BROOD YEAR 2018 JUVENILE SALMONID PRODUCTION AND PASSAGE INDICES AT RED BLUFF DIVERSION DAM

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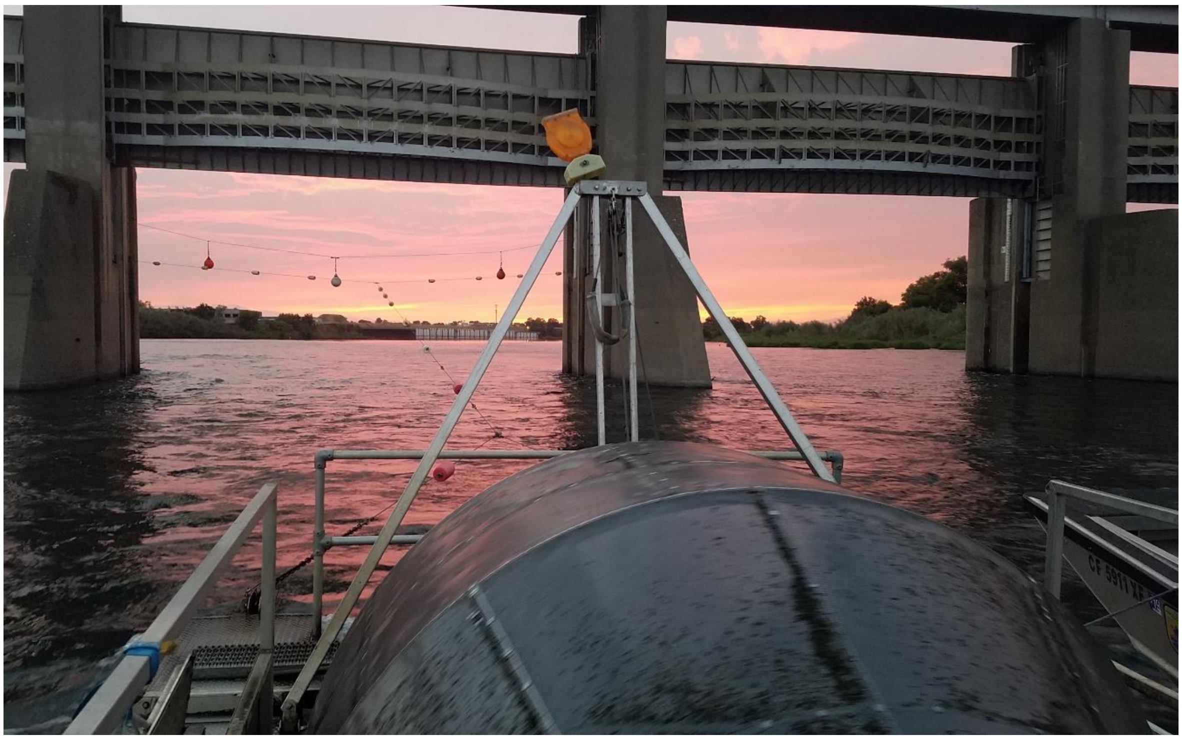

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Brood year 2018 juvenile salmonid production and passage indices at Red Bluff Diversion Dam.

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Abstract.— Brood year 2018 (BY2018) juvenile winter Chinook salmon estimated passage at Red Bluff Diversion Dam (RBDD) was 1,168,263 for fry and pre-smolt/smolts combined. The fry-equivalent rotary trap juvenile production index (JPI) was the highest value reported in the last five years; estimated at 1,477,529 with the lower and upper 90% confidence intervals (CI) extending from 824,706 to 2,130,352 juveniles, respectively. The estimated egg-to-fry (ETF) survival rate, based on the BY2018 winter Chinook fry-equivalent JPI was 26.6%, slightly above the 21-year average ETF survival rate of 25.0%. The range of ETF survival rates based on the 90% CI were 14.9% to 38.4%.

From analyses of mark-recapture trials conducted in the fall of 2018 with naturally produced winter Chinook fry, it was discovered that sampling four traps across the RBDD transect produced efficiency values higher than our regression model predicted due to a high rate of efficiency of one particular trap sampling the thalweg. Passage estimates for the months of September and October 2018 were therefore revised using data from three traps rather than four. Further, revisions were made following genetic analyses of fin clips taken from juvenile length-at-date (LAD) spring and winter Chinook in the fall of 2018.

Although little rainfall was received during the water year until March of 2018, precipitation and carry-over storage provided adequate cold-water pool availability in Shasta Reservoir. Thus, efforts to follow the 2018 Sacramento River temperature management plan were largely successful.

BY2018 juvenile spring Chinook salmon estimated passage was 303,154 fry and pre-smolt/smolts combined. The fry-equivalent JPI for 2018 spring Chinook was 495,489 with the lower and upper 90% CI extending from -191,811 to 1,182,788 juveniles, respectively. BY2018 fall Chinook juvenile estimated passage at RBDD was 6,051,567 fry and pre-smolt/smolts combined. The fry-equivalent JPI for 2018 fall Chinook was 6,837,157 with the lower and upper 90% CI extending from 1,108,574 to 12,565,741 juveniles, respectively. BY2018 late-fall Chinook juvenile estimated passage at RBDD was 48,111 fry and pre-smolt/smolts combined. The fry-equivalent JPI for BY2018 late-fall was 81,629 with the lower and upper 90% CI extending from 27,505 to 135,753 juveniles, respectively.

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Introduction

The United States Fish and Wildlife Service (USFWS) has conducted direct monitoring of juvenile Chinook salmon, *Oncorhynchus tshawytscha* passage at Red Bluff Diversion Dam (RBDD) river kilometer (RK) 391 on the Sacramento River, California since 1994 (Johnson and Martin 1997). Martin et al. (2001) developed quantitative methodologies for indexing juvenile Chinook passage using rotary-screw traps (RST) to assess the impacts of the United States Bureau of Reclamation's (USBR) RBDD Research Pumping Plant. Absolute abundance (production and passage) estimates were needed to determine the level of impact from the entrainment of salmonids and other fish community populations through RBDD's experimental 'fish friendly' Archimedes and internal helical pumps (Borthwick and Corwin 2001). The original project objectives were met by 2000 and funding of the project was discontinued.

From 2001 to 2008, funding was secured through a CALFED Bay-Delta Program grant for annual monitoring operations to determine the effects of restoration activities in the upper Sacramento River aimed primarily at winter Chinook salmon[1]. The USBR, the primary proponent of the Central Valley Project (CVP), has funded this project since 2010 due to regulatory requirements contained within the National Marine Fisheries Service's (NMFS) Biological Opinion for the Long-term Operations of the CVP and State Water Project (NMFS 2009).

Protection, restoration, and enhancement of anadromous fish populations in the Sacramento River and its tributaries are important elements of the Central Valley Project Improvement Act (CVPIA), Section 3402. The CVPIA has a specific goal to double populations of anadromous fishes in the Central Valley of California. Juvenile salmonid production monitoring is an important component authorized under Section 3406 (b) (16) of CVPIA (USFWS 1997) and has funded many anadromous fish restoration actions which were outlined in the CVPIA Anadromous Fisheries Restoration Program (AFRP) Working Paper (USFWS 1995), and Final Restoration Plan (USFWS 2001).

Martin et al. (2001) stated that RBDD was an ideal location to monitor juvenile winter Chinook production because (1) the spawning grounds occur almost exclusively above RBDD (Vogel and Marine 1991; Snider et al. 1997, USFWS 2011), (2) multiple traps could be attached to the dam and sampled simultaneously across a transect, and (3) operation of the dam could control channel morphology and hydrological characteristics of the sampling area providing for consistent sampling conditions for measuring juvenile fish passage.

Since 2002, the USFWS RST winter Chinook juvenile production indices (JPI's) have been used in support of production estimates generated from carcass survey derived adult

[1] The National Marine Fisheries Service first listed Winter-run Chinook salmon as threatened under the emergency listing procedures for the ESA (16 U.S.C.R. 1531-1543) on August 4, 1989 (54 FR 32085). A proposed rule to add winter Chinook salmon to the list of threatened species beyond expiration of the emergency rule was published by the NMFS on March 20, 1990 (55 FR 10260). Winter Chinook salmon were formally added to the list of federally threatened species by final rule on November 5, 1990 (55 FR 46515), and they were listed as a federally endangered species on January 4, 1994 (59 FR 440).

escapement data using NMFS' Juvenile Production Estimate (JPE) Model. Since 2014, the RBDD winter Chinook fry-equivalent JPI has been used as the basis of the NMFS' JPE Model. Moreover, RBDD JPI's are compared to adult escapement to evaluate adult spawning success in relationship to annual Sacramento River water temperature and flow management plans.

Fall, late-fall, spring, and winter Chinook salmon and steelhead/Rainbow Trout, *Oncorhynchus mykiss* spawn in the Sacramento River and tributaries upstream of RBDD throughout the year, resulting in year-round juvenile salmonid passage (Moyle 2002). Sampling of juvenile anadromous fish at RBDD allows for year-round quantitative production and passage estimates of all runs of Chinook salmon and steelhead/Rainbow Trout. Timing and abundance data have been provided in real-time for fishery and water operations management purposes of the CVP since 2004[2]. Since 2009, 90% confidence intervals, indicating uncertainty in weekly passage estimates, have been included in real-time bi-weekly reports to allow better management of available water resources and to reduce impact of CVP operations on both federal Endangered Species Act (ESA) listed and non-listed salmonid stocks. Currently, Sacramento River winter Chinook salmon are ESA-listed as endangered and Central Valley spring Chinook salmon and Central Valley steelhead (hereafter *O. mykiss)* are listed as threatened.

The objectives of this annual progress report are to: (1) summarize the estimated abundance of all four runs of Chinook salmon and *O. mykiss* passing RBDD for brood year (BY) 2018, (2) define temporal patterns of abundance for all anadromous salmonids passing RBDD, (3) correlate juvenile salmon production with adult salmon escapement estimates (where appropriate), and (4) describe various life-history attributes of anadromous juvenile salmonids produced in the upper Sacramento River as determined through long-term monitoring efforts at RBDD. This annual progress report addresses, in detail, our juvenile salmonid monitoring activities at RBDD for the period January 1, 2018 through November 30, 2019. This report includes JPI's for the 2018 brood year emigration period for the four runs of Chinook salmon and passage estimates of *O. mykiss* in the Sacramento River and is submitted to the US Bureau of Reclamation to comply with contractual reporting requirements for funds received through the Fish and Wildlife Coordination Act of 1934 under Interagency Agreement No. R15PG00067.

Study Area

The Sacramento River originates in northern California near Mt. Shasta from the springs of Mt. Eddy (Hallock et al. 1961). It flows south through 600 kilometers (km) of the state draining numerous slopes of the Coast, Klamath, Cascade, and Sierra Nevada ranges and eventually reaches the Pacific Ocean via San Francisco Bay (Figure 1). Shasta Dam and its associated downstream flow regulating structure, Keswick Dam, have formed a complete barrier to upstream anadromous fish passage since 1943 (Moffett 1949). The 95 River Kilometer (RK) reach between Keswick Dam (RK 486) and RBDD (RK 391) supports areas of intact riparian vegetation and largely remains unobstructed. Within this reach, several major tributaries to

[2] Real-time biweekly reports for download located at: http://www.fws.gov/redbluff/rbdd_biweekly_final.html

the Sacramento River upstream of RBDD support various Chinook salmon spawning populations. These include Clear Creek and Cottonwood Creek (including Beegum Creek) on the west side of the Sacramento River and Cow Creek, Bear Creek, Battle Creek and Payne's Creek on the east side (Figure 1). Below RBDD, the river encounters greater anthropogenic impacts as it flows south to the Sacramento-San Joaquin Delta. Impacts include, but are not limited to, channelization, water diversion, agricultural and municipal run-off, and loss of associated riparian vegetation.

RBDD is located approximately 3-km southeast of the city of Red Bluff, California (Figure 1). The RBDD is 226 meters (m) wide and composed of eleven, 18-m wide fixed-wheel gates. Between gates are concrete piers 2.4-m in width. The USBR's dam operators were able to raise the RBDD gates allowing for run-of-the-river conditions or lower them to impound and divert river flows into the Tehama-Colusa and Corning canals. USBR operators generally raised the RBDD gates from September 16 through May 14 and lowered them May 15 through September 15 during the years 2002-2008. As of spring 2009, the RBDD gates were no longer lowered prior to June 15 and were raised by the end of August or earlier in an effort to reduce the impact to spring Chinook salmon and Green Sturgeon, *Acipenser medirostris* (NMFS 2009). Since fall 2011, the RBDD gates have remained in the raised position due to the construction of a riverside pumping facility and fish screen (NMFS 2009). Adult and juvenile anadromous fish currently have unrestricted upstream and downstream passage through this reach of the Sacramento River. The RBDD conveyance facilities were relinquished to the Tehama Colusa Canal Authority (TCCA) by USBR as of spring 2012. The RBDD gates were permanently raised and infrastructure decommissioned in 2015.

Methods

Sampling Gear.—Sampling was conducted along a transect using three to four 2.4-m diameter RSTs (E.G. Solutions® Corvallis, Oregon) attached via aircraft cables directly to RBDD. The horizontal placement of rotary traps across the transect varied throughout the study period but generally sampled in the river-margins (east and west) and mid-channel habitats simultaneously (Figure 2). RSTs were positioned within these spatial zones unless sampling equipment failed, river depths were insufficient (< 1.2m), or river hydrology restricted our ability to sample with all traps (water velocity < 0.6 m/s).

Sampling Regimes.—In general, RSTs sampled continuously throughout 24-hour periods and samples were processed once daily[3]. During periods of high fish abundance, elevated river flows, or heavy debris loads, traps were sampled multiple times per day, continuously, or at randomly generated periods to reduce incidental mortality. When abundance of Chinook salmon was very high, sub-sampling protocols were implemented to reduce take and incidental mortality of listed species in accordance with NMFS' ESA Section 10(a)(1)(A) research permit terms and conditions. The specific sub-sampling protocol implemented was contingent upon the number of Chinook captured or the probability of successfully sampling various river

[3] 24-hr sample periods were defined as beginning at 0700 on day 1 and ending at 0659 on day 2.

conditions. Initially, RST cones were structurally modified to sample one-half of the normal volume of water entering the cones (Gaines and Poytress 2004). If further reductions in capture were necessary, the number of traps sampled were reduced from four to three. During storm events and associated elevated river discharge levels, each 24-hour sampling period was divided into four or six non-overlapping strata and one or two strata were randomly selected for sampling (Martin et al 2001). Estimates were extrapolated to un-sampled strata by dividing catch by the strata-selection probability (i.e., $P = 0.25$ or 0.17). If further reductions in effort were needed or river conditions were intolerable, sampling was discontinued or not conducted. When days or weeks were not sampled, mean daily passage estimates were imputed for missed days based on weekly or monthly interpolated mean daily estimates, respectively.

Data Collection.— All fish captured were anesthetized, identified to species, and enumerated with fork lengths (FL) measured to the nearest millimeter (mm). When capture of Chinook juveniles exceeded approximately 200 fish/trap, a random sub-sample of the catch was measured to include approximately 100 individuals, with all additional fish being enumerated and recorded. Chinook salmon race was field assigned using length-at-date (LAD) criteria developed by Greene (1992)[4]. Fin clips of juvenile salmonids >34 mm FL were sampled at a maximum rate of 10 fish, per run, per day for genetic analyses (Appendix 1) and potential run identification corrections.

Other data collected at each trap servicing included: length of time sampled, velocity of water immediately in front of the cone at a depth of 0.6-m, and depth of cone "opening" submerged. Water velocity was measured using a General Oceanic® Model 2030 flowmeter. These data were used to calculate the volume of water sampled by traps (X). The percent river volume sampled by traps (%Q) was estimated as the ratio of river volume sampled to total river volume passing RBDD. River volume (Q) was obtained from the California Data Exchange Center's Bend Bridge gauging station at RK 415 (USGS site no. 11377100, http://waterdata.usgs.gov/usa/nwis/uv?site_no=11377100). Daily river volume at RBDD was adjusted from Bend Bridge river flows by subtracting daily TCCA diversions, when diversions occurred.

Sampling Effort.—Weekly rotary trap sampling effort was quantified by assigning a value of 1.00 to a week consisting of four 2.4-m diameter rotary-screw traps sampling 24 hours daily, 7 days per week. Weekly values <1.00 represented occasions when less than four traps were sampling, one or more traps were structurally modified to sample only one-half the normal volume of water or when less than 7 days per week were sampled.

Mark-Recapture Trials.—Chinook salmon collected as part of daily samples were marked with bismark brown staining solution (Mundie and Traber 1983) prepared at a concentration of 21.0 mg/L of water. Fish were stained for a period of 45-50 minutes, removed, and allowed to recover in fresh water. Marked fish were held for 6-24 hours before being released

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[4] Generated by Sheila Greene, California Department of Water Resources, Environmental Services Office, Sacramento (May 8, 1992) from a table developed by Frank Fisher, California Department of Fish and Game, Inland Fisheries Branch, Red Bluff (revised February 2, 1992). Fork lengths with overlapping run assignments were placed with the latter spawning run.

approximately 4-km upstream from RBDD after official sunset. Recapture of marked fish was recorded for up to three days after release. Trap efficiency was calculated based on the proportion of recaptures to total fish released (i.e., mark-recapture trials). Trials were conducted as fish numbers and staffing levels allowed under a variety of river discharge levels and trap effort combinations.

Trap Efficiency Modeling.—To develop a trap efficiency model, mark-recapture trials were conducted as noted above. Estimated trap efficiency (i.e., the proportion of the juvenile population passing RBDD captured by traps; $\hat{T}_d$) was modeled with *%Q* to develop a simple least-squares regression equation (eq. 5). The equation (slope and intercept) was then used to estimate daily trap efficiencies based on daily proportion of river volume sampled. Each successive year of mark-recapture trials were added annually to the original trap efficiency model developed by Martin et al. (2001) on July 1 of each year. Since 2014, the trap efficiency model has been updated to include naturally produced fish sampled during monitoring activities without the RBDD gates in the lowered position (Poytress et al. 2014, Poytress 2016). The model for BY2018 relied on 79 mark-recapture trials using wild fish and conducted with the RBDD gates raised between 2002 and 2017 (r^2 = 0.70, P < 0.001, df = 78; Figure 3).

Daily Passage Estimates ($\hat{P}_d$).—The following procedures and formulae were used to derive daily and weekly estimates of total numbers of unmarked Chinook and *O. mykiss* passing RBDD. We defined C_{di} as catch at trap i (i = 1,…,t) on day d (d = 1,…,n), and X_{di} as volume sampled at trap i (i = 1,…t) on day d (d = 1,…n). Daily salmonid catch and water volume sampled were expressed as:

1.

$$C_d = \sum_{i=1}^{t} C_{di}$$

and,

2.

$$X_d = \sum_{i=1}^{t} X_{di}$$

The *%Q* was estimated from the ratio of water volume sampled (X_d) to river discharge (Q_d) on day d.

3.

$$\%\hat{Q}_d = \frac{X_d}{Q_d}$$

Total salmonid passage was estimated on day d (d = 1,…,n) by

4.

$$\hat{P}_d = \frac{C_d}{\hat{T}_d}$$

where,

5.

$$\hat{T}_d = (\alpha)(\%\hat{Q}_d) + b$$

and, $\hat{T}_d$ = estimated trap efficiency on day *d*.

Weekly Passage ($\hat{P}$).—Population totals for numbers of Chinook and *O. mykiss* passing RBDD each week were derived from $\hat{P}_d$ where there are *N* days within the week:

6.

$$\hat{P} = \frac{N}{n}\sum_{d=1}^{n}\hat{P}_d$$

Estimated Variance.—

7.

$$Var(\hat{P}) = \left(1 - \frac{n}{N}\right)\frac{N^2}{n}s^2_{\hat{P}_d} + \frac{N}{n}\left[\sum_{d=1}^{n} Var(\hat{P}_d) + 2\sum_{i\neq j}^{n} Cov(\hat{P}_i, \hat{P}_j)\right]$$

The first term in eq. 7 is associated with sampling of days within the week.

8.

$$s^2_{\hat{P}_d} = \frac{\sum_{d=1}^{n}\left(\hat{P}_d - \hat{\bar{P}}\right)^2}{n-1}$$

The second term in eq. 7 is associated with estimating $\hat{P}_d$ within the day.

9.

$$Var(\hat{P}_d) = \frac{\hat{P}_d\,(1-\hat{T}_d)}{\hat{T}_d} + Var\,(\hat{T}_d)\frac{\hat{P}_d(1-\hat{T}_d) + \hat{P}_d^2\hat{T}_d}{\hat{T}_d^3}$$

where,

10. *Var($\hat{T}_d$)* = error variance of the trap efficiency model

The third term in eq. 7 is associated with estimating both $\hat{P}_i$ and $\hat{P}_j$ with the same trap efficiency model.

11.

$$Cov(\hat{P}_i, \hat{P}_j) = \frac{Cov(\hat{T}_i, \hat{T}_j)\hat{P}_i\hat{P}_j}{\hat{T}_i\hat{T}_j}$$

where,

12. $$Cov(\hat{T}_i, \hat{T}_j) = Var(\hat{\alpha}) + \chi_i Cov(\hat{\alpha}, \hat{\beta}) + \chi_j Cov(\hat{\alpha}, \hat{\beta}) + \chi_i\chi_j Var(\hat{\beta})$$

for some

$$\hat{T}_i = \hat{\alpha} + \hat{\beta}\chi_i$$

Confidence intervals (CI) were constructed around $\hat{P}$ using eq. 13.

13.

$$P \pm t_{\frac{\alpha}{2}, n-1}\sqrt{Var(\hat{P})}$$

Annual JPI's were estimated by summing $\hat{P}$ across weeks.

14.

$$JPI = \sum_{week=1}^{52} \hat{P}$$

Fry-Equivalent Chinook Production Estimates.—The ratio of Chinook fry (<46 mm FL) to pre-smolt/smolts (>45 mm FL) passing RBDD was variable among years. Therefore, we standardized juvenile production by estimating a fry-equivalent JPI for among-year comparisons. Fry-equivalent JPI's were estimated by the summation of fry JPI and a weighted (1.7:1) pre-smolt/smolt JPI (inverse value of 59% fry-to-pre-smolt/smolt survival; Hallock undated). Rotary trap JPI's could then be directly compared to determine variability in production between years.

Egg-to-fry survival estimates.— Annual juvenile winter and fall Chinook egg-to-fry (ETF) survival rates were estimated by calculating fry-equivalent JPI's and dividing by the estimated number of eggs deposited in-river. Winter Chinook adult data were derived from carcass survey estimates (D. Killam, CDFW, personal communication). Fall Chinook female spawner data were estimated using adult escapement estimates derived from the California Department of Fish and Wildlife's (CDFW) Grandtab data set (Azat 2019) and calculating female spawners based on sex ratios obtained from Coleman National Fish Hatchery (CNFH). Average female winter Chinook fecundity data were obtained from the Livingston Stone National Fish Hatchery and fall Chinook fecundity estimates were obtained from CNFH annual spawning records.

Reducing bias associated with unmarked CNFH fall Chinook.—Annual releases of 75% unmarked fall Chinook from CNFH in the late winter to early spring months can impart positive bias to naturally produced spring and fall run Chinook passage and production estimates (Voss and Poytress 2019). In most years, CNFH fall Chinook are released at lengths that overlap with the spring Chinook LAD size category. Therefore, unmarked hatchery fish captures during and after CNFH fall Chinook production releases can affect fry to smolt size ratios, fry equivalent values, as well as ETF survival rates for both spring and fall LAD Chinook. In an effort to reduce bias to spring and fall Chinook natural production and passage estimates, daily captures of *marked* hatchery fall Chinook assigned to spring or fall Chinook runs using LAD criteria were multiplied by a factor of 3 to estimate unmarked hatchery fish within daily catch. These adjusted daily values were then subtracted from unmarked Chinook catch totals and daily passage estimates for each run were subsequently calculated. If adjusted daily passage of unmarked hatchery Chinook was greater than the original unmarked Chinook daily passage value, that day was given a value of zero for natural Chinook passage. After daily passage estimates were recalculated to exclude unmarked hatchery Chinook passage, weekly passage estimates and confidence intervals were recalculated. The efforts to reduce bias associated with unmarked CNFH fall Chinook fish were made post hoc to correct annual estimates and are not reflected in passage estimates reported within real-time biweekly reports. For clarity, passage and production estimates with and without the removal of hatchery fish are reported for fall and spring Chinook.

Results

Sampling effort.—Weekly sampling effort throughout the BY2018 winter Chinook salmon emigration period ranged from 0.00 to 1.00 ($\bar{x}$ = 0.67; *N* = 52 weeks; Table 1). Weekly sampling effort ranged from 0.50 to 1.00 ($\bar{x}$ = 0.80; *N* = 26 weeks) between July and the end of December, the period of greatest juvenile winter Chinook emigration, and 0.00 to 1.00 ($\bar{x}$ = 0.54; *N* = 26 weeks) during the latter half of the emigration period (Table 1).

Weekly sampling effort throughout the BY2018 spring Chinook emigration period ranged from 0.00 to 1.00 ($\bar{x}$ = 0.67; *N* = 52 weeks; Table 2). Weekly sampling effort ranged from 0.00 to 1.00 ($\bar{x}$ = 0.53; *N* = 26 weeks) between mid-October and mid-April, the period of greatest juvenile spring Chinook emigration, and 0.43 to 1.00 ($\bar{x}$ = 0.81; *N* = 26 weeks) during the latter half of the emigration period (Table 2).

Weekly sampling effort throughout the BY2018 fall Chinook emigration period ranged from 0.00 to 1.00 ($\bar{x}$ = 0.67; *N* = 52 weeks; Table 3). Weekly sampling effort ranged from 0.00 to 1.00 ($\bar{x}$ = 0.51; *N* = 26 weeks) between December and the end of May, the first half of the juvenile fall Chinook 2018 brood year, and 0.43 to 1.00 ($\bar{x}$ = 0.83; *N* = 26 weeks) during the latter half of the emigration period (Table 3).

Weekly sampling effort throughout the BY2018 late-fall Chinook emigration period ranged from 0.00 to 1.00 ($\bar{x}$ = 0.65; *N* = 52 weeks; Table 4). Weekly sampling effort ranged from 0.43 to 1.00 ($\bar{x}$ = 0.75; *N* = 26 weeks) between April and the end of September, the first half of the juvenile late-fall Chinook 2018 brood year, and 0.00 to 1.00 ($\bar{x}$ = 0.65; *N* = 26 weeks) during the latter half of the emigration period (Table 4).

Weekly sampling effort throughout the BY2018 *O. mykiss* emigration period ranged from 0.43 to 1.00 ($\bar{x}$ = 0.74; *N* = 52 weeks; Table 5). Weekly sampling effort ranged from 0.43 to 1.00 ($\bar{x}$ = 0.69; *N* = 26 weeks) between January and the end of June, the first half of the juvenile *O. mykiss* 2018 brood year, and 0.50 to 1.00 ($\bar{x}$ = 0.80; *N* = 26 weeks) during the latter half of the emigration period (Table 5).

The high variance in sampling effort throughout the reporting period was attributed to several sources. They included: (1) intentional reductions in effort resulting from sampling < 4 traps, cone modification(s), non-sampled days due to hatchery releases upstream of the transect or staffing limitations, (2) unintentional reductions in effort resulting from high flows and debris loads, (3) Section 10(a)(1)(A) permit catch limitations.

Mark-recapture trials.—Five mark-recapture trials were conducted in 2018 to estimate and validate RST efficiency. Three trials were conducted in October using naturally produced winter Chinook and two trials using naturally produced fall Chinook were conducted in late December. Sacramento River discharge sampled during the trials ranged from 5,498 to 7,747 cubic feet per second (cfs). Estimated *%Q* during trap efficiency trials ranged from 2.01% to 4.77% ($\bar{x}$ = 3.05%; Table 6).

Trials (*N* =5) were conducted using three or four traps with rotary traps sampling with unmodified cones for four of the five trials. All trials were conducted using Chinook sampled from rotary traps, and trap efficiencies ranged from 2.62% to 3.85% ($\bar{x}$ = 3.41%). The number of marked fish released per trial ranged from 1,073 to 1,247 ($\bar{x}$ = 1,147) and the number of marked fish recaptured ranged from 30 to 48 ($\bar{x}$ = 39). All fish were released after sunset and 99.5% of recaptures occurred within the first 24 hours, and 100% within 48 hrs.

Sub-sampled fork lengths of fish marked and released ranged from 30 to 62 mm ($\bar{x}$ = 36.5 mm). Fork lengths of recaptured marked fish ranged from 32 to 55 mm ($\bar{x}$ = 36.3 mm). The distribution of fork lengths of fish marked and released in mark-recapture trials was commensurate with the distribution of fork lengths of fish recaptured by RSTs and fish used were largely considered fry size class (97.3% fry, 2.7% pre-smolts).

Fish collected and used for all trials were obtained from all three spatial zones, east-margin, mid-channel and west-margin traps. The horizontal distribution of recaptured marked fish followed the catch distribution of unmarked fish well for three of the five trials (trials 2, 3, 4; Table 6). The other two trials showed slightly higher proportions of marked fish in the mid-channel traps compared to unmarked fish that had captures favoring the west margin trap over the mid-channel traps. It is believed that these differences in horizontal distribution during the first and last trials were likely a product of daily variability in movement patterns as wild fish captures often favor the mid-channel traps one day and shift to favoring the west margin trap the following day.

Trap efficiency modeling.— Elevated river flows and low fall Chinook catch numbers did not allow the opportunity to conduct mark-recapture trials for incorporation into the winter

Chinook 2018 brood year. A 79-trial model ($r^2 = 0.70$, $P < 0.001$, df = 78; Figure 4) was employed for passage estimation during the entire BY2018 winter Chinook, late-fall Chinook and *O. mykiss* outmigration period and part of the BY2018 spring Chinook and fall Chinook outmigration period covered in this report. Three mark-recapture trials using winter Chinook fry were conducted near the end of the reporting period in the fall of 2018; however, these and two additional fall Chinook fry efficiency trials conducted in late December 2018 were incorporated into the model at the start of the 2019 winter Chinook brood year.

Genetic corrections to LAD run assignments.—Genetic tissue samples from up to ten Chinook salmon per run, according to LAD, were collected on a daily basis as part of two genetic sampling projects known as "Improving Vital Rates Estimation Using Parentage-Based Mark Recapture Methods" and "Central Valley Salmonid Coordinated Genetic Monitoring Project". Samples collected from LAD winter and spring Chinook were analyzed (see Appendix I) to evaluate the accuracy of field-based run assignments used to generate Chinook passage and production estimates. A review of the genetic run analysis data indicated that winter Chinook were incorrectly assigned to spring Chinook using LAD criteria for a period of 34 days during BY2018 from mid-October thru late November. In-river spawner data analysis by California Department of Fish and Wildlife estimated the timing of last emergence for winter Chinook fry would occur in early November based upon later than average adult winter Chinook spawn timing in 2018 (D. Killam, CDFW, pers. comm.).

Based upon genetic and spawner data, LAD spring Chinook captured between October 16 and November 18, 2018 were re-assigned to the winter Chinook category and included in the passage and production estimates detailed in this report. Consequently, genetic re-assignment resulted in a net reduction for spring Chinook passage and production estimates and is reflected in the values reported herein. A genetic reassignment memo dated January 16, 2019 further outlines details of genetic-based revisions made to BY2018 winter and spring Chinook real-time biweekly passage estimates (Appendix II)[5].

Winter Chinook fork length evaluations.— BY2018 winter Chinook fork lengths ranged between 28 and 152 mm (Figure 6a). Winter Chinook were weighted (75.0%) to the fry size-class category (<46mm) with 93.3% of those measuring less than 40 mm (Figure 6a). The remaining 25.0% were attributed to the pre-smolt/smolt category (>45 mm) with 99.2% of the fish sampled between 46 and 100 mm.

Winter Chinook passage.—BY2018 winter Chinook juvenile estimated passage at RBDD was 1,168,263 fry and pre-smolt/smolts combined (Table 1). Fry sized juveniles (<46 mm FL) comprised 62.2% of total estimated winter Chinook passage (Table 1). Fry passage occurred from July through early December (weeks 29 thru 48; Figure 5a). Pre-smolt/smolt sized juveniles (>45 mm FL) comprised 37.8% of total passage and the first observed emigration past

[5] Genetic reassignment memo and affected biweekly reports can be found at the following web address: https://www.fws.gov/redbluff/RBDD%20JSM%20Biweekly/2018/rbdd_jsmp_2018.html

RBDD occurred in early September (week 35; Table 1). Weekly pre-smolt/smolt passage for the brood year concluded in mid-May (week 20; Figure 5b).

Winter Chinook JPI to adult comparisons.—The BY2018 winter Chinook fry-equivalent JPI was 1,477,529 with the lower and upper 90% CI extending from 824,706 to 2,130,352 juveniles, respectively (Table 7). Adult females contributing to in-river spawning of BY2018 winter Chinook were estimated to have been 1,080 individuals (D. Killam, CDFW, pers. comm.). The estimated ETF survival rate, based on the BY2018 winter Chinook fry-equivalent JPI and estimated number of female spawners and egg deposition in-river, was 26.6%. The range of ETF survival based on 90% CI's was 14.9% to 38.4% (Table 7).

Adult female spawner estimates derived from winter Chinook carcass surveys and rotary-screw trap data from brood years 1996-2018 were used to evaluate the linear relationship between the estimates. Twenty-one observations were evaluated using the carcass survey data as the winter Chinook carcass survey did not start until 1996 and rotary trapping at RBDD was not conducted in 2000 and 2001. Rotary trap JPI's were significantly correlated in trend to adult female spawner estimates ($r^2 = 0.87$, $P < 0.0001$, df = 20; Figure 7).

Spring Chinook fork length evaluations.— BY2018 spring Chinook fork lengths ranged between 31 and 151 mm (Figure 6b). Spring Chinook were heavily weighted to the pre-smolt/smolt size-class category (>45mm). Only 4.7% of all fish sampled as spring Chinook were designated fry with 66.0% measuring less than 40 mm FL (Figure 8a). The bulk of the catch (95.3%) was attributed to the pre-smolt/smolt category (>45 mm) with fish between 46 and 100 mm comprising 91.6% of this size group.

Spring Chinook passage.—After removal of estimated unmarked hatchery fish and genetic corrections noted above, BY2018 spring Chinook juvenile estimated passage at RBDD was 303,154 fry and pre-smolt/smolts combined (Table 2). Fry sized juveniles (<46 mm FL) comprised only 9.4% of total estimated spring Chinook passage (Table 2). Fry passage occurred from the end of November through mid-January (weeks 47 thru 2; Table 2). Pre-smolt/smolt sized juveniles (>45 mm FL) comprised 90.6% of total passage and the first observed emigration past RBDD occurred in early December (week 49; Table 2). Weekly pre-smolt/smolt passage for the brood year ended in July (week 29; Figure 8b). The fry-equivalent rotary trap JPI for BY2018 was 495,489 with the lower and upper 90% CI extending from -191,811 to 1,182,788 juveniles, respectively (Table 2). Spring Chinook ETF survival rates were not estimated due to inaccuracies with run designation and adult counts as noted in Poytress et al. (2014).

Fall Chinook fork length evaluations.—BY2018 fall Chinook fork lengths ranged between 26 and 183 mm (Figure 6c). BY2018 fall Chinook were composed of 59.7% in the fry size-class category (<46 mm) with 98.3% of those fry measuring less than 40 mm FL (Figure 9a). The remaining 40.3% were attributed to the pre-smolt/smolt category (>45 mm) with fish between 60 and 100 mm comprising 94.2% of the size group.

Fall Chinook passage.—After removal of estimated unmarked hatchery fish, BY2018 fall Chinook juvenile estimated passage at RBDD was 6,051,567 fry and pre-smolt/smolts combined (Table 3). Fry sized juveniles (<46 mm FL) comprised 81.5% of total estimated fall Chinook passage (Table 3). Fry passage occurred from December through the end of April (weeks 49 thru 17; Figure 9b). Pre-smolt/smolt sized juveniles (>45 mm FL) comprised 18.5% of total passage. The first observed pre-smolt/smolt passage occurred in late January (week 4; Table 3). Weekly pre-smolt/smolt passage for the brood year ended in November (week 47; Table 3).

Fall Chinook JPI to adult comparisons.—The fry-equivalent rotary trap JPI for BY2018 was 6,837,157 with the lower and upper 90% CI extending from 1,108,574 to 12,565,741 juveniles, respectively (Table 3). The total number of adult BY2018 fall Chinook females contributing to in-river spawning upstream of RBDD was estimated to be 11,631 individuals. The estimated ETF survival rate, based on the BY2018 fall Chinook fry-equivalent JPI, estimated number of female spawners and eggs deposited in-river, was 10.8%. The range of ETF survival based on 90% CI's was 1.8% to 19.9% (Table 8).

Late-Fall Chinook fork length evaluations.—BY2018 late-fall Chinook were sampled between 34 and 165 mm (Figure 6d). BY2018 late-fall Chinook sampled were heavily weighted to the pre-smolt/smolt size-class category (>45 mm). Only 0.2% of all fish sampled as late-fall were designated fry (<46 mm), with 100% of the fry measuring less than 40 mm FL (Figure 10a). The remaining 99.8% of juveniles were attributed to the pre-smolt/smolt category, with fish between 60 and 130 mm comprising 94.3% of that value.

Late-fall Chinook passage.—BY2018 late-fall Chinook juvenile estimated passage at RBDD was 48,111 fry and pre-smolt/smolts combined (Table 4). Fry sized juveniles (<46 mm FL) comprised 0.5% of total estimated late-fall Chinook passage (Table 4). Fry passage occurred from late April through mid-July (weeks 17 thru 29; Figure 10b). Pre-smolt/smolt sized juveniles (>45 mm FL) comprised 99.5% of total passage and the first observed emigration past RBDD occurred in late June (week 21; Table 4). Weekly pre-smolt/smolt passage for the brood year ended in late January (week 4; Figure 10b). The fry-equivalent rotary trap JPI for BY2018 was 118,896 with the lower and upper 90% CI extending from 46,821 to 190,971 juveniles, respectively (Table 4). Late-fall Chinook ETF survival rates were not estimated due to inaccuracies in adult count data as noted in Poytress et al. (2014).

O. mykiss fork length evaluations.—BY2018 juvenile *O. mykiss* were sampled between 22 and 280 mm (Figure 11a). Sub-yearling (41-138mm) and yearling (139-280 mm) *O. mykiss* were amongst the first sampled at the beginning of calendar year 2018 (Table 5). *O. mykiss* fry (<41mm) captures were highly variable, with the first fry of the year captured in late February, with a fork length of 23 mm; a 22 mm fry was captured 11 weeks later (mid-May; Figure 11a). Fry captures continued through week 32 (early August). Sub-yearling (41-138mm) captures began in January (week 1; Table 5) and continued through the end of the calendar year. Yearling captures occurred sporadically through the end of November (Table 5).

O. mykiss passage.—BY2018 *O. mykiss* juvenile total estimated passage at RBDD was 28,227 fry, sub-yearling and yearlings combined (Table 5). Fry sized juveniles (<41 mm) comprised only 2.4% of total *O. mykiss* passage. Fry passage occurred from late February through early August (weeks 8 thru 32; Figure 11b). Sub-yearling/yearling sized juveniles (≥41 mm) comprised 94.4% of total passage and the first observed emigration past RBDD occurred in week 1 (January; Table 5). Weekly sub-yearling/yearling passage for the brood year ended during week 52 (late December).

Discussion

Sampling effort. —Fluctuating river flows resulted in moderate sampling effort for the reporting period of January 1, 2018 through November 30, 2019 ($\bar{x}$ = 0.71). Mean sampling effort for BY2018 winter, spring, fall, late-fall Chinook and *O. mykiss* was 0.67, 0.67, 0.67, 0.65 and 0.74, respectively (Tables 1-5). During the primary juvenile winter Chinook salmon capture and passage period of July through December of 2018, mean sampling effort was fairly high (0.80), whereas the latter half of the brood year was markedly lower and more variable, averaging only 0.54.

Decreased sampling effort was primarily a product of winter storm activity resulting in high flows and debris loads occurring intermittently from January through the end of May 2019 (Figure 12a). Non-sample days due to high flow conditions totaled 45 days and mean daily flows averaged over 20,000 cfs during this period. Non-sample days due to hatchery releases from CNFH into Battle Creek in late March ("jump-start" winter Chinook and fall Chinook), late April (fall Chinook) and early May (fall Chinook) totaled eight days. Lack of staffing, sample days when multiple crews were not available to implement sub-sampling or multiple trap servicing, resulted in missing seven sample days during this period. Random daily sub-sampling strategies were employed for 39.5% of the samples that were collected from January through the end of May.

Patterns of abundance.—Juvenile winter Chinook began to emerge in mid-July in low numbers. Catch and subsequent passage generally increased, peaking in mid-October (Table 1; Figure 5b). Fry passage declined thereafter and ceased after the first week of December. Winter Chinook fry out-migrants represented 62.2% of total winter Chinook passage, with pre-smolt/smolts representing the remaining 37.8%. Through the first week of December 2018, 93.3% of the total annual passage estimate for BY2018 winter Chinook was collected (Table 1). With 96.6% of passage occurring in the first half of the brood year, the effects of lower sampling effort ($\bar{x}$ = 0.54) during the second half of the brood year were minimal for this run. Overall, interpolation for missed days of sampling accounted for only 7.1% of the total BY2018 estimate of 1,168,263 winter Chinook passing the RBDD.

Capture of BY2018 juvenile spring Chinook began on October 16, 2018 according to LAD criteria; however, genetic assignment results from tissue samples taken between mid-October and December of 2018 from RBDD traps indicated spring Chinook passage began in late November of 2018. Sampling effort was moderate throughout the fry passage period of weeks

47 thru 2 ($\bar{x}$ = 0.59, Table 2). A pronounced peak of fry passage, accounting for 74.4% of total spring Chinook fry passage occurred in early December (week 48; Table 2) following a flow event which increased flows three-fold and increased turbidity 40-fold over two days prior. Sampling effort during the remainder of the brood year was slightly higher yet variable ($\bar{x}$ = 0.66; Table 2). Storm activity and hatchery releases accounted for reductions in effort during periods of spring Chinook fry and pre-smolt/smolt passage. Interpolation for missed days of sampling accounted for 47.8% of the total BY2018 estimate of 303,154 spring Chinook passing the RBDD.

Spring Chinook fry out-migrants represented 9.4% of total passage, with pre-smolt/smolts representing the remaining 90.6%. This low percentage of fry out-migrants is substantially less than the 54% average noted in Poytress et al (2014), but likely a result of genetic assignments in contrast to assignments made solely using LAD criteria. Positive bias of spring Chinook passage estimates associated with 75% *unmarked*[6] CNFH production releases of fall Chinook that exceeded the fall LAD criteria were detected and removed as was done for BY2017 (Voss and Poytress 2019).

Fall Chinook fry passage accounted for 81.5% of the total passage for brood year 2018. Passage of fry began the second week of December, increasing through the end of the month. Fry passage was influenced by a number of runoff events throughout the passage period of weeks 49 to 17, with a peak in fry passage during week 3 (Figures 9b & 12). Sampling effort during fry passage was moderate to low, averaging 0.47 from week 48 thru week 17 and was therefore influenced by interpolation for missed sample days. For example, the week of peak fry passage (week 3) was comprised of three samples and four days of interpolated passage or non-sample days due to high flow conditions. Interpolation for missed samples, totaling 61 days, during the entire fry passage period accounted for 2,102,676 or 42.7% of the total fry passage estimate.

Fall Chinook passage in the pre-smolt/smolt size category, which comprised 18.5% of total brood year passage, began in late-January. Spikes in pre-smolt/smolt passage began in March (Table 3), coinciding with the timing of CNFH fall Chinook production releases and runoff events (Table 9 & Figure 9b), resulting in substantial positive bias to unmarked fall Chinook estimates. Positive bias of fall Chinook passage estimates associated with 75% *unmarked* CNFH production releases of fall Chinook were detected and removed as was done for BY2017 (Voss and Poytress 2019).

Approximately 185,000 dual-marked (adipose and left pelvic fin clipped) “jump-start” winter Chinook were released into Battle Creek in late March in concert with approximately 3.5 million CNFH fall Chinook during times of elevated creek and river flows. Although sampling effort was impacted by high flows, 48 “jump-start” winter Chinook were captured in the RBDD traps from March 29 to April 4, 2019. Three more were detected in late April and none of the

[6] Since 2007 CNFH fall Chinook production fish have been coded-wire tagged and adipose fin-clipped (i.e., marked) at a constant fractional mark rate of 25%. The remainder have no internal or external mark and cannot be field-identified as either natural or hatchery origin.

51 captures fell into the winter LAD size category, in fact 41 (80.4%) were LAD spring and the remaining 10 (19.6%) were LAD fall size fish.

Late-fall Chinook fry passage was limited and sporadic occurring in late April and again in mid-July (Table 4; Figure 10b). Fry passage accounted for a mere 0.5% of the brood year total, which falls well below the reported mean value of 38% (Poytress et al. 2014). Mean sampling effort of 0.75 for the first half of the brood year suggests that detection of late-fall Chinook fry was likely not an issue contributing to low fry passage estimates. Late-fall adult escapement above RBDD was estimated at 1,193 individuals with the 90% CI about the estimate ranging from a low of 1,043 to a high of 1,343 indicating good survey conditions (D. Killam, CDFW, personal communication). Following clear low water conditions during the winter, high flow events from mid-March to early April 2018 may have caused scouring of redds prior to fry emergence, lowering egg to fry survival.

O. mykiss passage began the first week in January (Table 5), with the first fry passing in late February. Passage peaked in early May and remained variable throughout the rest of the calendar year. Total passage for the brood year was 28,227 and interpolation accounted for only 9.0% of the total.

Bias associated with unmarked CNFH fall Chinook.— Brood year 2018 fall Chinook releases into Battle Creek (Figure 1) began in mid-March and continued through early May (weeks 11 thru 18; Table 9). Releases occurred coincident with elevated Battle Creek flows in an effort to increase the downstream movement and subsequent survival of production fish. During the release period, and including two weeks of recapture immediately following (weeks 11-20; Table 9), 26.5% of the marked CNFH fall Chinook fell into the spring LAD size category. Large numbers of unmarked hatchery fish falling into the spring size category encountered shortly after production releases, as well as data interpolation for missed samples, contributed greatly to increased spring Chinook fish passage from mid-March thru late April (weeks 12-17; appendix A1). Moreover, random sub-sampling around hatchery releases as well as throughout periods of elevated river flows contributed to increased variance and wide confidence intervals in the total passage estimate for spring Chinook.

RSTs were not sampled for a period of three weeks (weeks 9-11) due to high river flow conditions whereby equipment had to be physically removed from the river due to safety concerns. Without removal of unmarked hatchery fish from estimates, spring Chinook passage through week 10 and *prior* to hatchery releases accounted for 25.2% (835,327) of the brood year total (Appendix III, table A1). However, this value was influenced by unmarked hatchery fish falling into the spring LAD category present in passage estimates used to interpolate for the three-week period of missing data. Passage of unmarked LAD spring Chinook during week 13 (1,143,985) accounted for 34.5% of the brood year total (Appendix III, table A1). Without the removal of unmarked hatchery fish, interpolation accounted for an alarming 71.2% of the total spring Chinook passage estimate for BY2018 indicating substantial positive bias in the annual estimate had unmarked hatchery fish not been removed.

Real-time biweekly estimates for BY2018 spring Chinook total passage were 3,344,553 with lower and upper confidence intervals extending from -2,936,502 to 9,625,607, respectively (Appendix III, table A1). The BY2018 estimates for spring Chinook fry-equivalent JPI were 5,665,867 with lower and upper confidence intervals extending from -4,986,908 to 16,318,643, respectively. Adjustment to remove unmarked hatchery Chinook resulted in a total passage value of 303,154 with lower and upper confidence intervals extending from -115,508 and 721,815, respectively. Using adjusted values, the percentage of smolt spring Chinook represented 90.6% of total passage, whereas the original estimate was 99.2% smolts. Adjusted values for BY2018 spring Chinook fry-equivalent JPI were 495,489 with lower and upper confidence intervals extending from -191,811 and 1,182,788, respectively.

During the release period, and including two weeks of recapture (weeks 11-20; Table 9) immediately following, 73.5% of the marked CNFH fall Chinook fell into the fall LAD size category. Without removal of unmarked hatchery fish, pre-smolt/smolt passage during this period accounted for 80.2% (3,893,976) of all pre-smolt/smolt passage for BY2018. Interpolation for missed samples accounted for 43.3% of total pre-smolt/smolt passage. Overall, interpolation accounted for 7,442,307 or 43.5% of the BY2018 fall Chinook fry-equivalent JPI. Using an *uncorrected* BY2018 fall Chinook fry-equivalent JPI of 13,178,718 resulted in an ETF survival estimate of 20.8% for BY2018 (Appendix III, table A3).

Real-time biweekly estimates for BY2018 fall Chinook total passage were 9,781,897 with lower and upper confidence intervals extending from -153,674 to 19,717,469, respectively (Appendix III, table A2). Adjustment to remove unmarked hatchery fall Chinook resulted in a total passage value of 6,048,333 with lower and upper confidence intervals extending from 920,662 and 11,176,004, respectively. This lowered the original total smolt passage by 3,733,564, which resulted in 18.5% of BY2018 fall Chinook passing the RBDD transect as smolts. Adjusted values for BY2018 fall Chinook fry-equivalent JPI were 6,837,157 with lower and upper confidence intervals extending from 1,108,574 and 12,565,741, respectively, which results in an adjusted ETF survival of 9.3%. For comparison, the BY2018 fall Chinook fry-equivalent JPI *prior* to CNFH releases was estimated to be 5,405,078 with an ETF survival estimate of 8.5%.

Trap Efficiency and genetic-based run corrections.—Following mark-recapture trials conducted in the fall of 2018 with naturally produced winter Chinook fry, it was discovered that sampling four traps across the RBDD transect produced efficiency values that were higher than our regression model predicted due to a high rate of efficiency of one particular trap sampling the thalweg (Appendix II). Passage estimates for the months of September and October 2018 were therefore revised using data from three traps rather than four to align predicted or modeled efficiencies with those observed during mark-recapture trials in the fall of 2018 (i.e., excluding the thalweg trap). Further, revisions were made following genetic analyses of fin clips taken from juvenile LAD spring and winter Chinook in the fall of 2018 (Appendix II).

Genetic results indicated that field assigned (by LAD) BY 2018 spring Chinook prior to November 19, 2018 were genetically winter Chinook. Subsequently, when incorporating trap efficiency revisions, 106,852 LAD spring Chinook were estimated to be winter Chinook based on genetic identification during the period of October 16 thru November 18, 2018. A substantial amount of positive bias (26.1%) would have occurred without revision to spring passage estimates given that total BY2018 spring Chinook passage was estimated at 303,154. Conversely negative bias (9.1%) would have occurred for winter Chinook passage estimates prior to trap efficiency adjustments. Interestingly, after revisions due to trap efficiency adjustments (-94,485), the addition of 106,852 genetically assigned winter run from October 16 thru November 18 resulted in a net addition of 12,367 (1.1%) to the BY2018 winter Chinook passage estimate, and thus did not substantially affect the brood year total.

Winter Chinook JPI and ETF survival estimate.—The BY2018 winter Chinook fry-equivalent JPI value of 1,477,529 was the highest value reported in the last five years. Adult escapement for BY2018 was largely composed of spawners from BY2015 hatchery production and was estimated at 2,458 in-river adults (NMFS 2019). This adult estimate was twice the number estimated to return for BY2017. The higher return rate was likely due to the release of greater numbers of juvenile winter Chinook from LSNFH from BY2015 due to poor ETF survival caused by drought related factors in 2014 (Poytress 2016). The fry-equivalent based ETF survival rate for BY2018 was estimated at 26.6% (Table 7), slightly above the 21-year average ETF survival rate of 25.0%. Although little rainfall was received during the water year until March of 2018, precipitation and carry-over storage provided adequate cold-water pool availability in Shasta Reservoir. For 2018, USBR submitted a plan including a Balls Ferry compliance point with a target of 56°F daily average temperature from May 15 thru October 31, 2018. Similar to 2017, NMFS requested USBR to target a 53.5°F daily average temperature at the Sacramento River-Clear Creek gauging station and temperatures of 55°F within a seven-day average daily maximum at the most downstream winter Chinook redd during that same time period (NMFS 2019). Reclamation was able to meet a 53.0°F daily average temperature at the Clear Creek station for 68.4 percent of the temperature management period (NMFS 2019). Thus, efforts to follow the 2018 Sacramento River temperature management plan were largely successful.

Winter Chinook pathogen monitoring.— Pathogen monitoring of naturally produced winter Chinook juveniles was studied via histological analyses (Foott 2019) from samples collected (*N*=80) at RBDD traps from September through November 2018. From histological analyses of RBDD RST samples, Foott (2019) determined prevalence of infection for the parasites *Ceratonova shasta* and *Parvocapsula minibicornis* were 10% and 26%, respectively.

Additionally, Foott (2019) exposed CNFH late-fall Chinook sentinel fish to the Sacramento River for a period of four days across five separate sites, replicating exposures four times from August through November. Histological analyses of sentinel groups had prevalence of infections ranging from 0-93% and 0-67% for *C. shasta* and *P. minibicornis*, respectively. However, with regard to *C. shasta* prevalence, only three sentinel fish from the first exposure group (Red Bluff (*N*=1) and River Road (*N*=2)), appeared “diseased” (i.e., signs of clinical infection), while all other prevalence was determined to be asymptomatic.

In summary, there was prevalence of infection detected in RST collected winter run and CNFH sentinels, yet only a few sentinels exhibited a diseased state. Foott (2019) stated that based on low prevalence of clinical disease and mortality of sentinel fish exposed to the river in late summer and fall of 2016 and 2018, "*C. shasta* appears to represent a low to moderate disease risk for juvenile winter Chinook salmon during their outmigration" in water years classified as below normal or wetter.

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Tables

Table 1.— Sampling effort, weekly passage estimates, median fork length (Med FL) and juvenile production indices (JPI's) for winter Chinook salmon passing Red Bluff Diversion Dam (RK 391) for the period July 1, 2018 through June 30, 2019 (brood year 2018). Full sampling effort indicated by assigning a value of 1.00 to a week consisting of four 2.4-m diameter rotary-screw traps sampling 24 hours daily, 7 days per week. Results include estimated passage (Est. passage) for fry (< 46 mm FL), pre-smolt/smolts (> 45 mm FL), total (fry and pre-smolt/smolts combined) and fry-equivalents and include genetic corrections. Fry-equivalent JPI's were generated by weighting pre-smolt/smolt passage by the inverse of the fry to pre-smolt/smolt survival rate (59% or approximately 1.7:1; Hallock undated).

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
27 (Jul)	0.64	0	-	0	-	0	-	0
28	0.75	0	-	0	-	0	-	0
29	0.89	202	34	0	-	202	34	202
30	1.00	537	33.5	0	-	537	33.5	537
31 (Aug)	1.00	1,731	34	0	-	1,731	34	1,731
32	1.00	2,510	34	0	-	2,510	34	2,510
33	0.86	4,077	34	0	-	4,077	34	4,077
34	1.00	3,952	35	0	-	3,952	35	3,952
35 (Sep)	0.86	9,198	35	89	47	9,287	35	9,350
36	0.75	15,024	35	0	-	15,024	35	15,024
37	0.75	31,194	35	147	46	31,341	35	31,444
38	0.75	47,460	35	228	50	47,688	35	47,848
39	0.75	50,468	36	1,278	53	51,745	36	52,640
40 (Oct)	0.75	129,809	36	11,167	52	140,976	36	148,793
41	0.75	186,205	35	12,571	52	198,776	36	207,576
42	0.75	115,943	35	20,753	54	136,696	36	151,223
43	0.64	53,692	35	25,941	54	79,633	36	97,791
44 (Nov)	0.82	48,135	36	35,125	55	83,260	41	107,848
45	1.00	20,146	36	38,135	57	58,281	52	84,976
46	1.00	4,001	38	27,560	57	31,561	56	50,853
47	0.71	1,649	44	57,565	60	59,213	59	99,508
48 (Dec)	0.50	523	45	132,614	60	133,137	60	225,966
49	0.55	0	-	19,003	63	19,003	63	32,306
50	0.85	0	-	6,904	64.5	6,904	64.5	11,736
51	0.71	0	-	2,855	63.5	2,855	63.5	4,854
52	0.69	0	-	9,891	70.5	9,891	70.5	16,814

Table 1 – (continued)

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
1 (Jan)	0.36	0	-	6,699	71	6,699	71	11,389
2	0.36	0	-	5,061	76	5,061	76	8,603
3	0.16	0	-	619	74	619	74	1,052
4	0.43	0	-	2,125	78	2,125	78	3,612
5 (Feb)	0.29	0	-	0	-	0	-	0
6	0.71	0	-	921	105	921	105	1,566
7	0.43	0	-	4,198	114	4,198	114	7,137
8	1.00	0	-	1,487	99	1,487	99	2,529
9 (Mar)	0.00	0	-	3,010	-	3,010	-	5,118
10	0.00	0	-	3,010	-	3,010	-	5,118
11	0.00	0	-	3,010	-	3,010	-	5,118
12	0.84	0	-	2,956	114	2,956	114	5,026
13	0.21	0	-	3,173	121	3,173	121	5,394
14 (Apr)	0.50	0	-	2,906	109	2,906	109	4,940
15	0.25	0	-	0	-	0	-	0
16	0.70	0	-	500	114	500	114	850
17	0.77	0	-	135	142	135	142	229
18 (May)	0.57	0	-	71	131	71	131	121
19	0.89	0	-	42	146	42	146	71
20	0.64	0	-	57	145	57	145	96
21	0.82	0	-	0	-	0	-	0
22 (Jun)	0.43	0	-	0	-	0	-	0
23	0.75	0	-	0	-	0	-	0
24	1.00	0	-	0	-	0	-	0
25	1.00	0	-	0	-	0	-	0
26	0.82	0	-	0	-	0	-	0
BY total		726,455		441,808		1,168,263		1,477,529
90% CI (low : high)		(486,673 : 966,237)		(193,106 : 690,510)		(683,866 :1,652,660)		(824,706 : 2,130,352)

Table 2— Sampling effort, weekly passage estimates, median fork length (Med FL) and juvenile production indices (JPI's) for spring Chinook salmon passing Red Bluff Diversion Dam (RK 391) for the period October 16, 2018 through October 15, 2019 (brood year 2018). Full sampling effort indicated by assigning a value of 1.00 to a week consisting of four 2.4-m diameter rotary-screw traps sampling 24 hours daily, 7 days per week. Results include estimated passage (Est. passage) for fry (< 46 mm FL), pre-smolt/smolts (> 45 mm FL), total (fry and pre-smolt/smolts combined) and fry-equivalents with unmarked hatchery fish removed and genetic corrections. Fry-equivalent JPI's were generated by weighting pre-smolt/smolt passage by the inverse of the fry to pre-smolt/smolt survival rate (59% or approximately 1.7:1; Hallock undated).

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
42	0.75	0	-	0	-	0	-	0
43	0.64	0	-	0	-	0	-	0
44 (Nov)	0.82	0	-	0	-	0	-	0
45	1.00	0	-	0	-	0	-	0
46	1.00	0	-	0	-	0	-	0
47	0.71	2,896	37.5	0	-	2,896	37.5	2,896
48 (Dec)	0.50	21,124	39	0	-	21,124	39	21,124
49	0.55	1,388	36	148	46.5	1,536	37	1,640
50	0.85	893	37	164	47	1,057	37	1,172
51	0.71	619	39	142	49	761	39	860
52	0.69	37	43	417	51.5	454	51	746
1 (Jan)	0.36	0	-	329	53.5	329	53.5	559
2	0.36	1,432	45	1,248	54	2,681	46.5	3,554
3	0.16	0	-	14,160	52	14,160	52	24,072
4	0.43	0	-	1,457	50	1,457	50	2,476
5 (Feb)	0.29	0	-	120	51	120	51	204
6	0.71	0	-	2,219	55	2,219	55	3,772
7	0.43	0	-	1,142	56.5	1,142	56.5	1,942
8	1.00	0	-	2,443	61.5	2,443	61.5	4,152
9 (Mar)	0.00	0	-	19,505	-	19,505	-	33,159
10	0.00	0	-	19,505	-	19,505	-	33,159
11	0.00	0	-	19,505	-	19,505	-	33,159
12	0.84	0	-	26,007	74	26,007	74	44,212
13	0.21	0	-	0	77	0	77	0
14 (Apr)	0.50	0	-	85,183	78	85,183	78	144,811
15	0.25	0	-	30,761	82	30,761	82	52,294

Table 2—(continued)

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
16	0.70	0	-	15,118	85	15,118	85	25,701
17	0.77	0	-	7,545	91	7,545	91	12,827
18 (May)	0.57	0	-	14,988	93	14,988	93	25,480
19	0.89	0	-	5,278	99	5,278	99	8,973
20	0.64	0	-	3,843	103	3,843	103	6,533
21	0.82	0	-	2,032	107.5	2,032	107.5	3,454
22 (Jun)	0.43	0	-	1,162	112	1,162	112	1,976
23	0.75	0	-	185	117	185	117	314
24	1.00	0	-	110	119.5	110	119.5	188
25	1.00	0	-	0	-	0	-	0
26	0.82	0	-	0	-	0	-	0
27 (Jul)	0.93	0	-	0	-	0	-	0
28	1.00	0	-	0	-	0	-	0
29	1.00	0	-	46	151	46	151	77
30	1.00	0	-	0	-	0	-	0
31 (Aug)	1.00	0	-	0	-	0	-	0
32	1.00	0	-	0	-	0	-	0
33	0.86	0	-	0	-	0	-	0
34	0.96	0	-	0	-	0	-	0
35 (Sep)	0.93	0	-	0	-	0	-	0
36	0.70	0	-	0	-	0	-	0
37	0.70	0	-	0	-	0	-	0
38	0.71	0	-	0	-	0	-	0
39	0.63	0	-	0	-	0	-	0
40 (Oct)	0.68	0	-	0	-	0	-	0
41	0.54	0	-	0	-	0	-	0
BY total		28,389		274,765		303,154		495,489
90% CI (low : high)		(-949 : 57,727)		(-115,272 : 664,801)		(-115,508 : 721,815)		(-191,811 : 1,182,788)

Table 3.— Sampling effort, weekly passage estimates, median fork length (Med FL) and juvenile production indices (JPI's) for fall Chinook salmon passing Red Bluff Diversion Dam (RK 391) for the period December 1, 2018 through November 30, 2019 (brood year 2018). Full sampling effort indicated by assigning a value of 1.00 to a week consisting of four 2.4-m diameter rotary-screw traps sampling 24 hours daily, 7 days per week. Results include estimated passage (Est. passage) for fry (< 46 mm FL), pre-smolt/smolts (> 45 mm FL), total (fry and pre-smolt/smolts combined) and fry-equivalents with unmarked hatchery fish removed. Fry-equivalent JPI's were generated by weighting pre-smolt/smolt passage by the inverse of the fry to pre-smolt/smolt survival rate (59% or approximately 1.7:1; Hallock undated).

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
48 (Dec)	0.50	0	-	0	-	0	-	0
49	0.55	1,374	33.5	0	-	1,374	34	1,374
50	0.85	7,261	35	0	-	7,261	35	7,261
51	0.71	41,034	35	0	-	41,034	35	41,034
52	0.69	256,188	35	0	-	256,188	35	256,188
1 (Jan)	0.36	355,281	35	0	-	355,281	35	355,281
2	0.36	878,086	36	0	-	878,086	36	878,086
3	0.16	2,272,530	36	0	-	2,272,530	36	2,272,530
4	0.43	345,227	36	1,609	47	346,836	36	347,962
5 (Feb)	0.29	143,508	35	0	-	143,508	35	143,508
6	0.71	220,978	36	3,788	50	224,766	36	227,418
7	0.43	105,772	35	5,662	50	111,434	35	115,397
8	1.00	59,825	36	4,971	52	64,796	36	68,275
9 (Mar)	0.00	31,948	-	20,231	-	52,179	-	66,340
10	0.00	31,948	-	20,231	-	52,179	-	66,340
11	0.00	31,948	-	20,231	-	52,179	-	66,340
12	0.84	19,146	36	21,871	66	41,018	63	56,328
13	0.21	70,352	35	15,309	71	85,661	70	96,377
14 (Apr)	0.50	45,674	36	7,226	72	52,900	72	57,959
15	0.25	0	-	3,826	76	3,826	76	6,504
16	0.70	10,440	38	321,496	77	331,936	77	556,983
17	0.77	776	41	10,551	80	11,327	80	18,712
18 (May)	0.57	0	-	42,533	83	42,533	83	72,306
19	0.89	0	-	35,700	83	35,700	83	60,689
20	0.64	0	-	69,819	87	69,819	87	118,692
21	0.82	0	-	78,098	89	78,098	89	132,766

Table 3—(continued)

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
22 (Jun)	0.43	0	-	144,352	85	144,352	85	245,399
23	0.75	0	-	69,824	83	69,824	83	118,701
24	1.00	0	-	65,284	86	65,284	86	110,983
25	1.00	0	-	57,250	86	57,250	86	97,325
26	0.82	0	-	30,423	87	30,423	87	51,719
27 (Jul)	0.93	0	-	19,997	88	19,997	88	33,995
28	1.00	0	-	18,307	92	18,307	92	31,122
29	1.00	0	-	14,102	94	14,102	94	23,974
30	1.00	0	-	6,100	95	6,100	95	10,370
31 (Aug)	1.00	0	-	4,062	98	4,062	98	6,906
32	1.00	0	-	2,825	103	2,825	103	4,803
33	0.86	0	-	1,588	103	1,588	103	2,699
34	0.96	0	-	1,283	116	1,283	116	2,181
35 (Sep)	0.93	0	-	1,072	112	1,072	112	1,822
36	0.70	0	-	182	113	182	113	310
37	0.70	0	-	74	110	74	110	126
38	0.71	0	-	758	121	758	121	1,288
39	0.63	0	-	178	128	178	128	303
40 (Oct)	0.68	0	-	261	118	261	118	444
41	0.54	0	-	415	130	415	130	706
42	0.63	0	-	150	139	150	139	255
43	0.50	0	-	279	136	279	136	474
44 (Nov)	0.73	0	-	274	150.5	274	150.5	466
45	1.00	0	-	26	147	26	147	45
46	1.00	0	-	0	-	0	-	0
47	1.00	0	-	53	159	53	159	90
BY total		4,929,296		1,122,271		6,051,567		6,837,157
90% CI (low : high)		(628,894 : 9,229,698)		(221,286 : 2,023,257)		(922,932 : 11,180,202)		(1,108,574 : 12,565,741)

Table 4.— Sampling effort, weekly passage estimates, median fork length (Med FL) and juvenile production indices (JPI's) for late-fall Chinook salmon passing Red Bluff Diversion Dam (RK 391) for the period April 1, 2018 through March 31, 2019 (brood year 2018). Full sampling effort indicated by assigning a value of 1.00 to a week consisting of four 2.4-m diameter rotary-screw traps sampling 24 hours daily, 7 days per week. Results include estimated passage (Est. passage) for fry (< 46 mm FL), pre-smolt/smolts (> 45 mm FL), total (fry and pre-smolt/smolts combined) and fry-equivalents. Fry-equivalent JPI's were generated by weighting pre-smolt/smolt passage by the inverse of the fry to pre-smolt/smolt survival rate (59% or approximately 1.7:1; Hallock undated).

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
14 (Apr)	0.43	0	-	0	-	0	-	0
15	0.44	0	-	0	-	0	-	0
16	0.43	0	-	0	-	0	-	0
17	0.75	171	34	0	-	171	34	171
18 (May)	0.96	0	-	0	-	0	-	0
19	0.71	0	-	0	-	0	-	0
20	0.43	0	-	0	-	0	-	0
21	0.67	0	-	0	-	0	-	0
22 (Jun)	0.68	0	-	0	-	0	-	0
23	0.75	0	-	0	-	0	-	0
24	0.75	0	-	0	-	0	-	0
25	0.75	0	-	0	-	0	-	0
26	0.75	0	-	57	57	57	57	98
27 (Jul)	0.64	0	-	139	61	139	61	236
28	0.75	0	-	116	64.5	116	64.5	197
29	0.89	57	38	45	62	102	50	133
30	1.00	0	-	0	-	0	-	0
31 (Aug)	1.00	0	-	178	73	178	73	302
32	1.00	0	-	77	73.5	77	73.5	131
33	0.86	0	-	176	73	176	73	299
34	1.00	0	-	300	80.5	300	80.5	510
35 (Sep)	0.86	0	-	340	75	340	75	577
36	0.75	0	-	312	64	312	64	530
37	0.75	0	-	335	72	335	72	569
38	0.75	0	-	275	80.5	275	80.5	467
39	0.75	0	-	742	65	742	65	1,262

Table 4—(continued)

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
40 (Oct)	0.75	0	-	6,861	73	6,861	73	11,664
41	0.75	0	-	1,650	73	1,650	73	2,804
42	0.75	0	-	2,364	77	2,364	77	4,018
43	0.64	0	-	1,413	87	1,413	87	2,402
44 (Nov)	0.82	0	-	3,023	95.5	3,023	95.5	5,139
45	1.00	0	-	2,449	108	2,449	108	4,164
46	1.00	0	-	1,374	118	1,374	118	2,336
47	0.71	0	-	4,404	112	4,404	112	7,487
48 (Dec)	0.50	0	-	12,880	116	12,880	116	21,897
49	0.55	0	-	2,573	116.5	2,573	116.5	4,375
50	0.85	0	-	487	125	487	125	827
51	0.71	0	-	298	118	298	118	507
52	0.69	0	-	2,458	119.5	2,458	119.5	4,178
1 (Jan)	0.36	0	-	1,274	136	1,274	136	2,166
2	0.36	0	-	1,104	124.5	1,104	124.5	1,877
3	0.16	0	-	0	-	0	-	0
4	0.43	0	-	181	136.5	181	136.5	308
5 (Feb)	0.29	0	-	0	-	0	-	0
6	0.71	0	-	0	-	0	-	0
7	0.43	0	-	0	-	0	-	0
8	1.00	0	-	0	-	0	-	0
9 (Mar)	0.00	0	-	0	-	0	-	0
10	0.00	0	-	0	-	0	-	0
11	0.00	0	-	0	-	0	-	0
12	0.84	0	-	0	-	0	-	0
13	0.21	0	-	0	-	0	-	0
BY total		228		47,883		48,111		81,629
90% CI (low : high)		(-107 : 563)		(14,598 : 81,168)		(14,553 : 81,669)		(27,505 : 135,753)

Table 5.— Sampling effort, weekly passage estimates and median fork length (Med FL) for *O. mykiss* passing Red Bluff Diversion Dam (RK 391) for the period January 1, 2018 through December 31, 2018 (brood year 2018). Full sampling effort indicated by assigning a value of 1.00 to a week consisting of four 2.4-m diameter rotary-screw traps sampling 24 hours daily, 7 days per week. Results include total estimated passage (fry, sub-yearling and yearlings combined).

Week	Sampling Effort	Total Est. passage	Total Med FL	Week (cont.)	Sampling Effort (cont.)	Total Est. passage (cont.)	Total Med FL (cont.)
1 (Jan)	0.50	42	79	27 (Jul)	0.64	772	84
2	0.64	68	175	28	0.75	632	75
3	0.54	42	151	29	0.89	320	86
4	0.89	134	100	30	1.00	446	84.5
5 (Feb)	1.00	24	86	31 (Aug)	1.00	612	65
6	0.89	0	-	32	1.00	1,098	69
7	0.75	0	-	33	0.86	1,530	68
8	0.75	31	23	34	1.00	1,389	64
9 (Mar)	0.75	31	25	35 (Sep)	0.86	1,456	62
10	0.75	27	27	36	0.75	763	61
11	0.61	0	-	37	0.75	694	63
12	0.64	211	47.5	38	0.75	273	72.5
13	0.75	240	63.5	39	0.75	445	70
14 (Apr)	0.43	53	167.5	40 (Oct)	0.75	208	74.5
15	0.44	1,691	78	41	0.75	92	74.5
16	0.43	470	58	42	0.75	91	79.5
17	0.75	1,108	62	43	0.64	220	89
18 (May)	0.96	2,044	62	44 (Nov)	0.82	45	164.5
19	0.71	1,178	63	45	1.00	196	97
20	0.43	1,440	60.5	46	1.00	25	92
21	0.67	999	62	47	0.71	151	172
22 (Jun)	0.68	557	73	48 (Dec)	0.50	144	108
23	0.75	1,471	71	49	0.55	0	-
24	0.75	1,572	70	50	0.85	29	111
25	0.75	1,979	67.5	51	0.71	0	-
26	0.75	1,145	71.5	52	0.69	38	92
				BY total		28,227	
				90% CI (low : high)		(10,386 : 46,069)	

Table 6.—Summary of results from mark-recapture trials conducted in 2018 (*N* = 5) to evaluate rotary-screw trap efficiency at Red Bluff Diversion Dam (RK 391), Sacramento River, California. Results include the run of Chinook salmon used, number of fish released, mean fork length at release (Release FL), number recaptured, mean fork length at recapture (Recapture FL), combined trap efficiency (TE%), percent river volume sampled by rotary-screw traps (%Q), number of traps sampling during trials, and modification status as to whether or not traps were structurally modified to reduce volume sampled by 50% (Traps modified).

Trial#	Year	Run	Number Released	Release FL (mm)	Number Recaptured	Recapture FL (mm)	TE (%)	%Q	Number of traps sampling	Traps modified
1	2018	winter	1,177	37.1	45	36.4	3.82	2.97	3	No
2	2018	winter	1,247	36.1	48	36.7	3.85	2.64	3	No
3	2018	winter	1,147	36.5	30	36.5	2.62	2.84	3	No
4	2018	fall	1,073	36.2	41	35.9	3.82	4.77	4	No
5	2018	fall	1,090	35.9	32	35.8	2.94	2.01	3	Yes

Table 7.— Winter Chinook fry-equivalent juvenile production indices (JPI), lower and upper 90% confidence intervals (CI), estimated adult female spawners above RBDD (Estimated Females), estimates of female fecundity, calculated juveniles per estimated female (Estimated Recruits/Female) and egg-to-fry survival estimates (ETF) with associated lower and upper 90% confidence intervals (L90 CI : U90 CI) by brood year (BY) for Chinook sampled at RBDD rotary traps between July 2002 and June 2019.

BY	Fry Equivalent JPI	Lower 90% CI	Upper 90% CI	Estimated Females[1]	Fecundity[2]	Estimated Recruits/Female	ETF Survival Rate (%)	L90 CI : U90 CI
2002	7,635,469	2,811,132	13,144,325	5,670	4,923	1,347	27.4	(10.1 : 47.1)
2003	5,781,519	3,525,098	8,073,129	5,179	4,854	1,116	23.0	(14.0 : 32.1)
2004	3,677,989	2,129,297	5,232,037	3,185	5,515	1,155	20.9	(12.1 : 29.8)
2005	8,943,194	4,791,726	13,277,637	8,807	5,500	1,015	18.5	(9.9 : 27.4)
2006	7,298,838	4,150,323	10,453,765	8,626	5,484	846	15.4	(8.8 : 22.1)
2007	1,637,804	1,062,780	2,218,745	1,517	5,112	1,080	21.1	(13.7 : 28.6)
2008	1,371,739	858,933	1,885,141	1,443	5,424	951	17.5	(11.0 : 24.1)
2009	4,972,954	2,790,092	7,160,098	2,702	5,519	1,840	33.5	(18.7 : 48.0)
2010	1,572,628	969,016	2,181,572	813	5,161	1,934	37.5	(23.1 : 52.0)
2011	996,621	671,779	1,321,708	424	4,832	2,351	48.6	(32.8 : 64.5)
2012	1,814,244	1,227,386	2,401,102	1,491	4,518	1,217	26.9	(18.2 : 35.6)
2013	2,481,324	1,539,193	3,423,456	3,577	4,596	694	15.1	(9.4 : 20.8)
2014	523,872	301,197	746,546	1,681	5,308	312	5.9	(3.4 : 8.4)
2015	440,951	288,911	592,992	2,022	4,819	218	4.5	(3.0 : 6.1)
2016	640,149	429,876	850,422	653	4,131	980	23.7	(15.9 : 31.5)
2017	734,432	471,292	997,572	367	4,109	2,001	48.7	(31.3 : 66.2)
2018	1,477,529	824,706	2,130,352	1,080	5,141	1,368	26.6	(14.9 : 38.4)
					Average	1,201	24.4	(14.7 : 34.3)
					Standard Deviation	574	12.4	(8.3 : 17.0)

[1]Estimated females derived from carcass survey data; includes annual estimates of pre-spawn mortality.

[2]Female fecundity estimates typically based on annual average values from LSNFH winter Chinook spawning data. The exception being 2016 and 2017 values based on total egg deposition by size class (See Voss and Poytress 2019).

Table 8.— Fall Chinook fry-equivalent juvenile production indices (JPI), lower and upper 90% confidence intervals (CI), estimated adult female spawners above RBDD (Estimated Females), estimates of female fecundity, calculated juveniles per estimated female (Estimated Recruits/Female) and egg-to-fry survival estimates (ETF) with associated lower and upper 90% confidence intervals (L90 CI : U90 CI) by brood year (BY) for Chinook sampled at RBDD rotary traps between December 2002 and November 2019. Brood years 2006 through 2018 include estimates with unmarked hatchery fish removed to reduce bias to JPI estimates.

BY	Fry Equivalent JPI	Lower 90% CI	Upper 90% CI	Estimated Females[1]	Fecundity[2]	Estimated Recruits/Female	ETF Survival Rate (%)	L90 CI : U90 CI
2002	18,683,720	1,216,244	51,024,926	211,035	5,407	89	1.6	(0.1 : 4.5)
2003	30,624,209	10,162,712	55,109,506	79,509	5,407	385	7.1	(2.4 : 12.8)
2004	18,421,457	6,224,790	33,728,746	31,045	5,407	593	11.0	(3.7 : 20.1)
2005	22,739,315	4,235,720	49,182,045	37,738	5,407	603	11.1	(2.1 : 24.1)
2006	19,586,600	7,629,345	31,543,855	42,730	5,407	458	8.5	(3.3 : 13.7)
2007	12,822,401	6,546,684	19,098,118	16,996	5,407	754	14.0	(7.1 : 20.8)
2008	9,371,141	4,750,252	13,992,030	16,644	5,362	563	10.5	(5.3 : 15.7)
2009	8,498,417	3,071,022	13,925,813	6,531	5,318	1,301	24.5	(8.8 : 40.1)
2010	9,119,714	4,552,856	13,686,573	7,008	5,167	1,301	25.2	(12.6 : 37.8)
2011	6,457,455	3,490,844	9,424,066	9,260	5,945	697	11.7	(6.3 : 17.1)
2012	24,659,091	16,408,286	32,909,895	32,635	5,242	756	14.4	(9.6 : 19.2)
2013	33,201,448	5,766,067	60,636,829	39,422	5,390	842	15.6	(2.7 : 28.5)
2014	4,387,348	2,407,113	6,367,583	35,345	5,453	124	2.3	(1.2 : 3.3)
2015	19,406,341	214,690	38,597,991	23,302	4,971	833	16.8	(0.2 : 33.3)
2016	9,886,303	-2,666,309	22,438,916	5,240	4,778	1,887	39.5	(-10.6 : 89.6)
2017	1,723,831	980,638	2,467,025	4,437	4,455	389	8.7	(5.0 : 12.5)
2018	6,837,157	1,108,574	12,565,741	11,631	5,442	588	10.8	(1.8 : 19.9)
					Average	715	13.7	(3.6 : 24.3)
					Standard Deviation	446	9.1	(5.1 : 19.7)

[1]Estimated females derived from carcass survey; sex ratios used to determine female spawners based on RBDD fish ladder data between 2003 and 2007 and CNFH data between 2008 and 2018.

[2]Female fecundity estimates for years 2002 thru 2007 based on average values from CNFH fall Chinook spawning data collected between 2008 and 2012 (Poytress 2014).

Table 9.— Summary of Coleman National Fish Hatchery brood year 2018 fall Chinook released into Battle Creek from March 14 through May 3, 2019. Week number, release dates, total number of fish released per group, mean fork length (FL) of Chinook at release (mm), length-at-date (LAD) size ranges and percent of marked fall and spring Chinook captured in the RBDD rotary traps for each production release group.

Week	Release Date(s)	# Released	Mean FL of release group	Fall LAD range	Fall % captures	Spring LAD range	Spring % captures
10	3/14/2019	1,396,976	75.0	0 - 66	--	67 - 89	--
11	3/25/2019	1,428,672	75.0	0 -71	28.4%	72 - 95	71.6%
12	3/29/2019	2,132,659	75.0	0 - 72	37.1%	73 - 98	62.9%
13	4/8/2019	3,300,334	75.0	36 - 77	45.6%	78 - 105	54.4%
14	4/11/2019	174,038	75.0	37 - 79	81.6%	80 - 107	18.4%
15	4/19/2019	1,914,610	75.0	39 - 83	88.2%	84 - 112	11.8%
16	--	--	--	40 - 87	92.1%	88 - 119	7.9%
17	5/3/2019	2,350,716	75.0	42 - 91	95.7%	92 - 123	4.3%
18	--	--	--	44 - 95	96.9%	96 - 129	3.1%
19	--	--	--	46 - 100	92.1%	101 - 135	7.9%
Total		**12,698,005**			**73.5%**		**26.5%**

Figures

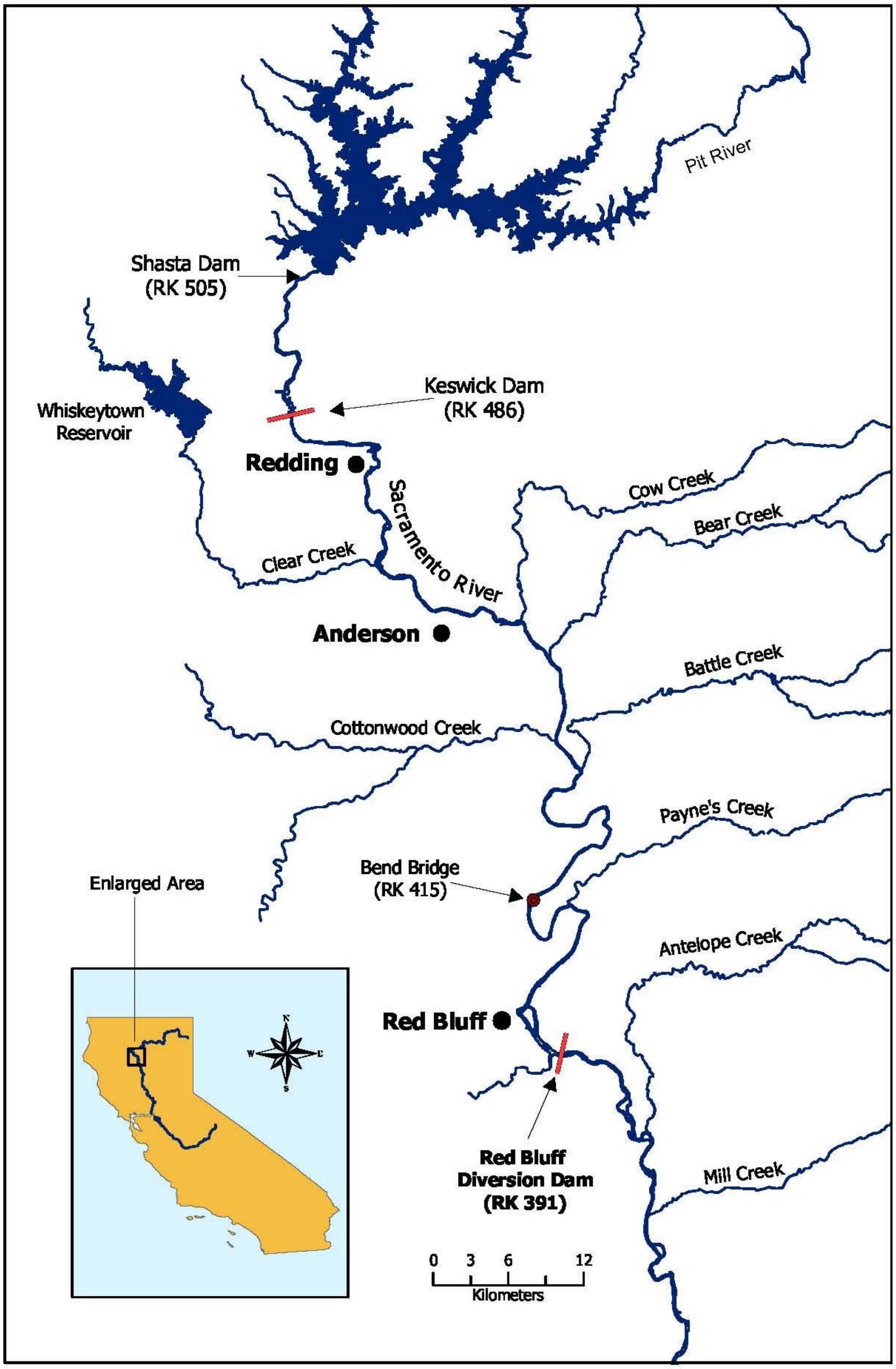

Figure 1. Location of Red Bluff Diversion Dam sample site on the Sacramento River, California, at river kilometer 391 (RKM 391)

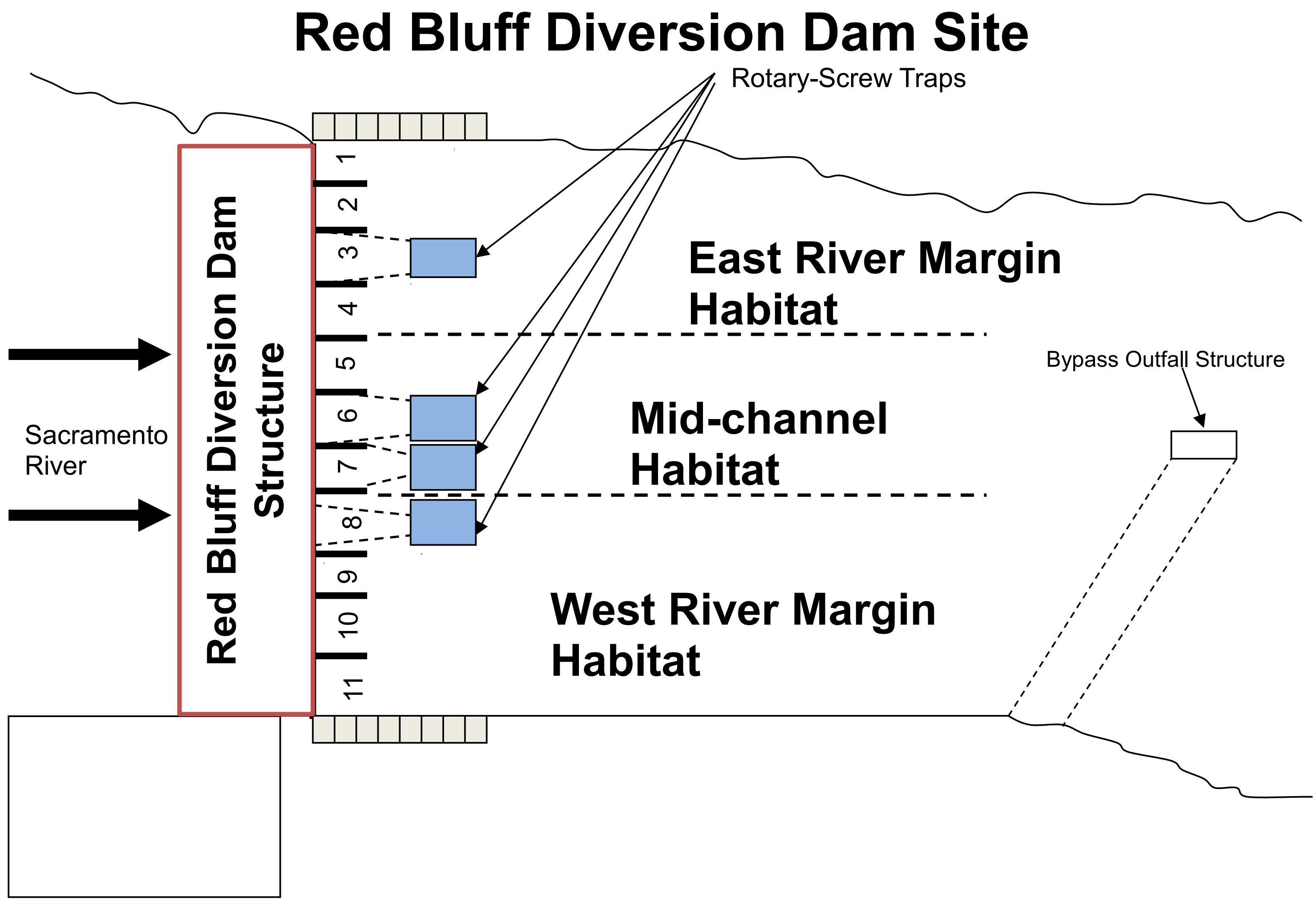

Figure 2. Rotary-screw trap sampling transect schematic of Red Bluff Diversion Dam site (RK 391) on the Sacramento River, CA.

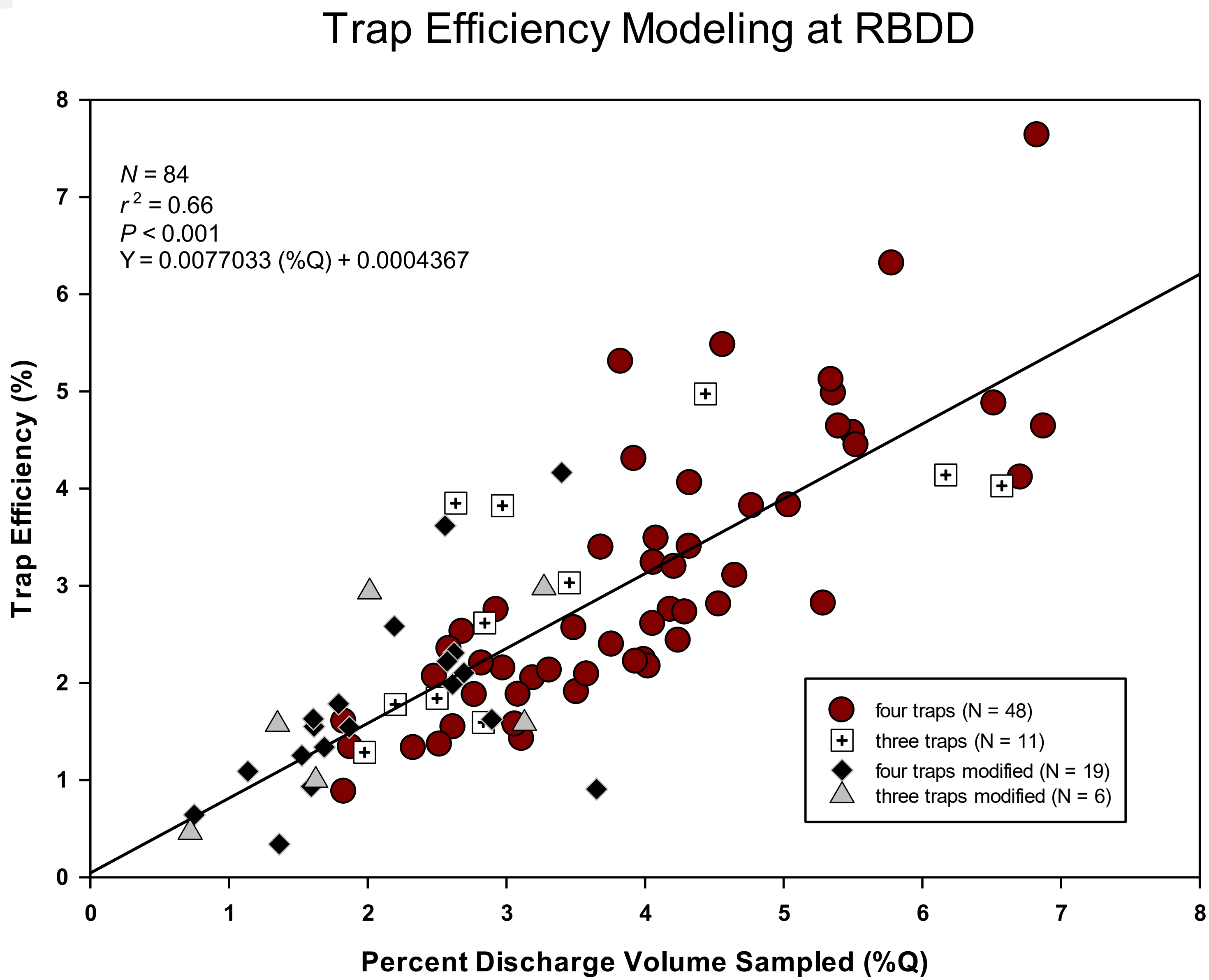

Figure 3. Trap efficiency model for combined 2.4 m diameter rotary screw traps at Red Bluff Diversion Dam (RK 391), Sacramento River, CA. Mark-recapture trials were used to estimate trap efficiencies and trials were conducted using either four traps (N = 47), three traps (N = 8), or with traps modified to sample one-half the normal volume of water (N = 24).

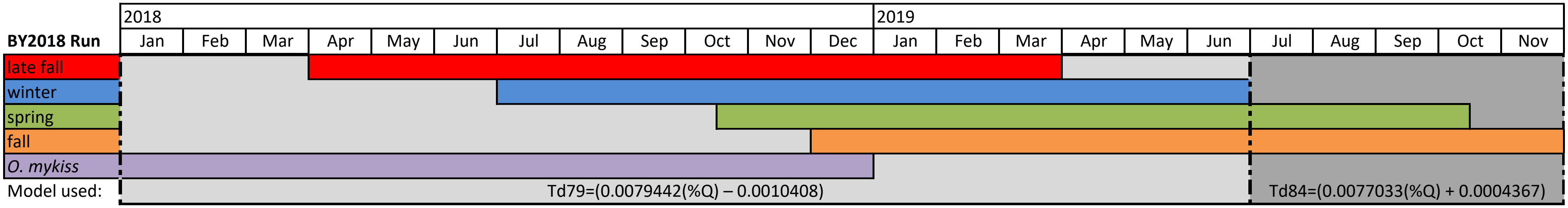

Figure 4.—Summary of trap efficiency models used for passage estimates during brood year 2018 for juvenile winter, spring, fall, late-fall Chinook salmon and *O. mykiss* from January 1, 2018, the start of the *O. mykiss* 2018 brood year through November 30, 2019, the end of the 2018 fall Chinook brood year.

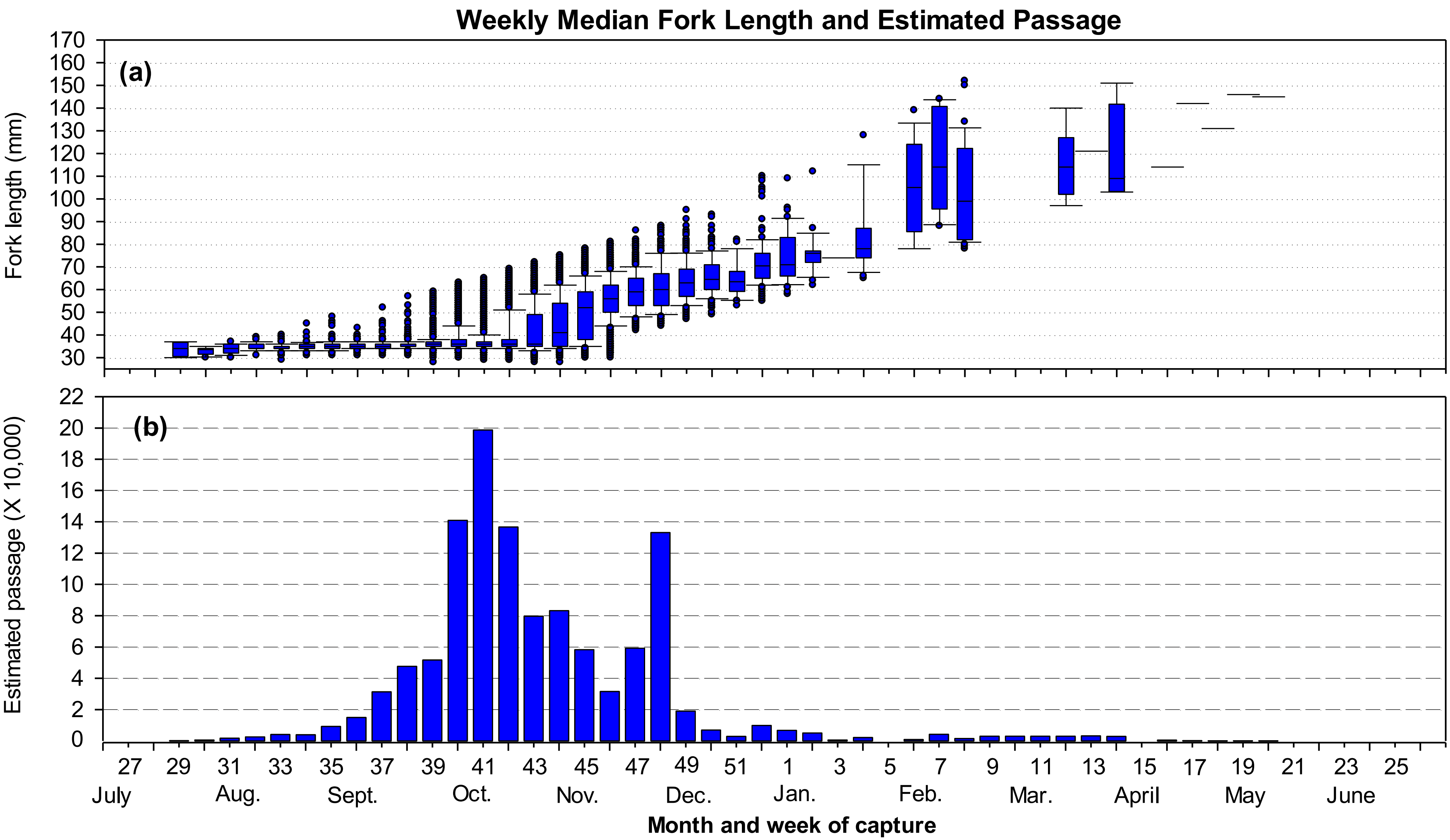

Figure 5. Weekly median fork length (a) and estimated passage (b) of brood year 2018 juvenile winter Chinook salmon passing Red Bluff Diversion Dam (RK 391), Sacramento River, California. Winter Chinook salmon were sampled by rotary-screw traps for the period July 1, 2018 through June 30, 2019. Box plots display weekly median fork length, 10^{th}, 25^{th}, 75^{th}, and 90^{th} percentiles and outliers.

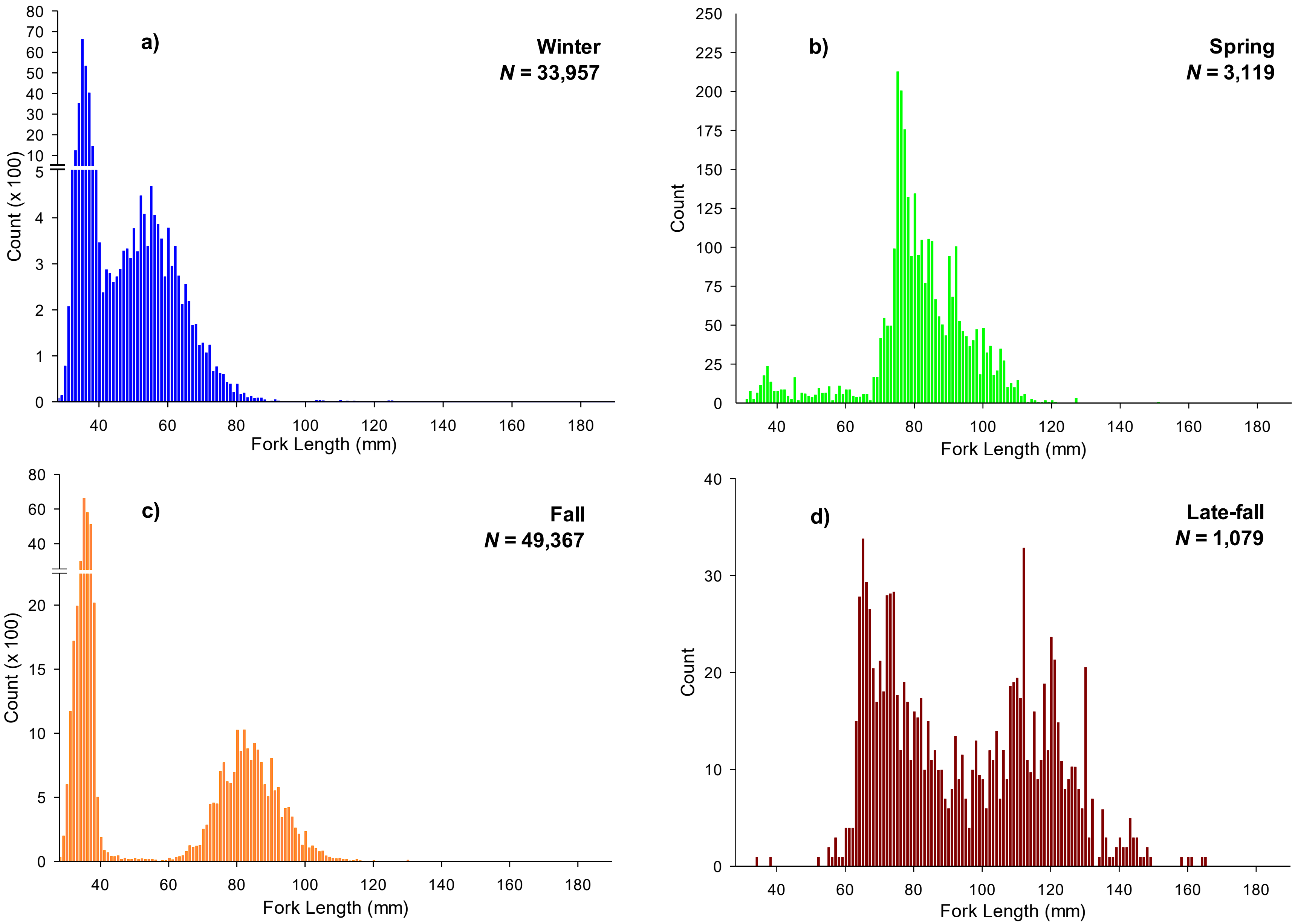

Figure 6. Fork length frequency distribution of brood year 2018 juvenile a) winter, b) spring, c) fall and d) late-fall Chinook salmon sampled by rotary-screw traps at Red Bluff Diversion Dam (RK 391), Sacramento River, California. Fork length data were expanded to unmeasured individuals when sub-sampling protocols were implemented. Sampling was conducted from April 1, 2018 through November 30, 2019.

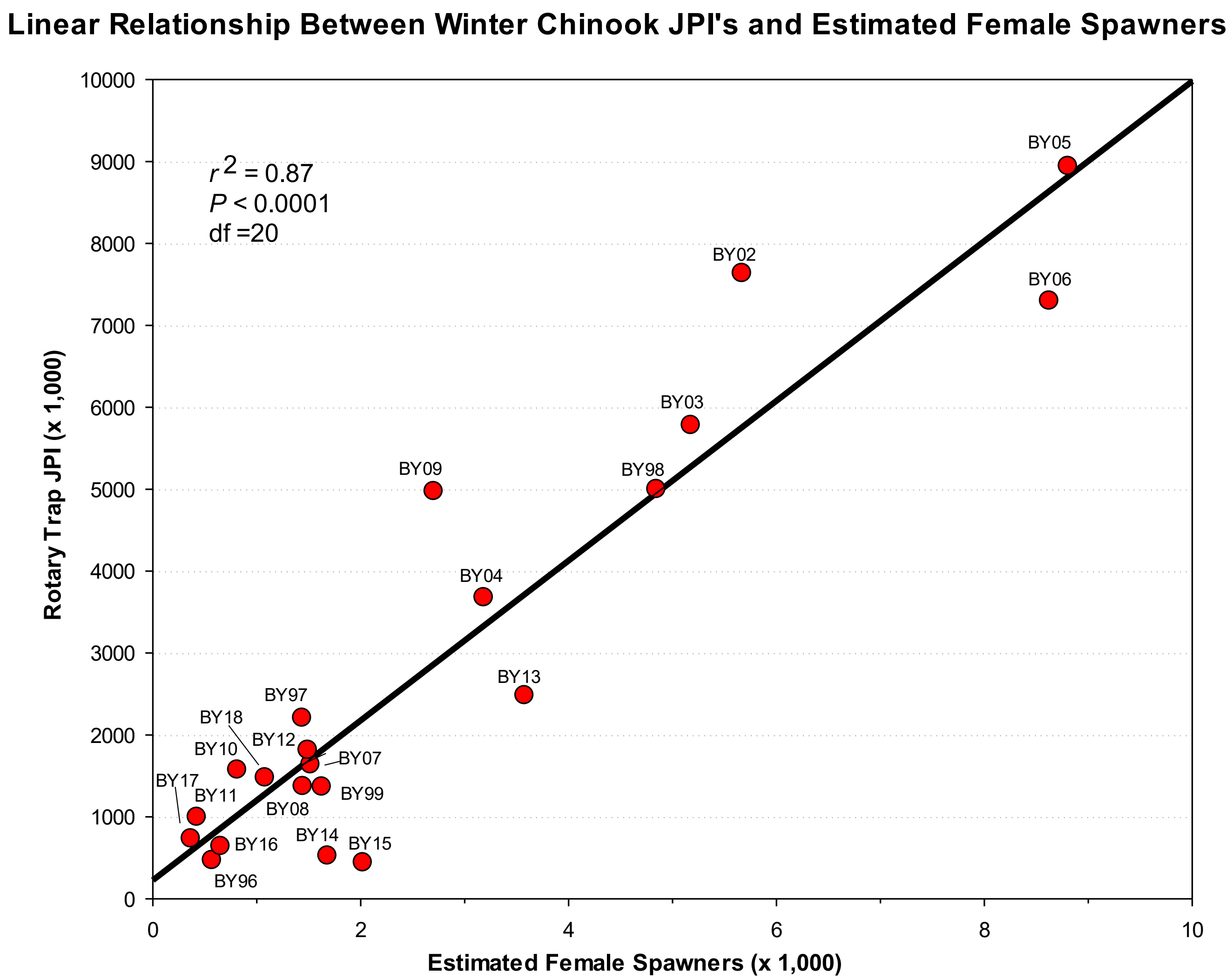

Figure 7. Linear relationship between rotary-screw trap juvenile winter Chinook fry-equivalent production indices (Rotary Trap JPI) and carcass survey derived estimated female spawners.

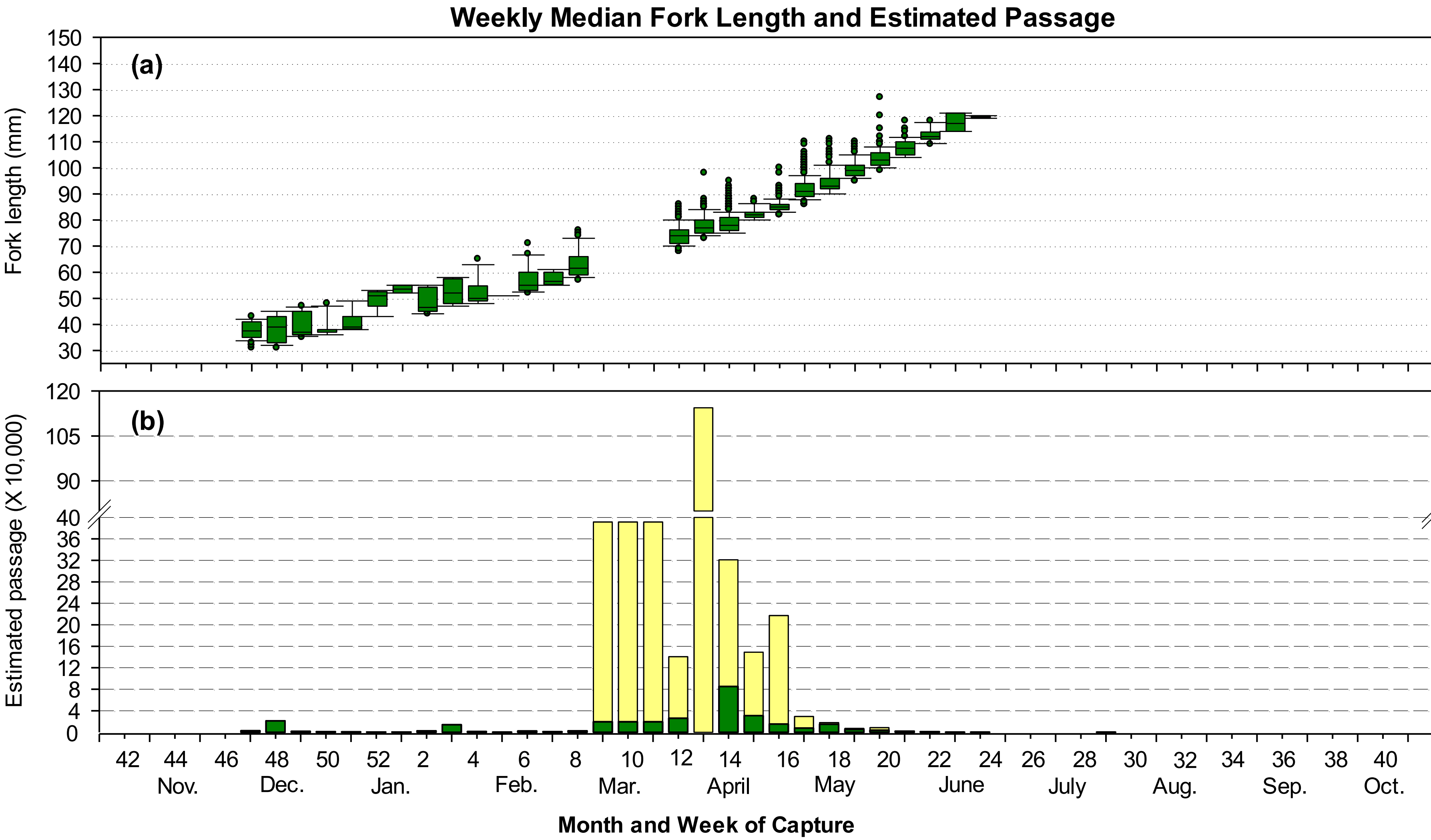

Figure 8. Weekly median fork length (a) and estimated passage (b) of brood year 2018 juvenile spring Chinook salmon passing Red Bluff Diversion Dam (RK 391), Sacramento River, California. Spring Chinook salmon were sampled by rotary-screw traps for the period October 16, 2018 through October 15, 2019. Box plots display weekly median fork length, 10th, 25th, 75th, and 90th percentiles and outliers. Yellow bars represent proportion of total passage of LAD spring Chinook that were estimated to be unmarked CNFH hatchery fall Chinook based on 75% unmarked ratio expansions.

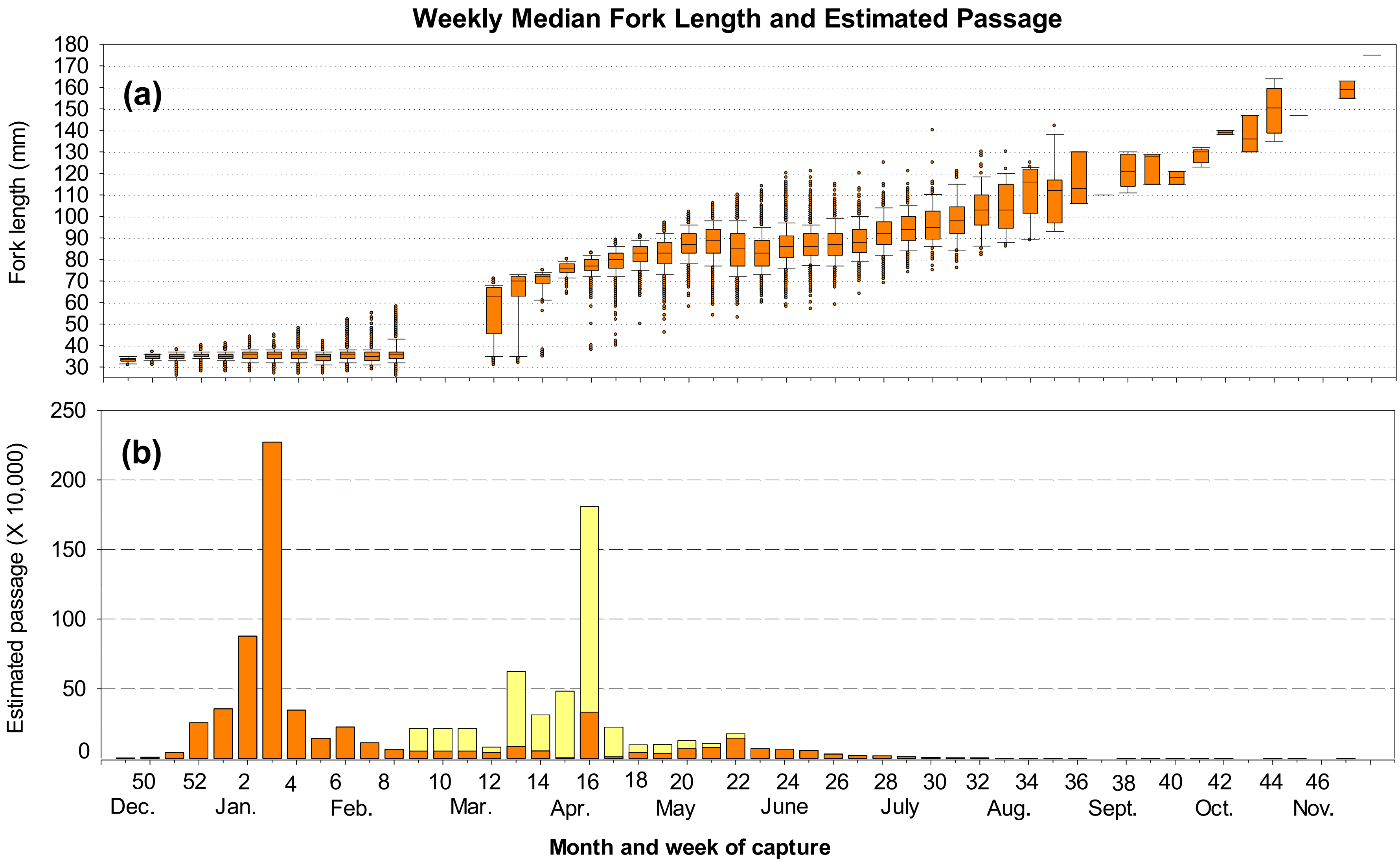

Figure 9. Weekly median fork length (a) and estimated passage (b) of brood year 2018 juvenile fall Chinook salmon passing Red Bluff Diversion Dam (RK 391), Sacramento River, California. Fall Chinook salmon were sampled by rotary-screw traps for the period December 1, 2018 through November 30, 2019. Box plots display weekly median fork length, 10^{th}, 25^{th}, 75^{th}, and 90^{th} percentiles and outliers. Yellow bars represent proportion of total passage of LAD fall Chinook that were estimated to be unmarked CNFH hatchery fall Chinook based on 75% unmarked ratio expansions.

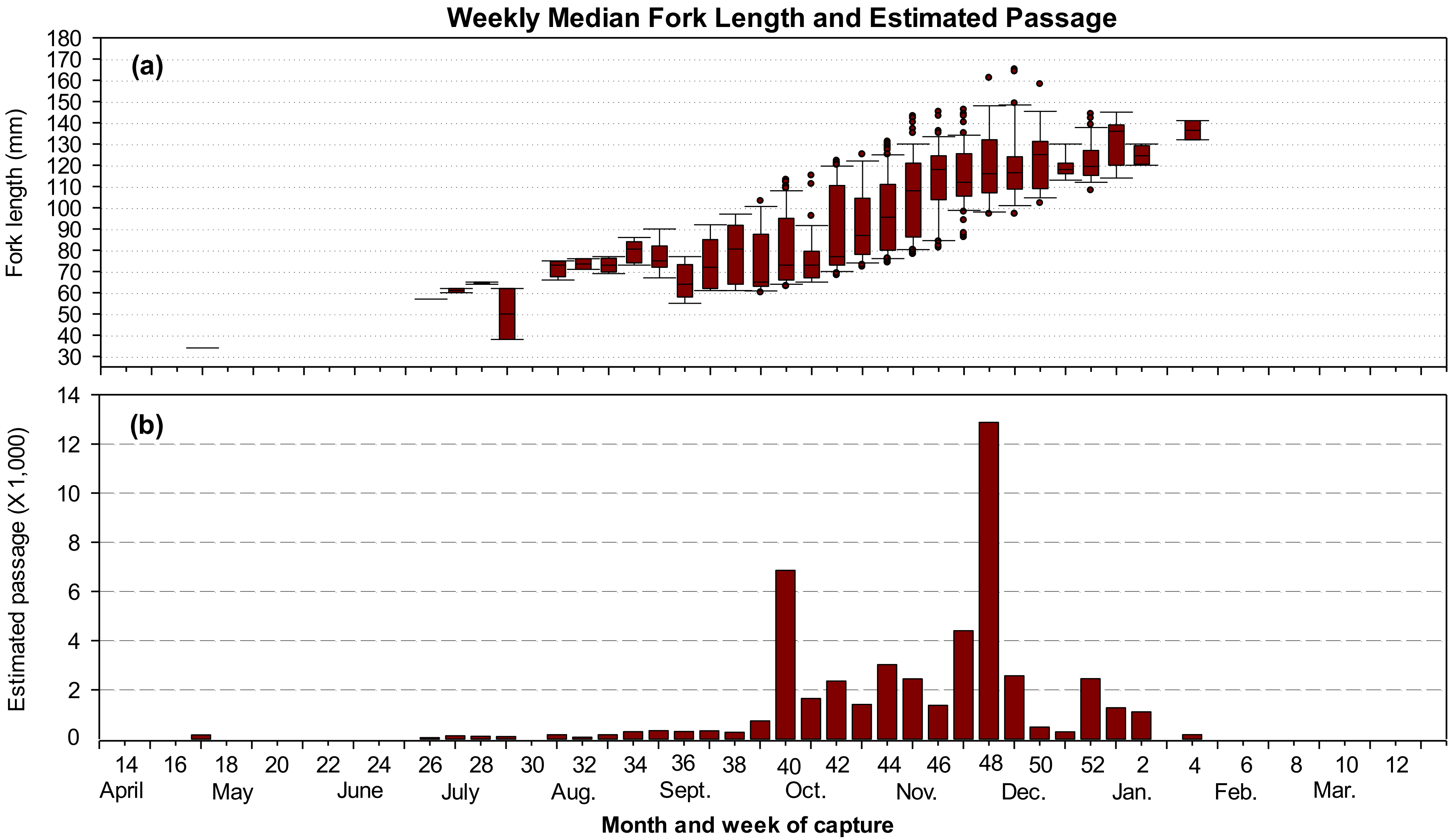

Figure 10. Weekly median fork length (a) and estimated passage (b) of brood year 2018 juvenile late-fall Chinook salmon passing Red Bluff Diversion Dam (RK 391), Sacramento River, California. Late-fall Chinook salmon were sampled by rotary-screw traps for the period April 1, 2018 through March 31, 2019. Box plots display weekly median fork length, 10th, 25th, 75th, and 90th percentiles and outliers.

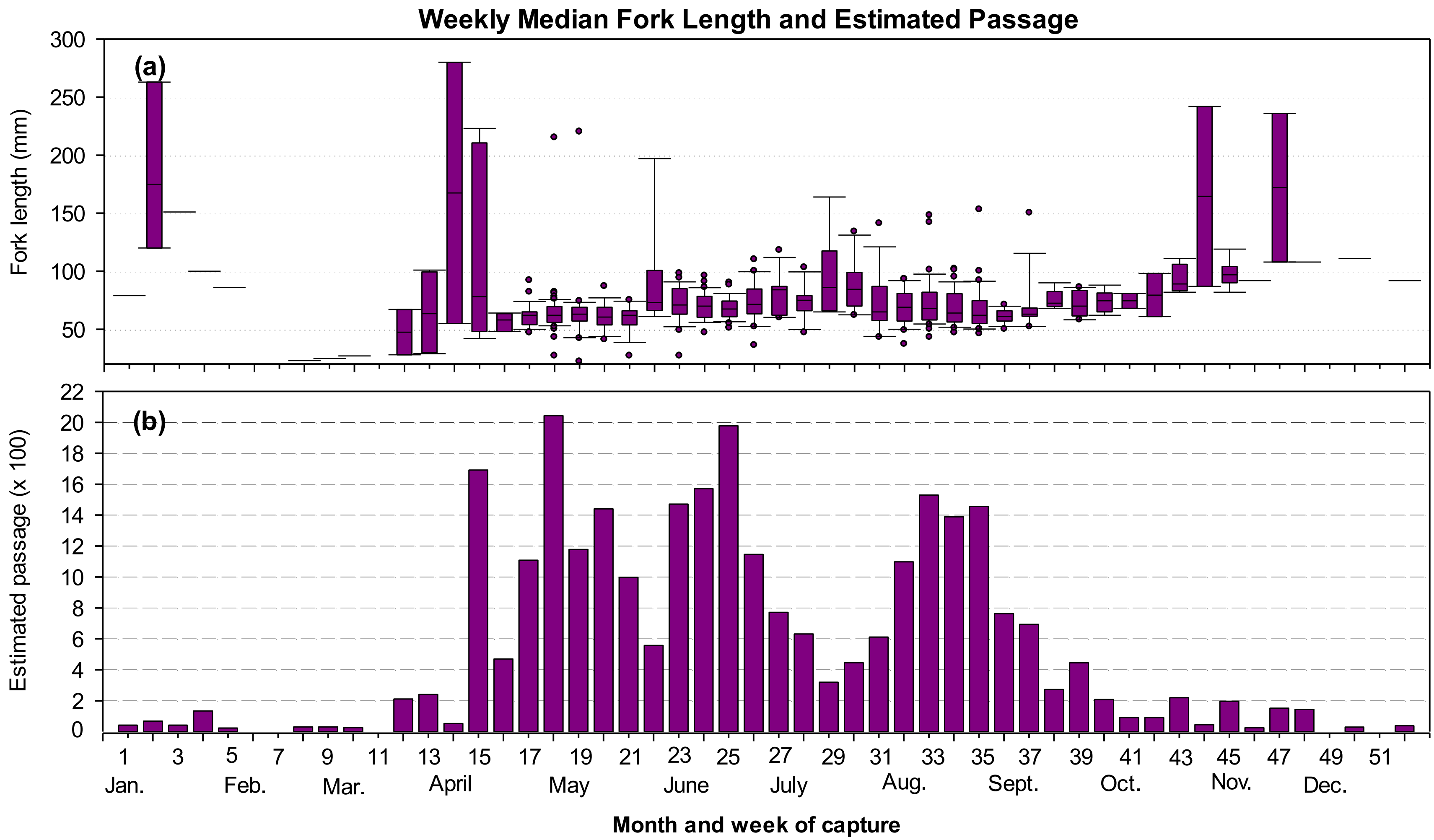

Figure 11. Weekly median fork length (a) and estimated passage (b) of brood year 2018 juvenile *O. mykiss* passing Red Bluff Diversion Dam (RK 391), Sacramento River, California. *O. mykiss* were sampled by rotary-screw traps for the period January 1, 2018 through December 31, 2018. Box plots display weekly median fork length, 10th, 25th, 75th, and 90th percentiles and outliers.

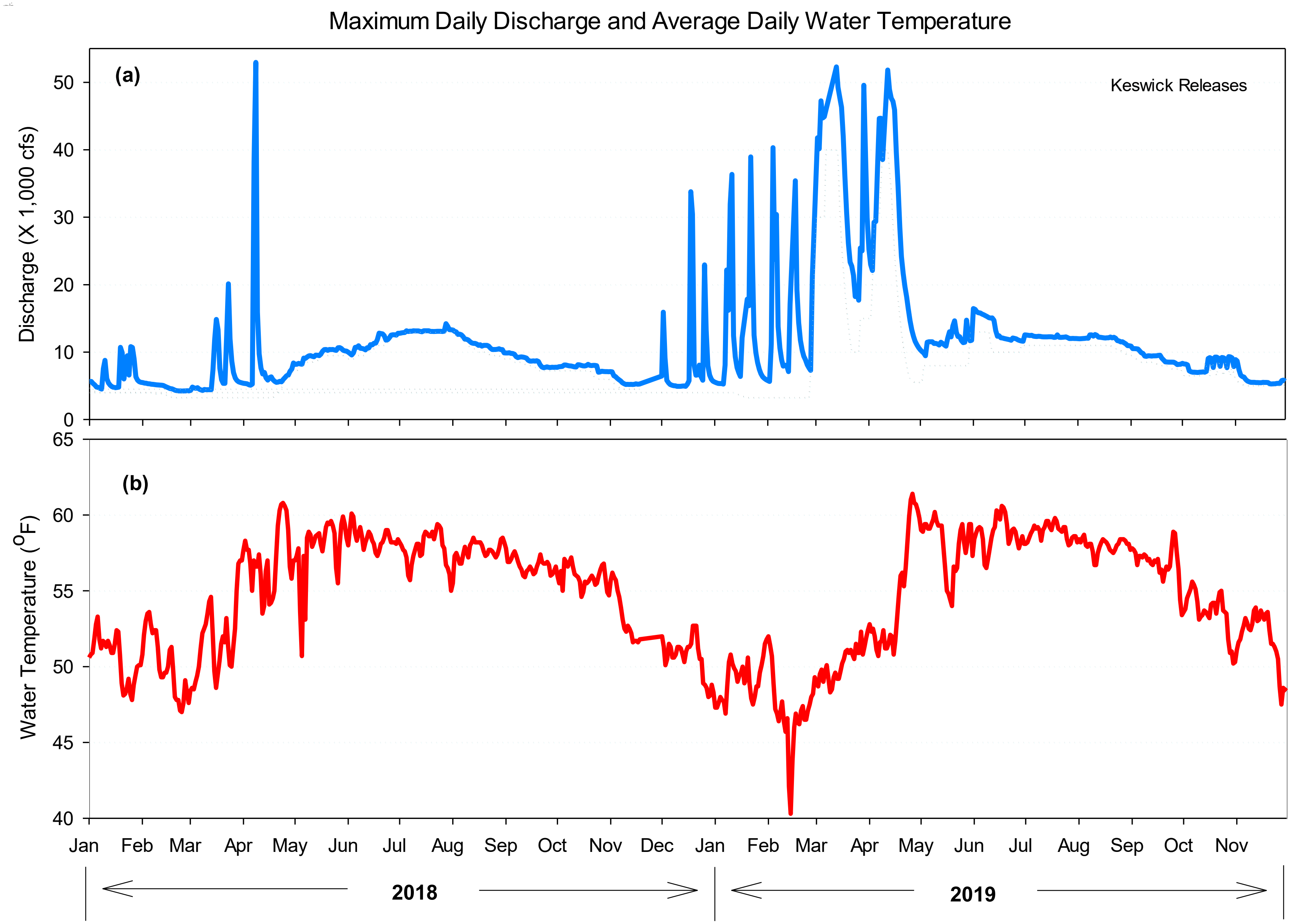

Figure 12. Sacramento River maximum daily discharge (a) observed at the California Data Exchange Center's Bend Bridge gauging station (blue line) showing water releases from Keswick Reservoir (gray shaded area) and average daily water temperatures (b) from rotary-screw traps at RBDD for the period January 1, 2018 through November 30, 2019.

Appendix I.

Appendix I. Genetic sampling and run assignment methodology (S. Blankenship, Cramer Fish Sciences, pers. communication 2019)

Genetic samples were genotyped using multi-locus single nucleotide polymorphisms (SNP's). The methods used to determine SNP genotypes were allele-specific polymerase chain reaction (ASP) and amplicon sequencing (GTSeq). Specific assays for each locus were developed by NOAA Southwest Fisheries Science Center (Clemento et al. 2011) and SNPType™ assays were obtained from Fluidigm Corp. (South San Francisco, CA) when conducting ASP. These same loci are available for use within a sequencing-based approach termed GTSeq (Campbell et al. 2014). Approximately 25% of the samples were genotyped using ASP and 75% using GTSeq, with the primary decision point being time. ASP is a faster process and is used in-season to report populations assignment. GTSeq is more amendable to post-season analysis. All laboratory procedures followed Blankenship et al. (2013). All genotypes were translated into HapMap nucleotide standards (A=1, C=2, G=3, T=4, insertion/deletion=5, and no data=0). Established QA/QC procedures and scoring rules were followed for each locus.

The genetic loci used were predominantly those markers that comprised the reference baseline constructed by NOAA Southwest Fisheries Science Center (Clemento et al. 2011). In total, 91 genetic loci overlap between the SNPType™ marker set and reference baselines. Population composition of mixture collections (i.e., captured juveniles) were estimated by using a partial Bayesian procedure based on the likelihood of unknown-origin genotypes being derived from genetic baseline reference populations given the allele frequencies for reference populations. The mixed stock analysis (MSA) procedure followed Blankenship et al. (2013), which results in a maximum likelihood solution for stock composition (Millar, 1987). Assignment posterior probabilities for a given genotype are estimated for each reference collection and reported by standard population aggregations (i.e., Winter; Spring; Fall/Late-Fall). We accomplished this by extracting the assignment data from the MSA and summing the final posterior probabilities over reference populations within a reporting group. Population assignment was conducted using the ONCOR software (Steven Kalinowski unpublished, Montana State University).

Appendix II.

United States Department of the Interior

FISH AND WILDLIFE SERVICE

In reply refer to:

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

Memorandum

To: File

From: Bill Poytress, Program Manager, Red Bluff Fish and Wildlife Office, USFWS

Subject: Linear-model and genetic-based revisions to brood year 2018 juvenile winter and spring Chinook salmon passage and production estimates

Linear-model revision.–With sufficient numbers of winter-run fry captured by rotary traps, three mark-recapture trials were performed during the peak winter Chinook salmon juvenile outmigration period in October of 2018. Trials were performed to validate expected (i.e., linear-regression modeled) daily trap efficiencies in relation to observed trap efficiencies and ultimately to add trials to the linear model as part of efforts to continually improve the Red Bluff juvenile monitoring program's passage and production estimates. It is not uncommon for the program to verify the accuracy of modeled trap efficiency estimates and/or make changes to trapping operations to better align with predicted or estimated trap efficiencies as fish numbers allow. In October of 2018, two trials were conducted with 4 traps at 100% sampling capacity using naturally produced winter Chinook caught in the Red Bluff traps. Fish were marked and released as part of standard trial practices and nearly identical and distinct differences in observed versus expected (i.e., modeled) efficiencies were noted for these two trials (Figure 1; highlighted in red circle). The third trial reduced the amount of water volume sampled by 50% for one thalweg trap and resulted in values within the prediction intervals (grey lines) of the model and was deemed consistent with modeled efficiencies.

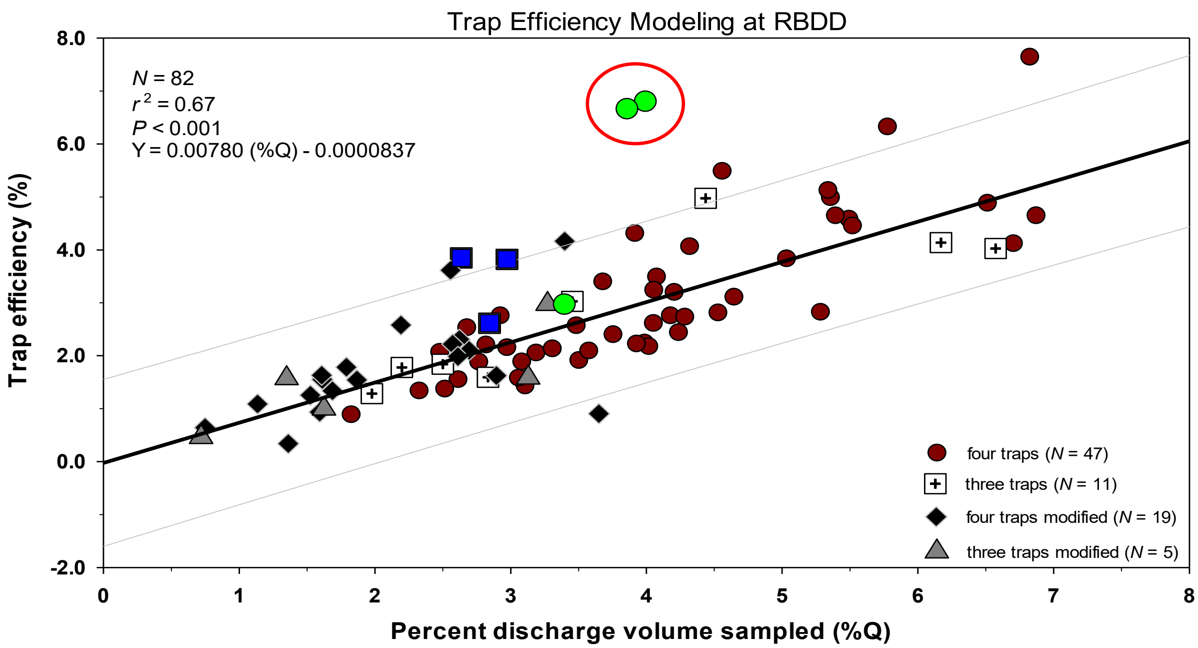

Figure 1. Trap efficiency model indicating fall of 2018 measured efficiency values plotted with (green circles) and without (blue squares) trap 6's recaptures.

TAKE PRIDE IN AMERICA

The reason(s) why the first two of three trials resulted in much greater efficiencies than would be predicted by the current model have not been fully determined. It is suspected that the arrangement of the traps across the transect, which varies within and between years, may have simply been sampling far more efficiently at the flows sampled (~ 7,200 cfs) than previous trials have observed. Moreover, changes in channel morphology in the absence of US Bureau of Reclamation operation of the Red Bluff Diversion Dam (RBDD) may have occurred in recent years. It is possible that high flow events, as were seen in 2017, resulted in channel changes upstream and at the RBDD sample site. Changes in stream channel configurations may have altered the migration routes juvenile salmon use during the fall period when the winter Chinook trap efficiency trials were conducted or simply increased the efficiency of the thalweg trap(s). Alternately, behavioral differences in migration patterns during peak fish abundance that could result in efficiencies greater than previously observed may have occurred that were previously undocumented.

Regardless of the actual reason(s) why the two trials were markedly different, the majority of the difference could be singled out to one of the four traps in operation. The trap in gate 6 (mid-channel or thalweg) appears to have been highly efficient at recapturing marked fish and, of the 4 traps was also sampling the greatest volume of water passing the transect (in absolute value and proportion). This situation likely resulted in the high efficiency values in relation to the percent of discharge sampled for the array of traps on the whole. Due to the consistency of the trial results under similar conditions and within a short time frame (i.e., days) during the peak period of winter run, the removal of trap 6's data for the months of September and October is expected to result in a more accurate depiction of modeled trap efficiency and subsequent calculations of daily passage.

The removal of trap 6 data from these calculations results in slightly lower daily passage estimates yet estimates that do not differ statistically (Mann-Whitney Rank Sum Test, $U=1652$, $P= 0.287$) with or without the inclusion of gate 6's data. The overall reduction in total passage for winter Chinook using 3-trap data versus 4 trap data is 9.2% for the 2018 brood year through November 18, 2018. The linear model used at the Red Bluff trapping location is flexible enough to allow for its use with 3 or 4 traps in operation and use with 3 or 4 traps, modified to sample 50 or 100% of their volume as has been done throughout the 20+ years of sampling at this location.

As a result, daily passage and production estimates tabulated in preliminary bi-weekly reports denoted as "revised" estimates will be posted in parallel with original reports and will include this adjustment for all salmonid passage estimates for the period September and October with results extending through December 31, 2018. Further adjustments to winter and spring Chinook due to genetics will be discussed below and be included as part of the revised estimates. Annual reporting of these findings and a final estimate for winter Chinook will discuss this information in greater detail after the conclusion of the outmigration year.

Genetic-based revision.–During the fall of 2018 and similar to 2017, we had fin clips genetically analyzed from juvenile winter and spring Chinook, designated by length-at-date (LAD) criteria, to verify run designation as part of two genetic sampling projects. These projects are known as the "Improving Vital Rates Estimation Using Parentage-Based Mark Recapture Methods" and the "Central Valley Salmonid Coordinated Genetic Monitoring Project". Both projects have been conducted for three consecutive years (2016, 2017, 2018) and genetic analyses has been conducted in prior years (BY 2015 and BY 2016) on a small sample of fish sacrificed for histological analyses (n = 80/yr) by Dr. Scott Foote of the California Nevada Fish Health Center during the latter half of the drought.

Using the data gathered from standardized genetic sampling (fin clips) of up to 10 winter and 10 spring Chinook salmon collected daily, we were able to evaluate the accuracy of our field-based LAD run assignments used, in part, to generate the brood year 2018 winter and spring Chinook passage and production estimates. The LAD run assignment method has been the standard model used by the Red Bluff Fish and Wildlife Office for run assignment at the RBDD rotary-trap sampling site since 1995. Genetic samples were taken from 2 out of 4 traps per day in a standardized rotation. For instance, when fish numbers were adequate in all traps, we would sample 10 of each run from 2 traps on day 1 and then do the same for the other 2 traps on day 2. During periods of low winter and/spring Chinook abundance, fin clips were collected from 3 or up to 4 traps per day to meet the targeted number of fin clips per day.

Genetic samples (n = 259) were collected from LAD designated spring Chinook between October 16 and November 27, 2018. Prior to November 19, 2018, all samples (n=233) were genetically identified as winter Chinook. As a result, genetically identified winter Chinook were incorrectly assigned to spring Chinook using LAD criteria for a period of 34 days. Incorrectly assigned spring Chinook using LAD during this time period (October 16 to November 18) contributed positive bias to spring run passage estimates and negative bias to winter run passage estimates. The genetic data indicated the need to revise our passage/production estimates for the two runs to more accurately portray juvenile passage and production in 2018 in a similar fashion as 2017, but to a lesser degree in magnitude.

Independently collected adult Chinook salmon data and information from the California Department of Fish and Wildlife (CDFW) provided additional support for the need to revise the winter and spring Chinook juvenile passage/production estimates. In the summer and fall of 2018, the adult winter Chinook carcass survey data indicated later spawning of adults as was seen in 2017 (Figure 2). Sacramento River water temperature analyses conducted by CDFW coupled with winter Chinook redd data estimated the last emergence timing of winter Chinook fry could occur as late as November 18, 2018. Other survey work of adult carcass and redd survey data collected by CDFW and USFWS indicated that spring-run Chinook adults upstream of our sample site in the mainstem Sacramento River and tributaries numbered less than 100 individuals. The first juvenile spring Chinook catch on Clear Creek and Battle Creek screw traps occurred on November 18 and 28, respectively. These data, when combined, provided evidence that the numbers of spring Chinook juveniles we estimated passage of between October 16 and November 18, 2018 was highly unlikely and represent mis-assignment through the use of the LAD criteria model.

Similar to 2017 and based on the contributing factors and data obtained in the fall of 2018, I felt it necessary to reassign fish that, according to LAD criteria, fell into the spring run category to the winter run category based on the results of genetic analyses. I used the genetic data to determine that the period of October 16 through November 18, 2018 was appropriate to reassign all spring run fish to winter run. Biweekly reports' passage data for both runs have been revised for the period of October 8, 2018 through November 18, 2018 to incorporate the revised daily estimates. This revision will be incorporated into passage estimates through the remainder of the brood year 2018 winter and spring Chinook outmigration period. These data will be used as the official passage and production estimates and be detailed in an annual report that will be completed in the coming year. Both sets of reports have been placed on the Red Bluff Fish and Wildlife Office's website biweekly report page for 2018 for interested parties to compare pre- and post-genetic correction passage estimates for each run.

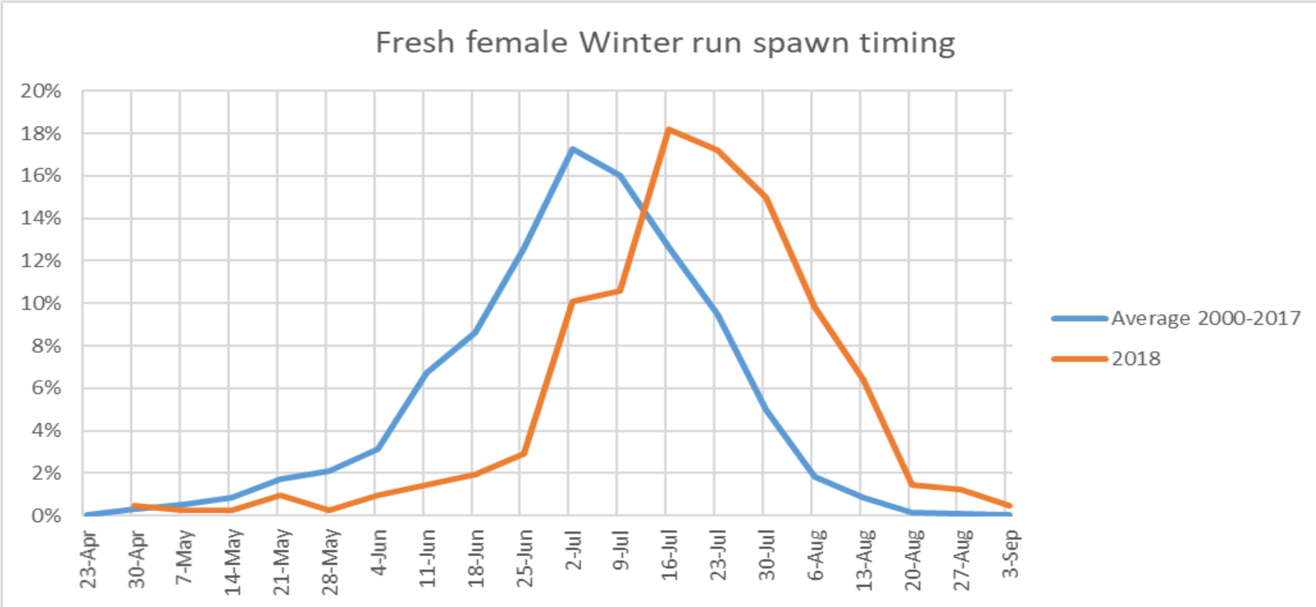

Figure 2. Winter Chinook spawning temporal distribution comparison on 2018 data to average of 2000-2017 data. Data based on carcass recoveries and provided by CDFW.

Appendix III.

Table A1— Sampling effort, weekly passage estimates, median fork length (Med FL) and juvenile production indices (JPI's) for spring Chinook salmon passing Red Bluff Diversion Dam (RK 391) for the period October 16, 2018 through October 15, 2019 (brood year 2018). Full sampling effort indicated by assigning a value of 1.00 to a week consisting of four 2.4-m diameter rotary-screw traps sampling 24 hours daily, 7 days per week. Results include estimated passage (Est. passage) for fry (< 46 mm FL), pre-smolt/smolts (> 45 mm FL), total (fry and pre-smolt/smolts combined) and fry-equivalents. Fry-equivalent JPI's were generated by weighting pre-smolt/smolt passage by the inverse of the fry to pre-smolt/smolt survival rate (59% or approximately 1.7:1; Hallock undated).

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
42	0.75	0	-	0	-	0	-	0
43	0.64	0	-	0	-	0	-	0
44 (Nov)	0.82	0	-	0	-	0	-	0
45	1.00	0	-	0	-	0	-	0
46	1.00	0	-	0	-	0	-	0
47	0.71	2,896	37.5	0	-	2,896	37.5	2,896
48 (Dec)	0.50	21,124	39	0	-	21,124	39	21,124
49	0.55	1,388	36	148	46.5	1,536	37	1,640
50	0.85	893	37	164	47	1,057	37	1,172
51	0.71	619	39	142	49	761	39	860
52	0.69	37	43	417	51.5	454	51	746
1 (Jan)	0.36	0	-	329	53.5	329	53.5	559
2	0.36	1,432	45	1,248	54	2,681	46.5	3,554
3	0.16	0	-	14,160	52	14,160	52	24,072
4	0.43	0	-	1,457	50	1,457	50	2,476
5 (Feb)	0.29	0	-	120	51	120	51	204
6	0.71	0	-	2,219	55	2,219	55	3,772
7	0.43	0	-	1,142	56.5	1,142	56.5	1,942
8	1.00	0	-	2,443	61.5	2,443	61.5	4,152
9 (Mar)	0.00	0	-	391,475	-	391,475	-	665,507
10	0.00	0	-	391,475	-	391,475	-	665,507
11	0.00	0	-	391,475	-	391,475	-	665,507
12	0.84	0	-	140,638	74	140,638	74	239,084
13	0.21	0	-	1,143,985	77	1,143,985	77	1,944,774
14 (Apr)	0.50	0	-	400,398	78	400,398	78	680,677
15	0.25	0	-	149,012	82	149,012	82	253,320

Table A1—(continued)

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
16	0.70	0	-	217,106	85	217,106	85	369,080
17	0.77	0	-	29,307	91	29,307	91	49,821
18 (May)	0.57	0	-	17,979	93	17,979	93	30,565
19	0.89	0	-	7,051	99	7,051	99	11,987
20	0.64	0	-	8,453	103	8,453	103	14,370
21	0.82	0	-	2,319	107.5	2,319	107.5	3,942
22 (Jun)	0.43	0	-	1,162	112	1,162	112	1,976
23	0.75	0	-	185	117	185	117	314
24	1.00	0	-	110	119.5	110	119.5	188
25	1.00	0	-	0	-	0	-	0
26	0.82	0	-	0	-	0	-	0
27 (Jul)	0.93	0	-	0	-	0	-	0
28	1.00	0	-	0	-	0	-	0
29	1.00	0	-	46	151	46	151	77
30	1.00	0	-	0	-	0	-	0
31 (Aug)	1.00	0	-	0	-	0	-	0
32	1.00	0	-	0	-	0	-	0
33	0.86	0	-	0	-	0	-	0
34	0.96	0	-	0	-	0	-	0
35 (Sep)	0.93	0	-	0	-	0	-	0
36	0.70	0	-	0	-	0	-	0
37	0.70	0	-	0	-	0	-	0
38	0.71	0	-	0	-	0	-	0
39	0.63	0	-	0	-	0	-	0
40 (Oct)	0.68	0	-	0	-	0	-	0
41	0.54	0	-	0	-	0	-	0
BY total		28,389		3,316,164		3,344,553		5,665,867
90% CI (low : high)		(-949 : 57,727)		(-2,936,265 : 9,568,593)		(-2,936,502 : 9,625,607)		(-4,986,908 : 16,318,643)

Table A2— Sampling effort, weekly passage estimates, median fork length (Med FL) and juvenile production indices (JPI's) for fall Chinook salmon passing Red Bluff Diversion Dam (RK 391) for the period October 16, 2018 through October 15, 2019 (brood year 2018). Full sampling effort indicated by assigning a value of 1.00 to a week consisting of four 2.4-m diameter rotary-screw traps sampling 24 hours daily, 7 days per week. Results include estimated passage (Est. passage) for fry (< 46 mm FL), pre-smolt/smolts (> 45 mm FL), total (fry and pre-smolt/smolts combined) and fry-equivalents. Fry-equivalent JPI's were generated by weighting pre-smolt/smolt passage by the inverse of the fry to pre-smolt/smolt survival rate (59% or approximately 1.7:1; Hallock undated).

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
48 (Dec)	0.50	0	-	0	-	0	-	0
49	0.55	1,374	33.5	0	-	1,374	34	1,374
50	0.85	7,261	35	0	-	7,261	35	7,261
51	0.71	41,034	35	0	-	41,034	35	41,034
52	0.69	256,188	35	0	-	256,188	35	256,188
1 (Jan)	0.36	355,281	35	0	-	355,281	35	355,281
2	0.36	878,086	36	0	-	878,086	36	878,086
3	0.16	2,272,530	36	0	-	2,272,530	36	2,272,530
4	0.43	345,227	36	1,609	47	346,836	36	347,962
5 (Feb)	0.29	143,508	35	0	-	143,508	35	143,508
6	0.71	220,978	36	3,788	50	224,766	36	227,418
7	0.43	105,772	35	5,662	50	111,434	35	115,397
8	1.00	59,825	36	4,971	52	64,796	36	68,275
9 (Mar)	0.00	31,948	-	184,373	-	216,321	-	345,382
10	0.00	31,948	-	184,373	-	216,321	-	345,382
11	0.00	31,948	-	184,373	-	216,321	-	345,382
12	0.84	19,146	36	61,538	66	80,685	63	123,761
13	0.21	70,352	35	552,878	71	623,230	70	1,010,245
14 (Apr)	0.50	45,674	36	266,141	72	311,815	72	498,114
15	0.25	0	-	482,330	76	482,330	76	819,960
16	0.70	10,440	38	1,798,438	77	1,808,878	77	3,067,785
17	0.77	776	41	223,273	80	224,049	80	380,340
18 (May)	0.57	0	-	96,374	83	96,374	83	163,836
19	0.89	0	-	100,465	83	100,465	83	170,790
20	0.64	0	-	128,167	87	128,167	87	217,883
21	0.82	0	-	106,523	89	106,523	89	181,089

Table A2—(continued)

Week	Sampling Effort	Fry Est. passage	Fry Med FL	Pre-smolt/smolts Est. passage	Pre-smolts/smolts Med FL	Total Est. passage	Total Med FL	Fry-equivalent JPI
22 (Jun)	0.43	0	-	175,792	85	175,792	85	298,847
23	0.75	0	-	69,824	83	69,824	83	118,701
24	1.00	0	-	65,284	86	65,284	86	110,983
25	1.00	0	-	57,250	86	57,250	86	97,325
26	0.82	0	-	30,423	87	30,423	87	51,719
27 (Jul)	0.93	0	-	19,997	88	19,997	88	33,995
28	1.00	0	-	18,307	92	18,307	92	31,122
29	1.00	0	-	14,102	94	14,102	94	23,974
30	1.00	0	-	6,100	95	6,100	95	10,370
31 (Aug)	1.00	0	-	4,062	98	4,062	98	6,906
32	1.00	0	-	2,825	103	2,825	103	4,803
33	0.86	0	-	659	103	659	103	1,120
34	0.96	0	-	896	116	896	116	1,523
35 (Sep)	0.93	0	-	542	112	542	112	922
36	0.70	0	-	68	113	68	113	116
37	0.70	0	-	0	110	0	110	0
38	0.71	0	-	333	121	333	121	565
39	0.63	0	-	126	128	126	128	215
40 (Oct)	0.68	0	-	215	118	215	118	365
41	0.54	0	-	261	130	261	130	444
42	0.63	0	-	59	139	59	139	101
43	0.50	0	-	0	136	0	136	0
44 (Nov)	0.73	0	-	120	150.5	120	150.5	204
45	1.00	0	-	26	147	26	147	45
46	1.00	0	-	0	-	0	-	0
47	1.00	0	-	53	159	53	159	90
BY total		4,929,296		4,852,601		9,781,897		13,178,718
90% CI (low : high)		(628,894 : 9,229,698)		(-829,008 : 10,534,210)		(-153,674 : 19,717,469)		(-724,690 : 27,082,125)

Table A3.— Fall Chinook fry-equivalent juvenile production indices (JPI), lower and upper 90% confidence intervals (CI), estimated adult female spawners above RBDD (Estimated Females), estimates of female fecundity, calculated juveniles per estimated female (Estimated Recruits/Female) and egg-to-fry survival estimates (ETF) with associated lower and upper 90% confidence intervals (L90 CI : U90 CI) by brood year (BY) for Chinook sampled at RBDD rotary traps between December 2002 and November 2019.

BY	Fry Equivalent JPI	Lower 90% CI	Upper 90% CI	Estimated Females[1]	Fecundity[2]	Estimated Recruits/Female	ETF Survival Rate (%)	L90 CI : U90 CI
2002	18,683,720	1,216,244	51,024,926	211,035	5,407	89	1.6	(0.1 : 4.5)
2003	30,624,209	10,162,712	55,109,506	79,509	5,407	385	7.1	(2.4 : 12.8)
2004	18,421,457	6,224,790	33,728,746	31,045	5,407	593	11.0	(3.7 : 20.1)
2005	22,739,315	4,235,720	49,182,045	37,738	5,407	603	11.1	(2.1 : 24.1)
2006	20,276,322	8,670,090	32,604,760	42,730	5,407	475	8.8	(3.8 : 14.1)
2007	13,907,856	7,041,759	20,838,463	16,996	5,407	818	15.1	(7.7 : 22.7)
2008	10,817,397	5,117,059	16,517,847	16,644	5,362	650	12.1	(5.7 : 18.5)
2009	9,674,829	3,678,373	15,723,368	6,531	5,318	1,481	27.9	(10.6 : 45.3)
2010	10,620,144	5,637,617	15,895,197	7,008	5,167	1,515	29.3	(15.6 : 43.9)
2011	7,554,574	4,171,332	10,960,125	9,260	5,945	816	13.7	(7.6 : 19.9)
2012	26,567,379	17,219,525	36,197,837	32,635	5,242	814	15.5	(10.1 : 21.2)
2013	34,163,943	6,247,962	62,079,924	39,422	5,390	867	16.1	(2.9 : 29.2)
2014	4,387,348	2,407,113	6,367,583	35,345	5,453	124	2.3	(1.2 : 3.3)
2015	30,728,228	-533,520	61,973,977	23,302	4,971	1,319	26.5	(-0.5 : 53.5)
2016 [3]	25,812,410	-22,447,165	74,071,986	5,240	4,778	4,926	103.1	(-89.7 : 295.9)
2017	3,482,430	1,927,884	5,036,976	4,437	4,455	785	17.6	(9.8 : 25.5)
2018	13,178,718	-724,690	27,082,125	11,631	5,442	1,133	20.8	(-1.1 : 42.8)
					Average	1,023	20.0	(-0.5 : 41.0)
					Standard Deviation	1,086	22.9	(23.4 : 67.2)

[1]Estimated females derived from carcass survey; sex ratios used to determine female spawners based on RBDD fish ladder data between 2003 and 2007 and CNFH data between 2008 and 2016.

[2]Female fecundity estimates for years 2002 thru 2007 based on average values from CNFH fall Chinook spawning data collected between 2008 and 2012 (Poytress 2014).

[3]2016 values prior to CNFH fall Chinook releases: Fry Equivalent JPI: 8,471,017 (-3,521,433 : 20,463,466); Estimated Recruits/Female: 1,617; ETF Survival Rate (%): 33.8% (-14.1 : 81.7).