Workshop Summary
Water Operations and Environmental Protection in the Delta: Scientific Issues

A CALFED Bay-Delta Science Program Workshop

Prepared by

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We have heard lots of discussion over the course of this workshop about whether the results of studies can be translated into population level effects. The need for water is a constant demand, but fish see a delta that is inherently variable and they have developed life history strategies to deal with this: it's a game of probabilities for the fish. We stand on the sidelines and try to determine the knobs we can turn to improve things for fish. Unimpaired flow may be the biggest knob but we don't have this knob anymore. So the question is whether CALFED can learn enough about the mechanisms of fish dynamics so that it can turn the right little knobs in such a way as to increase the average probability of population success over the long term.

Jim Cowan. April 22, 2002. Remarks made at the workshop on Water Operations and Environmental Protection in the Delta: Scientific issues

Executive Summary

The goal of this workshop was a balanced discussion among policy makers, stakeholders, and scientists aimed at characterizing the scientific issues underlying water operations affecting the San Francisco Estuary and associated watersheds. Technically complex issues are associated with balancing water allocations among environmental, urban, and agricultural uses in the estuary and its watershed. This workshop provided a forum to discuss a comprehensive set of those issues, at a level of detail policy makers need to make informed decisions and stakeholders need to understand the scientific basis of those decisions. Major findings from this workshop include:

Strong government support: There is high-level support at the State and Federal levels for CALFED and the Record of Decision. A complex program such as CALFED will require an investment in science to provide information important in making the necessary policy decisions. While acknowledging the importance of science, it is a major challenge for both the State and Federal governments to keep funding at a high level. Going forward, it is important that the science reflect what is most needed.

The X2 outflow standard: genesis and next steps: The X2 outflow standard is considered very robust because it was developed in a science-based process, and thus reflects a strong ecological basis. It is directly relevant to several policy issues, and includes a dynamic implementation process. Management through the X2 standard is largely based on relationships between the abundance or survival of various organisms and X2. However, elucidating the mechanisms underlying the relationships is the essential next step to examine efficiencies in the application of the X2 standard and the consequences of changes that are likely to occur as a result of CALFED actions and climate change.

New interest and information from an old facility: The Delta Cross Channel (DCC) has been the subject of intense studies over the last two years. The purpose of these collaborative and interdisciplinary studies is to better understand the influence operation of the DCC has on hydrodynamics, water quality and fish passage. Constructed in 1950-51, the DCC provides a shortcut for Sacramento River flows to the south delta for export and aids in meeting several salinity standards. Closure of the DCC for fish is largely based on the migration patterns of Chinook salmon through the delta. Initial results from recent investigations show DCC flows are strongly influenced by the tides, but there is a dramatic change in the hydrodynamics at the DCC: flows upstream of the DCC are largely riverine (unidirectional), while flows downstream of the DCC are tidal (bi-directional). It is now thought that salmon entrainment into the DCC largely depends on the flow field the fish encounter at the time of arrival. Results from these studies will help to determine optimal operations of the DCC to ensure

water supply reliability with minimal impacts to water quality and fish migration. The DCC study methods also will be useful in the evaluation of other CALFED Delta projects like a through-delta facility or the south delta barriers.

Conceptualizing water operations and environmental protection: how should we measure the results: A working conceptual model for water operations and environmental protection shows that CALFED uses a number of tools to manage water operations and meet ecosystem commitments. The tools are quite diverse and take the form of programs and regulatory requirements. These tools are generally used in combination, so it is difficult to separate the effects of any one tool from effects of the others. Measures of ecosystem performance reflect the aggregated effects of all actions; thus, it will be difficult to test the assumptions or hypotheses about individual tools in isolation. Assessments should focus on net effects of aggregated actions to changes in the overall condition of the ecosystem.

The Environmental Water Account: thoughts and information on the newest environmental protection tool: Discussions between stakeholder and agency representatives led to the Environmental Water Account (EWA). Application of the EWA was seen as a way to reduce or avoid such conflicts by stabilizing water supplies, while giving the fish protection agencies direct control over the water resources that would be used to make up for curtailments in pumping. The EWA allows for some adaptive management and integration of policy and science, at least in a broad sense. One challenge for implementation of the EWA is that the range of uncertainty for key factors such as hydrologic conditions and the necessity for fish actions increases during the time contract commitments for water are being secured. An independent panel of experts reviewed the first year of EWA implementation, and identified many positive factors including successful implementation, management, and decision-making. The panel suggested greater human intellectual investment, increasing management flexibility, and increasing the scientific basis for EWA decisions and actions are all key to the longer-term success.

Bringing science to bear on our knowledge of living resources and the effects of water diversions: Several presentations focused on the science challenges in understanding the population biology of fish species of concern, and managing water diversions to protect the estuary environment and its living resources. A central question was: is reducing the effects of the export pumps the best use of environmental water? Reductions in the amount of water exported can reduce the number of individual fish lost from the system, but it is a challenging question as to whether protecting individual fish is the same as restoring fish populations. Ultimately it will be important to integrate a more sophisticated population level approach into the present strategy of evaluating abundance indices, migration patterns and “take” as tools for managing water operations or making comparisons among alternative actions.

Current understanding of delta smelt population dynamics suggest there is a substantial stochastic element to what determines the abundance of this species. The potential consequences of serial events must be factored into any population model One conceptual model is that delta smelt must withstand an environmental gauntlet and it is the myriad of factors within this gauntlet that regulate the population size. The remaining science challenges for delta smelt require greater understanding of: 1) the basic biology; 2) population dynamics; and 3) causes/effect relationships.

The largest outstanding issue relative to understanding salmon population dynamics is the inability to consistently estimate natural production. In practice, the success of recovery and restoration actions will be measured in terms of natural production, whether it is high enough to sustain populations at levels meeting ESA requirements and allowing for some use of the salmon resources. The ability to confidently estimate natural production is critical to determining the success of recovery or restoration actions.

I. Introduction:

The CALFED Science Program has initiated a series of issue-based workshops. The goal of this workshop series is a balanced discussion among policy makers, stakeholders, and scientists aimed at characterizing the scientific issues underlying water operations affecting the San Francisco Estuary and associated watersheds. A primary objective is to explain the current state of scientific understanding and consider how the CALFED programs, CALFED agencies, existing facilities and operations, and policy decisions depend on and use this knowledge. The workshops will illustrate the contributions of science to the existing management system, address what we have learned since the existing policy requirements were set, and characterize important scientific questions or assumptions. Presentations and discussions are designed to highlight assumptions and bring out, in a balanced manner, areas of scientific agreement and disagreement. From these discussions, recommendations to further develop critical knowledge and to integrate knowledge into existing State and federal programs and projects will be presented.

The first workshop in the series was held on April 22-23, 2002 in Sacramento California. This workshop focused on issues associated with water operations and environmental protection in the San Francisco Estuary. A number of technically complex issues are associated with balancing water allocations among environmental, urban, and agricultural uses in the estuary and its watershed. This workshop was designed to present and discuss a comprehensive set of those issues, at a level of detail policy makers need to make informed decisions and stakeholders need to understand the scientific basis of those decisions. This first workshop was confined to three topics:

1. Using science to develop policy: X2 as an outflow standard.
2. Scientific issues associated with the Delta Cross Channel and their implications.
3. Managing State and federal water operations: regulatory requirements, scientific issues, state of knowledge, assumptions, range of interpretations and science needs.

Additional issues considered for future Science Program workshops include:

- Fish screens and screening facilities,
- Upstream flow enhancement and restoration,
- Sources of “indirect mortality” and other factors (e.g., harvest or contaminants) potentially influencing fish populations
- Exotic species,
- The interconnection between restoration and water quality,
- Cost-benefit considerations in managing environmental resources,
- Water supply reliability and its relation to climate variability,
- South delta barrier operations.

Following each workshop, the CALFED Science Program will assemble ad-hoc working groups composed mainly of scientists to follow-up on recommendations by developing detailed agendas of science needs. As they develop, these agendas, and the progress made in fulfilling the science needs, will be presented to CALFED's Policy Group, The Bay-Delta Public Advisory Council (BDPAC), and in other public forums as appropriate.

This document provides a summary of the information presented at the Science Program workshop on water operations and environmental protection in the San Francisco Estuary. Presentations are ordered according to the workshop agenda. An appendix is also part of this summary. Appendix A contains a write-up of the comments, questions and answers that occurred over the course of the workshop.

II. Framing the Workshop:

The information presented in this first workshop functions at the intersection between science and policy. Professor Helen Ingram (UC Irvine) pointed out that CALFED is considering the long-standing relationship between policy and science and how that might change over time. Qinford Pinchot championed the progressive idea of science management (i.e., bringing science to policy) in the 1960's. The initial interactions among science and policy had several limitations: 1) cumulative impacts were not fully assessed, 2) science generally took a back seat in the decision process, 3) not all parties were represented in the debates, and 4) the public was often excluded from the process and did not always have its own science representatives.

In the 1970's policy - science interactions began to change. Environmental groups and public interest groups started hiring scientists, while government looked internally to its own scientists, and occasionally to universities for science input. And most importantly, advocacy science started to emerge. Ingram defined advocacy science as that which occurs when value choices need to be made, and science is used to advocate various positions of value instead of providing objective information. In these situations, science can promote deadlock as each advocate promotes their own science.

An alternative is to place value on information from a diversity of disciplines and a diversity of sources, clearly presenting differences among scientists where they exist. A variety of aspects, including science, economics, legal issues are important to developing policy and decision-making in an environment as complex as the San Francisco Estuary. We are only beginning to understand natural systems where multiple levels of uncertainty interact, so we must accept that those uncertainties necessitate that managers make policy choices, and we are forced to adapt and adjust as we learn (i.e., use adaptive management processes) as those choices are implemented Failures with advocacy science

show the importance of an open process, confronting uncertainties and adaptive management.

Department of Interior Assistant Secretary for Water and Science, Bennett Raley helped introduce the workshop. Secretary Raley places high importance on science issues. He emphasized the importance of using the best science available in dealing with complex issues, and discussed the definitions of best available science and advocacy science. Full disclosure of all facts and information, clarifying what is known and not known, and identifying risks and uncertainty as clearly as possible are critical parts of using best available science It is also important to understand that there are few silver bullets; policy decisions will need to be made. Secretary Raley expressed a hope that the science used by CALFED would be transparent and consider all alternatives, and that nothing is off the table. He supported the use of adaptive management along with a full exchange of information.

In her introductory remarks, California Resources Agency Secretary, Mary Nichols identified the importance of understanding how science fits into policy issues and where science is leading us. Any complex policy activity like CALFED inherently requires consideration of the scientific aspects of the issues. Secretary Nichols pointed out that one important aspect of the workshop was that scientists were involved from many different groups: it is not just government science. She also emphasized that give and take is expected in scientific discussions and debate is necessary in the complex decisions associated with a large program like CALFED. The first step is to move closer to an understanding of what is known and not known and where the gaps are that really matter. Finally, she noted that while all parties acknowledge that science is important, it is a great challenge to find the funding to support that science. On the other hand, the responsibility of the science managers is to work hard to make sure the science that is conducted is that which is most needed.

III. Existing Water Operations Practices and Environmental Needs:

Three presentations (Diana Jacobs (DFG), Michael Thabault (FWS), and Perry Herrgesell (DFG)) briefly discussed some of the roles and responsibilities of the CA Department of Fish and Game, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service in Water Operations management. These agencies have the responsibility to ensure environmental protection/mitigation. In addition staff in these agencies: monitor and assess condition of the resource conduct focused research on life history or cause/effect relationships, evaluate information and make management decisions, as well as direct and assess restoration/recovery actions. Through CALFED these agencies are working to integrate these activities with water development/water management activities. This is most evident on the Water Operations Management Team and in the Environmental Water Account program.

Three types of interest groups are typically involved in complex programs like CALFED: 1) the regulated community, 2) stakeholder/advocates, and 3) academic scientists. The resource agency scientists swim in the vortex between these three parts of the triangle. Unfortunately, science is not a thin bright line and if information must be used in a regulatory context, concerns from these groups over uncertainty and interpretation can be very different. The agencies must deal rationally with those differences.

The agencies make a considerable investment in gathering data and disseminating information (Herrgesell). The Interagency Ecological Program (IEP) is a collaborative effort among Federal and State agencies (six Federal and three State agencies). The IEP conducts much of the monitoring and focused research in the aquatic environments of the upper San Francisco Estuary. It is appropriate to think of IEP as a precursor to CALFED in terms of collaboration to obtain science information. The IEP strengthens CALFED science in several ways:

- Through its work over the last 40 years, the IEP has provided a broad foundation of data and new findings that all can work from.
- The IEP has established and maintains several long-term monitoring programs. These provide a unique understanding of the status and trends in living resources and environmental conditions. The resulting information continuously demonstrates the value of consistent, long-term monitoring, which is so important in determining baseline conditions used to evaluate the type of actions described in the CALFED Record of Decision.
- Data and information generated by the IEP has provided the scientific underpinning for many of the policy and management decisions related to water operations and the protection of living resources. Information generated by the IEP is used for prescriptive standards (e.g., water right decisions), adaptive processes (e.g., the Data Assessment Team), environmental documents (e.g., San Francisco airport expansion), and analysis and modeling efforts (e.g., striped bass model, X2 standard, gaming of water operations).

State and Federal water project operations have long played a critical role in the complex management of water in the Bay-Delta (Creel). Water project operators must balance public safety (flood protection), protection of beneficial uses and the environment (e.g., salinity control in the delta), recreation, and water supply for municipal, industrial, and agricultural interests. In CALFED they are also working with the resources agencies to help manage environmental resources.

The Sacramento-San Joaquin Delta is the hub of water project operations, but operators must maintain a broad view of the Delta. Water to maintain Delta water quality standards and for exports can come from Lake Shasta (five days travel to the Delta), Lake Oroville (2.5 days travel) or Folsom reservoir (<1 day

travel). Operators must also think about the export facilities and conditions in San Luis reservoir, where water is stored for use south of the Delta. Fundamentally, there are only three factors the operators can manipulate: 1) export levels; 2) reservoir releases; or 3) delta hydraulics (e.g., operation of the delta cross channel can change flow patterns and water quality conditions in the central delta). Presently, water project operations in the Delta are controlled by several flow and water quality standards (Figures 1 and 2) that fall into three categories: 1) limits on export levels (export/inflow (E/I) ratio) 2) requirements for minimum flows (San Joaquin River flows at Vernalis and X2); and 3) requirements for water quality (municipal, industrial, and fish salinity requirements).

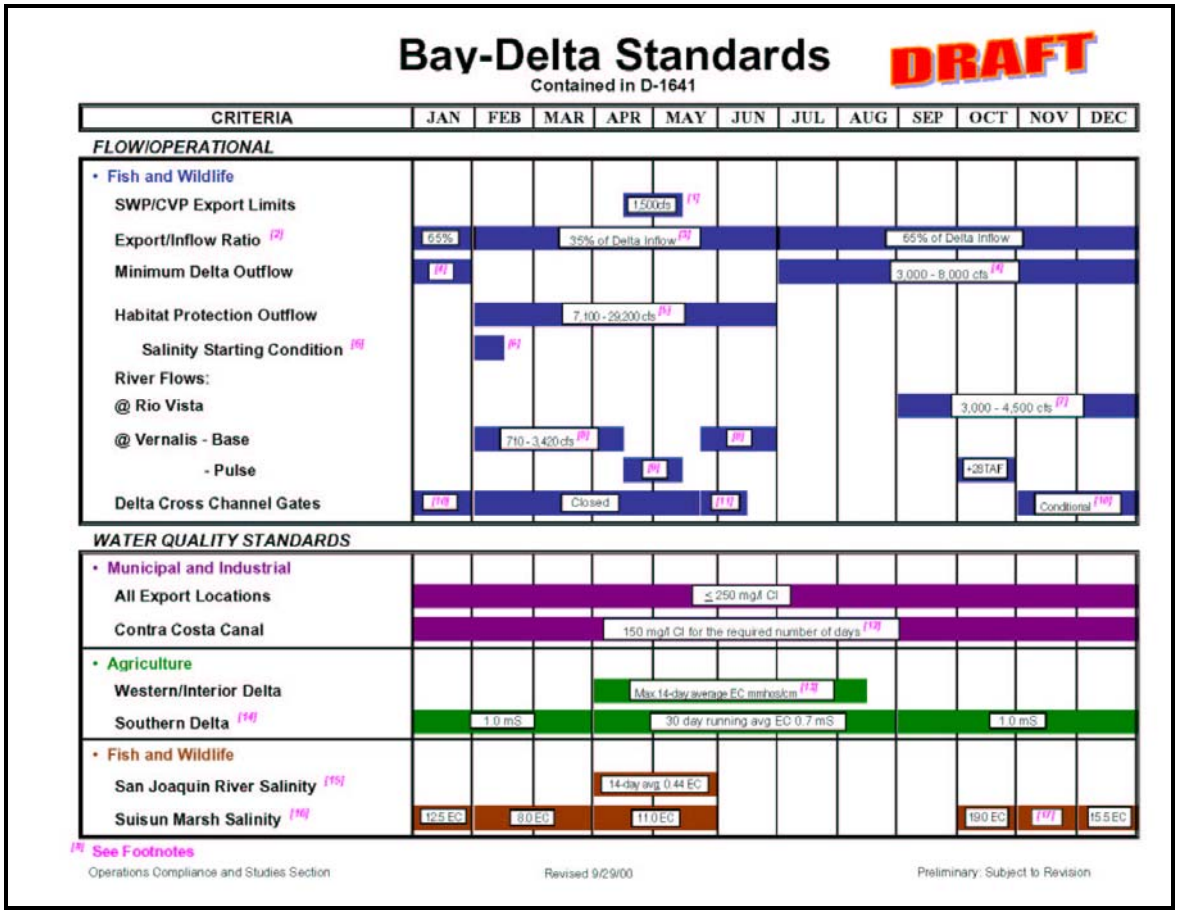
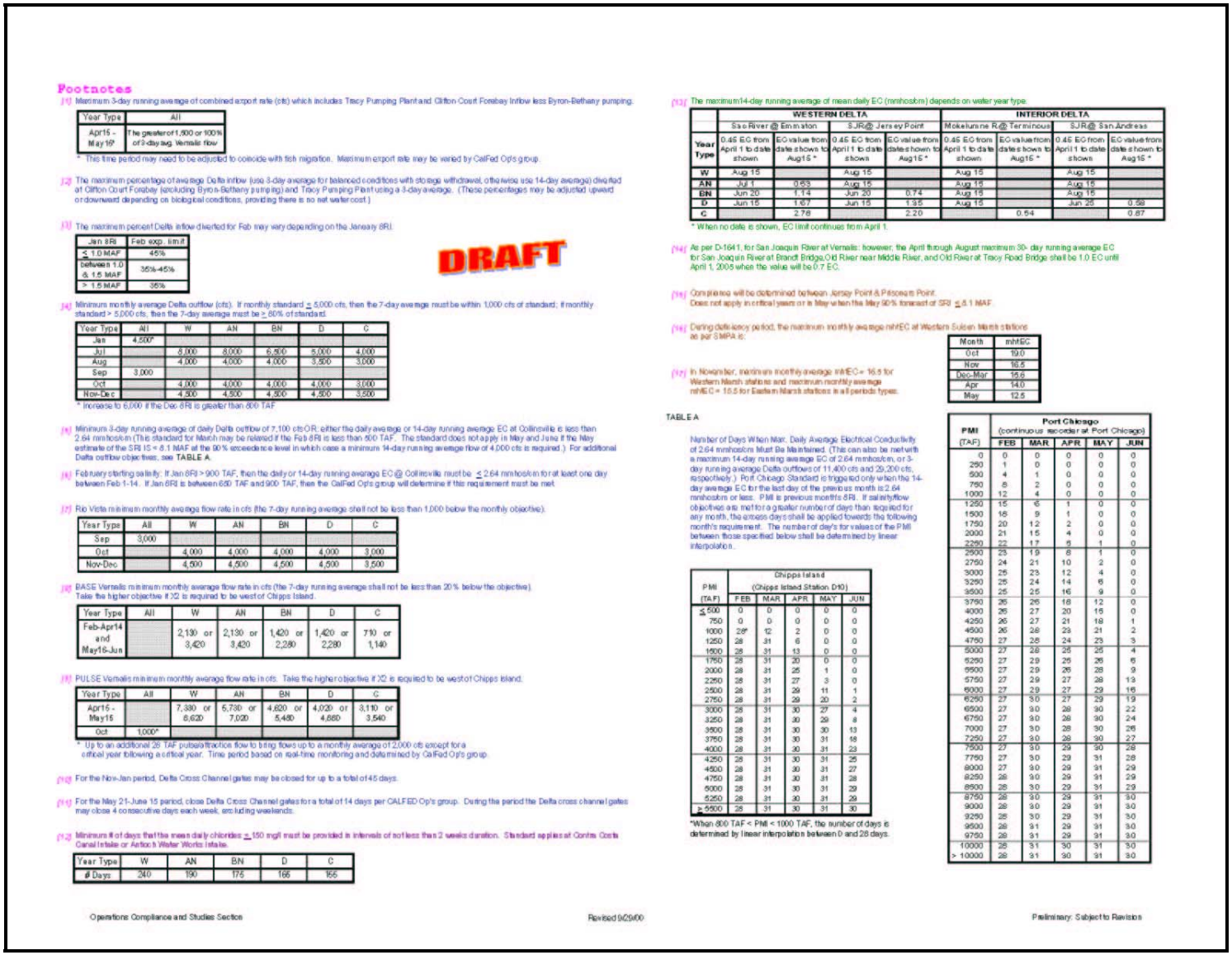


Figure 1. Flow and water quality standards limiting State and Federal water project operations in the Sacramento- San Joaquin Delta. The type and level of standard are shown for each month of the year. See Figure 2 for footnote details. (CLICK ON FIGURE FOR LARGER IMAGE).



Footnotes

[1] Maximum 3-day running average of combined export rate (cfs) which includes Tracy Pumping Plant and Clifton Court Forebay Inflow less Byron-Bethany pumping.

Year Type	All
Apr15 - May16*	The greater of 1,500 or 100% of 3-day avg. Vernalis flow

* This time period may need to be adjusted to coincide with fish migration. Maximum export rate may be varied by CalFed Ops group.

[2] The maximum percentage of average Delta inflow (use 3-day average for balanced conditions with storage withdrawal, otherwise use 14-day average) diverted at Clifton Court Forebay (excluding Byron-Bethany pumping) and Tracy Pumping Plant using a 3-day average. (These percentages may be adjusted upward or downward depending on biological conditions, providing there is no net water cost.)

[3] The maximum percent Delta inflow diverted for Feb may vary depending on the January 8RI.

Jan 8RI	Feb exp. limit
≤ 1.0 MAF	45%
between 1.0 & 1.5 MAF	35%-45%
> 1.5 MAF	35%

DRAFT

[4] Minimum monthly average Delta outflow (cfs). If monthly standard ≤ 5,000 cfs, then the 7-day average must be within 1,000 cfs of standard; if monthly standard > 5,000 cfs, then the 7-day average must be ≥ 80% of standard.

Year Type	All	W	AN	BN	D	C
Jan	4,500*					
Jul		8,000	8,000	6,500	5,000	4,000
Aug		4,000	4,000	4,000	3,500	3,000
Sep	3,000					
Oct		4,000	4,000	4,000	4,000	3,000
Nov-Dec		4,500	4,500	4,500	4,500	3,500

* Increase to 6,000 if the Dec 8RI is greater than 800 TAF

[5] Minimum 3-day running average of daily Delta outflow of 7,100 cfs OR either the daily average or 14-day running average EC at Collinsville is less than 2.64 mmhos/cm (This standard for March may be relaxed if the Feb 8RI is less than 500 TAF. The standard does not apply in May and June if the May estimate of the SRI IS < 8.1 MAF at the 90% exceedence level in which case a minimum 14-day running average flow of 4,000 cfs is required.) For additional Delta outflow objectives, see TABLE A.

[6] February starting salinity: If Jan 8RI > 900 TAF, then the daily or 14-day running average EC @ Collinsville must be ≤ 2.64 mmhos/cm for at least one day between Feb 1-14. If Jan 8RI is between 650 TAF and 900 TAF, then the CalFed Ops group will determine if this requirement must be met.

[7] Rio Vista minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 1,000 below the monthly objective).

Year Type	All	W	AN	BN	D	C
Sep	3,000					
Oct		4,000	4,000	4,000	4,000	3,000
Nov-Dec		4,500	4,500	4,500	4,500	3,500

[8] BASE Vernalis minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 20% below the objective). Take the higher objective if X2 is required to be west of Chipps Island.

Year Type	All	W	AN	BN	D	C
Feb-Apr14 and May16-Jun		2,130 or 3,420	2,130 or 3,420	1,420 or 2,280	1,420 or 2,280	710 or 1,140

[9] PULSE Vernalis minimum monthly average flow rate in cfs. Take the higher objective if X2 is required to be west of Chipps Island.

Year Type	All	W	AN	BN	D	C
Apr15 - May16		7,330 or 8,620	5,730 or 7,020	4,620 or 5,480	4,020 or 4,680	3,110 or 3,540
Oct	1,000*					

* Up to an additional 28 TAF pulse/attraction flow to bring flows up to a monthly average of 2,000 cfs except for a critical year following a critical year. Time period based on real-time monitoring and determined by CalFed Ops group.

[10] For the Nov-Jan period, Delta Cross Channel gates may be closed for up to a total of 45 days.

[11] For the May 21-June 15 period, close Delta Cross Channel gates for a total of 14 days per CALFED Op's group. During the period the Delta cross channel gates may close 4 consecutive days each week, excluding weekends.

[12] Minimum # of days that the mean daily chlorides ≤ 150 mg/l must be provided in intervals of not less than 2 weeks duration. Standard applies at Contra Costa Canal Intake or Antioch Water Works Intake.

Year Type	W	AN	BN	D	C
# Days	240	190	175	165	155

[13] The maximum 14-day running average of mean daily EC (mmhos/cm) depends on water year type.

	WESTERN DELTA				INTERIOR DELTA			
	Sac River @ Emmaton		SJR@ Jersey Point		Mokelumne R@ Terminous		SJR@ San Andreas	
Year Type	0.45 EC from April 1 to date shown	EC value from dates shown to Aug15 *	0.45 EC from April 1 to date shown	EC value from dates shown to Aug15 *	0.45 EC from April 1 to date shown	EC value from dates shown to Aug15 *	0.45 EC from April 1 to date shown	EC value from dates shown to Aug15 *
W	Aug 15		Aug 15		Aug 15		Aug 15	
AN	Jul 1	0.63	Aug 15		Aug 15		Aug 15	
BN	Jun 20	1.14	Jun 20	0.74	Aug 15		Aug 15	
D	Jun 15	1.67	Jun 15	1.35	Aug 15		Jun 25	0.58
C		2.78		2.20		0.64		0.87

* When no date is shown, EC limit continues from April 1.

[14] As per D-1641, for San Joaquin River at Vernalis: however, the April through August maximum 30- day running average EC for San Joaquin River at Brandt Bridge,Old River near Middle River, and Old River at Tracy Road Bridge shall be 1.0 EC until April 1, 2005 when the value will be 0.7 EC.

[15] Compliance will be determined between Jersey Point & Prisoners Point. Does not apply in critical years or in May when the May 90% forecast of SRI ≤ 8.1 MAF.

[16] During delta-keep period, the maximum monthly average mhEC at Western Suisun Marsh stations as per SMPA is:

Month	mhEC
Oct	19.0
Nov	15.5
Dec-Mar	15.5
Apr	14.0
May	12.5

[17] In November, maximum monthly average mhEC= 16.5 for Western Marsh stations and maximum monthly average mhEC = 15.5 for Eastern Marsh stations in all periods types.

TABLE A

Number of Days When Mar. Daily Average Electrical Conductivity of 2.64 mmhos/cm Must Be Maintained. (This can also be met with a maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average Delta outflows of 11,400 cfs and 29,200 cfs, respectively.) Port Chicago Standard is triggered only when the 14-day average EC for the last day of the previous month is ≥ 2.64 mmhos/cm or less. PMI is previous month's 8RI. If salinity/flow objectives are met for a greater number of days than required for any month, the excess days shall be applied towards the following month's requirement. The number of day's for values of the PMI between those specified below shall be determined by linear interpolation.

PMI (TAF)	Chipps Island (Chipps Island Station D10) FEB	MAR	APR	MAY	JUN
≤ 500	0	0	0	0	0
750	0	0	0	0	0
1000	28*	12	2	0	0
1250	28	31	6	0	0
1500	28	31	13	0	0
1750	28	31	20	0	0
2000	28	31	25	1	0
2250	28	31	27	3	0
2500	28	31	29	11	1
2750	28	31	29	20	2
3000	28	31	30	27	4
3250	28	31	30	29	8
3500	28	31	30	30	13
3750	28	31	30	31	18
4000	28	31	30	31	23
4250	28	31	30	31	25
4500	28	31	30	31	27
4750	28	31	30	31	28
5000	28	31	30	31	29
5250	28	31	30	31	29
≥ 5500	28	31	30	31	30

*When 800 TAF < PMI < 1000 TAF, the number of days is determined by linear interpolation between 0 and 28 days.

PMI (TAF)	Port Chicago (continuous, recorder at Port Chicago) FEB	MAR	APR	MAY	JUN
0	0	0	0	0	0
250	1	0	0	0	0
500	4	1	0	0	0
750	8	2	0	0	0
1000	12	4	0	0	0
1250	15	6	1	0	0
1500	18	9	1	0	0
1750	20	12	2	0	0
2000	21	15	4	0	0
2250	22	17	5	1	0
2500	23	19	8	1	0
2750	24	21	10	2	0
3000	25	23	12	4	0
3250	25	24	14	6	0
3500	25	25	16	9	0
3750	26	26	18	12	0
4000	26	27	20	15	0
4250	26	27	21	18	1
4500	26	28	23	21	2
4750	27	28	24	23	3
5000	27	28	25	25	4
5250	27	29	26	26	6
5500	27	29	26	28	9
5750	27	29	27	28	13
6000	27	29	27	29	16
6250	27	30	27	29	19
6500	27	30	28	30	22
6750	27	30	28	30	24
7000	27	30	28	30	26
7250	27	30	28	30	27
7500	27	30	29	30	28
7750	27	30	29	31	28
8000	27	30	29	31	29
8250	28	30	29	31	29
8500	28	30	29	31	29
8750	28	30	29	31	30
9000	28	30	29	31	30
9250	28	30	29	31	30
9500	28	31	29	31	30
9750	28	31	29	31	30
10000	28	31	30	31	30
> 10000	28	31	30	31	30

Operations Compliance and Studies Section

Revised 9/29/00

Preliminary: Subject to Revision

Figure 2. Detailed footnotes to Figure 1. (CLICK ON FIGURE FOR LARGER IMAGE).

Implementation of many standards limiting project operations is timed to occur when fish species of concern are in the Delta. For example, a reduction in the ratio of exports to inflows (E/I ratio) to 35% from February through June occurs at a time when salmon emigrate through the Delta and delta smelt, Sacramento splittail, and striped bass spawning occurs. Generally the standards controlling operations for protection of fish are based upon a relatively strong understanding of migration of at least selected fish especially in the spring and summer. A complex array of standards control one or more aspects of water project operations in every month of the year (Figure 1).

IV. Using science to develop policy: X2 as an outflow standard:

One of the standards used to manage environmental water inflows to the Delta is the X2 outflow standard. The discussion of X2 focused on the scientific basis, implementation, outstanding questions, and management issues.[1] Presentations included:

Existing X2 regulatory requirements: basis, structure and policy implications. Bruce Herbold (USEPA)

The continuing saga of X2: scientific basis, interpretation, and next questions. Wim Kimmerer (RTC/SFSU)

Management and policy implications of scientific knowledge and uncertainties. Steve Macaulay (DWR)

Bruce Herbold began with background information on the management issues that led to development of X2. In the late 1980's strong disagreement existed with respect to an appropriate delta outflow standard, although 40 years of data and associated analyses existed. In 1991 the San Francisco estuary project convened a panel to review the role of flow in restoring the estuary. The panel consisted of a diverse group of experts, who produced a "consensus" series of conclusions and recommendations.[2] As a follow-up, detailed analyses were published (papers by Kimmerer et al, Monismith et al, Jassby et al) examining the relationship between flow, salinity, estuarine habitat, and species abundance. Findings from the discussions and the publications included:

- A flow standard was needed for the estuary,
- X2 was a scientifically defensible basis for a flow standard,

[1] X2 is defined as the distance (in kilometers) upstream from the Golden Gate Bridge of the tidally averaged 2 PSU bottom salinity.

[2] Schubel, J.R. 1993. Managing Freshwater Discharge to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary: The Scientific Basis for an Estuarine Standard. San Francisco Estuary Project, U.S. EPA, San Francisco, CA.

- Using this standard policies could be created that should ensure better average conditions than those experienced during the drought period in the mid to late 1980's,
- One goal of the standard should be to retain a pattern resembling natural variability in inflows.

Staff from the USEPA, State Water Resources Control Board (SWRCB) and other agencies involved in developing the Bay-Delta Accord all worked to develop a regulatory standard from the X2 discussions. These staff used the scientific information developed by the special panel, as well as other information on the historical distribution of X2, hydrology, and system changes mediated by the State and Federal water projects. The staff delivered their findings to management in USEPA documents, the SWRCB Water Quality Control Plan, and the Bay-Delta Accord.

The resulting standard closely followed the main conclusions from the scientific work. In particular, the standard varies both temporally and spatially depending on water year type and recent hydrology. (Details for the X2 standard are provided in Figures 1 and 2 above "Habitat Protection Outflow" criteria.)

The resulting X2 standard has several management and policy implications:

- It protects the beneficial uses of "estuarine habitat" under the Clean Water Act.
- It defines (in part) critical habitat for delta smelt under the Endangered Species Act.
- Its requirements are closely tied to hydrologic conditions. The required outflow is set as a fraction of the total reservoir inflow.
- Habitat protection occurs across a range of hydrodynamic conditions.

The X2 standard is also linked to other Delta standards. For example, the Delta Cross Channel is closed from February 1 through May 20 and 50% of the time from May 21 through June 15. This results in enough freshwater inflow to meet interior delta salinity standards during these times; or a standard roughly comparable to positioning X2 west of Collinsville.

Overall, the X2 standard is considered very robust because of its strong ecological basis, direct relevance to several policy issues, and dynamic implementation process.

Wim Kimmerer further clarified the scientific underpinning of the X2 standard. He showed that:

- X2 is a measure of the physical response of the estuary to freshwater inflow. Although tidal influences dominate estuarine flow patterns, freshwater inflow is a primary influence on the salinity gradient. But,

salinity patterns in the estuary change more slowly than flow (i.e., the physical response of the low salinity zone lags any change in flow).

- X2 is closely correlated with freshwater flow. Flow causes the salinity gradient to move, so flow and X2 are statistically equivalent (Figure 3).
- Many species vary in abundance or survival with freshwater flow and X2 (Figure 4). The estuary's response to freshwater flow is complex, but generally more flow results in higher abundance of many species. The causes for these relationships vary with species.

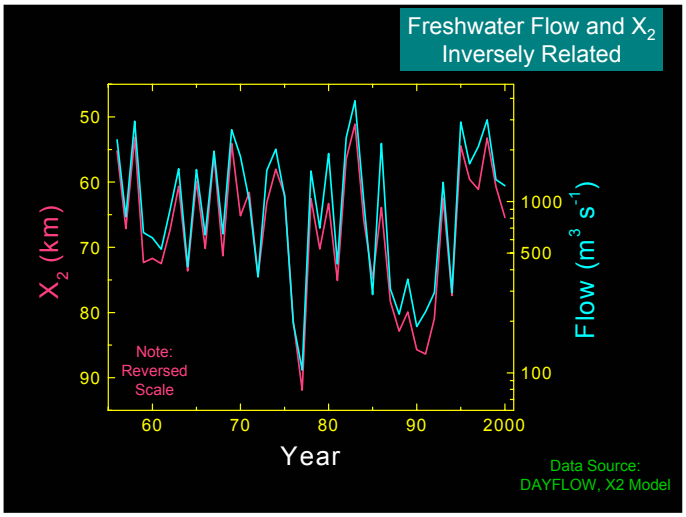


Figure 3. Time series plots of flow (delta outflow calculated from DAYFLOW) and X2 (calculated from the X2 model) showing the strong inverse relationship between these two variables.

There are several mechanisms that could explain the relationships between species abundance/survival and X2 (although none are well studied):

- Transport and entrainment: high inflows may result in rapid transport of organisms out of the delta and this may benefit species by moving them away from the area influenced by the export pumps or away from poor water quality conditions.
- Food input: increased flow may bring external sources of nutrients or food to the estuary and thereby stimulate the food web and food production.
- Habitat space: the area of suitable habitat may increase with increases in freshwater flow.
- Circulation: increases in flow benefit migration of some species by enhancing up-estuary transport of high salinity bottom waters.

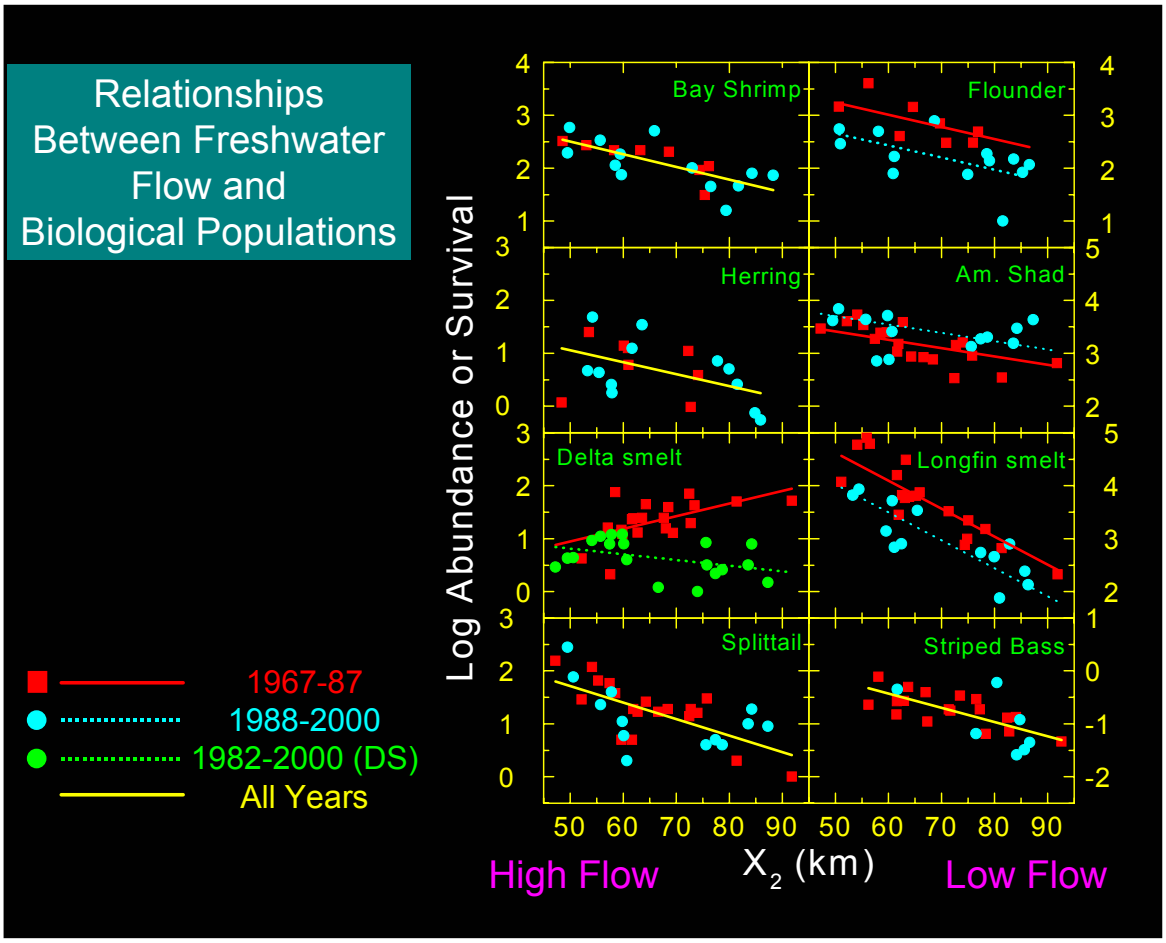


Figure 4. Graphs of the relationship between X2 and the abundance or survival of various organisms occurring within the San Francisco Estuary. Data in blue represent values of abundance or survival after the establishment of *Potamocorbula amurensis*. The establishment of *P. amurensis* correlates with a shift in the regression line for some organisms but not the slope. The more recent relationship for delta smelt (1982-2000 data in green) is contrary to its previous relationship (1967-2000 data in red) and cannot be explained.

There are many uncertainties about the mechanistic explanations of the benefits of inflows. Part of the problem is that multiple processes may support these mechanisms. It is difficult to separate the mechanisms statistically with existing data, especially where more than one cause is plausible for most species. But better mechanistic understanding is important because: 1) water is expensive. Understanding the mechanisms is one way to develop a more efficient or effective standard. 2) The system may change due to climate change or anthropogenic actions (e.g., CALFED actions), so the existing relationships may only apply to the current system. By understanding the mechanisms we can better predict future conditions.

In contrast to the science perspective, the management perspective (Steve Macaulay) must take a broad view in setting standards. In addition to correlations between environmental conditions and biotic responses, beneficial uses, system constraints, and economics must be considered. Thus, the ideal

standards from a management perspective will provide a balance among the various, sometimes competing, factors. It is also important to periodically revisit the existing standards and the available scientific information to see if the standards should be revised or to consider alternatives. For example, what if water devoted to X2 (about 400,000 acre-feet/year) was given to the resource agencies (DFG, FWS, and NMFS) to manage as part of the environmental water account? Would this provide equal or better benefits compared to the X2 standard?

A major challenge for managers is that the standards will work best as long as current conditions prevail. CALFED represents proposals for major changes to the system. Revisiting the standards, using new scientific information and considering effects of system changes could all be important in the future. New scientific information is critical if we are to contemplate changes to the standards.

V. Scientific issues associated with the Delta Cross Channel and their implications:

The Delta Cross Channel (DCC) has been the subject of intense studies over the last two years. The purpose of these studies is to better understand the influence operation of the DCC has on hydrodynamics, water quality and fish passage. Results will be used to generally understand how fish respond to flows, water course junctions and diversions in the delta; and specifically to determine if other operational scenarios of the DCC could provide a more favorable environment for fishes, while minimizing the impacts to water quality and water project operations. Presentations in this session included:

Delta Cross Channel operations: the four seasons. John Burke (USBR)

What are the fishery requirements for the Delta Cross Channel and what is their basis? Pat Brandes (FWS)

Translation of management issues into scientific questions and studies. Bruce Herbold (USEPA)

Scientific studies at the Delta Cross Channel: early results and new understanding. Jon Burau (USGS) and Mark Pierce (FWS)

Management implications of scientific knowledge and uncertainties generated through studies of the DCC. Ron Ott (CALFED)

John Burke provided a general overview of the physical and operational aspects of the DCC. Constructed in 1950-51, the DCC is considered one keystone of the Central Valley Project. Operation of the DCC: 1) provides a shortcut for Sacramento River flows (via the Mokelumne River) to the south delta for export; and 2) aids in meeting the salinity standards for the Delta Mendota Canal, Contra

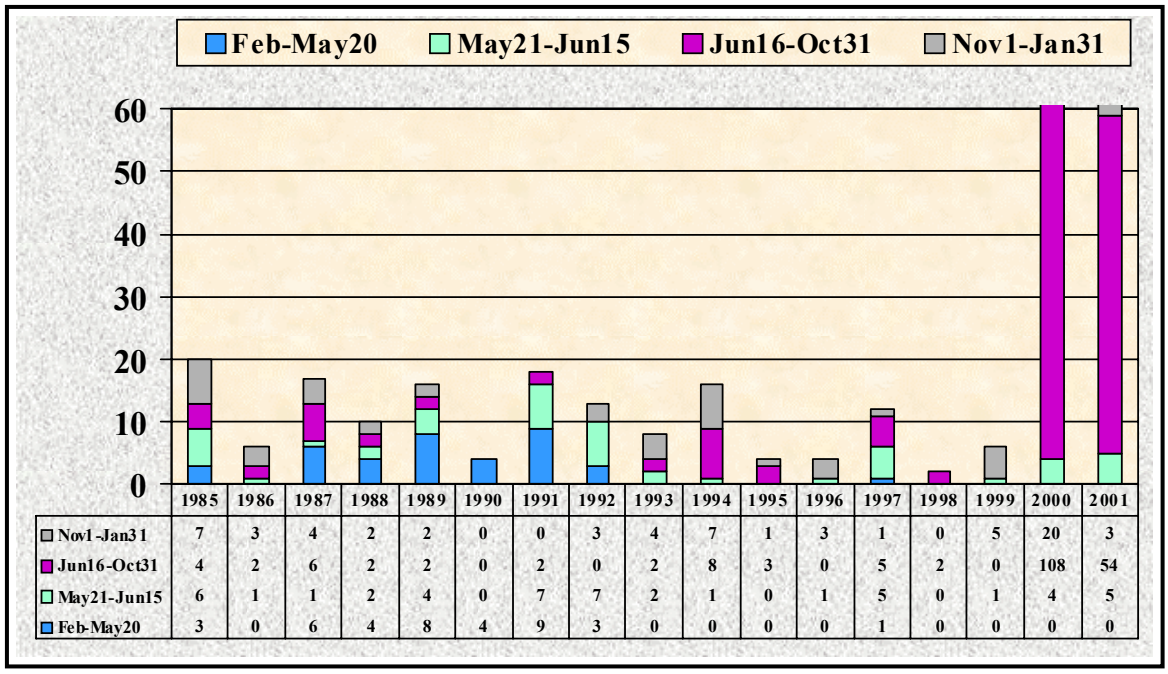
Costa export facilities, and lower San Joaquin River. The location and sizing alternatives for the DCC were explored using electrical analog models in the 1940's, and early alternatives to the DCC were "peripheral canal" like variants. The two 60'x30' gates at the head of the DCC are USBR's largest radial gates.

The standard operating procedures (SOP's) for the DCC are largely those established in 1968: the two radial gates are normally operated together, and the gates are generally closed if Sacramento River flows are greater than 20,000 – 25,0000 cfs. Other criteria affecting DCC operations also come from: 1) Water Right Decision 1485 (1978), 2) the NMFS winter-run Chinook salmon biological opinion (1993), 3) the Bay-Delta Accord (1994), 4) Water Right Decision 1641 (1999), and 5) the spring run protection plan (2000). Operating criteria in these documents are mainly for the purpose of protecting fish –principally salmon and striped bass; however, factors such as flood control, Delta salinity standards, and flow on the Sacramento River are also considered in determining DCC operations at various times of the year.

The criteria and factors affecting DCC operations generally lead to "four seasons of DCC operations":

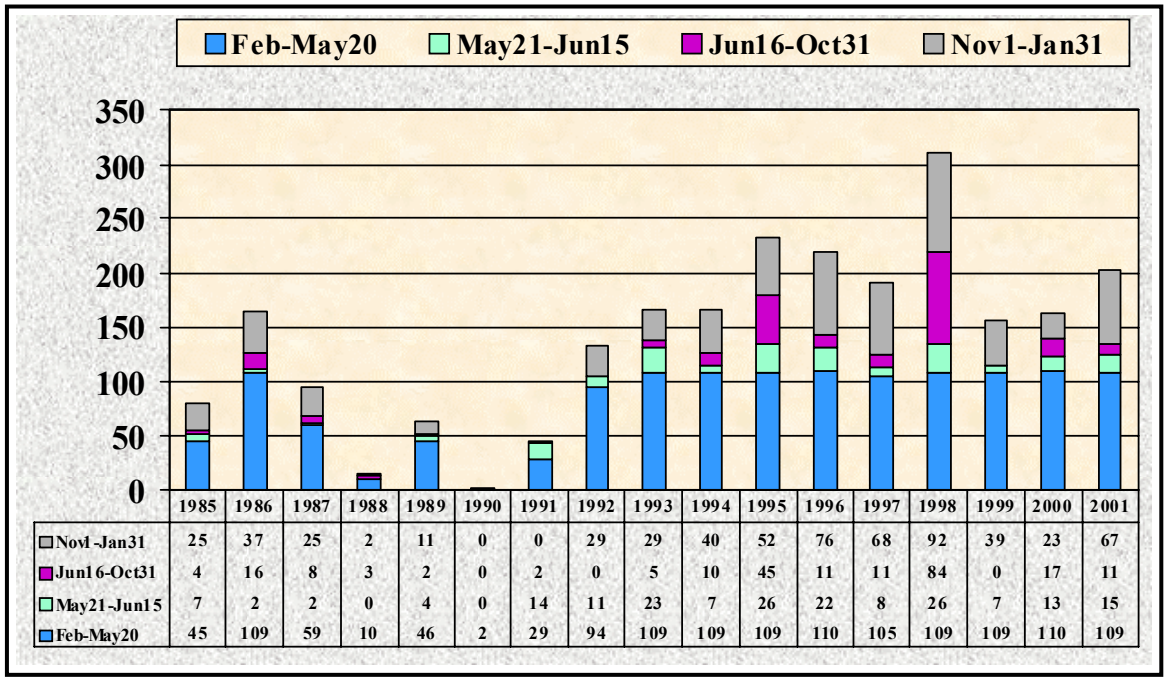
- February 1 – May 20: DCC gates are closed during this 109 day period to protect young salmon migrating down the Sacramento River.
- May 21 – June 15: DCC gates are closed 14 of the 26-day period. USBR determines the timing of gate closures after consultation with the CALFED Operations Group.
- June 16 – October 31: Holding the DCC gates open is the default position for the gates during this 138 day period, unless closure is required due to high flows on the Sacramento River, increases in salinity levels at Emmaton, or to increase minimum Sacramento River flow at Rio Vista.
- November 1 – January 31: Gates may be closed up to 45 days during this 92 day period to aid in the protection of emigrating salmon. The exact days of closure are determined based on real-time monitoring as prescribed in the spring run protection plan and the NMFS biological opinion for spring-run Chinook salmon.

Operation of the DCC (i.e., opening or closing the gates depending on initial condition) varied from 2 to 20 times between 1985 and 1999 (Figure 5), but increased dramatically in 2000 and 2001 during the June 16 – October 31 period in response to the DCC experiments described below. In contrast, the number of days the DCC gates were closed has varied from two to 311 days since 1985, with generally higher periods of closure occurring since 1992 (Figure 6).



	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Nov1-Jan31	7	3	4	2	2	0	0	3	4	7	1	3	1	0	5	20	3
Jun16-Oct31	4	2	6	2	2	0	2	0	2	8	3	0	5	2	0	108	54
May21-Jun15	6	1	1	2	4	0	7	7	2	1	0	1	5	0	1	4	5
Feb-May20	3	0	6	4	8	4	9	3	0	0	0	0	1	0	0	0	0

Figure 5. Number of DCC gate operations (opening or closing the DCC gates depending on initial condition) for each of four periods during the years 1985 through 2001.



	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Nov1-Jan31	25	37	25	2	11	0	0	29	29	40	52	76	68	92	39	23	67
Jun16-Oct31	4	16	8	3	2	0	2	0	5	10	45	11	11	84	0	17	11
May21-Jun15	7	2	2	0	4	0	14	11	23	7	26	22	8	26	7	13	15
Feb-May20	45	109	59	10	46	2	29	94	109	109	109	110	105	109	109	110	109

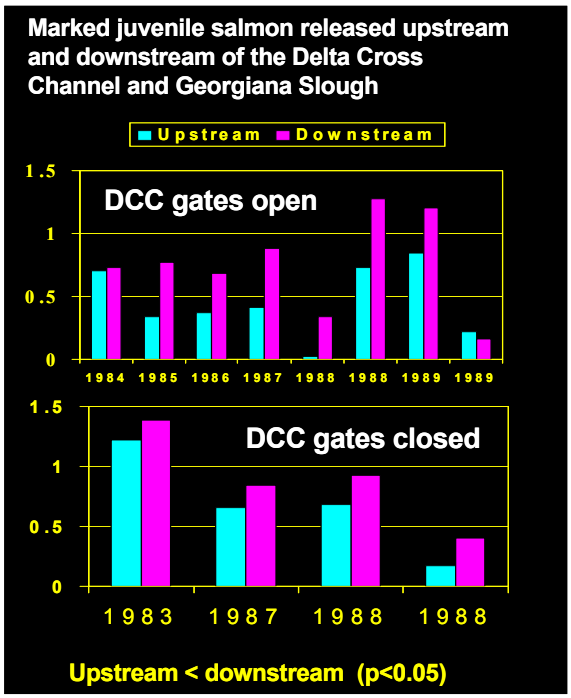
Figure 6. Number of days the DCC gates was closed during each of four periods in the years 1985 through 2001.

Pat Brandes provided detail about the basis for DCC operation restrictions to protect fish. Fish protection requirements for the DCC contained in the 1995 Water Quality Control Plan and are the same as those listed above under the four seasons of DCC gate operations.

Closure of the DCC for fish is largely based on the migration patterns of Chinook salmon, which were established through many years of monitoring at key locations in the rivers and the delta. The radial gates are closed when monitoring data show that high numbers of young salmon typically are entering the delta (Figure 7). These closures are intended to keep emigrating salmon in the main stem Sacramento River. Release studies with young hatchery salmon show that survival is higher if they migrate to sea via the Sacramento River than if they migrate through the delta (Figure 8). The DCC studies showed that fish movement (even young salmonids) is related to water flow. If closing the DCC allows less water into the Delta, then fewer fish should also move into the interior delta when the DCC is closed. Lower survival when fish migrate into the Delta could result from exposure to poor water quality conditions in the Delta, greater potential for entrainment at the export pumps, increased travel times leading to increased exposure to predation or other stresses that occur in the Delta. The relative importance of these factors is now known. There is evidence, again from salmonid mark/recapture studies, that when export rates are highest survival is most reduced; but the mechanistic reasons for this are also not established.

Figure 7. Timing of occurrence of emigrating salmon in the Sacramento River near the Delta Cross Channel relative to the DCC operations schedule. Gate closures are timed to occur when high salmon abundances occur in the north Delta, especially threatened spring-run and endangered winter-run Chinook salmon.

CLICK HERE FOR FIGURE 7



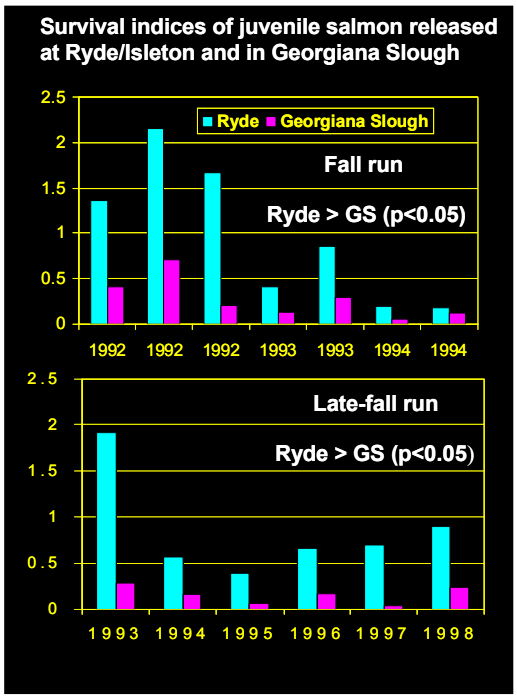


Figure 8. Results of mark/recapture salmon survival studies. Data in the left hand figure show that fish released downstream of the DCC consistently survive better than fish released upstream of the DCC. The differences in survival between upstream and downstream releases are significantly different. Similarly, the right hand figure shows fish released at Ryde (below the DCC and Georgiana Slough) exhibit consistently higher (and statistically significant) survival than fish released at the head of Georgiana slough.

Bruce Herbold discussed the management issues associated with the DCC, the resulting science questions, and the experimental approach to addressing these questions. Several management issues exist for the DCC:

- From November through January, when should the DCC gates be closed to protect emigrating salmon smolts? The existing rules allow the DCC gates to be closed up to 50% of the time between May and January. Closure of the DCC gates under low flow conditions, however, causes the State and federal export facilities to take more water from the western delta where salinity levels are higher. An episode in 1999 showed that this could compromise interior delta drinking water salinity standards. Spring-run yearling salmonids also show a high degree of variability in emigration, so predicting when to close the gates to protect these fish is problematic.
- Does operation of the DCC gates alter the path and timing of adult salmon immigration? There is a long-standing assumption that Sacramento River water moved through the DCC and into the central delta causes adult salmon to think the Delta is the Sacramento River and stray off-course as they migrate landward. Closing the DCC gates for water quality and/or

protection of emigrating spring run salmon smolts may prevent adult fall run salmon from migrating upstream out of the delta.

- Are there opportunities to improve water quality and salmon protection through alternative DCC operation scenarios? A section in the Central Valley Project Improvement Act specifically requires the Department of Interior to investigate improved operations of the DCC.
- Is new construction of a through delta facility (TDF) needed, and if so what can studies of the DCC tell us about the best way to design a new facility?
- Can the approach used at the DCC be applied to understanding fish movement and flow in other parts of the Delta where CALFED actions are proposed (e.g., the South Delta Improvement Program)?

These management issues led to three questions that are being tested through field experiments:

- How does the DCC affect interior delta water quality?
- How does the DCC affect adult salmon immigration through the delta?
- How does the DCC affect the emigration of salmon smolts?

The DCC studies involve an interdisciplinary team working in close collaboration. The principal investigators co-design all studies and interact throughout all phases of the studies. The studies are using new technologies where appropriate. CALFED management supported experimental manipulation of the DCC, and varied DCC gate operations in the fall of 2000 and 2001 as requested.

John Burau and Mark Pierce described some of the initial results from the DCC studies.

Ten to fifteen years ago people thought the most important aspect of water movement in the Delta was net-flow, or the net direction of water movement after taking out the effect of tides. Recent studies show, however, that tidal currents have a much greater influence on transport of materials and water than originally thought. In general, transport in the estuary has different zones defined by the predominant influences: riverine, export influenced, and tidally influenced. The location and size of these zones varies with amount of river flow and export conditions. Tidal influences dominate throughout much of the estuary. In the tidally dominated areas, some net water movement occurs in one direction, but large masses of water are moved long distances back and forth by the tides, during each tidal cycle (i.e., the tidal excursion is large) Most important, water and materials carried by the water do not just slosh back and forth, but unexpected net movements of both occur because of the complexity of the channels and the large forces involved. Unintuitive dispersion of materials by the tides alone is pervasive. For example, tidal currents that are much larger than net flow result in dramatic changes in velocity of water movement into the DCC (e.g., as water moving down the Sacramento River confronts the incoming tide during a flood tide water is forced at high velocity “upstream” and into the DCC).

On an outgoing tide, little out flowing river water enters the DCC. How these flow complexities affect fish is a major question the DCC studies are investigating. The question is difficult because the fish (salmon smolts) are highly mobile, move in three dimensions and their behavior can vary dramatically. The first results from the study showed that, despite the mobility of the fish, movement of the salmon smolts into the DCC was driven by strong inflows into the Channel; drifters released with the experimental fish tracked fish movement (in terms of density distribution).. Evidence is strong that salmon entrainment into the DCC will largely depend on the flow field they encounter at the time of arrival at the entrance to the DCC.

In summary, early findings from the DCC studies include:

1) Intensive measurements are required to understand the physical processes at the DCC, as described above.
2) Fish appear to move with the flow. Radio-tagged fish, hydroacoustic studies, fish traps and hydrodynamic measurements corroborate this finding. Initial results show most fish pass by the DCC on an ebb tide (no flow into DCC), but most fish go into the DCC on the flood tide with the strong inflows.
3) Intensive salmon mark/recapture studies suggest the fish sampling has a diel bias. Almost all recaptures occurred during the night, but hydroacoustic studies show there were fish present during the day. Fish may be avoiding the sampling nets during the day resulting in lower catch compared to the night.

Ron Ott then described how DCC results may be used in decisions about a through delta facility (TDF) and the south delta improvement program (SDIP). In addition to the DCC studies, a screened through-delta facility of up to 4,000 cfs is being evaluated on the Sacramento River. All types of discharges with different types of screens at different locations are being considered. The CALFED ROD states the TDF will only be considered after three separate assessments are satisfactorily completed.

1) A thorough assessment of DCC studies,
2) A through evaluation of technical viability,
3) A firm understanding of fish protection/impacts (i.e., screen effects).

Issues associated with the TDF include:

- Changes in migration path and increased straying. How would operation of the TDF modify the percentage of salmon moving into the central delta?
- Salinity intrusion into the Sacramento River and east delta. How would operation of the TDF modify relative contributions of various tributaries at various locations in the delta?

- Hydrodynamic changes in the delta. Would TDF operations modify the amount of water flowing seaward from the delta?

Indirect losses of fishes are a major concern associated with a TDF. Other concerns, which have not been systematically studied, are that predators may accumulate around TDF structures artificially increasing local predation, and how to move fish caught in the screens back into the Sacramento River. Plans exist to study how fish respond to a low barrier by studying response to a weir placed in the Yolo Bypass. There are also plans to see how fish respond to ship channel locks in the Sacramento Ship Channel and if it is possible to use ship channel locks to collect fish. Finally, laboratory studies at UCD and USBR will examine ways to get fish over barriers.

The present timeline calls for completing the water quality and fish studies associated with a TDF and get the information with recommendations to management by the end of 2003. If there is no clear alternative then the CALFED ROD requires a four year environmental review to look at all alternatives.

In the south delta structures are proposed to facilitate water supply reliability, but study is needed to find the best alternatives and simultaneously minimize impacts to water quality and fish. The operable barriers proposed for the south delta are intended to address water level concerns in south delta channels. New intakes for the SWP and CVP will require determining the most cost-effective way to screen the intakes, to reduce fish entrainment and loss.

Timing and uncertainty (perhaps sometimes conflicting issues) will factor into the necessary policy decisions associated with the proposed Delta facilities included in the CALFED ROD. The pace of, and investment in, the science process will influence how much new information can be brought to bear on these important decisions.

VI. Managing State and Federal Water Operations Exports:

The second day of the workshop focused on the state of knowledge, assumptions, range of interpretations, and science needs associated with management of water exports at the State (SWP) and Federal (CVP) delta export facilities. The specific intent was to discuss the science associated with management actions, in a balanced fashion and in public.

A number of technically complex issues are associated with balancing water allocations among environmental, urban, and agricultural uses in the estuary and its watershed. Presentations in this session identified many of these issues, as well as some of the newest approaches in use to help reduce the conflicts associated with water management for exports.

Topics and speakers in this session included:

- Conceptual model for environmental water assets in the context of water operations – Lester Snow (Consultant)
- EWA and Water Management – Tim Quinn (MWD)
- Delta Smelt Biological Opinion: Underlying regulations, science and management tools – Mike Thabault (FWS)
- Science underlying the existing management system: salmon science at the Department of Fish and game – Diana Jacobs (DFG)
- Environmental Water Account (EWA) review panel recommendations – Jim Cowan (LSU)
- Science challenges in managing water diversions to protect the environment – Wim Kimmerer (SFSU) and Zach Hymanson (CALFED)
- Science challenges in understanding threats to delta smelt – Bill Bennett (UCD)
- Management and policy implications of science knowledge and uncertainties associated with the EWA– Jerry Johns (DWR)
- Challenges in science-based salmon management: lessons from the northwest – Jim Anderson (UW)
- General state of science, new findings and needs for salmon – Steve Lindley (NMFS)

The purpose of the first talk (Lester Snow) was to provide an overview of the tools used to manage water operations and protect environmental resources. The conceptual model for water operations and environmental protection (Figure 9) provided by Snow shows that a number of tools are used to manage water operations and meet ecosystem commitments. These tools are quite diverse and take the form of programs (e.g., the Environmental Water Account) and regulatory requirements (e.g., Water Right Decision 1641) that were developed after 1992. These tools are used in combination to manage the system. For example, EWA water was used in 2002 to make up for the reduction of b(2) water (i.e., water allocated to environmental protection by the Central Valley Project Improvement Act) as a result of the Wanger decision. It is difficult to separate effects of any individual tool from effects of the others (Snow). Ecosystem performance measures (e.g. fish populations) probably reflect the aggregated effects of all actions. So it will be difficult to test the (usually implicit) assumptions or hypotheses of individual tools, in isolation.

For this reason, evaluating actions program-by-program or acre-foot-by-acre-foot may not be an effective way of accounting for the benefits of environmental water use. Instead, assessments should focus on the net effects of the aggregated actions to changes in the overall condition of the ecosystem. One implication is that CALFED should strive to move along the performance measure hierarchy from acre-foot accounting to comparing actual ecosystem-level benefits of individual actions. Another implication is that, even if performance of each

individual tool can be evaluated, effects of individual tools may be less than the aggregated benefits to the system as a whole.

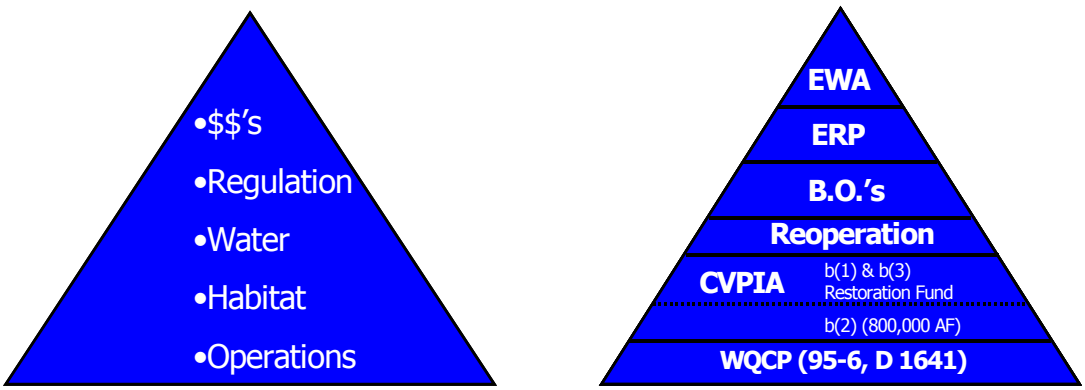


Figure 9. The program and regulatory foundation for managing water supply reliability and environmental resources in CALFED (left hand figure). Funding, existing regulations, water for environmental purposes, habitat restoration, and operational flexibility are used to reverse or minimize environmental impacts. A diverse set of tools (right hand figure) has been developed over time to assure ecosystem (fisheries) improvements. They include: WQCP 95-6 = Water Quality Control Plan 95-6, D 1641 = Water Right Decision 1641, CVPIA = Central Valley Project Improvement Act, B.O.'s = Biological Opinions, ERP = Ecosystem Restoration Program, EWA = Environmental Water Account.

The second speaker (Tim Quinn) was invited to provide information on the basis and application of a new tool, the Environmental Water Account (EWA). Events in 1999 related to SWP and CVP water operations and delta-smelt salvage provide an example of the difficult conflicts that can develop between human needs and environmental needs for water resources. Despite application of environmental water, high salvage of delta smelt was observed at the export facilities. This resulted in the curtailment of pumping in May and June, which placed extreme pressure on San Luis Reservoir and the availability of water resources. At the time, a tool did not exist to deal with this situation. Policy makers and stakeholders viewed the situation in 1999 as a pointed example of a "failed system" (Quinn). Some characteristics contributing to the "failure" were:

- Rigid, fixed rules incompatible with dynamic, poorly predictable patterns in both water availability and fish migration. Uses of ESA incidental take to compensate for rigidity resulted in black or white tradeoffs (i.e., the only option to preventing excess take was to reduce water availability).
- Because win-win options were not available, high levels of conflict forced the system.
- In this "dysfunctional system" 1) real-time operations were impossible, 2) water users were forced to oppose regulatory decision and science, 3) policy makers were constantly "putting out fires" and not focused on long-term solutions.

The concept of an Environmental Water Account (EWA) was developed in discussions among stakeholder and agency representatives. Application of the EWA was seen as a way to reduce or avoid conflicts by stabilizing water supplies, but giving the fish protection agencies direct control over the water resources that would be used to make up for curtailments of pumping. The EWA allows at least some form of adaptive management and integration of policy and science. Key benefits of the EWA are that it:

- Promotes balance,
- Reduces conflict,
- Promotes real-time fish management,
- Encourages support for objective science,
- Encourages more efficient use of environmental assets,
- Provides regulatory assurance to water users.

EWA does not do much to change the physical system, but it does change the social system. Under the EWA, biological managers are empowered to make decisions using water they control. These managers now have a much larger investment (and more direct stake) in the water they are using and a more direct investment in the consequences of water management decisions involving EWA. The EWA is not designed to solve all problems. But it does give managers at DFG, FWS, and NMFS the opportunity to use their real-time fish migration data to manage the system using water assets they control. The water users like it, because the water is paid for. At the same time, the water users commitment is assured, because they have agreed to make water assets available for EWA.

In the absence of EWA, both sides used their own interpretations of science to support their position. The EWA allows both sides to more directly confront uncertainties and assumptions and therefore helps work towards balance.

It is too simplistic to ask whether the EWA is working or not; it is more constructive to consider what is being accomplished and what could be done better. The 2001 winter-run Chinook salmon loss and associated EWA actions provided an example of both the challenges and the strengths of the approach. In February an unexpected pattern of salmon migration led to a large take of winter-run at the CVP and SWP, in excess of the regulatory limit (the “red light”; see definition below in Jacobs’ presentation). The fish managers had used their full allocation of water for the month and, rather than borrow water from future potential needs to curtail exports, they decided to allow the take to continue. This decision was partly facilitated by uncertainties about the size of the winter - run population (i.e. was the red light really exceeded?). In hindsight, NMFS and DFG staff determined that winter-run production was higher in 2001 than recognized by the counting approach called for in the biological opinion (counts of adults at Red Bluff Diversion Dam); the larger population was indicated by DFG adult carcass counts throughout much of the spawning habitat. So,

although take numbers were large they were probably not in excess of the proportion of the population that defined the “red-light” condition under which export curtailment could be considered (see the formal definition of the “red light” below). In 2002 the agencies agreed to use the more reliable carcass counts to set the red light level. It is also important to note that, although February 2001 was a time of controversy and potential conflict, the coalition of agencies and stakeholders held together despite their disagreements. This presentation and the ensuing questions (see Appendix A) brought out several different interpretations of the value of the EWA

One of the challenges for a new experience like EWA, is to define tools for measuring its performance. Several were suggested:

- Certainty for water users in terms of amount provided per year.
- Extent to which fish managers can show that real time control reduces take.
- The degree of ongoing, open discussion of science certainties and uncertainties, and the changes in management that result from that discussion.

The third talk in this session (Michael Thabault) described the basis that FWS uses to manage exports to protect fish species in the Sacramento-San Joaquin Delta and associated watersheds. First some general information was provided about various components of biological opinions under the Federal Endangered Species Act. This included:

The distinction between jeopardy and non-jeopardy: An action or project is considered to cause jeopardy if it reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of survival or recovery of the species. Determination of jeopardy is based on the status of the species, all of the effects of the actions as proposed, and the cumulative effects of other actions.

Incidental take is defined as the amount or extent of either the species or its habitat that is anticipated to be taken incidentally as a result of an otherwise lawful activity. Incidental take of delta smelt is based on the estimate of combined salvage at the SWP and CVP. Incidental take is not a projection of the impact on the population, nor is proof required relating incidental take levels to population benefits. Incidental take is a management tool. All of the following must occur when the incidental take level for a listed species is exceeded:

- The project proponent must reinitiate consultation
- Measures to minimize incidental take must continue
- Reinitiating consultation must lead to conclusions concerning jeopardy

But exceeding the incidental take level for a listed species does not necessarily mean cessation of all further take must occur.

Incidental take of delta smelt in the delta has two components: the yellow-light level and the red-light level. The yellow-light level is a warning level to trigger evaluation of the situation if exceeded. The yellow-light is triggered when the 14-day running average of combined daily salvage exceeds or equals 400 individuals. The basis for this number was not described.

The red-light level is a monthly value of combined salvage that varies among months and water year type (above normal and below normal). The red light level is based upon an estimate of the delta smelt incidental take that is expected from historical SWP and CVP salvage under: 1) export strategies called for in the project description (OCAP); 2) the expected future environmental conditions; and 3) other information available to FWS at the time it prepared the biological opinion.

Exceeding the red-light level places the CVP and SWP in a situation where the projects are no longer exempt from prohibitions of take under Section 9 of the Federal Endangered Species Act. Thus, reconsultation is necessary when the red-light level is exceeded. Red-light levels are generally higher for below normal water years. This is because historical salvage was generally higher in the dry years than in the wet years, likely because more delta smelt occurred in close proximity to the SWP and CVP delta export facilities in dry years. The reason for this is not fully understood, nor is the relationship simple.

The red-light level is responsible for much of the controversy related to delta smelt and water exports. So it is important to understand how FWS implements the incidental take statement. The approach to implementing the terms and conditions in the biological opinion for delta smelt includes three factors: 1) the operating paradigm for delta smelt; 2) data and information used as a basis for decisions about the status of the species; and 3) a risk assessment.

The FWS operating paradigm for delta smelt is as follows:

- Delta smelt generally do better the more days that X2 is west of the confluence in the spring (resulting from more days of higher inflows, reduced exports, or a combination of the two). It is recognized the correlation is weak and it is not predictive for all conditions. It is not known why deviations from the correlation occur, but several general characteristics of delta smelt life history support the conclusion that inflows are important.
- Spatial and temporal variability are desirable characteristics. That is, the potential benefits to the species (i.e., the species is likely to be more resilient) are thought to be greater when multiple cohorts are distributed among different regions of the upper estuary.

- The San Joaquin River plays an important role in estuarine health and, in some years, could provide important delta smelt spawning areas.
- The biological opinion covers operations of both the CVP and SWP from reservoirs to exports. Thus, management responses to adverse conditions can include changes in exports, changes in reservoir operations, or a combination of the two.
- There is a "zone of influence" for the export operations, and this zone is affected by tides, inflows, total exports, and population distribution.
- Larval stages are more susceptible to flow changes than adults.
- Incidental take is reduced and indirect effects are minimized if there is positive (westward) flow in lower Old River.

The paradigm is consistent with the existing state of knowledge about delta smelt. That said, the state of knowledge is limited; some data supports each of these concepts, but a systematic body of work is needed to better understand the uncertainties in the paradigm.

Several tools provide information that is used to directly manage delta smelt. These include: 1) real-time monitoring, 2) 20 mm survey, 3) summer tow net survey, and 4) fall midwater trawl. Some of these tools, such as the 20 mm survey, are specific to delta smelt, although others (e.g., the fall midwater trawl) collect data on Delta smelt but were designed to best sample other species of fish. The data from these surveys are combined with information on project operations and other information associated with the specific period (e.g., tidal regime, life stage, and length of proposed action) to make decisions about the status of the species and the impact of specific take levels.

Two of the most recent additions to the "information toolbox" are spatially intense near-real time surveys conducted in the spring and summer to establish the relative distribution of delta smelt and the use of a particle-tracking model to understand the influence of water operations on the distribution of larvae. There is a "zone of influence" for the export operations, and this zone is affected by tides, inflows, total exports, and population distribution. The model is especially useful in estimation of the relative effects on larval smelt, arising from alternative operational scenarios. Predictions are based on the estimated distribution of delta smelt relative to the zone of influence.

The above information is used in a qualitative risk assessment conducted by FWS staff and designed to develop an overall sense of the risk to the population. It is recognized that understanding of population level effects of either environmental factors or take is imperfect at this time. FWS reaches out to many groups (e.g., the Data Assessment Team, the Operations and Fish Forum, and the Delta Smelt Workgroup) to get a better overall understanding of risk based upon the available information and best professional judgment.

Information was also presented on delta-smelt recovery. Recovery is defined as improvement in the status of a listed species to the point which listing is no longer appropriate. There is a recovery plan in place for delta smelt.[3] Delta smelt recovery is based on two types of criteria: 1) meeting the quantitative criteria for abundance and distribution over five years including two extreme water years, and 2) reducing potential threats based on a threats analysis. Figure 10 provides the status of delta smelt relative to the quantitative criteria.

Diana Jacobs described some of the science underlying management of central valley Chinook salmon. Salmon are important both as commercial and recreational fisheries. Numerous studies are available of the salmon life cycle, salmon physiology, and the factors affecting the population biology, especially compared to other species. Estimating the population size of the various salmon runs, and trends in their abundance, is central to monitoring the status of the species. A variety of techniques are used to count adults and juveniles in the rivers, delta and oceans (Figure 11). The Sacramento River watershed has an especially extensive network of adult salmon escapement surveys (Table 1), which are used to estimate the abundance of adult fish returning to spawn. The results of these surveys are used in a variety of ways, including the establishment of escapement targets, which serve as the basis for managing the ocean and inland harvest. The estimates of abundance of certain salmon runs listed under the ESA are also used to manage take at the CVP and SWP delta export facilities (see discussion under winter-run below).

Fall-run Chinook salmon is the dominant run in the Central Valley. Fall-run spawn in the lower- to mid-rivers reaches, so many of the reservoir dams have not excluded fall-run from all of their historical spawning grounds. Other races of salmon are not doing as well as the fall-run, partly because of the anthropogenic barriers to upstream, cold-water habitat. For example, winter-run Chinook salmon escapement showed a dramatic decline through the 1970's (Figure 12). Beginning in 1986, actions were implemented (listing under the ESA, restoration projects, changes in ocean harvest) with the goal of helping to restore winter-run salmon (Figure 12). The benefits of individual actions are difficult to identify. But recent escapement estimates (i.e., 1995 and beyond) suggest populations have begun to increase. The aggregate effect of the restoration actions is likely to be one of the factors positively affecting winter-run, although contributions from changing climate and ocean conditions may be a factor as well.

[3] The delta smelt recovery plan is contained in: U.S. Fish and Wildlife Service. 1996. Sacramento-San Joaquin Delta native fishes recovery plan. U. S. Fish and Wildlife Service, Portland, Oregon.

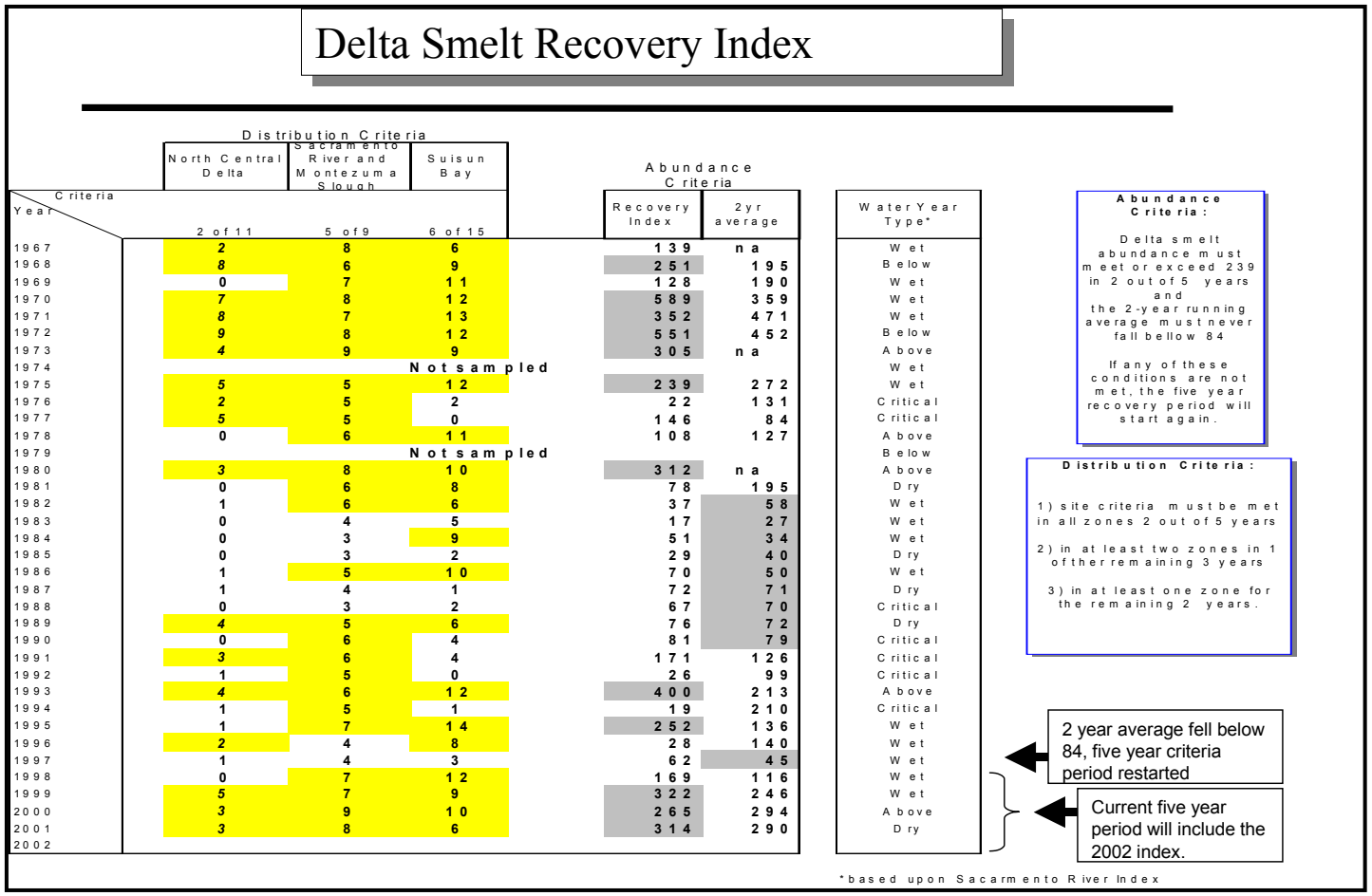


Figure 10. Historical data and criteria used to evaluate delta smelt recovery. Recovery is evaluated relative to both the distribution and abundance of delta smelt in three regions: 1) Sacramento-San Joaquin Delta, 2) Suisun Bay, and 3) Suisun Marsh (i.e., Montezuma Slough). To qualify as present in a specific region, at least one individual must be captured at a certain number of stations within the region (e.g., delta smelt must be captured from at least two of eleven stations in the North-Central Delta region). Yellow highlighted values are those that met the distribution criterion for a particular region. Abundance criteria include both annual values (listed as Recovery Index under Abundance Criteria) and a two-year running average. Grey shaded Recovery Index values meet the stated criterion. Grey shaded two-year average values do not meet the stated criterion. According to the recovery criteria (FWS, 1996) delta smelt will be considered recovered and qualify for delisting when the species goes through a five-year period that includes two sequential years of extreme outflows, as determined by water year type for the Sacramento River basin, one of which must be dry or critically dry. Data in this table were provided by the CA Dept. of Fish and Game.

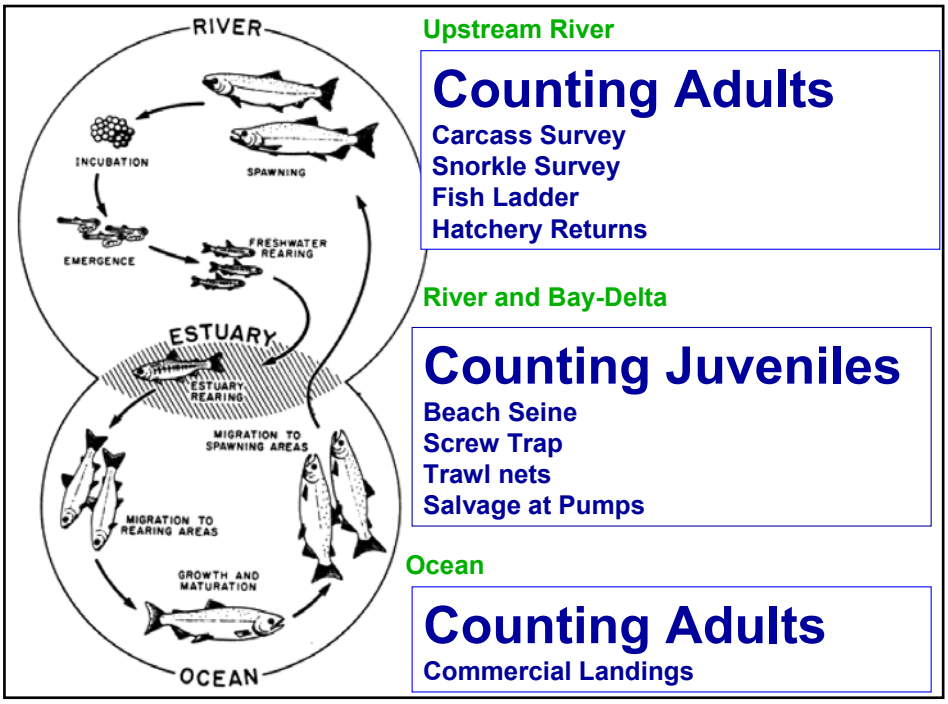


Figure 11. Methods used to count salmon at various life-stages and habitats.

Summary of Sacramento Valley Chinook Salmon Escapement Surveys

Stream	Race	Monitoring Program	Who Conducts or Funds
American River	Fall-run	Carcass survey	DFG
		Hatchery returns (Nimbus)	DFG
Antelope Creek	Spring-run	Snorkel survey	DFG
Battle Creek	Fall-run	Carcass survey	DFG
		Hatchery returns (Coleman)	USFWS
	Late fall-run	Carcass survey	DFG
		Hatchery returns (Coleman)	USFWS
Beegum Creek	Spring-run	Snorkel survey	DFG
Big Chico Creek	Spring-run	Snorkel survey	DFG
Butte Creek	Fall-run	Carcass survey	DFG
	Spring-run	Snorkel survey	DFG
		Carcass survey	DFG
Clear Creek	Fall-run	Carcass survey	DFG/USFWS
Cottonwood Creek	Fall-run	Carcass survey	Needed, but not currently conducted

Stream	Race	Monitoring Program	Who Conducts or Funds
Cow Creek	Fall-run	Carcass survey	Needed, but not currently conducted
Deer Creek	Fall-run	Carcass survey	Needed, but not currently conducted
	Spring-run	Snorkel survey	DFG
Feather River	Fall-run	Carcass survey	DFG/DWR
		Hatchery returns (Feather R)	DFG/DWR
	Spring-run	Hatchery returns (Feather R)	DFG/DWR
Mill Creek	Fall-run	Carcass survey	Needed, but not currently conducted
	Spring-run	Redd counts	DFG
Upper Sacramento River	Fall-run	Carcass survey	DFG/USFWS
	Late fall-run	Carcass survey	DFG/USFWS
	Winter-run	Carcass survey	DFG/USFWS
Yuba River	Fall-run	Carcass survey	YCWA

Table 1. List of surveys conducted in the Sacramento River watershed to estimate adult escapement of Chinook salmon.

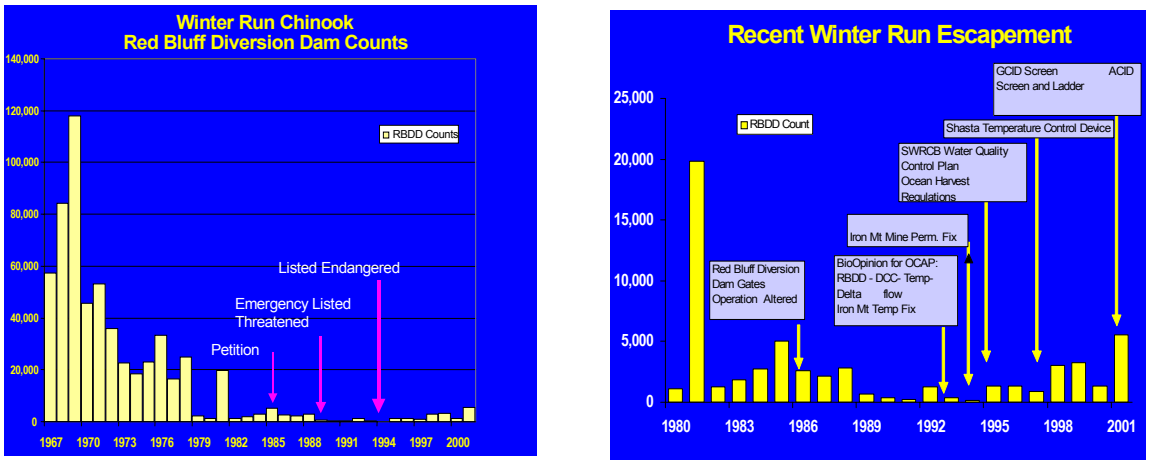


Figure 12. Winter-run adult escapement estimates 1976-2001 (left hand figure) showing dates of actions under the endangered species act. The right hand figure shows the timing of various actions taken to benefit the species relative to ongoing estimates of adult escapement.

In contrast to delta smelt, the yellow-light and red light levels for incidental take of winter-run salmon in the delta are based on estimates of the proportion of the spawning population salvaged at the south delta export facilities, rather than absolute numbers of fish taken at the CVP and SWP delta export facilities. An estimate of adult escapement is used to determine the juvenile production estimate (Figure 13). The adult escapement estimate is the key factor in determining the incidental take levels, so the accuracy of this estimate has important regulatory implications. Recent work focused on "fine-tuning" the adult escapement estimates for winter-run. USFWS observations suggest changes in operation of the red bluff diversion dam reduced the accuracy of escapement counts at that structure; DFG analyses suggested there was less uncertainty in carcass counts than in the diversion dam estimates, and that carcass count data were available with adequate timeliness to support real time analyses. After an analysis of events in 2001, DFG and NMFS switched the primary method for

2001-2002 Winter-run Chinook Juvenile Production Estimate (JPE)

Total Spawner escapement (Carcass Survey)	7,572
Number of females (64.4% Total)	4,876
Less 1% pre-spawn mortality	4,828
Eggs (4,700 eggs/female)	22,689,740
Less 0.5% due to high temp	113,449
Viable eggs	22,576,291
Survival egg to smolt (14.75%)	3,330,003
Survival smolts to Delta (56%)	1,864,802
Livingston Stone Hatchery release	252,684
Yellow light(1%natural + 0.5 hatchery)	19,911
Red Light (2% natural + 1% Hatchery)	39,823

Figure 13. Example of how the winter-run Chinook juvenile production estimate, yellow light and red light levels are calculated using 2001-02 adult escapement data.

estimating adult escapement from counts at the diversion dam to adult carcass surveys (i.e., counts of the bodies of adults that returned to spawn, then died). The management implications of that change were described above.

There is a draft recovery plan for winter-run Chinook salmon. The draft recovery criteria (adult escapement of ≥ 10,000 fish per year for 13 years) are used in the CALFED Record of Decision. The latest data show winter-run is on a trajectory towards recovery (Figure 14).

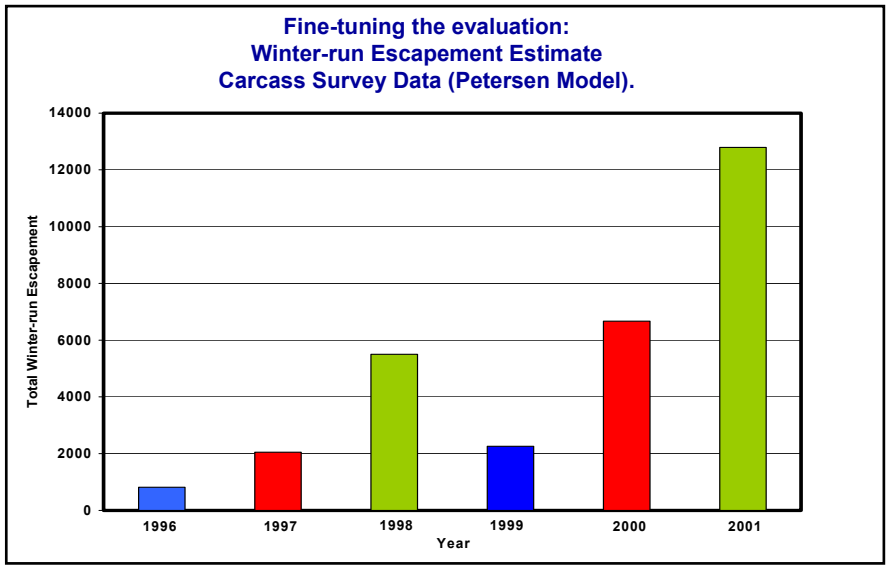


Figure 14. Estimates of adult winter-run Chinook escapement 1996-2001 using carcass survey data. Similar colored bars illustrate a positive trend in the cohort replacement rate (i.e., an increase in the number of offspring returning as adults three years later)

Spring-run Chinook salmon are also listed under the federal and State endangered species acts. Rotary screw trap sampling of young salmon (smolt) emigrating from the tributaries is the main mode of monitoring. Indicators described in the spring-run protection plan are used to determine when actions such as closing the delta cross channel or reducing exports are needed. Like the procedure for delta smelt, the fish agencies reach out to a number of groups and use best professional judgment to achieve the best possible assessment of risk to spring-run.

Steelhead is another salmonid listed as threatened under the Federal Endangered Species Act. Unfortunately, monitoring the status of this species is much more difficult because returning adults do not die after spawning. There is much uncertainty associated with the exact status and trends for steelhead, but

there is little question that populations have declined substantially. McEwan recently summarized the state of knowledge for steelhead.[4]

In October 2001, the first annual, technical review of the Environmental Water Account was convened by CALFED, in a public forum, as a way to provide expert evaluation and insights to aid water management in the delta. Thirteen experts, representing a variety of disciplines, conducted this review; their conclusions were summarized by panel chair James Cowan (Louisiana State University).[5]

The reviewers praised certain aspects of the first year of the EWA. Positive factors included:

- Successful purchase of the full amount of water,
- The management and project agencies, and stakeholders worked well together despite diverse missions,
- Decisions were made in a timely fashion,
- Decision trees were useful guides in decision making,
- Reports documenting outcomes were useful and timely,
- The science Advisors had beneficial effect on EWA process.

Two major findings pointed to issues requiring additional attention by CALFED.

- Adaptive management is a human-capital intensive activity. The current make-up of the CALFED team is probably inadequate in terms of the amount and kinds of expertise needed to fill gaps in knowledge, and the team needs to be strengthened.
- It is important to maximize the EWA's management flexibility within the confines of overall policy goals and constraints, and to ensure that the EWA team effectively uses this flexibility to promote the EWA's goals.

The panel also provided recommendations related to additional research, monitoring, and staffing.

Recommendation 1: CALFED should release sufficient agency staff time to support the development of the EWA, and to put as high priority CALFED projects that address EWA needs. This does not involve additional expenditures of funds, but it does require rescheduling of staff time.

Recommendation 2: In support of EWA-related research, CALFED should recruit and support as appropriate: visiting senior scientists, post-doctoral and graduate

[4] Mc Ewan, D.L. 2001. Central Valley Steelhead. Pages 1-44 in Brown, RL (ed) Contributions to the Biology of Central Valley Salmonids. Volume 1. California Department of Fish and Game, Fish Bulletin 179, Sacramento CA.

[5] The EWA review panel 2001 final report is available at: http://calfed.water.ca.gov/adobe_pdf/EWAReview_Final.pdf

students, targeted contracting, and requests for proposals for research outlined in a science workshop. New hires must work in close collaboration with the existing staff members of agencies comprising the EWA, as well as the new water market specialists.

Recommendation 3: Synthesize in a quantitative manner and a readily accessible location all available data on the salmonid species of concern. This data bank should include information on life history and the effects of Delta habitat conditions and hydrodynamics on threatened salmonid species.

Recommendation 4: Establish a research thrust to fill fundamental gaps in knowledge of the biology of delta smelt.

Recommendation 5: The management and project agencies should evaluate existing constraints on EWA flexibility.

Recommendation 6: Provide the EWA with resources and information needed to use flexibility effectively.

Recommendation 7: Improve the ways in which agencies are currently using the flexibility the EWA provides.

The foremost issue that emerged in the technical review was that the scientific basis for EWA decisions and actions must be statistically rigorous and based on sound science. In the Panel's opinion, there remain some critical gaps in knowledge needed to correctly forecast the real-time status of endangered fish species (related to water management operations) and to evaluate the ecological consequences of EWA and other water management activities in the Delta. The EWA would benefit from further evolution of the decision trees, synthesis of fish species life cycle information, and modeling of fish behavior in relation to hydrologic conditions.
The next set of presentations focused on the scientific challenges in understanding the population biology of species of concern in managing water diversions to protect the estuary environment and its living resources. Wim Kimmerer used salmon to discuss these challenges. A central question he raised was: is reducing the effects of the export pumps the best use of environmental water? Reductions in the amount of water exported can reduce the number of individual fish lost from the system, but how much does that benefit the fish population.

During their life cycle, salmon spend time in a variety of habitats between inland streams and the ocean. Important sources of mortality potentially affecting the population can occur in all of these habitats. Additionally, the life cycle and habitats are very interconnected. It is critical to understand how these sources of mortality, relative to one another and in aggregate, affect the salmon population as a whole.

Kimmerer identified several objectives for environmental water (Figure 15). Summaries of the information for each objective is presented below (with the exception of "reduce conflicts over water delivery"), while supporting data are contained in Kimmerer's presentation included in Appendix A.

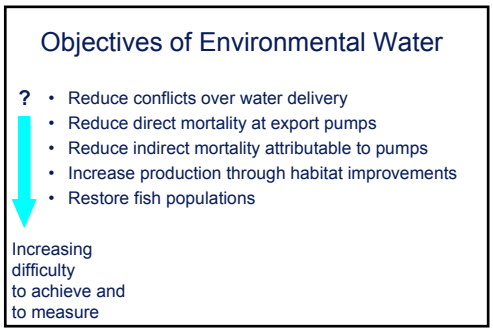


Figure 15. List of objectives for environmental water. The difficulty to achieve and to measure results of an action increase as you move down the list.

Reduce direct mortality at the export pumps: Direct mortality may be a small proportion of the Sacramento River salmon population for most of the year. Direct mortality of delta smelt may be a small proportion of the population at least part of the year (some raised uncertainties in the analyses that led to this conclusion), although direct mortality may be important in some years and some months.

Reduce indirect mortality attributable to the pumps: Indirect mortality is indicated in release studies, but the statistical significance of the effect is weak; so quantifying the influence of indirect mortality is difficult. Hydrodynamic influences of pumping appear to be limited to a zone of influence around the intake structures, although that zone and its effects are not well quantified.

Increase production through habitat improvements: Although significant changes in habitat are being made, even the direct effects on fish production are unknown.

Restore fish populations: We are unlikely to be able to attribute changes in populations to rather modest changes in survival.

Kimmerer thinks that some objectives for environmental water are being met. However, the available evidence points to small effects in the delta and as yet unquantified effects upstream. Bringing science to bear on the issues associated with environmental water requires a population level approach with comparisons among alternative actions.

In a follow-up presentation, Zach Hymanson focused on the use of environmental water to protect delta smelt. He enumerated the assumptions and uncertainty that accompany using counts of individuals salvaged at the CVP and SWP delta export facilities to protect delta smelt:

- Assumption: mortality is density independent. That is, the total number of individuals does not affect the survival of any one individual.
- Assumption: Population size is affected by regulating loss of individuals.
- Uncertainty: in some years the population level may be set by uncontrolled factors (e.g., density dependence), which cannot be predicted in advance.

In contrast, the recovery criteria for delta smelt are based on our best measure of the adult population, the fall midwater trawl index. Assumptions and uncertainty go along with this approach as well:

- Assumption: trends in the abundance index reflect trends in the population size of delta smelt.
- Assumption: there is a stock-recruitment relationship. That is, the larger the adult population the greater the number of offspring in the following year.
- Uncertainty: variability is not quantified but potentially large. The variability (confidence limits) associated with each year's population index must be known to understand the significance of different values among years (although not necessarily to evaluate aggregated interpretations like trends).

From the above it appears that a major challenge is better understanding of the population biology of delta smelt, so that the connections between actions affecting individuals and the response of the population can be quantified. The challenge for managers will be to incorporate an improved understanding of population biology into the management strategy for delta smelt.

Hymanson also noted that USBR and DWR staff are beginning to update the project description for the CVP and SWP. The goal is to have a new project description (also known as OCAP: Operations Criteria and Plan) by February 2003. A new OCAP is necessary for the USBR to enter into new long-term water supply contracts. Once the OCAP is done, all five biological opinions for the listed species of fish will need to be redone. These new biological opinions are the most direct way to address many of the issues associated with water operations and impacts to fish. He suggested it would be beneficial to start working now to identify the science questions and areas of uncertainty, as well as the data and information necessary to address the issues that the biological opinions must consider.

Bill Bennett described the science challenges in understanding the threats to the delta-smelt population. Delta smelt abundance declined substantially in the

1980's resulting in its listing as a threatened species under the ESA. Since that time understanding of its life history has improved (Figure 16). Important factors about delta-smelt life history include:

- A majority of the fish (> 90%) only lives one year, while a small proportion (≈3-6%) may live two years. Like multiple cohorts, a biannual life cycle has implications for avoiding extinction in years of poor survival
- Natural mortality is generally high through the life cycle and abundance is strongly affected by extreme events (e.g., droughts or floods).

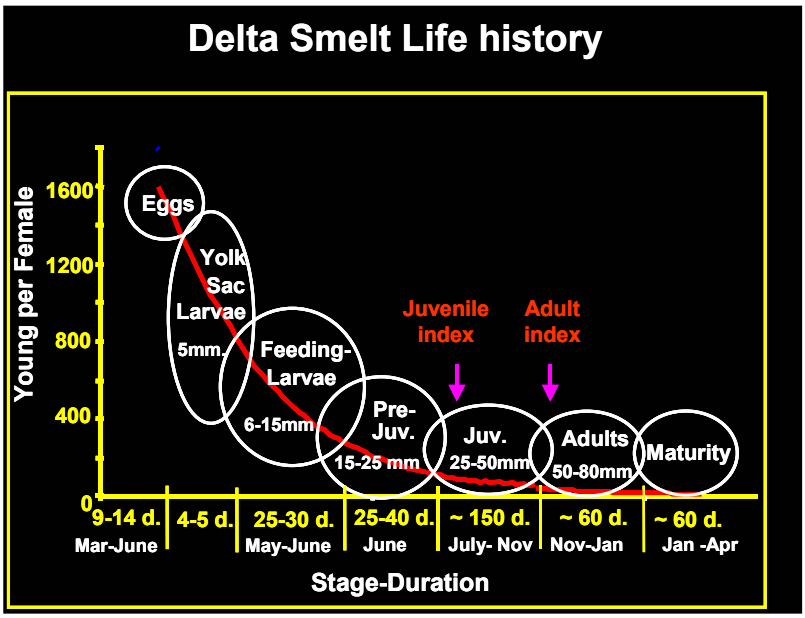


Figure 16. Diagram of delta smelt life history depicting the relative rate of mortality (red line) through the different life stages. Juvenile index = the index of juvenile abundance as determined by the DFG summer townet survey. Adult index = the index of adult abundance as determined by the DFG fall midwater trawl survey.

Potential causes for the decline of delta smelt include:

- Food web changes resulting from the establishment of introduced predators and competitors (e.g., inland silversides), and declines in a preferred food item, *Eurytemora affinis*.
- Direct mortality from CVP and SWP water project operations, which generally increased until the mid-1980's with extreme losses in the early 1980's.
- Other factors including: exposure to contaminants and parasitic infections.

Analysis of population dynamics suggests delta smelt population size might be density dependent (i.e., the survival of any one individual is dependent on the total number of individuals) at times. The available evidence suggests density

dependence occurs infrequently and was most evident in the 1970's. Understanding the mechanisms underlying density dependence (e.g., limitations in food supply) is important to estimating the consequences of various restoration actions (e.g., use of environmental water or habitat restoration).

Analysis of population dynamics also suggests a key factor for delta smelt is the length of time conditions remain suitable for reproduction and development of early life stages. A longer spawning season provides more opportunities to produce young, and can result in multiple cohorts. Risk from any source of mortality, including salvage, can be reduced if it is spread among more cohorts. Adding more water to the system when smelt are near the pumps (e.g, through an EWA action) does not necessarily prolong the spawning season, which is more directly influenced by water temperatures. It is useful to managing sources of mortality, like take, to know when multiple cohorts are more (or less) likely to be in the system.

One important conclusion from Bennett's analyses is that there is a substantial stochastic element to what determines the abundance of delta smelt. For example, the potential consequences of serial events (e.g., high levels of direct mortality from the water projects followed by extreme climatic events) must be factored into a population model for delta smelt. The challenge in understanding the mechanisms associated with the environmental gauntlet (Figure 17) that delta smelt face in their life cycle is that the mechanisms are:

- Not deterministic,
- May be interactive,
- Not important every year,
- May be subtle or episodic,
- Are difficult to identify and quantify.

Current work by university researchers is focused on unraveling the gauntlet (Figure 17) through studies aimed at distinguishing among three mechanisms: 1) food limitation, 2) contaminant exposure, and 3) parasitism. This work includes multiple studies looking at age and growth, histopathology, and genetic response.

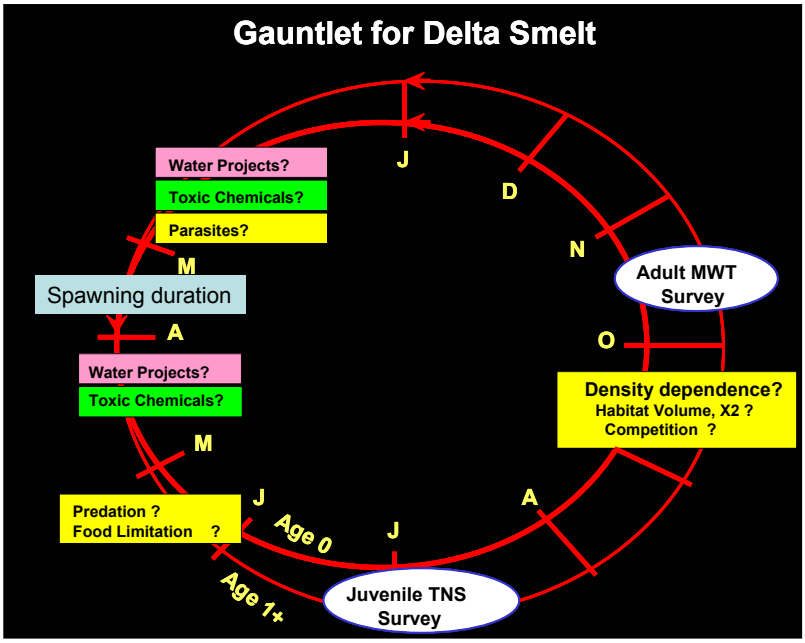


Figure 17. A conceptual model depicting the "gauntlet for delta smelt" relative to various stages in its life history. Yellow letters are months, starting at the top with J = January and proceeding counter clockwise through the year. The factors listed in pink, green, or yellow boxes may reduce or limit the population size. Surveys listed in the white ovules are points at which an index of population size is estimated. Spawning duration may be a key factor in determining cohort success.

Major scientific needs include:

- Understanding the basic biology. Biannual life cycle may provide a buffer for years of poor survival.
- Understanding population dynamics. Density dependence indicated the tendency for the population to absorb some level of mortality and rebound from low abundance. A broad spawning season allows the population to spread the risks of survival across several cohorts.
- Understanding causes and effects. Extreme events occurring in successive years can have dramatic effects on abundance and may have caused the decline documented in the 1980's. The "gauntlet of effects" interacts in complex ways. We will need to weight the relative importance of food web limitations with human impacts to understand population regulation.

Jerry Johns described how managing EWA involves managing uncertainty. That is, there is uncertainty associated with each of the elements central to the EWA, including:

- Fish actions needed,
- EWA budget,
- Price paid for water,

- Hydrologic conditions,
- Cross-delta capacity,
- Contract terms to access water.

Less uncertain is the strong desire to make EWA work, as manifested by how the agencies and stakeholders adapted to the experience in 2001: 1) fish agency staff learned about water operations and working within system constraints, 2) the water operators adapted to considering multiple issues, including EWA, when operating the projects, and 3) the water contractors helped finalize contracts in a timely manner, covered a 100,000 acre-foot shortfall, and helped to make EWA water available in the summer.

Managing EWA involves buying water, marketing water, and moving water. Purchasing water necessitates understanding pricing. The effective price of the water north of the delta is greater than the actual price because carriage water must be released to help move the water (Figure 18). The effective price of water purchased south of the delta is cheaper than the actual price as no carriage water is required. But moving water from north to south adds to the cost of water used in the south. Cross delta pumping capacity is also a constraint to turning north delta assets into south delta assets (Figure 18). In some years the pumping capacity may be insufficient to move EWA water.

Another challenge is that key factors, such as hydrologic conditions and the necessity for fish actions, are uncertain when the contract commitments for water must be made (Figure 18). At present, source shifting is used as a “bridge loan” to cover debt incurred in the fall. This is expensive.

To improve the situation: 1) the fish action targets could be identified earlier in the year. 2) Specific water purchase targets could be identified, recognizing these targets will constrain the actions under tier II. 3) Options on water purchases, later call dates, lower prices, and long-term EWA assets would allow better management. 4) Greater south of delta storage, greater stability in cross delta transfers by giving the EWA some capacity in new projects, and securing north of delta assets could provide long-term EWA assets.

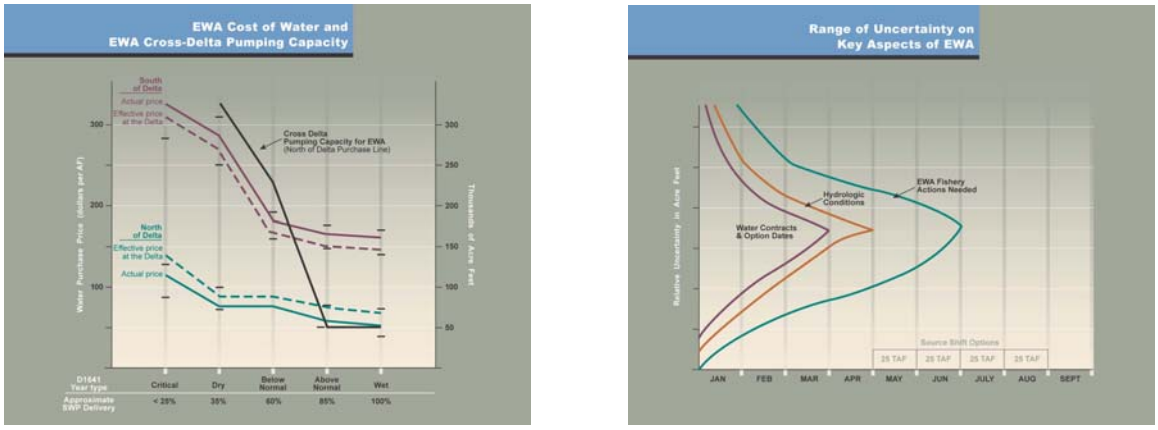


Figure 18. Costs of EWA water north and south of the delta relative to the effective price and cross delta-pumping capacity based on water year (left hand figure). Relative change in uncertainty associated with water contracts, hydrologic conditions and needed fish actions (right hand figure).

Jim Anderson provided an overview of the challenges in science-based salmon management in the Pacific Northwest. Similarities and differences exist between the situations in the San Francisco Estuary and that in the Columbia River Estuary. Three factors are thought to contribute to the decline of Columbia salmon stocks: 1) ocean harvest, 2) dams for hydro systems, and 3) hatcheries.

Harvest, a known factor in the decline, is technically feasible to limit, but politically difficult due to treaty rights, international agreements, and requirements for harvesting hatchery stocks.

Dams have also contributed to the continued decline of salmon stocks. Prior to the existence of many dams, harvest appeared to have eliminated some stocks (Figure 19). The number of dams in the system increased substantially between the 1930's and the 1980's. Now, three dams alone block about 60% of the spawning habitat. Data also showed that fish passage survival through hydro systems was poor. For example, emigration survival to Bonneville Dam is estimated at about 15%. The hydro systems are now required to pay for recovery of the salmon stocks.

Data through 1980 shows salmon survival was related to flow. Initially it was thought that restoring some flow would increase survival. Flow standards in the biological opinions are lower than the natural flow, although the hydrograph has the same structure. However, more recent data have shown that the flow augmentations did not increase survival.

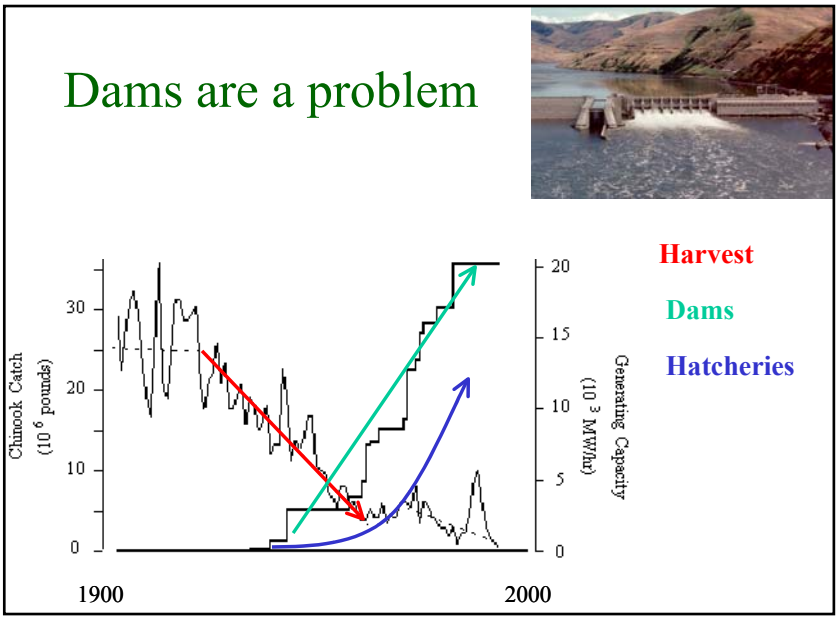


Figure 19. Catch of Columbia River Chinook over time showing the period of harvest-related declines, increasing number of dams, and the increasing influence of hatchery production.

Barge transportation of fish was also tested as a restoration tool, but after 15 years there was no conclusive evidence that barging helped. On the Snake River, survival declined during the period barging occurred.

More recently, there is some evidence that changes in ocean conditions (warm versus cold water temperatures) have an affect on salmon survival. There is also evidence of delayed mortality of barged fish. By 1995 two explanations were proposed for continued low stocks of Columbia basin fish: 1) dams reduce overall survivorship, and it is not mitigated by barging; 2) climate and ocean conditions have changed.

The evidence for the influence of ocean conditions on salmon survival is shown in Figure 20. Under warm ocean conditions, with hatchery releases, there is evidence of competition between wild and hatchery fish resulting in lower wild fish survival. When ocean conditions are cold and wet the relationship demonstrates that competition does not exist (Figure 20).

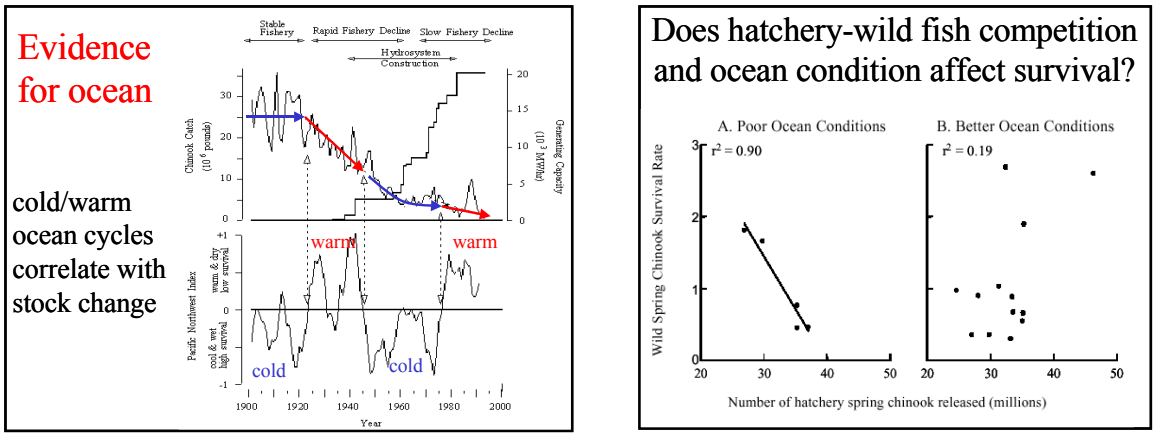


Figure 20. The left hand figure shows the relationship between ocean condition and the catch of Columbia basin Chinook salmon. The right hand figure shows the relationship between hatchery production and wild Chinook survival under different ocean conditions.

Over time the theories associated with Columbia River salmon stocks have changed:

<u>1950-1990</u>
- Simple theories
- Limited data
- Point estimates (No statistics)

<u>Post 1990</u>
- Complex theories
- More data
- Statistical confidence

Scientists and managers in the Columbia River basin are still faced with several difficult issues in fishery science that are relevant to restoring salmon stocks.

<u>Predicting the probability of extinction and determining recovery</u>. Because of the low stock levels there is interest in predicting the probability for extinction. Several estimates were made and all were different. These estimates are highly dependent on the data used. If it is difficult to estimate extinction then it is difficult to determine if recovery has occurred.

<u>Separating natural and human effects.</u> It is challenging to separate the effects of small incremental changes on salmonid stocks from large-scale natural events (e.g., climate change). But separating such causes may be a key to focusing restoration efforts.

<u>Connecting a fish's freshwater experience to its saltwater mortality</u>. It is essential to understand the connections among different parts of the Chinook salmon lifecycle and how the actions in one part of the life cycle result in consequences in another part of the life cycle.

Steve Lindley (NMFS) described the knowledge needed to recover Central Valley Chinook salmon stocks and the role of science in the recovery process. The issue of scale was central to this discussion: the temporal and spatial scales of

environmental variation are important to salmonid populations. Things that happen for a long time over large scales probably have the greatest impact.

NMFS has ESA responsibility for listing, delisting, and recovery planning for animals spending the majority of their lives in the ocean. While NMFS' interests are salmon oriented, there is a lot of overlap between its needs and the needs of CALFED. All ESA decisions are to be based on "best available scientific and commercial data." ESA recovery planning requires:

- Biological delisting criteria,
- Habitat-productivity relationships,
- Knowledge of limiting factors,
- Early recovery actions,
- Research, monitoring and evaluation needs.

Central valley salmon and steelhead, like most other west coast salmon and steelhead populations, evolved in a system that has been widely altered since the 1850's. Most (but not all) of the alteration has been in freshwater habitats. Many populations have been extirpated and many others are at low levels relative to their historical abundance. In many cases, the potential causes of decline can be listed:

- Mining: altered sediment supply, channel morphology, and increased pollution.
- Fishing: reduced population size and productivity.
- Water diversions: direct mortality, predator attraction, altered flow patterns.
- Habitat loss: Dams block spawning areas, alter hydrograph and geomorphic process, and fuel urban and agricultural development
- Artificial propagation: Results in relaxation of natural selection and increased straying, and supports fishing mortality not sustainable by wild populations.
- Other: Loss of off-channel habitat, losses of riparian vegetation and tidal marshes, and introduced species have all contributed to the decline of salmon stocks.

Some factors are obviously very important. For example, salmonid populations requiring access to higher elevations have been decimated (Figure 21). Fall Chinook spawn at lower elevations and are near historic levels, but much of the run is produced in fish hatcheries and released far downstream.

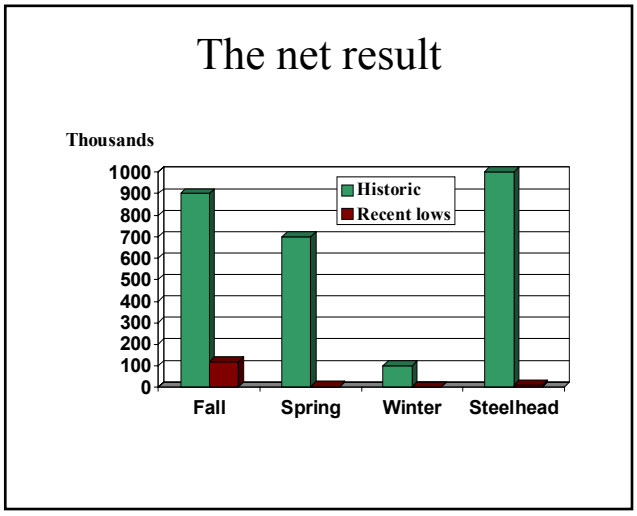


Figure 21. Estimates of historical and recent low production levels for various salmonids. Data are from Yoshiyama et al (1998) and McEwan (2001).

Although it is obvious that habitat changes have occurred with large effects on salmon; there are other important factors and there is probably no single silver bullet that will guarantee recovery.

The factors controlling salmon populations can generally be categorized as proximate and ultimate controls (Figure 22). Proximate controls (e.g., food supply) influence growth, which influences recruitment and mortality factors. For example, low food supply leads to smaller fish, which leads to increased vulnerability to predators. Many of these effects are relatively well studied and are amenable to experimentation or quantification through sampling. The biggest uncertainties are associated with the linkages between ultimate controls and survival (Figure 22).

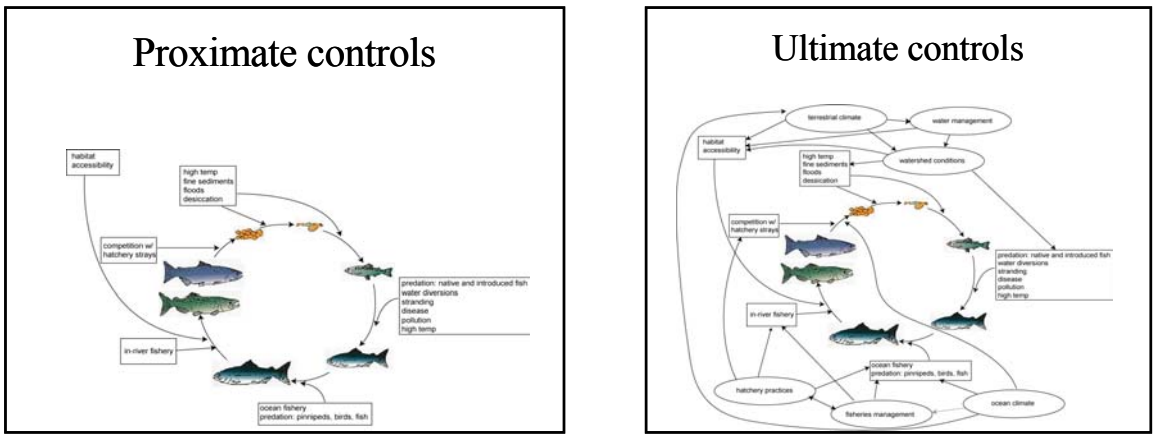


Figure 22. Diagrams illustrating the proximate (left hand figure) and some ultimate (right hand figure) controls on salmon populations. The life stage at which these controls are important is also shown.

For example, it is well supported that the ocean climate link (ultimate control) affects salmon survival. Ocean climate changes did not cause the collapse of salmonid populations in the 20th century. But there is a danger that increases in survival caused by ocean climate variation in the present decade will be mistaken for responses to changes in ecosystem management. When the system returns to an unfavorable state, populations could crash. Resource management should take into account the ocean climate, like water management should account for hydrological climate. To do that effectively, we need to reduce influences of other stresses so that when survival in the oceans again declines, net survival is sufficient to sustain the population. Some of the key uncertainties are:

- How do we predict or identify climate regimes?
- Can we understand the mechanisms behind the climate-fish link?
- Is human-mediated mortality compatible with the ocean climate regime?
- How do we separate the effects of management and climate?

Natural production is a key "endpoint" NMFS will use to assess recovery and restoration activities (e.g., ESA and AFRP). Naturally produced fish are the progeny of naturally spawning fish. Naturally spawning fish include fish born in hatcheries that return and reproduce in the streams. Conceptually, natural production is influenced by several factors:

- Spawning stock (including hatchery strays),
- Productivity of spawners,
- Carrying capacity (density dependence),
- Density-independent mortality (fishing, various environmental effects).

Presently, natural production is unknown for many stocks (especially fall Chinook and steelhead), because of the difficulty of accurately evaluating natural production in streams with hatcheries. Unfortunately a large and variable proportion of the hatchery production is unmarked, so it is difficult to quantify the proportion of hatchery fish in a population. Another issue is that hatchery fish stray. Strays may depress natural production and mask the dynamics of natural production. Thus, a key uncertainty is caused by the number of unmarked hatchery fish on spawning grounds. This uncertainty raises several concerns:

- How to quantify restoration if natural production is not measured.
- How to determine if hatchery production is suppressing natural production and thereby hindering recovery.
- Does co-mingling of hatchery and natural stocks have negative effects on the genetics of natural stocks.

To estimate natural production the following are needed:

- Precise escapement surveys
- Constant fractional marking of hatchery production
- Rigorous sampling for tags in freshwater
- Aging of fish

Presently, we have none of these. In practice, the success of recovery and restoration actions will be measured in terms of natural production, whether it is high enough to sustain populations at levels meeting ESA requirements and allowing for some use of the salmon resource.

Appendix A

Questions Answers and Comments Occurring During the Water Operations and Environmental Protection in the Delta: Scientific Issues Workshop

Day One:

Q: Steve Schafer. Perry, you showed trend data in your presentation. Is that enough? Is that all we need?

A: Perry Herrgesell. Trend data are crucial, but we also need to mine the data to learn what we can and do more special studies to understand the trends we see.

Q: Mary Nichols. What do we do to understand the trend charts? Do we use smoothing, trend analysis?

A: Perry Herrgesell. We have done some analyses to look at the off-set and other types of analyses, but the variability is large and difficult to deal with.

Q: Mary Nichols. Do we do analyses that compare fish populations and larger climate events (e.g., El Nino, etc.).

A: Perry Herrgesell. Yes we do these sorts of analyses. For example, we have analyzed changes in ocean temperatures to understand halibut abundance.

Follow-up: Sam Luoma. When we look at trend data there are many interpretations that emerge. We need to build a body of knowledge that helps clarify gray areas/uncertainty. Sam wants to accelerate the science work we do especially studies to get at cause/effect relationships.

Q: Sam Luoma. Are there limits to the IEP?

A: Perry Herrgesell. Yes there are limits. In the early years, funding entities and various parties wanted work to focus only on effects of outflow. We are doing more now, but the amount of money is limited.

Q: Patrick Wright. What are the biggest limits in the data?

A: Perry Herrgesell. Probably the take limits at the pumps and what affect that has on fish populations. We don't know the population size of various fish species so cause and effect is a big issue. W need to understand salvage and the effects of diversions. The big unknowns center around population size and the factors affecting these populations. We also need to do a better job of integration between the biology and hydrodynamics. The DCC studies you will hear about later are a good example of how we can do this.

Follow-up: Sam Luoma. In the early years, IEP monitoring centered around striped bass, but some fish occur in other habitats that are harder to sample or require other approaches.

Q: Unknown member of the audience: Did all operation constraints happen at once or progressively? What was the logic behind the complex set of standards?

A: Curtis Creel. The standards have built up over time. D-1485 came first, then winter-run and delta smelt biological opinions. Generally, Curtis thinks the develop of standards occurred as collaborative efforts.

Q: Unknown member of the audience: Is the X2 standard a critical standard EPA uses? Does EPA have other standards it uses?

A: Bruce Herbold. Yes, the X2 standard is a critical standard to EPA. However, the EPA also uses TMDL's and drinking water quality standards. The primary focus of X2 was water quality and habitat, it did not address take. There were a lot of questions about regulating flow for take of fish –this didn't matter to EPA in the end because of the fish listings under ESA.

Q: Unknown member of the audience. You have a variety of hypotheses of cause/effect relationships. What management decisions could you affect if you understood the mechanisms better.

A: Wim Kimmerer. Its really a matter of timing, that is, you may find that you don't need to worry about X2 in June or position of X2 during certain times of year.

Q: Unknown member of the audience. How much water does it take to move X2 a certain distance?

A: Wim Kimmerer. The further seaward X2 starts, the more freshwater it takes to move it further downstream. In a dry year you can more effectively move X2 because it starts out further upstream.

Q: Unknown member of the audience. Doesn't it make management more difficult when you identify the mechanisms and make decisions based on them?

A: Wim Kimmerer. Yes, it can be more difficult to make management decisions, so I do not recommend backing off of using X2. Really, it gets back to looking at the timing issue.

Q: Unknown member of the audience. You seem to be moving away from using X2 to replicate historical conditions, please comment?

A: Wim Kimmerer. No that is not what I'm doing. When we were involved in the flow workshops, we the scientists clearly stated that we do not know where to place X2, that was the policy call that was ultimately needed.

Q: Unknown member of the audience. Why does delta smelt buck the trend in the Fish/X2 relationships?

A: Wim Kimmerer. Before 1981 as flow increased you got fewer delta smelt. Post 1981 there seems to be a weak relationship in the opposite direction (more smelt as flow increases). This is especially peculiar given that long-fin smelt is in the same family and shows a different relationship.

Follow-up: Bill Bennett. I think the change around 1981 is related to the "crash" of the population in 1980 and it's ability to respond

Q: Unknown member of the audience. Didn't a change in the standards arise out of the needs resulting from fish population crashes?

A: Bruce Herbold. No other factors were an issue as well. For example, municipal and industrial beneficial uses.

Q: Unknown member of the audience. This is the only standard that is ecosystem based, but lacking causal mechanisms. What advice would scientists give policy makers to changing/revisiting the standard?

A: Sam Luoma. We have been lucky the last several years, it has generally been wet, so we really haven't tested some of the standards we have. Several of the trends we have for fish abundance suggest a change in the downward trajectory of these populations.

Follow-up: Steve Macaulay. Agree that trends have turned around, but the key is to understand why the trends have changed. We need to know this to change the standards.

Follow-up: Bruce Herbold. We do need to do the studies to understand the mechanisms underlying the observed relationships.

Q: Mary Nichols: What studies do we need to do to understand the mechanisms underlying the fish-X2 relationships?

A: Wim Kimmerer. Part of the issue is whether the standard works. If you assume relationships are correct through all water years, species introductions, etc., then we have this big knob to turn that can result in more fish, so it's really a matter of staying the course and preventing demise.

Q: Mary Nichols: Assume you are a policy maker. What studies would you do to help policy?

A: Wim Kimmerer: I would do studies to better understand the timing of X2 application and use.

Q: Bennett Raley: How much science is enough? CALFED is a very important effort, but there are other ecosystems in other parts of the nation that are in worse shape. The policy makers need to make a choice between adding more money for a marginal gain compared to investing in other systems where big gains are possible. Does the science allow us to explain the marginal gains we might expect from the millions or billions of dollars CALFED is asking for?

A: Sam Luoma. Doing the science work provides the knowledge base that allows you to greatly expand the information you can provide to managers. We can realize a large increase.

Q: Bennett Raley. I am interested in knowing the amount of water (and cost) it takes to move X2 a certain distance. We know if we have all the money we need we can do what is needed and if we have no money we cannot do any work. We need to identify the middle ground, what can we do with less money: what will we gain and what will we loose?

A: Patrick Wright: It is important to consider this standard relative to all other standards. X2 is a relatively well-accepted standard and the public cost is relatively low. So far, we have been able to meet this standard in every year at no government cost (i.e., no EWA or b(2) water). In contrast, the acceptance of take limits at the export facilities is generally lower, while the public cost to stay within the limits is much higher in terms of EWA or b(2) water.

Follow-up: BJ Miller. I think the policy makers should make X2 a flexible standard based on population level effects and the specific situation at the time (e.g., population status, water year type, etc.).

Stakeholder comments on X2 from Greg Gartrell (Contra Costa Water District) and Sprek Rosecrans (Environmental Defense).

Most issues/questions regarding X2 have already been discussed. We understand that X2 is a surrogate for other things that we do not understand.

It was mentioned that X2 has not cost a lot of water in the last six years. Really there has only been one year in the last six that we managed to X2.

One major limitation in all this is that we only get one number a year for fish –one annual abundance index. Sorting out the data and the factors influencing that number is really the important issue.

The approach needed in the science is many analyses on multiple fronts rather than a single approach.

As X2 gets closer to the Golden Gate Bridge, the amount of water you need to manage it goes way up:

X2 position	Amount of delta outflow required to maintain X2 position
81 km	7,100 cfs
74 km	11,400 cfs
64 km	29,200 cfs

In general the regression relationships between species abundance or survival and X2 improve as X2 moves downstream.

Gary Bobker. X2 is used as an ecosystem standard. Gary cautions against going down the road of modifying X2 for specific species. X2 is intended to be proactive. It is used to help maintain the abundance of species that we already have. It is not for restoration.

Bruce Herbold: We have a standard that is working well already. Yes, we can look at it and find ways to use it better, but he does not see us freeing up a lot of dollars or water in contrast to other issues (DCC, etc) where we can get a bigger bang for the buck.

Q: Unknown member of the audience. Is there anyway to flex the X2 standard based on hydrology?

A: Bruce Herbold. It already flexes based on hydrology from month to month and among water years. The knob to fiddle with is the level of development.

Q: Charlie Liston: Are alien species other than striped bass also helped by X2.

A: Bruce Herbold. Wet years have helped all species.

Follow-up: Sam Luoma: The X2 standard holds the baseline. We have other things helping restoration.

Q: Bennett Raley. I am concerned when something is presented as a baseline that we are not going to touch. If scientific tools don't allow us to experiment with this (i.e., move X2) then what is the point of investing in more science?

A: Wim Kimmerer: You have a hierarchy of goals and a hierarchy of studies. We are starting with a fairly crude tool that has been found generally acceptable. The specific standard is based on a policy call "standard of development."

Q: Bennett Raley: Does science allow us to determine all the costs of modifying X2?

A: Wim Kimmerer. No it does not.

Comment: Mary Nichols. X2 seems to allow a situation that maintains a quality of life, while not requiring substantial modification to meet this standard. But it doesn't really meet the definition of a standard in that we can get information/science studies that allow us to modify the standard and understand the impact.

Comment: Gary Bobker: None of the regulatory mechanisms we use are perfect. We should use knowledge to improve them. We need to look at the potential benefit. Work to develop X2 has resulted in a very resilient standard. It will take some time to come up with a better standard and the gain will likely be marginal. There is much more potential gains in looking at export levels and the impacts of exports.

Comment: Tom Clark: What would help policy makers in making decisions is some sort of decision trees. We all want things to be science based, but there are other factors that should be listed and considered. There could be complimentary actions: release water for a fish purpose that has other benefits to water quality. I think that X2 has a big water cost that we will see in a big way during a dry year. We need a three way matrix to help decision makers.

Q: BJ Miller. Pat, the results of releases at Ryde Vs. Georgiana are still somewhat equivocal because you could not demonstrate a statistical difference between upstream and downstream releases.

A: Pat Brandes. There is a significant difference between upstream and downstream releases. There is not a significant Difference in salmon survival between releases with the DCC gates open versus releases with the DCC gates closed.

Comment: Unknown member of the audience. There seems to be a random factor in all this: it depends on the condition of the gates and tide at the time the fish arrive near the gates so you shouldn't be surprised by the variability.

Q: Unknown member of the audience. Do these differences in survival show up at the population level, i.e., is there a population effect?

A: Pat Brandes. We do not know. There is variability at other levels (e.g., the ocean life stage). Also if you assume no density dependence in salmon then any increase in survival in the delta should translate into more fish in the ocean. Pat emphasized that a lot of these experiments were done before the Bay-Delta

Accord and other agreements, so it was much more challenging to get operational changes like DCC gate closures for these types of experiments.

Q: Unknown member of the audience. The methodology used in the DCC studies took on a very different approach than other studies done over the last 40 years. To what extent has that helped and can it be applied to other studies?

A: Bruce Herbold. The interdisciplinary, collaborative approach used in the DCC studies helped a lot. Marrying the hydrodynamic and biological studies has been critical.

Q: Chuck Hanson. Have there been thoughts about expanding this study to get at the issues of sources of mortality --especially indirect mortality.

A: Bruce Herbold. Yes, in fact we have started some work in the south delta to look as sources of mortality and the results are starting to come in.

Q: Unknown member of the audience. What are the plans to publish the DCC work?

A: Jon Burau. We are going to do additional field studies this fall and are working to write up the results by the end of 2002.

Q: Unknown member of the audience. What affect did ½ closures have on water quality?

A: Jon Burau. Early results suggest there is not a big signal in water quality changes at jersey point from DCC operation. We still need to look on the Mokelumne side. Changes in central delta water quality in relation to DCC operations is really a question of how much water you want to move into the central delta to effect a change. We need to use more sophisticated analyses to see if we can tease out a DCC effect.

Q: Unknown member of the audience. Ss a major retrofit of the DCC gates required to allow operation in real time?

A: John Burke. The DCC gates are not designed for frequent opening and closing, so some changes would be needed. Frequent use of the gates will require some different Operation and maintenance approaches as well.

Q: Unknown member of the audience. Does closing the DCC gates benefit water quality under some conditions?

A: John Burke. Yes under some conditions water quality can improve from DCC gate closure.

Q: Unknown member of the audience. Do the tides affect what goes into Georgina Slough relative to the results of radio tagged fish movement?

A: Jon Burau. Yes there is a tidal affect in Georgian Slough as well. As a result of local physiometry the physics are such that more fish may be going down Georgina than the DCC. We may learn a lot about the placement and orientation of new facilities from these sorts of studies.

Q: Unknown member of the audience. Can you comment on what's happening in Sutter/Steamboat sloughs?

A: Jon Burau. In future studies we may take more of a regional approach. Early results show that when the DCC gates are closed, up to ½ the water flowing down the Sacramento River can go down Steamboat and Sutter sloughs. These sloughs are also positioned at the end of a bend so local the physiometry may be contributing to the results we see.

Q: Unknown member of the audience. Are we generalizing about the behavior/movement of all fish based on a few releases?

A: Mark Pierce. Yes, but all the tests are giving similar results.

Q: Bruce Herbold. Do people think stopping the DCC fieldwork to analyze the data we have is the right decision at this time?

A: Sam Luoma. This is a judgment call by the folks doing the work. It's a choice between taking the time to understand everything your data can tell you Versus doing more studies that may provide more/new information.

Q: Unknown member of the audience. What about the through delta facility (TDF)? Do we have enough data to make decisions about the TDF or is more data needed?

A: Bruce Herbold. There is never enough data and we will need to do more studies, but I do think analyzing the data will help in designing future facilities.

Q: Unknown member of the audience. If we have a comprehensive ecosystem program then why do individual projects have to fully mitigate effects rather than lumping it all together?

A: Sam Luoma. All projects are intended to raise the ecosystem baseline. Some projects will have positive affect and some will have a negative effect.

Q: Unknown member of the audience. I'm Looking for a solution to the lag time between data analysis and publishing results in a journal. How do you get results published quickly?

A: Sam Luoma. You cannot speed up the thinking process and the analysis investigators need to do, but you can speed up journal output. We are working to develop an electronic based journal that is focused on the region. It will allow for longer articles and could include previous reports prepared by agencies.

Comment: Wim Kimmerer. The DCC studies are a great project, but at the moment it is just a story. Until it gets written up and peer reviewed it will remain a story. Peer review is crucial to the CALFED program in making the results as legitimate as possible.

Chuck Hanson. I Applaud the scientists involved in the DCC studies. These studies clearly demonstrate the power of integration.

Q: Chuck Hanson. Pat, will the data collected through these studies allow us to determine/evaluate the benefits to fish populations? Are the data we are collecting adequate to make an estimate of population level benefit? This is a key area for managers.

A: Pat Brandes. I think we can do this, but it is based on a series of assumptions. The key to getting the answer is to do the work in a variety of different ways and work to narrow the assumptions.

Q: Chuck Hanson. We are using short-term DCC closures in the fall to understand the effect of closures in the late winter/early spring. Do we have the understanding to make this type of application?

A: Pat Brandes. Comparing the survival among different races of salmon suggests seasonal differences (e.g., water temperature) is not a major force here. There is a consistent strong signal.

Follow-up: Bruce Herbold. The strong hydrodynamic effect of DCC diversions suggests there is a strong affect on fish. Also, work last year suggests we are not catching fish during the day and it might be better to just close the DCC during the night.

Comments from Chuck Hanson:

Detail of the DCC and Georgiana Slough studies show what level we may need to work at to get answers. This is in contrast to using monthly averages for a lot of other decisions we make.

Further investigation of transit time and flow are warranted. The fundamental issue is whether salmon go with the flow at flow splits: do salmon move directly proportional to the flow or are other factors influencing migration route.

There seems to be a real issue about catch and day/night sampling. More investigation of this is really needed as much of the routine sampling we do in the delta occurs during the day.

Comments from Tina Swanson:

The DCC studies represent a very good example of multidisciplinary studies. This speaks to the importance of taking this approach and the need to do more exploration of existing data using a multidisciplinary approach.

There is a big emphasis in doing good science and understanding cause and effect. We are looking to determine how water operations affect various populations. We are asking science to detect relatively small changes. This is a difficult task. We need to look at other side of the coin. For example, does opening the DCC gates provide a water quality benefit? If not, then that should be taken out of the equation. We need to look at both sides of the equation and take a balanced approach.

With regard to applying the DCC results to other facilities: there was no discussion of how these facilities would benefit fish. All of the discussion focuses on how these facilities can be operated to minimize impacts to biological resources.

Q: Jerry Johns. We are looking to increase fish populations even though density dependent mortality may limit the potential population size. What are we doing to evaluate density dependent mortality?

A: Pat Brandes. For salmon we look at recoveries at Chipps Island compared to recoveries in the ocean. The results are similar suggesting delta survival is important. Also, the correlation between survival and flow is a consistent relationship suggesting this is an important relationship.

Comment: Sam Luoma: What has struck me is how much we need to know. That's why we need to invest in science. We need to study various life stages in multiple ways. We are trying to start analyzing the existing data. We need to work just as hard to do the science on the other side of the equation. Biology is out on the table, but the other issues need the same level of work.

Q: Helen Ingram: Do we know if the DCC is delivering on it's operational expectations, especially in regard to helping water quality.

A: Chet Bowling: we have hypothesized that it is easier to maintain interior water quality with the DCC gates open. We do not have the data to support this hypothesis, but it certainly seems that way.

Q: Tom Clark: I thought that water quality benefits associated with operation of the DCC were pretty well known, but now this is questioned.

A: Curtis Creel: Under certain conditions, operating the DCC can affect water quality. Sometimes in the summer they would like to close the gates because the water quality concern is on the Sacramento River side. For interior delta water quality improvement, we need to couple opening the DCC gates with increased pumping and/or reservoir releases. A lot of these examples occur at relatively low exports. Curtis would like to see what happens under high export conditions.

Q: Tom Clark: I appreciate the science you are doing. I also understand the need to publish and make sure things are defensible. But this is an applied science issue and we are looking for rapid transfer of findings into management decisions. Aren't we talking about adaptive management here? This seems to be in conflict with the ROD, which sets things in concrete.

A: Helen Ingram: When you are talking about adaptive management then you are talking about experiments, not long term changes in policies. CALFED wants to move in that direction.

Follow-up: Bruce Herbold: We are looking at closing the gates for half the time. What half is the question: Day or night, May or June. Deciding this is key issue.

Comment: Jerry Johns: It would be fairly easy to go in and say standards don't need to be changed per se, but they need to be flexed. Don't change the boundaries but give us more flexibility. We might want to think about this approach.

Comment: Jim White: Flexing is a double edge sword. In 1999 when a water quality standard was violated by a small amount it seems the world stopped, so it's probably better to look at all the standards we have and get balance among them.

Comment: Sam Luoma: I want to return to the issue of academic versus applied science. We are not here to do academic science. But historically, we probably have not done enough of the type of science that we should be doing. We need a basic standard for the type of science that we use and this must include greater publication and peer review.

Comment: Rick Sitts: In cases like the DCC studies it would be good to see the results along the way to allow for input of alternative explanations.

Comment: Jim Cowan. We have heard lots of discussion about whether the results of studies can be translated into population level effects. The need for water is a constant demand, but fish see a delta that is inherently variable and

they have developed life history strategies to deal with this: it's a probability game for the fish. We stand on the sidelines and try to determine the knobs we can turn to improve things for fish. Unimpaired flow is the biggest knob but we don't have this anymore. So the question is whether CALFED can learn enough about the mechanisms of fish dynamics so that it can turn the right little knobs in such a way as to increase the average probability of success over the long term.

Comment: Jim Cowan. I want to comment on the issue of a regional journal. There are several examples of regional journals that are very successful. You have a couple of ways to go: one is a peer-reviewed journal the other is going with a technical series. Having only an electronic version may not maximize the journal's use. For quick stuff you could have some sort of technical bulletin, but where you want more rigor then think about peer review. The key is getting things off your computer and out for others to use.

Comment: Charlie Liston. 95% of the fish we now see in the Delta were not here before 1870. Can we manage against the introduced fish and give the natives some advantage in that way?

II. Day Two:

Q: Serge Birk for Mike Thabault. Clearly goals of CVPIA and CALFED go beyond operating facilities to affect incidental take. Are there any estimates of viable fish populations that allow us to determine if recovery is occurring?

A: Mike Thabault. Incidental take relates to a specific section of the ESA but it may or may not be connected to recovery. For salmon there is a direct connection between the incidental take level and population size because the take level is based on an estimate of adult population production. In contrast, we do not have a population estimate for delta smelt, so we use an anticipated level of take based on historical estimates of salvage.

Q: Dan ? Abundance data do not show confidence limits, but there is information on trends in the data (e.g., carcass survey data). This doesn't seem appropriate if you do not have confidence limits for the data.

A: Diana Jacobs. There are lots of other analyses on the carcass survey data that were not shown here including the application of various statistical techniques. Jim White added that the draft recovery plan for winter -run includes both abundance targets and estimates of rigor. The carcass survey does meet the rigor criteria.

Q: BJ Miller. The EWA panel review had questions about the marginal benefits of EWA water applied to ecosystem benefits. What happen to those statements?

A: Jim Cowan. The statements about ecosystem benefits are in the final report. Again, the issue is one of probabilities and is an iterative process. A combination of decisions and use of water will benefit species in the long term. The panel does recognize that in the long term, use of EWA water will benefit the ecosystem. The key is to find out which little knobs to turn and how much to turn them to maximize the overall benefit. Helen Ingram. Over time we envisioned the EWA becoming a more robust tool as it saves water in one year, which then becomes available for use in subsequent year.

Q: BJ Miller. Last year the take of winter-run at the pumps was 0.8%. Whatever EWA did last year could only affect a fraction of that 0.8%. How can anyone think that EWA could have a measurable effect on winter-run?

A: Mike Thabault. If you only look at 0.8%, you are looking at the wrong number, you need to consider indirect mortality. We can't quantify that effect but we think it exists. Jim Cowan. Further, you should not only focus on one year. You need to have a long-term perspective relative to population recovery. Helen Ingram. You also need to put the funds for EWA water in the context of the larger water budget costs for California.

Q: Tina Swanson. The take limits for smelt are based on historical take at the projects. For salmon the take limits are based on a population estimate. Now we have a change in how we calculate winter-run population size based on a different count method (carcass survey Vs. Red Bluff diversion dam counts). Is there a correlation between the two methods?

A: Mike Aceituno (NMFS). We think it is too early to tell what this methodological change means. We are starting out a bit differently, but we are using the same basic information to estimate the take limits. We won't really know the effect of all this until we see the number of returning adults three years later.

Q: Tina Swanson –follow-up question. If you begin at two different starting points with two different calculations, don't you have to justify the two methods?

A: Mike Aceituno. We just started doing this. We approached this change cautiously. We are looking at counting the end of the run using the old method, because the diversion gates are down, but we don't know what proportion of the total population this is. DFG began the carcass surveys several years ago and demonstrated that we can do good surveys. We think we can get a better estimate by carcass survey now given the change in operation of the Red Bluff diversion dam. If you compare the two, you find that red bluff counts don't work any more.

Q: Chuck Armor. We are taking a number of small actions, but we cannot quantify the overall net benefit. Should we focus on assessing individual benefits or overall net benefit in the monitoring we do?

A: Mike Thabault. It depends on the action, but generally we should focus on ecosystem as a whole and the greater good. Some of these actions don't lend themselves to targeted monitoring. Sam Luoma. Regional scale monitoring or individual project monitoring alone is not enough, we need to do some of both to gain an overall understanding of the effects of any action.

Q: Unknown member of the audience. Do we have a full accounting of the stressors to salmon and what CALFED's share is? For example, in the northwest they are looking at nutrient cycling. Are we doing that sort of work here? Also, how does the draft recovery target of 10,000 adult winter-run salmon for 13 years deal with variability? Finally, it seems like there needs to be some cost/benefit analysis of the cost for recovery and what is gained.

A: Diana Jacobs. We need to take a comprehensive look at the numbers the threats and the system situation. Sam Luoma. We probably know what all the stressors are for salmon, but we are not able to quantify the population level effect of each stressor. We need to accelerate the pace at which we are learning and in part this is what the science program draft proposal distributed at this workshop is intended to do. A: Diana Jacobs. Adult winter -run numbered less than 200 individuals total at their low point. At that point you are doing triage: make any changes you can to save the species. They are doing better now.

Q: Dan Odenweller. Wim, your graph showing delta smelt loss per day based on the summer townet data. How many days does that include?

A: Wim Kimmerer. The results are shown as lost per day so you can extrapolate to any number of days in the summer period.

Q: Unknown member of the audience. Bill, you identified a lot of factors affecting delta smelt. Is our investment in science great enough, is it on track to get the answers we need?

A: Bill Bennett. We are making a good start. We have a group of people working on this now and we can begin narrowing down the suspects.

Q: Tina Swanson. Wim, you used changes in delta hydrodynamics to demonstrate there is little direct loss. Are we using the right tool?

A: Wim Kimmerer. The reason I presented delta hydrodynamics information is to see if hydrodynamics are changing when EWA actions occur. The data suggest that at jersey point a fish cannot sense this change. It is also hard to

imagine another factor out there that is affected by the export facilities more than hydrodynamics.

Q: Rick Sitts. What do you see is necessary for science to get at a population estimate for delta smelt?

A: Bill Bennett. There are a couple of statistical approaches that we are thinking about and we can use. We have some tentative plans to try them out in the near future.

Q: BJ Miller. We seem to have a model for delta smelt that is fairly confused and complicated. An analogy is to assume you have 10 dice and each is rolled separately. The problem is you can't distinguish the multiple effects from one another, except in extreme events. So how can we ever hope to determine if the pumps are the culprit or not?

A: Bill Bennett. We can't really say if the pumps are having a big effect or not every year. We need to do more work to understand this.

Q: Pat Brandes. I have a question about the flow at old river data Wim presented. We have radio tagging information that suggests high pumping is correlated with higher entrainment. Just because we don't understand it doesn't mean it is not important.

A: Wim Kimmerer. I did not mean that hydrodynamics is such that nothing is going to the pumps. It's more that there is a zone of influence. Hydrodynamics in the delta are affected by the pumps only in the south delta region.

Q: Unknown member of the audience. Is it your sense that the science is at such level that we can engage in making decisions about trade-offs?

A: Bill Bennett. It's never too early to start, especially in reducing uncertainties. We need to talk about this. As far as how many smelt are out there and how many we can take, we will probably never get to this. The confidence intervals are too large. A: Wim, we need to take parallel tracks and move on several fronts, but we may never get to the clarity we all want.

Tim Quinn. We are currently incurring hundreds of millions of dollars in costs every year. We need to get better interaction between scientists and managers to get to a point where we can make decisions about changing direction.

Sam Luoma: This is an ongoing issue of how one creates the appropriate interaction between scientists and policy makers. I think it starts with an open dialog like we are having today.

Bennett Raley. He doesn't understand much of what he has heard, but he wants to ensure that the integrity of this process remains open and transparent. He wants to dispel the rumor that any options are off the table. We all need to acknowledge that people can raise the questions they want and move on past them. We can't put ourselves in a situation that no one understands what is going on. The Department of Interior wants transparency and open debate.

Q: Mary Nichols. So what does it all mean? And so what? Besides wanting to know what is going on we wanted to help provide focus and direction. A lot of information presented here is new. There is science coming from the CALFED program itself that is very new. Most of the people here today are those trying to manage programs and use science. I would want to ask agency folks here how do they respond to the science information presented today? For example, should we be doing what we are doing with EWA water, given the information that take at the pumps is loosely related to population effects?

A: Mike Thabault. The new biological opinions will provide a new opportunity very shortly to bring in new science and rethink how this information fits in and form new opinions. Sam Luoma. We can sit down and figure out what we can do in the short term to provide information that will help in forming the biological opinions.

Q: Mary Nichols: Lester's presentation on the hierarchy of environmental water available in the system showed several types of resources, while the focus is on EWA.

A: Sam Luoma: The focus has been on EWA but in the field we can't separate out specific types of water we are studying environmental water en-masse. Wim Kimmerer. The biggest part of environmental water is X2 and we do have plans to study that and understand it better. Chet Bowling. B(2) water is a lot like EWA water, but is actually more flexible in some ways than EWA water, so we are going to be thinking about using b(2) water in more ways and be more flexible. A lot of the information presented here applies to b(2) water as well.

Sam Luoma. We have been talking about water management here, but we have other big things going on. We just finished the ERP proposal selection process that has a focus on ecosystem restoration. We are also thinking about other CALFED programs.

Mary Nichols. I have a concern that the environmental community is not well represented at this workshop. This is a concern since CALFED was a negotiated program including the environmental community.

Q: Tim Quinn. In what direction are we going to start pushing this process? This was advertised as the first in a series of meetings, and it's a good place to start. Maybe in the future we should focus the meeting around policy options. Are we

throwing these ideas out or letting them go into the science process? We also need to factor economics into all this.

Q: Mary Nichols: What percent of the CALFED budget goes to science?

A: Kim Taylor: About 3 percent of the total CALFED budget is allocated for science.

Q: Steve Schafer: There is no silver bullet piece of information so what is the timeline to getting the science information we see today resulting in changes on the ground? And how are we going to set priorities?

A: Sam Luoma. In the perfect world you don't even see when knowledge get incorporated into policy and management. A recent example is the change in the method used to determine the winter-run population size. That just happened.

Steve Schafer. The goal we may want to shoot for is having the policy makers bringing their scientists into the room to ask what are the risks.

Q: Steve Schafer. What about hardware? We have been heading down a path to screening the facilities. For example we are going for the Tracy test facility. What we are finding though is that the needs of the fish are so different that maybe you don't want to spend $1 billion to screen these fish and instead do something else.

A: Bennett Raley. The last thing we want is to look back 10-15 years and see a fish screen sitting there that is unused and wishing that we had done something else with the money. My prediction is that there is going to be less federal dollars so the California public needs to consider all issues and be as comfortable as we can with the decisions we make. Sam Luoma. We have been talking about fish screens and test facilities. This is a difficult issue that has its own politics. We plan to look at that. What we really want is to have an open debate.

Unknown member of the audience. I think it is good to really bring science into the debate. For example, increasing banks pumping to 8500 cfs. We need to get to a decision on this issue and maybe a good test facility for the new science level we have.

Steve Schafer. Some of the uncertainty and questions also apply to the land use decisions we are making.

Wim Kimmerer. The work to develop the Tracy test facility is focused on the technical aspects of the facility. We haven't thought too much about whether this is a good way to spend our restoration dollars. We are also working to screen a bunch of small diversions in the Delta when we don't really have any evidence

that this will make a difference. The independent board for ERP sent a letter that said we should not spend ecosystem restoration program dollars on fish screens.

Tim Ramirez. The ERP proposal selection process was different this year. There was lots of discussion about fish screens and these discussions did have an impact on what was funded.

Charlie Liston. The Tracy facility is a test facility. It's up to you whether you want to implement it or not, but the fact is the current facilities are 1950's technology so we need to update technology. These are among the largest salvage facilities in the world.

Q: Patrick Wright. The 8500 cfs issue is a good project to test our new process, but people need to remember that before we get to that we have one million acre feet of water that needs to be allocated. How do you think the asset allocation strategy might change?

A: Diana Jacobs. Don't expect us to tell you today that we have changed our approach to dealing with listed species. We are integrating information all the time. I do agree that the 8500 cfs issue is a good test case. In general we will take a cautious approach because we are dealing with endangered species.

Jerry Johns. We have not had one export cut for fish since January. So we are seeing benefits already in that we can carry this water over.

Sam Luoma. We have two advisors working on EWA and we are continuing to work on that relationship. Having these experts hear the information we have is of general benefit.

Laura King. Thank you for organizing this workshop. Water users really appreciate information presented. There are a lot of policy implications from what was discussed today. We need an ongoing process to get interaction between policy and science. What are the questions and what are the management issues. I suggest a small step: pull together a small group of agency staff with a few outside folks to get some feedback and some ideas for future meetings.

BJ Miller briefly presented his thoughts on science and export curtailments.

There are five basic reasons to curtail exports:

- To reduce direct mortality (take). Direct mortality is fish mortality directly attributable to CVP and SWP export operations and is determined from estimates of expanded salvage, pre-screen predation, screen inefficiency, and handling and trucking losses.

- To reduce indirect mortality. Indirect mortality is fish mortality in the Delta that is not due to CVP and SWP export operations (e.g., predation, starvation, delta agricultural diversions, and toxic effects). There is also indirect, export-related mortality: indirect fish mortality caused (indirectly) by the CVP and SWP export operations (e.g., export changes to delta hydrodynamics "inhibiting" fish from moving to areas of higher food abundance).
- To decrease the export/inflow ratio.
- To increase outflow (decrease X2).
- To decrease salinity levels in the Delta.

Direct mortality of salmon is often less than 1 %. Indirect mortality is estimated to be 20-80% in the delta.

The direct mortality of delta smelt is not measured, but salvage is not correlated with abundance. For Sacramento fall-run Chinook the direct mortality data is equivocal in terms of a population effect, although indirect mortality may be important. For winter, spring, and late fall-run Chinook the data suggests there is a very small effect of exports.

For San Joaquin fall–run Chinook, no population level effect of direct mortality could be detected. Thus, we likely will not be able to determine the effect of VAMP.

Using his estimates of mortality and flow relationships, BJ provided two examples of how much water is needed to change survival due to direct and indirect mortality.

Winter, Spring, and Late Fall Indirect, Export-Related Mortality Examples

- Sacramento River flow: 20,000 cfs XCG closed
  Export curtailment: 4,000 cfs, 14 days, **111,000 AF**
  Population increase: **0.8%** (0.7-1.9%)

- Sacramento River flow: 10,000 cfs XCG closed
  Export curtailment: 4,000 cfs, 14 days, **111,000 AF**
  Population increase: **1.1%** (0.9-2.6%)

BJ contends that these results raise questions about the benefit of EWA, SWP and CVP screens, and X2.

BJ finds that we are able to estimate population effects using the same correlations developed to determine there is a concern. One can also estimate uncertainty and the amount of water cost. From these sorts of analyses we can get estimates of the percent population change per dollar. We can use these cost/benefit relationships to make choices about how to spend the money we have for environmental protection and restoration.

If this approach was used, BJ thinks we would have less emphasis on export curtailments with more flexible requirements. We would have more leverage on high benefit actions and there would be less conflict.

Q: Pat Brandes. BJ, what assumptions did you make to get your estimates?

A: BJ Miller. The spreadsheets I used and a description of the assumptions are on my web page. Yes, there are assumptions that go into these calculations, I generally used conservative assumptions, but you can vary these. The main point here though, is that we ought to routinely making these kinds of estimates.

Q: Dan Odenweller. BJ, you seem to be dividing the compensatory mechanisms between water use and the environment. How will we do that in reality?

A: BJ Miller. I assumed no density dependence in these calculations, with the intent of trying to get the largest effect.

Q: Sam Luoma. Are there other ways to do cost/benefit analysis?

A: BJ Miller. Yes there are other ways, but we ought to be trying to do this for all the actions we are proposing to take.

Q: Mike Thabault. Can you present a concurrent analysis of all the stressors (ecosystem wide) to understand the overall context of what we get from the Delta actions?

Q: Mary Nichols. I am comfortable regulating things that account for only 1% of the impact. We did this routinely in air pollution issues, which are quite complicated. If you are saying that the pumps are not the problem then what else should we be focusing on?

A: BJ Miller. For salmon I think you need to look at harvest –it's having a big effect, which is demonstrated in the harvest index.

Jim ?: BJ is using the wrong number to determine harvest index.

Bennett Raley. It is clear we won't solve this issue today, but we do need to have this discussion later so he can understand these issues.

Jim ?: We really do need a constant fractional marking program and the other tools Steve Lindley mentioned so we can get a real harvest rate.

Steve Schafer: We cannot exist on a steady diet of this sort of debate it is helpful to get the discussion going. The challenge is to know when enough is enough. We all need to have assumptions challenged.

Jim Anderson. This discussion is the same debate we have had in the Columbia. BJ needs to identify alternatives. Also, others need to do the same analysis that BJ has done (peer review). You can do an analysis of relative mortality but you need to compare back to a common point. They have done this for the Columbia salmon stocks.

Mary Nichols. Where is the science program spending its money, or where will it be spent if you get it?

Sam Luoma presented the following information in response:

CALFED Science Program Year 3 Federal Budget: Narrowing biological uncertainties in water management

Goal: Advance immediate scientific needs for regulatory and management activities

*Studies: Extend multi-discipline Cross Channel and other junction studies and improve abundance, production, and trend analysis of critical species (**$3.5 million**)*

Goal: Improve Ecosystem and Regional Monitoring

*Studies: 1) Better understand the bases of indices and relationship between indices and populations of critical species (**$2 million**);*
*2) Develop and monitor Performance Measures for ecosystem and critical species recovery and pilot new monitoring technologies (**$2M**)*

Year 3 Federal Budget (continued)

Goal: Better Understand Critical Unknowns

*Studies: 1) Better substantiate technical basis for baseline water: mechanisms underlying X_2 relationships (**$500k**);*
*2) Define relative importance of Delta habitat, predation, stressors such as temp. and contaminants, mortality at pumps, and ocean condition and harvest [salmonids] to pops. of critical species (**$3M**)*

Goal: Adaptive Management - Restoration & Water Management

*Studies: 1) Role of floodplains for populations of critical species - Yolo Bypass experiment (**$1 million**)*
*2) Comparison of hatchery and wild salmonid survival in regions and across life cycle (**$1.6 million**)*

Communication, Coordination & Oversight *(**$1.4 million**)*

TOTAL: $15 MILLION