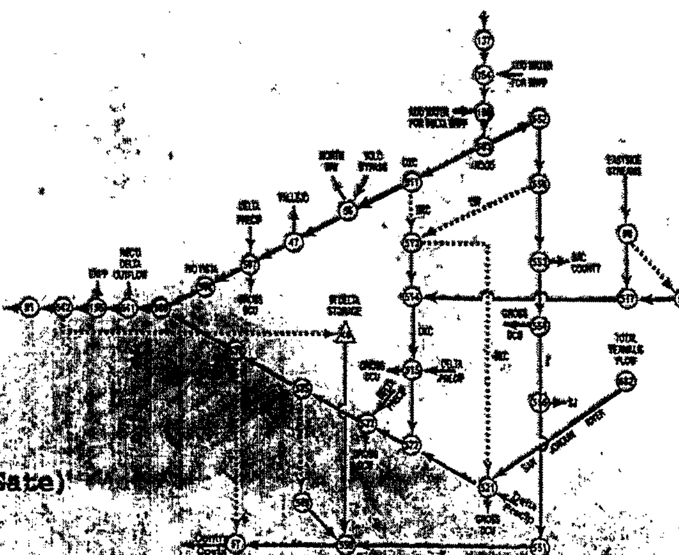
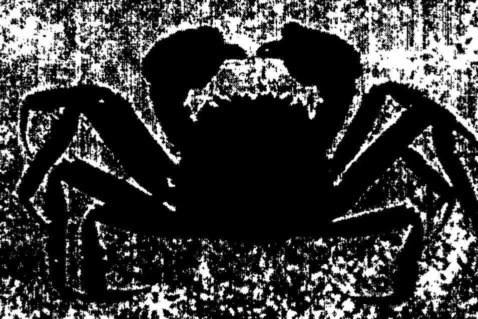
Science and the Bay-Delta

A Common-Sense Science-Based Approach to Balanced Resource Management



$$\text{Survival} = \frac{e^{flow}}{(1 + e^{flow})}$$

$$flow = -6.407 + 0.1148(\text{Sac}) + 0.5888(\text{Court}) + 1.4004(\text{In Sac Flowrate}) - 0.0950(\text{Release Temp}) - 1.9878(\text{Export/Inflow ratio}) - 0.6589(\text{Gate})$$



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E—039070

Science and the Bay-Delta

A Common-Sense, Science-Based Approach to Balanced Resource Management

Table of Contents

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In recent months, representatives of the state and federal governments have been meeting to hammer out one of the most important agreements in the history of California water. A key point of contention in these discussions is how the science of the Bay-Delta should be used to continue the fish recovery trends that have taken place since the signing of the 1994 Bay-Delta Accord. There are questions about how available science should be interpreted; how it is used in decision-making processes; and how it might be used more effectively in the future. This briefing book offers an assessment of the science of the Bay-Delta and recommends a new, common-sense approach to balanced resource management of the system.

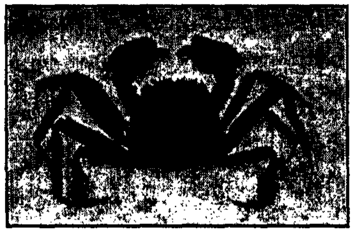
The Bay-Delta provides drinking water, recreation and critical habitat.

A decade ago, California's economy and environment were both in a state of crisis due to conflict in the water system. However, in the 1990s, regulatory pressure and proactive efforts of political leaders and the water user community resulted in a historically unprecedented environmental restoration effort. Up to 1.4 million acre-feet of water has been dedicated to the environment. Billions of dollars have been committed for habitat restoration with more than 450 projects in various stages of implementation. Hydrology has also improved and today the native fish species of concern have either stabilized or populations are on the rise.

Over the past ten years, it has also become increasingly apparent that we must learn to adaptively manage the natural resources of the Bay-Delta system. Simply put, adaptive management means learning from actual experience and adjusting strategies periodically to better manage the system for environmental and economic balance. The Accord ushered in a new adaptive management regime, providing a flexible approach to stabilizing fish populations and providing protections for fish in the next dry spell.

Now that these fish species are no longer in jeopardy, and a safety net has been provided to keep them out of jeopardy, it is time to balance environmental actions with broader public policy goals. Improved science and better application of existing science is key to achieving environmental and economic balance.

Fisheries of concern in the Bay-Delta watershed are affected by many factors, all of which should be considered as we define the next steps



Chinese Mitten Crab

beyond the Accord. Indeed, one of the major issues in ongoing discussions is how to arrive at the appropriate mix of resource investments to achieve fish recovery.

A review of emerging trends, particularly federal decisions taken for fish since the Accord, raises important questions about which actions provide the greatest benefit for fish at the lowest possible socio-economic cost. Recently, federal actions have placed great emphasis on further restrictions for water project operations, even when those actions yield little environmental benefit, yet the risks to water quality and supply were high. In contract, other restoration actions have been delayed or not implemented, despite scientific evidence that they could be highly effective in fish recovery efforts.

In order to determine the right mix for environmental recovery, we must ask the right questions. We must determine what factors are influencing fishery populations; what is the relative importance of these factors; and what is the appropriate overall resource commitment needed to achieve our environmental and economic goals.

Many investments in projects, which open up new habitat or improve existing physical habitat, appear enormously more cost-effective in increasing fishery abundance than further actions to reduce exports and augment flows in the Delta. Habitat projects can be targeted at improving key habitat conditions for a large percentage of the fishery population. In contrast, regulatory actions to restrict water project operations in the Delta, in many cases, offer substantially less fishery benefits because only a small fraction of the species of concern are impacted.

When we consider a more comprehensive set of resource actions and compare their relative costs and benefits, practical lessons emerge:

- Broaden the mix of environmental recovery investments, accelerating high-payoff habitat restoration actions and targeting restrictions on project operations where they are actually effective;
- Observe basic rules when flows are used to manage fisheries:
  - Leverage use of export curtailments by using environmental water for Delta species where it produces the greatest benefit, for example, for Delta smelt rather than salmon.
  - Use an environmental water budget, which forces the consideration of trade-offs and prioritization of actions.
  - Minimize supply impacts as a founding principle. Large increases in the amount of water dedicated to the environment are not justified now that species of concern are in recovery.
  - Rely on the no-net-loss of water principle of the 1994 Accord.

We strongly recommend that as a first step towards a new, common-sense approach to balanced management of the system, state and federal leaders convene a high-level, public policy review of the Bay-Delta science and its implications for resource management. Such a review should be conducted as soon as possible, by making major decisions regarding the next steps in adaptively managing the Bay-Delta system.

"Like all significant environmental challenges, our response here must be a combination of good science and good public policy."
(Oregon Governor John Kitzhaber)

E-039073

MOVING FROM CRISIS TOWARD RECOVERY

FISHERIES ARE NO LONGER IN CRISIS — POPULATIONS ARE INCREASING

The nation's most aggressive fishery restoration investments, the regulatory protections of the 1994 Accord, and favorable hydrology have significantly improved the picture for Bay-Delta fisheries. As the following series of graphs demonstrate, the populations of native fish species of concern have either stabilized or are on the rise. The dry-year regulatory protections of the Accord provide an additional safety net for the fish that should allow recovery to continue even during future droughts.

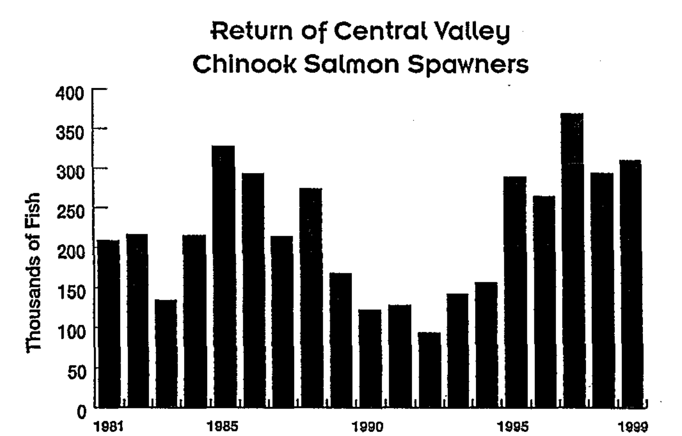


Figure 1: Chinook Salmon Populations Are Increasing
Stocks of all Central Valley Chinook salmon runs are rebounding. Adult salmon are returning to spawn in numbers not recorded since before the 1970s.

*Salmon data used from years 1981-1999 for consistency with most recent PFMC Reports

Salmon management problems remain, but the "emergency room crisis" of a decade ago has passed.

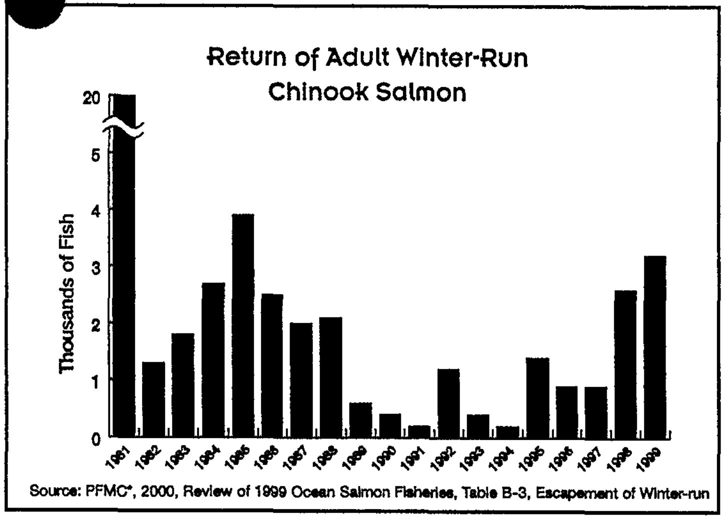


Figure 2: Winter-Run on the Rise
The winter-run population has been increasing since the mid-1990s, according to spawning surveys.

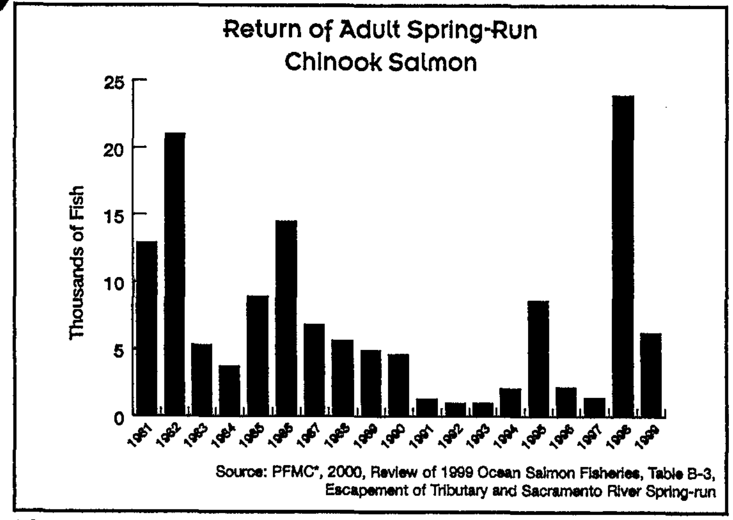


Figure 3: Spring-Run Rebounding
In 1998, spring-run Chinook salmon reached the highest abundance levels since 1981. In both 1998 and 1999, there were more than twice as many adults than in the 1995 and 1996 runs that produced them.

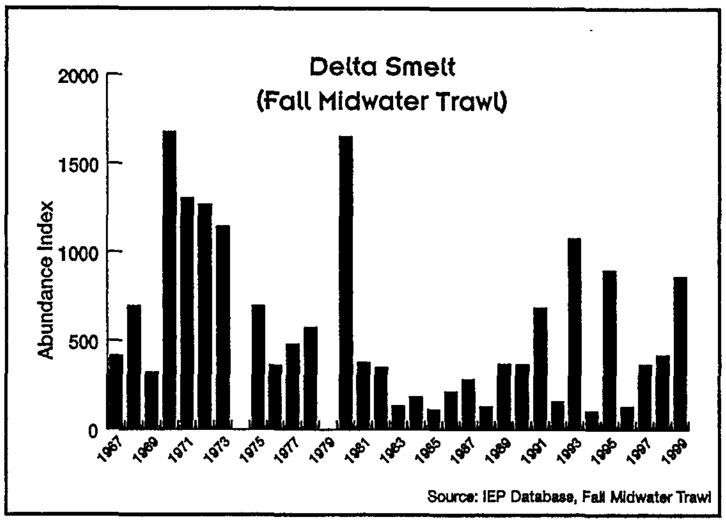


Figure 4: Delta Smelt Recovery Underway
During the 1990s, Delta smelt abundance (Fall Midwater Trawl Index) while continuing to be highly variable, has generally increased compared to the consistently low population levels of the mid-1980s.

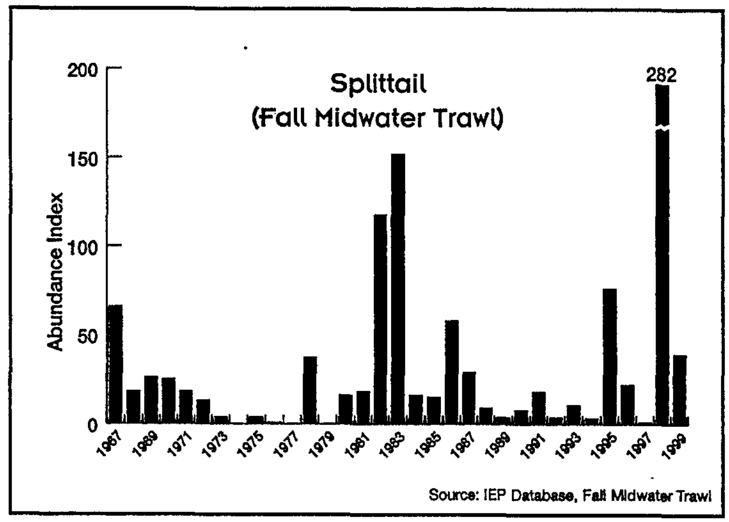


Figure 5: Highest Levels of Splittail Recorded
Splittail abundance in 1998 was the highest ever recorded. This record year class will begin producing a new generation when they start reaching sexual maturity later this year.

UNPRECEDENTED ENVIRONMENTAL RESTORATION PROGRAM

Since 1994, water users have committed billions of dollars to ecosystem restoration.

Figure 6: CALFED Restoration Projects (1997-1999)

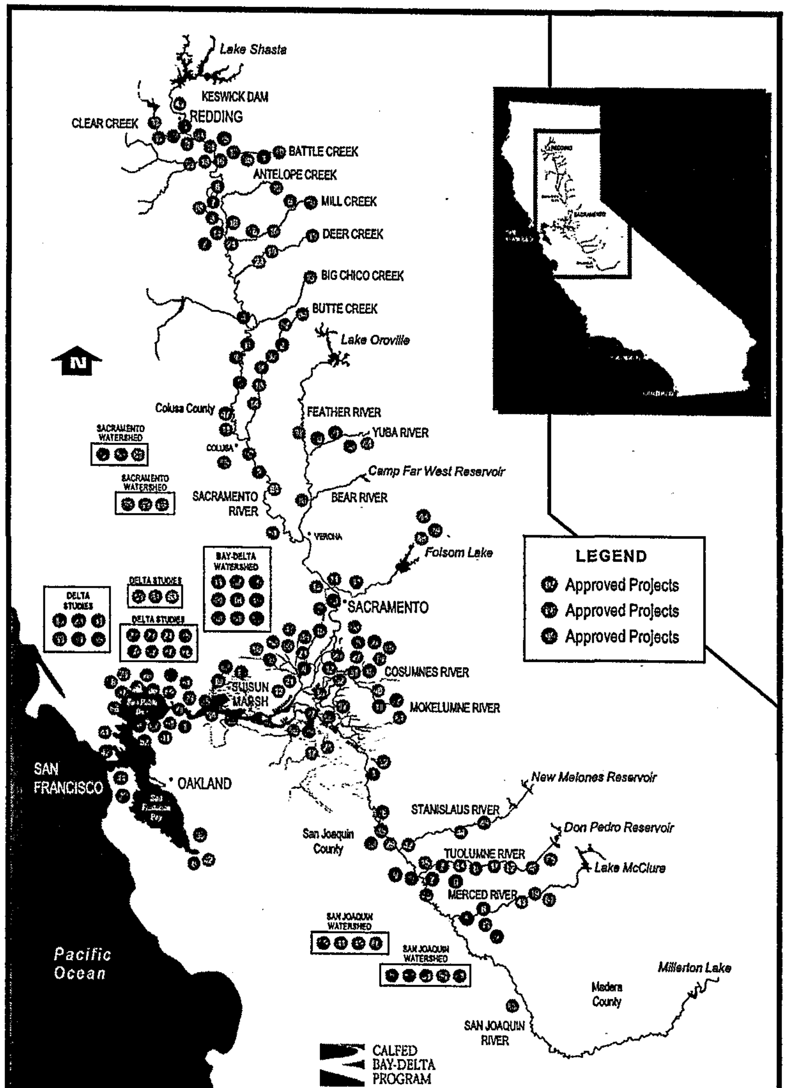
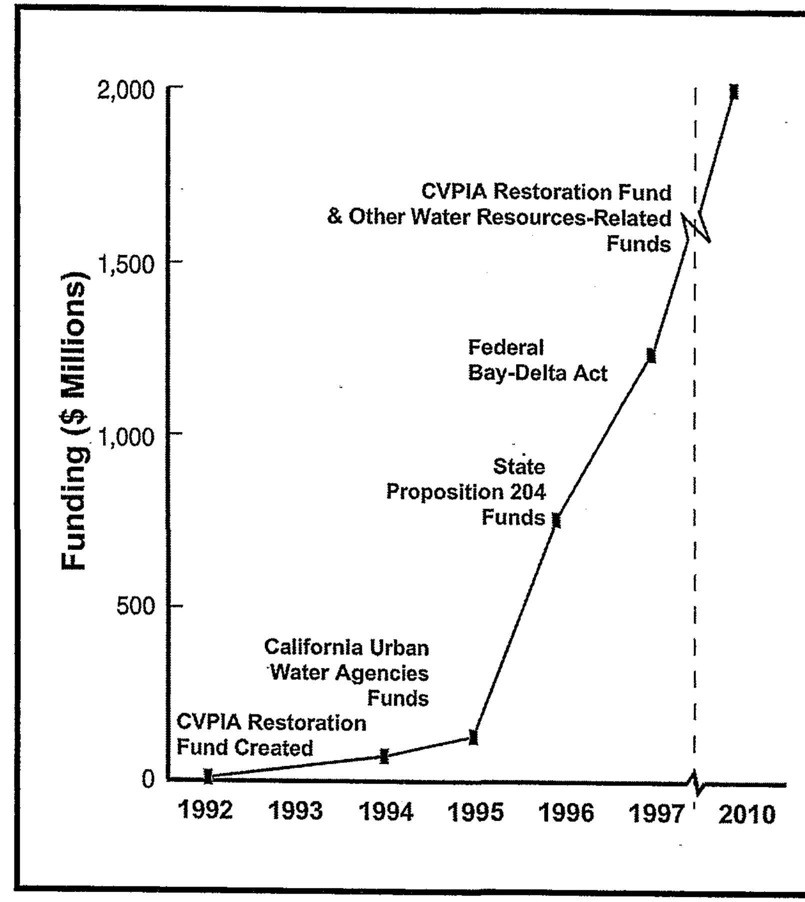


Figure 7: Funding Committed to Environmental Restoration



Billions of dollars for habitat restoration have been committed to improve these fisheries.

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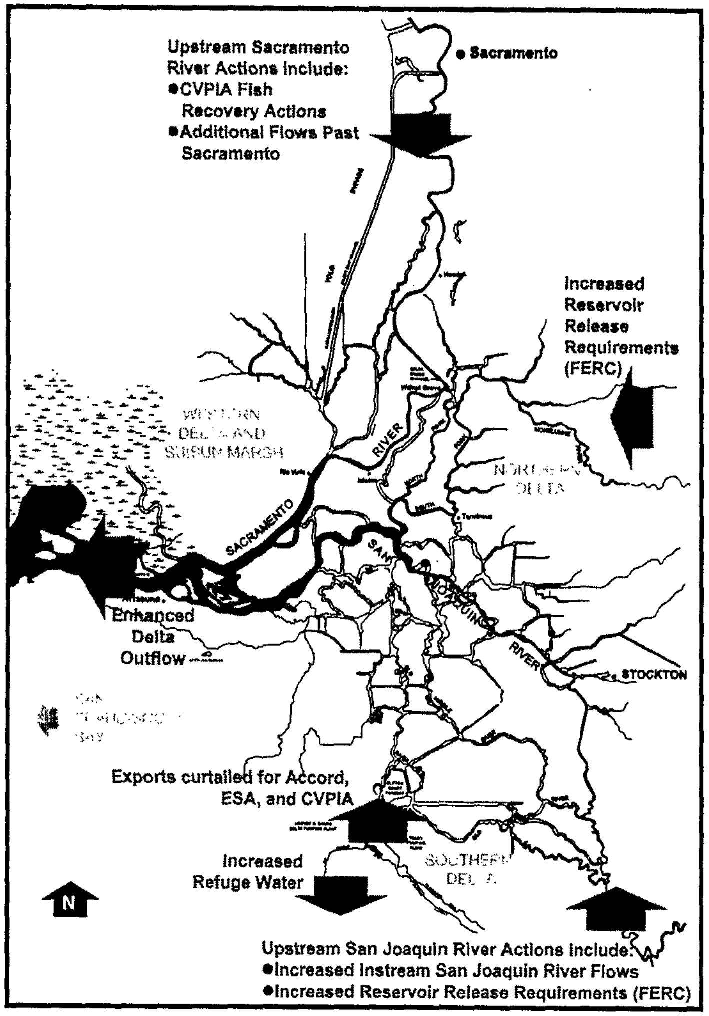
Figure 8: Actions Dedicating Additional Flows to the Environment



Dedicated flows for environmental purposes have been increased by up to 1.4 million acre-feet, including additional deliveries to refuges. (See *Looming Crisis*).

HABITAT RESTORATION INVESTMENTS CONTRIBUTE TO RECOVERING FISH POPULATIONS

- Largely as a result of the political leadership and cooperation among stakeholders, $2 billion is now committed to ecosystem restoration through 2010. Approximately $600 million has been spent or allocated to date.
- More than 450 ecosystem improvement projects throughout the Bay-Delta watershed are in various stages of implementation. Hundreds more are planned for the future.
- These projects are producing substantial increases in fish populations, in some cases with extremely promising results (see "Looming Crisis"). While there is uncertainty about the relative importance of various factors contributing to fish recovery, high natural flows and greater emphasis on habitat restoration appear to play major roles.

E-039077

FISH ARE OUT OF JEOPARDY — RECOVERY REQUIRES BALANCE

JEOPARDY AND RECOVERY

- While uncertainty remains about the relative contribution of various flow and habitat improvement factors, virtually all fish species are no longer on the threshold of extinction (i.e. they are out of "jeopardy").
- The ESA acknowledges the distinction between actions needed to prevent immediate jeopardy to an endangered species, versus the efforts needed to promote its recovery once jeopardy has been avoided.

  Jeopardy Avoidance: The ESA requires aggressive action to protect species in jeopardy of extinction, even though that could cause socioeconomic impacts. While the cost of avoidance should be minimized, the balance tilts toward species protection.

  Recovery: Once jeopardy has been avoided, the ESA allows a balanced approach to recovery. ESA agencies have substantial discretion to consider socioeconomic impacts in developing recovery strategies.

- In the future, Bay-Delta system fishery recovery plans must properly consider their impacts on other beneficial uses of Bay-Delta waters.

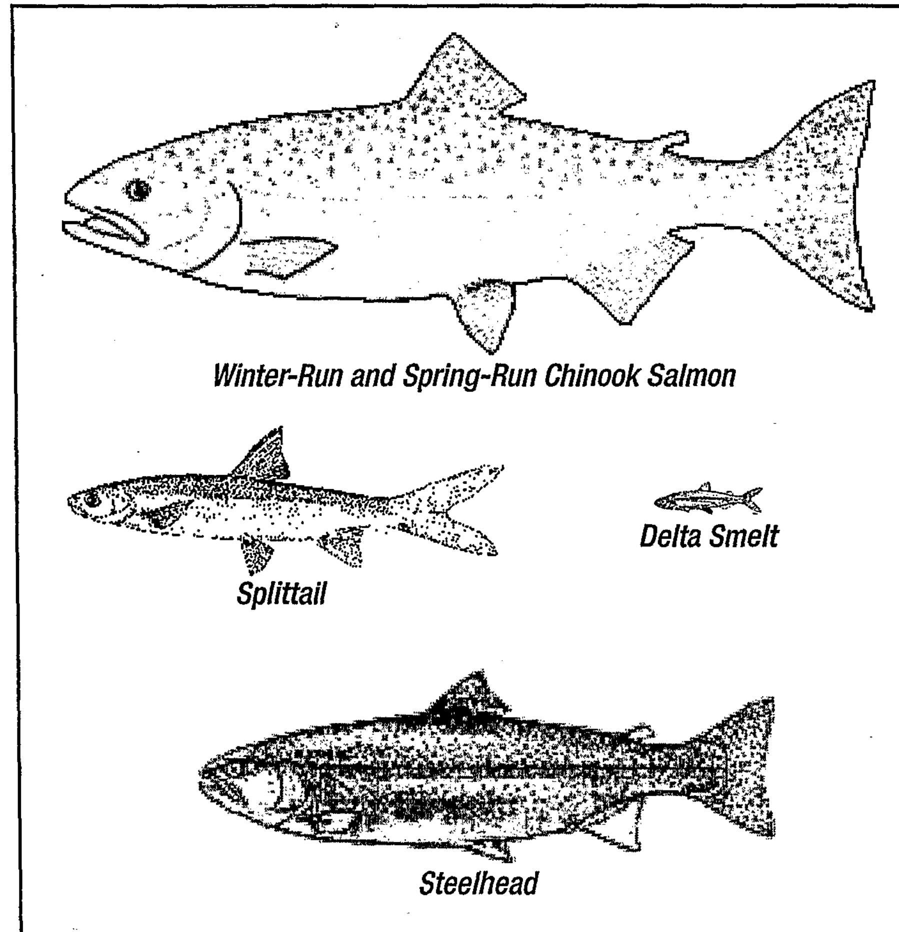


Figure 9: ESA Protected Species

The decisions confronting us today are a matter of public policy, not narrow legal mandates. The challenge today is RECOVERY. Recovery strategies must reflect today's circumstances, not those of ten years ago. A successful restoration program depends upon ENVIRONMENTAL AND ECONOMIC BALANCE.

ADAPTIVE MANAGEMENT

During the past decade, it has become increasingly apparent that we must learn to adaptively manage the natural resources of the Bay-Delta system. Simply put, adaptive management means learning from actual experience and adjusting strategies periodically to better manage the system for environmental and economic balance. The 1994 Bay-Delta Accord was the cornerstone of a new adaptive management regime. The purpose of the Accord was to provide a flexible approach to stabilizing fish populations, previously in precipitous decline, and to lay the foundation for future environmental and economic recovery. Since the Accord, fish populations have indeed stabilized and are on the road to recovery.

But, it is important to keep in mind that since the Accord, California has experienced an unprecedented string of six wet water years. During the next drought, fishery populations will likely decline again. However, the regulatory protections of the Accord were designed to assure that during future droughts these fish populations would do far better than they have in the past without such protections.

THE ISSUES TODAY ARE:

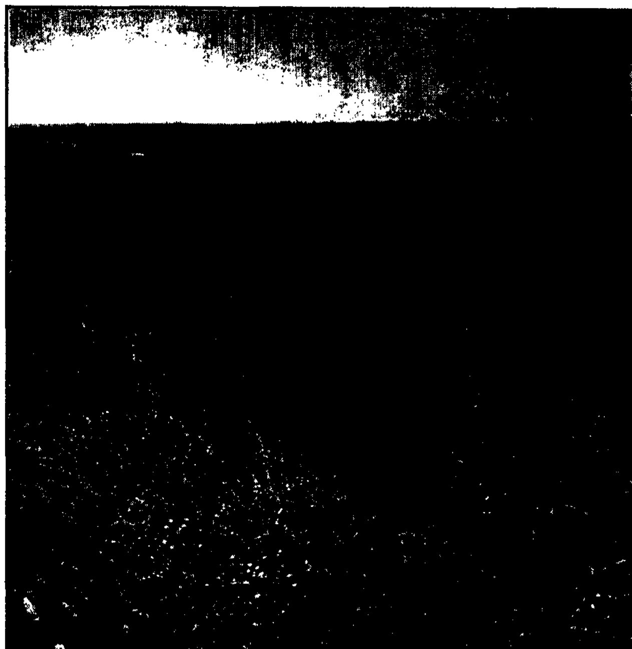
- Where do we go from here?
- What should be the next step beyond the Accord?
- Are there adjustments in how the Accord itself is implemented to make it work better?

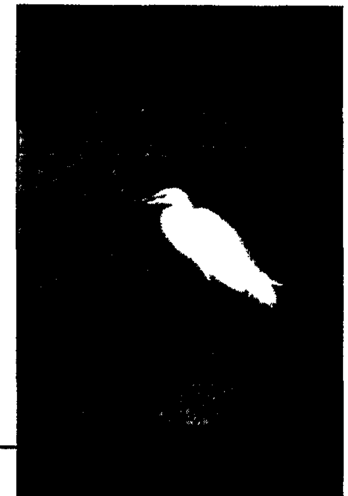
This briefing book is intended to inform that critical public policy debate by suggesting a broader framework for using scientific information to form balanced public policy.

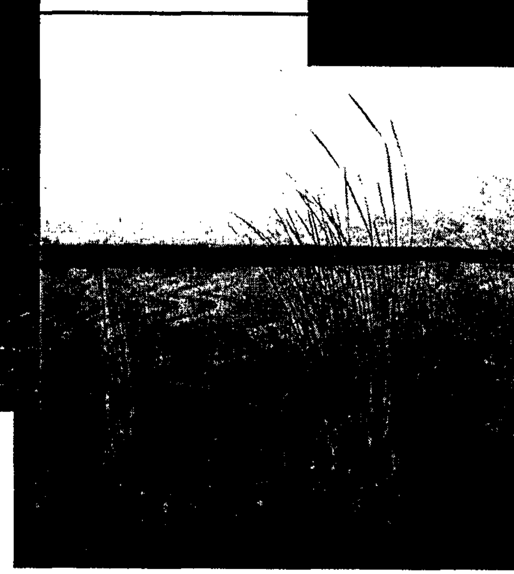
THAT WAS THEN, THIS IS NOW

THE BAY-DELTA THEN

Before 33 million people and the development of California's modern economy, the Bay-Delta was a vast natural system of rivers and tule marshes, providing habitat for fish and wildlife.



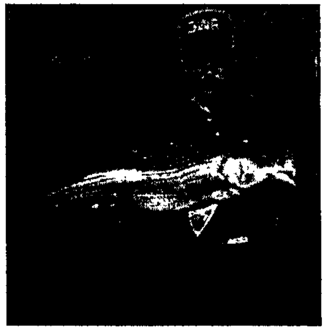




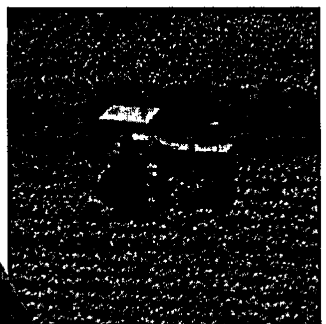
Habitat for Fish and Wildlife

THE BAY-DELTA NOW


Artificial Levees


Striped Bass

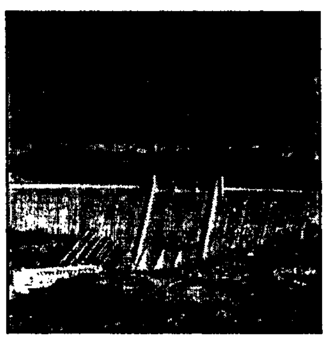

Power Plants


Delta Agricultural Economy


Recreation


Exotic Species


Water Project Pumping Plants


Upstream Dams


Commercial and Sport Fishing

California's native landscape has a long legacy of massive environmental change.

(Sierra to the Sea, The Bay Institute, 1998)

- Today, the Bay-Delta system is highly transformed and habitat conditions have been radically changed.
- The Bay-Delta now supports an agricultural and urban economy, provides drinking water for 22 million Californians, and yet remains the largest estuarine habitat on the western coast of the Americas.

There is no going back to the natural system. We have to learn how to manage this transformed system.

E-039081

A PATTERN OF SINGLE-FOCUS DECISIONS

Overemphasis on Water Project Operations May Prevent Achievement of Environmental Goals

The fisheries and species of concern in the Bay-Delta watershed are affected by many factors, all of which should be considered as we define the next steps beyond the Accord. Indeed, one of the major issues in ongoing discussions between the state and federal governments is: What is the appropriate mix of resource investments in the next round of adaptive management decisions for fish recovery?

A review of emerging trends, particularly in federal decisions since the Accord, raises important questions about which direction over the next decade will provide the greatest benefit for the fish, at the lowest possible socio-economic cost, and is therefore politically sustainable.

The following case studies suggest that the federal approach places a very strong emphasis on further restrictions on the operation of the water projects as the centerpiece of the next stage of restoration activity. Actions to restrict project operations have been implemented under a fairly wide range of circumstances, even when the scientific evidence suggested environmental benefits may be small and the risks to water quality and supply were high. In contrast, actions which do not involve restrictions on water project operations have been greatly delayed or not implemented, despite scientific evidence that they could be highly effective in fish recovery efforts.

The current federal emphasis on water project operations as the central element of the next round of adaptive management decisions, if pursued, will prevent achievement of important environmental goals and unnecessarily injure the California economy.

RECENT REGULATORY TRENDS

ACTIONS WITHOUT ENOUGH SCIENCE

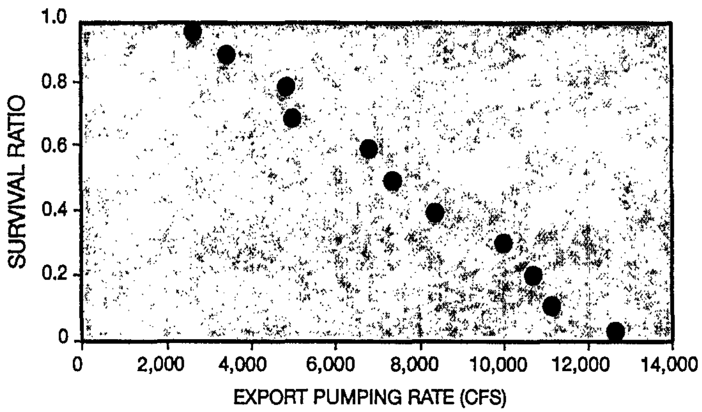
SCIENCE WITHOUT ENOUGH ACTION

E-039082

HYPOTHETICAL

Decisions are made as though the data looked like this:

Figure 10: Hypothetical Plot of Salmon Survival Ratio



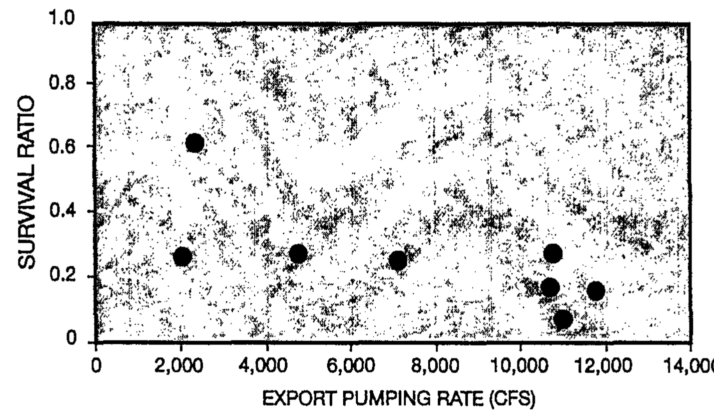
- We regulate water project operations as though a strong statistical case exists linking substantial increases in fish populations to changes in project operations.

Evidence establishing a link between project operations and fishery survival is often inadequate to justify the sometimes substantial economic costs of regulatory restrictions on project operations.

ACTUAL

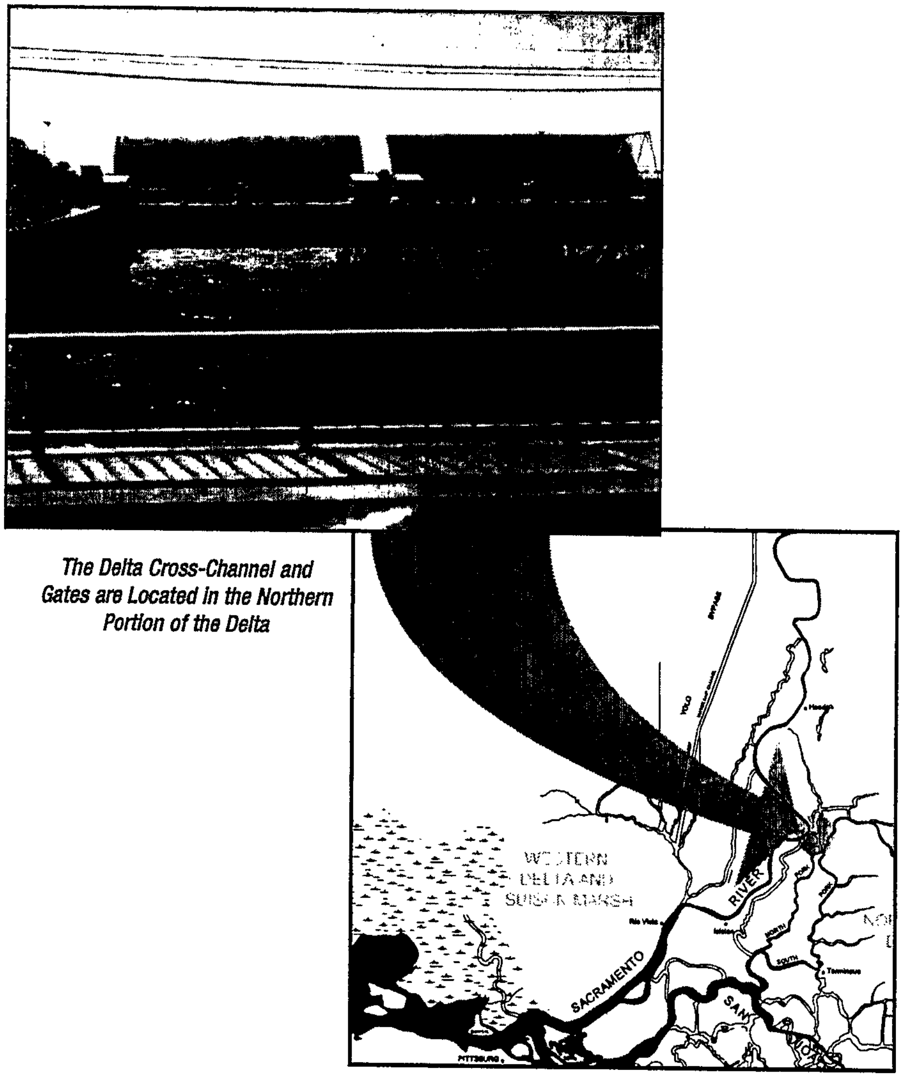
When in fact the data look like this:

Figure 11: Actual Plot of Outmigrating Salmon Survival Ratio



- Actual data rarely reveal such strong relationships. Scatter plots relating project operations to fishery survival are just that: SCATTERED.
- Where statistical relationships have been quantified, particularly for salmon populations, they are generally WEAK, suggesting that extraordinary modifications to project operations would be needed to achieve even minor fish population benefits (see Appendix A).
- These relationships do not appear to justify the large increases in environmental water being advocated by the federal government, particularly during normal and wetter years.

December 1999: Delta Cross-Channel Closure



The Delta Cross-Channel and Gates are Located in the Northern Portion of the Delta

- Operation of the Delta Cross Channel during December 1999, illustrates a decision-making process which tends to maximize benefits for a single resource — in this case the Spring-Run salmon — without adequate regard for impacts on other objectives.
- The initial closure of the cross channel gates in late November was justified, given information that salmon smolts were thought to be migrating toward the Delta. However, subsequent information indicated that relatively few fish were at risk during December, while concerns over deteriorating water quality grew.
- The regulatory decision not to adjust operations in response to these changing circumstances resulted in the worst water quality in the Delta since 1977 (a record drought year) and the loss of 300,000 AF of stored water (see *Averting Regulatory Drought*).

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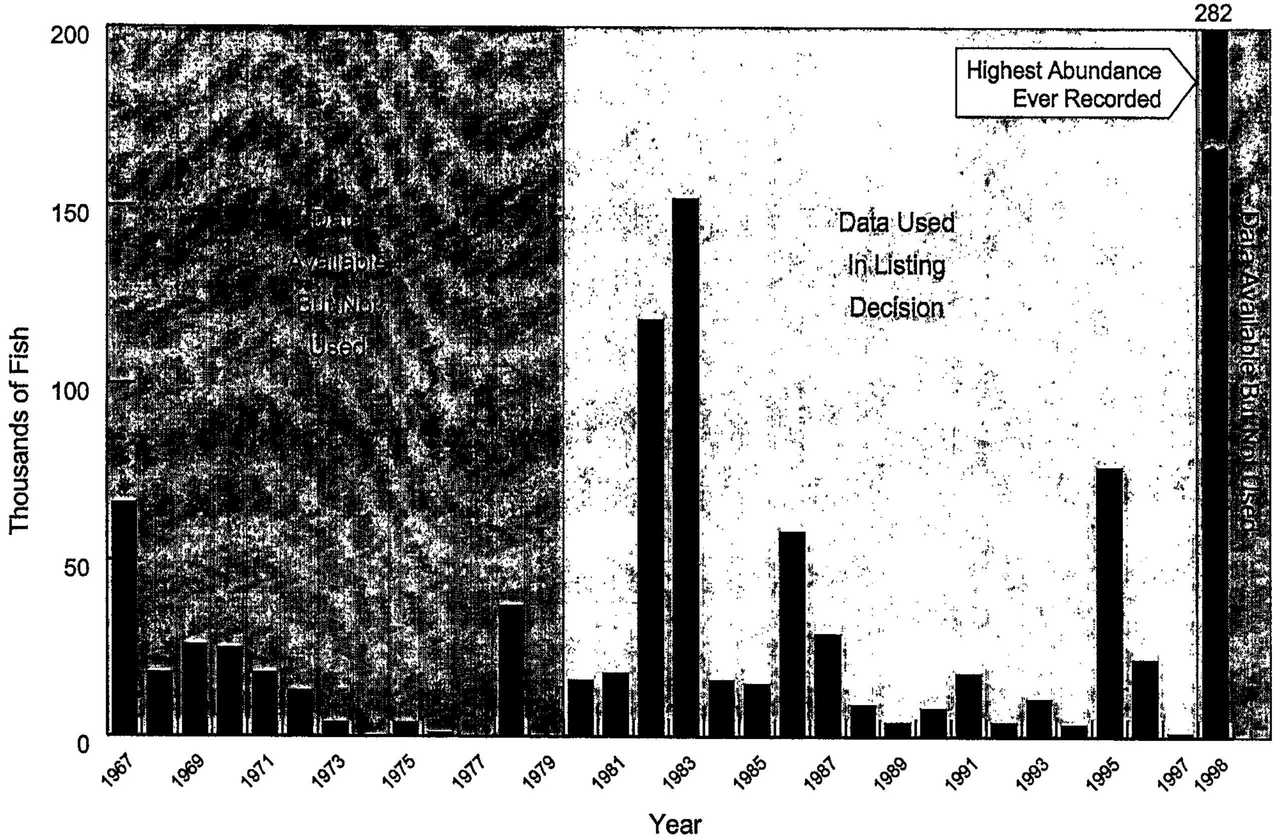
Figure 12: Splittail Fall Midwater Trawl



- The U.S. Fish and Wildlife Service selectively used data to justify its 1999 decision to list the splittail as threatened under ESA, despite the fact that scientists had observed record population levels of splittail for 1998. California Dept. of Fish & Game's biologists had recommended against listing.
- This listing will likely be used to justify additional restrictions on water project operations.

The USFWS' decision to list splittail dismissed the most definitive scientific work to date (Sommer et al. 1997), which concluded that splittail were highly resilient and well adapted to California's flood and drought cycles.

CASE STUDY 4: CVPIA IMPLEMENTATION — RAISING ECONOMIC COSTS WITH NO SCIENTIFIC JUSTIFICATION

In a highly controversial 1997 decision, the Department of Interior proposed a plan to implement the environmental water provision of CVPIA. Based on Interior's interpretation of the available science, the Plan was intended to provide:

"...a level of protection of the resources that is consistent with the goals of the Revised Draft Anadromous Fish Restoration Plan (AFRP), and sufficient to meet, for the term they are effective, the purposes set out in the CVPIA. The use of these real time response mechanisms is intended to provide better biological results while minimizing unnecessary adverse impacts to water supplies."

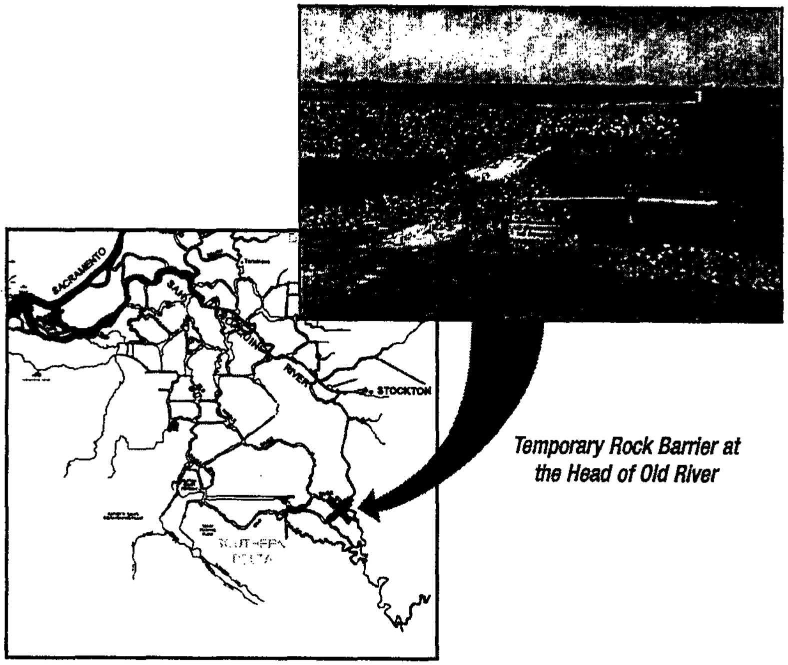
(1997 DOI CVPIA Final Administrative Proposal on b(2) Water, Page 6)

- The environmental water requirements of the 1997 Plan were based on Interior's interpretation of available scientific information. Following a legal challenge, in which the courts rejected the Plan for lack of an accounting mechanism, **Interior released a revised policy in 1999 that substantially increases water supply losses.**
- **The 1999 plan provides no scientific justification whatsoever for these additional economic impacts.** Indeed, the only change in scientific information between 1997 and 1999 was data suggesting a general improvement in fishery populations — a fact that was ignored by Interior in its decision.
- Both biological and economic common sense indicate that we should take advantage of wet periods to add water to storage, thereby reducing pressure on the system when it is dry. But, under exceptionally wet conditions, instead of increasing water allocations to CVP contractors, **in February 2000 allocations were actually cut by 50 percent due to b(2) requirements of the 1999 plan.**

"We do not, however, want to take actions simply because we may have water to do so, but the actions should be driven by how we can gain the most benefit."

(Dale Hall, USFWS Assistant Regional Director, Letter to David Behar, The Bay Institute, January 15, 1997)

CASE STUDY 5: OLD RIVER BARRIER — STYMIED DECISIONS PROLONG CONFLICT



Temporary Rock Barrier at the Head of Old River

- Despite overwhelming support for nearly a decade, no action has been taken to construct a permanent operable fish barrier at the head of Old River. Scientists have agreed this would be highly effective in protecting San Joaquin River salmon.
- At least in part, the delay in implementation is due to regulatory red tape: one group of fishery biologists who focus on a single species (Delta smelt) have stymied widely supported actions to help another species (San Joaquin River salmon).

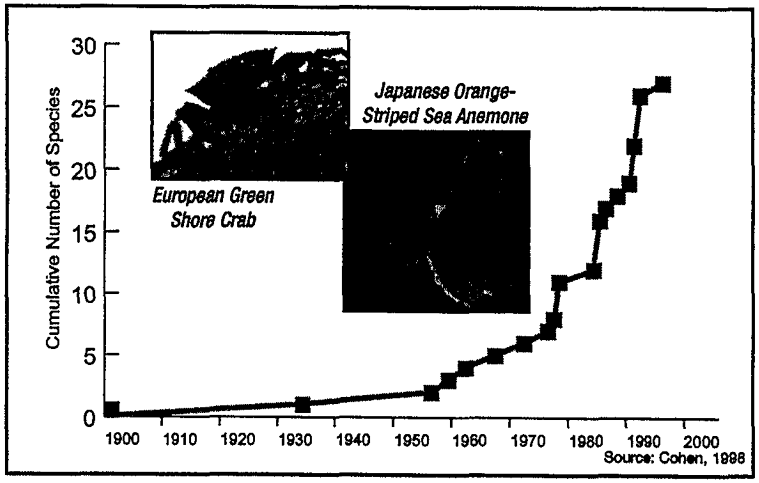
CASE STUDY 6: NEW APPROACH TO OCEAN HARVEST — FROM LOSE-LOSE TO WIN-WIN

Commercial and Sport Fishing

- In the mid-1990s, up to 58% of the adult endangered winter-run salmon population was harvested in the Pacific Ocean. While ocean harvest has been reduced from the inordinately high levels of the 1986 to 1995 period, sport and commercial fishing continues to take far more endangered salmon (equivalent adults) than are taken at the water export facilities.
- Harvest impacts on endangered salmon from commercial fishing can be reduced by the introduction of innovative programs. An approach successfully implemented in the Pacific Northwest is a selective fishery strategy, which has the potential to protect endangered species AND increase overall harvest.

CASE STUDY 7: INTRODUCED SPECIES: MAJOR IMPACTS, BUT NO EFFECTIVE PLAN OF ACTION

Figure 13: Exotic Invasions from Ballast Water in San Francisco Bay

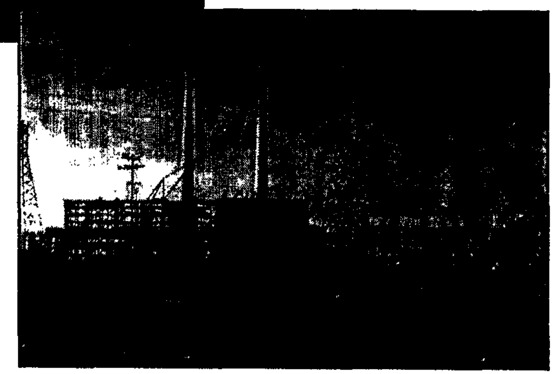


- An effective plan to deal with introduced species and to account for their effects is perhaps the most serious missing link in current regulatory efforts to restore native species.
- Dramatic increases of introduced species have disrupted the Bay-Delta ecosystem. Striped bass and Largemouth bass prey on native species, exotic clams and crustaceans consume their food. Exotic species are imperiling the recovery of native species.

> *"In the last three decades, introduced species have had a greater impact on the species composition and function of this region more than any other single human activity."*
>
> *(Strategic Plan for the Ecosystem Restoration Program, CALFED Bay-Delta Program, September 1998)*

CASE STUDY 8: DELTA POWER PLANTS: EQUITABLE REGULATORY ENFORCEMENT WILL BENEFIT FISH

Delta Smelt



Southern Electric Facilities

- The Pittsburg and Antioch power plants use high volumes of water for cooling. These facilities are neither adequately screened nor currently subject to regulation under the state and federal ESA to protect Delta smelt.
- The location of these facilities at the confluence of the Sacramento and San Joaquin rivers is at the "heart" of critical habitat for Delta smelt. These facilities kill many millions of adult and larval fish species, including Delta smelt.
- Formerly owned by Pacific Gas & Electric Company, the new owner and operator of these facilities, Southern Energy California, is prepared to aggressively test a new screening option. Despite the modest cost of actions to protect Delta smelt, no progress has been made on their implementation.

These cases studies illustrate a well-defined pattern. The emerging federal regulatory approach to deciding the next step in in recovering fishery populations is focused almost exclusively on water project operations and the scientific hypotheses about how these operations affect fish populations.

However, actions to further regulate project operations are being proposed even when the science suggests expected fish benefits would be minimal. Additionally, socioeconomic impacts have received little if any attention.

In contrast, even when available evidence suggests non-project protective actions would be highly effective, such measures are often not implemented. In some cases, regulators rely instead on far more costly and conflict-ridden project restrictions.

The bottom line: To develop a cost-effective program, we have to take a more comprehensive approach.

USING SCIENCE TO DETERMINE THE BEST NEXT STEPS

To establish the right investment mix for environmental recovery in the next round of adaptive decision-making, we must address three questions:

1) What factors influence fishery populations?

2) What is the relative importance of each factor and what should be our relative investments?

3) What is the appropriate overall resource commitment to environmental recovery, given the policy goals of improving water quality and water supply as well?

In California water we have used science only to answer the first question, and even then we have focused on a narrow range of factors. To determine the best next step — one that produces more fish and better habitat at a lower socioeconomic cost, and that is therefore politically sustainable — we must use scientific information to help answer all three questions. And as we do, it should not be surprising that a different investment mix will emerge.

E-039089

This section illustrates the importance of a broader analytical approach by comparing estimates of cost-effectiveness of a wide range of restoration actions to protect Sacramento River and San Joaquin River fisheries and in-Delta species.

Despite long-standing concerns about the relative effectiveness of various restoration actions, this is the first attempt to quantify the comparative cost-effectiveness of these actions.

The following methodology was used:

Step 1: Identify a wide range of restoration actions, including restrictions on export project operations, and other habitat and management actions.

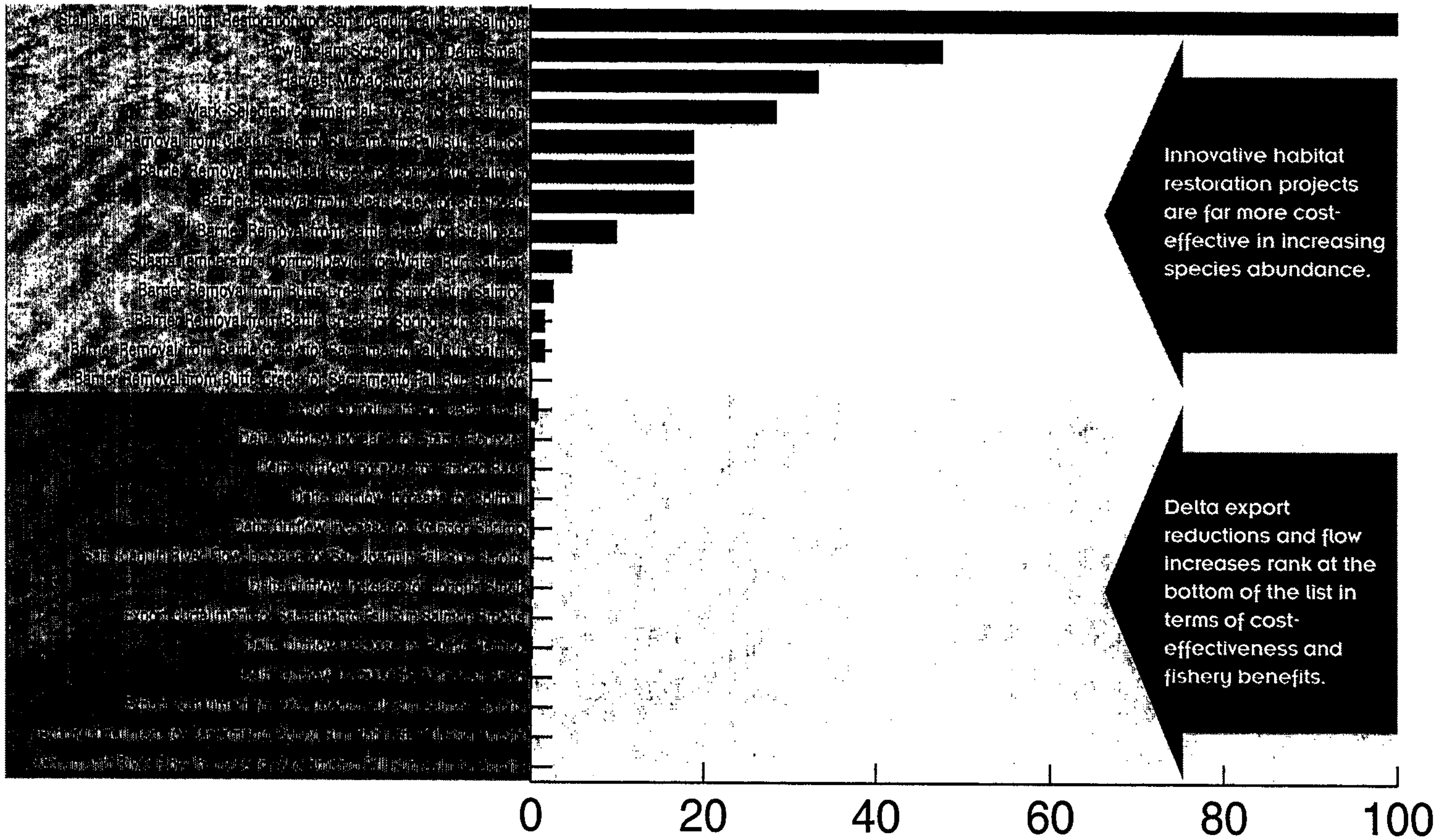
Step 2: Utilize the best available scientific information to estimate the benefits of each action in terms of the expected percentage increase in overall populations. For restrictions on water project operations, we have estimated direct and indirect population benefits using data from the Inter-Agency Ecological Program, despite ongoing disputes regarding the validity of relationships derived from these data. When multiple species are involved, we have estimated benefits separately for each species. (See Tables 1 and 2 in Appendix A).

Step 3: Estimate the cost of each action, including all annualized capital and O&M costs. For changes in water project operations, we assumed the value of water at $100/AF.

Step 4: Calculate a cost-effectiveness ratio for each action, as measured by the estimated percentage increase in overall abundance per $1 million of annual costs. (See Figure 14 and Appendix B).

Step 5: Convert cost-effectiveness estimates into an index by dividing the cost-effectiveness ratio for each action by the ratio for the most cost-effective action and multiplying the result by 100.

Figure 14: Index of Relative Cost-Effectiveness of Restoration Actions



*According to the Newman-Rice analysis (Newman and Rice, 1997) closing the Delta Cross channel improves survival of outmigrating salmon smolts through the Delta by 40%. Usually, such closures do not reduce water supply unless the closure allows Delta salinity to increase, as in 1999. Judicious use of these closures provides significant benefit to outmigrating salmon with little or no effect on water supply.
For assumptions, see Appendices A & B.

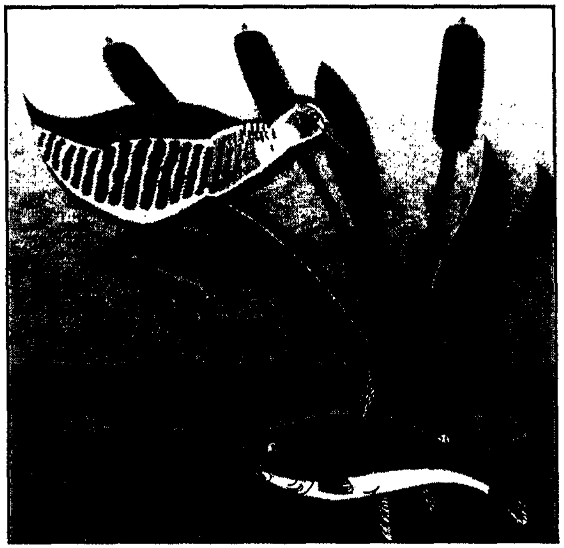
E-039091

- Although these results must be regarded as preliminary, the broader analytical approach used here obviously has important implications for the future direction of environmental restoration efforts within the CALFED process.
- Investments in selected physical habitat restoration projects can have a very favorable effect on fish abundance and are highly cost-effective. These projects can be well-targeted at a high fraction of the fish population of concern - e.g., every adult salmon returning to spawn in upstream creeks may enjoy the benefits of strategic dam removals and improvements in spawning habitat. Moreover, these projects have well-defined costs and pose little economic risk - in some cases, such as Butte Creek, they are accompanied by improvements in the water delivery system.
- For the salmon species considered here, further restrictions on export operations and increases in in-Delta flows do not appear to be cost effective. These actions may increase salmon abundance, but only by very small amounts in percentage terms and at high economic risk and costs. The reason may be that the migratory routes of these fisheries are physically more remote from the project pumps. Even ESA take requirements for the Sacramento River runs recognize that less than 2 % of the populations are at risk from the pumps. Accordingly, the correlations calculated in available statistical studies indicate that it may require from 50,000 to 550,000 AF per year to increase the abundance of salmon by a single percentage point. (See Appendix.)
- For other species such as Delta smelt, the population benefits of managing the export projects may be much higher. Preliminary analysis of project operations in 1999 suggests that export restrictions during the spring may have avoided the loss of a significant portion of that year's smelt population. But the risks associated with these protections were similarly high, with more than 400,000 AF of water withdrawn from San Luis Reservoir. If all of this water were lost to beneficial use, the gain in abundance would have been only about one-third of one percent per million dollars of cost. The message seems clear for such populations: improve management of the water projects but in ways that substantially reduce risk and associated water supply losses.

"Like all significant environmental challenges, our response here must be a combination of good science and good public policy."

(Oregon Governor John Kitzhaber)

MANAGING THE WATER PROJECTS FOR DIFFERENT SPECIES



The challenge of managing the water projects to help enlarge fish populations varies from species to species. For the Central Valley salmon species, the preliminary data available so far indicate that restrictions on exports provides little leverage to increase fish abundance. Water supply impacts can be extraordinarily high and yet produce only very small increases in abundance. For salmon, the best recovery path probably lies largely with other measures, such as upstream flows, better management of ocean harvest, and habitat investments. The notable exceptions involve keeping outmigrating salmon in the main river channels through the Delta - by closing the Delta Cross Channel and installing a barrier at the head of Old River. These tentative conclusions certainly do not justify dismantling the regulatory protections of the Accord, but neither do they justify the increased emphasis on export restrictions inherent in federal proposals.

For Bay-Delta resident species, such as Delta smelt, the situation at times is considerably different. Managing the pattern of exports can impact the overall smelt population. During 1999, for example, a substantial number of smelt were within areas of the Delta influenced by export pumping. As a result pumping operations were curtailed. These actions resulted in the loss of more than 400,000 AF of water from storage in San Luis Reservoir south of the Delta, making the risks and potential costs exceptionally high. For Delta smelt, export restrictions at key times may be important to recovery, but every effort should be made to minimize net supply impacts and economic costs.

RECOMMENDATIONS FOR COMMON-SENSE RESOURCE MANAGEMENT

When we consider a more comprehensive set of resource actions and compare their relative costs and benefits, some practical lessons for resource management emerge:

1) We must place much greater emphasis on broadening the mix of environmental recovery investments — **in particular, we must accelerate "high-payoff" investments in critical habitat restoration measures, including native habitat (riparian and riverine), fish spawning and rearing habitat, and fish passage improvement.**

2) When flows are used to manage fisheries, some basic rules should be observed:

a) Leverage use of export curtailments: Use environmental water for Delta species like Delta smelt rather than for salmon which have a much briefer exposure to the pumps. There are much more cost-effective ways to increase salmon through habitat, passage and fishery improvements.

b) Use an environmental water budget: Such an approach forces the consideration of trade-offs and prioritization of activities — considerations seriously lacking today.

c) Minimize supply impacts: A foundation principle must be to minimize the supply impacts and economic costs of operational measures to recover fishery populations. Large increases in the amount of water dedicated to the environment are not justified, especially given that the species of concern are no longer in jeopardy.

d) Rely on the No-Net-Loss Of Water Principle: Operations under a no-net-loss rule, as was included in the 1994 Bay-Delta Accord, can dramatically reduce the cost of operational protections and improve their cost effectiveness relative to non-flow measures.

3) Accordingly, we strongly recommend that as a first step towards a new, common-sense approach to balanced management of the system, **state and federal leaders convene a high-level, public policy review of the Bay-Delta science and its implications for resource management.**

E-039094

Recommendations

E-039095

COST AND ENVIRONMENTAL BENEFITS FOR DELTA WATER PROJECT REQUIREMENTS

SPECIES	CRITICAL PERIOD FOR REQUIREMENT	WATER ASSOCIATED WITH 1%* INCREASE IN POPULATION AND % POPULATION INCREASE PER $ MILLION/YEAR Average Flow Conditions (Assuming water value** = $100/acre-foot)				COMMENTS
		TYPE OF REQUIREMENT				
		EXPORT CURTAILMENT	RIVER FLOW INCREASE	DELTA OUTFLOW INCREASE	CROSS-CHANNEL GATE CLOSURE	
SACRAMENTO FALL RUN SALMON SMOLTS Newman-Rice Analysis	APRIL to JUNE	400,000 AF (0.03%/ $ million/yr)	1,800,000 AF (0.01%/ $ million/yr)	Not Applicable	Increases survival by 40% as compared to open, No water cost unless water quality problems	Values for export curtailment are for river flow of about 20,000 cfs, export rate of 4,000 cfs, and Cross Channel gates closed. Opening gates increases the amount by a factor of about 1.4. The amount of export curtailment required is proportional to river flow. Amount of river flow required decreases roughly proportionally with increasing export rate.
SACRAMENTO FALL RUN SALMON SMOLTS Revised Newman Analysis	APRIL to JUNE	110,000 AF (0.09%/ $ million/yr)	110,000 AF (0.09%/ $ million/yr)	Not Applicable	No benefit at about 20,000 cfs river flow. Benefits up to 50% for higher and lower flows	Probably a better estimate than Newman-Rice. Required export curtailment increases more than linearly with increasing river flowrate. Required river flow decreases less than linearly with increasing export rate. Cross Channel gate effects may be anomalous.
SACRAMENTO SPRING RUN AND LATE FALL RUN SMOLTS	DECEMBER to JANUARY	550,000 AF (0.02%/ $ million/yr)	Not Applicable	Not Applicable	Could probably assume same as for fall run smolts per Newman-Rice	This estimate is based on only six data points, only one of which drives the relationship. The data do not show a relationship between survival and river flow.
SAN JOAQUIN FALL RUN SMOLTS	MID APRIL to MID MAY	Not Applicable	70,000 AF (0.14%/ $ million/yr)	Not Applicable	Not Applicable	The data show a relationship between river flowrate and survival, but this relationship may be driven by higher flows only. No relationship has been found relating survival with export rate with a barrier at the head of Old River when river flowrate is 7,000 cfs or less.
DELTA SMELT	10 MAY to 6 JULY, 1999	27,000 AF (0.37%/ $million/yr)	Not Applicable	Not Applicable	Not Applicable	Delta smelt salvage for 1999 was expanded to estimate direct mortality (expansion factors of about 11 at SWP and 2.5 at CVP pumping plants). Density dependence, which probably occurred in 1999, was ignored. Total exports were taken from DWR DAYFLOW data.
SPLITTAIL	FEBRUARY to MAY	Not Applicable	Not Applicable	60,000 AF (0.17%/ $ million/yr)	Not Applicable	The relationship between splittail abundance and X2 is thought to be a surrogate for the actual relationship between splittail abundance and the amount of wetted vegetation to which splittail eggs attach. The amount of extra outflow required for a 1% population increse is roughly proportional to the Delta outflow rate from which the increase is desired.
STARRY FLOUNDER 1-Year Olds	MARCH to JUNE	Not Applicable	Not Applicable	50,000 AF (0.20%/ $ million/yr)	Not Applicable	The amount of extra outflow required for a 1% population increase is roughly proportional to the Delta outflow rate from which the increase is desired.
LONGFIN SMELT	JANUARY to JUNE	Not Applicable	Not Applicable	80,000 AF (0.13%/ $ million/yr)	Not Applicable	The amount of extra outflow required for a 1% population increase is roughly proportional to the Delta outflow rate from which the increase is desired.
AMERICAN SHAD	FEBRUARY to MAY	Not Applicable	Not Applicable	140,000 AF (0.07%/ $ million/yr)	Not Applicable	The amount of extra outflow required for a 1% population increase is roughly proportional to the Delta outflow rate from which the increase is desired.
PACIFIC HERRING	JANUARY to APRIL	Not Applicable	Not Applicable	110,000 AF (0.09%/ $ million/yr)	Not Applicable	The relationship between herring abundance and X2 is not statistically significant. The amount of extra outflow required for a 1% population increase is roughly proportional to the Delta outflow rate from which the increase is desired.
CRANGON SHRIMP	MARCH to MAY	Not Applicable	Not Applicable	60,000 AF (0.17%/ $ million/yr)	Not Applicable	The relevence of this relationship is questionable. Crangon are one species of a group of shrimp, all of which occupy the same ecological niche. The abundence of the group is not related to X2. The amount of extra outflow required for a 1% population increase is roughly proportional to the Delta outflow rate from which the increase is desired.
STRIPED BASS LARVAL SURVIVAL	APRIL to JUNE	Not Applicable	Not Applicable	50,000 AF (0.20%/ $ million/yr)	Not Applicable	The amount of extra outflow required for a 1% population increase is roughly proportional to the Delta outflow rate from which the increase is desired.

*All amounts of water are proportional to % increase in population. For example, a 5% increase in San Joaquin river smolt population would require (70,000 x 5%/1%) = 350,000 acre-feet.

**The value of water varies depending on the type of year (wet or dry) and the place where the water supply effect occurs.

E-039096

E-039096

COST AND ENVIRONMENTAL BENEFITS FOR SELECTED NON-FLOW MEASURES

ACTION	DESCRIPTION OF ACTION	PRIMARY AFFECTED SPECIES	BASIS OF BENEFIT ESTIMATES	COST, $			"RATIO, % POPULATION INCREASE PER $ MILLION/YR"
				CAPITAL	O & M	ANNUAL	
BARRIER REMOVAL FROM BUTTE CREEK	A suite of actions which involves removing barriers to fish passage and screening and laddering of diversions. Action also reduces delay during migration.	•Spring Run Salmon •Sacramento Fall Run Salmon	Benefits of 5% per site for spring run and 2% for fall run. Therefore, total benefit for creek is 35% for spring run, 14% for fall run. Percent of total Sacramento run in this creek is 3.4% for spring run and .6% for fall run. Therefore, benefits to entire runs are as follows: spring run 1.2%, fall run .08%.	$17,000,000	Negligible	$1,100,000	Spring run, 1.1% Sac. Fall run, 0.07%
BARRIER REMOVAL FROM BATTLE CREEK	Includes a suite of actions which involve removal of two diversions on the mainstem Battle Creek, three diversions on tributaries of Battle Creek, and construction of screen and ladders on diversions on the mainstem.	•Spring Run Salmon •Sacramento Fall Run Salmon •Steelhead	Benefits of 5% for each species for each of five structures removed or screen-laddered on the main stem and three structures removed on tributaries. Therefore total benefit for this creek is 40% for each species. Percent of total Sacramento run in this creek is 3.4% for spring run, 3.4% for fall run, and 20% for steelhead. Therefore, benefits to entire runs are as follows: spring run 1.3%, fall run 1.3%, steelhead 8%.	$30,000,000	Negligible	$1,900,000	Spring run, 0.7% Sac. Fall run, 0.7% Steelhead, 4.2%
BARRIER REMOVAL FROM CLEAR CREEK	Action includes a suite of actions which removes one diversion which provide unimpeded passage to 12 miles of salmonid habitat and instream restoration activity.	•Spring Run Salmon •Sacramento Fall Run Salmon •Steelhead	Removal of one diversion coupled with additional instream flows will provide an additional 12 miles or 50% more habitat for salmon. Percent of total Sacramento run in this creek is 12% for spring run, 12% for fall run, and 12% for steelhead. Therefore, benefits to entire runs are as follows: spring run 6%, fall run 6%, steelhead 6%.	$12,000,000	Negligible	$760,000	Spring run, 7.9% Sac. Fall run, 7.9% Steelhead, 7.9%
RED BLUFF DIVERSION DAM GATE REMOVAL AND SCREENING PROJECT	Construction of a state of the art pump and screening facility at RBDD could result with removal of gates at RBDD year round.	•Sacramento Fall Run Salmon •Late Fall Run Salmon •Winter Run Salmon •Spring Run Salmon	Percentage of juvenile fish whose passage at RBDD would change as a result of this action is as follows: fall run 36%, late fall run 26%, winter run 26%, spring run 0%. Predation on juveniles is reduced by at least 16%. Benefit to juveniles passing RBDD is follows: fall run 5.7%, late-fall 4.1%, winter run 4.1%. Although there is no change for spring run juvenile migration, there is a major benefit to adult spring run migrants, which affects approximately 80% of the adult population migrating past RBDD. Percent of total Sacramento run passing RBDD is 20% for fall run, 95% for late fall run, 95% for winter run, 20% for spring run. Therefore, benefits to entire runs are as follows: fall run 1.1%, late fall run 3.9%, winter run 3.9%, spring run unknown.	$150,000,000	$2,000,000	$11,500,000	Sac. Fall run, 0.1% Late Fall run, 0.3% Winter run, 0.3% Spring run, ??%
STANISLAUS GRAVEL AUGMENTATION AND SILTATION CONTROL	Add gravel, restore floodplains and control major sources of siltation in an upper reach, three miles long.	•San Joaquin Fall Run Salmon •Steelhead (benefits not estimated)	Restoring gravel in dredged upper reaches would increase fry production by 50%. Reconnecting floodplains would increase juvenile survival by 10% by increasing food availability. Therefore, these two effects together result in a 65% increase (1.5*1.1 - 1.0). Assume that Stanislaus River contributes 1/3 of total San Joaquin River salmon run. Therefore, percent increase in San Joaquin River fall run population would be 22% (65%/3).	$1,000,000 land acquisition $3,000,000 restoration	$150,000 monitoring 10 yrs; $30,000 sedimentation control	$530,000	San Joaquin Fall run, 42%
YOLO BYPASS FLOWS AND SEASONAL WETLAND IMPROVEMENTS	Consists of providing 5,000 cfs from Sacramento River via Fremont Weir, and improving and managing lands within the Yolo Bypass as habitat for various species. Requires modification of Fremont Weir.	•All Sacramento Salmon	1) Out-migration occurs October through June. 2) Upstream and downstream escapements are proportional. 3) Out-migrants spill into Yolo Bypass (YB) in proportion to Sacramento River flow diverted to YB. 4) No salmon from the Feather, Yuba, or American Rivers use YB. 5) 51% of adult escapement goes to the upper Sacramento River (US) above the Feather. 6) 50% of out-migrants reaching FW survive in the Sacramento River (SR) to reach Chipps Island. 7) CWT fry survivals in YB for 1998 and 1999 are 0.16 and 0.09, and in SR 0.09 and 0.07, respectively. 8) Ratio of smolt survival using YB instead of SR is the same as the average for fry, or 1.53. 9) 5,000 cfs (2.7MAF) more is diverted October-June into YB via Fremont Weir than would occur otherwise. 10) 10.9 and 4.0 MAF flow in the Sacramento to FW and into YB, respectively, during October through June, providing an estimated 5% increase in Central Valley salmon production among all runs combined.	$30,000,000	$500,000	$2,400,000	All Sacramento Salmon, 2.1%
SHASTA TEMPERATURE CONTROL DEVICE	Recently constructed temperature control device at Shasta Dam allows for temperatures standards to be met for winter run chinook salmon.	•Winter Run Salmon	Benefits accrue by meeting temperature standard. Without this device, mortality due to high temperatures would occur for winter run. Assume mortality of 10% without temperature control device unless significant changes in operation of reservoir.	$80,000,000	Negligible	$5,100,000	Winter run, 2%
GUNDERBOOM	Consists of two suspended fabric curtains in front of Southern Electric Power Plant intakes.	•Delta smelt •Longfin smelt •Striped Bass (analysis for Delta smelt)	Deployment all months; Contra Costa + Pittsburg intakes; delta smelt pop. now 50% of '79-'80 level; 0.5 mm openings = 90% effective protection; '78-'79 power plant impingement = 500,000; power plant "osmeridae" entrainment = 85 million (2/3 = delta smelt); fecundity = 1,730/female; equivalent adult factors (EAF): entrained = 350/adult, impinged = 10/adult. Therefore, 75% saved.	$16,000,000	$1,000,000	$1,500,000	Delta smelt, 20-50% (use 20%)
HARVEST MANAGEMENT	Reduce allowable harvest and subsidize dockside price of caught fish.	•All Salmon	Figures = 6-yr averages. Dressed weight = 10.5 lb; Price (dock-side) = $1.77/lb; lbs landed = 4,071,000; fish landed = 388,000; effort = 22,800 days; Time/area closures OR quota leads to 33% reduction in harvest. Assume: Overescapement NOT a straying or political problem; Willingness to accept; No shifting to other species; Reduced cost (effort) = excess profit incentive.	Not Applicable	$2,400,000 to fishermen	$2,400,000	All Salmon, 14%
MARK-SELECTED COMMERCIAL FISHERY	Mark all hatchery fish and allow harvest of marked fish only. Change gear types to reduce hooking-release mortality.	•All Salmon	Current 60% harvest rate. No density dependence in fresh water habitat. Current 24% hooking mortality, can be reduced by 50% or more. 75% of fish are now from hatcheries. Current hatchery production of 35 million smolts/yr will continue.	$1,900,000 additional equipment	$2,400,000 sampling 1,500,000 marking and tagging	$4,100,000	All Salmon, 12%

*Note that these estimates of percent population increase per million dollars per year were obtained by dividing the expected population increase by the cost in millions of dollars for each action. For those actions with a relatively low cost, the resulting percent population increase in this column may be higher than the population increase that could actually be obtained with that action.

Appendix

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E-039097

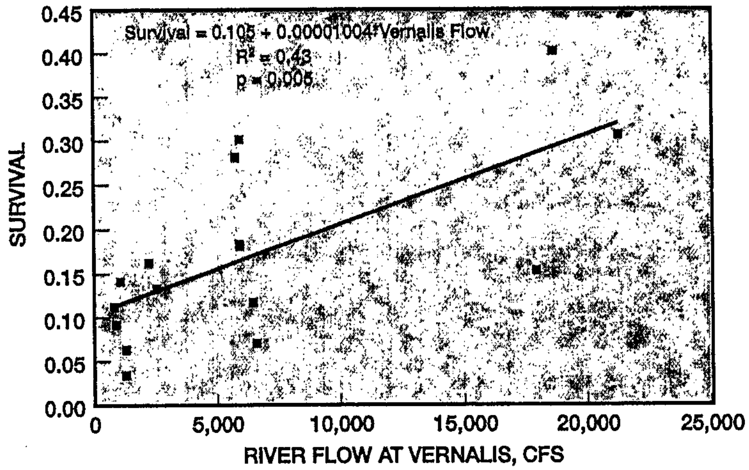
PERCENT OF ALL TAGGED SALMON SMOLTS RELEASED DURING 1993-98 THAT SUFFERED DIRECT MORTALITY AT EXPORT PUMPS

RIVER	SOURCE OF FISH	RACE OF SALMON	RELEASE LOCATION	NUMBER OF RELEASE GROUPS	AVERAGE NUMBER OF FISH PER GROUP	PERCENT DIRECT MORTALITY PER RELEASE GROUP					
						TRACY PUMPING PLANT			BANKS PUMPING PLANT		
						MINIMUM	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM
SACRAMENTO RIVER SYSTEM	COLEMAN HATCHERY	LATE FALL RUN	COLEMAN HATCHERY	59	68,900	0.00	0.02	0.16	0.00	0.34	2.08
			DELTA[1]	17	39,000	0.00	0.07	0.35	0.00	1.76	10.30
		WINTER RUN	COLEMAN HATCHERY	104	1,600	0.00	0.00	0.00	0.00	0.00	0.19
		FALL RUN	COLEMAN HATCHERY	75	50,900	0.00	0.00	0.03	0.00	0.00	0.09
	FEATHER RIVER HATCHERY	FALL RUN	FEATHER R. HATCHERY	29	51,500	0.00	0.00	0.00	0.00	0.00	0.00
			DELTA[1]	99	41,600	0.00	0.23	1.87	0.00	0.13	1.43
		SPRING RUN	DELTA[1]	2	49,600	0.00	0.01	0.02	0.00	0.13	1.43
	TRAPPED WILD FISH	SPRING RUN	BUTTE & MILL CREEKS	9	1,800	0.00	0.00	0.00	0.00	0.00	0.00
SAN JOAQUIN RIVER SYSTEM	MERCED HATCHERY	FALL RUN	MERCED HATCHERY	74	27,700	0.00	0.51	2.22	0.00	0.69	8.32
			DELTA[2]	21	34,700	0.00	0.11	0.77	0.00	0.10	0.65

1Consists of releases into the Sacramento River near Sacramento and downstream in the Delta.
2Consists of releases into the San Joaquin River near Mossdale and downstream in the Delta.

Appendix D - Statistical Relationships Underlying Bay-Delta Decisions Are Often Weak

VARIATION IN SURVIVAL WITH RIVER FLOW AT VERNALIS



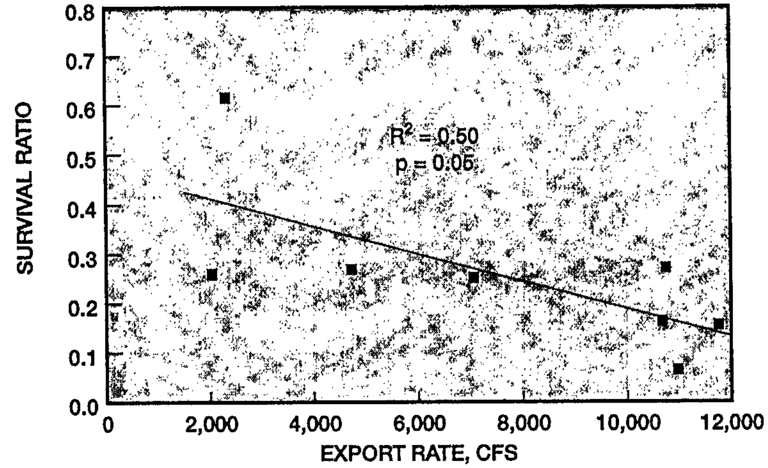
Data from Sheila Greene, Department of Water Resources. Data collected by Interagency Ecological Program according to specifications of federal and state fishery agencies.

Each point on the graph is the ratio of survivals of two groups of tagged smolts, one released at Vernalis, where the San Joaquin River enters the Delta, and one released at Jersey Point, downstream on the San Joaquin River. Both groups are netted in the western Delta at Chipps Island.

Using the slope of the line and estimating survival from Jersey Point to Chipps Island at 0.85, we can estimate the increase in river flowrate associated with a survival increase of 0.01. Applying that increase over the 28 days from Mid-April to mid-May produces an estimate of 70,000 acre-feet.

Note the scatter of data points for flows below about 7,000 cfs so that without the three data points at high flows, the relationship would not be statistically significant. Also note that these data show no correlation between export rate and smolt survival.

RELATIONSHIP BETWEEN EXPORT RATE AND THE SURVIVAL RATIO



Data from Sheila Greene, Department of Water Resources. Data collected by Interagency Ecological Program according to specifications of federal and state fishery agencies.

Each point on the graph is the ratio of survivals of two groups of tagged smolts, one released at the head of Georgiana Slough and one released at Ryde on the Sacramento River, just downstream of Georgiana Slough. Both groups are netted in the western Delta at Chipps Island.

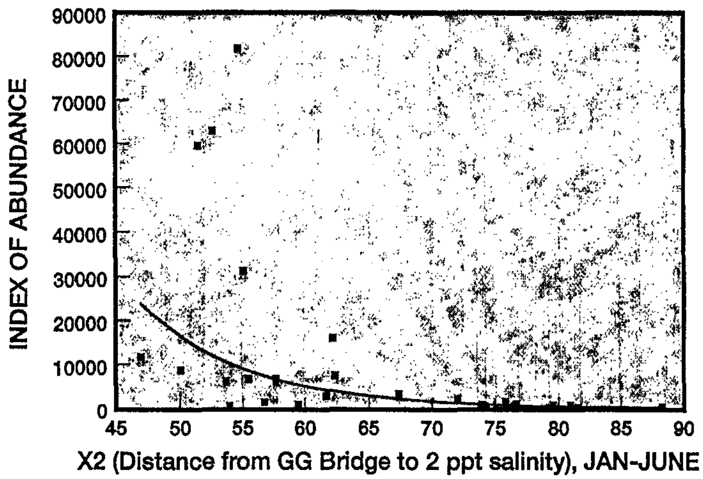
We are interested in the survival of smolts passing Sacramento. Therefore, we must estimate the fraction of smolts passing Sacramento that enter Georgiana Slough. We must also account for mortality of smolts released at Ryde. We used results from Dr. Charles Hanson's studies of salmon entering Georgiana Slough ("Evaluation of the Response of Juvenile Chinook Salmon to the Flow Split at the Confluence Between Georgiana Slough and the Sacramento River," draft memorandum by Charles R. Hanson, October 27, 1995) along with DAYFLOW estimates of the amount of water entering Georgiana Slough. We estimated survival from Ryde to Chipps Island at 0.85.

Using these data and the slope of the graph, we estimated the amount of export curtailment to increase survival by 0.01 during December and January. This estimate is 550,000 acre-feet.

Note that without the data point to the upper left, the line would be nearly flat and not statistically significant. Also, the amount of water associated with an increase in survival of 0.01 would be even larger.

Appendix

LONGFIN SMELT ABUNDANCE
VS.
X2 (A MEASURE OF WESTERN DELTA SALINITY)



Data are from routine monitoring by the Interagency Ecological Program. These data have been analyzed most recently by Kimmerer and by Miller et al. (Kimmerer, W.J., "A Summary of the Current State of the X2 Relationships," Newsletter of the Interagency Ecological Program for the Sacramento-San Joaquin Estuary, Fall, 1998, and Miller, W.J., Mongan, T.R., Britton, Alison, "Estuarine Species Abundance, X2, and Sacramento-San Joaquin Delta Exports," Newsletter of the Interagency Ecological Program for the Sacramento-San Joaquin Estuary, Spring, 1999).

These data show abundance vs. X2. The line of best fit is shown on the graph. X2 is closely related to (in fact, is determined by) the rate of Delta outflow. Starting with any value of outflow (the "initial" outflow), we can estimate X2 and the abundance associated with that value of X2. We can then increase abundance by 1% and reverse the calculation process to find the value of Delta outflow (the "final" outflow) associated with the 1% greater abundance. The difference in the initial and final outflow, over the critical months for the species (longfin smelt in this case), produces an estimate of extra outflow (in acre-feet) associated with a 1% increase in abundance.

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Delta Fish Sampling: photo by DWR
Watercolor by Vini S. (Riverdale School, Portland, OR - See Salmon Page at http://www.riverdale.k12.or.us)
Chinese Mitten Crab by CA DFG (http://www2.Delta.dfg.ca.gov/mittencrab/)
Link-Node diagram: Delta portion of the model schematic for DWRSIM.

Page 2
Boy drinking: photo by MWD
Man fishing: photo by DWR
Jet Skiers: photo by DWR
White Bird: photo by MWD

Page 3
Mitten Crab: photo by CA DFG (http://www2.Delta.dfg.ca.gov/mittencrab/pictures.html)

Page 6
CALFED Restoration Projects Map by CALFED

Page 8
Delta Smelt by CA DFG (http://www.delta.dfg.ca.gov/baydelta/monitoring/delta.html)
Splittail by CA DFG (http://www.delta.dfg.ca.gov/baydelta/monitoring/split.html)
Chinook Salmon by CA DFG (http://www.delta.dfg.ca.gov/baydelta/monitoring/chinook.html)

Page 10
Delta channel and bank (color) by Norm Hughes, DWR
Reeds (B&W): photo by DWR
White Bird: photo by MWD

Page 11
Artificial levees: photo by DWR
Striped Bass: photo by DWR
PG&E Power Plant: photo by DWR
Delta agricultural economy: photographer unknown
Jet Skiers: photo by DWR
Mitten Crab: photo by CA DFG (http://www2.delta.dfg.ca.gov/mittencrab/pictures.html)
Water Project Pumping Plants (SWP/Banks Pump Plant): photo by MWD
Upstream dams (Shasta Dam & Powerplant): photo by DWR
Fisherman: photographer unknown

Page 14
Delta Cross Channel: photo by MWD

Page 17
Temporary rock barrier at head of Old River: photo by DWR
Cleaned fish: photo by DWR
Fisherman: photographer unknown

Page 18
Photo of Japanese orange-striped sea anemone (Haliplanella lineata) by Caroline Kopp (in "Place Invaders Invaders in San Francisco Bay" by Andrew Neal Cohen from Pacific Discovery, Summer 1993 / Vol. 46)
Photo of European green shorecrab (Carcinus maenas) by Caroline Kopp (in "Place Invaders - Invaders in San Francisco Bay" by Andrew Neal Cohen from Pacific Discovery, Summer 1993 / Vol. 46)
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