Methods – Data Collection

Rotary screw trap operations

Sampling for juvenile salmonids in Clear Creek(CC) and Battle Creek (BC) is accomplished by using standardized rotary screw trap (RST) sampling techniques using traps manufactured by E.G. Solutions, Corvallis, Oregon. The CC RSTs are located at river miles (RM) 1.7 (lower Clear Creek [LCC]) and 8.4 (upper Clear Creek [UCC]), and the BC RST (upper Battle Creek [UBC]) RST is located at river mile 6.2.

This type of trap utilizes a 5-ft diameter cone-shaped auger covered with a stainless steel screen with one-eighth inch diameter perforations. This cone acts as a sieve, which separates fish from the sampled water. The cone and live-box are supported between two pontoons, and the cone's auger-type action passes water, fish, and debris to the rear of the trap directly into the live-box. This live-box retains fish and debris while passing water through screens located in its back, sides, and bottom.

Because of the high numbers of Chinook Salmon *Oncorhynchus tshawytscha* out-migrating from CC, modifications have been made to the RSTs and operations to reduce potential negative effects to juvenile salmonids created by high fish densities in the live-box. A "half-cone modification" has been made by placing an aluminum plate over one of the two cone discharge ports and removing an exterior cone hatch cover. This creates a condition in which 50% of the collected fish and debris are not passed into the live-box but rather are discharged from the cone into the creek, thereby reducing overcrowding of fish in the live-box. Both CC RSTs are operated in the half-cone configuration, while UBC is operated in the "full cone" condition. Other modifications to RST equipment that provided greater protection to collected fish include enlarging the size of the live-box and increasing the size of flotation pontoons (to accommodate the larger live-box). Inside the live-box, a midway fish exclusionary screen made of expanded aluminum is added, dividing the live-box into two halves: fore and aft. This screen prevents large predatory fish from harassing and preying on smaller salmonids. A panel of clear polycarbonate is attached to the rear screen of the live-box to reduce water velocities within the live-box. Modifications to RST operations included day and night sampling during the peak out-migration periods for spring-run and fall-run Chinook to minimize time fish spent in the live-box. To improve JPI computation, attempts are made to fish high flow events when juvenile salmonids are thought to out-migrate and to increase the frequency of mark–recapture trials during those events. Traps are not operated when flows in excess of 2,000 cfs at LCC, 800 cfs at UCC, and 1,000 cfs at UBC are encountered.

Clear Creek RSTs generally start operations in November; and cease operations on June 30; whereas UBC is now operated year-round. Attempts are made to operate the RSTs continually when staffing allows. Methods for access and data collection are identical for all RSTs.

Each RST is attached to a cable high line and positioned instream with a system of ropes and pulleys. The monitoring team typically accesses the RST by wading from the creek bank; however, during higher flows the RST is pulled into shallow water for boarding. After being servicing, the RST is returned to the thalweg as soon as possible to begin operating again. The RST is serviced daily unless conditions (high flows, heavy debris loads, or high fish densities) require more frequent RST checks to avoid mortality of captured fish or damage to equipment. During each RST servicing crews process the collected fish, clear the RST of debris, and provide

RST maintenance. Once per day (at the end of the approximately 24-h sampling period) the crew obtains environmental and RST data. Collected data includes dates and times of RST operation, creek depth at the RST, cone operating depth, number of rotations of the cone during the sampling period, the amount and type of debris collected, basic weather conditions, current velocity, and turbidity. Water depths are measured using a graduated staff to the nearest 0.1 ft. The cone operating depth (in) is measured with a gauge that is permanently mounted to the pontoon adjacent to the cone. The rate of rotation (revolutions per min) of the cone is measured with a mechanical stroke counter that is mounted to the RST railing adjacent to the cone. The amount of debris in the RST is volumetrically measured using a 10-gal plastic tub.

Water temperatures are continuously obtained at 30-min intervals with an instream data logger (HOBO® Water Temperature Pro v2 Logger; Onset Computer Corp, Bourne, MA) and those data are downloaded weekly. Water velocity is measured from onboard the RST in front of the cone using a mechanical flow meter (Oceanic® Model 2030 flowmeter; General Oceanics, Miami). Water turbidity is measured from a grab-sample with a Hach Model 2100D turbidimeter (Hach® Company, Ames, IA). Clear Creek mean daily discharge data are collected at the U.S. Geological Survey's Igo gage site (Station #11372000), located at Clear Creek near Igo CA, approximately 2.6 river miles upstream of UCC. Battle Creek mean daily discharge data are collected at the Coleman National Fish Hatchery gauging station (#11376550, [BAT]). At the RST site all environmental and biological data is or has been entered into a paper datasheet, or into a Microsoft Access database using a Mesa^3 ® tablet (Juniper Systems, Logan, UT), or Survey 123 using an IPad (Apple, Cupertino, CA).

Dip nets are used to remove the contents of the RST live-box (fish, aquatic vegetation, debris) and place them on a sorting table for examination. The RST catch is brought to shore in lidded 5-gal buckets where they are transferred to 10- or 25-gal buckets with aerators. They are then sampled as described below.

Counting and measurement

The monitoring team counts and obtains length measurements (to the nearest 1.0 mm) for all fish taxa, dead or alive, that are collected. However, when large numbers of Chinook are captured, or during intermediate trap clears (not at the end of the 24 h period) no length measurements are taken and the fish are simply identified, counted, and classified to an age-class. Live fish to be measured are anesthetized in a 1-qt plastic tub with approximately 1–3 ml of a 100 g/L solution of Tricaine Methanesulfonate (MS-222; Syncaine®, Syndel, Ferndale, WA) at a concentration of 60–80 mg/L. Fish are measured on a wet measuring board, placed in a 10-gal plastic tub filled with creek water and fish protectant, and allowed to recover from the anesthetic effects before being released back into the creek. Water in the tubs is replaced as necessary with fresh creek water to maintain adequate temperature and oxygen levels.

Chinook Salmon — At the end of the sample period when less than approximately 250 Chinook are collected in the RST, all are counted, measured to FL, and assigned a life stage classification: yolk-sac fry (C0), fry (C1), parr (C2), silvery parr (C3), or smolt (C4). All Chinook that are measured are assigned run designations using length-at-date tables (S. Greene, 1992 memorandum to Randall Brown, California Department of Water Resources, estimated winter-run Chinook Salmon salvage at the State Water Project and Central Valley Project Delta Pumping Facilities). These designations include fall-run, late-fall run, winter-run, and spring-run Chinook. At the UCC and UBC, all Chinook captured that are assigned fall-run Chinook by Greene are considered instead to be spring-run Chinook because at CC we install a picket weir to block fall Chinook from passing upstream of UCC. On Battle Creek the Coleman National Fish Hatchery's barrier weir provides the same function. There is undoubtedly overlap in the fork lengths of adjoining runs of juvenile salmon that are not accounted for in the dichotomous length-at-date criteria (Harvey et al. 2014).

At the end of the sample period when more than approximately 250 Chinook are collected in the RST, subsampling is conducted. This is accomplished by using a cylinder-shaped, one-eighth inch mesh "subsampling net." The bottom of the subsampling net is constructed with a metal frame that creates two equal halves. Each half of the subsampling net bottom is built with a mesh bag that is capable of being tied shut. One side of the net is tied shut and the other side is left open. This subsampling net is placed in a 25-gal bucket that is partially filled with creek water. All collected juvenile salmon are poured into this bucket. The net is then lifted resulting in halving of the sample. Approximately one-half of the salmon are retained in the side of the net with the closed mesh bag, and approximately one-half of the salmon in the side with the open mesh bag are left in the bucket. The RST catch is successively subsampled until approximately 150–250 individuals remain. All the fish in the final subsample are then measured. The number of successive splits that are used vary with the number of salmon collected.

O. mykiss — We use the term *O. mykiss* to refer to both the stream resident (Rainbow Trout) and anadromous (steelhead) life histories because of the difficulties in differentiating the anadromous and resident forms in the field. All *O. mykiss* that are encountered at the end of the sample period are counted, measured, and classified to life stage in much the same manner as salmon: yolk-sac fry (R1), fry (R2), parr (R3), silvery parr (R4), and smolt (R5). Fish that are found in the live-box during supplemental storm sampling are counted and assigned to a life stage classification. All live juvenile *O. mykis*s greater than 50 mm FL that are captured during the daytime (measured) sample are weighed to the nearest 0.1 g with an electronic scale (Scout Pro SP601; Ohaus Corp, Parsippany, NJ) for condition factor analysis.

Non-salmonid taxa — All non-salmonid taxa are counted, and up to 20 randomly selected individuals of each species are measured, either FL, or TL for species that do not have a forked caudal fin. Lamprey are recorded by life stage (ammocoetes, macropthalmia, or adult). Fish that are taken from the live-box during supplemental storm sampling are counted, but no length measurements are obtained. Catch data for all fish taxa are consolidated to represent monthly sums.

The LCC and UBC RSTs capture many small (usually < 25 mm), delicate non-salmonid fry. Many of these fish do not survive the extra handling required for measuring. We visually estimate the number of these fish in the live-box and designate them as unidentified fry. Once all the measurable fish are removed from the live-box, the back screen is removed from the RST and the fry are flushed from the live-box.

Sampling weeks are identified by year and number. Week 52 either has either eight or nine days depending on leap year.

Tissue and otolith sampling

Tissue samples are collected from select Chinook for the purpose of run identification. Samples are taken by removing a 1–2 mm^2 tissue sample from the top or bottom lobe of the caudal fin. The samples are divided into two equal parts and placed in duplicate 2-ml vials containing 0.5 ml 100% ethanol, each labeled with the same sample record number. The duplicate samples are taken for USFWS archive and for future analysis. Since 2022 we have switched to collecting dry tissue samples.

Samples at all RSTs are taken when the length-at-date tables designate the Chinook as winter-run Chinook, late-fall run Chinook, or when FL > 99 mm. In addition, at UCC and UBC samples are taken proportionately to the anticipated out-migration distribution of spring-run Chinook. An attempt is made to collect samples from a range of FLs to minimize sampling siblings, which might potentially bias the genetic analysis.

Mark–recapture trials

Since the RST only captures fish from a small portion of the creek cross section, it is necessary to implement a method to project the RST catch numbers to parts of the creek outside of the RST capture zone. Mark–recapture trials are conducted to determine the efficiency of the RST in catching juvenile salmonids moving downstream during a given time period.

Ideally separate mark–recapture trials would be conducted for each species, run, and life stage to estimate species and age-specific RST efficiencies; however, generally, at all RSTs catch rates for *O. mykiss* and late-fall run Chinook are too low to conduct separate trials. Therefore, all species and life stage passage estimates at all RSTs are calculated from valid mark–recapture trials using either spring-run or fall-run Chinook. Trials on CC are conducted with natural-origin Chinook, while those at UBC are conducted using hatchery-origin fish from Coleman National Fish Hatchery. An attempt is made to mark a minimum of 400 juvenile Chinook for each trial with a goal to recapture at least seven marked individuals in order to generate reliable estimates (Steinhorst et al. 2004). The Red Bluff Fish and Wildlife Office also conducts mark–recapture trials at the Red Bluff Diversion Dam (RBDD) for estimating RST efficiency while monitoring Sacramento River juvenile salmonid populations. Dual marks allows RBDD to distinguish CC and BC-marked Chinook from those marked at the RBDD. The methods used for marking are described below.

Marking procedures — All fish are enumerated, and FL is measured on a minimum of 30 individuals. Single marked fish consist of immersing the salmon in a solution of 1.6 g of Bismarck Brown Y stain in 20 gal of water for a duration of 50 min. This stain can be retained on the fish for up to a week. Dual marked fish are first anesthetized with a 60–80 mg/L solution of MS-222, and surgical scalpels are then used to remove an area of approximately 1–2 mm^2 from the corner of either the upper or lower caudal fin lobe. After the clipping process is complete, the salmon are stained with Bismarck Brown Y stain.

Recovery and release — Marked juvenile salmon are placed in a live-car and allowed to recover overnight in the RST live-box. This overnight retention allows for the detection of salmon with latent injuries and mortalities resulting from the marking procedure. On the following evening weak, injured, and dead fish are removed. The remaining fish are counted and transported for release 0.2 (UCC), 0.4 (LCC), and 1.0 (UBC) river miles upstream of the RST sampling site. The fish are released in batches of less than 50 fish, one batch immediately after another, no earlier than 15 min before sunset. The nighttime releases of marked fish are designed to reduce the potential for unnaturally high predation on the marked fish as they could possibly be experiencing temporary disorientation by the marking and holding procedure and transportation, as well as to imitate the tendency for natural populations of out-migrating juvenile Chinook to move downstream primarily at night (Groot and Margolis 1998; Schraml et al. 2018; Schraml and Chamberlain 2019a). To explore the relationship of RST efficiency to biological and environmental variables, we collect flow, water temperature, and turbidity data at the time of release. Marked Chinook that are recaptured in the RST are counted, measured, and subsequently released downstream of the RST to prevent them from being recaptured again. In most cases when stream flows are predicted to exceed 2,000 cfs, efficiency trials are not conducted to reduce the chance of fish mortalities and to ensure crew-related safety. In those cases, fish being held for a mark–recapture trials are released downstream of the RST.

Rotary screw trap efficiency

The number of fish released and recaptured during each trial are used to calculate the weekly RST efficiencies using a stratified Bailey's weekly estimator, which is a modification of the standard Lincoln-Peterson estimator (Bailey 1951; Steinhorst et al. 2004). The weekly estimator is used as it performs better with small sample sizes and is not undefined when there are zero recaptures (Carlson et al. 1998; Steinhorst et al. 2004). In addition, Steinhorst et al. (2004) found it to be the most accurate of those considered. Weekly RST efficiencies are calculated by use of the equation:

$$\hat{E}_h = (r_h + 1) / (m_h + 1),$$

where

$\hat{E}_h$ = the calculated RST efficiency in week *h,*
r_h = the number of marked fish recaptured in week *h,*
m_h = the number of marked fish released in week *h.*

Although RST efficiency is calculated for all mark–recapture trials, only trials with at least seven recaptures are used to estimate passage, as suggested by Steinhorst et al. (2004). When instream flow fluctuations occur which effectively altered RST efficiency mid-trial, or when a trial did not recapture at least seven fish to generate statistically sound estimates, the trial is excluded and the season average efficiency value is used instead. Additionally, for the periods preceding the first trial and proceeding a week after the last trial of the season, the season average efficiency is used for those strata. Season average efficiency values are calculated using the equation:

$$\bar{E}_s = (\bar{r} + 1) / (\bar{m} + 1),$$

where

$\bar{E}_s$ = the calculated season average RST efficiency,
$\bar{r}$ = the average number of marked fish recaptured from all valid trials at an individual RST during the sample season, and
$\bar{m}$ = the average number of marked fish released from all valid trials at an individual RST during the sample season.

O. mykiss — Brood year passage estimates (JPI) for *O. mykiss* are from January 1 through June 30 of the following year, requiring RST efficiencies from two sampling seasons.

Late-fall run Chinook — Brood year passage estimates (JPI) for late-fall run Chinook are from April 1 through March 31, requiring RSt efficiencies from two sampling seasons.

Winter-run Chinook — Brood year passage estimates (JPI) for winter-run Chinook are from July 1 through June 30, requiring RST efficiencies from two sampling seasons.

Fall and spring Chinook — The water year covers the spring-run and fall-run Chinook brood years, therefor the sample season mark–recapture trails are used to calculates the passage indices.

Interpolated data

When the RST could not be safely operated or the cone stopped rotating during the sampling period, the daily catch is interpolated. Depending on the creek conditions during the outage and the length of the outage, we use one of two methods to interpolate the data: either the average method or the hourly proportion of daily catch method (LCC only).

Average method — We use the average method to interpolate (generate) a daily catch on days when a RST was not operated at all during the 24-h sample period and on partially sampled days with a zero catch. Interpolated catch data are generated by use of the equation:

$$I = (C_b + C_a)/(D \cdot 2),$$

where

I = the interpolated catch for each day the RST did not fish in succession
D = the number of days the RST did not fish
C_b = the mean catch of D before the RST did not fish
C_a = the mean catch of D after the RST did not fish.

Hourly proportion of daily catch method — We use the hourly distribution of daily catch to estimate missing data for times when the RST sampled an incomplete portion of the 24-h sample period. This is only applied when at least some catch occurred prior to stoppage, and the RST stoppage time could be determined.

These distributions of daily catch are used in calculations to estimate what the total daily catch would have been had the RST operated a complete 24-h period, using the equation:

$$I_d = C/P,$$

where

I_d = the estimated total daily catch rounded to the nearest fish,
C = the actual catch for the time period the RST sampled,
P = the average expected proportion of the daily catch (based on the 24-h sampling events) for the time the RST sampled.

The missing catch is estimated by subtracting actual catch from the estimated total daily catch:

$$I_m = I_d - C,$$

where

I_m = the estimated missing catch for the time period that the RST did not sample.

Juvenile passage indices

The season is stratified into one-week periods (strata). Occasionally the one week period is subdivided into substrata. Weekly juvenile passage indices are calculated by dividing catch totals for a given period by the RST efficiencies for that period. Using methods described by Carlson et al. (1998) and Steinhorst et al. (2004), the weekly juvenile passage indices are estimated by:

$$\hat{N}_h = U_h \, / \, \hat{E}_h,$$

where

$\hat{N}_h$ = the passage during week h,
U_h = the unmarked catch during week h,
$\hat{E}_h$ = the calculated RST efficiency (either during week h, or the seasonal average).

The variance and 95% CI for each week's passage ($\hat{N}_h$) for all RSTS are calculated by the percentile bootstrap method with 1,000 iterations (Efron and Tibshirani 1986; Buckland and Garthwaite 1991; Thedinga et al. 1994). Using data with simulated numbers of migrants and RST efficiencies, Steinhorst et al. (2004) determined the percentile bootstrap method performed the best as it had the best coverage of a 95% CI. The variance for $\hat{N}_h$ is simply the sample variance of the 1,000 iterations of $\hat{N}_h$ produced by bootstrapping U_h, E_h and m_h for each week.

As described by Steinhorst et al. (2004) and demonstrated by Whitton et al. (2006), the 95% CIs for the weekly juvenile passage indices are found by producing 1,000 iterations of N_h and recording the 25th and 975th values of the ordered estimates. The 1,000 iterations are produced by using R (version 3.5.0, www.r-project.org), which uses the weekly catch, the calculated efficiency, and the number of marked fish for each trial. The SE of the sample means of each stratum are also included.

Mortality

The Red Bluff Fish and Wildlife Office is authorized by NMFS to take threatened and endangered species under an Endangered Species Act section 10(a)(1)(A) collection permit (permit) for scientific research and enhancement purposes. This permit limits the number of indirect mortalities that can occur because of RST operations. Note that it is impossible to differentiate dead or dying fish captured as part of the creek's drift and debris sieved by our RSTs from those that expired in our RSt directly due to our operations. Every fish encountered dead in our live-box is treated as a mortality.

Methods – Data Quality Assurance

The RST crews are teams of two individuals, one individual does the RST clear and collects the environmental data, while the other records the data while onshore. The individual on the RST is responsible measuring and counting the fish once the RST is clear, while the onshore individual records the biological data. Data quality assurance is a five step process.

Step One – Daily QA/QC

If the data are collected on a paper datasheet, the data is entered directly into an Access database at the office the day the data was collected. The data entry in Access is proofed by a second individual on the date of collection, and discrepancies are rectified.

If the data are entered directly into Access in the field, the data is proofed by the individual who did not enter those data, and discrepancies are rectified.

If the data are entered into Survey 123 in the field, the data is proofed by the individual who did not enter those data. Those data are proofed in Survey 123 and discrepancies are rectified. Those data are then imported into Access using R code (note: this process is not yet finalized)

Step Two – Biweekly or monthly QA/QC

Those RST data are then proofed at a regular interval (biweekly or monthly, yet to be determined). These data are then considered preliminary and likely to change based upon future mark–recapture trials.

Step Three – End-of-year QA/QC

At the end of the sample season these data are proofed by the project leader or another biologist. Chinook race assignments and brood years, *O. mykiss* brood years, season average RST efficiencies are confirmed. In general all data is reviewed one more time.

Step Three – Report preparation

At the end of the sample season these data are run through R code to generate tables and figures for report writing purposes. The last few errors are generally captured at this stage. Once the figures and tables are generated those data are considered final.

Methods – JPI tables with year-specific trapping information

Clear Creek

Table A.1. Brood year catch and passage indices (highlighted in gray) of juvenile spring-run Chinook Salmon for brood years 2003–2021 captured by upper rotary screw trap (UCC) at river mile 8.4 in Clear Creek, Shasta County California, with the lower (LCL) and upper (UCL) 95% confidence limits and SE. The adjusted passage index (proportionate to juveniles-per-redd) includes redds below the trap, yet above the separation weir.

Brood year	Actual brood year catch	95% LCL	Passage index	95% UCL	Standard error	Adjusted passage index	Juveniles per redd above UCC	Redds above UCC	Total redds	Redds below UCC
2003	5,223	84,370	104,869	139,723	469	106,886	2,017	52	53	1
2004	4,053	92,558	111,982	142,220	397	115,093	3,111	36	37	1
2005	4,683	86,898	104,565	129,396	337	106,615	2,050	51	52	1
2006	11,618	111,528	127,217	146,881	284	151,189	1,844	69	82	13
2007	8,461	85,529	101,659	124,619	322	114,637	2,163	47	53	6
2008	11,664	89,464	97,163	106,743	138	122,885	1,429	68	86	18
2009	5,399	62,738	68,135	75,102	101	73,910	1,155	59	64	5
2010	2,059	15,396	17,375	20,163	40	19,306	1,931	9	10	1
2011	4,614	50,357	55,737	62,157	94	59,453	3,716	15	16	1
2012	1,610	22,768	25,881	30,083	56	29,256	1,125	23	26	3
2013	28,529	211,815	228,556	248,517	293	255,136	1,772	129	144	15
2014	2,851	35,579	41,600	50,110	116	50,840	770	54	66	12
2015	4,473	45,232	51,010	58,452	104	52,832	1,822	28	29	1
2016	3,841	34,388	39,117	45,040	86	43,029	1,956	20	22	2
2017	1,268	10,595	12,381	15,143	36	12,381	1,376	9	9	0
2018[a]	165		2,471			2,471	618	4	4	0
2019[b]	9,595	85,754	100,026	117,434	255	107,346	2,440	41	44	3
2020	7,476	51,404	58,787	68,833	140	67,604	2,939	20	23	3
2021	77,435	622,997	712,925	825,997	1,624	876,767	1,743	409	503	94

[a] No confidence limits were calculated because the monthly historic efficiencies were used.

[b] The juvenile production index was not calculated because the trap did not operate from March 25 through June 30, 2020 because of COVID-19 restrictions.

Table A.2. Brood year (January through June of the following year) catch and passage indices (highlighted in gray) of juvenile Rainbow Trout/steelhead for brood years 1999–2021 captured by lower rotary screw trap (LCC) at river mile 1.7 in Clear Creek, Shasta County, California, with lower (LCL) and upper (UCL) 95% confidence limits and SE. The adjusted passage index (proportionate to juveniles-per-redd) includes redds below LCC.

Brood year	Actual brood year catch	95% LCL	Passage index	95% UCL	Standard error	Adjusted index
1999[a]	827	3,986	4,229	4,506	n/a	
2000[a]	761	7,951	8,507	9,162	n/a	
2001[a]		8,120	8,742	9,424	n/a	
2002[a]		11,731	12,803	14,193	20	
2003	486	7,936	8,827	9,965	17	
2004	1,030	25,686	30,396	37,532	102	
2005	1,219	21,617	24,497	28,171	53	
2006	352	9,078	10,478	12,247	25	
2007	1,187	28,469	34,701	43,047	120	
2008	1,898	33,092	36,178	39,886	57	
2009	2,101	29,150	31,707	34,769	46	
2010	434	11,063	12,202	13,513	20	
2011	1,149	18,606	20,246	22,090	28	
2012	1,444	20,146	21,519	23,074	24	
2013	3,162	46,774	53,371	63,401	137	74,674
2014	1,458	35,942	39,317	43,306	58	41,452
2015	811	11,246	12,448	13,800	20	13,525
2016	1,848	26,754	29,847	33,706	55	32,125
2017	703	11,511	12,534	13,774	18	14,462
2018	1,171	30,825	34,750	39,404	70	39,334
2019[b]	194	8,456	9,445	10,570	17	12,096
2020[c]	653	31,008	39,316	52,107	167	46,050
2021	1,713	59,508	67,640	77,237	145	80,625

[a] Passage is calculated for calendar year only.
[b] The trap did not sample from March 25 through June 30, 2020, due to COVID-19 restrictions.
[c] The trap did not sample during peak out-migration due to COVID 19 stay at home orders.

Table A.3. Brood year (April 1 through March 31) catch and passage indices (highlighted in gray) of juvenile late-fall run Chinook Salmon for brood years 1999–2021 captured by lower rotary screw trap (LCC) at river mile 1.7 in Clear Creek, Shasta County, California, with lower (LCL) and upper (UCL) 95% confidence limits and SE. The adjusted passage index (proportionate to juveniles-per-redd) includes redds below LCC.

Brood year	Actual brood year catch	95% LCL	Passage index	95% UCL	Standard error	Redds above LCC	Redds below LCC	Juveniles per reach 6 redd	Adjusted index
1999[a]	55,966	272,930	292,323	314,778	N/C	0	0		
2000[a]	9,496	90,576	101,347	116,274	N/C	0	0		
2001[a]	12,206	68,446	86,836	112,386	N/C	0	0		
2002[a]	12,069	156,297	172,708	192,685	298	0	0		
2003	1,410	28,734	33,042	39,529	89	24	0		
2004	497	10,059	12,314	15,865	47	20	0	616	
2005	1,564	18,210	20,713	23,579	43	28	0	740	
2006	2,833	70,349	86,258	112,999	338	14	0	6,161	
2007	7,117	155,980	210,840	326,567	1,419	25	0	8,434	
2008	2,539	39,967	46,037	53,289	103	17	0	2,708	
2009	4,792	64,205	72,437	82,678	154	122	0	594	
2010	776	19,932	23,028	27,694	61	33	0	698	
2011	554	7,786	8,707	9,871	17	21	0	415	
2012	1,643	22,257	24,935	28,434	49	18	0	1,385	
2013	1,153	19,105	25,997	39,349	165	17	11	1,529	42,819
2014	668	16,219	17,922	20,081	30	15	11	1,195	31,065
2015	908	12,475	13,938	15,823	28	70	29	199	19,712
2016	355	4,925	5,712	6,589	13	15	7	381	8,378
2017	812	12,653	14,383	16,431	29	15	5	959	19,177
2018	39	1,204	1,401	1,682	4	18	14	78	2,491
2019	142	4,319	5,320	6,866	21	22	8	242	7,255
2020[b]	18	N/C	468	N/C	N/C	45	9	10	562
2021	360	14,387	17,088	21,068	55	30	17	570	26,771

[a] Passage is calculated for calendar year only.
[b] The juvenile production estimate was not calculated because the trap was not operated during the peak out-migration due to COVID 19 stay at home orders.

Table A.4. Brood year catch and passage indices (highlighted in gray) of juvenile fall-run Chinook Salmon for brood years 1998–2021 captured by lower rotary screw (LCC) trap at river mile 1.7 in Clear Creek, Shasta County California, with the lower (LCL) and upper (UCL) 95% confidence limits and SE.

Brood year	Actual brood year catch	95% LCL	Passage index	95% UCL	Standard error	Female spawners	Juveniles-per-female
1998	688,083	5,656,571	6,395,638	7,303,438	N/A	2,485	2,573
1999	518,542	5,951,440	6,405,765	7,121,563	N/A	4,089	1,567
2000	362,680	13,535,844	14,955,182	16,483,244	N/A	3,349	4,466
2001	416,407	5,577,387	5,788,701	6,042,987	3,923	5,615	1,031
2002	227,010	3,560,468	3,858,446	4,174,685	4,783	8,176	472
2003	246,885	5,415,219	6,196,407	7,098,912	13,450	5,435	1,140
2004	199,718	5,361,827	6,197,566	7,398,091	15,920	3,722	1,665
2005	105,027	2,582,984	2,951,605	3,396,422	6,782	9,607	307
2006	163,687	4,221,698	4,938,624	5,790,590	12,969	5,208	948
2007	211,113	4,483,291	5,076,063	5,917,680	11,398	2,634	1,927
2008	327,334	7,050,464	8,519,113	10,725,432	30,215	4,429	1,923
2009	88,350	2,438,590	2,762,853	3,191,155	6,057	1,776	1,556
2010	238,578	3,316,993	3,568,541	3,895,600	4,667	3,697	965
2011	647,145	9,576,363	10,408,622	11,543,809	16,130	3,911	2,661
2012	403,826	6,356,381	7,083,512	7,912,526	13,058	4,693	1,509
2013	884,179	17,361,495	19,800,773	22,622,589	41,546	9,426	2,101
2014	146,823	2,793,125	3,199,177	3,758,440	7,496	6,724	476
2015	289,101	4,200,830	4,735,685	5,324,266	9,223	4,503	1,052
2016	47,655	917,716	1,022,700	1,152,794	1,918	1,434	713
2017	28,765	638,702	757,003	948,755	2,603	1,069	708
2018	25,133	1,803,431	2,122,775	2,574,706	6,243	5,171	411
2019[a]	108,638	3,223,322	3,762,836	4,406,258	9,513	2,425	1,552
2020	116,665	4,133,187	4,877,452	5,825,382	13,305	3,443	1,417
2021	152,249	4,133,187	5,652,768	5,825,382	13,305	8,135	695

[a] Trap did not operate from March 25 through June 30, 2019.

Battle Creek

Table A.5. Brood year passage indices (in gray) of juvenile Rainbow Trout/steelhead with the upper (UCL) and lower (LCL) 95% confidence interval and SE for brood years 2003–2021 captured by upper rotary screw trap at RM 6.2 in Battle Creek, Shasta, County, California.

Brood year	Actual annual catch	95% LCI	Passage index	95% UCI	Standard error	Adult escapement	Juveniles per adult
1999[a]	314	N/C	10,528	N/C	N/C	1,269	8
2000[a,b]	1,106	N/C	23,074	N/C	N/C	1,520	15
2001[a,c]	61					1,607	0
2002[a]	836	21,055	25,302	31,488	85.3	2,035	12
2003[a]	279	6,883	7,599	8,454	13.0	1,306	6
2004	219	2,987	3,294	3,665	5.5	633	5
2005[d]	214	4,660	5,880	8,007	30.1	344	17
2006[e]	10					439	
2007[f]	1					351	
2008[g]	235	3,328	3,629	4,009	5.5	277	13
2009	240	3,612	3,847	4,126	4.1	351	11
2010[h]	378	4,156	4,414	4,725	4.5	410	11
2011[h]	176	1,925	2,071	2,237	2.5	329	6
2012[h]	335	3,973	4,256	4,613	5.1	352	12
2013[h]	735	8,527	9,266	10,138	12.6	682	14
2014[h, i]	24					519	
2015[h, j]	654	17,064	18,767	21,199	33.7	447	42
2016[h]	82	2,329	2,602	2,950	5.2	523	5
2017[h]	101	2,552	2,922	3,363	6.3	489	6
2018[h]	131	3,005	3,364	3,805	6.4	213	16
2019[h, k]	97	1,530	1,673	1,835	2.4	222	7
2020[h, l]	131	10,900	13,057	16,091	2.4	246	53
2021[h]	118	2,793	3,212	3,802	8.0	485	7

[a] The trap was not fished from December 20 to December 31, 2005, and April 2–24, 2006.

[b] The trap was not fished from January 1–10, 15–19, February 2–6, February 28 to March 9, April 2¬–24, and July 1 to December 6, 2006, the passage index was not calculated.

[c] The trap was not fished from February 16 to November 27, 2007, peak out-migration, the passage index was not calculated.
[d] The trap was not fished from July 4 to November 15, 2008, this starts trapping pattern for BY08–BY19.
[e] Only nine fish were captured from January 1 to June 30, 2014 and the trap was not fished in December, the passage index was not calculated.
[f] Hatchery produced fish are likely to have spawned above the upper Battle Creek rotary screw trap. The trap was not fished from January 1–12, and February 5 to March 4, 2015.
[g] The trap was not fished from March 26 to July 5 because of COVID-19 restrictions.
[h] Hatchery produced fish are likely to have spawned above the upper Battle Creek rotary screw trap.
[i] The trap was not operated from March 25 through July 5, 2020.

Table A.6. Brood year passage indices (in gray) of juvenile spring-run Chinook Salmon with the upper (UCL) and lower (LCL) 95% confidence interval and SE for brood years 2003–2021 captured by upper rotary screw trap at RM 6.2 in Battle Creek, Shasta County, California.

Brood year	Actual annual catch	95% LCL	Passage index	95% UCL	Standard error	Spring-un juveniles per redd	Number of redds
1998[a]	37,458	758,222	1,220,127	2,060,077			
1999[a]	11,555	168,932	245,358	373,311			
2000[b]	1,522		43,946				
2001	723	13,479	21,536	37,183		673	32
2002[c]	717	16,410	18,380	21,204	39	236	78
2003	10,966	139,079	152,653	169,174	245	867	176
2004	994	24,115	29,979	39,141	121	882	34
2005[d]	282						47
2006[e]	2,381		106,498			873	122
2007[f]	2,528	62,979	75,432	98,525	278	571	132
2008	898	14,141	15,576	17,343	27	389	40
2009	7,538	87,407	96,524	108,763	172	1,097	88
2010	4,872	59,362	65,482	74,701	125	704	93
2011	4,380	49,956	54,840	60,951	89	831	66
2012	4,286	62,951	70,259	80,082	136	220	320
2013	7,785	76,709	82,660	89,322	102	695	119
2014[g]	201						99
2015	1,670	63,013	75,584	94,777	250	2,699	28
2016[h]	306	9,401	11,578	14,909	44	227	51
2017	384	8,816	10,235	12,077	27	2,047	5
2018	1,613	25,445	28,670	32,762	61	989	29
2019[i]	983	16,008	18,450	21,775	46	615	30
2020[i]	1,394	18,596	22,884	29,469	97	2,080	11
2021	3,153	61,841	75,332	92,214	250	1,256	60

[a] Fall-run Chinook Salmon are known to have spawned above the rotary screw trap.
[b] The trap fished for the entire brood year.

[c] No passage indices were made for the period October 1, 2005, to September 30, 2006, because high flows severely limited our ability to operate the traps.
[d] Methods used to calculate the BY06 spring-run Chinook Salmon passage index are described in an internal memo (Whitton 2010). The trap was only operated 4 d each week and was not operated after February 15, 2007.
[e] Starting at brood year 2007 the trap was no longer operated during the months of July through October.
[f] Trap was not fished from December 3, 2014, to January 12, 2015, and February 5 to March 4, 2015, and did not fish on the weekends because of limited staffing. The passage index was not calculated.
[g] High flow prevented us from fishing the trap from December 11–18, 2016, and January 7–24, 2017.
[h] The trap was not fished from March 25 through July 5, 2020 because of COVID-19 restrictions.
[i] The trap fished from October 1, 2020 through September 30, 2021; however it was not operated from June 15–August 1, 2021 because of high water temperatures.

Table A.3. Brood year passage indices (in gray) of juvenile winter-run Chinook Salmon with the upper (UCL) and lower (LCL) 95% confidence interval and SE for brood years 2003–2021 captured by upper rotary screw trap at RM 6.2 in Battle Creek, Shasta County, California.

Brood year	Actual annual catch	95% LCL	Passage index	95% UCL	Standard error	Adult escapement	Number of redds	Juveniles per redd
2020	341	3,080	3,515	4,049	8	945	66	53
2021[a]	1					226	1	

[a] Only one fish captured, no production estimate was calculated.

Table A.4. Brood year passage indices (in gray) of juvenile late-fall run Chinook Salmon with the upper (UCL) and lower (LCL) 95% confidence interval and SE for brood years 2003–2021 captured by upper rotary screw trap at RM 6.2 in Battle Creek, Shasta County, California.

Brood year	Actual annual catch	95% LCI	Passage index	95% UCI	Standard error	Adult Escapement	Juveniles-per-adult
1999[a]	10		192				
2000	2		50				
2001[b]	0					0	
2002[a]	147	5,868	7,652	10,392	39.50	249	31
2003	215	5,954	6,741	7,769	14.69	61	111
2004[a]	36	812	1,196	2,035	10.00	42	28
2005[a]	6	84	112	155	0.58	23	5
2006[c]	44	926	1,321	2,098	9.27	50	26
2007[d]	0					72	
2008[e]	3	32	39	49	0.14	19	2
2009	91	1,361	1,562	1,816	3.64	33	47
2010	68	694	770	860	1.35	27	29
2011	17	181	205	236	0.45	14	15
2012	10	90	103	117	0.22	14	7
2013	6	65	79	99	0.27	41	2
2014[f]	120	1,471	1,639	1,820	2.78	110	15
2015	159	3,558	4,131	4,802	10.11	103	40
2016	19	523	708	1,009	3.91	57	12
2017	15	266	352	498	1.87	43	8
2018	51	1,300	1,786	2,536	9.95	18	99
2019[g]	1					66	0.2
2020[g]	1					31	0.3
2021[g]	2					17	3

[a] The trap fished for the entire brood year.

[b] The trap did not fish from April 1 to July 12, 2001, peak outmigration, the passage index was not calculated.

[c] The trap was not fished from April 2 to April 24, 2006, the passage index is likely negatively biased.

[d] The trap was not fished from April 1 to November 28, 2007, peak outmigration, the passage index was not calculated.

[e] The trap was not fished from July 4 to November 15, 2008. This starts the current sampling pattern.
[f] The Coleman National Fish Hatchery barrier weir was breached three times by high flows. It is highly likely that hatchery production adult late-fall Chinook spawned above the upper Battle Creek trap.
[g] Too few fish were captured to calculate a passage index.

Methods – References

Bailey, N. T. J. 1951. On Estimating the Size of Mobile Populations from Recapture Data. Biometrika 38(3):293–306.

Buckland, S. T., and P. H. Garthwaite. 1991. Quantifying Precision of Mark-Recapture Estimates Using the Bootstrap and Related Methods. Biometrics 47(1):255–268.

Carlson, S. R., L. G. Coggins Jr, and C. O. Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fishery Research Bulletin 5(2):88–102.

Efron, B., and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science :54-75.

Greene, S. 1992. Estimated winter-run Chinook Salmon salvage at the State Water Project and Central Valley Project Delta Pumping Facilities, 8 May 1992. California Department of Water Resources. Memorandum to Randall Brown, California Department of Water Resources.

Groot, C., and L. Margolis editors. 1998. Pacific Salmon Life Histories. UBC Press, University of British Columbia, 6344 Memorial Rd, Vancouver BC.

Schraml, C. M., J. T. Earley, and C. D. Chamberlain. 2018. Brood Year 2011 Juvenile Salmonid Monitoring in Clear Creek, California. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Schraml, C. M., and C. D. Chamberlain. 2019. Brood Year 2016 Juvenile Salmonid Monitoring in Clear Creek, California. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Steinhorst, K., Y. Wu, B. Dennis, and P. Kline. 2004. Confidence intervals for fish out-migration estimates using stratified trap efficiency methods. Journal of Agricultural, Biological, and Environmental Statistics 9(3):284–299.

Thedinga, J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K. V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14(4):837–851.

Whitton, K. S., J. M. Newton, D. J. Colby, and M. R. Brown. 2006. Juvenile salmonid monitoring in Battle Creek, California, from September 1998 to February 2001. USFWS Data Summary Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.