Summary Report Science Symposium on Environmental and Ecological Effects of Proposed Long-term Water Project Operations

A California Bay-Delta Science Program Symposium June 19-20, 2003 Redwood Room, University Union Sacramento State University

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Executive Summary

On June 19-20, 2003, in Sacramento, the California Bay-Delta Authority (CBDA) Science Program convened the second in its series of symposia and workshops on water project operations and environmental management in the San Francisco Estuary and watershed. The first workshop, held on April 22-23, 2002 in Sacramento California, is summarized in a Science Program report available at: http://science.calwater.ca.gov/pdf/Workshop_Operations_Summary_April21-22-02.pdf.

The June 2003 symposium brought together more than 200 managers, scientists, and stakeholders to present and discuss information related to the environmental and ecological effects of proposed long-term operations of the Central Valley Project (CVP) and State Water Project (SWP). In this symposium, participants considered key science issues associated with the proposed long-term operations. The goals for this symposium were to:

- 1. Provide a forum for a balanced open discussion of proposed CVP and SWP operations, water management strategies, and the consequences to fish species of concern in the Delta and upstream project areas.
- 2. Help the public, stakeholders, and the agencies developing the biological opinions for CVP and SWP operations, pursue a common understanding of the state of knowledge and critical uncertainties associated with evaluating the implications of proposed water project operations and water management strategies in the Delta and upstream project areas.
- 3. Provide managers and policy makers a synopsis of the "state of knowledge and uncertainties" for some of the most important intersections between policy and science with respect to proposed changes in water project operations.

An inter-agency organizing committee developed the symposium agenda around several scientific issues related to water project operations:

- ? Upstream flow fluctuations and barriers to fish migration.
- ? Understanding Bay-Delta processes, and sources of fish mortality in the Delta.
- ? The effects of Delta inflow and water project operations on fish mortality: What have we learned from the Vernalis Adaptive Management Program (VAMP) and Delta Cross Channel (DCC) studies?

The symposium began with policy perspectives provided by key stakeholders and State and Federal representatives. Presentations to discuss the current state of knowledge followed from agency, stakeholder, and academic scientists. The agenda included audience question and answer sessions, as well as panel discussions of the technical information and its implications for managers. Here we provide a brief summary of some of the major findings.

Upstream flow fluctuations and barriers to fish migration

Upstream fluctuations in flow (duration, magnitude, and frequency) resulting from reservoir operations can affect salmon spawning success, embryo development, hatching success, and juvenile rearing. These direct biological consequences have all been measured and quantified, but linking these to population-level impacts, especially across a range of hydrological conditions, requires additional investigation and analysis.

Operation of the Red Bluff Diversion Dam (RBDD) can present a substantial barrier to fish migration. Present operations (gates closed 4 months and gates open 8 months of each calendar year) have removed RBDD as a migration barrier to winter-run Chinook salmon; however, spring-run Chinook salmon adults reach RBDD at a time when the gates are closed. Thus, the affects on fish immigration depend on the basic timing of the runs relative to RBDD gate operations. Present operations of RBDD have substantially reduced the sustained accumulation of predatory fish, thereby reducing the mortality of young salmon migrating past RBDD. The most direct management options to address remaining RBDD concerns involve enlarging the fish ladders or completing substantial modifications to the water diversion structures upstream of RBDD to shorten the period of gate-in operations.

Understanding Bay-Delta processes, and sources of fish mortality in the Delta

Our understanding of Delta hydrodynamics and ecological interactions (open-water processes) has advanced tremendously in the last decade. Researchers now have a much better understanding of how tidal forces shape the physical environment of the Estuary and the affects this environment can have on the distribution of various organisms. The more we learn, however, the more we come to realize how complex the Estuary is. Continued process-based studies, coupled with monitoring of long-term trends and analyses of these data in the context of understanding the consequences of water operations, will help to further reduce the uncertainties of how water project operations affect physical processes in the Delta and the subsequent abundance and distribution of living resources.

Mortality is an important ecological process that can affect population size. Studies of fish mortality in the Delta have generally considered total mortality (mortality from all sources) or direct CVP and SWP mortality (mortality resulting from entrainment in water project diversions). Yet, conceptually at least, we also hear about other types of fish mortality, including non-project anthropogenic mortality (e.g., fish mortality due to entrainment in delta agricultural diversions or fishing) and indirect mortality (e.g., increases in natural and non-project anthropogenic mortality arising from water project induced changes in Delta hydraulics or water quality). Quantifying the effects of any type of fish mortality is difficult, especially in the context of population-level effects. But quantifying the population-level effects of fish mortality is an important step for comparing the potential effectiveness of different management actions. Further, the current regulatory framework and management level responses often require quantification of the various types of mortality to assess impacts and prescribe mitigation.

We may be able to enhance our approaches by thinking about how to manage and reduce total fish mortality, rather than continuing to try and manage various types of mortality independently.

Relationships emerging from recent data and analyses may provide additional restoration opportunities for species of concern. Juvenile Chinook salmon appear most vulnerable to exports when actively emigrating through the Delta. Direct CVP and SWP entrainment mortality remains a management concern, but the data suggest direct loss is often small. Splittail analysis and modeling of abundance and distribution data show that this fish is highly resilient, but that long-term success of the species depends on seasonal floodplain inundation to promote successful spawning. For delta smelt population success, three key issues emerge from the current conceptual model: (1) water exports, (2) toxic chemicals, and (3) food web effects. Evidence suggests that direct mortality from CVP and SWP entrainment may be high enough in some years to reduce the population size of adult spawners. Similarly, toxic chemicals and food limitations may result in higher mortality rates of delta smelt in some years.

The effects of Delta inflow and water project operations on fish mortality: What have we learned from the Vernalis Adaptive Management Program (VAMP) and Delta Cross Channel (DCC) studies?

VAMP and DCC investigations examine relationships between Delta inflows, water project operations, and young salmon survival in the Delta. Although the studies differ in their experimental designs, both studies contribute scientific information important to future opportunities and management actions. VAMP and DCC research both show that fish are affected on all flow variance time scales (hourly to seasonal). The VAMP studies show that San Joaquin River quantity affects water quality, but determining smolt survival relative to flow requires additional investigation of various flow regimes under this 12-year study. The DCC studies have found that local velocity profiles and time of day drive fish distribution and catch.

The VAMP and DCC studies offer new insights and tools for examining how physical processes affect fish survival in the Delta. For example, in river bends and channel junctions, fish move with the velocity vectors (current structure), not simply the bulk flow discharge. The implication for managers is that understanding water velocity structure within bends and junctions and the interactions with fish behavior may lead to novel solutions to minimize impacts of existing and proposed water operation facilities. Further, integrating contaminant research into multidisciplinary studies like VAMP and DCC can also help to reduce the uncertainty associated with through-Delta salmon survival through the application of innovative tools and research strategies.

Background and Introduction

The goal of this meeting series is a balanced discussion among policy makers, stakeholders, and scientists aimed at understanding the scientific issues underlying water project operations and their effects on the San Francisco Estuary and associated watersheds. A primary objective is to explain the current state of scientific understanding and consider how the CBDA programs, CBDA agencies, existing facilities and operations, and policy decisions depend on and use this knowledge. Presentations and discussions are designed to highlight assumptions and bring out, in a balanced manner, areas of scientific agreement and disagreement. It is thought that these discussions will further aid the development of critical knowledge, as well as the integration of that knowledge into existing State and federal programs and projects.

The first symposium in the series was held on April 22-23, 2002 in Sacramento California. This symposium focused on issues associated with water operations and environmental protection in the San Francisco Estuary. This symposium summary report is available from the CBDA Science Program website at http://science.calwater.ca.gov/pdf/Workshop_Operations_Summary_April21-22-02.pdf.

The second symposium in the series was held on June 19-20, 2003 in Sacramento, California. This symposium considered some of the key policy and science issues associated with the long-term Operations Criteria and Plan (OCAP) proposed for the Central Valley Project (CVP) and State Water Project (SWP).

Consistent with the CBDA symposium series, the June 2003 symposium was designed to discuss scientific issues at a level of detail policy makers need to make informed decisions and stakeholders need to understand the scientific basis of those decisions. The June 2003 symposium focused on several of the complex scientific issues related to water project operations:

- ? Upstream flow fluctuations and barriers to fish migration.
- ? Understanding Bay-Delta processes, and sources of fish mortality in the Delta.
- ? The effects of Delta inflow and water project operations on fish mortality: What have we learned from the Vernalis Adaptive Management Program (VAMP) and Delta Cross Channel (DCC) studies?

Issues considered for future Science Program workshops include:

- ? The regulatory baseline for water operations.
- ? The effectiveness of water management strategies such as the Environmental Water Account (EWA).
- ? The basis and consequences of the X2 standard.

Additional Science Program workshops in July 2003 (Chinook salmon) and August 2003 (delta smelt) are listed on the Science Program website. Proceedings from all workshops

will be publicly available. This document provides a summary of the information presented at the June 2003 Science Program symposium.

I. Session One: Policy Perspectives

Sam Luoma, CA Bay-Delta Authority.

This symposium functions at the crossroads of science, policy, and management. The agenda stems from months of input from an inter-agency organizing committee with over 20 stakeholder and agency representatives that identified several scientific issues related to water project operations:

- ? Upstream flow fluctuations and barriers to fish migration.
- ? Understanding Bay-Delta processes, and sources of fish mortality in the Delta.
- ? The effects of Delta inflow and water project operations on fish mortality: What have we learned from the Vernalis Adaptive Management Program (VAMP) and Delta Cross Channel (DCC) studies?

Developing these science issues into sound policy decisions begins with a 3-legged foundation: **Policy = Process + Politics + Technical Basis**. Developing a common understanding and interpretation of new information, uncertainties, and management opportunities is an important goal.

The symposium will increase our understanding of available science by fostering scientific integration, collaboration, and evaluation, but it will not make policy calls. This is the beginning of a series of decisions about projects important to water management strategies throughout the Delta and Central Valley. Over the next year, environmental documents and decisions will be made for several significant projects affecting water operations. Figure 1 lists these projects with a draft timeline that includes key decision points. Also listed in Figure 1 is the timeline for the integration of scientific information. This information comes in the form of conferences, white papers, symposia, and workshops to provide relevant information and improve the technical foundation for policy decisions.

Our aim is to improve scientific understanding by repeatedly evaluating the state of knowledge and integrating science into the long-term process of management and policy decisions. Our scope includes, but also extends beyond, the current OCAP and South Delta Improvement Program (SDIP) challenges. With new research and enhanced understanding of water operations, environmental restoration, and Bay-Delta processes, our challenge is to optimize emerging management opportunities.

Figure 1: San Francisco Bay-Delta projects affecting water operations timeline including key decision points.

Working Draft

Integrated Key Milestones and Science Integration

Working Draft



* Trinity included.

File Name: Integrated Key Milestones & Science 6/12/03

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Patrick Wright, CA Bay-Delta Authority.

This symposium is the beginning of a process, setting the stage for collaborative approaches to guide water operations management decisions. The nature of these upcoming decisions and system projects offers flexibility and real-time decision opportunities to utilize scientific information. With this flexibility, however, comes additional risk. Flexible approaches require additional accountability, transparency, and coordination.

Opportunity exists to apply new scientific understanding to enhance transparency and improve clarity in our decision-making processes. CBDA is working with agencies and stakeholders to identify and clarify shared assumptions, data sets, and interpretation of our most recent state of knowledge. These inter-agency efforts can critique our strengths, weaknesses, and focus research needs, as well as help managers balance flexibility with accountability. The system must meet the needs of both decision makers (regulatory mandates) and stakeholders (water and environmental concerns). Such efforts require long-term vision, involving an on-going commitment.

Dave Fullerton, Metropolitan Water District of Southern California.

Fullerton discussed how California's water management landscape and operations have changed in recent decades. The State Water Project (SWP) offers a case study of how water operators use best-available information and scientific understanding to simultaneously balance export reliability, Delta needs, and fish protection. Historically, SWP contract deliveries remained constant in wet and dry years, but it has become clear over the past 20 years that water contractors cannot rely upon the existing SWP deliveries for 4.2 million acre feet per year. Environmental concerns beginning in the 1970s led export management to change toward more flexible deliveries based upon hydrology and system responses to wet/dry year conditions. Metropolitan Water District of Southern California (MWD) recently engaged in alternative strategies to reestablish water supply reliability and ensure fish protection. The Endangered Species Act (ESA) in 1995-1996 added even more environmental considerations.

To balance the often competing goals of water reliability and ESA fish protection, MWD introduced "demand management," which includes water conservation measures that prevent waste and promote the reasonable and efficient use and reuse of available water supplies (e.g., seasonal shift in deliveries, water scheduling changes, and peaking modification). Demand management is sufficient in wet years, but additional tools are needed to meet competing water demands in dry years. Such tools include EWA, water transfers, regional storage surpluses, reduced use, and integrated operator strategies. Successful project operation in dry years should also involve investment in infrastructure (additional storage) and understanding. The trend is to develop a suite of flexible, integrated tools that allow operators to circumvent problems and remove conflict.

Because tools are used in combination, it will be challenging to separate the effects of any one tool from effects of others. Ecosystem performance measures reflect the

aggregated effects of all actions. Due to the difficulty in testing the assumptions or hypotheses about individual tools, assessments should focus on net effects of aggregated actions compared to changes in the overall condition of the ecosystem.

Curtis Creel, CA Department of Water Resources.

Creel highlighted the technical aspects and differences between the Federal Central Valley Project (CVP) operations (i.e., often limited by the capacity of its conveyance canals) and the State Water Project (SWP) operations (i.e., often limited by the capacity of its reservoirs). Despite increasing demand, neither project has witnessed a substantial improvement in infrastructure, nor has California's overall operational strategy changed much in the last decade. To meet water supply and quality demands, operators have three options: (1) change upstream reservoir releases, (2) change Delta pumping, or (3) change Delta hydraulics.

Interactions between water operators, fishery agencies, and other stakeholders have changed dramatically since the 1980s. In the 1990s, operation criteria increased, placing upstream operations and Delta operations under greater scrutiny. Today, on nearly a daily basis, agencies and stakeholders engage in discussions about operations. The project agencies still make the final decisions about how projects are operated, but those decisions are generally made with a lot more input and information. Significant new tools, including EWA and b(2) water also address fishery concerns.

In the near future, opportunities such as the South Delta Improvement Project (SDIP) may further increase operational flexibility to provide overall benefits. The upcoming triennial review process of the water quality control plan and associated standards can allow for better management of water supply to meet beneficial use objectives. Two issues influencing future operator flexibility include: (1) a shrinking window within which to transfer and export water, and (2) the power market. Since 1994, the projects have shifted a substantial portion of export operations from the spring into the summer and fall. This constrains water transfer opportunities, essentially eliminating capacity for transfers from north to south of the Delta over 60% of the time. Soon, Reclamation will enter the power market in much the same way that DWR operates (the SWP is operated much like a large utility consuming and generating power to optimize power costs). This will constrain operational flexibility as power supplies and distribution rules tighten.

We can take management actions to improve operational balancing between water supply, water quality, and environmental needs.

<u>Find new knobs</u>: One challenge is to find new approaches to manipulate CVP and SWP projects to optimally balance multiple objectives (e.g., supply reliability, water quality, environmental requirements).

<u>Empower others</u>: Working with Management Agencies has taught us that information is power, especially if it is strategically disseminated where it is most useful.

<u>Improve decision-support</u>: As we use more of our flexibility to meet multiple objectives, we must introduce formal risk assessment to better understand risks and optimize decisions.

Susan Ramos, U.S. Bureau of Reclamation.

Ramos stated that the Reclamation mission is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. With CVP capacity currently maxed out (even under normal water conditions), Reclamation has strong commitment to work with other agencies, scientists, and stakeholders to prevent crisis, reduce conflict, and develop innovative approaches to balance supply reliability, water quality, and environmental needs. Crisis management is not an effective way to address long-term water management issues.

Reclamation's Water 2025 initiative provides the basis for a public discussion in advance of a water crisis and sets forth a framework to focus on meeting future water supply challenges. Water 2025 examines how science and management can work together to prevent water problems in California, including:

<u>Risk taking</u>: Science can help assess operations management decisions to evaluate and minimize risk.

Action: Science can help us identify what to do.

<u>Adaptive management</u>: Science can help Reclamation decide which incremental steps to take (e.g., increase pumping to 8,500, VAMP).

<u>Prioritization</u>: Science can help operators make the most of limited resources by providing insight into which programs to emphasize and how to optimize operations using real-time fish, environmental, and water data.

<u>Timeliness</u>: Science must be timely to be of any true value. Operators face a daily reality of having to make deliveries in the face of uncertainty while waiting for scientific information.

Balancing multiple objectives involves innovative, collaborative processes that incorporate science but does not compromise timely action.

Richard Denton, Contra Costa Water District.

Drinking water quality in the Delta impacts the public health of 23 million Californians. Delta water contains large bromide and organic carbon concentrations. Treatment is possible, but it is expensive and creates disinfection byproducts (suspected carcinogens that also cause short-term public health effects). Quality varies greatly with the source and with changes in water operations.

Multiple factors degrade drinking water quality. For example, fish management actions (e.g., water export reductions) frequently occur in the spring when water quality peaks. If exports and San Luis refill shifts to the fall, urban water users will receive water of reduced quality 60% of the time. When exports are cut, the South Delta experiences a buildup of agricultural drainage. If exports increase, saltwater intrusion occurs. To further complicate the situation, Delta Cross Channel operations, South Delta barriers, and wetland restoration projects all impact drinking water quality. Programs that offer

potential improvements to drinking water quality include the X2 estuarine habitat standards (February to January), increased Delta outflow, and Franks Tract modification.

To ensure that CBDA takes a balanced approach to implementing ROD actions, drinking water quality needs equal attention to supply reliability and ecosystem restoration. When developing water operations to protect fish, managers should also protect against drinking water quality impacts. A multifaceted protection approach to improve water quality addresses:

- ? Source water improvement
- ? Conveyance/operations
- ? Storage
- ? Local/regional source water exchange
- ? Treatment

Diana Jacobs, CA Department of Fish and Game.

When faced with scientific uncertainty, DFG as a trustee agency tends to take a cautious approach to protecting environmental resources by embracing the "precautionary principal." However, using the evolving state of knowledge and collaboration, it is within our capabilities to manage water operations in ways that promise species recovery, free operators from at least some regulatory constraints, and affirmatively move beyond jeopardy.

Resolving uncertainty in order to clarify how to best manage species for recovery means identifying system processes, further researching species life histories, and understanding which are the "big knobs" that impact species recovery. Ideally, our approach will involve an operations paradigm shift to greater flexibility. Adaptive management offers promise, but in practice is challenging to implement. ESA and Delta plumbing complexities complicate opportunities for experimentation. Regulatory laws mandate that trustee agencies cannot experiment with different management actions if uncertain about risks to endangered species. Inherently, however, experimental approaches mandate risk taking. To ensure that experimental approaches do not lead to irreversible mistakes, trustee agencies frequently make incremental changes. Such incremental steps, however, may not suffice as carefully planned experimentation.

If trustee agencies carry out larger actions in the future, they will require substantial monitoring, science, and other resources. We need to continue investing in learning as part of this improved interdisciplinary, transparent process. On-going communication and information exchange should continue between researchers, managers, and operators. Incorporating science into policy is a process that requires on-going communication.

Spreck Rosekrans, Environmental Defense and Environmental Water Caucus.

The public has a right to clean air, water, and other natural resources. Environmental Defense supports water transfers and believes that they are economically viable. Two kinds of protective operating criteria exist:

- ? Prescriptive Rules (e.g., Water Quality Control Plan, instream flow requirements)
- ? Real Time Management (e.g., CVPIA Section 3406 (b)(2), Environmental Water Account)

Rosekrans supports a balance of these two types of management strategies. From the environmentalist interpretation of the CBDA Record of Decision (ROD), however, the degree of benefit the environment receives from these two criteria is insufficient. The environmental community fears that as CBDA and operators move forward with flexibility, we risk losing ecosystem protection. To adequately protect fish, Bay-Delta water managers must embrace conservative water accounting and defensible take setting methodologies. We must also account for the Trinity-Klamath Watershed.

Long-term project operations must meet established environmental commitments. Recent storage projects, built without opposition from the Environmental Water Caucus, include Eastside, Los Vaqueros, and Kern Water Bank. Off-stream reservoirs generally have positive environmental effects, but beneficiaries of the program actions should (to the extent possible) pay costs. Applying this "beneficiaries pay" principle to new storage and conveyance projects can help equitably ensure that future operations offer environmental protection, even as operators embrace new flexible management strategies.

Ann Lubas-Williams, U.S. Bureau of Reclamation.

Lubas-Williams summarized the OCAP project description and findings from the draft biological assessment. Reclamation held a public meeting on June 16, 2003, to discuss the OCAP biological assessment (BA) and provide an overview of the ESA consultation. The ESA consultation is a Section 7(a)(2) consultation that addresses combined major hydrologic operations of the CVP and SWP. Reclamation is the lead Federal agency and consults with U.S. Fish and Wildlife Service and NOAA Fisheries. DWR is the lead State agency and consults with DFG.

Reasons for consultation include:

- ? CVP/SWP operations affect listed fish species (Coho salmon, winter-run and spring-run Chinook salmon, steelhead, delta smelt, and splittail)
- ? Existing long-term biological opinions (BO) are currently outdated (written between 1993 and 1995).
- ? Only a short-term spring-run/steelhead BO exists for OCAP.
- ? OCAP needs updating to circa 2003.
- ? Long-term BOs need congruence with CVP contracts (2004 2029).

The project agencies (USBR and DWR) produce two documents (the OCAP and BA) in preparation for consultation on the effects of listed species arising from the water project operations. The OCAP provides a detailed project description, analysis, and explanation of criteria and procedures for CVP/SWP operations. The OCAP includes historical modeling (past to present), as well as forecasting processes. The BA identifies proposed action descriptions (continuing operations) of CVP/SWP. It details the biology of listed species of concern and contains assumptions about the models that present conditions

through a future level of development. It analyzes CVP/SWP effects on species, as summarized below.

Salmonids: Factors under anthropogenic control that potentially influence steelhead and Chinook salmon distribution and abundance include: water temperature, flow, diversions, and fish passage. Additional factors beyond human control include: ocean conditions, habitat availability, habitat suitability, harvest, hatcheries, predation/competition, and food supply. Current understanding indicates that steelhead and Chinook salmon populations experience problems on the Sacramento River and Clear Creek during dry years. Direct take (entrainment in CVP and SWP export water) is usually a concern from January to May, although processes exist to reduce take. Water operations may adversely impact steelhead and spring-run populations in the upstream regions and the Delta. Winter-run populations may be negatively impacted in the Delta, but not likely upstream. Operations on the Trinity River may affect Coho salmon, but potential impacts do not appear to have adverse population-level effects.

<u>Delta smelt</u>: Factors that potentially influence delta smelt distribution and abundance include: climatic effects, food web changes, CVP/SWP export operations, stock-recruitment effects, predation pressures, contaminants, agricultural diversions, and power plant operations in the western Delta and Suisun Bay. Preliminary effect determination indicates that entrainment losses at the Delta export facilities will not significantly impact delta smelt populations. Entrainment losses at CVP/SWP pumps assume salvage density is independent of total pumping and assume salvage is an index of entrainment. A change in the export/import (E/I) ratio may prove detrimental to delta smelt.

<u>Sacramento splittail</u>: Seasonal floodplain inundation is important for splittail populations. Other factors influencing splittail abundance and distribution may include food web changes, CVP/SWP export operations, predation pressures, contaminants, agricultural diversions, stock-recruitment effects, and recreational harvest. A change in the E/I ratio would not likely impact splittail, but Yolo Bypass flows are important in frequency and magnitude. Preliminary effect determination indicates that entrainment losses at the Delta export facilities will not significantly impact splittail populations.

Reclamation does not currently foresee any major changes in operation, although future consultation efforts may lead to system changes. Reclamation supports on-going research, modeling, and consultation efforts.

Rick Sitts, Metropolitan Water District of Southern California.

Sitts introduced the idea of integrated fish management as a guiding concept for prioritizing science and policy decisions in the Delta. This proposed framework may help prioritize science and management actions in a collaborative manner, incorporating fish benefits, cost effectiveness, timeliness, technical feasibility, and other policy concerns.

Cost-benefit analyses can help managers prioritize actions benefiting fish. Management decisions will ideally leverage present value, capitol assets, operational and management costs, interest costs, and potential long-term returns. Scientific understanding helps guide the analysis and helps evaluate mixes of actions (Table 1).

Table 1: Management Actions with Potential to Affect Fish Species of Concern

Near-term Decisions Affecting Fish	Other Actions Affecting Fish
? BOs, including OCAP	? Upstream storage increases
? South Delta Improvements	? Upstream of DCC channel modifications
? Expanded Banks Pumping	? Delta Cross Channel (DCC) operation
? CVP/SWP Intertie	? Re-plumb Clifton Court Forebay
? EWA long-term operation	? Habitat restoration
? Red Bluff Diversion Dam	- Battle Creek
	- Dutch Slough
	- Suisun Marsh
	? Ocean harvest modifications

To optimize management actions, the California Urban Water Agencies (CUWA) is promoting collaboration with a new pilot initiative, which began in April 2003, when CUWA met with DFG, NOAA Fisheries, USFWS, CBDA, and R2/Cramer consultants (Portland, Oregon). R2/Cramer proposed a pilot framework for winter-run and delta smelt that emphasizes factors likely to cause large effects, provides an established analytical basis, and seeks to develop quantified life-cycle models for species of concern. Figures 2 and 3 show hypothetical examples of pilot outcomes.

Figure 2: Hypothetical Framework Example to Integrate and Quantify Science Data

SAMPLE FISH FRAMEWORK – SCIENCE SIDE								
Life Stage	Location	Survival factor	One of many potential actions	Fish benefits	Uncer- tainties			
Spawner	Upstream	Spawning area	Restore Battle Creek	A = C =	Area			
Embryos	Upstream	Flow fluctuations	Non-stranding flow regimes	A = C =	Minimal flows			
Fry	Rivers	Water temperature	Raise Shasta	A = C =	When needed			
Smolt	Delta	Entrainment	Re-plumb Clifton Court	A = C =	Population effect			
Ocean rearing	Ocean	Harvest	Adjust regulations	A = C =	Sampling			
Returning adult	Delta, rivers	Barriers	Modify RBDD or DCC	A = C =	Baseline passage			

SAMPLE FISH FRAMEWORK – POLICY SIDE One of many potential Fish Cost (NPV) Cost Other effectiveness Feasibility benefit actions concerns Restore Battle Creek A = ... \$ F/S tbd C = ... Non-stranding \$ F/\$? A = ... tbd flow regimes c = ... Raise Shasta A = ... \$ F/\$ tbd ? c = ... Re-plumb Clifton Court A = ... 69 F/\$ tbd ? c = ... Adjust A = ... \$ F/\$ tbd ? regulations c = ... Modify RBDD A = ... \$ F/\$ tbd ? or DCC c = ...

Figure 3: Hypothetical Framework Example to Integrate and Quantify Policy Data

The pilot proposed the following guidelines:

- ? Collaborate, within a budget
- ? Seek expert advice and peer review
- ? Substantiated evidence of relationships
 - Consistent with theory and data
 - Relate to effects of proposed actions
- ? Focus on factors likely to cause large effects
- ? Established analytical basis
- ? Ouantitative life-cycle model

Completion of the framework is proposed for January 2004.

II. Session Two: Upstream Flow Fluctuations and Barriers to Fish Migration

Flow Fluctuations

Bruce Oppenheim, NOAA Fisheries.

Some Delta effects stem from upstream water operations. The frequency of upstream flow alterations or fluctuations causes biological consequences, including fish stranding and isolation¹. Flow fluctuation is defined as unnatural rapid changes in stream flow over short periods resulting from reservoir operational changes. Flow alterations are changes in flows over long periods, which change the habitat. Stranding is the beaching of fish on or in the gravel substrate by the separation of fish from water as flows recede. Stranding typically occurs in areas where juveniles or redds are dewatered. Isolation is the trapping

¹ Hunter, M.A. 1992. Hydropower flow fluctuations and salmonids: a review of the biological effects, mechanical causes, an options for mitigation. Washington Dept. of Fisheries. Technical Report No.119. 46 pp.

of fish in side channels or scour holes within and outside the active channel, with no access to free flowing water. Repeated flow fluctuations can have population impacts, particularly on small populations (e.g., steelhead).

Recent studies² suggest salmonid populations are controlled by density-dependent mortality (e.g., competition for food or rearing space), but that density-independent factors such as flow and water temperature are critical at the fry life stage. Both stranding and isolation occurred on the American River in February 2003, after large flow reductions de-watered steelhead redds. This large flow reduction occurred after the CVP increased reservoir releases to meet a Delta water quality standard requirement. This resulted in a trade-off between fish survival and compliance with water quality standards. NOAA Fisheries estimated that 10% of American River steelhead redds were de-watered from this one change in flows.

Using the American River as a case study³ to examine the significance of flow fluctuations suggests high river flow fluctuations during peak spawning periods can significantly decrease egg and fish survival. The survival index also decreases as November flow variation increases. High river flows in January may scour out eggs and fry, thereby further decreasing survival. Most American River salmon (>95%) emigrate as fry. No apparent relationship exists between river flows and juvenile outmigration. Consequently, pulse flows like those occurring in the San Joaquin watershed as part of VAMP would not be an appropriate management strategy for the American River.

To maximize survival for species of concern on the American River, operators may want to avoid flow reductions below 2,500 cfs during October through March (October through December is the Chinook spawning period; January through March is the steelhead spawning period). Operators may also want to avoid flows above 4,000 cfs during January through June (juvenile Chinook and steelhead rearing period). The basic strategy is to keep flows stable during spawning and then maintain a minimum incubation flow until fish emerge ⁴.

These recommendations, specific to the American River, do not all translate to other river systems. However, they might provide a framework⁵ for sustainable water management

² Milner, N.J., Elliot, J.M., Armstrong, J.D., Gardiner, R., Welton, J.S., and M. Ladle, 2003. The natural control of salmon and trout populations in streams. Fisheries Research 62:111-125.

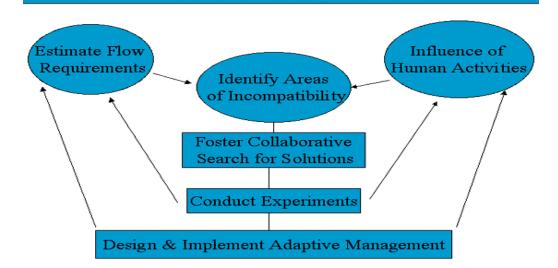
³ Snider, B., Titus, B. and K. Vyverberg. 2001. California Dept. of Fish and Game, Habitat Conservation Division, Stream Evaluation Program. Evaluation of the effects of flow fluctuations on the anadromous fish populations in the Lower American River. Prepared for U.S. Bureau of Reclamation. Technical Report No. 01-2. 49 pp.

⁴ Titus, R., Snider, B., and M. Brown. 2003. Overview of Chinook salmon ecology in the Lower American River. Unpublished study results from the first American River Science Conference, June 5-6. Sacramento State University.

⁵ Richter, B.D., Mathews, R., Harrison, D.L., and R. Wigington, 2003. Ecologically sustainable water management: managing river flows for ecological integrity. Ecological Applications 13(1): 206-224.

(Figure 4) that may help operators, scientists, and managers see the key issues and implement necessary effective solutions.

Figure 4: Conceptual Model for Managing Water Operations using Science Data Frame work for sustainable water management (Richter, et al. 2003. *Ecological Applications*)



Kenneth Rose, Louisiana State University and EWA Technical Review Panel.

Rose presented a model⁶ that quantifies the biological linkages from spawning to recruitment for the Central Valley Chinook salmon, and showed how the model could be used to predict optimal river flow patterns that maximized recruitment. The model uses daily time steps (October through July) for all life history stages of the fall and late-fall runs. The model spatially divides the Tuolumne River into 52 different 1.6 kilometer segments, spanning 3 reaches (adopted from an IFIM study). Model inputs include reach data (daily flows, densities of predators) and segment data (percent riffle versus pool/run, wetted usable area (WUA) for spawning/incubation, fry, and smolt life stages). Spawning information includes the number and sizes of females migrating upriver; fecundity depends on female size. For each river segment, the model assigns redd location(s) and determines redd quality from flow and WUA on day of spawning. Water temperature (expressed as degree-days) determines egg and alvin development. Mortality occurs from extreme water temperature, superimposition, and habitat loss via flows. The model bases growth rate of individuals on bioenergetics (temperature, food consumption related to flow and WUA, larger fish assigned higher food consumption).

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⁶ Jager, H.I., and K.A. Rose. 2003. Designing optimal flow patterns for fall Chinook salmon in a Central Valley, California river. North American Journal of Fisheries Management 23: 1-21.

To determine the optimal flow pattern, Jager ran hundreds of thousands of simulations and determined that the flow pattern that maximized recruitment for 5,000 spawners. Simulations were also run using 40,000 spawners. Model results suggest increasing recruitment is best achieved by first adding water in the spring and then by adding water in the fall. To maximize spawning diversity (estimated as a function of spawning duration), model results suggest adding pulse flows during peak spawning periods (i.e., winter months). Model-predicted optimal flow patterns changed with model objectives (recruitment versus diversity), total amount of annual water available, and the number of female spawners. Predicted recruitment was generally higher and the duration of spawning generally longer in wet years. There are trade-offs between egg survival and fry survival, but wetter conditions create larger population benefits. Population viability analysis (PVA) simulations for one hundred 100-year runs indicated that both river flow and ocean harvest exert significant population level effects, with ocean management actions appearing to have a larger effect. Certain combinations that reduce both ocean harvest and flow diversions showed the greatest population benefits.

Due to data gaps and scientific uncertainty, the model incorporates many assumptions and estimates based upon professional judgment. As with all models, conclusions must be weighed carefully against uncertainties. Further refinement and sensitivity analysis can help to identify critical inputs, increase precision, and prioritize data needs. The model demonstrates the type of strategic approach (e.g., dividing steps and uncertainties into a logical sequence and model framework) that will be necessary in order to develop quantified decision management tools for salmon, delta smelt, and other species of concern.

Barriers to Fish Migration: Red Bluff Diversion Dam (RBDD) Case Study

Serge Birk, Central Valley Project Water Association.

RBDD, located at about river mile 234 on the Sacramento River, affects fish access to upstream river habitat. The Red Bluff river region and upstream habitat historically provide productive spawning habitat for winter-run and spring-run Chinook, Central Valley steelhead, and other species of concern. RBDD gate operations (closed four months and open eight months each calendar year) impact adult fish migration, depending on fish run timing. Gate closure also creates a lake-effect in the river where predators (e.g., Sacramento pike minnow) congregate, possibly leading to increased predation. A fish ladder occurs in the center of the RBDD structure and on each side of the river. Recently installed fish screens and bypass structures have significantly reduced entrainment of smolts and fry into water diversions situated at RBDD.

Most of the scientific and policy debates surrounding RBDD focus on adult fish passage and the best operational alternatives. Alternatives must offer reliable water supply delivery, safe fish passage, and accommodate community preferences (e.g., local

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⁷ Jager, H.I., H.E. Caldwell, M.J. Sale, M.S. Bevelhimer, C.C. Coutant, and W.Van Winkle. 1997. Modeling the linkages between flow management and salmon recruitment in rivers. Ecological Modeling 103: 171-191.

recreational uses). The Environmental Impact Statement (EIS) identifies three RBDD alternatives, in addition to the existing condition and a no action alternative⁸. Environmentalists support removing the gates all year long to minimize or remove adverse impacts to salmonids and sturgeon, but this raises concerns for water supply reliability and the water users. Additional scientific understanding and fish information can help clarify our best alternative and future challenges.

Mike Tucker, NOAA Fisheries.

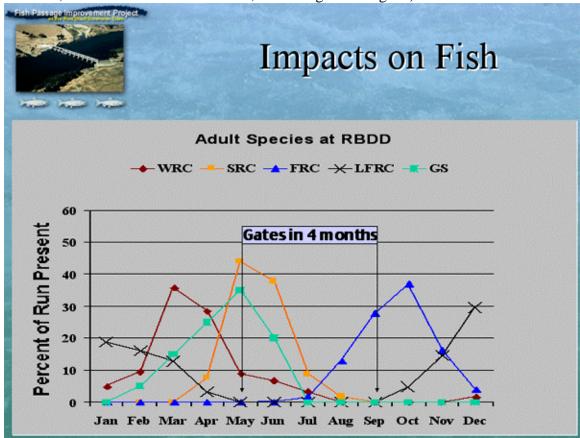
RBDD is an unusual dam with unique hydrology (e.g., no overspill or hydropower production) and management challenges (e.g., upstream and downstream fish migration impacts). RBDD impacts on adult fish migration depend on the basic timing of the runs relative to the four months of gate closure; thus, some runs experience more significant impacts on migration than other runs (Figure 5). Monitoring data suggest date closure may exclude fish from natal territories.

When RBDD gates are down, water travels through a one to three foot opening at the bottom of the river channel. This design creates extreme water velocity underneath the gates. Anadromous fish naturally seek high velocities and swim upstream into this high flow, probing the flow under the gates, but are unable to pass underneath the gates. The fish ladders do not support enough flow to attract the fish, so the fish repeatedly move into the high flow field and unsuccessfully try to pass under the gates. DFG radio tagging studies indicate that RBDD causes fish to experience an average migration delay of 16.5 days. The energy expended to pass RBDD is thought to adversely impact future survival and spawning success, especially for spring-run.

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⁸ U.S. Bureau of Reclamation, Mid-Pacific Regional Office. 2003. Sacramento River Division, Sacramento Canals Unit. http://www.usbr.gov/dataweb/html/sacramento.html

Figure 5: Adult Temporal Occurrence of Selected Fish at RBDD Relative to Gate Operations (WRC: winter-run Chinook; SRC: spring-run Chinook; FRC: fall-run Chinook; LFRC: late-fall-run Chinook; and GS: green sturgeon).



RBDD gate closure can be timed to optimize fish passage while preventing predator congregation. In the 1980s, dam closure created a "feeding station" for over 10,000 Sacramento pike minnow and striped bass that congregated below RBDD and fed on emigrating juveniles. By postponing gate closure until May 15th, operators now reduce this concentrated build-up of pike minnow and striped bass. By maintaining current operations (i.e., the no action alternative), models and assessment indices for species of concern suggest RBDD will mostly affect spring-run Chinook and green sturgeon, with some adverse impacts to fall-run Chinook. The preferred alternative is to achieve minimal impact by removing RBDD gates during fish migrations.

Dave Vogel, Natural Resource Scientists, Inc.

The RBDD EIS does not assess fishery resource impacts for some consequences of the various alternatives. For example, RBDD predation remains a significant factor, despite significant mitigation efforts. Removing gates year-round and ceasing all water delivery into the Tehama-Colusa Canal (TCC) would help upstream and downstream fish passage, but it is not realistic. The question really is how to divert a large amount of water from the Sacramento River into the TCC, while minimizing environmental impacts. All potential management actions should undergo careful environmental cost-benefit analysis

because RBDD actions will only affect a small percentage of some fish populations (e.g., 97% of spring-run Chinook spawning occurs in tributaries downstream of RBDD, so only 3% of spring-run spawners may benefit).

Uncertainties associated with a proposed large-scale, year-round pumping station involve the fish screens, gradient facility, flow control weir, and pump station. To work properly, fish screens need uniform flow velocities and a stable river channel. Operators achieve this by dredging and building training walls. Bathymetric surveys show that river channel and flow characteristics at the site have changed since 1984. This could prove problematic for existing headworks. Training walls would also likely create ideal predator fish habitat. Fish pumps within each fish screen structure would have to be designed, implemented, and maintained regularly to pump fish from internal bypasses. All such efforts are expensive and may cause more harm than benefit to fish.

Given resource and engineering constraints, the most cost-effective improvements may involve upgrading RBDD fish ladders. Forcing a higher percentage of the Sacramento River through the fish ladders could potentially reduce the adult salmon migration delay and reduce predation. Upgrading existing fish ladders from their original 1960s design appears feasible and beneficial.

III. Session Three: Understanding Bay-Delta Processes, Fish Mortality, and the impacts of water project operations

Wim Kimmerer, Romberg Tiburon Center.

The white paper on Open Water Processes of the San Francisco Estuary, produced for the CBDA Ecosystem Restoration Program, is currently undergoing peer review. A draft of the white paper is publicly available at http://science.calwater.ca.gov/white_papers.shtml. The white paper describes the Estuary's physical environment (freshwater flow, tides, climate change); chemical environment (nutrients, sediment); organic carbon sources (phytoplankton, microalgae, river and marsh sources); primary consumers (zooplankton, benthos); fish and macroinvertebrates (key species, the "fish-X2" relationships, and diversion effects); and the consequences for habitat restoration. Physical processes and their linkages with biological processes drive the estuarine system. The estuary acts as a single, interconnected ecosystem with no distinct boundaries. As Figure 6 depicts, physical forcing by tides and other ocean conditions, freshwater flow, and wind have influences on all parts of the estuarine ecosystem.

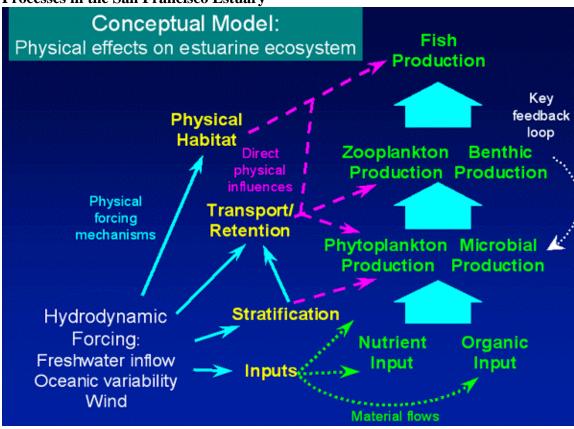


Figure 6: A Conceptual Model Relating Physical, Chemical and Biological Water Processes in the San Francisco Estuary

Salinity exerts a significant effect on the Estuary. Salinity affects the physical habitat and thereby influences distribution and abundances of plankton, fish, and benthos. Salinity gradients cross geographic boundaries, rather than having distinct basin-wide differences. These salinity gradients affect the distribution of various biota. For example, copepod distributions correlate more strongly with salinity than with geography. Similarly, fish distribution depends on estuarine salinity, hydrodymanic transport, stratification, and other physical processes. Neither plankton nor fish distributions align with their species-specific optimal salinity ranges, suggesting other ecological factors also drive population distributions.

Two competing physical factors, tidal effects and freshwater flow, drive important ecosystem dynamics. Tidal effects increase seaward and freshwater effects increase landward and with greater river flow. Net freshwater flow causes seaward advection. Tidal flows involve complicated processes that result in both advection and dispersion. Net freshwater flow causes advection. Both processes must be considered, but our current understanding suggests physical processes throughout most of the system are dominated by tidal flow, especially west of the Delta. The physical effects of tidal forces are detectable far up estuary (e.g., at Vernalis on the San Joaquin River and on the Sacramento River at Sacramento). This new understanding alters the historical concept that water flows through the Delta like a river (i.e., net-flow conceptual model). The net-flow concept only applies in the Delta under certain high flow conditions.

Freshwater inflow is highly variable both seasonally and interannually. As Delta outflow increases, the low-salinity zone moves seaward. This salinity response is "stiff," meaning that larger flows are needed to move the freshwater-seawater boundary (X2) the farther downstream the boundary occurs. Moving the low-salinity zone affects tidal mixing and estuarine circulation patterns, and may affect habitat for fish and invertebrates, as well as entrainment into the estuary of species that spawn in the coastal ocean. Modeling and planning for research to further investigate the "fish-X2" relationships will begin in 2004.

To manage flow and environmental quality, managers use principal tools, including flow regulation (X2, E:I ratio), export reduction, EWA, habitat construction, and adaptive management, each with its own drawbacks and unresolved issues as shown in Table 2.

Table 2: Some Drawbacks and Constraints Associated with Various Management and Restoration Tools

Principal Management and Restoration Tools	Drawbacks and Constraints
Flow regulation, X2	Cost, lack of knowledge
Export reduction, EWA	Effectiveness unknown
Habitat construction	Depends on habitat type
Adaptive management	Largely untested

Increased understanding of estuarine physical processes may enhance the effectiveness of these tools. For example, the E:I ratio assumes the net-flow conceptual model and treats the Delta like a river. This approach may work for high flow conditions (i.e., when E:I is small), but not for low flow conditions. Scaling export flows to incorporate tidal processes and internal Delta mixing may be a better approach during periods of low flow (typically periods of high management concern). Daily Delta water removal rate is relatively small (maximum 2-3% per day for exports) on a volume basis, but cumulative amounts are considerable and are a source of concern for delta smelt and other fish species of concern.

Plans for management and restoration should factor in seasonal and long-term changes to ecosystem dynamics (e.g., climate change, increasing human population, increasing water demands, decreasing sediment supply). Relationships between freshwater flow and biological populations generally show that abundance declines with low flow, but each trend is species specific. Whether naturally or anthropogenically induced, system changes of physical and biological processes have management and restoration implications. Principal unresolved issues include:

- ? How to increase productivity.
- ? How to make X2 regulation more effective.
- ? Population-level effects of export entrainment on fish.
- ? Effect of contaminants on the estuarine foodweb.

Jon Burau, U.S. Geological Survey.

Understanding fundamental physical and biological processes is a necessary part of developing management solutions that enhance ecosystem function within the Delta while maintaining water supply reliability. Two case studies highlight how innovative management strategies can directly evolve from an understanding of how fundamental processes work in the Delta. The first case study involves a series of multi-disciplinary studies conducted at the Delta Cross Channel (DCC). The second draws from work at Franks Tract.

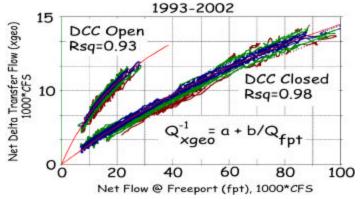
DCC study results suggest the migration pathways of individual juvenile salmon may largely depend on the tidal conditions (tidal current phase) they experience at channel junctions. For example, tidal current phase appears to control whether individual juvenile salmon are entrained in the DCC, are entrained in Georgiana Slough, or continue down the Sacramento River toward the ocean. First-year DCC investigations, conducted under a variety of flow conditions and gate operations, reported that juvenile salmon "go with the flow." Within the straight sections of the characteristically prismatic channels of the North Delta, fish do appear to "go with the flow." However, this result is purely an artifact of the spatial homogeneity of the currents within the north delta channels. The North Delta channels are nearly devoid of the geomorphologic features typically found in natural channels and therefore the spatially variable current structures that accompany these features are also absent. Thus, the flow structures (velocity distributions) within the channels of the north delta are relatively uniform and more closely resemble those found in a concrete canal than they do a naturally flowing river.

Within the spatially uniform flow structures that occur in the straight reaches of the north Delta channels, juvenile salmon appear to be homogeneously distributed within the cross section leading to the first-year study conclusion that fish "go with the flow." However, second-year DCC study data suggest juvenile salmon aren't homogenously distributed across the channel within channel bends - juvenile salmon appear to be concentrated in the outside of the bend by the complex flow structures that occur there. In the DCC area, fish appear to be concentrated on the DCC and Georgiana Slough side of the Sacramento River, potentially increasing entrainment of juvenile salmon into both of these channels. Therefore, in bends and junctions, juvenile salmon move with the velocity vectors (current structures), not the bulk discharge, or flow. This implies that we cannot predict entrainment of juvenile salmon in a given channel within a junction based on the bulk flow alone. Further, it implies that the influence of bends and junction geometry on juvenile salmon distributions within channels should be considered in the sighting of new intake structures and that solutions like "stripping off" fish in bends and steering them into favorable habitats seem possible with creative channel design.

The DCC case study also highlights the need to exercise caution when using onedimensional models to study problems that are fully three-dimensional. For example, since one-dimensional models are unable to simulate the non-homogenous velocity and juvenile salmon distributions observed within bends and junctions because of inherent simplifying assumptions in their formulations, they will incorrectly apportion juvenile salmon among the channels within a junction. In essence, the one-dimensional models assume that fish "go with the flow", which our second-year DCC study results suggest is probably false.

The Franks Tract case study demonstrates the degree to which salinity intrusion is influenced by the tidal currents and water project operations. In the north delta, for example, the so-called Delta Transfer Flow (the combined net flow through the Delta Cross Channel and Georgiana Slough) in significantly correlated (R²> 0.93) with the Sacramento River flow (measured at Freeport) and DCC gate operations (Figure 7). This relationship is completely independent of the SWP and CVP export rate, which strongly suggests the export facilities do not draw water directly from the Sacramento River through the Mokelumne system into the Central Delta. Rather, the Mokelumne system delivers Sacramento River water to the Central Delta, virtually independent of pumping in the South Delta, creating a "pool of freshwater."

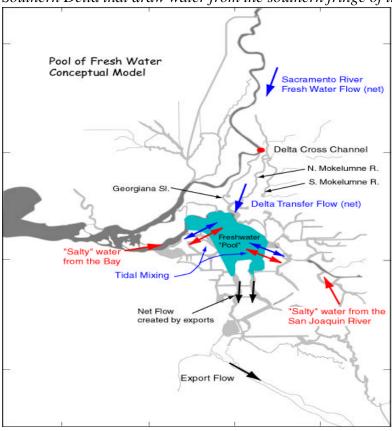
Figure 7: Net Delta Transfer Flow Plotted as a Function of the Net Flow on the Sacramento River Measured at Freeport (based on 10 years of data: 1993-2002). The net Delta Transfer Flow is computed by subtracting the flows on the Sacramento River measured above the Delta Cross Channel (USGS flow station WGA) from the flow measured on the Sacramento River below Georgiana Slough (USGS flow station WGB). A simple two-parameter non-linear relation was fit to these data using a least-squares regression under DCC gate open (a=4.219x10-5, b=1.543) and closed (a=2.382x10-5, b=4.64) conditions. This non-linear relation was selected over a linear model, which also fit the data well, because it naturally goes through the origin (e.g. Qfpt = Qxgeo = 0).



This "pool" of fresh Sacramento River water is sandwiched between, and mixed with, lower quality water (e.g. higher salinity water) from the Bay to the west and the lower quality water from the San Joaquin River to the east. The boundaries of this fresh water pool are indistinct, because strong tidal mixing in the Central Delta tends to homogenize the waters from these different sources. In addition, the residual flows in the Central Delta are relatively weak, overall, when compared to the tidal flows (typically less than 2% during low outflow periods); thus the export pumps direct influence on transport processes within the Central Delta is correspondingly weak. Although the influence of the export pumps in the Central Delta is weak, their influence increases as one moves south, suggesting the export pumps draw water from the southern fringe of the "fresh water pool" - not directly from North Delta. Therefore, conceptually, water moves from the north to the export pumps as a weakly coupled three-part process (Figure 8):

Figure 8: The "Pool of Fresh Water" Conceptual Model of the Central Delta

Movement of fresh water from North Delta to the export facilities in the South is accomplished as a decoupled three-part process. First, fresh water from the Sacramento River is introduced into the Central Delta (the so-called net Delta transfer flow) at flow rates that are dependent on the Sacramento River flow (at Freeport) and DCC gate position and independent of the export flow rate (See Figure 8). The net Delta Transfer Flow is Sacramento River water that flows through Georgiana Slough and the Mokolumne River via the Delta Cross Channel to the San Joaquin River. Second, the fresh water introduced from the Mokelumne system creates a "pool" of fresh water in the Central Delta that mixes with "salty" water from the Bay on its western flank and with salty San Joaquin River water to the east. Third, the export pumps create net flows in the Southern Delta that draw water from the southern fringe of this pool.



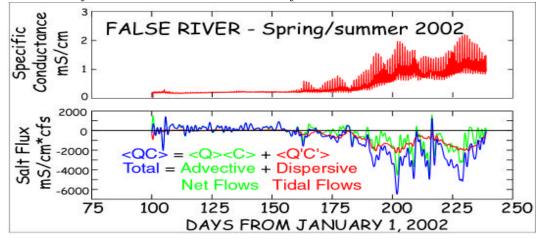
The idea of this pool of fresh water in the Central Delta is a useful conceptual framework for thinking about water project operations. More specifically, water project operations (a combination of reservoir releases, gate and pump operations) can be thought of as essentially "managing" this "pool" of fresh water to meet water quality (i.e. salinity) standards during low inflow periods (late fall through early winter), when salinity intrusion from the Bay is a serious management concern.

It is appealing to consider Franks Tract when thinking about salinity management in the Delta because it is located in the middle of the fresh water "pool," and, as such, changes to or operations within the Franks Tract area will have a direct influence on the spatial

structure and temporal evolution of this fresh water "pool." The existing salinity management tools – reservoir releases, the Delta Cross Channel gates, and the export facilities – are all located on the Delta's periphery, and as a consequence have a relatively weak, indirect influence on the fresh water pool because tidal mixing dominates transport in the Central Delta, where the fresh water pool resides. Because transport in the Central Delta is controlled to a large degree by tidal mixing, salinity response to water project operations in the Western and Central Delta is relatively slow, requiring relatively large quantities of water to repel salinity as it intrudes into the Delta from the Bay during low inflow periods. Recent analysis of salt flux data (Figure 9) collected in False River shows that Franks Tract adds significantly to the dispersive transport of salt into the Central Delta during low inflow periods. A series of proposed modifications to the Franks Tract area, such as levee construction and/or tide gates, could reduce Franks Tract ability to store salt. Reducing Franks Tracts ability to store salt effectively increases the fresh water connectivity between the water supplies in the North and beneficial uses in the South. Furthermore, these proposed modifications are not only expected to lower salinities in the Central and South Delta, but also could decrease the response time of salinities in the Central Delta to existing water project operations. Increasing the coupling between water project operations and salinity response in the Central Delta could lead to greater control in meeting water quality standards in the Western and Central Delta and could therefore lead to more efficient use of existing Sacramento River supplies.

Figure 9: Time Series Plot of Specific Conductance (top panel) and Tidally Averaged Salt Flux (bottom panel) Measured in False River During 2002.

The salt flux is a measure of the quantity of salt passing a given measurement location, in this case the mouth of False River. It is computed simply as the product of the discharge, Q, and the specific conductance concentration, C. The total tidally averaged salt flux, <QC>, is shown in blue, the advective flux is shown in green and the dispersive flux in red in lower panel. The discharge measured in False River is, by convention, positive toward the San Joaquin (west) and thus, negative salt fluxes indicate an eastward movement of salt into the Franks Tract area from False River.



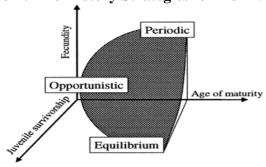
The salt flux can be decomposed into two components – the advective and dispersive fluxes. Mechanistically, in the case of False River, the advective flux simply represents

the amount of salt that enters Franks Tract from the net flows alone – in other words through the combined influence of the rivers, export pumps, tidal non-linearities and meteorological effects. The dispersive flux represents the amount of salt that moves into Franks Tract past our False River sampling location due to dispersive processes, such as shear flow dispersion, and tidal trapping and pumping mechanisms that occur within a tidal excursion of the mouth of False River. In essence, the dispersive flux evolves from the difference between what goes past a sampling location on flood and what comes back on the ebb. In the case of our False River sampling station, during periods where the dispersive flux is large and negative it means that a large fraction of the salt moving down False River towards Franks Tract on flood tide (e.g. "pumping") does not come out on the subsequent ebb tide (e.g. "trapping"). In other words, when the dispersive flux is large and negative, salt is stored in Franks Tract every single tidal cycle. The dispersive flux in Franks Tract (red curve in the lower panel, Figure 9) is very large compared to other locations in the Bay and Delta.

Jim Cowan, Louisiana State University and EWA Technical Review Panel.

Mortality influences population dynamics in estuaries in a manner similar to that in other aquatic environments because most fish have similar life cycles, even though life history strategies can vary widely⁹. In the absence of information necessary to construct detailed population dynamics models, much still can be learned about how a fish species may respond to anthropogenic stressors simply by identifying the life history strategy of the species of interest. Cowan described an approach offered by Winemiller and Rose (1992) developed by analyzing 16 traits for 216 species that organizes life cycle information and vital rates into a graphical life-history plot. The plot allows you to place species onto a tri-lateral surface (endpoint strategies are periodic, opportunistic, equilibrium strategists)¹⁰. Species can fall anywhere on the surface shown Figure 10, based on their life cycle and vital rates.

Figure 10: Three Endpoint Life-History Strategies for Fish¹¹.



Periodic strategists (e.g., striped bass) are long-lived species with high fecundity but, low larval survivorship in most years. Thus, these year-class dominated populations are resistant to stress such as over exploitation, but often are not very resilient (i.e., do not

⁹ Houde, E. D. (1987). "Fish early life dynamics and recruitment variability." Am. Fish. Soc. Symp. 2: 17-

¹⁰ Winemiller, K. O. and K. A. Rose (1992). "Patterns of life-history diversification in North American fishes: implications for population regulation." Can. J. Fish. Aquat. Sci. 49: 2196-2220.

¹¹ Derived from Winemiller and Rose (1992).

recover quickly from chronic mortality). Opportunistic strategists (e.g., anchovies) have short, colonizing life histories that respond rapidly to favorable conditions and can recover in the short-term. These species are less able to withstand high fishing pressure (mortality), but can recover quickly if the mortality is reduced. Equilibrium strategists (e.g., salmonids) are typically moderately sized, moderately long-lived, and live in resource limited environments. It is common for equilibrium strategists to skip the early high-mortality life history stages due to an increased amount of parental care, and often exhibit high density-dependence.

Typically, fish possessing all of the life history strategies live in an estuary. For example, no single life history strategy dominates in the San Francisco Estuary. However, because different life history strategists are capable of responding differently to the same kind of stress, it is possible to predict in a general way how a fish species might respond to specific anthropogenic stressors based simply on its life history strategy. In addition to using life history theory to characterize possible responses, with just a little more information mortality can be placed into a conceptual framework that allows quantification of the potential for relative cohort success, both on an annual basis or among different cohorts spawned in the same year 12. This can be accomplished by comparing the M:G ratio (i.e., the ratio of cohort-specific instantaneous mortality rate to weight-specific growth rate) between cohorts or year classes. Most cohorts of fish lose biomass initially (e.g., in response to high egg and larval mortality rates and low growth rates) after which growth increases and mortality decreases as the cohort begins to gain biomass. In general, the more quickly a cohort reaches the point where M=G, the greater cohort survival rate. Typical M:G ratios can be quite different for different fish species, but this relatively simple metric can be used to estimate intra-specific relative cohort success and enhance our understanding of population dynamics even in the absence of a great deal of species-specific life history information. Growth rate measurements have become routine with the discovery of daily and annual increments in otoliths. Mortality rates are more difficult to know exactly, but are not impossible to measure in situ.

Mechanisms that control the survivorship curve and recruitment process are complex and include physical processes, food limitation, predation, disease, density dependence, and other environmental and anthropogenic factors, including fishing. Nevertheless there is a hierarchy of approaches available to researchers and managers to better understand anthropogenic effects on fish populations in San Francisco Estuary. I have discussed a couple of the most simple and least data intensive. It is important not to become paralyzed if we cannot yet create high-resolution, species-specific individual based models for all of the species of interest. Comparative approaches like life history theory and M:G ratios can be informative long before we learn enough to construct more sophisticated population models such as the one described below.

If data are available, however, the other extreme is possible. In this example we used a spatially-explicit individual-based population model (IBM) of striped bass in the San

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Houde E. D. (1997). "Patterns and trends in larval-stage growth and mortality of teleost fish." J. Fish. Biol. 51 (Suppl A): 52-83.

Francisco Estuary to evaluate a suite of factors believed to have contributed to the decline of striped bass observed in the 1980s and 90s¹³. In this example, a hydrodynamics transport model was used to develop movement rules of striped bass early life stages, after which a spatially-explicit IBM coupled to a matrix model of adult stages was used to test specific hypotheses about the causes of the population decline. Model results showed that no single factor dominated and caused the decrease in striped bass populations. The cumulative effect from multiple stressors best explains the observed decline, although some sources might be of greater importance than others. While the model does not sufficiently capture all of the subtle environmental variability in the system, this type of structured approach provides insight for managers that can be refined with additional research.

Zach Hymanson, CA Bay-Delta Authority.

Operational definitions for various types of fish mortality in the Delta include:

- ? <u>Natural mortality</u>: mortality that occurs as a result of natural processes (predation, competition, disease, old age)
- ? <u>Direct mortality</u>: Loss of fish entrained into the CVP and SWP south delta export facilities
- ? <u>Non-project anthropogenic mortality</u>: fish mortality arising from humaninduced factors other than CVP and SWP operations (e.g., Delta agricultural diversions, contaminants, or fishing).
- ? <u>Indirect mortality</u>: increases in natural and non-project fish mortality caused by water project operations, but not including direct mortality.

The relationship between indirect mortality and other sources of mortality is unknown, although many assume that indirect and direct mortality have additive effects. Possible mechanisms for indirect mortality include the alteration of Delta hydrodynamics and alterations in Delta water quality. Delta hydrodynamic changes mediated by water project exports may impede fish movement and increase residence time. Increased residence time in the Delta may lead to increased chances of predation, increased chances of agricultural diversion entrainment, and/or decreased chances of reaching more suitable habitat. Water project induced alterations to water quality are thought to arise from longer water residence times, which may lead to localized degradation of water quality (e.g., increased contaminants, salinity, water temperature, or decreased dissolved oxygen levels) and increased mortality of fish or fish food. SWP and CVP water project induced changes to Delta circulation may also lead to unnatural water distributions (e.g., Sacramento River water in the South Delta) disrupting migration routes or, under chronic conditions, may lead to habitat alterations (e.g., maintaining the Delta as tidal freshwater habitat fosters the establishment of *Egeria densa*).

The Zone of Influence (ZOI) concept unifies these physical and chemical mechanisms for indirect mortality in the Delta. ZOI may be defined as a region in the Delta where the

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¹³ Rose, K.A., J.H. Cowan, Jr., L.W. Miller, D.E. Stevens, W.J. Kimmerer and R.l. Brown. A model analysis of the factors causing the decline in the Sacramento-San Joaquin estuary striped bass population. In prep.

physical or chemical mechanisms of indirect mortality can be measured. It is not a distinct region with a defined boundary line, but could be described as a probability distribution. Each water project feature (South Delta export facilities, delta cross channel gates, or the South Delta temporary barriers) has a ZOI. The size of each zone is determined by the interaction among tides, inflow, and water project operations. CVP and SWP export pumping each affect the ZOI differently due to the fundamentally different ways in which these projects divert water from the Delta. The CVP continually exports a set amount of water, operating much like a power plant cooling water diversion. The SWP exports are more episodic, removing substantial amounts of water from the delta at certain phases of the tide. Various features in the Delta (e.g., deep channels or large lakes) also affect the ZOI by influencing interactions among tides, inflow, and project operations. The size of the ZOI may be highly variable on short (tidal time scale) and longer (spring/neap or seasonal) time scales.

Studies to date are only able to estimate direct and total mortality. Nevertheless, management approaches to reducing mortality try to address specific types of mortality:

- ? <u>Direct mortality</u>: fish screens; modify collection/handle/transport/release (CHTR) processes at large screens; constrain exports.
- ? <u>Natural and non-project anthropogenic mortality</u>: habitat restoration; project specific mitigation.
- ? <u>Indirect mortality</u>: regulatory constraints on water project operations; DCC operations (exclusion of fish from the Delta); VAMP.

Fully managing fish mortality ultimately means managing total fish mortality in all habitats occupied during the life cycle (e.g., ocean, Bay, Delta, and rivers). Studies are needed to clarify key mechanisms, quantify total mortality, and the associated variance by region. Ideally, managers and scientists should strive for a situation where actions and activities are evaluated based on resulting change in total mortality or the average probability of population success over the long term.

Ted Sommer, CA Department of Water Resources.

The U.S. Fish and Wildlife Service listed Sacramento splittail in 1999 because of concerns about a decline in abundance, range restriction, and deteriorating conditions in the Delta. The existing state of knowledge about this species is reviewed at http://science.calwater.ca.gov/white_papers.shtml.

Splittail reach adulthood in approximately two years and can live five years or more. Splittail still occupy much of their historical range in Central Valley rivers, inhabiting virtually all Central Valley river areas below the major dams. Small rivers, such as the Napa and Petaluma rivers, can also support substantial concentrations. Associated with high flow periods, adults migrate up the Sacramento River and San Joaquin Rivers to spawn and rear. Reproduction does occur in some of these river channels, but off-channel intertidal floodplains serve as key habitat. Young splittail rely on shallow water habitat during day and night. Many young splittail apparently become entirely benthic at night.

After spawning and rearing, splittail move to the Delta. Water temperature may trigger downstream movement from Yolo Bypass into the estuary.

Population indices are used to evaluate splittail abundances. Less is known about absolute population abundances. Hydrology and seasonal inundation of habitat appear to drive splittail populations. Annual fall mid-water trawl indices suggest high variability in splittail populations with strong peaks in abundance occurring after wet year conditions. Complex, non-homogenous habitat and extended floodplain inundation may improve growth and juvenile survival. Thus, floodplain inundation is thought to largely determine year class strength and abundance. Splittail abundance is low with minimal flooding (less than three weeks between March and May) and strong with large flooding (three or more weeks of flooding between March and May). Floodplain habitat, such as Yolo Bypass, is likely important because it has more rearing habitat and food resources than river channels ¹⁴.

Although not yet observed, increased YOY movement into the Delta interior during years with low spring outflow may potentially lead to: (1) increased within-Delta entrainment, (2) placement of small fish in less favorable habitat conditions (3) increased probability of adverse affects from agricultural pollutants. Juveniles and adults of most floodplain-adapted species are likely able to avoid stranding from artificial water elevation fluctuations, unless fluctuations are very rapid. Eggs and larvae, however, cannot move with rapidly receding water.

A splittail life-cycle model¹⁵ suggests abundant populations occur when conditions favor spawning over multiple years. A long series of dry years does not seem to drive splittail to extinction in the model. The model indicates that population size is not sensitive to juvenile survival rates and that increased adult mortality from spawning, fishing, and diversions has little impact on the population dynamics. Model assumptions and hypotheses include:

- ? Adult splittail migrate up river towards potential spawning areas every year regardless of flows.
- ? Fish spawn several times during the spawning period in response to pulses of water in flooded areas.
- ? Development of strong year classes requires extensive inundation of floodplains during March and April.
- ? Stock-recruit effects may occur at low population levels or with a low effective number of spawners.

The effects of reservoir operations on floodplain inundation need investigation. Present upriver storage (and discharge) capacity is sufficient to prevent inundation in most low

¹⁴ Meng, L., and S.A. Matern, 2001. Native and alien larval fishes of Suisun Marsh, California: the effects of freshwater flow. Transactions of the American Fisheries Society: 130:750-765.

¹⁵ Moyle, P.B., R.D. Baxter, T.R. Sommer, T.C. Foin and S. A. Matern. 2003. Biology and population dynamics of Sacramento splittail (Pogonichthys macrolepidotus): A Review. White paper submitted to CALFED Science Program. 67 pp.

outflow years. However, Shasta and Oroville dams are capable of releasing sufficient water to inundate the lower Sutter Bypass and river flood terraces, so some reservoir operations could be managed to favor splittail. If water storage capacity is increased (e.g., by raising Shasta Dam) floodplain inundation frequency and duration in the Sacramento Valley is likely to decrease, unless some of the water is reserved for floodplain inundation.

Researchers should look for specific locations of spawning in dry years, examine how flow relates to entrainment, and strive to develop better abundance estimates. Significant management implications could result if splittail exhibit genetic/phenotypic diversity with distinct sub-populations (e.g., distinct San Joaquin and Sacramento river populations). Other key uncertainties related to water operations involve clarifying the relationship between splittail migration and hydrodynamics. Historical conditions and relationships may no longer serve as valid baseline conditions; thus, the effects of proposed future changes (e.g., habitat restoration, new facilities, invasive species, or global warming) may not be predicted from historical conditions.

Analysis of CVP and SWP salvage patterns show no evidence that entrainment negatively affects splittail populations. Predominant take peaks in May to June, and to a lesser extent in July. More splittail salvage occurs in wet years, with low take during dry years. The present approach to setting splittail take levels is based on historical salvage trends, not population biology. Monthly "red lights" are based on the average of upper quartile of monthly salvage for above and below normal years. An alternative approach for setting splittail take levels can be based on minimizing take when populations are small. To do this, we need to know the relationships between: (1) flow and abundance, and (2) abundance and salvage. Because flow is tightly correlated with abundance and abundance determines salvage, flow appears to be a good predictor of splittail salvage. Confidence intervals for this relationship may provide a new way to define "extreme" levels of salvage relative to predicted population size. This approach only works for juveniles.

Bill Bennett, UC Davis, Bodega Marine Laboratory.

CBDA's delta smelt white paper is currently undergoing peer review and revision. Much of the analyses included in this white paper focuses on trying to understand what drives the annual pattern of growth, mortality, and reproduction.

Delta smelt is one of several *Hypomesus* species found in the Pacific Rim. Delta smelt has a primarily annual life cycle (Figure 11) and may have evolved relatively recently in San Francisco Estuary.

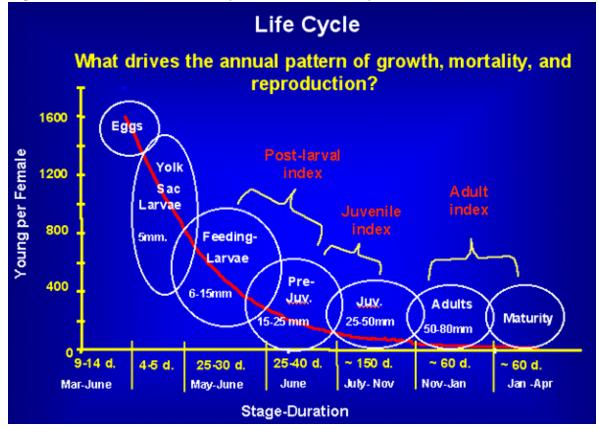


Figure 11: San Francisco Estuary Delta Smelt Life Cycle

The known geographic range of delta smelt spans from San Pablo Bay into the Sacramento and San Joaquin Rivers. Although most delta smelt live one year, approximately 3-4% of individuals live two years. Otolith analysis shows that adult and juvenile indices are self-correlated two years later. Two-year old delta smelt may be important to the population because they have three to five times the fecundity of one-year old fish. More importantly, however, the two-year old fish add security to the population: when one-year cohorts fail, then the persisting two-year olds may help prevent population extinction.

Two processes are thought to regulate delta smelt abundance:

- (1) Longer spawning seasons provide more opportunities to produce young. This can spread the risks of mortality among more cohorts.
- (2) Density dependence occurs during late summer (the period of transition from juvenile to adult life stages) when populations are sufficiently large.

As shown in Figure 12, a multitude of factors may affect delta smelt populations, and it is difficult to tease out the effect of any one factor. The spawning season for delta smelt is regulated by water temperature (15-20°C), with most spawning occurring during spring tidal phases. Thus, cooler springs lengthen the spawning window. Incubation lasts approximately 10 to 14 days, with most hatching occurring during neap tidal phases.

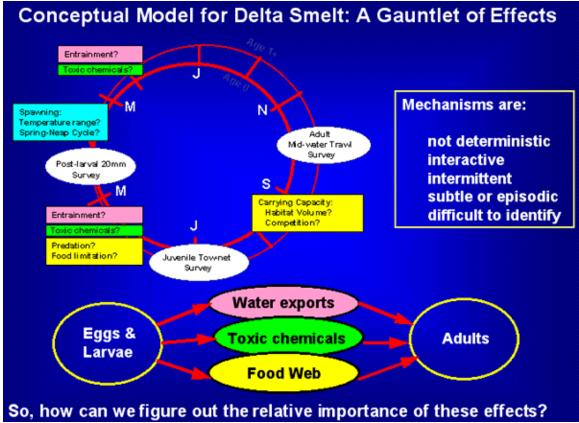


Figure 12: Factors Influencing Delta Smelt Populations

Three other key factors are: (1) water exports, (2) toxic chemicals, and (3) food web influences. Otolith, histopathology, and comet assay analysis are used to distinguish effects by different types of mortality mechanisms. Results suggest both toxic exposure and food limitation occur, but that undernourishment affects more individuals. Overall food abundance has changed, with a step decline occurring in 1990. This suggests food web dynamics have changed, perhaps significantly impacting delta smelt populations. Potential low food abundance during the fall season translates into depleted glycogen levels and slow growth rates (one mechanism where by density dependence could be manifested).

Impacts of water project operations are also evident. Salvage estimates correlate well with juvenile abundance. Current salvage estimates only track losses of fish larger than 20mm, but exports likely also serve as a proxy for losses of younger (smaller than 20mm) delta smelt. The cumulative proportion of the population lost to exports relative to abundance can be as high as 30%, although there is still some uncertainty about the significance of this figure. Several sources of mortality are operating simultaneously and more data is needed to distinguish these and tease out the impacts of each.

Tracking cohorts may help to distinguish the impacts of water project operations. Analysis of 1999 data suggests one delta smelt cohort may have been significantly impacted by water project exports while others were not. The correlation between delta

smelt year-class success and water temperature might provide opportunities to identify years with few cohorts.

Stock recruitment models suggest density dependence is important to the population dynamics, and that X2 and salinity do not significantly affect carrying capacity, even though X2 position in Suisun Bay during spring seems to measure the probability of high delta smelt abundance. Modeling could help optimize delta smelt conservation and restoration. Some suggestions include using environmental water to influence carrying capacity in the fall (i.e., late summer environmental releases) and saving water use for years with less than 60 spawning days or when the spawning season ends before mid-May (when year classes may be weakest). Models estimate that there is a 12-14% chance that the adult index could drop below 100 (considered the "critical level") for two consecutive years within the next 10 years, although more reliable estimates of effects on population size are needed. Models also suggest managers should expect high population variability and very low delta smelt abundance in the near future.

John Williams, Independent Consultant.

Questions that define the objectives of a 1947 USFWS study to assess the effects on salmonids of the Tracy Pumping Plant and the Delta Cross Channel also define what we need to know today:

- (1) Learn the biology, magnitude, and composition of the fishery resources that depend upon or utilize Delta waters.
- (2) Determine the hydrodynamics of the Delta.
- (3) Determine the possible effects of project operations on hydrodynamics.
- (4) Determine the effects on fishery resources of hydrodynamics altered by project operation.
- (5) Devise ways and means to mitigate damage to, or improve conditions for, present fishery resources.
- (6) Assess the degree of success of ways and means, adopted for the protection and improvement of fishery resources.

The persistence of these questions indicates the difficulty and complexity of the Delta system and the salmonid life cycles.

The basic life history patterns of Chinook salmon may be broken into stream-type and ocean-type. Stream-type fish (e.g., winter-run, spring-run) enter streams months before spawning, rear for a year in the stream before emigrating, and forage in the open ocean. Day length affects the growth rate of stream-type Chinook salmon, with growth apparently controlled by a photo-periodic density switch. Fish exposed to a short day (e.g., winter conditions) grow rapidly and quickly reach appropriate size to develop salt water tolerances. Ocean-type fish (e.g., fall-run) enter streams shortly before spawning, emigrate in their first year, and forage in coastal waters.

We cannot say what the "typical" fish does. Even with a composite of a number of years, high annual and seasonal variation occurs in timing as fish go from one life history stage to the next (e.g., eggs, alevin, fry, smolts, ocean maturing, adult migration, adult

spawning). Such variation occurs on all runs, driven by genetic differences between and within runs. Even under identical environmental conditions, the population distributions of body weight and fork length vary over time for a run. So, based on genetic analysis, dividing runs by fish size creates a high rate of false positives (e.g., designated "winterrun" salmon are not really winter-run). This variation and timing of migration is further confounded by variation in fish behavior. Migration patterns vary locally and temporally. Some fish migrate in the center of the channel, some prefer the side channels; some move head first, others back down the channels; some migrate at night, others prefer to move during the day. Therefore, extreme care is necessary when generalizing results obtained in one study to another species, stocks, or even the same stock under slightly different conditions.

Given our current state of knowledge, detailed Central Valley salmonid modeling does not yet seem possible. Individual based monitoring, perhaps with otolith research, may lead us to better modeling capabilities in the future.

Jim Buell, Buell and Associates.

Key south Delta water project issues include CVP/SWP entrainment, Clifton Court Forebay (CCFB) predation, and collection, handling, transport, and release (CHTR) salvage operation procedures. CVP and SWP have different physical diversion styles, technology differences, and salvage patterns. Predation loss in CCFB overshadows take and facilities losses. Available data shows that predation is a problem at CCFB for Chinook salmon (63-99+% estimated mortality) and striped bass (74-90% estimated mortality).

Predation is likely comparable for other species, but data is available only for striped bass and salmon. Loss assumptions do not account for water temperature changes, but temperature likely influences predation rates. Loss increases with residence time in CCFB and varies inversely with pumping rate (current assumptions do not account for pumping rate changes). Loss equations factor in louver efficiency, pre-screen losses (CCFB predation), CHTR, and other system factors. Biases in current estimates could be removed by factoring additional data into the loss equation (e.g., day/night predation patterns, predator movement in and out of CCFB).

Buell presented a conceptual model for SWP entrainment and salvage fish loss that compares the relative impacts of multiple sources of loss. The model could serve as a tool to compare the effects of alternative strategies to reduce fish loss, but it requires refinement of multipliers and process steps.

Jim White, CA Department of Fish and Game.

Legal requirements under ESA mandate an incidental take statement and a specified amount of authorized take for each listed species (i.e., winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and delta smelt). Regulatory agencies gauge the effectiveness of the conservation measures in the project description and the biological

opinion by comparing actual take to the expected (authorized) take. The approach for setting take limits at the SWP/CVP is better for some species than for others. Improvements are possible for all species of concern, with a specific need to relate the authorized take level to annual abundance.

Winter-run Chinook salmon: Authorized take is based on a juvenile production estimate (JPE) of salmon arriving in the Delta calculated from a carcass survey-based estimate of the spawning population and survival rates from early life stages. Authorized take by the SWP/CVP was based on loss of 1% of JPE, using the historical percentage loss. Managers later changed the authorized take level to 2% when genetic characterization showed that only about half of the "winter-run" take (identification based on size) consisted of true genetic winter-run fish. Managers do not know how indirect mortality, direct mortality, and total mortality relate, so take is only managed based on direct mortality. In the 1990s, winter-run allowable take was generally not exceeded. The exception was in 2001, when winter-run losses at Delta fish facilities exceeded allowable take by approximately three times (actual take was 20,008; "red light" allowable take was 7,404). Further analysis showed that the brood year 2000 JPE estimate was based on a low estimate of spawning adult salmon from counts at RBDD in 2000 and likely underestimated the number of juvenile winter run salmon migrating in the Delta in 2001. Consequently, beginning with brood year 2001, JPE estimates shifted to carcass surveys for more accurate spawner escapement estimates. Additional improvements in winterrun JPE calculations are possible, but not necessarily easy to achieve.

<u>Spring--run Chinook salmon</u>: Managers do not use the JPE approach to set allowable take for spring-run because of their complicated life history. Once spring-run yearlings from tributaries enter the Sacramento River, we cannot accurately distinguish them from other juvenile Chinook, including winter-run, based on length. To set take limits, coded wire tagged (CWT) late-fall-run salmon are used as surrogates for spring-run yearlings (Mill Creek, Deer Creek) in winter months. A 1% loss is allowed for the surrogates released from Coleman National Fish Hatchery, which is roughly comparable to the 2% loss of winter-run. No take limit exists for spring-run smolts emigrating in spring months.

White noted managers are considering modification of the surrogate approach. In-river survival of juveniles (currently assumed to be 50%) may overestimate mortality due to upstream survival improvements (e.g., more screened diversions). The surrogate approach does not equally represent groups or account for behavior of wild versus hatchery fish. Additional genetic characterization of emigrating juveniles might allow more accurate estimates of when spring-run are near the pumps. A JPE- type approach may prove feasible, given the increasing state of knowledge.

<u>Steelhead</u>: Steelhead incidental take levels, derived from a historical average number salvaged at the CVP and SWP, were rarely exceeded until recently. However, the relationship of number salvaged at CVP/SWP to number "taken" is not known because we lack information on mortality factors associated with the SWP and CVP salvage

facilities. We also lack population estimates, partly because the life history is complex and populations occur in many different rivers.

Delta smelt: Delta smelt salvage from SWP/CVP operations have exceeded take limits several times in recent years. Allowable take is based on historical salvage with different limits for wetter and drier water-years, but the relationship of salvage to loss remains unknown. The initial concern indicator ("yellow light") is based upon a 14-day running average of the daily number salvaged at both facilities. The authorized take limit ("red light") is a monthly total, determined by the average of the highest 25% of monthly salvage from 1980 – 1992 for a given water year classification. Current authorized take levels do not account for annual variation in adult abundance. Substantial loss can occur before larval smelt reach the size at which they are counted in salvage samples. When assessing risk to the fish and making decisions to curtail pumping, biologists consider apparent smelt distribution (are fish near the pumps) and information on abundance. Improvements to delta smelt management might come from better abundance estimates from trawl surveys; accounting for the relative importance to the population of taking adults versus YOY; deriving a measure for adult equivalents from juvenile take; or considering the duration of spawning period and, hence, the age range of YOY fish each year in assessing impacts from water project operations.

Bryan Manly, Western EcoSystems Technology Inc.

Manly analyzed three sets of data to assess the possible effects of water exports on salmon smolt survival:

- (1) VAMP mark-recapture data.
- (2) Late-fall-run mark-recapture data.
- (3) Newman's paper on modeling of paired release-recapture data.

With only five VAMP data points currently available it is difficult to hypothesize about possible limiting effects, but comparison of the VAMP smolt recaptures from upstream and downstream releases can estimate survival rates. A weak correlation exists between survival and exports. Survival is most strongly correlated with the ratio of flow to exports, but more data are needed to verify that the flow/export ratio explains salmon mortality. The relationship between survival, flow, and exports is likely not a simple linear one. The correlation between exports and flow makes it difficult to separate their effects.

The second case study of late-fall mark-recapture data has a similar experimental design to VAMP. It estimated survival from upstream releases of salmon smolt into the north end of Georgiana Slough (possibly affected by exports) and downstream releases at Ryde or Isleton (assumed not to be affected by exports). Survival is negatively correlated with water temperature and average exports in the three days following release day. The export correlation depends upon a single data point. Flow rates do not appear very important. Manly suggested water temperature effects may account for the correlation between exports and survival and concluded that the data did not show clear statistical evidence for an effect of exports.

Newman's paper on modeling of paired release-recapture data is similar to the late-fall mark-recovery experiment, but factors in the ocean element. Manly's evaluation of three models presented in Newman's paper suggested that parameter estimates may be generally reasonable, but the standard errors (and hence the significance of the estimates) are questionable. Additional analyses are needed to assess the robustness of the models to their assumptions.

Tina Swanson, The Bay Institute.

Swanson examined the broad and conceptual issues surrounding uncertainty in evaluating the environmental and ecological effects of proposed long-term water project operations. Specific types of uncertainty include response, magnitude, precision, and mechanisms. Statistics is one tool used to resolve uncertainty using very specific rules to evaluate results. Some of the traditional rules (e.g., P = 0.5) may be too demanding for volatile biological systems like San Francisco Estuary. Flexible approaches to statistics may, at times, be appropriate when evaluating systems with wide natural variations.

Uncertainty surrounding system mechanisms may be the most important for managers and this cannot be determined statistically. By better understanding underlying mechanisms and processes, we address why responses occur. For example, opening the DCC gates leads to reduced salmon survival, but uncertainty surrounds the causal mechanisms (e.g., predation, migration delay, loss at the pumps).

We also must examine the relative importance of biological uncertainty in the context of the physical system. Uncertainty surrounding Delta hydrology can confound ecological results, leading to an accumulation of uncertainty from multiple sources. A conceptual model or hypothesis of how the system works is one approach to examine interactions of ecosystem, fish, and operations. Past conditions may also help resolve uncertainty by providing context. Hydrologic and fish data both offer good examples of useful legacy information.

Uncertainty is inherent in the system, so we must learn to manage with it, using a precautionary approach. Management decisions should favor actions that:

- ? prevent harm.
- ? do not approach the "margins of tolerance" of a system.
- ? facilitate study to resolve uncertainty (adaptive management).
- ? include exploration of alternative actions to achieve the desired goal.

Placing the responsibility for demonstrating no adverse effect of an action should be on those taking that action is also consistent with ESA requirement to give species the "benefit of the doubt." A fundamental aspect of managing with uncertainty is to recognize whether the proponent of the action or the resource manager bears the burden of proof.

IV. Session Four: Bay-Delta Processes and Export-Related Linkages to Fish Mortality: What have we learned from VAMP and DCC

Bruce Herbold, U.S. Environmental Protection Agency.

Delta Cross Channel (DCC) and Vernalis Adaptive Management Plan (VAMP) investigations examine relationships between Delta flows and fish population success. Both studies contribute different retrospective experiences, scientific understanding, and future opportunities. DCC and VAMP experimental designs differ. The DCC studies examine late-fall-run and spring-run yearlings (120-150 mm) emigration survival through the Delta in late October to November with a small geographic and hourly focus. In contrast, VAMP studies focus on fall-run smolt (40-60 mm) emigration survival in April and May. VAMP has a Delta-wide focus, designed as a 12-year study on Delta survival of San Joaquin salmon. VAMP uses experimental flow/export combinations, with data supplied by midwater trawl, Kodiak trawl and ocean recovery surveys. Physical and regulatory requirements set target VAMP conditions, with analysis predicting that the full range of desired flows will occur within 12 years. So far, tests at higher flow rates targets have not happened (Table 3).

A November 1999 DCC gate closure (i.e., high salinity conditions), which combined with high exports created the worst Delta water quality in 20 years, led to recognition that interactions of flow, fish movement, and water quality were poorly known. Results show that tides strongly influence flow through the cross-channel. Patterns vary with tidal cycles and extreme flow variability exists. Mark-recapture, hydroacoustic, and radio-tag studies indicate that salmon travel during the night with flow velocity vectors, rather than simply moving with the bulk flow of water. A regional perspective is important to understanding DCC operations, Delta hydrology, fish movement, and water quality.

Since VAMP implementation, San Joaquin River flows and water quality at Vernalis appear to have improved in the spring. The 12-year study is still in the beginning stages, so current data limitations make it difficult to draw conclusions about implications for fish populations. Table 3 shows VAMP conditions studied to date.

Table 3: VAMP Target Flow Conditions Achieved From 2000 Through 2003

	Flow at Vernalis cfs (year achieved)				
Combined		3,200	4,450	5,700	7,000
CVP & SWP	1,500	(2002), (2003)	(2001)		Untested
Exports	2,250			(2000)	
cfs	3,200				Untested

Conclusions stemming from the DCC and VAMP studies show that all time scales of flow variance – hourly to seasonal – affect fish. Local velocity profiles and time of day control a part of fish distributions we estimate from field sampling; water quality varies greatly with flow and tidal effects.

Chuck Hanson, Hanson Environmental Consulting, Inc.

VAMP evolved at the intersection of science and management. VAMP goals and objectives are to:

- ? Provide an experimental program with a high probability of detecting statistically significant relationships, if they exist, between juvenile Chinook salmon survivals and managed alteration in San Joaquin River flow, Old River Barrier operations, and CVP and SWP exports.
- ? Improve protection and survival of naturally produced Chinook salmon.
- ? Provide an experimental design framework for adaptively managing flow and export conditions based on environmental conditions.

Before VAMP, salmon studies involved uncontrolled monitoring, not experiments. High variability made detection and interpretation of cause and effects difficult. An alternative approach is hypothesis testing, where controlled or semi-controlled test conditions may improve the signal to noise ratio. Large-scale experiments like VAMP involve coordinated operations of reservoir releases, instream flows, and biological tests. Experimental design of VAMP required multiple considerations: San Joaquin River/export rates, availability of salmon smolts from the Merced River hatchery, avoiding ESA species incidental take, compliance with the delta smelt BO, Old River Barrier installation, and uncertainty in hydrologic conditions and water supply impacts.

Export targets are established in advance, but flows dominate VAMP management. On a weekly basis, managers select among the flow and exports, given uncertainty about how hydrologic conditions later that year will likely appear (e.g., examine snow pack, weather, iterative feedback conditions). Three upstream reservoir areas (Merced, Stanislaus, Tuolumne), each with its own constraints, create a VAMP network of coordination and communication essential to meet flow targets. The experiment requires extensive interdisciplinary coordination to manage controlled conditions and respond to opportunities and constraints. Researchers control and document test conditions and variables that may affect analyses, interpretation, and confidence in test results. Contingency plans, compatible with test objectives and design, are required. Researchers and managers must complete the full 12-year investigation before drawing final conclusions.

Pat Brandes, U.S. Fish and Wildlife Service.

Monitoring data help us to understand when various races of salmon are in the Delta. Salmon races are identified by size criteria (i.e., fork length at time of capture). Table 4 summarizes salmon occurrence and residence time in the Delta. The conceptual model of juvenile migration through the Delta suggests runs essentially behave the same among years, although timing varies, as they migrate with flow to the ocean.

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Race		Observed Period (peak) in Delta	Observed Period (peak) leaving Delta	
Late-fall	Larger fish	Aug-Feb (Oct-Dec)	Aug-Feb (Dec)	
	Fry	Apr-Jul (Apr-May)	May-Jul (Jun)	
Winter		Oct-Apr (Dec-Feb)	Dec-May (Mar)	
Fall/spring	Yearlings	Aug-Nov	Aug-Dec	
	Fry	Nov-Mar (Feb)	Few Dec-Mar (Feb), most wait	
			until Apr-May	
	Smolts	Apr-Jul (Apr)	Apr-Jul (Apr-May)	

Table 4: Summary of Residence Time of Juvenile Salmon in the Delta

Results of monitoring data show that juvenile salmon appear most vulnerable to exports when emigrating. Little take is observed when fish are not moving (possibly nursery periods in the Delta). Several independent mark-recapture studies suggest juveniles that enter the interior Delta have lower survival (all life stages and races) than those that do not. DCC gate closure likely reduces the number of fish entering the interior Delta and reduce overall mortality. Greater diversion into Old River appears to decrease survival to Chipps Island for salmon released at Mossdale on the San Joaquin River.

Depending on the run, juvenile salmon survival through the Delta appears higher with lower exports from the Sacramento and San Joaquin rivers during fall and late-fall emigration periods. High variability occurs at lower exports, but there is a statistically significant trend of increasing interior Delta survival when exports are lower. Modeling supports these conclusions. Export effects on salmon survival can still be detected when a cohort returns as adults (ocean returns) two to four years later.

Dave Vogel, Natural Resource Scientists, Inc.

Radio tagged fish studies at the DCC, Mokelumne, North Delta, Central Delta, and South Delta examined individual fish responses to hydrodynamics. Tidal effects strongly influence salmon movement. Typically, smolts move many miles each day in correspondence with the ebb and flood tides. Net smolt movement is more rapid in some Delta regions compared to others. Although highly site-specific, smolts usually migrate within the main river channels. Comparing fish migration rates with ambient water velocities suggests smolts generally move slightly slower than the water flow. Smolts also exhibit diel vertical movements, moving deeper in the channels during the day and swimming higher in the water column at night. Predation on smolts in some areas of the Delta is consistently higher than other areas.

The effects of project exports is strong enough to overcome natural ebb tide conditions in the South Delta. This leads smolts in close proximity to the South Delta pumps to move towards Clifton Court Forebay. A first-time effort to integrate DWR DSM2 model outputs with fish telemetry data using a USGS time-series program has proven to be an invaluable tool to interpret fish movements in the Delta. Initial results suggest:

? Fish do not just go with net flows at channel junctions, but that they move with water velocity flow structures.

- ? Smolt movements on the main-stem Sacramento River are more "simple" than movements in the San Joaquin River which are relatively "complex."
- ? Localized hydrodynamic conditions at flow splits affect migration route.
- ? Greater duration of smolt exposure to flow splits increases the probability of movements into side channels.
- ? Delta regions with large tidal prisms greatly affect migration (tend to retain fish).
- ? Smolts moving into channels south of the San Joaquin River do not readily move back into the San Joaquin River.

Susan Anderson, UC Davis, Bodega Marine Laboratory.

To clarify uncertainty surrounding toxicant exposure as a potential source of stress on fish populations, researchers investigated biological effects of landscape-scale pesticide contamination on California native fish at the individual and population levels. To maximize understanding, Anderson combined different types of tools and analyzed:

- (1) Allman Assay to measure acetylcholinesterase (AChE) activity (high-specificity biomarker).
- (2) Comet Assay to measure DNA strand breaks (low-specificity biomarker).
- (3) Ames Assay to measure mutagenicity (low-specificity biomarker).

These laboratory investigations, combined with field studies, tested whether or not dormant season pesticide runoff events of sufficient intensity can induce these sublethal responses in native resident fish. The study found low concentrations of insecticides in 1999, relative to previous years, and no significant effects of AChE enzyme inhibition. However, comet assays on fish in the San Joaquin and laboratory detected a dramatic induction of strand breaks associated with timing of dormant season pesticide pulse. The Ames mutagenicity analysis shows that San Joaquin River fish have unusually high levels of mutation. Possible consequences of genotoxic effects include decreased reproductive success, cancer, and mutations affecting development and populations—all potential manifestations of indirect mortality.

Initial Central Valley results indicate that exposure to dormant season pesticide runoff does not lower genetic diversity in fish. No significant partitioning of variation occurs between exposed and downstream reference populations. Similarly, no outstanding shifts occur in band/allele frequencies. Genetic differences and evidence of recent bottlenecks appear more correlated with Central Valley geography than with system toxicity.

Integrated studies with biomarkers, chemistry, and toxicity tests can help managers determine the relative importance of contaminants on fish populations in San Francisco Bay-Delta.

Kevin Fleming, CA Department of Fish and Game.

The distribution of adult delta smelt varies annually and seasonally. The lower estuary boundary appears constrained by salinity, as delta smelt cannot tolerate salinity above 19

psu. The boundary moves upstream in dry conditions. Delta smelt young of year distribution is roughly correlated to X2 location. With X2 upstream, a larger percentage of delta smelt are more susceptible to entrainment and loss due to proximity to the South Delta export facilities.

Delta smelt spawning does not necessarily correlate with larval distribution. For example, 2003 supported many spawners, but few larvae were found. This mis-match in survival may explain some of the delta smelt stock-recruitment mis-matches. Adult delta smelt distribution and maturity status in the winter and spring vary by geographic region. Distribution of the youngest smelt often corresponds with water temperature, with the upper estuary distribution boundary constrained below 25°C. When upstream water temperatures increase, fish appear to move out of the Delta.

Delta smelt length frequencies from salvage during April to June 2000 show a bell-shaped mortality curve. This loss only measures fish longer than 20mm, so a large proportion of the post-larval mortality remains unmeasured. Researchers do not yet know if pulse flows, like VAMP, affect delta smelt distribution. The most significant VAMP benefit may occur from reduced exports, which likely reduces the take of uncounted delta smelt juveniles. Consequently, environmental water used to curtail exports in the spring may have indirect population benefits. Delta agricultural diversions likely cause additional impacts. Diversions that result in net flows moving south may adversely impact fish.

Delta smelt abundance is highly variable. Managers use delta smelt salvage to calculate indices, but this is not a population estimate. Understanding density dependent and density independent measures may help us improve delta smelt indices. Salvage loss apparently has population-level impacts, but the red-light approach for regulating incidental take may not be the best way to manage for long-term species recovery.

Tara Smith, CA Department of Water Resources.

The particle tracking model (PTM) tracks the movement of individual particles. PTM is a module of DSM2. PTM relies on hydrodynamic inputs from the Delta Simulation Model-II (DSM2) hydrodynamics module (Hydro). PTM takes the one-dimensional component from DSM2 Hydro and creates a three dimensional velocity field. This presentation shows two applications of PTM. The first is its use in Real Time Modeling to aid in making operation decisions when Delta Smelt take at the SWP and CVP exports is an issue. Model output from DWR's real time modeling group is presented to the Delta Smelt Workgroup. Operation recommendations from the workgroup are presented to the Water Operations Management Team. To obtain the output, recent historical conditions and near term forecasts are made with the hydrodynamic and PTM modules.

PTM is used to compare the fate of particles among different operational scenarios to determine relative differences. There is no behavior added to particles, so the model is showing flow patterns within the Delta. Output types include zone of influence plots, animation of particle movements, and difference plots. All of these different types of

output show the movement and fate of particles in the Delta over time. This information in conjunction with trawl data and other data such as water temperature data has been used in making operation decisions.

The second example of a PTM application is a comparison of PTM output to historical fish survey data. Various simple behaviors were added to the particles based on recommendations from the Resident Fish Project Work Team. A comparison of PTM results and historical fish survey data found the model results did not match survey results well in any of the simulations. This disparity is likely due to several weaknesses in the model.

Weaknesses of using this model to model fish movement are that fish behavior may not be well defined, there is a lack of continuous "fish" data for calibrating and validating the model. DSM2 does not model the complex velocity fields at junctions or large open water areas well. In addition, DSM2 PTM requires fairly complete boundary and initial conditions to model movement. The time step for the model is small, less that one minute. The survey data is sampled at select locations in the Delta once every couple of weeks. One of the strengths of DSM2 is that it accurately represents basic hydrodynamics and dispersion. (The calibration and validation can be found at http://www.iep/dsm2pwt/dsm2pwt.html). A strength of using DSM2 PTM over a multi dimensional model is that the model covers the entire Delta and it can run in a few hours. This speed and spatial extension is necessary when operation decisions have to be made quickly.

How can we resolve the conflict between better representation of the physical environment by a multi dimensional model versus the speed and spatial extension of a quasi multi dimensional model? A first step would be to compare multi dimensional modeling results from programs such as the Delta Cross Channel experiments to DSM2 simulations and then utilize that information when running DSM2 and analyzing output. A second step would be to continue with data collection and multi-dimensional model development.

Longer-term plans for the Delta Modeling Section involve working with experts in various fields to develop a decision support tool that can better answer the questions we have. This tool would incorporate multi – dimensional particle tracking in addition to other features.

Additional model information, assumptions, and results are available at http://modeling.water.ca.gov.

Summary Panel Discussion and Remarks

Bob Twiss and Sam Luoma, Facilitators

Appendix B contains a more detailed account of this panel discussion. Bob Twiss, Sam Luoma, and Wim Kimmerer presented independent perspectives to highlight Bay-Delta

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accomplishments, new scientific knowledge, and the potential management applications of now-accepted models and shared understanding. They described coalescence as the unity (vs. divergence) of scientific opinion. Twiss proposed potential approaches to measure the degree of coalescence and identify a general level of consensus among the scientific community. Main sources of divergence often stem from differences in the interpretation of the data, the model (or lack thereof), or model results. Identifying causes of divergence may enable researchers and managers to define steps towards more unified interpretation. Example coalescent assertions, formerly points of divergence that now appear generally accepted, are outlined in Appendix B.

Bay-Delta Science Symposium	June 2003
Appendix A: Symposium Agenda and Organizing Co	ommittee
Appendix A: Symposium Agenda and Organizing Co	ommittee

Agenda Overview and Introduction

Science Symposium on Environmental and Ecological Effects of Proposed Long-term Water Project Operations June 19-20, 2003 Redwood Room, University Union Sacramento State University

The California Bay-Delta Authority has planned a series of symposia and workshops to present and discuss information related to the environmental and ecological effects of proposed long-term water project operations, the South Delta Improvement Program, and water management strategies such as the Environmental Water Account (EWA).

The June symposium will consider some of the key policy and science issues associated with the long-term Operations Criteria and Plan (OCAP) proposed for the Central Valley Project (CVP) and State Water Project (SWP). ¹⁶ Workshops in July and August on Chinook salmon and delta smelt (respectively) will consider new information on modeling and the population biology of these fish, and consider how actions under the EWA program protect these fish. A workshop in October will include an in-depth review of the EWA and discuss the X2 standard. The goals for this series of symposia and workshops are:

- 4. Provide a forum for a balanced open discussion of proposed CVP and SWP operations, water management strategies, and the consequences to fish species of concern in the Delta and upstream project areas.
- 5. Help the public, stakeholders, and the agencies developing the biological opinions for CVP and SWP operations, pursue a common understanding of the state of knowledge and critical uncertainties associated with evaluating the implications of proposed water project operations and water management strategies in the Delta and upstream project areas.
- 6. Provide managers and policy makers a synopsis of the "state of knowledge and uncertainties" for some of the most important intersections between policy and science with respect to proposed changes in water project operations.

¹⁶Background information for many of the management and science issues relevant to water project operations in the Sacramento-San Joaquin Delta are presented in a written summary of the Science Program's April 2002 Water Operations workshop. This summary is available at http://science.calwater.ca.gov, click on "Workshops and Conferences", click on "Past Workshops" and then scroll down until you see "Water Operations and Environmental Protection in the Delta."

Agenda Schedule of Presentations

Day One: June 19, 2003

Session One: Introduction and Policy Perspectives

Welcome

8:00 – 8:25: Sam Luoma, CA Bay-Delta Authority.

Welcome; logistics, symposium goals, context, and approach; review schedule and purpose of upcoming related workshops/symposia.

Policy Perspectives

8:25 – 8:45: Patrick Wright, CA Bay-Delta Authority.

Policy context and policy challenges for water operations and environmental management as the CALFED ROD is implemented, with special emphasis on upcoming OCAP and SDIP projects.

8:45-8:55: David Fullerton (for Tim Quinn), Metropolitan Water District of Southern California.

What are the critical technical and management issues in proposals for future project operations and what is there importance to balancing water supply, quality and reliability with habitat restoration and recovery of listed species?

8:55 – 9:05: Curtis Creel, CA Department of Water Resources.

Future operations of the State and Federal Water Projects: Operational challenges in balancing water supply, quality and reliability with habitat restoration, and recovery of listed species.

9:05 – 9:15: Susan Ramos, US Bureau of Reclamation.

What are the critical technical and management issues in balancing water supply, quality and reliability with habitat restoration, and recovery of listed species?

9:15 – 9:25: Richard Denton, Contra Costa Water District.

The effects of water operations and environmental management on drinking water quality.

9:25 – 9:35: Spreck Rosekrans, Environmental Defense.

What are the important technical and management issues in crafting an environmental water policy with regard to the proposals for long-term water operations?

9:35-9:50: Diana Jacobs, CA Department of Fish and Game.

What are the important technical and management challenges in managing environmental resources under the proposals for long-term water operations?

9:50 – 10:05 BREAK

10:05 – 10:25: Ann Lubas-Williams, US Bureau of Reclamation.

A summary of the project description and findings from the draft OCAP assessment including identification and treatment of uncertainties.

10:25 – 10:45: Rick Sitts, Metropolitan Water District of Southern California. A framework for assessing the merits of actions affecting fish: integrated fish management as a guiding concept for prioritizing science and policy decisions in the Delta.

Session Two: Upstream Flow Fluctuations and Barriers to Fish Migration

Flow Fluctuations

10:45 – 11:15: Bruce Oppenheim, NOAA Fisheries.

Understanding the consequences of flow fluctuations in managed river systems: Definition of key terms and presentation of a conceptual model. Overview of Chinook salmon ecology and the significance of flow fluctuations in the Lower American River.

11:15 – 11:45: Kenneth Rose, Louisiana State University and EWA Panel.

What we know about managing optimum flows for Chinook salmon in Central Valley streams, combining models with biological needs.

11:45 – 12:45 LUNCH

Barriers to Fish Migration: Red Bluff Diversion Dam (RBDD) Case Study

12:45 – 12:55: **Serge Birk, Central Valley Project Water Association.** Introduction and summary of present RBDD operations and policy issues: the need for operational changes to improve fish passage and water supply reliability

12:55 – 1:15: Mike Tucker, NOAA Fisheries.

How do RBDD operations affect fish mortality, fish distribution, and our ability to estimate salmon escapement.

1:15 – 1:35: Dave Vogel, Natural Resource Scientists, Inc.

Scientific uncertainties associated with RBDD fish passage.

Assessing the intersections between scientific information and policy issues: what can we do with the knowledge we have?

1:35 – 2:05: Panel Discussion and Audience Question and Answer. (Serge Birk, Facilitator)

A panel consisting of Kenneth Rose, Dave Vogel, Mike Tucker, Max Stodolski, Bob Williams (invited), and Bruce Oppenheim will present thoughts and discuss the questions below.

- a) What are the benefits and costs to listed and non-listed fish species by choosing an alternative at RBDD? (i.e., redesign fish passage, gates out all year, more pumps and screens, etc). What are the uncertainties?
- b) What flow patterns are optimal for fish protection?
- c) What are the benefits, limits, and uncertainties in managing reservoir releases for salmon?

2:05 – 2:20 BREAK

Session Three: Understanding Bay-Delta Processes, Fish Mortality, and the impacts of water project operations

2:20 – 2:50: Wim Kimmerer, Romberg Tiburon Center.

Open water processes in the Bay-Delta and their linkages to water operations-induced fish mortality.

2:50-3:20: Jon Burau, US Geological Survey.

The affects of river flows, tides, exports and Delta physiography on Delta hydrodynamic processes and the implications for fish movement.

3:20 – 3:50: Jim Cowan, Louisiana State University and EWA panel.

Fish mortality and population dynamics: a conceptual framework for understanding anthropogenic effects on fish populations and the sources of fish mortality in a highly disturbed estuary.

3:50 – 4:10: Zach Hymanson, CA Bay-Delta Authority.

Definitions and conceptual models for the types of fish mortality we think about in the Delta.

4:10-4:40: **Ted Sommer, CA Department of Water Resources.** Understanding the Sacramento Splittail lifecycle and the effects of environmental stressors on population dynamics: insights into measuring and managing mortality associated with water project operations.

4:40 – 5:10: Bill Bennett, UC Davis, Bodega Marine Laboratory.

Understanding the delta smelt lifecycle and the effects of environmental stressors on population dynamics: insights into measuring and managing mortality associated with water project operations.

5:10-5:30: Sam Luoma and Speakers.

Audience Question and Answer, Day one wrap-up and concluding remarks.

Day Two: June 20, 2003

Session Three, Continued: Understanding Bay-Delta Processes, Fish Mortality, and the impacts of water project operations

8:15-8:45 **John Williams, Independent Consultant.** Understanding the salmonid lifecycles and the effects of environmental stressors on population dynamics: insights into measuring and managing mortality associated with water project operations.

8:45-9:15: Jim Buell, Buell and Associates.

Sources of direct mortality: understanding the data, assumptions and uncertainties in estimating fish entrainment loss at the south Delta export facilities.

9:15-9:35: Jim White, CA Department of Fish and Game.

Regulatory approaches to direct mortality (take management), the legal basis, derivation, historical experience and reasons to consider changes.

9:35 – 9:50 BREAK

9:50 – 10:20: Bryan Manly, Western EcoSystems Technology Inc.

Use/appropriateness of the available statistical tools in assessing and quantifying fish mortality in the delta. How do proportional estimates of salmon mortality differ and why?

10:20-10:40: Tina Swanson, The Bay Institute.

Understanding and evaluating uncertainties: Approaches and opportunities for managing fish in the face of uncertainty.

Session Four: Bay-Delta Processes and Export-Related Linkages to Fish Mortality: What have we learned from VAMP and DCC

10:40 – 10:55: Bruce Herbold, US Environmental Protection Agency.

Introduction, impetus for VAMP and DCC; overview of study designs and questions.

10:55 – 11:15: Chuck Hanson, Hanson Environmental Consulting, Inc.

Sampling adequacy and statistical considerations: lessons for other Delta projects and experiments.

11:15 – 12:00: Pat Brandes, US Fish and Wildlife Service.

Fish mortality and residence time in the Delta, Assessing the effects of water project operations and VAMP.

12:00 – 1:00 LUNCH

1:00 – 1:30: Dave Vogel, Natural Resource Scientists, Inc.

What have we learned about salmon movement in the Delta from DCC and VAMP experiments?

1:30 – 2:00: Susan Anderson, UC Davis, Bodega Marine Laboratory.

Effects of toxic substances on native fish: A perspective linking molecular and population responses.

2:00 – 2:15 BREAK

2:15 – 2:45: Kevin Fleming, CA Department of Fish and Game.

How are delta smelt distribution, growth, and salvage affected by pulse flows like VAMP? Movement and behavior of delta smelt in a tidal system: what are the relative effects of different water management strategies?

2:45 – 3:05: Tara Smith, CA Department of Water Resources.

Using a particle-tracking model to understand how water project operations affect fish distribution?

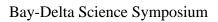
3:05 – 4:30: Panel discussion (Bob Twiss, Sam Luoma, and Wim Kimmerer).

- Identify and discuss linkages between scientific understanding and water operation management issues, with a focus on delta smelt and spring-run Chinook salmon.
- Where uncertainty exists, what is the degree of coalescence in our understanding of:
 - > The data
 - > Existing models
 - > Current interpretations
- What can we do to reduce the uncertainties that remain?

4:30-5:00 Audience Question, Answer and concluding remarks

Special Thanks and List of Contributors

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Appendix B: Panel Discussions, Public Comments, Questions, and Answers

General Discussion

Panel Discussions, Public Comments, Questions, and Answers from the June 2003 Science Symposium on Environmental and Ecological Effects of Proposed Long-term Water Project Operations

Throughout the two-day symposium, members of the public had several opportunities to ask questions and provide comments. Discussions reflect speaker statements and opinions; they are not endorsed by the California Bay Delta Authority (CBDA, formerly CALFED), nor are they necessarily reflective of the Symposium goals or CALFED Science Program mission. Discussion questions (Q), answers (A), and comments (C) are summarized below:

General Discussion

2004.

Q (Wim Kimmerer): Can CALFED give an update on the current status of the white papers?

A (Sam Luoma): The CBDA Science Program website currently has two downloadable draft white papers at http://science.calwater.ca.gov/white_papers.shtml:

- (1) Biology and Population Dynamics of Sacramento Splittail in the San Francisco Estuary: A Review (Moyle, et. al.)
- (2) Open Water Processes of the San Francisco Estuary (Kimmerer) These papers are in draft stage, undergoing final peer review and should not be cited. The authors have submitted these papers for publication in the new E-Forum online science journal, so peer review will follow the journal guidelines. The tidal wetland processes paper (Brown) has completed the peer review stage and will be published as multiple papers in the first edition of the new science journal. The delta smelt white paper (Bennett) is currently undergoing draft review. The initial white paper draft for salmonids

(Williams) should be completed in December 2003, with a targeted public release in early

Science Program staff will work to post a table on the Science Program website that summarizes the status and anticipated release dates for all white papers.

Q (Wim Kimmerer): VAMP aside, are Bay-Delta researchers going to have opportunities to do adaptive management ¹⁷ experiments?

A (Susan Ramos): Room for experimentation exists, but science must occur without compromising the timeliness of water delivery schedules and operations decision-making processes.

¹⁷ "Adaptive management" describes an approach to managing complex systems by conscious experimentation, careful monitoring, and regular adjustment of practices based on scientific findings and lessons learned.

A (Diana Jacobs): The Management Agencies have the political will to support adaptive management experiments, but technical questions exist (e.g., Can we? How? Where?). Science may help answer these technical questions, but we must assess the feasibility of proposed adaptive management experimental designs.

A (Patrick Wright): Adaptive management is a "buzz word" without a clearly agreed-upon definition or approach on how to do it. The CALFED definition of adaptive management differs from the definition typically used in scientific literature. CALFED uses "adaptive management" as an approach to integrate ecosystem services and functions. For example, the Environmental Water Account (EWA) may not technically be adaptive management, but it is a multi-disciplinary, multi-objective, inter-agency experiment. CALFED hopes for more such opportunities to balance water supply, water quality, and ecosystem/fish needs in innovative ways, even if it does not technically fall under the traditional "adaptive management" definition.

Q (Christina Swanson): Please clarify the SWP objectives and priorities, as they relate to water supply delivery, water quality, and environmental protection.

A (Curtis Creel and Susan Ramos): Reliable water supply delivery remains paramount, but SWP and CVP increasingly recognize the importance of balancing multiple factors and inter-agency approaches to make water allocation decisions. USBR hopes to continue working with CALFED to promote understanding of how to best balance quantity, quality, and environmental protection decisions.

Q (Unknown member of the audience): SWP and CVP managers talk about operating the water projects pro-actively and allowing science to lead some decisions. Generally speaking, working with Reclamation has been collaborative and worked well in the past, but recently with ESA and Section 7 some difficulties have arisen. Reclamation has become more of a hard-line decision maker with no outside input.

A (Susan Ramos): Hopefully, collaboration and cooperation will increase with future Reclamation efforts. Reclamation acknowledges that sometimes it makes hard-line decisions, but is striving to increase multi-agency and multi-objective balance, as exemplified in our Water 2025 initiative.

Q (Rick Sitts): What is the general public reaction to the MWD proposal to develop an integrated fish management framework as a guiding concept for prioritizing science and policy decisions in the Delta?

A (general audience): It will be very difficult to fill in many of the matrix cells. Unknowns and uncertainties abound, so it may not be feasible or accurate enough to be of use to policy makers. Frameworks are good though -- they can formalize and structure processes so that researchers and policy makers can better identify critical unknowns.

Q (Unknown member of the audience): Can you use the integrated fish framework to put a number on modernizing the fish facilities (i.e., calculate savings in fish)?

A (Rick Sitts): Yes, but many factors require consideration when looking at reducing take.

Q (Unknown member of the audience): What kind of costs or units would you include in the harvest action?

A (Rick Sitts): Dollars cost, water cost, fish costs. Economists, fishery experts, and others can help us determine costs.

Q (Christina Swanson): From the perspective of potential restoration actions, we want to maximize return on investment using ecological process restoration with a multi-species approach. Are you incorporating this into your framework and do you think this is important?

A (Rick Sitts): Yes and yes.

Upstream flow fluctuations and barriers to fish migration

C (Bob Williams): U.S. Fish and Wildlife Service (FWS) produced a coordinated act report in August 2002 that addressed CVP issues, including Red Bluff Diversion Dam (RBDD). Current operations do not meet the Central Valley Project Improvement Act (CVPIA) requirements and Reclamation will not meet section b(1) requirements without project changes. Water supply reliability is key; status-quo RBDD operations do not meet farmer needs. When RBDD gates are not in (8 months out of every calendar year), research pumping plants and Stony Creek are the two sources of water for farmers, and neither source is reliable. New efforts by fishery agencies to restore Stony Creek anadromous fish populations could lead to additional farmer/environmentalists conflicts.

Until four months ago, Reclamation was working collaboratively with the Canal Authority. Now, Reclamation has not picked a preferred RBDD alternative, although all other stakeholders have. Collaboration is much more effective than stonewalling. Williams urged Reclamation to increase process transparency and work with stakeholders.

C (USBR representative): Since initiating the RBDD 4-month gate closure approach, water supply reliability has been a problem. Previously, when RBDD gates were in 12 months each calendar year, water reliability was not an issue for farmers. Now, a lot of ground and crops are water limited, not producing to their full capacity.

Q (Serge Birk): Can you give a final summary of fish-friendly pumps and why it is not included in a RBDD alternative?

A (USBR representative): The fish passage program at RBDD is a pilot research plumbing plan to determine if installing fish-friendly pumps is a practical alternative. We

installed large drum screens with pumps and used an Archimedes lift to pass water with juvenile fish. We experimented with a hydrostal pump and may install a second pump because the Archimedes lift was not designed to pump such large amounts of water. This technology and application (designed in the late 1980s to early 1990s) is outdated and no longer practical, given the preferred alternative of fish screens.

Q (Unknown member of the audience): In reference to Fullerton's discussion of future project operations, did MWD look at the Glenn-Colusa Canal using a cost-benefit approach or just best technology available?

A (Dave Fullerton): All measures are driven by hydrology and water supply reliability, with benefits to fish included as an "add-on" feature, but they are equal priorities.

Q (Sam Luoma): Some uncertainty surrounds whether or not RBDD is a "big-knob" or "little-knob" for managers to balance multiple goals of supply reliability, water quality, and fish survival. Is this uncertainty based on interpretation of historical information?

A (Dave Fullerton): No, this is a water supply issue. Uncertainty surrounds the effects of some RBDD alternatives. By minimizing alternative uncertainties, we can better avoid unanticipated reliability problems or ecological disasters.

Q (Bruce Herbold): The Oppenheim presentation shows that the American River differs from the Tuolumne River. To incorporate this type of local knowledge into the Jager model is not a small undertaking. What kind of timeframe might it require?

A (Ken Rose): It would not be a small effort, but if we could get the right local knowledge at a small round-table, we could progress quickly by bringing together locals with empirical information and the model programmers. This would require an intensive workshop to think through and work with the data. Then, we code the model. I do not believe that different parties using only email correspondence can do this type of work. One approach could develop a general model, obtain local buy-in on this general model, and then adapt this general model to each local region in the system. If each system area truly operates differently, we will have to start from scratch on each model and it will take significant time.

Q (Patrick Kelly): The Jager model shows the relative benefits of flow volume vs. ocean harvest, but can any conclusions be drawn about Delta operations?

A (Ken Rose): The model accounts for Delta operations in a crude way (wet vs. dry years), but we can factor in operations at a higher resolution to refine capabilities. This would ultimately lead to integrating a Delta operations model into the Jager model framework.

Q (Diana Jacobs): How much concern should we have that models do not sufficiently account for natural variation and diversity, specifically when it comes to salmonids with multiple age classes, runs, and life history patterns?

A (Ken Rose): Models should be used as a tool, but viewed with skepticism. We must consider their constraints when interpreting model outputs. One model is not sufficient to answer all our questions about salmon and highly variable systems. A series of nested models and competing models using different assumptions/scenarios can help reduce uncertainty and bracket likely outputs of highly variable systems. Also remember that models are only as good as the data that go into them, so it is very important that we carefully critique the data, assess information, and interpret system process information to the best of our abilities.

Q (Jim White): How usable is the Jager model to the average person?

A (Ken Rose): It is not very user friendly. To increase usability, we might want to consider working closely with three or four local experts to go through the model code line by line to identify switches that people will want to adjust (e.g., hatcheries). Another approach is reverse engineering. For example, we could ask how much survival would have to differ to give different outputs or recommendations. Models need to be customized and site-specific for management usefulness, but we need to keep the intellectual intelligence of the modeler with the code.

C (John Williams): The Jager model could be called a collection of hypotheses. To the extent that this model draws attention to working salmon hypotheses, it is a success. To maintain this perspective, researchers and managers should remember that models only offer computation outputs that help to inform our hypotheses.

A (Ken Rose): Agreed. Competing/dueling models are acceptable, but competing hypotheses are not. We need to trust researchers to give modelers the best available data and data interpretations to use this understanding to develop many different modeling tools, each of which should be viewed with a healthy dose of skepticism.

C (Rick Sitts): We should also recognize that model outputs will also reflect policy questions (e.g., what do we value most and want to maximize? Population numbers? Run diversity?). Model outputs will differ depending on managerial priorities, so people should collaborate to prioritize what we value most in the Bay-Delta system.

C (Jim White): Please consider hatcheries in the models. The impacts and modeling calibration of the Bay-Delta system may be tricky without placing hatcheries into their proper perspective.

Q (Tina Swanson): Can you compare current fish population estimates to estimates 30-40 years ago? For example, spring-run populations are currently low, probably because their range is now very small. Perhaps part of recovery is to expand their range.

A (Dave Vogel): Only about 3% of spring-run salmon populations migrate above RBDD. Many restoration activities are currently planned for Cottonwood Creek and Battle Creek, but there are likely alternatives to upstream restoration and habitat changes.

A (Mike Aceituno): Habitat above RBDD certainly could support larger fish populations, so something is causing them to not thrive upstream. We should ask why do only 3% migrate above RBDD, survive upstream, and maintain upstream populations. We really don't know what is going on, but upstream habitat does exist.

Q (Wim Kimmerer): What percentage of spring-run historically spawned above RBDD?

A (Mike Aceituno): Prior to dam construction, Red Bluff estimates were 20,000 or higher, even given poor habitat conditions (e.g., no temperature control, Butte Creek and Clear Creek not restored). This is changing now, and much upstream restoration potential exists, but spring-run population numbers were significantly larger before Shasta Dam.

A (Dave Vogel): The vast majority of spring-run previously spawned in Mill and Deer creek. Butte Creek was also important.

Q (Wim Kimmerer): In the Bay-Delta system, 95% of salmon leave the American River as fry, but Tuolumne River modeling shows that fish leave as smolts in this part of the system. Is there a modeling approach to bridge this gap?

A (Bruce Oppenheim): We don't know what happens to fish after they go into the Delta. We have to decide whether to manage for fry or smolts, but cannot yet answer this question for the American River.

C (Sam Luoma): Models break down complex challenges into manageable steps with a logical sequence. Agreeing on common definitions, assumptions, and methodologies forwards this process. Such accomplishments require significant investment and time commitments and will likely require a process involving decades of work. We're now understanding the hydrology and beginning to tie in the biology. We have to develop an inter-agency, multi-stakeholder trust and strive for cooperative buy-in from the beginning to avoid developing dueling models. Even if we need to develop multiple models to achieve multiple objectives, this approach can help us constrain likely system responses and help us identify what we know, don't know, and need to know.

Understanding Bay-Delta processes, fish mortality, and the impacts of water project operations

Q (Dan Odenweller): Did Ted Sommer's splittail take numbers adjust for effort? In other words, are we seeing that fish are not located there or could the pumps simply be off?

A: (Ted Sommer): They are raw salvage numbers, not adjusted. We could refine it and we welcome audience ideas on how to approach this.

Q (Sam Luoma and Wim Kimmerer): Choosing a red light level involves setting take limits, but the current approach penalizes options when there are large splittail

populations. Can we use abundance/flow correlations or a larval index to predict population estimates and establish allowable take limits?

A (Ted Sommer): We do not have a good estimate for overall splittail abundance, but flow is a metric that is easy to continuously monitor and flow appears to accurately indicate juvenile abundance. No doubt, constraints exist with our current red light methodology, but establishing different take measurements based on estimated annual populations would involve significant investment. We're moving in that direction with more splittail research, but we cannot yet accurately quantify population estimates.

C (Sam Luoma): When mortality occurs, we need to figure out if it is important to the lifecycle and has population-level impacts.

C (Jim Cowan): Yes, that is certainly true. We need to get away from take as the only metric of cohort performance. For example, fast growth rate could be misleading because it could be coupled with high mortality.

Q (Bruce Herbold): Plotting X2 days vs. delta smelt abundance shows an "empty corner effect" that can offer some non-statistical interpretations, but applying statistical evaluations makes the relationship insignificant and noisy. Are there other statistical tools we can use to investigate such relationships?

C (Tina Swanson): This "empty corner effect" occurs as a pattern in other relationships in the Bay-Delta, suggesting other factors beyond exports and survival affect populations. Even without statistically significant relationships, it may be appropriate for managers to use such patterns and evidence to guide decisions in a non-statistical way.

A (Bryan Manly): Ordinary regression is not the best tool to deal with these sorts of data relationships, but other statistical methods exist. Email "Bryan Manly" at

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C (Wim Kimmerer): Many techniques exist, and although we use regression analysis frequently in the Bay-Delta community, we must remember that regression has very restrictive assumptions that should not be ignored. We need to be aware of these assumptions and learn about new statistical methods and tools.

Q (Pete Rhoads): Should we research the effectiveness of screening intakes?

A (Jim White): Yes, this is likely testable. Given the large investment in screening intakes, there has likely been some improvement in fish survival that we could quantify.

A (Jim Buell): Available data indicates that larger diversions take more significant numbers of salmonids. One way to test this would be to remove the screens, but this experiment is not recommended.

A (Jim White): An alternative experimental approach could involve an analysis of the past 10 years of downstream release CWT fish re-capture data.

Q (Unknown member of the audience): Juvenile delta smelt can be very vulnerable to direct loss in the spring. Is it true that a strong density dependent relationship exists and that this salvage loss may not be important because the fish would die anyway?

A (Bill Bennett): This varies year to year and we do not yet know which ones will die without knowing the level of density dependence each year. This is difficult to assign, but the analyses suggest in some years many salvaged fish would have died from other mechanisms. The stronger the density dependence, the larger the number of fish that die, and the lower the relative impact of take at the population-level.

Q (B.J. Miller): If export pumps take 30% of delta smelt juveniles, doesn't that mean 30% less population?

A (Bill Bennett): Not if the pumps are taking juveniles that would have died from other mortality sources (e.g., natural mortality). It depends on density dependence.

Q (B.J. Miller): I do not see density dependence in the data. Statistical evidence seems inconclusive, like there are no statistically significant export related effects or indirect effects on fish populations. Are these the same?

A (Bill Bennett and Bryan Manly): No, these are not the same.

Q (Ted Sommer): Given the complex life history of salmonid and multiple factors affecting fish populations, how can you manage these moving targets? More information may not always help managers if the populations are changing year-to-year. How do you prioritize which life history, survival strategy, or environmental factors for management actions?

A (John Williams): Salmonid life history variation is not helter skelter. It makes sense. We just need to learn how to make sense of it, perhaps by further investigating individuals with additional otolith and tracking research.

A (Christina Swanson): When we start looking at recovery on a species-by-species basis, we are missing the bigger picture. Although managers are driven to do this to satisfy the legal requirements of the Endangered Species Act, emerging science suggests the best approach to multi-species protection in a complex system involves restoring system processes. This involves identifying and understanding key ecological and geomorphological processes.

A (Jim Buell): Complex life histories reflect unstable environments, so that at least one life history strategy remains advantageous when others fail. It becomes especially important in fluctuating systems like the San Francisco Estuary to focus on prioritizing

all of these life history strategies because each one represents a safety valve for the population.

A (Jim White): With all the tools at hand, a certain commonality emerges among species and offers managers some obvious focus areas. We cannot, however, focus only on these targeted elements or we will leave out some crucial components necessary for restoring system processes and health.

Q (Charlie Liston): Does quantitative data exist to show that predation is an overriding factor at Tracy Pumping Plant? We know predation occurs, but so do other operational problems.

A (Jim Buell): My proposed conceptual model for SWP entrainment and salvage fish loss compares the relative impacts of multiple sources of loss. To make the model useful, we will need to refine the multipliers and process steps, but this offers a framework to maximize fish survival. Additional information is also available from data comparing the SWP and CVP projects and their relative environmental impacts, including predation.

Bay-Delta processes and export-related linkages to fish mortality: What have we learned from Vernalis Adaptive Management Plan (VAMP) and Delta Cross Channel (DCC) studies?

C (Tim Ramirez): The current Bay-Delta system is not the same historical ecosystem that fish inhabited. Estuaries offer essential habitat for salmon, but this habitat has been highly urbanized and impacted. VAMP flows in spring may not have a significant impact on fish survival, given all of the strong tidal hydrodynamic forces, but it may encourage managers to reduce exports. No doubt, it is difficult to get our hands around so many different rivers, many of which we cannot control. However, these are important management challenges and we can do a better job. Raising all of these thought provoking questions is helpful to the BA and BO process.

Day 1 Panel Discussion, Question, and Answer

C (Unknown member of the audience): Our current construct of managing take levels may not be the best approach. Operators can, and do, go over the red light limit. It seems like we are not managing to take levels, but managing to a water scenario for delta smelt. Perhaps we should try to improve conditions so that the fish should be where they are supposed to be, away from the pumps and in good habitat in the western Delta, as a preventative strategy to minimize take.

C (Sam Luoma): One challenge is to make sure that we're all speaking the same language. To clarify, there is nothing wrong with managing take, but incorporating management flexibility to reflect the current status of fish populations would be an improvement. Opportunities exist to do this. We can learn much more about Estuary

hydrology and how delta smelt and fish move with water. It makes a lot of sense to manage fish based on estimated population levels.

Q (B.J. Miller): One major question is how to manage direct mortality? This is broader than take. If we manage for population levels, then take may not be too important for salmon, but will be important in some years for delta smelt. For delta smelt, we may want to pay more attention to juveniles in given years, using flexible management approaches like temperature driven cues. How can we best do this? For indirect mortality, we need more information and agreement about how to interpret data (e.g., is indirect mortality a "big-knob," "little-knob," or inconclusive?). If indirect mortality is not important for salmon, then perhaps we pay more attention to direct or total mortality. We have learned that river junctions significantly impact juvenile salmon mortality. If we want to estimate smolt survival, count the number of river forks.

C (Jerry Johns): The EWA experiment cost about \$40 million per year. Have we spent these resources well or have we just been incredibly lucky? To continue EWA, we will need to demonstrate its successes.

C (Bill Bennett): Given current capabilities, it is difficult to prove that EWA water has a direct effect, but it is probable that EWA has had a positive impact and helped to steer delta smelt away from the pumps. For example, if operations drove delta smelt cohorts into the pumps in a year like this, such a take impact could potentially drive the population into extinction. The particle tracking model might offer one approach to determining and quantifying EWA effects.

C (Wayne White): It is important to remember the origins of EWA. Prior to EWA, operators used a prescriptive regulatory approach. The EWA experiment intended to offer a flexible bank of water to better meet water supply requirements. Using environmental water to meet multiple objectives (supply, quality, and environmental requirements) gives flexibility that is an improvement over the former prescriptive approach.

C (Wim Kimmerer): EWA is not an adaptive management experiment because we cannot figure out how to see if it has any effect.

Q (Unknown member of the audience): In the absence of EWA the past couple of years, what would have happened with regulator challenges, operations, and delta smelt populations?

A (Rick Sitts): Bob Twiss's list of next steps proposes a framework of how to compile the information needed to answer these questions and relate it to policy decisions. It is important to keep science and policy talking and to find a common ground to organize such efforts.

A (Bob Twiss): The Ecological Restoration Program (ERP) has done a retrospective look at EWA and what might have happened if this environmental water had not been available. Our list of next steps includes additional simulations, decision support tools,

and independent briefings to make information available to higher level policy decision makers. We want to do this, but don't necessarily know how to do it right. We need better feedback loops and integration. This Symposium offers one example of constructive, collaborative feedback.

C (Unknown member of the audience): To address EWA and EWA management effectiveness, we likely have to develop some conceptual hypothesis (e.g., EWA helps keeps exports down, reduces the ZOI, aids delta smelt westward movement out of pump range). An EWA analysis could also be put into the context of a water use efficiency report. Managers can put EWA cost/effectiveness into perspective by comparing EWA to the prescriptive cost of other water programs and municipal/agricultural costs. Such a comparative approach will likely demonstrate the efficiency of flexible environmental water use.

C (B.J. Miller): If regulators and operators will not change their approach to water management with respect to direct mortality, then we have to keep EWA. It is highly political. If managers can shift to using population levels, then we have to work with Bay-Delta ecology experts to figure out how to interpret information and apply it to optimize management decisions.

Q (Rick Sitts): For such population-level efforts, we should develop an integrated modeling framework. Ideally, such a framework would compile existing modeling efforts into one context that takes a big-picture ecosystem approach. How can we step forward to make this a reality?

C (Steve Cramer): One observation is that several Symposium presenters have emphasized individual-based models. I have less excitement for individual-based models, although they have utility. The goal is to understand how individuals will respond to system changes, and then translate this understanding into population effects. Ultimately, we will return to population questions and we will want data to support population-level changes. We could benefit from building population-level conceptual models and then quantify them.

C (Sam Luoma): This approach sounds similar to filling in cells in Rick Sitt's matrix and Bob Twiss's list of uncertainty characteristics.

Q (Zach Hymanson): Do you agree with the observation that adaptive management is treated as a lower priority than water supply, water quality, and endangered species requirements, thereby constraining potential adaptive management options and opportunities?

A (Wim Kimmerer): Yes, not much as happened since CALFED's 2002 adaptive management workshop. If the Bay-Delta community is not going to prioritize and practice adaptive management, let's not call it that. Perhaps we should rename our efforts "experimental management." Either way, opportunities remain where adaptive/experimental management would be useful and feasible in the Bay-Delta.

A (Bob Twiss): A recent discussion by the Independent Science Board about adaptive management acknowledged that it is hard to do, particularly at the highest policy level in a large state with large costs (e.g., in California). We can, however, embrace the same philosophy and science-based approach. Perhaps we should work to build adaptive management at the mid-level. We are already seeing some small-level Bay-Delta adaptive management experiments that build mechanisms into research plans. No one has really been successful in applying adaptive management, but it is a good idea and we remain committed.

C (Unknown member of the audience): Opportunity may exist to use adaptive management as part of the ESA, but we'll have to work as long-range planners and thinkers. Huge variability exists in California's system, so measuring Bay-Delta experimental responses may take a long time.

A (Diana Jacobs): Implementing active adaptive management experiments is tough, but a passive approach appears feasible. Bay-Delta systems naturally fluctuate, so researchers can measure system responses to variation and then analyze the data to tease out system responses. We should be patient and take advantage of research opportunities presented by Mother Nature.

A (Wim Kimmerer): Passive adaptive management means that we don't anthropogenically manipulate the system for responses, but we still need to design feedback loops. We have not yet successfully done that in the Bay-Delta system.

Day 2 Panel Discussion

(Bob Twiss and Sam Luoma, Facilitators)

Bob Twiss, Sam Luoma, and Wim Kimmerer presented their independent perspectives on the material presented at this symposium. Their charge was to:

- Identify and discuss linkages between scientific understanding and water operation management issues, with a focus on delta smelt and spring-run Chinook salmon.
- Where uncertainty exists, what is the degree of coalescence in our understanding of:
 - > The data
 - > Existing models
 - > Current interpretations
- What can we do to reduce the uncertainties that remain?

Bob Twiss Perspective:

Coalescence can be characterized as the unity (vs. divergence) of scientific opinion. It is challenging to measure the degree of coalescence and to identify a general level of

consensus among the scientific community. We can, however, attempt to identify main sources of divergence:

- ? Interpretation of model results.
- ? The model itself (or lack thereof).
- ? The data?

Identifying main causes of divergence may enable researchers and managers to define steps that might build a more unified set of opinions in the short run. Some recent conclusions that we may want to assess for coalescence could include:

(From Oppenheim:)

- ? Low relationship between flow and salmon out-migration.
- ? Flow fluctuations during spawning are bad.
- ? High flows in January causes bad scour.
- ? Avoid < 2,500 cfs October-December
- ? Avoid < 4,000 cfs June

(From Rose/Yaeger model interpretations:)

- ? Beneficial to increase number of spawning days
- ? Vary flow based upon the number of fish
- ? Winter pulse flow important to diversity
- ? 2-day intensive workshop could strengthen model
- ? Run such a model for delta smelt

(From Burau:)

- ? Salmon don't go with the flow
- ? 1 D models won't work
- ? Go with velocity, not location

(From Cowan:)

? Focus on life-stage past M:G = 1.0

(From Sommer:)

- ? Seasonal inundation of habitat is key > 3 weeks
- ? Entrainment is not a big deal
- ? Look for multiple wet years
- ? Need March/April inundation

(From Bennett:)

- ? Abundance tied to number of spawning days
- ? Fall water temperature at Ft. Point is a key
- ? Push for 60 good low-temperature days
- ? Carrying Capacity may limit restoration of delta smelt

Table 5 presents several draft caricatures to depict potential types of divergence (e.g., divergence among the data, model, or interpretation differences).

Table 5: Framing Types of Divergence as a Potential Way to Assess Coalescence

Caricature	Data	Model	Interpret-	Short-term Steps	
			ation		

DATA	Great Pyramid	High degree of coalescence; publish results, give policy briefing
THAT A	Tree House	Coalescence weak between data and model; scale back interpretation, strengthen model
BATA	Gold Mine	Lots of work to do; dig, interpret, report, build model
DAFA	Mickey Mouse®	Coalescence exists within a group but differs among two groups; consensus- building exercise, white paper
ME.	Conceptual Blimp	Work remains to achieve coalescence useful to management; add local knowledge and strengthen model (e.g., Rose/Jaeger Salmon by 2003 target)

Sam Luoma Perspective:

Luoma presented 12 topics as example coalescent assertions. These points of knowledge were seriously misunderstood five to ten years ago, but now appear generally accepted.

- (1) We cannot rely on hydrology (supply alone) to provide California with the reliable supply of water that is needed. Demand management, management to protect ecosystem functions, water transfers and judiciously applied increases in storage are also critical (Fullerton).
- (2) Policy makers recognize that water management strategies must be devised that avert crises before they occur; this involves risk-taking and learn-as-you go (adaptive?) management (Ramos, Wright). Managers recognize that adaptive management involves a serious investment in learning (Jacobs).

- (3) Models (biological populations; hydrodynamics) that are useful in raising critical questions and roughly constraining the implications of at least some management actions can be developed under the present state of knowledge (Burau, Rose, Sommer, Cowan).
- (4) Red Bluff is a case study where management geared to first protect water supply then manage fish, has changed to management that protects salmon migration and is now trying to find ways to make water supply more reliable within those constraints (conclusion by panel; suggestion by Jacobs).
- (5) The conceptual model of how water moves in the Delta has changed. Recognition of the role of tidally driven hydrodynamics, as compared to the net flow concept, is completely changing basic concepts of how to manage operations for water supply reliability, water quality and environmental protections.
- (6) Fish (salmon smolt) move with velocities of water movement, not net flows. This offers opportunities to engineer (divert inside bends) or manage (with tidal phase) diversions in ways that will capture water without capturing as many fish as would occur otherwise.
- (7) New understanding of tidally driven flows show that working with tidal dispersion might offer opportunities to manage water quality with small adjustments of delta configuration (small engineering structures). For example, strategic changes in the levees of Frank's Tract could reduce the influence of that water body as a source of high salinity water (trapped by tidal dispersion) to the South Delta.
- (8) Direct mortality from exports probably affect populations of delta smelt; effects on splittail populations are conceivable but unproven; the probability of substantial effects on salmonids populations seem low (flows, harvest, upstream habitat seem bigger knobs). However, effects of multiple stressors, some of whose effects may not be detectable in isolation, can be synergistic, so it is important to be cautious when attributing effects or lack of effects to single stressors (striped bass example Cowan).
- (9) At the present state of knowledge tools exist (have been proposed) for population-based management of take at the export facilities for winter run salmon, spring run salmon, splittail and delta smelt on a real time basis. This approach could better protect the species and increase the flexibility of operations at least under selected circumstances.
- (10) Mortality at some times in a species life history might be much more important to population success than mortality at other times. Simple tools might exist to provide approximate understanding of which stages are most likely to be vulnerable (mortality/growth) for which species. Data on mortality alone or abundance alone, is not enough to draw such conclusions.
- (11) Key factors interacting (at different times) in determining abundance of delta smelt include occurrence of X2 in Suisun Bay, number of spawning days each year (determined by water temperature and thereby climate), carrying capacity (food limitation could be

especially important), and exports (especially in years with few cohorts). Monitoring water temperature could be very powerful in alerting managers to years when delta smelt might be most sensitive to catastrophic effects from mortality associated with water operations.

(12) Understanding processes and mechanisms (how water moves; life cycles; life histories; basic ecology) provides insights that observations and correlations cannot, and is often necessary before science coalesces sufficiently to be transferred to management practices.

Wim Kimmerer Perspective:

Research in the last 10-15 years has led to significant scientific and management progress, including:

Physical dynamics:

- ? Prehistorical record of droughts and floods greater than historical
- ? Shift to earlier runoff peak (recorded and forecast)
- ? Importance of tidal dynamics in the Delta
 - Tidal velocity distributions
 - Tidal mixing
 - Zone of influence concept
- ? Dynamics of the Low-Salinity Zone (formerly entrapment zone)
- ? Dynamics of stratification and gravitational circulation at tidal time scale
- ? Circulation patterns on shoals

Organic carbon sources:

- ? Importance of phytoplankton in fueling the Delta's foodweb
- ? High bacterial production in Suisun Bay (based on freshwater phytoplankton)
- ? Complex interaction of flow patterns, stratification, water depth, and benthic grazing in controlling phytoplankton growth.
- ? Controlling influence of benthic grazing in many parts of the estuary Foodwebs:
- ? High frequency of food limitation in all locations(zooplankton, clams)
- ? Strong biological interactions in spite of high physical variability
- ? Lack of strong response to freshwater flow (except for benthos)

Fish:

- ? "Shallow water habitat": value depends on type of habitat
- ? Importance of floodplains as rearing habitat for some native fishes
- ? Striped bass controlled mainly by adult mortality (ocean temperature) and density dependence
- ? Delta smelt: individual histories and variability, food limitation, density dependence
- ? Flow (X2) dependence probably through physical habitat
- ? Genetic identification of salmon races: temporal, spatial, size distributions
- ? Individual variability, movement patterns, growth rates of salmon

Contaminants:

- ? High levels (concentration and bioassay) in all parts of the estuary (some more than others), all times of year
- ? Individual-level effects demonstrated, e.g., on bivalves, striped bass, salmon, delta smelt
- ? Interaction between phytoplankton blooms and metal concentrations

In the past five to ten years, Bay-Delta researchers have embraced different approaches and new technologies, including:

Hydrodynamics: New instruments (ADCP, ADV, UVM).

Climate: Isotope analysis of sediments.

<u>Biological</u>: Otoliths, histopathology, individual information, stable isotope analysis.

<u>Models</u>: Hydrodynamic: Box, 1D, 2D, and 3D; particle tracking and biological: Box, individual based models.

<u>Analytical</u>: Modern statistical tools (e.g., regression, multivariate), data display, animation, use of natural/anthropogenic perturbations

Bay-Delta organizational approaches have also improved. Good communication exists between agencies and academic scientists. Managers have successfully integrated various programs and program elements. Ample opportunity now exists to discuss science, policy, and management issues and their applications to real-world challenges.