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

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6

Assessment of the RPAs

INTRODUCTION

The RPAs include many specific actions that fall into several categories for each species. The RPA in the FWS biological opinion for delta smelt focuses on limiting OMR negative flows in winter to protect migrating adults (Actions 1 and 2) and to protect larval smelt (Action 3) from entrainment at the export pumps. It also aims to protect estuarine habitat for smelt during the fall by managing the position of X2 (Action 4). Action 5 is to protect larval and juvenile smelt from entrainments by refraining from installing the Head of Old River Barrier (HORB) depending on conditions; if the HORB is installed, then the Temporary Barrier Project's gates would remain open. Finally, Action 6 calls for restoration and construction of 8,000 acres of intertidal and tidal habitat.

The RPA in the NMFS biological opinion for Chinook salmon, Central Valley steelhead, and green sturgeon is divided into far too many specific actions (72) to summarize here, but the biological opinion describes 10 major effects of the RPA on the listed species. They include management of storage and releases to manage temperature in the Sacramento River for steelhead and salmon; maintaining flows and temperatures in Clear Creek for spring-run Chinook salmon; opening gates at the Red Bluff Diversion Dam (RBDD) at critical times to promote passage for salmon and sturgeon; improving rearing habitat for salmon in the lower Sacramento River and in the northern delta; closure of the gates of the Delta Cross Channel (DCC) at critical times to keep juvenile salmon and steelhead out of the interior delta and instead allowing them to migrate out to sea; limiting OMR negative flows to avoid entrainment of juvenile salmon; increased flows in the San Joaquin River and curtailment of water exports to improve survival of San Joaquin steelhead smolts, along with an acoustic tagging program to evaluate the effectiveness of this action; flow and temperature management on the American River for steelhead; a year-round flow regime on the Stanislaus River to benefit steelhead; and the development of Hatchery Genetics Management Plans at the Nimbus (American River) and Trinity River hatcheries to benefit steelhead and fall-run Chinook salmon.

Rather than review every action and every detail, the committee comments on the broader concepts at issue and general categories of actions. Three important goals are to consider how well the RPAs are based on available scientific information; whether there are any potential RPAs not adopted that would have lesser impacts to other water uses as compared to those adopted in the biological opinions, and would provide equal or greater protection for the listed fishes; and whether there are provisions in the FWS and NMFS biological opinions to resolve potential incompatibilities between them. In addition we assess the integration of the RPAs within and across species and across all actions.

Addressing these goals requires explicitly recognizing the fundamental differences in the main conflicting arguments. There is concern, on one hand, that the increasing diversions of water from the delta over a period of many decades and the alteration of the seasonal flow regime have contributed to direct effects on populations of native species through mortality at the pumps, changes in habitat quality, and changes in water quality; and to indirect, long-term effects from alterations of food webs, biological communities, and delta-wide habitat changes. The RPAs propose that their collective effects will offset the impacts of the proposed operations of the SVP and the CWP by manipulating river flows and diversions, along with other actions. An alternative argument is that the effects of water diversions on the listed fishes are marginal. It is argued that the changes imposed by the RPAs would result, therefore, only in marginal benefits to the species, especially now that the delta environment and its biota have been altered (to a new ecological baseline) by multiple stressors. Those stressors obviously include water exports, but this argument suggests a smaller role for water exports in causing the fish declines and hence a smaller role for managing the exports to reduce or halt those declines. However, even with the copious amounts of data available, it is difficult to draw conclusions about what variable or variables are most important among the pervasive, irregular, multivariate changes in the system that have occurred over the past century.

The committee's charge was to provide a scientific evaluation, not a legal one, and that is what is presented below. 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.

DELTA SMELT

Actions Related to Limiting Flow Reversal on the Old and Middle Rivers (OMR)

The general purpose of this set of actions is to limit the size of the zone of influence around the water-diversion points at critical times. The actions would limit negative OMR flows (i.e., toward the pumps) by controlling water exports during crucial periods in winter (December through March) when delta smelt are expected to be in the central delta (FWS, 2008). The data supporting this approach show an increase in salvage of delta smelt as OMR flows become more negative. However, there are important disagreements about how to express salvage and the choice of the trigger point or threshold in negative flows above which diversions should be limited.

An important issue is whether and how salvage numbers should be normalized to account for delta smelt population size. An increase in salvage could be due to an increase in the number of smelt at risk for entrainment, an increase in negative flows that bring smelt within range of the pumps, or both. Thus, an increase in salvage could reflect a recovery of the smelt population or it could reflect increasingly adverse flows toward the pumps for the remaining smelt population. The biological opinion (FWS, 2008) recognizes this relationship, and that is why salvage is used to calculate the percentage of the population entrained, rather than absolute numbers (FWS, 2008, Figures E-4 and E-5). However, the historical distribution of smelt on which the relationship with OMR flows was established no longer exists. Delta smelt are now sparsely distributed in the central and southern delta (*www.dfg.ca.gov/delta/data*), and pump salvage also has been extremely low, less than four percent of the 50-year average index. Since 2005, a significant portion of the remaining smelt population, 42 percent (Sommer et al., 2009), is in the Cache Slough complex to the north and is therefore largely isolated from the central delta. These changes in the distribution of delta smelt increase the uncertainty surrounding current estimates of the population and its likely response to alterations in delta hydraulics, and until the numbers of smelt rise closer towards the pre-2005 levels, they do not provide a reliable index for incorporation into models for the effects of pumping on smelt salvage.

Different authors have taken different statistical approaches to analyzing the data to interpret the relationship between OMR flows and effects on smelt, and thus chose different thresholds at which OMR flows should be limited. The choice of the limit to negative flows in the RPA gives the benefit of the doubt to the species. But there are important uncertainties in the choice. The different trigger points suggested by the different analyses have important implications for water users. The committee concludes that until better monitoring data and comprehensive life-cycle and fish-movement models are available, it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt. We note as well that actions 1 and 2 of the FWS RPA are adaptive in that they depend for their implementation on a trigger related to measured turbidity and measured salvage numbers; they also may be suspended during three-day average flows of 90,000 cfs or greater in the Sacramento River at Rio Vista and 10,000 cfs or greater in the San Joaquin River at Vernalis. However, the portion of the existing smelt population in the Cache Slough complex appears not to move downstream towards the brackish areas (Sommer et al., 2009) and thus they should be largely insulated from the effects of the OMR flows and actions 1 and 2.

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 OMR flows and salvage rates, but the available 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.

Some monitoring and reporting is required in RPA component 5 (monitoring and reporting). However, more should be required, recognizing limits to the agencies' and operators' human and fiscal resources. Given the uncertainties in any choice of a trigger point, a carefully designed study that directly addresses measures of the performance (effectiveness) of the action is essential. This could include monitoring of variables like salvage at the pumps and numbers of delta smelt adults and larvae at the south ends of OMR channels during pumping actions, but it should also include other variables that might affect both salvage and populations. History shows that salvage and delta smelt indices have been insufficient for such an analysis alone, partly because the populations are small and partly because of the uncertainties in the salvage numbers (e.g., to what degree do they accurately reflect mortality, and to what degree are they affected by sampling error?). This deficiency in the data needs to be remedied. But other "proximate" measures such as monitoring of flows over the tidal cycle between and during the pumping limitations could help to understand the driving mechanism for the predicted entrainment mortality associated with pumping. Measuring mean daily discharges also is not sufficient. Temperature, salinity, turbidity, and possibly other environmental factors should also be monitored at appropriate scales as this action is implemented, to determine the availability of suitable habitat in the south delta during periods of reduced pumping. Information also is needed on how fish movement is affected by the immediate water-quality and hydraulic environment they experience. Because the effectiveness of the pumping needs to be expressed in terms of the population, the influence of pumping needs to be identified in more life-stage and area specific measures, In particular, the relevance of the Cache Slough complex needs to be resolved in assessing the effectiveness of pumping restrictions. In addition, because uncertainty is high regarding several aspects of this action, it would be helpful to include an accounting of the water requirements. Ongoing evaluation of performance measures could ultimately reduce the water requirements of actions and increase the benefits to the species. Addressing the effectiveness of the proposed actions on a long-term basis could also support consensus conclusions about the effectiveness of specific actions and increase public trust. To the degree that such studies could be jointly planned and conducted by the agencies and other interested parties, transparency and public trust would be enhanced.

X2 Management for Delta Smelt

Although the mean position of X2, the isohaline (contour line of equal salinity) of total salinity 2, is a measure of the location of a single salinity characteristic, it is used in this system to indicate the position and nature of the salinity gradient between the Sacramento River and San Francisco Bay. The position of X2 is measured in kilometers from the Golden Gate Bridge. In the RPA, it has been used by the agencies as a measure of the amount of smelt habitat—influenced by salinity as well as temperature and turbidity, which are also driven by the river-estuary interaction—and thus to approximate the seasonal extent and shifting of that habitat within the ecosystem. By this reasoning, the position of X2 affects the size of delta smelt habitat (Feyrer et al., 2007; Kimmerer, 2008a).

The RPA's action 4 (FWS, 2008, page 369) proposes to maintain X2 in the fall of wet years at 74 km east of the Golden Gate Bridge and in above-normal years at 81 km east. (The action was restricted to wetter years in response to consultation with the NMFS, which expressed concern that in drier years, this action could adversely affect salmon and steelhead [memorandum from FWS and NMFS to this committee on coordination, January 15, 2010].) The action is to be achieved primarily by releases from reservoirs. The objective of the component is to manage X2 to increase the quality and quantity of habitat for delta smelt growth and rearing.

The relationship between the position of X2 and habitat area for delta smelt, as defined by smelt presence, turbidity, temperature, and salinity (Nobriga et al, 2008; Feyrer et al., in review), is critical in designing this action. A habitat-area index was derived from the probability of occurrence estimates for delta smelt (fall mid-water trawl survey, FMT) when individuals are recruiting to the adult population. Presence/absence data were used because populations are so small that quantitative estimates of populations probably are unreliable. The authors show a broad relationship between the FMT index and salinity and turbidity, supporting the choice of these variables as habitat indicators. The statistical relationship is complex. When the area of highly suitable habitat as defined by the indicators is low, either high or low FMT indices can occur. In other words, delta smelt can be successful even when habitat is restricted. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha. This could mean that reduced habitat area is a necessary condition for the worst population collapses, but it is not the only cause of the collapse. Thus, the relationship between the habitat and FMT indexes is not strong or simple. Above a threshold on the x-axis it allows a response on the y-axis (allows very low FMT indices).

The controversy about the action arises from the poor and sometimes confounding relationship between indirect measures of delta smelt populations (indices) and X2. 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 (Feyrer et al., 2007), the relationship of that distribution and smelt abundance indices is unclear. The X2 action is conceptually sound in that to the degree that habitat for smelt limits their abundance, the provision of more or better habitat would be helpful. However, the examination of uncertainty in 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), with each step being uncertain. The relationships are correlative with substantial variance being left unexplained at each step. The action also may have high water requirements and may adversely affect salmon and steelhead under some conditions (memorandum from FWS and NMFS, January 15, 2010). As a result, how specific X2 targets were chosen and their likely beneficial effects need further clarification.

The X2 action for delta smelt includes a requirement for an adaptive management process that includes evaluation of other possible means of achieving the RPA's goal and it requires the establishment and peer review of performance measures and performance evaluation. It also requires "additional studies addressing elements of the habitat conceptual model" to be formulated as soon as possible and to be implemented promptly. Finally, it requires the FWS to "conduct a comprehensive review of the outcomes of the Action and the effectiveness of the adaptive management program ten years from the signing of the biological opinion, or sooner if circumstances warrant." This review is to include an independent peer review; the overall aim is to decide whether the action should be continued, modified, or terminated. It is critical that these requirements be implemented in light of the uncertainty about the biological effectiveness of the action and its high water requirements.

Tidal Habitat Action

The proposed RPA calls for the creation or restoration of 8,000 acres of intertidal and associated subtidal habitat in the delta and in Suisun Marsh. A separate planning effort also is under way for Suisun Marsh. The justification provided in the biological opinion is that the original amount of approximately 350,000 acres of tidal wetland has been reduced to less than 10,000 acres today, that the near-complete loss of tidal wetlands threatens delta smelt by reducing productivity at the base of the food web, and that delta smelt appear to benefit from the intertidal and subtidal habitat in Liberty Island, which includes tidal wetlands. This action has been less controversial than the others because it does not directly affect other water users.

However, although the concept of increasing and improving habitat to help offset other risks to smelt is conceptually sound, the scientific justification provided in the biological opinion is weak, because the relationship between tidal habitat and food availability for smelt is poorly understood, and it is inadequate to support the details of the implementation of this action. The opinion notes the importance of high-quality food sources to delta smelt and the association of these food resources with tidal habitats (including wetlands), and it references recent monitoring data from Liberty Island showing that such freshwater tidal habitats can be a source of high-quality phytoplankton that contribute to the pelagic food web downstream (p. 380). However, the specifics of which attributes of tidal habitat are essential to providing these food sources are not addressed.

In addition, the California Department of Fish and Game has raised questions about the details of this action (Wilcox, 2010). They include questions about the relative benefits of vegetated tidal marsh as opposed to open water; the extent to which invasive clams may divert new primary production; the amount of suitable productivity exported from restoration areas; the potential effect of the restored habitat on predation; the importance of productivity from vegetated tidal marsh directly or indirectly to the smelt; and the degree to which other fish species might use the habitat, possibly to the detriment of the smelt In briefings to the panel, the importance of ongoing studies in resolving these issues was identified. Identifying the characteristics of the "intertidal and associated subtidal habitat" that the action is expected to produce is needed to ensure that expectations of the outcomes, in terms of both habitat type and species benefits, are clear to all. The relative roles of areas of emergent vegetation, unvegetated intertidal and shallow, highly turbid subtidal habitat must be identified for the action to be effectively implemented.

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. More justification for the extent of the restoration is needed. The committee supports the monitoring program referred to in Action 6, and appropriate adaptive management triggers and actions.

SALMONIDS AND STURGEON

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 actions 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. The committee agrees with this approach. The conceptual bases of the strategies underpinning many of the individual actions are generally well-founded, although the extent to which the intended responses are likely to be realized is not always clear. Given the absence of a clear, 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.

The assortment of actions among the three habitat realms (watersheds, mainstem rivers, and delta) is designed to improve survival and to enhance connectivity throughout this system. This approach is consistent with the contemporary scientific consensus on improving ecosystem functioning as a means to improve productivity of anadromous and other migratory species (e.g., NRC 1996, 2004a, 2004b; Williams 2005). Watershed actions would be pointless if mainstem passage conditions connecting the tributaries to, and through, the delta were not made satisfactory.

Watershed and Mainstem River Actions

Watershed-level actions that are implemented in the tributaries are organized and formulated to meet the needs of specific listed populations in that system. The actions target limiting factors specific to those locales and populations. In general, the rationale for conducting the actions appears to be well-founded. However, it is difficult to ascertain to what extent, or even whether, the collective actions will appreciably reduce the risk to the fishes within the watershed or throughout the entire river system. We suggest that inclusion of some type of quantitative analysis using a tool like Ecosystem Diagnosis and Treatment (EDT) model during the planning process may have provided an even stronger justification for the set of actions selected (*http://jonesandstokes.com/*). We understand there is a recent application of EDT in the lower San Joaquin River, by Jones & Stokes, thus providing a precedent for its use in California's Central Valley. EDT is presented here as an example of a quantitative modeling approach that integrates the effects of various actions to produce relative changes in productivity and abundance. The committee emphasizes the need for a quantitative assessment framework, and does not necessarily specifically advocate the use of EDT.

The RPA also prescribes actions to improve mainstem passage conditions, most notably at the Red Bluff Diversion Dam (RBDD). The objective is to provide unobstructed upstream passage at the RBDD, to ensure more efficient access of adult salmonids to restored watersheds, and access for adult sturgeon to spawning grounds. Without such actions connectivity could not be fully realized. Furthermore, the passage improvement at the diversion dam, in combination with increased water delivery from storage reservoirs, is expected to improve smolt survival during downstream migration. This component is well justified scientifically, although the absence of a system-wide salmon survival model limits our ability to evaluate the extent to which this action contributes to improved survival for the populations in question.

Smolt Survival Near and Through the Delta

The net survival of salmonid smolts though the mainstem rivers and the delta under different water-management operations is of keen interest. Several RPA actions are intended to improve survival of the juveniles as they migrate seaward. Some of these actions have significant water requirements, and so they are controversial. The common goal of these actions is improve smolt survival by retaining a high proportion of the migrating smolt population in the mainstem Sacramento and San Joaquin Rivers. This involves two general approaches: block entrances to the interior delta, or manipulate currents in major channels to reduce the transport of smolt towards the pump facilities and possible entrainment or locations where they may be lost to predation, starvation, or disease. Here we focus on three pivotal actions: the closure of the Delta Cross Channel, the manipulation of OMR flows, and water-management actions in the lower San Joaquin River.

Delta Cross Channel (DCC)

As smolts migrate seaward from the upper Sacramento River they encounter the DCC near Walnut Grove. The DCC can at times draw large volumes of water from the Sacramento River, and some of the smolts follow that current toward the interior delta, where salmon mortality is high.

The objective of this action is to physically block the entrance of the DCC at strategic times during the smolt migration, thereby preventing access to the interior delta. This is a long-standing action that appears to be scientifically justified. However, Burau et al. (2007) estimated that when the DCC gates are open, approximately 45 percent of the Sacramento River flow measured at Freeport is redirected into the delta interior through the DCC and Georgiana Slough. The salmon action (Action Suite IV.1), which under certain triggers requires prolonged closure of the DCC gates from October 1 through June 15, must also consider the effects on delta smelt. The Smelt Working Group (notes from June 4, 2007 meeting) concluded that there could be a small beneficial effect on delta smelt from having the DCC gates open from late May until mid-June.

Although this action does not appear to constitute an important conflict between the needs of smelt and salmon, it illustrates the potential for conflict among the two opinions and the need for closer integration of the actions within the delta that have consequences for more than one of the listed species. This is an example where a systematic analysis of the implications for both species of actions would seem to be a scientific requirement.

Managing OMR Flows for Salmonids

This RPA action (IV.2.3, Old and Middle River Flow Management) also seeks to limit smolt excursion into part of the delta associated with high smolt mortality, but it does so by manipulating current direction and intensity within the Old and Middle River (OMR) drainages. The objective is to reduce current velocity toward the SWP and CVP facilities, thereby exposing fewer smolts to pump entrainment and being drawn into other unfavorable environments.

To accomplish the objective, the action calls for, reducing exports from January 1 through June 15, as necessary, to limit negative OMR flows to -2,500 to -5,000 cfs, depending on the presence of salmonids. The reverse flow will be managed within this range to reduce flows toward the pumps during periods of increased salmonid presence. The flow range was established through correlations of OMR flow and salmon entrainment indices at the pumps, and from entrainment proportions derived using the particle-tracking model (PTM). While the flow management strategy is conceptually sound, the threshold levels needed to protect fish is not definitively established. The response of loss at the pumps to OMR flow (e.g. figure 6-65 from NMFS, 2009) does not suggest a significant change in the vicinity of the flow triggers, but it does suggest that the loss rate increases exponentially above the triggers. The PTM suggests a gradual linear response in the vicinity of the trigger. However, no analysis was presented for the entrainment rate above the trigger (Figure 6-68 from NMFS, 2009), and it is not clear whether the salvage *rates* as well as salvage numbers were modeled. Therefore, the committee is unable to evaluate the validity of the exponential increase in loss rate above the trigger. Uncertainty in the effect of the flow triggers needs to be reduced, and more flexible triggers that might require less water should be evaluated.

The committee concludes that the strategy of limiting net tidal flows toward the pump facilities is sound, but the support for the specific flows targets is less certain. In the near-term telemetry-based smolt migration and survival studies (e.g, Perry and Skalski, 2008) should be used to improve our understanding of smolt responses to OMR flow levels. Reliance on salvage indices or the PTM results alone is not sufficient.

Additionally, there is little direct evidence to support the position that this action alone will benefit the San Joaquin salmon, unless it is combined with an increase in San Joaquin River flows. Furthermore, we understand this and other flow management actions are coordinated with the delta smelt actions. But we found no quantitative analysis that integrates across the actions to systematically evaluate their aggregate effects on both salmonids and smelt. Understanding those interactions will benefit from the development and use of multiple single-species models, including movement models.

Managing Exports and Flows in the San Joaquin River

The objective of this action (IV.2.1) is to reduce the vulnerability of emigrating Central Valley steelhead within the lower San Joaquin River to entrainment into the channels of the south delta and at the pumps by increasing the inflow-to-export ratio. It seeks to enhance the likelihood of salmonids' successfully exiting the delta at Chipps Island by creating more suitable hydraulic conditions in the mainstem of the San Joaquin River for emigrating fish, including greater net downstream flows.

The action has two components: reducing exports, and augmenting San Joaquin River flows at Vernalis. The rationale that increasing San Joaquin inflows to the delta will benefit smolt survival through this region of the delta is based on data from coded-wire tags on smolts. This statistical evidence provides only a coarse assessment of the action, but it indicates that increasing San Joaquin River flows can explain observed increases in escapement. Historical data indicate that high San Joaquin River flows in the spring result in higher survival of outmigrating Chinook salmon smolts and greater adult returns 2.5 years later (Kjelson et al., 1981; Kjelson and Brandes, 1989), and that when the ratio between spring flows and exports increase, Chinook salmon production increases (CDFG, 2005; SJRGA, 2007). In its biological opinion, NMFS therefore concludes that San Joaquin River Basin and Calaveras River steelhead would likewise benefit under higher spring flows in the San Joaquin River in much the same way as fall-run Chinook do. NMFS recognizes this assumption is critical, and thus the biological opinion calls for implementation of a six-year smolt-survival study (acoustic tags) (Action IV.2.2), using hatchery steelhead and fall Chinook.

The controversy lies in the effectiveness of the component of this action that reduces water exports from the delta. The effectiveness of reducing exports to improve steelhead smolt survival is less certain, in part because within the VAMP (Vernalis Adaptive Management Plan) increased flows and reduced exports are combined, and in part because steelhead smolts are larger and stronger swimmers than Chinook salmon smolts. Furthermore, it is not clear in the biological opinion how managing exports for this purpose would be integrated with export management for other actions. The choice of a 4:1 ratio of net flows to exports appears to be the result of coordinated discussions among the interested parties. Given the weak influence of exports in all survival relationships (Newman, 2008), continued negotiation offers opportunities to reduce water use in this specific action without great risk to steelhead. Further analysis of VAMP data also offers an opportunity to help clarify the issue.

The committee concludes that the rationale for increasing San Joaquin River flows has a stronger foundation than the prescribed action of concurrently managing inflows and exports. We further conclude that the implementation of the six-year steelhead smolt survival study (action IV.2.2) could provide useful insight as to the actual effectiveness of the proposed flow management actions as a long-term solution.

Increase Passage through Yolo Bypass

This action would reduce migratory delays and loss of adult and juvenile salmon and green sturgeon at structures in the Yolo Bypass. For sturgeon there is substantial evidence that improved upstream passage at Yolo will be beneficial. For salmon, the purpose is to route salmon away from the interior delta and through a habitat that is favorable for growth. This action is scientifically justified and prudent, but its implications for the routing of flows through the system as a whole were not transparently evaluated. For example, moving water through the Yolo Bypass results in less water coming through the Sacramento River. Were the effects of less flow in the Sacramento River considered in the design of the action? Similarly, how were the possible negative consequences of increased flooding of the Yolo Bypass on mercury cycling considered? This exemplifies a general tendency throughout the discussion of the actions to focus on the biologically beneficial aspects but to not fully present how any conflicting consequences or potential for such consequences were considered.

Floodplain Habitat

The floodplain habitat actions (Actions I.6.1-4) involve increasing the inundation of private and public lands within the Sacramento River basin to increase the amount and quality of rearing habitat for juvenile salmon. This action suite appears scientifically justified on the basis of a number of studies (e.g., Moyle et al., 2007; Sommer et al., 2001; Whitener and Kennedy, 1999). Given the strong basis, the committee recommends early implementation of these actions providing the implications for releases and routing of flows on other actions, and any potential negative consequences, e.g., mobilization of mercury, are adequately considered. In addition, the committee suggests detailed studies of the outcome of these actions to provide important data for improved life cycle models for these species.

INTEGRATION OF RPAs

The RPAs lack a quantitative analytical framework that ties them together within species, between smelt and salmonid species, and across the watershed. This type of systematic, formalized analysis is necessary to provide an objective determination of the net effect of the 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 would help to establish the credibility of the effort overall. Instances of coordination certainly exist. For example, the analysis done by NMFS for the Action IV.2.1 (Appendix 5), is an example of coordination, where the water needs for the 4-to-1 flow-to-export ratio for steelhead were determined and used to refine the action. But coordination is not integration. The lack of a systematic, well framed overall analysis is a serious deficiency. The interagency effort to transparently 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. Full documentation of decisions is an essential part of such an effort, as is 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. This was acknowledged by the FWS and NMFS, as well by many of the other presenters during the two days of public session of the committee meeting. There has been significant investment in operations and hydrodynamic models for the system, which have been invaluable for understanding and managing the system. An investment in ecological models that complement the operations and hydrodynamics models is sorely needed. This issue has been raised repeatedly in peer reviews, but still has not been incorporated in the NMFS and FWS analyses. Without a quantitative integration tool, the expected effects of individual actions on the listed species will remain a matter of judgment based on the interpretation of many disparate studies. The NMFS and FWS had to therefore determine the cumulative effects of the multiple actions in each RPA in a qualitative manner. This leads to arguments and disputes that are extremely difficult to resolve and that can undermine the credibility of the biological opinions. Commitment to a long-term effort to develop a quantitative tool (or tools) should be part of the RPA, with the explicit goal of formalizing and focusing the sources of disagreement and allowing for the clear testing of alternative arguments.

Transparent consideration of the implications of water requirements also would seem well advised because some of the actions have significant water requirements. DWR and NMFS used CalSim-II and Calite to simulate a collection of actions to determine water needs associated with the NMFS RPA, and concluded that they would amount to 5-7 percent of total water allocations (NMFS, 2009). (Because the actions involving negative OMR flows were similar in timing and magnitude in both the NMFS and the FWS RPAs, all OMR flow management was included in this estimate.) Those, and complementary efforts, should be extended to as many of the actions in combination as feasible, recognizing that the adaptive nature of many aspects of the RPAs, along with variations in environmental conditions and in water demands, limit the degree of certainty associated with such estimates. 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.

OTHER POSSIBLE RPAs

The committee's charge included the task that the committee should identify, if possible, additional potential RPAs that would provide 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 RPAs that had been considered and rejected by the agencies or that were recommended to the committee for its consideration (Hamilton, 2010). They included using bubble-curtain technology instead of hard barriers to direct migration of salmon and steelhead smolts, use of weirs to protect wild steelhead from interbreeding and competition, use of weirs to reduce spring-run Chinook from inbreeding and competition with fall-run Chinook, habitat restoration and food-web enhancement, restoration of a more-natural hydrograph, reducing mortality caused by nonnative predators, reducing contaminants, reducing other sources of 'take," implementation of actions to reduce adverse effects of hatcheries, and ferrying San Joaquin River steelhead smolts through the delta.

Some of these are already included to some degree in the RPAs (e.g., reduction of adverse hatchery effects, habitat restoration), and some might not be within the agencies' authorities as RPA actions under the ESA (e.g., contaminant reduction and reduction of other sources of "take"). The committee did not attempt to evaluate whether these suggestions represent good actions to help reduce risks to the listed species in a general attempt at restoration, as that will be addressed in the committee's second report. The committee concludes that none of the above suggested alternative RPAs has received sufficient documentation or evaluation to be confident at present that any of them would have the potential to provide equal or greater protection for the listed species while requiring less disruption of delta water diversions.

Several long-term actions described above have the potential to increase protections for the species while requiring the use of less water for that purpose, because they will result in a better understanding of the system. That better understanding should allow for a better matching of water for species needs, thus potentially reducing the amount of water used in less-effective actions. However, no short-term measure was identified that would provide equal protection to the fishes while reducing restrictions on water diversions.

RESOLVING INCOMPATIBILITIES BETWEEN THE RPAs

The committee noted in its discussion of the Delta Cross Channel action for salmon that it has a small potential for conflict with the requirements for smelt, although the action itself includes a consideration of the effects on smelt. In addition, the agencies have coordinated, and in some cases changed, their actions to avoid or reduce such conflicts, including actions concerning the installation of a "non-physical" barrier at the Head of Old River and the possibility of constructing a barrier across Georgiana Slough (NMFS and FWS, 2010). However, as the committee has noted elsewhere, coordination is not integration, and while it commends the agencies for working together to avoid incompatibilities between the RPAs, it concludes that this coordination is not sufficient to achieve the best results or full evaluation of incompatibilities. To achieve those goals requires an integrated analysis, because without such an analysis it is difficult or impossible to properly evaluate potential conflicts among RPA actions. More important, such an analysis would help to produce more-effective actions. The lack of an integrated analysis also prevented the committee from a fuller evaluation of potential incompatibilities between the RPAs.

EXPECTATIONS AND PROXIMATE MEASURES

The committee heard several times at the public sessions that the RPA actions for delta smelt are not working as there has been no response in the standard annual abundance indices during the last three years when action-related restrictions have been imposed. Such comments are appropriate, but only if realistic expectations are used to judge effectiveness. In this case, it is unrealistic to expect immediate and proportional responses to actions in annual indices of delta smelt, especially within the first few years of implementation. There are several reasons for this. First, fish abundances are influenced by many factors not affected by the actions. This is true in all estuarine and marine systems, and is simply inherent in fish population dynamics. For example, in the case of the species here, three drought years coincided with the implementation of the actions. Other factors have also varied that would further mask any response in the annual indices.

Second, delta smelt populations are very small. The ability of the annual indices to show changes in response to actions is compromised due to the inherent lack of precision in sampling and constructing indices of abundance when populations are very small. Unlike salmon and steelhead, the adults of which can be counted with great precision as they migrate upstream, delta smelt are more difficult to count as well as being rare. While this is frustrating, little change in the annual indices over a few years neither invalidates the utility of the actions nor do they demonstrate that the actions are effective. Finally, there were no prior quantified estimates of response to calibrate expectations. Expectations would be better established if the RPA proposals more explicitly quantified the nature and the expected timescale of responses in the target species, and detailed exactly what would be done to assess the validity of those predictions.

RPA RECOMMENDATIONS

The committee concluded that the uncertainties and disagreements surrounding some of the RPA actions could be reduced by some additional activities. In general, the committee recommends that, within the limits the agencies face with respect to human and financial resources, a more-integrated approach to analyzing adverse effects of water operations and potential actions to reduce those effects would be helpful. The approach would include a broader examination of the life cycles of each fish species and where possible, integrating analyses across species. Although there is much general evidence that the profound reduction and altered timing of the delta water supply has been part of the reason for the degradation of these species' habitats, the marginal benefits of beginning to reverse the damage will be difficult to recognize for some time and there is much uncertainty about how to design attempts at the reversal. At this time, the best that can be done is to design a strategy of pumping limitations that uses the best available monitoring data and the best methods of statistical analysis to design an exploratory approach that could include enhanced field measurements to manage the pumping limitations adaptively while minimizing impacts on water users. Such an approach would include a more explicit and transparent consideration of water requirements, despite the variability in environmental conditions and water demand; and population models to evaluate the combined effects of the individual actions.