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

JAN 29 2018

Mr. Jeff Rieker
Operations Manager, Central Valley Project
U.S. Bureau of Reclamation
3310 El Camino Avenue, Suite 300
Sacramento, California 95821

Re: Winter-Run Chinook Salmon Juvenile Production Estimate for Brood Year 2017

Dear Mr. Rieker:

This letter provides the U.S. Bureau of Reclamation (Reclamation) with the estimated number of juvenile Sacramento River winter-run Chinook salmon (winter-run, *Oncorhynchus tshawytscha*) expected to enter the Sacramento-San Joaquin Delta (Delta) during water year (WY) 2018. This juvenile production estimate, or JPE, is calculated by NOAA's National Marine Fisheries Service (NMFS) pursuant to the June 4, 2009, biological opinion on the long-term operations of the Central Valley Project (CVP) and the State Water Project (SWP, CVP/SWP operations Opinion). The JPE is calculated annually and is used to determine the authorized level of incidental take for winter-run, under Section 7 of the Endangered Species Act (ESA), while operating the CVP/SWP Delta pumping facilities in a given water year (NMFS 2009).

The winter-run JPE for brood year (BY) 2017 is **201,409 natural-origin juvenile winter-run entering the Delta during WY 2018**. This JPE calculation is described in detail below, and is developed as a function of the number of adult spawners (and estimated number of viable eggs) combined with estimated egg-to-fry and fry-to-smolt survivorship rates for the coming year. Despite a decrease in the adult escapement relative to last year, estimated winter-run egg-to-fry survivorship to Red Bluff Diversion Dam (RBDD) increased from 24% in 2016 to 44% in 2017, leading to an increase in JPE for BY 2017 as compared to the 2016 BY JPE (166,189).[1]

The authorized incidental take for naturally-produced winter-run has been established in the CVP/SWP operations Opinion as 2 percent of the JPE to allow for errors in fish identification due to use of length-at-date (LAD) criteria to determine Chinook salmon race (i.e., differentiating from fall-run, late-fall run, and spring-run Chinook salmon). In WY 2018, as in WY 2017, genetic race identification will be used. The use of genetic data to determine race of juvenile Chinook salmon observed at the CVP/SWP Delta pumping facilities eliminates the uncertainty that was included in previous (2015 and earlier) annual incidental take limits for winter-run. Therefore, the authorized level of incidental take (i.e., reported as loss at the Delta fish facilities) under the ESA for the combined CVP/SWP Delta pumping facilities from October 1, 2017, through June 30, 2018, is set at 1 percent of the JPE, or **2,014 natural-origin (non-clipped)** winter-run.

[1] http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/winter-run_juvenile_production_estimate__jpe__-_february_3__2017.pdf

The incidental take for hatchery-origin winter-run is set at 1 percent of each release (i.e., Sacramento River and Battle Creek release groups). Therefore, the incidental take limit for juveniles released from Livingston Stone National Fish Hatchery (LSNFH) into the Sacramento River is **932 hatchery-produced (adipose fin clipped)** winter-run for WY 2018, which represents a higher level of incidental take than was authorized last year. This increase in the incidental take level of hatchery winter-run is reflective of the LSNFH production level (*i.e.*, approximately 217,270 winter-run juveniles to be released in 2018 from BY 2017 compared to the release of 141,922 winter-run in 2017 from BY 2016). The incidental take limit of juveniles released from LSNFH into Battle Creek is **909 hatchery produced (adipose fin clipped and left ventral fin clipped)** winter-run.

Status of Winter-run Chinook salmon, BY 2014-2017

One of the most significant impacts to winter-run in recent time is California's extended drought. In 2014, 2015, and 2016, we collectively planned (with our Federal and State agency and our water and irrigation district partners) release schedules for Shasta Reservoir that sought to meet the needs of all users, including fish and wildlife, given the limits the drought placed on available supplies. These plans were critically important for winter-run in particular, given their imperiled status and downward population trajectory. In fact, NMFS selected winter-run as one of eight species highlighted in our "Species in the Spotlight" initiative[2]; an effort designed to focus attention and resources to manage our eight most critically endangered species.

Despite significant partnership and commitment from all partners involved, execution of drought contingency plans were more successful in some drought years than in others. Temperature-dependent mortality estimates ranged from 77% of the winter-run population in BY 2014, to 85% temperature dependent mortality in BY 2015, to 2% temperature dependent mortality in BY 2016. Temperature-dependent mortality estimates in 2016 were a noteworthy success given our circumstances, and resulted from substantial partnership from all parties to ensure successful execution of the 2016 temperature management plan.

As described above, juvenile winter-run experienced very low survival in 2014 and 2015 during the recent California drought due to unfavorable temperature conditions on 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 reinitiating the Winter Chinook Captive Broodstock Program at LSNFH. The primary purpose of the Captive Broodstock Program is to maintain a refugial population of winter-run 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 500 juvenile winter-run propagated at LSNFH have been retained annually for the Captive Broodstock Program since it was reinstated in 2015 (with the exception of BY 2014, when approximately 1,035 juveniles were retained).

The 2017 BY is largely comprised of winter-run that spawned in 2014, and whose fry were subjected to temperature conditions during their outmigration that resulted in an estimated 85% mortality. Not surprisingly, the escapement estimate for BY 2017 was low (total 1,155 fish) and comprised of a high proportion of hatchery returns (>70%)[3]. However, WY 2017 turned into one of the wettest years on

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[2] http://www.nmfs.noaa.gov/stories/2015/09/spotlight_chinook_salmon.html

[3] In 2014, as a result of drought conditions and anticipated adverse spawning and incubation habitat conditions in the upper Sacramento River resulting from high water temperatures, LSNFH took in additional broodstock, and in early 2015, released over 600,000 hatchery juvenile winter-run into the Sacramento River, compared to an estimated 665,572 natural juvenile winter-run emigrating past RBDD.

record, and included flood management releases of up to 79,000 cfs from Keswick Dam, and a full Shasta Reservoir in the spring. In addition, Reclamation and NMFS coordinated the development of an amendment to the reasonable and prudent alternative (RPA) Action Suite I.2.1 which focused on the operation of Shasta Reservoir. On January 19, 2017, NMFS issued a draft proposed Shasta RPA amendment[4], and during the temperature management season in 2017, Reclamation agreed to meet the temperature compliance point of 56.0° Fahrenheit (F) daily average temperature (DAT) at Balls Ferry. In addition, since overall conditions were better than forecasted, Reclamation successfully implemented a pilot operational study to target a 53.0°F DAT at the Clear Creek California Data Exchange Center gage station (approximately 13 miles downstream of Keswick Dam) as a surrogate for a temperature metric of 55.0°F 7-day average of the daily maximum temperatures to the downstream most winter-run redd, respectively. As a result of this favorable WY 2017 hydrology and a relatively large cold water pool in Shasta Reservoir, we are happy to report that the estimated egg-to-fry survival to RBDD for juveniles from BY 2017 is 44%.

JPE Development Process

The process for developing the JPE was the similar to what was done in 2016. A technical team from the Interagency Ecological Program (IEP), the Winter-run Project Work Team (WRPWT), met throughout the year and provided recommendations in a letter to NMFS (Enclosure 2). The method used to calculate the 2017 JPE is derived from the number of juveniles passing RBDD, as estimated by USFWS. This estimate is known as the Juvenile Production Index, or JPI, and it is based on fry-equivalents at RBDD. This is the same method that was used in 2016, however for BY 2017, the USFWS provided alternative JPI estimates to account for errors associated with using LAD criteria to determine Chinook salmon race/run (see Enclosure 2).

In 2017, several juvenile spring-run-sized Chinook salmon were sampled at RBDD, although very few spring-run Chinook salmon adults were detected in spawning surveys upstream of RBDD. These spring-run were identified using the river LAD criteria, but the timing and numbers suggested these fish sampled at RBDD were likely late-emerging winter-run. Tissue samples were genetically analyzed, which determined that many of the LAD spring-run were genetic winter-run. Alternative JPIs have been calculated incorporating the additional winter-run. These genetically-identified run results from the RBDD rotary screw traps have been independently supported by water temperature data, carcass surveys, and redd observations from 2017 field surveys. The JPE calculation methods that use this corrected number are denoted with an "a" both in the text of this letter and within Enclosure 2.

JPE Model Investigation: Examination of 2017 Data

The CVP/SWP operations Opinion defines the JPE as juvenile survival to the beginning of the Delta (*i.e.*, Tower Bridge in Sacramento), but not through the Delta. The calculation of the winter-run JPE for BY 2017 begins with estimates of winter-run adult escapement for 2017, which are derived from carcass surveys conducted in the upper Sacramento River by CDFW. This escapement information was provided to NMFS via a January 8, 2018, letter (Enclosure 1). The CDFW estimate for total winter-run escapement in 2017 was **1,155 spawners** (90% confidence interval: 109 to 1,888)[5]. Of this total number of spawners, 180 were collected at the Keswick Dam fish trap for LSNFH to be used as broodstock, leaving an estimated 975 to spawn naturally in-river.

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4 http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/nmfs_s_draft_proposed_2017_rpa_amendment_-_january_19__2017.pdf

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

The number of adult spawners in 2017 (1,155) decreased approximately 25% from 2016 (1,546), and was considerably lower than the 10-year average (*i.e.,* 2,802) for 2008–2017 (Figure 1). The cohort replacement rate (CRR), which is a measure of the population's growth rate, was negative (0.38 < 1.0) in 2017, for the 7th time over the same 10-year period (Figure 2), indicating an overall population decline. However, despite the fewer adults and fewer females returning in 2017, the estimated number of juvenile winter-run emigrating past RBDD is higher than in previous years (2014-2016), likely due to increased survival during the egg-to-fry life stage and better estimates of the JPI which incorporate the additional number of winter-run due to misclassification of spring-run using the river LAD criteria (as described above).

Figure 1. Winter-run Spawning Escapement 2008-2017 (CDFW 2017 and Enclosure 1).

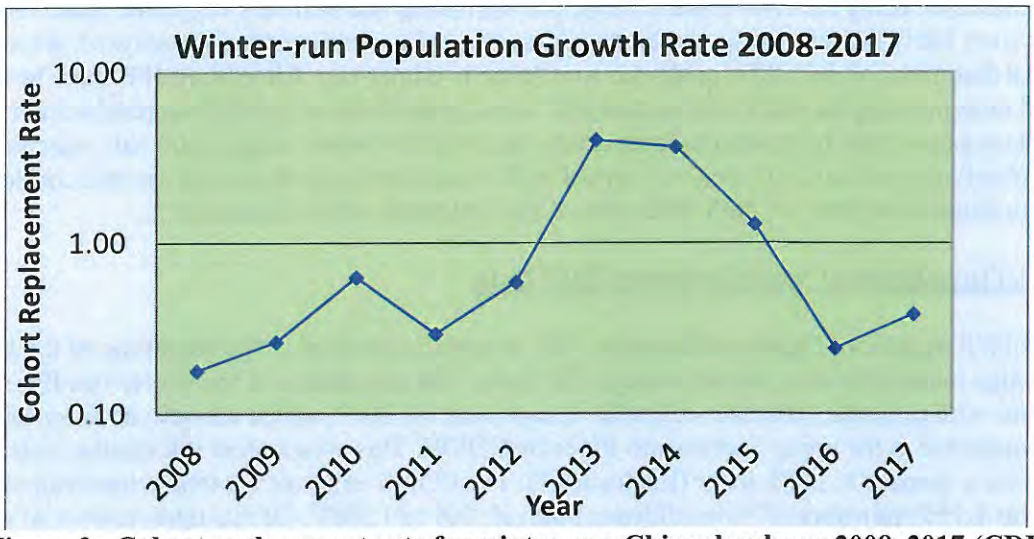

Figure 2. Cohort replacement rate for winter-run Chinook salmon 2008–2017 (CDFW 2017).

The JPE for BY 2017 incorporates the recommendations of the Independent Review Panel (IRP, Delta Science Program 2014) and advice from the WRPWT (Enclosure 2). The WRPWT identified four factors in calculating the JPE, similar to last year, that they would advise continuing or updating for BY 2017:

1. Estimated number of fry passing the RBDD
2. Survival rate of natural-origin fry to smolts
3. Survival rate of natural-origin smolts from RBDD to Delta entry
4. Estimated survival rate of hatchery-origin winter-run to be released from LSNFH in January or February of 2018

A fry-to-smolt survival rate of 0.59, based on fall-run Chinook salmon, has been used as a surrogate for winter-run fry-to-smolt survival since 1993. This value is based on previous studies by Hallock (undated), and confirmed through a literature review in 1995 (B. Poytress, USFWS, personal communication). Without this factor, survival from fry to smolts is assumed to be 100 percent, which is unrealistic. The WRPWT has expressed reservations about the accuracy of the 0.59 term, and thus have interest in considering alternative approaches.

As part of the "Species in the Spotlight" initiative, the NMFS Southwest Fisheries Science Center (SWFSC) was awarded funding in 2016 to develop alternative approaches for forecasting the natural-origin winter-run JPE. The alternative forecasting methods follow the same basic JPE model adopted for use in recent years (Method 1). Appendix A in Enclosure 2 describes two alternative methods (Methods 2 and 3) for forecasting the natural-origin JPE, both of which include a new approach for forecasting the fry-to-smolt survival rate. The fry-to-smolt survival rate forecast described in Appendix A of Enclosure 2 is based on fitting a zero-intercept linear model to estimates of hatchery-origin and natural-origin juvenile survival rates from the same brood years. This new methodology results in a lower fry-to-smolt survival rate for both Method 2 and Method 3, as shown in Table 1 and Appendix A in Enclosure 2.

Based on these latest recommendations, NMFS examined three methods for calculating the JPE for BY 2017, as follows:

1. Method 1 (JPI) uses the estimated juvenile passage at RBDD based on rotary screw trap monitoring. The JPI is a better estimate of fry survival to RBDD than the long-term average egg-to-fry survival rate used prior to 2014 in the JPE.
2. Method 2 uses the same general form as Method 1, but replaces the fry-to-smolt survival rate of 0.59 with 0.4725. It also accounts for observation error in the JPI, the fry-to-smolt survival rate, and the smolt survival rate (Appendix A in Enclosure 2).
3. Method 3 has the same general form as Methods 1 and 2. However, Method 3 assumes that the JPI error distribution is Lognormal. The approach used to forecast the fry-to-smolt survival rate is the same as described for Method 2. The forecast of smolt survival to the Delta is based on application of a hierarchical Bayesian model fitted to acoustic tag data (Appendix A in Enclosure 2).

As mentioned earlier, Methods 1a, 2a and 3a incorporate the additional estimated number of genetic winter-run due to misclassification of spring-run using the river LAD criteria. Each of the methods used to calculate the JPE begins with the same adult escapement estimate from CDFW, which uses data from carcass surveys to estimate the number of adult female spawners.

Estimates of egg-to-fry survival rate (S1) are based on the JPI estimate at RBDD. The JPI method is considered a more accurate estimate of S1 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). Differences in S1 among the various methods considered here are due to the alternative JPI calculations used for Methods 2 and 3 (Appendix A in Enclosure 2).

Table 1. Summary of JPE Model Runs for BY 2017.

JPE Method	Adult Escapement[6]	Estimate of Viable Eggs	Estimated Egg to Fry Survival Rate (S1)[7]	Juveniles passing RBDD (JPI)[8]	Survival to Delta (S2)[9]	Juveniles to Delta (JPE)
Method 1	795	1,507,924	0.36	545,132	0.5129	164,963
Method 1a	795	1,507,924	0.44	665,572	0.5129	201,409
Method 2	795	1,507,924	0.40	606,039	0.5158	147,695
Method 2a	795	1,507,924	0.48	726,479	0.5158	177,047
Method 3	795	1,507,924	0.40	605,784	0.4731	135,226
Method 3a	795	1,507,924	0.48	726,537	0.4766	163,469

The survival of juvenile winter-run to the Delta (S2) 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. This year, based on recommendations from the WRPWT, smolt survival (S2) to the Delta was calculated based on a weighted average of acoustically-tagged hatchery winter-run releases in 2013, 2014, 2015, 2016, and 2017 (Enclosure 2) from RBDD to the Tower Bridge (at Sacramento). NMFS considers the Tower Bridge as the point of Delta entry.

Method Selection and JPE Calculation

After reviewing the recommendations from the WRPWT technical team (Enclosure 2), NMFS chose Method 1a (JPI method) to calculate the BY 2017 natural-origin winter-run JPE. There is significant interest in continuing to explore the use of alternative methods in the future (Methods 2 and 3), however complete documentation of these forecast methods is currently in preparation and has not been subject to peer review. These alternative methods will continue to be considered in subsequent years following adequate review and vetting. There was unanimous agreement within the WRPWT on the inclusion of the additional winter-run genetically identified from those initially identified as spring-run using the river LAD. Using the JPI, and based upon the WRPWT recommendation to use Method 1a, NMFS estimates a JPE of **201,409 natural-origin juvenile winter-run entering the Delta during WY 2018** (Table 1, Enclosure 2). Winter-run juveniles are expected to emigrate into the Delta from November 2017 through April 2018, based upon CDFW historical monitoring data at Knights Landing rotary screw traps.

In early February 2018, approximately 217,207 winter-run juveniles propagated at LSNFH will be released into the upper Sacramento River near Redding (Caldwell Park). This year, an estimated 600 juvenile winter-run from LSNFH will be acoustically-tagged (JSAT) to monitor their survival and movement downstream. Of these, 200 may be released up to 30 days prior to the production release. The

[6] Total in-river escapement from CDFW CJS model includes natural-origin and hatchery-origin spawners, but not hatchery fish retained for broodstock at LSNFH.

[7] Based on the JPI estimate at RBDD/Total Viable Eggs.

[8] Juvenile Production Index = the estimated number of fry equivalents based on passage at RBDD as of December 16, 2017, plus 4.1 percent interpolation at RBDD (Enclosure 2).

[9] Average weighted survival of acoustically tagged winter-run in 2013, 2014, 2015 (2 values in 2015) and 2016 (2 values in 2016) and one value in 2017 between RBDD and I-80 Tower Bridge in Sacramento (A. Ammann, NMFS, personal communication). Survival is estimated from the Salt Creek receiver site, located 3 miles downstream of RBDD, to estimate survival from RBDD for acoustic tag studies (See Appendix A in Enclosure 2, for further description of how the weighted average acoustic tag survival was used for Methods 2, 2a, 3 and 3a).

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. The hatchery production at LSNFH was not increased this year as it had been in 2014 and 2015 (due to drought conditions). This was due to more favorable Shasta storage conditions, allowing operators to meet temperature needs throughout the 2017 temperature management season.

All hatchery-produced winter-run 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 have not been released yet, their survival rate is unknown.

Based on the WRPWT advice (Enclosure 2), NMFS used a weighted average survival rate (*i.e.,* 0.4276) of the hatchery acoustic tag releases in 2013, 2014, 2015, 2016, and 2017 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 **92,904 juvenile winter-run released into the Sacramento River from LSNFH will survive to enter the Delta during WY 2018** (Enclosure 2).

In 2017, the first group of winter-run captive broodstock withheld and maintained at LSNFH reached maturity and became ready to spawn. It was determined that the estimated in-river escapement for winter-run during 2017 was adequate and did not require additional supplementation from the Captive Broodstock Program. Given the precarious status of winter-run 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 first juvenile winter-run to experience the recently restored conditions in Battle Creek, providing a unique opportunity to learn vital information about release strategies, marking and tagging regimes, habitat utilization, survival, *etc.*

Preliminary estimates of the number of juveniles can be calculated by taking the product of average fecundity of captive broodstock and the median rate of in-hatchery survival for winter-run observed at the LSNFH (Table 2). Based on this calculation, USFWS estimates that approximately 212,638 winter-run smolts will be released from the spawning of captive broodstock during the 2017 spawning season.

Although data are lacking on survival rates from juvenile Chinook salmon released in Battle Creek (2018 will be the first release of juvenile winter-run into Battle Creek), the size at release and the distance traveled to the Delta is comparable to the releases occurring in the Sacramento River. Therefore, for 2018, the weighted average survival rate described above (*i.e.*, 0.4276) has been used to estimate how many hatchery winter-run released into Battle Creek would enter the Delta. A subset of the winter-run released in Battle Creek during 2018 will receive acoustic tags, allowing for the estimation of survival rates specific to releases occurring in Battle Creek. As releases of acoustically-tagged winter-run continue in Battle Creek 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 released in Battle Creek that survive to the Delta. NMFS estimates that approximately **90,924 juvenile winter-run released into Battle Creek will survive to enter the Delta during WY 2018**.

Table 2. Preliminary Estimates of Smolt Production Resulting from the Spawning of BY 2017 Winter Chinook Captive Broodstock at LSNFH.

Females Spawned	244
Average Fecundity (eggs/female)[A]	1,263
Estimated Green Number of Eggs	308,172
Estimated Survival (Green Egg to Release)[B]	0.71
Estimated Smolt Production	212,638

[A] Average fecundity based on the egg inventory of the first 69 captive broodstock females inventoried through September 22, 2017.
[B] Estimated survival from green egg to release, based on median survival of winter Chinook at the LSNFH, BYs 1998-2014 (USFWS 2016).

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, as both are necessary components of the population for survival and recovery of the species. The authorized incidental take for naturally-produced winter-run has been established in the CVP/SWP operations Opinion as 2 percent of the JPE to allow for errors in fish identification due to use of the LAD criteria to determine Chinook salmon race (*i.e.*, differentiating from fall-run, late-fall run, and spring-run Chinook salmon). In WY 2018, as in WY 2017, genetic race identification will be used. The use of genetic data to determine race of juvenile Chinook salmon observed at the CVP/SWP Delta pumping facilities eliminates the uncertainty that was included in previous annual incidental take limits for winter-run. Therefore, the authorized level of incidental take (*i.e.*, reported as loss at the Delta fish facilities) under the ESA for the combined CVP/SWP Delta pumping facilities from October 1, 2017, through June 30, 2018, is set at 1 percent of the JPE, or **2,014 natural-origin (non-clipped)** winter-run. In addition, the incidental take for hatchery-origin winter-run is set at 1 percent of each release (*i.e.*, Sacramento River and Battle Creek release groups). Therefore the incidental take for juveniles released from LSNFH into the Sacramento River is **932 hatchery-produced (adipose fin clipped)** winter-run, and the incidental take of juveniles released into Battle Creek is **909 hatchery produced (adipose fin clipped and left ventral fin clipped)** winter-run. If the incidental take for natural production (non-clipped) exceeds 0.5 percent of the JPE entering the Delta (*i.e.*, 1,007), or 0.5 percent of the hatchery (adipose fin clipped) production released in the Sacramento River (*i.e.*, 466), or 0.5 percent of the hatchery (adipose fin clipped and left ventral fin clipped) production released in Battle Creek (*i.e.*, 455), Reclamation and DWR must immediately convene the Water Operations Management Team (WOMT) to consider actions to minimize incidental take, pursuant to the CVP/SWP operations Opinion.

As was the case for BY 2016, the JPE is low enough that the older juvenile Chinook salmon loss density based triggers used for Old and Middle River flow management Reasonable and Prudent Alternative Action IV.2.3 would be below the minimums established in the CVP/SWP operations Opinion. NMFS allows for flexibility in water operations by using the minimum (*i.e.,* loss density of 2.5 older juvenile Chinook salmon per thousand acre-feet of water exported) for the first stage trigger rather than a lower trigger based on the BY 2017 JPE (*i.e.*, 1.0 older juvenile Chinook salmon per thousand acre-feet of water exported). This minimum loss density will allow for more water to be exported before a loss density trigger is exceeded in WY 2018.

The initial identification of naturally-produced (non-clipped) winter-run at the CVP/SWP Delta fish facilities shall be based on the length-at-date criteria for the Delta. As additional information becomes available through genetic analysis of tissue samples and other fisheries monitoring programs (*e.g.*, continued acoustical tag studies) in the Central Valley, estimates of the incidental take at the Delta fish facilities may be adjusted, if deemed scientifically sound by NMFS. NMFS will continue to monitor daily fish salvage and loss, and loss densities of winter-run and other ESA-listed species at the Delta fish salvage facilities, through participation in the Delta Operations for Salmonids and Sturgeon technical team, WOMT, and Fish Agency Coordination.

NMFS acknowledges that additional research using acoustically-tagged winter-run (both hatchery and wild) is necessary to provide a more robust estimate of in-reach survival of winter-run in the Sacramento River and would also provide direct calculation of survival, thereby greatly improving the accuracy of the JPE. We recommend that funding be continued for acoustic tag studies on winter-run for BYs 2018 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 2018 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,

Maria Rea

Maria Rea
Assistant Regional Administrator

Enclosures:

1. CDFW updated brood year 2017 winter-run Chinook salmon escapement letter to NMFS, dated January 8, 2018
2. Winter-Run Project Work Team letter to NMFS, dated January 12, 2018

cc: California Central Valley Office
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SACRAMENTO, CA

January 8, 2018

Mr. Barry Thom
Regional Administrator
West Coast Region
NOAA Fisheries
7600 Sand Point Way Northeast
Seattle, WA 98115

Dear Mr. Thom:

Winter-run Chinook Salmon Escapement Estimates for 2017

The California Department of Fish and Wildlife (Department) has developed Sacramento River winter-run Chinook salmon escapement estimates for 2017. These estimates were developed from data collected in the Upper Sacramento River Winter-run Chinook Salmon Escapement Survey (carcass survey) by Department and U.S. Fish and Wildlife Service (USFWS) personnel.

Escapement estimates based on the application of the Cormack-Jolly-Seber (CJS) mark-recapture population model to the carcass survey data for 2017 are shown below:

Estimated Total In-river Escapement (hatchery and natural origin)	**975**
Estimated In-river Escapement (hatchery origin)	**824**
Estimated Number of In-river Adult Females (hatchery and natural origin)	**373**

These estimates include naturally spawning winter-run Chinook salmon (winter-run) in the upper Sacramento River. In addition, **180** winter-run were collected at the Keswick trap site upstream from RBDD for spawning at Livingston Stone National Fish Hatchery (LSNFH). These fish are not included in the above estimate of naturally spawning winter-run. The total winter-run spawning escapement estimate in 2017, including in-river spawners and fish collected for hatchery broodstock, is **1,155** fish. The 90% confidence interval on this total estimate is from **109 to 1,888** fish.

This year, the escapement estimate was again calculated from the carcass survey data using a CJS model. The CJS model has been used from 2012 to present. From 2003-2011, the escapement estimate had been based on application of the Jolly-Seber model. In 2012, based on the recommendations of the *Central Valley Chinook Salmon In-River Escapement Monitoring Plan* (DFG 2012), the winter-run carcass survey used field and analysis methods consistent with application of the CJS model. In simulation studies performed in the development of the Monitoring Plan, the CJS model was shown to more accurately estimate escapement based on mark-recapture data than any other available model. Due to its similarity to the Jolly-Seber model previously used to estimate winter-run escapement, we consider the data from 2012- 2017 to be directly comparable for trend analysis with escapement estimates from 2003 through 2011. The CJS model allows the calculation of confidence intervals; we began reporting confidence intervals on our total estimate for the first time in 2012 and continue doing so this year. The total escapement number above is the winter-run total estimate modelled to date and is a final number subject to revision. This estimate is subject to revision if additional data becomes available after the date of this letter. The additional data would then be used in the CJS model to recalculate the final escapement number. The most up to date modelled estimate calculation can be found in the GrandTab spreadsheet which is updated periodically after this letter is sent in the event that new information is received (https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381&inline=1).

We look forward to further discussion and collaboration with NOAA Fisheries 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, Doug.Killam@wildlife.ca.gov or Mr. Daniel Kratville, Daniel.Kratville@wildlife.ca.gov and at the address and phone number above.

Sincerely,

Kevin Shaffer, Branch Chief

cc: Ms. Maria Rea, Assistant Regional Administrator
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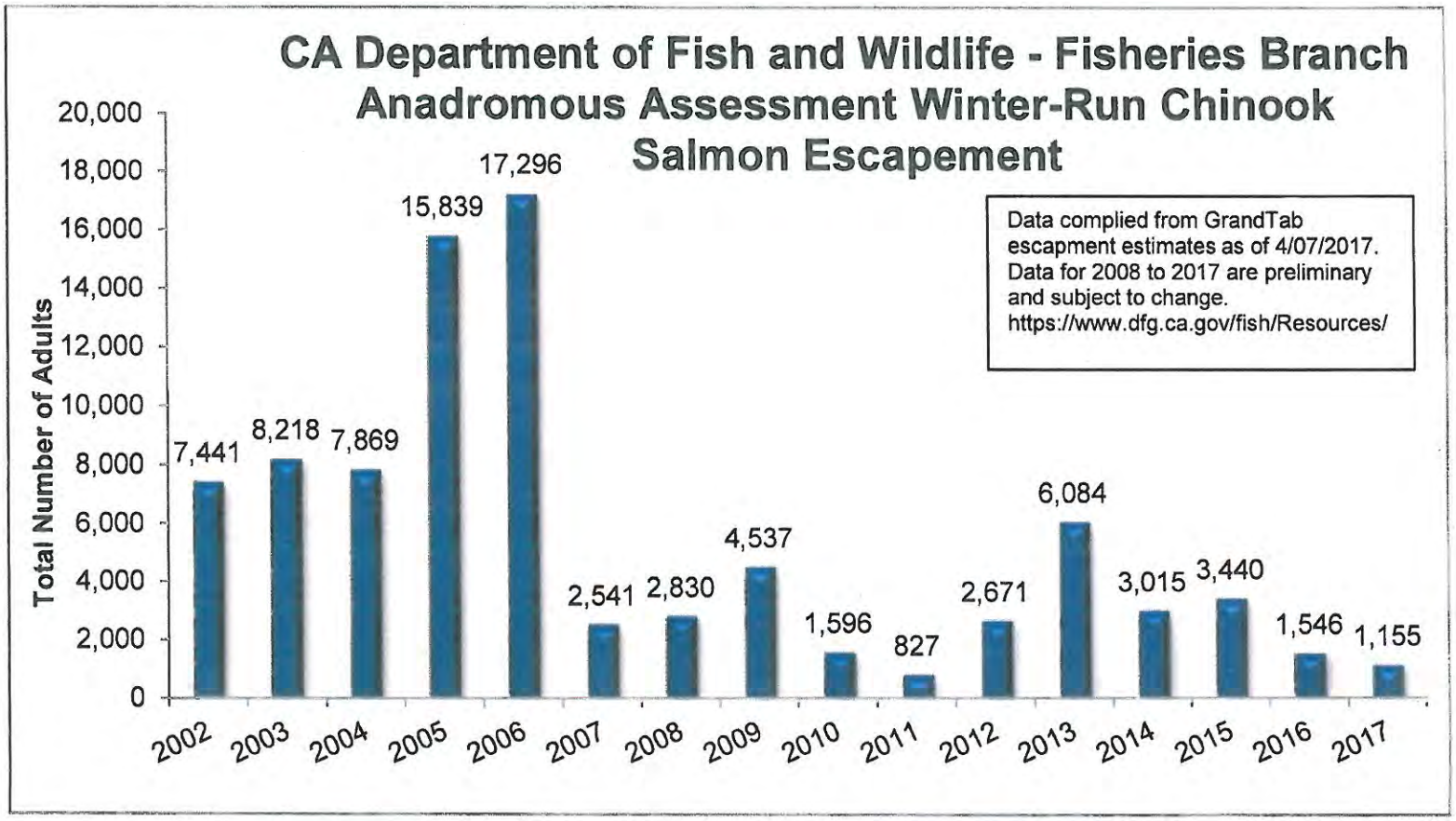
CA Department of Fish and Wildlife - Fisheries Branch
Anadromous Assessment Winter-Run Chinook
Salmon Escapement
Data complied from GrandTab escapment estimates as of 4/07/2017. Data for 2008 to 2017 are preliminary and subject to change. https://www.dfg.ca.gov/fish/Resources/
Total Number of Adults
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
7,441
8,218
7,869
15,839
17,296
2,541
2,830
4,537
1,596
827
2,671
6,084
3,015
3,440
1,546
1,155
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Fisheries Branch
830 S Street
Sacramento, CA 95814

EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

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January 12, 2018

Mr. Garwin Yip
National Marine Fisheries Service
650 Capital Mall, Suite 5-100
Sacramento, CA 95814

Dear Mr. Yip:

Four years ago, the Interagency Ecological Program's (IEP) Winter-Run Project Work Team (WR PWT) recommended that the NOAA Fisheries Juvenile Production Estimate (JPE) be revisited annually and updated as needed with any new or improved information. A sub-team of the WR PWT met in 2017 to review the factors used to calculate the brood year (BY) 2017 JPE. The JPE is used to calculate the incidental take limit of winter-run Chinook salmon in the Delta at the State Water Project (SWP) and Central Valley Project (CVP) export facilities. The sub-team also reviewed the status of monitoring and research that was recommended last year, that would improve future JPE estimates and provide better information for managing water project operations.

JPE Recommendations:

The WR PWT identified four factors in in calculating the JPE, similar to last year, that they would advise continuing or updating for BY 2017:

1) estimated number of fry passing Red Bluff Diversion Dam (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 I-80/I-50 Bridge)

4) estimated survival rate of the winter-run hatchery fish to be released in January or February of 2018

The California Department of Fish and Wildlife (CDFW) estimated 975 winter-run adults returned to the upper river in 2017, and of these, 795 were estimated as in-river escapement in the JPE (Table 1). Of those, 46.9 percent were female, for a total in-river spawning female escapement estimate of 373 (Table 1). Pre-spawning mortality was estimated at 1.7% resulting in 367 female winter-run estimated to have spawned (Table 1). Fecundity in 2017 was calculated based on a weighted average of fecundity from 2-yr old and 3-yr old fish from Livingston-Stone National Fish Hatchery (LSNFH) broodstock sampled in 2016-2017 and applied to fish found on the carcass survey in

2017 by length. Using separate linear models to estimate fecundity for 2-yr old and 3+ yr old fish resulted in an estimate of 1,507,924 eggs deposited naturally in the Sacramento River, corresponding to an average of 4,109 eggs/female (Table 1).

While we believe the eggs and alevins survived better in 2017 than during the drought years of 2013-2015; the WR PWT's first recommendation is to use the Juvenile Production Index (JPI) in the JPE for BY 2017, which is based on fry-equivalents at RBDD (Figure 1). This has been used in the calculation since 2014. The JPI seasonal estimate as of December 31, 2017 (week 52) was 531,504 (B. Poytress, USFWS, personal communication). The value through December 31 accounts for approximately 97.5% of annual winter-run passage at RBDD based on data collected from 2002 to 2016 and, including an interpolation of the remaining 2.5% for the remainder of BY 2017 would equate to an estimate of 545,132 (Table 1). We believe the JPI is a better estimate of fry survival to RBDD than the long-term average egg-to-fry survival rate used prior to 2014 in the JPE. The JPI is an annual empirical estimate and better represents the response of fish to annual environmental conditions during spawning, egg incubation and outmigration. With this estimate of fry production at RBDD, the estimated egg-to-fry survival is calculated to be 36.2% (Table 1).

In 2017, several juvenile spring-run-sized Chinook salmon were sampled at RBDD, although very few spring-run Chinook salmon adults were detected in surveys upstream of RBDD. These spring-run were identified using the river length-at-date criteria (LAD), but the timing and numbers suggested these fish sampled at RBDD were likely late-emerging winter-run. Tissue samples were genetically analyzed, which determined that many of the LAD spring-run were genetic winter-run. Alternative JPIs have been calculated incorporating the additional winter-run. The JPE calculation methods that use this corrected number are denoted with an "a" both in the text of this letter and within Table 1 and Appendix A. For Method 1a this resulted in an egg to fry survival rate of 44%, as opposed to 36.2% reported above for Method 1. These genetically-identified run results, from the Red Bluff rotary screw traps, have been independently supported by water temperature data, carcass surveys and redd observations from this year's field surveys (D. Killam, personal communication).

The second recommendation of the Winter Run PWT is the continued inclusion of a survival factor between the peak of fry catch at Red Bluff (generally in October) and the smolt life-stage at Red Bluff for naturally produced winter-run. This is necessary because the available survival estimates between RBDD and the Delta are based on releases of acoustically telemetered (AT) smolts. These fish have a higher survival rate than fry due to their larger size and faster migration rates. A fry-to-smolt survival rate of 0.59, based on fall-run Chinook salmon, has been used as a surrogate for winter-run fry-to-smolt survival since 1993. This value is based on previous studies by Hallock (undated), and confirmed through a literature review in 1995 (B. Poytress, USFWS, personal communication). Without this factor, survival from fry to smolts is assumed to be 100%, which is unrealistic.

We have had reservations about the accuracy of the 0.59 term (incorporated into method 1 and 1a) and thus have interest in considering alternative approaches.

Appendix A describes two alternative methods (method 2 and 3) for forecasting the natural-origin JPE, both of which include a new approach for forecasting the fry-to-smolt survival rate. The fry-to-smolt survival rate forecast described in Appendix A is based on fitting a zero-intercept linear model to estimates of hatchery-origin and natural-origin juvenile survival rates from the same brood years. This new methodology results in a lower fry-to-smolt survival rate for both Method 2 and Method 3 (Table 1, Appendix A).

The third recommendation of the WR PWT is related to the smolt survival term for estimating survival from RBDD (*i.e.,* Salt Creek) to the Delta (*i.e.*, Sacramento at the I-80/I-50 Bridge) for naturally produced winter-run smolts. We recommend using averaged estimates from the results of acoustic tagging of LSNFH smolts in 2013 – 2017 for this term. There were two release groups in each year in 2015 and 2016, and based on recommendations from Ken Newman (former U.S. Fish and Wildlife Service 2016), we pooled individual estimates in 2015 and again for 2016, prior to calculating the weighted average of annual survival from RBDD to the Delta of 0.5129 (A. Ammann, NMFS, personal communication). All hatchery releases were made at Caldwell Park, Redding, except in 2016 when they were made at Bonnyview boat ramp, approximately six miles further downstream. The survival estimate of 0.5129 is used for naturally produced winter-run in Method 1. Method 2 and 3 use a forecasting model (Appendix A).

The fourth recommendation from the WR PWT is updating the term for estimating survival of hatchery winter-run to the Delta (Table 1 and Figure 1). This term is the average of BYs 2013-2017 hatchery acoustic tag survival to the Delta. Again, the estimates in each year in 2015 and 2016 were pooled prior to averaging them. The weighted average of the five estimates of annual survival is 0.4276. This survival rate is lower than the one reported in the preceding paragraph because it is for the full migration survival for acoustically tagged hatchery fish from the release point (~60 miles upstream of the RBDD) to the Delta. In the preceding paragraph, for the natural origin survival estimate, we are only using a portion of the migration distance (from RBDD to the Delta).

We considered three methods for estimating the natural-origin JPE:

- Method 1 is the JPI * 0.59 (fry-to-smolt survival rate) * 0.5129 (smolt survival of acoustic tag hatchery winter run from RBDD to the Delta) = 164,963.
- Method 1a results in a JPE forecast of 201,409.
- Method 2 uses the same general form as Method 1, but replaces the fry-to-smolt survival rate of 0.59 with 0.4725. It also accounts for observation error in the JPI, the fry-to-smolt survival rate, and the smolt survival rate (Appendix A). This results in a JPE forecast of 147,695, with a 95% confidence interval of 58,340 – 237,051.
- Method 2a results in JPE forecast of 177,047, with a 95% confidence interval of 69,934-284,160.
- Method 3 has the same general form as methods 1 and 2. However, Method 3 assumes that the JPI error distribution is Lognormal. The approach used to forecast the fry-to-smolt survival rate is in the same as described for Method 2.

The forecast of smolt survival to the Delta is based on application of a hierarchical Bayesian model fitted to acoustic tag data (Appendix A). Method 3 yields a mean JPE forecast of 135,226, with a 95% credible interval of 19,025 – 318,744.

- Method 3a results in JPE forecast of 163,469, with a 95% credible interval of 22,649-381,952.

As mentioned earlier, Methods 1a, 2a and 3a incorporate the additional number of winter-run due to misclassification of spring-run using the river LAD criteria.

We believe it is helpful to NMFS to provide the calculations for all 6 combinations of the JPE for their assessment. However, the majority of the Winter Run PWT recommends that method 1a be used for the calculation of the BY 2017 JPE, because methods 2 and 3 have not been fully vetted. The WR PWT was unanimous on the inclusion of the additional winter-run genetically identified from those initially identified as spring-run using the river LAD.

While we acknowledge that there will still be uncertainty in the JPE estimate, even if these recommendations are incorporated, we believe it to be the best information available from which to derive a JPE. To reduce the uncertainty in the JPE in future years, we have suggested in our past JPE letters that additional monitoring and analyses be conducted. We have restated those recommendations and provide an update on them below.

Monitoring Recommendations:

One of the models we have been developing to support the JPE is associated with the migration time and survival of winter-run acoustic tagged hatchery fish to the Delta. When using the first four years of data (six data points) from the acoustic tag releases of hatchery fish, it appeared that survival to the Delta was related to migration time to the Delta. The lowest survival was in 2013, when the migration time to the Delta was the greatest at 40 days. The highest survival was for the second release in 2015 when migration time to the Delta was only 10 days. The data for BY 2016 collected in 2017 show higher survival to the Delta (0.70). These fish held for an extended period up river before moving to the Delta (43 days). BY 2016 was unique as the flows this BY experienced were much higher than in the previous 4 years.

Monitoring or research that the WR PWT has supported in the past and its respective update is as follows:

1. *Tag a portion of hatchery winter-run with acoustic tags annually:*

NMFS has funding from the U.S. Bureau of Reclamation (USBR) and CDFW to tag a portion of the hatchery winter-run with acoustic tags in 2018 and 2019, but a funding source is needed after 2019, to assure this tagging is continued in the long-term.

2. *Acoustic tag smaller hatchery origin winter-run and release them earlier in the season (December and January):*

The Winter Run PWT believes that there is a data gap within the acoustic tag survival estimate. The hatchery fish, which receive the tags, are all of smolt size. As stated previously, we use this information to estimate survival of smaller-sized fish. To fill this gap we recommend tagging a portion of the hatchery fish and releasing them in December and January.

3. Acoustic tag wild winter run at Red Bluff Diversion Dam.

While there is support to tag natural origin winter-run, efforts to tag BY 2016 were unsuccessful at catching enough natural origin winter-run at Red Bluff Diversion Dam.

4. Place acoustic receivers in the central and south Delta to understand movement of acoustically tagged winter-run:

JSATS receivers were unable to be deployed in time to detect acoustic tagged winter run in the central and south Delta in 2017. UC Davis and NOAA plan to deploy a few receivers in the south Delta during the winter-run emigration period (Jan – April) in 2018.

5. Place real time monitoring receivers in locations where detections can be converted to actual numbers passing a particular site as the tagged hatchery winter-run move into and through the Delta:

The placement of real-time receivers is not likely to occur in 2018, due to the delay in purchasing the receivers.

6. Fund winter-run otolith microchemistry and synthesis work to learn where the successful adult survivors reared and how long they spend in different habitats as juveniles:

Additional winter-run otolith work is being funded through a Delta Stewardship Fellow, Pedro Morais, (U.C. Berkeley) and Rachel Johnson (NMFS-Southwest Fisheries Science Center) working on winter-run escapement years 2016-2018. This will add drought years to a growing time series that Pedro will also synthesize with Corey Phillis (Metropolitan Water District) and Maya Friedman (U.C. Santa Cruz) and colleagues. Previous work has recently been published in Biological Conservation highlighting the role of tributary/Delta rearing in winter-run[1].

7. Increase sampling effort at Sacramento and Chipps Island trawls to better estimate trawl efficiency and estimate abundance of juvenile winter-run at both locations.

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[1] Phillis CC, Sturrock AM, Johnson RC, Weber PK. 2018. Endangered winter-run Chinook salmon rely on diverse rearing habitats in a highly altered landscape. Biological Conservation 217: 358-362.

During 2017, increased sampling was conducted at Sacramento and Chipps Island from February to May, to increase the number of coded wire tag recoveries to better inform our efficiency estimates. Increased sampling is also planned at these two locations in 2018, although earlier in the migration period (December – March at Sacramento, and January – April at Chipps Island). This should increase the number of genetic winter-run captured. In 2016, only 3 genetic winter-run were caught at Chipps Island, which resulted in a preliminary abundance estimate at Chipps Island of only 3,274 winter-run (SE = 2,299). Only one genetic winter run was captured at Sacramento in 2016. Abundance estimates have not been calculated for Sacramento in 2016.

8. *Fund the development of run-specific abundance estimates entering and exiting the Delta recommended by the IEP Salmon Assessment and Indicators by Life-stage (SAIL) recommendation of the (Johnson et al. 2017[2]). If an abundance estimate of winter-run entering and exiting the Delta can be achieved, this would provide additional empirical data necessary to test the accuracy of the current calculations for estimating the JPE and for developing the incidental take limit of winter-run Chinook salmon at the SWP and CVP pumping facilities.*

The Brandes et al. (2016[3]) proposal was funded as a pilot effort in 2016, and as a full project in 2017. This study has been funded for 2018 by the USBR-Bay-Delta office and for 2019 with CVPIA funding. This work will improve trawl efficiency estimates for the existing Sacramento and Chipps Island trawls using paired coded wire tagged and acoustically tagged juvenile salmon and genetic sampling in order to generate winter-run abundance estimates. It will also expand previously collected genetic winter-run samples at Sacramento (2009-2011) to estimate the winter-run production at the Delta to compare with the estimated JPE in those years.

Some members of the Winter Run PWT would like to explore the use of genetic identification and coded wire tags compared to export rates and entrainment at the SWP and CVP export facilities. The Winter Run PWT has not been able to fully vet this analytical method and alternative approach to managing the take limits at the export facilities.

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[2] Windell, Sean, Patricia L. Brandes, J. Louise Conrad, John W. Ferguson, Pascale A.L. Goertler, Brett N. Harvey, Joseph Heublein, Joshua A. Israel, Daniel W. Kratville, Joseph E. Kirsch, Russell W. Perry, Joseph Pisciotto, William R. Poytress, Kevin Reece, Brycen G. Swart, and Rachel C. Johnson. 2017. Scientific framework for assessing factors influencing endangered Sacramento River winter-run Chinook salmon (Oncorhynchus tshawytscha) across the life cycle. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-586. 49 p. DOI: http://doi.org/10.7289/V5/TM-SWFSC-586

[3] Brandes, P, M. Dekar, T. Miller, J. Kirsch, L. Smith, B. Pyper, A.Ammann, R. Perry, J. Israel, and R. Johnson. Estimating the abundance of juvenile winter-run Chinook salmon entering and exiting the Delta form genetic monitoring data and estimates of trawl efficiency from coded wire tag and acoustic telemetry releases. Proposal submitted to IEP. June 1, 2016

In summary, we hope these additional analyses and technical advice from the IEP's Winter-Run Project Work Team will help improve the JPE and the accuracy of the incidental take limit for water year 2018 at the CVP and SWP export facilities.

Sincerely,

Daniel Kratville
Winter Run PWT Chairperson

cc: Ms. Maria Rea, Sacramento Area Supervisor
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Sacramento CA, 95814

ec: Kevin Shaffer, Chief
Fisheries Branch
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Winter-Run Project Work Team

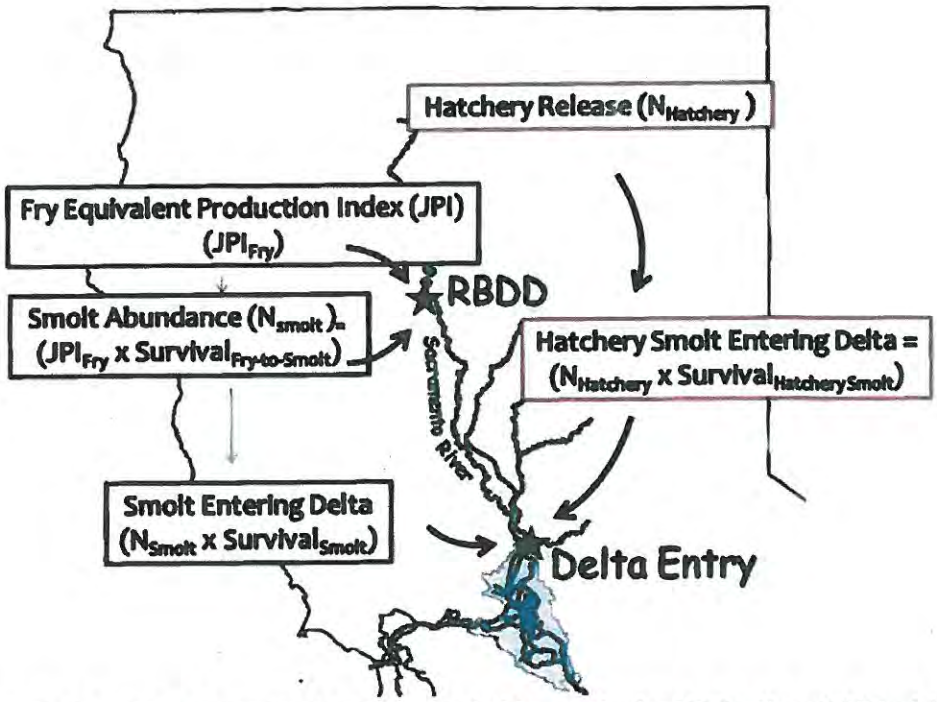

Figure 1: Location and formula's recommended for use in the JPE for the wild (black boxes) and hatchery (red boxes) components of the winter run population estimated in 2015-2016.

Appendix A: Alternative approaches to forecasting the natural-origin JPE

O'Farrell, M. R.[4], Satterthwaite, W. H. [1], Hendrix, A. N.[2], and M. S. Mohr[1]

January 2, 2018

The National Marine Fisheries Service's Southwest Fisheries Science Center has developed two alternative approaches for forecasting the natural-origin winter Chinook Juvenile Production Estimate (JPE). Complete documentation of these forecast methods is in preparation and has not yet been subject to peer review. Here we provide a brief description of the two approaches, which we refer to as methods 2 and 3.

The alternative forecasting methods follow the same basic JPE model adopted for use in recent years (method 1),

$$\widehat{\mathrm{JPE}}_{n,t} = \widehat{\mathrm{JPI}}_{t-1} \times \hat{f} \times \hat{s}_n \qquad (1)$$

where $\widehat{\mathrm{JPI}}_{t-1}$ is the Juvenile Production Index estimate in fry-equivalent units, $\hat{f}$ is a forecast of the fry-to-smolt survival rate, and $\hat{s}_n$ is a forecast of the smolt survival rate of natural-origin fish (*n*) from Salt Creek to the Delta entrance in Sacramento. The year *t* JPE forecast is informed by the year *t-1* JPI estimate because most of the juvenile winter Chinook passage at Red Bluff Diversion Dam (RBDD) occurs in the calendar year prior to the JPE forecast year.

For Method 2, the variance associated with observation error is estimated for each of the components on the right hand side of Equation (1). These error variances are then used to derive a variance estimate for the overall JPE forecast. The variance in the forecast JPE does not include uncertainty associated with year-to-year variation in the survival rates $\hat{f}$ and $\hat{s}_n$.

A new approach to forecasting $\hat{f}$ was used for Method 2. Here, $\hat{f}$ was forecasted using a zero-intercept linear model fitted to estimates of hatchery-origin juvenile survival rates and estimates of natural-origin juvenile survival rates from the same year (Figure 1). Hatchery-origin juvenile survival rates (spanning the period of time from release as pre-smolts to the end of age-2 in the ocean) are estimated using cohort reconstruction methods applied to coded-wire tag recovery data (O'Farrell et al., 2012). Natural-origin juvenile survival rates (spanning fry-equivalent passage at RBDD to the end of age-2 in the ocean) are estimated using a Bayesian state-space population dynamics model (Winship et al., 2014). While this is not a direct measure of fry-to-smolt survival, we note that the differences in the hatchery and natural-origin juvenile survival rates represent

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[4] Fisheries Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Santa Cruz, CA.

[2] QEDA Consulting, LLC, Seattle, WA

different durations in the river environment but similar durations in the marine environment. Using this method, $\hat{f} = 0.4725$. The smolt survival rate ($\hat{s}_n$) was calculated as a variance-weighted mean of annual survival estimates based on acoustic tagging data from 2013-2017, where the 2017 data are considered preliminary.

Under Method 2, $\widehat{\text{JPE}}_{n,2018} = 606{,}039 \times 0.4725 \times 0.5158 = 147{,}695$ with a 95% confidence interval of 58,340 to 237,051.

Under Method 2a, which incorporates an estimate of genetic winter run, $\widehat{\text{JPE}}_{n,2018} = 726{,}479 \times 0.4725 \times 0.5158 = 177{,}047$ with a 95% confidence interval of 69,934 to 284,160.

For Method 3, each of the components on the right hand side of Equation (1) are expressed as distributions. The distribution of the $\widehat{\text{JPI}}_{t-1}$ observation error was assumed to be Lognormal. The fry-to-smolt survival rate, $\hat{f}$, was forecast in the same manner as described for Method 2 and Method 2a and the distribution of observation error was assumed to be Normal. A posterior predictive distribution of the smolt survival rate $\hat{s}_n$ was derived from a hierarchical Bayesian model, fitted to acoustic telemetry data, that accounts for both observation and process error. The model assumes that year-specific smolt survival rates are equal to a mean survival rate across years plus a year-specific random effect. The forecast of s_n was based on acoustic telemetry data from 2013-2017, noting that the 2017 data are preliminary. The distribution of $\widehat{\text{JPE}}_{n,2018}$ was determined by taking the product of random samples from the component distributions of $\widehat{\text{JPI}}_{2017}$, $\hat{f}$, and $\hat{s}_n$.

Under Method 3, $\widehat{\text{JPE}}_{n,2018} = 135{,}226$ with a 95% credible interval of 19,025 to 318,744.

Under Method 3a, which incorporates an estimate of genetic winter run, $\widehat{\text{JPE}}_{n,2018} =$ 163,469 with a 95% credible interval of 22,649 381,952.

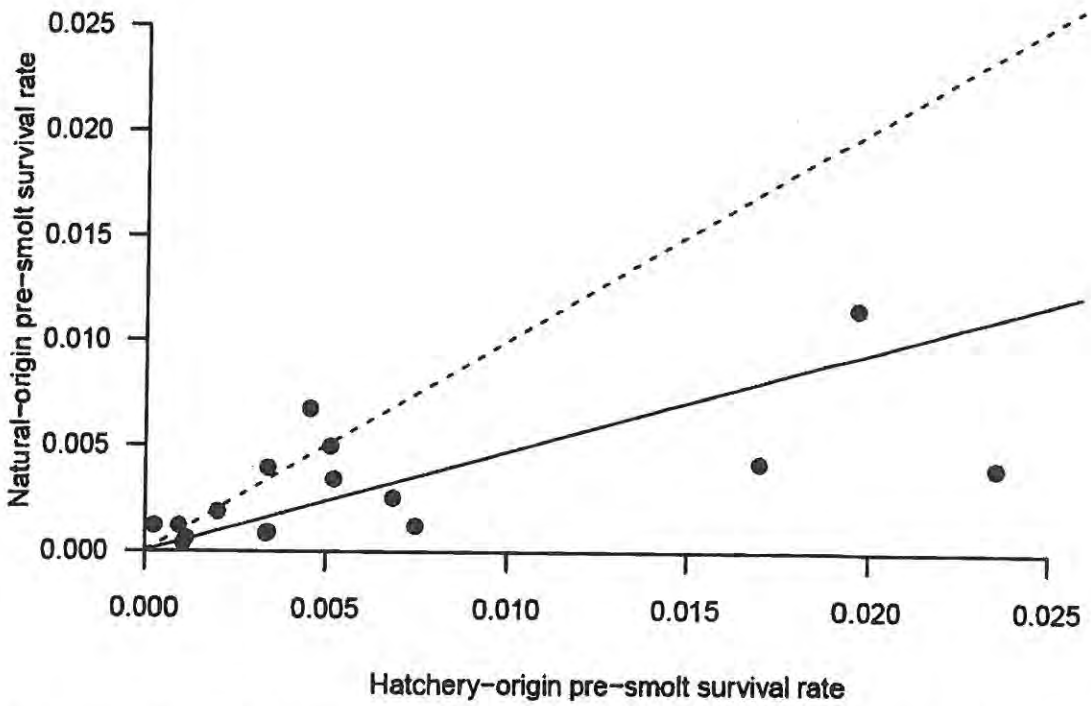

Figure 1. Relationship between hatchery-origin and natural-origin survival rates. Solid line is the fitted zero-intercept model and the dashed line is the 1:1 line.

References

O'Farrell, M. R., M. S. Mohr, A. M. Grover, and W. H. Satterthwaite (2012). Sacramento River winter Chinook cohort reconstruction: analysis of ocean fishery impacts. U.S. Dept. Commer., NOAA Tech. Memo. NOAA-TM-NMFS-SWFSC-491, 68p.

Winship, A. J., M. R. O'Farrell, and M. S. Mohr (2014). Fishery and hatchery effects on an endangered salmon population with low productivity. Transactions of the American Fisheries Society 143, 957–971. doi: 10.1080/00028487.2014.892532.

Table 1: Factors in the Juvenile Production Estimate and the resulting estimates for 2017-2018, using the Winter-Run PWT approach. Methods 1a, 2a and 3a, incorporate additional winter run based on genetic testing of spring run length at date fish sampled at Red Bluff Diversion Dam. Hatchery components in red text

Natural Components		Method 1	Method 1a	Method 2	Method 2a	Method 3	Method 3a
Total in-river escapement [1]		795	795	795	795	795	795
Female spawner estimate (FSE) [2]		373	373	373	373	373	373
ASE minus pre-spawn mortality [3] (1.7%)		367	367	367	367	367	367
Average Fecundity [4]		4,109	4,109	4,109	4,109	4,109	4,109
Total Viable Eggs		1,507,924	1,507,924	1,507,924	1,507,924	1,507,924	1,507,924
Estimated egg to fry survival based on JPI at RBDD/Total Viable eggs		0.36	0.44	0.40	0.48	0.40	0.48
Fry equivalents of juvenile production @ RBDD (JPI) [5]		545,132	665,572	606,039	726,479	605,784	726,537
Fry-to-smolt survival estimates from October (peak at RBDD in most years) to February at RBDD		0.59[6]	0.59[6]	0.4725	0.4725	0.4720	0.4721
Number of smolts at RBDD		321,628	392,688	286,353	343,261	285,930	342,998
Estimated smolt survival – RBDD to Delta [7]		0.5129	0.5129	0.5158	0.5158	0.4731	0.4766
Total natural production entering the Delta		164,963	201,409	147,695	177,047	135,226	163,469
Level of concern for naturally produced fish (1%)		1650	2014	1477	1770	1352	1635
Incidental Take limit for Natural Production (2%)		3299	4028	2954	3541	2705	3270

Hatchery Components	Values
LSNFH Hatchery release [8]	217,270
Total hatchery production Entering the Delta [9] (based on survival rate from release to Sacramento of 0.4276).	92,904
Level of concern for hatchery fish (0.5%)	466
Incidental Take limit for hatchery production (1%)	932

Footnotes:

1/ Total in-river escapement from CDFW Cormack-Jolly Seber (CJS) model includes natural and hatchery origin, but not hatchery fish retained for brood stock at Livingston Stone National Fish Hatchery.

2/ The number of adult females is derived from carcass survey and then the number of males is derived using sex ratio at Keswick trap

3/ Pre-Spawn mortality was estimated from carcass surveys of females (CDFW)

4/ Preliminary (subject to change) average # eggs/female from weighted estimate based on two year and three old fish spawned at Livingston Stone Hatchery and from the carcass survey).

5/ Preliminary number of fry-equivalents estimated on December 16, 2017 plus 4.1% interpolation at RBDD – JPI – Bill Poytress, (USFWS), personal communication

6/ Estimate of fry to smolt survival based on fall run at Tehama Colusa Spawning Channel (Hallock undated)

7/ Average weighted survival of acoustically tagged winter-run in 2013, 2014, 2015 (2 values in 2015) and 2016 (2 values in 2016) and one value in 2017 between RBDD and I80 Tower Bridge in Sacramento – A. Ammann, NMFS, personal communication. Survival is estimated from the Salt Creek receiver site, located 3 miles downstream of RBDD, to estimate survival from RBDD for acoustic tag studies (See Appendix A, for further description of how the weighted average acoustic tag survival was used for methods 2, 2a,3 and 3a). This is the derivation of the numbers of fish arriving to Salt Ck (RBDD) and Sacramento (Tower, SacI80/50) from the acoustic tagged LSNFH winter run pre-smolts. The number of fish arriving to Salt Ck and SacI80/50 are derived by looking at receivers at this location and all locations downstream. It uses fish directly detected at that site plus any fish that were missed at that site but detected at a site downstream. This was done for all years 2013-2017. The 2017 year was the only year that had significant flows over Fremont Weir. Fish that went over the weir and into the Yolo Bypass would bypass the Sacramento I80/50 Bridge and other nearby receiver locations. If these fish were detected at locations downstream of Liberty Island they were considered to have survived to the Delta and thus added to the number of the fish counted at Sacramento I80/50 Bridge.

8/ LSNFH estimated production release as of 1/8/17 (100% tagged and adipose clipped). 500 to 1000 of these fish may be held back for the captive broodstock program. Final number should be updated when the number of those held back are finalized.

9/ Weighted average of acoustically tagged winter-run survival in 2013, 2014 and 2015 and 2016 (2 values in 2015 and 2016) and 2017 between release location and I80/I50 Bridge in Sacramento. The estimates were derived in a similar manner as those from Salt Creek to Sacramento (Footnote 7).