UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

January 20, 2022

Kristin White, Operations Manager
U.S. Department of the Interior
Bureau of Reclamation
Central Valley Operations
2800 Cottage Way
Sacramento, California 95825-1898

Electronic transmittal only

Dear Ms. White:

This letter provides the U.S. Bureau of Reclamation (Reclamation) with the estimated number of juvenile Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) from brood year (BY) 2021 expected to enter the Sacramento-San Joaquin Delta (Delta) during water year (WY) 2022. This juvenile production estimate (JPE) is provided by NOAA's National Marine Fisheries Service (NMFS) pursuant to the October 21, 2019, biological opinion for the reinitiation of consultation on the long-term operations of the Central Valley Project (CVP) and the State Water Project (SWP, NMFS 2019). The JPE is calculated annually and is used to determine the authorized level of incidental take for winter-run Chinook salmon, under Section 7 of the Endangered Species Act (ESA), while operating the CVP/SWP Delta pumping facilities in a given water year (NMFS 2019).

The authorized incidental take limits for natural origin winter-run Chinook salmon and hatchery winter-run Chinook salmon have been established in Table 140 in NMFS (2019) as follows:

- Loss of natural winter-run Chinook salmon is 1.3% of the JPE on a three-year rolling average or 2.0% of the JPE in any single year.
- Loss of Sacramento River hatchery winter-run Chinook salmon is 0.8% of the estimated hatchery JPE (fish surviving to the Delta) from Livingston Stone National Fish Hatchery (LSNFH) released into the upper Sacramento River on a three-year rolling average or 1.0% of the JPE in any single year.
- Loss of Battle Creek hatchery winter-run Chinook salmon is 0.8% of the estimated hatchery JPE (fish surviving to the Delta) from LNSFH released into Battle Creek on a three-year rolling average or 1.0% of the JPE in any single year.

The winter-run Chinook salmon JPE for BY 2021 is **125,038 natural-origin juvenile winter-run Chinook salmon expected to enter the Delta during WY 2022**. The incidental take limits for natural origin winter-run Chinook salmon are 1,625 (1.3% of 125,038) on a three-year rolling average loss and 2,501 (2% of 125,038) for single year loss during WY 2022. The JPE calculation is developed as a function of the estimated number of juveniles passing RBDD and fry-to-smolt survival rates. Although adult escapement increased in 2021 to 10,269 compared to 6,390 in 2020, there was a significant decrease in the JPE for BY 2021 due to a decrease in egg-to-fry survival (2.6% this year compared to 11.5% last year).

The incidental take limit for hatchery-origin winter-run Chinook salmon is set separately for each release (*i.e.,* Sacramento River and Battle Creek releases). Based on projected releases, the **JPE for BY 2021 hatchery-produced (adipose fin-clipped) winter-run Chinook salmon juveniles released from LSNFH into the Sacramento River is 151,544** (estimated release of 537,771 juveniles). The incidental take limit for hatchery-produced winter-run Chinook salmon juveniles released from LSNFH into the Sacramento River is 1,212 (0.8% of 151,544) on a three-year rolling average loss and 1,515 (1% of 151,544) for single year loss during WY 2022. The **JPE for BY 2021 hatchery-produced (adipose fin clipped and left ventral fin clipped) winter-run Chinook salmon juveniles released from LSNFH into Battle Creek is 7,311** (estimated release of 139,000 juveniles). The incidental take limit for hatchery-produced winter-run Chinook salmon juveniles released from LSNFH into Battle Creek is 58 (0.8% of 7,311) on a three-year rolling average annual loss and 73 (1% of 7,311) for single year loss during WY 2022**.**

Status of Winter-Run Chinook Salmon

Juvenile winter-run Chinook salmon experienced very low survival in 2014 and 2015 due to drought conditions causing unfavorable temperatures in the spawning grounds. The California Department of Fish and Wildlife (CDFW), NMFS and the U.S. Fish and Wildlife Service (USFWS) responded to this crisis in part by reinstating the winter-run Chinook salmon Captive Broodstock Program at LSNFH. The primary purpose of the Captive Broodstock Program is to maintain a refugial population of winter-run Chinook salmon in a safe and secure environment to be available for use as hatchery broodstock in the event of a catastrophic decline in abundance. A secondary purpose of the program is to provide fish, when possible, to fulfill multi-agency efforts to reintroduce winter-run Chinook salmon into the restored habitats of Battle Creek and above Shasta Dam. Approximately 1,000 juvenile winter-run Chinook salmon propagated at LSNFH have been retained annually for the Captive Broodstock Program since it was reinstated beginning with BY 2014 (with the exception of BY 2016, when approximately 534 juveniles were retained).

Similar to BY 2020, BY 2021 was affected by a thiamine deficiency in returning adults, which transferred to low thiamine in their eggs, and resulted in a decreased number of successful fry upstream of RBDD. BY 2021 was also subject to low flows and low turbidity due to limited precipitation events. Outmigrating juveniles will also likely encounter challenging water conditions in certain areas where high debris from wildland fires in 2021 will travel into streams and rivers. Approximately 570,000 BY 2021 juvenile winter-run Chinook salmon were estimated to pass RBDD in BY 2021, compared to 2.1 million juveniles from BY 2020.

JPE Development Process

The process for developing the BY 2021 JPE was similar to what was done for BY 2020. A technical team from the Interagency Ecological Program (IEP), the Winter-run Project Work Team (WRPWT), met in December 2021 and January 2022, and provided recommendations to NMFS and CDFW (Enclosure 2) on January 14, 2022. The method used to calculate the BY 2021 JPE is derived from the USFWS' estimated number of juveniles passing RBDD. This estimate is known as the Juvenile Production Index (JPI) and is based on fry-equivalents at RBDD.

NMFS (2019) defines the JPE as the estimated number of juvenile winter-run Chinook salmon to enter the Delta (*i.e.,* Tower Bridge in Sacramento), but not through the Delta. The calculation of the winter-run Chinook salmon JPE for BY 2021 begins with estimates of winter-run Chinook salmon adult escapement in 2021, which are derived from carcass surveys conducted in the upper Sacramento River by CDFW. Escapement information was provided to NMFS via a November 15, 2021, letter (Enclosure 1). The CDFW estimate for total adult winter-run Chinook salmon escapement in 2021 was 10,269 spawners[1]. Of this total number of spawners, 313 were collected at the Keswick Dam trap site for spawning at LSNFH, leaving an estimated 9,956 to spawn naturally in-river. An estimated 5,860 of these spawners were females.

The number of adult spawners in 2021 was the highest in the past 10 years (Figure 1). The cohort replacement rate (CRR), which is a measure of the population's growth rate, was positive again this year (*i.e.,* 3.89), meaning the population is currently replacing itself (Figure 2), however, the trend is heading towards a negative growth rate.

Similar to BY 2020, genetic analyses were conducted on some length-at-date (LAD) juvenile spring-run Chinook salmon sampled from the RBDD RSTs, and the estimate of juvenile winter-run Chinook salmon emigration past RBDD was adjusted to include the LAD spring-run Chinook salmon that were determined to be genetic winter-run Chinook salmon.

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[1] The methodology used by CDFW (*i.e.*, Cormack-Jolly-Seber Model) to estimate escapement is the same model that has been used since 2012.

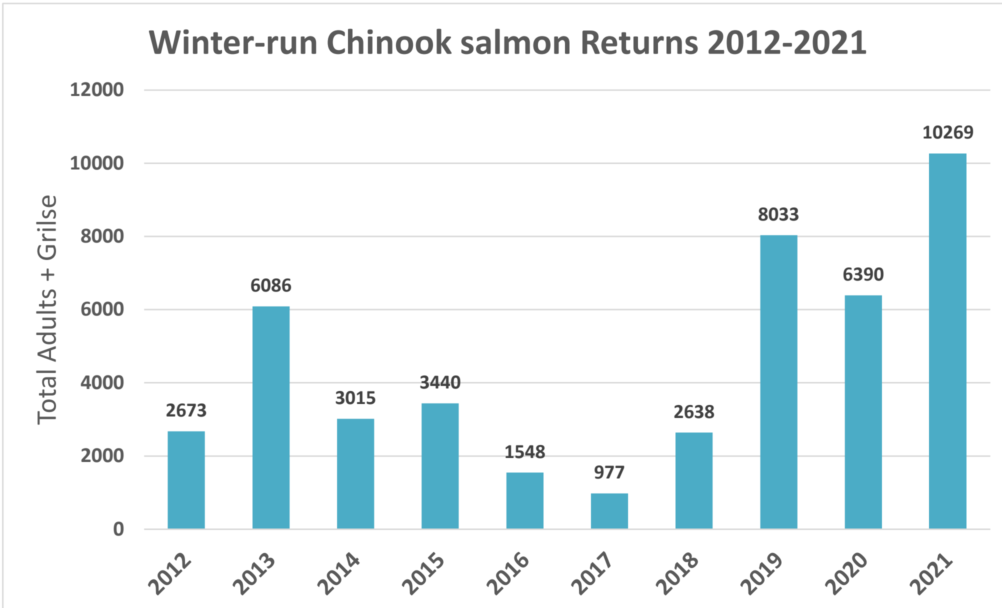

Figure 1. Winter-run Chinook Salmon Spawning Escapement 2012-2021 (CDFW 2021 and Enclosure 1).

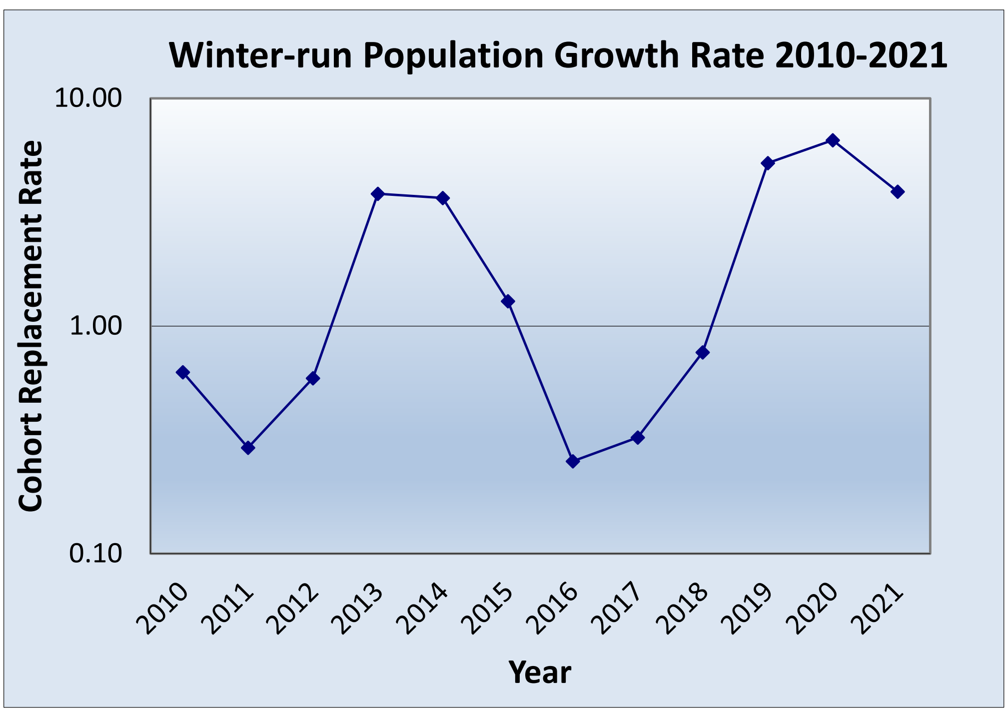

Figure 2. Cohort replacement rate for winter-run Chinook salmon 2010–2021 (CDFW 2021).

The JPE for BY 2021 incorporates the recommendations from the WRPWT (Enclosure 2). The WRPWT identified four factors in calculating the JPE, similar to last year, that it advises continuing for BY 2021:

1. Estimated number of fry passing the RBDD
2. Survival rate of natural-origin fry to smolts
3. Survival rate of smolts from RBDD to Delta entry (defined as Sacramento at the Tower Bridge)
4. Estimated survival rate of winter-run Chinook salmon hatchery fish to be released in February 2022

Estimates of egg-to-fry survival rate are based on the JPI estimate at RBDD. The JPI method is considered a more accurate estimate of the egg-to-fry survival rate because it is an annual estimate, which better represents the response of fish to the environmental conditions at the time of spawning (see recommendations from the WRPWT in Enclosure 2).

Another reason to use the JPI, rather than historical measures of egg-to-fry survival, is that the JPI approach may at least partially account for the potentially lower than average egg-to-fry survival that may be occurring in naturally spawned winter-run Chinook salmon due to issues related to thiamine deficiency in returning spawners. Any thiamine deficiency impacts manifested in egg viability or early fry stages will lead to a reduced JPI compared to what would have been observed absent thiamine deficiency impacts. USFWS has only one observation of abnormal fry behavior at the RBDD rotary screw traps, suggesting that any mortality caused by thiamine deficiency occurred primarily upstream of RBDD, though there may be latent impacts to young-of-year winter-run Chinook salmon downstream of RBDD that are not estimable based on information available this year. The assumption that most mortality would occur in early life history stages is consistent with observations at Central Valley hatcheries, where mortality and behavioral abnormalities associated with thiamine deficiency were documented soon after hatch.

The egg-to-fry survival rate has ranged from 2.56 percent to 49 percent from BY 2005 to BY 2021, with an average of 22 percent (see Figure 3). BY 2021 egg-to-fry survival rate is estimated at 2.56 percent. This low survival rate is likely largely due to thiamine deficiency and temperature-related mortality during egg incubation.

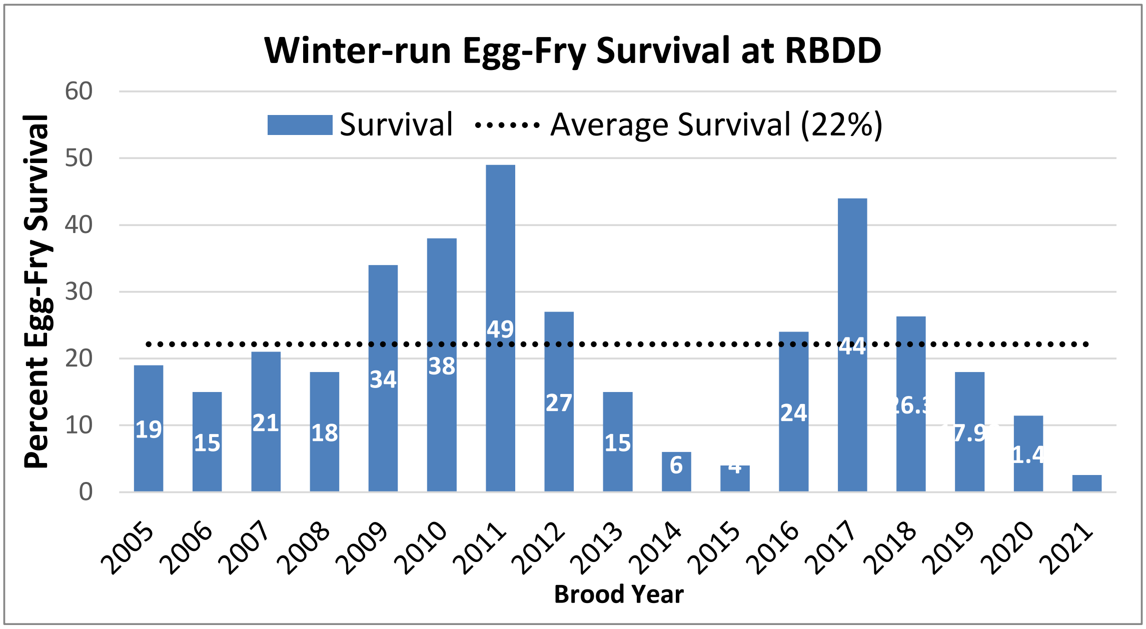

Figure 3. Winter-run egg-to-fry survival estimated at Red Bluff Diversion Dam 2005-2021 (Poytress et al. 2014, Voss and Poytress 2020, and Enclosure 2)

The calculation of the JPE is based on assumed environmental conditions (*e.g.,* temperature, flows, and turbidity) in the Sacramento River. However, actual environmental conditions, which may occur after the JPE is calculated, may be different than those assumed in the calculation of the JPE. The WRPWT recommends the fry-to-smolt survival rate forecasting method developed by O'Farrell et al. (2018), which uses recent winter-run Chinook salmon survival data and is updated with new survival data annually. The WRPWT also recommends the smolt survival to the Delta calculation based on a weighted average of acoustically-tagged hatchery winter-run Chinook salmon releases from RBDD to the Tower Bridge (in Sacramento). NMFS considers the Tower Bridge as the point of Delta entry.

Using the JPI, and based upon the WRPWT recommendation, NMFS estimates a JPE of **125,038 natural-origin juvenile winter-run Chinook salmon entering the Delta during WY 2022** (Table 1 in Enclosure 2). Juvenile winter-run Chinook salmon are expected to emigrate into the Delta from November 2021 through April 2022, based upon CDFW historical monitoring data at Knights Landing rotary screw traps.

In early 2022, approximately 537,771 juvenile winter-run Chinook salmon propagated at LSNFH will be released into the upper Sacramento River near Redding (Caldwell Park). A portion of the juvenile winter-run Chinook salmon from LSNFH may be acoustically-tagged (JSAT) to monitor their survival and movement downstream, some of which may be released up to 30 days prior to the production release. The objective of the early tag release is to use this information to parameterize the JPE equation of survival versus holding time upstream in the river. All hatchery-produced winter-run Chinook salmon will be coded-wire tagged and marked (100 percent) with an adipose fin-clip before release so that they can be identified from other hatchery fish. Since the hatchery winter-run Chinook salmon have not been released yet, their survival rate is unknown.

Based on the WRPWT advice (Enclosure 2), NMFS used a weighted mean survival rate (*i.e.,* 0.2828) of the hatchery acoustic tag releases between Caldwell Park in Redding and the Tower Bridge in Sacramento to estimate how many hatchery fish released in the Sacramento River would enter the Delta. The survival rate for hatchery-origin fish is different than the natural-origin fish because it is measured over a longer distance (Caldwell Park vs RBDD). NMFS estimates that approximately **151,544 juvenile winter-run Chinook salmon from BY 2021 released into the Sacramento River from LSNFH will survive to enter the Delta during WY 2022**.

In 2017, the first group of winter-run Chinook salmon captive broodstock withheld and maintained at LSNFH reached maturity and became ready to spawn. Given the precarious status of winter-run Chinook salmon resulting from numerous years of drought, CDFW, NMFS, and USFWS determined that the progeny from captive broodstock could be used to "jump start" the Battle Creek Winter-Run Chinook Salmon Reintroduction Plan. The reintroduction of winter-run Chinook salmon to Battle Creek is an extremely important step in the conservation of this endangered species, highlighted by the fact that only a single population exists today. The progeny of the captive broodstock proposed for release into Battle Creek will be the fourth year that juvenile winter-run Chinook salmon will experience portions of Battle Creek that were recently restored, providing a unique opportunity to learn vital information about release strategies, marking and tagging regimes, habitat use, and survival.

Based on the WRPWT advice (Enclosure 2), NMFS used the weighted mean survival (*i.e.,* 0.0526) to estimate how many hatchery winter-run Chinook salmon released into Battle Creek would enter the Delta. In spring of 2022, approximately 139,000 juvenile winter-run Chinook salmon will be released into Battle Creek. This year, a subset of the winter-run Chinook salmon released in Battle Creek during WY 2022 may receive acoustic tags, allowing for the estimation of survival rates specific to releases occurring in Battle Creek. As releases of acoustically-tagged winter-run Chinook salmon continue during subsequent years, the data collected will allow for the refinement of the survival rates specific to Battle Creek and better estimates of the number of winter-run Chinook salmon released in Battle Creek that survive to the Delta. NMFS estimates that approximately **7,311 juvenile winter-run Chinook salmon from BY 2021 released into Battle Creek will survive to enter the Delta during WY 2022**.

Incidental Take Limits for Natural and Hatchery Juvenile Winter-Run Chinook Salmon

The authorized incidental take limit for the combined CVP/SWP Delta pumping facilities includes both the natural-origin (wild) and hatchery-produced juvenile winter-run Chinook salmon, as both are necessary components of the population for survival and recovery of the species. Incidental take limits are summarized below:

- For natural origin winter-run Chinook salmon: 1,625 on a three-year rolling average loss and 2,501 for single year loss.
- For hatchery-produced winter-run Chinook salmon juveniles released into the Sacramento River: 1,212 on a three-year rolling average loss and 1,515 for single year loss.

- For hatchery-produced winter-run Chinook salmon juveniles released into Battle Creek: 58 on a three-year rolling average annual loss and 73 for single year loss.

The JPE-related incidental take limits allow for errors in fish identification due to use of LAD criteria to determine Chinook salmon run (*i.e.,* differentiating from fall-run, late-fall-run, and spring-run Chinook salmon). The authorized level of incidental take for natural-origin winter-run Chinook salmon (*i.e.,* reported as loss at the CVP/SWP Delta fish facilities) under the ESA for the combined CVP/SWP Delta pumping facilities from October 1, 2021, through June 30, 2022, is for natural-origin winter-run-sized fish, based on LAD criteria.

The initial identification of naturally-produced (non-clipped) winter-run Chinook salmon at the CVP/SWP Delta fish facilities shall be based on the LAD criteria for the Delta. NMFS will continue to monitor fish salvage and loss, and loss densities of winter-run Chinook salmon and other ESA-listed species at the CVP/SWP Delta fish facilities, through participation in the Salmonid Monitoring Team technical team and the Water Operations Management Team.

NMFS acknowledges that additional research using acoustically-tagged winter-run Chinook salmon (both hatchery and wild) is necessary to provide a more robust estimate of in-reach survival of winter-run Chinook salmon in the Sacramento River and would also provide direct calculation of survival, thereby greatly improving the accuracy of the JPE. We recommend that funding continues for acoustic tag studies on winter-run Chinook salmon for BY 2022 and beyond to provide data on survival rates over a range of hydrologic conditions.

In closing, we look forward to continuing to work with Reclamation and the other State and Federal agencies to manage water resources in WY 2022 in a way that supports both water supply and fish and wildlife resources. If you have any questions regarding this correspondence, or if NMFS can provide further assistance, please contact Mr. Garwin Yip at (916) 930-3611, or via email at Garwin.Yip@noaa.gov.

Sincerely,

A. Catherine Marcinkevage

Cathy Marcinkevage
Assistant Regional Administrator
California Central Valley Office

Enclosures:

1. CDFW letter with winter-run escapement estimate for BY 2021, dated November 15, 2021
2. Winter-Run Project Work Team letter to NMFS, dated January 14, 2022

cc: Copy to file: ARN 151422SWR2006SA00268

Electronic copy only:

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References Cited

California Department of Fish and Wildlife (CDFW). 2021. Unpublished data, GrandTab Spreadsheet of Adult Chinook Escapement in the Central Valley, 6/30/2021. CDFW Fisheries Branch Anadromous Resources Assessment

NMFS. 2019. Biological Opinion for the Re-initiation of Consultation on the Long-Term Operation of the Central Valley Project and State Water Project. U.S. Department of Commerce National Marine Fisheries Service. 900 pages plus appendices. 21 October 2019. Available at: NMFS 2019 Biological Opinion

O'Farrell M.R., W.H. Satterthwaite, A.N. Hendrix, and M.S. Mohr. 2018. Alternative Juvenile Production Estimate (JPE) Forecast Approaches for Sacramento River Winter-Run Chinook Salmon. San Francisco Estuary & Watershed Science. Volume 16, Issue 4 | Article 4. Alternative Juvenile Production Estimate

Poytress, W. R., J. J. Gruber, F. D. Carrillo and S. D. Voss. 2014. Compendium Report of Red Bluff Diversion Dam Rotary Trap Juvenile Anadromous Fish Production Indices for Years 2002-2012. Report of U.S. Fish and Wildlife Service to California Department of Fish and Wildlife and US Bureau of Reclamation.

U.S. Fish and Wildlife Service (USFWS). 2022. Biweekly Report of Passage at Red Bluff Diversion Dam (December 17, 2021 - December 31, 2021). Red Bluff Fish and Wildlife Office. Available at Juvenile Salmonid Monitoring at RBDD

Voss, S. D., and W. R. Poytress. 2020. Brood year 2018 juvenile salmonid production and passage indices at the Red Bluff Diversion Dam. Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Sacramento, California.

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GAVIN C. NEWSOM, Governor
CHARLTON H. BONHAM, Director

November 15, 2021

Mr. Barry Thom
Regional Administrator, West Coast Region
National Marine Fisheries Service
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WINTER-RUN CHINOOK SALMON ESCAPEMENT ESTIMATES FOR 2021

Dear Mr. Thom:

The California Department of Fish and Wildlife (CDFW) has developed Sacramento River winter-run Chinook Salmon escapement estimates for 2021. These estimates were developed from data collected in the Upper Sacramento River winter-run Chinook Salmon Escapement Survey (carcass survey) conducted by CDFW and U.S. Fish and Wildlife Service (USFWS) personnel.

Escapement estimates shown below were calculated using the Cormack-Jolly-Seber (CJS) mark-recapture population model:

Estimated Total In-river Escapement (hatchery and natural origin)	**9,956**
Estimated In-river Escapement (hatchery origin)	**3,030**
Estimated Number of In-river Spawning Females (hatchery and natural origin)	**5,860**

These estimates include only naturally spawning winter-run Chinook Salmon in the upper Sacramento River. An additional **298** winter-run Chinook Salmon were collected at the Keswick Dam trap site for spawning at Livingston Stone National Fish Hatchery. The total 2021 Sacramento River winter-run spawning escapement estimate, including in-river spawners and fish collected for hatchery broodstock, is **10,269** fish. The 90% confidence interval on this total escapement estimate is **9,280 to 11,258** fish.

The total escapement estimate includes spawned and unspawned carcasses from the winter-run carcass survey, ten female carcasses that were observed during the late-fall-run carcass survey earlier in the year, and five moribund fish collected for disease assay during the winter-run spawning season. Not included in these estimates are winter-run returns to Battle Creek into and upstream of the Coleman National Fish Hatchery as part of the Battle Creek “jumpstart” reintroduction effort. Twenty-three

Battle Creek winter-run Chinook Salmon carcasses from were recovered during the Sacramento River carcass survey and are included in the escapement estimate.

The CDFW has used the CJS model to estimate winter-run Chinook Salmon escapement since 2012. Due to its similarity to the Jolly-Seber model used previously, we consider escapement estimates from 2012-2021 to be directly comparable to those from 2003-2011. Figure 1, below, shows the Sacramento River winter-run Chinook Salmon spawner escapement estimates from 2003 to present. The reported total escapement estimate for 2021 is considered final, subject to revision if additional data becomes available after the date of this letter. Updated estimates can be found in the GrandTab spreadsheet which is updated if and when new information is received (https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381).

We look forward to further discussion and collaboration with National Marine Fisheries Service staff regarding the application of this information. Inquiries regarding the methodology and development of the estimates in this letter should be directed to Mr. Douglas Killam at Doug.Killam@wildlife.ca.gov or Ms. Erica Meyers at Erica.Meyers@wildlife.ca.gov.

Sincerely,

DocuSigned by:
Valerie Cook
96D42C58E092466...
Valerie Cook, Acting Fisheries Branch Chief

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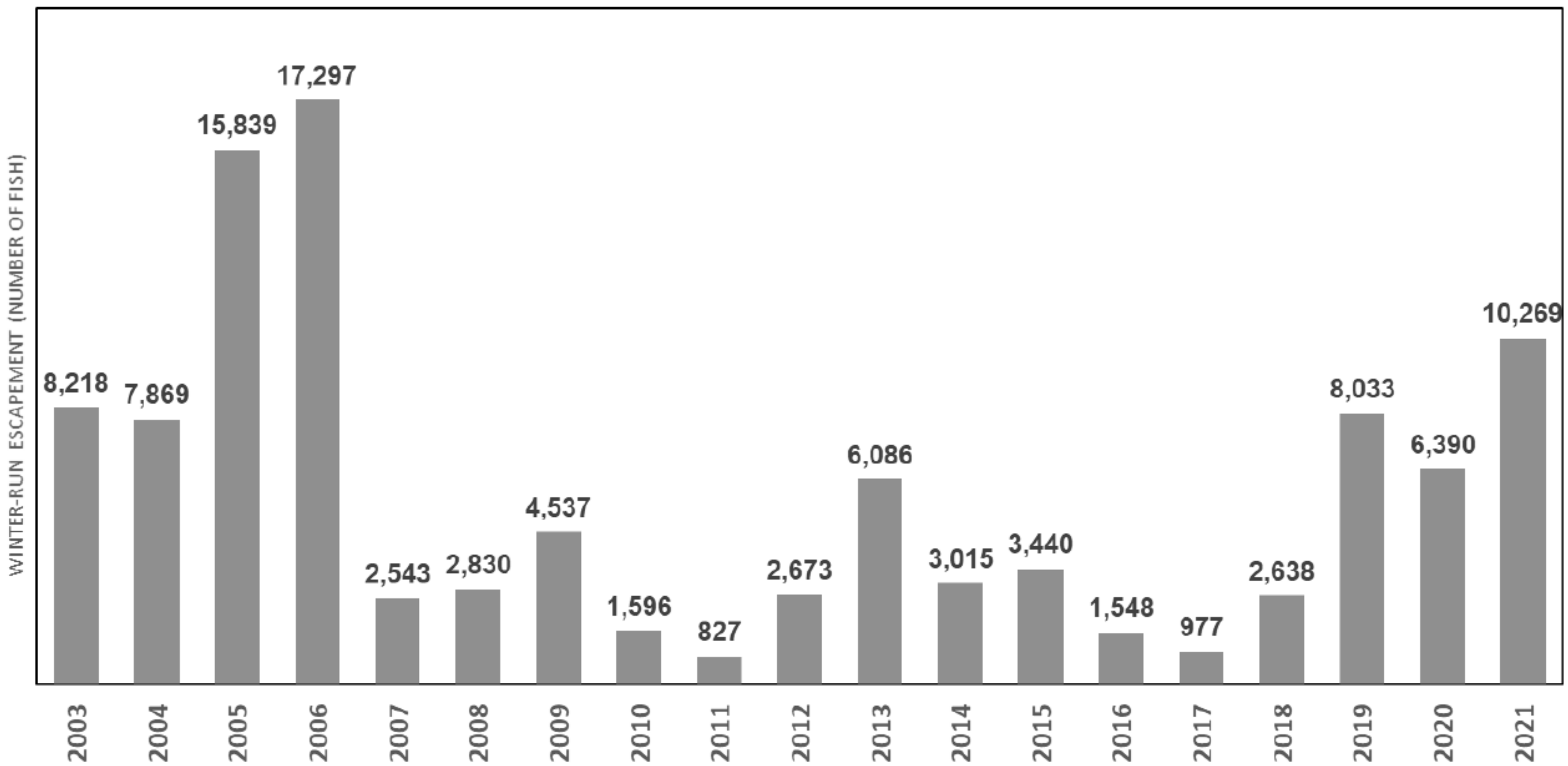

Figure 1. Estimated escapement of winter-run Chinook Salmon to the Upper Sacramento River Basin, 2003-2021. Data compiled from GrandTab (CDFW 2021; https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381). Data for 2009-2021 are preliminary and subject to change.

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January 14, 2022

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National Marine Fisheries Service
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650 Capital Mall, Suite 5-100
Sacramento, CA 95814

Dr. Brooke Jacobs
California Department of Fish and Wildlife
State Water Project Permitting Unit
1010 Riverside Parkway
West Sacramento, CA 95605

FINAL WINTER-RUN JUVENILE PRODUCTION ESTIMATE (JPE) FOR BROOD YEAR 2021

Dear Mr. Yip and Dr. Jacobs:

In 2013, the Interagency Ecological Program's Winter-Run Chinook Salmon Project Work Team (Winter-Run PWT) recommended that the National Marine Fisheries Service (NMFS) Juvenile Production Estimate (JPE) be revisited annually and updated as needed with any new or improved information. The annual JPE is used to calculate loss thresholds for Long-Term Operation of the Central Valley Project and the State Water Project, as described in the NMFS Biological Opinion, No. WRCO-2016-00069 (2019 NMFS BiOp) and required by CDFW Incidental Take Permit No. 2081-2019-066-00 (2020 ITP). A subgroup of the Winter-Run PWT met four times in December 2021 to review and update the factors used to calculate the brood year (BY) 2021 JPE, and to develop recommended draft winter-run JPE for BY 2021. The final JPE recommendation includes data through December 31, 2021 and was approved at the Winter-Run PWT meeting on January 14, 2022. The Winter-Run PWT's recommendations for the BY 2021 winter-run Chinook Salmon JPE are described below.

<u>JPE Recommendations</u>

The Winter-Run PWT identified several factors in calculating the JPE that we advise be continued or updated for BY 2021. We considered one method for forecasting natural-origin JPE—The "Method 2" approach used for the BY 2019 and BY 2020 JPEs and described in O'Farrell et al. (2018). The data inputs for the calculations include estimates of the following parameters for calculating JPE for natural-origin BY 2021 winter-run Chinook Salmon ($JPE_{Natural}$) (Figure 1):

1) Number of winter-run fry equivalents passing Red Bluff Diversion Dam (RBDD)(JPI_{Fry})
2) Survival rate of natural-origin fry to smolts ($Survival_{Fry\text{-}to\text{-}Smolt}$)
3) Survival rate of smolts from RBDD to Delta entry (defined as Sacramento at the I-80/I-50 Bridge) ($Survival_{Smolt}$)

Hatchery Release JPE Recommendations

Additionally, we used the number of winter-run hatchery smolts expected to be released from Livingston Stone National Fish Hatchery (LSNFH) in February 2022 ($N_{Hatchery}$) and their predicted survival rate ($Survival_{HatcherySmolt}$) to estimate a JPE of hatchery-origin winter-run juveniles in the Delta ($JPE_{Hatchery}$) (Figure 1). We present the data inputs used in the calculations in Table 1 and describe each in the sections below.

For the second year in a row, we also include estimates of hatchery-origin winter-run smolts released in Battle Creek as part of the "Jumpstart" reintroduction ($N_{BCJumpstart}$), their survival ($Survival_{BCJumpstart}$), and a forecast of the number entering the Delta ($JPE_{BCJumpstart}$). Although there was natural spawning in Battle Creek in 2021, we do not differentiate naturally produced juveniles from Battle Creek from Sacramento River juveniles, and both are included in the Juvenile Production Index (JPI_{Fry} or JPI).

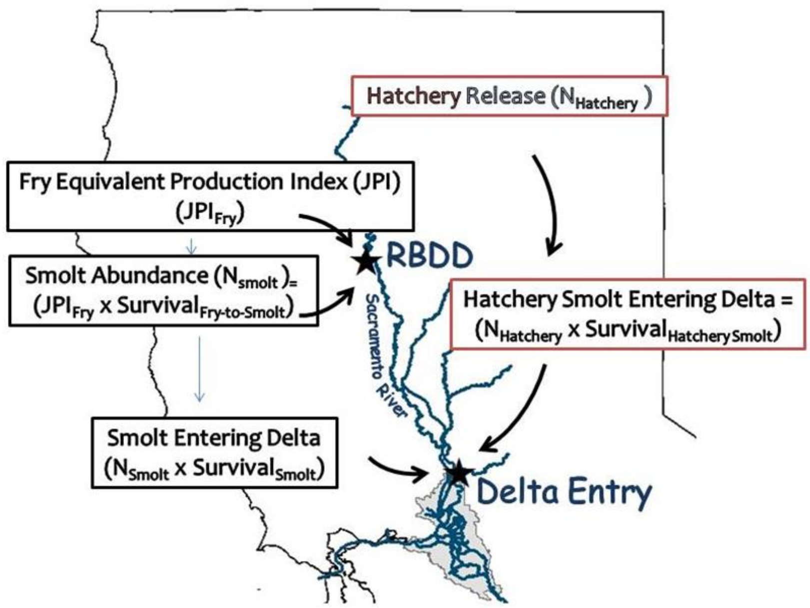


Figure 1. Location and formulas recommended for use in the JPE for the natural-origin (black boxes) and hatchery-origin (red boxes) components of the winter-run population estimated for BY 2021. Hatchery JPEs are estimated for hatchery releases from Livingston Stone National Fish Hatchery into the Sacramento River ($N_{Hatchery}$) and for the Battle Creek Jumpstart hatchery releases into Battle Creek (not shown).

Winter-Run JPE Methods for 2021-2022

The Winter-Run PWT focused on a single method for forecasting the JPE for BY 2021, as was done for BY 2020. This method was recommended in O'Farrell et al. (2018) and was the chosen method for BY 2019. It is the opinion of the Winter-Run PWT that this method represents the best available science for estimating an annual JPE given currently available data.

Juvenile Production Index - For the BY 2021 JPE, the Winter-Run PWT continues to recommend using the JPI, which is based on an estimate of fry equivalents at RBDD. The JPI has been used in the calculation since 2014 and better represents the response of fish to annual environmental conditions during spawning, egg incubation, and outmigration, as compared to the long-term average egg-to-fry survival rate used in the JPE prior to 2014. This is of particular importance this year, as the JPI approach at least partially accounts for lower than average egg-to-fry survival in naturally spawned winter-run Chinook Salmon expected for BY 2021 due to thiamine deficiency in spawners and temperature-related mortality during egg incubation.

There are two updates worth noting about the winter-run Chinook Salmon JPI estimate this year. The first update is to the trap efficiency model employed in 2021. In response to changes in river channel geometry and juvenile trap configurations, USFWS updated the least-squares regression model used to predict daily trap efficiency, which expands RST catch to estimate the JPI. The new model uses data from efficiency trials conducted between 2018 and 2021 using natural-origin fall- and winter-run Chinook Salmon (n=32 trials; B. Poytress, USFWS, pers. comm.) and incorporates 13 trials conducted under the new trap configuration (four 5-ft traps and one 8-ft trap). Due to low catches of naturally produced winter-run Chinook Salmon in 2021, a single efficiency trial was conducted in Fall 2021. That trial has not yet been incorporated into the 32-trial model, but it fell within the 90 percent prediction interval of the current model, which supports use of the currently active model for winter-run Chinook Salmon in 2021.

The second difference in the 2021 JPI estimate was the need to interpolate passage data for 2 unsampled days during an unprecedented storm and runoff event in October when juvenile traps at RBDD could not safely operate. Juvenile capture during that time was interpolated using the weekly mean, which is the standard procedure (as described in Voss and Poytress 2020). Because the data gap occurred during the season's largest increase in flow, which oftentimes triggers increased juvenile migration (Poytress et al. 2014), the JPI may underestimate juvenile passage during that period.

Fry-to-Smolt Survival - The Winter-Run PWT recommends the continued inclusion of a fry-to-smolt survival factor ($Survival_{Fry\text{-}to\text{-}Smolt}$). This is necessary because the available survival estimates between RBDD and the Delta are based on releases of acoustically telemetered smolts, which have a higher survival rate than fry. Without this factor, the survival rate from fry to smolts is assumed to be 1.00, which is unrealistic. The same factor is used to adjust juvenile passage at RBDD to fry equivalents, based on the peak of fry catch at RBDD (generally in October) and the smolt life-stage at RBDD for naturally produced winter-run Chinook Salmon.

The Winter-Run PWT recommends the fry-to-smolt survival rate forecasting method developed by O'Farrell et al. (2018), which uses recent winter-run Chinook Salmon survival data and is updated with new survival data annually. Incorporating updated survival rate estimates, this method results in a winter-run Chinook Salmon fry-to-smolt survival rate of 0.4429 for BY 2021. The team recommends using this forecasting method to estimate fry-to-smolt survival in calculations of JPE and updating the fry equivalent multiplier to 2.258 (the factor 2.258 is the inverse of 0.4429). It is the opinion of the Winter-Run PWT that these updated values, which are based on peer-reviewed methodologies and more recent winter-run Chinook Salmon data, improve the JPE forecast compared to values used prior to 2019.

Fry Production - The JPI seasonal estimate of fry equivalents using the 0.4429 fry-to-smolt survival rate was 773,439 as of December 31, 2021 (week 52; B. Poytress, USFWS, personal communication). The value through December 31 accounts for approximately 96.90 percent of annual winter-run passage at RBDD based on data collected from 2002 to 2020. Including an interpolation of the remaining 3.10 percent to account for the remainder of BY 2021, the total BY 2021 estimate is 798,183 fry equivalents (Table 1). This value accounts for in-season winter-run genetic corrections, which have a minimal effect on the estimate. With this estimate of fry production at RBDD, the estimated egg-to-fry survival is calculated to be 0.0256 (Table 1).

Table 1 – Reported population estimates and survival factors for brood year 2021

*(Factors used in the JPE calculations and the resulting JPEs are shown in bold and marked with a *.)*

Component	Natural	Hatchery
Total Sacramento River escapement[1]	9,956	
Adult female estimate (AFE)[2]	6,199	
AFE minus pre-spawn mortality[3] (5.5%) ($N_{Spawners}$)	5,860	
Average fecundity[4] (AF)	5,312	
Total eggs	31,128,320	
Estimated egg-to-fry survival rate based on JPI at RBDD/Total eggs[5]	0.0256	
Fry equivalents of juvenile production at RBDD (JPI or JPI_{Fry})[6]*	**798,183***	
Fry-to-smolt survival ($Survival_{Fry\text{-}to\text{-}Smolt}$)[7]*	**0.4429***	
Number of smolts at RBDD	353,515	
Estimated smolt survival term: RBDD to Delta ($Survival_{Smolt}$)[8]*	**0.3537***	
Total natural production entering the Delta (JPE)*	**125,038***	
JPE 95 percent confidence interval	59,064 – 191,013	
LSNFH Hatchery release ($N_{Hatchery}$)[9]*		**537,771***
Survival rate from release to Sacramento ($Survival_{HatcherySmolt}$) [10]*		**0.2818***
Total LSNFH production entering the Delta*		**151,544***
Battle Creek Hatchery release ($N_{BCJumpstart}$)[11]*		**139,000***
Survival rate from release to Sacramento ($Survival_{BCJumpstart}$) [12]*		**0.0526***
Total Jumpstart production entering the Delta*		**7,311***

1/ Total Sacramento River in-river escapement from CDFW Cormack-Jolly Seber (CJS) model includes natural- and hatchery-origin winter-run Chinook Salmon, but not hatchery fish retained for brood stock at LSNFH.

2/ The number of adult females is derived from carcass surveys on the Sacramento River. Naturally spawning winter-run Chinook Salmon in Battle Creek are not included.

3/ Pre-spawn mortality was estimated from carcass surveys of females (Doug Killam, CDFW, pers. comm.).

4/ Preliminary (subject to change) average number of eggs per female from 118 female fish spawned at LSNFH (Kaitlin Gooding, USFWS pers. comm.).

5/ Back calculated survival between estimated eggs laid in-river and fry production estimates at RBDD based on numbers of fry equivalents (JPI) using the 0.4429 fry-to-smolt survival rate estimate based on method described in O'Farrell et al. (2018).

6/ Preliminary number of fry equivalents estimated on December 31, 2021 plus 3.1% interpolation to account for remainder of estimated passage for the 2021 brood year at RBDD; using 0.4429 fry-to-smolt survival rate estimate (Bill Poytress, USFWS, pers. comm.). This estimate includes and does not differentiate between the number of fry equivalents outmigrating from Battle Creek and the Sacramento River.

7/ Estimate of fry-to-smolt survival rate based on O'Farrell et al. (2018), updated using data from BY 1998-2016.

8/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2013 to 2021 between RBDD and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018). Survival is estimated from the Salt Creek receiver site, located 3 miles downstream of RBDD, to estimate survival from RBDD for natural-origin smolts.

9/ Estimated LSNFH production release as of December 15, 2021 (100% tagged and adipose clipped).

10/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2013 to 2021 between release location and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018).

11/ Estimated Battle Creek Jumpstart release as of January 14, 2022 (100% tagged and marked).

12/ Variance-weighted mean survival rate of acoustically tagged hatchery winter-run Chinook Salmon from 2019 to 2021 between release location in North Fork Battle Creek and I-80/Tower Bridge in Sacramento (based on O'Farrell et al. 2018). The survival rate of 64 fish on released on May 18, 2020 was not included in this calculation because fish size and environmental conditions did not represent expected conditions during the BY 2021 winter release. The change in survival to 0.0526 from 0.0519 in the draft letter issued December 31, 2021 reflects a correction to the weights assigned to each survival rate; although the estimate in the draft letter excluded the May 2020 release survival rate, the variance-based weights had not yet been adjusted to exclude that release.

Natural-origin Smolt Survival - To estimate survival of natural origin winter-run Chinook Salmon smolts from RBDD (i.e., Salt Creek) to the Delta (i.e., Sacramento at the I-80/I-50 Bridge)($Survival_{Smolt}$), the Winter-Run PWT recommends using the variance-weighted mean of survival estimates from acoustically tagged LSNFH smolts released in 2013–2021, as described in O'Farrell et al. (2018). This calculation is updated each year to incorporate survival and variance estimates from the previous year and uses the Cormack-Jolly-Seber model, which accounts for variation in detection probabilities. The estimated annual survival rate using this method is 0.3537. Note that the release-specific survivals for all years were recalculated for this year's estimate based on an updated filtering algorithm (Danner and Ammann, 2021).

Hatchery Smolt Survival – To estimate survival of hatchery-produced winter-run Chinook Salmon released in the Sacramento River near Redding ($Survival_{HatcherySmolt}$), we recommend using the variance-weighted mean of 2013–2021 survival rates from the LSNFH release point to the Delta. This survival rate is 0.2818. For hatchery-produced winter-run released in North Fork Battle Creek ($Survival_{BCJumpstart}$), we recommend using the variance-weighted mean of 2019–2021 survival rates from the Battle Creek release point to the Delta (excluding the May 2020 release because fish size and environmental conditions did not represent expected conditions during the BY 2021 winter release). This survival rate is 0.0526. Because both release points of hatchery fish are upstream of RBDD, the overall survival to the Delta is lower compared to the survival applied to natural-origin smolts. As for natural-origin smolt survival, these estimates of hatchery smolt survival use the Cormack-Jolly-Seber model to account for variation in detection probabilities and are updated annually to incorporate survival and variance estimates from the previous year.

Discussion on low estimated egg-to-fry survival for BY 2021

The approach described above allows us to back-calculate egg-to fry survival based on estimates of the number of successful female spawners ($N_{Spawners}$), average female fecundity (AF), and JPI, as described under "Fry Production" and in Equation 1. This calculation can be a useful metric to compare to average or expected survival in order to identify mortality occurring during egg incubation and fry emergence. Using this equation, estimated BY 2021 egg-to-fry survival for winter-run Chinook Salmon is 0.0256. The two primary factors contributing to low egg-to-fry survival in BY 2021 are thought to be temperature dependent mortality and thiamine deficiency complex.

Equation 1:

$$Survival_{Egg-to-Fry} = \frac{JPI_{Fry}}{N_{Spawners} \times AF}$$

Winter-run Chinook Salmon in 2021 spawned during one of the warmest and driest years on record, and Sacramento River water temperatures during the majority of the incubation period exceeded limits for successful egg incubation. Using the Martin et al. (2017) model, NMFS estimated mean annual temperature dependent mortality of winter-run Chinook Salmon eggs at 75 percent (25–75% confidence interval of 64–81%), based on measured water temperatures and mapped winter-run Chinook Salmon spawning locations in the Sacramento River in 2021 (SWFSC, 2021).

Additional early life stage mortality was likely due to thiamine deficiency complex syndrome, thought to be the result of shifts in marine forage fish species off the coast of California. Thiamine concentrations in egg samples from 30 females spawned at LSNFH in 2021 showed 83 percent of females with thiamine low enough where some fry mortality would be expected (T. Lipscomb, USFWS, pers. comm.). Any thiamine deficiency impacts manifested in egg viability or early fry stages will lead to a reduced JPI compared to what would have been observed absent thiamine deficiency impacts. USFWS had only one observation of abnormal fry behavior at the RBDD rotary screw traps (B. Poytress, USFWS, pers. comm.), suggesting that mortality caused by thiamine deficiency occurred primarily upstream of RBDD, though there may be latent impacts to young-of-year winter-run Chinook Salmon downstream of RBDD that cannot be estimated based on information available this year. The assumption that most mortality would occur prior to outmigration is consistent with observations at Central Valley hatcheries, where mortality and behavioral abnormalities associated with thiamine deficiency in hatchery-origin juveniles were documented soon after hatch. Survival studies of untreated fish would be necessary to understand lower survival due to latent effects of thiamine deficiency.

Uncertainty exists within all three of the variables used to calculate an estimate of egg-to-fry survival. Female spawners and fecundity estimates are not used in the JPE calculation, and their uncertainty is not quantified during JPE development. Uncertainty in the JPI is quantified, and it is a factor considered in the JPE calculation and in the back-calculation of egg-to-fry survival. For 2021, the nonoperation of the juvenile traps at RBDD for two days during a substantial storm event in October, and potential underestimate of passage during that event for the JPI, may contribute to the relatively low estimate of egg-to-fry survival. Standard methods used to interpolate juvenile fish passage data for unsampled days (see Voss and Poytress 2020) during the October flow event likely resulted in a slight negative bias to the juvenile passage estimates for those days. However, the impact of those two interpolated days on the total JPI calculated for the entire BY 2021 outmigration season is likely captured within the uncertainty (confidence intervals) of the 2021 JPI. The current range of uncertainty around the preliminary point estimate JPI would result in an egg-to-fry survival estimate of between 0.0166 and 0.0353.

It is unknown how much each of these factors may be contributing to the low estimated egg-to-fry survival for BY 2021, but there are ongoing efforts to better understand the contribution of each and any interactions between them. It is important to note that because the method used to calculate the JPE uses the JPI approach, any uncertainty about the mortality does not affect the JPE. Uncertainty in the JPE as a result of uncertainty in the JPI is captured in the 95 percent confidence intervals shown in Table 1.

Winter-Run PWT Recommended Method for BY 2021

The Winter-Run PWT recommends the previously described inputs and the following equations be used for estimating the BY 2021 natural-origin (Equation 2) and hatchery-origin (Equations 3 and 4) JPE:

Equation 2:

$$JPE_{Natural} = JPI_{Fry} \times Survival_{Fry-to-Smolt} \times Survival_{Smolt}$$

$$= 798{,}183 \times 0.4429 \times 0.3537 = 125{,}038$$

Equation 3:

$$JPE_{Hatchery} = N_{Hatchery} \times Survival_{HatcherySmolt}$$
$$= 537{,}771 \times 0.2818 = 151{,}544$$

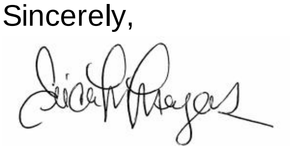
Equation 4:

$$JPE_{BCJumpstart} = N_{BCJumpstart} \times Survival_{BCJumpstartSmolt}$$
$$= 139{,}000 \times 0.0526 = 7{,}311$$

It is the opinion of the Winter-Run PWT that this method represents the best available science for estimating a JPE given currently available data. It accounts for detection probabilities and quantifies uncertainty associated with estimates of JPI_{Fry} and smolt survival rates, which are used to develop the 95 percent confidence intervals for the JPE forecast. Because it does not capture process error, or the variation in true survival rates from year to year, these confidence intervals likely underestimate the uncertainty in the JPE forecast. We acknowledge that this method still has considerable uncertainty, and that confidence intervals may have limited utility to water managers under the current management setting. However, there is uncertainty with any forecast method for a JPE, and we believe there is value in quantifying and reporting that uncertainty.

It is the opinion of the Winter-Run PWT that this recommendation is the best information currently available from which to derive a JPE and the best method for arriving at estimates. We conclude that this analysis and these technical recommendations from the Winter-Run PWT will establish the most accurate forecast of JPE for use in the 2022 water year at the Central Valley Project and State Water Project export facilities.

Sincerely,



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