A Scientific Assessment of Alternatives for Reducing Water Management Effects on Threatened and Endangered Fishes in California's Bay Delta

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Committee on Sustainable Water and Environmental Management in the California Bay-Delta; National Research Council

Summary

California's Bay-Delta estuary is a biologically diverse estuarine ecosystem that plays a central role in the distribution of California's water from the state's wetter northern regions to its southern, arid, and populous cities and agricultural areas. In addition to its ecological functioning and the ecosystem services it provides, there are numerous withdrawals of freshwater from the delta, the largest being pumping stations that divert water into the federal Central Valley Project (CVP) and the State Water Project (SWP), primarily for agriculture and metropolitan areas. Most former wetland and marsh areas of the delta have been drained for agriculture, and are protected by an aging collection of levees. Some of those areas also contain small urban settlements.

This hydrologic and engineered system has met the diverse water-related needs of Californians for decades. But operation of the engineered system, along with the effects of an increasing population of humans and their activities, has substantially altered the ecosystem. These ecosystem changes have contributed to changes in the abundance, distribution, and composition of species in the delta, including the decline of many native species and the successful establishment of many species not native to the region.

Recently, the Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) issued biological opinions under the federal Endangered Species Act (ESA) that required changes ("reasonable and prudent alternatives," or RPAs) in water operations and related actions to avoid jeopardizing the continued existence and potential for recovery of delta smelt, winter-run and fall-run Chinook salmon, Central Valley steelhead, and green sturgeon. Those changes have reduced the amount of water available for other uses, and the tensions that resulted have been exacerbated by recent dry years.

The RPAs are divided into many separate actions. The RPA in the FWS opinion, divided into six actions, applies to delta smelt and thus focuses primarily on managing flow regimes to reduce entrainment of smelt and on extent of suitable water conditions in the delta, as well as on construction or restoration of

habitat. The NMFS RPA, divided into five actions with a total of 72 subsidiary actions, applies to the requirements of Chinook salmon, steelhead, and green sturgeon in the delta and farther upstream. In addition to its focus on flow regimes and passage, it includes purchasing water to enhance in-stream flow, habitat restoration, a new study of acoustic-tagged steelhead, and development of hatchery genetics management plans. This committee did not evaluate all 78 actions and subsidiary actions in the two RPAs in detail. It spent most of its time on the elements of the RPAs that have the greatest potential to affect water diversions. It also spent time on elements whose scientific justifications appear to raise some questions.

Protecting all the listed species, as required by the ESA, while simultaneously trying to minimize impacts on existing and projected uses of the region's water, is a serious challenge. In addition, many anthropogenic and other factors, including pollutants; introduced species; and engineered structures such as dams, canals, levees, gates, and pumps adversely affect the fishes in the region, but they are not under the direct control of the CVP or the SWP, and thus are not subjects of the biological opinions.

The complexity of the problem of the decline of the listed species and the difficulty of identifying viable solutions have led to disagreements, including concerns that some of the actions in the RPAs might be ineffective and might cause harm and economic disruptions to water users, and that some of the actions specified in the RPAs to help one or more of the listed species might harm others. In addition, some have suggested that the agencies might be able to meet their legal obligation to protect species with less economic disruptions to other water users. Those concerns led the Department of the Interior and Congress to ask for advice from the National Research Council (NRC), which appointed a special committee of experts to carry out this study.

THE COMMITTEE'S CHARGE

The committee's charge includes the following tasks (the full statement of task is in Appendix A).

The committee was asked to undertake two main projects over a term of two years resulting in two reports. The first report, prepared on a very short timeline, was to address scientific questions, assumptions, and conclusions underlying water-management alternatives (i.e., the RPAs) in the two biological opinions mentioned above, and this is where the committee focused most of its attention. In addition, three specific issues were to be addressed. First, are there any "reasonable and prudent alternatives" (RPAs) that, based on the best avail-

able scientific data and analysis, would provide equal or greater protection for the listed species and their habitat while having lesser impacts to other water uses than those adopted in the biological opinions? Second, are there provisions in the biological opinions to resolve the potential for actions that would benefit one listed species while causing negative impacts on another? And finally, to the extent that time permits, the committee was asked to consider the effects of other stressors (e.g., pesticides, ammonia discharges, invasive species) on federally listed and other at-risk species in the Bay-Delta. The committee's second report, due in late 2011, will address how to most effectively incorporate science and adaptive management concepts into holistic programs for management and restoration of the Bay-Delta.

The committee's charge was to provide a scientific evaluation, not a legal one, and that is what the committee did. **Nothing in this report should be interpreted as a legal judgment as to whether the agencies have met their legal requirements under the ESA.** The committee's report is intended to provide a scientific evaluation of agency actions, to help refine them, and to help the general attempt to better understand the dynamics of the delta ecosystem, including the listed fishes.

THE COMMITTEE'S PRINCIPAL CONCLUSIONS

Context

The California Bay-Delta is a system that has undergone significant anthropogenic changes for more than a century. Those changes include water withdrawals; draining of wetlands; introduction of many nonnative species of plants and animals, some deliberate; construction of canals, gates, marinas, roads, levees, pumps, dams, and other structures that affect the hydrology of the system; the damming of almost all the major rivers and tributaries to the system, which also has altered the seasonal flow regime and other hydrologic aspects of the system; and the release of contaminants, pollutants, and nutrients into the system as a result of the above changes and the increase of agriculture, industrial and residential development, and other human activities. All these changes have affected the distribution, abundance, and composition of species in the delta, some of which have increased dramatically and some, including the species listed under the Endangered Species Act (Chinook salmon, delta smelt, steelhead, and green sturgeon), which have declined precipitously. The biological opinions with their associated RPAs that the committee has reviewed relate only to proposed changes in operations of the CVP and the SWP in the delta and

methods to reduce the adverse effects on the listed species of those changes. Some restrictions on CVP and SWP water diversions have been initiated to protect the listed fish species, but so far have not produced measurable effects in slowing their declines.

The committee concludes that reversing or even slowing the declines of the listed species cannot be accomplished immediately. Even the best-targeted methods of reversing the fish declines will need time to take effect amid changing environmental conditions such as multi-year droughts and continued pressures on the system from other human-caused stresses. Especially for fishes whose populations are very low already, the effects of any actions will be difficult to detect at first, and detecting them will be made more difficult by the effects of other environmental changes and uncertainties inherent in sampling small populations.

The FWS Biological Opinion and RPA

The committee considered the six actions contained within the RPA, most of which were judged to have a sound conceptual basis. The committee then focused on the RPA actions that involved Old and Middle River (OMR) flows, the management of the mean position of the contour where salinity is 2[1] (X2), and the creation or restoration of tidal habitat for smelt. The first two actions involve significant requirements for water; the third does not.

The management of OMR flows is predicated on the concept that pumping of water for export from the south delta creates net negative (toward the pumps) flows, averaged over the tidal cycle, that cause delta smelt (and some juvenile salmon) to be experience increased mortality in the south delta, especially in winter. The RPA action limits the net OMR flows to levels that depend on conditions during this period, with a variety of environmental triggers and adaptive-management procedures. **Although there are scientifically based arguments that raise legitimate questions about this action, the committee concludes that until better monitoring data and comprehensive life-cycle models are available, it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt populations. Thus, the concept of reducing OMR negative flows to reduce mortality of smelt at the SWP and CVP facilities is scientifically justified.**

[1] This is often expressed as a concentration, e.g., "2 parts per thousand," but more recently it has been expressed as a ratio of electrical conductivities, hence it has no units.

However, there is substantial uncertainty regarding the amount of flow that should trigger a reduction in exports. In other words, the specific choice of the negative flow threshold for initiating the RPA is less clearly supported by scientific analyses. The biological benefits and the water requirements of this action are likely to be sensitive to the precise values of trigger and threshold values. There clearly is a relationship between negative OMR flows and mortality of smelt at the pumps, but the data do not permit a confident identification of the threshold values to use in the action, and they do not permit a confident assessment of the benefits to the population of the action. As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management, and additional analyses that permit regular review and adjustment of strategies as knowledge improves.

The management of the mean position of X2 during the fall (Action 4 of the FWS RPA) is based on observations that relate smelt use of spawning habitat with various salinity regimes. X2 is interpreted by the agencies not as a single line, but rather as an indicator of the spatial pattern of salinity in the delta and thus as indicative of the extent of habitat favorable for delta smelt.

The relationships among smelt abundance, habitat extent, and the mean position of X2 as an indicator of available habitat are complex. The controversy about the action arises from the poor and sometimes confounding relationship between indirect measures of delta smelt populations (indices) and X2. Although there is evidence that the position of X2 affects the distribution of smelt, the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand. In addition, although the position of X2 is correlated with the distribution of salinity and turbidity regimes, the relationship of that distribution and smelt abundance indices is unclear. **The X2 action is conceptually sound in that to the degree that the amount of habitat available for smelt limits their abundance, the provision of more or better habitat would be helpful. However, the derivation of the details of this action lacks rigor.** The action is based on a series of linked statistical analyses (e.g., the relationship of presence/absence data to environmental variables, the relationship of environmental variables to habitat, the relationship of habitat to X2, the relationship of X2 to smelt abundance). Each step of this logical train of relationships is uncertain. The relationships are correlative with substantial variance left unexplained at each step, yet the analyses do not carry the uncertainty at each step to the next step. The action also may have high water requirements and may adversely affect salmon and steelhead under some conditions. **As a result, the committee concludes that how specific X2 targets were chosen and their likely beneficial effects need further clarification. It also is critical that the adaptive-management requirements**

included in the RPA be implemented in light of the uncertainty about the biological effectiveness of the action and its possibly high water requirements.

The tidal habitat management action in the RPA requires creation or restoration of 8,000 acres of intertidal and subtidal habitat in the delta and in Suisun Marsh. This action has not been controversial because it does not affect other water users. **The committee finds that the conceptual foundation for this action (Action 6) is weak because the relationship between tidal habitats and food availability for smelt is poorly understood. The details of its implementation are not fully justified in the biological opinion. The committee recommends that this action be implemented in phases, with the first phase to include the development of an implementation and adaptive management plan (similar to the approach used for the floodplain habitat action in the NMFS biological opinion), but also to explicitly consider the sustainability of the resulting habitats, especially those dependent on emergent vegetation, in the face of expected sea-level rise.** In addition, there should be consideration of the types and amounts of tidal habitats necessary to produce the expected outcomes and how they can be achieved and sustained in the long term. The committee supports the monitoring program referred to in Action 6, and appropriate adaptive management triggers and actions.

The NMFS Biological Opinion and RPA

The NMFS RPA for salmon, steelhead, and green sturgeon is a broad complex of diverse actions spanning three habitat realms: tributary watersheds, the mainstem Sacramento and San Joaquin Rivers, and the delta. **On balance, the committee concludes that the actions, which are primarily crafted to improve life-stage-specific survival rates for salmon and steelhead, with the recognition that the benefits also will accrue to sturgeon, are scientifically justified.** The strategies underpinning many of the individual actions are generally well supported by more than a decade of conceptual model building about the requirements of salmonids in the region, although the extent to which the intended responses are likely to be realized is not always clearly addressed in the RPA. Given the absence of a transparent, quantitative framework for analyzing the effects of individual and collective actions, it is difficult to make definitive statements regarding the merits of such a complex RPA. Indeed, absent such an analysis, the controversial aspects of some of the RPA actions could detract from the merits of the rest of the RPA.

In general, as described in detail in Chapter 6, the committee concludes that although most, if not all, of the actions in this RPA had a sound conceptual basis, the biological benefits and water requirements of several of the actions are, as with the delta smelt actions, likely quite sensitive to the specific triggers, thresholds, and flows specified. As a result, the committee recommends that the specific triggers, thresholds, and flows receive additional evaluation that is integrated with the analyses of similar actions for delta smelt.

In particular, the committee concludes that it is difficult to ascertain to what extent the collective watershed and tributary actions will appreciably improve survival within the watershed or throughout the entire river system. The committee concludes that the actions to improve mainstem passage for salmonids and sturgeon, in particular those concerning the Red Bluff Diversion Dam, are well justified scientifically. The committee recommends some kind of quantitative assessment framework for assessing survival be developed and implemented.

The management of OMR flows to reduce entrainment mortality of salmon smolts is similar in concept to the smelt OMR action, and like that action, **the committee concludes that its conceptual basis is scientifically justified, but the scientific support for specific flow targets is less certain. Uncertainty in the effect of the triggers should be reduced, and more-flexible triggers that might require less water should be evaluated.**

Another set of actions in this RPA focuses on managing exports and flows in the San Joaquin River to benefit outmigrating steelhead smolts. The actions are intended to reduce the smolts' vulnerability to entrainment into the channels of the south delta and the pumps by increasing the inflow-to-export ratio of water in the San Joaquin River. It thus has two components: reducing exports and increasing San Joaquin River inflows into the delta. **The committee concludes that the rationale for increasing San Joaquin River flows has a stronger foundation than does the prescribed export action. We further conclude that the action involving a six-year study of smolt survival would provide useful insight into the effectiveness of the actions as a long-term solution.**

The final two actions considered here were improving the migratory passage of salmon and sturgeon through the Yolo Bypass and the inundation of additional floodplain lands to provide additional rearing habitat for juvenile salmon. **The committee concludes that both actions are scientifically justified, but the implications for the system as a whole of routing additional flows through the Yolo Bypass for the system were not clearly analyzed.** In particular, the consequences of the action for Sacramento River flows and for the potential mobilization of mercury were not clearly described.

Other Possible RPAs

The committee's charge requires the identification, if possible, of additional potential RPAs that might have the potential to provide equal or greater protection to the fishes than the current RPAs while costing less in terms of water availability for other uses. **The committee considered a variety of possible actions not in the RPAs (see Chapter 6), and concluded that none of them had received sufficient documentation or evaluation to be confident at present that any of them would have the potential to provide equal or greater protections for the species while requiring less disruption of delta water diversions.**

Other Stressors

Based on the evidence the committee has reviewed, the committee agreed that the adverse effects of all the other stressors on the listed fishes are potentially large. Time did not permit full exploration of the issue in this first report, but examples of how such stressors may affect the fishes are described. The committee will explore this issue more thoroughly in its second report.

Modeling

The committee reviewed the models the agencies used to understand the basis for the resource agencies' jeopardy opinion and to determine to what degree they used the models in developing the RPAs. **The committee concluded that as far as they went, despite flaws, the individual models were scientifically justified, but that they needed improvements and that they did not go far enough toward an integrated analysis of the RPAs. Thus the committee concluded that improving the models by making them more realistic and by better matching the scale of their outputs to the scale of the actions, and by extending the modeling framework to be more comprehensive and to include features such as fish life cycles would improve the agencies' abilities to assess risks to the fishes, to fine-tune various actions, and to predict the effects of the actions.**

Potential Conflicts Between RPAs and Integration of RPAs

The committee concludes that the RPAs lack an integrated quantitative analytical framework that ties the various actions together within species, between smelt and salmonid species, and across the watershed. This type of systematic, formalized analysis, although likely beyond the two agencies' legal obligations when rendering two separate biological opinions, is necessary to provide an objective determination of the net effect of all their actions on the listed species and on water users.

An additional overall, systematic, coordinated analysis of the effect of all actions taken together and a process for implementing the optimized, combined set of actions is required to establish the credibility of the effort overall. The committee is aware that instances of coordination among the agencies certainly exist, including modification of actions to reduce or eliminate conflicting effects on the species. Indeed, the committee did not find any clear example of an action in one of the RPAs causing significant harm to the species covered in the other RPA. But coordination is not integration. The lack of a systematic, well-framed overall analysis is a serious scientific deficiency, and it likely is related to the ESA's practical limitations as to the scope of actions that can or must be considered in a single biological opinion. The interagency effort to clearly reach consensus on implications of the combined RPAs for their effects on all the species and on water quality and quantity within the delta and on water operations and deliveries should use scientific principles and methods in a collaborative and integrative manner. Similarly, this committee's efforts to evaluate potential harmful effects of each RPA on the species covered in the other RPA were hampered by the lack of a systematic, integrated analysis covering all the species together. Full documentation of decisions should be part of such an effort, as should inclusion of the environmental water needs of specific actions and for the entire RPA.

It is clear that integrative tools that, for example, combine the effect over life stages into a population-level response would greatly help the development and evaluation of the combined actions. There has been significant investment in hydrological and hydrodynamic models for the system, which have been invaluable for understanding and managing the system. An investment in ecological models that complement and are integrated with the hydrological and hydrodynamics models is sorely needed. Clear and well-documented consideration of water requirements also would seem well advised because some of the actions have significant water requirements. Credible documentation of the water needed to implement each action and the combined actions, would enable an even clearer and more logical formulation of how the suite of actions might be

coordinated to simultaneously benefit the species and ensure water efficiency. **This recommendation for integration of models and across species responds to the committee's broad charge of advising on how to most effectively incorporate scientific and adaptive-management concepts into holistic programs for managing the delta, and likely goes beyond the agencies' legal obligations under the ESA, and will be addressed more thoroughly in the committee's second report.**

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Committee on Sustainable Water and Environmental Management in the California Bay-Delta

Water Science and Technology Board

Ocean Studies Board

Division on Earth and Life Studies

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COMMITTEE ON SUSTAINABLE WATER AND ENVIRONMENTAL MANAGEMENT IN THE CALIFORNIA BAY-DELTA*

ROBERT J. HUGGETT, *Chair*, Professor Emeritus, College of William and Mary, Seaford, Virginia
JAMES J. ANDERSON, University of Washington, Seattle
MICHAEL E. CAMPANA, Oregon State University, Corvallis
THOMAS DUNNE, University of California, Santa Barbara
ALBERT E. GIORGI, BioAnalysts, Inc., Redmond, Washington
PATRICIA M. GLIBERT, University of Maryland Center for Environmental Science, Horn Point Laboratory, Cambridge
CHRISTINE A. KLEIN, University of Florida College of Law, Gainesville
SAMUEL N. LUOMA, John Muir Institute of the Environment, University of California, Davis
MICHAEL J. MCGUIRE, Michael J. McGuire, Inc., Santa Monica, California
THOMAS MILLER, University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, Maryland
JAYANTHA OBEYSEKERA, South Florida Water Management District, West Palm Beach
MAX J. PFEFFER, Cornell University, Ithaca, New York
DENISE J. REED, University of New Orleans, New Orleans, Louisiana
KENNETH A. ROSE, Louisiana State University, Baton Rouge
DESIREE D. TULLOS, Oregon State University, Corvallis

NRC Staff

DAVID POLICANSKY, NRC Study Director, Scholar
LAURA J. HELSABECK, Deputy Study Director
STEPHEN D. PARKER, WSTB Director, Scholar
SUSAN ROBERTS, OSB Director
ELLEN A. DE GUZMAN, Research Associate
HEATHER CHIARELLO, Senior Program Assistant

* Biographical information for committee members is in Appendix E. This project was organized and overseen by the NRC's Water Science and Technology Board (lead) and Ocean Studies Board, whose rosters are in Appendixes B and C, respectively.

Preface

California, like many states, faces challenges related to water. Much of the state is too dry to support many human activities, such as municipal and industrial water use and irrigated agriculture, without supplementing the natural water supply. It has done this through an extensive series of engineering projects that include reservoirs, canals, levees, and pumps, largely to move water from the more humid north to the more arid and densely populated south. Much of California's natural surface-water supply flows into and through the Sacramento and San Joaquin watersheds into California's Bay-Delta, and from there through San Francisco Bay into the ocean. The delta itself is a biologically diverse estuarine ecosystem, and is the main point of diversion for water that is transported to the south.

As California's population and economic activity have increased, along with water diversions from the delta, conflicts over various water uses have increased as well, especially surrounding the bay-delta. Those conflicts have been brought to a head by restrictions on water diversions that have been required by two biological opinions, one by the U.S. Fish and Wildlife Service, covering delta smelt, and one by the National Marine Fisheries Service, covering salmon, steelhead, and sturgeon, to protect those fishes, which are listed as threatened or endangered under the federal Endangered Species Act. In addition, several recent dry years have exacerbated the situation. Conflicts over water are not new in California, but the current conflicts over the bay-delta appear to be unprecedented in their scale. Few parts of the state are unaffected by what happens to delta water.

Protecting all the listed species and preserving existing and projected uses of the region's water is a serious challenge. The complexity of the problem and the difficulty of identifying solutions have been highlighted by a plethora of scientific publications and arguments, in which many qualified and distinguished experts have reached differing conclusions. Nobody disagrees that engineering changes; the introduction of many exotic species, the addition of contaminants to the system, and the general effects of an increasing human population have contributed to the fishes' declines. There are, however, disagreements

about the relative contributions of those factors and the appropriate remedies for them. This is the context in which the National Research Council was asked by Congress and the Department of the Interior to help resolve the issue by evaluating the scientific bases of the biological opinions. In response, the NRC appointed a special committee of experts to carry out a complex and challenging study in two phases.

In its first phase, the committee was tasked to focus on the scientific bases of the reasonable and prudent alternatives (RPAs) in the two biological opinions. The committee also assessed whether the RPAs might be in conflict with one another, as well as whether other options might be available that would protect the fishes with lesser impacts on other water uses. Finally, we were asked to consider the effects of "other stressors" on the fishes if sufficient time were available. The results of this first-phase analysis are the subject of this report. The committee did consider other stressors, but it did not evaluate them in depth. They will be more thoroughly addressed in a second report, scheduled to be published late in 2011, which will focus on broader issues surrounding attempts to provide more sustainable water supplies and to improve the ecological sustainability of the delta, including consideration of what ecological goals might be attainable.

The committee met in Davis, California for five days in January 2010. The committee heard presentations from representatives of federal and state agencies and a variety of other experts, and from members of several stakeholder groups and the public (see Appendix D). The information gathering sessions of this meeting were open to the public and widely advertised. The committee sought to hear from as many groups and individuals as possible within the time constraints. All speakers, guests, and members of the public were encouraged to provide written comments during and after the meeting. All presentations and written materials submitted were considered by the committee as time allowed. The committee thanks all the individuals who provided information.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise in accordance with the procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the NRC in making its published report as sound as possible, and to ensure that the report meets NRC institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following for their reviews of this report: Joan G. Ehrenfeld, Rutgers University; Mary C. Fabrizio, Virginia Institute of Marine Science; Peter Gleick, Pacific Institute; William P. Horn, Birch, Horton, Bittner & Cherot;

D. Peter Loucks, Cornell University; Jay Lund, University of California, Davis; Tammy Newcomb, Michigan Department of Natural Resources; and Andrew A. Rosenberg, Conservation International.

Although these reviewers provided constructive comments and suggestions, they were not asked to endorse the report's conclusions and recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Michael Kavanaugh, Malcolm Pirnie, Inc., who was appointed by the NRC's Report Review Committee and by Leo Eisel, Brown and Caldwell, who was appointed by the NRC's Division on Earth and Life Studies. They were responsible for ensuring that an independent examination of this report was conducted in accordance with NRC institutional procedures and that all review comments received full consideration. Responsibility for this report's final contents rests entirely with the authoring committee and the NRC.

I am enormously grateful to my committee colleagues for their diligence, enthusiasm, persistence, and hard work. The schedule for the preparation of this report was short, and without everyone's engagement, it could not have been completed. I also am grateful to David Policansky, Stephen Parker, Laura Helsabeck, Heather Chiarello, Ellen de Guzman, and Susan Roberts of the NRC staff for their efforts in facilitating the committee's meeting and for their work in helping to get this report completed on schedule in the face of historic snowstorms.

California will continue to face great challenges in managing, allocating, and using water, including managing California's Bay-Delta. We hope the committee's reports can help in that difficult process.

Robert J. Huggett
Chair

Contents

Acronyms and Abbreviations

AF	Acre-feet
BA	Biological Assessment
BO	Biological Opinion
(C)DFG	California Department of Fish and Game
(C)DWR	California Department of Water Resources
C.F.R.	Code of Federal Regulations
Cir	Circuit Court (federal system)
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DCC	Delta Cross Channel
DOI	(U.S.) Department of the Interior
DSM2	Delta Simulation Model II
EDT	Ecosystem Diagnosis and Treatment
ESA	Endangered Species Act
EWA	Environmental Water Account
FMT	Fall Midwater Trawl (survey)
FWS	(U.S.) Fish and Wildlife Service
HORB	Head of Old River Barrier
MAF	Million acre-feet
M&I	Municipal and Industrial
NAS	National Academy of Sciences
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OCAP	Operations Criteria And Plan
OMR	Old and Middle River
OSB	Ocean Studies Board of the NRC
PTM	Particle-Tracking Model
RBDD	Red Bluff Diversion Dam
RPA	Reasonable and Prudent Alternative
SWP	State Water Project
TAF	Thousand acre-feet
USBR	United States Bureau of Reclamation
U.S.C.	United States Code
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Plan
WSTB	Water Science and Technology Board of the NRC
X2	Contour line of salinity 2