DRAFT

ROTARY SCREW TRAP PROTOCOL FOR

ESTIMATING PRODUCTION OF JUVENILE CHINOOK SALMON

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Cover: U.S. Fish and Wildlife Service staff servicing a rotary screw trap deployed below the Red Bluff Diversion Dam in Tehama County, California.

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TABLE OF CONTENTS

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BACKGROUND

Monitoring data can provide the foundation for successful management programs if data are collected in a systematic, consistent, and comprehensive manner. Too often, data are collected with methods that are not standardized, are collected during different time periods, or in a manner that is not designed to maximize the quality and utility of the data. Many monitoring programs also experience problems because their reports do not adopt standardized reporting templates, the quality or limitations of the data that are collected are not characterized, or reports are issued years after data were collected. The latter problem is especially troublesome when the personnel that collected data are no longer associated with the monitoring program and other staff who were not involved in the data collection efforts are left to develop long-overdue reports. The ability to successfully address each of these problems compromises the ability to monitor trends in species or habitats of interest, and limits the ability to develop successful management programs because they lack access to timely, accurate, and complete data.

To avoid the abovementioned problems, the Comprehensive Assessment and Monitoring Program (CAMP) developed this protocol with the objective of estimating the production of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) that emigrate from watersheds in the Central Valley of California. For the purposes of this protocol, the word "production" refers to the total number of juvenile Chinook salmon that swam past a rotary screw trap (RST) during a particular month or year; this value includes the number of juvenile salmon caught by the RST plus the estimated number that swam past the trap without being caught.

The CAMP Implementation Plan (Montgomery Watson et al. 1997) recommends that the production of juvenile Chinook salmon should be monitored with a RST. This protocol therefore is limited to procedures and methods that pertain to the use of those traps. Unlike other RST protocols, the CAMP protocol provides a series of templates that: (1) provide standardized forms, figures, and tables that will make it easier to compare temporal data within and among watersheds, and (2) provide an ability to understand the quality and limitations of the data that are collected.

This version of the CAMP RST protocol is considered to be a draft because the program has not completed a review of the equations that could be used to estimate juvenile fish production. Until the CAMP identifies the equations it believes are best used to estimate juvenile fish production, the program recommends that production estimates and confidence intervals are developed using the equations described by Volkhardt et al. (2007). After the CAMP has finished its review and identifies what it believes are the optimal formulas for estimating juvenile fish production, it will develop a final version of its RST protocol.

DATA COLLECTION PROCEDURES

Gear Type

Rotary screw traps (E.G. Solutions®, Corvallis, OR) are commonly used to monitor the production of juvenile salmonids (Baranski 1989; Orciari et al. 1994; Thedinga et al. 1994). These traps are also being used in some locations to assess the success of restoration activities (Solazzi et al. 2000; IMW SOC 2004; Johnson et al. 2005).

Rotary screw traps consist of a funnel-shaped cone that is screened with 3-millimeter (mm) diameter perforated plate. The trap cone is suspended above the water between two aluminum pontoons. Baffles in the trap cone cause the trap cone to rotate as water flows past the trap. As the trap cone rotates, fish that are moving downstream past the trap are guided into a livebox that is attached to the rear of the trap cone.

Depending on stream size, a 5-foot or 8-foot diameter RST can be used to collect juvenile salmon. If a 8-foot diameter trap can successfully be operated at a trap site (i.e., hydraulic conditions or water depth at a trap site do not impair cone rotation), the CAMP recommends that this size trap be used to collect juvenile salmon because it will sample a greater volume of water than a 5-foot diameter trap. If past sampling activities at a trap site have used more than one trap (e.g., two traps have been fished side-by-side), the same number of traps should continue to be used at the trap site to ensure consistent data collection.

The CAMP does not recommend that electric motors be used to turn a RST during low discharge conditions. At present, there are insufficient data to demonstrate that motorized RSTs are able to accurately quantify the number of juvenile salmon that move past a trap.

Rotary screw traps that are used to collect juvenile salmon should possess a variety of features. They should possess a mechanical counter that measures the number of revolutions the RST makes each day; this device will provide an indication of how well the trap is operating. To reduce fish losses from the livebox, fish refuge devices and debris separators should be installed within the livebox to dissipate water velocities and reduce predation. If fish refuge devices and debris separators cause size-selective mortality with respect to Chinook salmon, these features should be modified to reduce their adverse effects. RSTs should also possess a variety of safety features that protect people that work on, or encounter, the traps. These features are described in the "Safety Measures" section below. If there is a potential that seals on the trap livebox will allow fish to escape from the trap, the seals should be replaced before the trap is deployed at the beginning of the sampling season.

Trap Placement

Because the CAMP is interested in estimating the number of juvenile salmon that emigrate from a stream or river, the CAMP recommends that RSTs be deployed as close as possible to the mouth of a watershed. If a site with suitable hydraulic conditions and reliable access cannot be located near the mouth of a watershed, the trap may be located further upstream, but it should be positioned downstream of the area where Chinook salmon spawn. Once a suitable trap site has been found, the trap distance upstream from the mouth of the watershed should remain fixed each year unless changes in channel configuration or hydraulic conditions warrant adjustments.

To the extent possible, traps should be positioned in locations: (1) where a relatively high percentage of the total stream or river discharge flows through the trap cone; (2) where they can operate effectively over the entire range of discharge conditions (including floods) that may exist during a sampling season; (3) directly downstream of a riffle, as opposed to the downstream end of a pool; and (4) in the thalweg of the river or stream channel, unless high discharge or flood conditions dictate the trap should be moved to a position with lower water velocities. Water velocities at a trap site where an 8-foot diameter RST is operated should not be less than 0.6 meters/second (2.2 feet/second) at the lowest discharge that will be sampled (Mark Wade, E.G. Solutions®, pers. comm.). Under optimal conditions, the water velocities at a trap site with an 8-foot trap should be 1.5 meters/second (4.9 feet/second).

Low stream gradients and water velocities may exist in the lower portions of some streams and rivers. Under these conditions, a low proportion of the total discharge may be sampled by the trap, and the trap may not collect juvenile salmon in an efficient manner. In these locations, channel modifications to divert more flow into the trap cone may be needed to increase trap efficiency. If the watershed where the RST is operated is not prone to “flashy” conditions, sandbag walls, gabion walls, fyke-net guidance panels, or hardware fence panels may be used to divert a greater percentage of the total stream volume into the RST. Permits from state or federal agencies may be required prior to the installation of some of the structures.

Traps should be held in place with 6 millimeter diameter or thicker cable fastened to large, permanent structures on the bank. If possible, overhead cables should be used to secure traps. A safety cable should be attached to the rear of the trap, such that the trap will swing to shore if the other cables fail.

Sampling Period

The sampling periods when RSTs are used to monitor juvenile Chinook salmon will vary depending on the race of Chinook salmon being targeted for capture. As a general guideline, the CAMP recommends that RSTs in the Central Valley of California be operated during the following sampling periods:

- In streams that only possess fall-run Chinook salmon, sampling should occur from December 1 through July 15.

- In streams that possess fall- and spring-run Chinook salmon, sampling should occur from September 1 through July 15.

- In the upper Sacramento River where fall-, late fall-, spring-, and winter-run Chinook salmon occur, sampling should occur year-round.

The actual dates when sampling begins and ends may be modified to account for a variety of environmental factors. For example, stream temperature data and emergence models can be used to strategically select the date when trapping should be initiated; trapping early in a field season may not be feasible until sufficient water is present to cause trap cone rotation; and trapping at the end of a field season may be terminated when water temperatures exceed 18 degrees Celsius (64° F) because relatively few juvenile salmon will be able to survive in waters that exceed this threshold.

Collecting Fish and Assessing Trap Reliability

Quality assurance/quality control procedures should be established for each location where a RST is used to monitor the abundance of juvenile Chinook salmon. These procedures should be designed to ensure that accurate, complete data are collected and recorded. For example, new personnel should be trained to properly collect and record data prior to working in the field, procedures should be developed to ensure data are accurately transferred from raw data sheets to digital files that are used to analyze data, and a document that describes the field names in digital tables, i.e., a data metafile, should be prepared so future users of the data know what the data represent.

Staff that operate RSTs should assess the potential that listed fish species may be captured during trapping activities. If listed fish species could be captured during trapping activities, personnel operating a RST should contact staff in the National Marine Fisheries Service and California Department of Fish and Game to determine if a permit is required. If one or more permits are required, the terms and conditions in each permit must be followed.

Traps should be fished continuously for a minimum of five days each week for the duration of the sampling period. When a relatively large proportion of the season's total Chinook salmon catch could be caught, traps should be fished seven days a week to avoid the need to extrapolate data to estimate the number of fish that would have been caught during periods when the trap was not operated. Traps should be checked at least twice each day they are operated (i.e., in the morning and evening) to remove debris and process captured fish. When water velocities or debris loads are relatively high, traps should be checked: (1) several times per day, e.g., every two hours; (2) monitored continuously; or (3) at randomly selected intervals to reduce the potential for fish mortality. When staff are not scheduled to service traps at least once every 24 hours, the trap cone should be stored in the nonfishing position.

During each trap check, debris and fish inside the livebox should be retrieved using long-handled nets. To ensure their safety, project personnel should not climb or reach into the trap as the contents are removed from the livebox. Fish should be carefully separated from debris and a special effort should be made to look for smaller fish. As fish are found, they should be placed in buckets of fresh water for processing. If captured piscivorous fish species have the potential to harass or eat Chinook salmon during the period when fish are processed, piscivorous fish and salmon should be held in separate buckets.

As fish are processed, several steps should be taken to reduce stress in the fish. During processing, fish should be anaesthetised using MS-222, CO_2, or Tricaine-S. The dosage of the anaesthetics should be adjusted to avoid fish mortality. Anaesthetised fish should be allowed to recover in fresh water with small amounts of PolyAqua prior to release. A battery-operated air bubbler should be used to oxygenate the water in the bucket used to hold juvenile salmon, and the water temperature in the bucket should be continuously monitored with a thermometer. The water in the bucket should be changed as frequently as needed to prevent stress or mortality of fish. For example, the water in a bucket should be changed every 30 minutes to prevent the accumulation of waste products, and it should be changed frequently on days when high air temperatures or intense sunlight could elevate the bucket water temperature above the water temperature in the stream being sampled.

Each of the captured fish should be counted, salmon should be examined for clips or marks that indicate they originated at a fish hatchery, and salmon should be classified according to one of four life stages that include fry, parr, smolts, and yearlings. Field staff may elect to classify salmon according to other life stages (e.g., silvery parr), if desired. Appendices A and B provide photographs and narratives that can be used to distinguish the four life stages. Under ideal circumstances and because the external characteristics that are used to classify salmon are not mutually exclusive, the same personnel should be used to classify salmon to minimize bias on how salmon are classified. If this is not possible, all the staff that potentially could classify salmon should be trained to classify fish in a consistent fashion.

Data should be collected to characterize the length of captured fish to the nearest millimeter. If less than 100 juvenile Chinook salmon are likely to be captured during a day, the fork length of each captured salmon should be measured. If more than 100 juvenile Chinook salmon are likely to be captured during a day, at least 50 randomly selected Chinook salmon should be measured each time the trap is checked. For non-salmon species, the fork lengths of a random subsample of up to 20 individuals of each species should be measured each day. After all the fish are processed, they should be released far enough downstream of the RST that they are not likely to re-enter the trap, e.g., at least 300 meters from the trap.

Biologists should attempt to identify which runs of Chinook salmon are being captured in watersheds that possess two or more runs. At times, this may be difficult because stream-specific or generic daily length tables may not be applicable and different runs of Chinook salmon in a stream may have similar emergence periods and therefore lengths. The following tools, in decreasing order of reliability, should be used to identify the taxonomic identity of Chinook salmon in watersheds that possess two or more runs: genetic markers, stream-specific daily length tables, or generic daily length tables that apply to Chinook salmon from the Central Valley. If a RST in a watershed is located near the mouth of a watershed and multiple salmon runs could be caught simultaneously, it may not be feasible to classify Chinook salmon according to run and it may be more appropriate to simply record data in a generic way, i.e., number of Chinook salmon caught (as compared to the number of fall-run Chinook salmon caught).

In watersheds where hatchery releases occur upstream from a RST, staff that operate RSTs should maintain regular contact with hatchery staff to obtain data on the timing, magnitude, and size of salmon released from the hatchery. Ideally, the staff that operate RSTs should obtain information about the release of hatchery-reared salmon before these animals are released; this information may be critical to successfully determining if the salmon that are caught in a RST are wild or have a hatchery origin. If hatcheries release unmarked salmon and substantial size differences in wild and hatchery-origin salmon occur, staff that operate a RST should attempt to differentiate wild and hatchery-origin salmon by size differences to the extent that is possible. After fish are processed, debris outside the trap cone should be cleared using brushes. Mud and debris should be swept off pontoons, and all equipment should be removed from the trap platform after each trap check.

Live box retention tests should be conducted if chronic, significant losses of salmon are suspected to occur from a rotary screw trap live box. Such losses can occur because of predation or faulty seals on the live box. The tests are not recommended if substantial problems are not expected to exist. Retention rate tests can be conducted by releasing uniquely marked groups of at least 100 fish of each life stage into the live box and counting the number of recoveries in the subsequent trap check. If substantial numbers of salmon are being lost from the livebox due to predation, additional refuges should be created in the box to provide cover. If salmon are being lost due to faulty livebox seals, the seals should be replaced.

A rotary screw trap's ability to generate high quality data, i.e., trap reliability, is affected by the: (1) orientation of the trap to stream flow, (2) instantaneous rotation rate of the trap cone, (3) total number of rotations the trap cone makes each 12- or 24-hour period, (4) velocity of water moving into the trap cone, and (5) amount of debris collected by the trap. It is therefore important to document each of these variables each time the trap is checked. Ideally, the trap's long axis should be parallel to the axis of the stream flow. The instantaneous rotation rate of the trap cone should be measured each time fish are processed at the trap; these measurements should be made before and after the trap cone is cleaned. Instantaneous rotation rate of the trap cone should be quantified by measuring the average amount of time it takes the trap cone to make three revolutions. The total number of rotations the trap cone makes during a 12- or 24-hour period is quantified using a mechanical counter mounted on the RST. The mechanical counter should be reset each time fish are processed. Velocity of water moving into the trap cone should be measured using a mechanical or digital meter. The location where the water velocity is measured should ideally be in the center of the trap cone just below the water surface. If a measurement at this location is not possible, the location where the velocity is measured should be done at a consistent X, Y, and Z coordinate and this location should be noted on a datasheet. The amount of debris collected by the trap should be documented in a qualitative, if not quantitative, way each day. For example, the physical makeup of the debris could be described (e.g., leaves, aquatic vegetation, sticks/woody debris) and the amount could be measured using 10-gallon tubs. This debris data will provide insight into whether or not small fish may have been missed as fish were processed.

Standardized data sheets should be used to document fish captures and trap reliability. Appendices C and D of this document provide examples of data sheets that could be used to document fish captures and trap reliability, respectively. If trapping or handling operations lead to the injury or mortality of fish, this should be recorded on the data sheets and measures should be implemented to avoid and minimize similar injuries or mortalities in the future.

Conducting Trap Efficiency Tests

To estimate the number of juvenile Chinook salmon that outmigrate from each watershed, trap efficiency tests should be conducted to convert raw catch data to estimates of total salmon production. Trap efficiency tests should not be conducted when water temperature or other conditions could result in elevated levels of salmon mortality. For the purposes of this report, the term "test fish" will refer to salmon used to conduct trap efficiency tests.

Wild Chinook salmon should be used to the maximum extent practicable when trap efficiency tests are conducted. In most, if not all cases, these fish will be captured with the same RST being used to develop production estimates. If sufficient numbers of wild salmon can be caught with the RST to conduct a trap efficiency test, they should be caught in the one to four day period prior to the test; a shorter holding period (e.g., one to two days) is preferable. If a RST cannot be used to capture a sufficient number of wild test fish, field staff should attempt to use other gear, e.g., beach seines or fyke nets, to collect the requisite number of test fish. This approach may require logistical planning to obtain the necessary permits. On streams where wild juvenile Chinook salmon are relatively scarce and hatchery salmon are available, hatchery-reared Chinook salmon may be used during efficiency tests. If hatchery salmon are used during efficiency tests, close coordination with hatcheries will be needed to obtain the appropriate numbers and size classes of test fish. To the maximum extent possible, the life stage of hatchery-origin test fish should be the same as the wild salmon that will be caught during an efficiency test.

Efficiency tests should be conducted with the goal of recapturing a sufficient number of fish that the trap efficiency estimate is not altered by more than 5% if an additional salmon is captured during a given test. In many cases, many hundreds or a few thousand test fish may be required during an efficiency test to achieve this goal. The total number of test fish needed during an efficiency test will depend on trap efficiency, and may be heavily dependent on the stream or river discharge during the efficiency test. Previous RST efficiency tests in the watershed should be used to infer how many test fish should be released to produce an efficiency estimate that does not change by more than 5% if an additional fish is captured during a given test.

Trap efficiency tests should be conducted frequently during a sampling period, particularly when changes in fish size or environmental conditions (e.g., stream or river discharge, turbidity, etc) have the potential to significantly affect trap efficiency. To the extent feasible, several trap efficiency tests should be conducted during high flow conditions because these events frequently coincide with large numbers of outmigrating juvenile salmon. If large numbers of test fish can be obtained, several (i.e., 10 or more) efficiency tests should be conducted during a sampling period. Replicate trap efficiency tests should be conducted on different days with similar environmental conditions. Similarities (or the lack thereof) in the replicate tests will provide a quantitative basis for understanding how trapping success is affected by similar environmental conditions.

Trap efficiency test releases should be conducted at dusk and dawn to assess the effect of light conditions on trap efficiency. If substantial numbers of test fish are not available to conduct trials at dusk and dawn, emphasis should be given to conducting trials during evening conditions because this is when larger numbers of juvenile wild salmon tend to move downstream.

The process for marking and holding test fish until they are used involves multiple steps. A variety of techniques are currently available to mark test fish, e.g., fish can be marked with fin clips, tags, photonic guns and dye, or Bismark brown dye. One to four days prior to release, test fish should be marked. Once marked, test fish should be held in pens where they are allowed to recover at least 24 hours prior to release during an efficiency test. Structures that provide a refuge from high water velocities should be provided within the pens, and the pens should be enclosed in a locked cyclone fence enclosure such as a dog kennel to prevent vandalism. Prior to their release, the fork length of at least 100 test fish should be measured so their lengths can be compared to non-test fish caught during the efficiency test.

The site where test fish are released during an efficiency test should generally be 400-800 meters upstream from the trap site. The optimal distance between the trap site and the release site must be great enough that it results in the mixing of fish across the stream channel and within the water column, but short enough that predation effects do not result in the loss of fish before they have an opportunity to arrive at the trap site. Under ideal conditions, test fish should be released in an area with a noticeable current, i.e., in a channel constriction, that has a greater potential to disperse test fish in the water column and across the stream channel.

Prior to release, test fish should be examined to ensure they have a recognizable mark. If they do not, they should not be used during the efficiency test. During the efficiency test, test fish should be selected at random and released in small groups (~10-20 fish) a few minutes apart until all the salmon are released. By releasing test fish in small groups over a period of time, the salmon should be less likely to behave as a single school and facilitate the mixing of marked and unmarked fish as they move downstream. If access to both sides of the river at the release site is possible, test fish should be released on randomly alternating sides of the stream or river channel to aid in uniform mixing of unmarked and marked fish.

Rotary screw traps should be checked at two hour intervals following the release of test fish to monitor the timing and number of recaptures and ensure problems with the trap do not invalidate the efficiency test. Traps should continue to be checked several times per day until four consecutive daily checks do not result in the capture of a test fish.

The effort to mark test fish, conduct efficiency tests, and document the environmental conditions during an efficiency test should be summarized on standardized data sheets. Appendix E provides an example of a datasheet that can be used to summarize these data.

Over the course of a sampling season, the duration of marks and the effects of marking and handling mortality on various life stages should be tested. Small groups of salmon should be marked and held in net pens for seven days after they are marked. A matched group of unmarked salmon should be held as a control group. Loss of marks and the amount of delayed mortality should be recorded for each group of salmon that are sequestered.

Collecting Environmental Data

Several types of environmental data should be collected at a site where a RST is operated.

Stream discharge data should be obtained from the stream gauge closest to, and upstream of, the RST. These data are routinely collected by the U.S. Geological Survey or the California Department of Water Resources.

If feasible, water depth-velocity profiles across the stream or river channel at the trap site should be conducted to document the bathymetry and channel profile at the trapping site and assess the total volume of water moving past the trap. These profiles should be conducted: (1) at the beginning of the trapping season, and (2) after each event that causes a significant change in channel morphology.

Instantaneous water temperature measurements at the trap site should be quantified with a hand-held thermometer at least once, and preferably twice, each day. A recording thermograph should also be installed at the trap site to monitor water temperature on a continuous basis. If a recording thermograph is used to monitor water temperature, its' accuracy should be checked at least once per week using an accurate thermometer.

Turbidity should be measured with a turbidity meter each time the trap is serviced. If dissolved oxygen levels in the stream have the potential to adversely affect salmon, this variable should also be quantified each time the trap is checked.

DATA ANALYSIS AND REPORTING

Documenting Diel Fish Captures

To the maximum extent practicable, capture data should be summarized using a standardized 24-hour diel collection period, e.g., 8:00 AM to 7:59 AM the following day. When multiple trap checks are performed in one 24-hour period, captures from different trap checks should be combined to produce a daily tally of the number of individuals for each species and Chinook salmon run, and separate totals should be presented for each life stage of Chinook salmon. Appendix F provides a template for summarizing the number of salmon caught each day.

For days when traps are not operated, daily catch should be estimated by averaging the actual catch on an equal number of days before and after the days not fished. For example, if a trap did not fish for two days, the daily catch for those days would be estimated by averaging the catch from two days before and two days after the period when the trap did not operate.

Developing Fish Production Estimates

Volkhardt et al. (2007) describes procedures and formulas that can be used to develop estimates of the number of Chinook salmon that are produced (emigrate) from a watershed. The text below summarizes two procedures and a variety of equations described in that document. These procedures use a regression model or average monthly or seasonal trap efficiency to estimate the number of Chinook salmon emigrating from a watershed. Prior to developing salmon production estimates, project staff that collect data with an RST should read and become familiar with the text in Volkhardt et al. (2007).

Using a regression model to estimate fish production: with this method, trap efficiency estimates are based on an independent variable such as mean daily discharge, and a regression model is used to estimate trap efficiency over a range of conditions pertaining to the independent variable. If this approach is used to estimate salmon production, several efficiency tests must be conducted over a range of conditions pertaining to the independent variable, and a significant relationship must exist between trap efficiency and the variable. Data from previous trapping activities in a given watershed should be analyzed to characterize the relationship between trap efficiency, the independent variable (e.g., stream discharge, turbidity, average water velocity), and length of migrating salmon to identify the variable most suitable for extrapolating daily catch data to total production estimates. Draper and Smith (1998) suggest the observed F statistic should exceed the chosen test statistic by a factor of four or more if an efficiency estimate is to be successfully modeled using an independent variable.

If a regression model is used to estimate trap efficiency, migration during day i is calculated using equations 1 and 2.

$$N_i = \frac{\hat{n}_i M_i}{m_i} = n_i \hat{e}_i^{-1} \qquad \text{Equation 1}$$

where

$$\hat{e}_i = \frac{m_i}{M_i} \qquad \text{Equation 2}$$

and where

$\hat{N}_i$	=	Estimated number of downstream migrants during period i
M_i	=	Number of salmon marked and released during period i
n_i	=	Number of salmon captured during period i
m_i	=	Number of marked salmon captured during period i
$\hat{e}_i$	=	Estimated trap efficiency during period i

The variance of this estimate is calculated using equation 3.

$$V(\hat{N}_i) = V(\hat{e}_i)\left(\frac{\hat{n}_i}{\hat{e}_i^{2}}\right)^2 + \frac{Var(\hat{n}_i)}{\hat{e}_i^{2}} \qquad \text{Equation 3}$$

where:

$\hat{e}_i$	=	Trap efficiency predicted for period *i* by the regression equation, *f(Xi)*
MSE	=	Mean square error of the regression
k	=	Number of trap efficiency tests used in the regression
Xi	=	Independent variable during day *i*

If linear regression is used to estimate trap efficiency, the variance is estimated using equation 4.

$$V(\hat{e}_i) = \text{MSE}\left(1 + \frac{1}{n} + \frac{(X_i - \overline{X})^2}{\sum_{i=1}^{k} (X - \overline{X})^2}\right) \qquad \text{Equation 4}$$

The precision of the production estimate should be characterized using 95% confidence intervals. The formula for calculating these confidence intervals is provided in equation 5.

$$\hat{N} \pm 1.96\sqrt{V(\hat{N})} \qquad \text{Equation 5}$$

<u>Using a seasonal or monthly average to estimate fish production</u>: recaptures of marked salmon may be pooled from different efficiency tests during the entire trapping season or a given month to create an average efficiency estimate. This approach should only be used if project staff can demonstrate that similar recapture rates were likely to occur during the different efficiency tests. This may be difficult to demonstrate unless similar environmental conditions (e.g., stream discharges) occur during all the efficiency tests. It is also important to note that test fish captured in an RST during an efficiency test must not be included in the population estimate because they were either counted as wild unmarked fish before they were collected and marked as test fish or they were of hatchery origin and should not be part of the migration estimate pertaining to wild salmon.

If data from different efficiency tests are pooled to develop an average estimate of trap efficiency, equation 6 is used to estimate the number of unmarked salmon during period *i*, and equation 7 is used to calculate its variance.

$$\hat{U}_i = \frac{u_i(M_i + 1)}{m_i + 1} \qquad \text{Equation 6}$$

$$V(\hat{U}_i) = \frac{(M_i + 1)(u_i + m_i + 1)(M_i - m_i)u_i}{(m_i + 1)^2 (m_i + 2)} \qquad \text{Equation 7}$$

where:

U_i	=	Number of unmarked salmon migrating during discreet period *i*
u_i	=	Number of unmarked salmon captured during discreet period *i*
M_i	=	Number of salmon marked and released during period *i*
m_i	=	Number of marked salmon captured during period *i*

Total juvenile production $\hat{U}$ and its associated variance $V(\hat{U}\, i)$ are estimated by equations 8 and 9, respectively.

$$\hat{N} = \sum_{i=1}^{n} \hat{U}_i \qquad \text{Equation 8}$$

$$V(\hat{U}) = \sum_{i=1}^{n} V(\hat{U}) \qquad \text{Equation 9}$$

The precision of the production estimate should be characterized by presenting 95% confidence intervals. The formula for calculating these confidence intervals is provided in equation 10.

$$\hat{U} \pm 1.96 \sqrt{V(\hat{U})} \qquad \text{Equation 10}$$

Report Content

Reports that synthesize and summarize data collected with a RST should contain the following information:

1. An abstract that describes the trapping activities and provides a summary of the data collected.

2. An introduction section describing the precise location of the trap with Universal Transverse Mercator coordinates in a WGS-83 datum, a general description of the trap location and where the trap was installed in the stream (e.g., thalweg, right shore, left shore, etc), the stream habitat type (run, glide etc…), multiple photographs showing the trap and environment around the trap, etc.

3. A methods section that describes, in detail, how data were collected and processed. Staff that prepare reports should not assume readers will have access to other documents that describe trapping activities or formulas used in prior years or other locations.

4. A results section that provides:

    a) one or more figures illustrating when the RST began and ended operations and when the trap operated with a high degree of reliability and when it did not, i.e., figures that reflects a synthesis of the information in Appendix D. See Appendix I for figure examples;

    b) a tabular summary of efficiency test results. See Appendix J for an example;

    c) if a regression model is used to predict juvenile salmon capture, graphs that plot capture data and the independent variable, e.g. stream discharge, and a regression line with an R^2 value; and

    e) a table providing monthly and annual estimates of the total production of different runs of Chinook salmon in the watershed, i.e., Appendices G and H.

5. A discussion section that:

    a) describes how the trapping location in the current year compares to prior years, e.g., did the trap location move upstream or downstream relative to the river mouth, did the trap move laterally in the river channel, etc.;

    b) describes environmental or operational problems that may affect the production estimates, e.g., did low water velocities or stream discharges substantially affect the RST's reliability and therefore fish production estimates during a particular period, did low funding levels preclude the ability to operate the trap during the entire sampling period, were trapping efficiencies lower in the current year relative to past years, did consistently large numbers of non-native piscivorous fish in the trap live box affect the ability to accurately count the number of Chinook salmon caught, did the stream or river morphology change during the sampling period, etc.;

    c) describes how trap efficiency tests from the current year compare with prior years;

    d) describes how interpretations of the data should be constrained, given the operational difficulties, trap efficiencies, or environmental conditions that occurred as data were collected; and

    e) explains how the juvenile production estimates in the current year compare to previous years.

6. A series of appendices that provide:

   a) the number of Chinook salmon captured each day according to the four aforementioned life stages, i.e., Appendix F;

   b) a table that characterizes trap reliability on a daily basis based on instantaneous trap rotation rates, daily trap rotation rate, water velocity at the trap, and debris load, i.e., Appendix D;

   c) a summary for each efficiency test, i.e., Appendix E;

   d) figures that compare the number of captured juvenile Chinook salmon with daily maximum and minimum water temperatures, stream discharge, and turbidity at or near the trap site. See Appendix K for an example;

   e) graphs that plot the relationship between timing of outmigration and (a) salmon size and (b) life stage. See Appendix L for an example; and

   f) photographs that show the landscape at and around the trap site.

SAFETY MEASURES

In many cases, sampling sites will be located in areas that receive heavy recreational use for swimming, angling, and boating (canoes, rafts, inner-tubes, and float tubes). Since water velocities around and under the traps are high, there is a potential drowning hazard if people were to get caught on the sides or under the trap platforms, between the traps and the platforms, or on the cables upstream. If someone were to enter the trap cone, drowning or crushing could result from the force of the screw mechanism. The following measures should be included at each sampling site to minimize risks to sampling personnel and the public:

1) Life jackets will be worn at all times by personnel working on the trap platforms. A minimum of two people will always be present and within visual contact while working on the trap platform.

2) Personnel will wear footgear with non-skid soles while working on the trap platform. Personnel will not cross the trap in front of the mouth while it is fishing, except when necessary to raise or lower the trap cone, or take measurements of environmental data. If a person enters into the trap cone, the cone will be immediately raised to stop it from rotating. A worm gear will be installed on the trap cone winch to prevent it from free-wheeling.

3) Before getting on the trap platform, personnel will check visually for mechanical problems, such as loose or broken cables or debris blocking the trap cone. If needed, debris will be cleared or the trap re-secured before getting on the platform. Personnel will check all welds, cable attachments, and moving parts for excessive wear on a daily basis.

4) For crew safety, a catwalk and hand rails will be installed across the front of the trap. A metal grate/trash rack will also be installed in front of the trap cone to prevent large objects from entering the trap (including swimmers, animals, rafts, inner-tubes, etc.).

5) Personnel will use a net to recover the contents in the livebox. Personnel will not reach into the live box with their hands or wade in the live box; hypodermic needles and rattlesnakes have been found in live boxes.

6) Every effort will be made to keep the public out of the trap area. To warn boaters moving downstream of the potential hazard, at least one large sign will be suspended above the river upstream from the trap site warning boaters of the trap location and potential hazard. For example: "DANGER AHEAD, Instream Obstacle, Stay Left ← (or right →)".

7) Signs will be posted on the shoreline immediately adjacent to a trap warning of the drowning hazard. Signs will be in English and Spanish. If needed and practical, the shoreline adjacent to a trap will be fenced to keep the public from wading or swimming to a trap platform from the shore.

8) Battery-operated orange strobe lights (similar to ones used at road construction sites) will be placed on a trap for increased trap visibility at night.

9) All cables at the water surface will be marked with bright colored buoys along their length to make them visible to anyone floating in the water.

10) Traps will be moored such that they can be quickly retrieved in case of high water. Emergency procedures will be developed for retrieving traps; appropriate crew training and frequent monitoring of conditions when high discharges are imminent will be emphasized. Crew safety will always be the first priority; however, following standard emergency procedures may reduce loss of equipment.

The U.S. Fish and Wildlife Service has developed an inspection checklist identifying several items that should be addressed to ensure that a RST is safely operated. This checklist can be obtained by contacting Douglas Threloff, the CAMP Program Manager, at (916) 414-6726.

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Baranski, C. 1989. Coho smolt production in ten Puget Sound streams. State of Washington Department of Fisheries, Technical Report 99, Olympia.

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

Volkhardt, G.C., S.L. Johnson, B.A. Miller, T.E. Nickelson, and D.E. Seiler. 2007. Rotary Screw Traps and Inclined Plane Screen Traps. Pages 235-266, *In* Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations. Amercian Fisheries Society, Bethesda, Maryland.

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APPENDIX A

Morphological Criteria To Determine Chinook Salmon Life Stage

Life stage	Criteria
fry	• recently emerged with yolk sac absorbed ("button up-fry") • pigmentation undeveloped
parr	• darkly pigmented with distinct parr marks • no silvery coloration • scales firmly set
smolt	• parr marks highly faded or absent • bright silver or nearly white coloration • scales easily shed • black trailing edge of caudal fin • more slender body • typically possess a fork length of less than 100 millimeters
yearling	• Similar in appear to a smolt; in rare cases may have parr marks • typically possess a fork length greater than 110 millimeters prior to the period when smolts are present

APPENDIX B

Figures Illustrating Different Chinook Salmon Life Stages

Figures courtesy of Andrea Fuller, FISHBIO Environmental, LLC
and Clark Watry, Cramer Fish Sciences

fry	**parr**	**smolt**
		
yearling	**parr (above) and fry (below) captured on same day**	
		

APPENDIX C

Data Sheet For Documenting Daily Fish Captures

Completion of columns that record weight data is optional.

DATA SHEET FOR DOCUMENTING DAILY FISH CAPTURES

Watershed: _______________ Trap Location: ___________________ Recorder: _________________________ Crew: ________________________ Pg ___of ___

Time: _______ Date: __________ # hours fished: ____ Debris code: _____ Water temp: ____°C Weather code: _______ Staff gauge: _____
Water velocity: ____m/s Turbidity: ____ NTU Debris code: ______ Total revs: ________ Before RPMs:_____ After RPMs:_______
Comments:____
____

Species code	1			2			3			4			5			6			7			8			9			10			Plus count
	FL	LS	WT	FL	LS	WT	FL	LS	WT	FL	LS	WT	FL	LS	WT	FL	LS	WT	FL	LS	WT	FL	LS	WT	FL	LS	WT	FL	LS	WT	

FL = fork length in mm; LS = Life Stage (SF=sac fry, F=fry, P=parr, SP=silvery parr, S= smolt); WT = weight in grams

Other species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Plus count

Entered by:______________________ **On date:**___________________

APPENDIX D

Data Sheet For Documenting Daily Trap Reliability

If one trap check is done per day, enter pertinent data in the "maximum trap rotation" and "maximum water velocity" columns and leave the "minimum trap rotation" and "minimum water velocity" columns blank. If multiple trap check are done per day, enter the minimum and maximum values in each of the appropriate columns.

An assessment of the overall trap reliability is based on the following categories:

good: minimum trap rotations were ≥ 1.5 RPMs, minimum water velocities were ≥ 1.5 m/sec, no debris problems;

fair: minimum trap rotations were 0.8-1.5 RPMs, minimum water velocities were 0.9-1.5 m/sec, and debris problems existed;

poor: minimum trap rotations were ≤ 0.8 RPMs, minimum water velocities were ≤ 0.9 m/sec, and debris problems existed;

EF: extreme water flows precluded the operation of the trap; and

NF: the trap was not fished due to scheduled down time (e.g., personnel were not scheduled to work on a weekend).

DATA SHEET FOR DOCUMENTING DAILY TRAP RELIABILITY

Watershed:			Trap location:			Year:		
Date	Trap orientation to flow	Minimum trap rotation (RPMs)	Maximum trap rotation (RPMs)	Total daily trap rotations	Minimum water velocity (m/sec)	Maximum water velocity (m/sec)	Debris volume	Overall trap reliability (good/fair/poor)

APPENDIX E

Data Sheet For Summarizing Individual Efficiency Tests

A separate datasheet should be completed for each efficiency test.

DATA SHEET FOR SUMMARIZING INDIVIDUAL EFFICIENCY TESTS

Watershed: ________________ Trap location: _______________ Trap UTM coordinates (WGS-83): _______N _______E

Fish type: wild / hatchery

Marking method: fin clip / tagging / photonic marking gun / bismark brown dye

Distance between trap & release sites: ____m

Turbidity during efficiency test: ____ NTU

Release beginning date: ___/___/___

Release beginning time: ___:___

Release ending date: ___/___/___

Release ending time: ___:___

Recapture beginning date: ___/___/___

Recapture beginning time: ___:___

Recapture ending date: ___/___/___

Recapture ending time: ___:___

Minimum fish size released: ____ mm

Maximum fish size released: ____ mm

Average fish size released: ____ mm

Life stage: parr / smolt

Minimum fish size recaptured: ____ mm

Maximum fish size recaptured: ____ mm

Average fish size recaptured: ____ mm

Total number of fish recaptured: _____

Total number of fish marked: _____

Estimated mark retention rate: ______ %

# of released test fish: ______

Estimated trap efficiency: _____ %

95 % lower confidence interval: _____ %

95% upper confidence interval: _____ %

Minimum stream discharge during efficiency test: _____ CFS

Maximum stream discharge during efficiency test: _____ CFS

Minimum stream velocity during efficiency test: _____ m/s

Maximum stream velocity during efficiency test: _____ m/s

Minimum trap rotations during efficiency test: __RPM

Maximum trap rotations during efficiency test: __RPM

% of river flow sampled during trap efficiency test:___%

APPENDIX F

Data Sheet For Summarizing Daily Catches Of Chinook Salmon

The entries in the cells are for illustrative purposes only, and assume trapping was not done during a two-day weekend.

Shaded cells represent interpolated catch estimates during days when trapping was not done.

DATA SHEET FOR SUMMARIZING DAILY CATCHES OF CHINOOK SALMON

Watershed:	Trap location:									
Calendar date	**Number of unmarked juvenile Chinook salmon caught**					**Number of marked juvenile Chinook salmon caught**				
	Fry	Parr	Smolt	Yearling	Total	Fry	Parr	Smolt	Yearling	Total
01/01/07	34	12	0	0	46	0	0	0	0	0
01/02/07	45	3	0	0	48	0	0	0	0	0
01/03/07	99	5	0	0	104	0	0	0	0	0
01/04/07	22	4	0	0	26	0	0	0	0	0
01/05/07	44	11	0	0	55	0	0	0	0	0
01/06/07	47	10	0	0	57	0	0	0	0	0
01/07/07	47	10	0	0	57	0	0	0	0	0
01/08/07	88	22	0	0	110	0	0	0	0	0
01/09/07	33	2	0	0	35	0	0	0	0	0
01/10/07	11	10	0	0	21	0	0	0	0	0
01/11/07	34	12	0	0	46	0	0	0	0	0
01/12/07	88	4	0	0	82	0	0	0	0	0

APPENDIX G

Data Sheet For Summarizing Monthly Chinook Salmon Production Estimates

The table should be expanded to include data from other months if sampling occurred outside a January 1 to June 30 period.

A separate template should be prepared for each run of Chinook salmon e captured in a watershed.

DATA SHEET FOR SUMMARIZING MONTHLY CHINOOK SALMON PRODUCTION ESTIMATES

Watershed:		Trap location name:		BroodYear:	Salmon run: fall late fall spring winter	
Life stage/ date	Number of days trap operated	Actual catch	Catch per unit effort	Fish production estimate	95% CI For Fish production estimate	
WILD FRY						
Jan. 1 - Jan. 31						
Feb. 1 - Feb. 28						
March 1 - March 30						
April 1 - April 30						
May 1 - May 30						
June 1 - June 30						
total						
WILD PARR						
Jan. 1 - Jan. 31						
Feb. 1 - Feb. 28						
March 1 - March 30						
April 1 - April 30						
May 1 - May 30						
June 1 - June 30						
total						
WILD SMOLTS						
Jan. 1 - Jan. 31						
Feb. 1 - Feb. 28						
March 1 - March 30						
April 1 - April 30						
May 1 - May 30						
June 1 - June 30						
total						
WILD YEARLINGS						
Jan. 1 - Jan. 31						
Feb. 1 - Feb. 28						
March 1 - March 30						
April 1 - April 30						
May 1 - May 30						
June 1 - June 30						
total						
GRAND TOTAL						

APPENDIX H

Data Sheet For Summarizing Annual Chinook Salmon Production Estimates

DATA SHEET FOR SUMMARIZING ANNUAL CHINOOK SALMON PRODUCTION ESTIMATES

Watershed:		Trap location name:		BroodYear:	Dates of operation:	
	Number of days trap operated	Actual catch	Catch per unit effort	Fish production estimate	95% CI For Fish production estimate	
FALL-RUN						
Wild Fry						
Wild Parr						
Wild Smolts						
Wild Yearlings						
Total						
LATE FALL-RUN						
Wild Fry						
Wild Parr						
Wild Smolts						
Wild Yearlings						
Total						
WINTER-RUN						
Wild Fry						
Wild Parr						
Wild Smolts						
Wild Yearlings						
Total						
SPRING-RUN						
Wild Fry						
Wild Parr						
Wild Smolts						
Wild Yearlings						
Total						
ALL SALMON						
Wild Fry						
Wild Parr						
Wild Smolts						
Wild Yearlings						
Total						

APPENDIX I

Example Of Figures That Illustrate When Trapping Operations With A Rotary Screw Trap Began And Ended, And When The Trap Operated Or Did Not Operate Reliably

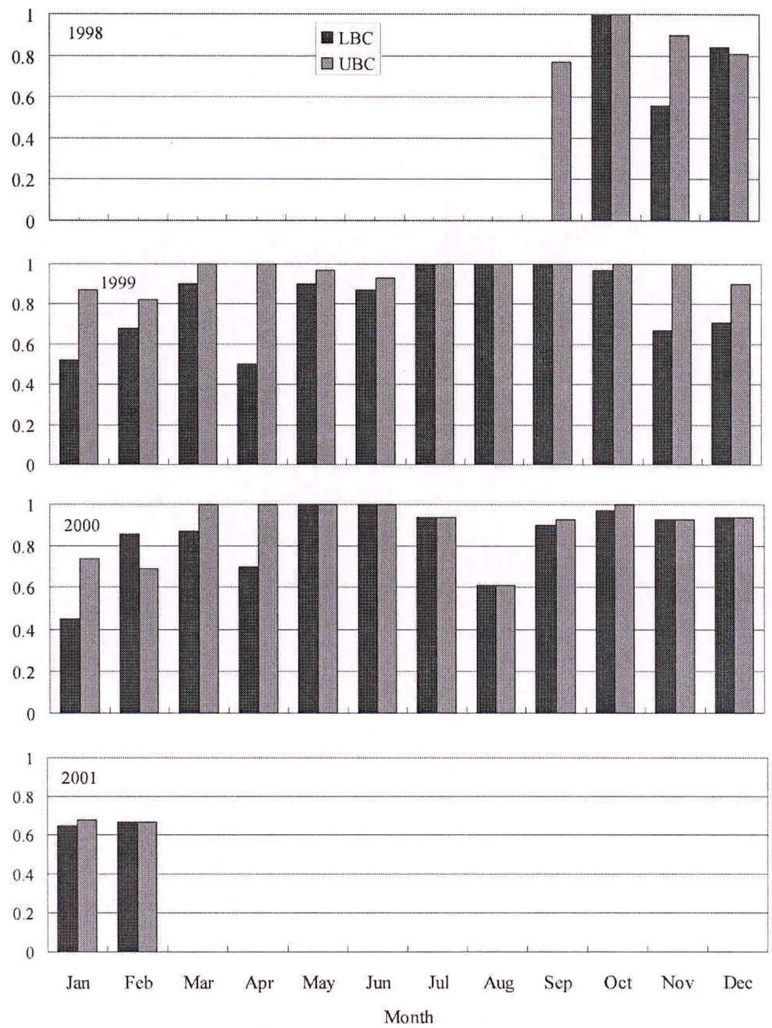

Figure 2. Sampling effort summarized as the proportion (range: 0 to 1) of days fished each month at the Upper and Lower Battle Creek rotary screw traps from September 1, 1998 to February 9, 2001.

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

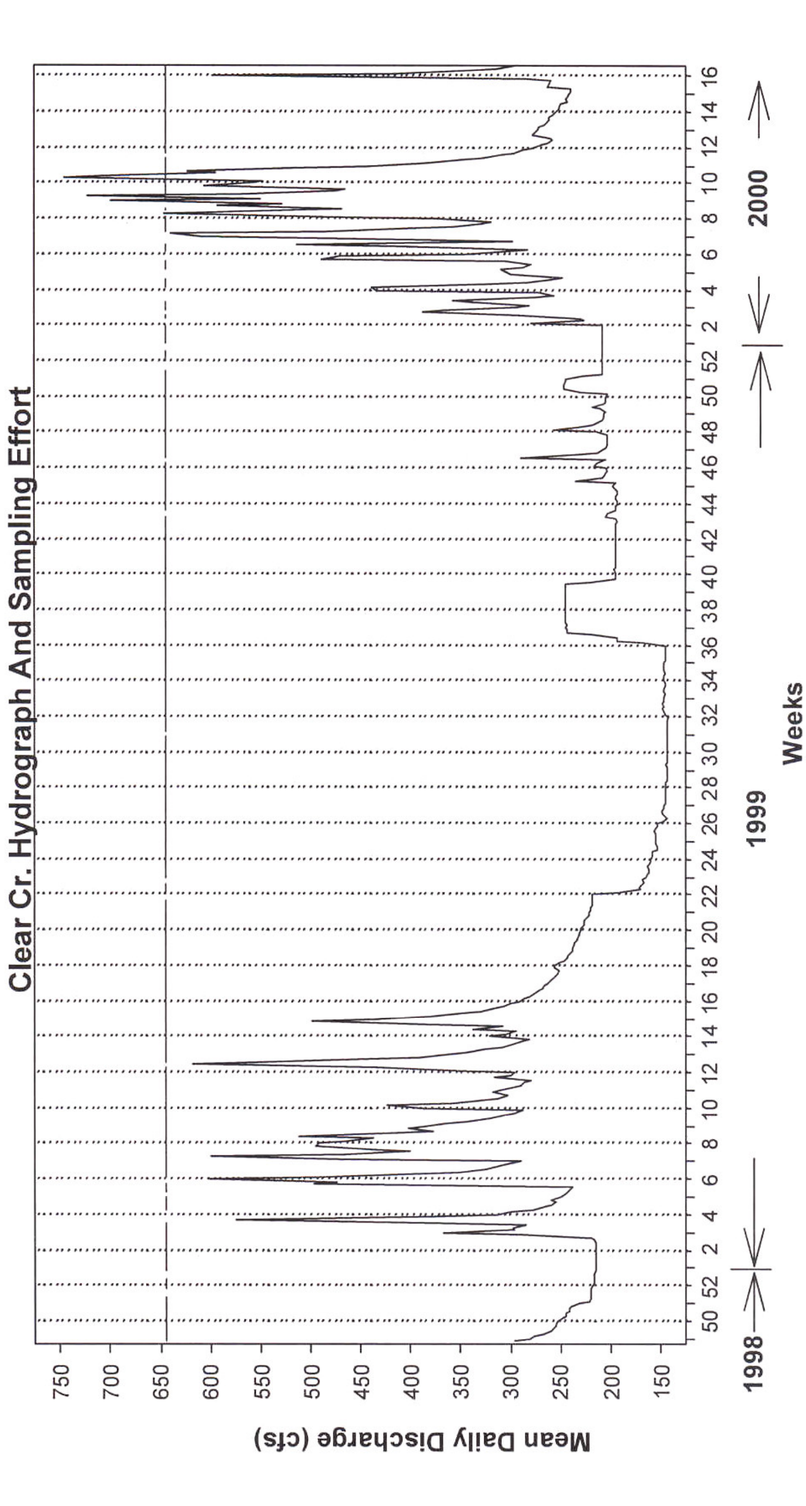

Figure 2. Daily mean discharge (cfs) and rotary-trapping effort on Clear Cr. (SM 1.7) from 5 December 1998 through 21 April 2000. The horizontal dashed line indicates 24-hr. samples. Breaks in the line represent days when rotary trapping was not conducted (usually due to high flow events).

Figure from: Gaines, P.D., R.E. Null and M.R. Brown. 2003. Estimating the abundance of Clear Creek juvenile Chinook salmon and steelhead trout by use of a rotary-screw trap. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office. Progress Report (Vol.1), February 2003.

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APPENDIX J

Example Of A Tabular Summary Of Efficiency Test Results

Summary of efficiency releases of marked, natural juvenile Chinook salmon in the Merced River, 2007. Trap efficiency estimates and corresponding upper (UCI) and lower (LCI) 95% confidence intervals (based on binomial distribution) were calculated for each experimental release, along with the estimated proportion of flow sampled by both traps.

Release Date	**Release time**	**Life stage released**	**Fish stock**	**Mean length released (mm)**	**Adjusted number released**	**Number Recaptured**	**Trap Efficiency**			**Flow at Cressy gage (cfs)**	**Flow Sampled (CFS)**	**Proportion Flow Sampled (CFS)**
							Estimate	**LCI**	**UCI**			
4/24/2007	*08:15*	*fry*	*wild*	*35*	2,025	18	0.89%	0.49%	1.33%	378	33.8	8.9%
5/1/2007	*08:30*	*parr*	*hatchery*	*40*	2,037	9	0.44%	0.20%	0.74%	619	40.1	6.5%
5/7/2007	*07:45*	*parr*	*hatchery*	*43*	2,010	13	0.65%	0.30%	1.00%	988	48.0	4.9%
5/15/2007	*08:00*	*smolt*	*wild*	*75*	2,014	5	0.25%	0.05%	0.50%	679	39.6	5.8%

Table adopted from: Montgomery, J., A. Gray, C.B. Watry, and B. Pyper. 2007. Using Rotary Screw Traps to Determine Juvenile Chinook Salmon Out-migration Abundance, Size and Timing in the lower Merced River, California 2007 Annual Data Report. Unpublished report prepared for the U.S. Fish and Wildlife Service, Sacramento, California. Text in italics is for demonstration purposes only.

APPENDIX K

Example Of A Figure That Compares The Number Of Captured Juvenile Chinook Salmon With Daily Water Temperatures

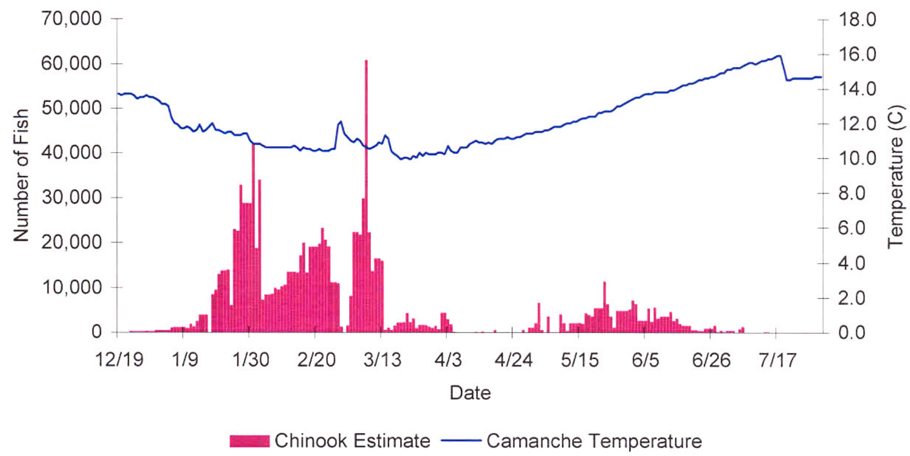

Figure 7. Juvenile Chinook salmon emigration on the lower Mokelumne River and Camanche release temperatures, December 19, 2005 - July 28, 2006.

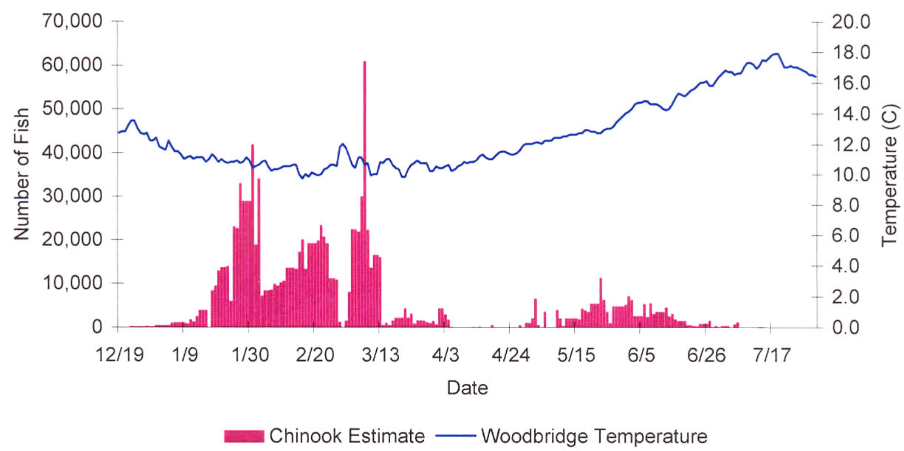

Figure 8. Juvenile Chinook salmon emigration on the lower Mokelumne River and temperature at Woodbridge, December 19, 2005 - July 28, 2006.

Figure from: Workman, M.L. 2006. Downstream Fish Migration Monitoring at Woodbridge Irrigation District Dam Lower Mokelumne River, December 2005 through July 2006. Unpublished report prepared for the East Bay Municipal Utility District, Lodi, California.

APPENDIX L

Example Of A Figure Plotting The Relationship Between Timing Of Fish Outmigration And (A) Fish Size And (B) Life Stage

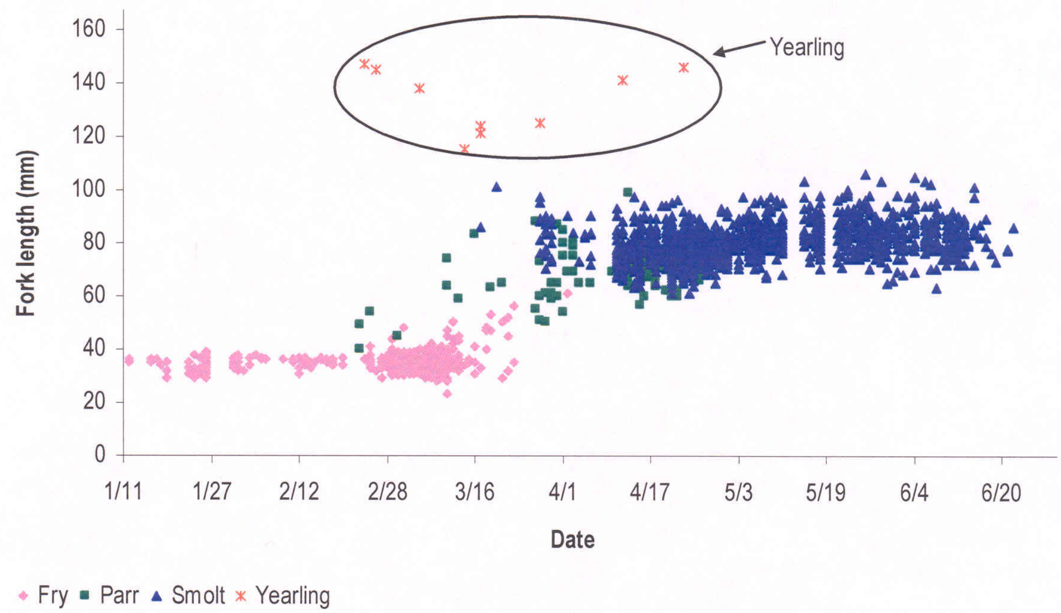

Figure 1.10. Fork length (mm) distributions for fry, parr, smolts, and yearlings at Caswell, 2007.

Figure from: Watry, C.B., A. Gray, R. Cuthbert, B. Pyper, and K. Arendt. 2007. Out-migrant abundance estimates and coded wire tagging pilot study for juvenile salmonids at Caswell State Park in the lower Stanislaus River, California 2007 annual data report. Unpublished report prepared for the U.S. Fish and Wildlife Service.