Salmonid Populations of the Upper Sacramento River Basin In 2017

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Cover photo by author D. Killam of Sacramento River in Iron Canyon.

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TABLE OF CONTENTS

SUMMARY

Population sizes were estimated for Chinook Salmon and steelhead (where possible) passing upstream of Princeton, CA in the upper Sacramento River basin (USRB), (Figure 1). Annual population estimates for the USRB were determined through a number of methodologies including: carcass surveys, hatchery counts, aerial and in-stream redd surveys, snorkel counts, angler interviews, and video, DIDSON (acoustic sonar) or Vaki Riverwatcher counts in streams and in fish ladders. This report does not include salmonid information from tributaries that enter into the Sacramento River downstream of the town of Princeton (Butte Creek, Feather and American River). These and other lower Central Valley waterways are detailed in reports from other projects. A summary of the entire California Central Valley Chinook Salmon stocks is available annually in the California Department of Fish and Wildlife (CDFW) reports titled “Annual Report: Chinook Salmon Spawning Stocks in California’s Central Valley” (CDFW Annual Reports).

In 2017, there were an estimated **21,217** mature Chinook Salmon returning to the USRB to pass upstream of Princeton Ferry (includes angler catch). This includes an estimate of **4,967 late-fall-run, 977 winter-run, 544 spring-run, and 14,729 fall-run** Chinook Salmon (Table 1). The majority (91%) of these salmon migrated above the Red Bluff Diversion Dam (RBDD) to spawn in the tributaries or the Sacramento River upstream of Red Bluff. Although no longer used as a tool to determine population estimates, the RBDD location is still utilized to maintain historical data consistency in the reporting of salmonid populations in the USRB, (up and downstream of RBDD). Additionally 2,410 adult steelhead (Rainbow Trout greater than 16 inches) were counted during monitoring operations for the 2016-2017 reporting year.

The numbers of salmon of the USRB were at record lows in 2017. Historical data from CDFW shows that the 18,181 total salmon spawners in the USRB was the lowest on record. Data back going back to 1952 shows that this was the lowest count for spring and fall-run Chinook Salmon. Winter and late-fall-run Chinook Salmon estimates have been lower since 1980, but these runs were still much lower than historical averages in 2017. While California was no longer in the record setting multi-year drought, its effect on salmon lingered on. Salmon spawning in 2014 experienced some of the worst drought effects in the USRB including low flows, and egg killing warm water that likely led to very poor survival and the extremely low numbers of natural origin salmon returning to spawn in 2017. Additionally, much of the 2014 Coleman National Fish Hatchery (CNHF) production was trucked to the Delta area to avoid drought conditions in the lower Sacramento River. This led to very poor adult returns to the USRB in 2017 due to straying of these salmon into downstream of the USRB tributaries (i.e. American, Feather, and San Joaquin River(s)). Much of the runs in 2017

consisted of two-year old grilse hatchery salmon indicating that few three-year old adults of either natural or hatchery origin returned from the drought conditions of 2014.

Readers interested in conducting further analysis of the data provided in this report should be aware that the summaries of data herein might be generalized to fit the limited scope of the report. Summary details for specific waterways and other details are typically provided in bold font to emphasize data that is of frequent use for general readers. For specific analytical data needs, readers should directly contact the authors for their needs and any limitations to the data. The authors can be reached via e-mail at bmache@psmfc.org or doug.killam@wildlife.ca.gov. This report, and others from this project, can be found on the Calfish.org website. If interested, readers may also download the associated tables from this report in the original Excel formats to allow further analysis based on their individual needs or requirements. Interested readers can go to the Calfish.org website to view and download this and other files:

http://www.calfish.org/ProgramsData/ConservationandManagement/CentralValleyMonitoring/CDFWUpperSacRiverBasinSalmonidMonitoring.aspx

To view: Open the website's Data Access tab and select the desired report or other file after scrolling through available pages from within the download menu.

INTRODUCTION

Readers of this and earlier reports should be aware that revisions to population estimates might occur at any time. Reader comments received by the authors in the past have indicated that readers can be surprised by population numbers changing from one year to the next or inconsistent reporting between reports. Many of the estimates are dependent on multiple sources of information (hatchery sex ratios, hatchery counts, aerial redd data, etc.) that may be revised after periods of time. These revisions are outside the control of the authors and represent efforts to obtain the most accurate estimates for historical purposes. Should a conflict arise between a number in this report and a later report, readers should use the most recently published data as the most up-to-date source of information. An online summary of salmon populations is available in the California Department of Fish and Wildlife's (CDFW) electronic summary report of salmon counts titled "GrandTab".

Please note that the CDFW was formerly the Department of Fish and Game (CDFG) and historical reports written before January 2013 will have the former name. Persons interested in receiving the latest Chinook numbers should check the GrandTab file that is updated once a year, or contact the authors. The GrandTab file is now online at the following link or by "searching" the term "GrandTab fish":

https://www.wildlife.ca.gov/Conservation/Fishes/Chinook-Salmon/Anadromous-Assessment

The upper Sacramento River basin (USRB) of California's Central Valley is unique worldwide because it has four separate runs of Chinook Salmon (*Oncorhynchus tshawytscha*) each year. The USRB for purposes of this report refers to the anadromous portions of the Sacramento River watershed upstream of Princeton, CA at river mile 164 (RM-164). Each run of Chinook Salmon, hereafter referred to as salmon or run, (e.g., winter-run) has adopted a different life history (spawning locations, and seasonal timing) that allows it to survive many different environmental conditions found over the course of a year in the USRB (Figure 1).

The historical migration timing of the four adult salmon runs into the USRB is provided in Appendix Table A1. This data came from historical trapping operations at the Red Bluff Diversion Dam fish ladders. The data represents the timing of upstream migrating adult salmonids at Red Bluff (RM-243) prior to spawning. The naming of the runs can be confusing (e.g., winter-run spawn in July). The salmon run names originate from the time salmon canneries operated in the lower river (i.e., 1860's). The name of each run described when the peak of the salmon run was passing through the San Francisco Bay.

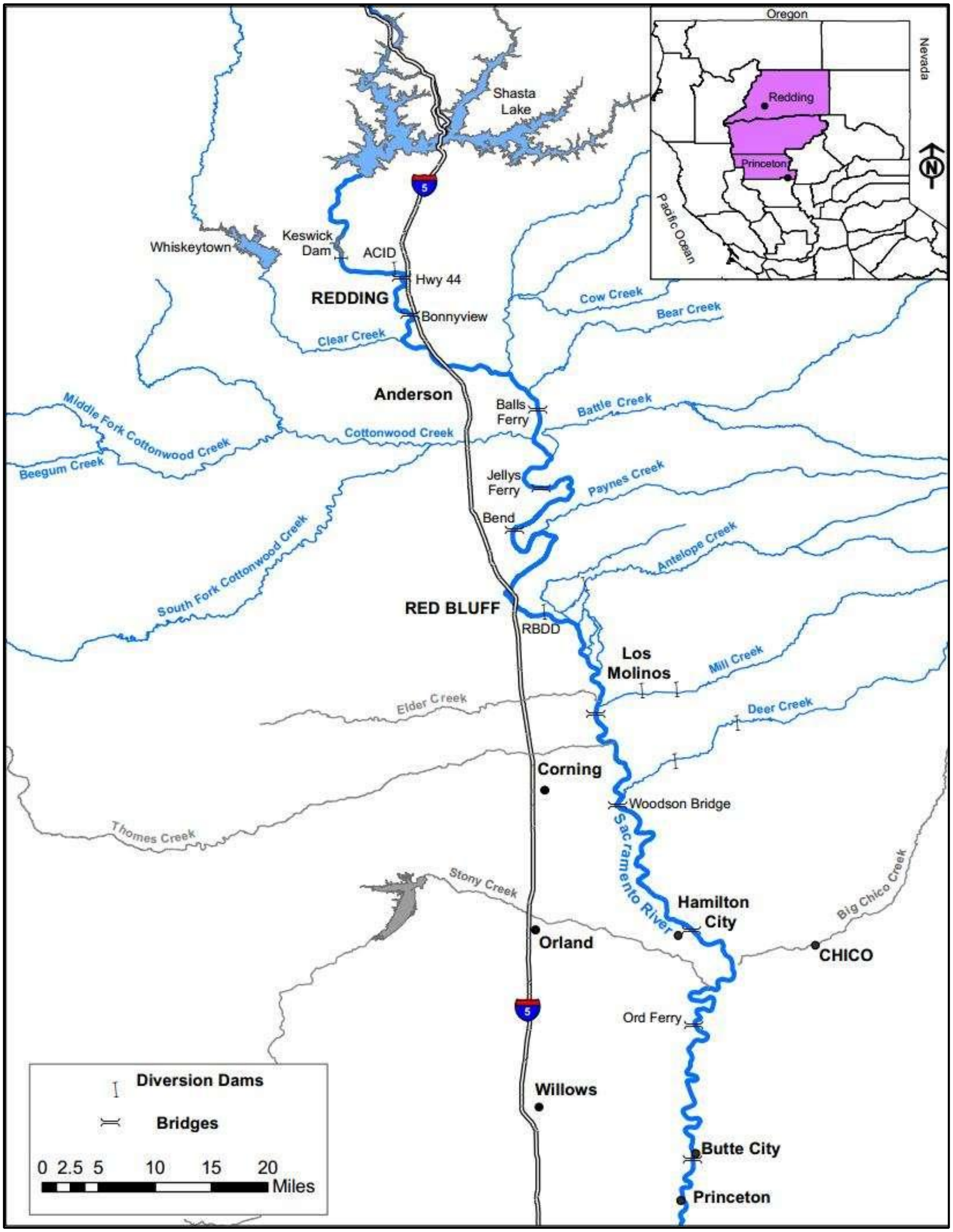

Figure 1. Map of the upper Sacramento River basin (Princeton to Keswick Dam).

Monitoring for salmon populations in the USRB has been routinely conducted annually since 1953 (CDFW Annual reports). During earlier years, the primary purpose for monitoring salmon was to manage for commercial and sport salmon harvest. The USRB has salmon and steelhead (*Oncorhynchus mykiss*) stocks, **but no** perennial spawning populations of the other Eastern Pacific-genus *Oncorhynchus* (*O.*) salmon species including Chum/Dog (*O. keta*), Coho/Silver (*O. kisutch*), Humpback/Pink (*O. gorbuscha*), and Sockeye/Red (*O. nerka*). In recent years, the focus of monitoring has been directed to include monitoring for restoration activities (including protection of listed stocks), and water transfers in the Central Valley, drought impacted water quality, as well as the traditional role of managing stocks for sport and commercial harvest.

This report provides a summary of the late 2016 and 2017 USRB salmonid monitoring activities conducted by staff from the CDFW's Upper Sacramento River Basin Fisheries Program (USRBFP) primarily staffed at the Red Bluff Field Office. The USRBFP (formerly the RBFO) staff included two CDFW Environmental Scientists. In addition, there were seven full time USRBFP staff from the Pacific States Marine Fisheries Commission (PSMFC) and additional PSMFC seasonal staff working on salmonid monitoring activities in the office.

In 2017, the USRBFP staff conducted independent monitoring surveys as well as cooperative surveys. Cooperative surveys occurred with the staff from several organizations: the U.S Fish and Wildlife Service's Red Bluff Fish and Wildlife Office (USFWS), the Coleman National Fish Hatchery (CNFH), the U.S. Forest Service Lassen National Forest (USFS), the National Marine Fisheries Service (NMFS) and a variety of other watershed related organizations. Details of other specific monitoring surveys in the USRB can be found on the internet sites of these groups. The data found in this report is a compilation of the different sources and methodologies used to produce population estimates within the USRB. Annual reports providing data on the USRB salmon populations are available going back to the early 1950's, (CDFW Annual reports). In the earlier years, data is often lacking for particular streams due to no monitoring from lack of funding and personnel. Fish ladders, walking surveys, and hatchery counts were the primary methods of data collection until 1967.

From 1967 until 1986, the Red Bluff Diversion Dam (RBDD) provided a method of monitoring all four salmon runs, as well as steelhead trout and other fish species. During this period, the RBDD was typically operated throughout the year. This allowed for nearly complete accounting of salmon and steelhead escapement above the dam (the dam was removed during flooding periods). The RBDD was operated by lowering 11 large steel gates (15-feet tall) into the Sacramento River at Red Bluff. The resulting pool formed Lake Red Bluff and provided gravity flow water "free" (no pumping necessary) into agricultural diversions. During RBDD "gates down" operation, adult salmon migrating into the

USRB had to find and use one of the three fish ladders at the dam. The delay in finding these ladders at the RBDD was thought to be a major reason for the decline of the winter-run Chinook Salmon (winter-run) populations (NMFS 1996). Beginning in 1987, the period of operation of the RBDD was limited for portions of each year to facilitate improved passage of winter-run. When not in operation, the RBDD gates were raised up completely out of the water. This returns the river to natural flow conditions and eliminates any passage delay. This action was deemed necessary for winter-run, which were at critically low and declining population levels, and had been previously petitioned for listing (October 1985) under state and federal Endangered Species Act (ESA).

From 1995 to 2007, the RBDD was operated from approximately May 15 through September 15. Beginning in 2008, the gates were removed on September 01 in response to a Federal District court order issued to protect salmon and steelhead populations. For years 2009 to 2011, the RBDD operations were even further curtailed and lasted only from June 15 until the first week of September. The RBDD ceased operation in 2011 and the gates on the dam are now raised permanently out of the water.

Construction of a large-scale pumping plant with modern in-river juvenile fish screens just upstream of the RBDD was completed during the spring of 2012. Although still in place, the RBDD is no longer seen as a fish passage problem. The dam will remain in place for the near future with the gates permanently raised above the river and the outdated fish ladders inoperable.

METHODS AND RESULTS

The USRBFP personnel utilized different methodologies to obtain the fisheries data presented in this report. Methods utilized in 2017 include walking and boat based carcass surveys, hatchery counts, live fish counts from video stations at fish ladders or weirs, snorkel surveys, and salmon redd surveys utilizing counts made by walking, kayak, jet boat, and aerial transport (airplane or helicopter).

Carcass surveys using modern mark-recapture methodologies were initiated in 1996 on the Sacramento River above RBDD using jet boats. Currently there are three annual carcass surveys used to estimate the winter-run, late-fall-run and fall/spring-run Chinook Salmon escapements by the USRBFP.

The **late-fall Chinook** Salmon (late-fall-run) escapement on the Sacramento River is monitored through a boat mark-recapture carcass survey and aerial redd counts (mid-December-early May). In addition to the Sacramento River, small numbers of late-fall-run are known to spawn in many tributaries of the USRB. Mark-recapture late-fall-run carcass surveys are normally difficult to conduct on these tributaries due to small numbers of carcasses and typically high flow (or flood) conditions that make consistent, weekly mark-recapture surveys impractical. The use of video monitoring allowed tributary late-fall-run monitoring in late 2016 into early 2017 on Clear Creek (with additional USFWS carcass and redd counts) and on Bear, Antelope, Mill and Deer Creek's. Late-fall-run on Battle Creek were also monitored at the CNFH (hatchery, trap and video counts). Monitoring for late-fall-run was also planned for Cow and Cottonwood Creek(s) but the large floods that occurred in late December of 2016 into March of 2017 resulted in sedimentation at the resistance board weirs on these streams. The weirs were buried and crews were unable to repair them until flows receded in April by which time the late-fall run was over.

A **winter-run** Sacramento River carcass survey (late-April to early-September) has been conducted since 1996. Since 2001, the survey has provided the "official" annual escapement estimate for this federally and state-listed endangered species (replacing the RBDD estimate). This species currently spawns only in the Sacramento River and is the focus of many restoration and management activities throughout the Central Valley, Bay-Delta and Pacific Ocean. The winter-run estimate forms the scientific basis for establishing the allowable juvenile winter-run "take" limits at the pumping facilities in the Sacramento-San Joaquin Delta, and also is directly linked to the management of California's ocean based salmon fisheries (mainly the fall and late-fall-run). Additional winter-run data is obtained from operations of the USFWS Livingston Stone National Fish Hatchery (LSNFH). This hatchery is located at base of Shasta Dam and collects hatchery brood stock from a trap at Keswick Dam (Figure 1) to supplement the small population of naturally spawning winter run. In 2017, ongoing drought concerns and uncertainty about low numbers again resulted in the LSNFH staff collecting additional broodstock (total of 180) for spawning as a precaution against collapse of the in-river spawners due to low numbers and possible poor water quality (high water temperatures).

Spring-run Chinook Salmon (spring-run) inventories have been sporadically conducted since the 1940's on USRB waterways. Methodologies from the 1940's through the 1980's were incomplete, inconsistent and not replicable. In many years, surveys were not conducted. Spawning escapement estimates were derived from incomplete spawning ground surveys, carcass surveys with unknown expansion factors, and partial ladder and weir counts. Since the early 1990's, there has been an effort to standardize sampling methods to provide consistent and reproducible spring-run population estimates. On Mill Creek this standardization was an annual redd count through 2012. For Antelope and Deer Creeks, standardized snorkel surveys provided annual spring-run population estimates through 2013. Beginning in 2012, video and DIDSON (Dual Frequency Identification Sonar) counts replaced redd counts on Mill Creek, and in 2014, video counts replaced snorkel counts on Antelope and Deer Creeks as the escapement methodology following the development video stations on these tributaries. In 2017 the USRBFP continued conducting redd counts on Mill, and snorkel counts on Deer and Antelope to maintain established trend data, and to monitor summer holding distribution patterns and survival of adult spring-run through the summer months.

The record setting rainfall in the USRB in the winter-spring of 2016-2017 combined with extremely low adult spring-run returns resulted in the video data population estimate on Deer and Mill Creek(s) being lower than the snorkel (Deer) and redd survey (Mill) that were conducted later in 2017. The flooding at the stations during spring months, and smaller two-year-old (grilse) salmon that made up a large portion of the spring-run population in 2017, made video station counts lower than later spring-run counts. As a result, the snorkel survey and redd counts were used for reporting purposes. The grilse that were prevalent in all salmon runs in 2017 were the result of drought related mortality of the 2013 and 2014 adult salmon three years earlier. Smaller grilse are similar in size to other common species at the video stations. During flooding, salmon and other species are unable to be distinguished (tallied as unknowns) resulting in the undercounts from the Mill and Deer video stations in the spring of 2017.

Since 1953, **fall-run Chinook** Salmon (fall-run) surveys were routinely conducted on the USRB tributary streams. Prior to 1988, Peterson mark-recapture methodologies, ladder counts, walking surveys and aerial redd surveys were used with varying sampling intensity and reliability of estimates. Since 1988, mark-recapture surveys have been standardized into weekly surveys for the duration of the spawning run on some tributaries. The mark-recapture estimator used on each creek (Peterson, Schaefer or Jolly-Seber), was based on the total carcasses encountered and weekly percent recovery of tags.

Beginning in 2003, video stations have been utilized to obtain fall-run escapement estimates in the larger tributaries of the USRB. These stations use multiple cameras to record 24/7 video footage of passing fish through existing fish ladders or in-stream portable weirs. In 2017 video stations were used to monitor fall-run escapement in Clear, Cow, Bear, Cottonwood, Battle, Antelope, Mill and Deer Creek(s).

Since late 2015, the use of the resistance board weirs has allowed better steelhead tributary accounting. Steelhead (anadromous forms of Rainbow Trout) will be included in this report when information is available. Because steelhead do not die after spawning (although many do) counting them is not possible on traditional carcass surveys. The video stations on fish ladders have provided counts of steelhead for many years but as more in-stream stations utilize resistance board weirs the USRBFP is collecting more steelhead information over the winter periods. Steelhead in this report generally refer to fish over 16 inches long. Currently there is no consistent way to distinguish a larger resident trout from a steelhead without handling and sacrificing the fish for bio-samples that can be analyzed for ocean life history. Resident trout are common in the USRB waters year round and it is possible that larger resident trout and steelhead are included together in the counts. USRBFP biologists use their best judgement based on their knowledge of local steelhead populations when tallying fish as steelhead.

In the fall of 2017, the USRBFP staff used a Vaki Riverwatcher (VAKI) on the fish ladder of the Edwards Dam on Antelope Creek. The VAKI is a metal tunnel with computer-linked sensors that trigger cameras to record motion in the tunnel. The VAKI was used to count salmonids and other species passing through the fish ladder. Continued deployments of acoustic cameras including DIDSON and Adaptive Resolution Imaging Sonar (ARIS) cameras also complemented and enhanced video monitoring efforts by USRBFP staff to be able to provide population estimates in many USRB streams.

The goal for monitoring by USRBFP staff is to utilize the video stations to collect information year-round on Chinook and steelhead and other fish species. Data collected by using combinations of video and other technologies such as DIDSON, ARIS, and VAKI provides possibilities to overcome the lack of monitoring opportunities during the typical high flow and muddy water periods of fall, winter, and spring in the USRB. However, the extreme flooding of early 2017 challenged all fish counting technologies available to USRBFP staff.

Readers may note the lack of metric equivalents for distances and volumes in this report. River miles are used as descriptors of locations rather than river kilometers. Conventional use in the USRB is the English system (used by other state and federal agencies) and this report maintains these conventions to simplify reading except in the case of fork length data, which is in millimeters (mm), by tradition. Readers wishing to convert to kilometers can multiply the miles written by roughly 1.6 and can convert water volumes written in cubic-feet-per second (cfs) to cubic-meters-per second (cms) by multiplying cfs by 0.028 to get cms. Temperatures in Fahrenheit can be converted to Celsius by subtracting 32 and then multiplying by 5/9. (e.g., 2 miles = 3.2 km, and 200 cfs = 5.6 cms, 59^{o}F = 15^{o}C).

<u>Carcass Mark-Recapture Surveys</u>

Carcass mark-recapture surveys (carcass surveys) have been used by CDFW and other agencies for many years to estimate salmon populations on rivers throughout the state. Since all Chinook Salmon die after spawning, a population can be counted by estimating how many carcasses are present each year. The carcass surveys have been used as the “official” alternative to the RBDD count for the Sacramento River since the late 1990’s (fall-run, late-fall-run) and in 2001 (winter-run) due to the limited operation of the RBDD.

Carcass surveys can be conducted by boat or by wading along a tributary creek examining carcasses. Carcasses are tagged with a colored tag or numbered disc or some other type tag to enable personnel to recognize them on subsequent surveys. Carcasses that were tagged in previous periods and recaptured in new periods form the basic proportion of “carcasses tagged” to “carcasses recaptured” that creates a population estimate. Data is normally collected on sex, fork length; adipose fin clips, location, and other categories of interest.

There are different methods and/or population models that can be employed to create an estimate from a carcass survey. The population models were originally created for populations of live organisms and each model has a list of sampling assumptions that must be met in order for the model to reflect an accurate portrayal of the population size. The three models previously used by the USRBFP staff in the USRB are the Peterson, the Schaefer, and the Jolly-Seber. Beginning with the September fall-run surveys of 2011 (Sacramento River and Clear Creek) a newer “Cormack-Jolly-Seber” (CJS) method was utilized for the first time in the USRB, allowing generation of confidence limits surrounding each estimate. Regardless of the model used, each has been modified from the original intent of studying live organisms and applied to carcasses. In 2010, the CDFW and PSMFC created the Central Valley Chinook Salmon In-river Escapement Monitoring Plan that provides recommendations for a consistent approach to monitoring salmon populations throughout the Central Valley (Bergman et al. 2012). This plan recommends all carcass surveys in the Central Valley use the newer CJS model for consistency between watersheds. Details of the CJS process (and video station) methods and instructional information for expanding the estimates based on redd counts and other expansions are available in Appendix E of Killam et al. 2017.

Each mark-recapture model has built in advantages and disadvantages.The Peterson model is the simplest, and is useful in developing an estimate when major disruptions to the sampling schedule occur. The Peterson treats the entire survey timeframe as two periods, a tagging period and a recapture period. This is the most simplistic mark-recapture model but in some surveys is the only one that can be used due to flooding causing low numbers of recaptures, budget cuts, or other survey disruptions.

The Schaefer and the Jolly-Seber (JS) models are more complicated because they depend on repetitive survey periods and recaptured carcasses throughout the survey. Of the two, the JS is the more complicated to analyze but software programs have been developed to allow simpler calculation of this method. The CJS method differs from the Schaefer and JS models in that it can account for different survival rates of different size or sex fish and accounts for survival of carcasses between survey periods. The CJS method requires that all carcasses be individually tagged and allows for the inclusion of smaller 2-year old salmon (grilse) and adipose fin clipped fish into the pool of mark-recapture survey data. The CJS method has now generally replaced the other mark-recapture methods used in the Central Valley. Beginning with the last survey of 2011 (fall-run) the new CJS methodology was implemented for all mark-recapture carcass surveys in the USRB. The protocols of the 2017 CJS mark-recapture method used on the Sacramento River included:

1 Every fish (carcass) observed was checked for a CJS numbered tag.
2 Fish in good condition (including hatchery fish) received a numbered tag on the lower jaw and were released back to the waterway.
3 Fish in poor condition were chopped in half upon first observance.
4 Tagged fish that were recaptured were chopped upon first recapture.

The option of releasing (instead of chopping them) recaptured tagged fish to produce multiple recaptures is available during CJS surveys with expected low abundance of carcasses but this option was not utilized in 2017.

The CJS estimates used only data from female carcasses for the mark-recapture portion of the data analysis. This is because some unknown portion of post-spawning male Chinook are known, through observations, to leave the spawning areas and swim slowly downstream moving outside the survey locations before they die. Female Chinook typically guard their redds until close to death and are much more abundant (as carcasses) than males in survey databases compared to the sex ratios of live fish observed at hatcheries for the same run of salmon. The CJS mark-recapture method accounts only for carcasses and not live fish. The tendency of males to move downstream out of the survey area while alive reduces the number of male carcasses available to the CJS survey and results in an underestimation of the true number of males (if only CJS methods are used). These and other details are summarized for each run later in this report.

Sacramento River Carcass Survey Methods

The final population estimate of each run of salmon was produced through a five-step process. These steps included:

1 Estimate females within survey area using the CJS methodology.
2 Estimate total females using redd counts of survey and downstream areas.
3 Estimate large males using ratio of females to males from live fish counts.
4 Estimate small male salmon from survey ratio of fresh adult male to fresh male grilse.
5 Add in any salmon that were removed for hatchery spawning or other observations.

The CJS mark-recapture survey (described below) was the first of the five steps in each population estimate and resulted in an estimate of the number of female salmon in the survey area. The survey area comprises the 26 miles in the Sacramento River between Balls Ferry Bridge near Anderson, California and Keswick Dam in Redding (see Figure 1).

The second step was to expand the CJS total female number for additional females spawning downstream of the survey area. The results of a series of aerial redd surveys (described below) were used to determine the number of female spawners downstream of the survey locations based on the number of new redds observed downstream of the lowermost survey area (Balls Ferry Bridge) and the number observed within the survey area. The resulting expansion, based on the ratio of redds within the survey to those downstream of the survey area, and the CJS females within the survey area produced an estimate of the total females in the Sacramento River.

The third step was to estimate the large males (defined as males >609 mm). The large male component of each population estimate was derived from data using the ratio of females to males from the CNFH (for fall-run and late-fall-run) or the LSNFH data comparing ratios of females to large males (for winter-run).

The fourth step was to estimate the number of male grilse or “jacks”. The data on all fresh male carcasses from the survey was used to calculate an estimate of the generally smaller jack salmon. The ratio of fresh small and large male carcasses was used to develop a proportion that was compared to the total large male numbers. This “proportion based” calculation resulted in the total small number of males. The total females (Steps 1-2) and the total males (Steps 3-4) were summed resulting in a total in-river spawning estimate.

The fifth step was to tally any additional fish that were removed for hatchery brood stock purposes. Combining all five steps provided the final estimate for each run of salmon.

Once the overall population estimate was developed, additional steps were undertaken to produce sub-estimates of adults and grilse and hatchery and natural origin categories of interest for management purposes. The CJS survey data of fresh carcasses of both sexes was analyzed and allowed development of a variety of categories of interest to fisheries managers. These are shown in Appendix Tables A4-A6 for each run of monitored salmon.

Traditionally, the Sacramento River carcass surveys are conducted by boat, each having two or more observers. Three multi-month surveys are conducted each year with crews normally on the river year-round. Survey protocols and methods may change slightly in each survey but in general terms the protocols have remained similar since 2003. The late-fall-run survey begins typically in mid-December and ends in early-May. The winter-run survey begins in late-April or early-May and ends in late-August or early-September. The fall/spring-run survey begins in early-September and ends in late-December or early-January. The beginning or end of each survey is determined by the number of carcasses observed by the crews at those times. The spawn timing of each run can vary by a few weeks each year so survey dates are flexible and can overlap from one survey to another. Normally, two boats are used with each boat surveying the areas from either shore out to the center of the river. At some times during high carcass numbers, three or more boats may be used to finish the daily survey section. At times of very low carcass numbers or staff shortages, a single boat may be used if the entire section can be surveyed effectively. In some areas of high carcass concentrations (e.g., Turtle Bay at RM 296.5), the boats work side-by-side to process the carcasses, while at other times they may be out of sight of each other. Carcasses are not accessible in some areas of the river due to hazards or deep water so crews will typically bypass these areas and focus in areas where observations are possible. In addition, crews are instructed to search all areas of the visible river bottom to avoid pre-determining search patterns based upon their prior experiences in locating carcasses.

The surveys are divided into four sections. The sections were chosen as convenient areas for crews to start or stop work for the day. The sections are as follows:

1. Keswick Dam to ACID (Anderson-Cottonwood Irrigation District) Dam– RM-302 to RM-298.8,
2. ACID Dam to Highway 44 Bridge – RM-298.8 to RM-296.5,
3. Highway 44 Bridge to Clear Creek power lines – RM-296.5 to 288.5,
4. Clear Creek power lines to Balls Ferry Bridge – RM-288.5 to 276.

Each of the three surveys is broken down into individual survey periods with each period representing a single complete coverage of all sections of the river by the boats. Each carcass survey, when completed, has numerous survey periods. Survey periods for fall/spring and late-fall-runs are one week long. Crews begin a new survey period in the lower end of section four (or three during busy years) on Tuesdays and work their way upstream normally finishing near Keswick Dam on Thursday or Friday of each week. Winter-run survey periods are three days long and repeat throughout the survey without skipping any days. This is done because the flows in the river are higher at this time of year and the winter-run is the focus of intense management concern. Increased effort is put forth to capture as many carcasses as possible given the increased flows, deeper waters, and low numbers of winter-run available for crews to sample.

Typically, all carcasses encountered that are not in an advanced state of decay are marked (tagged). Carcasses not receiving tags are tallied then cut in two (chopped). All chopped carcasses are disregarded in subsequent survey periods. All carcasses upon tagging are returned to flowing water near where they were collected in an attempt to simulate “natural” carcass dispersion. All “recaptured” carcasses bearing a tag from a previous survey period are tallied according to tag number. Chopped carcasses are normally tallied by their size (small <610 mm and large >609 mm), and by their sex (female, male, or unknown-typically skeletons).

Sacramento River Carcass Sampling

The following summary provides the techniques and methods used to collect information on the Sacramento River carcass surveys. Carcasses are collected by crews standing on the bow of a jet boat using 16-foot wooden poles with a five-pronged spearhead attached to one end. Data is collected from carcasses after they are speared and lifted onto the deck of the boat (or held on the surface for chopping). Each carcass is then categorized using the following criteria:

1. recaptured (previously tagged) or new encounter,
2. fresh (recently died-with clear eyes) or non-fresh (decayed),
3. adipose fin absent (hatchery), present, or unknown,
4. male or female,
5. spawned or not spawned (eggs present in females, males not scarred from fights),
6. fork length and biological samples if taken,
7. location (river mile and GPS waypoint),
8. carcass to be tagged or chopped.

Recaptured fish (recaptures) are chopped in two pieces using a USRBFP fabricated “V” shaped “choppinator” (two modified machetes welded together and bolted on a pole). Recaptures are tallied on the reverse side of the datasheet, and the GPS location and tag number are recorded for each recaptured fish.

If the fish does not have a previously applied tag then the freshness condition of the carcass is determined. Carcasses are classified as either fresh or non-fresh. A fresh carcass is one with at least one clear eye and or reddish gills, and normally has a firm body indicating a recent death. All tagged carcasses are tagged in the lower jaw using a 1.25-inch round aluminum numbered “disc” tag. Both fresh and non-fresh fish can be tagged or chopped. Crews evaluate the condition of the fish and make a decision on tagging the fish based on the carcass characteristics. If the carcass is missing parts because of scavenging by otters, turkey vulture, etc., then it is normally chopped. As the carcasses decay, they become soft and rotten making tagging difficult. If a crew determines that a fish is not suitable for tagging due to decay, then it is chopped and tallied. This distinction between what is a non-fresh carcass to be tagged and a non-fresh carcass to be chopped is one area that is very subjective and is difficult to qualify as each carcass can be different and each crewmember may have slightly different views on this distinction.

At the other end of the decay process timeline are the carcasses tallied as skeletons. These fish are severely decayed, resembling a bony skeleton or a bag of skin over a skeleton. Skeletons are carcasses missing the adipose fin area that prevents crews from determining if the fish was clipped. If the skeletal carcass is missing its lower jaw then it is chopped and ignored for purposes of the mark-recapture data (it is tallied separately). If the skeletal carcass has the lower jaw present then it is observed for a tag recapture. All skeletons are chopped after processing. An important distinction of skeletons from other, better condition fish, is that no heads are removed and sampled for coded wire tags on skeletons due to missing soft tissue from advanced decay.

A carcass with a missing adipose fin (indicating hatchery origin) has the upper portion of the head removed. Crews leave the lower jaw intact so that if the fish meets the tagging criteria for freshness and is non-scavenged, then it is tagged for CJS purposes. The head is placed in a bag and labeled for future dissection of the coded wire tag (CWT) within the head tissue to enable analysis of the hatchery of origin for it. Carcasses of “unknown” adipose fin clip status (area around the fin was eaten or rotten) are treated similarly to adipose fin clipped carcasses to ensure collection of all possible hatchery origin CWT fish. The USRBFP motto of “when in doubt, take the snout” is useful in reminding new crew to always check for adipose fin status on all carcasses. An important exception to this motto is that no heads are ever collected from skeletons due to their advanced decay.

The sex of carcasses is typically readily apparent and experienced crews normally have little difficulty in classifying carcass sex. Smaller carcasses (and some larger ones) can be difficult to determine. Crews are instructed to check gonads (cut with knife to observe) for any carcasses they are not positive of sex determination.

Spawn condition is determined by observing the external appearance of each carcass. Female carcasses are classified as spawned if few eggs remained in the carcass and the caudal (tail) fin is worn from redd construction. Unspawned females typically are those with unworn caudal fins indicating they have not constructed redds or those where numerous eggs remain in the carcass after it has died. Male carcasses are by default classed as spawned. The few males that are classed as unspawned have no fighting scars and wounds that are typical of the spawning males that constantly bite each other in their struggle to obtain a dominant position near a spawning female.

Nearly all fresh (and some non-fresh) carcasses are measured for fork length to determine age structure of the population. Additionally, tissue samples, otoliths (limited to winter-run), scales (all runs), and heads (all runs) are collected from fresh carcasses for further analysis. Sub-sampling for biological samples occurs when carcass counts are expected to be high. Sub-sampling (if used) commences and ends in complete survey periods to allow subsequent expansion of the results. All clipped or unknown clipped fish (except skeletons) are sampled (heads removed and checked for CWT) without sub-sampling to ensure maximum information on hatchery origin is collected.

For each carcass that is measured the river mile and a GPS location is recorded. This allows analysis of carcass distributions to determine if differences exist between different categories of fish or for other management queries. Other data collected by survey day includes the following:

1. outflow from Keswick Dam,
2. water temperature,
3. water clarity,
4. weather conditions.

River flow based on the outflow from Keswick Dam is obtained from the California Data Exchange Center (CDEC) using the KWK gauge at http://cdec.water.ca.gov. Water temperature is collected for each survey section via a handheld thermometer and recorded in degrees Fahrenheit. Water clarity is measured by lowering a Secchi disc attached to a spear into the water column. When the Secchi disc disappears/reappears, the measurement at the water surface is recorded. Water clarity distances greater than 15 feet are recorded as "15.9" for survey purposes since the maximum depth crews can spear a carcass is limited by the spear length. Weather conditions are noted as to the daily conditions (rain, clear, etc.) encountered for each section.

Sacramento River Aerial Flight Redd Distribution

In 2017, a CDFW airplane was used to conduct monthly surveys for the late-fall-run and fall/spring-run redd distributions. During the winter-run spawning period, a helicopter was used to conduct surveys to enable detailed inspection of winter-run spawning areas.

Aerial redd maps are created by USRBFP staff on the flights to document the location of spawning areas and distributions in the Sacramento River (scanned versions available upon request of author: doug.killam@wildlife.ca.gov). These maps are used in conjunction with the corresponding carcass surveys to expand the overall population estimate for each run of salmon. Appendix Table A2 presents the data from the aerial redd surveys conducted by the USRBFP. These surveys also create a historical database on redd distribution in the Sacramento River from Princeton (RM-164) to Keswick Dam (RM-302) (1969-present), available in Appendix Table A3. The aerial redd data is also used to estimate spawning escapement in the Sacramento River downstream of both the RBDD (for historical comparisons) and carcass survey areas. The ratio of redds upstream to redds downstream is used in conjunction with the upstream escapement estimate of the carcass surveys. A simple proportion is used to calculate the downstream estimate. The proportion is constructed as follows: number of salmon downstream = (salmon upstream after harvest in Sacramento River / redds upstream) * redds downstream.

Aerial redd surveys do not provide complete counts of new redds. Variability in turbidity, river depth, riparian vegetation, weather and wind all effect the ability of the observer to count new redds. Not all redds that are new are able to be counted but it is assumed that the proportion of redds visible in the various sections during a single flight are identical. The aerial redd data should be used with caution. The USRBFP recommends using aerial redd data only for comparisons of redd distributions by river sections or for specific needs such as use of a specific area as a spawning location.

The USRBFP conducted 13 aerial redd flights on the Sacramento River for the 2017 escapement surveys (Appendix Table A2). One late-fall-run flight was conducted in 2017 with 39 new redds observed and all located upstream of the Balls Ferry Bridge. Eight winter-run flights were conducted using a helicopter from June 09 through August 16, 2017. All of the 26 new winter-run redds were observed in the sections from the ACID Dam downstream to the Airport Road Bridge. Poor water visibility caused by turbidity in Shasta Lake prevented observers from viewing any redds in the deep water of the uppermost section between ACID and Keswick Dam. This section contains the coolest water available to the winter-run and all salmon entering into the Keswick Fish Trap for use at LSNFH must pass through this section. Many of the fish trapped are returned to the river and are likely to spawn in this section but unfortunately, conditions prevented their observation in the summer of 2017. One spring-run survey was conducted in the month of September and two new redds were reported. Three fall-run flights between October 19 and November 29, 2017 observed 126 fall-run redds from Woodson Bridge (RM-218) upstream to Keswick Dam (RM-302).

In summary, during 2017 there were 193 new redds observed in the Sacramento River from Keswick Dam to Woodson Bridge (RM-218) over 13 separate flights. The majority of these redds (98.4%) were upstream of Red Bluff Diversion Dam.

Historically the fall-run, and to a lesser extent the late-fall-run, are observed to spawn throughout the upper river from Princeton (RM 164) to Keswick Dam (see Appendix Table A3). In 2017 only three redds were observed in the 79 miles of river below the RBDD. This is likely is due to the drought conditions from recent past years reducing survival of juveniles that were originally from this section of the USRB. Water temperatures in the USRB decline in the autumn and winter months (as air temperatures decline) and this allows these runs to spawn in suitable habitat further downstream than the summer and early autumn spawning winter-run and spring-run. Drought conditions in 2013-2015 resulted in warmer than normal water temperatures in the Sacramento River and could have reduced survival of the eggs from fish spawning in this lowermost section.

Video Station Monitoring Methods

In 2017, video monitoring stations (stations) were constructed on eight tributaries to monitor fish passage. Tributaries with stations included: Clear, Cow, Bear, Cottonwood, Battle, Antelope, Mill, and Deer Creek(s). Details of each station's data analysis are available later in this report. Each station was constructed by staff from the USRBFP (with assistance from USFWS crews on Clear and Battle Creek stations). Discussion of the construction of each station can be divided into two basic groups of equipment for discussion purposes.

Weir System:

1. stream or fish ladder bottom white plates,
2. resistance board weir panels (in-river stations only).

Electronics:

1. power supply-(solar or power company electric)
2. lock box and equipment,
3. backup batteries power supply,
4. lights,
5. overhead camera with supporting structural cables and electronic cables,
6. underwater cameras with supporting plates and electronic cables,
7. digital video recording devices (DVR's) or DIDSON, ARIS, or VAKI.

The stations functioned by video recording salmon and other migrating fish as they passed through an opening in a partial in-stream weir (Clear, Cow, Bear, Cottonwood, and Battle) or fish ladders (Antelope, Mill and Deer (Deer has two ladders, each with a separate station).

Since 2015, the USRBFP has used resistance board weirs in waterways without fish ladders. The weirs are constructed of polyvinyl chloride (PVC) pipe. They use the force of water flowing past an adjustable underwater "resistance" board to lift the downstream end out of the water. An advantage of the resistance board weir over the previously used "horizontal panel" USRBFP weir is that flood debris can push the panels underwater allowing most debris to move past the weir without destroying it. Resistance board weirs allow monitoring at much higher flows typical of steelhead passage periods (winter-spring). The weirs funnel the upstream moving salmonids through an opening in the main channel of the streams. At the opening, the fish swam above a white plastic plate attached on the stream bottom. As fish swim through the weir opening, they are video recorded by a camera system positioned on cables directly overhead of the white plate. A through description of video station methods including detailed discussion of equipment, construction, maintenance, and data analysis is available in the 2011 annual report by the USRBFP titled “Chinook Salmon Populations for the Upper Sacramento River Basin In 2011” (Killam 2012). Additional specific details of constructing resistance board weirs are available in Stewart 2012. There were not significant changes to the counting methodology and procedures for the 2017 stations compared to 2011 so the authors direct interested readers to the earlier report for detailed discussion of USRBFP video stations methods.

In 2017, both DIDSON and ARIS cameras were used at various stations. These cameras incorporate a relatively new and expensive technology to view underwater objects including fish. The ARIS camera is the newest version of the sonar technology and replaces the no longer available for purchase DIDSON. The cameras are about the size of a small watermelon (ARIS is slightly smaller) and must be submerged to function. The cameras send images to a computer through a waterproof cable. The computer saves the video like images to a hard drive and the DIDSON or ARIS software enables viewers to play the footage on a computer and view it in many different ways. The monochromatic footage resembles the ultrasound images of a human baby in the womb. The USRBFP requested the cameras to assist in counting fish during the fall, late-fall, and spring-run migration periods at the video stations.

The sonar cameras can “see” in turbid water enabling fish counting to continue during periods of flooding and snowmelt on streams in the USRB. The use of the cameras supplemented the regular video coverage during these muddy water periods. The DIDSON or ARIS pairs well with the video station equipment as it functions by “shooting” a sonar beam across the entire opening of the weir or fish ladder allowing for wide relatively unrestricted passage both up and downstream for multiple species. A disadvantage of the sonar cameras (beside the cost) is that it is difficult to distinguish different fish species of similar size. USRBFP staff viewing DIDSON and ARIS footage reported little difficulty in identifying the larger adult salmon. However, for the smaller fish (e.g., 18 to 24-inch, (46 to 61-cm)) common to the USRB, viewers often were unable to identify individual species. Species such as steelhead, smaller salmon, Sacramento Pikeminnow, (*Ptychocheilus grandis*), Hardhead, (*Mylopharodon conocephalus*), Sacramento Sucker, (*Catostomus occidentalis*) and even beavers and river otters were difficult to distinguish using just the DIDSON footage.

A Vaki Riverwatcher (VAKI) was used the fish ladder of the Edwards Dam in Antelope Creek in October of 2017. The VAKI uses both a traditional video camera and infrared light beams to monitor fish passage. An advantage of the device is that is capable of collecting silhouettes of passing fish in turbid water (using infrared multi beams) as well as video images of fish passage during clear water. Fish are funneled into a narrow (16”x19”) tunnel opening where they are recorded and characterized by a control box computer that allows users to rapidly (relative to continuous video) tabulate fish counts. The VAKI has some limitations for use in the USRB tributaries. These include a substantial size and weight, (making placement and flood removal complicated), a substantial cost, debris clogging, and limited ability to review and analyze the recorded passage events. In addition, all fish passage (including downstream passage) must be funneled through the narrow tunnel possibly interfering with normal fish migration of both salmonids and non-salmonids alike. Many other non-fish species travel in the USRB tributaries on daily migrations (otters, beavers, turtles, ducks, etc.) and the ability (or behavior) of these non-target species passing through the narrow tunnel opening is uncertain.

Details of the various surveys including carcass surveys, bio-sampling surveys, video stations, DIDSON-ARIS sonar cameras, and Vaki Riverwatcher use in 2017 are discussed in the specific waterway section later in this report.

Tributary Walking, Snorkeling and Kayaking Survey Methods

During various times of the year the USRBFP staff and other cooperating staff conduct numerous surveys to collect salmonid population data in tributary streams of the USRB. These surveys involve surveying specific reaches or sections of tributaries and documenting the number of salmonids or other categories of interest. Typically, methods can include boating, walking, snorkeling (swimming), or kayaking and counting and collecting data on salmonid populations. Data collected can include number of live fish observed, number of carcasses observed (data is then collected on each carcass), number of redds observed and locations of these observances.

In 2017, salmon carcass bio-sampling surveys of individual USRB waterways were used to evaluate the characteristics of the populations for origin, age, sex, and spawning success. No mark-recapture is currently done in the tributaries because video stations provide population estimates. Fresh carcasses are normally the only ones sampled when counts are high. Crews are instructed to ignore non-fresh carcasses after the first weekly survey to avoid sampling the same fish twice.

The estimate of natural and hatchery origin ratios of fall-run spawning in the waterways in the USRB is based on fresh carcass examinations. Usually less than a few days old since the death of the salmon, fresh carcasses allow reliable determination of the presence or absence of the adipose fin. Fresh carcasses are also more likely to retain their CWT before the decay process allows rotten tissue to shed the tag.

Age structure is determined by post-season analysis of fork lengths of both males and females separately. CWT information is used to assist in determining length “cut-offs” for both sexes. Fish under a certain fork length are listed as “grilse” or two-year olds (jacks-male, jills-female), while fish greater than the cut-off are listed as adults (3-years or greater). Scale samples are taken from all fresh carcasses on each creek in the expectation that they allow a more accurate method to age a fish. At present time, scale reading of samples collected by USRBFP crews has not been adequately funded to provide any up-to-date age information so the fork length and CWT methodology is used to determine the age structure of the population.

Sex is determined through visual observation or by cutting the body cavity of questionable fish and visually checking for eggs or milt. Spawned females normally have eroded tails from digging redds and have little or no eggs remaining. Spawned males typically show the presence of wounds, scratches and sores along their sides indicating they were in competition with other males for prime spawning positions when females were laying their eggs. The wounds are caused by other males biting at the sides of other males to force them away from the female.

Spawn success is determined by comparing the ratio of fully spawned out females to those that died prior to expelling their eggs. Normally in low count years unspawned females are uncommon, as most can find room to construct redds and lay their eggs. In some years, large counts can result in high numbers of unspawned females, as many die before finding a suitable redd location. Disease, poor water quality, and predators are other causes of pre-mature death for female and male salmon. Male salmon are normally not noted as unspawned unless it is obvious a male died prior to competing with other males.

In 2017 USRBFP staff conducted bio-sampling surveys to supplement video data on Clear, Cow, Bear Cottonwood, Paynes, Antelope, Mill and Deer Creek(s). Details are described for each creek below.

<u>The 2017 Salmon Escapement Results for Specific Waterways</u>

Table 1 presents a summary of the information collected for salmonid populations in the USRB using the methods described above. In addition, information is presented from data collected by the USFWS on Clear and Battle Creek and from hatchery operations including Livingston Stone and Coleman Hatcheries.

The CDFW’s 2017 GrandTab file (version- April 09, 2018) provides a summary of California’s Central Valley Chinook Salmon population estimates for each monitored waterway. Note that the 2017 estimates in this report are the most-up-to-date, many calculated after the GrandTab file was updated. Numbers in

Table 1. Summary of the 2017 Chinook Salmon and steelhead population estimates for the USRB, (Sacramento River and tributaries from Keswick Dam downstream to Princeton Ferry).

Location **Run**	*Late-Fall-Run*	*Winter-run*	*Spring-Run*	*Fall-Run*	*Steelhead* [1]
Keswick Dam to Red Bluff (upstream of RBDD) [2]					
Sacramento River Up	3,069	795	4	1,711	n/a[3]
Keswick Trap	13	180	0	111	n/a
Clear Creek	55	2	25	2,353	307
Cow Creek	n/a	n/a	n/a	288	0
Bear Creek	5	n/a	0	2	9
Cottonwood Creek	n/a	n/a	n/a	124	42
Battle Creek in CNFH	1,638	0	0	6,395	1,422
Battle Cr. above CNFH	48	0	30	0	489
Battle Cr. below CNFH	n/a	n/a	n/a	354	n/a
Paynes Creek	n/a	n/a	n/a	0	n/a
Angler Harvest	106	n/a	0	2,017	n/a
SUB-TOTAL UP	*4,934*	*977*	*59*	*13,355*	*2,269*
Red Bluff to Princeton (downstream of RBDD) [2]					
Sacramento Riv. Down	0	0	0	41	n/a
Antelope Creek	0	0	8	5	23
Mill Creek	2	0	258	342	68
Deer Creek	7	0	219	106	50
Big Chico Creek	n/a	0	0	n/a	n/a
Angler Harvest	24	0	0	880	n/a
SUB-TOTAL DOWN	*33*	*0*	*485*	*1,374*	*141*
SYSTEM TOTALS	**4,967**	**977**	**544**	**14,729**	**2,410**
2017 SALMON ALL COMBINED:			**21,217**		
Please view GrandTab file for most up-to-date information.					
1 Steelhead data are totals from autumn of 2016 to summer of 2017					
2 There are numerous smaller creeks not surveyed for some runs					
3 n/a: Is Not available, represents salmon possibly present but no survey					

GrandTab are usually considered draft for a few years giving time for quality control reviews and other updates to estimates to occur. Readers should also note that **GrandTab does not include the sport angler catch** in the USRB shown in Table 1. Readers should use caution when comparing GrandTab totals to totals in Table 1 and throughout the text below. Typically, the most recent source of information, based on date, will provide the most up-to-date estimates. Significant revisions can be made to numbers during agency reviews and these often go undocumented in prior reports and older GrandTab files. The following section of this report provides details of the salmonid escapement surveys made on the USRB waterways in 2017.

Readers should note that electronic spreadsheets of the data discussed in this report to develop population and other information is available online, and upon request, from the authors. This report provides summary information for the numerous surveys the USRBFP conducts. Readers wishing to access in-depth data of the USRB monitoring should download the accompanying summary file detailing specific waterways or contact the authors directly for larger needs.

Sacramento River

Late-fall-run. Please note that late-fall-run spawn over the calendar year change. For the purposes of reporting late-fall-run numbers it is customary to report estimates based on when the juveniles emerge from redds. Late-fall-run spawning in November and December are classified as belonging to the following year, (i.e., December of 2016 spawners are put into the 2017 estimate, and December of 2017 spawners will be part of the 2018 estimate). As a result, **all late-fall-run data described in this report is for the period from late 2016 to early 2017 and not from the period late in 2017 that is reported as 2018 numbers**.

A Sacramento River mark-recapture carcass survey was conducted from December 27, 2016 through January 11, 2017. Record setting rainfall during the 2016-2017 winter resulted in the survey being shortened significantly due to dangerously high flows on the Sacramento River below Keswick Dam. Crews can survey the river in flows up to around 20,000 cfs. However heavy rain in December of 2016 quickly filled Shasta Lake, and flows reached nearly 80,000 cfs during the normal late-fall-run survey period. Crews conducted only three weekly surveys (normal late-fall survey is 20 or more weeks) over the 26-mile section of the Sacramento River between Keswick Dam, (RM-302), and the Balls ferry bridge (RM-276). The weather during late-fall-run surveys can often make surveying difficult or impossible and 2017 was exceptionally bad. Conditions for observing carcasses were poor; with visibility ranging from one to eight feet during the short three weeks of the survey, (visibility greater than 16 feet is fairly common in the Sacramento River). Using an expansion factor to account for the cancelled survey periods an estimated **3,082 late-fall-run** were present with 13 of these transferred to the CNFH for broodstock purposes. Confidence limits for the estimate were not calculated for this survey. The expansion used to obtain the final estimate was developed from late-fall-run surveys in prior years that were not impacted by flooding. The data from 2017 was expanded based the average counts from previous years for the missing period after January 11,

2017. This expansion (89%) was applied to the 2017 data and used to develop the 3,082 value.

Crews observed 74 carcasses. Crews tagged 36 of these and recaptured three for a recapture rate of 8.3%. Crews measured 35 fresh carcasses, and a grilse (2-year old) percentage of 4.1% was estimated based on a length cut-off of 610 mm for both females and males. Males represented 44.8% of the population. Females were checked for egg retention following spawning. None of the 24 fresh females were unspawned. Keswick Dam flow releases ranged from a low of 7,510 to a high of 78,046 cfs during the survey (from CDEC gauge KWK). Water temperatures taken by USRBFP crews ranged from 47 to 52 degrees over the three weeks of the survey. Details of the late-fall-run survey are available in Appendix Table A4

All fish examined were checked for adipose fin clips representing hatchery origin (except skeletons). Of the 74 late-fall-run carcasses, 73 were checked for clips, while the other one was a skeleton that was too decayed for crews to check for a clip. Crews removed heads for CWT checks on three carcasses and determined that all of these were of hatchery origin. One of these was from the late-fall-run production at the CNFH. The other two heads had tags that could not be read.

The late-fall-run are subject to sport fishing in the Sacramento River below Deschutes Road Bridge (RM-280.9). In late 2016, anglers were estimated to have harvested 130 late-fall-run from the Sacramento River. The sport-fishing season for what are classified as 2017 late-fall-run spawners was from July 16 to December 16, 2016 below RBDD, and from August 01 through December 16, 2016 above RBDD. The CDFW’s Angler Harvest Survey reported angler harvest numbers during the 2016 late-fall-run season as 24 below RBDD and 106 above RBDD for the total of 130, (Table 1). All of these were determined to be late-fall-run (i.e. they could have been strays from other systems) after CWT analysis.

Based on the Sacramento River carcass survey, angler harvest estimate, CNFH data, various tributaries, and aerial redd data it is estimated that **at least 4,967 late-fall-run** were present in the USRB above Knights Landing in late 2016 and early 2017 (Table 1). The USRBFP monitoring begins at Princeton; angler data above Knights Landing was included since fish caught above Knights Landing were likely destined to spawn in the USRB. This estimate does not include the tributaries that had no surveys due to flooding, limited staffing and typically poor weather and turbidity conditions during late autumn and winter.

Winter-run. The CJS mark-recapture carcass survey for winter-run was conducted on the Sacramento River (Figure 1) from May 01 through September 06, 2017. The total spawner population estimate for the 2017 Sacramento River **winter-run was 975** with a 90% confidence interval of 109-lower and 1,888-

upper. In-river winter-run were estimated at 795. The LSNFH staff collected 180 winter-run for broodstock in 2017.

Crews observed 143 carcasses. Crews tagged 93 of these and recaptured 20 for a recapture rate of 21.5%. Crews measured 75 fresh fish, and a grilse (2-year old) percentage of 49.8% was estimated for all fish based on a length cut-off of 645 mm for females and 720 mm for males. Males represented 55.7% of the total population (including the fish from LSNFH). An estimated 373 females were estimated to have spawned in-river (including 137 jills). Females were checked for egg retention following spawning. Only one of 60 fresh females (1.7%) had not completely spawned. Keswick flow releases ranged from a low of 5,080 to a high of 13,113 cfs during the survey. Water temperatures taken by joint USFWS-USRBFP crews ranged from 49 to 57 degrees over the four-month survey. Details of the winter-run survey are available in Appendix Table A5

All fish examined were checked for adipose fin clips representing hatchery origin (except skeletons). Of the 143 winter-run carcasses, 133 were checked for clips (10 skeletons not checked). Crews removed heads for CWT checks on 112 carcasses and determined that 109 of these were of hatchery origin. An estimated 824 of the 975 (85%) of the spawning population were hatchery origin. This and additional winter-run data (including historical annual data) can be accessed in the supplemental Excel file on the CALFISH website referenced earlier in this report.

Other winter-run data. One additional winter-run redd (assumed two salmon) was observed in Clear Creek leading to a final escapement of 977. Eight helicopter aerial redd surveys (Appendix Table A2) were conducted to count new redds and determine winter-run spawning distributions in the Sacramento River from the RBDD (RM-243) to Keswick Dam (RM-302). In 2017, all 26 winter-run redds were found upstream of the Airport Road Bridge (RM-284) in Anderson, CA. The 2017 winter-run spawner count of 975 represents a negative cohort replacement from the three-year-ago count of 3,015 (i.e. 2014).

There was zero estimated in-river angler harvest of winter-run based on limited angling season and no reported catch of winter-run from the CDFW Angler Harvest Survey. It is likely that some winter-run mortality is associated with angling and poaching but no quantitative data was available to quantify this. In 2017, CDFW again took an additional protective step of closing the Sacramento River to all angling from Keswick Dam downstream to the State Highway 44 Bridge just below Turtle Bay from April to July 31, 2017. In past years, this uppermost anadromous river section was open to non-salmon angling year round. Expected low winter run counts, drought concerns, and observational reports of incidental hooking of salmon in this area led to the closure.

Spring-run. Spawning of natural origin spring-run natal to the Sacramento River is considered by the CDFW to have largely been eliminated through competition plus hybridization with fall-run (CDFG 1998). Historically spring-run migrated upstream in the spring and early summer and held over the summer in higher elevations with cooler water temperatures. These fish were then spatially separated from the later arriving fall-run by low flows and warmer temperatures in the lower sections of the waterways. Presently, Keswick Dam prevents the spring-run from being spatially isolated from the fall-run. Since spring-run are spawning around the same time as early spawning fall-run each year (mid-September into October) in the same location they may not be genetically isolated.

Currently, the USRBFP cannot make reliable carcass survey estimates of natural spring-run upstream of RBDD in the Sacramento River. This is because of the overlap between spring and fall runs and the lack of a suitable means of distinguishing them. In 2017, carcass surveys continued with little break between winter-run and the fall-run survey. The total number of carcasses counted in September was three indicating very few salmon spawned during this period. Previous limited genetic analysis in 2013 indicated that fish from the winter-, spring- and fall-runs were all present in small numbers during this segue period between the winter and fall runs (Killam et al., 2014). The traditional process of estimating spring-run uses the aerial redd data and assigns a spring-run number based on new redds observed in late August through September. In 2017, one spring-run flight was conducted in late September and **two redds** observed (Appendix Table A2). Because the fall-run carcass survey started shortly after the end of the winter-run survey any carcasses of spring-run spawners would have been incorporated into the CJS estimate for fall-run (see below). Based on the two redds an estimate of four was made for the natural origin spring-run in the Sacramento River (Table 1).

No carcasses from the Feather River Hatchery (FRH) spring-run were encountered during the fall-run surveys on the Sacramento River in 2017. Typically, FRH strays are historically found early on the fall-run surveys in the USRB indicating their early spawn timing and persistence. There is considerable uncertainty and discussion amongst biologists as to the exact nature of the spring-run population in the Sacramento River. Until further research is conducted, this uncertainty will continue.

Fall-run. A CJS mark-recapture carcass survey for fall/spring-run was conducted on the Sacramento River (Figure 1) from September 18, 2017 through January 04, 2018. The expanded population estimate for the 2017 Sacramento River fall-run was **1,863**. Ninety percent confidence limits for the expanded estimate were 822-lower and 2,845-upper. This year's estimate for the mainstem Sacramento River is the lowest on record likely due to poor in-river survival in 2014 during the drought and subsequent trucking of CNFH hatchery fish leading to straying. Crews observed 304 carcasses. Crews tagged 134 of these and recaptured 20 for a recapture rate of 14.9% for the survey. Crews measured 110 fresh carcasses, and a grilse (2-year old) percentage of 57.6% was estimated based on a length cut-off of 675 mm for females and 765 mm for males. Males represented 54.6% of the population. An estimated 797 females spawned in-river (including 305 jills). Females were checked for egg retention by survey crews. One of 68 fresh females (1.5%) had not completely spawned. Details of the fall-run survey are available in Appendix Table A6.

Note, for record keeping purposes that four spring-run are subtracted from the 1,752 in-river fish to calculate for the fall-run only. Due to the shortage of fall-run in the USRB in 2017, staff from the CNFH took the unusual step of operating the Keswick Trap and removing 111 fall-run from the Sacramento for broodstock at the CNFH. Historically, there are more than enough fall-run in Battle Creek to collect enough fish for CNFH purposes but low numbers throughout the USRB resulted in this action.

All fish examined were checked for adipose fin clips representing hatchery origin (except skeletons). Of the 304 fall/spring-run carcasses, 265 were checked for clips (39 skeletons not checked). Crews removed heads for CWT checks on 22 carcasses and determined that 20 of these were of hatchery origin. Of the total 1,752 in-river fall/spring-run an estimated 414 (23.6%) were of hatchery origin. Of the 111 removed at the Keswick Trap an estimated 72 were of hatchery origin. These values were calculated from a hatchery fish expansion based on the data from the Constant Fractional Marking Program (CFM). Fresh fish data were utilized in this expansion and specific CWT codes were expanded based on the percentage of juvenile tagging that each CWT code represented. Specific CWT information and tag codes recovered in the USRB by the USRBFP, on this and other surveys, is available on the aforementioned CALFISH site.

Water temperatures taken by USRBFP crews ranged from 49 to 56 degrees over the three-month long survey. Keswick Dam flow releases ranged from a low of 4,204 to 9,150 cfs during the survey in a flow regime that typically starts high and progressively decreases as agricultural needs decrease during the period from summer to early winter. These systematic flow reductions during fall-run and late-fall-run spawning in the Sacramento River can lead to redd dewatering and subsequent egg and juvenile stranding and mortality. From the summer of 2016 to the spring of 2017 a continuing effort to document dewatered redds was made by USRBFP staff. Results of this redd dewatering effort are available in (Memeo et. al, 2018). Redd dewatering can impact all four salmon runs that occur in the Sacramento River, and large numbers of fall-run redds can be dewatered after autumn reductions in flow. Dewatering of redds and stranding of juveniles is of concern to fisheries agencies, and the USRBFP crews continue to investigate impacts to salmon redds and juvenile stranding of salmon in the river.

The CDFW Angler Harvest Survey reported that anglers in the Sacramento River caught 2,897 fall/spring salmon upstream of Knights Landing from July 16 through December 16, 2017, (J. Lyons CDFW pers. comm.). This included 880 caught below the RBDD (includes zero during the traditional late-fall period after October 31) and 2,017 upstream of the RBDD including 64 fall-run caught after November 01 (Table 1). Note that the 738 late-fall-run fish caught in the 2017 sport-fishing season (through December 16) are tallied and reported as 2018 angler caught late-fall-run fish. In 2017, the in-river angling season was from July 16 to December 16, 2017. These dates, along with the customary two fish daily limit, represent a fully open (normal) fishing season bracketed by seasonal closures for concern of angling take of winter-run from late-December to mid-July.

Steelhead. No steelhead monitoring surveys take place in the mainstem Sacramento River in the USRB. Boat crews measure, check for PIT tags, and tally all trout/steelhead carcasses they encounter, but no population mark and recapture effort is conducted. Crews observed 84 trout/steelhead carcasses on the river from September 06, 2016 to September 06, 2017. The average forklength of these was 17.5 inches (446 mm). The majority of these were thought to be resident-trout carcasses and were observed on the fall-run 2016, late-fall-run 2016-2017, and winter-run-2017 mark recapture surveys.

Clear Creek

Clear Creek is a western tributary of the USRB. Unlike other anadromous tributaries to the USRB Clear Creek has a large dam upstream limiting the anadromous portion to below Whiskeytown Reservoir's dam. Clear Creek enters the Sacramento River at RM-289 (Figure 1). In recent decades, Clear Creek has benefited from extensive restoration and recovery actions. These actions include channel reconstruction, spawning gravel augmentation, and prescribed Whiskeytown Reservoir releases. Fall-run have responded to these improvements. Clear Creek normally contains the third largest fall-run population in the USRB. Clear Creek late-fall and spring-run populations (monitored by the USFWS) have not responded to restoration actions as well as fall-run. Video monitoring, snorkel surveys, carcass surveys, and redd surveys were used to estimate Clear Creek Chinook Salmon and steelhead numbers in 2017.

Late-fall-run. Chinook entering Clear Creek after December 15 are within the period of late-fall-run migration and spawning observed in the Sacramento River and Battle Creek (Killam 2012). During the winter and early-spring months USFWS personnel conduct redd counts and collect biological data on late-fall-run carcasses encountered in Clear Creek using kayak-based surveys. A mark-recapture survey is not possible due to low numbers of carcasses and frequent flooding. The Clear Creek video station is operated by the USFWS from December 16 through August 14 each year. Redd count data from USFWS during late-fall-run spawning periods resulted in an estimate of **55 late-fall-run** salmon based on 20 redds and a 2.75 male expansion. The video station data was not used, but observed a net migration of 28 salmon upstream but much of that time the station was flooded and no expansion was attempted, (R. Cook USFWS pers. comm.). Late-fall-run data from previous years is available on the Red Bluff USFWS internet site at: (www.fws.gov/redbluff/).

Winter-run. No perennial winter-run populations exist in Clear Creek at this time. This may change in future years as conditions in the Sacramento River and favorable flow management strategies in Clear Creek designed to attract and enhance spring-run populations may attract winter-run into Clear Creek. In recent years some winter-run have been observed milling around the video station site located near the confluence of Clear Creek and the Sacramento River. In 2017 four winter-run carcasses were observed in Clear Creek. Two carcasses were on the video weir and two further upstream, where one redd was observed. Based on this redd, Clear Creek was thought to have **two winter-run** in it in 2017. Winter-run observed at the weir are not unusual as the weir is located in the backwater of the Sacramento River during summer months. High summer flows in the river back up into the creek making the very lower end of Clear Creek cool enough to support salmonids and may serve to attract winter-run from the river to Clear Creek during summer months as the fish ready for spawning. USFWS reported a video count of 123 winter-run upstream and 107 downstream indicating frequent use of that area by wandering winter-run, (R. Cook USFWS pers. comm.).

Spring-run. The USFWS conducts snorkel and redd surveys in summer and early fall to determine an annual index of spring-run abundance. A reported **25 spring-run** were present in Clear Creek in 2017. This was based on a redd expansion of 2.75 fish per redd and nine redds. Raw video counts before flood expansions were nine spring-run (J. Cook USFWS pers. comm.). A temporary picket weir was again installed in 2017 to spatially separate spring-run from fall-run in Clear Creek. Details for this effort are available in the reporting by the USFWS at (www.fws.gov/redbluff/).

Fall-run. A final estimate of **2,353** fall-run, with 90% confidence intervals of 1,953-lower and 2,779-upper, was obtained using data collected at the Clear Creek video station in 2017. The Clear Creek video station is located adjacent to the Redding City Wastewater Treatment Plant (RM-0.1) and has been in continuous operation since June of 2012. The USRBFP annually maintains the station from August 15 through December 15 for fall-run and steelhead escapement and life history information.

Biological Sampling. Twelve kayak carcass surveys were made weekly on Clear Creek during the fall in 2017. The survey area encompasses Clear Creek's primary fall-run spawning habitat, located between RM-6.3 and the mouth. The data from the bio-sampling is used to categorize the video count's official number of 2,353. There were 99 carcasses observed. These fish were used to describe the characteristics of the population by recording the fork-length, sex, and the presence or absence of the adipose fin.

In 2017, Clear Creek fall-run spawners were 96% natural origin (2,258), 16% adults (380) using a fork cut-off of 665 mm-female, 745 mm-male, and 45.5% females (including 285 adults and 784 jills). No females were unspawned. Males numbered 95 adults and 1,188 jacks. Note, during expansions and analysis, fish categories typically contain totals that are not whole numbers. As a result, the rounding often results in totals that are different from the overall total by a fish or two. Crews collected one head from these sampled carcasses and dissected them at the RBFO for CWT extraction and reading. One CWT was recovered. The tag code revealed that the stray hatchery origin fish was a fall-run from Nimbus hatchery.

Steelhead. Anadromous forms of Rainbow Trout begin migration into the USRB in July and continue entering through the early summer months of the following year (Appendix Table A1). An estimated 103 steelhead passed the station in fall of 2016 (through December 15). These fish form the early portion of the 2016-2017 Clear Creek steelhead population. The USFWS is responsible for counting the remainder of the 2016-2017 steelhead and reported 204 additional steelhead (R. Cook USFWS pers. comm.) resulting in **307 steelhead** for the entire 2016-17 season in Clear Creek (Table 1). The actual total may differ due to the flooding at the video station making station operation impossible for long periods this year. The 307 total should be noted as a minimum value. Note that because of the close proximity (0.1 miles) to the Sacramento River's large population of resident-trout, steelhead data obtained at the station is based on fish lengths (Rainbow Trout >16 inches are tallied as steelhead for USRBFP reporting purposes) and should be interpreted with caution.

Cow Creek

Cow Creek is a large eastern tributary that is known as a mid-size producer of fall-run. The creek drains the foothill slopes northwest of Mount Lassen but does not have the cool summer water temperatures necessary to support spring-run in its areas of anadromy. The creek has five forks, most are moderately populated, and significant water diversions impact surface flow before it reaches the mouth (at RM-280) in late spring to late fall during the warm weather period. In its lower reaches the creek can flood quickly creating large scouring flows that likely limit fall-run egg survival and late-fall-run spawning.

Late-fall-run. Floods in December of 2016 destroyed the video station on Cow Creek (details in Killam et.al, 2017) and prevented monitoring of any late-fall 2017 spawners. Continued flooding in early 2017 prevented repairs to the station due to high flows and the severe damage to the stations equipment.

Late-fall-run spawn from December through April in the nearby Sacramento River. The low flow and high temperatures in Cow Creek (Figure 1) during the summer months may inhibit survival of any juvenile late-fall-run produced by spawners in the creek. Late-fall-run populations are currently known to persist in waterways with flows and lower water temperatures suitable for juvenile salmon survival in the summer months (Battle, Clear, and Sacramento River). Large schools of juvenile late-fall-run commonly rear over the summer in the uppermost section of the cool Sacramento River indicating the need for a cool water refuge for survival of the late-fall-run populations. Additionally the bigger tributaries of the Sacramento River (Clear, Cow, Bear, Cottonwood, Battle, Antelope, Mill, Deer, Butte) can typically have large redd scouring floods that likely limit the successful and consistent success of late-fall-run spawners in these creeks.

Spring and winter-run. No persistent populations of either species are known to exist in Cow Creek, although individuals of either run may stray into the creek. Warm water and the normal low summer flows (agricultural diversions and lack of rain) in Cow Creek would likely prove lethal to any of the over-summering fish of either run.

Fall-run. In the summer of 2017, the Cow Creek video station was moved upstream to a new location to prevent sediment problems occurring from severe bank erosion at a site upstream of the former station. The new video monitoring station located in lower Cow Creek (RM-4.4) was used to estimate the passage of **288 fall-run** in 2017. The Cow Creek video station recorded fish passage continuously using a single overhead and three underwater cameras from September 19 to December 15, 2017. Confidence intervals around this estimate were made at the 90% level and were 237 and 566 respectively.

Four kayak bio-sampling surveys on Cow Creek observed only one carcass. Due to this low sample size, video data of live fish and the bio-sampling at Clear Creek were used as surrogates for the Cow Creek population characteristics. Accordingly, in 2017, Cow Creek fall-run spawners were grilse with 84% (242), while adults were only 16% (47) of the population. Females were 45.5% (35 adults, 96 jills) and males were 54.5% (12 adults, and 146 jacks) based on ratios from Clear Creek surrogates. The single carcass observed was not fin clipped so no CWT information was obtained. Video recordings of the adipose fin area on live fish determined that 74% of the fall-run in Cow Creek were hatchery origin after an expansion for non-clipped hatchery fish was applied.

Steelhead. No steelhead were noted in Cow Creek (Table 1) during the period from September 19 to December 10, 2016 when the station was flooded for the remainder of the monitoring season (June 2017).

Bear Creek

Bear Creek is a smaller east side tributary draining the western slopes of Mount Lassen and enters the Sacramento River at RM-277.6. It located between Cow and Battle Creek but does not have the capacity or volume of water to support huge runs of salmonids. It is known to support large populations of trout/steelhead but salmon numbers have never reached significant sizes since monitoring at the video station began in 2008-2010 and again in 2016-2017.

Late-fall-run. From Dec 16, 2016 to February 19, 2017, the Bear Creek station reported **five late-fall-run** passing upstream. Confidence intervals around this estimate were made at the 90% level and were -1 and 25 respectively. Video observations of passing fish indicated that all five were adults and all were non-adipose fin clipped fish, likely indicating natural origin fish. Flooding affected monitoring in Bear Creek but was not as severe as in larger neighboring waterways. The DIDSON camera was used a total of 210 hours (equivalent of a total 8.75 days) during this 66 day period. Flooding and associated equipment failures also prevented monitoring during 346.5 hours (14.4 days). Data for these missing periods was determined by using the R software MGCV package that utilizes a GAM process to calculate missing periods at the video stations. This process is thoroughly explained in Appendix D of Killam et.al, 2017.

Spring-run. A negative three count of salmon tallied as spring-run was made in Bear Creek between February 19, and June 19, 2017. Turbid water from flooding resulted in use of the DIDSON camera for 205 hours (8.5 days). An additional 122 hours (5.1 days) of time occurred where passage was not monitored and was estimated. It is likely that Bear Creek (see Figure 1) will support consistently only fall-run and steelhead spawners, with other runs testing the watershed for suitability by straying into it. Spring-run, winter-run and late-fall-run (multiple life stages) typically require the cooler summer water temperatures that are not available in Bear Creek for successful reproduction and rearing.

Fall-run. The Bear Creek video station recorded fall-run and other passage from September 21 through December 15, 2017. The station counts resulted in only **two fall-run** in 2017. Confidence intervals were negative three and nine around this estimate. Both fish were non-adipose fin clipped grilse salmon. Two bio-sampling surveys downstream of the video station did not count any carcasses, redds, or live fish. No DIDSON use occurred in this period and passage was estimated for 57 hours when passage could not be monitored.

Steelhead. During the period from September 30, 2016 through June 19, 2017, there were nine Rainbow Trout greater than 16 inches, and therefore counted as steelhead moving into Bear Creek (Table 1). Steelhead counts in the fall of 2017 will be part of the 2018 reporting.

Cottonwood Creek

Cottonwood is the largest western tributary in the USRB. It drains a vast watershed with three main forks and numerous smaller tributaries and enters the Sacramento River at RM-273.5. Currently it supports all salmonids but winter-run. Water temperatures in its mountainous upper anadromy areas are at the near-lethal limit for adult spring-run during summer months and recent hot summers have reduced the numbers of spring-run numbers once observed. Since Shasta dam closed the Sacramento River to anadromous salmonids in the 1940’s, Cottonwood Creek is now the furthest a salmonid can get from the ocean in California.

Late-fall-run. In December of 2016, large floods resulted in sedimentation and severe damage to the Cottonwood video station. Continued storms and high residual flows prevented repair of the station until late in the spring of 2017. Therefore, no late-fall-run estimate for 2016-2017 Cottonwood spawners is available.

The juvenile late-fall-run salmon that may be produced from the adult spawners likely find lower Cottonwood Creek conditions inhospitable for survival similar to Cow Creek and must migrate downstream soon after emergence in the spring to the cooler Sacramento River. The lower sections of Cottonwood Creek (Figure 1) and other similar USRB streams can heat up quickly in the spring months, attracting predatory, warm water tolerant, species including: Sacramento Pikeminnow, Hardhead, Largemouth Bass and Smallmouth Bass (*Micropterus salmoides*, *M. dolomieu*) and recently Striped Bass (*Morone saxatilis*). (Note: since the RBDD gates were removed in 2011, upstream observations of Striped Bass in the river and tributaries are now common). These species may contribute to the lack of an adult late-fall-run population in Cottonwood Creek by predating on the out-migrating juveniles that would return to the creek in future years.

Winter-run. No winter-run populations are known to exist in Cottonwood Creek due to high water temperatures unsuitable for adult salmon spawning in the summer months.

Spring-run. Similar to the late-fall-run monitoring, spring-run migration monitoring at the video station in Cottonwood Creek was not possible since the station was damaged during the majority of the 2017 spring monitoring period. Stream bed load (sand and gravel) migrated during high flows and partially buried the resistance board weir, making repairs possible only after flows receded.

No spring-run were observed during a snorkel survey in Beegum Creek a tributary to the Middle Fork of Cottonwood Creek in 2017. In the summer of 2008, a large wildfire burned much of the Beegum watershed resulting in severe loss of soil stabilizing vegetation. In June of 2009, an intense and prolonged rain from a large thunderstorm system produced massive mudflows in the watershed. This mud filled the entire reach of Beegum Creek that salmon are known to over-summer in and probably killed any adult salmon and trout that were present in 2009. In 2017, the creek was continuing to flush out much of the smaller sediments from this event. Of note were an unusually large number of Rainbow Trout both medium and large size in Beegum Creek this year.

No spring-run were observed in the North Fork of Cottonwood Creek. This location is at the upper limit to anadromy at a large waterfall downstream of Rainbow Lake. Temperature monitoring below the falls indicates that creek temperatures can reach near lethal limits so large self-sustaining populations of spring-run in this creek are probably limited annually by extreme heat spells during summer months.

<u>Fall-run.</u> The Cottonwood Creek video station fall-run count was **124** in 2017. The station is located close to the mouth of the creek at RM-1.2. Confidence limits around this estimate were made at the 90% level and were 97-lower and 156-upper. The station recorded fish passage continuously from September 20 to December 15, 2017. Six bio-sampling kayak surveys observed no carcasses, four redds, and one live fall-run fish. Due to low carcass numbers, the population characteristics of the Cottonwood Creek fall-run was made using video observations of the adipose fin for live fish and surrogating Clear Creek bio-sampling data to account for age and sex composition. Accordingly, grilse made up the majority of fish with 84% (104), while adults were 16% (20) of the population. Females were 45.5% (15 adults, 41 jills) and males were 54.5% (5 adults, and 62 jacks) based on Clear Creek surrogates. Based on video recordings of clipped fish at the station 90% were of natural origin (111) after expanding for the non-clipped hatchery fish using an expansion factor of four. Turbid water and equipment failure resulted in 172 hours of missing footage during this period. Staffing shortages prevented DIDSON deployment during the brief turbid sporadic periods and repairs on equipment occurred as soon as possible after problems were observed.

<u>Steelhead</u>. During the fall of 2016, the video station obtained a partial count of **42 steelhead** before flooding resulted in the total shutdown of the station. Since there were no further recordings during the 2016-2017 steelhead season (through June), this number should be considered a partial count. In the fall of 2017 three additional steelhead were observed and will be part of the 2018 reporting.

Battle Creek

Battle Creek is a large east side tributary that drains from the southwestern slopes of Mount Lassen and enters the Sacramento River just below Cottonwood Creek at RM-271.5. The creek is recognized as a major contributor to salmon and steelhead numbers in the Central Valley, thanks to the CNFH that is located about 6 miles from the mouth of the Sacramento River. The creek has two forks both capable of supporting viable populations of all salmonid runs present in the USRB. The North Fork is identified as having water temperatures capable of supporting winter-run spawning in the summer months due to its numerous spring fed inputs. The creek is currently the focus of a large salmonid restoration project involving the future reintroduction of winter-run into the upper anadromous regions of the creek.

Late-fall-run. No in-river surveys were planned or made for late-fall-run in lower Battle Creek in 2016-2017. Weather conditions during late-fall-run spawning make consistent surveying on an annual basis difficult to conduct in Battle Creek and other USRB tributaries. With the CNFH ladder and trapping facility a short distance upstream, the USRBFP acknowledges that late-fall-run monitoring in Battle Creek is more efficiently conducted at the CNFH that actively cultures and produces late-fall-run.

The CNFH staff observed, excessed and spawned late-fall-run from November 01, 2016 through March 08, 2017 (note: spawning operations commenced December 28). Additionally, the USFWS Tributary Monitoring Program also handled late-fall after CNFH staff completed operations. Combined both sources resulted in a count of **1,686 late-fall fish** spawned, trapped, released upstream, and excessed. This does not include the 13 removed at Keswick Trap and transferred (accounted as Sacramento River fish) to the CNFH. Forty-eight (of the 1,686) natural origin (adipose fin present) were allowed to pass upstream of the barrier weir at the CNFH (see Table 1). The CNFH allows natural origin salmon to pass upstream, as these fish may be natural origin late-fall-run, spring-run, or winter-run salmon.

Final accounting of Battle Creek late-fall-run can be time consuming and revisions are common, as there are numerous sources of data to compile from different programs with individual timelines and program reporting efforts. It is difficult for CNFH staff to identify fall-run and late-fall-run fish that are present in late-November and December. The CNFH late-fall-run are 100% marked with an adipose fin clip and CWT that enables identification and accurate accounting but processing the CWT information from the two large runs at the CNFH requires a large amount of staff time. The best source (other than the USFWS Red Bluff office) of late-fall-run final accounting is the GrandTab file after a year or more has passed giving different programs an opportunity to conduct quality control on databases and assign run identifications to each salmon observed.

Winter-run. No winter-run were observed in Battle Creek in 2017. The GrandTab file documents the winter-run numbers in previous years. The Battle Creek Restoration Program is a large-scale restoration project ongoing in the upper watershed to provide increased habitat for winter-run and other fish species. One goal of this project is to establish a second population of naturally spawning winter-run in Battle Creek (the only existing population being in the Sacramento River). Details of this restoration effort are available on the Bureau of Reclamation's website: http://www.usbr.gov/mp/battlecreek/

Spring-run. The USFWS monitors spring-run passage in Battle Creek using the CNFH fish ladder and pre and post-spawn snorkel, carcass, and redd surveys. If water temperatures were below 60ºF (16ºC) spring-run would be trapped in the hatchery for adipose fin clip observations and for genetic sample collection. Trapped spring-run with an adipose fin clip representing hatchery origin were taken into the hatchery. Salmon with no fin clip were allowed to pass upstream. When water temperatures were at or above 60ºF, a video monitoring system installed in the ladder recorded salmon as they passed the camera. In 2017 a reported **30 spring-run** were observed passing upstream of the CNFH into upper Battle Creek (R.J. Bottaro USFWS pers. comm.). Further information on this monitoring can be found online at www.fws.gov/redbluff/.

Fall-run. The Battle Creek video monitoring station counted incoming salmon and steelhead including both those heading into the hatchery and those spawning in the creek below the hatchery. The station was operated from August 23 through December 07, 2017. The station is located downstream of the known spawning grounds at RM-1.7. The station reported a salmon passage of 8,532. Of these, 1,783 were determined to be early arriving late-fall-run fish. The remaining fall-run numbered 6,749 and the CNFH took in **6,395**, leaving **354 in-river** spawners in Battle Creek (Table 1).

Confidence intervals around the 354 in-river spawners are (-182) and 964. The large number of grilse in the USRB and lack of adults in general was very apparent in Battle Creek this year. Population characteristics are made from live fish taken into CNFH. Grilse represented 93.5% of the population and the majority of these were jacks as evident by the 82.5% overall male numbers. All salmon entering into Battle Creek were determined to be hatchery origin fish based on the proportions observed at the CNFH. Note that if revisions to the CNFH number are made it will subsequently reduce or augment the in-stream number, as they are interdependent.

Steelhead. The CNFH raises, spawns, collects and samples the majority of steelhead that enter into Battle Creek. Readers can obtain information on these fish by contacting the USFWS at (www.fws.gov/redbluff/). The video station only collects a partial count of these fish during the fall. Data from USFWS reported a steelhead count in 2016-2017 of 1,422 into the CNFH, and an additional 489 (Table 1) that passed upstream of the CNFH after spawning operations were done for the season, (152-hatchery origin and 337 natural origin).

Paynes Creek

Paynes Creek is a small tributary that flows into the Sacramento River (at RM-253) from the east above Red Bluff (Figure 1). The Paynes Creek watershed is not of sufficient size to enable cold water holding habitat during the summer months. The lower watershed has agricultural diversions that remove most of the in-stream water during summer months. Paynes Creek is primarily a fall-run and possibly a steelhead stream. Success of either species is dependent on rainfall on a year-to–year basis.

Late-fall-run. It is possible that some late-fall-run may spawn in Paynes Creek but summer temperatures make juvenile survival unlikely unless the small salmon are able to migrate downstream to the Sacramento River immediately after emerging from the gravel. No surveys are conducted.

Spring and winter-run. High water temperatures and low flow in Paynes Creek in summer months make the survival of any pioneers from these runs unlikely. No surveys are conducted.

Fall-run. Three walking surveys from the power line crossing in the Bend Recreational Area to the mouth were made in 2017. No redds, carcasses or live fish were noted. The estimate for Paynes Creek in 2017 **is zero**.

Steelhead. No video station is used on Paynes Creek. No steelhead information is available as a result.

Antelope Creek

Antelope Creek is a medium sized east-side tributary entering the Sacramento River downstream of Red Bluff (Figure 1) and contains small numbers of all salmonids but winter-run. Antelope Creek after reaching the valley floor uniquely branches into four smaller distributary channels each flowing into the Sacramento River. These are, from north to south, New Creek, Craig Creek, Butler Slough, and Antelope Creek. The largest of these, Craig Creek, enters the Sacramento at RM-239. During low flow periods, it is the dominant migration corridor for adult and juvenile salmonids. Adult Chinook Salmon and steelhead were monitored using a video station at Edwards Dam (RM-4.1).

Late-fall-run. Late-fall-run counting on Antelope Creek occurred from December 16, 2016 through February 19, 2017. No late-fall-run were observed at the station. The station experienced frequent flooding during this period and no suitable location exists for a DIDSON camera at the dam. The video station was non-operational due to flood related issues for sporadic intervals totaling about 23 days indicating the difficult monitoring conditions experienced at this and other creeks throughout the USRB in late 2016 and early 2017.

<u>Spring-run.</u> The Antelope station was operated to count spring-run and steelhead from February 20 through July 14, 2017 there were **eight spring-run** observed. These passed the station from March 14 through May 05. A snorkel survey to discover the upstream locations of these fish observed only four. These were located from the north and south fork confluence down to the Paynes Bridge. Two of the four were adipose fin clipped possibly indicating Feather River spring-run hatchery stock.

<u>Winter-run.</u> No winter-run are known to exist in Antelope Creek due to warm summer water temperatures inhibiting egg survival.

<u>Fall-run.</u> The station was operated from September 30 to December 15, 2017 with a VAKI mounted in the fish ladder. The VAKI at the station reported three fall-run passing upstream. An additional two salmon were estimated to have spawned downstream of the video station based on a single redd counted. The total count of **five fall-run** had confidence intervals of two and eight. Three downstream surveys were conducted but no live fish or carcasses observed. Vaki video footage showed all three salmon to be adults with no fin clips.

<u>Steelhead</u>. Steelhead counts in Antelope creek from October 13, 2016 to July 14, 2017 **were 23**. It is likely that more steelhead passed the station during the late-fall-run monitoring period when the station was frequently flooded. The station remained operational until mid-July but no steelhead were noted after June 17. Steelhead counts beginning in September of 2017 will be provided in the 2018 annual report.

<u>Mill Creek</u>

Mill Creek is a medium size east-side tributary entering the Sacramento River at RM-230 near Los Molinos (Figure 1). Mill Creek is a critical stronghold for wild Central Valley spring-run and steelhead populations. The Mill Creek video station is located at the Ward Dam fish ladder (RM-2.7). The creek drains the southern slopes of Mount Lassen and has no major forks. It has no major waterfalls or impassable dams and salmonids can volitionally reach high elevations (5,000 +) feet to access cooler waters.

<u>Late-fall-run.</u> **Two** late-fall-run passed the Mill Creek video station during monitoring from December 16, 2016 through February 19, 2017 although major floods prevented station operation for much of this period. Despite the use of a DIDSON camera in the fish ladder, the creek during rain events can get so large that fish can avoid the fish ladder at Ward Dam and simply swim over the dam

face. Monitoring during high flows even with advanced DIDSON technology can be very challenging.

Winter-run. Winter-run are not present in Mill Creek due to warmer water in summer months inhibiting egg survival.

Spring-run. The severe flooding in early 2017 and large number of smaller salmon (grilse) resulted in an underestimate of the video station estimate for spring-run. The Mill Creek video estimate was 99 spring-run and includes both fish swimming up the ladder and those observed using the face of the dam. During higher flows and turbid water events, those fish swimming up the dam face are likely under estimated. The video estimate is lower than the Mill Creek autumn redd survey estimate of **258 spring-run** based on observations of 129 redds. Because it was larger, the redd survey estimate was used as the official number this year. Grilse salmon are undistinguishable from other smaller fish on the DIDSON camera as they pass by the fish ladder. During spring, periods of hot weather triggers snow melting that results in unusually muddy water in Mill Creek and makes the use of the DIDSON critical to identifying passage events. Many smaller salmon that were of similar size to other species were classified as "unknown". This likely led to the undercounting of salmon at the video station in spring of 2017. The spring-run redd surveys were completed from October 04 to October 18, 2017. Thirty-two miles of spring-run spawning habitat were surveyed. One hundred twenty nine completed redds were counted. Crews observed three spring-run carcasses. All were natural origin (no adipose fin-clip).

Fall-run. An estimated **342 fall-run** (90% confidence interval of 301 to 415 fish respectively) returned to Mill Creek in 2017. This estimate is from the video passage estimate (314) and redd counts below Ward Dam. Fourteen completed redds were counted below Ward Dam. It was assumed that each redd equals one female and one male or 28 fish. Only three carcasses were observed during six fall-run bio-sampling kayak surveys conducted between the mouth and Upper Dam (RM-5.2) to collect CWT and other information. None of the carcasses was adipose fin clipped. Due to low sample size, the video data (for hatchery origin) and the Clear Creek bio-sampling data was used for a surrogate to estimate the Mill Creek population. Hatchery origin fish represented 83.8% (257) of the 342 fall-run based on video footage of passing salmon missing adipose fins and expanding this number by the four used, on average, by the CFM program for fall-run in the Central Valley. Adult females-41, jills-114, adult males-14 and jacks-173 were estimated using the Clear Creek proportions.

Steelhead. There were **68 steelhead** estimated passing the Mill Creek video station from October 13, 2016 through the end of operation in August 18, 2017. The last steelhead was observed on March 25. Steelhead counts in the fall of 2017 will be reported in the 2018 report.

Deer Creek

Deer Creek is a large east-side USRB tributary entering the Sacramento River at RM-220 near Vina (Figure 1). This tributary (in tandem with Mill Creek) is an important stronghold for populations of wild Central Valley spring-run and steelhead. Adult Chinook Salmon and steelhead are monitored using two video stations located on the north and south fish ladders at Stanford Vina Ranch Irrigation Company (SVRIC) Dam (RM-5).

Late-fall-run. **Seven late-fall-run** were observed at the two Deer Creek video stations during the limited times the station was operational from December 16, 2016 to February 19, 2017. During this period, the north station was not able to monitor 27.5 days or 42% of the late-fall period. The south station was out of action for 40 days or 60% of the period. Both video stations in the fish ladders are highly susceptible to flood damage and are normally temporarily removed before large rain events to prevent loss of cameras and other monitoring infrastructure. Late-fall-run may spawn in Deer Creek below SVRIC Dam. Late-fall-run bio-sampling surveys were not conducted in this stream section due to high flows.

Spring-run. An estimated **219 spring-run** returned to Deer Creek in 2017. The Deer Creek spring-run population estimate was based on a snorkel survey conducted on July 17 and August 15, 2017. This snorkel survey was completed to document the distribution of spring-run over-summering in upper Deer Creek. Crews surveyed 22.4 miles of stream beginning at Upper Deer Creek Falls and ending 2.7 miles below Ponderosa Way. Similar to Mill Creek, the Deer Creek video stations located at SVRIC Dam experienced periods of high flows and muddy water. Use of a DIDSON camera at SVRIC Dam is difficult due to both ladders needing coverage and concern over flood debris and riverbed load movement from high flows causing loss of the DIDSON cameras. The north station was unable to monitor 5.2% of the salmonid passage period, while the south station was unable to monitor 7.2% of the salmonid passage time. The video stations reported only 159 spring-run. Observations during the snorkel survey later in the summer reported many grilse in the population. During high flows, grilse were likely tallied as unknown fish by readers leading to an underestimate of the salmon population using video counts.

Winter-run. No winter-run population exists in Deer Creek due to warm summer water temperatures affecting egg survival.

Fall-run. An estimated **106 fall-run** returned to Deer Creek in 2017. Confidence intervals were 81-lower and 133-upper around this estimate. This estimate is based on a combination of video monitoring at SVRIC Dam, and redd counts below SVRIC Dam. A combined 72 fall-run went above the video stations (52 North ladder, 20 South ladder). An estimated 34 fall-run spawned below SVRIC

Dam in 2017 based upon 17 redds noted during six kayak bio-sampling surveys. No carcasses were observed during surveys this year. Due to low sample size, the video data (for hatchery origin) and the Clear Creek bio-sampling data was used for a surrogate to estimate the Deer Creek fall-run population. Hatchery origin fish represented 69% (73) of the 106 fall-run based on video footage of passing salmon missing adipose fins and expanding this number by the four used on average by the CFM program for fall-run in the Central Valley. Adult females-13, jills-35, adult males-4 and jacks-53 were estimated using the Clear Creek proportions.

Steelhead. There were **50 steelhead** estimated passing the Deer Creek video stations from October 12, 2016 through the end of operation on July 31, 2017. The last steelhead was observed on June 20. Steelhead counts in the fall-summer of 2017 will be reported in the 2018 report.

Other Tributaries

There are numerous unmonitored smaller tributaries in the USRB that salmon migrate into to spawn (primarily the fall-run). The USRBFP priority on any given year is to conduct surveys on the larger tributaries as staff time, management priorities, and budgets allow. Many of the other tributaries remain unmonitored because they are not expected to have more salmon going into them then the monitored creeks during pre-season monitoring planning. These tributaries include: Big Chico Creek for fall-run (note Big Chico is not a USRBFP responsibility), Stoney Creek, Thomes Creek, Toomes Creek, Dye Creek, Elder Creek, Coyote Creek, Salt Creek, Red Bank Creek, Reeds Creek, Inks Creek, Ash Creek, Stillwater Creek, Churn Creek, Olney Creek, Sulfur Creek, Jenny Creek, Middle Creek, and Salt Creek near Redding. All of these creeks have the potential to have salmonid spawners in them, typically during autumn months with early rainfall.

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APPENDIX DATA TABLES

Appendix Table A1. Average migration timing for the various salmonid runs passing the Red Bluff Diversion Dam 1970-1988.

	Week	Years--82-86 **Winter-Run**		1970-1988 **Spring-Run**		1970-1988 **Fall-Run**		1970-1986 **Late-Fall**		1970-1988 **Steelhead**	
		%	cum.%	%	cum.%	%	cum.%	%	cum.%	%	cum.%
JAN	1	1.70	3.45					6.50	55.39	0.97	91.84
	2	1.78	5.23					6.32	61.71	0.80	92.64
	3	0.35	5.57					3.07	64.77	0.61	93.25
	4	1.28	6.85					2.91	67.69	0.50	93.75
FEB	5	2.38	9.23					3.58	71.26	0.29	94.05
	6	3.12	12.35					4.08	75.34	0.45	94.50
	7	3.08	15.44					4.19	79.54	0.56	95.06
	8	0.97	16.41					4.38	83.91	0.53	95.59
MAR	9	6.35	22.76					3.29	87.20	0.49	96.09
	10	7.72	30.48					2.14	89.34	0.46	96.54
	11	9.23	39.70	start				1.74	91.08	0.38	96.92
	12	7.79	47.49	0.10	0.10			3.39	94.47	0.30	97.22
	13	4.91	52.40	0.25	0.35			2.08	96.55	0.28	97.50
APR	14	7.64	60.04	0.59	0.93			1.82	98.37	0.35	97.85
	15	8.26	68.29	0.96	1.89			1.39	99.76	0.28	98.12
	16	9.19	77.48	1.38	3.27			0.24	100.00	0.19	98.31
	17	3.47	80.95	1.63	4.90			end		0.17	98.48
MAY	18	2.02	82.98	1.60	6.50					0.16	98.63
	19	1.60	84.58	1.71	8.21					0.17	98.80
	20	2.17	86.75	2.16	10.37					0.23	99.03
	21	3.09	89.84	2.63	13.00	start				0.18	99.20
JUN	22	2.03	91.87	2.86	15.86	0.01	0.01			0.20	99.40
	23	1.63	93.50	2.61	18.47	0.00	0.02			0.13	99.54
	24	1.84	95.34	2.93	21.40	0.01	0.03			0.14	99.68
	25	0.51	95.85	3.50	24.89	0.03	0.06			0.15	99.82
	26	0.76	96.61	3.10	27.99	0.08	0.14			0.18	100.00
JUL	27	1.60	98.20	3.67	31.66	0.10	0.24			0.13	0.13
	28	0.31	98.52	6.02	37.68	0.29	0.53			0.18	0.31
	29	1.04	99.55	4.75	42.44	0.49	1.02			0.18	0.49
	30	0.44	99.99	3.21	45.65	0.70	1.72			0.22	0.72
AUG	31	0.01	100.00	4.12	49.77	0.96	2.68			0.26	0.98
	32	end		6.97	56.74	1.68	4.36			0.39	1.36
	33			6.07	62.81	2.95	7.31			0.68	2.04
	34			6.75	69.55	3.53	10.84			1.12	3.16
	35			5.74	75.29	3.91	14.75			2.36	5.52

Appendix Table A1 continued.

	Week	Years--82-86 **Winter-Run** %	cum.%	1970-1988 **Spring-Run** %	cum.%	1970-1988 **Fall-Run** %	cum.%	1970-1986 **Late-Fall** %	cum.%	1970-1988 **Steelhead** %	cum.%
	36			7.22	82.51	4.54	19.29			3.82	9.34
SEP	37			6.68	89.19	5.59	24.88			5.80	15.14
	38			5.23	94.42	8.58	33.46			7.54	22.67
	39			3.70	98.12	9.24	42.70			8.95	31.63
	40			1.19	99.31	10.49	53.19	start		11.75	43.37
OCT	41			0.69	100.00	10.59	63.78	0.26	0.26	11.27	54.65
	42			end		8.97	72.75	2.06	2.32	9.79	64.44
	43					6.99	79.74	2.33	4.65	6.51	70.95
	44					6.70	86.44	3.27	7.92	5.17	76.12
NOV	45					4.68	91.12	4.24	12.16	4.04	80.17
	46					2.71	93.83	3.42	15.58	2.44	82.61
	47					2.23	96.06	3.65	19.23	2.21	84.82
	48	start				1.68	97.74	5.37	24.60	2.05	86.87
DEC	49	0.17	0.17			0.90	98.64	5.27	29.87	1.44	88.31
	50	0.38	0.55			0.66	99.30	5.27	35.14	1.04	89.35
	51	0.49	1.04			0.51	99.81	6.94	42.08	0.69	90.04
	52	0.71	1.75			0.19	100.00	6.81	48.89	0.83	90.87

Appendix Table A2. Summary of new redd count data collected from aerial flights for year 2017.

2017 Summary of Aerial Redd Survey Data*										
Late-Fall	**% Dist.**	**Winter**	**% Dist.**	**Spring**	**% Dist.**	**Fall**	**% Dist.**	**ALL**	**% Dist.**	**RIVER SECTIONS**
21	54%	0	0%	0	0%	36	29%	57	30%	**Keswick to A.C.I.D. Dam.**
6	15%	23	88%	1	50%	25	20%	55	28%	**A.C.I.D. Dam to Highway 44 Br.**
8	21%	3	12%	1	50%	28	22%	40	21%	**Highway 44 Br. to Airport Rd. Br.**
4	10%	0	0%	0	0%	12	10%	16	8%	**Airport Rd. Br. to Balls Ferry Br.**
0	0%	0	0%	0	0%	5	4%	5	3%	**Balls Ferry Br. to Battle Creek.**
0	0%	0	0%	0	0%	7	6%	7	4%	**Battle Creek to Jellys Ferry Br.**
0	0%	0	0%	0	0%	5	4%	5	3%	**Jellys Ferry Br. to Bend Br.**
0	0%	0	0%	0	0%	5	4%	5	3%	**Bend Br. to RBDD**
0	0%	0	0%	0	0%	1	1%	1	1%	**RBDD to Tehama Br.**
0	0%	0	0%	0	0%	0	0%	0	0%	**Tehama Br. To Woodson Bridge**
0	0%	0	0%	0	0%	0	0%	0	0%	**Woodson Br to Hamilton City Br.**
0	0%	0	0%	0	0%	0	0%	0	0%	**Hamilton City Br. to Ord Ferry Br.**
0	0%	0	0%	0	0%	2	2%	2	1%	**Ord Ferry Br. To Princeton Ferry.**
39		**26**		**2**		**126**		**193**		**TOTALS**

* Summary of: 1 late-fall-run, 8 winter-run, 1 spring-run, and 3 fall-run Chinook Salmon aerial redd counting flights.

Appendix Table A3. Summary of aerial redd count percentages for the Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam-RBDD (% Up) and RBDD downstream to Princeton Ferry (% Down) for years 1969-2017.

Percentages of Chinook redds in Sacramento River from aerial flights (up and down of RBDD)										
YEAR	**Late-Fall**		**Winter-Run**		**Spring-Run**		**Fall-Run**		**ALL COMBINED**	
	% Up	% Down	% Up	% Down	% Up	% Down	% Up	% Down	% Up	% Down
1969	n/a[1]	n/a	n/a	n/a	n/a	n/a	74.4%	25.6%	74.4%	25.6%
1970	n/a	n/a	n/a	n/a	n/a	n/a	85.6%	14.4%	85.6%	14.4%
1971	n/a	n/a	n/a	n/a	n/a	n/a	68.5%	31.5%	68.5%	31.5%
1972	67.2%	32.8%	n/a	n/a	n/a	n/a	63.5%	36.5%	64.8%	35.2%
1973	75.9%	24.1%	n/a	n/a	n/a	n/a	69.9%	30.1%	74.7%	25.3%
1974	n/a	n/a	n/a	n/a	n/a	n/a	60.9%	39.1%	60.9%	39.1%
1975	n/a	n/a	n/a	n/a	n/a	n/a	56.4%	43.6%	56.4%	43.6%
1976	64.7%	35.3%	n/a	n/a	n/a	n/a	72.9%	27.1%	71.9%	28.1%
1977	n/a	n/a	n/a	n/a	n/a	n/a	45.1%	54.9%	45.1%	54.9%
1978	25.6%	74.4%	n/a	n/a	n/a	n/a	46.0%	54.0%	43.2%	56.8%
1979	42.7%	57.3%	n/a	n/a	n/a	n/a	53.9%	46.1%	52.0%	48.0%
1980	n/a	n/a	n/a	n/a	n/a	n/a	48.7%	51.3%	48.7%	51.3%
1981	63.5%	36.5%	87.8%	12.2%	n/a	n/a	63.0%	37.0%	63.5%	36.5%
1982	n/a	n/a	97.0%	3.0%	n/a	n/a	67.1%	32.9%	67.5%	32.5%
1983	71.2%	28.8%	n/a	n/a	81.1%	18.9%	47.6%	52.4%	59.3%	40.7%
1984	78.9%	21.1%	n/a	n/a	93.3%	6.7%	66.6%	33.4%	67.2%	32.8%
1985	81.5%	18.5%	71.8%	28.2%	78.6%	21.4%	55.5%	44.5%	56.3%	43.7%
1986	72.8%	27.2%	n/a	n/a	100.0%	0.0%	64.5%	35.5%	64.9%	35.1%
1987	64.1%	35.9%	95.5%	4.5%	n/a	n/a	71.4%	28.6%	71.0%	29.0%

Appendix Table A3 continued

Percentages of Chinook redds in Sacramento River from aerial flights (up and down of RBDD)										
YEAR	**Late-Fall**		**Winter-Run**		**Spring-Run**		**Fall-Run**		**ALL COMBINED**	
	% Up	% Down	% Up	% Down	% Up	% Down	% Up	% Down	% Up	% Down
1988	98.9%	1.1%	74.5%	25.5%	97.4%	2.6%	77.9%	22.1%	78.3%	21.7%
1989	41.9%	56.4%	97.9%	2.1%	100.0%	0.0%	83.3%	16.7%	82.6%	17.4%
1990	87.4%	12.6%	93.3%	6.7%	100.0%	0.0%	66.8%	33.2%	67.8%	32.2%
1991	81.6%	18.4%	100.0%	0.0%	100.0%	0.0%	66.9%	33.1%	67.8%	32.2%
1992	85.8%	14.2%	96.3%	3.7%	100.0%	0.0%	73.8%	26.2%	75.1%	24.9%
1993	100.0%	0.0%	97.7%	2.3%	100.0%	0.0%	72.5%	27.5%	72.7%	27.3%
1994	77.0%	23.0%	100.0%	0.0%	85.1%	14.9%	77.8%	22.2%	77.8%	22.2%
1995	61.9%	38.1%	99.4%	0.6%	90.9%	9.1%	83.5%	16.5%	83.5%	16.5%
1996	n/a	n/a	100.0%	0.0%	100.0%	0.0%	85.5%	14.5%	85.9%	14.1%
1997	n/a	n/a	100.0%	0.0%	99.0%	1.0%	82.8%	17.2%	83.6%	16.4%
1998	97.2%	2.8%	97.9%	2.1%	100.0%	0.0%	90.6%	9.4%	92.5%	7.5%
1999	n/a	n/a	99.9%	0.1%	100.0%	0.0%	78.8%	21.2%	98.9%	1.1%
2000	98.6%	1.4%	100.0%	0.0%	100.0%	0.0%	90.8%	9.2%	94.6%	5.4%
2001	95.2%	4.8%	99.6%	0.4%	96.6%	3.4%	76.9%	23.1%	86.2%	13.8%
2002	100.0%	0.0%	99.8%	0.2%	100.0%	0.0%	69.3%	30.7%	80.5%	19.5%
2003	97.3%	2.7%	99.7%	0.3%	100.0%	0.0%	74.5%	25.5%	79.8%	20.2%
2004	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	78.1%	21.9%	87.1%	12.9%
2005	90.2%	9.8%	100.0%	0.0%	84.8%	15.2%	78.8%	21.2%	90.9%	9.1%
2006	75.5%	24.5%	99.7%	0.3%	100.0%	0.0%	84.0%	16.0%	86.5%	13.5%
2007	90.4%	9.6%	100.0%	0.0%	100.0%	0.0%	82.6%	17.4%	88.1%	11.9%
2008	92.7%	7.3%	100.0%	0.0%	82.6%	17.4%	93.5%	6.5%	96.4%	3.6%
2009	98.1%	1.9%	100.0%	0.0%	n/a	n/a	91.1%	8.9%	95.1%	4.9%

Appendix Table A3 continued

Percentages of Chinook redds in Sacramento River from aerial flights (up and down of RBDD)										
YEAR	**Late-Fall**		**Winter-Run**		**Spring-Run**		**Fall-Run**		**ALL COMBINED**	
	% Up	% Down	% Up	% Down	% Up	% Down	% Up	% Down	% Up	% Down
2010	89.7%	10.3%	100.0%	0.0%	100.0%	0.0%	84.4%	15.6%	89.7%	10.3%
2011	100.0%	0.0%	100.0%	0.0%	n/a	n/a	88.8%	11.2%	92.9%	7.1%
2012	99.6%	0.4%	100.0%	0.0%	n/a	n/a	78.2%	21.8%	83.8%	16.2%
2013	n/a	n/a	100.0%	0.0%	100.0%	0.0%	80.4%	19.6%	86.3%	13.7%
2014	90.9%	9.1%	100.0%	0.0%	n/a	n/a	85.9%	14.1%	89.3%	10.7%
2015	n/a	n/a	100.0%	0.0%	n/a	n/a	75.9%	24.1%	78.7%	21.3%
2016	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	92.8%	7.2%	96.4%	3.6%
2017	100.0%	0.0%	100.0%	0.0%	100.0%	0.0%	97.6%	2.4%	98.4%	1.6%
AVERAGE	**82%**	**18%**	**97%**	**3%**	**96%**	**4%**	**74%**	**26%**	**77%**	**23%**

1 n/a = not available: no flights conducted or water turbid during period

Appendix Table A4. Summary of the 2017 Late-fall-run Chinook Salmon carcass survey results for the Sacramento River.

2017 Sacramento River Late-Fall-Run Chinook Salmon Survey		
Dec 27, 2016 to Jan 11, 2017		Dates Survey conducted during total of 3 weekly periods
3,082		Final Population Estimate using Cormack Jolly-Seber method and downstream redd expansion
N/A		90% Lower and Upper Confidence Limits (includes Keswick transfers to CNFH)
3,069		Total in-river salmon numbers
13		Total salmon into Keswick Dam Trap (11 natural to CNFH, 2 hatchery-sacrificed)
266	**8.6%**	Hatchery Origin estimated in-river and CNFH numbers.
2,815	**91.4%**	Natural Origin estimated in-river and CNFH
2,944	**95.9%**	Adult in-river salmon
125	**4.1%**	Grilse in-river salmon
1,693	**55.2%**	Adult Females >2 yrs (in-river)
1,250	**40.7%**	Adult Males >2 yrs (in-river)
0	**0.0%**	Female Grilse-2yr old based on fresh fish and 610 mm fork length cut-off (in-river)
125	**4.1%**	Male Grilse-2yr old based on fresh fish and 610 mm fork length cut-off (in-river)
36		Number of salmon carcasses tagged
38		Number of salmon carcasses chopped
3		Number of salmon carcasses recaptured
1		Number of aerial redd surveys conducted during carcass survey time frame
39		Number of new redds observed
0	**0.0%**	Number and % of redds downstream of Balls Ferry Survey to expand mark-recapture results
44.8%		Percent of males from CNFH data: used to develop an estimate of males on the survey
0.0%		Percent of unspawned females observed on Survey
7,510	**78,046**	Minimum and maximum flows (cfs) (KWK) during Survey
47	**52**	Minimum and maximum water temperatures (Fahrenheit) of river during Survey
1	**8**	Minimum and maximum water visibility (feet) during Survey

Appendix Table A5. Summary of the 2017 Winter-run Chinook Salmon carcass survey results for the Sacramento River.

2017 Sacramento River Winter-Run Chinook Salmon Survey		
May 01, 2017 to Sep 06, 2017.		Dates Survey conducted during total of 43 continuous three day periods
975	Final Population Estimate Cormack Jolly-Seber method	
109	90% Lower Confidence Limit	
1,888	90% Upper Confidence Limit	
795	Total in-river salmon numbers	
180	Total salmon taken into Livingston Stone NFH for use as hatchery broodstock	
2	WR salmon observed on other surveys	
824	**84.5%**	Hatchery Origin in-river and into LSNFH (n = 169).
151	**15.5%**	Natural Origin estimated in-river numbers and into LSNFH (n = 11).
490	**50.2%**	Adult in-river and into LSNFH (n = 133)
486	**49.8%**	Grilse in-river and into LSNFH (n = 47)
293	**30.0%**	Adult Females >2 yrs in-river and into LSNFH (n = 57)
197	**20.2%**	Adult Males >2 yrs in-river and into LSNFH (n = 76)
140	**14.3%**	Female Grilse-2yr old in-river, 645 mm fork length cut-off and into LSNFH (n = 3)
346	**35.5%**	Male Grilse-2yr old in-river, 720 mm fork length cut-off and into LSNFH (n = 44)
93	Number of salmon carcasses tagged	
50	Number of salmon carcasses chopped	
20	Number of salmon carcasses recaptured	
8	Number of aerial redd surveys conducted during carcass survey time frame	
26	Number of new redds observed	
0	**0.0%**	Number and % of redds downstream of Balls Ferry Survey to expand results
66.6%	Percent of fish (> 609 mm) males from Keswick Trap data: to estimate "large" males.	
1.7%	Percent of unspawned females observed on Survey	
5,080	**13,113**	Minimum and maximum flows (cfs) (KWK-CDEC) during Survey
49	**57**	Minimum and maximum water temperatures (Fahrenheit) of river during Survey
2	**9**	Minimum and maximum water visibility (feet) during Survey

Appendix Table A6. Summary of the 2017 Fall-run Chinook Salmon carcass survey results for the Sacramento River.

2017 Sacramento River Fall-Run/spring-run Chinook Salmon Survey		
Sep 18, 2017 to Jan 04, 2018		Dates Survey conducted during total of 16 weekly periods
1,863	Final Population Estimate using Cormack Jolly-Seber method and other expansions	
882	90% Lower Confidence Limit	
2,845	90% Upper Confidence Limit	
414	**23.6%**	Hatchery Origin in-river numbers + Keswick transfers (111) with CFM 486 hatchery.
1,338	**76.4%**	Natural Origin estimated in-river numbers
742	**42.4%**	Adult in-river salmon
1,010	**57.6%**	Grilse in-river salmon
492	**28.1%**	Adult Females >2 yrs
250	**14.3%**	Adult Males >2 yrs
305	**17.4%**	Female Grilse-2yr old based on fresh fish and 675 mm fork length cut-off
706	**40.3%**	Male Grilse-2yr old based on fresh fish and 765 mm fork length cut-off
134	Number of salmon carcasses tagged	
170	Number of salmon carcasses chopped	
20	Number of salmon carcasses recaptured	
4	Number of aerial redd surveys c (note 1 Spring run flight in 2017)	
128	Number of new redds observed	
25	**19.5%**	Number and percentage of redds downstream of Balls Ferry expansion
54.5%	Percent of males Clear Ck data: used to estimate of males on the Sacramento River	
1.5%	Percent of unspawned females observed on Survey	
4,204	**9,150**	Minimum and maximum daily average flows (cfs) (KWK) during Survey
49	**56**	Minimum and maximum water temperatures (Fahrenheit) of river during Survey
4	**11**	Minimum and maximum water visibility (feet) during Survey
0	Hatchery Spring-run estimated from carcass survey. Subtracted to determine fall-run	

Appendix Table A7 Summary of the Chinook Salmon population estimates by run in the upper Sacramento River basin, upstream of Princeton (RM-164) for years 1987 to 2017. Angler catch not included. Table is summary of GrandTab file.

GrandTab Chinook Totals for the Upper Sacramento River Basin above Princeton [1,2]					
YEAR [3]	**Late-Fall**	**Winter**	**Spring**	**Fall**	**TOTALS**
1987	16,571	2,165	12,661	132,277	163,674
1988	13,218	2,857	10,810	155,675	182,560
1989	12,872	691	5,785	94,193	113,541
1990	8,078	426	5,540	70,383	84,427
1991	8,263	210	1,624	50,574	60,671
1992	10,131	1,237	817	48,121	60,306
1993	1,267	378	754	68,140	70,539
1994	889	186	2,072	105,745	108,892
1995	489	1,297	2,324	156,424	160,534
1996	1,385	1,337	1,289	163,595	167,606
1997	4,578	880	905	230,960	237,323
1998	42,419	2,992	4,644	109,701	159,756
1999	15,758	3,288	2,690	289,094	310,830
2000	12,883	1,352	1,469	178,481	194,185
2001	21,813	8,224	3,750	211,463	245,250
2002	40,406	7,441	4,445	547,445	599,737
2003	8,882	8,218	4,631	254,128	275,859
2004	14,150	7,869	2,380	144,494	168,893
2005	16,282	15,839	3,727	238,418	274,266
2006	15,089	17,296	4,188	148,732	185,305
2007	18,843	2,541	2,357	47,714	71,455
2008	10,372	2,830	861	48,764	62,827
2009	10,196	4,537	753	19,736	35,222
2010	9,986	1,596	971	49,416	61,969
2011	8,448	827	934	77,250	87,459
2012	5,986	2,671	2,371	157,982	169,010
2013	9,004	6,084	2,620	163,459	181,167
2014	13,050	3,015	2,042	106,038	124,145
2015	9,410	3,440	626	59,671	73,147
2016	5,613	1,546	722	19,484	27,365
2017 [4]	4,828	977	544	11,832	18,181
AVERAGE	**11,469**	**3,984**	**5,240**	**127,732**	**148,426**
1 Data from RBDD counts + aerial redd flights + tributary surveys beneath RBDD + other methods noted					
2 Note: **Angler harvest not** included in this table, see Table 1 or text for angler harvest estimate numbers					
3 Totals reflect available data, many streams not surveyed have populations of salmon					
4 Numbers from 2017 are newer than April 2017 GrandTab numbers. Estimates calculated using carcass survey results, hatchery counts, video counts, and redd surveys. Includes Big Chico Creek, but not Butte Cr.					