementation was broken into two stages, Stage 1 (2000-2007) and Stage 2 (2008 – 2030), to allow re-evaluation of its preferred (through-Delta) conveyance alternative after Stage 1. The focus of the Sacramento-San Joaquin Delta EMZ (Delta EMZ) in this Conservation Strategy responds to indications, from analysis of Stage 1 implementation, that CALFED's through-Delta conveyance alternative has not achieved sufficient progress in sustaining viable populations of endangered and threatened aquatic species or in ecosystem restoration, levee stability, or water supply reliability. In the interest of readability, findings of ERP implementation during Stage 1 are presented in this document only to the extent that they demonstrate how scientists' understanding of the system has changed since the ROD was certified in 2000. The reader is encouraged to refer to the original Ecosystem Restoration Program Plan documents for the descriptions and rationales of the ecological processes, habitats, and stressors in the Delta EMZ, and to the ERP End of Stage 1 Report for more information on the specific projects funded and lessons learned during ERP Stage 1 implementation.

This document was written specifically in anticipation of impending changes to how water is conveyed to the state and federal water export facilities in the southern Delta. The ERP Implementing Agencies will continue to implement the ERP throughout the ERP Focus Area. The Delta Conservation Strategy will guide ERP implementation in the Delta EMZ and is expected to serve as the ecosystem component of any future comprehensive Delta Plan developed by the Delta Stewardship Council.
Since the ROD was signed, additional concerns such as impacts associated with climate change have been added to the list of issues that need to be considered by this Conservation Strategy. Many of the issues presented in this document are being analyzed in other planning initiatives for the Delta and nearby areas. This Conservation Strategy provides guidance for those Delta-related activities, as it reflects changes in knowledge, conditions, and understanding of the system. The Conservation Strategy will:

- Identify how ERP goals and objectives will be reviewed in light of new information;
- Identify types and locations of actions that may be taken to meet those goals and objectives;
- Serve as an organizational framework to ensure program implementation is guided by science and is transparent to the interested public.

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Introduction

This document describes the Ecosystem Restoration Program (ERP)'s Stage 2 Conservation Strategy for the Sacramento-San Joaquin Delta Ecological Management Zone (Delta Conservation Strategy). It was developed by the California Department of Fish and Game (DFG), U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS), collectively known as the ERP Implementing Agencies. ERP has prepared Conservation Strategies for the Sacramento River Region and the San Joaquin River Region as well. Presently the development of Conservation Strategies for the East Side Tributaries Ecological Management Zone (EMZ) or the Bay Region are not considered necessary. Used together these Conservation Strategies will provide a comprehensive ecosystem Conservation Strategy for the ERP Focus Area (Figure 1).

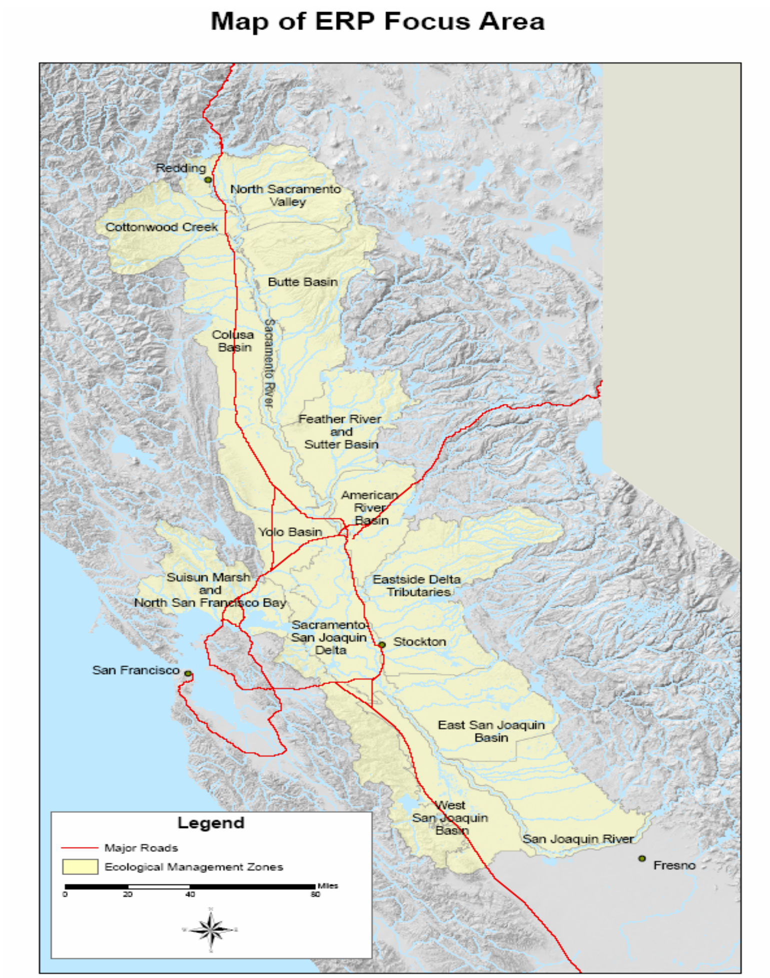

Figure 1: Map of CALFED ERP Focus Area

This document describes the ERP Implementing Agencies' ecosystem restoration goals, objectives, and priorities for the Delta Ecological Management Zone (Delta EMZ) for the Stage 2 of the CALFED Bay-Delta Program. It is a biological view of the most promising ecosystem restoration opportunities in the Delta EMZ, and provides the rationale for Delta-specific restoration actions. While earlier drafts of this document included restoration actions in Suisun Marsh, specific Suisun Marsh and Bay restoration actions are discussed in the forthcoming Habitat Management, Preservation, and Restoration Plan for the Suisun Marsh (Suisun Marsh Plan), and are incorporated by reference into this Conservation Strategy.

> **ERP Single Blueprint**
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> A single blueprint for the Delta represents a unified and cooperative approach defined by three primary elements:
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> 1. integrated, shared science and a set of transparent ecological conceptual models which provide a common basis of understanding about how the ecosystem works;
> 2. a shared vision for a restored ecosystem; and
> 3. a management framework that defines how management and regulatory authorities affecting the Delta will interact and how management and regulatory decisions (including planning, prioritization, and implementation) will be coordinated and integrated over time. *(ERP Strategic Plan, 2000)*

This document serves as an update to the ERP Strategic Plan as it relates to restoration actions in the Delta EMZ, and follows the ERP principle of a single blueprint for ecosystem restoration and species recovery in the Delta in accordance with the principles of ecosystem-based management. All agencies, groups, or individuals interested in resource conservation and management within the Delta are encouraged to use this document as a shared vision to coordinate and integrate actions. To develop this shared vision, the Conservation Strategy used information from Milestones Reports, Annual Reports, End of Stage 1 Report, review of best available science on current ecological conditions, coordination with related programs and planning efforts, potential future actions assessment, and input from stakeholders and the general public. The ERP Implementing Agencies will use this Conservation Strategy for Stage 2 of the ERP, anticipated to last from 2009–2030.

The concept of uncertainty is threaded throughout this strategy. Uncertainty in this document can include all, a combination, or just one of the following: (1) the inability to predict the future state of dynamic systems; (2) how future conditions depend on unpredictable or unforeseen external drivers; (3) incorrect or incomplete information about underlying processes that make predicting outcomes difficult; or (4) disagreement about the underlying processes based on alternative interpretations of data. Although there is uncertainty in many aspects of Delta management, several key variables are expected to change over the course of Stage 2 implementation. The following briefly describes these key variables.

Relationship to other geographic areas. ERP focuses on a large territory that includes the Sacramento and San Joaquin Valleys, in addition to the Bay-Delta estuary (Figure 1). The ERP Implementing Agencies realize that conditions in the estuary are directly influenced by how water and species are managed upstream. ERP Conservation Strategies for Sacramento River Region and the San Joaquin River Region need to be integrated, and coordinated as to be complementary the Delta Conservation Strategy in unforeseen ways.

Conveyance assumptions. The two major efforts regarding conveyance that informed this Conservation Strategy, the Delta Vision process and the Bay-Delta Conservation Plan (BDCP), are described more fully later in this section. In the recently completed Delta Vision process, the Blue Ribbon Task Force endorsed the concept of a new system of dual water conveyance through and around the Delta to assist with its co-equal goals of ecosystem restoration and water supply reliability. BDCP, which is analyzing different alternatives for an isolated water conveyance facility, is anticipated to complete its first draft environmental document in early 2010.

This Conservation Strategy assumes that a new conveyance system is the most promising approach for achieving both ecosystem and water supply goals for the Delta, depending upon the design, operations, and institutional considerations of new points of diversion and an isolated conveyance facility around the Delta. The Conservation Strategy also assumes that modifications to existing export facilities in the south Delta would be pursued to reduce entrainment and otherwise improve the State Water Project's (SWP) and Central Valley Project's (CVP) ability to convey water through the Delta in the near term.

Since the construction and operation of an isolated facility is uncertain, that is, it is unknown if or when such a facility may be built, this assumption dictates that in the short-term, continued water conveyance through the Delta will accommodate habitat restoration actions mainly in the north Delta and Suisun areas because they are furthest removed from the influence of the export facilities. In the long-term, if an isolated conveyance system becomes operational, habitat restoration in the South, Central/West, and East Delta Ecological Management Units (EMUs) would be pursued more actively.

Development of near- and long-term restoration actions and performance measures. Conceptual models highlight what is known about how a system works or how a species develops, hypothesize how specific changes could effect the system or species, and identify where information gaps exist. Several conceptual models developed during Stage 1 of ERP implementation are being used to analyze potential ecosystem restoration actions not only in this Conservation Strategy, but also in parallel planning processes such as the Delta Steawardship Council's Delta Plan and BDCP. This analysis can point out incorrect or incomplete information regarding a proposed action, so some actions listed in this strategy may need to be modified to reach the desired outcome. These models also will be used to develop and refine restoration actions as they are carried out, in the context of allowing flexibility in management of the program based on what we learn over time (a process called adaptive management).

The conceptual models also will be used to develop and implement performance measures by which ERP progress can be evaluated. Since using conceptual models to analyze actions could lead to revisions of those actions, the respective performance measures may be revised as well, to reflect the new expected outcomes of the revised actions.

Species information. Over the last 10 years, a lot has been learned about key Delta resident and migratory species. DFG is compiling this information into "species-stressors" tables that identifies the importance, level of understanding, and certainty or predictability of those species' interactions with environmental conditions. This is another example of how incomplete information can lead to uncertainty. As this information is developed for both aquatic and terrestrial species, it will be used to inform and prioritize management decisions relating to ecosystem restoration actions in the Delta. Changes in priorities or management decisions, based on newly developed information, is another example of the adaptive management concept.

Governance. The issue of Delta governance was recently resolved by the adoption of legislation establishing a new Delta Stewardship Council. The ERP Implementing Agencies will continue to implement the ERP, but that this Conservation Strategy specific to the Delta EMZ will serve as the ecosystem component of any future comprehensive Delta Plan.

Despite the many variables and uncertainties involved in trying to manage ecological resources in the Delta, this component of the overall ERP Conservation Strategy should be implemented as the single blueprint for Delta ecosystem restoration and species recovery. It is important, in using this document, to have an understanding of its underpinnings; therefore, the following provides a brief description of CALFED, the ERP's founding documents, and the other Delta planning processes that should be integrated with the Conservation Strategy.

Background

CALFED began in 1994 with the signing of an agreement called the Bay-Delta Accord. Over the next six years, the Multi-Species Conservation Strategy (MSCS), the Stage 1 Strategic Plan, a Programmatic Environmental Impact Statement/Environmental Impact Report (PEIS/R), and the Record of Decision were prepared and certified (CALFED 2000e). These documents outlined and highlighted the goals and objectives of CALFED for the next 30 years. The four goals of CALFED are:

- Provide good water quality for all beneficial uses (Water Quality Program).
- Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species (ERP).
- Reduce the mismatch between Bay-Delta water supplies and current and projected beneficial uses dependent on the Bay-Delta system (Water Supply Reliability Program).
- Reduce the risk to land use and associated economic activities, water supply, infrastructure and the ecosystem from catastrophic breaching of Delta levees (Levee System Integrity Program).

The four CALFED program objectives and the respective programs to achieve them were designed to complement each other. The ERP is the principal CALFED component designed to restore the ecological health of the Bay-Delta ecosystem, and supports the objective of improving water management for beneficial uses of the Bay-Delta system. To achieve this, the ERP approach is to restore or mimic ecological processes and to increase and improve aquatic and terrestrial habitats to support stable, self-sustaining populations of diverse and valuable species.

Since CALFED is a 30-year program, the founding documents called for an evaluation at the end of the first seven years of the program to assess progress and develop subsequent Stage 2 strategies. The ERP Stage 1 assessment evaluates:

- Progress towards achieving Multi-Species Conservation Strategy (MSCS) milestones CALFED 2000d)
- Efficacy of the Environmental Water Account (EWA) (see also Brown et al. 2006);
- Progress of overall ERP implementation
- Progress towards achieving Key Planned Actions provided for in the Biological Opinions (CALFEDf, g)

Below is a brief description of the CALFED documents that are the foundational documents for the ERP and this Conservation Strategy.

Ecosystem Restoration Program Plan (ERPP). The ERPP consists of four volumes: Volume 1 presents visions for the ecosystem elements in the Central Valley that serve as the ERP's foundation and scientific basis. Volume 2 of the ERPP presents visions for the 14 ecological management zones and their respective ecological management units (Figure 1). Each ecological management zone vision contains a brief description of the management zone and units, important ecological functions associated with the zone, significant habitats, species that use the habitats, and stressors that impair the functioning or use of the processes and habitats. ERPP Volume 2 also contains restoration targets, programmatic actions, the rationale for targets and actions, and conservation measures that balance and integrate ERP implementation with the needs of the MSCS. Volume 4 contains maps of the ERP ecological management zones and units.

ERP Goals

- Achieve recovery for at-risk species
- Rehabilitate natural processes
- Maintain or enhance populations of selected species for sustainable commercial or recreational harvest
- Protect or restore functional habitat types
- Prevent or reduce harmful impacts from nonnative species
- Improve or maintain water quality and sediment quality conditions that support healthy ecosystems

ERP Strategic Plan 2000

Volume 3 is the ERP Strategic Plan. This volume lists ERP goals and objectives and provides the scientific and practical framework for implementing restoration in the Bay-Delta watershed. The six strategic goals that define the scope of the program are further divided into more specific objectives, each of which are intended to help determine whether or not progress is being made toward achieving the respective goal (see

Appendix B for complete list of ERP goals and objectives). Specific actions based on the ERPP Volumes 1 and 2 also are identified in the ERP Strategic Plan.

Progress on these goals and objectives over the years has been varied. ERP has made progress on some, especially those relating to habitat restoration, but others have not fared as well, particularly those regarding protecting and recovering at-risk Delta aquatic species. Some of these species have declined since 2000; for example, the Pelagic Organism Decline (POD) in the Delta includes the listed delta smelt and longfin smelt (IEP 2007a). Despite the POD, the Stage 1 evaluation shows that some ERP activities during Stage 1 have benefited at-risk species by:

- Enabling a better understanding of important processes such as hydrodynamics, temperature regimes, and instream flow
- Assessing hatchery impacts on natural Chinook salmon and steelhead populations
- Developing a methodology to culture all life stages of delta smelt
- Assessing various contaminant effects on aquatic species
- Planning and on-the-ground aquatic and terrestrial habitat restoration
- Increasing understanding of salmonid populations through monitoring and genetic studies
- Increasing understanding of the value of floodplains to native fish species

Information from the ERP End of Stage 1 assessment was used in writing this Conservation Strategy, which will serve as an addendum to the ERP Strategic Plan when it is approved.

Multi-Species Conservation Strategy. The MSCS designed to meet the requirements of the federal Endangered Species Act (ESA), California Endangered Species Act (CESA), and the Natural Community Conservation Planning Act (NCCPA). The MSCS provides a programmatic approach for evaluating potential impacts of CALFED projects to specified biological resources. A program-level evaluation of CALFED similar to programmatic environmental impact documents under the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA).

The MSCS identified and evaluated 244 special status species and 20 Natural Community Conservation Plan (NCCP) communities that could be affected by CALFED program implementation. Conservation goals for each species and community were identified as well. Species goals are: (1) recovery of 19 evaluated species (“R species”), (2) contribute to recovery of populations for 25 evaluated species (“r species”), and (3) maintain existing levels of populations and habitats for 155 evaluated species (“m species”). Goals for NCCP communities fall into four categories: (1) substantially increase extent and quality of habitat; (2) protect, enhance, and restore habitat; (3) avoid, minimize, and compensate for habitat loss; and (4) avoid, minimize, and compensate for loss of individuals where evaluated species are affected.

Relationship of ERP Conservation Strategy for the Delta EMZ to Other Planning Efforts

The Delta is a complex and dynamic system influenced by land use, water use, and socio-economic factors. The physical Delta crosses five counties, and various local, state, and federal agencies have jurisdiction over all or part of the area. Delta planning efforts are just as complex and dynamic as the physical system itself. This Conservation Strategy was written recognizing that these efforts must complement and integrate with each other to successfully achieve desired outcomes for a sustainable Delta.

Several concurrent planning efforts are evaluating the status of Delta resources, future use of those resources, and the risk to those resources from controllable and uncontrollable drivers of change. The Conservation Strategy both informs and was informed by these efforts, and information exchange will continue as respective efforts are carried out. Below is a brief description of the numerous planning efforts that have been important to the development of this Conservation Strategy. The ERP Implementing Agencies anticipate that this Conservation Strategy will provide a biological foundation for these other planning efforts.

Delta Vision. The Delta Vision process began in 2006 after Executive Order S-17-06 was issued. That Executive Order established the Delta Vision Committee, the Delta Vision Blue Ribbon Task Force (Task Force), and established a timeline for a vision document and strategic plan to be completed. The goal of the Delta Vision process was to "develop a durable vision for sustainable management of the Delta." The seven-member Task Force completed their vision in 2007 and their strategic plan in 2008. In December 2008, recommendations on how to implement the Delta Vision Strategic Plan were submitted to the Governor and Legislature by the Delta Vision Committee (DVC). The DVC was comprised of the secretaries for The Resources Agency; Business, Transportation, and Housing; California Environmental Protection Agency; Department of Food and Agriculture, and the President of the Public Utilities Commission.

The Delta Vision effort had a broader focus than the ERP, and a longer time frame (to 2100). The Task Force members issued their recommendations that addressed an array of natural resources, infrastructure, land use, and governance issues necessary to achieve a sustainable Delta. The Delta Vision effort began with the consensus that the current mix of uses, resources, and ecosystem of the Sacramento-San Joaquin Delta estuary, including the Suisun Bay and Marsh, is unsustainable over the long-term. The process took into consideration changing climatic, hydrologic, environmental, seismic, and land use conditions that can jeopardize the Delta's natural and human infrastructure.

In *Our Vision for the California Delta*, the Task Force made 12 integrated and linked recommendations, the key one being "The Delta ecosystem and a reliable water supply for California are the co-equal goals for sustainable management of the Delta" (BRTF 2007). These co-equal goals became focal points for the Delta Vision Strategic Plan, which listed seven goals and strategies to achieving those goals (BRTF 2008). Goal 3 in their strategic plan is to restore the Delta ecosystem as the heart of a healthy estuary, and includes five strategies and twenty associated actions to achieve that goal. Among the other recommendations the DVC made is for an inclusive Delta Plan to be written. For more information, go to www.deltavision.ca.gov.

In its Implementation Report (DVC 2008), the DVC noted several important actions required to carry out many of its recommended actions toward achieving the two co-equal goals, many of which are described below. In addition to continued implementation of the ERP, these include: completion of the Bay-Delta Conservation Plan (BDCP); updating of Bay-Delta water quality standards; evaluation and initial construction of gates and barriers in the Delta; development and implementation of instream flow recommendations; control of aquatic invasive species; evaluation of other potential stressors to ecological processes, habitats, and species; and initiation of comprehensive monitoring of Delta water quality and fish and wildlife health. DFG presented drafts of the Conservation Strategy to the DVC, who considered and included many of the Conservation Strategy's concepts into their own documents.

As the Delta Plan is written over the next few years, the ERP Implementing Agencies anticipate that this Conservation Strategy will serve as the biological foundation for that plan. The adaptive management framework laid out in the Conservation Strategy will include implementation of ERP as the initial "ecosystem enhancement" element that could be the basis of a more comprehensive program under the Delta Plan.

State of Bay-Delta Science Report. The CALFED Science Program in 2008 released a report synthesizing the state of knowledge about ecological processes, habitats, stressors, and species in the Delta, as well as about other CALFED program elements (levees and water quality and supply) (science.calwater.ca.gov/publications/sbds.html). Much of the information in that report is consistent with findings from ERP implementation during Stage 1.

The report offers new perspectives on the Delta derived from recent science which, includes:

- The Delta is continually changing, so uncontrolled drivers of change (e.g. population growth, land subsidence, and seismicity) mean the future Delta will look very different than that which exists today
- Because of this continuous change, consequences of management solutions cannot be predicted; solutions will need to be robust but provisional, and responsive and adaptive to future changes
- It is neither possible nor desirable to "freeze" the Delta in its present or any other form, so strengthening of levees will not be a sustainable solution for all Delta islands
- The problems of water and environmental management are interlinked, requiring the strong integration of science, knowledge, and management methods
- The capacity of the system to deliver human, economic, and environmental services is likely at its limit, so tradeoffs must be made – fulfilling more of one water-using service means accepting less of another

- Good science provides knowledge for decision-making, but for complex environmental problems, new areas of uncertainty will continue to arise as learning continues
- Climate change dictates that species conservation is no longer simply a local habitat problem, so conservation approaches need to include a broad range of management tools other than habitat restoration

For more information, go to www.science.calwater.ca.gov.

Bay-Delta Conservation Plan (BDCP). The BDCP is an applicant-driven process through which covered activities (i.e. water export operations of the SWP and CVP and power plant operations of Mirant Energy in the Pittsburg/Antioch area) are authorized under ESA, and NCCPA in the context of an overall Conservation Strategy for the covered listed species. A Steering Committee is guiding BDCP development; committee members represent numerous applicants seeking incidental take coverage, as well as State and federal fisheries agencies, nonprofit groups, and other interested stakeholders. The intent is to develop a joint NCCP and Habitat Conservation Plan (HCP).

The BDCP Steering Committee members signed a Planning Agreement in 2006, in accordance with the NCCPA, that included preliminary identification of the planning area, covered activities, covered species, and natural communities that would be included in the conservation plan.

In the first half of 2007, the Steering Committee identified a number of stressors affecting the aquatic species listed in the Planning Agreement, and came up with four conceptual options for water conveyance through or around the Delta to address those stressors. In late 2007, an initial evaluation of the four conveyance options was completed. Based on that evaluation, the Steering Committee agreed that the Dual Conveyance Option provided the best opportunity to meet the objectives of the Planning Agreement. During 2008 and 2009, modeling to evaluate conveyance operations of the options and conservation actions were completed. NEPA and CEQA environmental documentation began in early 2009. The final environmental document is expected to be certified and all necessary permits issued by the end of 2010. For more information, go to www.baydeltaconservationplan.org.

Delta Risk Management Strategy (DRMS). The CALFED ROD required the completion of a risk assessment that would evaluate sustainability of the Delta, as well as assess major risks to Delta resources and infrastructure from flooding, seepage, subsidence, and earthquakes.

Assembly Bill 1200, chaptered in October 2005, requires that DWR evaluate the potential impacts on Delta resources and infrastructure, based on 50-, 100-, and 200-year projections, from subsidence, earthquakes, floods, climate change and sea level rise, or a combination of these factors. DWR and DFG are then required to develop principal options for the Delta and evaluate and comparatively rate the options with regard to these variables. DWR's report, which summarizes progress on evaluations of potential impacts, improvements, and options for fishery and water supply uses of the Delta was submitted to the Legislature in early 2008 and was provided to the DVC for consideration in the Delta Vision. For more information, go to www.drms.water.ca.gov.

Public Policy Institute of California (PPIC) Reports. PPIC and experts from the University of California, Davis, wrote two reports evaluating the vulnerability of the Sacramento–San Joaquin Delta to a variety of risk factors and describing options for addressing current and likely future problems. The first report, *Envisioning Futures for the Sacramento–San Joaquin Delta* (Lund et al. 2007), describes why the Delta matters to Californians and why the region is currently in a state of crisis. The report concludes with recommendations for several actions, some regarding technical and scientific knowledge, and others regarding governance and finance policies.

The second report, *Comparing Futures for the Sacramento-San Joaquin Delta* (Lund et al. 2008), continued their analysis of future changes to the Delta, and the system's potential responses to those changes. That report focused on which water management strategies would best meet the co-equal goals of environmental sustainability and water supply reliability established by the Delta Vision Blue Ribbon Task Force. In comparing different water management alternatives, this report concludes that an isolated conveyance facility is the best option of all the export alternatives for achieving the co-equal goals. For more information, go to www.ppic.org/.

Pelagic Organism Decline (POD) Studies. Abundance indices calculated by the Interagency Ecological Program (IEP) through 2005 suggest recent, marked declines in numerous pelagic fishes in the Delta and Suisun Bay (IEP 2007a). Although several species show evidence of long-term declines, recent low levels were unexpected given the relatively moderate winter-spring flows of the late 1990s and early 2000s.

In response to these changes, the IEP formed a POD work team to evaluate the potential causes of the decline. Issues emerging from POD studies, most of which were already identified in ERP documents, emphasize a subset of stressors, namely ecological foodweb declines and invasive species, toxic pollution, and water operations (IEP 2007b). The POD work team is conducting multiple investigations, including the effects of exotic species on food web dynamics, contaminants, water project operations, and stock recruitment (www.science.calwater.ca.gov/pod/pod_index.html).

State and Regional Water Quality Control Boards' Bay-Delta Strategic Workplan. The State Water Resources Control Board and the Central Valley and San Francisco Regional Water Quality Control Boards (Water Boards) completed a *Strategic Workplan for Activities in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* in July 2008. The workplan was written in response to two State Water Resources Control Board (SWRCB) resolutions directing the Water Boards to describe the actions they will complete to protect the beneficial uses of water in the Bay-Delta estuary. The workplan activities are divided into nine broad elements:

- Water Quality and Contaminant Control
- Comprehensive Delta Monitoring Program

- Southern Delta Salinity and San Joaquin River Flow Objectives
- Suisun Marsh Objectives
- Comprehensive Review of the Bay-Delta Plan, Water Rights, and Other Requirements to Protect Fish and Wildlife Beneficial Uses and the Public Trust
- Methods of Diversion of the State Water Project and the Central Valley Project
- Water Right Compliance, Enforcement, and Other Activities to Ensure Adequate Flows to Meet Water Quality Objectives
- Water Use Efficiency for Urban and Agricultural Water Users
- Other Actions

These actions fall within the Water Boards' existing responsibilities and authorities. The actions also are responsive to the priorities identified in the Delta Vision BDCP, Delta Plan, and ERP. The workplan identifies activities that will need to be coordinated with other efforts, such as this Conservation Strategy. For more information, go to www.waterrights.ca.gov/baydelta/strategic_workplan.htm.

Suisun Marsh Plan. *The Habitat Management, Preservation, and Restoration Plan for Suisun Marsh* (Suisun Marsh Plan) is being developed by The Suisun Marsh Charter Group Principal Agencies, a team of local, State, and federal agencies. The Suisun Marsh Plan is focused on protecting and enhancing Suisun Marsh's contributions to the Pacific Flyway and endangered fish and wildlife species' habitats, maintaining and improving strategic exterior levees, and restoring tidal marsh and other habitats. A draft programmatic EIS/EIR (PEIS/EIR) is anticipated in 2010 and will include action-specific elements (Suisun Marsh Charter Principal Agencies 2007). The authors of the Suisun Marsh Plan anticipate that it can be implemented as a distinct element in any future vision, Conservation Strategy, or implementation plan for the Delta and Suisun. For more information, go to http://www.iep.ca.gov/suisun/program/index.html.

Central Valley Project Improvement Act (CVPIA) Programs. The CVPIA was enacted in 1992 and mandated changes in management of the CVP, particularly for the protection, restoration, and enhancement of fish and wildlife. Among other provisions relating to water transfers and contracts, CVPIA calls for 800,000 acre-feet of water dedicated to fish and wildlife annually; special efforts to restore anadromous fish populations by 2002; a restoration fund financed by water and power users for habitat restoration and enhancement and water and land acquisitions; and firm water supplies for Central Valley wildlife refuges (USBR 2008).

Some CVPIA programs were integrated with ERP implementation during Stage 1, such as the Anadromous Fish Restoration Program (AFRP), which addresses environmental limiting factors for anadromous fish; Dedicated Project Yield, which augments flows on CVP-controlled streams and moderates CVP pumping from the Delta; and the Anadromous Fish Screen Program (AFSP), which assists in the screening of water diversions to protect fish (DFG 2008b). These and other CVPIA programs complement the actions listed in the Conservation Strategy for the Delta EMZ. For more information, go to www.usbr.gov/mp/cvpia/

Federal Biological Opinions and Recovery Plans. In response to the POD, court-mandated restrictions in the amount of water pumped by the SWP and CVP were implemented in late 2007, while the USFWS and NOAA Fisheries developed new Biological Opinions on the coordinated operations of the State and federal water projects. The USFWS Biological Opinion for delta smelt was completed in December 2008, and the NOAA Fisheries Biological Opinion for salmonids and green sturgeon was completed in June 2009. In combination, these two Biological Opinions include Reasonable and Prudent Alternative (RPA) actions that restrict the amount of reverse flows (and thus the amount of water that can be exported by the projects) in Old and Middle Rivers during certain times of the year, provide for new X2 requirements in fall, and require modified operation of Delta Cross Channel (DCC) gates in late fall and early winter. These Biological Opinions are now driving operations of the SWP and CVP, and provide the current regulatory baseline for export operations from the Delta. To view the two Biological Opinions: http://swr.nmfs.noaa.gov/ocap.htm (NMFS 2009a), and www.fws.gov/sacramento/es/documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf (USFWS 2008). Additionally, for the purposes of setting goals and objectives for species and their habitats in the Delta, there are a number of species recovery plans that are integrated with this Conservation Strategy. Two recovery plans of particular note include:

U.S. Fish and Wildlife Service (USFWS) Delta Native Fishes Recovery Plan. Significant new information regarding status, biology, and threats to Delta native species has emerged since USFWS originally released its recovery plan in 1996 (USFWS 1996). The plan is revised as new information is reviewed. The information then is used to develop a strategy for the conservation and restoration of Sacramento-San Joaquin Delta native fishes. Species covered by this plan are delta smelt, longfin smelt, Sacramento splittail, and Sacramento perch. The goal of the Delta Native Fishes Recovery Plan is to establish self-sustaining populations of these species. To be effective, recovery planning must consider not only species or assemblages of species but also habitat components, specifically, their structure, function and change processes. Restoration actions may also include establishing genetic refugia for delta smelt. A draft of the revised recovery plan is expected in 2010; the recovery plan adopted in 1996 is available from ecos.fws.gov/docs/recovery_plan/961126.pdf.

NOAA Fisheries Central Valley Recovery Plan. The NOAA Fisheries Technical Recovery Team (TRT) produced four documents about (1) current and historical population distributions of winter- and spring-run Chinook salmon, (2) historical population distribution of Central Valley steelhead, (3) population viability, and (4) research and monitoring needs. These documents provide the foundation for the draft Central Valley Recovery Plan (2009b). Species addressed in the draft recovery plan include Sacramento River winter-run and Central Valley spring-run Chinook salmon and Central Valley steelhead. Initial review drafts of the draft recovery plan include a detailed and prioritized list of threats and a lengthy list of recovery actions to respond to the prioritized threats. The draft Recovery Plan was released in October 2009. For more information, go to swr.nmfs.noaa.gov/recovery/centralvalleyplan.htm

California Wildlife Action Plan. The DFG, in partnership with U.C. Davis's Wildlife Health Center, developed the California Wildlife Action Plan to identify the State's species and habitats that are of greatest conservation need, the major stressors affecting native wildlife and habitats, and actions needed to restore and conserve wildlife to reduce the likelihood of more species becoming threatened or endangered (Atkinson et al. 2004). The information contained in that publication provides guidance on implementing adaptive management for conservation plans that address multiple species. For more information, go to www.dfg.ca.gov/wildlife/wap/report.html.

Central Valley Joint Venture (CVJV) 2006 Implementation Plan. The Central Valley Joint Venture (CVJV) was formed to protect, restore, and enhance wetlands and associated habitats for waterfowl, shorebirds, waterbirds, and riparian songbirds through partnerships with conservation organizations, public agencies, private landowners, and others interested in Central Valley bird habitat conservation. The *CVJV 2006 Implementation Plan* incorporates new information and broadens the scope of conservation activities to include objectives for breeding waterfowl, breeding and non-breeding shorebirds, waterbirds, and riparian-dependent songbirds. It lists specific goals and objectives for these species, and considered both-biological and non-biological factors in establishing bird-group conservation objectives. The *CVJV 2006 Implementation Plan* also contains Central Valley-wide objectives for protecting, restoring, or enhancing seasonal and semi-permanent wetlands, riparian areas, rice cropland, and waterfowl-friendly agricultural crops; it also includes basin-specific recommendations for the Delta, the Yolo Basin, and the Suisun Marsh (CVJV 2006).

Ducks Unlimited, one of the partners in the CVJV, has completed 46 wetland restoration and protection projects benefiting migratory birds and other wildlife on approximately 20,000 acres in the Delta alone, in accordance with the recommendations in the CVJV Implementation Plan. ERP Implementing Agencies anticipate that these efforts to benefit waterfowl and other avian and terrestrial species will continue to enhance ecosystem function and survival of those species. Although the initial focus of the Conservation Strategy will be on actions contributing to the recovery of pelagic fish species and enhancement of aquatic resources in the Delta, actions benefiting waterfowl and terrestrial species in the CVJV 2006 Implementation Plan are consistent with this Conservation Strategy (www.centralvalleyjointventure.org/plans/).

Regional Habitat Conservation Plans). There are a number of HCPs for the five Delta counties; the HCP's listed below are in different stages of development or have been completed:

- ***South Sacramento County HCP/NCCP****.* This HCP/NCCP is under development. The focus of the is to protect vernal pool and upland habitats that are being diminished by vineyards and housing development, and on several special status terrestrial species including Swainson's hawk and burrowing owl. The geographic scope generally does not include the Sacramento-San Joaquin Delta portions of Sacramento County; the westernmost boundary of the planning area is Interstate 5. Aquatic species are not addressed by this HCP/NCCP, and have historically been covered by U.S. Army Corps of Engineers' (Army Corps) 404 permits, DFG Streambed Alteration Agreements, and CEQA documents. Sacramento County is working with the Army Corps, U.S. Environmental Protection Agency, and DFG to develop programmatic permits that may be incorporated into the HCP/NCCP. Sacramento County expects draft environmental documentation for this HCP/NCCP to be completed in 2010, and to have all permits in place by 2011. More information is available from the website: http://www.msa2.saccounty.net/planning/Pages/SSHCPPlan.aspx.

- ***Eastern Contra Costa County HCP/NCCP.*** This HCP/NCCP, permited in August 6, 2007, was developed, in part, to address indirect and cumulative impacts to terrestrial species from development supported by increases in water supply provided by the Contra Costa Water District. Although the HCP/NCCP planning area includes land areas within the legal Delta (Water Code §12220 et seq.), the highest priority area for acquisition include some lands just west of the Byron Highway. Dutch Slough/Big Break area, lower Marsh Creek, and lower Kellogg Creek are identified as key restoration priorities. Investments in land acquisition and habitat improvements are otherwise focused outside of the legal Delta. Fish species, including salmonids, were not covered in the HCP/NCCP. Impacts to fisheries are addressed through separate ESA/CESA consultation and permitting. For more information: www.co.contra-costa.ca.us/depart/cd/water/HCP/documents.html.
- ***Yolo County HCP/NCCP***. This county-wide HCP/NCCP is under development. It will provide for the conservation of between 70-80 species in five habitat types: wetland, riparian, oak woodland, grassland and agriculture. No aquatic species are being addressed in this HCP. Project-specific mitigation will be developed for projects affecting aquatic resources. Some initial draft chapters are available, and environmental documentation is expected to be initiated in 2010. For more information, go to www.yoloconservationplan.org/.
- ***Solano County HCP***. The Solano HCP is under development. A final administrative draft was released in June 2009. It will address species conservation in conjunction with urban development, flood control and infrastructure improvement activities. Covered species will include federally- and State-listed fish species and other Species of Concern. The geographic scope includes lands within the Legal Delta. Solano County expects to have permits in place by 2010. To view the administrative draft: www.scwa2.com/Conservation_Habitat_FinalAdminDraft.aspx.
- ***San Joaquin County Multi-Species Conservation Plan (SJMSCP).*** This HCP/NCCP was approved in 2001. This plan was developed to guide land uses, preserving agriculture, and protecting listed species and other Species of Concern. The geographic scope includes lands within the legal Delta. For more information, click on the "Habitat" link on www.sjcog.org.

Appendix C contains a listing of the species covered by each of these plans.

FloodSAFE California and the Central Valley Flood Protection Plan. In early 2006, the DWR initiated a collaborative planning effort to integrate flood management in California. The goals of the program are to reduce the risks and consequences of flooding, while sustaining economic growth, protecting and enhancing ecosystems, and promoting sustainability. This would be accomplished by improving flood management systems, operation and maintenance of those systems, and emergency response, as well as informing and assisting the public. As part of a longer-term effort, the Central Valley Flood Protection Board (formerly the State Reclamation Board) is tasked with formulating a comprehensive statewide flood control plan.

Integration with these programs may provide opportunities for the ERP to pursue floodplain habitat restoration projects that have the mutual benefit of controlling the risks and consequences of flooding. Some opportunity areas in the Delta EMZ in which such activities could occur include the Yolo Bypass, the Cosumnes/Mokelumne confluence, and along the lower San Joaquin River).

SECTION 2: STAGE 2 CONSERVATION STRATEGY

I. Ecosystem Processes

The ERPP identifies several ecological processes which shape the system through direct, indirect, and synergistic means. The most notable processes affecting conditions in the Delta EMZ are: hydrodynamics and hydraulics (including the amount of flow entering the Delta from rivers and tributaries and the movement of water within Delta channels as affected by ocean tides, channel geometry, diversions, and barriers); channel-forming processes (including floodplain connectivity and inundation and coarse sediment supply); and the cycling and transport of nutrients and aquatic organisms through the aquatic food web.

Throughout this section, there are references to the Delta Vision Strategic Plan and related actions contained therein, as there is a direct connection between the recommendations in other Delta planning efforts and the continued implementation of the ERP over Stage 2.

I.A. Hydrodynamics/Delta Hydraulics

> ERPP Vision for Central Valley Streamflows: Protect and enhance the ecological functions that are achieved through the physical and biological processes that operate within the stream channel and associated riparian and floodplain areas in order to assist in the recovery of at-risk species, harvested species, biotic communities, and the overall health of the Delta.
>
> ERPP Vision for Bay-Delta Hydraulics: Restore channel hydraulics to conditions more like those that occurred during the mid-1960's to provide migratory cues for aquatic species; transport flows for eggs, larvae, and juvenile fish; and transport of sediments and nutrients.
>
> *ERPP, volume 1, July 2000*

Hydrology is the overarching term for the science regarding the waters of the earth, their distribution on the surface and underground, and the water cycle involving evaporation, precipitation, flow to the seas, etc. In the ERPP, hydrology and hydraulics (the branch of physics having to do with the mechanical properties of water and other liquids in motion and with the application of these properties in engineering) were further subcategorized into Central Valley streamflows and Bay-Delta hydraulics. For the purposes of updating the Conservation Strategy specific to the Delta EMZ, only Bay-Delta hydraulics is discussed in this section. Central Valley streamflows will be addressed in Conservation Strategy documents specific to the upstream EMZs.

The *Delta Vision Strategic Plan* listed as essential to a revitalized ecosystem, changes in: (1) freshwater flow conditions; (2) channel geometry; and (3) water quality standards, including X2 standards (X2 is the mixing zone between saline and freshwater). In that plan, there are two strategies and several actions that relate to Bay-Delta hydrology and hydraulics: Strategy 3.2 "Establish migratory corridors for fish, birds, and other animals along selected Delta river channels"; and Strategy 3.4 "Restore Delta flows and channels to support a healthy Delta estuary".

Central Valley Streamflows (freshwater flows). The amount and timing of freshwater flow is an important feature of ecological processes and aquatic habitats in the Delta. Theory and experience show that the more water that flows through the Delta into Suisun Bay and eventually the ocean, the greater the health of the estuary overall. In its natural, unaltered state, an ecosystem adapts to water flow variations; generally, high river flows have been linked to greater abundance of harvested species in other estuaries (Healey 2007 and references therein). Inflow to and outflow from the Delta presents challenges in ecosystem water management because the system has been so altered over the last century. For several reasons, a return to its original, unaltered state is no longer feasible for the Delta if the co-equal goals laid out by the Delta Vision Strategic Plan are to be met (BRTF 2008). Therefore, it is important for ERP scientists and managers to look for ways to manipulate the system of freshwater flow in the Delta to achieve desired ecological responses, rather than strive to restore the system to an historic flow regime that may not yield the same benefits as it did in the past.

Just as at the outset of ERP implementation, it is still hypothesized that a "variable flow" regime, where flows vary by season to more closely reflect the natural hydrograph (including seasonal increases in salinity as freshwater flows into the Delta decrease during summer months) would likely favor native species which have evolved life history characteristics that respond to that seasonal pattern of flow (Moyle and Bennett 2008). Likewise, it is believed that managing a "variable flow" regime would eliminate the static nature of Delta aquatic habitats that has been sustained for decades in the interest of maintaining a common freshwater pool year-round, which tends to favor non-native species and influence many other environmental factors.

Because of the substantial changes in the Delta environment, it is difficult to identify a set of specific environmental flow requirements for the Delta ecosystem and guarantee that such flows would be sufficient for recovery and sustainability of the Delta's aquatic species and food web. However, it is known that flow alone (i.e. absent restoration of habitats) will not be sufficient to enhance species recruitment, as it is the interaction between water quality and structural components of habitat that drives important biotic relationships (Peterson 2003). Although the amount of freshwater flow required to support a healthy estuary is under

Proposed Stage 2 Actions for Freshwater Flows and Natural Flow Regimes

Action 1: Revise the Ecological Flow Tool, originally developed for the Sacramento River, to include the Delta.

Action 2: Develop local projects to test the "Variable Delta" hypothesis to see if manipulating salinity and flows can help control invasive aquatic species and to see how native species use or avoid these conditions.

Action 3: Improve monitoring of in-Delta hydrodynamics and fish assemblage response to hydrologic conditions to assist with developing ecosystem management decisions and tools.

Action 4: Obtain needed information on water diversion and use, including groundwater use (DV)

Action 5: Accelerate completion of in-stream flow analyses (DV) discussion, scientists still believe the most desirable freshwater flow pattern through the Delta is seaward (westerly), which would more closely resemble the natural hydrograph than current flow patterns which draw fresh water south to the export pumps. To achieve this pattern year-round while maintaining exports, what may be needed is a fall or early winter pulse that emulates the first "winter" rain, and higher late winter and spring flows that coincide with the melting of winter snow. These more natural-type flows would provide attraction cues for anadromous fish moving upstream, improve survival of juvenile Chinook salmon rearing in the Delta, and provide downstream passage for fish moving through the Delta. In conjunction with improved channel configuration that connects channels to marshes and increases water residence time in some areas (see discussion on channel geometry below), these enhanced flows could improve food productivity and transport through the Delta to downstream areas on a localized basis. Improved flows also the potentially toxic effects of contaminants, transport sediment, and promote growth of riparian vegetation. These improved flows are particularly important in normal and dry years, because human demand for freshwater supplies for beneficial uses is higher in normal and especially dry years than it is in wet years, and has resulted in more freshwater being diverted from the system.

Bay-Delta Hydraulics (Channel Geometry). At the outset of ERP implementation, it was believed that returning Delta hydrodynamics to conditions present in the mid-1960s would enable better movement of sediments, nutrients, eggs, larvae, and juvenile fish, in addition to providing migration cues for anadromous fish moving through the Delta. Specifically, it was believed that factors such as CVP and SWP export pump operations, the Suisun Marsh Salinity Control Structure (SMSCS), the Delta Cross Channel (DCC), and other flow barriers in the Delta created unnatural flow patterns with respect to water movement, velocity, and salinity. These beliefs still reflect current scientific thinking. There are numerous references in the Delta Vision Strategic Plan, the BDCP, and other efforts to the need to restore attributes of the historic dendritic (branchlike) channel system in the Delta, to slow water velocities and increase water residence time in some areas. It is believed that by closing off some of these connections, anadromous fish migrating through the Delta won't be diverted into areas of the Delta where their mortality from non-natural causes can be increased (such as entrainment at the south Delta export pumps due to their presence in Central Delta channels, or mortality from predation in Georgiana Slough, after traveling through the DCC). Some additional benefits that are expected to accrue to native species from increased water residence time include enhanced production of algae and aquatic invertebrates that comprise the food sources for different life stages of numerous native fish species (also known as primary and secondary production, respectively). This is further discussed in the Bay-Delta Aquatic Food Web section.

Proposed Stage 2 Actions for Channel Geometry

Action 1: Conduct further Delta Cross Channel operational studies

Action 2: Conduct further experiments with salinity control gates in Suisun Marsh.

Action 3: Study Two-Gates and the effectiveness of barges as barriers.

Action 4: Study bubble curtain effectiveness as barriers, and their effects on other species.

However, there are also cautions that must be employed when managers consider manipulating flows through the use of barriers to facilitate certain ecological processes. Specifically, since the Delta is a nutrient-rich estuary, closing existing connections to increase water residence time can also have adverse impacts to water quality (e.g. eutrophication, a condition in which accumulation of nutrients supports a dense growth of algae and other organisms, decay which depletes shallow waters of oxygen in summer) and the movement of aquatic species (Monsen et al. 2007).

Water Quality Standards. Positive relationships between "historical flows" and fish abundance or survival are documented for the Bay-Delta estuary (e.g. for Chinook salmon, striped bass, and longfin smelt), and in some cases these relationships have served as the scientific basis for the formulation of water quality standards designed to sustain fish populations in the Delta.

Delta outflow and X2. Management of the Bay-Delta system is based in part on a salinity standard known as the "X2" standard. This standard is based on empirical relationships between various species of fish and invertebrates and X2 (or freshwater flow in the estuary). The location of X2 moves with the varying tides and flows into and out of the Bay-Delta. X2 is related to outflow, and pelagic habitat quality in the estuary can be characterized by changes in X2 (i.e. abundance of numerous species increases in years of high outflow, when X2 is pushed seaward) (Jassby et al. 1995, IEP 2008). Based on correlations with abundance of several Delta aquatic species, requirements for X2 in the winter and spring months are in the SWRCB's Bay-Delta Water Quality Control Plan.

Today, relationships between species abundance and outflow, as measured by X2, may or may not hold up. Over time, some of the fish-X2 relationships have changed. Establishment of the overbite clam (*Corbula amurensis*) in the mid-1980s reduced the amount of phytoplankton available for zooplankton and in turn may have reduced food supplies for young fish. For those X2 relationships which remain intact, the fish indicator variables have been lower recently for a given X2 condition (e.g. longfin smelt continue to show a relationship, but that relationship has changed likely due to the introduction of the overbite clam) (Figure 2). Other possible mechanisms that could have altered this relationship include, but are not limited to, the increasing presence of toxic blue-green algae (*Microcystis aeruginosa*) during summer months; increasing loads and/or concentrations of other contaminants in the system; and changes in water turbidity transparency that have occurred in the Delta and upstream areas.

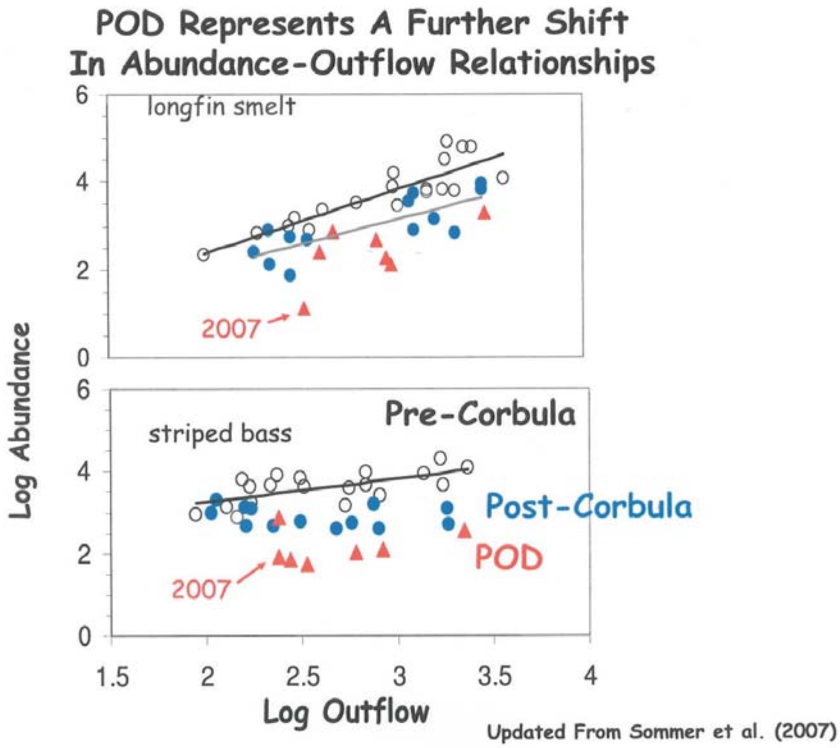

Figure 2: Change in Some Abundance-Outflow Relationships. Source: Sommer, 2008. PowerPoint presentation to State Water Resources Control Board, see notes.

> Potential Stage 2 Actions for X2:
>
> Action 1: Examine the mechanics that demonstrate the importance of X2 for a number of estuarine species.
>
> Action 2: Investigate whether the mechanism of gravitational circulation accounts for the X2-abundance relationships for specific species by recurring mortality during migration to nursery habitats during higher flows
>
> Action 3: Determine X2 mechanisms for additional species.
>
> Action 4: Determine the importance of X2 and pelagic habitat quality in the spring and fall for delta smelt.

While many species derive benefits from the flow and associated salinity distribution, the aspect of ecosystem function that provides the benefit is not the same for all species, given life history differences some reside year-round in or near the Delta (e.g. delta smelt) whereas others range farther downstream, including to the ocean (e.g. longfin smelt, starry flounder, bay shrimp). Mechanisms responsible for X2 benefits to species still are not fully understood, but research, monitoring, data analysis, and modeling continue to increase understanding of mechanisms underlying X2 relationships. Such understanding will be crucial to evaluating ideas about how to modify the X2 standard to improve water management for ecological benefit. Some of the research findings that have increased our understanding of X2 since 2000 include (but are not limited to):

- Relationships of flow to abundance of fish and shrimp don't occur through upward trophic transfer, so variation in fish abundance may occur through physical habitat attributes that vary with flow (Kimmerer 2002).

- For delta and longfin smelt, larval and juvenile fish distribution was strongly linked to outflow conditions, but fish distribution with respect to X2 was not affected by outflow. No obvious relationship exists between outflows and annual smelt abundance indices from the IEP's ongoing 20 mm survey (Dege and Brown 2004).
- Kimmerer and Bennett (2005) reviewed the history of X2 standard development, identified three potential mechanisms (transport, food, and habitat) that might explain relationships between outflow and fish abundance, and offered species-specific considerations and a research plan for further exploring these mechanisms.
- Feyrer et al. (2007) identified a decline in fall habitat suitability for three species in recent decades; for delta smelt the detrimental factors were increased water transparency (Secchi depth) and increased salinity, the latter likely due to decreased river flow into the estuary in the fall.

In summary, data and findings support the idea that X2 is important to several native estuarine species. For some species the likely mechanisms have been identified; but for others, mechanisms remain unclear or poorly understood. For example, seasonal variations in X2, especially in the spring and fall, appear to be important, but why that is remains a mystery.

Internal Delta Hydrodynamics. In addition to X2, several internal Delta hydrodynamic parameters, including net flow in Old and Middle Rivers (OMR), Rio Vista flow, and Qwest, are among the characteristics of the Delta ecosystem that have historically driven water management in the Delta, and that may need to be further investigated and refined.

- *OMR*. Recent analyses suggest a strong statistical correlation between water exports/San Joaquin River flow and fish salvage/entrainment at the SWP and CVP export pumps. Net reverse flow in OMR in winter months, a function of decreased San Joaquin River flow into the Delta, export pumping rate, and tides, is correlated with the salvage of adult delta smelt (USFWS, 2008), and has recently been used as a method to minimize the effects of SWP and CVP export pumps. Some modeling studies demonstrate a probable effect of net upstream flow on free-floating delta smelt larvae, leading to constraints on OMR flow to minimize impacts on larvae and juvenile delta smelt. OMR requirements were included in the recent OCAP Biological Opinions (USFWS 2008 and NMFS 2009a).
- *Rio Vista flow*. Sacramento River flow at Rio Vista is an important cue for adult Chinook salmon migration (Stein 2004), and the SWRCB Bay-Delta Water Quality Control Plan contains a flow objective at Rio Vista.
- Sacramento and San Joaquin Rivers' flows have also been identified as an important factor for juvenile Chinook salmon survival during emigration from these basins (Newman and Rice 2002, Newman 2003, Newman 2008).
- *Qwest.* Net flow (i.e. flows adjusted for tides) in the lower San Joaquin River in the western Delta (Qwest) has been used in past Biological Opinions to define conditions acceptable for juvenile Chinook salmon. The Qwest parameter may also be pertinent to delta smelt and other species (NMFS 1993).

Hydrologic models for the Delta developed by several planning efforts help define these characteristics. ERP funded the development of an ecological flows modeling tool for the Sacramento River during Stage 1 (SacEFT), and has recently provided additional funding to develop a similar modeling tool for the Delta. As part of its activities in development of the BDCP, ERP Implementing Agencies are pursuing the development of a hydrologic model that will include anticipated sea level rise and flooding regimes, as well as their implications for ecological processes and habitats in the Delta. The DRMS effort is also evaluating how future climate conditions may affect flows as well as risks to Delta levees and other infrastructure. Until these models are available, however, recommendations for a flow regime to sustain the estuary's health are based on a combination of the aforementioned historical relationships; tools such as DWR's CALSIM, DSM-2, TRIM3D, and RMA models; and professional judgment.

I.B. Channel-Forming Processes

Another key ecological process listed in the ERPP is the channel forming process, comprised of: stream meander, natural floodplains, flood processes, and coarse sediment supply. These channel forming processes affect the geomorphology of rivers; the physical attributes of a river are connected to food productivity and overall ecosystem health. For the purposes of updating the implementation strategy specific to the Delta EMZ, only natural floodplains, flood processes, and coarse sediment supply, are discussed in this section. Stream meander will be addressed in Conservation Strategy documents specific to the upstream EMZs.

> ERPP Vision for Stream Meander: Conserve and reestablish areas of active stream meander, where feasible, by implementing stream conservation programs, setting levees back, and reestablishing natural sediment supply to restore riverine and floodplain habitats for fish, wildlife, and plant communities.
>
> ERPP Vision for Natural Floodplains and Flood Processes: Conserve existing intact floodplains and modify or remove barriers to overbank flooding to reestablish aquatic, wetland, and riparian floodplain habitats.
>
> ERPP Vision for Coarse Sediment Supply: Provide a sustained supply of alluvial sediments that are transported by rivers and streams and distributed to riverine bed deposits, channel bars, riffles, shallow shoals, and mudflats, throughout the Sacramento-San Joaquin Valley, Delta, and Bay regions to contribute to habitat structure, function, and food web production throughout the ecosystem.
>
> *ERPP, volume 1, July 2000*

There were two strategies in the *Delta Vision Strategic Plan* that incorporated some ideas regarding channel forming processes: Strategy 3.1, "Restore large areas of interconnected habitats—on the order of 100,000 acres—within the Delta and its watershed by 2100"; and Strategy 3.2, "Establish migratory corridors for fish, birds, and other animals along selected Delta river channels." These two strategies list actions regarding improvements to floodplains and restoring tidal and riparian habitats, and have been also discussed in the Delta Corridors Plan (www.deltacorridors.com/DC_Plan_Description.html)

Natural Floodplains and Flood Processes. Several projects funded by ERP and other entities during Stage 1 have demonstrated beneficial effects of restoring floodplains for the dual purposes of flood control and ecosystem restoration. Specifically, studies on the Cosumnes River and Yolo Bypass floodplains showed that salmonids and splittail exhibited enhanced growth (and thereby, it is assumed, enhanced overall fitness for survival) than fish rearing in the Sacramento River; similar results were reported for native fish using the Cosumnes-Mokelumne floodplain area. One uncertainty that remains is the importance of productivity in floodplains and flood bypasses to the larger estuarine food web. Another uncertainty is the extent to which seasonal floodplains create and/or transport methylmercury. Research is currently determining appropriate floodplain restoration and management methods to reduce this floodplain hazard.

Coarse Sediment Supply. An adequate sediment supply is needed to rebuild subsided areas to typical elevations for wetlands and to keep pace with projected sea level rise. The influence of the river systems that feed the Delta, and the need for changes in water management upstream to enhance the rivers' contribution of nutrients and water to the system, are recognized as part of the larger overall vision under development for the State's water resources. For the purposes of this Conservation Strategy for the Delta, discussion will largely be focused on sediment transport into and through the Delta, and implications for restoration of ecosystem processes and habitats within the Delta EMZ.

At the outset of ERP implementation, scientists recognized that an adequate coarse sediment supply from upstream areas through the Delta to San Francisco Bay was essential to the creation and maintenance of new habitat areas. Projects funded by the ERP during Stage 1 have concluded that: (1) less coarse sediment is being supplied to the Delta from upstream areas, largely due to the trapping of sediments behind reservoirs; implementation of various bank protection measures; the gradual reduction of sediments from hydraulic mining; and (2) the Delta is actually a sediment sink – more sediment enters the Delta than leaves it – so San Francisco Bay is receiving less and less sediment from the Delta. Together, these findings indicate that sediment yield to the Delta is expected to continue decreasing, and also if sediments were supplied to the Delta at the same levels they were historically, this would likely not be successful, in itself, at restoring processes and habitats to sustain species in the Delta and downstream areas.

I.C. Cycling & Transport of Nutrients, Detritus, and Organisms

I.C.1. Bay-Delta Aquatic Food Web.

ERPP Vision for Bay-Delta Aquatic Food Web. Increase estuarine productivity and rehabilitate estuarine food web processes to support the recovery and restoration of native estuarine species and biotic communities.

ERPP, volume 1, July 2000

Aquatic food web productivity in the Delta EMZ is comprised of phytoplankton, zooplankton, and other organisms that provide food for larger organisms, such as fish. Primary productivity is defined as lower-order organisms including algae, phytoplankton (specifically diatoms), bacteria, and detritus, and secondary productivity consists of aquatic invertebrates such as rotifers, cladocerans, and copepods. Primary productivity is most important as a food source for the aquatic invertebrates which in turn are an important source of food for early life stages of fish and wildlife species in the Delta (Figure 3).

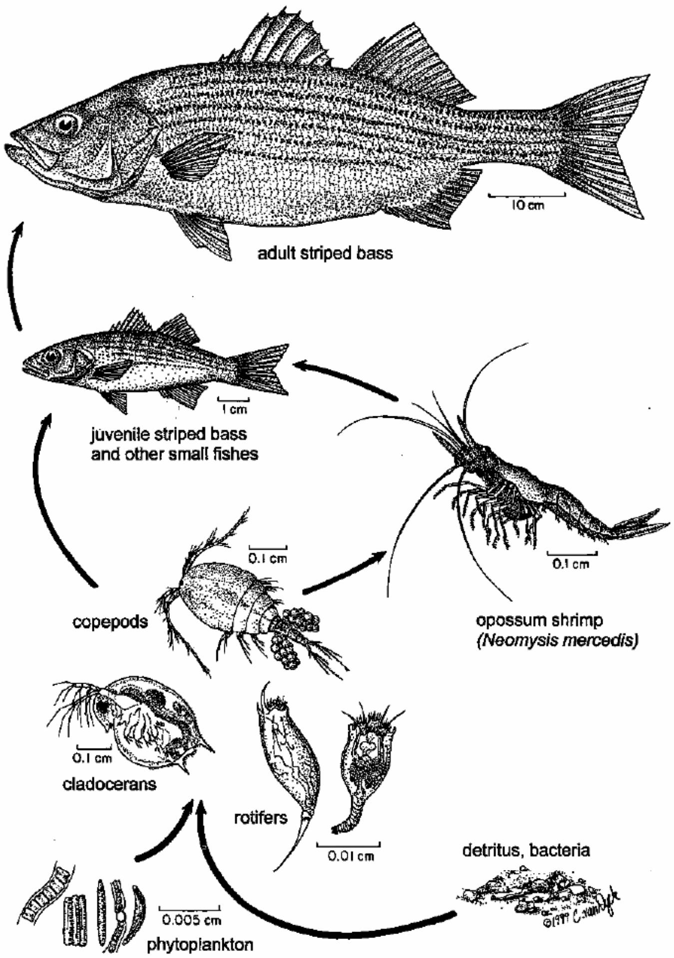

Figure 3: Food web involving striped bass in the Delta. Source: Moyle 2002

There were two strategies in the *Delta Vision Strategic Plan* that incorporated some ideas regarding the Bay-Delta aquatic food web: Strategy 3.4, "Restore Delta flows and channels to support a healthy Delta estuary"; and Strategy 3.5, "Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals." These two strategies list actions including the reconfiguration of channel geometry to increase variability in water circulation patterns (increase the residence time of water in some areas to enhance primary productivity), as well as a number of actions to improve the quality of water discharged from wastewater treatment plants and irrigated agriculture to address potential stressors to both primary and secondary productivity.

At the outset of ERP implementation, the northern San Francisco Bay and Delta had been experiencing a long-term decline in productivity, with a dramatic reduction following the introduction of the non-native overbite clam in 1986 (Kimmerer et al. 1994, Kimmerer and Orsi 1996, Lehman 1996, Jassby et al. 2002). Some, but not all, of the recent decline in productivity could be attributed to the introduction of overbite clam. The decline in productivity in the northern San Francisco Bay and Delta was accompanied by declines in several species of higher trophic level groups, including mysid shrimp and longfin smelt, suggesting the possibility that recovery of these higher trophic level groups might be limited by food production.

Availability of good food resources is a main factor in fish abundance. Although phytoplankton production (as measured by Chlorophyll *a* concentration) makes up a small portion of the system's organic matter, studies show that it forms the base of the Delta pelagic food web (Jassby and Cloern 2000, Sobczak et al. 2002); therefore, a decline in this form of primary productivity translates up the food web.

The aforementioned improvements in freshwater flow, channel geometry, water quality conditions, and floodplain inundation, in combination with tidal marsh restoration, are expected to result in a more productive aquatic food web by increasing water residence time in some areas (i.e. slowing water velocities to provide conditions more conducive to primary production), and by providing more detritus and organic material into the Delta transported from floodplain areas when they become inundated. Recognizing the caution that should be employed when analyzing such proposals (e.g. avoidance of adverse water quality conditions such as low dissolved oxygen [DO]), these processes, in conjunction with a substantial increase in tidal wetlands, could increase primary and secondary productivity in the Delta (Jassby and Cloern 2000).

Several uncertainties regarding the decline in productivity that were identified in the ERP Strategic Plan are still relevant, and under investigation, today:

- How much of the decline in productivity is attributable to overbite clam and what other factors may be affecting productivity?
- Is the decrease in productivity limiting recovery of higher trophic level species?
- How much effect would more frequent inundation of floodplains and bypasses have on estuarine and riverine productivity?
- Will restoration projects, including tidal wetlands and riparian habitat, contribute to an increase in productivity and exchange with open water habitats?

ERP and Science Program research findings that have increased our understanding of the Bay-Delta aquatic food web since 2000 include (but are not limited to):

- Overbite clam continues to have a significant effect on the Bay-Delta food web and ecosystem (Kimmerer 2002, 2004). It has been suggested that overbite clam's distribution may be managed by increasing freshwater outflows from the Delta into Suisun Bay in the spring, to push distribution of the brackish water clams further west of the Delta, but there is not consensus among scientists on this. While some scientists believe that repelling overbite clam for even a few weeks in spring could result in phytoplankton (diatom) blooms that could be utilized by copepods, others are skeptical that these blooms wouldn't just be consumed by the clams, whose filter-feeding impacts extend far upstream of their physical distribution. It remains unknown whether overbite clam can be managed in this system, but many experts believe it cannot be (CALFED Science Program 2008).

- Copepods, which feed on diatoms and are a valuable food source for Delta fishes, are food-limited in the Delta (Kimmerer and Orsi 1996, Müller-Solger et al. 2002, Sobczak et al. 2002), most likely due to overbite clam grazing. The general conclusion from these studies is that growth or reproductive rate in copepods is severely impacted by food-limitation most of the time (DFG 2008b).
- The decrease in diatoms caused by overbite clam grazing has also had variable effects on species of higher trophic levels. Longfin smelt showed the greatest declines. The abundance of delta smelt did not change following the introduction of overbite clam (Kimmerer 2004), although individual delta smelt were often food-limited (Bennett 2005), with a reduction in mean length that may be related to reduced productivity.
- Although overbite clam has had a documented impact on the estuarine food web, it is unlikely the only cause of low productivity. One study showed that at relatively low concentrations in Suisun Bay, ammonium has been shown to inhibit uptake of nitrate by phytoplankton (Wilkerson et al. 2006, Dugdale et al. 2007). Spring phytoplankton (diatom) blooms occur only when ammonium concentrations are less than 4 μmol/L (Wilkerson et al. 2006, Dugdale et al. 2007). At these low concentrations, the inhibitory nature of ammonium is relieved and diatom blooms fueled by the more abundant nitrate can occur. Diatom blooms typically occur following high spring flow events, when ammonium in the system is diluted and stratification of the water column increases light penetration (Cloern 1991), although presently the stratification must be maintained longer for diatoms to reduce the ammonium concentration to low enough levels to enable absorption of nitrate. During a high spring bloom, diatoms can temporarily out produce clam grazing in key Delta areas (Wilkerson et al. 2006), but a bloom in Suisun Bay occurred only once over the four springs from 2000 to 2003 due to stratification events of insufficient length to overcome the high ammonium concentrations. Even more recent work conducted on the Sacramento River indicates that ammonium is not the limiting factor, suggesting that herbicides or other chemicals may play a role (Werner et al. 2009, see notes.)
- A study investigating the trends and causes of phytoplankton abundance concluded that the trend in primary productivity in the Delta between 1996 and 2005 has been positive (Jassby 2008). This finding does *not* support the argument that fish declines (at least those during the pelagic organism decline) were caused by food limitation from reduced primary production (phytoplankton); rather, it suggests that some other mechanism could be limiting food availability (e.g. contaminant toxicity to zooplankton). Ongoing studies are supporting the hypothesis that various chemicals released from wastewater treatment plants and agriculture have both chronic and acute toxic effects on zooplankton, (Werner et al. 2009, see notes.)
- Along with the toxicity to food web organisms, there has been a change in the composition of the Delta foodweb. In many cases, the most abundant foodweb organisms are introduced species. These new species compete with native species for resources, and are often harder to catch, or are of lower nutritional quality than native foodweb organisms. As a result, the Delta's freshwater food web structure has changed in terms of energy creation and retention, and may not be as beneficial to the Delta's native species as it was previously.

Another mechanism under investigation is the connection between food web production and habitat. An ongoing ERP funded project in Suisun Marsh measured primary and secondary productivity and fish abundance and compared these to adjacent open water habitats. The comparison shows that the highly productive brackish tidal marshes provide important habitats to native fish; however, phytoplankton production in marsh channels appears to be limited when overbite clam is present. Recent studies have demonstrated that tidal marsh restoration would likely increase phytoplankton biomass in the estuary and enhance the planktonic food web. In a study of carbon types and bioavailability, tidal marsh sloughs had the highest levels of dissolved and particulate organic carbon and phytoplankton-derived carbon (Sobczak et al. 2002). Tidal sloughs were also the highest in Chlorophyll *a* concentration, an important factor in zooplankton growth rate (Müller-Solger et al. 2002). Delta and Suisun zooplankton appear to be food-limited much of the time, due to low levels of phytoplankton (Müller-Solger et al. 2002, Sobczak et al. 2002, Kimmerer et al. 2005). It appears that high residence time of water, nutrient availability, and absence of alien clams contribute to high levels of primary production (Jassby et al. 1995) and empirical studies (Lopez et al. 2006) suggest that productivity from high-producing areas, such as marsh sloughs, is exported to other habitats.

Many studies have shown floodplains to be important to native fish, especially as rearing habitat for juvenile salmon and as spawning and rearing habitat for splittail. Recent research (Lucas et al. 2006) has shown that floodplains have much higher primary production than adjacent river channels and that much of this production is exported to downstream estuarine habitats.

In summary, the extensive changes that have occurred in the aquatic environment of the Bay-Delta system have substantially changed the structure of the food webs in both the Delta and Suisun Bay. In terms of energy creation and retention, the freshwater food web structure in the Delta is now "shorter" than the longer, more complicated brackish food web structure in Suisun Marsh; thus, the freshwater food web may be more important for native species (Kimmerer 2008, see notes); however, organisms in the freshwater foodweb are also more susceptible to contaminants and entrainment. Restoration actions that improve Delta primary production could help to increase zooplankton production and augment the pelagic food web. Actions could include increasing water residence times to allow for phytoplankton accumulation, reducing inputs of ammonium and other contaminants into the system by improving treatment and wastewater treatment plants and agricultural practices, and restoring large tracts of tidal marsh to increase nitrification rates to remove

Potential Stage 2 Actions for Decline in Productivity and the Aquatic Food Web:

Action 1: Determine how to alleviate the negative impacts of non-native species (e.g. *Corbula*) and contaminant toxicity on the pelagic foodweb.

Action 2: Determine how much tidal marsh restoration efforts in the Delta and Suisun Marsh can supplement pelagic fish production.

Action 3: Determine potential impacts of ammonia and other contaminants on primary productivity (studies underway by State and Regional Water Quality Control Boards).

ammonium from the system (see “Tidal Marsh” section within discussion of Intertidal areas).

Although much has been learned about the Bay-Delta food web since 2000, scientists still are uncertain about the importance of food limitation to native fishes. Overbite clam had a demonstrably negative impact on the food web of Suisun Bay and the western Delta, but the significance of this to higher trophic levels is still being investigated. It seems likely that an increase in zooplankton in the Delta would provide better habitat conditions for fish; however, studies present conflicting results about changes in system productivity and its effect on fish populations. Research seems to support tidal marsh restoration as a means of improving system productivity, but no large-scale restoration project has been completed, and monitoring data synthesized, that could verify this conclusion for the freshwater portion of the estuary Floodplains have been shown to provide important habitat to native fish and to increase estuarine productivity. Ongoing work on the pelagic organism decline may help to address some of the remaining uncertainties.

I.D. Environmental Water Quality

Amounts and patterns of freshwater flow, and the transfer of energy through the food web, are just part of the ecological processes that influence the health of the Delta ecosystem and its species. Several physical and chemical aspects of water quality must be considered in addition to flows. These include salinity, turbidity, water temperatures, DO, pH, and dissolved and particulate organic carbon. Other constituents (contaminants and heavy metals) also are important components of water quality, because they can have negative impacts on native aquatic and other desirable species; these harmful constituents are discussed in more detail in the “Stressors” section of this document. In general, several aspects of water quality, most notably salinity and water temperatures, are expected to change significantly as both sea level and air temperatures rise due to climate change.

Salinity. Salinity is the primary water quality constituent affecting fish distribution in the estuary (Nobriga 2008 and references therein, see notes). Fall salinity has been relatively high since 1985; this decreases fall habitat quality for delta smelt in particular, and could be significant because this is the time juveniles are in the system (Feyrer et al. 2007). Other contributing factors to increased fall salinity may include longer closure times of the DCC, operations of the SMSCS, and changes in export and inflow ratios, or E/I ratios (i.e. Delta export and reservoir releases) (IEP 2008).

Periodic salinity intrusion and a more heterogeneous environment in the Delta recently have been proposed as important processes to be restored in the Delta (e.g. Lund et al. 2007). Continuous heterogeneous environments are better able to absorb random disturbances and provide a variety of habitat types for fish and wildlife (van Nes and Scheffer 2005). Greater variability in Delta environmental water quality, especially salinity, might provide a competitive advantage for desired estuarine fishes over non-native invasive species (Lund et al. 2007). Salinity fluctuations in the Delta may also help to control invasive organisms such as *Egeria densa*.

Turbidity. Recent information suggest that juvenile and adult delta smelt distribution is associated with turbid water, and that turbidity serves as an environmental trigger for upstream migration of delta smelt and longfin smelt. Turbidity also reduces predation risk to migrating Chinook salmon in other estuaries (e.g. Fraser River) (Nobriga 2008, see notes). Scientists hypothesize that higher flows during summer will increase the extent of low-salinity, higher-turbidity habitat for delta smelt, and that removing aquatic plants that trap sediments would also enhance turbidity and increase habitat for delta smelt (DSWG 2006). This element of the Conservation Strategy calls for additional study regarding the importance of turbidity to native species as it relates to habitat diversity.

> ERPP Vision for Water Temperature: Restore natural seasonal patterns of water temperature in streams, rivers, and the Delta to benefit aquatic species by protecting and improving ecological processes that regulate water temperature and reducing stressors that change water temperatures.
>
> *ERPP volume 1, July 2000*

Water temperature. The ERP includes targets for Central Valley stream temperatures, including maintaining specified water temperatures in salmon and steelhead spawning, summering, and migration areas during certain times of the year (CALFED 2000a). Maintaining stream temperatures upstream of the Delta are important for individual species' tolerances, metabolic and production rates, and mobilization rates of toxics and nutrients (e.g. development of toxic algal blooms from cyanobacteria *Microcystis aeruginosa*) (Swanson 2008, see notes). While riparian habitat helps to lower water temperatures in the tributaries to the Delta and in smaller Delta sloughs, temperatures in Delta channels are driven primarily by ambient air temperature. It is possible that the creation of tidal marsh areas in the Delta and Suisun could help lower water temperatures on a very small and localized scale, if inundation of marsh plains on the flood tide at night results in cooler water being returned to the channels on the ebb tide; this should be investigated further as tidal marsh creation is pursued.

Dissolved Oxygen. Most aquatic life depends upon sufficient levels of gaseous oxygen dissolved in water. DO is provided by photosynthesis, atmospheric diffusion, and aeration from wind and wave action. DO is consumed by microbial processes such as respiration and nitrification (the naturally-occurring process by which ammonia is converted to nitrates), both of which are stimulated by nutrients such as nitrogen and carbon.

The optimum range of DO for fish and aquatic life is 5-9 mg/L (milligrams per liter) (DFG 2008b). When DO levels drop below this range, behaviors such as feeding, migration, predator avoidance, and reproduction are negatively affected for some fish species. DO levels approaching 2 mg/L can serve as a barrier to fish migration and can negatively impact food web organisms (DFG 2008b).

II. Habitats

Consistent with existing CALFED and Delta Vision policy, the Delta EMZ element of the overall ERP Conservation Strategy intends to implement ecosystem restoration using land acquisitions (both fee and easement title) and cooperative agreements with willing sellers only. This policy is also consistent with the restoration planning process underway for the Suisun Marsh.

> ERPP Strategic Objective for Habitat Restoration is to restore large expanses of all major habitat types, and sufficient connectivity among habitats, in the Delta, Suisun Bay, Suisun Marsh, and San Francisco Bay to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes.
>
> *ERPP, volume 1, July 2000*

The ERP Strategic Plan states that "…the ERP will restore wetland habitats throughout the Bay-Delta ecosystem as part of an ecosystem-based management approach." The ERPP identified a number of habitat types that would be pursued in the Delta EMZ. These habitat types are currently being reviewed and evaluated as a part of a comprehensive effort to analyze various habitat conservation plans in terms of the natural communities they seek to conserve. It is envisioned that once this exercise is completed, scientists and managers will have a better understanding of these natural communities, and will also be better able to monitor status and trends in these natural communities at a regional scale.

There were two strategies in the *Delta Vision Strategic Plan* that incorporated some ideas regarding the creation and restoration of habitat: Strategy 3.1, "Restore large areas of interconnected habitats—on the order of 100,000 acres—within the Delta and its watershed by 2100"; and Strategy 3.2, "Establish migratory corridors for fish, birds, and other animals along selected Delta river channels". These two strategies list actions regarding inundation of floodplain areas, restoration of tidal and riparian habitat, and protection of grasslands and farmlands.

Development of the Conservation Strategy Map.
This element in the Conservation Strategy identifies restoration opportunities within the Delta EMZ, primarily based on land elevations with consideration of current urban land use constraints (Figure 4). Existing non-urban land uses, infrastructure, and other constraints at these locations were not considered for this map. These features will be addressed in future analyses of site-specific proposals. Figure 4 presents a preliminary view of how the Delta could be configured to restore habitat areas to the maximum extent within the Delta EMZ. For this element of the Conservation Strategy, several broad habitat types were identified for restoration, and in the interest of readability, these habitat types are classified according to three ranges of land elevation in which they would primarily occur: upland areas; intertidal areas; or subsided lands/deep open water areas. After incorporating an elevation map of the Delta (DWR 2007), rough contour lines were drawn to identify potential restoration opportunity areas. Appendix D provides a crosswalk between habitat categories in this Conservation Strategy for the Delta EMZ and those in the ERP Plan.

Aquatic Habitat. In accordance with the recommendations in the Delta Vision Strategic Plan and in light of expected sea level rise, the areas of the Delta EMZ that are of highest priority for restoration include lands that are in the existing intertidal range, floodplain areas that can be seasonally inundated, and transitional and upland habitats. Assuming a rise in sea level of ~55" over the next 50-100 years (Cayan et al. 2009), these areas would become shallow subtidal, seasonally inundated floodplain, and intertidal and upland habitats in the future, respectively. In the near term, managers are also interested in conducting experiments on the creation of deep open water areas such as Franks Tract, which is very important for some of the Delta's native pelagic fish species, to test whether these areas can be managed to optimize the quality of habitat in open waters for native fish species.

Agricultural Lands. It is important to note that despite the significant areas of the Delta currently in agricultural production that are suitable for creation of habitat areas, most areas of the Delta are expected to remain in active agricultural production well into the future. Expected reductions in the availability of freshwater for all beneficial uses due to changing precipitation patterns and extended droughts means that sea level rise will increase salinity into some areas of the Delta, particularly the western and central Delta, even absent any natural perturbations such as an earthquake. There simply will not be enough freshwater in the future to continue maintaining all parts of the Delta as a freshwater pool year-round. It is therefore probable that Delta agriculture will adapt naturally over time to these expected changes in the Delta, through a combination of planting more drought- and salt-tolerant crops as agricultural biotechnology becomes more widely available; growing crops that can be used to produce ethanol or other biofuels; seeking more opportunities for cultural/economic diversification (e.g. ecotourism); and managing wetlands and associated plants for wildlife benefits and/or toward development of a carbon emissions offset trading market. Some U.S. Department of Agriculture programs already exist that provide financial incentives for landowners to manage natural areas on their properties (including but not limited to the Wildlife Habitat Incentives Program, the Environmental Quality Incentives Program, and the Conservation Reserve Program), and while largely successful in other states, funding for implementation of these programs in California must be augmented to make participation more attractive to landowners who face higher capital and production costs.

To accommodate future shifts in habitats and species' distribution, ERP will continue to fund projects on agricultural lands which benefit wildlife and ensure that agricultural properties are not developed or converted to land uses that will not be as well-suited for adaptation to the Delta's future conditions.

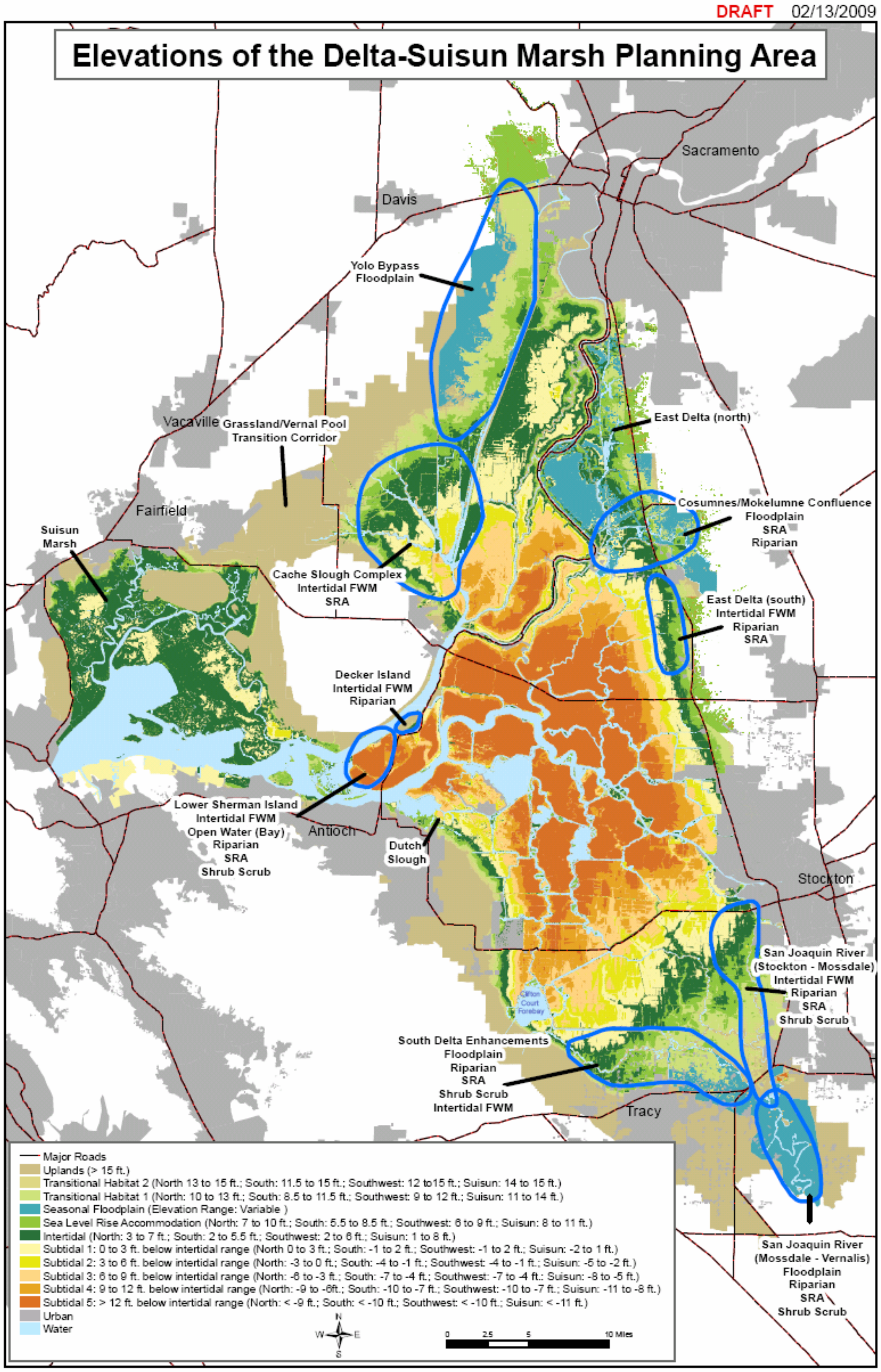

Figure 4: Land elevations in the Delta EMZ will largely determine what habitat types can be accommodated.

II.A. Upland Areas

With increasing sea level, global warming, and regional climate change, Delta habitats and species are going to require connectivity to higher elevation areas. Changes in regional climate are expected to result in precipitation patterns of more rain and less snow, shifting tributary peak runoff from spring to winter, making extreme winter runoff events more frequent and intense, and bringing about longer dry periods in summer. In light of these expected changes, and ongoing conversion of open space lands to urban uses, some of these higher elevation areas will be expected to accommodate additional flood flows in new or expanded floodplain areas.

Upland areas in the Delta EMZ are best characterized as lands well above current sea level (greater than ~5 feet in elevation, depending on location). Aquatic habitats in this category include seasonally-inundated floodplain, seasonal wetlands (including vernal pools), and ponds, while terrestrial habitats in this category include riparian areas, perennial grasslands, and inland dune scrub, as well as agricultural lands. Creating a mosaic of different upland habitat types, increasing their geographic distribution, and enhancing the connectivity between them is important for maintaining genetic diversity of the numerous species which use these areas for all or part of their life cycle. The aquatic and terrestrial habitat types that comprise upland areas often co-occur (e.g. agricultural lands that are seasonally inundated to benefit waterfowl, and perennial grasslands that support vernal pools). Thus, this habitat category highlights the importance of preserving and enhancing a diversity of habitats in support of numerous species and ecological processes, as well as allowing the system to respond to drivers of change such as sea level rise.

The rationales for protection and enhancement of seasonal wetlands, vernal pools, riparian areas, perennial grasslands, and inland dune scrub are contained in the ERPP, and the reader is encouraged to refer to these volumes for more information. For the purposes of this Conservation Strategy, the discussion on restoring upland habitats will be focused on seasonally-inundated floodplains, a proposed corridor of upland transitional habitat linking the Cache Slough area to Suisun Marsh, and protection of agricultural and open space lands for wildlife-compatible uses.

Much has been learned about creating habitats in upland areas since 2000,

Potential Stage 2 Actions for Upland Areas:

Action 1: Acquire land and easement interests from willing sellers in the East and South Delta that will accommodate seasonal floodplain areas, and shifts in tidal and shallow subtidal habitats due to future sea level rise.

Action 2: Conduct research to determine scale and balance of flow, sediment, and organic material inputs needed to restore riverine ecosystem function.

Action 3: Develop a better understanding of species-habitat interactions, species-species interactions, and species' responses to variable ecosystem conditions in order to better determine natural versus human-induced responses of upland habitat restoration.

Action 4: Determine contaminant and runoff impacts of agriculture and urban areas, and anticipate effects on the ecosystem from future expansion of these land uses.

Action 5: Pursue large-scale riparian vegetation along waterways wherever feasible, including opportunities for setback levees.

particularly with respect to seasonally-inundated floodplains and their importance to many of the Delta's aquatic species. As knowledge has increased, the risk and uncertainty associated with restoring this habitat is decreasing. Thus, restoration of seasonally-inundated floodplains is a very high priority for the Delta EMZ in the near term.

Floodplain. A natural floodplain is an important component of rivers and estuaries that allows many essential ecological functions to occur. Healthy floodplains are morphologically complex, including backwaters, wetlands, sloughs, and distributaries that carry and store floodwater. Floodplain areas can constitute islands of biodiversity within semi-arid landscapes, especially during dry seasons and extended droughts. The term *floodplain* as used here means the generally flat area adjoining rivers and sloughs that is flooded by peak flows every 1.5-2 years and exceed the capacity of the channel ("bankfull discharge"). Peak flows in winter and spring that happen every 1.5-2 years are considered by river geomorphologists to be the "dominant discharge" that contributes the most to defining the shape and size of the channel and the distribution of sediment, bar, and bed materials. Larger flood events can cause major changes to occur, but they do not happen often enough to be the decisive factor in river geomorphology.

Floodplain areas have the potential to support highly productive habitats, as they represent a heterogeneous mosaic of habitats including riparian, freshwater tidal marsh, seasonal wetlands, perennial aquatic, and perennial grassland habitats, in addition to agricultural lands. Floodplains are used by numerous native fish for spawning and growth during their life cycles (Moyle 2002). There has been extensive research on the Yolo Bypass and lower Cosumnes River (in addition to some research in the Sutter Bypass) indicating that native resident and migratory fish show a positive physiological response (i.e. enhanced growth and fitness) when they have access to floodplain habitats (Ribeiro et al. 2004, Moyle et al. 2007), which likely benefits them as they complete subsequent stages of their respective life cycles. Inundated floodplain areas provide important spawning and rearing habitat for splittail and rearing habitat for Chinook salmon (Sommer et al. 2001, Sommer et al. 2002, Moyle et al. 2007). Splittail must spawn in floodplains (Moyle et al. 2004); without access to adequate floodplain spawning habitat, splittail reproduction declines drastically as seen during the 1990s.

Managing the frequency and duration of floodplain inundation during the winter and spring, followed by complete drainage by the end of the flooding season, could favor native fish over non-natives (Moyle et al. 2007, Grimaldo et al. 2004) and reduce nuisance insect problems. Duration and timing of inundation are important factors that influence ecological benefits of floodplains. PWA and Opperman (2006) have defined a Floodplain Activation Flow for floodplains on the Sacramento River: desired ecological outcomes likely would arise from an inundation regime that:

- Occurs between March 15 and May 15
- Accommodates active flooding for a minimum of seven days (although floodplain inundation would likely persist considerably longer); and
- Occurs two out of every three years

Floodplain Activation Flows are very important, as are periodic large volume flows. Large-scale events are more effective at reworking the floodplain landscape in a natural way. Studies on the Cosumnes and Sacramento Rivers indicate that dynamic processes are needed to support complex dynamic riparian habitats and upland systems which form the floodplain habitat (Moyle et al. 2007). Native plants and animals adapted to random events that are characteristic of California's hydrology; these random events help to control non-native plants and animals.

In the Sacramento Valley, the Yolo Bypass has the greatest promise for large-scale (8,500+ acres) restoration of floodplain areas and processes at modest flow rates (2,000 cfs) (PWA and Opperman 2006). The Floodplain Activation Flows timing and rate of inundation are minimum values for ecological benefits; as the flow rate increases the ecological benefit increases as well. PWA and Opperman (2006) outlined a methodology to use with other floodplains that can be applied to the San Joaquin River and the lower Mokelumne River.

Research on the Cosumnes River also shows the many ecosystem benefits that floodplains provide. The Cosumnes River is the only remaining unregulated mainstem river on the western slope of the Sierra Nevada. The Cosumnes River Preserve comprises 46,000 acres and includes all associated Central Valley. The free-flowing nature of the river allows frequent and regular winter and spring overbank flooding that fosters the growth of native vegetation and the wildlife dependent on those habitats. In addition to the value of floodplain habitat to the Delta's native species, floodplains are believed to enhance the estuarine food web, as they support high levels of primary and secondary productivity by increasing residence time and nutrient inputs into the Delta (Sommer et al. 2004). Ahearn et al. (2006) found that floodplains that are wetted and dried in pulses can act as a productivity pump for the lower estuary. With this type of management, the floodplain exports large amounts of Chlorophyll *a* to

> Potential Stage 2 Actions for Floodplains:
>
> Action 1: Continue Aquatic Restoration Planning and Implementation (ARPI) activities such as habitat enhancement and fish passage improvements in the Yolo Bypass. Continue coordination with Yolo Basin Foundation and other local groups to identify, study, and implement projects on public or private land with willing participants, to create regionally significant improvements in habitat and fish passage.
>
> Action 2: Continue working with the participants in the Yolo Bypass Strategic Plan process to ensure the project scope builds upon investments in the Lower Bypass.
>
> Action 3: Continue implementing projects at the Cosumnes River Preserve, such as restoring active and regular flooding regimes and flood riparian forest habitat; measuring flora and fauna response to restoration; and monitoring surface and groundwater hydrology and geomorphic changes in restored areas.
>
> Action 4: Pursue opportunities for land and easement acquisitions in the Yolo Bypass and along the lower Cosumnes and San Joaquin Rivers, which could be utilized as floodplain inundation areas in the near term or in the future.

the river. Native fish have shown many benefits from floodplain habitat on the Cosumnes Preserve (Moyle et al. 2007, Swenson et al. 2003, Ribeiro et al. 2004, Grosholz and Gallo 2006).

Because floodplain areas are inundated only seasonally, many other habitat types that occur in upland areas can be accommodated on floodplains when high winter and early spring flows are not present. The Department of Water Resources' Flood Protection Corridor Program provides grant funding to local agencies and nonprofit organizations for nonstructural flood management projects that include wildlife habitat enhancement and/or agricultural land preservation, and acquisition of flood easements. Such easements provide a way to bring floodplain benefits to species seasonally, while also accommodating agricultural production in summer, fall, and early winter. Delta crops such as rice, grains, corn, and alfalfa provide food for waterfowl and other terrestrial species, and serve as surrogate habitat in the absence of historical habitat such as tidal marsh. From Highway 99 west to the Cosumnes River Preserve is a good example of an area that provides wildlife-friendly agriculture mix. It is the largest conservation easement acquisition funded by ERP during Stage 1. The ERP also provided funding for planning or for property acquisitions and restoration of wildlife friendly agriculture in the Yolo Bypass, along the Cosumnes River, and along the San Joaquin River near Mossdale Crossing.

Although the benefits of floodplains have been demonstrated, there are a few cautions that must be realized considering seasonal floodplain areas for restoration:

- Restoration must incorporate as much natural connection with the river as possible, to reduce potential stranding of native fish. Large-scale flooding events also help reduce stranding by creating channels on the landscape which allow for natural drainage, and multiple pulse flows help ensure fish receive the migratory cues they need.
- The periodic wetting and drying of floodplain areas make these areas especially prone to methylmercury production and transport. Within the context of the Delta Total Maximum Daily Load (TMDL) for methylmercury that is currently under development, floodplain restoration activities should include the investigation and implementation of Best Management Practices (BMPs) to control methylmercury production and/or transport.

Upland Transitional Corridor. There is interest in establishing a corridor of upland habitats between the Delta's Cache Slough area and the Suisun Marsh, both to protect valuable habitats that occur there and to facilitate the movement of wildlife between the two areas. This proposed corridor currently contains a mosaic of perennial grasslands and vernal pool areas, and has been identified by local planners as having great potential for ecological benefits from restoration. It is possible that channels may also be constructed in this corridor, to provide a migratory route for endemic species that use the Delta and Suisun Bay (e.g. delta and longfin smelt and anadromous fish species).

II.B. Intertidal Areas

Tidal marshes play a critical role for native fish including salmonids by providing forage and refuge from predators (Boesch and Turner 1984, Baltz et al. 1993, Kneib 1997, Kruczynski and Ruth 1997) resulting in higher growth rates.

Intertidal areas in the Delta EMZ are best characterized as lands between one and seven feet above sea level, depending on location (Figure 4). All lands in the intertidal range are assumed to have the ability to support some tidal marsh habitats (either brackish or freshwater) with associated sloughs, channels, and mudflats. Some areas are capable of supporting large areas of contiguous habitat, and others may support only small patches (e.g. mid-channel islands and shoals). Properly functioning tidal marsh habitats have subtidal open water channels with systems of dendritic (branchlike), progressively lower-order intertidal channels that dissect the marsh plain. These diverse habitats provide structure and processes that benefit both aquatic and terrestrial species.

The rationales for protection and enhancement of fresh and brackish tidal marsh areas are contained in the ERPP, and the reader is encouraged to refer to these volumes for more information. For the purposes of this Conservation Strategy, the discussion on restoring habitats in intertidal areas will be focused on what has been learned about the importance of these areas since 2000, particularly as it relates to various species' use of tidal marsh areas and the role of these areas in enhancing the aquatic food web.

Studies of species' use of tidal marsh habitat in the Delta are limited, but ERP and other programs have conducted several studies since the ROD that continue to augment the knowledge regarding the role of intertidal habitats for desirable aquatic species. The largest effort to study tidal marsh habitat in the Delta and its benefits to native fish was a series of projects known as the BREACH studies (http://depts.washington.edu/calfed/breachii.htm), which investigated geomorphology, sedimentation, and vegetation at four reference and six restored tidal marsh sites in the Delta. Of the one reference and three restored sites sampled for fish and invertebrates, relative density of both native and introduced fish species was higher at the reference marsh (Simenstad et al. 2000). Although all of the sites were dominated by non-native fish, the abundance of native fish was highest in winter and spring (Grimaldo et al. 2004). In stomach content analyses, all life stages of chironomids (midges) were shown to be a very important food source for fish, both adjacent to tidal marsh habitats and in open water areas. Chironomids' association with marsh vegetation indicates the importance of this habitat to the aquatic food web. Overall abundance of fish larvae was highest in marsh edge habitat when compared to shallow open water and river channels (Grimaldo et al. 2004). Unfortunately the BREACH study sites are not representative of the Delta's large historic marshes. Most sites are small and severely degraded areas located along the edge of levees or on small channel islands.

An example of an ongoing study of species' use of tidal marsh within intertidal land elevations is the ongoing monitoring associated with restoration of Liberty Island, a 5,209-acre island in the northern Delta that breached naturally nearly ten years ago. The

Liberty Island project provides a good example of passive restoration to various habitat types, including some deeper, open water, subtidal, areas at the southern end and freshwater emergent tidal marsh, and sloughs with riparian habitat at the higher elevations at the northern end. Liberty Island's sloughs are populated with otters, beavers, muskrats, and numerous species of ducks and geese. Native fish species using the area include Chinook salmon, Sacramento splittail, longfin and delta smelt, tule perch, Sacramento pike minnow, and starry flounder. In some areas, native species account for up to 21% of the fish collected, for reference, native species only account for ~2-10% elsewhere (Malamud-Roam et al. 2004). Ongoing monitoring at Liberty Island is showing that fish species assemblages at this restored area, which is approaching eight years', increasingly resembles assemblages at reference marsh sites. The ERP hopes to build upon the success of this restoration project by increasing the size of the project and developing a dendritic channel system on its interior (DFG 2008b).

A number of additional studies are demonstrating that regardless of species' actual use of tidal marsh areas, these habitats could be extremely important for their possible role in augmenting the Delta's aquatic food web, particularly in the saline portion of the estuary.

- Tagging and stomach content studies show that Chinook salmon fry may use intertidal habitat. According to Williams (2006), tagged hatchery fry remain in the Delta up to 64 days and tend to occupy shallow habitats, including tidal marsh. Stomach contents of salmon rearing in the Delta are dominated by chironomids and amphipods, suggesting that juvenile salmon are associated with marsh food production. Juvenile salmon in the Delta also undergo substantial growth (Kjelson et al. 1982, Williams 2006). These findings coincide with studies elsewhere in the Pacific Northwest (Healey 1982, Levy and Northcote 1982, Simenstad et al. 1982), which found that Chinook salmon fry usually occupy shallow, near-shore habitats including tidal marshes, creeks, and flats, where they feed and grow and adapt to salt water (Healey 1982; Levy and Northcote 1982; Simenstad et al. 1982), and that they often move into tidal wetlands on high tides and return to the same channels on several tidal cycles (Levy and Northcote 1982). Also, in estuaries throughout Washington, subyearlings and fry occur mainly in marshes when these habitats are available (Simenstad et al. 1982). In fact, Healey (1982) identified freshwater tidal marshes as the most important habitat to juvenile salmon in the Pacific Northwest. More recently, in the Columbia River estuary, emergent tidal marsh has been shown to support the greatest abundance of insects and highest stomach fullness scores for juvenile salmon (Lott 2004), with chironomids again being the dominant prey item.
- In a study of carbon types and bioavailability, tidal marsh sloughs in Suisun Bay had the highest levels of dissolved, particulate, and phytoplankton-derived carbon (Sobczak et al. 2002). Chlorophyll *a* concentration, used as a measure of standing crop of phytoplankton, was highest in tidal sloughs and supports the greatest zooplankton growth rate (Muller-Solger et al. 2002) when compared to other habitat types, such as floodplains and river channels. High levels of primary production (as measured by chlorophyll a) seen in several regions in the interior of Suisun Marsh is likely due to high residence time of water, nutrient availability, and absence of non-native clams (DFG 2008b).

- Modeling (Jassby et al. 1993 and Cloern 2007) and empirical studies (Lopez et al. 2006) show that productivity from high-producing areas, such as marsh sloughs, is exported to other habitats. Phytoplankton biomass location is only weakly correlated with phytoplankton growth rates across several aquatic habitats, therefore other processes, including mixing and transport, are important in determining phytoplankton distribution in the Delta. The data shows that Suisun Marsh plays a significant role in estuarine productivity by providing an abundant source of primary production and pelagic invertebrates, both of which are significantly depleted in bay and river channel areas (DFG 2008b).
- In a nutrient-rich estuary, tidal freshwater marsh has the ability to transform or retain up to 40% of ammonia entering the marsh during a single flood tide. Nitrification (the conversion of ammonia to nitrate) accounted for a large portion of the transformation (30%). Nitrification rate in the marsh system was measured at 4-9 times that which occurs in the adjacent water column (Gribsholt et al. 2005). The marsh sediment and biofilm (mudflats) are important sites at which this nitrification occurs. Tidal marsh may therefore have the ability to improve the base of the aquatic food web in the Delta by increasing primary production within the marsh itself, and by increasing the ratio of nitrate to ammonia in the estuary. In the absence of actions to reduce inputs of ammonia into the system, tidal marsh restoration is a promising method of mediating the effects of these inputs. Tidal marsh may increase the likelihood of phytoplankton blooms in the estuary through nitrification and retention of ammonia; as presented in the discussion of the aquatic food web, ammonia inhibits phytoplankton blooms in Suisun Bay and possibly other open-water habitats in the Delta, therefore lowering overall productivity (Wilkerson et al. 2006, Dugdale et al. 2007).

Potential Stage 2 Actions for Tidal Marsh (intertidal areas):

Action 1: Continue habitat restoration, property acquisition, planning, and monitoring on specified sites:

- Hill Slough habitat restoration (Suisun Marsh)
- Mein's Landing restoration (Suisun Marsh)
- Blacklock restoration monitoring (Suisun Marsh)
- Cache Slough complex, including Prospect and Liberty islands, and Lindsey Slough.
- Yolo Bypass Wildlife Area (tidal and seasonal wetlands on 700 acres)

Action 2: Implement and monitor the Dutch Slough restoration project, which would restore up to 483 acres of emergent wetland (a portion of which would be tidal), and generate information on how to best restore tidal marsh habitat.

Action 3: Continue studies in the lower Yolo Bypass to greatly improve understanding of aquatic species' response to tidal wetland restoration. Evaluate physical and geomorphic processes and monitor connectivity and key ecological variables (comparing Yolo Bypass and Cosumnes River systems) to assess effects of seasonal and interannual hydrologic variability.

Action 4: Conduct studies to determine whether fish benefits from tidal marsh that have been demonstrated in the saline portion of the estuary are also true for the freshwater portion of the estuary.

Action 5: Conduct studies to determine whether inundation of marsh plains on the flood tide at night results in cooler water being returned to the channels on the ebb tide.

At the outset of ERP, restoration of intertidal and shallow subtidal areas (at that time, termed "shallow water habitat", defined as water less than two meters in depth at mean lower low water) was a very high priority, and based on what has been learned since 2000, continues to be a very high priority for the Delta EMZ. However, the extensive spread of non-native submerged aquatic vegetation (SAV) in intertidal and shallow subtidal areas renders them less suitable for native fish (Nobriga and Feyrer 2007, Nobriga et al. 2005, Brown and Michniuk 2007). Brown and Michniuk (2007) reported a long-term decline in native fish abundance relative to nonnative fish. This decline in native fish abundance occurred coincident with the range expansion of non-native SAV (principally *Egeria densa*) and non-native black bass (centrarchids), both of which are discussed further in the Stressors section below. Predation by largemouth bass is one mechanism hypothesized to result in low native fish abundance where SAV cover is high (Brown 2003, Nobriga et al. 2005). Largemouth bass have a higher per-capita predatory influence than all other piscivores in SAV-dominated intertidal zones (Nobriga and Feyrer 2007). Restoration Delta intertidal habitats must, therefore, be designed and managed to discourage non-native SAV, or native fish may not benefit from them (Nobriga and Feyrer 2007, Grimaldo et al. 2004).

In summary, restoration of tidal marsh areas in the Delta remains a very high priority for the ERP; however, several cautions must be kept in mind. A major concern is that restored tidal marsh would be colonized by non-native species, which would in turn limit the benefits to native species. Other potential constraints facing the restoration of intertidal habitats include the methylation of mercury in sediments, and contamination from the placement of dredge spoils to achieve optimal land elevations for marsh creation. Therefore, restoration of tidal marsh within intertidal land elevations should be designed as large-scale experiments, and should be rigorously monitored to establish relationships between this habitat and species' population abundance. As this information continues to be collected and synthesized, the risk and uncertainty associated with restoring this habitat are expected to decrease.

II.C. Subsided Lands/Deep Open Water Areas

Subsided land areas in the Delta EMZ are best characterized as land well below current sea level (deeper than ~ -6 feet in elevation), and include both terrestrial areas (islands that have subsided over time) and deep open water areas (subsided islands that flooded in the past and were never reclaimed). Aquatic habitats in this category include seasonal wetlands and ponds that occur within subsided land areas, in addition to deep open water areas such as Franks Tract (also called pelagic habitat).

With increasing sea level, global warming, and regional climate change, the existing configuration of Delta levees and deeply subsided islands is not expected to remain intact over the long term. A forecast rise in sea level of approximately 55 inches over the next 50-100 years (Cayan et al. 2009) is expected to increase pressure on the Delta's levee system. Changes in regional climate and the shift of tributary peak runoff from spring to winter are expected to make extreme winter runoff events more frequent and intense, further compounding pressure on Delta levees seasonally. In light of these expected changes, in addition to human-induced impacts (e.g. increased runoff from continued conversion of open space lands to urban uses), there is a considerably higher likelihood of Delta levee failure and subsequent island flooding in the future. ERP implementation must therefore adapt to these expected pressures, including planning for optimizing the value of newly-flooded deep islands for the aquatic species that may utilize them in the future.

Terrestrial areas in this category include mainly agricultural lands, some of which are not in active agricultural production. Central Valley Joint Venture (2006) recognizes that agricultural easements to maintain waterfowl food supplies and buffer existing wetlands from urban development may become increasingly important in basins where large increases in human populations are predicted. In addition, ongoing rice cultivation may help minimize subsidence. Subsidence reversal, carbon sequestration, and wildlife-friendly agricultural projects are appropriate on these deep islands in the near term, as they are expected to begin reversing land subsidence and to provide benefits to the local economy, wildlife, and waterfowl while protecting lands from uses that may be unsustainable over the longer term.

The rationales for protection and enhancement of seasonal wetlands and wildlife-friendly agriculture are contained in the ERPP, and the reader is encouraged to refer to these volumes for more information. For the purposes of this Conservation Strategy, the discussion on restoring habitats on subsided lands will be focused on subsidence reversal and carbon sequestration, and on restoring deep open water areas for the Delta's pelagic fish species.

Subsidence reversal. The exposure of the bare peat soils to air causes oxidation which results in subsidence, or a loss of soil on Delta islands. Flooding these lands and managing them as wetlands reduces their exposure to oxygen, so there is less decomposition of organic matter, which and stabilizes land elevations. Biomass accumulation sequesters carbon and helps stop and reverse subsidence (Fujii 2007). As subsidence is reversed, land elevations increase and accommodation space, the space in the Delta that lies below sea level and is filled with neither sediment nor water (Mount and Twiss 2005), on individual islands is reduced. A reduction in accommodation space decreases the potential for drinking water quality impacts from salinity intrusion in the case of one or more levee breaks on deeply subsided Delta islands.

A pilot study on Twitchell Island funded by the ERP in the late 1990s investigated methods for minimizing or reversing subsidence which have shown great promise for the Delta's subsided lands. By flooding soils on subsided islands approximately one foot deep, peat soil decomposition is stopped, and conditions are ideal for emergent marsh vegetation to become established. In the Twitchell Island pilot project, researchers saw some initial soil accumulation during the late 1990s and early 2000s, and noted that accretion rates accelerated and land surface elevation began increasing much more rapidly after about seven years, as plant biomass was accumulated over time. Land surface elevation is estimated to be increasing at an annual rate of around 4 inches, and is expected to continue to increase (Fujii 2007).

The USGS is interested in implementing a subsidence reversal program Delta-wide, given the results of their Twitchell Island pilot study. Such a program would involve offering financial incentives to landowners to create and manage wetland areas on their lands (Fujii 2007). Large-scale, whole-island approaches to reversing subsidence would be beneficial for multiple purposes. Programs that offer incentives for 10- or 20-year studies for subsidence reversal on large tracts of land could help improve Delta levee stability and reduce the risk of catastrophic failure. Assuming that accretion rates continue at about 4 inches annually, estimates suggest a 50% reduction in accommodation space in 50 years if subsidence could be pursued throughout the Delta. This reduction in accommodation space jumps to 99% over the next 100 years) (Fujii 2007). Some deeply subsided lands could also be used as disposal sites for clean dredged sediments, providing local flood control improvements while helping raise land elevations on subsided islands more quickly. This accommodation space reduction, in addition to helping stabilize levees over the longer term, would allow future restoration of additional tidal marsh habitats.

Potential Stage 2 Actions for Subsided Lands/Deep Open Water Areas:

Action 1: Implement wildlife-friendly agriculture and wetland projects (e.g. in partnership with Farm Bill programs).

Action 2: Secure easements and land interests on which subsidence reversal projects can occur (e.g. in partnership with USGS).

Action 3: Conduct experiments on the creation and management of deep open water areas. Some potential locations include:

- Lower Sherman Island
- Little Egbert Tract

Action 4: Continue to monitor deep open water areas on Liberty Island for environmental conditions and species use

While the primary objectives of creating wetlands on deep Delta islands would be to reverse subsidence and sequester carbon, there would be significant ancillary benefits to wildlife such as waterfowl. Delta agricultural lands and managed wetland areas provide a vital component to Pacific Flyway habitat for migratory waterfowl by increasing the availability of natural forage, ensuring improved body condition and breeding success (CALFED 2000b).

Deep open water areas. All permanent aquatic habitats in the Delta are occupied by fish of some type. In planning for restoration of Delta aquatic habitats, it is important to consider which fish will occupy what habitat and when; and what type of benefits fish will gain from the habitat. Fish assemblages in the Delta, each with a distinct set of environmental requirements, include native pelagic species (e.g. delta and longfin smelt), freshwater planktivores, dominated by non-native species such as threadfin shad and inland silverside; anadromous species (e.g. salmon and steelhead), slough-residents associated with beds of SAV (e.g. black bass), and freshwater benthic species (e.g. prickly sculpin) (Moyle and Bennett 2008). Habitat diversity is necessary to support multiple fish assemblages in the delta. Restoration efforts need to focus on creating habitats required by desirable species assemblage, while avoiding habitats dominated by undesirable species.

With the increasing threats of levee failure from continuing land subsidence, exacerbated by sea level rise, higher seasonal runoff, and random events such as an earthquake, the Delta is likely to have more large areas of deep, open water in the future (Moyle and Bennett 2008). Important managed attributes include salinity, contaminant inputs, and connectivity to surrounding habitats, to increase habitat variability, and provide a greater diversity in water quality conditions (Moyle and Bennett 2008). Fish assemblages will respond differently to future environmental changes.

New open water habitats may also result from intentional activities on a smaller and more managed scale than whole-island flooding. The intentional removal of levees on islands at the periphery of the Delta in order to create marsh habitat on intertidal land elevations would result in open water below the tidal zone similar to what's developing at Liberty Island. Exchange of materials between the restored tidal marsh with adjacent open water could result in higher productivity in open water habitat. As mentioned in the discussion of tidal marsh restoration, the potential for SAV dominated by non-native species to establish in new shallow water environments is a concern. On Liberty Island, SAV has not become a dominant component of the open water habitat. This may be a result of tidal flow velocities, wind-induced disturbance, or some other factor. Continuing research and monitoring of the Liberty Island project will improve understanding of the dynamics of a large island breach at the periphery of the Delta, and help plan for future marsh or open water restoration projects.

There are many unknowns about future characteristics of flooded island, and open water habitat (Moyle and Bennett 2008). These include configuration and location of flooded islands; physical properties such as depth, turbidity, flow, and salinity; biological properties such as productivity of phytoplankton and copepods; and susceptibility to invasion by non-native species such as *Egeria densa*, centrarchids, and invasive non-native clams. Creation of pelagic habitat is therefore not guaranteed to have a population-level benefit to native fish (Moyle and Bennett 2008). Adaptive management, combined with large-scale experimentation on new open water habitat, would help to reduce uncertainties. This could occur through the planned flooding of at least one Delta island, or through an organized study plan that would go into effect in the event of an unplanned levee breach (Moyle and Bennett 2008).

II.D. Ecological Management Unit (EMU) Restoration Priorities

Based upon the ERPP descriptions of habitat types that fit into the upland, intertidal, and subsided/deep open water classifications, some near-term land acquisition and habitat enhancement priorities have been identified for the four Delta Ecological Management Units (EMUs) of the Delta EMZ (Figure 5). As agricultural lands comprise a significant amount of area within each EMU, it is intended that some conversion of land from agricultural uses will occur to accommodate specific habitat types. In some cases, this conversion would occur over the course of a few years. In others, acquired lands may not be converted to other uses unless or until a new water conveyance facility is constructed and operational. Therefore, it is expected that most agricultural lands will remain in productive agriculture for the foreseeable future, and any funding from the ERP for wildlife-friendly agriculture projects, subsidence reversal projects, or long-term easements to protect lands from permanent crops (i.e. orchards and vineyards) and other development will be considered on a case-by-case basis. Therefore, discussion of agricultural lands is not included within the descriptions of EMU restoration priorities.

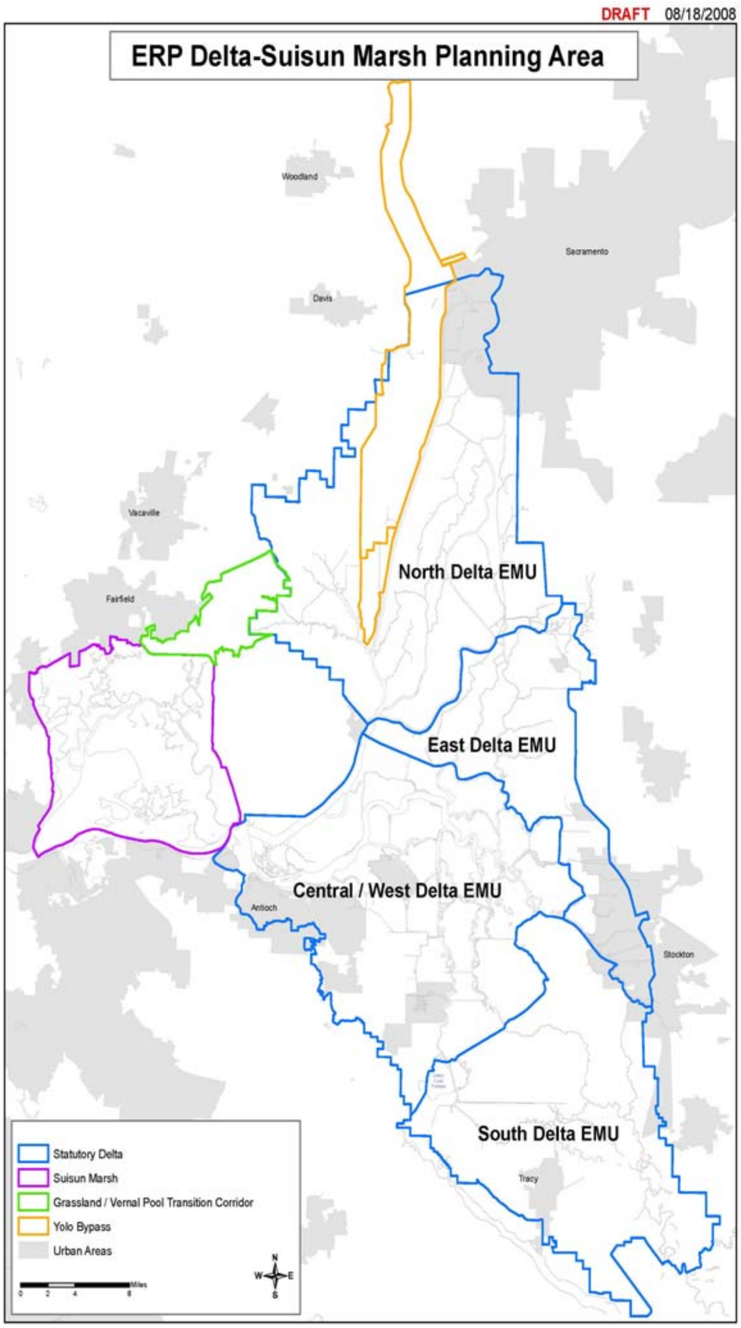

Figure 5: Map of EMUs within the Delta EMZ

North Delta EMU.

- *Cache Slough Complex.* Restore a mosaic of deep open water, shallow subtidal, tidal marsh, riparian, perennial grasslands, and vernal pool habitats. The Cache Slough Complex includes some properties that are currently in public ownership or are already protected for conservation purposes: Prospect Island, which could accommodate tidal marsh, and Liberty Island, which could accommodate deep open water, shallow subtidal, and tidal marsh areas. The Cache Slough Complex also includes Little Egbert Tract, which could accommodate some seasonal floodplain just south of Liberty Island; the elevation of Little Egbert Tract also makes it a good candidate for experimentation on the creation of shallow subtidal and deep open water areas, to help design future restoration projects geared toward benefiting delta smelt.
- *Yolo Bypass.* Restore a mosaic of seasonal floodplain, riparian, perennial grasslands, and vernal pool habitats. The Yolo Bypass area has been under investigation for several years for its potential to provide floodplain habitats benefiting Delta species, and it is a high priority of the ERP to provide these functions in this area in the near term. In addition, private entities are currently acquiring properties in the Yolo Bypass with the intent of restoring habitats and securing water supplies. Over the longer term, this area is expected to also include tidal marsh, as it accommodates sea level rise.

Central/West Delta EMU.

- *Deeply Subsided Islands.* Levees around at least one of these deep subsided islands could be breached or removed in order to create deep open water areas. Recognizing that the land area of the Central/West Delta EMU consists of primarily deeply subsided islands which could accommodate subsidence reversal experiments and wildlife-friendly agricultural practices, land elevations in this area also provide a major opportunity to increase delta smelt habitat area.
- *Dutch Slough.* Construct the Dutch Slough habitat restoration project. This project proposes to create tidal marsh and shallow subtidal areas on lands adjacent to the deep open water areas of Big Break, north of Oakley. Due to the expenditure of funds to acquire the properties, the ecological benefits the project is expected to yield, and the unique opportunity that the design of this project gives to experiment with restoration techniques, this is a high-priority project for implementation in the near term. Implementation of this project is expected to help answer a key question of whether an island will support sustainable native fish habitat (i.e. tidal marsh) if it’s surrounded by non-native fish habitat (i.e. shallow subtidal areas at Big Break).
- *Upper Sherman Island.* Pursue opportunity to experiment with creation of deep open water areas. Sherman Island is currently owned by the State of California, and its land elevation, which is significantly below sea level, offers a unique opportunity to create deep open water areas that are expected to benefit the Delta’s native pelagic fish species.

East Delta EMU.

- *Cosumnes-Mokelumne Confluence.* Create a mosaic of seasonal floodplain, riparian, shallow subtidal, and tidal marsh areas. The confluence of the Cosumnes and Mokelumne river systems has been an area of extensive property acquisitions (Cosumnes River Preserve), and continues to be an important area for restoring floodplains and seasonal wetlands. In the near term, ERP plans to restore acquired properties (e.g. McCormack-Williamson Tract). In addition, areas north and south of the Cosumnes-Mokelumne confluence are at land elevation, which would accommodate tidal marsh and shallow subtidal areas.
- Acquisition of lands at the eastern periphery of the Delta EMZ, could be restored to shallow subtidal and tidal marsh areas in the future as sea level rises, will also be pursued in the near term; however, restoration of these properties (many of which are currently in private ownership) may not become a high priority unless and until a new water supply conveyance facility is in place.

South Delta EMU.

- *Lower San Joaquin River.* Create a mosaic of seasonal floodplain, riparian, shallow subtidal, and tidal marsh areas. Acquisition of lands in the South Delta EMU that will accommodate shallow subtidal and tidal marsh areas in the future as sea level rises may be pursued in the near term; however, restoration of these properties (many of which are currently in private ownership) may not become a high priority unless and until a new water supply conveyance facility is in place.

Upland Transition Corridor.

- In addition to habitat restoration actions in the four Delta EMUs that comprise the Delta EMZ, there is significant interest in establishing a new connection between the Delta and the Suisun Marsh, by way of a new corridor connecting the Cache Slough Complex to northeastern Suisun Marsh. This proposed corridor currently contains a mosaic of perennial grasslands and vernal pool areas, and has been identified by local planners as having great potential for ecological benefits from restoration. ERP will therefore seek to protect existing habitat areas, and to secure land and easement interests from willing landowners to enhance these resources.

III. Stressors

Restoration of ecosystem processes to help improve the quality and extent of desirable habitats is only part of the solution to species recovery in the Delta. The ERP identified several stressors that negatively affect the Delta’s ecosystem health as measured by native species, ecological processes, and habitats. The focus in this element of the Conservation Strategy for the Delta EMZ is on stressors including water diversions, barriers to connectivity of habitats (such as levees), non-native and invasive species, and water quality.

III.A. Water Diversions and Barriers

Water diversions affect the Delta ecosystem in two fundamental ways: (1) through entrainment of fish and other aquatic organisms, and (2) through alteration of water circulation patterns which leads to changes in water quality and Delta habitats. Entrainment and impingement of fish and organisms can occur at diversions of any size, but is believed to be a problem mainly at those diversions that are relatively large in comparison to the channels from which they are drawing water. Alteration of water circulation patterns in the Delta occur primarily through seasonal barriers and gates that alter freshwater flows such as the Head of Old River barrier and the Delta Cross Channel, which were installed to protect drinking water quality (by controlling salinity) and guide migratory fish passage.

There was one strategy in the *Delta Vision Strategic Plan* that incorporated some ideas regarding management of water diversions and barriers: Strategy 3.3, "Promote viable, diverse populations of native and valued species by reducing risks of fish kills and harm from invasive species." This strategy includes actions to institute diversion management measures, implement conveyance improvements, and relocate diversions to less ecologically sensitive areas.

There are more than 2,000 diversions that take water from the Delta. Most of them are small (< 100 cubic feet per second [cfs]) and provide water to agricultural parcels in the Delta. The ERP Strategic Plan states that it is unclear how important the Delta's agricultural diversions are as a source of mortality for fish. Nobriga et al. (2004) conclude that small Delta agricultural diversions are likely to have a minor impact on pelagic (open water) fishes such as delta smelt because the hydrodynamic influence of such diversions is small and because pelagic fish are primarily distributed offshore, outside the zone of influence. Fish screens on small diversions were not widely pursued in the Delta during ERP Stage 1, primarily due to high costs and potentially low native fish population benefits compared to other screening projects (i.e. screens to protect anadromous fish at larger upstream diversions). Increasing material costs, the relatively small size of the diversions, and the limited data regarding the cumulative effects of small diversions indicate that few of these small unscreened diversions in the Delta are likely to be screened during the next 20 years (DFG 2008b). A prioritized list of criteria for potential fish screen projects within and upstream of the Delta was generated by the Anadromous Fish Screen Program (AFSP) authorized under the Central Valley Project Improvement Act (CVPIA), and will be used to evaluate mostly larger (>250 cfs) fish screen projects in the future. A team of State and federal fish screen experts hold regular workshops to share information, discuss upcoming projects, and discuss priorities for future fish screen projects.

> ERPP Vision for Water Diversions: Reduce the adverse effects of water diversions, including entrainment of all life stages of aquatic species, by installing fish screens, consolidating or moving diversions to less sensitive locations, removing diversions, or reducing the volume of water exported.
>
> ERPP Vision for dams and other structures: Reduce their adverse effects by improving fish passage and enhancing downstream movement.
>
> *ERPP volume 1, July 2000*

The largest water diversions in the Delta EMZ are the export facilities for the SWP and CVP in the south Delta. There are two power plants in Antioch and Pittsburg that divert large amounts of water, and several diversions that supply water to Contra Costa Water District serving cities outside of the Delta. The Contra Costa and Pittsburg Power Plant diversions are believed to have relatively small impacts on rearing and outmigrating juvenile winter-run salmon and steelhead, and medium impacts on rearing and outmigrating spring-run and fall or late-fall run Chinook (NMFS 2008). The effects of these power plant diversions on pelagic fishes such as delta and longfin smelt have not been ascertained, but non-consumptive water use by these diversions may approach 3,200 cfs at times, possibly enough to create a substantial entrainment risk. This is a topic that the IEP is studying as part of its evaluation of the POD.

The ERP Strategic Plan stated that it is unclear to what extent and by what mechanisms SWP and CVP export operations affect the population size of any one species of fish or other biota. However, culmination of a recent three-year study of pre-screen delta smelt entrainment at Clifton Court Forebay (i.e. delta smelt that are diverted into the Clifton Court Forebay before being transported to the SWP's screened Skinner Fish Facility) is demonstrating that the diversion into Clifton Court Forebay is likely having far larger population impacts on delta smelt than salvage operations at the screened facility itself (http://www.science.calwater.ca.gov/publications/sci_news_1009_salvage.html), accessed 9/28/09). While it remains very difficult to quantify the relative contribution of export operations on fish declines (Kimmerer and Nobriga 2008), there is a growing body of evidence that indicates they are having a significant contribution through a combination of entrainment as well as habitat effects (USFWS 2008, NMFS 2009a).

Export operations substantially affect water movement through Delta channels and usually result in net reverse flows OMR, the San Joaquin River at its confluence with the Sacramento River in the western Delta, and other channels and sloughs near the export facilities. Changes in hydrodynamics (e.g. reverse flows) have direct effects on fish by bringing them toward the export pumps, increasing their risk of entrainment. While there is great effort put into salvaging fish from the export facilities and returning them to suitable Delta habitats, mortality rates can be high due to predation in Clifton Court Forebay (Gingras 1997) and stress from handling (Bennett 2005). Newman (2008) concluded that outmigrating salmon from the Sacramento River had reduced survival when the DCC was open because fish move into the interior Delta where they are more vulnerable to the influence of the SWP and CVP export pumps.

Reverse flow in OMR in winter months, a function of San Joaquin River flow into the Delta as well as SWP/CVP pumping rates and tides, is strongly correlated with entrainment of adult delta smelt (Grimaldo et al. 2009, Kimmerer 2008). Due to their small size, delta smelt larvae are currently not salvaged or sampled effectively. Therefore particle modeling studies have been used to demonstrate that reverse flows can also result in high levels of larval entrainment (Nobriga and Kimmerer 2008, Kimmerer 2008). To protect delta smelt from the effects of reverse flows, limitations on OMR were incorporated by the USFWS into the OCAP Biological Opinion for delta smelt (USFWS 2008).

Recent analyses correlating SWP and CVP salvage with population indices show an estimated loss rate of migrating juvenile Chinook salmon of 10% or less, depending on pre-screen mortality (Kimmerer 2008). From a population perspective, this calculated loss rate at the export facilities is a significant element of direct anthropogenic mortality. Similar analyses for delta smelt show that pre-spawning adults, as well as larvae and early juveniles, may suffer substantial losses. A combination of the results for these life stages indicate delta smelt losses can be as high as 40% of the population throughout winter and spring (Kimmerer 2008). Ongoing analysis by the IEP in its evaluation of the POD asserts that substantial increases in winter SWP and CVP salvage occurred contemporaneously with the recent decline in pelagic species, suggesting that the SWP and CVP diversions played a role in the POD.

> Potential Stage 2 Actions for Water Diversions:
>
> Action 1: Continue participation in the Sacramento Valley-Delta Fish Screen Program to reduce entrainment mortality of juvenile fish by installing state-of-the-art fish screens on Sacramento River and Delta diversions
>
> Action 2: Continue ERP coordination with State and Regional Water Quality Control Boards, and IEP, studies and activities geared toward determining population dynamic consequences of fish entrainment.
>
> Action 3: Further investigation of role of E/I ratio as dominant factor in particle fate, in relation to entrainment of pelagic organisms (including eggs and larvae) in SWP and CVP pumps and other diversions. (E/I ratio range of .17 to .35). Salmon smolts may not be accurately captured by this model because their behavior likely makes their fate substantially different from neutrally buoyant particles such as pelagic species' eggs and larvae.
>
> Action 4: Continue monitoring pre-screen losses of delta smelt in Clifton Court to interpret the relation between salvage statistics and direct entrainment losses in the State Water Project

Studies also indicate that indirect causes of mortality to Delta's aquatic organisms may be due to hydrologic effects of the SWP and CVP pumps and flow barriers on Delta water quality. These facilities have been determined to cause changes in flushing time and transport routes, which results in alteration of salinity and dissolved oxygen levels in certain areas of the Delta (Monsen et al. 2007). Changes to water quality parameters, , are likely to affect habitat for aquatic organisms. Water exports may also reduce residence time, which affects the rate at which water is diverted from Delta channels, which affects primary and secondary production (DFG 2008b).

Currently, the SWP and CVP must comply with Water Board Decision 1641 (D-1641), which regulates the proportion of water that can be exported in relation to the amount of water entering the Delta in terms of E/I ratio. E/I ratios are permitted to be a maximum of 65% July through December, and a maximum of 35% February through June when Delta inflows are typically higher (NMFS 2009a). The E/I ratio is used in management of Delta aquatic resources because it measures the influence of SWP and CVP diversions (Newman and Rice 2002, Kimmerer and Nobriga 2008). Kimmerer and Nobriga (2008) evaluated E/I ratio as a predictor of entrainment probability for neutrally buoyant particles to represent larval fish, using a two-dimensional model and associated particle tracking model developed by DWR. The E/I ratio was found to be useful as a predictor of entrainment probability for organisms with limited mobility, although the model may be less applicable to more competent swimmers such as salmon smolts (Kimmerer and

Nobriga 2008). One criticism of using the E/I ratio to manage effects on Delta fish is that the actual volume of exports can increase substantially while maintaining the same overall E/I ratio. Better resolution of the relationship(s) between salvage and E/I ratio may be achieved if either the export or import term is held constant (NMFS 2009a). Due to their very large hydrodynamic footprint, reducing the negative effects of the SWP and CVP pumps cannot be accomplished through screening and will depend in part on the alternative conveyance chosen in the BDCP planning process.

On August 22 and September 11, 2007, the CALFED Science Program convened workshops to identify and discuss key scientific and technical issues pertaining to conveying Sacramento River water through or around the Delta to the SWP and SVP. Several important broad conclusions emerged:

- All conveyance options involve trade-offs and compromises
- Science can help select, but not choose, the "best" water conveyance alternative
- Clear objectives are critical to a thorough evaluation of conveyance alternatives
- A coastal ocean to watershed perspective is needed to effectively evaluate conveyance alternatives
- Through-Delta conveyance must be made to work effectively for decades into the future
- Adaptive management should be used in implementing any conveyance alternative
- Alternative financing must be found to fund the construction of an alternative conveyance system

III.B. Invasives

> Mission of the CALFED Nonnative Invasive Species Program: Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.
>
> *ERPP Strategic Plan, July 2000*

Non-native invasive species (NIS) have produced immense ecological changes throughout the Bay-Delta ecosystem by altering food webs and habitats, competing with native species for resources, and directly predating upon native species. NIS represents one of the biggest impediments to restoring habitats and populations for native species (CALFED 2000a). NIS have been introduced into the Delta over time via several mechanisms, the most common being discharge of ships' ballast water in ports. Invasive species are also transported from one place to another on recreational boats, "planted" for recreational or other purposes (e.g. largemouth bass), or released from aquariums into the environment. In 2006, the Water Board listed the Delta, upper San Joaquin River, and Cosumnes River on its 303(d) list as impaired for exotic species and is expected to formulate a TMDL program for these waterways within the next ten years (SWRCB 2007).

The *Delta Vision Strategic Plan* that incorporated some ideas regarding the control of harmful invasive species: Strategy 3.3, "Promote viable, diverse populations of native and valued species by reducing risks of fish kills and harm from invasive species." This strategy includes actions to control harmful invasive species at existing locations and minimize or preclude new introductions and colonization of new restored areas.

Much has been learned about NIS since 2000 from activities that have occurred under ERP, as well as from other planning and monitoring efforts. ERP has funded many projects since 2000 to try to control and educate the public about the threat of invasive exotic species. Some projects included a study on the feasibility of ships exchanging their ballast water out in the ocean rather than discharging ballast water into destination ports. While other ERP projects provided outreach geared toward educating recreational boaters and anglers, and individuals involved in the aquarium trade, on the threats posed by exotic species.

As part of the CALFED NIS Program, a Strategic Plan and Implementation Plan were developed, and the Non-Native Invasive Species Advisory Council (NISAC) was established. The NISAC coordinates and implements activities and projects that address NIS issues in CALFED's area of concern, and is currently promoting an invasive species prevention approach known as Hazard Analysis and Critical Control Points (HACCP). HACCP is a planning tool that originated with the food industry, but has been modified to include natural

Potential Stage 2 Actions for Non-Native Invasive Species:

Action 1: Continue implementing the CALFED NIS Strategic Plan and DFG's California Aquatic Invasive Species Management Plan (CAISMP) to prevent new introductions; limit or eliminate NIS populations; and reduce economic, social and public health impacts of NIS infestation.

Action 2: Continue funding the Department of Boating and Waterways *Egeria densa* mapping program. Also, begin investigating whether non-chemical means of control are possible.

Action 3: Continue research and monitoring programs to increase understanding of the invasion process and the role of established NIS in the Delta's ecosystems including:

- Investigate invasions by *Egeria* or *Microcystis* to newly restored areas.
- Investigate recreating habitats that have a high variability in abiotic factors (e.g. salinity, flows, depth, etc.) as a means of limiting the overbite and Asian clams and *Egeria.*

Action 4: Continue studies on the effectiveness of local treatment of zebra and quagga mussels using soil bacterium.

Action 5: Standardize methodology for sampling programs to measure changes in NIS populations over a specific timeframe.

Action 6: Collect and analyze water quality sampling data (e.g. salinity and water temperature) for correlation analysis between NIS distribution and habitats.

Action 7: Complete an assessment of existing NIS introductions and identify those with the greatest potential for containment or eradication; this assessment also would be used to set priority control efforts.

Action 8: Establish a program to monitor for new invasions of non-native wildlife, and develop responses to quickly contain and control them.

Action 9: Continue investigating potential parasite(s) as a means to control invasive clam or mussel populations.

resource management. HACCP identifies and evaluates potential risks for introducing "non-targets", such as invasive species, chemicals, and disease, during routine activities, and focuses attention on critical control points where "non-targets" can be removed.

As a separate effort, DFG issued its California Aquatic Invasive Species Management Plan (CAISMP) in January 2008. CAISMP's focus is on coordinating the efforts of State agencies to minimize the harmful ecological, economic, and human health impacts from aquatic invasive species. CAISMP provides a common platform of background information from which State agencies and other entities can work together to address the problem of aquatic invasive species, and identifies major objectives and associated actions needed to minimize these impacts in California. Depending on the species and the level of invasion, there are different management responses that could be pursued. The CAISMP includes examples of management responses to specific invasive species in the Delta. Some of the NIS that are of highest management concern in the Delta include:

Centrarchids. The most common centrarchids in the Delta are largemouth bass, smallmouth bass, spotted bass, bluegill, warmouth, redear sunfish, green sunfish, white crappie, and black crappie. The increase in non-native SAV has provided conditions that likely assisted with increased populations of these fish (Brown and Michniuk 2007). Centrarchids, which benefit from the use of SAV, can have a large negative impact on native fish through predation and competition (Nobriga and Feyrer 2007, Brown and Michniuk 2007).

Thus, the presence and distribution of centrarchids may be manipulated by managing environmental conditions such as water velocity, salinity, turbidity, and the extent of SAV. Management actions and the resulting impacts to centrarchids are being evaluated using DRERIP conceptual models for potential site-specific restoration.

Overbite Clam. The overbite clam (*Corbula amurensis)*, was first observed in 1986 and has since become extremely abundant in Suisun Bay and the western Delta (Carlton et al. 1990). This species is well adapted to the saltwater areas of the estuary and is largely responsible for the reduction of phytoplankton and some zooplankton in the Bay-Delta region (Kimmerer 2006). This loss of primary and secondary production has drastically altered the food web and is a contributing cause of the POD (IEP 2007b). Overbite clam have been shown to strongly bioaccumulate selenium (Linville et al. 2002); this could have reproductive implications for fish (e.g. sturgeon, splittail) and diving ducks that feed on overbite clam.

Asian Clam. The Asian clam (*Corbicula fluminea)*, was also introduced from Asia. It was first described in the Delta in 1946 (USGS 2001). This clam does not tolerate saline water. It is now very abundant in freshwater portions of the Delta and in the main stem of rivers entering the Delta. Ecologically, this species can alter benthic substrates and compete with native freshwater mussels and clams for food and space (Claudi and Leach 2000); however, Asian clam has not historically been viewed as significantly impacting the aquatic food web.

Because overbite clam and Asian clam have become so well-established in the estuary, there is currently no known environmentally acceptable way to treat or remove these invertebrates (DFG 2008a). The only apparent management action at this time is to determine whether the manipulation of environmental variables, such as salinity, can be used to manage their distribution in the estuary during certain months of the year. There is not consensus among scientists that manipulation of salinity would do much to affect the distribution of these clams or diminish their impacts on the estuarine food web. Many experts believe that the distribution and impacts invasive clams cannot be controlled (CALFED Science Program 2008).

Zebra Mussel. The zebra mussel (*Dreissena polymorpha)* is not yet in the Delta, but it is highly invasive and could become established if introduced there. This species poses threats to the ecosystem similar to those posed by overbite clam and Asian clam. Zebra mussels typically colonize at densities greater than 30,000 individuals per square meter. One of the most predictable outcomes of a zebra mussel invasion and a significant abiotic effect is enhanced water clarity linked to a greatly diminished phytoplankton biomass. For example, rotifer abundance in western Lake Erie declined by 74% between 1988 and 1993, the same time that an enormous zebra mussel population became established in that area. [Claudi and Leach 2000]

Quagga Mussel. Threats from the quagga mussel (*Dreissena bugensis)* are thought to be similar to those of the zebra mussel (Claudi and Leach 2000). Quagga and zebra mussels have very similar life history strategies, with the exception that quagga can live at greater depths (Claudi and Leach 2000). An interagency state and federal coordination team was established to coordinate management responses to the threat of further quagga spread in California. Three subcommittees were established: Outreach and Education, Monitoring, and Sampling/Laboratory Protocols. The quagga mussel scientific advisory panel, convened in April 2007, was charged with considering the full range of eradication and control options without respect to cost. Under the direction of DFG, the San Francisco Estuary Institute is performing a phased risk assessment of California waters in order to rank sites for further monitoring based on the likelihood that quagga or zebra mussels will become established.

There are a couple of relatively recent developments with respect to controlling both zebra and quagga mussels. A common soil bacterium, *Pseudomonas fluorescens*, has proven to be very effective in controlling populations, with a 95% kill rate at treatment sites. The bacterium produces a toxin which destroys the invasive mussels' digestive gland, killing them. Research has indicated that the bacterium does not harm untargeted native fish and mussel species (Science Daily 2007). Also, research is showing that a potassium salt solution may be an effective measure to control relatively localized and isolated infestations. It is possible that these control methods could be used to control zebra and quagga mussel populations, but they should be tested in small, isolated experiments.

Zooplankton. An extensive set of monitoring data from the IEP continues to show how introduced zooplankton species have become important elements of the Bay-Delta.

Eurytemora affinis was probably introduced with striped bass around 1880. Until recently, it was a dominant calanoid copepod in the estuary. In the last decade, however, *Eurytemora* has been replaced by two calanoid copepods introduced from China. It has been postulated that this replacement was a result, in part, of *Eurytemora*'s greater vulnerability to overbite clam grazing (Bouley and Kimmerer 2006).

Populations of the native mysid shrimp *Neomysis mercedis*, another form of zooplankton, began dwindling in the late 1970s. Its population decline was affected by competition with the smaller *Acanthomysis aspera*, an introduced mysid shrimp with similar feeding habits. The decline of the native shrimp species has been identified by the POD work team as one possible cause for the food web decline in the Delta (2007b). Synthesis of IEP's extensive modeling data could help assess trends in rates of invasion and different invasive species' populations.

Plants. Non-native aquatic weeds in the Delta pose serious problems to native flora and fauna. Research, monitoring, mapping, and control are needed for *Egeria densa*, water pennywort, Eurasian watermilfoil, parrot feather, and water hyacinth. These weeds flourish in a wide geographic area, sometimes in high densities, and are extremely harmful because of their ability to displace native plant species, harbor non-native predatory species, reduce food web productivity, reduce turbidity, or interfere with water conveyance and flood control systems. Areas with large densities of SAV have been implicated in reduced native fish larvae and adults (Grimaldo et al. 2004, Nobriga et al. 2005, Brown and Michniuk 2007). Restoration of habitats in intertidal areas must be designed and managed to reduce non-native SAV if conservation goals are to be met (Nobriga and Feyrer 2007).

The California Department of Boating and Waterways (CDBW) is the lead agency for the survey and control of *Egeria densa* and water hyacinth in the Delta. CDBW's control programs use two tools to determine coverage and biomass of these aquatic weeds: hyperspectral analysis and hydroaccoustic measurements. This technology has aided in the assessment of *Egeria densa* coverage and biovolume, which in turn was instrumental in evaluating the effectiveness of mechanical and chemical treatment; a key asset of the technology is that it yields a very rapid, verifiable characterization of the entire water column beneath the transducer (Ruch and Kurt 2006). While this technology has been helpful in controlling localized patches of SAV, ongoing efforts of CDBW's control program may not be successful over time because other aquatic weeds (such as Eurasian watermilfoil or curlyleaf pondweed) may replace *Egeria densa*. Both of these plants have different growth properties that may require different control techniques than those employed in the current control program (CDBW 2006).

Other non-native plants that have been the focus of ERP NIS-related activities include the control of *Arundo donax*, tamarisk, and purple loosestrife in terrestrial areas. Grazing of perennial grasslands has helped control the spread of some invasive weeds in some areas (Stromberg et al. 2007).

As mentioned earlier, NIS have become particularly problematic in the Delta as its management has reduced the historic variability in which native species evolved, in the interest of maintaining a common freshwater pool for water export and in-Delta agricultural use. It is hypothesized that periodic salinity intrusion into the Delta may help to reduce the abundance and/or distribution of certain harmful invasive species, and give native species a competitive advantage. The Pelagic Fish Action Plan (IEP 2007b) suggests the following actions to address invasive aquatic species in the estuary:

- Support California State Lands Commission's (CSLC) work to control ballast water, including DFG oversight of studies to determine the location and geographic range of NIS in the estuary and assessment of ballast water controls
- Assist CSLC, DFG, and others in the development of regulations or control measures for hull-fouling
- Support implementation of the CAISMP

III.C Water Quality Stressors

The Bay-Delta ecosystem receives a large variety of potentially toxic chemicals, including but not limited to pesticides from agricultural and urban runoff, contaminants discharged from wastewater treatment plants, mercury from gold mining and refining activities, selenium from agricultural practices, and other metals from different mining activities. Scientists must consider the synergistic effects of multiple contaminants when looking at environmental water quality. In addition, stressors such as high water temperatures and low dissolved oxygen levels threaten habitat suitability for a wide range of species.

There were two strategies in the *Delta Vision Strategic Plan* that incorporated ideas for improving environmental water quality in the Delta: Strategy 3.2, "Establish migratory corridors for fish, birds, and other animals along selected Delta river channels"; and Strategy 3.5, "Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals." These strategies include actions to improve fish migration corridors, control contaminants from urban runoff, discharges from wastewater treatment plants and irrigated agriculture, and establishing or implementing TMDL programs for mercury, selenium, and low dissolved oxygen.

Water Temperature. Water temperature is a key factor in habitat suitability for aquatic organisms. Unnaturally high water temperature is a stressor for many aquatic organisms, particularly because warm water contains less dissolved oxygen. Lower water temperatures can also hinder growth and distribution of some non-native species, thus reducing their predation, and competition for food and habitat with native species. Major factors that increase water temperature and negatively impact the health of the Delta are disruption of historical streamflow patterns, loss of riparian vegetation, reduced flows releases from reservoirs, and discharges from agricultural drains.

It may be difficult to manage water temperatures in the Delta, because Delta water temperatures are driven mainly by ambient air temperature. With expected localized warming of air temperatures due to regional climate change, particularly in summer, the problem of maintaining sufficiently low water temperatures in the Delta to sustain native species will become more problematic. While creating patches of riparian habitat may help cool water in small Delta sloughs through shading, and creating tidal marsh habitat may help cool water locally through nocturnal inundation of marsh plains, managers should seek to facilitate species' access to the water temperature conditions they require rather than focusing resources to achieve water temperatures in a specific area. Provided adequate floodplain and tidal habitat it is likely that individual species' distributions will change during certain times of the year, as they attempt to adapt to future conditions in the Delta.

Dissolved Oxygen. A sufficient level of dissolved oxygen (DO), is critical to the health and survival of aquatic species. When more DO is consumed than is produced—called oxygen depletion—fish and other aquatic organisms die. Oxygen depletion is exacerbated by warm water temperatures, since warm water holds less DO than cold water. Therefore, DO concentrations typically are lowest during the summer when river temperatures are warmer. Factors that can lead to low DO conditions include high water temperatures, insufficient water flow or circulation to adequately aerate water in channels, high loads of ammonia, and high levels of algal production transported from upstream areas (DFG 2008b). Low DO is a chronic problem in the lower San Joaquin River at the Stockton Deep Water Ship Channel (DWSC) and occasionally in the Suisun Marsh.

When DO concentrations are reduced to a level that is detrimental to aquatic organisms, hypoxia (oxygen depravation) occurs. Sublethal effects of hypoxia may include malformed or delayed fish embryonic development or altered balance of sex hormones during embryonic stages. Subsequent sexual development may also be affected. Studies show that hypoxia can cause endocrine disruption in adult fish (Wu et al. 2003, Thomas et al. 2007). Impairment at earlier life cycle stages may subsequently reduce the fitness and chance of survival of individuals in natural populations (Shang and Wu 2004).

There is evidence that low DO levels in the San Joaquin River DWSC create a migration barrier for fall-run Chinook salmon. In addition to impairment of fish production, migration, and juvenile rearing, low DO is a potential cause of mortality in other aquatic organisms (CALFED 2000a,b). Low DO levels may negatively affect the San Joaquin River's benthic and water column biotic communities and ecological processes (CALFED 2000a), with implications for the aquatic food web and quality of aquatic habitat. The Water Board adopted a phased TMDL program for the lower San Joaquin River in 2005. Additional studies toward development of a final TMDL that also addresses upstream areas will likely be initiated in 2010.

Studies funded by the ERP during Stage 1 identified three main contributing factors to the low DO levels in the DWSC: (1) loads of oxygen-demanding substances from upstream sources that react by numerous chemical, biological, and physical mechanisms to remove DO from the water column; (2) DWSC geometry impacts that add or remove DO from the water column, resulting in increased net oxygen demand; and (3) reduced flow through the DWSC that adds or removes DO from the water column, resulting in increased net oxygen demand (DFG 2008b, San Joaquin River DO Technical Working

Group 2007.) Low DO can also facilitate blooms of toxic blue-green algae or exacerbate negative impacts to organisms of other toxic chemicals in the water column. In addition to negative impacts to species in the vicinity of the lower San Joaquin River and DWSC, low DO appears to be a problem for aquatic species in the Suisun Marsh. Evidence of fish kills and early results of some studies indicate that low DO in water and drainage from managed wetlands are significant threats to aquatic species in the Suisun Marsh and Bay (DFG 2008b).

The Water Boards have assembled extensive data on the DO problem through its TMDL process. ERP Implementing Agencies will continue to work cooperatively with the Water Boards in updating Basin Plans and taking actions to meet mutual goals for improving DO conditions in the Delta.

> ERPP Vision for Contaminants: Ensure that all waters of mainstem rivers and tributaries entering the Bay-Delta, and all waters of the Bay-Delta, are free of deleterious concentrations of toxic substances.
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> *ERPP volume 1, July 2000*

Contaminants. Contaminants are organic and inorganic chemicals, and biological pathogens and metabolites that can cause adverse physiological response in humans, plants, fish and wildlife. Contaminants are found in many forms and have the ability to affect the ecosystem in many ways and at different life stages of individual species. They may cause acute toxicity (mortality) or chronic toxicity that results in growth, reproductive impairment, or other subtle behavioral effects that increase mortality. They can also affect the sustainability of healthy aquatic food webs and interdependent fish and wildlife populations. Some contaminants occur naturally at low levels, but with human disturbance, contaminants can be present in the environment at amounts or concentrations high enough to pose chronic life-altering effects.

Contaminant loadings from the Delta watershed have a significant effect on the Delta ecosystem. Pesticides applied in agricultural and residential landscapes, metals and toxins from highway and industrial facilities, mercury from historic mining activities, selenium from agricultural drainage, ammonia and other nutrients from sewage outfalls, all have a substantial impact on the living organisms in the Delta. Controlling these contaminants at their sources must be an important component of ecosystem restoration.

Pesticides and other chemicals. Herbicides and pesticides have potential toxicity to species in the Delta. Toxicity documented in shellfish, fish, mammals, and birds from the Bay-Delta and its mainstem rivers and tributaries is most frequently caused by runoff from agriculture, urban areas, and abandoned mines (CALFED 2000a). Genotoxic effects (changes to DNA) are considered among the most serious of the possible side effects from agricultural chemicals. If a chemical reacts with nuclear DNA, it can cause mutations or cancer in the exposed organisms. A chemical can also alter gene expression without altering an organism's DNA. The prolonged exposure to such chemicals may lead to effects such as heritable genetic diseases, carcinogenesis, reproductive dysfunction, and birth defects (Patel et al. 2007).

Potential Stage 2 Actions for Contaminants and Toxics:

Action 1: Provide technical and financial support to the SWRCB and CVRWQCB for TMDL implementation efforts that complement ERP goals:

- Continue developing BMPs to control methylmercury transport from restored wetlands
- Assist in Cache Creek Settling Basin improvements to reduce the amount of methylmercury entering the Yolo Bypass and Delta.
- Describe the impacts of upstream San Joaquin River algae loads on dissolved oxygen in the Stockton Deep Water Ship Channel

Action 2: Coordinate with the SWRCB, CVRWQCB, and SFRWQCB in their comprehensive five-year strategic work plan for the Delta, including TMDL implementation and miscellaneous water quality studies.

- Participate in a comprehensive monitoring program, including collecting and analyzing water quality data.
- Study the relationships between contaminant exposure and organism effects, and the magnitude of these effects in terms of population impacts.
- Investigate the possibility of synergistic (rather than additive) impacts of multiple contaminants on species.
- Study and describe the potential effects of ammonia on primary production and on aquatic species in the Delta.
- Conduct selenium research to fill data gaps to refine regulatory goals of source control actions, and determine bioavailability of selenium under several scenarios
- Investigate the impact of EDCs on species' health and reproduction

Since ERP implementation began in 2000, pesticide use has changed from organophosphate (OP) pesticides such as diazinon and chlorpyrifos to pyrethroid pesticides. Pyrethroid pesticides are less acutely toxic to vertebrates, but are more difficult to detect in water due to their tendency to adsorb strongly to sediment particles. Pyrethroid pesticides can have sublethal effects to aquatic vertebrates and lethal effects to invertebrates, and are believed to be one of the factors in the pelagic organism decline. Preliminary data suggest that both organophosphate and pyrethroid pesticides may have contributed to the higher incidence of toxic events in 2007, a dry year (IEP 2008). Higher incidences of toxic effects in dry years suggest that adequate flows to dilute the concentrations of pesticides and other chemicals to non-toxic levels may be important. Recent results from studies indicate that pyrethroids are causing significant toxicity to benthic organisms in 25-60% of tested waterbodies, particularly creeks and drainages. Other studies show that very low concentrations of OP pesticides may interfere with sensory cues needed for salmonid migration (DFG 2008b). Laboratory studies of salmon with sublethal exposures to pyrethroids show significant increased susceptibility to death from disease (DFG 2008b).

Contaminants toxic to fish and wildlife could be reduced by changing land management practices and chemical uses on urban and agricultural lands that drain into the Delta. The effects of these contaminants need to be viewed from an ecosystem perspective. However, in order to characterize ecosystem effects, individual components such as fate and transport, distribution and concentrations throughout the watershed, toxicity to individual species, and other parameters need to be defined and better understood (DFG 2008b). Sublethal impacts on fish and food web organisms' populations are difficult to document, since these impacts don't result in immediate mortality, assumptions about cause-and-effect must be made). However, monitoring shows that many Central Valley waterways contain high levels of agricultural and urban discharges. Predominant pesticides detected throughout Central Valley waterways were diazinon, chlorpyrifos, the herbicides simazine and diuron, and DDT breakdown products (CVRWQCB 2007).

Scientists are increasingly concerned about some contaminants because they act as endocrine disrupters in humans or animals. Diethylstilbestrol (the drug DES) and certain pesticides (e.g. dioxin, PCBs, and DDT) are known endocrine disrupters in humans. In addition, plasticizers such as polybrominated diphenyl ethers (PBDEs) used as a fire retardant in furniture, televisions, and computers may bioaccumulate in fish and result in sublethal toxic effects. Studies conducted as part of IEP's pelagic organism decline investigations showed some evidence of low frequency endocrine disruption in adult Delta smelt males, likely due to exposure to endocrine disrupting chemicals (EDCs) in the water column. In 2005, 6% of individuals were intersex, with immature oocytes in their testes (IEP 2008).

The length of time during which toxicity remains in the system is an important aspect of water quality contamination because of the potential for resident organisms' increased exposure and subsequent chronic effects. Delta sloughs, and the organisms that live in them, are particularly susceptible because of longer water residence time. Quarterly monitoring results show that several Delta sloughs receiving both urban and agricultural runoff, notably French Camp and Paradise Cut, had toxicity that persisted for up to 15 days (DFG 2008b). In light of the expressed management objective to enhance heterogeneity of habitats throughout the Delta during Stage 2 of ERP implementation, in part by increasing the residence time of water in channels and sloughs, toxicity will need to be evaluated in terms of individual contaminants and the species that may be affected. The ERP Implementing Agencies will therefore continue to work cooperatively with the Basin Plans and implement actions to improve water quality.

Ammonia. Ammonia appears in the aquatic environment as both a dissolved gas, which can be toxic to fish, and as un-ionized ammonia, also known as ammonium. Ammonium is a contaminant that is receiving more attention for its potential role in the decline of the aquatic food web. The availability of nitrate in the estuary is a key component of primary productivity, as phytoplankton requires uptake of nitrate to produce food for zooplankton and other species that fuel the aquatic estuarine food web. If phytoplankton do not uptake nitrate, primary production by phytoplankton may occur more slowly, and the food web is affected. Field measurements in enclosure experiments show that when concentrations of ammonium greater than 4 micromoles per liter are present in some portions of the estuary, the uptake of nitrate by phytoplankton is inhibited, thereby causing low nitrate use most of the year (Dugdale et al. 2007). One consequence is that the nitrogen component of the ammonium produces toxic blue-green algae blooms rather than diatoms, since diatoms grow faster in the presence of nitrate than ammonium (Swanson 2008 and Kimmerer 2008, see notes).

Advanced secondary treatment at wastewater treatment plants could convert ammonium to nitrate, making all forms of dissolved inorganic nitrogen available for primary production. This could result in substantial increases in potential phytoplankton biomass and primary production in Suisun Bay, western Delta and San Francisco and San Pablo Bays during spring and perhaps summer (Dugdale et al. 2007). One of the largest uncertainties that remain, however, is whether this advanced treatment would yield enhanced primary production in the system, and even if it did, whether this productivity would be consumed by invasive clams before it could be consumed by zooplankton.

Mercury and methylmercury. Mercury is a toxic metal that has no known beneficial biological function in fish, birds, or mammals. Historical mercury mining in the Coast Range and mercury use associated with gold mining in have left an environmental legacy of pervasive mercury contamination in many northern California watersheds. The dominant forms of mercury in mining wastes are inorganic (cinnabar and quicksilver), but under certain environmental conditions. A small proportion of the inorganic mercury is converted by microbial activity to methylmercury, a more toxic, organic form of mercury that readily bioaccumulates in aquatic and terrestrial food webs. Because methylmercury increases in concentration with each step up the food chain, the species at greatest risk to exposure are top predators including bass, sturgeon, and fish-eating birds.

Some habitats more readily facilitate mercury methylation, resulting in greater wildlife exposure. These habitats include high tidal marsh, seasonal wetlands, and floodplains. Perennial aquatic habitats and low tidal areas have relatively lower methylation potential. A working hypothesis that explains these variations recognizes that higher methylmercury habitats have extended dry periods in which soil and sediment completely dry out, which raises the possibility that oxidation of mercury during the dry periods leads to higher concentrations of reactive mercury during subsequent flooding, when sulfate- or iron-reducing bacteria facilitate methylation. The oxidation of carbon and sulfur compounds during dry periods may also play an important role in increasing mercury methylation rates during subsequent flooding.

Before ERP implementation began in 2000, a favored working hypothesis among mercury scientists was that the Delta would be a zone of net mercury methylation. Since then, water and fish monitoring indicate that the central Delta is actually lower in methylmercury concentration than tributary areas (the Yolo Bypass and Cosumnes and San Joaquin Rivers). Preliminary mass balance calculations indicate a net loss of methylmercury in water as it flows through the Delta (CVRWQCB 2006). This methylmercury loss may be caused by breakdown of methylmercury from exposure to light and sedimentation. Another possible contributing factor is that high concentrations of reduced sulfur may make reactive forms of mercury less available to the methylation process. Mercury demethylation processes may be important in the Delta, although additional study is needed to quantify these processes. [Alpers 2007].

The current regulatory environment for mercury includes developing a TMDL for mercury and methylmercury. A TMDL-based Basin Plan Amendment was approved by the Water Board for San Francisco Bay in 2006, and a TMDL-based amendment is now under development for the Delta. If current regulatory trends continue, TMDLs for mercury and methylmercury in San Francisco Bay, the Delta, and their tributaries will be key drivers of mercury research, monitoring, and remediation over the next several years (Alpers 2007). Improvement of the sediment trapping efficiency of the Cache Creek Settling Basin was identified as one of the most cost-effective ways to reduce loads of mercury and methylmercury in the Yolo Bypass, one of the largest contributors of these contaminants to the Delta and areas downstream to San Francisco Bay (CVRWQCB 2006).

Reducing methylmercury production is key to reducing its concentrations in Delta waterways. Management tools to minimize methylmercury formation include:

- Participating in the Water Boards TMDL programs for mercury and methylmercury in the Delta
- Developing and implementing TMDLs in areas upstream of the Delta to reduce loads of organic and inorganic mercury entering the Delta from tributary sources
- Developing BMPs to control the production of methyl mercury at aquatic habitat sites, and to control the transport of methyl mercury into the system.

There are a number of uncertainties which managers must be mindful of, both in terms of the anticipated impacts of regional climate change from global warming and the desired recovery of species through restoration of ecological processes and habitats in the Delta. Changes in water clarity associated with changes in hydrology will likely affect the efficiency of mercury photodemethylation. For example, an increase in turbidity or dissolved organic carbon will decrease light penetration, which will decrease the rate of photodemethylation. Therefore, ecosystem restoration projects that might cause increased turbidity should be carefully monitored for impacts on net mercury methylation and bioaccumulation. There is also a possibility that future changes in nutrient management and hydrology could result in a significant increase in primary production that will be of great benefit in reversing the pelagic organism decline. Associated changes in concentrations of dissolved and particulate organic matter and their complex interactions with mercury methylation processes are difficult to predict. Nevertheless, if methylmercury production rates were to remain constant or increase at a slower rate than the increase in primary productivity, then concentrations of methylmercury could decline at the base of the food web because of biodilution, which would likely result in lower levels of mercury bioaccumulation throughout the food web. Potential increases in algae would need to be controlled so as not to occur in areas already experiencing problems with dissolved oxygen, because algal decay consumes oxygen (Alpers 2007).

There is a general concern that increased concentrations of methylmercury in water, sediment, and biota might result from any of several types of actions being taken or contemplated by the ERP, including wetland and floodplain habitat restoration in the Bay-Delta and changes in the fresh water conveyance across the Delta. In accordance with the TMDL under development for the Delta, ongoing studies at the Yolo Bypass Wildlife Area include the development of BMPs to manage new habitats in ways that avoid or minimize potential methylation of mercury at restoration sites. In general, potential mercury methylation from actions to create or enhance important aquatic habitats, or from other actions geared toward increasing turbidity or primary production, must be weighed against the negative impacts associated with not restoring critical aquatic habitat types and recover species.

Selenium. Selenium is a naturally-occurring metal, but it is mobilized from soil and enters surface water from irrigation return flows and groundwater. Refineries in the San Francisco Bay area also contribute selenium to the ecosystem. Selenium is present with salts in the western San Joaquin Valley. In general, when it reaches a concentration of 5-10 micrograms per gram, it becomes toxic to some aquatic species (e.g. overbite clam) and the species that consume them. Ecological effects of selenium are largely governed by dry season and low flow conditions. This is when selenium concentrations are highest. Documented effects of selenium toxicity include deformities in white sturgeon larvae and inability of white sturgeon eggs to hatch. Reproductive effects of selenium on white sturgeon is highest in Suisun Bay during fall and early winter, coinciding with the "first flush" rain event. It is believed that mature splittail may also be adversely affected by selenium (Luoma 2008).

Changes in Delta infrastructure and conveyance could result in different transport routes, source mixtures, and flushing times of water and contaminants within the Delta (Monsen et al. 2007). Conveying fresh Sacramento River water around the Delta, for example, could result in a higher amount of San Joaquin River water flowing into the estuary. The San Joaquin River currently provides the bulk of selenium to the estuary. A change in water conveyance would likely require management strategies to reduce the potential for selenium bioaccumulation rates in Delta species and downstream in San Francisco Bay.

Further participation with the Water Boards is needed to implement TMDLs for selenium, including financial support. Of particular importance are:

- Conducting selenium research to fill data gaps to refine regulatory goals regarding source control actions and to determine bioavailability of selenium under several scenarios
- Expanding and implementing source control, treatment, and reuse programs, including real-time management, if appropriate
- Coordinating with other programs; including San Joaquin Valley Drainage Implementation Program, and the CVPIA for retiring lands with drainage problems that are not subject to correction in other ways
- Supporting implementation of the TMDL for selenium in the San Joaquin River watershed

Other metals such as copper and nickel also are being investigated for their potential effects on species. Dissolved copper concentrations are elevated in the estuary where its toxic effects are not buffered by organic ligands like in the more saline waters of the Bay (Werner et al. 2008). Nickel, primarily from urban runoff and wastewater treatment plants, may also have effects on species. Synthetic organometallic compounds such as Tributyltin (TBT), used in antifoulant paints for boats, are highly toxic to aquatic invertebrates (Werner et al. 2008).

Consistent water quality monitoring is essential to identifying and reducing the impacts of contaminants to aquatic ecosystems.

Key steps in successfully improving Delta water quality include:

- Developing a regulatory approach that can expeditiously address emerging contaminant problems as they are identified
- Implementing advanced treatment at wastewater treatment plants discharging to Delta source waters and implement source control programs for their service areas
- Implementing BMPs and source control necessary to meet water quality objectives
- Implementing BMPs for agricultural discharges to reduce pesticides and other contaminant loads, and for all agricultural activities
- Developing land use policies that ensure adequate protection of waterways from non-point source contamination, including mandatory buffer areas between urban or agricultural development, and waterways to allow percolation of run-off
- Encouraging infiltration into the soils at or near points of precipitation to reduce flood flows and, slow the release of water into streams. Stormwater management and infiltration must become a high priority throughout the Delta watershed in order to manage flood risks and prepare for the potential effects of climate change

The ERP Implementing Agencies will continue to work cooperatively with the Water Boards to update Basin Plans and implement actions to improve water quality. The Water Boards have extensive data on water quality in the Delta through their TMDL processes and the Irrigated Lands Conditional Waiver program (DFG 2008b). ERP Stage 1 implementation included funding for various water quality studies, which showed a trend toward reducing pesticide use and developing BMPs for pesticide use and agricultural runoff control. If pesticide use trends continue downward, and BMPs become more widely used, then impairments in water quality from pesticides are likely to decrease in both distribution and severity (DFG 2008b). It is necessary to monitoring and analysis BMPs to assure their use, determine resource response, and identify what modifications to BMPs may be necessary.

> ERPP Strategic Goals relating to Species:
>
> Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in the Bay-Delta estuary and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.
>
> Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals.
>
> *ERPP volume 1. Julv 2000*

IV. Species

Despite ERP's expressed intent to continue working toward species' recovery by focusing on restoring environmental processes, creating suitable habitat areas, and reducing stressors, rather than taking a species-by-species approach to conservation managers must be mindful keep all available options open. Diversifying the array of tools that managers have available to them to improve the resilience of species in a changing environment will reduce the risks associated with uncertainties. However new literature suggests that species-by-species approaches to conservation become particularly important when a system has been altered so drastically that it is unlikely to recover, despite managers' best attempts to address shortcomings in broad ecosystem processes.

There were two strategies in the *Delta Vision Strategic Plan* that incorporated some ideas regarding improving species' ecological health: Strategy 3.2, "Establish migratory corridors for fish, birds, and other animals along selected Delta river channels"; and Strategy 3.3, "Promote viable, diverse populations of native and valued species by reducing risks of fish kills and harm from invasive species." These two strategies list actions including improvements in physical habitats and connectivity between them as well as addressing stressors such as diversions and invasive species.

The CALFED MSCS to meets the requirements of ESA, CESA, and NCCPA. The MSCS identified and evaluated 244 special status species and 20 NCCP communities that could be improved by CALFED program implementation. Conservation goals for each species and community were identified as well. Species goals are:

- Recovery of 19 evaluated species ("R species")
- Contribute to recovery of populations for 25 evaluated species ("r species")
- Maintain existing levels of populations and habitats for 155 evaluated species ("m species")

Potential Stage 2 Actions for Species:

Action 1: Investigate the feasibility and sustainability of establishing broodstocks or refuge populations of species at high risk of extinction.

Action 2: Investigate whether individual species' respective range of distribution can be extended or changed, so they may persist in changing future conditions

Action 3: Investigate whether species' genetic material can be manipulated to improve their resilience in changing future conditions

Action 4: Preserve species' genetic material in seed banks, and utilize it to maintain genetic diversity within species populations in the future

Action 5: Continue monitoring individual species' status and trends using new and existing data sets

Action 6: To the extent possible, limit interaction between wild and hatchery-reared fish.

Some of the ERP Stage 1 and Science Program research findings that have increased our understanding of specific species since 2000 include, but are not limited to:

Delta smelt

- Delta smelt distribution appears to be influenced mostly by turbidity, with salinity and temperature as secondary considerations. Delta outflow has two distinct but related impacts: low outflow shifts preferred habitat closer to the pumps and contributes to entrainment, and decreases the extent and quality of delta smelt habitat.
- Researchers have developed reliable methodologies for improving Delta smelt spawning efficiency and in-vitro fertilization in the laboratory. As a result, the number of hatched larvae per female in the laboratory has been increasing while natural smelt populations have been declining.
- Spawning success appears to be timed to lunar periods within a water temperature range of about 15-20°C; longer spawning seasons in cooler and wetter years produce more cohorts and higher numbers of delta smelt.
- In response to an observed trend of declining size and viability in delta smelt over the last ten years, researchers hypothesize that export pumping operations in late winter and early spring may entrain larval offspring of the largest and healthiest early-spawning individuals.
- Life stage population models suggest that population growth rates are mostly influenced by factors operating between juvenile and pre-adult life stages, or during the summer months with growth-associated recruitment failure as the most likely process affecting the delta smelt population. Density dependence in late summer, when juveniles are most abundant but suitable habitat is decreasing and competition with other planktivorous fishes is increasing, is believed to limit the number of juveniles surviving to the adult stage.

Chinook salmon

Much of what has been learned about the four runs of Chinook salmon (winter, spring, fall, and late-fall), as well as steelhead, is the result of genetic research and management programs that occurred in upstream areas and at hatcheries. Within the Delta EMZ, ERP funded projects studied the migration and movement of adult and juvenile Chinook salmon. Findings include:

- Some tagged adult fall-run Chinook appeared to roam the Delta before committing to one river system. Behavior was highly individualistic, resulting in variable migration times and distance traveled. Most salmon tagged on the San Joaquin River exited the Delta on the Sacramento River, indicating that they may be using the Delta Cross Channel and Georgiana Slough to cross over to the Sacramento River.
- Radio telemetry was used to analyze the migratory behavior of juvenile salmonids, and demonstrated that the fish utilize the middle portions of the channels during migration, and that the fish move with the flood tide and then migrate on ebb tides.

Green and white sturgeon

Much of what has been learned about green and white sturgeon is the result of studies and activity that occurred in areas upstream of the Delta EMZ. Within the Delta EMZ, ERP funded projects studied the effects of selenium on the health and reproduction of white sturgeon. Some findings include:

- High variation in selenium levels could be linked to seasonality, and specifically the seasonal presence of overbite clam in the Delta and Suisun Bay.
- Microinjection of over 15 milligrams per gram of selenium in white sturgeon larvae significantly increased mortality and abnormality rates (including edema and spinal deformities).

Splittail

- Splittail are obligate floodplain spawners, and can maintain healthy population levels due to their high fecundity on inundated floodplains, even if floodplain inundation hasn't occurred in several years due to dry conditions.

Terrestrial Species Habitats

While many ERP activities focused on fish and aquatic resources, the ERP restoration projects also funded numerous studies, land acquisitions, and habitat creation designed to benefit terrestrial species and plant communities. Some of these findings and activities include:

- Genetic studies on the western pond turtle, foothill yellow-legged frog, California tiger salamander, and western spadefoot toad yielded information on distinct lineages and management units and developed management recommendations.
- A study on the Yellow Warbler, Common Yellowthroat, Black-headed Grosbeak, and Tricolored Blackbird found little evidence of fine-scale population structure or isolated populations, and recommended that each species be managed individually. In addition, observations suggest that there are two distinct populations of Tricolored Blackbird that might be separate subspecies.
- Acquisition of fee or easement title of lands along the Stanislaus and San Joaquin Rivers, and restoration of riparian and floodplain habitat for riparian brush rabbits and riparian woodrats.
- Acquisition and management of a 320-acre site in Yolo County supporting alkali vernal pools, Crampton's tuctoria, Colusa grass, alkali milk-vetch, and several other rare plants, animals, and vernal pool species. The grass-dominated upland areas provide foraging habitat for Swainson's Hawk and western burrowing owl.

Species' population viability is generally assessed through four factors: (1) abundance or number of individuals; (2) productivity or reproductive rate; (3) spatial distribution; and (4) genetic diversity. All of these factors need to be kept in mind as managers look for tools they can utilize to increase species' resilience in light of the Delta's unpredictable and ever-changing ecological conditions. Some hatcheries are operated with the goal of producing a certain number of individuals; others are operated to maintain genetic diversity among the fish that are produced. Other tools under development include: establishment of captive broodstocks of winter-run Chinook and delta smelt as a hedge against catastrophe that could lead to their extinction or extirpation in the Delta; extending species' range of distribution so they can adapt to changing temperature or climate conditions in their present range; preservation of genetic material in "seed banks"; and genetic manipulation to improve individuals' and species' resistance to new conditions.

Managers must exercise extreme caution, however, in utilizing some of these tools. Many of them, particularly some of the more recent tools under development, have not been tested in the Delta or anywhere else, and may yield significant unanticipated consequences. Therefore, it is important that managers also consider the level of uncertainty and risk associated with some of these proposals, as well as whether an action can be "reversed" in the case of unexpected negative outcomes, and ensure those considerations are weighted into management decisions and actions. These considerations are described further in Section 3, within the discussion of ERP adaptive management.

SECTION 3: IMPLEMENTATION

This section briefly describes how ERP Implementing Agencies will proceed with Stage 2 implementation of the Delta EMZ element of the overall Conservation Strategy. First, it establishes the relationship of the ERP and its Implementing Agencies with the new Delta Stewardship Council. Next, it describes proposed Stage 2 implementation in terms of the principle of adaptive management, including both the development and use of conceptual models to evaluate restoration actions and the monitoring of restoration actions to judge progress toward ecosystem objectives and assess overall program performance.

Relationship to Delta Stewardship Council

The ERP Implementing Agencies currently have a framework through which they implement the ERP. Management-level representatives of the agencies, called ERPIAMs (ERP Implementing Agency Managers), meet regularly to discuss ERP program priorities in light of annual findings related to program milestones, develop annual program plans and proposal solicitation packages reflecting those priorities, select which grant proposals to fund, and consider amendments to ongoing ERP-funded projects. This existing framework will be utilized as ERP implementation continues in the Delta EMZ and throughout the ERP Focus Area.

The ERP Implementing Agencies participated in the development of the ecosystem component of the Delta Vision Strategic Plan. The Delta Vision Blue Ribbon Task Force recommended that the ERP Conservation Strategy, which serves as ERP's "single blueprint" for ecosystem restoration in the Delta EMZ, be the foundation of what will ultimately become the ecosystem component of several regional plans including the BDCP; and will meet the two co-equal goals of ecosystem health and water supply reliability.

To the extent that the ERP Delta EMZ Conservation Strategy priorities and funding recommendations involve actions in the Delta, the ERPIAMs will periodically present their recommendations for ERP implementation actions to the Delta Stewardship Council and Delta Science Program to discuss consistency with the Delta Plan and other planning efforts. Council recommendations will be incorporated into ERP implementation actions to the extent that they forward both Delta Plan and ERP goals in a consistent manner.

Adaptive Management and Monitoring

Adaptive Management Process. Due to the uncertainties in the function of the Delta ecosystem presented throughout this document, the effects of restoration and management actions cannot always be accurately predicted. Restoring and managing the Bay-Delta ecosystem requires a flexible management framework that can generate and incorporate new information and adapt to changing conditions. Adaptive management is generally defined as a rigidly structured and repetitive process of making the best possible decisions in light of uncertainty, with a goal of reducing this uncertainty over time through continuous monitoring of the system. The adaptive management process described in the ERP Strategic Plan (CALFED 2000c) provided a framework that included numerous assessments and feedback loops to ensure that management decisions are based on the best and most current information, and conceptually this framework is still relevant to ERP program management today.

However, implementation of ERP over the course of Stage 1 has demonstrated some aspects of the ERP's adaptive management process that need further attention in order to make the overall process more functional. Specifically, while the ERP has been successful at defining the structured decision-making process for activities in the Delta EMZ, there remains a need to begin utilizing this process and to initiate the continuous monitoring and data synthesis that is intended to reduce some of the uncertainty in the system and ultimately result in more informed decisions over time.

Atkinson et al (2004) provides more detail on the adaptive management process, particularly with respect to the monitoring and data synthesis that is so critical to its effectiveness. It provides a useful reference for documenting what ERP has accomplished during Stage 1 and what activities need to be undertaken during Stage 2 to make the adaptive management process more useful in gathering and synthesizing new information and more responsive to changes in the system over time.

Figure 6 provides a flowchart of the ERP's adaptive management feedback loop. The ERP foundational documents, which identified the rationales for the program's goals, objectives, and targets, were based on scientific principles and the best information available at the time. It is only more recently, however, that conceptual models were generated for Delta resources (these are further described below in the discussion of the Delta Regional Ecosystem Restoration Implementation Plan, or DRERIP). Ongoing management of the ERP during Stage 2 will therefore be more focused on using and updating those conceptual models to refine monitoring approaches and the design of ecological reserves.

As one example, the ERPP identified acreage targets for different natural community types and habitats in the Delta EMZ, and basically split those target acreages equally among the four Delta EMUs to generate acreage targets for each EMU. As the program has been implemented in the Delta over the course of Stage 1, it has become apparent that this arbitrary split of those acreages among the EMUs does not make sense ecologically, largely due to the different ecological conditions within each EMU, and also that some of the initial thinking on the desired habitat types to be created has changed. This has resulted in efforts to better define the attributes of physical habitats that are desired in the Delta EMZ (e.g. Appendix D), and points to the need to refine habitat targets for the four EMUs to better align with the resources and other considerations of feasibility (e.g. land elevations) in each (Figure 4).

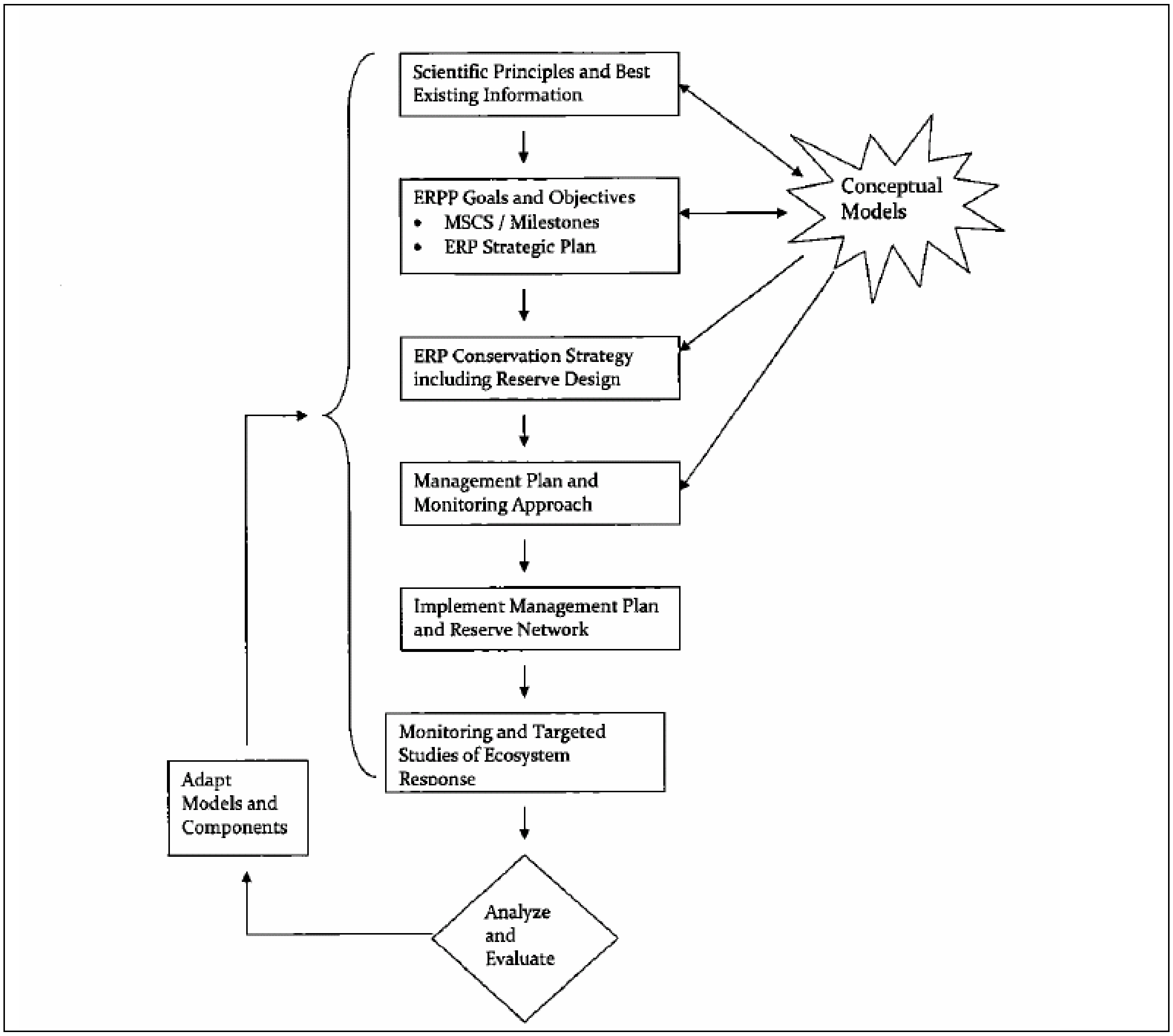

Figure 6: ERP's Adaptive Management Framework. Adapted from Atkinson et al. 2004

DRERIP Conceptual Models and Action Evaluation Process. An important activity undertaken by ERP during Stage 1 was an effort known as the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). The DRERIP effort included the formation of a team of scientists, the Adaptive Management Planning Team (AMPT), and culminated in a suite of analytical tools for conducting scientific evaluations of potential ecosystem restoration actions and other resource management activities for the Delta (Appendix E). These tools, including conceptual models and an associated evaluation protocol, are well suited to evaluate potential actions at preliminary and in-depth levels, in cases where quantitative models are not available. The conceptual models are either complete or nearing the final stages of scientific peer review, and capture the most recent understanding of ecological processes, habitats, stressors, and species interactions within the system. The associated evaluation protocol allows for transparency, standardization, and documentation of conservation decisions. The model outputs are useful for identifying the range of effects – positive and negative, intended and unintended – and gauging the magnitude, predictability, and reversibility of those anticipated effects.

These tools also set the foundation for adaptive management by identifying where there are science needs and which actions are suitable for hypothesis testing.

The fundamental approach to DRERIP modeling is an "action-approach-outcome" format that uses deterministic models of ecosystem components linked together with cause-and-effect relationships of interacting variables and outcomes. There are numerous drivers and intermediate outcomes leading to ultimate outcomes in a DRERIP analysis. Using conceptual models to improve understanding of the overall environment, and the relationships between its components, results in better predictability regarding the magnitude and certainty of the effects of potential restoration actions. These effects include positive or negative effects that may or may not be anticipated, thereby providing for scientifically defensible courses of action for restoration or land and water management.

Evaluating potential restoration actions in a conceptual framework also helps to identify important gaps in data or ecological understanding. A related product of the DRERIP effort was the development of the protocol for evaluating potential restoration actions using the conceptual models. This protocol uses an 11-step process to assign a restoration action to an adaptive management category (i.e. discard the action, or pursue it as either targeted research, a pilot/demonstration project, or full-scale implementation) based on the scale of the action, potential positive and negative outcomes (and the magnitude, certainty, and risk associated with potential negative outcomes), whether the action can be reversed, and overall opportunity for learning. The 11-step evaluation process is included as Appendix E. This evaluation protocol is particularly important because it allows for thorough documentation of rationales for management and project-funding decisions, which in turn facilitates the timely revision of assumptions and incorporation of new scientific information into the models. It also promotes transparency in decision-making to policymakers and the interested public.

Monitoring of Restoration Actions and Program Performance. Atkinson et al. (2004) discusses three main components of a monitoring program: implementation (compliance) monitoring; effectiveness monitoring; and targeted studies.

Implementation monitoring for the ERP has been occurring over the course of Stage 1. Documents detailing the status of plan implementation include, but are not limited to, annual Milestones reports and the End of Stage 1 report. Information from these reports is largely compiled from mandatory reports submitted by recipients of ERP grants, and tracks the number of acres acquired and/or preserved, as well as the number of grants issued and the total amount of funding dedicated to projects in the Delta EMZ. Other compliance documents that could be generated could include reports summarizing management activities (e.g. update on the status of invasive species control activities under the CAISMP).

Effectiveness monitoring provides information on how successful the ERP is at meeting the biological goals and objectives called out in ERPP Volumes 1 and 2 and the Strategic Plan. Although recipients of ERP grants are required to collect some monitoring data and compile this into quarterly reports, synthesis of this information has varied, depending on what is being monitored. Over the course of Stage 2 implementation, more attention will be dedicated to collecting and synthesizing a longer-term suite of quantitative data on native and invasive species, flows, vegetative structure and density, and contaminants, in order to determine status and trends of resources, species populations, and stressors, and the effects of management actions on each of these.

Directly related to effectiveness monitoring, targeted studies will continue to improve knowledge about the system and management actions. The aforementioned DRERIP conceptual models capture the most recent state of knowledge about specific aspects of the system, and also identify areas of uncertainty or data gaps. The models and associated action evaluation process will regularly be used to generate topics for short-term targeted study, with the intention of reducing uncertainty over time. New information from these targeted studies, and the creation and synthesis over time of longer-term monitoring data sets, will be critical in periodically updating the conceptual models and evaluation process.

There are several efforts underway to develop monitoring metrics and performance indicators for the Delta, which are in the process of being integrated into a comprehensive monitoring program involving numerous entities. The CALFED Science Program is developing a new monitoring framework which will combine data from multiple monitoring programs, identify gaps in these programs, and regularly assess this data to see how the system is changing in response to changes in infrastructure and water management, ecosystem restoration activities, and variability due to climate change or ocean processes. As part of the attempt to define appropriate monitoring metrics and project and program performance measures, ERP personnel will continue to coordinate with the CALFED Science Program's ongoing performance and tracking activities. Some of the monitoring programs that will be integrated include, but are not limited to:

- ERP staff currently is assessing the needs for monitoring and performance measures in conjunction with end of Stage 1 progress assessments and species recovery planning. Monitoring and performance measures development is linked with the information contained within the DRERIP conceptual models.
- CVRWQCB is conducting a comprehensive evaluation of numerous water quality parameters as part of the State and Regional Boards' Bay-Delta Strategic Work Plan.
- Other miscellaneous data collection efforts, including those the IEP is conducting for the POD investigations and monitoring data from CVPIA and its associated programs.

In terms of monitoring, Atkinson et al. (2004) calls out three "phases" of monitoring that occur, with more specific monitoring questions and variables as the program progresses through the phases. Phase 1 involves inventorying resources and identifying relationships. Because much information was collected during Stage 1 implementation, the types of questions answered during the first phase of progressively specific monitoring can be answered (e.g. distribution and status of species in the planning area, what specific habitats a species is associated with, and stressors on the species and habitats). In fact, much of the information collected during Stage 1 (as well as from other available data sources) was used to generate the DRERIP conceptual models.

ERP is currently in the second phase of its monitoring efforts (pilot testing of long-term monitoring and resolving critical management uncertainties) where the monitoring objectives need to be more specific. For this second phase, and the third and final phase (implementing long-term monitoring and adaptive management), long-term objectives would likely fall into:

- Status and trends questions – estimated abundance of a species, whether this is within bounds of baseline range of variation, and if not, whether it's increasing or decreasing
- "early warning of problem" questions – whether the areal extent of a species' habitat is changing, e.g. abundance or proportion of area occupied by competitors or predators
- "targeted study" questions – e.g. the rate at which competition or predation has a measurable impact on reproductive success of a species, and which habitat restoration techniques result in species' reproductive success rate at or above level sufficient to sustain populations.

ERP Science Review. To ensure scientific integrity of developing, reviewing, and implementing its Conservation Strategy for the Delta EMZ during Stage 2 of implementation, the ERP is coordinating with the CALFED Science Program, and the Interagency Ecological Program (IEP), among others, to obtain the most current data, most robust analytical tools, and soundest scientific oversight. The ERP will continue to work with the CALFED Science Program, as part of the overall framework of Delta Stewardship Council governance that will be developed to implement the comprehensive Delta Plan, to convene a standing panel of scientists to review certain topic areas of aspects of the program upon request.

The ERP Implementing Agencies have determined that the DRERIP conceptual models and evaluation process represent the acceptable scientific standard for ERP planning and implementation purposes, as well as the standard by which they would judge proposed activities by other entities. They advocate the use of these models as the tools necessary to understand the condition and function of the system, assess how potential actions would affect it, and develop and implement prescriptions for ecosystem restoration and/or management. The conceptual models and associated evaluation protocol allow for transparency into the thought process, standardization, and documentation of conservation decisions, which will be particularly important when sharing information with the interested public.

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Appendix A - Acronyms and Abbreviations

AFRP	Anadromous Fish Restoration Program
AFSP	Anadromous Fish Screen Program
ASIP	Action-Specific Implementation Plan
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Delta Estuary (including Suisun Marsh)
BDCP	Bay-Delta Conservation Plan
BMPs	Best Management Practices
BO	Biological Opinion
CAISMP	California Aquatic Invasive Species Management Plan
CDBW	California Department of Boating and Waterways
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
CSLC	California State Lands Commission
CVJV	Central Valley Joint Venture
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVRWQCB	Central Valley Regional Water Quality Control Board
D-1641	State Water Resources Control Board Decision 1641
DCC	Delta Cross Channel
DDT	Dichlor-diphenyl-trichlorethylene
DES	Diethylstribestrol
DFG	California Department of Fish and Game
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DRMS	Delta Risk Management Strategy
DSWG	Delta Smelt Working Group
DVC	Delta Vision Committee
DWR	California Department of Water Resources
DWSC	Deep Water Ship Channel
E/I	Export/Inflow ratio
EIS/EIR	Environmental Impact Statement/Environmental Impact Report
EMU	Ecological Management Unit
EMZ	Ecological Management Zone
ERP	Ecosystem Restoration Program
ERPP	Ecosystem Restoration Program Plan
ESA	Endangered Species Act
EWA	Environmental Water Account
HACCP	Hazard Analysis and Critical Control Points planning
IEP	Interagency Ecological Program
μmol/L	micromoles per liter
Legal Delta	Confluence of the Sacramento and San Joaquin Rivers (as defined in Water Code section 12220)

MSCS	Multi-Species Conservation Strategy
NCCP	Natural Community Conservation Plan
NCCPA	Natural Community Conservation Planning Act
NEPA	National Environmental Policy Act
NIS	Non-native Invasive Species
NISAC	Non-native Invasive Species Advisory Council
NOAA Fisheries	National Marine Fisheries Service
OCAP	Operations Criteria and Plan
OMR	Old and Middle Rivers
OP	Organophosphate (pesticides)
PBDEs	Polybrominated Diphenyl Ethers
PCBs	Polychlorinated Biphenyls
POD	Pelagic Organism Decline
PPIC	Public Policy Institute of California
PWA	Phillip Williams Associates
ROD	Record of Decision
RPA	Reasonable and Prudent Alternative
RWQCBs	Regional Water Quality Control Boards
SacEFT	Sacramento River Ecological Flows Tool
SAV	Submerged Aquatic Vegetation
SBDS	State of Bay-Delta Science Report
SMSCS	Suisun Marsh Salinity Control Structure
SWP	State Water Project
SWRCB	State Water Resources Control Board
Task Force	Delta Vision Blue Ribbon Task Force
TBT	Tributiltin
TMDL	Total Maximum Daily Load
TRT	NOAA Fisheries Technical Recovery Team
USEPA	U.S. Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
X2	The distance in kilometers from the Golden Gate Bridge of the 2 parts per thousand isohaline at a depth of one meter from the bottom of the channel

Appendix B - ERP Strategic Goals and Objectives

GOAL 1. ENDANGERED AND OTHER AT-RISK SPECIES AND NATIVE BIOTIC COMMUNITIES: Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species. Support similar recover of at-risk native species in San Francisco Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

OBJECTIVE 1: Achieve, first, recovery and then large self-sustaining populations of the following at-risk native species dependent on the Delta, Suisun Bay and Suisun Marsh, with emphasis on Central Valley winter-, spring- and fall/late fall-run Chinook salmon ESUs, Central Valley steelhead ESU, delta smelt, longfin smelt, Sacramento splittail, green sturgeon, valley elderberry longhorn beetle, Suisun ornate shrew, Suisun song sparrow, soft bird's-beak, Suisun thistle, Mason's lilaeopsis, San Pablo song sparrow, Lange's metalmark butterfly, Antioch Dunes evening primrose, Contra Costa wallflower, and Suisun marsh aster.

OBJECTIVE 2: Contribute to the recovery of the following at-risk native species in the Bay-Delta estuary and its watershed: Sacramento perch, delta green ground beetle, giant garter snake, salt marsh harvest mouse, riparian brush rabbit, San Pablo California vole, San Joaquin Valley woodrat, least Bell's vireo, California clapper rail, California black rail, little willow flycatcher, bank swallow, western yellow-billed cuckoo, greater sandhill crane, Swainson's hawk, California yellow warbler, salt marsh common yellowthroat, Crampton's tuctoria, Northern California black walnut, delta tule pea, delta mudwort, bristly sedge, delta coyote thistle, alkali milk-vetch, and Point Reyes bird's-beak.

OBJECTIVE 3: Enhance and/or conserve native biotic communities in the Bay-Delta estuary and its watershed, including the abundance and distribution of the following biotic assemblages and communities: native resident estuarine and freshwater fish assemblages, anadromous lampreys, neotropical migratory birds, wading birds, shore birds, waterfowl, native anuran amphibians, estuarine plankton assemblages, estuarine and freshwater marsh plant communities, riparian plant communities, seasonal wetland plant communities, vernal pool communities, aquatic plant communities, and terrestrial biotic assemblages associated with aquatic and wetland habitats.

OBJECTIVE 4: Maintain the abundance and distribution of the following species: hardhead minnow, western least bittern, California tiger salamander, western spadefoot toad, California red-legged frog, western pond turtle, California freshwater shrimp, recurved larkspur, mad-dog skullcap, rose-mallow, eel-grass pondweed, Colusa grass, Boggs Lake hedge-hyssop, Contra Costa goldfields, Greene's legenere, heartscale, and other species designated "maintain" in the Multi-Species Conservation Strategy.

GOAL 2. ECOLOGICAL PROCESSES: Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities.

OBJECTIVE 1: Establish and maintain hydrologic and hydrodynamic regimes for the Bay and Delta that support the recovery and restoration of native species and biotic communities, support the restoration and maintenance of functional natural habitats, and maintain harvested species.

OBJECTIVE 2: Increase estuarine productivity and rehabilitate estuarine food web processes to support the recovery and restoration of native estuarine species and biotic communities.

OBJECTIVE 3: Rehabilitate natural processes to create and maintain complex channel morphology, in-channel islands, and shallow water habitat in the Delta and Suisun Marsh.

OBJECTIVE 4: Create and/or maintain flow and temperature regimes in rivers that support the recovery and restoration of native aquatic species.

OBJECTIVE 5: Establish hydrologic regimes in streams, including sufficient flow timing, magnitude, duration, and high flow frequency, to maintain channel and sediment conditions supporting the recovery - and restoration of native aquatic and riparian species and biotic communities.

OBJECTIVE 6: Reestablish floodplain inundation and channel-floodplain connectivity of sufficient frequency, timing, duration, and magnitude to support the restoration and maintenance of functional natural floodplain, riparian, and riverine habitats.

GOAL 3. HARVESTED SPECIES: Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals.

OBJECTIVE 1: Enhance fisheries for salmonids, white sturgeon, pacific herring, and native cyprinid fishes.

OBJECTIVE 2: Maintain, to the extent consistent with ERP goals, fisheries for striped bass, American shad, signal crayfish, grass shrimp, and nonnative warmwater game fishes.

OBJECTIVE 3: Enhance, to the extent consistent with ERP goals, populations of waterfowl and upland game for harvest by hunting and for non-consumptive recreation.

OBJECTIVE 4: Ensure that Chinook-salmon, steelhead, trout, rearing, and planting programs do not have detrimental effects on wild populations of native fish species and ERP actions.

GOAL 4. HABITATS: Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics.

OBJECTIVE 1: Restore large expanses of all major habitat types, and sufficient connectivity among habitats, in the Delta, Suisun Bay, Suisun Marsh, and San Francisco Bay to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes. These habitat types include tidal marsh (fresh, brackish, and saline), tidal perennial aquatic (including shallow water and tide flats), nontidal perennial aquatic, tidal sloughs, mid-channel island and shoal, seasonal wetlands, riparian, shaded riverine aquatic, inland dune scrub, upland scrub, and perennial grasslands.

OBJECTIVE 2: Restore large expanses of all major aquatic, wetland, and riparian habitats, and sufficient connectivity among habitats, in the Central Valley and its rivers to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes. These habitat types include riparian and shaded riverine aquatic, instream, fresh emergent wetlands, seasonal wetlands, other floodplain habitats, lacustrine, and other freshwater fish habitats.

OBJECTIVE 3: Protect tracts of existing high quality major aquatic, wetland, and riparian habitat types, and sufficient connectivity among habitats, in the Bay-Delta estuary and its watershed to support recovery and restoration of native species and biotic communities, rehabilitation of ecological processes, and public value functions.

OBJECTIVE 4: Minimize the conversion of agricultural land to urban and suburban uses and maintain open space buffers in areas adjacent to existing and future restored aquatic, riparian, and wetland habitats, and manage agricultural lands in ways that are favorable to birds and other wildlife.

OBJECTIVE 5: Manage the Yolo and Sutter Bypasses as major areas of seasonal shallow water habitat to enhance native fish and wildlife, consistent with CALFED Program objectives and solution principles.

GOAL 5. NONNATIVE INVASIVE SPECIES: Prevent the establishment of additional non-native invasive species and reduce the negative ecological and economic impacts of established non-native species in the Bay-Delta estuary and its watershed.

OBJECTIVE 1: Eliminate further introductions of new species from the ballast water of ships into the Bay-Delta estuary.

OBJECTIVE 2: Eliminate further introductions of new species from imported marine and freshwater baits into the Bay-Delta estuary and its watershed.

OBJECTIVE 3: Halt the unauthorized introduction and spread of potentially harmful non-native introduced species of fish or other aquatic organisms in the Bay-Delta and Central Valley.

OBJECTIVE 4: Halt the release of non-native introduced fish and other aquatic organisms from private aquaculture operations and the aquarium and pet trades into the Bay-Delta estuary, its watershed, and other California waters.

OBJECTIVE 5: Halt the introduction of non-native invasive aquatic and terrestrial plants into the Bay- Delta estuary, its watershed, and other central California waters.

OBJECTIVE 6: Reduce the impact of non-native mammals on native birds, mammals, and other organisms.

OBJECTIVE 7: Limit the spread or, when possible and appropriate, eradicate populations of non-native invasive species through focused management efforts.

OBJECTIVE 8: Prevent the invasion of the zebra mussel into California.

GOAL 6. WATER AND SEDIMENT QUALITY: Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

OBJECTIVE 1: Reduce the loadings and concentrations of toxic contaminants in all aquatic environments in the Bay-Delta estuary and watershed to levels that do not adversely affect aquatic organisms, wildlife, and human health.

OBJECTIVE 2: Reduce loadings of oxygen-depleting substances from human activities into aquatic ecosystems in the Bay-Delta estuary and watershed to levels that do not cause adverse ecological effects.

OBJECTIVE 3: Reduce fine sediment loadings from human activities into rivers and streams to levels that do not cause adverse ecological effects.

Appendix C - Draft Species List for HCP/NCCPs in Delta and Suisun Planning Area

	Common Name/Scientific Name	**Solano**	**Natomas Basin**	**San Joaquin**	**East Contra Costa**	**South Sacramento**	**Yolo**	**Rarity/Status**
	Suisun Marsh Aster, *Symphyotrichum lentum* (*Aster lentus*)	**X**		**X**				**CNPS 1B.2**
	Ferris's Milk-vetch, *Astragalus tener* var. *ferrisiae*	**X**						**CNPS 1B**
	Alkali Milk-vetch, *Astragalus tener* var. *tener*	**X**		**X**			**X**	**CNPS 1B.2**
	Heartscale, *Atriplex cordulata*	**X**		**X**				**CNPS 1B.2**
	Brittlescale, *Atriplex depressa*	**X**		**X**	**X**		**X**	**CNPS 1B.2**
	San Joaquin Spearscale, *Atriplex joaquiniana*	**X**			**X**		**X**	**CNPS 1B.2**
	Vernal Pool Smallscale, *Atriplex persistens*	**X**						**CNPS 1B.2**
	Big Tarplant, *Blepharizonia plumosa*				**X**			**CNPS 1B.1**
	Bristly Sedge, *Carex comosa*			**X**				**CNPS 2.1**
	Succulent Owl's Clover aka Fleshy Owl's Clover, *Castilleja campestris ssp. succulenta*			**X**				**Fed Threat CA Endang**
	Slough Thistle, *Cirsium crassicaule*			**X**				**CNPS 1B.1**
	Suisun Thistle, *Cirsium hydrophilum* var. *hydrophilum*	**X**						**Fed Endang CNPS 1B.1**
	Soft Bird's-beak, *Cordylanthus mollis* ssp. *mollis*	**X**						**Fed Endang CA Rare CNPS 1B.2**
	Palmate-bracted Birds Beak, *Cordylanthus palmatus*						**X**	**Fed Endang CA Endang CNPS 1B.2**
	Recurved Larkspur, *Delphinium recurvatum*	**X**		**X**	**X**			**CNPS 1B.2**
	Dwarf Downingia, *Downingia pusilla*	**X**				**X**		**CNPS 2.2**
	Delta Button-celery/Delta Coyote Thistle, *Eryngium racemosum*			**X**				**CA Endang CNPS 1B.1**
	Diamond-petaled (California) Poppy, *Eschscholzia rhombipetala*			**X**				**CNPS 1B.1**
	Fragrant Fritillary, *Fritillaria liliacea*	**X**						**CNPS 1B.2**
	Boggs Lake Hedge-hyssop, *Gratiola heterosepala*	**X**	**X**			**X**		**CA Endang CNPS 1B.2**
	Hogwallow Starfish, *Hesperevax caulescens*	**X**						**CNPS 4.2**
	Wooly Rose-mallow, *Hibiscus lasiocarpus*	**X**			**X**			**CNPS 2.2**
	Carquinez Goldenbush, *Isocoma arguta*	**X**						**CNPS 1B.1**
	Ahart's Dwarf Rush, *Juncus leiospermus* var. *ahartii*					**X**		**CNPS 1B.2**
	Ferris's Goldfields, *Lasthenia ferrisiae*	**X**						**CNPS 4.2**

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	Delta Tule Pea, *Lathyrus jepsonii* var. *jepsonii*	X	X	X				**CNPS 1B.2**
	Legenere, *Legenere limosa*	X	X	X		X		**CNPS 1B.1**
	Heckard's Pepper-grass, *Lepidium latipes var. heckardii*	X					X	**CNPS 1B.2**
	Mason's Lilaeopsis, *Lilaeopsis masonii*	X		X				**CA Rare CNPS 1B.1**
	Delta Mudwort, *Limosella subulata*	X		X				**CNPS 2.1**
	Showy Madia, *Madia radiata*			X	X			**CNPS 1B.1**
	Cotula Navarretia, *Navarretia cotulifolia*	X						**CNPS 4.2**
	Baker's Navarretia, *Navarretia leucocephala* ssp. *bakeri*	X						**CNPS 1B.1**
	Pincushion Navarretia, *Navarretia myersii* spp. *myersii*					X		**CNPS 1B.1**
	Adobe Navarretia *Navarretia nigelliformis* ssp. *nigelliformis*				X			**CNPS 4.2**
	Colusa Grass, *Neostapfia colusana*	X	X				X	**Fed Threat CA Endang CNPS 1B.1**
	Slender Orcutt Grass, *Orcuttia tenuis*		X			X		**Fed Threat CA End CNPS 1B.1**
	Sacramento Orcutt Grass, *Orcuttia viscida*		X			X		**Fed Endang CA Endang CNPS 1B.1**
	San Joaquin Valley Orcutt Grass, *Orcuttia inaequalis*	X						**Fed Threat CA Endang CNPS G2/S2.1**
	Gairdner's Yampah, *Perideridia gairdneri* ssp. *gairdneri*	X						**CNPS 4.2**
	Marin Knotweed, *Polygonum marinense*	X						**CNPS 3.1**
	Delta Woolly-marbles, *Psilocarphus brevissimus* var. *multiflorus*	X						**CNPS 4.2**
	Lobb's Aquatic Buttercup, *Ranunculus lobbii*	X						**CNPS 4.2**
	Sanford's Arrowhead (Sagittaria), *Sagittaria sanfordii*		X	X		X		**CNPS 1B.2**
	Side-flowering Skullcap, *Scutellaria lateriflora*			X				**CNPS 2.2**
	Rayless Ragwort, *Senecio aphanactis*	X						**CNPS 2.2**
	Wright's Trichocoronis, *Trichocoronis wrightii* var. *wrightii*			X				**CNPS 2.1**
	Saline Clover, *Trifolium depauperatum* var. *hydrophilum*	X						**CNPS 1B.2**

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	Caper-fruited Tropidocarpum, *Tropidocarpum capparideum*			X				**CNPS 1B.1**
	Orcutt Grass (*Orcuttia viscida*)/Greene's Tuctoria, *Tuctoria greenei*			X				**Fed Endang CA Rare CNPS 1B.1**
	Crampton's Tuctoria (Solano Grass), *Tuctoria mucronata*	X					X	**Fed Endang CA Endang CNPS 1B.1**
ANIMALS	BIRDS							
	Cooper's Hawk, *Accipiter cooperii*	X		X		X	X	**CA CSC**
	Sharp-shinned Hawk, *Accipiter striatus*	X		X		X		**CA CSC**
	Western Grebe, *Aechmophorus occidentalis*			X				**CA FGC**
	Tricolored Blackbird *Agelaius tricolor*	X	X	X	X	X	X	**CA CSC**
	Bell's sage sparrow, *Amphispiza belli belli*			X				**CA CSC**
	Golden Eagle, *Aquila chrysaetos*	X		X	X	X		**CA CSC**
	Great Egret, *Ardea alba* (rookery)			X				**CA FGC**
	Great blue Heron, *Ardea herodias* (rookery)			X				**CA FGC**
	Short-eared Owl *Asio flammeus*	X				X	X	**CA CSC**
	Long-eared Owl, *Asio otus*					X		**CA CSC**
	Burrowing Owl, *Athene cunicularia*	X	X		X	X	X	**CA CSC**
	Aleutian Canada Goose, *Branta hutchinsii leucopareia*		X	X				
	Ferruginus Hawk, *Buteo regalis*					X		**CA CSC**
	Swainson's Hawk, *Buteo swainsoni*	X	X	X	X	X	X	**CA Threat**
	Northern Harrier, *Circus cyaneus*	X				X	X	**CA CSC**
	Mountain Plover *Charadrius montanus*	X		X				**Fed Candit CA CSC**
	Western Yellow-billed Cuckoo, *Coccyzus americanus occidentalis*			X			X	**Fed Candit State Endang**
	California Yellow Warbler, *Dendroica petechia*						X	**CA CSC**
	White-tailed Kite, *Elanus leucurus*					X		**CA FP**
	Merlin, *Falco columbarius*					X		**CA FP**
	American Peregrine Falcon, *Falco peregrinus anatum*		X			X		**CA Endang CA FP**
	Salt Marsh Common Yellowthroat, *Geothlypis trichas sinuosa*	X						**CA CSC**
	Greater Sandhill Crane, *Grus canadensis tabida*		X	X		X		**CA Threat**
	Bald Eagle, *Haliaeetus leucocephalus*					X		**Fed Threat CA Endang**
	Yellow-breasted Chat, *Icteria virens*	X				X		**CA CSC**

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	Loggerhead Shrike, *Lanius ludovicianus*		**X**			**X**	**X**	**CA FP**
	California Black Rail *Laterallus jamaicensis coturniculus*	**X**		**X**				**CA Threat**
	Suisun Song Sparrow, *Melospiza melodia maxillaris*	**X**						**CA CSC**
	White-faced Ibis, *Plegadis chihi*		**X**			**X**	**X**	**CA CSC**
	California Clapper Rail, *Rallus longirostris obsoletus*	**X**						**G5 S1**
	Bank swallow, *Riparia riparia*		**X**	**X**			**X**	**CA Threat**
	AMPHIBIANS							
	California Tiger Salamander, *Ambystoma californiense*	**X**	**X**	**X**	**X**	**X**	**X**	**Fed Endang CA CSC**
	Foothill Yellow-legged Frog, *Rana boylii*	**X**		**X**	**X**		**X**	**CA CSC**
	Western Spadefoot, *Spea hammondii*		**X**			**X**	**X**	**CA CSC**
	REPTILES							
	Western Pond Turtle, *Actinemys marmorata*	**X**	**X**	**X**	**X**	**X**	**X**	**CA CSC**
	Silvery Legless Lizard, *Anniella pulchra pulchra*				**X**			**CA SCS**
	San Joaquin Whipsnake, *Masticophis flagellum ruddocki*			**X**				**CA CSC**
	Alameda Whipsnake, *Masticophis lateralis euryxanthus*				**X**			**Fed Threat CA Threat**
	Giant Garter Snake, *Thamnophis gigas*	**X**	**X**	**X**	**X**	**X**	**X**	**CA Threat**
	MAMMALS							
	Pallid bat, *Antrozous pallidus*					**X**		**CA CSC**
	Ringtail, *Bassariscus astutus*					**X**		**CA FP**
	Townsend's Western Big-eared Bat, *Corynorhinus townsendii townsendii*				**X**			**CA CSC**
	Western Red Bat, *Lasiurus blossevillii*					**X**		**CA CSC**
	Yuma Myotis Bat, *Myotis yumanensis*					**X**		**CA CSC**
	Riparian Woodrat, *Neotoma fuscipes riparia*			**X**				**Fed Endang CA CSC**
	Salt Marsh Harvest Mouse, *Reithrodontomys raviventris halicoetes*	**X**						**Fed Endang CA Endang**
	Suisun Shrew, *Sorex ornatus sinuosus*	**X**						**CA CSC**
	Riparian Brush Rabbit, *Sylvilagus bachmani riparius*			**X**				**Fed Endang CA Endang**
	American Badger, *Taxidea taxus*					**X**		
	San Joaquin Kit Fox, *Vulpes macrotis mutica*			**X**	**X**			**Fed Endang CA Threat**
	INVERTEBRATES							

	Common Name/Scientific Name	Solano	Natomas Basin	San Joaquin	East Contra Costa	South Sacramento	Yolo	Rarity/Status
	Ciervo Aegialian Scarab Beetle, *Aegialia concinna*			**X**				**G1 S1**
	Conservancy Fairy Shrimp *Branchinecta conservatio*	**X**	**X**	**X**	**X**		**X**	**Fed End**
	Vernal Pool Fairy Shrimp, *Branchinecta lynchi*	**X**		**X**	**X**	**X**	**X**	**Fed Threat**
	Longhorn Fairy Shrimp, *Branchinecta longiantenna*		**X**	**X**	**X**			**Fed Endang**
	Mid Valley Fairy Shrimp *Branchinecta mesovallensis*	**X**	**X**	**X**	**X**	**X**	**X**	**G2 S2**
	Valley Elderberry Longhorn Beetle *Desmocerus californicus dimorphus*	**X**	**X**	**X**		**X**	**X**	**Fed Threat**
	Delta Green Ground Beetle, *Elaphrus viridis*	**X**						**Fed Threat**
	Curved-foot Diving Beetle, *Hygrotus curvipes*			**X**				**G1 S1**
	Ricksecker's Water Beetle, *Hydrochara rickseckeri*	**X**				**X**		**G1G2 S1S2**
	Vernal Pool Tadpole Shrimp, *Lepidurus packardi*	**X**	**X**	**X**	**X**	**X**	**X**	**Fed Endang**
	Callippe Silverspot Butterfly, *Speyeria callippe callippe*	**X**						**Fed Endang CA Endang**
	FISH							
	Green Sturgeon, *Acipenser medirostris*			**X**				**CA Threat**
	Delta Smelt, *Hypomesus transpacificus*	**X**		**X**				**Fed Endang CA Candit End**
	Chinook Salmon - Winter-run, *Oncorhynchus tshawytscha*	**X**						**FED Endang CA Endang**
	Chinook Salmon-Central Valley fall/late fall-run ESU, *Oncorhynchus tshawytscha*	**X**						**Fed SC**
	Chinook Salmon - Spring-run, *Oncorhynchus tshawytscha*	**X**						**Fed Threat CA Threat**
	Steelhead - Central Valley ESU, *Oncorhynchus mykiss*	**X**						**Fed Threat**
	Sacramento Splittail, *Pogonichthys macrolepidotus*	**X**		**X**				
	Longfin Smelt, *Spirinchus thaleichthys*			**X**				**CA Threat**

Appendix D - Habitat Crosswalk

The following table provides a crosswalk between habitat categories in the Conservation Strategy map for the Delta and Suisun Planning Area and those in the ERP Plan (2000).

	Subsided Lands	**Intertidal**	**Floodplain**	**Uplands**	**Grassland/ Vernal Pool Transition Corridor**	**Water**
Tidal Perennial Aquatic Habitat		X	X			X
Nontidal Perennial Aquatic Habitat			X	X		X
Delta Sloughs (dead-end)		X				
Delta Sloughs (open-ended)		X				
Mid-channel Islands and Shoals		X				
Saline Emergent wetland		X				
Fresh Emergent Wetland	X	X	X			
Seasonal Wetlands	X		X	X	X	
Riparian and Shaded Riverine Aquatic Habitats			X	X	X	
Riparian and Riverine Aquatic Habitats (scrub, woodland, forest)		X	X	X	X	
Freshwater Fish Habitats		X	X			X
Essential Fish Habitats		X	X			X
Inland Dune Scrub Habitat				X		
Perennial Grassland			X	X	X	
Agriculture Lands (wetlands)	X					
Agriculture Lands (uplands)	X					

Appendix E: 11-Step DRERIP Evaluation Process

Scientific Evaluation Worksheet

The scientific evaluation process provides a framework for evaluating and documenting the scientific basis for potential Delta restoration actions. Instructions and definitions for completing the worksheet are provided at the end of the worksheet.

Evaluation Team:

Date:

Action:

Step 1: Is the action written in such a way that it can be evaluated?

If yes, list the action, approach, and outcome below and continue.

Action:

Approach:

Outcome(s):

If no, explain why below, reject the action as written and move on to another action. Do not attempt to rewrite the action.

Problem(s) with Action as written:

Step 2: Assess Support for Action-Outcome Relationship Using Outcomes and Stressor Tables

Is the cause-effect relationship inferred in the Action supported by the Conceptual Models or Other Source Information?

If yes, document the specific model sections and/or page numbers, or other source materials that support this conclusion and continue.

Models used:

Other sources:

If no, document the rationale for the finding and stop.

Rationale:

Comments and suggestions for changing Action:

Identify data gaps and information that would be helpful in evaluating the action.

Step 3: Identify Scale of Action (Large, Medium, Small: see instructions)

Scale:

Rationale:

Step 4: Describe Relation to Existing Conditions

Would the action result in a change to system dynamics (either within the Delta or as inputs to the Delta) such that the current understanding of how the system works may no longer hold?

If yes, describe the specific boundary conditions that are expected to change and the likely extent of the change. Consider how the changes may affect the ability to evaluate the action using existing models and information.

If no, describe why not and continue.

Step 5: Identify Positive and Negative Outcome(s) to Evaluate

Positive Outcomes to Evaluate

Outcome	**Source (name of Conceptual Model or external reference)**
Outcome P1 (intended):	
Outcome P2:	
Outcome P"X":	

Negative Outcomes to Evaluate

Outcome	**Source (name of Conceptual Model or external reference)**
Outcome P1 (intended):	
Outcome P2:	
Outcome P"X":	

Step 6: Score Magnitude, Certainty, and Worth of Potential <u>Positive</u> Ecological Outcome(s)

Outcome P1:

	Criteria Score[1]	**Rationale for Scoring, Document DLO paths/additional information used**
Magnitude		
Certainty		

Worth Score P1:

Outcome P2:

	Criteria Score	**Rationale for Scoring, Document DLO paths/additional information used**
Magnitude		
Certainty		

Worth Score P2:

Outcome P3:

	Criteria Score	**Rationale for Scoring, Document DLO paths/additional information used**
Magnitude		
Certainty		

Worth Score P3:

Comments and/or Assumptions used in scoring:

[1] See Appendix A

Step 7: Score Magnitude, Certainty and Risk of Potential <u>Negative</u> Ecological Outcome(s)

Outcome N1:

	Criteria Score	Rationale for Scoring, Document DLO paths/additional information used
Magnitude		
Certainty		

Risk Score N1:

Outcome N2:

	Criteria Score	Rationale for Scoring, Document DLO paths/additional information used
Magnitude		
Certainty		

Risk Score N2:

Outcome N3:

	Criteria Score	Rationale for Scoring, Document DLO paths/additional information used
Magnitude		
Certainty		

Risk Score N3:

Comments and/or assumptions used in scoring:

Step 8: Identify any Important Gaps in Information and/or Understanding

Data Needs *(indicate specific models, DLO relationships, or other information indicating the need)*:

Research Needs *(describe specific research activities that could be employed to increase understanding):*

Step 9: Estimate Overall Degree of Worth and Risk

Combined Worth and Risk Scores

Outcome	Worth Scores	Risk Scores
P1		
P2		
N1		
N2		
Cumulative Score		

Provide rationale for the overall scores:

Step 10: Assess Reversibility and Opportunity for Learning

Reversibility *(yes/easy, no/hard - see instructions):*

Comments:

Opportunity for Learning *(high, low - see instructions):*

Comments *(refer to specific sources of information that support the above determination and identify high priority research questions and testable hypotheses):*

Step 11: Assign the Adaptive Management Category Using the Decision Tree

Adaptive Management Category *(full, pilot project, targeted research, discard):*

Comments:

Instructions

Step 1: **Is the action written in such a way that it can be evaluated?**
The action should be clearly written and contain basic components (action, approach, and outcome) as outlined in the Guidelines for Writing and Parsing Actions (*7/16/07*). An action can include multiple outcomes, but should list only one approach.

Step 2: **Is the cause and effect relationship between the action, approach, and outcome supported by the conceptual models, or other source material?**
Review General Outcomes table to identify conceptual models that include the general type of outcome identified in the action. Use these models and any other relevant source materials to assess if the relationship inferred by the action has been documented. If it is determined that the cause and effect relationship is not supported, document why and provide suggestions for how the actions might be re-cast to better achieve the desired outcome based on information in the conceptual models and other available scientific information. These suggestions can be used by action developers to improve the action for the next round of screening.

Step 3: **Identify Scale of Action**
Identify the scale of the Action 'scope' based on the following criteria. The purpose of establishing Action scale is to assist with determining the magnitude of effect on the ecosystem. Large, medium and small should be considered relative to the Delta and the temporal dynamics of processes being manipulated.

Large: Broad spatial extent, significant duration and/or frequency, and/or major reversal compared to existing conditions. Landscape scale.

Medium: Moderate spatial extent, moderate duration and/or frequency, and/or moderate change compared to existing conditions. Regional scale.

Small: Small acreage, short duration or only occasionally, and/or small change compared to existing conditions. Local scale.

Step 4: **Describe Relation to Existing Conditions**
Review the Boundary Conditions paper to assess whether or not the action has the potential to change system dynamics (either within the Delta or as inputs to the Delta) beyond the existing range conditions (i.e. change in inflows to the Delta, modified hydrodynamic conditions, or salinity regimes) such that the current understanding of how the system works may no longer hold? Consider how the changes may affect the ability to evaluate the action using existing models and information.

Step 5: Identify Positive and Negative Outcome(s) to be Evaluated

Using the standardized lists of outcomes and stressors from the Outcomes Table, identify as many positive and negative outcomes as possible (including the intended outcome). Outcomes should not be evaluated at this step, just simply listed. Outcomes not captured in models but identified based on other available information should be included, with notes describing the information used to identify the outcomes.

Identify positive and negative outcomes focusing only on covered species, but ensuring that all covered species anticipated to be affected are addressed, i.e. if the action is intended to benefit salmon, still look at effects on smelt.

Step 6: Score Magnitude, Certainty and Worth of Potential Positive Ecological Outcome(s)

Using the conceptual models and other relevant source materials, identify and score the expected magnitude and certainty of the identified positive ecological outcomes. Record the magnitude and certainty for each positive outcome. ***Use one table per positive outcome.*** Add additional tables as needed to reflect additional outcomes.

Use the definition, criteria, and conversion tables in Appendix A to guide the scoring determination and to select an estimate of "Worth". Document how scores for magnitude and certainty were arrived at, including citation of specific model sections and page numbers, and/or additional information used in the rationale section.

Step 7: Score Magnitude, Certainty and Risk of Potential Negative Ecological Outcome(s)

Using the conceptual models and other relevant source materials identify and score the expected magnitude and certainty of each negative ecological outcome. Record the magnitude and certainty in the tables below. ***Use one table per outcome***. Add additional tables as needed to reflect additional outcomes.

Use the criteria and conversion tables in Appendix A to guide the scoring determination and to select an estimate of "Risk". Document how scores for magnitude and certainty were arrived at, including citation of specific model sections and page numbers, and/or additional information used in the rationale section.

Step 8: Identify any Important Gaps in Information and/or Understanding

Using the levels of understanding assigned to the DLO relationships used in the evaluation thus far, and/or any additional information from other sources, identify important data or research needs, that could enhance future evaluation of this or similar actions.

Step 9: Estimate Overall Degree of Worth and Risk

Enter scores for Worth and Risk from Steps 5 and 6 above into the table below and estimate the overall Worth and Risk scores for the Action as a whole. Add additional rows to the table as needed to reflect additional positive or negative outcomes.

Overall Worth score should be determined based on consideration of the cumulative positive outcomes (several medium outcomes could justify an overall score of “High” worth).

Overall Risk should be based on the highest single risk score (i.e. if any one of the outcomes has a high risk, then the overall Risk should be “high”).

Step 10: Assess Reversibility and Opportunity for Learning

Assess reversibility and opportunity to learn using the criteria below.

<u>Reversibility</u>

Yes/Easy Outcome could likely be reversed as, or more quickly and cheaply than implementing the action.

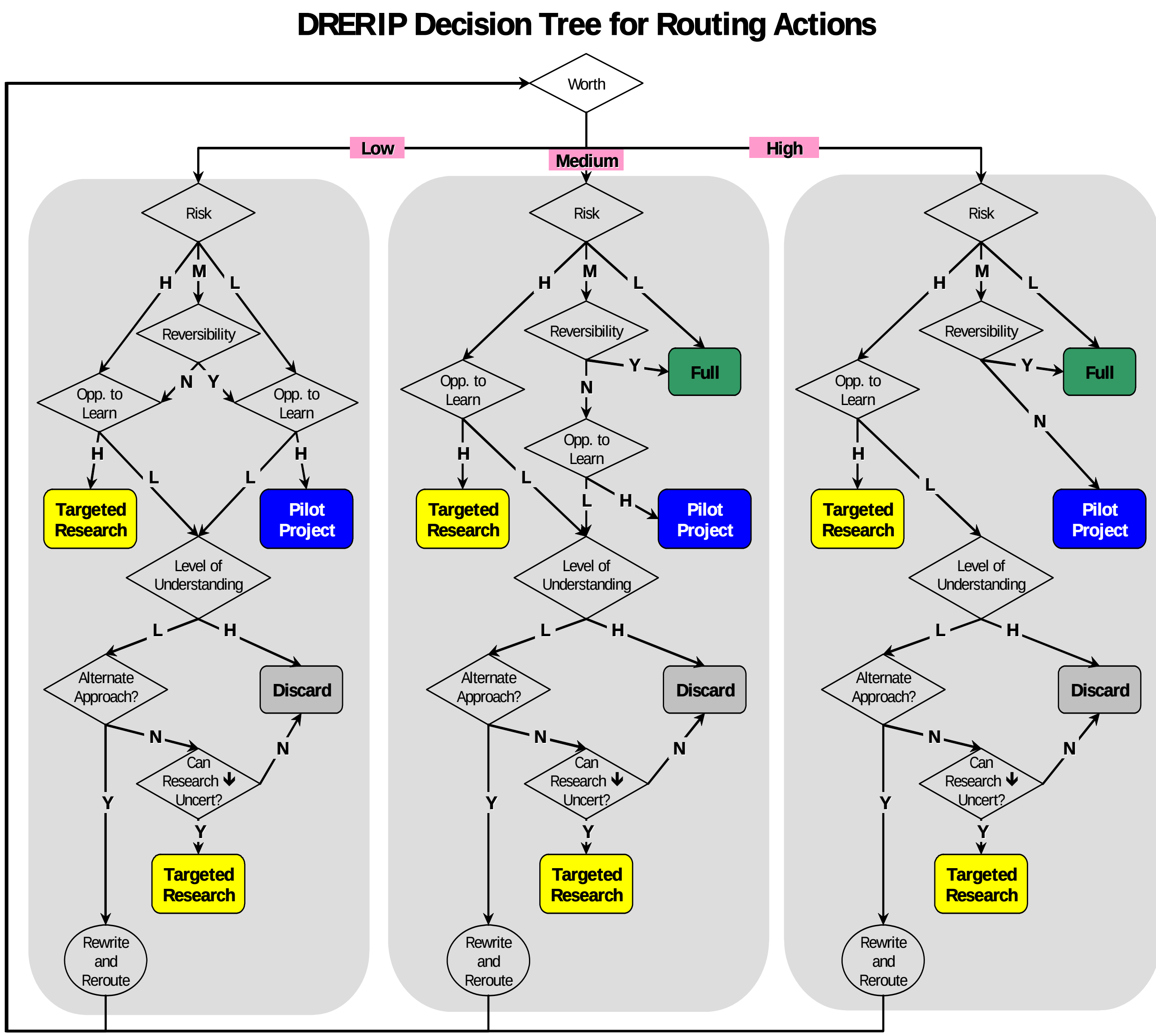
No/Hard Reversing outcomes would require more time or more money than implementing the action; outcomes may not be completely reversible.

<u>Opportunity for Learning</u>

High Expect to advance our understanding of critical uncertainties as identified in Conceptual Models in a quantifiable manner

Low Impractical or excessive time or resources likely required to achieve such understanding.

Step 11: Assign the Adaptive Management Category Using the Decision Tree



Definitions, Criteria and Conversion Matrices

The following definitions, criteria, and conversion matrices, are provided to aid the Scientific Evaluation process. Some of the definitions pertain to terms used in the conceptual models, such as understanding and predictability. Other definitions relate directly to completion of the Scientific Evaluation worksheet.

Scientific Evaluation Terms

The terms ***scale, magnitude, and certainty*** are Scientific Evaluation terms used to characterize the cumulate "path" or "chain" found between a Restoration Action being evaluated and each Outcome being considered within Scientific Evaluation. Such a path or chain is not the same as the linkages in the conceptual models that describe the cause-effect relationships between a single driver and a single outcome (see conceptual model terms below).

The terms ***worth, risk, reversibility, and opportunity for learning*** are Scientific Evaluation terms that combine considerations of magnitude and certainty to assess the consequences of an action and recommend whether the action should be considered as targeted research, a pilot study, a full-scale implementation project, or discarded using the Scientific Evaluation decision tree.

> ***Scale*** - Scale addresses temporal and spatial considerations, quantity and/or degree of change contained within the Action.
>
> ***Magnitude*** **–** Magnitude assesses the size or level of the outcome, either positive or negative, as opposed to the scale of the Action. It can be assigned using consideration of population or habitat effects, and higher scores require consideration of the scale of the Action shown to result in the outcome. Magnitude scores are assigned by expert assessment, documented in the Scientific Evaluation worksheet, of the DLO pathway linking the action and the outcome, and/or any additional information available to the Scientific Evaluation team, the use of which must be documented in the Scientific Evaluation worksheet.
>
> ***Certainty*** - Certainty describes the likelihood that a given Restoration Action will achieve a certain Outcome. Certainty considers both the predictability and understanding of linkages in the DLO pathway from the action to the outcome. Generally, high importance-low predictability linkages drive the scoring; it is important to ensure that certainty is not unduly weighted by a comparatively low-importance, albeit low-predictability linkage.
>
> ***Worth*** - Combines the ***magnitude*** and ***certainty*** of positive outcomes to convey the cumulative "value" of a Restoration Action toward achieving an Outcome.

Risk - Combines the ***magnitude*** and ***certainty*** of negative outcomes to convey the cumulative "potential" for a Restoration Action to result in an adverse, or negative Outcome.

Reversibility - The ease and predictability with which the outcome(s) of a Restoration Action or a group of Restoration Actions can be undone and/or reversed. For example, if the Action changes the ecosystem structure, can the original form be re-established? Have such outcomes been un-done in the past? A change to a flow regime is relatively easy to reverse; successful introduction of a new species is relatively difficult to reverse.

Opportunity for learning - Opportunity for learning is the likelihood that a Restoration Action or a group of Restoration Actions will increase the level of understanding with regard to the species, process, condition, region or system that is in question or of concern, assuming that appropriate monitoring and evaluation is conducted.

Conceptual Model Terms

The terms ***importance, predictability, and understanding*** are used in the conceptual models to characterize individual linkages (depicted as arrows in the models) between a driver and an outcome. The terms <u>pertain to specific processes</u> or mechanisms within a given model (e.g. how important is the supply of organic matter to mercury methylation?). The graphical forms of the conceptual models apply line color, thickness, and style to represent these three terms.

Importance - The degree to which a linkage controls the outcome *relative to* other drivers and linkages affecting that same outcome. Models are designed to encompass all identifiable drivers, linkages and outcomes but this concept recognizes that some are more important than others in determining how the system works. If a driver is potentially more important under particular environmental conditions, the graphic should display the maximum level of importance of this driver with the narrative describing the range of spatial and temporal conditions associated with this driver.

Predictability - The degree to which the performance or the nature of the outcome can be predicted from the driver. Predictability seeks to capture the variability in the driver-outcome relationship. Predictability can encompass temporal or spatial variability in conditions of a driver (e.g. suspended sediment concentration or grain size), variability in the processes that link the driver to the outcome (e.g., sediment deposition or erosion rate as influenced by flow velocity), or our level of understanding about the cause-effect relationship (e.g. magnitude of sediment accretion inside vs. outside beds of submerged aquatic vegetation). Any of these forms of variability can lead to difficulty in predicting change in an outcome based on changes in a driver.

Understanding – A description of the known, established, and/or generally agreed upon scientific understanding of the cause-effect relationship between a single driver and a single outcome. Understanding may be limited due to lack of knowledge and information or due to disagreements in the interpretation of existing data and information; or because the basis for assessing the understanding of a linkage or outcome is based on studies done elsewhere and/or on different organisms, or conflicting results have been reported. Understanding should reflect the degree to which the model that is used to represent the system does, in fact, represent the system.

Scientific Evaluation Scoring Criteria

The following tables should be used to inform ***magnitude and certainty*** scores for Scientific Evaluation. These entail looking holistically at the cumulative value (positive or negative) of an action.

Table 1 - Criteria for Scoring Magnitude of Ecological Outcomes (positive or negative)

4 - High: expected sustained major population level effect, e.g. the outcome addresses a key limiting factor, or contributes substantially to a species population's natural productivity, abundance, spatial distribution and/or diversity (both genetic and life history diversity) or has a landscape scale habitat effect, including habitat quality, spatial configuration and/or dynamics. Requires a large-scale Action.
3 - Medium: expected sustained minor population effect or effect on large area (regional) or multiple patches of habitat. Requires at least a medium-scale Action.
2 - Low: expected sustained effect limited to small fraction of population, addresses productivity and diversity in a minor way, or limited spatial (local) or temporal habitat effects.
1 - Minimal: Conceptual model indicates little effect.

Table 2 - Criteria for Scoring Certainty of Ecological Outcomes (positive or negative)

4 - High: Understanding is high (based on peer-reviewed studies from within system and scientific reasoning supported by most experts within system) and nature of outcome is largely unconstrained by variability (i.e. predictable) in ecosystem dynamics, other external factors, or is expected to confer benefits under conditions or times when model indicates greatest importance.
3 - Medium: Understanding is high but nature of outcome is dependent on other highly variable ecosystem processes or uncertain external factors or understanding is medium (based on peer-reviewed studies from outside the system and corroborated by non peer-reviewed studies within the system) and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors
2 - Low: Understanding is medium and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors or understanding is low (based on non peer-reviewed research within system or elsewhere) and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other external factors
1 - Minimual: Understanding is lacking (scientific basis unknown or not widely accepted), or understanding is low and nature of outcome is greatly dependent on highly variable ecosystem processes or other external factors

Conversion Matrices

The following two matrices are designed to combine scores for magnitude and certainty to develop overall values for Worth and Risk.

Table 3. Conversion Matrix for Determining Worth from the Criteria Scores for Positive Outcomes.

Is It Worthwhile?

Combining Magnitude and Certainty

		Certainty			
		1	2	3	4
Magnitude	1	***Low***	***Low***	***Med***	***Med***
	2	***Low***	***Med***	***Med***	***High***
	3	***Med***	***Med***	***High***	***High***
	4	***Med***	***High***	***High***	***High***

Table 4. Conversion Matrix for Determining Risk from the Criteria Scores for Negative Outcomes.

Is It Risky? (rev 6-28-07)

Combining Magnitude and Certainty

		Certainty (understanding + predictability)			
		1	2	3	4
Magnitude	1	***Med***	***Med***	***Low***	***Low***
	2	***High***	***Med***	***Med***	***Low***
	3	***High***	***High***	***Med***	***Med***
	4	***High***	***High***	***High***	***Med***