Brood Year 2013 Winter-run Chinook Salmon Drought Operations and Monitoring Assessment

March 2015

Winter-run Chinook Salmon Drought Operations and Monitoring Assessment

Prepared by

U.S. Department of Interior, Bureau of Reclamation, Bay-Delta Office
Joshua Israel

California Resource Agency, California Department of Water Resources, Special Studies Research Program
Brett Harvey

California Resource Agency, California Department of Fish and Wildlife, Water Branch
Kenneth Kundargi

California Resource Agency, California Department of Fish and Wildlife, Inland and Anadromous Fisheries Branch
Daniel Kratville

U.S. Department of Interior, U.S Fish and Wildlife Service, Red Bluff Fish and Wildlife Office
Bill Poytress

California Resource Agency, California Department of Water Resources, Office of Regulatory Compliance
Kevin Reece

U.S. Department of Commerce, National Oceanic and Atmospheric Administration-Fisheries West Coast Region, California Central Valley Area Office
Jeff Stuart

Table of Contents

Page

List of Tables

List of Tables - Continued

List of Figures

List of Figures - Continued

This page intentionally left blank

Introduction

In this report, possible effects of drought and management actions implemented during a drought on the freshwater phases of Winter-run Chinook Salmon (*Oncorhynchus tshawytscha,* WRCS) are reviewed. When reliable monitoring data were available, analyses were based on predictions from a conceptual model of drought operations and impacts on WRCS. We assess various metrics for consideration of impacts from the drought's environmental and management drivers for brood years 2007 through 2012, between Water Year (WY) 2008 and 2013, of WRCS. We compare these years' measures with regard to the environmental conditions and operational events in their freshwater and estuarine life stages with similar measures from Brood Year (BY) 2013 to determine if the salmon population was affected by the river flow and temperature management actions implemented during the drought year. We also describe modifications to federal and state regulations made during the spring of 2014, which increased Central Valley Project/ State Water Project (CVP/SWP) operational flexibility to maximize coldwater storage and exports, and how these modifications may have affected WRCS viable salmonid population characteristics. Lastly, we identify recommendations for further monitoring and research to identify drought's impact on WRCS and better inform decisions regarding operational impacts.

Timeline of Drought Operation Plan

For the past three years, climatic conditions have resulted in below average precipitation for the state of California. 2013 was one of the driest years on record for the State of California and December 2013 through January 2014, typically the wettest part of the year, featured a record-breaking lack of precipitation. In January 2014, following this dry period, the United States Bureau of Reclamation (Reclamation) and Department of Water Resources (DWR) grew increasingly concerned that CVP and SWP reservoirs would be depleted if they were to successfully meet outflow levels as required under the Delta water quality objectives, D-1641, which were to start February 1. Depletion of the reservoirs would compromise the long-term ability of the CVP and SWP to maintain water delivery for human health and safety, effectively repel saltwater in the Delta, and provide sufficient carryover storage for the needs of endangered WRCS. The concern was warranted, as the period from October 1, 2013 through September 30, 2014 (WY 2014) ended up being one of the driest in decades.

On January 29, 2014 Reclamation and DWR sought a temporary modification to their water rights permits and licenses. On January 31, the Executive Director of the State Water Board issued an Order that granted the temporary 180 day modification in response to drought conditions. The modification allowed the Projects to reduce Delta outflow and thus conserve upstream storage for use later and it allowed the Projects to pump at a minimal level to supply essential human health and safety deliveries when Delta outflow was lower than would typically allow such pumping (USBR 2014). Subsequent requests and modified Orders followed as conditions changed in response to precipitation events, changing water quality, and the need to modify stored water releases based upon re-evaluation of these stored amounts.

Following the initial request from Reclamation and DWR and the subsequent issuance of the Order, a Real Time Drought Operations Management Team (RTDOMT) comprised of representatives from the fisheries agencies (National Marine Fisheries Service (NMFS), US Fish and Wildlife Service (USFWS), and California Department of Fish and Wildlife (CDFW)), the State Water Resources Control Board (SWRCB), Reclamation and DWR to discuss more flexible operations while protecting beneficial uses was convened. Through the RTDOMT, the agencies strove to balance the export of water supplies needed to meet essential human health and safety needs while providing protection for, and minimizing adverse effects to, federally listed fish species. Additional efforts were undertaken to capture abandoned flows in the few instances when precipitation events occurred.

The Temporary Urgency Change Petitions (TUCP) resulted in modifications to the implementation of several actions in the NMFS Biological Opinion (BiOp) on the Long-term Coordinated Operation on the CVP and SWP, specifically allowing for further flexibility of Actions IV.1.2, IV.2.1, and IV.2.3 (Table 1). Delta Cross Channel (DCC) gate operation requirements were relaxed from the D-1641 and Action IV.1.2 requirements for a total of 10 days between February 1 and February 10, 2014 and were closed for the remainder of the relevant period per usual implementation of these regulations. D-1641 requirements were relaxed and implementation of IV.1.2 was made more flexible when the DCC gate opening was conditionally allowed per the guidelines outlined in Appendix G of the Drought Operation Plan (DOP), which was developed by an interagency technical team and evolved with the drought contingency plan. The inflow to export ratio (I:E ratio, Action IV.2.1) was modified such that prior to and following the Vernalis spring pulse flow the Projects were not required to operate to the I: E ratio of 1:1, if there was natural flow in the Delta. Because storm events did cause natural flow in the Delta before the pulse period, but not after the pulse period, the projects operated to the 1:1 I:E ratio from April 18-May 31, 2014. The third BiOp action, which sets OMR flows (Action IV.2.3), was modified such that the 14-day average of the OMR index, based on the OMR-index demonstration project values, was allowed to be more negative than -5,000 cfs for up to 7 days in mid-March, and CVP and SWP exports were limited to the minimum health and safety levels of 1,500 cfs in late March to provide more positive OMR flows as an offset. The more negative OMR was balanced with more positive OMR from March 22-31, 2014, and included minimum health and safety combined exports at 1,500 cfs from March 27-31, 2014.

Table 1. Delta RPA Actions that were Modified During WY 2014 as Part of the Drought Operation Plan

RPA Action	Usual Implementation	2014 Implementation
IV.1.2 (DCC operations)	Mandatory gate closure from February 1 to May 20	DCC gate opening was conditionally allowed per the guidelines in the “DCC Trigger Table,” which was developed by an interagency technical team and evolved with each drought contingency plan. The DCC gates were opened on 2/1/14 and closed the morning of 2/10/14
IV.2.1 (I:E ratio)	In a critical year, the projects shall operate to an I:E ratio (inflow at Vernalis: combined CVP/SWP exports) of not less than 1:1 from April 1 to May 31	Before and after the spring pulse flow at Vernalis, the projects were not required to operate to the I:E ratio of 1:1 if there was natural flow in the Delta. Because storm events did cause natural flow in the Delta before the pulse period, but not after the pulse period, the projects operated to the 1:1 I:E ratio from 4/18/14-5/31/14
IV.2.3 (OMR flow management)	The 14-day average of the OMR index shall not be more negative than -5,000 cfs anytime between January 1 and June 15. If the temperature offramp condition is met, this action may end sooner than June 15	The 14-day average of the OMR index was allowed to be more negative than -5,000 cfs for up to 7 days in mid-March; CVP and SWP exports were limited to the minimum health and safety levels of 1,500 cfs in late March to provide more positive OMR flows as an offset

On April 8, 2014 Reclamation, through collaboration with DWR, CDFW, USFWS, NMFS, and the SWRCB, released the CVP and SWP Drought Operations Plan and Operational Forecast for April 1, 2014 through November 15, 2014 (DOP), which provided and requested a number of operational flexibilities to help balance the multiple water uses during a drought. Specifically, these flexibilities strove to allow water delivery to users south of the Delta while maintaining sufficient Delta water quality and fish habitat suitability. Additional changes were made to the TUCP throughout the summer and fall WY 2014. A more detailed summary of actions undertaken, and submitted letters, are available on the SWRCB website at *(http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp.shtml)*.

As the urgency for real-time operational decisions relaxed when listed species were no longer present in the Central and south Delta, a Technical Team was assembled to evaluate the hypotheses in Attachment E of the DOP. This team met six times between July and October 2014 to assess predictions in the DOP and additional questions pertinent to drought effects on WRCS. The assessment results for these WRCS predictions in the DOP are presented in this report.

Sacramento River Winter-run Chinook Salmon Life History

Naturally spawning WRCS return to the Sacramento River during the winter to lay their eggs in the spring and summer in a single reach downstream of Keswick Dam. This dam is a flow regulating feature just downstream from Shasta Dam. Because their historical spawning and egg incubation habitat were higher elevation spring-fed headwaters, the water temperature in their current spawning and egg incubation area is directly managed seasonally using a temperature control device constructed at Shasta Dam in 1996. Eggs incubate for more than two months during the summer, and fry emerge and move downstream of Red Bluff, California during the fall. Winter-run Chinook fry rear in the Sacramento River for a highly variable period of time until temperatures exceed thresholds for growth and flows stimulate rearing fish to leave. Then juveniles emigrate down the river as presmolts and smolts to rear in the lower Sacramento River and Delta for a variable period of time. Migration into San Francisco Bay occurs during March when environmental conditions and physiological cues further out-migration. They enter the ocean where food-web productivity can greatly influence early ocean survival, and is reliant upon favorable physical conditions including temperature, wind and currents (Lindley et al 2009). They remain in the ocean for two to four years before returning to spawn.

Drought Operations and Fish Management Conceptual Model

In the DOP, a conceptual model regarding salmon migration through the South Delta was included to identify relevant management and environmental drivers, processes, and outcomes related to salmonid management and ecology in the Delta (Figure 1). The Team reviewed this model and drafted new conceptual models during its meetings regarding management actions pertinent to the DOP (Figure 2). These regulatory actions were linked through physical habitat changes to fish population responses for associated life stages. The outcomes were described in a manner that could use observational data collected from Central Valley river and Delta fish monitoring surveys. Over the course of clarifying hypotheses and data availability, the Team was able to further describe the outcomes, so that these described both the exposure to, and the effect on salmonids from modifications in water operations and the subsequent ecological changes due to the drought (Figure 3).

Some important aspects of the model, as well as other aspects of WRCS ecology and management, are described below.

Shasta Reservoir Storage

Winter-run Chinook salmon are limited to cold water spawning and rearing habitat in the upper Sacramento River through cold water (< 56°F) released from deep within Shasta Reservoir. The water within the reservoir for this use is called the ‘cold water pool’. The cold water pool is a finite resource for WRCS and is largely dependent on year-to-year precipitation and reservoir management. When agencies enter into the summer temperature control period, the coldwater pool volume is at its greatest amount for the year. Therefore, how Shasta Reservoir volume is managed throughout the year and during the summer has an effect on the coldwater pool, either by affecting the total volume available for the summer or the way in which this water is accessed with the Shasta Reservoir temperature control device. Negative effects, include running out of cold water releases, and increased mortality rates for in-river eggs and juveniles when they are most vulnerable in the late summer and early fall. In drought years, when the cold water pool is already constrained, releases from Shasta Reservoir to support Delta outflow standards may have a negative impact on juvenile WRCS in the upper Sacrament River.

Drought Operations and Fish Management Conceptual Model

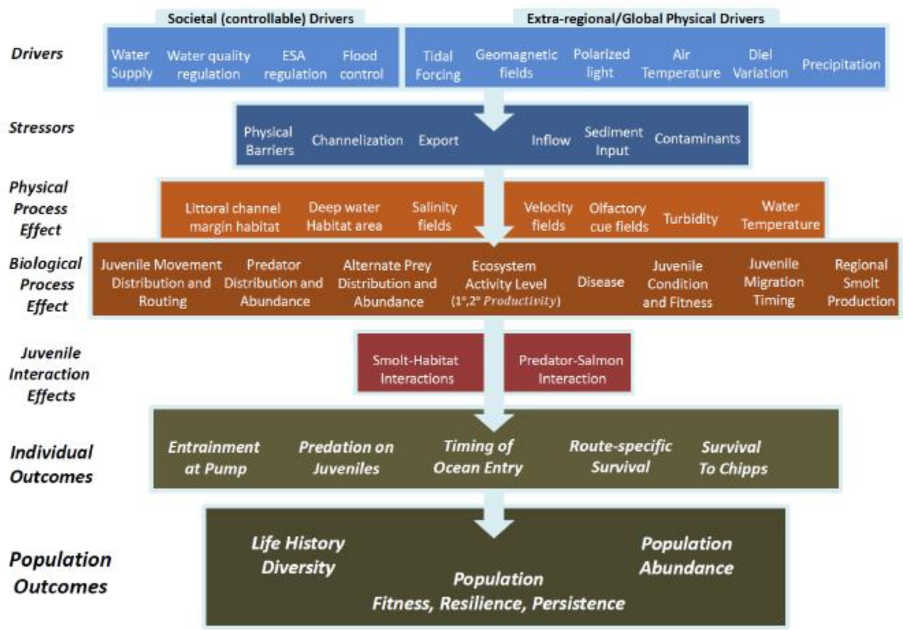

Figure 1. A Conceptual Model Developed for the South Delta Salmon Research Collaborative Team Used in the Drought Operation Plan (USBR 2014)

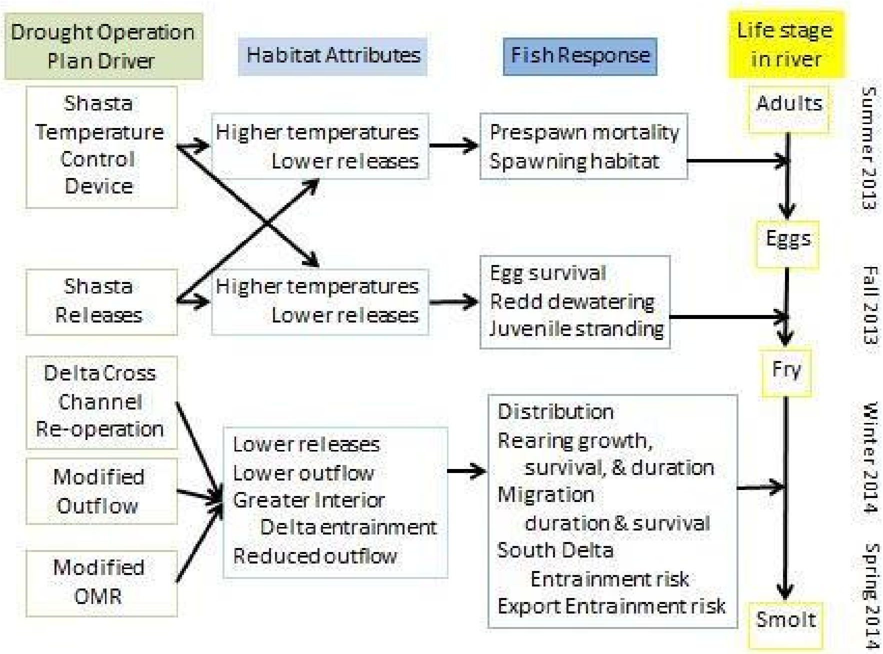

Figure 2. A Conceptual Model for Evaluating Effects of the Drought on Sacramento River and Delta Life Stages of Winter-run Chinook salmon

Drought Operations and Fish Management Conceptual Model

MANAGEMENT	**DCC Gate Operation** (Interior delta salinity)	**Outflow (NDOI)** (Change in Location)	**Inflow** (Storage impacted by DOP, seasonal depletions)	**OMR** (pilot calculation, change in criteria)	**Exports** (change in OMR & E:I calculation)
LINKAGE	• DCC open/close • GS barrier deployed • Route selection	• Migrating • Residence time • locations	• Wilkins Slough flow (May/june) • Migrating • Rearing	• Residence time • Survival/outmig. Success	• OMR calculation • Change in OMR criteria • Change in E:I calculation
OUTCOME	**Exposure** • KLCI and SCI values • DJFMP periodicity **Effect** • Tidal geographic intrusion • P/A of acoustic fish • Delta survival	**Exposure** • Median date past Chipps • DJFMP periodicity **Effect** • Delta survival • Apparent growth in delta (yolo samples) • ND utilization	**Exposure** • Median date past KNL,TS,GCID,RBDD **Effect** • River/Delta residence time • River survival-jsats • Apparent growth in river	**Exposure** • Median date past Chipps • Facility and DJFMP periodicity **Effect** • Facility salvage (Density,total, timing) • SD/CD DJFMP pres/absence	**Exposure** • Median date past Chipps • Facility and DJFMP periodicity **Effect** • Delta survival • Facility salvage (Density,total, timing) • SD/CD DJFMP pres/absence

Figure 3. A Conceptual Model for Evaluating Exposure and Effects of Management Actions on Sacramento River and Delta Life Stages of Winter-run Chinook salmon

Water Temperature

Water temperature is an important habitat attribute during every freshwater life stage of the WRCS life cycle. Temperatures influence the survival, behavior, and physiology of the species. Therefore, the DOP included relaxation of Delta outflow requirements in an attempt to accumulate and conserve coldwater pool during the winter and spring of WY 2014 for summer and fall temperature management WRCS egg and fry, which are the most temperature sensitive life stages. As previously mentioned, the Shasta Dam temperature control device regulates water temperature downstream of Keswick Dam.

Delta and Riverine Outflow

Seasonal monthly average outflow standards are an important element of D-1641 for maintaining ecological and biological processes in the Bay-Delta. While the management focus has been on how these standards influence salinity and habitat for many native pelagic species, increased Sacramento and San Joaquin River inflows during the winter and spring also support increased salmonid survival through the system (Dauble et al 2010, Perry 2010, Newman 2008). The flow relationship to survival remains unclear and multiple correlated mechanisms may explain this positive relationship (Brandes and McClain 2001, Perry et al 2010, Cavallo et al 2013). Additionally, this relationship may be different in riverine habitats. In the DOP, which modified D-1641 Delta outflow requirements in order to conserve Lake Shasta coldwater pool, WRCS survival through the Sacramento River and Delta portions of their outmigration were predicted to be lower than if CVP/SWP releases were made to meet the D-1641 Delta outflow requirements.

Floodplain Access

The Lower Sacramento River below Colusa is largely a trapezoidal channel with large floodplains that are only inundated and accessible at a couple locations when flows reach a certain threshold. This river channel geometry prevents a linear relationship between side channel and floodplain activation. The relationship is a step function throughout the river with certain threshold flows creating access to floodplain habitat. Linear increases in outflow below these thresholds provide no access and benefit from this habitat type. Fishery managers and biologists believe that greater volitional entrainment onto seasonally floodplains can increase cumulative survival, since these migratory routes increase the extent of suitable rearing habitat that have greater productivity, lower densities of predators, and slower velocities for rearing. In the DOP (USBR 2014), it was assumed that because of the drought these habitats were not accessible and all juvenile Winter-run Chinook would be subject to Sacramento River migration pathways through the Delta.

Turbidity

Turbidity associated with increases in outflow are also a factor in WRCS migration and survival (Poytress et al. 2014). During wet periods, rain events create overland flow that introduces large amounts of particulates into the water column and increases turbidity levels. This effect is hypothesized to influence rates of migration and increase survival by reducing predation rates. Most predatory fishes in California are visual cue predators and the increase in turbidity reduces the distance that a predator prey encounter can occur and thereby increase the likelihood that a juvenile salmon will survive. Given that WY2014 was characterized by a lack of precipitation, it is expected that turbidity levels may have been lower than previous years and thus salmon may have been subject to increased predation rates.

An effect of decreased turbidity may be an increase in primary productivity within the Delta and the system as a whole, which is currently hypothesized to be lower than historical conditions. Previous studies have observed the condition of smolts exiting the Sacramento River and Bay-Delta to be poor (Sommer et al. 2001). Thus, an increase in primary productivity due to decreased turbidity (or in wet years, increased overland flows) may increase survival simply by boosting the base of the food web for juvenile salmon. Further evaluations are needed to determine the tradeoffs between the positive and negative effects of turbidity on salmon survival, but it is expected that the benefits of high turbidity on survival outweigh any benefits of increased primary productivity from lower turbidity.

Drought Questions and Prediction

The team had multiple early discussions about whether its focus was to be limited to evaluating biological effects due to drought operational modifications or a broader evaluation regarding the effect of the drought on the populations of interest. Only a small portion of the monitoring undertaken during WY 2014 focused on measures useful to the evaluation of the effects of drought on population attributes. Even fewer were useful to assess the exposure of the population to modification in operations due to the drought although some additional monitoring was added during the winter to reduce risks associated with DCC operations. Thus, while some hypotheses were described in the DOP (USBR 2014) that could use empirical monitoring observations for evaluating the effect of the drought, not all effects were related to management decisions. Further, during the analysis phase, the Team ran into multiple accessibility and metadata issues with monitoring datasets, and these limitations detracted from the Team's ability to assess predictions. In the end, the Team decided to focus on answering the questions germane to understanding the distribution, diversity, productivity, and abundance of BY 2013 WRCS and then using these data to analyze the exposure and effect of the drought on fish during the winter and spring of WY 2014. This section focuses on interpreting monitoring results that shed light on the aforementioned questions.

The basin-wide approach was important for evaluating the impacts from the modified regulations in the context of all the other impacts in the freshwater and estuarine ecosystems due to the drought. Thus, the Team formalized predictions in the DOP and others related to viable salmon population criteria to ensure that a holistic approach was being considered to address many of them (Table 2). These predictions are used to evaluate the impact of management actions and drought conditions on the habitat attributes and biological response on WRCS.

Table 2. Predictions Regarding the Biological Response of Winter-run Chinook Salmon to Habitat Attributes and Management Drivers

Conceptual Model Tier and Variable	Adults (Dec-May)	Eggs (June-Oct)	Fry (Aug-Dec)	Presmolts (Sep-Feb)	Smolts (Nov-May)
Biological Response					
Prespawn mortality	↑				
Egg survival		↓			
Juvenile stranding			↑	↑	↑
River rearing duration			↑	↑	
Rearing growth			↑	↑	
Rearing survival			↓	↓	↓
Lower river and Delta rearing duration			↓	↓	↓
Migration duration				↓	↓
Migration survival				↓	↓
Habitat Attributes					
Redd dewatering		↑			
Water temperature		↑	↑	↔	
Habitat capacity	↓	↔	↓	↓	↓
Outflow volume			↔	↔	↔
Interior Delta flow entrainment				↑	↑
Management Drivers					
Temperature control operations	No effect	No effect			
Shasta releases	↓	↓	↓	↓	↓
Delta Cross Channel gate opening			Did not alter RPA	↑	↑
Modified outflow				↓	↓
Modified OMR				↓	↓
Exports					↔

Note: Green boxes are when the response, attribute, or driver does not influence that life stage

Adults

1. Was prespawn mortality higher for BY13 adult spawners due to habitat conditions?

To evaluate the impact of the WY 2014 drought of BY 2013 WRCS, the Team determined it should consider whether environmental and management decisions may have affected the parents of the 2013 Brood Year. In 2013, 6,075 WRCS returned to spawn in the Sacramento River. This is twice the WY 2007-2013 mean of 3,011 spawners. During the 2013 spring holding period (April 1-May 30), water temperatures ranged from 51°F to 55°F at Red Bluff. These temperatures should not have influenced migration or prespawn mortality in these adult Chinook (McCullough 1999). Flows were similar to recent historical flows during the spring, suggesting flow should not have influenced migration of these adults. Sacramento River carcass surveys showed very low levels of pre-spawning mortality in 2013 (<1%; D. Killam, CDFW, unpublished data). The Anderson-Colusa Irrigation District Diversion Dam was installed in late March during 2007-2012, but in 2013 was installed in late February. It is hypothesized that this installation did not seem to influence adult migration or access to suitable spawning habitat in 2013.

Escapement to Livingston Stone Nation Fish Hatchery totaled 608 adults in 2013. These fish were collected in the Keswick fish trap between March 13 and July 13, which is normal timing for broodstock collection by USFWS staff (J. Reuth, USFWS, pers comm.). Observed broodstock did not show disease issues or pre-spawn mortality greater than normal levels. It therefore appears that no examined factors influenced the success of the parents of the 2013 Brood Year to contribute to the juvenile populations.

This page intentionally left blank

Eggs

2. Was BY13 egg to fry survival survival lower due to temperature and flow during summer and fall 2013?

Tools to evaluate temperature and flow effects on WRCS are limited, although temperature, flow and fishery data is collected during the egg life stage of WRCS. We use these data with two existing models to calculate temperature-related egg mortality and reviewed agency monitoring reports. Egg and juvenile mortality can be estimated using a dynamic simulation framework developed by Cramer Fish Science (CFS 2010) to estimate juvenile WRCS production. Relationships for daily mortality of incubating eggs and rearing juveniles (Bartholow and Heasley 2006) are parameterized with results from temperature mortality studies undertaken by USFWS (1999).

The dynamic simulation model uses observed spawn timing, temperature, and flow data to estimate temperature-related egg and juvenile mortality during incubation and rearing. Carcass data from 2007-2013 was used to model spawning time, in which the date of egg deposition was shifted 14 days before a carcass was observed (K. Niemela, pers comm in CFS 2010). Thus, daily cohorts of incubating eggs experience the observed temperature and flows conditions. The model used observed daily flows measures at Freeport and temperature measured at the monitoring location closest to the downstream extent of at least 99% of the annual redds to estimate egg survival, egg to fry, and smolt survival (Table 3, smolt survival results not evaluated). Freeport flows are used to estimate smolt survival, but not in the estimation of egg and fry survival. These data were downloaded for the appropriate stations through California Data Exchange Center (CDEC). The model runs on a daily time step, and a mean proportional mortality of the incubating eggs is estimated from the daily water temperature using a polynomial daily mortality relationship. A mean mortality of rearing juveniles is predicted from the daily water temperature using an exponential relationship. The model was run for 1000 iterations and the predicted mean survivals are reported for both life stages (Table 3). BY 2010 egg to fry modeled survival appeared anomalous and the sensitivity of this result was examined. When another year’s temperature data was used, the survival estimate was found to be 21%, which is approximately what temperature and flow effects were on this measurement in other years. We think this result reflects an anomaly in the temperature data from summer 2010. The average egg to fry survival for the comparison period was 23.0% (with BY 2010 results removed), which is a nominally higher survival value than estimated for BY 2013 (21%). Temperatures and flows experienced by BY 2013 WRCS were similar to those in the comparative period (Figure 4 and 5), and thus model-estimated early life stage survival as a function of temperature and flow was similar. Model results do not suggest egg and fry Winter-run Chinook survival was affected by temperature and flow during the summer and fall of 2013.

Table 3. Egg Mortality and Egg-to-Fry Survival Estimates Using Different Models for Brood Years 2007 to 2013 Winter-run Chinook Salmon

BY	WY (Summer/ Winter)	Compliant Point Past June 1	Lowest Redd	Tempera- ture Data	Egg Mortality (CGS Model)	Egg to Fry Survival (CFS Model)	Egg to Fry Survival (RBDD Estimate)
2007	2007/08	Balls Ferry	Jellys Ferry Bridge To Bend Bridge	Jelly Ferry	0.93%	21.00%	21.10%
2008	2008/09	Airport Road/Clear Creek	Airport Road Bridge to Balls Ferry Bridge	Airport Road/ Clear Creek	0.01%	21.20%	17.50%
2009	2009/10	Jellys Ferry	A.C.I.D. Dam to Highway 44 Bridge	Airport Road/ Clear Creek	0%	21.21%	33.30%
2010	2010/11	Jellys Ferry	Highway 44 Bridge to Airport Road Bridge	Airport Road/ Clear Creek	0%	96.25%	37.50%
2011	2011/12	Jellys Ferry	Highway 44 Bridge to Airport Road Bridge	Airport Road/ Clear Creek	0%	30.11%	48.60%
2012	2012/13	Airport Road/Clear Creek	Highway 44 Bridge to Airport Road Bridge	Airport Road/ Clear Creek	0%	21.22%	26.60%
2013	2013/14	Airport Road/Clear Creek	Battle Creek to Jellys Ferry Bridge	Airport Road/ Clear Creek	0%	21.26%	15.10%

The second approach to estimating egg-to-fry survival used Winter-run Chinook passage data from Red Bluff Diversion Dam (RBDD) to estimate egg to fry survival. By multiplying 1.7 to all fish sampled in the pre-smolt/smolt category (>45 mm) annual Winter-run Chinook production above the RBDD transect could be estimated (Poytress et al. 2014, See more detailed methods in Question 4). These standardized production estimates were derived using annual average fecundity from LSNFH production records and escapement data, based on CDFW carcass survey to generate egg-to-fry survival estimates (Table 4). The average egg-to-fry survival rate of the comparative period was approximately twice (30.8%) the BY 2013 estimate (15.1%), which is the lowest value estimated. We believe this low survival estimate was affected by observed temperature and flow habitat attributes, but unrelated to drought operational management of these attributes. We hypothesized other habitat attributes not incorporated into our conceptual model, yet affected by flow and temperature, include food resources, disease, and predation risk in the Sacramento River above RBDD may be influential on egg to fry survival.

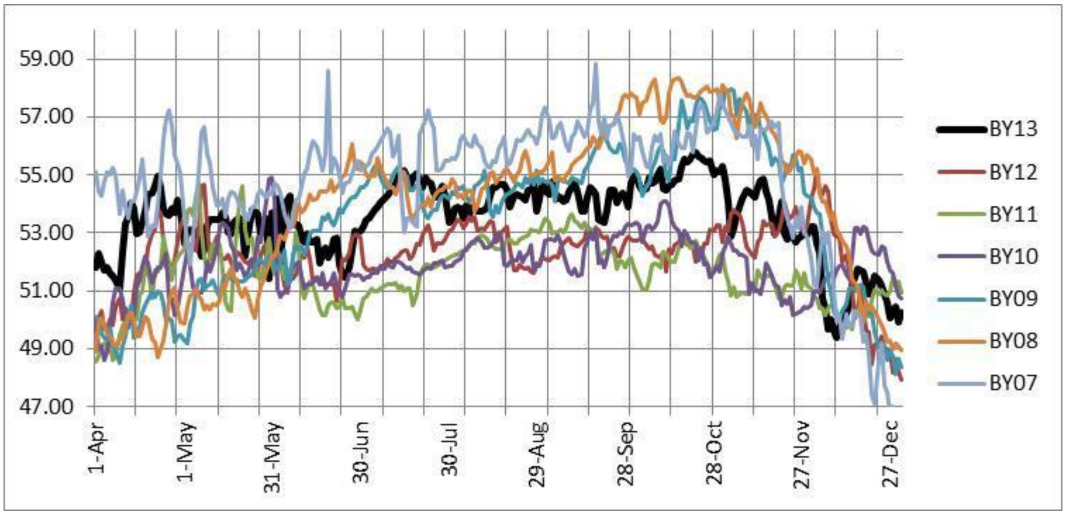

Figure 4. Temperatures (°F) Used for Modeling Egg Mortality and Egg-to-fry Survival Using the Cramer Fish Science Production Model. Location of CDEC 15-minute temperature data queried is listed in Table 2 from Brood Year 2007-2013

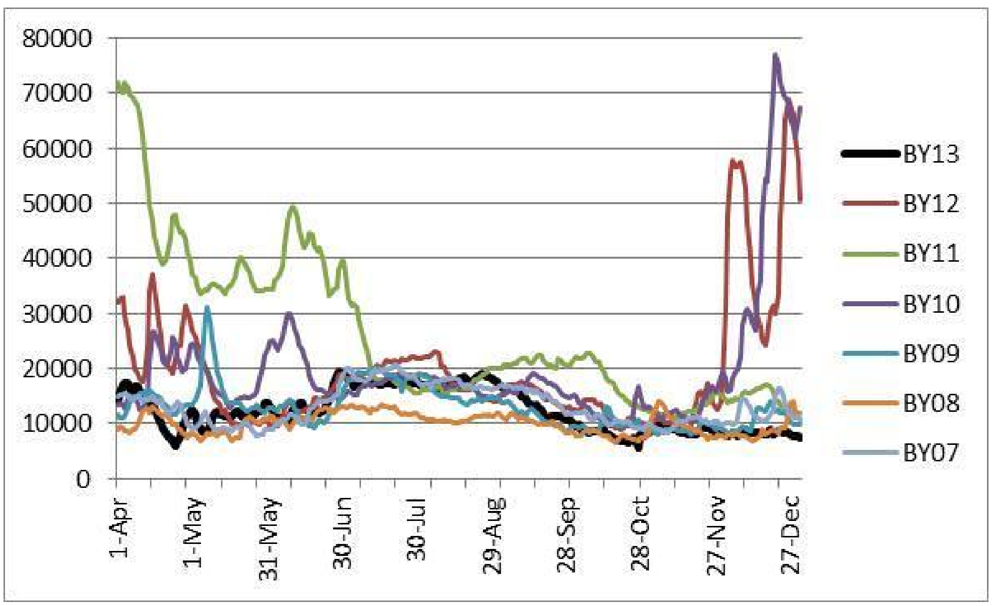

Figure 5. Freeport Flow Data (cfs) Used for Modeling Egg-to-fry Survival Using the Cramer Fish Science Production Model from Brood Year 2007-2013

Table 4. Redd Dewatering and Juvenile Stranding Monitoring Observation for Brood Years Between 2012 and 2014

	Water Year 2012	Water Year 2013	Water Year 2014
Redd Dewatering Observations	Pilot year, not investigated	Pilot year, not investigated	5 Winter-run Chinook Redds (0.2%) and 23 Spring run Chinook Redds (3.1%) were dewatered
Juvenile Stranding Observations	Pilot year, not investigated	659 Winter-run Chinook juveniles were observed stranded and 14 were characterized as unlikely to survive	2,143 Winter-run Chinook juveniles were observed stranded and 179 were characterized as unlikely to survive

3. Was BY 2013 fry survival lower due to stranding and redd dewatering in summer/fall 2013?

Pilot and broader spatial and temporal monitoring studies of redd dewatering and juvenile stranding have been completed since fall 2011 (Jarrett and Killam 2014, Revnak and Killam 2013, Olsen et al. 2012). Results of these monitoring activities were summarized and Winter-run Chinook redd dewatering and stranding occurred when Reclamation reduced releases to reduce fall exports and conserve coldwater storage (Table 4). Redd dewatering and juvenile stranding was greater for BY 2013 than in a very limited number of comparative years. Although stranding surveys attempted to evaluate the impacts of this stressor systematically, reports indicated not all stranding could be surveyed and that estimates represented a minimum level of impact. The CFS model (CFS 2010 used above) evaluating flow effects on egg-to-fry survival did not incorporate potentially reduced survival due to dewatering and stranding (USFWS 2006). Due to the spatial and temporal limitations of the stranding and redd dewatering monitoring, the Team was unable to contextualize the observations at the population scale, but agreed these processes may have influenced the lower egg-to-fry survival observed above RBDD.

Fry

4. Was the 2013 RBDD Juvenile Production Index (JPI), using standard interpolation methods, representative of the 2013 juvenile winter Chinook production or was it negatively biased when also compared to the NOAA Juvenile Production Estimate (JPE) model estimate?

Monitoring of annual WRCS juvenile abundance has been conducted by the USFWS, Red Bluff Fish and Wildlife Office (RBFWO) since 1995. Using rotary traps and a daily trap efficiency model, daily passage estimates for juvenile Winter-run passing RBDD have been estimated for the past 16 years. Martin et al. (2001) determined that RBDD was an ideal location to monitor juvenile Winter-run production as it is in close proximity to and downstream of the winter Chinook spawning grounds. Poytress et al. (2014) found a high correlation between number of adult Winter-run spawners and juvenile migrants (R2 = 0.90, df = 10, P = <0.001). Moreover, the average estimated value of egg to fry survival was calculated at 26.4% using 16 years of data. Trends in juvenile Winter-run abundance have indicated a high percentage, 80% on average, pass RBDD as fry size class fish (<46 mm fork length). The overall trend in annual Winter-run Chinook passage at RBDD indicates that peak daily juvenile passage occurs by the end of September, although in recent years passage appears to have been delayed 2-4 weeks (Figure 6 and 9).

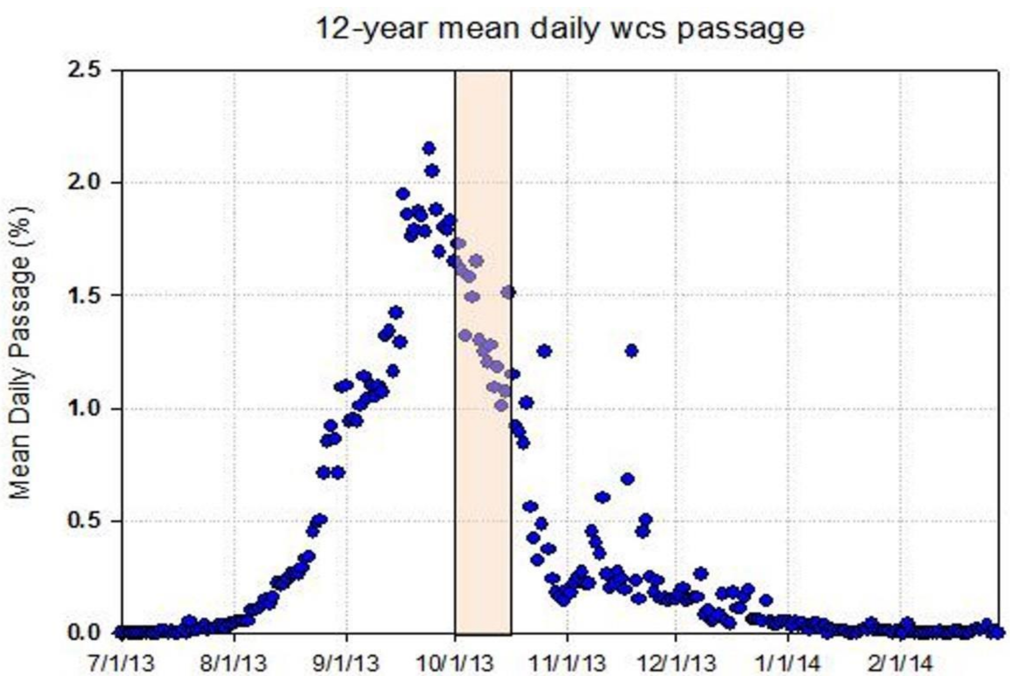

Figure 6. Mean Daily Percent Passage of Annual Winter Chinook at RBDD between 2002 and 2012. The box is Representative of the Unsampled Period During 2013

Fry

Significant pulses of pre-smolt/smolt (>45mm fork length) fish typically occur with fall storms that result in 150% or greater increases in flow (see Figure 7, typically in late October through December). To account for variation in fry and pre-smolt/smolt ratios, a back calculation of smolts equaling 1.7 fry (inverse of 59% survival value; Hallock, undated) is typically calculated to standardize juvenile passage into a fry-equivalent juvenile production index (Martin et al. 2001).

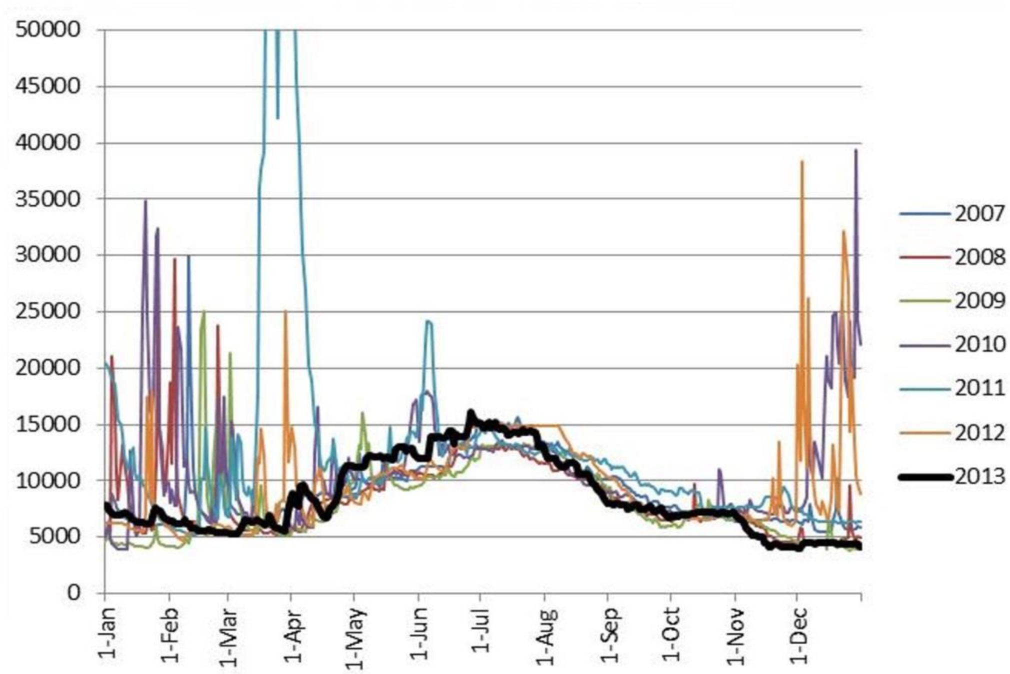

Figure 7. Annual Bend Bridge flow (cfs) Data from 2007 through 2013

The standard procedure for interpolating missed days of sampling is to apply a monthly mean passage value for unsampled weeks based on the data collected throughout the month and impute the mean value for each missed day. Using this method, the 2013 Winter-run Chinook fry-equivalent juvenile production index (JPI) was calculated at 2,485,787 juveniles. When compared to the NOAA Fisheries Winter-run Chinook Juvenile Production Estimate (JPE, NMFS 2014) value of 4,431,064, using adult females as the primary variable, the JPI was 44% less than what was predicted based on the JPE model. Differences in JPE and JPI values are common and the range of differences between the two estimates over the past sixteeen years has ranged from 15% less to 38% more. The 2013 JPI estimated value does fall outside of the range of differences detected within the last 16 years.

During WY 2014, the estimated JPE reflected an estimate outside the previous range of differences when compared to the JPI. It is unlikely the large difference between the value estimated by the JPE and the JPI was due to a significant proportion of WRCS passing during the lapse in sampling. To compare closely with the 2013 NOAA JPE would require that 50% of winter Chinook juveniles would have passed during the 17 day unsampled period at RBDD. The JPI daily passage values would have required that 150% of the maximum daily passage values seen in the prior 11 years occurred for 17 consecutive days. The resulting JPI would be 4,319,838 juveniles or 2.5% less than the 2013 NOAA JPE estimate of 4,431,064 juveniles. The Team believes the low value may reflect influences of other environmental and management impacts on juvenile production instead of missed significant daily passage.

The JPI may have been negatively biased due to the use of the 13 days following the shutdown (remainder of October sampled) to interpolate for the prior 17 days (monthly mean method) as daily passage estimates were considerably less in the latter half of October as compared to September when juvenile passage appeared to peak 4 days prior to the Government shutdown. The Team believes the estimated JPI, which is outside the previous range of deviation from expected JPI values, and its overall low value may reflect effects of other environmental and management drivers on juvenile production above RBDD and not just lost sample effort alone. The flows and temperatures (Figure 7 and 8) passing Red Bluff Diversion Dam and above this location during the expected migration period (Figure 6) were within previous years' flows and temperature ranges upstream of Bend Bridge (approximately 20 km downstream of RBDD), and thus other mechanisms not investigated in this report may be influencing the observed negative deviations in WRCS production in the upper River.

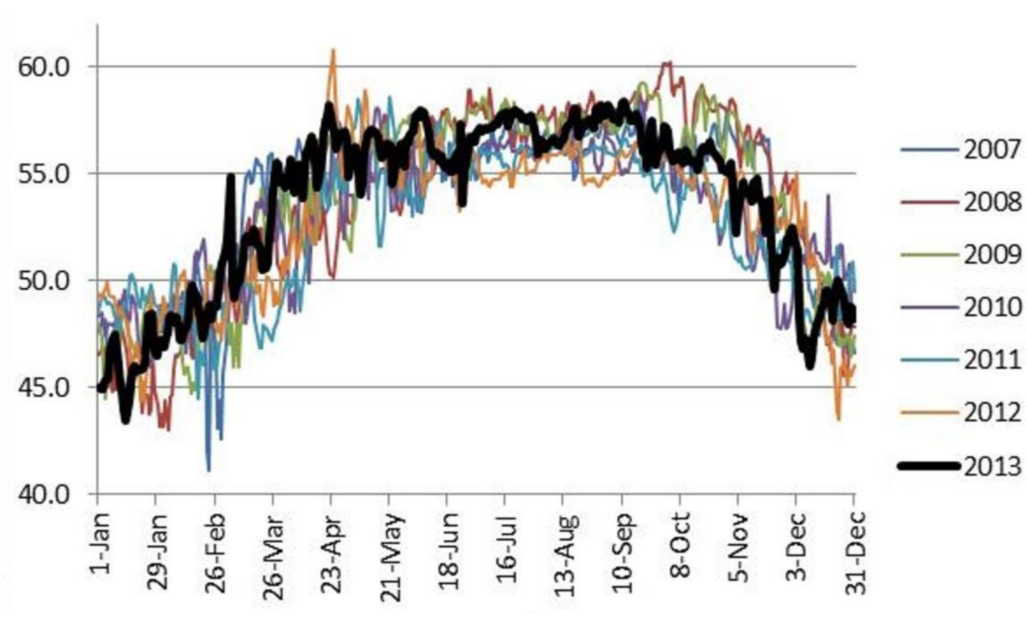

Figure 8. Annual Bend Bridge Temperature (°F) data from 2007 through 2013

5. Did a significant proportion of the juvenile Winter-run Chinook salmon migrate out of the upper Sacramento River during the 2013 lapse in RBDD fish monitoring?

In 2013, the RBFWO's juvenile monitoring operation was halted mid-season due to the shutdown of the Federal Government which resulted in 17 unsampled days between October 1-17, 2013. The first half of October can be a period of substantial fry (<45 mm) passage at RBDD, and on average accounts for 23% of the annual Winter-run Chinook juvenile passage estimate. This period is not usually associated with storm events or subsequent flow increases and flows are primarily the result of releases from the Shasta-Keswick Dam complex. Flows in 2013 remained stable around 7,000 cfs with slight variation (+/- 250 cfs) during the shutdown period.

To evaluate what proportion of the Winter-run juvenile passed RBDD during the 17 days unsampled, one can begin by looking at recent trends in juvenile winter Chinook passage. During the period of October 1-17, data from Poytress et al. (2014), indicate that, on average, 23% of the annual winter Chinook juvenile passage is estimated during this time frame (based on 11 complete years of sampling). By employing an 11-year annual average passage interpolation method accounting for 23% of the annual estimate, the resultant JPI would be 2,786,992 (Table 5). Using this trend data to compare with the monthly mean interpolated value increased the JPI value by ~300,000 juveniles. These data indicate that the 2013 JPI is negatively biased by at least 9% when compared to the average annual passage during this time frame. When compared to the JPE, the JPI using mean 11-year annual percentage interpolated passage estimate, would result in a difference of 37% less than the JPE.

Table 5. Comparisons of Fry Equivalent JPI Values to (a) the Winter-run JPE and (b) if all Spring Chinook Sampled at RBDD were Incorrectly Assigned to the JPI

	Monthly Mean	Annual Mean	Daily Max Percentage	150% Daily Max Percentage
17-day Proportion	14%	23%	40%	50%
Winter Fry Eq. JPI	2,488,356	2,786,992	3,595,220	4,319,838
JPE Comparison (a)	-44%	-37%	-19%	-3%
Spring Juveniles estimated at RBDD	426,325	426,325	426,325	426,325
Winter + Spring	2,914,681	3,213,317	4,021,545	4,746,163
JPE Comparison(b); Winter + Spring	-34%	-27%	-9%	7%

These JPI estimates are compared to (a) NOAA Fisheries winter Chinook JPE for Brood Year 2013 and (b) assuming all spring Chinook sampled at RBDD were late-emerging winter Chinook incorrectly assigned to spring Chinook run using length-at-date criteria

On average, 1.36% of the annual passage of Winter-run juveniles occurs daily during October 1-17 of each year. There is considerable variability around this average and maximum daily passage has ranged from 1.8 to 8.1% of annual daily passage (mean = 3.1%). If maximum daily percentage of passage based on the prior 11 years was inputed for the 17-day period, the resultant 2013 JPI would total 3,595,220 juveniles (Table 5). The estimate would indicate that during the missed sample period 40% of the juveniles passed by Red Bluff, unsampled during the Government shutdown. When compared to the 2013 JPE, the maximum daily passage interpolation estimate would result in a difference of approximately 19% less than the JPE.

6. Did the observed late spawning of Winter-run in 2013 result in substantial numbers of juveniles falling into the spring run category by using standard length-at-date criteria used to assess their run identity resulting in the disparity between the NOAA JPE and USFWS JPI in 2013?

To investigate potential incorrect assignment of run to juveniles passing RBDD requires some assumptions to be made regarding juvenile passage data at RBDD. One assumption regarding fish identification is the accuracy of the length-at-date criteria for identifying WRCS. The
length-at-date criteria were developed from data in Red Bluff and the Team's discussion suggested that WRCS misclassification at Red Bluff is quite low compared to other locations further from the natal reach. On average, Poytress et al. (2014) found that 19% of fish annually classified as spring Chinook in RBDD traps occurred prior to capture of spring Chinook in tributaries producing them (range 2.6 to 44.2%) and most likely are Winter-run Chinook. Length-at-date (LAD) criteria presume emergence of juveniles in the spring category in mid-October, but rarely have fish been detected in primary production areas as outmigrants before the end of November. Moreover, no significant correlation was detected between estimated spring Chinook females and JPI's over 11 years of data and spring Chinook passage typically accounts for a small fraction (2.1%) of annual Chinook passage at RBDD and does not significantly affect Winter-run or Fall-run JPI's.

Assuming all 2013 juveniles categorized as spring Chinook based on LAD criteria were late emerging winter Chinook juveniles would result in an increase of 426,325 juveniles to the 2013 winter Chinook JPI (Table 7). This value incorporates the assumption that all fish outmigrating between mid-October and the end of March (prior to Coleman National Fish Hatchery fall Chinook production release of 4.4 million smolts) were incorrectly assigned from the winter to the spring Chinook category due to late emergence. Whether or not the LAD criteria properly identifies each run, especially in years where flows and temperatures are at the extremes, needs to assessed through genetic characterization, both at RBDD and further downstream at Knights Landing.

To evaluate the effect of potential incorrect assignment of juveniles to the spring category from the presumed winter Chinook category we simply added the 426,325 juveniles to the previously discussed values derived from various winter Chinook JPI interpolation methods (Table 7). The results would indicate that the standard monthly mean interpolation with the inclusion of all incorrectly assigned juveniles would raise the 2013 JPI to 2,914,681 winter juveniles passing RBDD. If included with the annual mean passage estimate data, the JPI would be estimated at 3,213,317 juveniles. If included with the maximum daily percentage of passage the JPI would be estimated at 4,021,545 juveniles. If included with the 150% of the maximum daily percentage of passage the JPI would be estimated at 4,746,163. In comparison to the JPE, the JPI estimates using the interpolation methods above would differ by, -34%, -27%, -9% and +7%, respectively (Table 5).

During WY 2014, the estimated JPI reflected an estimate outside the previous range of deviation from expected JPE values. The Team believes the low JPI value may reflect influences of environmental and management impacts on BY 2013 Winter-run Chinook juvenile production and not misclassification of other Evolutionarily Significant Units (ESUs) of salmonids.

7. Did fish monitoring at Red Bluff Diversion Dam screw traps indicate a larger proportion of Winter-run Chinook salmon spent a prolonged rearing period and slower emigration period through the upper Sacramento River above Red Bluff than in comparative years?

To evaluate winter-run residency period above Red Bluff Diversion Dam, the Team characterized a number of temporal measures to look at the migration of WRCS past Red Bluff Diversion Dam. From data prepared by USFWS (Poytress et al. 2014) depicting the running cumulative percentage of passage, starting with July 1st, and ending with June 30th of the next year to correspond to the respective Brood Year (Figure 9), we calculated period of time between (1) the first and last WRCS passage, and (2) the 25th and 75th percentiles of passage. We also calculated the 50th percentile (median) of passage (Table 6). However, the Team considered the time span between the first and last, and between the 25th and 75th percentiles more useful than information derived from date comparisons of any individual percentile of passage past RBDD because patterns in individual percentiles between years (e.g., comparing median massage from year to year) were strongly affected by the fact that spawning period has occurred later in the summer over the last few years. This trend in spawning period is apparent in the cumulative passage curves from recent years (Figure 9). On the other hand, time span between percentiles reflects dispersion of juveniles, an indicator of prolonged or contracted rearing that is less affected by spawning period.

Table 6. Comparisons of Fry Equivalent JPI's Values to (a) the Winter-run JPE and (b) if all spring Chinook Sampled at RBDD were Incorrectly Assigned to the JPI

Passage at Red Bluff Diversion Dam

Winter-run Chinook Brood

	2007	2008	2009	2010	2011	2012	2013
First	07-17-07	07-15-08	07-04-09	07-13-10	07-31-11	07-16-12	07-09-13
25%	09-15-07	08-30-08	09-03-09	09-14-10	09-26-11	10-06-12	09-28-13
50%	09-30-07	09-08-08	09-18-09	10-05-10	10-06-11	10-26-12	10-24-13
75%	10-15-07	09-26-08	10-15-09	10-26-10	10-27-11	11-19-12	11-25-13
Last	04-17-08	05-11-09	04-28-10	04-26-11	04-19-12	05-04-13	04-27-14

Passage at Knights Landing

Winter-run Chinook Brood

	2007	2008	2009	2010	2011	2012	2013
First	12-11-07	12-28-08	*See note	10-25-10	10-11-11	10-13-12	10-03-13
25%	01-07-08	12-31-08	*See note	10-29-10	01-24-12	11-25-12	03-02-14
50%	01-12-08	02-19-09	*See note	12-09-10	01-25-12	11-26-12	03-06-14
75%	01-15-08	02-27-09	*See note	12-18-10	01-27-12	12-05-12	03-07-14
Last	06-27-08	06-25-09	*See note	06-27-11	06-25-12	12-15-12	06-06-14

*Note: Column for 2009 and all rows - Monitoring incomplete due to permitting

Passage at Sherwood Harbor

Winter-run Chinook Brood

	2007	2008	2009	2010	2011	2012	2013
First	01-07-08	12-22-08	10-23-09	10-29-10	01-25-12	11-23-12	02-09-14
25%	01-07-08	02-17-09	11-04-09	12-12-10	03-15-12	11-25-12	02-13-14
50%	01-16-08	02-17-09	02-05-10	02-19-11	03-17-12	11-26-12	02-15-14
75%	02-05-08	02-18-09	02-17-10	03-19-11	03-29-12	11-29-12	03-04-14
Last	03-03-08	02-27-09	02-26-10	04-15-11	04-13-12	12-07-12	04-04-14

Passage at Chipps Island

Winter-run Chinook Brood

	2007	2008	2009	2010	2011	2012	2013
First	01-09-08	02-20-09	01-25-10	01-05-11	01-24-12	12-21-12	02-14-14
25%	01-25-08	03-01-09	03-03-10	03-16-11	03-22-12	03-18-13	03-05-14
50%	03-15-08	03-12-09	03-13-10	04-04-11	04-07-12	03-26-13	03-09-14
75%	03-25-08	03-26-09	03-31-10	04-15-11	04-11-12	04-04-13	03-14-14
Last	04-28-08	05-19-09	04-28-10	04-22-11	04-27-12	04-15-13	04-11-14

Period of Residency Between Locations

Winter-run Chinook Brood

	2007	2008	2009	2010	2011	2012	2013
RBDD to Knights Landing	104 days	164 days	N/A	65 days	111 days	N/A	133 days
Knights Landing to Sherwood Harbor	4 days	-2 days	N/A	72 days	52 days	N/A	-19 days
Knights Landing to Chipps Island	63 days	21 days	N/A	116 days	73 days	N/A	3 days

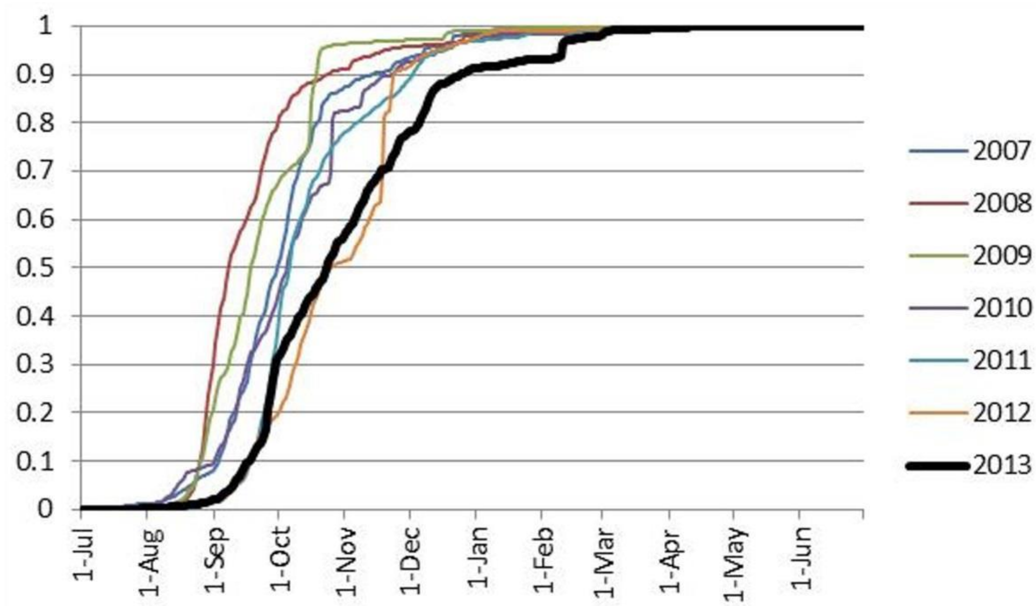

Figure 9. Cumulative Passage Curve of Winter-run Chinook salmon Passed Red Bluff Diversion Dam for Brood Year 2007 and 2013

For the 2013 brood year of WRCS, passage at Red Bluff Diversion Dam occurred over a 291 day period between July 9, 2013 and April 27, 2014. This period was within the range of WRCS passage periods for the 2007 and 2012 broods (range = 261 to 299 days, average= 284 days). The 25th to 75th percentile of Winter-run Chinook passage occurred between September 28 and November 25, 2013, a period of 58 days. This duration is approximately 1.6 times as long as the average period (36 days) and outside of the range (27-44 days) observed for brood years migrating during the comparison period. Passage of the final 50% of Brood Year 2013 WRCS remained above Red Bluff Diversion Dam for 184 days between October 24, 2013 and April 27, 2014. This period was lower than the average (210 days) and outside the range of rearing period durations (189 to 244 days) above Red Bluff Diversion Dam observed during the comparison period, suggesting Winter-run Chinook were following a pattern of unusually extended rearing above Red Bluff Diversion Dam, that was then abruptly truncated by a quick emigration at high density of the remaining individuals toward the end of the rearing period.

The lengthening of time around the center of passage and shortening of passage at the end of rearing were informative results. The DOP predicted a majority of the population to be rearing above Red Bluff Diversion Dam during a majority of the winter since due to the lack of flows during the winter period prior to the DOP, which is supported by the longer duration of rearing for the 25% to 75% of Winter-run Chinook passage. One explanation of the shorter period at the end of passage may be that fish residing longer were exposed to greater mortality upstream of RBDD and this reduced the period of passage for fish rearing upstream the longest. The Team hypothesizes greater mortality may have been caused by habitat attributes unrelated to temperature and flow. These attributes may potentially be influenced by the drought, but our conceptual model's focus on management actions does not characterize mechanisms that capture this complexity.

8. Did fish monitoring at the Knights Landing screw traps indicate Winter-run Chinook salmon spent a prolonged rearing period and slower emigration period through the Sacramento River above Knights Landing than in comparative years?

The Team characterized the cumulative passage of WRCS at the Knights Landing screw trap for Brood Years from WY2008-2014. Data from Knights Landing was provided by California Department of Fish and Wildlife personnel (Chris McKibbin, pers. comm.). Unlike passage data from Red Bluff Diversion Dam, which is standardized (Poytress et al. 2014) for evaluating production and migration characteristics, data for Knights Landing screw trap required data standardization to allow for a comparison. Results from WY2010 and WY2012 were not available due to trap nonoperation caused by permitting issues. Data were segregated into water years starting on October 1, and ending on September 30, of the following year (e.g., October 1, 2007, through September 30, 2008 for WY 2008). Data for each year was then further segregated into those days in which catches of WRCS occurred and the sum of catch per day and the mean fork length of all fish caught within each sampling day were displayed. To minimize the influence of hatchery fish on catch records, we only considered Chinook salmon with intact adipose fin clips. Raw catch was standardized by catch effort, measured as hours fished for each rotary screw trap.

Similar metrics were considered to look at the spatial distribution and timing through the lower Sacramento River (Table 6). The Team did not believe that the dates fish were observed passing Knights Landing was related to emergence time of fry, but a directed pulse migration from the Upper Sacramento River into the Lower Sacramento reflected catch "spikes" at the Knights Landing rotary screw traps. An indicator of this behavior has been described in Del Rosario et al (2013) as greater than 5% of the annual total catch typically being observed at Knights Landing the first day Wilkins Slough flows were at least $400 m^3/s$. Data prepared by CDFW (Chris McKibbin and Colin Purdy, CDFW, pers. comm.) was used to calculate the running cumulative passage starting on October 1 of the respective brood year, and ending on September 1 of the following year (Figure 10).

Fry

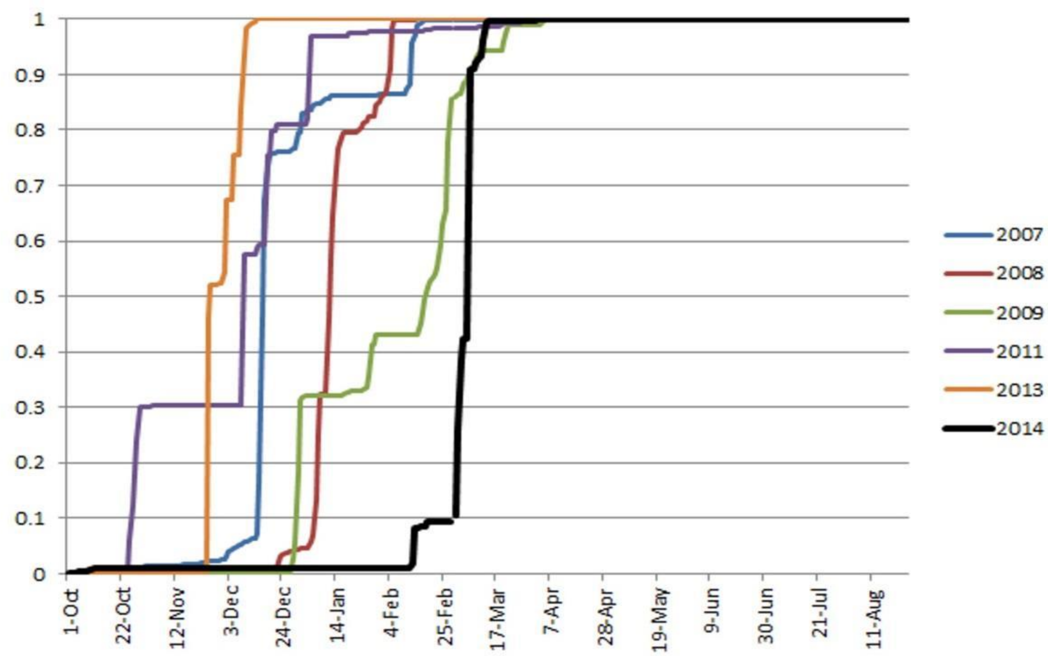

Figure 10. Cumulative Catch Curve of Winter-run Chinook salmon at Knights Landing rotary screw traps during Water Year 2007 and 2014

For BY 2013 WRCS, passage at Knights Landing occurred over a 246-day period between October 3, 2013 and June 6, 2014. This period was within the range of WRCS passage periods between 2007 and 2012 (range = 179-258, average = 220 days). The 25% to 75% of Winter-run Chinook passage happened between March 2, 2014 and March 7, 2014, which was a narrow five-day period. The passage time of the 25% to 75% of WRCS has been observed to occur over a shorter time period in BY 2011 (3 days), but has also taken longer, up to nearly two months (58 days) in BY 2008. The last half (50%) of Winter-run Chinook passed Knights Landing between March 7 (passage of median fish) and June 6, 2014 (passage of last fish). This period was substantially shorter (by 57%) than the average (161 days) period for passage of the last half of the brood year. The first date with Wilkins Slough flows greater than $400 m^3 s^{-1}$ for BY 2013 WRCS was February 14, 2014, more than three weeks later than this flow condition occurred for BY 2007 to 2011. During these other years, the passage spike was observed as early as October 25 in WY2011, and as late as January 24 in WY2012. The time between the passage of the median cumulative catch (50th percentile) at Red Bluff Diversion Dam and Knights Landing, an indicator of average travel time and residency between the two stations, was 133 days (Table 6). This duration of residency was within the upper half of the residency periods from 2007-2011, greater than the average residency (111 days), but within the range of these other years (65-164 days), and less than the longest period (164 days, BY 2008/WY 2009).

Similar dry winters, such as WY2009, were associated with longer winter-run Chinook rearing periods between Red Bluff Diversion Dam and Knights Landing. Based on previous study's results, these longer periods of emigration were hypothesized in the DOP to reduce outmigration survival (Singer et al. 2013). Similarly, preliminary results from ongoing WRCS outmigration studies using acoustic telemetry are showing longer outmigration periods upstream of the Delta are associated with reduced overall survival (J. Hassrick, USBR, pers. comm.). In these studies, upstream-of-Delta survival for an average passage period of 40 days declined to half the value observed the prior year, when the average outmigration period was only 20 days. During WY 2014, a majority of the Winter-run Chinook juveniles spent more than 133 days between Red Bluff and Knights Landing, experiencing the same conditions as juveniles in the second year of the acoustic telemetry study. The team suspects some reduction in Winter-run survival was similarly related to lower inflows and longer residence in between RBDD and Knights Landing.

In WY 2014, Winter-run Chinook timing in the river was distinct from overall observations in the previous five years. The Team observed the WY 2014 weather pattern and hydrology, reflecting the drought condition, led to extremely low tributary inflows. The lack of contributing tributaries to mainstem flow was a primary reason winter-run Chinook exhibited a prolonged riverine emigration period. Although emergency drought decisions led to lower Keswick releases during the emigration period than would have been required to meet D-1641 outflow standards in the winter and spring, the Team did not believe that flow requirements necessitating Keswick releases would have been substantial enough to affect the emigration period. This is because none of the WY 2014 outflow requirements would have exceeded the $400 m^3 s^{-1}$ inflow level associated with WRCS salmon passage spikes (Del Rosario et al. 2013). Thus, it is still likely that drought conditions affected survival, due to linkages between mortality and prevailing flow and habitat conditions. However, our conceptual model lacks the complexity to characterize mechanisms that capture this important relationship.

9. Did fish monitoring in the Delta indicate a shorter Delta rearing period and quicker emigration of Winter-run Chinook in spring 2014 than in comparative years?

Similar to data from Knights Landing, data from the Delta Juvenile Fish Monitoring Program required processing to allow for a comparison. Data from the Chipps Island trawls and the Sacramento trawls for the years 2007 through 2014 (up through August 30, 2014) was accessed through the United States Fish and Wildlife Service Delta Juvenile Fish Monitoring Program website (http://www.fws.gov/stockton/jfmp/). Data were treated in a similar fashion as Knights Landing screw trap data, except that raw catch was standardized to a daily catch effort of 10 trawls per day at either the Chipps Island location or the Sherwood Harbor location for the Sacramento trawl. To accomplish this, catch for days in which less than 10 trawls per day occurred were increased, and catch for days in which more than 10 trawls occurred were decreased according to the following formula:

$$\frac{\# \, Fish \; caught \; per \; day}{\left(\frac{number \; of \; trawls \; perday}{10 \; trawls \; standard \; day \; effort}\right)}$$

Cumulative standardized catch, cumulative percentiles of annual catch, were calculated the same as for RBDD and Knights Landing screw traps.

Concurrent with observations at Knights Landing screw trap, the majority of the Brood Year 2013 WRCS population entered the Delta later than normal, reared for a shorter period than normal, and emigrated more quickly than normal, as detected by the Sacramento River trawl at Sherwood Harbor From WY 2008 to WY 2013. The mean date of the first capture of a winter-run sized Chinook salmon at the Sherwood Harbor trawling location was December 7. The earliest date of first capture during this 6-year baseline period was October 23rd in WY 2010. The latest date at which the first catch occurred was January 25th in WY 2012. In WY 2014, the first Winter-run sized Chinook salmon was captured on February 9th at the Sherwood Harbor location. This is 64 days later than the mean date from the baseline period, and two weeks later than the previously seen latest date of first capture. The mean date at which the median cumulative annual catch (50th percentile) was observed for winter-run sized Chinook salmon during the baseline years at Sherwood Harbor was February 1st. Although the first date of winter-run catch at Sherwood Harbor for WY 2014 was the latest in the years we examined, the median for the WY 2014 cumulative annual catch occurred only six days later on February 15, well within the latter half of median dates from baseline years. Both first passage and the passage of the median cumulative catch were associated with the first flow event of the season. Another 45% of the cumulative catch was recorded during a 19-day period, beginning with a second high flow event on February 25. By the end of the second flow event on March 16, 96% of the cumulative catch at Sherwood Harbor had occurred. Therefore nearly the entire BY2013 entered the Delta over a five week period.

In comparison to passage duration during the baseline years, the movement of fish past the Sherwood Harbor appeared to be considerably faster in WY 2014 than was observed in the baseline years. The time to have the middle 50% of the population pass (i.e., days between passage of the 25th and 75th percentiles) was 19 days in WY2014, compared to an mean of 41.5 days for the other years examined. The mean number of days required to have 90% of the population pass Sherwood Harbor (days between the 5th and 95th percentiles) was only 30 days, relative to a mean passage period of 80.5 days for WYs 2008-2013.

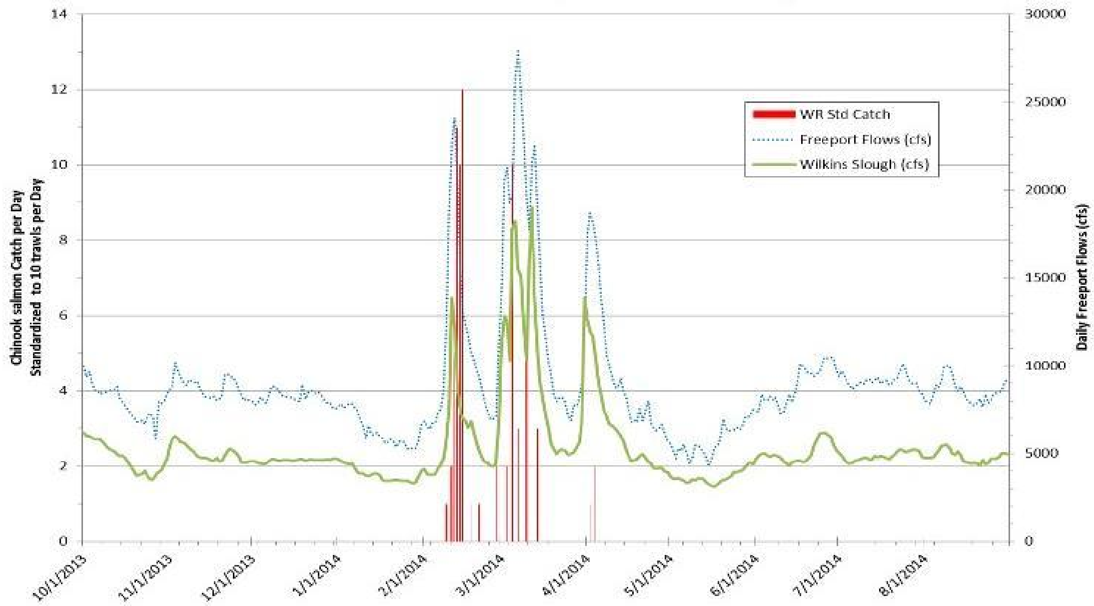

Figure 11. Standardized Daily Catches of winter-run Chinook Salmon at Sherwood Harbor in Water Year 2014

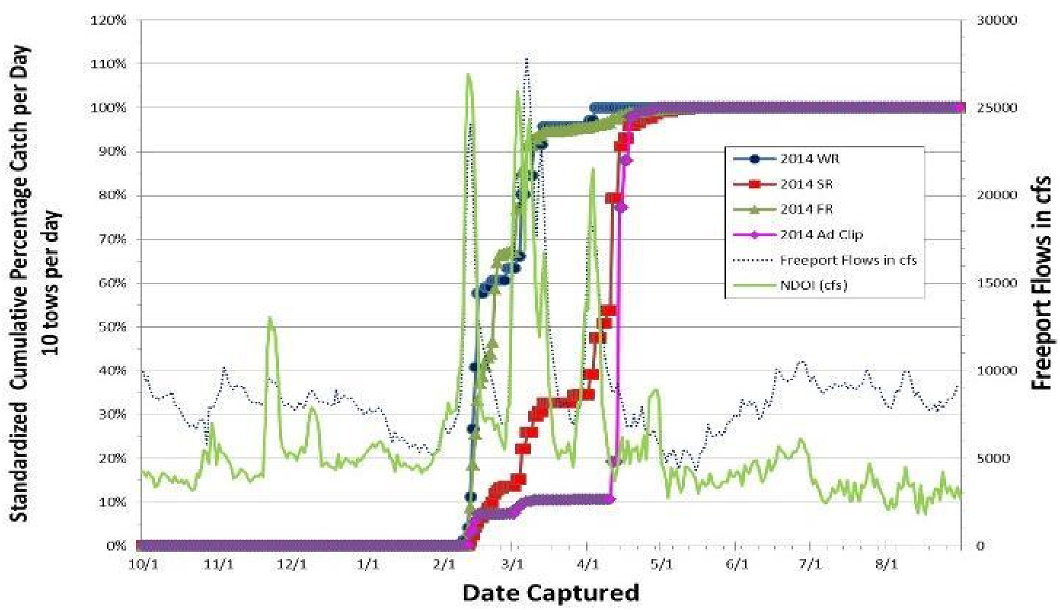

Figure 12. Cumulative Percentiles of Standardized Daily Catch of Chinook salmon at Sherwood Harbor in Water Year 2014

While the bulk of the juvenile population moved into the Delta during a short time period relative to most years examined, Chipps Island trawl captures suggest the population moved even more swiftly through and out of the Delta. Similar to observations at Sherwood Harbor, a pattern of late-arriving, but swift migration past Chipps Island was observed for WY 2014 relative to the other years. First capture of winter-run occurred on February 14, later than the mean of January 17 and near the latter end of the distribution of first captures from WYs 2008 through 2013, which ranged from December 21 in WY 2012 to February 20 in WY 2009. In each of the water years examined, the first catch of a winter-run sized Chinook salmon at Chipps Island corresponded with a significant flow event in the system, as measured by average daily flows at Freeport, and WY 2014 was no exception. Representative figures for WY2013 and WY 2014 are given in Figures 13 and 14 showing the association of flow events with the standardized daily catches of winter-run sized Chinook salmon at Chipps Island.

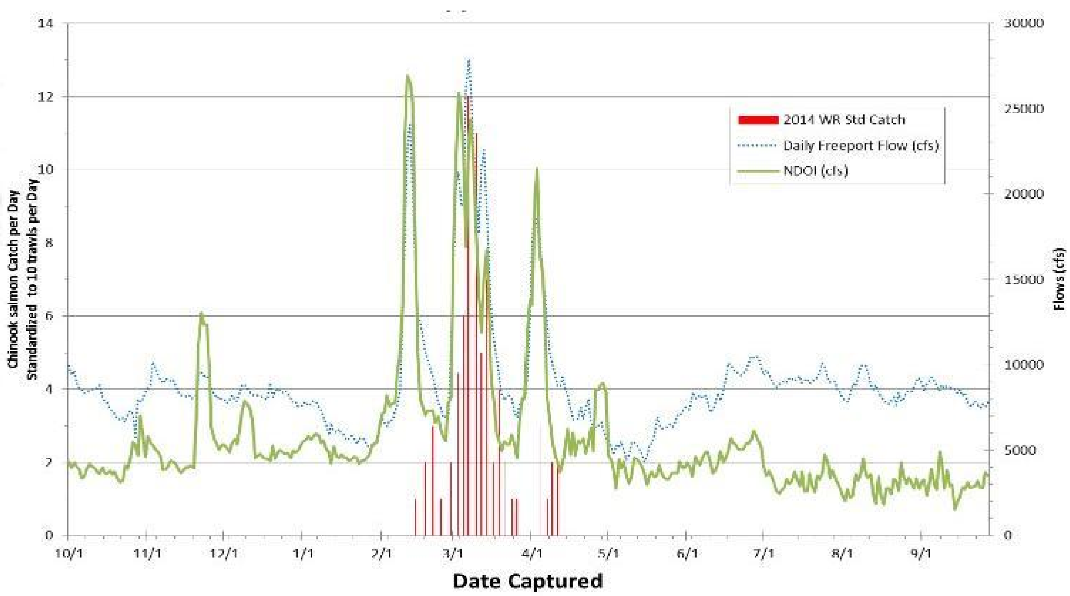

Figure 13. Standardized Daily Catches of Winter-run Chinook Salmon at Chipps Island in WY 2014

The period during which Brood Year 2013 WRCS were observed to pass Chipps Island (56 days), was half the average period (101 days), and a shorter period of time than previously observed values during WYs 2007-2012 (88-115 days). The passage timing of the 25th to 75th percentile of winter-run Chinook at Chipps Island, which happened between March 5 and 14, occurred roughly 10-20 days following the 25th to 75th percentile passage at Sherwood Harbor, which occurred between February 13 and March 4. The difference between the median passage of WRCS at Sherwood Harbor and Chipps Island, as indicated by cumulative catches, was only 3 days (Table 6). Together, these evidence convincingly demonstrate that WRCS spent a very short period of time rearing in the Delta in WY 2014.

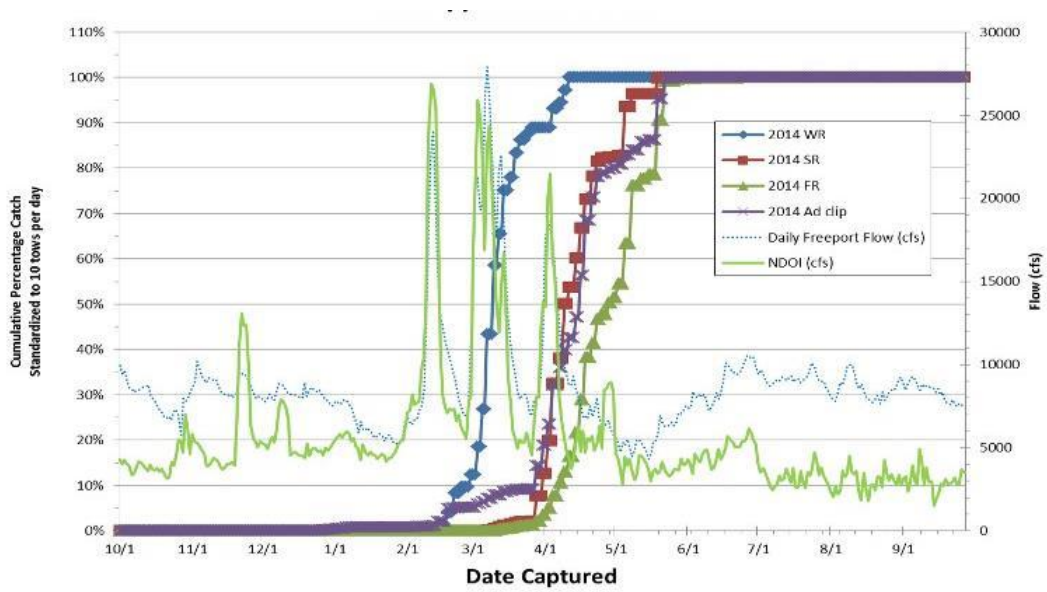

Figure 14. Cumulative Percentiles of Standardized Daily Catch of Chinook salmon at Chipps Island WY 2014

In WY 2014, Winter-run Chinook passage in the Delta was substantially different than what was observed in the previous seven years. Salmon arrived later, and had the shortest residence time of any year since 2008. The Team believes multiple potential mechanisms affected these observed migration patterns. Drought associated weather patterns and hydrology created distinct habitat attributes in WY 2014. In particular, river flow greater than 400 m^3/s, which have been identified to stimulate outmigration of rearing WRCS (del Rosario et al 2013), were not observed until February, coincident with the passage of the majority of the juvenile population into the Delta. Low survival rate of juveniles prior to entering the Delta in WY2014, caused by drought-related habitat conditions and a longer residency in the river, may also have influenced the truncated observations of juvenile winter-run residency in the Delta. This is because low density of juveniles preceding and following the detected juvenile pulses would have been difficult to detect. Similarly, low flow and low turbidity may have reduced the catchability of juveniles migrating through the Delta between the storm events due to shifts of juvenile position in Delta channels during these conditions. Finally, important environmental drivers of mechanisms responsible for emigration timing may have served as cues to exit the Delta early. These mechanisms may have included drought-related linkages to Delta habitat, temperature, community diversity, and to juvenile salmonid condition that are not explicitly included in the conceptual model.

Smolts

10. Was a significantly greater proportion of juvenile winter-run Chinook salmon caught above Knights Landing smolt-sized juveniles?

The Team reviewed RBDD screw trap monitoring results to evaluate the proportion of juveniles of different life history strategies. These data indicated that 57% of the Winter-run Chinook juvenile salmon captured in the traps had reached the smolt size stage which is significantly greater than the 20% average (range 10-47%) observed in years 2007-2012 (Poytress et al. 2014). The Team did not feel it could use the Knights Landing screw trap results for evaluating this question due to the late timing of Winter-run Chinook emigration in WY 2014 and a presumed bias in the length-at-date criteria employed at the Knights Landing screw trap.

The Team concluded this upward shift in the proportion of smolts could simply be linked to fish rearing above RBDD for longer and observations of these fish in the most upstream monitoring sites first. As previously stated, significant pulses of pre-smolt fish (>45mm fork length) into the Delta typically occur with fall storms that result in 150% or greater increases in flow over a matter of days, usually occurring in late October through December. These rainfall driven flow events greater than 400 m^3/s, which normally result in emigration downstream, did not materialize in 2014 until February. It was hypothesized in the DOP that juvenile WRCS reared for a longer period upstream of Knights Landing due to the lack of this environmental emigration cue. However, the lack of a flow cue in WY2014 alone does not explain the prolonged rearing period above RBDD. In most years, including WY 2014, most juveniles have passed RBDD by the end of September (Poytress et al. 2014). Since high flow events rarely occur prior to the end of September, some combination of other environmental drivers or physiological-developmental cues must drive emigration patterns from the upper river and tributaries above RBDD (Figure 15). The longer rearing period above RBDD and the higher proportion of fish emigrating past RBDD at smolt size, suggest drought affected juvenile salmon response to these non-flow-related drivers and cues, affecting the diversity of life-history traits exhibited by BY 2013.

11. Were Winter-run and Spring-run Chinook salmon passing Chipps Island larger in size in WY2014?

The Team was interested in this question to evaluate multiple hypotheses in the DOP regarding growth of salmonids during the drought. One hypothesis described drought conditions leading to larger fish due to presumed better rearing conditions during the prolonged rearing in the Sacramento River compared to years when Winter-run Chinook reared in the Delta. An alternate hypothesis described by the Team had fish growing smaller while rearing in the river since river temperatures were presumed to be cooler than Delta water temperatures.

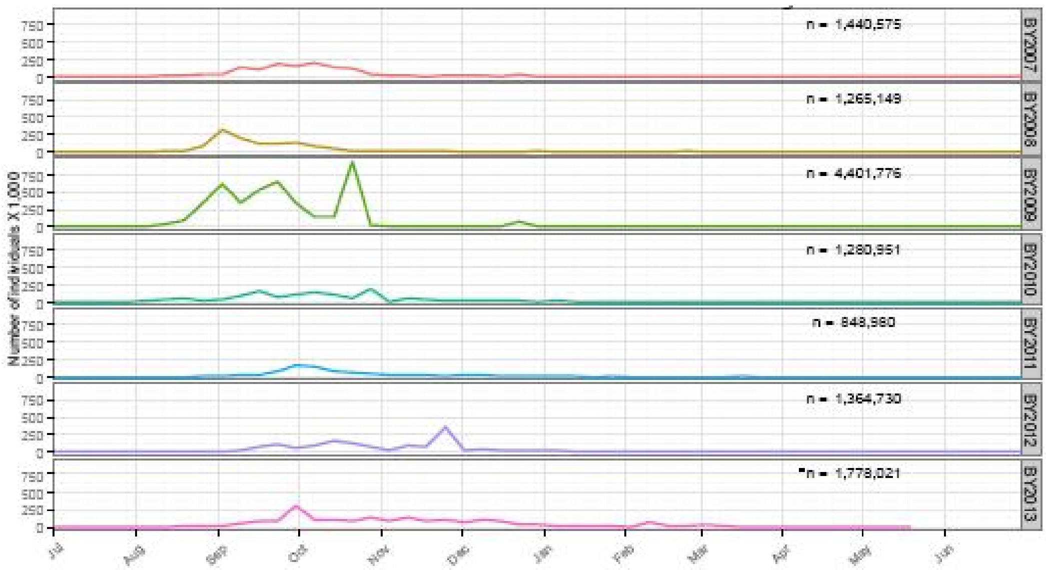

Figure 15. Weekly estimated passage of juvenile Winter-run Chinook at Red Bluff Diversion Dam from July 1, 2007 to May 20, 2014. WY 2014 Winter-run passage value interpolated using a monthly mean for the period October 1-17, 2013. Figure from USFWS-RBFWO.

Fork length distributions of WRCS captured in the Chipps Island trawl were similar between WY2014 and the six baseline years. The mean fork length for the 6 baseline years ranged from 114 mm to 118 mm, with a large degree of overlap in the ranges of fork lengths seen in the captured fish between individual years (Table 7, Figure 16). The mean fork length for WRCS captured in WY 2014 is 114 ± 3.6 mm, which overlaps with the values seen in the previous six years of data where the peaks were typically centered from approximately 100 mm to 130 mm. However, in WY 2014, the peak was flatter, as shown by the kurtosis value of 0.398, and the width of the peak of the histogram was spread out over a wider range of fork lengths (90 – 140 mm). Except for fish in WY 2011, the distribution of fork lengths for each year (not shown) were skewed in a positive direction, indicating that there are more fish in the smaller size ranges over the year than in the larger size classifications.

The Team discussed the data plotted in these figures, and concluded that apparent growth and juvenile condition of specific ESU's of fish cannot be accurately examined from current monitoring surveys, since the length-at-date criteria used to identify juveniles as Winter-run causes bias in fork length-identified samples. The Team felt there was insufficiently accurate information to substantiate or refute either hypothesis. The Team believes further monitoring efforts using classifying ESU of fish using genetics, instead of length, will provide necessary information to evaluate these hypotheses.

Table 7. Descriptive Statistics for Fork Lengths of Winter-run Salmon Captured at Chipps Island WY 2008-14

WY	Mean (mm)	Median (mm)	Kurtosis	Skewness	Min (mm)	Max (mm)	SEM (mm)
2008	114.1	114	0.33	0.29	97	139	2.79
2009	114.6	111	1.21	1.08	93	151	2.64
2010	115.1	112	2.47	1.53	100	152	2.66
2011	114.9	114	7.02	-1.62	68	132	2.49
2012	118.3	118	2.54	1.18	100	163	3.71
2013	116.7	113	4.77	1.46	80	185	3.92
2014	113.5	111	0.40	0.87	93	164	3.66

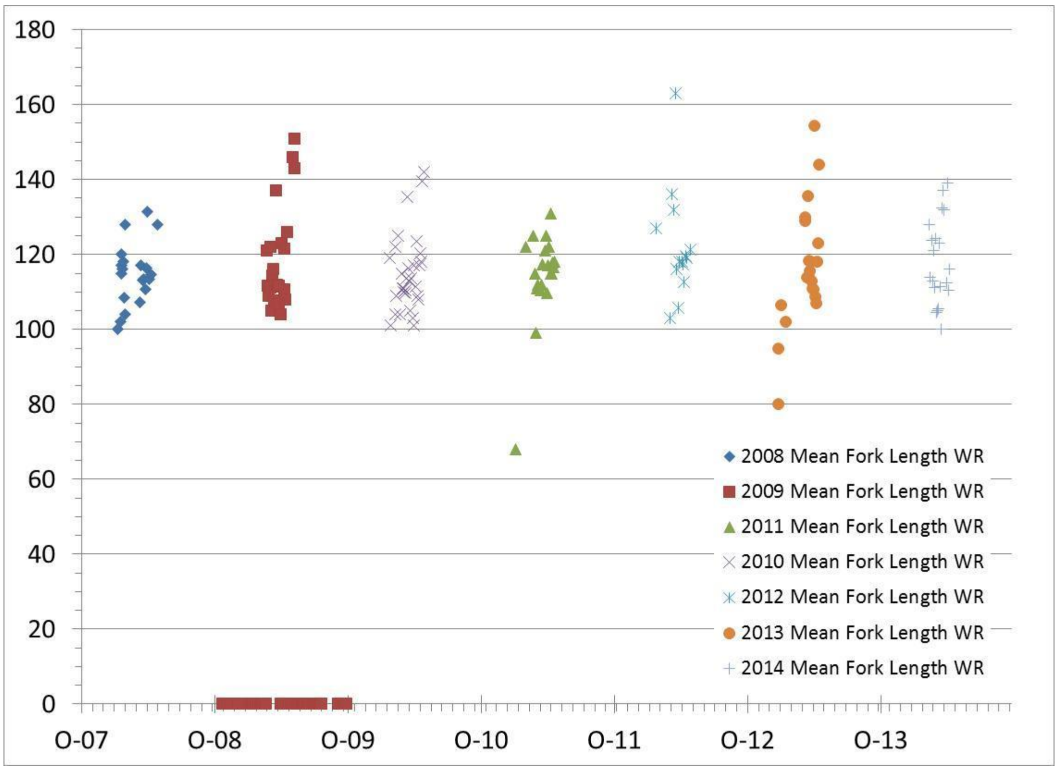

Figure 16. Weekly Mean Size of Juvenile Winter-run Salmon Observed During 2007-2014 at Chipps Island

This page intentionally left blank

Discussion

Productivity of Winter-run Chinook and Exposure and Risk in Water Year 2014 Drought Operations

While the winter-run Chinook monitoring data suggested that the abundance of juveniles surviving to the Delta was likely reduced by the drought conditions experienced in WY 2014, the Team was less certain about whether temperature operations in Fall 2013 influence on temperature and flow were a direct factor in this reduction. Redd dewatering and juvenile stranding were observed, but not at a level that would explain the greatly reduced production of juveniles observed upstream of Red Bluff Diversion Dam. The Team felt there was insufficient monitoring information to understand alternative mortality mechanisms likely linked to the low BY 2013 Winter-run Chinook survival above Red Bluff Diversion Dam, and its conceptual model lacked complexity to evaluate many of these processes and mechanisms. In particular, recent study results indicate a high prevalence of pathogens in outmigrating juvenile Central Valley salmonids. This most likely caused substantial mortality in exposed fishes (Foott 2014, Foott 2013) examined from the Lower Sacramento River during recent springs. Some of these samples were collected during March 2014, when BY 2013 Winter-run Chinook were emigrating out of the Sacramento River.

Distribution of Winter-run Chinook salmon and Exposure and Risks from Water Year 2014 Drought Operations

The Team's review of Winter-run Chinook monitoring data suggests that the spatio-temporal distribution of Brood Year 2013 juveniles was affected in the Sacramento River and Delta. Evidence for this included delayed passage for a substantial portion of the population past Red Bluff Diversion Dam and Knights Landing. While passage through the Delta did not appear delayed, the contracted and rapid passage period for Winter-run Chinook past Knights Landing and Chipps Island suggested the drought influenced migration rates, as well as timing. Concomitant with a shorter Delta residency in WY 2014 was a shorter window of exposure to the modified DCC Gate operation and increased exports that were part of modified drought operations. In WY 2014, there were 42 days between the first and last salvage date of older-sized juvenile salmon (a classification including Winter-run Chinook and yearling Spring-run sized Chinook salmon), which was substantially shorter than the average span of salvage dates during WYs 2007 and 2013 (150 days, range: 109-216 days). Due to the reduced Delta residency of BY2013 in WY2014, the Team considered the cumulative exposure of winter-run Chinook to modified

Delta operations, and associated mortality risk, to be reduced compared to other water years examined.

Between WY 2007 and 2013, multiple regulatory frameworks imposed by different biological opinions controlled operation of the DCC gates to protect migrating juvenile Chinook from entrainment into the south Delta during these years. To attempt to standardize the potential impact open DCC gates had on ESA-listed species, the number of days when fish protection values for the Sacramento and Knights Landing Catch indices exceeded threshold values was measured. Between WY 2007 and 2013, the number of days when the Sacramento Trawl or Knights Landing Catch Indices triggered a mandatory closure of open DCC gates during these years was typically zero, but on occasion up to 2 days. In WY 2014, modified drought contingency monitoring at Knights Landing resulted in the Knights Landing Catch Index being exceeded. This led to an initial closure of the DCC gates, after which the gates remained closed for the season. Thus, in WY 2014, the Team believes the increased monitoring upstream of the Delta Cross Channel benefited a modified operation of the Delta Cross Channel and reduced risks to interior Delta entrainment at this location given the distribution of the population.

A review of Delta Juvenile Fish Monitoring Program seine data found WRCS in a small portion (1 out of 18 surveys) of the south and central Delta seining sites during WY 2014. Although this low level of presence is typical of these surveys (during the comparative period of WYs 2008 through 2013 only 18 out of 225 total surveys detected winter-run Chinook in these regions), the WY 2014 detection was on March 12, while in the other years seines typically detected winter-run Chinook in these regions starting in December or January. Nevertheless, the Team felt there were insufficient non-zero monitoring samples to evaluate how juvenile exposure to DCC entrainment may have changed due to longer DCC gate opening or increased OMR reverse flow resulting from DOP regulatory modifications. The Team suggests some specific modeling and empirical information be required to better understand DCC entrainment exposure and associated risks to salmonids resulting from future OMR flow regulation modifications.

Modification of export levels included in the DOP allowed for periods during the spring when Old and Middle River (OMR) reverse flows exceeded those allowed in the BiOp (NMFS 2009). These modifications allowed for OMR flow more negative than -5000 cfs for between seven and twelve days in March 2014, depending on the averaging calculation used (Table 8). This coincided with the same time period when the majority of WRCS were captured in the Chipps Island trawl, 100% of the annual Winter-run Chinook loss at the SWP, and 77% of the annual loss at the CVP occurred, with a majority of this loss occurring when OMR levels were modified by the DOP (Figure 17). This was not suprising, since March is typically the month with greatest loss of Winter-run Chinook, ranging between 4% to 95% of the total annual loss at the SWP, and 55% to 83% of the total annual loss at the CVP

(Table 6). Total WRCS loss during WY 2014 was 338 fish, only 1% of the annual take limit. In the comparative WY period of 2007-2014, loss was approximately 25% on average of the annual take limit, and ranged between 7-66% (Table 9-10).

Table 8. Old and Middle River Flows During March 2014. Highlighted Periods Indicate Period When Flows Were More Negative than -5000 cfs.

Date	USGS Tidally Filtered OMR (cfs) Mean 5-Day	USGS Tidally Filtered OMR(cfs) Mean 14-Day	OMR Index Calculation (cfs) Mean Daily	OMR Index Calculation (cfs) Mean 5-Day	OMR Index Calculation (cfs) Mean 14-Day
03-01-14			-1150	-1230	-2410
03-02-14			-3240	-1630	02290
03-03-14			-3590	-2100	-2210
03-04-14			-3970	-2640	-2170
03-05-14			-4920	-3380	-2280
03-06-14	-3750		-5050	-4150	-2420
03-07-14	-4370		-5980	-4700	-2690
03-08-14	-4790		-6020	-5190	-2950
03-09-14	-5140		-5790	-5550	-3280
03-10-14	-5210		-6020	-5770	-3620
03-11-14	-5160		-5960	-5950	-3960
03-12-14	-5150		-5600	-5880	-4270
03-13-14	-5340		-6250	-5920	-4630
03-14-14	-5340		-5520	-5870	-4930
03-15-14	-5280	-4720	-5660	-5800	-5250
03-16-14	-5410	-4970	-5900	-5780	-5440
03-17-14	-5440	-5130	-4810	-5630	-5530
03-18-14	-5230	-5230	-5000	-5380	-5600
03-19-14	-5060	-5210	-4320	-5140	-5560
03-20-14	-4920	-5130	-3830	-4770	-5470
03-21-14	-4420	-4990	-2420	-4080	-5220
03-22-14	-3730	-4750	-2030	-3520	-4940
03-23-14	-3020	-4470	-1610	-2840	-4640
03-24-14	-2420	-4210	-1620	-2300	-4320
03-25-14	-1980	-4000	-1890	-1920	-4030
03-26-14	-1690	-3750	-1920	-1820	-3770
03-27-14	-1520	-3390	-1550	-1720	-3430
03-28-14	-1490	-3090	-1500	-1700	-3150
03-29-14	-1470	-2850	-1480	-1670	-2850
03-30-14	-1270	-2520	-1480	-1590	-2530
03-31-14	-1160	-2220	-1430	-1490	-2290

Discussion

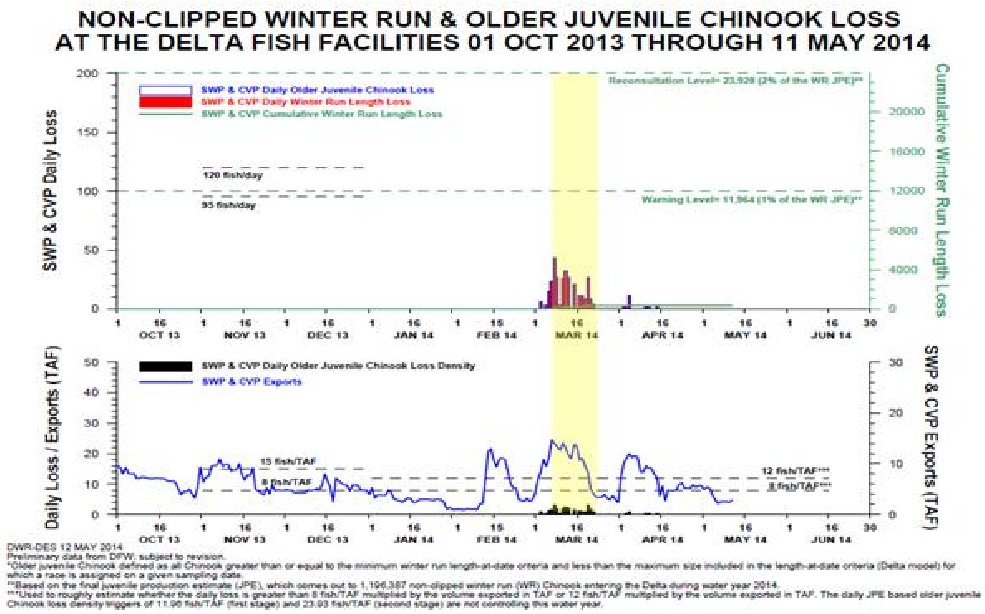

Figure 17. DAT Figures Showing Daily Loss of Winter-run Chinook salmon and Older Juvenile Classified Salmon During WY 2014. Yellow highlight is the Period when Daily OMR was More Negative than -5000 cfs

Table 9. Annual Loss Metrics at the Skinner Collection Facility (SWP) and Tracy Fish Collection Facility (CVP) for Winter-run Chinook Salmon for Water Year 2008-2014.

Water Year	SWP Loss	CVP Loss	Total Loss	Annual Take Limit	Loss (% of ATL)	1st Date of Older Juvenile (Combined)	Last Date of Older Juvenile (Combined)	Salvage Period (Days)
2008	917	381	1298	11798	11%	12-12-2007	04-29-2008	140
2009	1291	224	1515	12356	12%	12-30-2008	04-17-2009	109
2010	1072	588	1660	23593	7%	12-08-2009	04-28-2010	142
2011	3783	577	4360	6640	66%	10-14-2010	05-17-2011	216
2012	1702	377	2079	3241	64%	12-10-2011	05-29-2012	171
2013	633	98	731	10656	7%	12-03-2012	04-06-2013	124
2014	220	118	338	23928	1%	03-03-2014	04-14-2014	42

Table 10. Monthly Loss Metrics at the Skinner Collection Facility (SWP) and Tracy Fish Collection Facility (CVP)

State Water Project

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2008	0%	0%	0%	14%	36%	46%	4%	0%	0%	0%	0%	0%
2009	0%	0%	0%	0%	4%	95%	1%	0%	0%	0%	0%	0%
2010	0%	0%	0%	13%	22%	63%	2%	0%	0%	0%	0%	0%
2011	0%	0%	4%	15%	32%	47%	1%	0%	0%	0%	0%	0%
2012	0%	0%	0%	15%	77%	4%	3%	0%	0%	0%	0%	0%
2013	0%	0%	36%	10%	0%	52%	3%	0%	0%	0%	0%	0%
2014	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%

Central Valley Project

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2008	0%	0%	0%	9%	35%	55%	1%	0%	0%	0%	0%	0%
2009	0%	0%	4%	8%	14%	73%	1%	0%	0%	0%	0%	0%
2010	0%	0%	1%	3%	33%	59%	4%	1%	0%	0%	0%	0%
2011	0%	0%	1%	3%	33%	59%	4%	1%	0%	0%	0%	0%
2012	0%	0%	0%	3%	7%	83%	7%	0%	0%	0%	0%	0%
2013	0%	0%	14%	3%	6%	73%	3%	0%	0%	0%	0%	0%
2014	0%	0%	0%	0%	0%	77%	23%	0%	0%	0%	0%	0%

The Team considered salvage and winter-run distribution patterns in the South and Central Delta during WY 2014 to be distinctly different from previous years. In the BiOp, winter-run distributions extending into the South and Central Delta are predicted to occur more frequently at more negative OMR flows due to entrainment by reverse flows (NMFS 2009). Also, the South and Central Delta have historically been rearing habitat for salmonids since well before construction of the federal and state water projects (Erkkila et al. 1951), and remain an important, yet degraded, rearing habitat for them during the winter and spring. The Team believed monitoring in WY 2014 supports the conclusion that Winter-run Chinook spent less time in the South and Central Delta than is currently considered normal given low flows and less negative OMR conditions, a combination presumed to drive relatively low export driven entrainment risk. The low detection of winter-run Chinook in the South Delta, including low detection in salvage, may indicate a reduced effect of less negative OMR on entrainment risk relative to other years. Alternatively, these observations may simply reflect low numbers of Winter-run Chinook reaching the Delta due to substantial mortality in the Sacramento River prior to entering the Delta (discussed under abundance below). Evidence suggested a combination of both these scenarios likely accounted for lower than expected entrainment into the Central and South Delta, and into the water projects, thus the Team felt there was insufficient monitoring information to more specifically evaluate how increased OMR reverse flow as part of the DOP modifications affected population level risks. The Team suggests some specific monitoring information in the next section and believes this information would be of high value to understanding risks (or benefits) to salmonids in these regions with variable OMR flow regulations.

Life History Diversity of Winter-run Chinook and exposure and risk in Water Year 2014 Drought Operations

The Team's review of WRCS suggested that the typically observed migratory timing of Brood Year 2013 juveniles was altered by drought conditions, both in the Sacramento River and the Delta. Juveniles appeared to spend an extended period rearing in the upper and middle Sacramento River, resulting in a greater proportion of smolt-sized juveniles being observed further upriver. The Team does not believe modified outflow or Delta operation, due to the DOP, influenced this observation. This information was solely available at Red Bluff Diversion Dam, and the Team believed similar quality of information from other Sacramento locations between RBDD and Knights Landing would allow better characterization of Sacramento River migration patterns in future assessments. At Chipps Island, WRCS observations did not demonstrate these fish to be larger than normal (Figure 16 and 18), but the Team believed this may be a bias due to the length-at-date criteria used.

Abundance of WRCS and exposure and risk in DOP

The Team's review of Winter-run Chinook monitoring data suggested that the abundance of WRCS was likely affected by drought conditions experienced upstream of the Delta in WY 2014. The Team believed that the elongated rearing period of Brood Year 2013 Winter-run Chinook juveniles in the Sacramento River resulted in an abnormally low proportion of hatched juveniles surviving to enter the Delta. There was insufficient monitoring information to evaluate with certainty how DOP regulatory modifications affected survival and abundance in the Delta. However, a low abundance of WRCS entering the Delta, coupled with the observed rapid passage through the Delta were likely the primary factors responsible for the limited distribution of juveniles in the South and Central Delta, and for the low level of loss at the water project facilities, despite increased negative OMR during the period of passage. The closure of DCC gates during this passage period in March presumably limited the number of winter-run juveniles entrained into the Central and South Delta and water project facilities. The Team considered this interpretation to be more likely than the alternate interpretation that increased negative OMR had little influence on water-project loss since Winter-run Chinook generally bypassed the South and Central Delta in WY 2014.

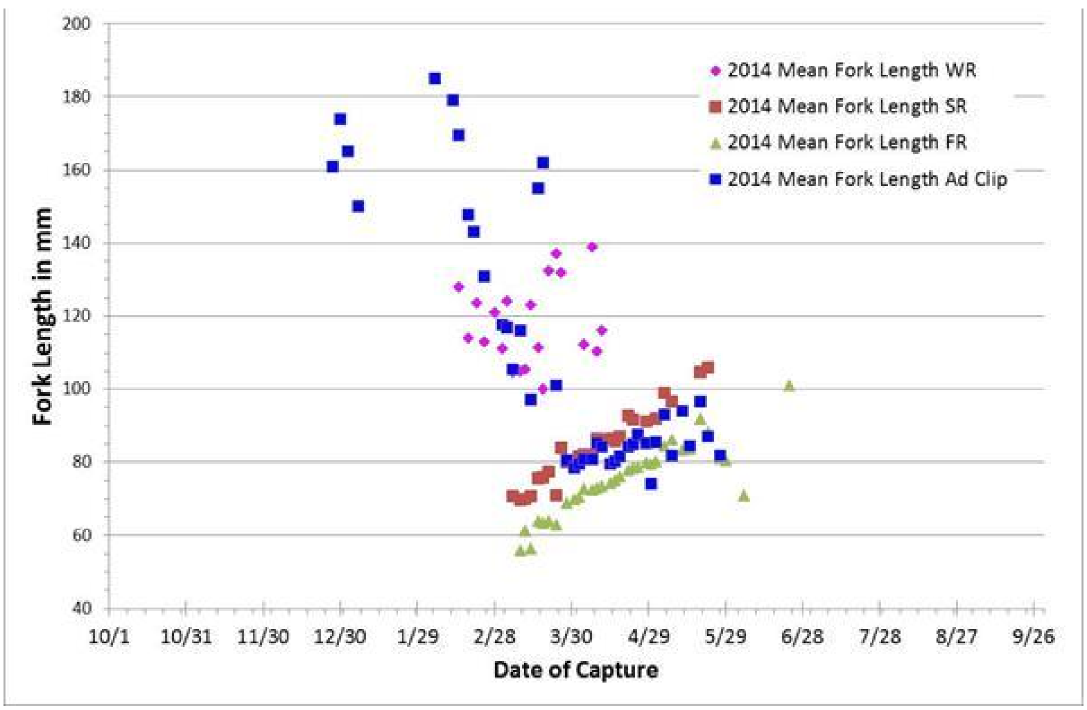

Figure 18. Mean fork length of Chinook salmon captured at Chipps Island in WY 2014

Although the Team found there was insufficient monitoring information to evaluate the population-level risk imposed by DOP modifications in isolation from other drought-related changes in ecosystem drivers, we felt there was sufficient information to conclude that the drought's effects on winter-run Chinook abundance puts the population at greater risk. This means as long as the drought continues, it will become an increasing management concern beyond simply how Sacramento River and Delta water management decisions affect the population. The Team's suggested addition of more intensive specific monitoring of Winter-run Chinook and other Central Valley salmon populations (discussed below) will be essential to defining how holistic management decisions interact with other drought-related effects on population abundance.

Suggested Improvement to Monitor Status of Salmonids and Operational Interactions During a Drought

The Team working on assessing the effects of the drought on Winter-run Chinook, and operational modification due to the drought, initially developed more questions (Table 11) than they were able to address given the 1) time limitation of the evaluation phase, 2) curation of monitoring data sets, and 3) shortcomings of the currently available monitoring for addressing these questions. The Team only met 7 times over 4 months and decided early on that it would not have time to evaluate similar questions for Green Sturgeon (*Acipenser medirostris*), steelhead (*Oncorhynchus mykiss*), or other Chinook salmon ESUs. Given our findings, we believe it is necessary for agencies to commit staff time and effort to such an endeavor since drought appears to be a major stressor on cold water species' viability. As future assessment efforts are considered, agencies should consider not focusing on solely the species of greatest concern since it may not be a good conservation surrogate for all species. Finally, monitoring of Winter-run Chinook is occurring in the Sacramento River and Delta that is not organized in a format that was useful for evaluating some of the questions considered by the Team. The long-term datasets from Glenn-Colusa Irrigation District screw trapping was problematic for the Team and greater emphasis on recording and presenting individual fish biological data is necessary.

We are reasonably confident in our interpretations regarding drought conditions impacting the spatial-temporal distribution of BY 2013 Winter-run Chinook. We have moderate certainty in our interpretations of how drought conditions influenced early survival and diversity of migration timing of the 2013 brood, and note multiple interpretations of monitoring results were presented in this report. Evidence for how drought and modified operations affected Winter-run Chinook could be strengthened with additional information. Based on gaps in our assessment and additional consideration of how the drought has affected WRCS, the Team suggests additional monitoring during all life stages (Table 12). This monitoring will provide scientists and managers the ability to more accurately evaluate important freshwater and estuarine population and operational metrics to characterize stressors and impacts caused by the drought on salmonids and their habitats.

An important foundation for undertaking expanded monitoring, and to undertake a more complete review of drought and operations impacts, is a broader, more complete conceptual model of the entire life cycle of winter-run Chinook and its habitats. Such a model may be a work product as part of the developing Interagency Ecological Program's (IEP) Salmon/Sturgeon/Steelhead Analysis and Indicators by Lifestage (SAIL) Project. Such a conceptual model may be similar to those recently advanced by

Table 11. Questions Raised by the Team but not Addressed Due to Time Limitations, Shortcomings of Monitoring, or Data Set Curation

Questions Not Evaluated
Did only an extremely small proportion of Winter-run remain above RBDD after April 2014?
Does Glenn-Colusa Irrigation District screw traps monitoring show the majority of Winter-run spent a prolonged residency period of juvenile Winter-run Chinook between RBDD and GCID?
Did the dry spring of WY 2013 and resultant lack of spring natural flow variability increase the proportion of Upper Sacramento River Chinook that over-summered and reared in the cold water refugia below Keswick Dam compared to normal conditions?
Was misclassification of older juvenile Chinook salmon at the state and federal fish collection facilities during the earliest portion of the WY 2014 salvage season due to greater life history diversity in non-Winter-run salmon ESUs.

Table 12. Suggestions for More Accurately Evaluating Population Metrics to Characterize Stressors and Impacts Caused by the Drought on Salmonids and Their Habitat

Abundance	Productivity	Spatial Distribution	Diversity
Adults			
• Expanded Ocean Fishery Monitoring		• Evaluate pre-spawn escapement using DIDSON to assess potential pre-spawn mortality	• Evaluation of growth and life history diversity in returning adult using otoliths
Eggs			
	• Recalibration of Sacramento Temperature Model using WY 2014 temperature dataset		
Juveniles			
• Habitat utilization study to estimate carry capacity in mainstem rearing areas • Remote sensing vegetation survey during migration period (spring)	• Complete a juvenile condition and pathogen monitoring • Increased count duration in salvage monitoring • Complete tagging of any in-river releases hatchery fish to better evaluate spring season productivity, spatial distribution, and diversity	• Increased monitoring at Knights Landing until population is determined to emigrate past this location into Delta to evaluate exposure • Modeling of daily proportion reverse flows at key Delta junctions to evaluate exposure into Delta • Develop migration passage model for RBDD, Knights Landing, and Chipps Island	• Use of genetic stock identification in salvage and monitoring surveys to accurately categorize ESU
Subadults			
• Expanded Ocean Fishery Monitoring	• Continued Ocean Condition Monitoring		

IEP for Delta smelt with the life cycle nested inside tiers of biological responses, habitat attributes, management and environmental drivers, and landscape attributes.

Increased monitoring of salmonids during the remainder of the current drought and for at least 2 years following the end of the drought are imperative to understand the influence of drought conditions and operations on the returning adults of brood years impacted by drought in their early riverine life history. For example, for BY 2013 WRCS, it is imperative that more extensive monitoring occurs in the ocean during 2015 and 2016, and upon return in 2016 and during winter and spring of WY 2017, to understand the impact of the drought on this population. While some drought and operational questions may never be answered for WY 2014, the Team felt that impacts of drought, and desired modification due to the drought, may be similar to what environmental and operational conditions may look like under some climate change scenarios. Although management processes may be slow to adapt to climate change and drought conditions, populations may be impacted by them rapidly, and the near-term drought provides a unique opportunity to assess how environmental and habitat-based processes predicted under climate change are likely to impact the resilience and viability of WRCS. Immediate efforts will require rapid integration of innovative tools and novel information to support greater flexibility and communication among both fish and water managers. If flexibility and communication is embraced, uncertainty can be further addressed through adaptive management and similar management paradigms.

This page intentionally left blank

Bibliography

Bartholow, J. M. and J. Heasley. 2006. Evaluation of Shasta Dam Scenarios Using a Salmon Production Model. U.S. Geological Survey, Reston, Virginia.

Brandes, P.L. and J.S. McLain. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento-San Joaquin Estuary. Intranet, Series: California Department of Fish and Game Fish Bulletin, Vol. 179, Page(s): 39-136

Cramer Fish Sciences (CFS). 2010. A Revised Sacramento River Winter Chinook Salmon Juvenile Production Model. Prepared for NOAA. 30 p.

Cavallo, B, P. Gaskill and J. Melgo. 2013. Report: Investigating the Influence of Tides, Inflows, and Exports on Sub-daily Flow in the Sacramento-San Joaquin Delta. Prepared for DWR. 70 p.

Dauble D., D. Hankin, J.J. Pizzimenti and P. Smith. 2010. The Vernalis Adaptive Management Program: Report of the 2010 Review Panel. Prepared for the Delta Science Program.

Del Rosario, R.B, Y.J. Redler, K. Newman, P.L. Brandes, T. Sommer, K. Reece and R. Vincik. 2013. Migration Patterns of Juvenile Winter-run-sized Chinook Salmon (*Oncorhynchus tshawytscha*) through the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 11(1): 24 p.

Erkkila, L.F., J.W. Moffett and O.P. Cope. 1951. Sacramento-San Joaquin Delta Fishery Resources: Effects of Tracy Pumping Plant and Delta Cross Channel. Special Scientific Report-Fisheries, No. 56. Department of Interior, U.S. Fish and Wildlife Service 109 p.

Foott, J.S. 2013. Sacramento and Feather River Juvenile Chinook Pathogen Survey, Spring 2013. Report for National Wild Fish Health Survey. CA-NV Fish Health Center, USFWS, Anderson, CA. 11 p.

Foott, J.S. 2014. Sacramento and Feather River Juvenile Chinook Pathogen Survey, Spring 2014. Report for National Wild Fish Health Survey. CA-NV Fish Health Center, USFWS, Anderson, CA. July 28, 2014. 11 p.

Jarrett, P. and D. Killam. 2014. Redd Dewatering and Juvenile Stranding in the Upper Sacramento River Year 2013-2014. RBFO Technical Report No 01-2014. California Department of Fish and Wildlife, Northern Region. 60 p.

Lindley, S.T., C.B Grimes, M.S. Mohr, W. Peterson, J. Stein, J.T. Anderson, L.W. Botsford, D.L. Bottom, C.A. Busack, T.K. Collier, J. Ferguson, J.C.

Garza, A.M. Grover, D.G. Hankin, R.G. Kope, P.W. Lawson, A. Low, R.B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F.B. Schwing, J. Smith, C. Tracy, R. Webb, B.K. Wells, and T.H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse? NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-447.

Martin, C.D., P.D. Gaines and R.R. Johnson. 2001. Estimating the Abundance of Sacramento River Juvenile Winter-run Chinook Salmon with Comparison to Adult escapement. Red Bluff Research Pumping Report Series, Volume 5. U.S. Fish and Wildlife Service, Red Bluff, CA.

McCollough, D.A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. Columbia River Inter-Tribal Fish Commission. A report to the U.S. Environmental Protection Agency, Seattle, WA. 291 p.

National Marine Fisheries Service. 2009. Biological and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project. Central Valley Office, Sacramento CA.

National Marine Fisheries Service (NMFS). 2014. Letter from Mrs. Maria Rea to Mr. Ron Milligan. Re: Juvenile Product Estimate and Annual Take Limit. Central Valley Office, Sacramento CA.

Newman, K.B. 2008. An Evaluation of Four Sacramento-San Joaquin River Delta Juvenile Salmon Survival studies. US Fish and Wildlife Service, Stockton California. Available at: *http://www.science.calwater.ca.gov/pdf/psp/PSP_2004_final/PSP_CalFed_FWS_salmon_studies_final_033108.pdf*.

Olsen, D, R. Revnak and P. Bratcher. 2012. Redd Dewatering, AFRP-N02-10, Pilot Study Year 2: November 30, 2011 to March 16, 2012. Central Valley Project Improvement Act, Anadromous Fish Restoration Program. Annual Report to U.S. Fish and Wildlife Service. 35 p.

Perry R.W. 2010. Survival and Migration Dynamics of Juvenile Chinook Salmon in the Sacramento–San Joaquin River Delta. Doctoral dissertation. University of Washington.

Perry, R.W., P.L. Brandes, P.T. Sandstrom, A. Ammann, B. MacFarlane, A.P. Klimley and J.R. Skalski. 2010. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento–San Joaquin River Delta. North American Journal of Fisheries Management 30:142-152.

Poytress, W.R., J.J. Gruber, F.D. Carillo, and S.D. Voss. 2014. Compendium Report of Red Bluff Diversion Dam Rotary Screw Trap Juvenile

Anadromous Fish Production Indices for Years 2002-2012. Report of U.S. Fish and Wildlife Service to the California Department of Fish and Wildlife and US Bureau of Reclamation.

Revnak, R and D. Killam. 2013. Redd Dewatering and Juvenile Stranding in the Upper Sacramento River Year 2012-2013. RBFO Technical Report No 01-2013. California Department of Fish and Wildlife, Northern Region. 45 p.

Singer, G.P, A.R Hearn, E.D Chapman, M.L. Peterson, P.E. LaCivita, W.N. Brostoff, A. Bremmer, and A.P. Klimley. 2013. Interannual variation of reach specific migratory success for Sacramento River hatchery yearling late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Oncorhynchus mykiss*). Environmental Biology of Fishes 96: 363-379.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain Rearing of Juvenile Chinook salmon: Evidence of Enhanced Growth and Survival. Canadian Journal of Fisheries and Aquatic Science 58:325–333.

United States Bureau of Reclamation (USBR). 2014. Central Valley Project and State Water Project Drought Operations Plan and Operations Forecast, April 1, 2014 through November 15, 2014. April 8, 2014.

United States Fish and Wildlife Service (USFWS). 1999. Effects of Temperature on Early-life Survival of Sacramento River Fall-and Winter-run Chinook salmon. Final Report.

United States Fish and Wildlife Service (USFWS). 2006. Relationships Between Flow Fluctuations and Redd Dewatering and Juvenile Stranding for Chinook Salmon and Steelhead in the Sacramento River Between Keswick Dam and Battle Creek. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office. 94 p.