



Independent Review Panel (IRP) Report for the 2014 Long-term Operations Biological Opinions (LOBO) Annual Science Review

**A report to the
Delta Science Program**

Prepared by

Dr. James J. Anderson – University of Washington

Dr. James A. Gore (Panel Chair) – University of Tampa

Dr. Ronald T. Kneib (Lead Author) – RTK Consulting Services & University of Georgia (Senior Research Scientist Emeritus)

Dr. Nancy E. Mosen – Stanford University (Visiting Scholar, Department of Civil and Environmental Engineering, Environmental Fluid Mechanics Laboratory)

Dr. John M. Nestler – Fisheries and Environmental Services & USACE Engineer Research and Development Center (Retired)

Dr. John Van Sickle – U.S. Environmental Protection Agency, Western Ecology Division (Retired)

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Scope and Intent of Review: This report presents findings and opinions of the Independent Review Panel (IRP) assembled by the Delta Science Program to inform the National Marine Fisheries Service (NMFS) and the U.S. Fish & Wildlife Service (USFWS) as to the efficacy of water operations and certain regulatory actions prescribed by their respective Long-term Operations Biological Opinions' (LOBO) Reasonable and Prudent Alternative Actions (RPAs) as applied from October 1, 2013 through September 30, 2014 (Water Year 2014).

This year's annual review focused primarily on: (1) implementation of NMFS's RPAs associated with modified Delta Cross Channel (DCC) Gate opening criteria in the Drought Operations Plan, (2) proposed modifications to the Juvenile Production Estimate (JPE) calculation and use/application of data from acoustically-tagged Chinook Salmon releases, (3) proposed calculations for Cumulative Salvage Index values used in estimating take of adult Delta Smelt under the USFWS Old and Middle River flow RPAs, and (4) general implementation of RPA actions under dry year conditions based on prior IRP concerns about RPA implementation under such conditions.

After reviewing a required set of written documents (Appendix 1), the IRP convened at a public workshop in Sacramento, CA on 6-7 November 2014. The first day of the 2-day workshop included agency presentations and provided a forum for the IRP to consider information on water operations, activities, and findings related to RPA Actions as implemented in the critically dry 2014 water year. On the second day, the IRP deliberated in a private session beginning at 8:00 a.m. in order to prepare and present their initial findings at the public workshop at 2:00 p.m., after which there was an opportunity for agency representatives, members of the public, and the IRP members to comment and otherwise exchange impressions and information. Subsequent IRP communication and deliberations were conducted via email and conference calls in the course of drafting this final report.

EXECUTIVE SUMMARY

The 2014 LOBO IRP recognizes that the critically dry 2014 water year (WY) compounded the usual challenges and constraints faced by all of the agencies charged with seeking to balance existing commitments and mandated coequal goals of (1) providing a reliable water supply for California, and (2) protecting, restoring and enhancing the Delta environment, associated Central Valley ecosystems and the threatened or endangered species dependent on those systems.

Concerns regarding the capacity to achieve specific RPA targets under dry conditions have been expressed in previous IRP reports (Anderson et al. 2010 to 2013), along with the prediction that some physical targets may not be routinely achievable. After five years of operating under the RPA actions, observations are now available for water years ranging from wet to critically dry. The 2014 WY extended a trend of beginning the WY with less reservoir storage than the previous year and ending with even lower levels of water reserves entering the subsequent WY. Even those with senior water rights recognized the need to voluntarily postpone or forego delivery of water allotments. Much of the shortfall in surface water availability may have been offset by increased pumping of groundwater resources. California has only recently passed legislation that recognizes the connection between above-ground and below-ground sources of water and the Department of Water Resources will begin prioritizing basins and monitoring groundwater beginning in 2015.

The first of four charges to the LOBO IRP in 2014 involved the operation of the Delta Cross Channel (DCC) gates to protect both water quality in the southern Delta and emigrating salmon smolts. The effectiveness of gate closures intended to deter entrainment of emigrating smolts into the interior Delta via the DCC cannot be assessed at this time because the passage of smolts is not routinely monitored in the DCC downstream of the gates. Even if there were adequate fish monitoring downstream of the DCC gates, smolts can be drawn into the interior Delta downriver at the junction with Georgiana Slough, where tidal effects can have a strong influence on hydrodynamics that may increase entrainment. A complex diurnal/tidal DCC gate operation plan, which was not used in WY 2014 but proposed for possible application in the near future, was based on observations of diel and tidally-influenced smolt migration behavior. The plan would result in short-term pulses of freshwater directed toward the interior and southern Delta. Currently, it was unclear if the addition of this level of complexity to DCC gate operations would achieve either greater protection for protected species or the expected benefits to water quality in the southern Delta. Nonetheless, this is an example of the

type of thinking that previous LOBO IRPs have encouraged. That is, to link fish behavior and survival to water operations and RPA Actions.

The Juvenile Production Estimate (JPE), which is used to set allowable take of winter-run Chinook Salmon smolts at the CVP/SWP pumping facilities, was another issue considered by the 2014 LOBO panel. A combination of extreme environmental conditions and a transitional approach to the estimation of juvenile survival from spawning grounds downriver to the Delta contributed additional uncertainty to the JPE in WY 2014. In the present report, the panel makes suggestions for reducing the substantial uncertainty in future estimates of JPE by applying a proportional hazards approach to statistically modeling survival rates as a function of environmental conditions, and considering using a form of “trickle releases” rather than batch releases of acoustically tagged winter-run Chinook Salmon as a means of improving the statistical modeling of smolt survival. The continued use of late fall-run Chinook Salmon as surrogates for winter-run Chinook in future acoustic tagging studies is discouraged. Not only are the late-fall run fish larger, but they exhibit a much shorter migration travel time than winter-run fish that may interrupt their migration in response to changes in flow and turbidity. The panel encourages further analysis of the effects of environmental condition on all early life stages of winter-run Chinook Salmon.

An interim approach to calculating the Cumulative Salvage Index (CSI) for use in the estimation of allowable incidental take of Delta Smelt at the State and federal pumping facilities was proposed as an alternative to the method currently used by the U.S. Fish & Wildlife Service. There is substantial uncertainty associated with both methods of calculating CSI and when this uncertainty is considered, values generated by each method are not statistically distinguishable. Consequently, the panel had no basis to recommend replacement of the current method with an interim approach. Both methods should soon be superseded by a Delta Smelt life history model that may lead to a more realistic estimate of the at-risk population size of Delta Smelt and improve the future calculation of allowable take for this species.

The 2014 WY was the third consecutive year of dry conditions and between April and mid-November 2014 water resources were managed under a collaborative State and federal Drought Operations Plan. California has experienced longer periods between wet years in the recent past (e.g., 2000-2004 and 1987-1992), and so it is prudent to recognize that real-time resource management must include the flexibility to adjust to a “new normal” set of expectations with the realization that there may be even more protracted periods of drought than expected from the historical climatic record.

The panel remained encouraged by signs of movement toward the application of research aimed at linking the survival and behavior of fishes to water operations, but clear, quantifiable associations between specific RPA actions and population-level responses in species targeted for protection remain elusive. The LOBO IRP continues to encourage the development of methods that will explicitly link the success or failure of achieving desired temperatures, flows, and other physical targets to the biological/ecological responses of the listed species. As the IRP has noted before, this is the only way that the intended goals (e.g., protection of listed species) of RPA Actions can be assessed in a scientific context.

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INTRODUCTION

Surface water resources of California's Central Valley flow through a highly-engineered storage/delivery system that has developed to meet the needs of farms, industry, and millions of people residing within municipal districts within this watershed. Added to the complex infrastructure and landscape alterations is an equally complex suite of rules governing the distribution of water, which affect flows and water quality of riverine and deltaic ecosystems associated with California's Central Valley. These and other anthropogenic alterations over time have been accompanied by substantive changes in aquatic flora and fauna, including a persistent decline in native fishes. Some of these species have been afforded protection under the Endangered Species Act (ESA) and government agencies have been charged with developing ways of protecting these populations from further jeopardy associated directly or indirectly with water operation projects in the region.

Drought conditions have persisted in the Central Valley for the past three years and water reserves have been steadily declining with each passing year, making the coequal goals increasingly difficult to achieve. Ground water resources have been seriously depleted because California has been relatively slow to formally recognize the connection between surface and ground water resources.

Water operations are currently conducted to meet the coequal goals of providing a reliable water supply to California and ecosystem restoration and enhancement, including the protection of endangered species. Ultimately, the ability to meet this mandate appears to rest largely on adjusting existing water operations in a region where precipitation is highly variable in both space and time. This constrains the options for meeting the aforementioned coequal goals largely to modifications in water operations that amount to serial adjustments in reservoir releases and export pumping from the system so as to avoid jeopardizing protected fish populations while continuing to ensure the availability of water for other human uses.

Background on the LOBO RPA review process: NOAA's National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) have each issued Biological Opinions on long-term operations of the Central Valley Project (CVP) and State Water Project (SWP, hereinafter CVP/SWP; Long-term Operations Biological Opinions) that include Reasonable and Prudent Alternatives (RPA) designed to alleviate jeopardy to listed species and adverse modification of critical habitat. NMFS' Opinion requires the U.S. Bureau of Reclamation (USBR) and NMFS to host a workshop no later than November 30 of each year to review the prior water year's operations and to determine whether any measures prescribed in the RPA should be altered in light of new information (NMFS' OCAP Opinion, section 11.2.1.2, starting on page 583).

Amendments to the RPA must be consistent with the underlying analysis and conclusions of the Biological Opinions and must not limit the effectiveness of the RPA in avoiding jeopardy to the ESA listed species or result in adverse modification of critical habitat.

The purpose of this annual review of the Long-term Operations Biological Opinions (LOBO) is to inform NMFS and USFWS as to the effectiveness of operations and regulatory actions prescribed by their respective RPAs in the 2014 Water Year, and to make recommendations/review proposals for changes to implementation of actions consistent with the purpose of the RPA.

Since the Long-term Operations Biological Opinions were issued, NMFS, USFWS, USBR, U.S. Geological Survey (USGS), California Department of Fish and Wildlife (CDFW) and the Department of Water Resources (DWR) have been performing scientific research and monitoring in concordance with the implementation of the RPAs. Technical teams and/or working groups, including the geographic divisions specified in the NMFS' Long-term Operations Biological Opinion, have summarized their data and results following implementation of the RPA Actions within technical reports. The data and summary of findings related to the implementation of the RPAs provide the context for scientific review regarding the effectiveness of the RPA Actions for minimizing the effects of water operations on ESA listed species and critical habitat related to the operations of the CVP/SWP. A subset of these technical reports, some of which included responses to IRP recommendations offered in previous years, was presented for consideration by the 2014 LOBO IRP (see Appendix 1).

General charge and scope for the 2014 LOBO IRP: Annual reviews prior to 2012 considered all of the RPA Actions but in subsequent years, the panel's charge has focused on a subset of the operations and RPAs.

This year's (2014) annual review included:

- (1) Modified Delta Cross Channel Gate opening criteria as described in Attachment G of the Central Valley Project (CVP) and State Water Project (SWP) Drought Operations Plan and Operational Forecast, April 1, 2014 through November 15, 2014;
- (2) Modifications to the winter-run Chinook Salmon Juvenile Production Estimate calculation and use/application of survival data from acoustically-tagged Chinook Salmon releases;
- (3) A proposal for calculating Cumulative Salvage Index values used for estimating take likely to occur under the USFWS Old and Middle River flow RPA for adult Delta Smelt; and

- (4) A general consideration of RPA actions under dry year conditions based on questions and concerns expressed in prior annual science reviews.

As in previous years, the specific scope of the 2014 LOBO review was defined by questions posed to the 2014 IRP by the agencies and technical teams/task groups that presented materials for review. This IRP report addresses each of the questions posed from a scientific perspective, and provides additional observations, opinions and recommendations where, in the panel's opinion, they seemed potentially useful to agency staff for consideration, especially in regard to near real-time decision making.

Acknowledgments: The members of the IRP appreciate and acknowledge the efforts of the agency and technical team representatives and contractors who responded to questions and suggestions made by previous IRPs, prepared the written materials, and delivered the workshop presentations on which this report is based. Each year we are cognizant that much of the material has to be compiled, analyzed, and organized in a relatively short time. We also recognize that government agency personnel faced additional pressures resulting from a critically dry 2014 Water Year, continuing government budget uncertainties, and a partial federal government shutdown early in the water year. Despite the many competing demands on the workshop participants, the materials were presented professionally, concisely, and on schedule. The panel wishes to express a special thanks to Peter Goodwin (Lead Scientist) and the entire staff of the Delta Science Program for providing the organization and logistical support to facilitate our task. In particular, Lindsay Correa (Senior Environmental Scientist), as usual, expertly attended to a wide variety of technical and provisional details in support of the IRP's efforts before, during and following the workshop. Title page photo credit: <http://jonjost.files.wordpress.com/2010/10/sacramento-delta-copy.jpg>

LOBO IRP COMMENTS ON RPA ACTIONS IN WATER YEAR 2014

General comments and observations

The 2014 LOBO IRP was asked to read a number of technical team reports that described RPA actions that were not highlighted at the 2014 workshop in Sacramento. These reports contained team responses to previous (2012 LOO) panel comments, and the IRP was generally gratified to know that many of the concerns of previous panels were recognized and some were being addressed.

The agencies and technical teams appear to be gradually shifting their perspective from short-term reactionary (crisis management) to a more long-term anticipatory view. The relevance of several categories of forecasting analysis and models (from climate change to computational fluid dynamics modeling) are increasingly applied as important management tools in the region. Hopefully, this trend continues to help address the many emerging management challenges associated with the “new normal” condition of reduced water availability.

It was obvious that progress on some types of projects (e.g., gravel augmentations in Clear Creek, the Lower American River, and the Stanislaus River) is a source of pride in accomplishment for the technical teams. The IRP does not intend to diminish these valuable contributions to habitat improvement in any way. With that said, the IRP would be remiss if it did not point out that the ultimate success of such projects is inextricably tied to other aspects of the overall plan. For example, improvements in the structural value of spawning habitat (i.e., suitable gravel for redds) will have little realized benefit to salmonid populations if appropriate water temperatures and flows cannot be maintained within redds and juvenile rearing habitats to support improved survival of fry and smolts. The critically dry conditions in WY 2014 presented a real challenge in this regard and temperature and flow targets could not be met. Also, some projects affecting cold-water delivery capacity seem to be on long-term hold (e.g., Oak Bottom Temperature Control Curtain (OBTCC) at Whiskeytown Lake).

These delays clearly affect progress in other areas. For example, according to the Clear Creek Technical Team Report, the Spring Creek Temperature Control Curtain (SCTCC) was replaced but its effectiveness has not been tested because it was designed to operate in unison with the OBTCC and separate tests of effectiveness were deemed to have no useful purpose. So while claiming success toward meeting an RPA Action (i.e., replacement of the SCTCC), there is no basis on which to judge the effectiveness in terms of the intended purpose of the Action. Connecting the effects to the larger issue of maintaining temperature targets in Clear Creek to improve the survival of salmonid early life stages seems an even less attainable expectation. This harks back to the recommendations of previous panels which consistently encouraged progress toward demonstrable connections between biological responses of the protected species and the RPAs.

Modified Delta Cross Channel (DCC) Gate Opening Criteria per Attachment G in the Drought Operations Plan

RPA Actions IV.1.1 and IV.1.2 include modifications in the operation of the Delta Cross Channel Gate (DCC) to reduce the exposure risk of emigrating spring- and winter-run Chinook Salmon yearlings to mortality associated with water operations in the interior Delta. However, multi-year drought conditions prior to, and including, the critically dry 2014 WY resulted in a decision to modify RPA Actions involving the DCC to balance fish protection with the need for maintaining Delta water quality standards mandated by Water Right Decision 1641 (December 1999). Some modifications to the DCC operation were applied in the 2014 WY and others proposed for continued use during drought conditions in the future. These modifications involved a series of triggers based on combinations of water quality conditions within the Delta and the anticipated or actual presence of juvenile winter-run and spring-run Chinook as well as steelhead based on catch indices from the Knight's Landing rotary screw trap, Sacramento trawl, and beach seine collections, which are all located upstream of the DCC gates. Additional operational complexity using a diurnal schedule to open and close the DCC gates during ebb tides was proposed based on recent studies of diurnal/tidal movement patterns of young emigrating salmonids, but was not applied in WY 2014.

Whether or not relatively brief periods of DCC Gate openings under drought conditions would provide enough freshwater to have the desired effect on water quality in the interior Delta remains an open question. Also, the numbers of salmonids (or green sturgeon) that pass through the DCC or enter the interior Delta via Georgiana Slough are not directly monitored. Consequently, it remains unclear as to whether the modified DCC Gate operations will achieve the water quality and salmonid protection objectives intended.

Daytime, diurnal (ebb-only) operation of the DCC is a new criterion that was proposed for future operations under continued drought conditions, and it may be important to analyze the benefits of this modification. The rationale for the diurnal/tidal operation of the gates is based on three key field observations:

(1) Recent salmonid tagging studies (e.g., Chapman et al. 2013; Steel et al. 2013; and other references cited in Attachment G of the Revised DCC Gate Triggers Matrix for April 1 through November 15, 2014) have shown that most migrating smolts travel past the DCC Gate at night and have a positive response to high-velocity flows.

(2) Hydrodynamic field experiments (Bureau 2014) have shown that the junction of the Sacramento River and the DCC is a confluence point during flood tides, directing all Sacramento source water around the junction into the DCC during flood tides.

(3) Field observations and numerical modeling studies (e.g., Monsen et al. 2007) confirm that electrical conductivity levels decrease at key stations in the central Delta when the DCC remains open continuously for multiple days.

The Delta Operations for Salmonids and Sturgeon Group (DOSS) made a reasonable argument for developing this operating criterion based on their current understanding of the science. However, other hydrodynamic factors, such as those supported by field observations in the Mokelumne system (Gleichauf et al. in press), may need to be considered. The net benefit of short-term diurnal/tidal gate openings may not be as significant as currently anticipated for the electrical conductivity criteria at interior Delta stations.

The intended benefit of opening the DCC gates is that freshwater from the Sacramento will be diverted into the Mokelumne system and travel through that system toward the San Joaquin and the interior Delta. It is assumed that this pulse of water will be capable of preventing additional saltwater intrusion on the San Joaquin stem of the Delta. This assumption is based on experience of pump operators and other studies that have shown that when the DCC remains opened for multiple days, better water quality in the central Delta is the end result.

When the DCC gate is continuously open, flow in the North Mokelumne is driven by the head difference between the Sacramento and San Joaquin rivers. Therefore, there is a net flow downstream through the Mokelumne system towards the interior Delta. This net flow when DCC remains open was observed by Gleichauf et al. (in press) during 2012 field experiments at the junction of Georgiana Slough and the Mokelumne.

When the DCC gate is closed, flow in the North Mokelumne is driven by the head difference between the east-side streams and the San Joaquin River. Because there is a very minimal flow in the east-side streams, the North Mokelumne River can experience tidal flows when the DCC is closed (Gleichauf et al. in press)

When the DCC gate is pulsed open and closed, the head difference that will drive flow in the Mokelumne will alternate. When the gate is open, the head difference between the Sacramento and the San Joaquin will drive the flow. When the gate is closed, tidal conditions will likely occur in the Mokelumne. As a result the “freshette” that enters the Mokelumne through the DCC gates will likely tidally slosh and may disperse in the Mokelumne until the next freshette enters the next day when the DCC is re-opened. Therefore, the travel time of the Sacramento sourced water through the Mokelumne to the central Delta will be much longer than would normally occur when the DCC

gate is continuously open. Depending on how long this operation is used, the benefit of reducing salinity in the central Delta may or may not be achieved.

At the LOBO Workshop on November 6, 2014 in Sacramento, Barbara Byrne presented a clear and detailed explanation of NMFS challenges to develop decision triggers to close the Delta Cross Channel in order to prevent the entrainment of juvenile salmonids into the southern Delta where smolts are subject to increased mortality risk during outmigration. Several potentially conflicting objectives and constraints on operation of the Delta Cross Channel (DCC) were recognized based on information provided to the IRP (i.e., Attachment G REVISED DCC GATE TRIGGERS MATRIX, as well as presentations and discussions at the LOBO 2014 workshop).

Freshwater flows diverted through the DCC are required to reduce salinity in the interior Delta, but flows are also needed to reduce salinity in the Sacramento River (presumably to move X2 westward toward the estuary). At the same time, there is a need to discourage the outmigration of salmonid smolts via the DCC to reduce entrainment into the interior Delta and associated mortality risk due to water operations.

In addition to the potentially conflicting needs associated with the volume and routing of freshwater flows, there are constraints on the operational flexibility of the DCC gates associated with public access and mechanical limitations. The boating public routinely uses the DCC to move between the Sacramento River and the interior and southern Delta. Under present operations, anticipated gate openings and closings are disseminated as a public service announcement. Short-term, unannounced gate operations may strand boaters on the wrong side of closed gates causing boater inconvenience and potential safety issues. Mechanical constraints permit the DCC gates to be operated in either fully closed or fully open positions, and there is some concern regarding the potential for mechanical failure of the gates if frequency of operation exceeds design parameters.

Biological triggers requiring gate closures focus on the portion of the system extending from Knights Landing to the DCC and currently do not consider the presence of emigrating salmonids downstream of the DCC. Sampling of smolts is restricted to stations upstream of the DCC in order to provide for an early warning trigger because average smolt travel time from Knights Landings to the DCC is approximately 2.5 days. However, sampling is not conducted at the entrance to the DCC or routinely downstream of the DCC gates. Consequently, it is difficult to determine the effectiveness of the DCC gate closures in protecting smolts from entrainment risks in the interior Delta.

There are several reasons that neither the Sacramento Trawl Catch Index (STCI) nor the Sacramento Beach Seine Index (SBCI) are useful in providing a high degree of protection for salmonids or other species of interest lingering near the DCC. For example, fish movement is typically episodic and appears to be associated with environmental cues such as flow, temperature, daylight duration, or tidal dynamics. Episodic events (e.g., many zeros or low numbers and occasional high numbers) are difficult to accurately sample with a regular, but infrequent sampling schedule relative to the time scale inherent to the episodic event. The frequency of sampling with beach seines and trawls is implied to be daily when the DCC gates are open. Unless these samples are timed to coincide with conditions that trigger fish movements, there is considerable risk of the datasets including false negatives that compromise the protection the catch indices were intended to provide.

Most of the catch indices' triggers are small in magnitude ranging from the capture of one to five fish and it is unclear how the catch relates to the number of fish actually present in the sampling area. Such small numbers complicate the challenge of accurately protecting emigrants by gate closures at the DCC.

It may be possible to operate the gates to better protect emigrating salmonid smolts if passage for boat traffic were not considered as a purpose equal in importance to emigrant protection. Perhaps other provisions for recreational boat passage could be integrated into the DCC facilities as they have been in other parts of the Delta (e.g., the small boat lock at the Suisun Marsh Salinity Control gates).

The IRP encourages efforts to increase operational flexibility of the DCC gates. However, operational changes within tidal and diel cycles will have impacts on fish and salinity distributions throughout the Delta, some of which may be unanticipated and perhaps even detrimental.

The addition of fish sampling stations downstream of the DCC gates would improve estimates of the efficacy of DCC gate operations for fish protection. Fish should be sampled south of the entrance to the DCC and within the channel to ensure that episodic events are not missed by the DCC gate closure triggers. In any case, the catch data will be difficult to interpret because of the complex movements of salmon over tidal and diel cycles. The IRP suggests that a first step in tracking the movements of fish in the vicinity of the DCC would be to expand the acoustic tag sampling with the goal of tracking fish movements between DCC and Georgianna Slough over the relevant temporal cycles.

Proposed Modifications to the Juvenile Production Estimate (JPE) Calculation and Use/Application of Data from Acoustically-Tagged Chinook Salmon Releases

The Juvenile Production Estimate (JPE) for winter-run Chinook Salmon (WRCS) is used to set the allowable take of WRCS at the CVP/SWP pumps during the juvenile migration. It is therefore estimated prior to the migration and is based on spawner carcass surveys and survivals of the juveniles over their life stages prior to entering the Delta where they are susceptible to entrainment in the pumps. The analysis presented below was extracted from the primary material in the Juvenile Production Estimates Calculation Report (JPECR 2014), the background material, and the presentations of Stuart and Oppenheim at the IPR 2014 workshop.

The approach to estimating JPE has not been consistent from year to year and is without an accurate benchmark of survival. The process seems largely based on the ever-changing “best judgment” of those serving collectively in the DOSS work group. The method of calculating the JPE was in transition in 2014 due to the first-time use of acoustic tagged WRCS to estimate survival. In addition, the migration occurred during the third year of an ongoing drought, which may have resulted in anomalous fish migration behavior and survival in the current WY. This new information and extreme conditions increased the uncertainty on the estimates of JPE and illustrated the need for a better understanding of how environmental conditions (e.g., flow, temperature, and turbidity) affect fish behavior and survival.

The methodology for estimating the JPE in the 2014 migration season began with a simple budget (spreadsheet) model based on carcass surveys in the upper Sacramento River to estimate total Adult Escapement (AE). This was expanded to the number of viable eggs per adult (E) and then adjusted downward by a prediction of the survival (S1) of fish to Red Bluff Diversion Dam (RBDD) and a prediction of survival (S2) from RBDD to a location defined as the top of the Delta. The formula is $JPE = AE * E * S1 * S2$. The allowable take at the pumps was then set at x percent of the number of fish at the top of the Delta using the formula, $Take = x * JPE / 100$, where $x = 2\%$ for wild WRCS.

The JPE uses predicted survivals S1 and S2 calculated from historical direct and surrogate measures. In the 2014 WY, S1 was calculated as the mean of the time series of the ratios of juveniles passing RBDD (the Juvenile Production Index, JPI) divided by the adult carcass survey adjusted for fecundity data and pre-spawning mortality. In past years, S2 was calculated by surrogate measures based on survival of late fall-run Chinook Salmon (LFCS). In 2014, S2 was replaced with survival estimated from a

weighted mixture of four years of acoustic tagged survival estimates from LFCS and one year estimated from acoustic tagged WRCS. The weighting was agreed upon in a working group and the total survival in the JPE was lowered 6% (0.078 to 0.073) compared to the method used in previous years.

The validity of the JPE was based on the assumption that the 2014 WY environment was similar to that of earlier dry years in which the LFCS studies were conducted. However, WY 2014 was an anomalous year. At the end of migration in 2014, the JPI data revealed a very low estimate of S1. Also, the weighted mixture of acoustic tagged LFCS and WRCS likely biased the estimate of S2. Both factors would result in a significantly overestimated JPE for 2014, as is illustrated in Table 1 below. Scenario 1 in Table 1 essentially recreates the information used in producing the JPE for 2014. Scenario 2 illustrates the JPE if only the WRCS survival were used to estimate S2. Scenario 3 uses the S1 calculated from the JPI for 2014 and S2 from Scenario 2. The table suggests that the JPE estimated for the 2014 drought year could have been overestimated by up to a factor of three. However, even at this level the actual take (338 WRCS) would be only 4% of the Annual Take Limit. Thus, even if the JPE were significantly overestimated in WY 2014, the run was not likely endangered by water export operations.

Table 1. Calculations of JPE using three scenarios. Numbers based on Attachment 1 of “Juvenile Production Estimate (JPE) Calculation and Use/Application of Survival Data from Acoustically-tagged Chinook Salmon Releases prepared for the 2014 Annual Science Panel Review Workshop”.

Scenario	Adult Escape (AE)	Viable egg per Adult (E)	Viable egg estimate	Survival to RBDD (S1)	Juveniles passing RBDD	Survival RBDD to Delta (S2)	Juveniles to Delta (JPE)	Annual Take Limit
1 NOAA method	5,958	2,755	16,411,348	0.27	4,431,064	0.27	1,196,387	23,928
2 Use WR S2	5,958	2,755	16,411,348	0.27	4,431,064	0.16^A	708,970	14,179
3 Use JPI & WR S2	5,958	2,755	16,411,348	0.15 ^C	2,485,787^B	0.16	397,726	7,955

A. WRCS acoustic tag estimated survival for 2013.

B. JPI for 2014 based on real-time rotary screw trap catch at RBDD.

C. Calculated S1 based on JPI and viable egg estimate.

Issues with S2: Survival from RBDD to Delta

There were several reasons that S2 determined using LFCS was likely biased high. First, LFCS smolts were 1.8 times the length of the WRCS smolts. Second, the LFCS smolts moved through the river below RBDD approximately a month sooner than the WRCS fish. Third, the WY 2014 flow was lower than flows in which the LFCS and WRCS survivals were measured. Conventional understanding suggests that all three factors (smolt size, travel time, and flow) would contribute to overestimates of JPE: big fish survive better than small fish, faster migration increases fish survival, and fish migrating in higher flows should survive better than fish migrating in lower flows. Thus, all factors suggest S2 was overestimated in 2014.

The panel found no compelling justification for including LFCS in estimates of S2 other than to maintain continuity with earlier tagging studies when LFCS were used as surrogates for estimating S2 in WRCS. However, it also seemed plausible that using S2 derived from WRCS studies conducted in low flow years would overestimate the JPE in high flows years. Several approaches aimed at adjusting S2 for flow year were discussed by the Winter-run Sub-team (Attachment 4 Winter-run Sub-team final call 12-19-13 in the JPE Calculation Report [JPECR] 2014) but the methods yielded unrealistically low estimates of S2. Given the limitations of data and theory, the panel outlines below two possible approaches and encourages the Winter-run Sub-team to include these among other future considerations.

Approach 1–Match flow method: In the next few years, when the JPE will be calculated with limited WRCS survival data, it is reasonable to use S2 estimates that best match S2 values associated with years having similar flow conditions.

Approach 2–Mechanistic method: As a companion to simply selecting results from similar water years, it may be possible to derive S2 based on mechanisms. The approach is based on the observation from the WRCS acoustic tag study in 2013 that smolts may interrupt their downstream migration in low flow conditions. Under this hypothesis juvenile migration survival will need to be described in two parts: an active migration part and a holdover part. For illustration, assume survival is distance dependent in active migration and time dependent in holdover behavior. Then survival is:

$$S2(X, T_{hold}) = S_{active}(X)S_{hold}(T_{hold}) = \exp(aX + bT_{hold})$$

where X is distance traveled in active migration and T_{hold} is the duration of the holdover part of the migration. Note this equation is different from one in which prey actively migrate and predators may exhibit stationary and roaming foraging (Anderson et al. 2005).

The regression technique for estimating the coefficients in the above equation depends on the available data. The following method outlines a statistically rudimentary approach in which the active migration coefficient, a , is calculated by simply removing the holdover portion of the data and estimating the coefficient in the regression:

$$\log S_{active}(X) = a_0 + aX$$

where a_0 is a nuisance parameter. The coefficient for holdover part of the migration is estimated in a similar manner with:

$$\log S_{hold}(T_{hold}) = b_0 + bT_{hold}$$

The next step is to identify environmental conditions that induce fish holdover behavior. If the duration of holdover were a function of flow and otherwise fish move at a fixed velocity then the holdover behavior could be estimated with data on the total travel time of fish. The regression requires a functional form of the relationship between holdover duration and the controlling variables. Finding a suitable form of the relationship is problematic, but one possible approach begins with a graphical analysis plotting total travel time T_x over distance x , (e.g., RBDD to Interstate 80), against likely controlling variables (e.g., flow, turbidity, etc.) For example, assume holdover duration decreases exponentially with flow (F) such that fish exhibit diminishing holdover behavior as flow increases. Then the holdover duration might fit the equation:

$$T_{total} = T_{active} + T_{hold} = T_{active} + \alpha e^{\beta F}$$

where T_{total} and T_{active} are the durations of the total migration and the active portion of the migration. While in this example the flow vs. holdover relationship is determined separately from the survival elements, the two components could be determined with multiple linear or multiple nonlinear techniques if sufficient data were available.

Juvenile tagging to support the statistical modeling of survival S2

Acoustic tagging is a promising method for addressing a number of questions related to fish movement and behavior, but acoustic telemetry monitoring has a number of limitations, including technological issues with the reliability of detection under conditions of varying noise interference, water depth, turbulence, water quality, etc. (Donaldson et al. 2014). The application of acoustic tagging to estimate fish survival in variable environments is especially challenging, but improvements in modeling approaches are beginning to resolve some of the problems (e.g., Perry et al. 2010). The panel was not provided with much specific information on the potential contributions to uncertainty in estimates of juvenile salmonid survival that could be traced to technological or experimental design limitations of the acoustic tagging program, so those concerns are not explicitly considered in the following discussion.

There is very substantial uncertainty in JPE due to uncertainty in estimates of S1 and S2. This may motivate NMFS to increase their efforts to statistically model survival rates as a function of temperature, flow, and other factors. The approach is known as analysis of survival under proportional hazards. The analytical tools are available in the R statistical language or as standalone packages. For example, the SURPH model from the University of Washington (<http://www.cbr.washington.edu/analysis/apps/surph/>):

Survival Under Proportional Hazards

SURPH is an analytical tool for estimating survival using release-recapture data as a function of environmental and experimental effects. These effects may apply to a population (such as ambient temperature) or an individual (such as body length). SURPH provides flexible modeling capability for selecting the most parsimonious models, and diagnostic reports and graphs for analyzing data and selected models. Hypothesis testing can be done with Likelihood Ratio Test, AIC, or Analysis of Deviance.

Current Version:

[SURPH 3.5.2](#)

Discussion of the value of the proportional hazards approach

The standard approach for estimating survival is to release a large batch of tagged juveniles (either acoustic or coded-wire tags) upstream, and then record the proportion that are ultimately detected or recovered as they exit the Delta. If survival rate estimates are available from a large number of such batch releases, it is possible to statistically model the survival rate as a function of environmental covariates. An example is shown in Figure 7 of Cramer Fish Sciences (CFS) (2014).

However, it takes many batch-release experiments to accumulate enough data for such modeling. Tagged-fish releases could make much more efficient use of their data if individual tagged fish, rather than individual batches of fish, could supply independent replicates for modeling. The individual-fish approach to modeling is impractical for batch releases, however, because all tagged fish in the same batch will experience nearly identical environmental conditions (flow, temperature, etc.) during their passage to the Delta. This means that individual fish within one batch cannot be used as independent replicates.

Perhaps a more efficient tag-release strategy, for the purpose of statistical modeling of survival rates, would be to release tagged fish in a small, steady stream over time, instead of all together in a large batch. This “trickle-release” strategy would yield a broader representation of covariate values during a single migration season. It also would greatly increase sample sizes for modeling because individual fish, not batches, would serve as independent replicates. Because individual fish (i.e., tags) can be identified, one can statistically summarize the environmental conditions experienced by each fish that was eventually detected at Chipps Island, over the time period between its upstream release and its downstream detection. Tagged fish that were not detected downstream could be assumed, perhaps unrealistically, to have the same average transit time as the detected fish, so that one could also estimate the environmental factors experienced by individual non-detected fish. The detected (“present”) and non-detected (“absent”) individual fish could then serve as replicates in a binary logistic regression model that predicts the probability of presence (that is, the survival probability) for individual fish, as a function of their environmental covariates experienced during outmigration.

Note that the trickle-release strategy can also be used in the same way as a single batch release, namely to estimate a single, net survival proportion based on counting the “detects” and “non-detects” from many released fish. However, a trickle-release estimate based on N released fish should be more reliable than the estimate obtained by releasing those same N fish in a single batch. That is because the transit and survival “events” that comprise the trickle-release estimate are more spread out over time than they would be for a batch release, thus better representing the range of conditions experienced by all juveniles during the full season of outmigration.

The panel recognizes that logistical and practical factors, such as the availability of captured juveniles, would constrain any proposed trickle-release strategy. The JPE team may wish to consider ways of loosening these constraints and look into a trickle-release strategy in order to rapidly improve the statistical modeling of survival.

Issues with S1: Survival egg to RBDD

The first survival component of the JPE (i.e., the survival prior to reaching RBDD), S1, was found to be biased low for 2014. S1 was estimated at 0.27, but based on the JPI the survival was 0.16 (Table 1). This bias resulted in an overestimate of the JPE (compare Scenario 1 to 2 in Table 1).

In considering Egg to Fry Survival (Attachment 3 of JPECR 2014) the panel concluded that the ratio of the S1 calculated from the JPI ($S1_{JPI}$) and S1 used in the JPE ($S1_{JPE}$) was highly uncertain (Figure 1). Ideally, the ratio would be 1 and, because the ratio directly reflects bias in the JPE, the panel concludes that JPE, just from S1 alone, is highly uncertain. The panel also noted that the ratio in 2014 was 0.59, which was the third lowest of the record.

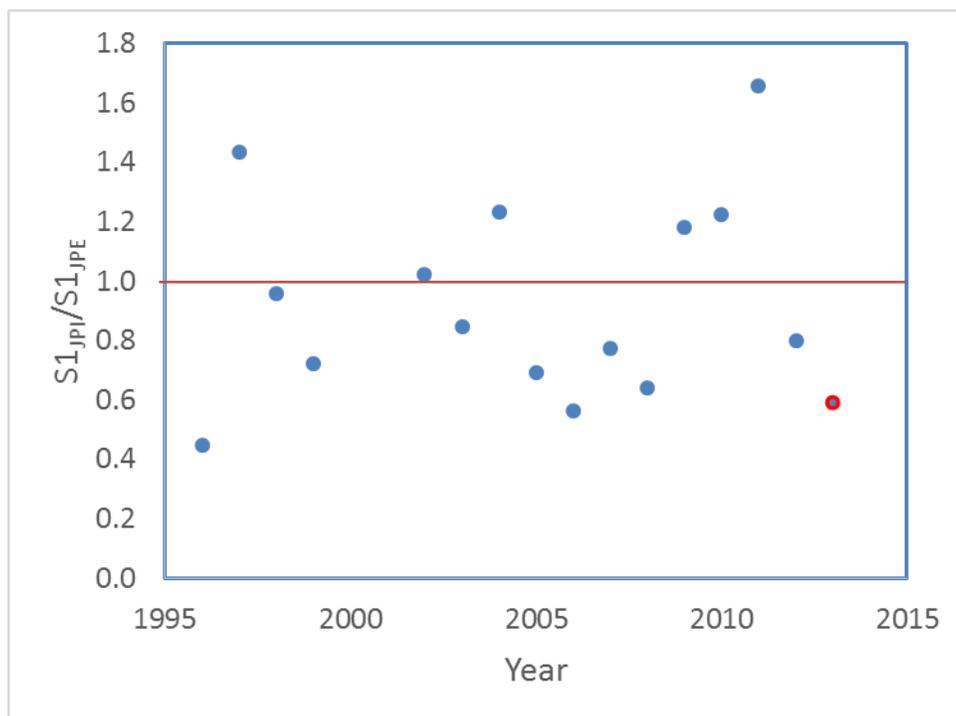


Figure 1. Ratio of S1 calculated from JPI to the corresponding value of S1 used in calculating the JPE. The ratio can be interpreted as a measure of the adjustment in JPE for errors in S1. The 2014 ratio (in red) indicates, that from errors in S1 alone, the JPE was 59% of the reported estimate. Data from Egg to Fry Survival in Attachment 3 of JPECR (2014).

Recommendations on JPE

The current overall conclusion on JPE is that the method of calculating JPE results in a highly uncertain value and has weak support in data and theory. Some of these problems can be resolved with future research, but the challenges in improving JPE estimates are considerable. Therefore, the panel suggests applying the precautionary principle when estimating the JPE until additional data is acquired on survivals of WRCS. To assist in developing an improved JPE the panel suggests the following incomplete list of actions:

1. Derive and report JPE by alternative methods (e.g., NOAA current model, the Cramer Fish Science Sacramento River Winter Chinook Salmon Juvenile Production Model (CFS 2014), and other methods as modified with suggestions for S1 and S2 estimations).
2. Make separate estimates, with confidence intervals, of S1, S2, and JPE from each method.
3. To develop better estimates of S1 (egg to RBDD) the panel suggests conducting retrospective analysis of models using the existing data (1996-2014) from the smolt carcass surveys, JPI, and environmental monitoring. The analysis could include both statistical (multinomial regressions) and mechanistic (e.g., CFS WRCS juvenile production model) approaches. The panel is not aware that either NOAA or CFS conducted a retrospective analysis of their methods using available data.
4. Commit resources to developing improved estimates of WRCS survival below RBDD (i.e., S2). The panel concluded that neither the data nor theory is sufficient to reliably estimate S2 survival at the present time. Approach 1 outlined above is likely to provide the most conservative estimated of S2. Additionally, the panel encourages estimating survivals using alternative methods such as outlined in Approach 2 above.
5. Explore the trickle release strategy combined with proportional hazards approach for estimating survivals and identifying the controlling environmental covariates.

Proposed Alternative Method to Calculate Cumulative Salvage Index Values Used for Estimating Take Likely to Occur Under the USFWS Old and Middle River Flow RPA for Adult Delta Smelt

Issues with the method used to determine incidental take of adult Delta Smelt have persisted for years. Most of the issues involve the accuracy of estimates of (1) Delta Smelt population sizes and (2) mortality associated with water operations. In this year's review, the IRP was asked to consider an alternative method of calculating a Cumulative Salvage Index (CSI) for Delta Smelt proposed by the Metropolitan Water District and to comment as to it whether it should be used to temporarily replace the method currently being applied by the USFWS. Even if there were a reasonable basis to consider one method of calculating CSI superior over the other, both are based on some measure of historical salvage, which has never been associated with any reliable estimate of Delta Smelt population size. If CSI is considered independent of population size, its application in the calculation of allowable incidental take must be dependent on a reliable estimate of population size, which has remained elusive. The lack of an accurate at-risk population estimate for Delta Smelt is a larger issue than the value of CSI in determining a reasonable level of incidental take, but the charge presented to the panel in 2014 was to consider alternative methods of calculating CSI.

The cumulative salvage index (CSI) for Delta Smelt in a historical water year t is the ratio between the cumulative salvage (CS) of smelt at the water-project pumping stations during December-March of that year, and the Fall Midwater Trawl Index (FMWT _{$t-1$}) from the previous year. The USFWS averaged the three CSI values for years 2006-2008 to determine the allowable incidental take (ITL) of smelt for the projects during any upcoming year. They set ITL equal to this average CSI (= 8.63) multiplied by the (FMWT _{$t-1$}) value for the upcoming year.

The "Proposed Alternative Method..." document (PAM) argues that the three years selected for averaging the CSI do not adequately represent years with high entrainment risk to smelt from first-flush events. The PAM argument appears to be that salvage during 2006-2008 did not capture the full CSI variability that could be expected due to non-anthropogenic factors (i.e., first flushes) that are beyond the control of flow management, where flow is measured by OMR.

The PAM suggests that a broader range of realistic CSI values can be obtained from a linear regression model that predicts CSI from two predictors: i) OMR flow, and ii) an inadequately-defined Secchi depth variable as a surrogate for turbidity, known to strongly influence smelt movement. The PAM describes how the regression model, which predicts $\log(\text{CSI})$, was fitted to CSI, OMR, and Secchi data from $n = 18$ years

between 1993 and 2012 (1997-98 were omitted). The PAM then assumes scenarios of how the historical OMR flows for those 18 years would have been altered, if RPA controls on OMR had been implemented in some years. These altered flows are then inserted back into the model, along with the observed Secchi values from those years, to predict new CSI values that might have been observed historically, if the RPA controls on flow had been implemented (Figure 12, PAM).

The PAM interpretation of these predictions is very brief and unclear (Sec. 4, PAM). By implication, their point seems to be that, even if the RPA controls on OMR had been implemented during those 18 years, one would still have seen values of CSI that were much larger in many years than the 8.63 average from 2006-2008. Thus, the PAM believes that $CSI = 8.63$ defines an unrealistically low multiplier for estimating the expected smelt salvage, given the natural variation in factors other than OMR flow that determine smelt entrainment.

The final PAM document, as reviewed by the panel, stops short of stating exactly how their historical predictions from the CSI regression might be used to set an alternative, higher CSI threshold that would increase the ITL. However, that is clearly the purpose of PAM's regression model, as seen in an earlier draft of the PAM and in written responses to that draft from K. Newman and the NRDC, all of which were available to the panel.

In the Charge questions, the IRP was asked to evaluate the "scientific robustness" of the PAM's proposed regression model, its assumptions, and its predictions.

Prediction uncertainty of the regression model.

The panel supports the basic concept behind the PAM effort, namely, to use modeling to extend the years of historical data that inform an ITL determination assuming, of course, that the current Delta Smelt population size is within the range of historical population sizes. The panel did not find the PAM's modeling method to be a sufficient advance over the current ITL-setting method to warrant a recommendation that USFWS switch to the PAM approach. The substantial statistical uncertainties surrounding both methods is sufficient justification for the reluctance to support a change in approach.

Although the PAM's regression model's fit was "very good" (p. 13, PAM) with $R^2 = 0.75$, individual predictions of CSI from the model are highly uncertain, due to the effects of back-transforming from the $\log(CSI)$ scale. This prediction uncertainty can be illustrated by first refitting the regression model (their Eq. 1), using the data in Table 1 of PAM, and then using the model to predict CSI for the 18 historical years of Tables 1 and 2 (PAM).

Like the PAM predictions in their Table 3, our predictions assumed the PAM Scenario 1 (Table 2) for altered OMR, and used historical observed Secchi values. However, we also computed 95% confidence intervals (CI's) on predicted CSI for each year (Neter et al. 1983). See Fig. 2 below.

The PAM argues that model predictions of CSI (red X's on the plot in Fig. 2) represent levels of CSI that one might expect to see in the future if RPA controls on flow are implemented. However, the CI's on these predictions are quite wide. In 16 of 18 years, the CIs cover the (2006-2008) mean value of 8.63, which is currently used by USFWS as the most likely future value of CSI under RPA controls on flow.

The mean value of 8.63 itself also has a wide CI [0, 25] based on being an average from CSI values from only three years. Note that the CI [0, 25] covers the regression model's point predictions in all but one historical year. In short, there is no significant difference between the mean value from the USFWS's "representative" years, and the regression model predictions when both are interpreted as likely values of future CSI under RPA controls.

Given these uncertainties, the panel was not persuaded that the PAM regression model produces more accurate predictions of the CSI levels one might expect to see in the future as compared with the 2006-2008 mean of 8.63. We do not recommend switching to the regression model for setting an ITL, especially because both models should soon be superseded for that purpose by a smelt life cycle model that would presumably also account for uncertainty in estimates of population size. Neither the draft PAM proposal nor the current USFWS implementation of the 8.63 multiplier account for CSI prediction uncertainty (Fig. 1) in their use of CSI to determine an ITL. Future ITL determinations, however they are calculated, will be more scientifically credible if they do account for such uncertainties.

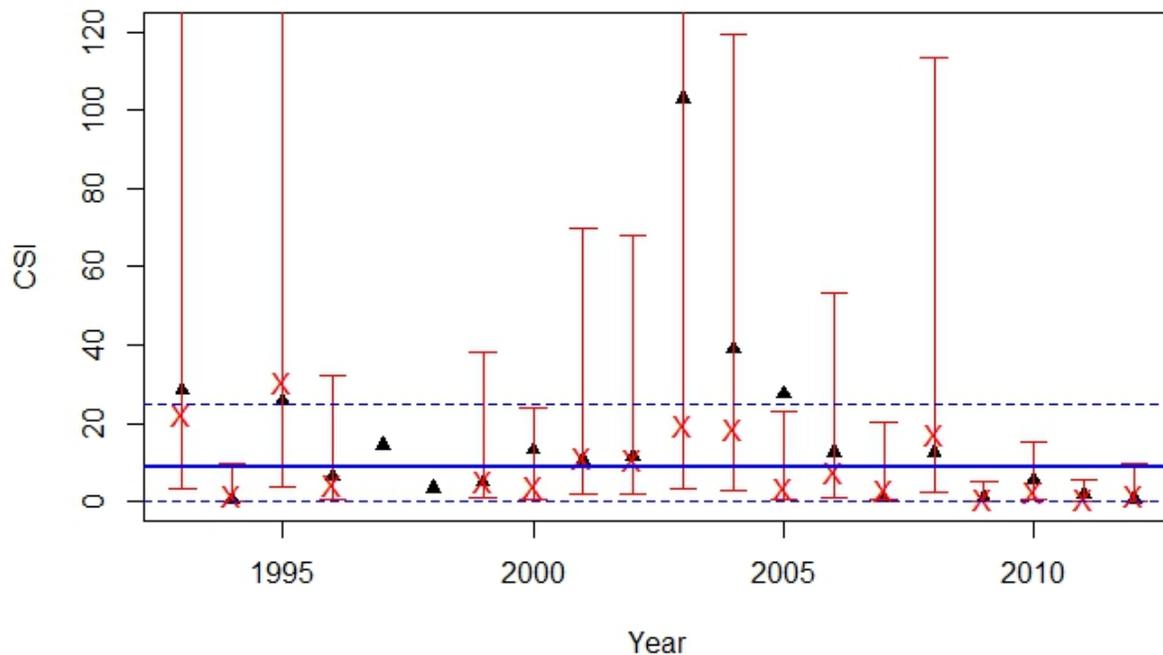


Figure 2. PAM regression model predictions of smelt CSI (red X's) and their 95% prediction intervals (red error bars), for 18 historical years (1993-2012), under PAM Scenario 1 of altered OMR flows. Black triangles are observed values of CSI. The solid blue line is mean CSI = 8.63, which is the multiplier currently used for the ITL. Dashed blue lines are the 95% CI on the estimated mean of 8.63.

The modeled response of CSI to river flow.

In their workshop presentations, the PAM authors noted that their regression approach to estimating CSIs, as well as the 3-year mean CSI, will be superseded by a more complex and realistic, process-based smelt model within a few years. It is the panel's understanding that the goal is to develop a spatially-explicit life cycle model of Delta Smelt that simulates population distributions throughout the Delta, as a function of freshwater inflows and withdrawals, sediment regimes, temperature, and other factors. Such a model would be valuable for a generally improved understanding of smelt population dynamics. However, our focus here is on how such a life cycle model might be used to better manage flow near the pumping projects, thus reducing entrainment and smelt loss.

The PAM's regression model reveals challenges that will arise when the more complex life cycle model is applied to the flow management problem. One such challenge is to

make assumptions about the independence of a model's driving variables. The PAM report made regression model predictions only for the 18 historical years whose data was used to develop the model. To make the predictions, the PAM authors used the observed values of Secchi depth measurements for those years, but they altered the observed OMR values from those years under two scenarios of hypothetical flow management. These decisions assume that OMR and Secchi measurements can vary independently of each other, and the PAM (p.13) argues for this independence because their Secchi variable was measured in the Sacramento River, at some distance from the water projects. In his comments on the draft PAM report, K. Newman reported an apparent nonlinear relationship between Secchi and negative OMR values in the 18-year record, thus challenging PAM's independence assumption. Newman's apparent relationship is suggestive, but cannot be resolved without additional data.

The PAM's strategy of predicting only for the 18 historical years, using their observed Secchi values and altering their observed OMR flows, seems to imply that these Secchi and OMR values are specifically linked to particular years and hence are linked to each other, which is inconsistent with the PAM's independence assumption. Thus, although PAM's historical predictions are an interesting exercise, we could not recommend using the observed Secchi values from specific historical years, along with their paired, scenario- adjusted OMR values from corresponding years, is not recommended for predicting likely future values of CSI.

Instead, the panel suggests using a Monte Carlo approach to predict likely future values of CSI. This approach would repeatedly choose random, independent values of Secchi and OMR from their respective distributions, which could be estimated from the 18-year record. The random (OMR, Secchi) pairs would then be inserted into the regression model, to repeatedly predict CSI. Likely future values of CSI would then be described by the resulting distribution of predicted CSI values, which could be summarized by its mean, variance, and shape (probably lognormal). This approach recognizes that Secchi and OMR in a future year are highly unlikely to be identical to the values from some historical year, and it is also consistent with the PAM's independence assumption.

The Monte Carlo approach attempts to characterize the response of the regression model to OMR and Secchi in a more general fashion. For example, the relative effects of these two predictor variables can be compared by their standardized regression coefficients, which are computed by multiplying each coefficient in Eq. 2 of PAM by the standard deviation of its predictor variable and dividing by the standard deviation of $\log(\text{CSI})$, as estimated from the model-fitting data (Neter et al. 1983). The standardized coefficients of Secchi and OMR are -0.76 and -0.36, respectively. This means that an increase in Secchi of one standard deviation is predicted by the model to result in a

change of -0.76 standard deviation units in $\log(\text{CSI})$. A similar interpretation applies for the standardized OMR coefficient. Thus, in standard deviation units, a given change in the Secchi value has about twice the effect on $\log(\text{CSI})$ as does an equivalent change in OMR flow.

The secondary importance of OMR as a controller of CSI can also be demonstrated by plotting the regression model's predictions of CSI versus OMR, while fixing Secchi at lower (25thile), median (50thile) and higher (75thile) values of its observed historical distribution (Fig. 3). The plot shows that the predicted value of CSI at any level of OMR flow depends strongly on what one assumes for a Secchi value.

In short, any application of the regression model to limit salvage through OMR flow management (that is, setting an ITL) requires one to also make quantitative assumptions about turbidity (i.e., Secchi) levels in a future year. The above analysis shows that these assumed levels of Secchi will play a dominant role in determining the ITL.

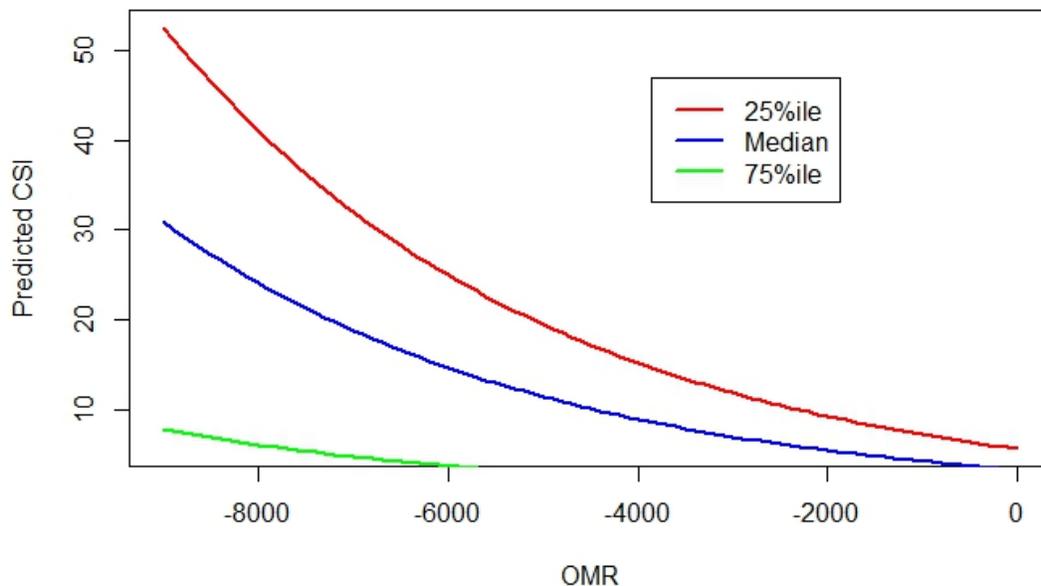


Figure 3. PAM regression model predictions of CSI versus OMR flow, with Secchi held fixed at its 25th, 50th, and 75th percentiles.

The above analysis has implications for the ongoing development of the smelt life-cycle model, and its planned role in setting an ITL. The historical data and our PAM model analysis suggest that river flow, as indexed by OMR or other flow variable(s), will be a

relatively weak predictor of cumulative smelt salvage in any realistic model. This conjecture is consistent with the well-known, process-based effects of turbidity on smelt dynamics. We expect that turbidity, along with other factors, will exert a strong control on the overall level and changes in smelt salvage that could be expected from any managed flow regime.

To use the life cycle model in a forecasting mode, as is needed for setting an ITL for a future year, values of these other factors must be projected or assumed for the future. This process will add considerable uncertainty to any future projections of flow effects on CSI. As model complexity increases, so will the cumulative effort and uncertainty of making such assumptions and projections. Hence, the panel advises the life cycle model development team to think in advance about the challenges of using their model in a strict forecasting mode to help set ITLs for Delta Smelt. Hopefully, these considerations will influence the level of realism and complexity that the life cycle modelers will attempt to represent.

General Consideration of RPA Actions Under Dry Year Conditions

With a third year of increasing drought severity, participating agencies were faced with a series of experimental and operational challenges. There must be careful consideration of hydrologic events in the future and what impacts might be foreseen on operations and concurrent monitoring and research opportunities.

In its annual report on Drought Operations and Forecasts, DWR suggests that:

“... the forecasted carryover storage of approximately one million acre-feet in Lake Oroville by the end of water year 2014 (September 30, 2014) will be sufficient to meet human health and safety needs in 2015 (projected as 260,000 af) and other project purposes, including maintaining Delta salinity control. This level of storage should be sufficient under a conservative 90% exceedance hydrologic assumption for water year 2015, while still meeting regulatory and contractual commitments.”

This plan does not propose a reserve for the following year, 2016, in the event that the drought is not relieved. Presumably this forecast is based upon a historical record that indicates a likely return to wetter conditions. However, another consideration must be made; that this drought may be the leading edge of a climate change event of indeterminate intensity and duration. Therefore, it behooves DWR and other agencies to consider alternative targets and strategies.

The importance of accurate forecasting tools is highlighted by the recent series of dry water years with the possibility that this trend will continue into the future. Different tools

are used to optimize reservoir operation to meet downstream temperature targets over short- versus long-time periods. Both categories of tools are needed to ensure that a dam is operated to maximize benefit to target biota. Short-time period tools address questions such as, “what blend of reservoir water by depth and temperature is required to meet a downstream temperature target based on daily or weekly forecast meteorological conditions?” Such a tool is expected to give relatively accurate forecasts ($\sim 1.0^{\circ}$ C) because it can be supported with reasonably accurate meteorological forecasts. It can be used to adjust daily-weekly operation in near real-time. Long-time period tools address questions such as, “what blend of reservoir water by depth and temperature is required to meet a downstream water temperature target (i.e., the temperature control point) requirement over an annual cycle or other extended time period?” Such a tool cannot be as accurate as the short-term operations tool because it must employ input data synthesized over the annual cycle. Consequently, in long-term operations, a particularly critical time period (e.g., hottest and driest year in the period of record) is analyzed to determine the most downstream point in the river so that a downstream target can be reliably met. It makes little sense to operate to an overly ambitious, downstream target early in the water year and then retreat later in the season to a temperature control point closer to the dam because of a shortage of cold water storage. Worse yet, it is possible to deplete cold water storage or for reservoir water levels to be reduced to a point where it cannot be discharged using the water withdrawal system of the dam as happened this past year at Shasta Dam.

Efforts are underway to build a sophisticated temperature monitoring/modeling system for the Upper Sacramento River to improve the short time period management of river water temperature. This should allow USBR to better manage the cold water resource. However, the existing legacy water quality model upon which the long time period release patterns are based continues to be HEC-5Q, for which neither a user-manual nor calibration report are available. In the original formulation of HEC-5Q, a 1-D (vertical) reservoir stratification model (all that was available at the time of development of HEC-5Q) was used to forecast reservoir stratification patterns. Unfortunately, a 1-D formulation to simulate reservoir stratification is usually inadequate because most reservoirs are inherently 2-D (longitudinal and vertical). Based on satellite imagery, Shasta Lake is clearly a 2-D system. Use of a 1-D model for reservoir simulation requires that model parameters be manipulated (i.e., values are used outside of recommended ranges) to force the model to simulate a condition for which it was not designed. Inappropriate use of a 1-D model for an application that is inherently 2-D affects model accuracy. A more accurate formulation (e.g., CE-QUALW2) should be used to replace HEC-5Q. From the Sacramento River Temperature Task Group Report of WY 2014, it is clear that USBR continues to use HEC-5Q with no apparent movement towards use of an alternate model. The continued use of HEC-5Q will severely limit the

ability of USBR to manage water to meet the co-equal goals, particularly to perform scenario analysis over an annual cycle to evaluate the existing carry over storage and develop reasonable downstream temperature control points.

During presentations by USBR, the panel was informed that water levels within Shasta Lake were lowered below the level of the opening to the Temperature Control Device. This device was designed to release shallow water in the spring and early summer and deep water in the late summer and early fall (Higgs and Vermeyen 1999). Information on the water stratification pattern upstream of the dam and how the stratification pattern related to the elevation of the other release ports was not presented. Consequently, it is not possible to make a complete assessment of how extremely low forebay water levels affected the ability of the outlets to blend water to meet downstream water temperature targets. It might be useful to investigate reservoir destratification techniques to determine if they could be useful to bring colder, deeper water closer to the surface at the elevation of the lowest port of the Temperature Control Device. These well-established techniques were originally developed to mix warmer, oxygenated surface water with deep oxygen-depleted water to improve the water quality of hypolimnetic (deep) releases. In the case of Shasta Dam, these same reservoir destratification techniques could be used to solve the inverse problem of bringing deeper colder water to the elevation of the lower ports on the Temperature Control Device.

One consideration might be including an end-of-year storage target as part of the in-season management. Currently, operations focus upon water quality and temperature targets throughout the year but do not include an end-of-year storage target.

As has been mentioned in previous reports, it is becoming evident that the possibility of long-term changes in weather pattern must be considered for research and management purposes. Normal oscillations in both Pacific and Atlantic oscillations, including the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO), and the El Niño Southern Oscillation (ENSO), have been shown to have dramatic effects on agricultural production (Maxwell et al. 2013), river flow patterns (Kelly and Gore 2008), and a series of landscape effects that drive ecosystem function in river ecosystems (Gaiser et al. 2009; Johnson et al. 2013; Sheldon and Burd 2013; Keellings and Waylen 2014; Olin et al. 2014). These far-reaching changes suggest that many new challenges to management and research must include predictable changes in these oscillations, but also with climate change, the possibility of dampening or alteration of the oscillations which might influence temperature and water quality targets for management (Olin et al. 2014).

The potential impact of long-term climate change will necessitate some creative analysis of various scenarios for future research and management decisions. Although there are a wide variety of potential impacts, there is considerable potential for significant changes in water availability and allocations in the next 100 years. Cayan et al. (2008) have demonstrated that, depending upon a variety of carbon-dioxide levels, water availability [as snow water equivalents] can be significant to future decisions (Table 2).

Table 2. Changes in April 1 snow water equivalents for the San Joaquin, Sacramento, and parts of the Trinity drainages (adapted from Cayan et al. 2008).

ELEVATION	MEAN 1961-1990 (Km ³)	2005-2034	2035-2064	2070-2099
1000 – 2000 m	4.0	-13 to -48%	-26 to -68%	-60 to -93%
2000 – 3000 m	6.5	+12 to -33%	-08 to -36%	-25 to – 79%
3000 – 4000 m	2.49	+19 to -13%	-02 to -16%	-02 to -55%
All Elevations	13.0	+06 to -29%	+0.12 to -42%	-32 to -79%

With these potential changes, it is imperative that various scenarios of flow loss be conducted in order to determine long-term management, research, and monitoring strategies. At a minimum, a time-series analysis of historical records [accounting for decadal or multi-decadal patterns] with 20%, 30%, and 40% losses should be examined. These losses, then, can be used to determine critical months for alteration of management and monitoring schedules.

We are gratified that the Clear Creek Technical Team continues to complete its PHABSIM analysis, as reported this past year. Although there has been considerable effort to demonstrate that RIVER2D provides more accurate habitat assessments than IFG4, for example, the ultimate output still remains a relationship between habitat availability and daily, weekly, or monthly discharge. These outputs present an opportunity for a new project to analyze the ultimate gain or loss in habitat under reduced flow scenarios. A relationship between habitat and discharge under flow reduction scenarios can be created from the model output. Time-series analysis, through TSLIB or other exceedance programs, should be based upon frequency and duration of habitat events rather than the discharges associated with those values. These graphical presentations can create the decisions necessary to create more effective management and monitoring strategies. See example in Figure 4.

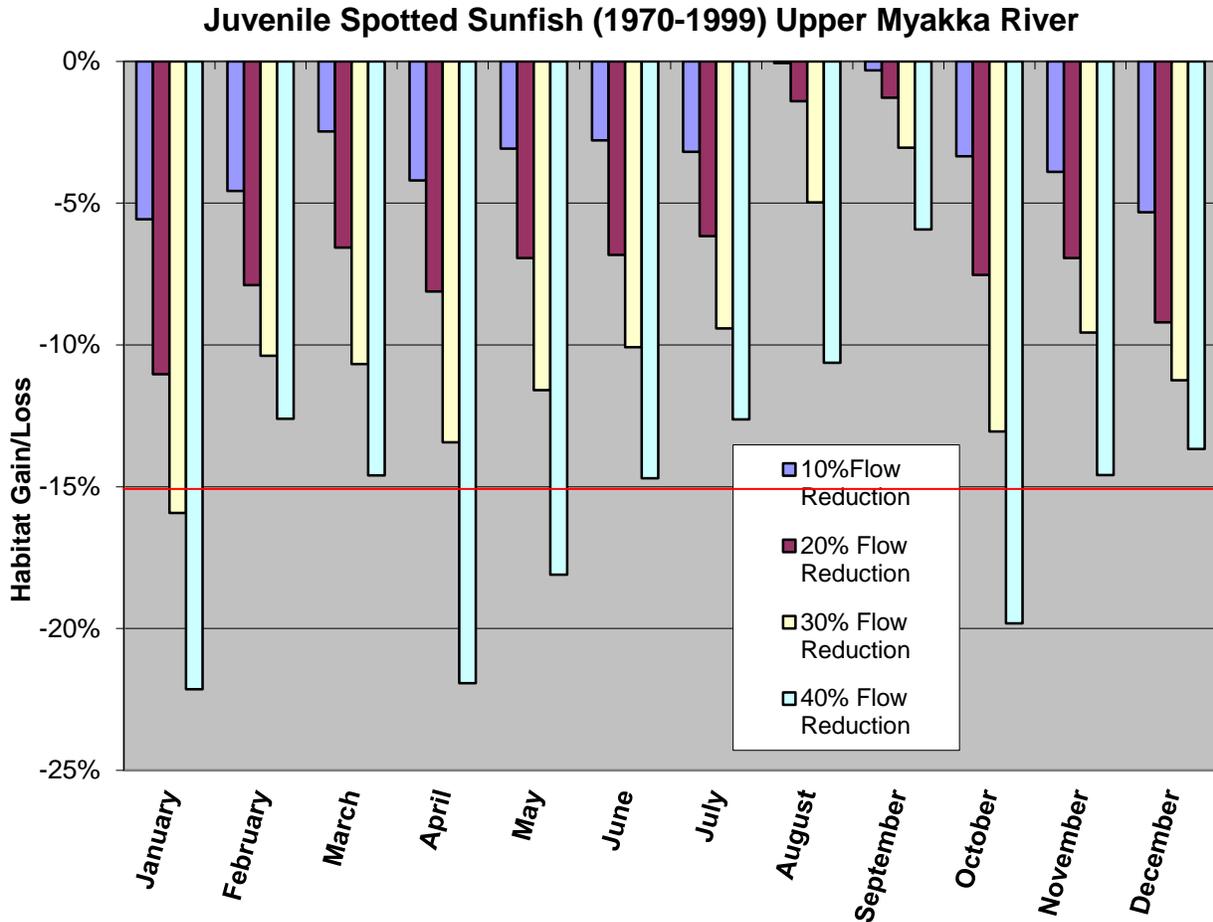


Figure 4. An estimate of habitat gain or loss during the AMO dry period on the Myakka River. If a 15% habitat loss cannot be exceeded, this model predicts that a 20% flow reduction is acceptable in January but in September even a 40% flow reduction does not significantly impact juvenile spotted sunfish. This analysis is repeated for a suite of target fish and macroinvertebrates.

The panel recognizes that water operation actions are driven by a set of mandated rules and that the agency personnel manning reservoir operations may not have the authority to take actions outside of the framework of these rules. However, it would appear that additional flexibility (altered rules) could be authorized by the appropriate agency management under critically dry conditions such as occurred in WY 2014 in order to conserve scarce water resources.

IRP RESPONSES TO QUESTIONS DEFINING THE SCOPE OF THE 2014 LOBO ANNUAL REVIEW

Responses of 2014 IRP to questions regarding modified Delta Cross Channel (DCC) Gate opening criteria per Attachment G in the Drought Operations Plan

- 1) Is using the upstream trigger at Knights Landing protective of 95% of the juvenile population monitoring for downstream emigrating fish given their travel time to the DCC?**

The question presumes that the size of the juvenile population at risk is known (i.e., 95% of what number?) However, the panel is unaware of any information that provides an accurate estimate of population size and so is unable to provide an answer. To answer the question even in terms of relative population size requires some quantitative measure of the population at Knights Landing and a site in the Sacramento River downstream of the DCC for comparison.

In any case, it seems highly unlikely that protection of 95% of the juvenile population could ever be demonstrated. The 95% confidence interval around any estimate of 95% of the juvenile population size would likely be so large as to be meaningless.

- 2) Are the localized triggers of the Sacramento trawl and area beach seines protective of 95% of fish lingering in the area of the DCC?**

See answer to Question 1 above. In addition, the uncertainty of the estimates of population size made using either the trawl or beach seine data would have to be known as well. Given that these methods provide essentially an instantaneous snapshot of catch at discrete locations, the accuracy of these methods is likely considerably less than that of the Knights Landing rotary screw trap, which samples a location continuously for an extended period of time. It seems unlikely that any method currently in use could provide the information necessary to answer either Question 1 or 2.

- 3) Are there other (possibly more sensitive) recommended methods or other station locations, both upstream and downstream of the DCC, for use as the basis for a DCC trigger in the future?**

The time delay of approximately two days currently required to close the Delta Cross Channel should be shortened, if possible. Sampling locations that are closer than two-days travel time to the DCC gates would improve the ability to predict fish arrival times

at the DCC gates, but would require a more rapid response time for gate closure, which may be impractical.

4) What studies or methods would you recommend to evaluate the effectiveness of the DCC gate operations?

The question of DCC operations effectiveness involves both fish diversion and Delta water quality since DCC operations must consider both criteria.

Considerations for studying operations for fish passage effectiveness

The April 2014 Delta Science Program workshop entitled, "Interior Delta Flows and Related Stressors" is of direct relevance to improving the effectiveness of fish diversion at the DCC. In particular, the workshop presentation by Jon Burau (USGS/Sacramento) on the hydrodynamic field studies at the junction of the Sacramento River with Georgiana Slough and the Delta Cross Channel appear relevant to improving the operational effectiveness of the DCC.

This presentation, described a 2008 acoustic telemetry study that has relevance to the operations of the DCC over diel and tidal cycles. Three findings were relevant to the effective DCC operations:

Based on the Burau (2014) presentation, the IRP suggests testing the hypothesis that an effective DCC operation is to open the gates on the ebb tides during the day. Further studies of the behavior of acoustically tagged fish in the DCC over diel and tidal cycles may be required to evaluate this hypothesis.

- a. a majority of the fish arrived at night at the DCC.
- b. with DCC gates open fish may be drawn into the interior Delta with the convergence of velocity streamlines on the flood tide
- c. with DCC gates closed fish can be drawn into the interior Delta by the convergence of velocity streaklines into Georgiana slough

Considerations for studying operations for water quality effectiveness

Studies also suggest that tidally coordinated DCC operations would be effective for improving Delta water quality (i.e., low interior Delta salinity). The issues to consider here are the primary assumptions that opening the DCC gates, especially if operations include a diurnal/tidal component, will allow sufficient freshwater flows through the Mokelumne system to significantly reduce salinity in the interior Delta.

The benefit of opening the DCC gates is assumed to be that freshwater from the Sacramento will be diverted into the Mokelumne system and flow towards the San Joaquin and the interior Delta. It is further assumed that these pulses of water will be capable of preventing additional saltwater intrusion on the San Joaquin stem of the Delta. These assumptions are based on the collective experience of pump operators and studies that have shown that when the DCC is open continually for multiple days, the end result is better water quality in the interior Delta.

Therefore, there is a continuous net flow downstream through the Mokelumne system towards the central Delta. This net flow on the North Mokelumne River when DCC gates are open was observed during 2012 field experiments at the junction of Georgiana Slough and the Mokelumne River by Gleichauf et al. (in press) who observed that the river was tidal when the DCC was closed. Depending on how long this operation is used, the expected benefit for salinity in the central Delta may or may not be realized.

Balancing the needs of water quality and fish protection are important enough to justify further analysis of the water quality benefit that will result from this modified DCC gate operation. A hydrodynamic modeling analysis and associated salinity transport modeling should be done to analyze whether improvements in water quality in the central Delta justifies this operation. The simulation should use the observed Sacramento and San Joaquin inflow, Clifton Court Forebay gate operations, and State and federal facility pump operations for WY 2014. The operation of the DCC should be modeled in three conditions. In the first condition, model the DCC operations with the actual gate operations in 2014. In the second condition, model the proposed pulsed open and closed operation. In the third simulation, model the period with the DCC set open for the entire period when the DCC pulse flow was modeled in the second simulation. From this modeling exercise, the travel time of the Sacramento River freshette to the interior Delta water quality stations can be calculated and compared to the travel time when the DCC remains continually open.

Responses of 2014 IRP to questions regarding proposed modifications to the juvenile production estimate (JPE) calculation and use/application of data from acoustically-tagged Chinook Salmon releases

1) How important is it to eliminate overlap in survival terms vs. potentially not including the survival rate of the fry life history stage?

Given the considerable uncertainty and variability in the survival estimates used to calculate JPE, the adjustment for the fry life history stage outlined in the presentation for the overlap in the survival terms is not warranted. The current two-term model based on S1 and S2 is of sufficient complexity.

Eliminating the overlap in survival stages reduces bias in the final JPE. The downside is that there is no longer a distinct survival term for fry, which might be biologically less realistic. However, for the narrow but important purpose of making an unbiased JPE, the panel suggests using a model that is structured primarily by the data that can be collected, rather than by biological realism. If the data required for a good estimate of fry survival is currently unobtainable, then the best option may be to exclude a fry survival term from the JPE calculator. In short, the panel supports the current approach in which survivals are defined in terms of data collection sites not by specific life stages.

The panel also noted that the anomalous conditions in 2014 illustrate that fish migration behavior cannot be simply defined by distinct life stages in which well-defined transitions from fry to smolt stages occur at specific times and locations. Winter-run Chinook Salmon migrate through the river system over a protracted period of time at different sizes. Examples of the anomalous conditions in 2014 include:

- The migration was characterized by an extended period of rearing at upriver locations, higher percentage of smolt-sized fish passing the RBDD, a distinct response of fish to a precipitation and turbidity event, and shorter Delta residence time (Stuart IRP Presentation 2014).
- Fish passed RBDD later than in other years but passed Chipps Island earlier. Additionally, the passage date is quite variable; 50% passage at Knights Landing varied by four months over a 7-year observation record.
- The CFS Juvenile Production Simulation model did not capture the unusual conditions in this drought year and therefore the JPE based on numbers from carcass surveys is highly uncertain. The CFW model significantly under-predicts

the uncertainties (Jones and Bergman 2010) and could not account for the discrepancy.

- 2) How should the missing life-stages (i.e., fry-to-smolt) and the gap in juvenile rearing from Red Bluff Diversion Dam (RBDD) to Salt Creek (approximately 2.5 RM downstream of RBDD) be accounted for in the current JPE methodology?**

Not accounting for mortality in the 2.5 RM reach between RBDD and Salt Creek is not significant compared to survival to Tower Bridge, a distance of approximately 370 RM. Using the WRCS to characterize the survival per RM, then ignoring the 2.5 RM reach would increase survival from 13.8% to 14%. This level of change is insignificant compared to other forms of uncertainty and bias.

Accounting for the fry-to-smolt survival stage appears problematic because when and where a fry becomes a smolt is not measurable.

- 3) Hatchery origin juvenile winter-run have shown a unique life-history strategy not seen in other runs, in that they hold upstream in dry years for 30-50 days. How should this behavior be incorporated into the JPE?**

The panel was unable to provide advice on this difficult problem. However, a similar problem has been studied concerning the migration of Snake River sub-yearling fall Chinook. In that system initiation of migration was highly variable and involved temperature and growth rate thresholds. See the MS thesis: Widener, D. *Migration and bioenergetics of juvenile Snake River fall Chinook salmon*. 2012. Available from: http://www.cbr.washington.edu/sites/default/files/papers/widener_thesis.pdf

- 4) The weighting for the JPE brood year 2013 was 50% for the 5 years of late fall-run acoustic tag data, and 50% for the one year of winter-run acoustic tag data.**
- a. The late fall-run acoustic tag data included data from various water year types, and the year of winter-run acoustic tag survival was conducted in a dry water year. How should water year type be considered and factored into the weighting in any given water year?**

See section *Issues with S2: Survival from RBDD to Delta* above for possible approaches.

- b. What should the weighting be between late fall-run and winter-run acoustic tag data with each additional year of winter-run acoustic tag data? At what**

point (how many years of winter-run acoustic tag data) should we not consider the late fall-run acoustic tag data to develop the winter-run JPE?

Use of late fall-run acoustic studies to estimate winter-run JPE is not encouraged until sufficient data are available to compare WRCS and LFCS survival and migration properties.

Furthermore, it is unrealistic to calculate any sort of average survival rate, regardless of the weighting scheme, and then assume that it is an accurate single estimate for next year's survival. Instead, the panel suggests that when sufficient WRCS survival data become available the JPE be estimated using Monte Carlo methods in which the terms in the JPE are repeatedly and randomly selected from individual historical years of survival rates and other vital rate parameters.

5) What additional studies or methods would you recommend to improve the accuracy of the JPE in the future?

Develop Monte Carlo methods to estimate a distribution of likely future JPE values from the spreadsheet model, rather than a single point estimate of JPE. Alternatively, replace the spreadsheet calculator with some version of the Cramer Fish Sciences model (CFS 2014). Future tagging studies may wish to consider using trickle releases, rather than large batch releases in order to facilitate survival-rate modeling.

Some possible methods for estimating the survival terms in the JPE are discussed in the JPE Section of the 2014 IRP report.

6) Given that approximately 4.43 million fry were estimated to pass RBDD from the JPE calculator, but only 1.78 million fry were estimated to pass RBDD based on U.S. Fish and Wildlife Service's rotary screw trapping, how should these conflicting data be interpreted?

The discrepancy can be largely explained by the variability in the model's egg-to-fry survival parameter (see Fig. 1). If one considers the multiplicative effect of uncertainty in the egg production rate, it is surprising that the discrepancy isn't actually much larger. The estimate of S_1 used in the calculation of JPE from carcass surveys is highly uncertain. See JPE Section "*Issues with S_1* " and "*Recommendations on JPE*" above.

Responses of 2014 IPR to questions regarding the proposal for calculating cumulative salvage index values used for estimating take likely to occur under the USFWS Old and Middle River flow RPA for adult Delta Smelt

- 1) Is the proposed calculation more scientifically robust than the method, based on cumulative salvage index (CSI) values from 2006-2008, that is currently used to estimate incidental take?**

The meaning of “scientifically robust” is unclear. Predictions from the regression method and the current method do not significantly differ due to their high uncertainties. Thus, there is no objective basis upon which to recommend switching from the current method to the regression method for purposes of setting an ITL.

- 2) Is the proposed calculation more scientifically robust than the RPA of (in) accounting for the effects of variable physical and biological conditions on incidental take that may be expected in the future?**

The proposed regression model does account for one additional environmental factor (turbidity, as indexed by the Secchi measurement), and so may be more realistic than the current method. However, this increased realism adds the burden of making future projections of Secchi, if the proposed model is used to estimate future expected take. Also, there is no connection to the size of the Delta Smelt population at risk. As the smelt population approaches zero, relationship between salvage and environmental variables such as turbidity or flows should not be expected to match historical correlations that may have held when smelt were more abundant.

- 3) Is it scientifically appropriate to use model-adjusted OMR values but historical turbidity values to adjust historical salvage values, as is done in the proposal?**

This action is appropriate, as long as you assume that OMR and Secchi are independent, which is a questionable assumption. However, even if this independence is true, the use of only the 18 historical CSI predictions to determine an ITL is unrealistic because it understates the true variability of likely future CSI values.

- 4) Are there additional aspects of the proposed calculation of CVP/SWP salvage of adult Delta Smelt that could be refined?**

Yes. Seriously consider the uncertainty in any such calculations and the subsequent effect on allowable take.

5) Are there alternative methods or studies that would improve future estimates of take?

The panel understands that a smelt life cycle model is currently under development, for making future estimates of take. We encourage that effort and suggest that it incorporate estimates of model uncertainty.

One of the key metrics in this proposed calculation is OMR flow, a daily, tidally-averaged index. This metric is also being considered in other future calculations of entrainment. What is missing in the discussion of entrainment at the export facilities, in general, is the recognition that the export facilities are located in the tidal zone of the South Delta and that flows around those facilities cannot be simplified to daily, tidally-averaged flows when considering entrainment issues. Entrainment is a tidal timescale problem.

Responses of 2014 IPR to questions regarding the general implementation of the RPA Actions under dry year conditions based on prior science review questions about RPA implementation

1) Were the scientific indicators, study designs, methods, and implementation procedures used appropriate for evaluating the effectiveness of the RPA actions under dry conditions? Are there other approaches that may be more appropriate under dry conditions?

The effectiveness of RPA Actions as measured in terms of biological responses has remained elusive under all conditions. Certainly, some actions and triggers were altered as a result of limited available water resources in this critically dry water year, but there were no outstanding biological metrics that could be used to evaluate effectiveness of the actions in terms of population benefits in the present or subsequent year.

2) How can implementation of RPA actions be adjusted to more effectively meet their objectives under dry conditions?

As previous IRP reports have noted consistently, effectiveness must be tied to biological response metrics, which continue to be associated with so much uncertainty that it has not been possible for the panel to provide a satisfactory response to this question in any water year type, at least thus far.

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APPENDIX 1 – Materials for 2014 IRP Review

Review Materials Available to the 2014 LOBO Independent Review Panel

- I. The following documents were provided in electronic format as required reading by the IRP prior to the 2-day workshop in Sacramento, CA on 6-7 November 2014:***
- 1) Attachment G of the CVP and SWP Drought Operations Plan and Operational Forecast, April 1, 2014 through November 15, 2014
 - 2) Juvenile Production Estimate (JPE) Calculation and Use/Application of Survival Data from Acoustically-tagged Chinook Salmon Releases Report
 - 3) Proposal for Calculating Cumulative Salvage Index Values Used For Estimating Take Likely to Occur under the USFWS Old and Middle River Flow RPA for Adult Delta Smelt prepared by Metropolitan Water District
 - 4) Sacramento River Temperature Task Group (SRTTG) Annual Report of Activities
 - 5) Clear Creek Technical Team (CCTT) Annual Report of Activities
 - 6) American River Group (ARG) Annual Report of Activities
 - 7) Stanislaus Operations Group (SOG) Annual Report of Activities
 - 8) Delta Operations for Salmonids and Sturgeon Group (DOSS) Annual Report of Activities
- II. The following additional reports were made available in electronic format for supplemental use in providing historical context for the IRP:***
- 1) Interagency Fish Passage Steering Committee (IFPSC) Annual Report of Activities
 - 2) The Smelt Working Group (SWG) Annual Report of Activities
 - 3) Water Year 2014 Winter Run Chinook Drought Operations Assessment
 - 4) RPA Summary Matrix of the NMFS and USFWS Long-term Operations BiOps RPAs
 - 5) Central Valley Project and State Water Project Drought Operations Plan and Operational Forecast, April 1, 2014 through November 15, 2014

- 6) Proposal for a Revised ITL and Expected Take for Adult Delta Smelt Metropolitan Water District July 29, 2014 Draft
- 7) DRAFT Comments on "Proposal for a revised ITL and expected take for adult Delta Smelt" (Ken Newman, August 21, 2014)
- 8) Proposed Response to Ken Newman Comments on Proposed ITL Method Paper (David Fullerton, September 8, 2014)
- 9) USFWS Biological Opinion Sections for ITL

III. ***The following additional materials were made available following the Workshop in Sacramento at the request of the IRP for supplemental use of the IRP:***

- PowerPoint Presentations from the LOBO Workshop (held November 6, 2014 in Sacramento, CA)
- Public Comments on Proposal to Revise the Delta Smelt CSI and Adult ITL Calculation (Natural Resources Defense Council and The Bay Institute, October 24, 2014)

Additional background information from the Science Program website was also available, including reports from previous IRPs.