2008 CVP/SWP Coordinated Operations Delta Smelt Fall Habitat Action Adaptive Management Program Implementation Plan

U.S. Fish and Wildlife Service
Bay Delta Fish and Wildlife Office

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Executive Summary

The U.S. Fish and Wildlife Service's (Service) Biological Opinion (BO) for the California Central Valley and State Water Project Operations included 5 components of a Reasonable and Prudent Alternative (RPA) to avoid jeopardy and adverse modification to critical habitat of delta smelt (*Hypomesus transpacificus*), a small pelagic fish endemic to the San Francisco estuary. RPA component 3 restored flow variability to the estuary during the fall (September through November) to improve habitat conditions for rearing juveniles. The performance metric for this measure is based on X2 (a descriptor for the position in the estuary of the 2 part per thousand isohaline) during above normal and wet water years.

Delta smelt abundance has historically varied with flow conditions (variability, habitat area, habitat quality, etc.). Published (peer-reviewed) science provides explanations for how changes in flow conditions degraded habitat conditions available to rearing delta smelt. The Service indicated in the BO that this science is sufficient to warrant an explicit fall action to preclude jeopardy and adverse modification of critical habitat. The Service acknowledges, however, that the specific mechanistic link(s) relating variability in fall X2 to variability in survival and recruitment of delta smelt are not fully understood.

To address this uncertainty, a scientifically-based adaptive management process – the Fall Habitat Action (RPA Component 3) Adaptive Management Program (FHA AMP) was established, and a ten-year adaptive management program initiated. This program includes a monitoring, assessment, and adaptive learning plan (included here). The program also incorporates research elements administered by the Interagency Ecological Program (IEP) Pelagic Organism Decline (POD) management team. The IEP will participate in the described study by helping to address questions provided by agency and academic scientists with specific expertise in the ecology of the San Francisco estuary, and the Habitat Study Group (HSG), described in more detail below.

The HSG is an independent subgroup of the POD team within the IEP. The POD team constructs study plans to investigate the decline of several pelagic fishes in the San Francisco estuary and synthesizes results. The HSG is unique in that it was created in accordance with the 2008 delta smelt biological opinion and addresses effects that manifest in the fall, which could be affected by changes in X2. The HSG closely coordinates its efforts with the POD management team while maintaining supervision by the Service (in coordination with the Bureau of Reclamation) to ensure compliance with the components implemented as the Biological Opinion.

FHA AMP will focus on X2 (flow) and its effects on recruitment (growth, fitness, and survival) of juvenile delta smelt. These effects may be direct or indirect, and all elements or interactions are relevant to the domain of the Program. FHA AMP will be integrated with the broader IEP-POD investigations and clearly follow the charge prescribed in the biological opinion. POD elements focusing on drivers other than flow and on other fish will complement and contextualize the research element within FHA AMP.

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1.0 Introduction

Four historically-common pelagic fishes of the upper San Francisco Estuary have recently shown decreasing trends in abundance: delta smelt (*Hypomesus transpacificus*) longfin smelt (*Spirinchus thaleichthys*), striped bass (*Morone saxatilis*), and threadfin shad (*Dorosoma petenense*). There is evidence of long-term decline in delta smelt, longfin smelt, and striped bass populations (Kimmerer et al. 2000; Bennett 2005; Rosenfeld and Baxter 2007). The condition of these species' fish populations has deteriorated to record and near-record lows in abundance in recent years. By 2004, these abundance declines became widely recognized and discussed as a serious management issue. These population crashes have collectively become known as the "Pelagic Organism Decline, or POD."

Abundances of striped bass and longfin smelt have varied with outflow into the estuary. Before 2001, fall delta outflows were much higher and more variable from month to month during years with wet springs. Since 2001, fall outflows have been low and have varied little, irrespective of springtime conditions. Fall Midwater Trawl (FMWT) abundance indices for all of these fishes began to decline sharply around 2000 despite moderate outflows that historically would have supported modest population increases (Sommer et al. 2007).

In 2005, as a response to the POD, the Interagency Ecology Program (IEP) formed a study team to evaluate the potential causes of the decline (Sommer et al. 2007). The team organized an interdisciplinary multi-agency effort including staff from California Department of Fish and Game, California Department of Water Resources, Central Valley Regional Water Quality Control Board, U.S. Bureau of Reclamation, U.S. Environmental Protection Agency, U.S. Geological Survey, California Bay Delta Authority, San Francisco State University, and the University of California at Davis.

The POD has been the focus of an ambitious research effort to discover and describe the causes of the decline, which likely include a combination of factors: a decline in habitat quality, increased mortality rates, stock-recruitment effects, and reduced food availability (Sommer et al. 2007; Baxter et al. 2008). Sommer et al. (2007) describe the POD phenomenon and discuss many of the related management issues. Results of various POD studies through 2007 are summarized by Baxter et al. (2008). Additional findings from a POD-related working group at the National Center for Ecological Analysis and Synthesis (NCEAS) show that the declines are not due to chance variation, nor are they fully explained by a variation in a suite of environmental covariates (Mac Nally et al. 2010; Thompson et al. 2010).

An important point of emphasis 2010 POD Progress Report is discussion of a *regime shift* in the system – from a diatom-based system supporting nutritious zooplankton and native pelagic fishes to an alternative, flagellate and microbial-based system dominated by invasive species (clams, zooplankton, jellyfish, littoral and benthic fish, and proliferations of toxic algae [e.g. *Microcystis*], and aquatic weeds).

The POD team has proposed a suite of "drivers" that may have contributed through more gradual "slow erosion" of system resilience as well as rapid disturbance effects. These drivers include: changes in patterns of freshwater flow, turbidity, temperature, nutrient and contaminant loading; species introductions; and mortality from diversions and predators.

Delta Smelt and the 2008 CVP/SWP Operations Biological Opinion

The delta smelt is a small fish endemic to the San Francisco Estuary, currently listed as *endangered* by the California Department of Fish and Game and *threatened* by the U.S. Fish and Wildlife Service (Service). Delta smelt are associated with the low-salinity zone of the upper San Francisco Estuary (Moyle et al. 1992; Bennett 2005; Feyrer et al. 2007). During late winter and early spring, adult delta smelt migrate upstream to freshwater regions of the upper estuary for spawning. Juveniles typically move to the low salinity zone in early summer where they rear to maturity, before undergoing the spawning migration to complete the annual life cycle and produce the next generation of progeny. Many factors likely interact to affect the abundance of delta smelt, including changes in the abundance and composition of prey, predation, physical and chemical habitat, decreasing adult stocks, and water diversions (Moyle 2002; Bennett 2005; Sommer et al. 2007; Feyrer et al. 2007). The abundance of delta smelt has declined over the period of record (4-5 decades) and has dropped to persistently near-record lows in recent years (Sommer et al. 2007). In 2010 the Service issued a determination that up-listing delta smelt to *endangered* species status was warranted, but precluded.

On December 15, 2008, the U.S. Fish and Wildlife Service issued a Biological Opinion (BO) on the effects of the continued operation of the federal Central Valley Project (CVP) and State Water Project (SWP) on delta smelt and its critical habitat (FWS 2008). Among a number of factors discussed, the BO stated that CVP and SWP operations were negatively affecting delta smelt habitat during fall each year.

The general problem identified in the BO, described in more detail below, was that by reducing fall outflow to consistently low levels (thereby increasing fall X2), project operations were significantly reducing the amount of available habitat for maturing delta smelt, leading to reduction of the delta smelt population. Further, it was surmised that the interaction of habitat distribution and quality (as determined by flow) with other environmental stressors may effectively degrade habitat and thereby negatively impact the year-class cohort.

The BO provided a regulatory mechanism to address this problem in Component 3 of the Reasonable and Prudent Measures (RPA) to avoid jeopardizing continued existence of delta smelt and the adverse modification of its habitat. The objective of RPA Component 3 is to improve fall habitat for delta smelt by increasing *variability* in Delta outflow during this important life stage. The conceptual model for the relationship between flow and habitat posits that increased inter-annual outflow variability will influence fall habitat *quality* and *quantity* to benefit critical habitat of delta smelt. This regulatory action (RPA Component #3) requires that during September and October in years when the preceding precipitation and runoff period is *Wet* or *Above Normal* as defined by the Sacramento Basin 40-30-30 index (SWRCB 1995), the CVP and SWP will provide sufficient Delta outflow to maintain monthly average X2 no further eastward than 74 km in Wet water years (WYs) and 81 km in Above Normal WYs.

X2 is a metric representing the distance from the Golden Gate Bridge to the "2-Practical Salinity Scale" salinity isohaline. A larger value of X2 represents lower freshwater Delta outflow conditions where salinity is relatively farther upstream. A lower value of X2 represents higher freshwater outflow. This index is commonly used in the San Francisco Estuary since salinity is relatively easy to measure versus net flow in heavily tidal environments (Jassby et al. 1995; Kimmerer 2002). Further, previous research has shown that flow indexed by X2 can represent a useful integrator of many hydrodynamic factors in the estuary (Jassby et al. 1995; Kimmerer 2002).

The monthly X2 value will be separately targeted during the months of September and October. During any November when the preceding water year is Wet or Above Normal, all inflow into CVP/SWP reservoirs in the Sacramento Basin must be added to reservoir releases to provide an additional increment of outflow from the Delta to augment Delta outflow up to the fall X2 of 74 km (for Wet WYs) or 81 km (for Above Normal WYs). In the event there is an increase *in storage* during any November in which this action applies, the increase in reservoir storage shall be released in December to augment the December outflow requirements in SWRCB D-1641.

Given uncertainty about the environmental and ecological mechanisms underlying establishment of high-quality fall habitat, and many of the known fish-X2 relationships (Jassby et al. 1995; Kimmerer 2002; Feyrer et al. 2007; Kimmerer et al. 2009), the BO clearly acknowledged that there may be means other than increasing Delta outflow variability to avoid adverse effects to delta smelt during fall. Consequently, the RPA provides for targeted research and management of the Component #3 action based on improved understanding of and practical experience in implementing the action. After 10 years, or sooner, the Service will conduct a comprehensive review of the action, any new science supporting or refuting it, and the associated FHA AMP, to determine its efficacy. Depending on the outcome of this future review, the Service will then continue, modify, or discontinue the action. An interim report on progress in this regard is expected in Year Five of the FHA AMP.

The Habitat Study Group

To adaptively manage RPA Component 3, the Service has established a Habitat Study Group (HSG) as specified in the BO. Membership includes representatives from National Marine Fisheries Service (NMFS), U.S. Bureau of Reclamation (USBR), California Department of Water Resources (CDWR), California Department of Fish and Game (CDFG), Delta Science Program (DSP), U.S. Geological Survey (USGS), U.S. Environmental Protection Agency (USEPA) and San Francisco State University (SFSU). This group is chaired by the U.S. Fish and Wildlife Service (Service). As described in the Habitat Study Group Framework document, the mission of the HSG is to provide for adaptive management of fall delta smelt habitat quality. Consistent with the requirements described in the BO, an adaptive management process will develop, require, and use the best available scientific information to guide research, monitoring, assessment, decision-making, and reporting in a timely and transparent fashion, and shall include quantitative and clearly defined performance measures. Specifically, the main function of the HSG is to assist the Service in implementing FHA AMP – to provide advice to guide the Service's efforts to manage fall delta smelt habitat for successful juvenile growth and development within the operational parameters set forth in the BO. The HSG will also support the Service through scientific peer review, and the Service will ensure that the best available scientific information is used to inform the activities under RPA Component 3.

The Service will work to keep HSG activities consistent with the terms of the BO and provide assistance in facilitation and coordination. The HSG comprises seven Federal and State agencies entrusted with management of Delta habitat quality, and is augmented with members from academia with specific expertise in estuarine community ecology.

This Plan was prepared by the Service with technical assistance from HSG members to: 1) elaborate the conceptual basis underpinning RPA Component 3, as specified by the BO; 2) articulate the framework for adaptive management of the Fall Action; 3) identify a general implementation and reporting schedule; and 4) propose a process for adaptive environmental assessment of the Action, including the formulation of performance measures.

This report follows the June 18, 2009 public information session, where the general framework and draft implementation schedule were presented to the technical stakeholder and academic communities, along with a list of study questions and ideas formulated to address critical uncertainties via applied research. These study questions (appearing as Section 3.3, below) were refined through the June 2009 workshop and transmitted to the IEP POD Management Team for consideration in an upcoming POD Work Plan.

The purpose of this Program is to examine the effects of fall X2 on delta smelt habitat (as prescribed in the BO). Integrating with IEP POD investigations is critical because fall habitat impacts must be considered within the broader context of the full range of factors likely to affect delta smelt abundance. Understanding the effects of fall X2 relative to other factors will be an important consideration in managing RPA Component 3.

2.0 The Issue: How Does Fall X2 Affect Delta Smelt?

This background section on effects of fall X2 on delta smelt relies heavily on the effects analysis contained in the BO (FWS 2008). However, this document further elaborates on the account in the BO to provide updated information and to more explicitly integrate the relationship of fall outflow to habitat quantity and quality within the scope of the greater POD.

In the fall, maturing delta smelt pre-adults are found in the low-salinity portion of the estuary. This four-month period of growth and maturation represents a quarter of the delta smelt's typical 1-year life span, and it is axiomatic that successful rearing during this life stage is critical to recruitment and reproduction. Biotic components of suitable delta smelt habitat include a sufficient amount and quality of available food, and (conceptually, at least) a sufficiently low predation rate. Abiotic components of habitat include tidal flow patterns, water quality (especially salinity and turbidity), and contaminants. Interactions (overlap?) between the size or location of suitable abiotic delta smelt habitat and important biotic components are possibly important determinants of smelt lifecycle parameters (survival and growth) during rearing. Delta smelt life-cycle model investigations are currently ongoing (Nobriga and Culberson, unpublished data; Newman and others, unpublished data), and will be used to inform HSG and IEP POD Fall Habitat Action-related studies as appropriate information becomes available. Much of the conceptual information discussed herein will be incorporated by reference into ongoing HSG/Fall Habitat Action Plan implementation, and via discussed conceptual models.

The examination of habitat suitability in the BO relied on published literature (Feyrer et al. 2007) and unpublished information (Feyrer et al., in review) that together: (1) defined key components of delta smelt habitat in fall, (2) demonstrated a long-term decline in the area of suitable abiotic habitat (Figure 1), (3) showed a strong relationship between X2 and the area of suitable abiotic habitat (Figure 2), (4) provided both direct and indirect circumstantial links between habitat area and population abundance, and (5) used modeling simulations to suggest the effect on habitat area was likely to persist under project proposed CVP/SWP operations.

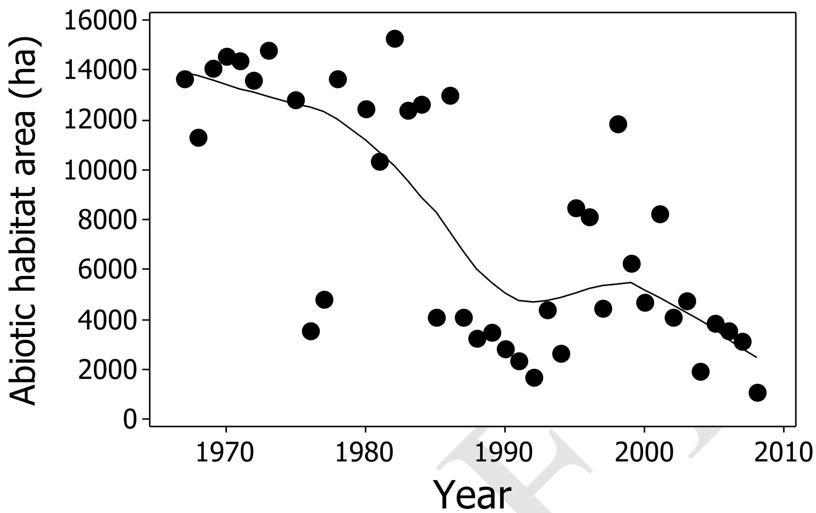

Figure 1. Time series of the area of suitable abiotic habitat defined as a function of salinity and water clarity from Feyrer et al. (in review). Curve is a LOWESS smooth.

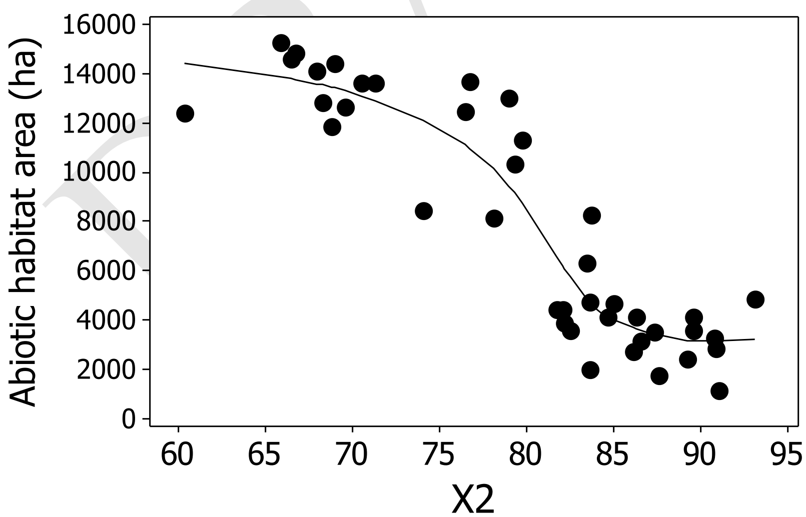

Figure 2. Relationship between the area of suitable abiotic habitat from Feyrer et al. (in review). Curve is a LOWESS smooth.

The BO linked the observed decline in fall habitat of delta smelt to CVP/SWP water export operations in the Delta. Evidence supporting this linkage included: (1) a positive long-term trend in CVP/SWP exports and the associated export:inflow (EI) ratio; (2) a negative long-term trend in Delta outflow (Figure 3); (3) reduced variability in fall outflows in the fall since 2001, and; (4) no long-term change in Delta inflow.

The overall interpretation of these results in the BO was that the CVP/SWP operations were exporting an increasing proportion of delta inflow, reducing delta outflow, thereby moving X2 consistently upstream and reducing the quantity (and perhaps quality) of suitable abiotic delta smelt habitat available in the fall. The immediate goal of RPA Component 3 was to reverse this effect of CVP/SWP operations on fall outflow and ensure that it would not persist into the future (Figure 4).

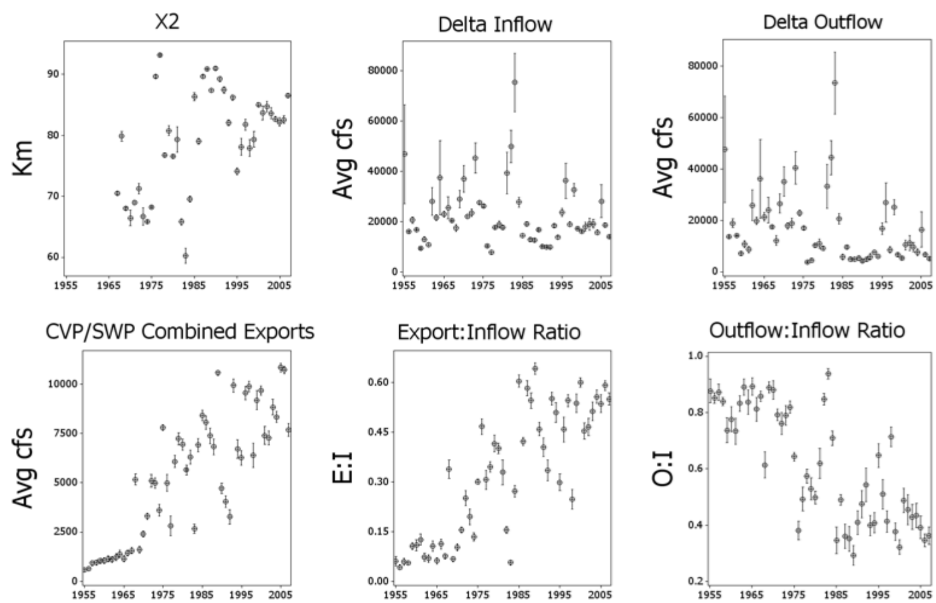

Figure 3. Time series for several variables during fall.

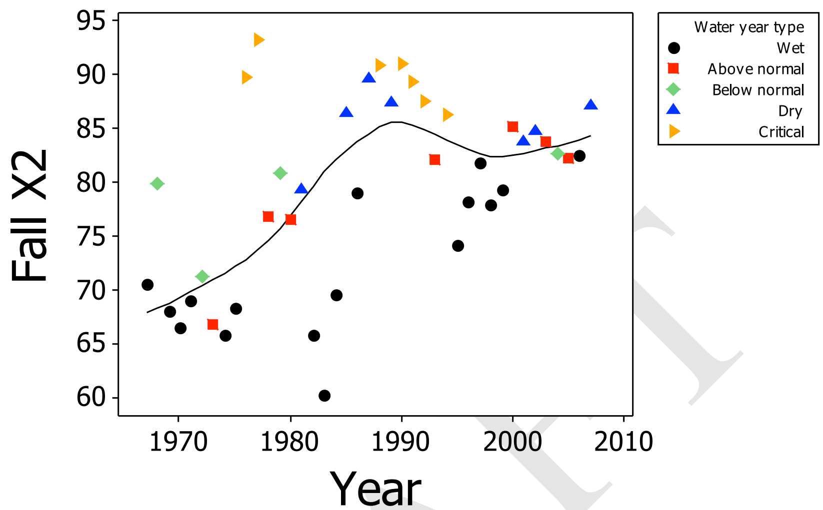

Figure 4. Time series of fall X2 grouped by water year of the preceding spring.

Conceptual Model Underlying the Fall Action

For the purpose of examining the importance of fall X2 location we developed a simple conceptual model organized around how X2 may affect delta smelt population parameters – abundance, distribution, mortality rate, and individual health, and their interactions (Figure 5). Here, individual health includes: fecundity, recent growth and feeding rate, body condition and vitality, and the presence of diseases or parasites. The underlying hypothesis of this model is that population parameters of adult delta smelt will vary with fall X2 position, leading to different outcomes (population estimates) for delta smelt through time. Specifically, the BO asserted a positive population response to higher inter-annual fall X2 variability (such as those X2 values found in pre-POD years prior to 2000).

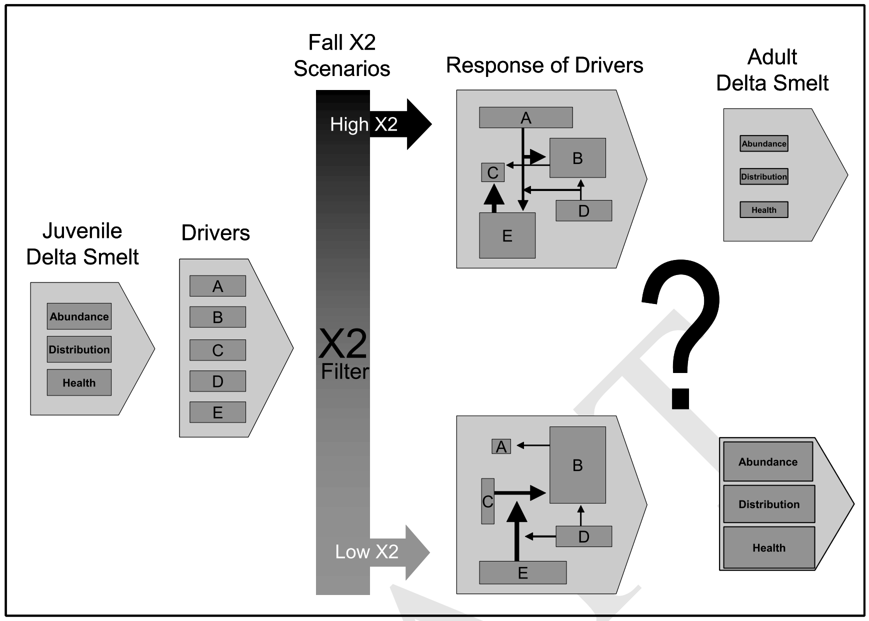

Figure 5. Flow/Delta Smelt Population Ecology Conceptual model.

The model uses population parameters for juvenile delta smelt prior to the fall. The model chooses one of two potential pathways – high or low X2 – and the resulting alternative population states for adult delta smelt after fall. This is illustrated in the conceptual model (Figure 5) as an X2 filter with either a negative (smaller boxes) or positive (larger boxes) response in delta smelt population parameters. The model assumes that the X2 filter modulates the effects of the drivers and their interactions in some way, as illustrated by different sized and shaped boxes and arrows in the two X2 scenarios. Note that the model also captures the possibility that X2 may not affect some drivers (e.g., the size and shape of driver D does not vary between the two scenarios).

3.0 The Fall Habitat Action Adaptive Management Program (FHA AMP)

The Service recognizes the uncertainty involved in the implementation of a fall habitat action to protect delta smelt, and includes an adaptive management program as part of RPA Component 3 of the BO. FHA AMP is meant to monitor, assess, and (if necessary) improve the implementation of the Fall Action by increasing our scientific understanding of the estuarine community and the relationship with population dynamics of delta smelt.

The key attributes of adaptive management (paraphrased from the 2009 U.S. Department of Interior Technical Guide) are:

1) Management is framed within a structured decision-making context.
2) There is an emphasis on uncertainty and the value in reducing it to improve management.
3) Learning is a means to an end, not an end in itself (learning while doing).
4) The proximate goal is good management.
5) The ultimate goal is reaching your objectives.
6) These objectives need to be clearly defined.
7) These objectives need to be measurable, relevant to the management problem, and should be useful for decision-making, evaluation, and learning.

The process of adaptive management includes:

1) Exploring alternative ways to meet management objectives.
2) Using conceptual models built on presumed structure and function of the system.
3) Predicting outcomes based on the current state of knowledge.
4) Stating differences of opinion or different model outputs as alternative, testable hypotheses.
5) Implementing one or more alternatives.
6) Monitoring to assess the impact of the actions.
7) Systematically using data to improve understanding.
8) Using results iteratively to adjust management.

FHA AMP will utilize adaptive environmental assessment (see Walters 2001) in a structured decision-making process to the extent possible. Because of the regulatory mandate and standards of formal review via ESA consultation, some of the fundamental assessment and decision-making has already been completed and is included in the coordinated operations BO. However, as mentioned previously, the Service acknowledges uncertainty in the BO when implementing the FHA AMP.

The structure of the Program allows for exploration of alternative ways to meet the management objective. In some cases, these actions are outside the purview of the BO, but still within the management domain of the implementing agencies. In the broader context of the BDCP process it is hoped that the efforts of FHA AMP, in coordination with related research conducted via POD and Delta Science proposals, will provide guidance to identify and mitigate factors that reduce growth and survivorship of juvenile delta smelt during the fall. The goals and objectives of the program are listed below.

The following are conditions for a successful adaptive management program:

1) There must be a mandate to take action given uncertainty.
2) There must be institutional capacity and commitment to undertake and sustain the program (leadership and support).
3) Consequential decisions must be made.
4) An opportunity for learning must exist.
5) Management objectives must be clear.
6) Uncertainty should be explicitly recognized as a key attribute of management.
7) The value in reducing uncertainty is high.
8) Uncertainty can be expressed as a set of competing, testable models.
9) A monitoring system with a reasonable expectation of reducing uncertainty is practical (needs to be realistic, and scaled to resolution of alternative hypotheses). The level of effort should be commiserate with the level of expected value of the outcome (e.g. high value outcome should be accompanied by high value investment for reducing uncertainty)
10) A shift from "expert" to collaborative learning is likely necessary (see Adaptive Environmental Assessment process in Walters 2001).
11) Stakeholder involvement is important.

Items 1 and 3, above, are answered by the BO itself. The ESA requires that a tangible action, not simply study, is required for addressing project activities with identified jeopardy and/or adverse modification to critical habitat effects. This document is meant to serve as the foundational roadmap for implementation of the Program in light of element 2, above. The Program is established as a formal process to manage with uncertainty and reduce unknowns via active learning. The Service is committed to assisting the action agencies in meeting the requirements of RPA Component 3 and maintaining a flexible approach to implementation within the confines of rigorous technical review and objective science. It must be recognized, however, that risk and uncertainty are interrelated. The charge before all interested parties is to effectively and efficiently advance our state of understanding so that aquatic habitat management may be appropriately directed.

Process

The operational steps of adaptive management typically follow a two-phased approach:

Setup Phase

Step 1) Stakeholder involvement—commitment for long-term program success
Step 2) Objective Definition—to guide decision making and evaluate management effectiveness
Step 3) Identify Management Actions—a key set for decision making
Step 4) Modeling—identify models that characterize different ideas about system functionality
Step 5) Monitoring—design and implement plan to track resource status and other key attributes

Iterative Phase

Step 6) Decision Making—select actions based on objectives, resource condition, and learning potential
Step 7) Follow-up Monitoring—tracking system responses to management actions
Step 8) Assessment—improve understanding of dynamics by comparing predicted to observed responses
Step 9) Iteration—cycle back to step 6 (or occasionally, Step 1)

FHA AMP is currently in the midst of the setup phase. Step 4 and 5 remain to be completed. The objectives and management actions are outlined in the BO and this document. Stakeholder involvement was solicited during a preliminary brainstorming at a spring 2009 Estuarine Ecology Team meeting, then again at the June 18, 2009 public workshop. Comments have been received and incorporated to the current research plan. In addition, considerable discussion between the Service and implementing agencies took place during the formal consultation process. This involvement will continue through the course of the Program, more so as the more formal process of adaptive environmental assessment is implemented. At the same time, FHA AMP will maintain a clear connection to the BO and function with appropriate scientific standards of objectivity. Accordingly, the FHA AMP will be implemented by the Service using the HSG with membership comprising agency and academic technical experts.

Goals and Objectives

The goal of FHA AMP is to achieve improved rearing conditions for, and recruitment of, the sub-adult delta smelt life stage into the year-class spawning cohort by successfully managing fall habitat. All the elements of the program, from monitoring and assessment, research, predictive modeling and adaptive learning are meant to meet the proximate goal of better scientific understanding of the mechanisms driving delta smelt growth and survival during the fall, and how these drivers relate to outflow. The monitoring and assessment elements are meant to track the performance of the action (to the extent feasible), and to serve as tests of our predictions. Monitoring and assessment will facilitate learning – which, in turn, frames the evolution of the decision making process and adjustments to the action as our knowledge improves.

A primary goal of the research element is to more specifically define the effects of fall delta outflow relationships (as X2) to delta smelt growth and survival. Our expectation is that addressing this need will simultaneously provide key information about the apparent regime shift identified by the POD. The HSG is tasked to assist the Service with the technical assessment and implementation of the optimal strategy to improve rearing of delta smelt juveniles through management of fall habitat. At a minimum, this charge includes the assessment of the performance of the fall action (within the constraints of the ability we have to discern it); and to identify and focus research, monitoring, and assessment in order to improve our understanding of the mechanistic relationships underlying fall habitat quality and quantity to delta smelt abundance.

A secondary goal of this program is to describe and elucidate more specifically the role of different "drivers" of the POD and apparent regime shift.

Adaptive Learning

The Service has defined the flow required to remove jeopardy and adverse modification of critical habitat for delta smelt in the BO. It should be understood that these flows are in the Service's opinion what is required to meet the bare minimum for delta smelt under the ESA standards. Other things being equal, flows needed to meet a higher conservation standard of "contribution to" or meeting recovery needs for delta smelt and the wider suite of T&E species and native flora and fauna would be an amount greater than this. The Delta Native Fishes Recovery Plan is currently undergoing revision and should contain more specific information regarding flow requirements, including volume and timing to meet these broader conservation objectives. However, as the conceptual model indicates, other things are unlikely to be equal as flows themselves change. Managing other parameters in concert with flows may provide greater benefit than managing flows alone. However, while intricately linked with the implementation and evaluation of the Fall Action, these other habitat drivers are beyond the purview of the BO remedy.

Because of the specific regulatory requirements outlined above, the Fall Habitat Action Adaptive Management Program is experimentally constrained, such that the process itself may best be considered "quasi-adaptive." Within this construct, it is clear that managers must necessarily implement a risk-averse strategy involving habitat management for protecting threatened and endangered species. Moreover, the inherent objective of the action agencies to conserve water resources in order to maximize water supply reliability discourages experimental allocation of flows to environmental restoration and recovery objectives. Despite these constraints, opportunities for learning and adaptive implementation remain. The benefits of monitoring and assessment and improved scientific understanding of the underlying dynamics of the estuary are accrued even in a passively-experimental structured decision making process.

For the foreseeable future, the remedy to meet the 2008 BO is represented by the wet and above normal WY X2 standards. This amount may be augmented (either naturally by storm events or by explicit design), and such events will be monitored to ascertain the beneficial effects of flow volume and variability with respect to key indicators in the estuarine community. The framework initiated by the Service within the HSG process may be expanded to other seasons and management endpoints to develop a comprehensive adaptive management process crossing regulatory governance, stakeholder domains, spatio-temporal scales, and geographic boundaries. The development of such a comprehensive adaptive management program for the Delta is likely the only effective vehicle to achieve the required breadth of coverage to realize the various recovery objectives for the system.

Program Components

The suite of components required to implement adaptive management for the Fall Action comprises monitoring, assessment, research, and iterative adjustment to the Action itself as science and technical understanding improve. This implementation plan provides the specific elements of FHA AMP within the overall framework laid out in the DOI technical guidebook (DOI, 2009), here tailored to the more narrow focus of growth and survival of a single life stage of an estuarine fish residing in a dynamic and complex natural environment.

3.1 Monitoring

It is anticipated that monitoring for RPA Component #3 will utilize existing IEP resources, augmented where necessary in accordance with IEP Annual Plans. Coordination between IEP and the HSG/Service will occur via the IEP Lead Scientist and the HSG Chairperson. Regular communication is anticipated via Service participation in the IEP POD management team and the IEP Coordinators group.

The BO (RPA Component 5) mandated monitoring to ensure that: 1) the Fall Action is properly implemented; 2) that the physical result of the Action is achieved; and, 3) that information is gathered to evaluate the effectiveness of these actions on the targeted life stage of delta smelt to refine the Action if needed. It is likely that the current level of monitoring is not sufficient for measuring ecosystem, population, and individual level response to implementation of fall flow restoration.

Additional monitoring activities suggested as an outcome of adaptive environmental assessment and planning should be considered within item 3 of Component 6 of the BO. It should be clear that such additional elements of the FHA AMP will be fundamental to reducing uncertainty and learning.
[What is basic monitoring design behind Grand Transect?]

SCulberson 7/7/10 2:22 PM
Not informed of this discussion. To be put before the HSG when convened next.

3.2 Assessment

Reporting

It is anticipated that monitoring will be covered under existing programs; these efforts already involve periodic data reporting. Data from IEP trawls are reported on a regular basis and archived at: http://www.iep.ca.gov/data.html . Research results from the IEP POD effort are reported intermittently in the IEP Newsletter, in POD synthesis reports, and IEP Annual meetings, and many studies and data form the basis of peer reviewed literature.

In addition to ongoing monitoring and reporting, an additional effort will be required to compile, synthesize, interpret and report data relevant to the implementation of the Fall Action. This task will be performed by the Service, and released in interim (after Year 5) and final (after Year 10) Program reports. By the end of the ten year evaluation cycle outlined in the BO a formal assessment will occur including: agency compliance, program activity, ecological assessment, current status of scientific understanding, re-evaluation of underlying operating models, and formal recommendation from the HSG to the Service regarding recommendations for modifying, continuing, or curtailing the Fall Habitat Action.

Performance Measures

Two basic categories of performance measures will be associated with FHA AMP. The first performance measures category is *ecological indicators*, or metrics to gauge resource response to the implementation of the Fall Action. These indicators will target individual, population, or community level metrics, as appropriate. The challenge to the responsible agencies and technical staffs will be to: (1) gather sufficiently detailed monitoring data with enough statistical power to draw relevant inference given foreseeable budgets; and (2) efficiently target application of limited resources (Delta outflow) to the appropriate measurement endpoints. IEP resources within the agencies are already committed to the limits of available personnel and equipment. Concerns over minimizing take are another constraint upon additional monitoring. Limited research funding is a constant restriction. This reality makes rapid technical progress a challenge, even before adding the complexity of the system under study. Nevertheless, the identification and quantification of relevant and informative ecological indicators is critical to the efficient function of FHA AMP.

The second category consists of *programmatic performance measures*, and tracks program components like compliance of action agencies in meeting the RPA prescription. Also included in this category are measures to assess agency activity (e.g., annual funding allocation), HSG performance (e.g., responsiveness to peer review comments and meeting reporting deadlines), and implementing entity or contractor performance (e.g., completion of monitoring and reporting in a satisfactory timeframe; timeliness in meeting deliverables to contracting agencies).

Programmatic Performance Measures: The following programmatic performance measures, at minimum, will be provided at each reporting period (Year 5 and Year 10):

1) Did projects meet X2 criteria as defined and measured by X?
2) Level of POD Work Plan funding
    a. Breadth of funded studies (from study questions)
    b. Number of studies funded
3) Response to peer review comments
    a. How did Program implement suggestions of panel
    b. Frequency of interaction with advisory panel, etc.
4) Study tracking and reporting
    a. Were results from research studies delivered on schedule?
    b. Did monitoring data get disseminated in a timely fashion?
    c. Is QA/QC'ed data compiled and publicly available in an accessible format?
    d. Are reports and assessment of available data and research completed on schedule?
5) Stakeholder involvement (through EET?) within the Adaptive Environmental Assessment process

SCulberson 7/8/10 10:02 AM
What means do we use to measure and track compliance? Calsim? Dayflow? Empirical measurement?

Environmental Indices.

SCulberson 7/8/10 10:45 AM
This will likely be first priority for the HSG once reconvened.

This is a daunting additional task. Will be hard to get something sufficient for peer review very soon. Suggest a deadline for provision of PM's within the assessment framework, but deal with this by proposing a process and ideas, use the peer review to focus this effort. It sounds like from our last meeting that CalFed has moved from the urgency of performance measures. This is well enough, but be aware we have the Phase 1 performance measures report hanging out there with the State legislature and ERP submitted a plan for that. It doesn't directly impact this effort, but would be a help to

ERP to meet the promises. I recommend that the ERP effort focus on this aspect since there is a clear regulatory mandate and need. BDFWO would need to work this out with Carl Wilcox.

3.3 Research

Interface with the IEP POD Work Plan

SCulberson 7/8/10 10:46 AM
The "crosswalk" document in development will lay out the components of this interface. Details will have to be worked out at the HSG- and Agency-levels.

This plan provides a foundation with which the action agencies will direct the domain and application of the FHA AMP via the IEP-POD program. We have organized the study into testable hypotheses and questions following the base conceptual model. During 2009-2010 the POD Management Team developed a Proposal Solicitation Package (PSP) based upon POD-related research topics. The 2010 POD work plan represents a continuing effort to refine an underlying conceptual model of pelagic ecosystem dynamics, particularly with respect to any possible regime shift. For the purposes of the work plan much of the focus will be on flow changes, indexed by salinity (X2). Salinity changes due to altered flow have been shown to result in regime shifts in other estuaries (Petersen et al. 2008).

Adapting a *regime shift investigation* perspective with respect to freshwater flow within the Estuary, the IEP-POD team designed the 2010 work relying heavily on the X2 indexbecause of important recent regulatory requirements (described below). Note that this emphasis does not mean that the only work to be conducted is related to flow. Instead, the FHA AMP work is part of an integrated investigation that examines the effects of flow while providing insight into other drivers that may have contributed to the "regime shift."

POD and Regime Shift

The FHA AMP studies are based on a series of integrated conceptual models. First, there are linkages between Fall X2 and the more broad-based POD investigations (food web, contaminants, life cycle impacts, nutrients). As noted above, the emerging story from the POD investigations is that the upper San Francisco Estuary has undergone a "regime shift" toward a system dominated by less desirable species.

Ecological "regime shifts" are rapid, large-scale, lasting changes in ecosystems from one more-or-less stable regime (or state) to another (Scheffer and Carpenter 2003). Regime shifts have been observed worldwide in a variety of ecosystems including oceans, lakes, estuaries, and terrestrial systems, and have been widely documented in peer-reviewed publications (reviewed in Folke et al. 2004). Support for a recent regime shift in the upper San Francisco estuary comes from Manly and Chotkowski (2006), the IEP-sponsored NCEAS work mentioned above (Mac Nally et al. 2010; Thomson et al. 2010), and from independent work by authors working with the Public Policy Institute of California (Moyle and Bennett 2008).

Regime shifts can occur naturally (e.g. as a response to large natural disturbances such as fire or floods) or in response to human actions, and often come as a surprise. A popular analogy (see Figures 6 and 7) uses an image of a ball to represent a community or ecosystem, and posits the ball rolling from one valley (representing one stable state) across a ridge (or unstable state, or threshold) into an adjacent valley (or alternative stable state) as representing such a regime shift (Beisner et al 2003).

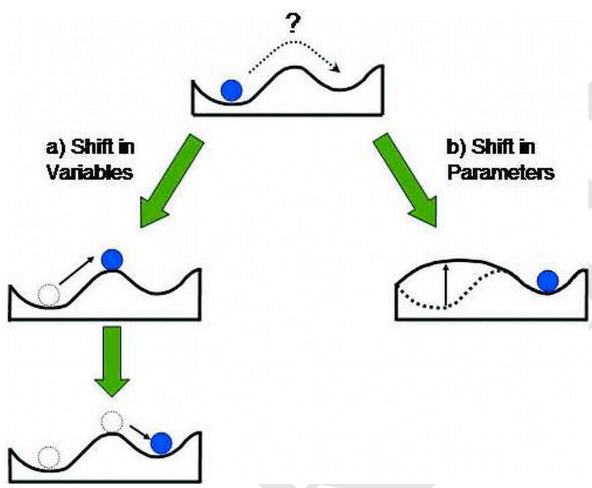

Figure 6.
Two-dimensional ball-in-cup diagrams showing (left) the way in which a shift in state variables causes the ball to move, and (right) the way a shift in parameters causes the landscape itself to change, resulting in movement of the ball. SOURCE: Beisner et al 2003

These shifts are generally regarded as undesirable due to costly consequences to humans and natural resources, and from the difficulties in reverting back to more desirable stable states. The extent of the subsequent response to a regime shift – and thus the severity of the shift and the potential for reversal – depends on the *resilience* of the ecosystem. Ecological resilience is defined as the magnitude of disturbance that a system can absorb before it morphs into a different state (Holling 1973). Resilience does not mean that changes do not occur in systems – rather, the system may absorb disturbance by reorganizing and adapting such that essential "functions, structure, identity, and feedbacks" of the system are maintained (Folke et al 2004).

In theory, regime shifts happen either because large disturbances "push" communities beyond the limits of their resilience and into an alternate stable state within a constant environment (the ball moves from one valley to another), or because environmental drivers change the environment so the stability of one state is reduced while an alternate state becomes more stable (the valley and ridge topography changes -- Beisner et al 2003). The former mechanism can be caused, for example, by overfishing and species invasions and may include trophic cascades (Daskalov et al 2007). The latter mechanism can include a slow and often imperceptible "erosion" of resilience (valley topography) by many different drivers until a threshold is passed and there is a rapid and unexpected regime shift. Evidently, often such shifts are not "undoable" by similarly small "reverse" changes due because of the presence of *hysteresis* (the concept of having several alternative stable states and system memory – in other words, pushing the ball back "uphill" is hard).

Finally, chance (*stochasticity*) also plays an important role in regime shifts – the final "push" into a different state may come from random variability in populations and communities (the ball "vibrates") or the environment (the topography "trembles") and can even lead to rapid extinction (Melbourne and Hastings 2008).

As noted above, we propose that the upper San Francisco estuary has undergone a regime shift – from a diatom-based system that allowed native pelagic fishes to survive (or even thrive) to an alternative, flagellate and microbial-based system that favors non-native and harmful species. The drivers that may have contributed to these changes include many drivers already under investigation by the POD study and represented in previous POD conceptual models (demographic factors; habitat aspects such as freshwater flow, salinity, turbidity, temperature, water column stability, nutrient loading, contaminant loading; bottom-up and top-down effects due to species introductions; mortality due to diversions and predators; interactions between drivers).

The difference with previous models is that the regime shift concept integrates drivers and affected communities and populations in a cohesive "story" with gradual "slow erosion" of ecosystem resilience and "rapid" disturbance and random effects on populations and communities. Examples of drivers that may have produced slow erosion of resilience include relatively gradual changes in nutrient loadings, turbidity, temperature, and freshwater flows. Strong physical and biological disturbance events include prolonged drought and the introduction and subsequent rapid spread of the invasive clam *Corbula amurensis* in the late 1980's. Random effects may come into play with respect to Allee effects (Allee 1931; Dennis 1989; Courchamp et al. 1999; Berec and Courchamp 2006).

In addition to providing a useful narrative outline, the regime shift concept also focuses attention on the ideas of system stability, resilience, and thresholds—all of which have implications for choice of management approach. A regime shift approach also provides a scheme of comparison with other systems undergoing similar changes, and for

SCulberson 7/12/10 9:45 AM
To be handled largely within the HSG?

investigating ways to turn the Delta and other such systems "back from the brink" (Biggs et al. 2009).

Organization of Study Plan:

To remain consistent with the current POD conceptual model and previous POD study plans, the drivers affecting delta smelt population parameters (illustrated as boxes labeled A-E in the conceptual model) have been grouped into three main categories: (I) *Bottom-up*, which includes invasive species effects and food web interactions; (II) *Top-down*, which includes predation and losses to diversions, and ; (III) *Abiotic habitat*, which includes all pertinent non-biotic components of habitat. A fourth category includes *interactions among these drivers*. For each individual driver working hypotheses include: (a) the driver affects some combination of delta smelt abundance, distribution, or health, and (b) the effect of the driver is modulated by some combination of X2 and other drivers (i.e., interactions among drivers).

3.3.1 Delta Smelt Population Parameters

Basic delta smelt life history parameters under consideration are: abundance, mortality, and health (including fecundity, recent growth and feeding rate, body condition, and the presence of diseases or parasites). Essentially, these are the responses that integrate the effects of the different conceptual component factors (e.g. abiotic habitat, top-down, food web) and variation in fall X2. For this discussion we use flow and X2 interchangeably, generally referring to "low flow" to mean conditions that accompany low riverine flows (e.g. high X2, long Delta hydraulic residence time, and little gravitational – salinity-generated – stratification).

A. Abundance and Mortality

The primary abundance data for delta smelt are gathered by the Fall Midwater Trawl, Spring Kodiak Trawl, 20 mm survey, Bay Study, and Summer Townet Survey conducted by the California Department of Fish and Game under the auspices of the IEP. Although none of these monitoring surveys was designed specifically to measure population size, indices such as the FMWT appear to track "ballpark" estimates of population size (Newman 2008). Recent abundances have been extremely low (near the lower detection limits for some of the surveys), so there is low confidence in our ability to interpret patterns of abundance during the recent POD years. For this reason it is also difficult to estimate mortality rates of the delta smelt population from the recent survey data. However, it may be possible to derive general patterns of mortality from information contained in otoliths by examining the life history success of different cohorts or life history patterns (Hobbs et al. 2007; Bennett, unpublished data).

Testable hypotheses associated with abundance and mortality include:

- *Population Hypothesis A1: Low fall flow results in lower abundance of delta smelt*

    Support: There is evidence that fall flow conditions can have population-level consequences for delta smelt. Feyrer et al. (2007) found that the inclusion of fall salinity in the delta smelt stock-recruit relationship improved the fit of the model, suggesting habitat conditions interact with adult abundance to influence subsequent recruitment. Similarly, Feyrer et al. (in review) found that fall abundance of delta smelt was correlated with habitat area, primarily a function of fall flow in their analysis.

Questions:

How does delta smelt adult abundance vary with fall X2?

Example Studies/Analyses:

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This will be linked explicitly to IEP POD workplans via the "crosswalk document" under development July 2010.

How does X2 in fall affect production of juvenile delta smelt in the following year?

Example Studies/Analyses:

- *Population Hypothesis A2: Low flow affects life history*

    Support: As noted above some details of life history and cohort success can be used to infer survival pattern (Hobbs et al. 2007; Bennett, unpublished data). Additionally, patterns of delta smelt distribution and otolith "histories" suggest that delta smelt may have variable life history strategies (Sommer et al. 2009; Hobbs, unpublished data). To our knowledge spatial analyses and/or cohort reconstruction using otoliths have not yet been used to examine how flow may affect survival or cohort success during fall and winter.

Question:

How does fall X2 affect population spatial structure or life history characteristics of delta smelt?

Example Studies/Analyses:

B. Growth

Growth rates are basic measurements used to evaluate the condition of organisms and, by extension, populations. For fishes, length and weight changes over a span of age or time are the most common metrics for growth, but there are other measures including volume, energy content, or the amount of a specific component such as protein.

- *<u>Population Hypothesis B1</u>: Low fall flow reduces delta smelt growth rate*

  Support: There has been a substantial decrease since the late 1980s in the mean size of delta smelt in the fall (Sweetnam 1999; Bennett 2005). It is unclear whether size has changed further during the recent POD years when fall flows were lower. Also, a change in mean size does not necessarily represent a decrease in growth rates, but can also result from a change in size-selective mortality or timing of reproduction.

Question:

How does delta smelt growth vary with fall X2?

  Example Studies/Analyses:

C. Fecundity

For rare and imperiled species such as delta smelt, fecundity (or, rather, a change in fecundity) is an important indicator of population condition. Fecundity (eggs per female) can serve as a measure of population growth rate (as total population egg supply) and of individual energy storage related to growth. In addition to the actual number of eggs produced per female it is important to consider overall egg quality since egg size and viability can affect recruitment (Bunnell et al. 2005; Ostrach et al. 2008).

- *<u>Population Hypothesis C1</u>: Low fall flow results in lower fecundity of delta smelt*

  Support: Delta smelt fecundity increases with fish length (Bennett 2005), and the previously-described long-term decrease in mean length if smelt in the fall therefore represents a drop in egg supply. As for growth, it is unclear if there has been a recent change in fecundity or egg quality.

Questions:

How does delta smelt fecundity vary with fall X2?

  Example Studies/Analyses:

How does delta smelt egg quality vary with fall X2?

Example Studies/Analyses:

D. Health and Condition

"Health" is used here to include fecundity, recent growth and feeding rate, body condition, and the presence of diseases or parasites (as above). For fishes, there are several ways to evaluate health including condition factor (a measure of deviation from a normative length-weight relationship), the incidence of disease, energy reserves, specific biomarkers, contaminant body burdens, and other histological or genetic indicators. Growth and fecundity can also reflect the health of individual fish.

- *Population Hypothesis D1: Low flow reduces delta smelt condition factor*

  Support: Since fish caught in IEP surveys are not all routinely weighed, condition factor has not yet been used to evaluate flow effects on delta smelt.

Question:

How does delta smelt condition factor vary with flow?

Example Studies/Analyses:

- *Population Hypothesis D2: Low flow reduces health of delta smelt*

  Support: The POD investigations into potential contaminant effects include the use of biomarkers that have been applied previously to evaluate toxic effects on POD fishes (Bennett et al. 1995; Bennett 2005). The POD team also commissioned a white paper on the use of biomarkers for assessing the health of POD fishes (Anderson et al 2007) and work is ongoing. Results to date have been equivocal. Adult delta smelt collected from the Delta during winter 2005 were considered healthy, showing little histopathological evidence for starvation or disease (Teh et al., unpublished), but there was some evidence showing low frequency endocrine disruption. In 2005, 9 of 144 (6%) of adult delta smelt males were intersex, having immature oocytes in their testes (Teh et al. unpublished). The limited results to date are insufficient to address flow effects.

Question:

How does delta smelt health vary with flow?

Example Studies/Analyses:

3.3.2 Bottom-Up Drivers

This group of drivers is predicated on the existence of at least some degree of food limitation in delta smelt. Although food limitation in a species can be detected, the converse (absence of food limitation) is difficult to demonstrate. Therefore, although this driver is a necessary condition for the other foodweb drivers to influence delta smelt, ruling this driver out could prove impossible. In addition to food limitation, bottom-up effects on delta smelt in the also require an association of food resources with X2/flow and often involve interactions among several trophic levels and with other drivers.

- *Bottom-Up Hypothesis 1: Delta smelt are food limited*

    Support: Juvenile to sub-adult delta smelt consume calanoid copepods, mainly *Pseudodiaptomus*, *Sinocalanus*, and *Acartiella* in the fall (Slater, CA Dept Fish and Game, in preparation). Food limitation of delta smelt can be inferred from a few lines of evidence. First, glycogen stores of delta smelt in summer 1999 were depleted, which implies food was in short supply for maintenance and growth of individuals (Bennett 2005). Second, correlative relationships between survival of delta smelt from summer to fall and the abundance or biomass of calanoid copepods are consistent with food limitation of survival (Miller unpublished, Kimmerer 2008). Third, abundance/biomass of calanoid copepods in summer-fall is low compared to that observed in many other estuaries, suggesting the possibility that Delta-resident fish are food limited. From a management and/or performance-measure perspective we expect that growth, survival, or fecundity would be higher if the concentration of food for delta smelt was higher. Food limitation may occur continuously or sporadically, and it may be important all the time or only during some time periods. Food limitation need not require starvation.

amueller 3/9/10 4:43 PM
Reference? (Marissa Bauer was working on this for a while, but I don't know how far she got)

Questions:

To what extent are individual Delta smelt limited by food supply in terms of their ingestion rate, growth rate, development, or survival?

Example Studies/Analyses:

How does subsequent fecundity of delta smelt in late winter-early spring respond to feeding conditions in the fall?

Example Studies/Analyses:

- <u>*Bottom-Up Hypothesis 2*</u>*: Low flow results in reduced transport of Pseudodiaptomus copepods from the freshwater Delta into the LSZ*

  Support: *Pseudodiaptomus* abundance in freshwater is not known to vary with flow. Therefore, only reduced transport of *Pseudodiaptomus* could account for a decrease in the LSZ as Delta outflow decreases. This will be investigated quantitatively under the SFSU/CALFED Foodweb study if and when the funds are reinstated. This mechanism may play out differently as the proportion of outflow from the Sacramento vs. San Joaquin River changes.

Question:

What is the quantitative change in transport and in the subsidy to the copepod populations in the LSZ as X2 changes?

Example Studies/Analyses:

- <u>*Bottom-Up Hypothesis 3*</u>*: Low flow results in reduced transport of dissolved and particulate organic materials (detritus, phytoplankton, bacteria, and microzooplankton) from the freshwater Delta into the LSZ.* This in turn results in reduced supply of suitable food to copepods, which are generally food limited in the LSZ

  Support: Food limitation of copepods in the LSZ is inferred from very low fecundity rates (Kimmerer, unpublished). Much of the phytoplankton carbon supply in the LSZ is produced upstream and the importance of this upstream loading to the LSZ has increased in recent years because of a greater decline in phytoplankton biomass and production in Suisun Bay than in the Delta (Jassby 2008). Jassby further found that in contrast to earlier periods, and in comparison to the Delta, Suisun Bay phytoplankton biomass now has a positive relationship with flow, implying a net gain of phytoplankton at higher flows. Historically, higher flows resulted in a net loss due to the relatively lower phytoplankton biomass in the Delta before the invasion of *Corbula* in Suisun Bay. No comparable studies exist about trends and transport of other potential food sources for copepods.

Questions:

How does the transport rate of food materials for copepods to the LSZ change as X2 changes?

Example Studies/Analyses:

What is the relative importance of transport and turnover rates of these materials in the LSZ?

Example Studies/Analyses:

How does food quality for copepods change as X2 changes?

Example Studies/Analyses:

- Bottom-Up Hypothesis 4*: Low flow allows organisms, including phytoplankton, microzooplankton, and copepods (esp. Pseudodiaptomus) to remain closer to the export facilities which, in turn, may result in greater pumping losses and lower copepod abundance in the LSZ*

Support: The fraction of the Delta freshwater volume that is exported depends on export rates, but as X2 moves landward (higher) the freshwater habitat shrinks and the fraction of the freshwater volume that is exported increases at any export rate. Jassby et al. (2002) showed that export losses of phytoplankton were fairly large but did not investigate the joint effects of X2 and export rate.

Questions:

How does the fractional daily loss of chlorophyll and labile organic matter change with X2 and export pumping rate?

Example Studies/Analyses:

What fraction of the *Pseudodiaptomus* population is lost to export pumping?

Example Studies/Analyses:

How do these losses affect conditions in the LSZ?

Example Studies/Analyses:

- Bottom-Up Hypothesis 5*: Production or abundance of Microcystis increases with low flow. Microcystis may interfere with the LSZ foodweb through various mechanisms* *including toxic effects, nutritional deficiency, and interference with feeding by copepods*

Support: *Microcystis* can have numerous effects on planktonic grazers (e.g., Paerl 1988, Ger et al. 2010; Ger et al. 2009). Blooms of this nuisance cyanobacterium have increased in the last decade (Lehman et al. 2008), and its range has expanded (Baxter et al. 2008). Low stream flow and high water temperature are strongly associated with the seasonal variation of *Microcystis* cell density and toxin (microcystins) concentration in the Delta (Lehman et al. 2008).

Questions:

What are the trophic dynamics by which *Microcystis* changes the zooplankton community composition?

Example Studies/Analyses:

What is the population-level impact of *Microcystis* on copepods such as *Pseudodiaptomus*?

Example Studies/Analyses:

How do pelagic foodwebs change when *Microcystis* blooms?

Example Studies/Analyses:

How do *Microcystis* bloom dynamics change with X2?

Example Studies/Analyses:

- *Bottom-Up Hypothesis 6: Persistent low flows result in recruitment of Corbula and, in turn, reduction in biomass of phytoplankton, bacteria, microzooplankton, and mesozooplankton through increased grazing*

Support: A stable X2 during the "right" season will allow *Corbula* to settle in and near the LSZ; benthic data from long-term monitoring sites bears this out to some extent. Whether the reduction in phytoplankton, bacteria, microzooplankton, and mesozooplankton occurs more often at low flow/high X2 is unknown. There may be an interaction between the timing of the movement of X2 into the Delta and the availability and size (and therefore grazing impact) of clams that can recruit there and become established.

Questions:

What is the response of *Corbula* to changing salinity/variable X2? For example, how does recruitment vary with salinity?

Example Studies/Analyses:

What conditions promote large recruitment events?

Example Studies/Analyses:

What conditions limit recruitment or limit successful growth of *Corbula* into juveniles?

Example Studies/Analyses:

- *Bottom-Up Hypothesis 7: Movement of X2 causes a mismatch between the location of Corbula populations and the LSZ, reducing consumption of phytoplankton and zooplankton by clams; conversely, a stable X2 (particularly during clam recruitment periods) allows for these locations to match over a period of time, maximizing consumption by clams*

Support: The overlap between high biomass of clams and abundance of copepods is greatest in the fall, based on preliminary calculations from IEP sampling. However, the effect of movement of X2 on this interaction has not been investigated.

Questions:

Does tidal and longer-term movement of X2 result in mismatch of clam, phytoplankton, and copepod populations?

Example Studies/Analyses:

How much difference does that mismatch make to overall consumption?

Example Studies/Analyses:

What is the magnitude of consumption of phytoplankton, microzooplankton, and mesozooplankton? What is the resulting effect on calanoid copepods in the LSZ?

Example Studies/Analyses:

- Bottom-Up Hypothesis 8: *Low flow results in higher concentration of ammonium, suppressing diatom growth and therefore biomass accumulation.*

Support: This is supported by results from enclosure experiments using water taken from the LSZ and elsewhere (Wilkerson et al. 2006; Dugdale et al. 2007). The proposed mechanism is based on the finding that nitrogen uptake and growth rates of different groups of algae and higher plants vary with nitrogen source (Dortch 1990; Britto and Kronzucker 2002). This could occur in the Delta at large (reducing the flux of phytoplankton to the LSZ), or confined within the LSZ itself. Diatoms, usually the dominant group of algae in turbid, energetic estuaries, and a high-quality food resource for copepods, preferentially take up ammonium, but grow faster on nitrate. In situations when the water is clear enough to allow for rapid phytoplankton growth, high ammonium concentrations can thus prevent diatoms from taking up nitrate and inhibit rapid diatom growth. Along with *Corbula* grazing (Kimmerer 2005), this may prevent the formation of diatom blooms. Most of the ammonium in the estuary comes from wastewater treatment plants (Jassby 2008); the contribution of ammonium excretion by *C. amurensis* to the ammonium budget in Suisun Bay is low, suggesting that *Corbula*'s impact is limited to grazing rather than ammonium excretion by the clams (Kleckner 2009).

Questions:

How important is ammonium suppression of diatom growth in the freshwater and LSZ regions of the estuary, compared with the consumption of biomass by clam grazing, and inhibition of growth by high turbidity?

Example Studies/Analyses:

How do the relative magnitudes of these limits on phytoplankton change as X2 changes?

Example Studies/Analyses:

- Bottom-Up Hypothesis 9: *Low flow favors nutritionally inferior phytoplankton and zooplankton species*

Support: Planktonic organisms move according to the prevailing flows and have developed a variety of adaptations to reproduce and prosper under a variety of flow regimes (Lytle and Poff 2004). Diatoms, for example, can have fast growth rates which allow them to "outgrow" higher flushing rates associated with high flows. Green algae and cryptophytes have intermediate growth rates allowing them to thrive at moderate flows. These phytoplankton groups are generally considered to be highly to moderately nutritious (Brett and Mueller-Navarra 1997). On the other hand, many of the least nutritious and/or toxic algae such as cyanobacteria and dinoflagellates grow slowly and require low flows with longer residence times and more stable conditions to form blooms (Adolph et al. 2006; Valdes-Weaver et al. 2006; Lehman et al 2008; Paerl et al. 2009). Long-term trends in phytoplankton community composition in the Delta and Suisun Bay include a decline in diatoms and an increase in cyanobacteria, green algae, and various flagellate species (Kimmerer 2005; Lehman et al 2005; Lehman 1996). These relative changes result in a decline of the more-nutritious species (adapted to higher, more turbulent flows) and an increase of less-nutritious species (adapted to lower-flow, more stable conditions) – perhaps also evidence of changing conditions Delta-wide that culminate in the recent spread of *Microcystis* blooms within the Delta and into Suisun Bay.

Zooplankton biomass tends to be lowest in turbid rivers with high advective flows where small, rapidly reproducing rotifers tend to dominate, intermediate in tidal estuaries with greater residence times and dominance by copepods, and highest in physically stable lakes where the zooplankton community often undergoes seasonal succession with strong biotic influences (Pace et al 1992, Lair 2006). In the LSZ of the San Francisco estuary, the zooplankton community has shifted from larger calanoid copepods to dominance by the small, more evasive cyclopoid copepod *Limnoithona tetraspina* which may be an inferior food source for fish, representing a "trophic dead-end" (Bouley and Kimmerer 2006). The relationship of *Limnoithona* and flow may be similar to that of jellyfish which thrive in flagellate dominated, more stable systems (Richardson et al. 2009). Several small jellyfish species have invaded the estuary in recent decades (Mills and Sommer 1995; Schroeter 2008; Richardson et al. 2009). Similar to *Limnoithona*, these jellyfish may also represent a nutritionally inferior trophic dead-end. By extension, it is possible that increasing dominance by other such ancient life forms (cyanobacteria and smaller flagellates) could be part of a change to a "Cambrian future" without fish, as described in a review of the recent world-wide "jelly-fish joyride" (Richardson et al. 2009).

Question:

To what extent does low flow affect the community composition and nutritional quality of phytoplankton and zooplankton in the LSZ?

Example Studies/Analyses:

- *<u>Bottom-Up Hypothesis 10</u>: Changes in the shape or size of the LSZ cause a reduction in production during low flow*

  Support: The western Delta is deeper with less shallow area than Suisun Bay, which should make the average depth greater when the LSZ is in the western Delta (low flow). However, the estimated pattern of volume, area, and mean depth within the LSZ as a function of flow and X2 is not monotonic (Figure 7). Furthermore, the overall change in depth distribution as X2 moves between Carquinez Strait and the western Delta is not very large.

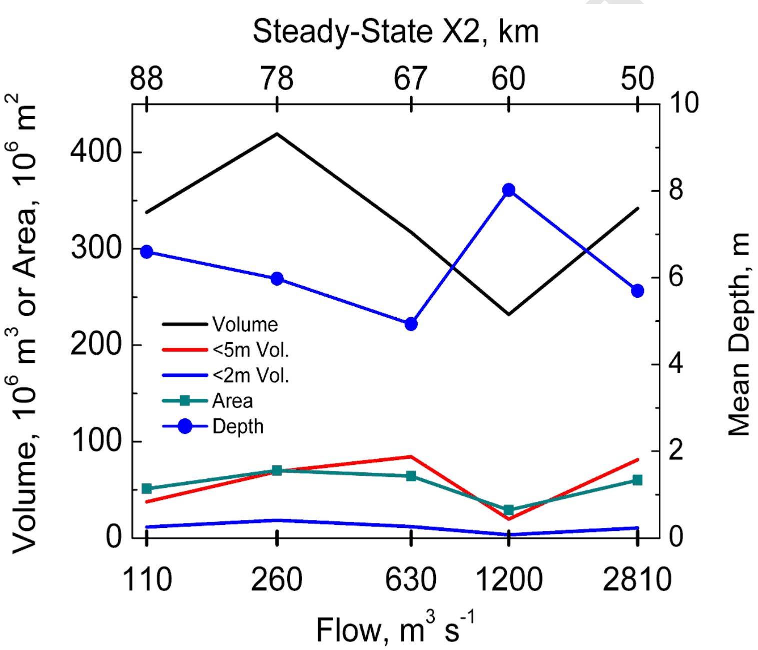

Figure 7. Volume, area, and mean depth as a function of Delta outflow (bottom) and equivalent steady-state X2 (top). Values are from runs of the TRIM3D model at five steady flows and repeating tides (Kimmerer et al. 2009). For each run the volume of the estuary by depth with salinity between 1 and 5 was tabulated, and the total volume and volume shallower than 2 and 5 meters was calculated. Area was also determined, and mean depth as the ratio of total volume to area.

Questions:

Using more refined models than that used for Figure 7, how does the size and shape of the LSZ change as X2 changes?

Example Studies/Analyses:

How does the change in depth (or fraction of the area shallow enough for net phytoplankton production) translate to changes in phytoplankton productivity or impact of benthic grazers on all foodweb components?

Example Studies/Analyses:

- Bottom-Up Hypothesis 11: *Overlap between Pseudodiaptomus and Limnoithona increases with a landward X2, intensifying competition for food between these apparent competitors*

  Support: Both copepods feed largely on ciliates in the LSZ (Bouley and Kimmerer 2006; Gifford et al. 2007), and both appear to be food limited in the estuary (Bouley and Kimmerer 2006; Gould 2009; Mueller-Solger et al. 2006 CALFED report; Kimmerer unpublished). The high abundance of *Limnoithona* in the LSZ may imply a large loss of ciliates to consumption by this copepod, which is not heavily consumed by most fish because of its small size. Note that grazing by clams is also an important loss for ciliates (V. Greene, SFSU, unpublished).

Question:

What is the nature and magnitude of competition for food between the copepods in the LSZ and freshwater region of the estuary? How does this change with X2?

Example Studies/Analyses:

- Bottom-Up Hypothesis 12: *Overlap between Pseudodiaptomus and Acartiella increases under low flow, intensifying predation by Acartiella on early stages of Pseudodiaptomus.*

  Support: *Acartiella* species are assumed to be predaceous because of the shape and configuration of their mouthparts. Preliminary experiments have shown that they consume *Limnoithona* nauplii (Kimmerer unpublished), but they probably also consume other life stages and other species.

Questions:

What is the predation rate of *Acartiella* on different life stages of *Pseudodiaptomus*, and is it an important source of mortality?

Example Studies/Analyses:

How does mortality and predation rate change with X2?

Example Studies/Analyses:

- <u>Bottom-Up Hypothesis 13</u>*: Recruitment of gelatinous plankton to the LSZ is higher during low flow; this increases predation on zooplankton which in turn causes reduction in abundance of food for delta smelt*.

  Support: A strong increase in invasive jellyfish abundance (especially *Maeotias marginata*) has taken place in Suisun Marsh since approximately 2000 (Schroeter 2008; Wintzer, unpublished). In addition to concerns about their ecological effects in Suisun Marsh this has also raised concerns about their importance in Suisun Bay and the LSZ. The IEP has recently initiated jellyfish monitoring, but no long-term data on their abundance are available to detect any changes or to determine whether abundance changes with flow.

Questions:

Are jellyfish important components of the plankton in terms of their consumption rates?

Example Studies/Analyses:

Does jellyfish abundance in the LSZ vary with flow?

Example Studies/Analyses:

3.3.3 Top-Down Drivers

This model component covers: (A) predation by piscivorous fishes (principally striped bass and largemouth bass), and (B) losses to water diversions. Top-down effects are predicated on the hypothesis that consumption or removal of delta smelt by piscivores and water diversions (SWP/CVP exports, power plant diversions, local agricultural diversions) is negatively correlated with X2. This is can occur if piscivorous fishes became more abundant relative to delta smelt, fish distribution shifts to locations with higher predation risk, or if delta smelt became more vulnerable to predation as a consequence of flow-related changes in habitat.

A. Predation

Predation is common and widespread in aquatic ecosystems. However, increased predation can be a manifestation of other changes in the ecosystem like decreasing habitat suitability, starvation, or disease – which makes prey species more vulnerable to predators. Flow can also affect distributional (range) overlap of predator and prey (and resulting encounter rates). Predator/prey mechanics are also affected by other abiotic factors like turbidity – that is itself mediated by flow. It may be difficult to convincingly distinguish these effects one from another.

- *Top-Down Hypothesis A1*: *High X2 results in increased predation by striped bass*

  Support: Adult striped bass abundance increased in the latter 1990s, which may have affected predation rates. Moreover, fall is thought to be part of the critical recruitment period for young striped bass (Kimmerer 2000), so changes in flow during this period could affect bass growth and predation rate. Finally, turbidity has been decreasing in recent decades (Feyrer et al. 2007; Jassby 2008), which may increase predator effectiveness. Water clarity in the Delta is not strongly related to flow, but resuspension plays a part (Jassby et al. 2002). The primary mechanisms used to explain the increasing water clarity are: 1) reduced sediment supply due to dams in the watershed (Wright and Schoellhamer 2004); 2) sediment washthrough from high inflows during the 1982-1983 El Nino (Jassby et al. 2005); and, 3) biological filtering by submerged aquatic vegetation (Brown and Michniuk 2007). However, the proximate causes of fall turbidity are less understood. It is possible, for example, that fall salinity conditions affect SAV growth, which in turn may increase water clarity and predation rates (via positive feedback loops).

Questions:

Does X2 affect the spatial overlap of delta smelt and striped bass habitats and populations?

Example Studies/Analyses:

Does low flow increase striped bass predation rates on delta smelt?

Example Studies/Analyses:

How does flow affect the relative prey availability for striped bass and predation pressure on delta smelt?

Example Studies/Analyses:

How does fall turbidity decrease during low flow years?

Example Studies/Analyses:

- *Top-Down Hypothesis A2: High X2 results in increased predation by largemouth bass*

  Support: Largemouth bass abundance has increased in the Delta over the past few decades (Brown and Michniuk 2007). Analyses of fish salvage data show this increase occurred somewhat abruptly in the early 1990s and has been sustained since. The increase in salvage of largemouth bass occurred during the time period when *Egeria densa*, an introduced aquatic macrophyte, was expanding its range in the Delta (Brown and Michniuk 2007). Beds of *Egeria densa* provide good habitat for largemouth bass and other centrarchids. Largemouth bass have a much more limited distribution in the estuary than striped bass, but a higher per capita impact on small fishes (Nobriga and Feyrer 2007). Increases in largemouth bass may have a more important effect on threadfin shad and striped bass than delta smelt – these prey fish inhabit mainly open-water regions, and (after early summer) occur in brackish water where largemouth bass are uncommon (Grimaldo et al. 2004; Nobriga and Feyrer 2008).

Questions:

How does vulnerability to predation (any predators) depend on health and nutritional status of delta smelt?

Example Studies/Analyses:

How do low flows affect largemouth bass predation rates on delta smelt?

Example Studies/Analyses:

How does flow affect the relative prey availability for largemouth bass and striped bass and the associated predation rate on delta smelt?

Example Studies/Analyses:

How does flow affect the spatial overlap of DS and LB habitats and populations?

Example Studies/Analyses:

B. Water Diversions

Major water diversions in the delta include the SWP and CVP export facilities, power plants, and agricultural diversions. This component analyzes whether fall flow conditions may affect entrainment in the fall or if perhaps there is a "carry-over" effect that manifests later in time.

- *Top-Down Hypothesis B1: Low flow increases losses to agricultural diversions*

Support: There are over 2000 agricultural diversions in the region which can be a source of fish losses (Herren and Kawasaki 2004). A portion of these diversions are located within the range of delta smelt. A detailed study of one diversion found evidence that their effects on pelagic fishes are small during summer (Nobriga et al. 2004). However, similar data have not been collected during fall.

Questions:

How does low flow affect agricultural diversions?

Example Studies/Analyses:

What is the relationship between flow, magnitudes and location of agricultural diversions, and delta smelt distribution and agricultural losses in the fall?

Example Studies/Analyses:

- *Top-Down Hypothesis B2: Low flow increases losses to power plants at Antioch and Pittsburgh*

Support: Non-consumptive water use by the power plants may reach 3200 cubic feet per second (cfs), which might be enough to create a substantial entrainment risk for fishes residing in the vicinity (Matica and Sommer, in preparation). Studies in the late 1970s indicated that losses of pelagic fishes to these power plants can be very high (Chuck Hansen, personal communication). The recent effects of the diversions are unknown; however, some life stage distributions of some pelagic fish (including young striped bass and delta smelt) are centered near these diversions. There may also be some risk to fish created by power plant thermal pollution or residual chlorine from antifouling activities. The magnitude of these risks is unknown. However, operators of these facilities report that the power plants were run relatively infrequently during recent years.

Questions:

Does low flow shift delta smelt distribution to an area with a higher risk of power plant entrainment?

Example Studies/Analyses:

Do power plant losses of delta smelt vary with flow?

Example Studies/Analyses:

Does power plant entrainment present a substantial risk of mortality?

Example Studies/Analyses:

- <u>*Top-Down Hypothesis B3*</u>*: Low flow increases losses to SWP and CVP export facilities*

  Support: Because large volumes of water are withdrawn from the estuary (millions of acre-feet per year), water exports and inadvertent fish entrainment at the SWP and CVP export facilities are among the best-studied top-down effects in the San Francisco Estuary (Sommer et al. 2007). The export facilities are known to entrain most species of fish found in the upper Estuary (Brown et al. 1996), and are of particular concern in dry years when the distributions of young striped bass, delta smelt, and longfin smelt shift closer to the diversions (Stevens et al. 1985; Sommer et al. 1997). Fall has historically been a period of relatively low delta smelt entrainment at the export facilities, so it unlikely that changes in X2 would have a major effect on losses during that season. It is possible, however, that a more upstream smelt distribution during fall would result in an increased probability of entrainment once upstream migration is triggered by "first flush" conditions, which typically occurs in the period December-March.

Question:

Do low fall flows increase the probability of fish entrainment during winter upstream migration?

Example Studies/Analyses:

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Bruce started, awaiting comments. Fred to finish.

SCulberson 7/12/10 2:55 PM
To be added with HSG input.

3.3.4 Abiotic Habitat Drivers

- *Abiotic Hypothesis 1: The amount of abiotic habitat for delta smelt varies with X2*

Support: Abiotic habitat area (defined as a function of salinity and water clarity) is negatively correlated with X2 in fall (Feyrer et al. in review). During summer and fall delta smelt are closely associated with the low-salinity zone. Changes of location of the low-salinity zone may affect the abiotic habitat of delta smelt. Habitat volume defined by salinity during spring varies with X2, but this model needs to be updated to include more of the Delta (Kimmerer et al. 2009).

Questions:

How does X2 affect habitat volume/area based on salinity and water clarity?

Example Studies/Analyses:

- *Abiotic Hypothesis 2: High X2 exacerbates toxic effects*

Support: Flow appears to affect the presence and concentration of contaminants in delta smelt habitats during spring (Kuivila and Moon 2004), but this has not been studied during fall. Stable low-flow conditions may distribute delta smelt closer to sources of contaminants or to where toxin concentrations are higher. High flows associated with low X2 may dilute the concentrations of contaminants. *Microcystis* blooms during warm low-flow conditions in summer and early fall in fresh to mildly brackish water. Studies from the this and other areas (Lehman et al 2008, Paerl and Huisman 2008) show that *Microcystis* does well in conditions of high water-column stability, warm temperatures, and high concentrations of diverse forms of nitrogen including ammonium (Moisander et al 2009).

Questions:

How does X2 affect the abundance, distribution, or effects of *Microcystis*?

Example Studies/Analyses:

Does X2 affect the distribution, concentration, and effects of ammonia and ammonium?

Example Studies/Analyses:

Does X2 affect the distribution, concentration, and effects of other contaminants?

Example Studies/Analyses:

3.3.5 Interactions Between Seasons and Drivers

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Dividing drivers and studies into categories is important in constructing a tractable, feasible workplan. However, ecosystems, especially estuaries, are complicated. California's Mediterranean climate includes high variability in weather conditions from year to year, which is broadly assumed to shift the importance and mechanisms of ecosystem drivers. In analyzing the importance of fall flow variability and the effects of RPA 3 we must look for evidence of sporadic, non-linear, or interactive effects of flows in the fall with other drivers and in other seasons.

- *Interaction Hypothesis 1: Conditions in the spring change flow effects on delta smelt in the fall*

  Support: High springtime outflows lead to greater dispersion of young delta smelt in the spring and summer while in years of low spring outflow delta smelt are less widely distributed throughout the estuary in the subsequent seasons (Bennett 2005?). Temperature, exports, outflows, and food resources in the spring and summer interact to produce "cohorts" of more early or late spawned fish with different survival and growth rates (Bennett et al. 2008; unpublished). Agricultural water use patterns in the Delta or water use by power plants in Suisun Bay also change with springtime conditions and may affect delta smelt distribution and growth in spring and summer. Contaminants are usually mobilized during storm run-off events occurring in the first half of the year but also found year-round in urban and agricultural discharges to the estuary. Kuivila et al. (2004) found evidence for potential pesticide exposure of larval and juvenile delta smelt in the Delta during dry years. In a wetter year, larval and juvenile delta smelt were distributed away from the pesticide sampling sites in the Delta. Werner et al. (2008) found toxicity to invertebrates and delta smelt in the upper estuary throughout the year (and most often in the northern delta) and during a dry year. It is unclear if any of the observed toxicity might have been due to elevated levels of microcystins associated with *Microcystis* blooms in the Delta that are promoted by stable low flow conditions in the summer and early fall. However, ambient levels of microcystins reported for the Delta have been below levels considered acutely toxic (Lehman et al. 2007). Nevertheless the summer *Microcystis* blooms might have an effect on delta smelt growth, survival, and distribution into the fall.

Questions:

How does distribution of delta smelt in the spring and summer affect their distribution and growth in the fall?

Example Studies/Analyses:

How do delta smelt “find” suitable fall habitat?

Example Studies/Analyses:

How do pesticide exposure and toxicity to delta smelt in the fall vary with flows?

Example Studies/Analyses:

How do pesticide exposure and toxicity in the spring affect the delta smelt population in the fall?

Example Studies/Analyses:

What is the fate of contaminants mobilized in wet springs under different fall flow conditions?

Example Studies/Analyses:

Do summertime *Microcystis* blooms affect delta smelt distribution in the fall? How do flows affect this interaction?

Example Studies/Analyses:

How do agricultural use patterns in the Delta or energy demands on power plants in Suisun Bay change with springtime conditions, and does this amplify the impacts on delta smelt in the subsequent fall?

Example Studies/Analyses:

- *<u>Interaction Hypothesis 2</u>: Interactions between food supplies and predation modulate bottom-up and top-down effects associated with fall flows*

  Support: The importance of food limitation on a population is related to population mortality rates; conversely, a population suffering high population losses is more likely to maintain itself if its growth and fecundity (and, by implication, feeding rate) are high. Furthermore, an individual fish must weigh predation risk against its need to feed, so that high predation risk may suppress feeding and reduce growth rate. In addition, individual fish or groups of fish may move to avoid predation, reducing their feeding rate, or they may move to find a better food supply, exposing them to greater predation risk. These mechanisms comprise interactions between food supply and predation risk.

Questions:

How does X2 affect the habitat of delta smelt predators such as striped bass and largemouth bass?

Example Studies/Analyses:

Does X2 affect the abundance and distribution of submerged aquatic vegetation (SAV) such as *Egeria*?

Example Studies/Analyses:

Does SAV proliferation affect delta smelt spawning habitat?

Example Studies/Analyses:

- *Interaction Hypothesis 3*: *Turbidity affects feeding and predation risk and modulate bottom-up and top-down effects associated with fall flows*

  Support: Turbidity, described above as an abiotic effect, may owe its importance to effects on predation risk or the inability (or unwillingness) of smelt to feed when the water is clear (Bennett 2005). Low turbidity may therefore result in some combination of three outcomes: the smelt move to more turbid water (better abiotic habitat), they are more likely to be eaten (interaction between abiotic habitat and predation risk), or they are less likely to feed and suffer lower growth rate (3-way interaction).

Questions:

Is predation rate on delta smelt higher when water is clear than when it is turbid?

Example Studies/Analyses:

Is feeding rate of delta smelt a function of turbidity?

Example Studies/Analyses:

Does the latter relationship depend on the presence of predators?

Example Studies/Analyses:

3.4 Adaptive Learning and Action Amendment

SCulberson 7/14/10 9:40 AM
How best to incorporate this notion into what is mostly an IEP research agenda?

The Learning Process

Additional refinement and development of the underlying conceptual model must occur before FHA AMP can fulfill its charge. For the purpose of "learning by doing" the Service intends to follow the adaptive environmental assessment framework outlined in Walters (2001). In this approach quantitative modelers, technical experts, and decision-makers are brought together for working learing/modeling sessions. Predictive models (even if crude at first) are defined, linked, and tested in order to clearly advance understanding and inform a structured decision-making process. It is an objective of this process to simultaneously refine a working conceptual model and to make progress in measuring performance of the FHA AMP itself. This is an important initial step towards deriving reliable performance measures (environmental indicators) for the Fall Habitat Action. Testing and validating these are a central part of the long-term implementation of the FHA AMP.

Amending the Action

Alternative approaches to meet the intent of the action (e.g., the Delta outflow target approach) are allowed within the BO. However the approach, support and justification for such alternatives must be clearly articulated and thoroughly vetted before such alternatives achieve a peer-reviewed/agency standard required to supplant the current prescription within the BO. The Service believes, consistent with our ESA mandate and associated responsibility and jurisdiction, that the state of the science supports the current action as defined in the BO. The BO simultaneously acknowledges uncertainty regarding the specific magnitude of X2 changes and associated mechanisms driving delta smelt growth and survival in the fall. This reality *is* the basis for the adaptive management of the action.

However, significant progress will be needed before alternative means to meet the BO objective can be justified. While the adaptive management of the study is a technical and iterative process, the adaptive management of the action has a clear regulatory basis. The Service is providing support to the HSG in terms of facilitation and guidance to ensure that the adaptive management of X2 is consistent with the requirements of the biological opinion. Our mandate under the ESA necessitates a risk-averse approach to habitat management. The precautionary principle encourages that management recommendations and "action experimentation" practiced within the FHA AMP process only occur after technically (if not necessarily *statistically*) robust analysis.

Integration of the Action Effects with other ecosystem drivers

FHA AMP has clear objectives and an underlying regulatory mandate. However, it is clear that the resource domain of the action (the ecology of the Delta) cannot be narrowly controlled using one species and one environmental variable. The Biological Opinion

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Help on these?

acknowledges that multiple stressors affect any life stage of delta smelt, and therefore monitoring, research and assessment must be comprehensive. For this reason the sErvice must work closely with the POD Management Team and IEP to coordinate and execute studies and provide proper context and analysis.

In order to function effectively within the adaptive management paradigm, it is the Service's preference that the efforts of the HSG and FHA AMP be integrated with other ongoing initiatives. These include: the IEP, SFEI(?), SWAMP(?), IRWM(?), CMARP (find out new name), AFRP/CAMP, Delta Science Program, and any eventual monitoring and assessment infrastructure entrusted with tracking the BDCP. At the same time, the regulatory requirement of FHA AMP necessitates independence and close Service oversight while the principles of effective adaptive management require stakeholder input. In general, it is intended that the HSG/FHA AMP process work in a fashion similar to that for the SWG-WOMT process.

It is thought that with the appropriate technical resources, active participation of agency scientists and regulators, and accountable through the process of independent peer review, the Service can support the implementation of an adaptively-managed Fall Habitat Action and chair the Habitat Study Group to meet the aims described in this Plan.

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Not sure this needs to be a separate section. Cross-check for citations, if needed.

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