State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Fisheries Branch
830 S Street
Sacramento, CA 95811

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

January 4, 2017

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

Dear Mr. Yip:

Three years ago, the Interagency Ecological Program (IEP)'s Winter Run Project Work Team (WRPWT) 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 WRPWT met five times in 2016 to review the factors used to calculate the JPE. The JPE is used for estimating the incidental take limit of winter-run Chinook Salmon in the Delta at the State Water Project (SWP) and Central Valley Project (CVP). The sub-team also discussed priority monitoring and research that would improve future JPE estimates and provide better information for managing water project operations.

JPE Recommendations:

The sub-team identified four factors in the JPE similar to last year that they would advise continuing or updating for the 2016 broodyear:

1) estimated number of fry passing Red Bluff Diversion Dam (RBDD)

2) survival rate of fry to smolts

3) survival rate of smolts from RBDD to Delta entry (defined as Sacramento, at the I80/I50 Bridge)

4) estimated survival rate of the winter-run hatchery fish to be released in January or February of 2017

In 2016, California Department of Fish and Wildlife (CDFW) estimated 1,546 winter-run adults returned to the upper river, and of these, 1,409 were counted as in-river escapement in the JPE (Table 1). Of those, 46.7 percent were female, for a total in-river adult female escapement estimate of 658 (Table 1). Pre-spawning adult mortality was estimated at .008 (Table 1) resulting in 653 adult female winter-run estimated to have spawned. A change to fecundity in 2016 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 (see Attachment A). This weighted estimate of fecundity (3907.4) resulted in an estimate of 2,551,585 total eggs laid in-river in 2016 (Table 1).

While we believe the eggs and alevins survived better than the past two years, the sub-team's first recommendation is to use the Juvenile Production Index (JPI) in the JPE for 2016-2017 which is based on fry equivalents at RBDD, as was used in 2014-2015 and 2015-2016 (Figure 1). The JPI seasonal estimate as of December 16, 2016 was 613,675 (B. Poytress, USFWS, personal communication; Table 1). The value through week 50 (December 16) accounts for approximately 96% of annual winter-run passage at RBDD based on data collected from 2002 to 2014 and includes an interpolation of the remaining 4% in 2016-2017 (590,969 / 0.963 = 613,675). We believe the JPI is a better estimate of fry survival to RBDD, than the average long-term egg to fry survival rate used previously in the JPE, because it 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 .24 (Table 1).

The second recommendation of the sub-team is the continued inclusion of a factor to account for survival between the peak of fry catch at Red Bluff (generally in October) and the smolt life-stage at Red Bluff for the naturally produced winter-run. There can be as many as four months during the fry to smolt transition and a survival estimate is needed during this time period. The available survival estimates between RBDD and Delta entry are based on releases of acoustically telemetered (AT) smolts, which have a higher survival rate than fry due to their larger size and faster migration rates. These fish are released in the spring depending on conditions. A survival rate of 0.59, based on fall-run salmon survival from fry to smolt has been used for winter-run fry to smolt survival since 1993. This value is based on previous studies (Hallock, undated), and confirmed through a literature review in 1995 (B. Poytress, USFWS, personal communication). Without this survival factor, survival from fry to smolts is assumed to be 100%, which is unrealistic. While we have reservations about the accuracy of this term (0.59; Table 1 and Figure 1), we believe it should continue to be used, until a better estimate of fry to smolt survival is available. To address this critical uncertainty we suggest that additional studies be conducted in the future to better estimate fry to smolt survival (see monitoring recommendations below).

The third recommendation of the sub-team 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/I50 Bridge) for naturally produced winter-run smolts. We recommend using results from acoustic tagging of LSNFH smolts in 2013, 2014, 2015, and 2016 for this term. There were two release groups in 2015 and 2016. Based on recommendations from Ken Newman (statistician from the U.S. Fish and Wildlife Service, Lodi Office), we first pooled individual estimates in 2015 and again for 2016, prior to estimating the weighted average of annual survival from RBDD to the Delta of 0.459 (A. Ammann, NMFS, personal communication; Attachment B). All hatchery releases were made at Caldwell Park, except in 2016 where they were made at Bonnyview Boat ramp, approximately six miles further downstream. The survival estimate used for naturally produced winter-run, is the acoustic tagged hatchery fish survivals from RBDD to the Delta, from the confluence of Salt Creek to the I80/I50 Bridge in Sacramento.

The fourth recommendation from the sub-team is updating the term for estimating survival of hatchery winter-run to the Delta (Table 1 and Figure 1). Last year, this term was the average of the 2013, 2014 and the two estimates from 2015 of winter-run survival to the Delta (0.37). This year the sub-team recommends that the weighted average of the four estimates of annual survival be used, which results in an estimate of 0.410. This is the estimate obtained when pooling the 2015 and 2016 data prior to averaging it with results from 2013 and 2014 (Attachment B). The reason these survival rates are different than those used for the wild winter-run (used in the previous paragraph) is because we want an estimate of survival for the hatchery fish which are to be released at Caldwell Park, whereas for the wild winter-run we only want an estimate that is from RBDD to I80/I50 Bridge to apply to the JPI fry equivalents at RBDD.

Monitoring Recommendations:

One of the models we have been developing to support the JPE is associated with the migration time of winter-run acoustic tagged hatchery fish to the Delta and their survival to the Delta. In using the last four years of data (six data points) from the acoustic tag releases of hatchery fish we have found that survival to the Delta appears to be 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 and the highest survival was for the second release in 2015 when the migration time to the Delta was only 10 days (Figure 2). To be able to apply this model to smaller-sized winter-run, we are recommending that hatchery winter-run be acoustically tagged and released at a smaller size (which is possible now due to smaller tag sizes), earlier in the season (*e.g.*, December, or early January), to inform our model for future application to smaller winter-run observed at RBDD. We are unable to acoustically tag the earliest/smallest migrating winter-run fish, even with the smallest acoustic tags available to date.

This recommendation of acoustic tagging a small number of the hatchery winter-run and releasing them earlier in the season was supported by the sub-team as a way to estimate a portion of the fry-to-smolt survival from RBDD to the Delta for the JPE and is likely to be implemented in 2017. While most members of the sub-team thought that continuing to acoustically tag a portion of the hatchery winter-run over the next 10 years is important, although not funded after 2017, there is also support to develop a wild winter-run tagging proposal. While this is proposed for 2016-2017 there is not enough wild winter-run at a taggable size to complete this task.

A recommendation from the IEP Salmon Assessment and Indicators by Life-stage (SAIL) is to develop run-specific abundance estimates entering and exiting the Delta (Johnson et al. *in review*). If an abundance estimate of winter-run entering and exiting the Delta could be achieved, this would provide additional empirical data necessary to test the accuracy of the current calculations for estimating the incidental take limit of winter-run Chinook Salmon in the Delta at the SWP and CVP.

In response to this recommendation, a proposal has been developed to the IEP to improve trawl efficiency estimates for the existing Sacramento and Chipps Island trawls using paired coded wire tagged and acoustically tagged juvenile salmon with genetic sampling in order to generate winter-run abundance estimates. As part of this proposal, an analysis of previously collected genetic samples at Sacramento could provide a broader time series (2009-2011) to compare with the estimated JPE and estimated loss at the salvage facilities. IEP is working to implement this recommendation in 2017 and will continue to seek input from the winter-run PWT as well as the broader scientific community at the IEP workshop in March 2017 considering some of the unique technical challenges anticipated with this proposal.

Other monitoring or research that was discussed by the sub-team, that we continue to support include:

1) placement of acoustic receivers in the central and south Delta to understand movement of tagged winter-run;

2) placement of real time monitoring receivers to provide accurate proportions of acoustic tagged hatchery winter-run at various locations as they move into and through the Delta;

3) funding winter-run otolith and synthesis work to learn where the successful adult survivors reared and how long they spend in different habitats as juveniles and;

4) increasing effort at Sacramento and Chipps Island trawls to better estimate winter-run abundance.

Most of these elements are being funded in 2017, with the exception of number 3, funding additional winter-run otolith work, but it has been proposed to the Delta Stewardship Council as a Delta Science postdoctoral fellowship opportunity. We also generally support monitoring recommendations in the IEP SAIL report (Johnson et al. *in review*).

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 some additional monitoring and analyses to be conducted in 2017.

To better manage exports for improving juvenile winter-run survival in the Delta, a suggestion was made last year, during sub-team discussions, to estimate patterns of entrainment using genetic and coded-wire tag information for exporting water at the SWP and CVP in ways that entrainment loss estimation could be targeted to be below required limits. We are continuing to evaluate such an analytical method, but as of yet, have not determined it would be better than using the JPE methodology.

In summary, we hope these additional analyses and technical advice from the sub-team of the IEP's Winter Run Project Work Team will help improve the JPE and the incidental take limits for 2016-2017. Drought conditions in the past two years have likely resulted in significant impacts to the wild winter-run population. The Winter Run PWT continues to try to increase the accuracy of the JPE for the SWP and CVP water projects in water year 2017, for minimization of incidental take impacts to the winter-run Chinook Salmon population.

Sincerely,

Daniel Kratville
Winter Run PWT Chairperson

cc: Ms. Maria Rea, Sacramento Area Supervisor
National Marine Fisheries Service
SWR Sacramento Area Office
650 Capitol Mall, Suite 8-300
Sacramento CA, 95814

ec: Kevin Shaffer, Chief
Fisheries Branch
Kevin.Shaffer@wildlife.ca.gov

Winter-Run Project Work Team

Table 1: Factors in the Juvenile Production Estimate and the resulting estimates for 2016-2017, using the Winter-Run PWT approach. Hatchery components in red text.

| | Factors | 2016-2017 Result using suggested methodology |
|---|---|---|
| Total in-river escapement [1] | | 1,409 |
| Adult female estimate [2] | | 658 |
| Pre-spawn mortality [3] | | 0.8% |
| Average Fecundity [4] | | 3907.4 |
| Total Viable Eggs | | 2,551,585 |
| In redd loss and fry loss upstream of RBDD due to temperature and other factors[5] | 0.76 | |
| Estimated survival: egg to fry (at RBDD) [6] | 0.24 | |
| Estimate of fry production at RBDD [7] | | 613,675 |
| fry survival from October (peak at RBDD in most years) to February for smolt at RBDD [8] | 0.59 | 362,068 |
| Estimated smolt survival – RBDD to Delta [9] | 0.459 | 166,189 |
| Total natural production entering the Delta | | 166,189 |
| hatchery release [10] | | 139,500 |
| Total hatchery production entering the Delta [11] | 0.41 | 57,195 |
| Level of concern for naturally produced fish (1%) | | 1,662 |
| Level of concern for hatchery fish (0.5%) | | 286 |
| Incidental Take limit for Natural Production (2%) | | 3,324 |
| Incidental Take limit for hatchery production (1%) | | 572 |

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/ Average # eggs/female from weighted estimate based on two year and three old fish spawned at Livingston Stone Hatchery and in the carcass survey(Attachment A).

5/ Estimated mortality between egg and fry upstream of Red Bluff based on numbers of fry equivalents at RBDD divided by total number of eggs laid

6/ Egg to fry survival based on 1 minus the estimated loss on previous line

7/ Number of fry equivalents estimated on December 16, 2016 at RBDD – JPI – Bill Poytress, (USFWS), personal communication

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

9/ Average weighted survival of acoustically tagged winter-run in 2013, 2014 and 2015 (2 values in 2015) 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.

10/ LSNFH estimated release as of 12/16/16 (100% tagged and adipose clipped). 11/ Weighted average of acoustically tagged winter-run survival in 2013, 2014 and 2015 and 2016 (2 values in 2015 and 2016) between release location and I80/I50 Bridge in Sacramento, (Pat Brandes, USFWS and A. Ammann, NMFS, personal comm; Attachment B).

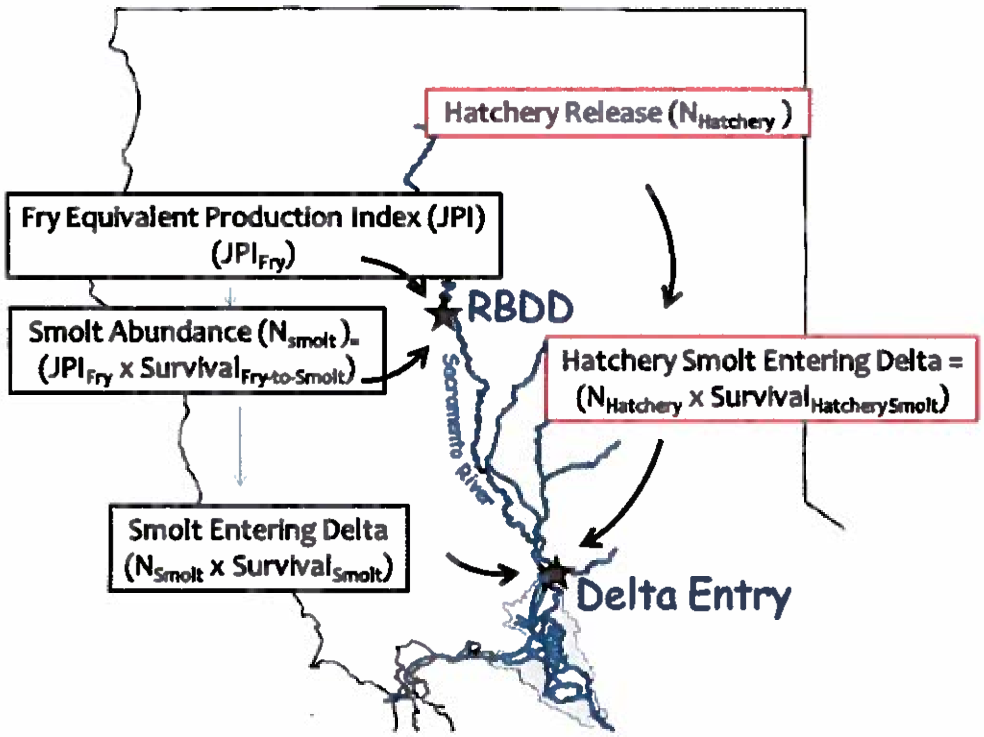



Figure 1: Location and formula's recommended for use in the JPE for the wild (black boxes) and hatchery (red boxes) components of the winter run population estimated in 2015-2016.

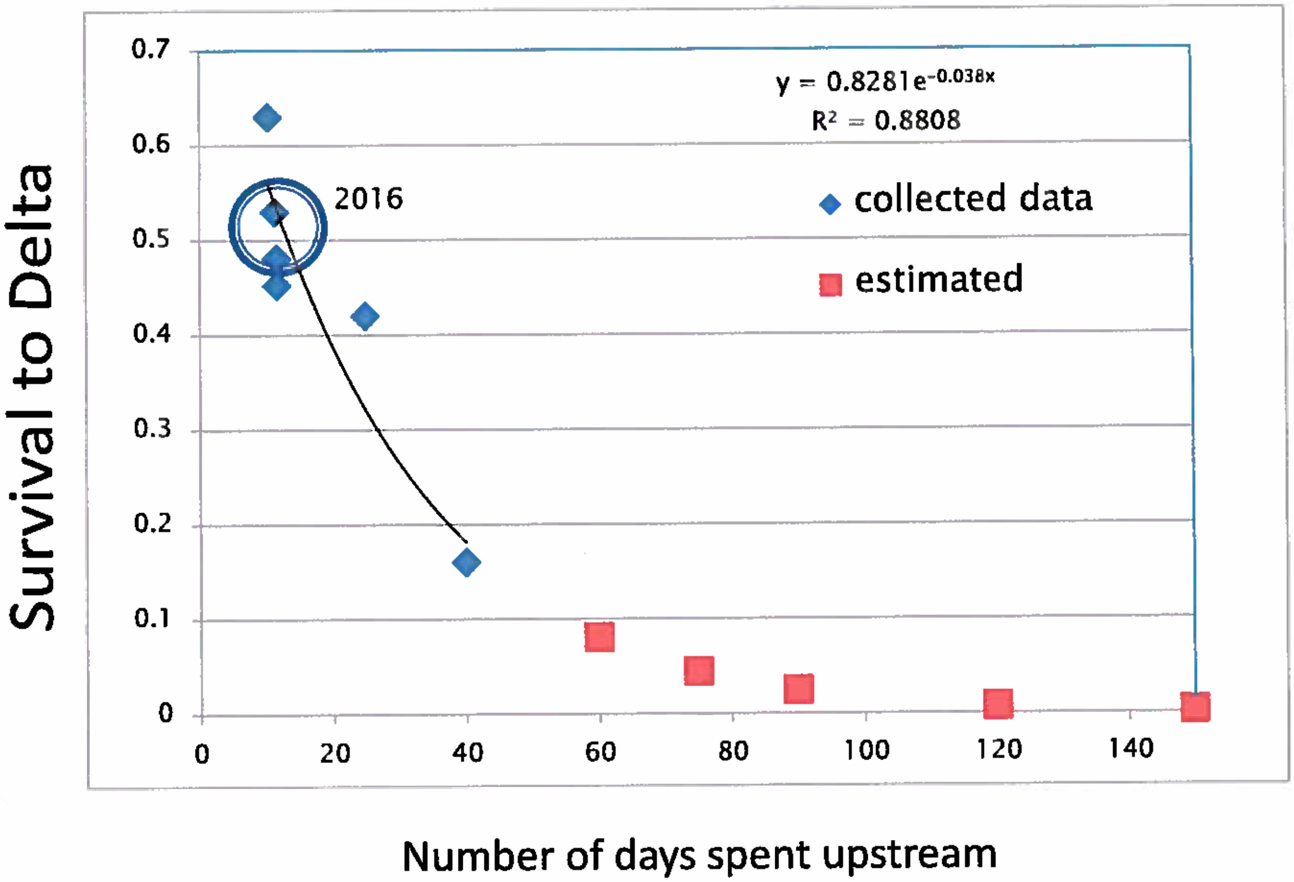



Figure 2: Relationship between the number of days spent upstream and survival to the Delta. Collected data has only been for 40 days spent upstream or less (diamonds). Survival data for greater than 40 days (squares) was estimated based on the relationship from actual data.

Attachment A

# United States Department of the Interior

FISH AND WILDLIFE SERVICE

Red Bluff Fish and Wildlife Office
10950 Tyler Road, Red Bluff, CA 96080
Phone: (530) 527-3043; FAX (530) 529-0292

In reply refer to:

Memorandum

DEC 15 2016

To: File

cc: Bill Poytress and Kevin Niemela, Program Managers, Red Bluff Fish and Wildlife Office

From: James G. Smith, Project Leader, Red Bluff Fish and Wildlife Office *James G. Smith*

Subject: Documentation of a change to the methodology of estimating winter-run Chinook egg-to-fry survival for brood-year 2016

An unusually and relatively large proportion of the female winter-run Chinook broodstock collected at the Keswick Dam Fish Trap in 2016 were age-2, in comparison to the lower proportion of age-2 fish observed in the natural spawning population. As a result of differing age compositions in the hatchery and natural spawning populations, the standard method of calculating juvenile winter-run Chinook egg-to-fry (ETF) survival rates using RBDD rotary trap fry-equivalent production estimates could produce a positively biased estimate of egg-to-fry survival. This memo documents changes to the methodology for calculating egg-to-fry survival for brood year 2016 juvenile winter-run Chinook, which are intended to correct for this apparent bias.

The standard methodology of estimating egg-to-fry survival of winter-run Chinook, which has been used since 1995 (Martin et al. 2001, Poytress et al. 2014, Poytress 2016), entails the use of average annual fecundity data from the Livingston Stone National Fish Hatchery (LSNFH; 2002-2015) multiplied by the number of natural spawning females, as estimated using the annual carcass survey. Annual fry-equivalent production values for winter-run Chinook (based on length-at-date criteria) are then divided by the product of the average fecundity and in-river female spawner estimates (Eq 1).

1. $$E\hat{T}F_w = \frac{J\hat{P}I_f}{S_f * (F_e)}$$

*where,*

$ETF_w$ = estimated egg-to-fry survival (winter-run Chinook)
$JPI_f$ = estimated fry-equivalent production
$S_f$ = estimated female spawners
$F_e$ = estimated in-river egg deposition

However, during September of 2016 fishery agency representatives from the IEP winter-run project work team met and agreed that the discrepancy of ages observed between winter-run Chinook that were used for hatchery broodstock and the natural spawning population would likely result in a positive bias of the estimated survival of juvenile winter-run Chinook. At the same meeting, it was determined that a more appropriate methodology for estimating the number of winter-run eggs deposited in the Sacramento River in 2016 would be to differentiate between the fecundity values of two different size classes of winter-run Chinook spawners (Attachment 1); generally fractionating the run into age-2 (i.e., "jill") and age-2+ (i.e., adult) length categories. A fork length break at 630 mm was determined to be an appropriate length to generally differentiate between jill and adult female winter-run Chinook in 2016. Fecundity estimates were then averaged separately for the two size classes of female spawners at LSNFH. Estimates of female winter-run Chinook spawning naturally were determined from length data resulting from the Upper Sacramento River winter-run Chinook carcass survey. The result is the application of two different egg counts for the two different size classes of females spawning naturally (Table 1). Two other methodologies were also considered and included in attachment 1.

Table 1. Average fecundity of female winter-run Chinook spawned at the LSNFH applied to two length categories from the winter-run Chinook carcass surveys in 2016.

| | | |
|---|---|---|
| Average Fecundity < 630mm (n=34) | | 3,140 |
| Average Fecundity ≥ 630mm (n=19) | | 4,043 |
| Estimated number naturally spawning females < 630mm | | 98 |
| Estimated number naturally spawning females ≥ 630mm | | 555 |
| Estimated egg deposition (in-river) | < 630mm | 307,720 |
| | ≥ 630mm | 2,243,865 |
| | **Total** | **2,551,585** |

For the 2016 winter-run Chinook ETF calculation, the above estimated value of **2,551,585** eggs in the river will be used as product of the two estimates of fecundity applied to two estimates of female spawners categorized by length. The 2016 RBDD fry-equivalent juvenile production index (JPI) will therefore be divided by the estimated egg deposition (in-river) value in Table 1 as follows (Eq 2):

$$2.\quad E\hat{T}F_w = \frac{J\hat{P}I_f}{((S_j * F_j) + (S_a * F_a))}$$

*where,*

$ETF_w$ = estimated egg-to-fry survival (winter-run Chinook)
$JPI_f$ = estimated fry-equivalent production
$S_j$ = estimated female spawners (<630 mm)
$F_j$ = estimated in-river egg deposition (<630 mm)
$S_a$ = estimated female spawners (≥630 mm)
$F_a$ = estimated in-river egg deposition (≥630 mm)

**Attachment 1. Comparison of three potential methods to estimate egg deposition by naturally spawning winter-run Chinook Salmon in the Sacramento River in 2016.**

The NMFS-NOAA Fisheries uses a spreadsheet model as one method to estimate the number of winter-run Chinook juveniles entering the Delta. This method considers the estimated abundance of eggs deposited by female winter-run Chinook spawners and subtracts estimates of mortality through the stages of incubation, hatching, swim-up, early-rearing, and emigration to the Delta. Implicit in calculating this estimate is knowledge of the abundance of eggs deposited by natural spawning winter-run Chinook.

In the past, the number of eggs deposited in the river has been estimated by multiplying the estimated number of naturally spawning female winter-run Chinook from the Winter Chinook Carcass Survey times the average fecundity of winter-run Chinook spawned at the LSNFH. The validity of this methodology assumes that the fecundity of winter-run Chinook females spawned at the LSNFH portrays an accurate representation of winter Chinook spawning in the Sacramento River. This assumption is generally believed to be valid because LSNFH broodstock typically consist of only natural origin fish and, as such, they are generally considered a representative subset of the natural spawning population. However, protocols for selecting hatchery broodstock in 2016 differed from typical years; in an effort to maintain a high-level of production, it was necessary to dramatically increase the use of hatchery origin broodstock in 2016. Thus, the fecundity of LSNFH broodstock spawned in 2016 may not provide an accurate representation of winter-run Chinook spawning naturally. For example, female winter-run Chinook broodstock at the LSNFH differed in length and origin compared to winter Chinook carcasses recovered from natural spawning areas of the Sacramento River. Seventy percent (n=39) of the female winter Chinook spawned at the LSNFH were of hatchery origin, whereas, hatchery fish are estimated to comprise only 30% (n=465) of the natural spawning winter Chinook. Sixty-four percent (n=36) of the female broodstock at the LSNFH were less than 630mm whereas, in natural spawning areas, females less than 630mm are estimated to comprise only 15% of the winter-run Chinook spawners. Because a strong relationship exists between body length and fecundity (Figure 1), these discordances between LSNFH broodstock and natural spawning winter Chinook may affect the validity of the assumption that the fecundity observed at LSNFH is representative of the fecundity of natural spawners.

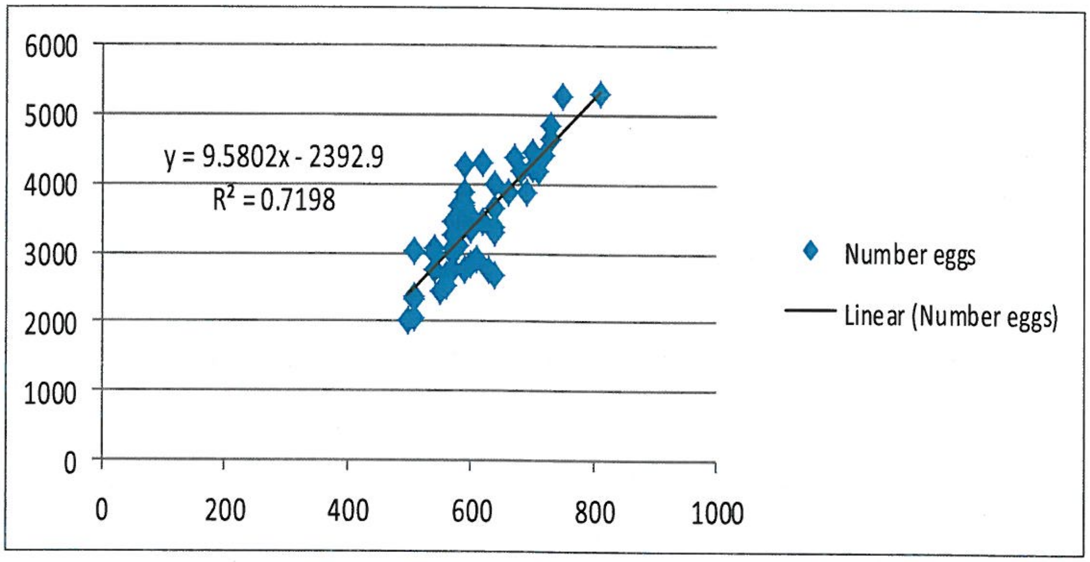
We evaluated three methodologies for estimating egg deposition through fecundity measures of natural spawning winter-run Chinook for comparison purposes. The three methodologies evaluated for estimating fecundity included the following: 1) the methodology used in most of the previous years, which consider the average fecundity of female winter-run Chinook spawned at LSNFH in the year of interest, 2) taking a 14-year average of the annual fecundity values gathered at LSNFH for the years 2002-2015 (Table 1), and 3) estimating fecundity for two size categories of female winter-run Chinook spawned at LSNFH, and then applying these two fecundity estimates to the appropriate fractions of natural spawning winter-run Chinook that fall within each size range.

The third methodology is equivalent to applying a weighted average of fecundity for two length categories of winter Chinook. The two length categories we used to categorize winter Chinook fecundity (small < 630mm; large ≥630mm) are based on the length delineation used by D. Killam (CDFW) to differentiate between age-2 and age-3 female winter Chinook observed on the 2016 carcass survey (Figure 1).

Table 1. Annual average number of eggs per winter-run Chinook female spawned at LSNFH between 2002 and 2015 with summary statistics below.

| **Year** | **Egg/Female** |
|---|---|
| 2002 | 4,820 |
| 2003 | 4,854 |
| 2004 | 5,200 |
| 2005 | 5,251 |
| 2006 | 5,382 |
| 2007 | 5,056 |
| 2008 | 5,424 |
| 2009 | 5,231 |
| 2010 | 5,161 |
| 2011 | 4,776 |
| 2012 | 4,364 |
| 2013 | 4,596 |
| 2014 | 5,191 |
| 2015 | 4,819 |
| min | 4,364 |
| **Ave** | **5,009** |
| max | 5,424 |
| **StDev** | **310** |

Figure 1. Linear regression of winter-run Chinook female spawner fork length and fecundity (number of eggs) in 2016 at Livingston Stone NFH.




By direct comparison, methods 1 and 3 result in the most similar estimates (Table 2). The method of applying separate estimates of fecundity for two different length categories of female winter-run Chinook yields an estimate of egg deposition that exceeds the estimate that considers an overall average of fecundity by 289,593 (12.8%). The method of using a historic average of 14 years of prior fecundity data results in a substantially greater number of eggs estimated to be deposited in the river at 1,008,885 (44.6%) and 719,292 (28.2%) when compared to methods 1 and 3, respectively.

Based upon observed differences in the characteristics of female winter Chinook broodstock at the LSNFH and natural spawning winter-run Chinook in the Sacramento River, we consider the length-based methodology to provide the most appropriate estimator of egg deposition for the 2016 spawning year. Although this change in methodology, we believe, results in values more reflective of in-river egg deposition, the overall difference between the Method 1 and 3 is rather small. Therefore, we believe that using this methodology in 2016 will not affect comparisons of annual survival between years.

Table 2. Numerical results of the three methods evaluated.

| | |
|---|---|
| **Method 1. Average fecundity of LSNFH spawners (2016).** | |
| Average Annual Fecundity at LSNFH (n=53) | 3,464 |
| Estimated number of females spawning naturally (minus DK pre-spawn adult morts (n= 5) | 653 |
| Estimated egg deposition | **2,261,992** |

| | |
|---|---|
| **Method 2. Historic annual average fecundity of LSNFH spawners (2002-2015).** | |
| Average Annual Fecundity at LSNFH (n=14) | 5,009 |
| Estimated number of females spawning naturally (minus DK pre-spawn adult morts (n= 5) | 653 |
| Estimated egg deposition | **3,270,877** |

| | | |
|---|---|---|
| **Method 3. Average fecundity applied to two length categories of female winter-run Chinook spawned at LSNFH (2016).** | | |
| Average Fecundity <630 mm FL (n=34) | | 3,140 |
| Average Fecundity >/=630 mm FL (n=19) | | 4,043 |
| Estimated number of naturally spawning females <630 mm FL | | 98 |
| Estimated number of naturally spawning females >/=630 mm FL (minus DK pre-spawn adult morts (n= 5) | | 555 |
| Estimated egg deposition <630 mm FL | | 307,720 |
| Estimated egg deposition >/=630 mm FL | | 2,243,865 |
| | **Total** | **2,551,585** |

Attachment B: Estimates of survival of hatchery winter run from acoustic tag fish for 2013-2016.
Request by Pat Brandes and Noble Hendrix for use in JPE.
Date Produced: 10/24/2016
From: Arnold Ammann NOAA Fisheries ERD Santa Cruz lab, data from JSATS acoustic tagging and tracking of hatchery winter-run out migration

| | | | | | | | **Cumulative CJS survival estimates with error calculated using Delta Method with RMark: SaltCk to Sac I80/50 Bridge** | | | | **Cumulative CJS survival estimates with error calculated using Delta Method with RMark: Release to Sac I80/50 Bridge** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Study** | **Run** | **release date** | **Number AT fish released in Redding** | **Number fish to SaltCk*** | **Number fish to Sac I80/50 Bridge**** | **Survival** | **SE** | **LCI** | **UCI** | **Survival** | **SE** | **LCI** | **UCI** |
| 2016 | LSNFH - Pooled | Winter-run | 2/17, 2/18 | 570 | 538 | 288 | 0.535 | 0.022 | 0.493 | 0.577 | 0.505 | 0.021 | 0.464 | 0.546 |
| 2016 | LSNFH - rel 1 | Winter-run | 2/17/2016 18:00 | 285 | 273 | 137 | 0.502 | 0.030 | 0.443 | 0.561 | 0.481 | 0.030 | 0.426 | 0.539 |
| 2016 | LSNFH - rel 2 | Winter-run | 2/18/2016 18:30 | 285 | 265 | 151 | 0.570 | 0.030 | 0.509 | 0.628 | 0.530 | 0.030 | 0.472 | 0.587 |
| 2015 | LSNFH - Pooled | Winter-run | 2/4,2/6/2015 | 567 | 471 | 269 | 0.571 | 0.023 | 0.526 | 0.615 | 0.474 | 0.021 | 0.434 | 0.516 |
| 2015 | LSNFH - rel 1 | Winter-run | 2/4/2015 17:30 | 249 | 230 | 105 | 0.457 | 0.033 | 0.393 | 0.521 | 0.422 | 0.031 | 0.362 | 0.484 |
| 2015 | LSNFH - rel 2 | Winter-run | 2/6/2015 17:30 | 318 | 241 | 164 | 0.680 | 0.030 | 0.619 | 0.736 | 0.516 | 0.028 | 0.461 | 0.570 |
| 2014 | LSNFH | Winter Run | 2/10/2014 17:30 | 358 | 325 | 135 | 0.415 | 0.027 | 0.363 | 0.470 | 0.374 | 0.026 | 0.326 | 0.426 |
| 2013 | LSNFH | Winter Run | 2/7/2013 17:30 | 148 | 137 | 22 | 0.161 | 0.031 | 0.108 | 0.232 | 0.149 | 0.029 | 0.100 | 0.215 |

Note: SaltCk is 4.77 river km downstream of Red Bluff Diverson Dam
Note: sample of hatchery fish implanted with 0.42 to 0.30 gram JSATS transmitters. Size ranged from 95-100mmFL.
* total of all fish detect at or below SaltCk receiver location
** total of all fish detected at or below Sacramento I80/50 Bridge (or Tower Bridge) receiver location

X = w2013*s2013+w2014*s2014+w2015*s2015+w2016*s2016

wi= 1/var (i)/(1/var(2013)+1/var(2014)+1/var(2015)+1/var(2016)

Weighted averages: calculated by Pat Brandes 12/5/16

Salt Creek to I80/50 bridge

| | var | 1/var | w | s | +w*s" | |
|---|---|---|---|---|---|---|
| 2016 | 0.0005 | 2066.115702 | 0.324412 | 0.535 | 0.17356 | |
| 2015 | 0.000529 | 1890.359168 | 0.296816 | 0.571 | 0.169482 | |
| 2014 | 0.000729 | 1371.742112 | 0.215385 | 0.415 | 0.089385 | |
| 2013 | 0.0010 | 1040.582726 | 0.163388 | 0.161 | 0.026305 | |
| | | 6368.79971 | | | 0.458732 | salt creek to I80/50 bridge |

| | var | 1/var | w | s | +w*s" | |
|---|---|---|---|---|---|---|
| 2016 | 0.0004 | 2267.574 | 0.314788 | 0.505 | 0.158968 | |
| 2015 | 0.0004 | 2267.574 | 0.314788 | 0.474 | 0.149209 | |
| 2014 | 0.0007 | 1479.29 | 0.205357 | 0.374 | 0.076804 | |
| 2013 | 0.0008 | 1189.061 | 0.165067 | 0.149 | 0.024595 | |
| | | 7203.498 | | | 0.409576 | Release to I80 bridge |