# Red Bluff Diversion Dam Rotary Screw-Trap Sampling Methods

Sampling Gear.— Prior to June 30, 2020, 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 RSTs 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 (< 1.2 m), or river hydrology restricted our ability to sample with all traps (water velocity < 0.6 m/s).

Changes in river morphology after the decommissioning of the RBDD gates in 2011 resulted in variable river depths across the RST transect. Changes to the riverbed transect can occur annually or over multiple years, within or between all or some gates and can be subtle or significant in terms of sediment transport and deposition/erosion rates. Substrate aggradation has caused insufficient river depths across many gates for RST cones to sample, especially during periods of low flows (e.g., < 5kcfs). Insufficient depths lead to equipment damage and/or failure when 2.4-m RST cones interact heavily with river substrates. Oftentimes, RST cones created their own depression in the river bottom allowing continued sampling, but in some instances this resulted in conditions unfit to sample, and necessitated the use of smaller RSTs. Beginning on July 1, 2020, four 1.5-m diameter RSTs were used in concert with one 2.4-m RST, lending flexibility to sample a total of either four or five traps across the transect.[[1]](#footnote-1)

Sampling Regimes.—In general, RSTs sampled continuously throughout 24-hour periods and samples were processed once daily[[2]](#footnote-2). 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 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 was reduced from four to three, or after June 30, 2020 from five to four. 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)[[3]](#footnote-3). 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.

Green Sturgeon and Lamprey species were measured for total length (TL) to the nearest mm. Identification of Green Sturgeon larvae was possible based on meristic traits for individuals > 46 mm TL and identified to genus for all individuals <46 mm but assumed to be Green Sturgeon based on spawning adult data (Poytress et al. 2015; Mora et al. 2018). Lamprey species were identified to the genus level during the ammocoete stage and described as ammocoetes. Adult and macrophthalmia (eyed juveniles) were identified to the genus and species level using dentition patterns, specifically by the number of inner lateral horny plates on the sucking disk (Moyle 2002).

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 (2.4-m diameter cone) or 0.37 m (1.5-m diameter cone), 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 gaging station at RKM 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 RST sampling effort was quantified by assigning a value of 1.00 to a week consisting of four 2.4-m diameter RSTs sampling 24 hours daily, 7 days per week. After 6/30/2020, a value of 1.00 was assigned to a week consisting of four 1.5-m diameter and one 2.4-m diameter traps sampling 24 hours daily, 7 days per week. Weekly values <1.00 represented occasions when less than all 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 Bismarck 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 45-60 minutes, removed, and allowed to recover in fresh water. Marked fish were held for 6-24 hours before being released 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; *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 had been updated to include naturally-produced fish sampled during monitoring activities without the RBDD gates in the lowered position (Poytress 2016; Voss and Poytress 2020). Initially, the model for BY2020 relied on 99 mark-recapture trials using wild fish and conducted with the RBDD gates raised between 2002 and 2020 (*r*2 = 0.66, *P* < 0.001, df = 98), which added the 15 most recent trials conducted to the 84-trial model used during BY2019. Biweekly reports during BY2020 used the 99-trial model for near real-time estimates. After review of trap efficiency trial results conducted post-RBDD gate operations, it was determined to employ a 42-trial model using results from wild fish trials conducted from January 2012 to February 2020 (*r*2 = 0.61, *P* < 0.001, df = 41; Figure 3). This document reports passage estimates using the 42-trial model.

Daily Passage Estimates (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 *Cdi* as catch at trap *i* (*i* = 1,…,*t*) on day *d* (*d* = 1,…,*n*), and *Xdi* 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.

and,

2.

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

3.

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

4.

where,

5.

and, *d* = estimated trap efficiency on day *d*.

Weekly Passage ().―Population totals for numbers of Chinook and *O. mykiss* passing RBDD each week were derived from *d* where there are *N* days within the week:

6.

*Estimated Variance*.―

7.

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

8.

The second term in eq. 7 is associated with estimating *d* within the day.

9.

where,

10. *Var(d)* = error variance of the trap efficiency model

The third term in eq. 7 is associated with estimating both *i* and *j* with the same trap efficiency model.

11.

where,

12. *Cov(I,j)* = *Var*() + χi*Cov()* + χj*Cov()* + χiχj*Var*()

for some

Confidence intervals (CI) were constructed around using eq. 13.

13.

Annual JPI's were estimated by summing across weeks.

14.

Relative Abundance.*—*Catch per unit volume (CPUV; Gaines and Martin 2002; Poytress et al. 2014) was used as an index of relative abundance (RA) for Green Sturgeon and Lamprey species at RBDD.

15.

= Relative abundance on day *d* by trap *t* (catch/acre-foot),

= number of fish captured on day *d* by trap *t*, and

= volume of water sampled on day *d* by trap *t*.

The volume of water sampled (Vdt) was estimated for each trap as the product of one-half the cross sectional area (wetted portion) of the cone, water velocity (ft/s) directly in front of the cone at a depth of 0.6 m (2.4-m cone) or 0.37 m (1.5-m cone), cone modified (multiplied by 0.5) or not (multiplied by 1.0), and duration of sampling.

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 for spring, fall, and late-fall Chinook 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.

A run-specific, annually calculated fry-to-smolt survival hindcast estimate based on O’Farrell et al. (2018) was employed for winter Chinook in 2020 as the best available science. This survival estimate was employed, as recommended by the Interagency Ecological Program’s Winter-Run Project Work Team, for the production of a winter Chinook juvenile production estimate to guide incidental take at the Sacramento-San Joaquin Delta pumping facilities in 2020 (NMFS 2021). O’Farrell’s method incorporates summation of fry JPI and a weighted (2.235:1) pre-smolt/smolt JPI (inverse value of 44.75% fry-to-pre-smolt/smolt survival) for estimation of BY2020 winter Chinook fry-equivalents. All BY2020 winter Chinook fry-equivalent production estimates reported within the following text, tables and graphics were calculated using O’Farrell’s estimate of fry-to-smolt survival.

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 2021), 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 (LSNFH) 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 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, captures of unmarked hatchery fish 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* (adipose fin clipped) 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, using a 42-trial trap efficiency model, with and without the removal of hatchery fish are reported for fall and spring Chinook.

1. Sampling of (4) 1.5-m and (1) 2.4-m RST is equivalent to sampling 87.5% volume of (4) 2.4-m RST’s. [↑](#footnote-ref-1)
2. 24-hr sample periods were defined as beginning at 0700 on day 1 and ending at 0659 on day 2. [↑](#footnote-ref-2)
3. 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. [↑](#footnote-ref-3)