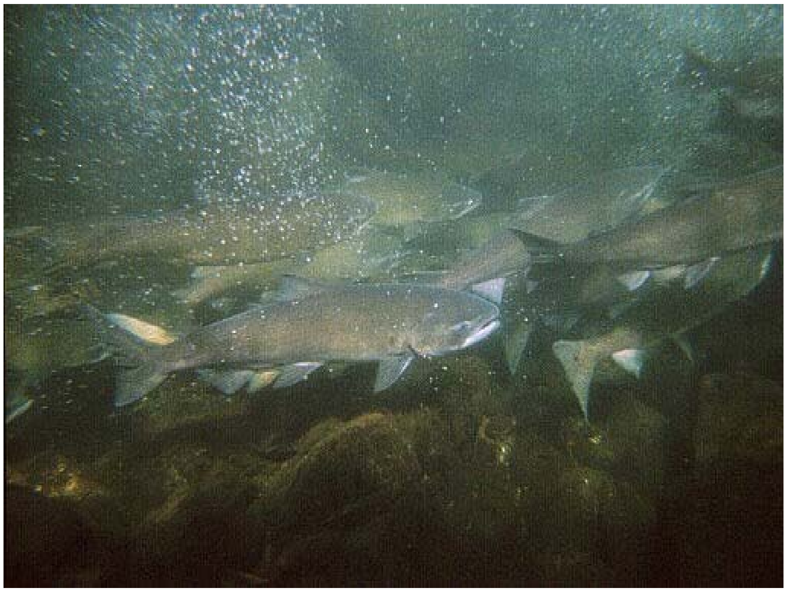
State of California
The Natural Resources Agency
DEPARTMENT OF FISH AND GAME

CENTRAL VALLEY CHINOOK SALMON IN-RIVER ESCAPEMENT MONITORING PLAN



By
Jennifer M. Bergman
Fisheries Biologist
Pacific States Marine Fisheries Commission

Ryan M. Nielson
Biometrician/Project Manager
Western EcoSystems Technology, Inc.

and
Alice Low
Staff Environmental Scientist
California Department of Fish and Game

Fisheries Branch
Administrative Report Number: 2012-1
January, 2012

NOTE TO READERS

The Central Valley Chinook Salmon In-river Escapement Monitoring Plan is a science-based collaborative approach to improve monitoring of adult Chinook salmon returning from the ocean to spawn in CV streams (escapement) and harvested in freshwater. Accurate estimates of escapement are critical to sound management of ocean and inland harvest and monitoring the recovery of listed stocks. A result of requests from fisheries resource managers, the development of this plan was funded in 2007 by the CALFED Ecosystem Restoration Program.

From 2008 to 2011, the project team conducted a thorough statistical review of methods currently used in CV escapement surveys. Sampling designs were reviewed and recommendations were made for improvement of the field and analytical methods used in the existing programs. The most appropriate survey/monitoring technique (i.e., mark-recapture carcass surveys, redd surveys, snorkel surveys, and fish device counters) was identified for each watershed. To improve data management and reporting, an online database was reorganized and updated to provide a centralized location for sharing CV Chinook salmon escapement estimates and annual monitoring reports.

Various population models have been used to estimate escapement from mark-recapture carcass survey data, without measures of precision and bias. The pooled Petersen, modified Schaefer, and Jolly-Seber models have been used for many years in the CV. Based on a review of the available mark-recapture models and simulation modeling, this plan recommends replacement of the models currently used with the superpopulation modification of the Cormack-Jolly-Seber (CJS) model.

Successful implementation of this monitoring plan will rely on continuation of the collaborative and dedicated efforts of multiple agencies and entities throughout the CV. As with all of its products, Fisheries Branch is very interested in ascertaining the utility of this document, particularly regarding to its application to the monitoring and management decision process. Therefore, we encourage you to provide us with your comments. Please be assured that they will help us direct future efforts. Comments should be directed to Dr. Russell Bellmer, Fisheries Branch Monitoring Program Lead, 830 S Street, Sacramento, CA 95814, 916 327-8840, rbellmer@dfg.ca.gov.

Stafford Lehr
Chief, Fisheries Branch

TABLE OF CONTENTS

This document can be cited in the following manner:

Bergman, J. M., R. M. Nielson, and A. Low. 2012. Central Valley in-river Chinook salmon escapement monitoring plan. Fisheries Branch Administrative Report Number: 2012-1. California Department of Fish and Game. Sacramento, CA.

EXECUTIVE SUMMARY

Chinook salmon in the Central Valley (CV) are a valued part of California's cultural and natural heritage. Four distinct Chinook salmon runs are recognized in the CV, differentiated by the timing of the adult spawning migration (fall, late fall, winter, and spring-run Chinook salmon). Fall-run Chinook salmon, supported largely by hatchery production, support major commercial and recreational fishing in ocean and inland areas. Winter and spring-run Chinook populations are at fractions of their historic abundance. Sacramento River winter-run Chinook salmon are now state and federally-listed as endangered. Central Valley spring-run Chinook salmon are state and federally-listed as threatened.

Accurate estimates of the numbers of adult Chinook salmon migrating from the ocean to spawn in CV streams (escapement) and harvested in freshwater are critical to sound management of ocean and inland harvest and monitoring the recovery of listed stocks. Adult escapement data are currently used for several key management purposes:

- Providing a basis for assessing recovery of listed stocks,
- Monitoring the success of restoration programs,
- Evaluating the contribution of hatchery fish to CV populations, and
- Sustainably managing ocean and inland harvest.

Estimates of the number of Chinook salmon returning to spawn have been made since the early 1950's, and in some cases since the 1940's. Programs have evolved over the years, and vary in methods used, intensity of sampling effort, and reliability of estimates. Mark-recapture carcass surveys are now widely used as the standard method to estimate in-river spawning escapement of most Chinook races. Despite their widespread use in the CV, models to estimate in-river spawning escapement based on mark-recapture carcass survey data require a number of assumptions which may not be met in the surveys. Field and data analysis methods used in the existing CV escapement surveys have not been reviewed for adequacy of statistical power or potential bias. In addition, data management and reporting in the Central Valley is not standardized; escapement data and reports are not readily accessible in a timely way by other researchers, stakeholders, or the public.

In response to the need to coordinate and improve escapement monitoring programs in the CV, the Interagency Ecological Program (IEP) Salmonid Escapement Project Work Team (SEPWT) was formed in 2001. The team includes biologists working on salmon escapement monitoring surveys throughout the CV. In 2004, the Salmonid Escapement Project Work Team completed a proposal for the development of the current monitoring plan, a comprehensive plan for monitoring CV adult Chinook escapement.

As envisioned, the primary objective of this monitoring plan is to improve estimates of the number of Chinook salmon (*Oncorhynchus tshawytscha*) that spawn in California's CV streams, along with statistically valid estimates of accuracy and precision. The second objective of this monitoring plan is to ensure that escapement estimates are made in conjunction with collection of biological data for estimation of the age-, length-, and sex-composition of each tributary/run, and will provide for the statistically valid recovery of coded-wire tag (CWT) data in a manner consistent with the objectives of the CV Constant Fractional Marking (CFM) program.

The plan focuses on improving estimation of adult Chinook salmon escapement and harvest in CV streams. Programs to monitor escapement at CV hatcheries were not reviewed, but are the focus of other ongoing review programs. This plan was also not envisioned as a comprehensive management plan for CV Chinook salmon.

From 2008 to 2011, a team consisting of a project coordinator, biologist/planner, database specialist, and biostatistician developed this Plan. A thorough statistical review of methods currently used in CV escapement surveys was conducted. Sampling designs were reviewed and recommendations were made for improvement of the field and analytical methods used in existing programs.

The most appropriate survey/monitoring technique (i.e., mark-recapture carcass surveys, redd surveys, snorkel surveys, and fish device counters) was identified for each watershed (Table 1). Fish device counters, when used appropriately, can be an efficient method for estimating total escapement with high accuracy and precision. Wherever possible, a fish device counter was recommended for monitoring Chinook salmon escapement in the CV. Snorkel surveys are recommended to continue for two monitoring programs where escapement numbers have been too small for a mark-recapture carcass survey and too small to justify the cost of a fish device counter and weir. Mark-recapture carcass surveys are recommended for the remaining watersheds. Recommended procedures were developed for estimating Chinook salmon with a fish device counter and with a mark-recapture carcass survey.

Various population models have been used to estimate escapement from mark-recapture carcass survey data, without measures of precision and bias. The pooled Petersen, modified Schaefer, and Jolly-Seber models have been used for many years in the CV. Based on a review of the available mark-recapture models and simulation modeling, this plan recommends replacement of the models currently used with the superpopulation modification of the Cormack-Jolly-Seber (CJS) model.

Field and analytical methods used in the CV Angler Harvest Survey were also reviewed in this plan. Recommendations were made for improving estimates of the number of Chinook salmon harvested in CV streams.

Recommended monitoring programs in the plan are organized by NMFS diversity groups, watershed, and Chinook salmon run. The NMFS draft Recovery Plan (2009) for salmonid populations divides the CV into six eco-regions or diversity groups based on differences in climatological, hydrological, and geological conditions. Recommended monitoring programs are within four of these diversity groups, which include the Basalt and Porous Lava group, the Northwestern California group, the Northern Sierra Nevada group, and the Southern Sierra Nevada group. The use of these diversity groups in the plan are for organizational purposes.

To improve data management and reporting, in the development of this plan, an online database was reorganized and updated to provide a centralized location for sharing CV Chinook salmon escapement estimates and annual monitoring reports. Annual Chinook salmon in-river escapement estimates and indices for all programs were updated through 2009. Annual Chinook salmon escapement reports used to update the database were digitized; digital copies were uploaded to the CDFG Digital Document Library and are now available on-line.

Costs of the recommended CV monitoring programs were estimated for existing and new programs. Costs included in this Plan should be considered approximate or ‘ball-park’ estimates. Year one will have large start-up costs for some programs and total cost for all programs was estimated to be $6,521,682. After the first year, annual costs were estimated to total $4,314,762.

Successful implementation of this monitoring plan will rely on continuation of the collaborative and dedicated efforts of multiple agencies and entities throughout the CV. Additional dedicated staff is recommended to implement this Plan, including a plan coordinator, database architect, and statistician. Many of the recommended monitoring programs are already in place, but this plan has recommended changes to improve Chinook salmon escapement estimates, biological data collection, CWT recovery, and data management. This monitoring plan should be considered dynamic; the plan and individual monitoring programs should have on-going evaluation and refinement.

Table 1. Monitoring technique(s) recommended for California's Central Valley watersheds to estimate Chinook salmon escapement.

Stream	Target Run	Monitoring Techniques(s)
Mainstem Sacramento R.	F, LF, W	Aerial Redd Survey
		Mark-Recapture Carcass Survey
Cottonwood Creek	F	Fish Device Counter
Cow Creek	F, LF	Fish Device Counter
Bear Creek	F,LF	Fish Device Counter
Antelope Creek	F, LF, S	Fish Device Counter
Mill Creek	F, LF, S	Fish Device Counter
Deer Creek	F, LF, S	Fish Device Counter
Clear Creek	F, LF, S	Fish Device Counter
Beegum	S	Snorkel Survey
Big Chico Creek	S	Snorkel Survey
Butte Creek	S	Fish Device Counter
	F	Mark-Recapture Carcass Survey
Battle Creek	LF, W, S	Fish Device Counter/Trapping
	F	Fish Device Counter
Feather River	S	Fish Device Counter
	F	Mark-Recapture Carcass Survey
Lower Yuba River	F, LF, S	Fish Device Counter
	F, S	Mark-Recapture Carcass Survey
American River	F	Mark-Recapture Carcass Survey
Mokelumne River	F	Fish Device Counter
Cosumnes River	F	Fish Device Counter
Stanislaus River	F	Fish Device Counter
Tuolumne River	F	Fish Device Counter
Merced River	F	Fish Device Counter

F=Fall-run, LF=Late fall-run, W = Winter-run, S=Spring-run

ACKNOWLEDGEMENTS

The authors of this document would like to express their thanks to many people who contributed during multiple phases of plan development. Trent L. McDonald, WEST Inc., helped develop the recommended mark-recapture carcass survey procedures. Jim D. Griswold, WEST Inc., helped develop the recommended procedures for using a device counter to estimate Chinook salmon escapement, and he helped review and recommend improvements for the Central Valley Angler Survey program. Lyman L. McDonald, WEST Inc., reviewed multiple draft reports used to develop Chapters 2-5. Connie Shannon, PSMFC, developed the maps and assisted with Chapter 10. Jim Hopelain, PSMFC, reviewed multiple drafts of the document. Stan Allen, PSMFC, provided overall project guidance. Dr. Russell Bellmer, CDFG, provided numerous reviews and input during the development of this document.

We appreciate and thank all of the Central Valley biologists who provided information about their program(s), reviewed our documentation of their programs, answered our questions, provided data sets upon our request, and involved us in field surveys or visits to the rivers. Biologists include: Doug Killam, CDFG; Colleen Harvey Arrison, CDFG; Matt Brown, USFWS; Jess Newton, USFWS; Sarah Giovannetti, USFWS; Tracy McReynolds, CDFG; Clint Garman, CDFG; Kyle Hartwigsen, CDWR; Ryon Kurth, CDWR; Jason Kindopp, CDWR; Duane Massa, PSMFC; Mike Healy, CDFG; Robert Vincik, CDFG; Jeanine Philips, CDFG; Casey Del Real, EBMUD; Robyn Bilski, EBMUD; Trevor Kennedy, FFC; Tim Heyne, CDFG; Steve Tsao, CDFG; Jennifer O'Brien, CDFG; Dennis Blakeman, CDFG; Ryan Cuthbert, FISH BIO; Chrissy Sonke, FISH BIO; and Jesse Anderson, Cramer Fish Sciences. Thanks to the IEP Salmonid Escapement Project Work Team for providing feedback throughout the development of this plan.

Thank you to the following individuals that reviewed and provided comments on various parts of the final draft plan: Sean Gallagher, CDFG; Allen Grover, NMFS; Michael Mohr, NMFS; Doug Threloff, USFWS; Brad Cavallo, Cramer Fish Sciences; Brett Kormos, CDFG; Colleen Harvey Arrison, Doug Killam, Mike Berry, CDFG; CDFG Region 4, Jeanine Philips, CDFG; Sarah Giovannetti, USFWS; and Kyle Hartwigsen, CDWR.

Funding for the development of this plan was provided by the CALFED Ecosystem Restoration Program (ERP).

CHAPTER 1

INTRODUCTION

There are four recognized distinct runs of Chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley (CV): fall-run, late fall-run, winter-run and spring-run. Salmon runs are named after the season in which they begin migrating from the ocean to freshwater holding or spawning habitat. Runs can also be distinguished by their distinct timing of immigration, maturity of fish entering fresh water, timing of spawning, spawning areas, and genetically (Moyle 2002, Moyle et al. 2008).

Typically, fall-run Chinook migrate upstream in the Sacramento River basin of the CV from June through December, with peak migration in September through October, and spawn shortly after arrival (Moyle 2002). Late fall-run typically migrate upstream in October through April with peak migration in December and spawn shortly after arrival. The migration period for winter-run Chinook is from December through July with peak migration in March, and they spawn from late April-early August (Moyle 2002). Spring-run migrate upstream in the spring (March-September), hold all summer in pools, and spawn in mid-September (Moyle 2002). In the San Joaquin River Basin, fall-run migrate upstream from October through early-January.

The National Marine Fisheries Service (NMFS) has identified several distinct Evolutionarily Significant Units (ESU) in the CV. An ESU is defined as a distinct population that is substantially reproductively isolated from other conspecific population units, and the population represents an important component of the evolutionary legacy of the species (Waples 1991). The ESUs in the CV include Sacramento River winter-run, CV spring-run, and the CV fall-run (Myers et al.1998). The CV fall-run ESU includes late fall-run and are a species of concern (FR 69 73 19975-19979; Myers et al.1998).

Fall-run Chinook salmon historically may have been the most abundant of the four runs or had similar abundance with spring-run Chinook salmon, and they spawned in all major rivers of the CV, however, their historic numbers are difficult to determine based on incomplete monitoring (Yoshiyama et al. 1998). In the 1960s-90s, the abundance of adult CV fall-run usually varied between 200,000 and 300,000 fish annually (Moyle et al. 2008). Escapement of fall-run Chinook salmon was at a record low number in the CV in 2009 with a in-river abundance estimate of only 39,942 fish and a total estimate of 53,624 fish (in-river and hatchery returns)(CDFG 2010).

Late fall-run Chinook salmon historic run size abundance and distribution is not well known or documented. Their average abundance from 1967-1976 was about 22,000 fish and from 1981-1991 was about 9,700 fish (Yoshiyama et al. 1998). Late fall-run Chinook are believed to have spawned in the upper Sacramento and McCloud rivers (reaches now blocked by Shasta Dam) and in the San Joaquin River watershed (Yoshiyama et al. 1998). Today, late fall-run Chinook are found in the mainstem of the Sacramento River below Keswick Dam, and have been observed in Battle, Cottonwood, Clear, and Mill Creeks, and the Feather and Yuba Rivers (Moyle et al. 2008). In 2009, the total estimated abundance of late fall-run Chinook in the CV was 9,982 fish (CDFG 2010).

Winter-run Chinook salmon historically spawned in the Upper Sacramento, Pit and McCloud Rivers and Battle Creek (Yoshiyama et al. 1998) and abundance might have reached 200,000 fish per year (Fisher 1994). The Sacramento River winter-run Chinook salmon was listed by the state as an endangered species in 1989 and was federally listed as endangered in 1994 (59 FR 440 (January 4, 1994). Today, only one population of winter-run exists in the CV, spawning in the mainstem of the Sacramento River below Keswick Dam. Abundance of winter-run varies, but was estimated to be 4,658 total fish (in-river and hatchery returns) in 2009 (CDFG 2010).

Historically, CV spring-run Chinook salmon run sizes were between 500,000 and 1.5 million fish per year (Yoshiyama et al. 1998), and were found throughout the Sacramento and San Joaquin watersheds (Moyle et al. 2008). CV spring-run Chinook salmon ESU was listed both by the state and federally as a threatened species in 1999 (64 FR 50394 (September 16, 1999). Since 1990, the estimated number of adult CV spring-run Chinook has ranged from 3,044 (1992) – 31,649 (1998) fish annually (CDFG 2010). In 2009, the number of CV spring-run was estimated to be 3,802. CV spring-run Chinook are currently extirpated from the San Joaquin watershed, and in the Sacramento River system and are found in Clear, Battle, Mill, Deer, Antelope, Butte, Big Chico, and Begum Creeks. In addition, CV spring-run Chinook salmon are found in the mainstem of the Sacramento River below Keswick Dam, the Feather River, and potentially the Yuba River (data limited) (Moyle et al. 2008). However, only two populations are genetically distinct; the populations in Deer and Mill Creeks and the population in Butte Creek. The population in the Feather River is genetically similar to fall-run Chinook (Garza et al. 2008).

Chinook Salmon Escapement Monitoring Needs

During the past several decades the purpose of Chinook salmon escapement[1] monitoring in the CV was focused on providing data for ocean harvest management and for evaluating the general status of the individual populations. Today, escapement monitoring is needed to provide data for a broad range of management purposes including: managing sustainable ocean and inland fisheries, evaluating the recovery of federally and state-listed winter-run (endangered) and spring-run (threatened) Chinook salmon, evaluating the contribution of hatchery fish to CV populations, accessing the success of restoration programs that are mandated by several federal and state programs, and evaluating hatchery genetic management plans. Monitoring programs for Central Valley Chinook salmon must be scientifically defensible. Ultimately, the wider scientific community will make decisions on whether species listed under the ESA have been recovered, or if ocean harvest goals are being met satisfactorily. Such support is unlikely if data are not collected in a statistically-rigorous way to produce unbiased estimates of escapement and examine trends.

---

[1] Chinook salmon escapement is defined as fish that migrate from the ocean to spawn in freshwater streams.

Fisheries Management – Ocean salmon fisheries on the west coast are managed by the Pacific Fishery Management Council (PFMC) using conservation goals and objectives for the long-term sustainability and viability of each stock in their area of jurisdiction. For Central Valley Chinook stocks, the PFMC uses Sacramento River fall Chinook as the indicator stock with a goal of achieving an annual escapement in the range of 122,000 to 180,000 adults in both hatchery and natural areas. The Sacramento Index (SI) model is used to evaluate harvest and set the level of ocean and river harvest that will result in achieving the conservation objectives.

Accurate estimates of the numbers of Chinook salmon returning to Central Valley streams to spawn, including those harvested in freshwater and spawned at hatcheries are critical to sound scientific management of ocean and inland harvest. Estimates of uncertainty in Chinook salmon escapement estimates are also necessary for sound management of the population. Currently, salmon escapement estimates in the Central Valley are not perceived to be accurate enough for development of age-specific models of salmon abundance. CDFG Ocean Salmon Project and NMFS Ocean Management data needs include: (1) Chinook salmon escapement estimates, (2) coded-wire tag (CWT) recoveries, (3) the number of Chinook salmon harvested in the inland fishery, and (4) the age-structure and cohort structure of the returning adults (CDFG and NMFS, pers. comm., 2008).

Population Restoration – Several state and federally-mandated programs are required to examine the status and trends of Chinook salmon escapement in the CV. The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act, enacted by the California Legislature in 1988, directed the CDFG to develop a program to double naturally spawning anadromous fish populations by the year 2000 (Fish and Game Code Sections 6900-6924). The Central Valley Project Improvement Act (CVPIA) enacted by Congress in 1992 (Public Law 102-575), requires the Department of Interior to develop and implement a program that ensures the long-term sustainability and viability of anadromous fish in the CV, at population levels not less than twice the average levels from 1967 – 1991 (Section 3406(b)(1)). The U.S. Fish and Wildlife Service (USFWS) Anadromous Fish Restoration Program (AFRP) is tasked by CVPIA to make all reasonable efforts to at least double the natural production of anadromous fish in the CV on a long-term sustainable basis.

Recovery of Listed Chinook Salmon – Escapement monitoring is needed for monitoring the recovery of federal and state-listed Chinook salmon. In 2009, the NMFS Southwest Region released a public draft recovery plan for the ESUs of Sacramento River winter-run and CV spring-run Chinook salmon ESUs (Recovery Plan; NMFS 2009). The plan recommends the steps, strategy, and actions to be taken to return winter-run and spring-run Chinook salmon to a viable population status. A viable salmonid population (VSP) is an independent population of any Pacific salmonid that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time frame (McElhany et al. 2000). McElhaney et al. (2000) recognize that in addition to evaluating population viability over long time periods, analyzing short-term risks to persistence of a population is important. Four parameters were identified by McElhaney et al. (2000) as the key to evaluating population viability status: abundance, population growth rate (productivity), population spatial structure, and diversity. These parameters are the focus for NMFS for three reasons: (1) they are reasonable predictors of viability, (2) they reflect general processes that are important to all populations of species, and (3) the parameters are measurable. Lindley et al. (2007) developed criteria for assessing the level of extinction and viability for populations of Pacific salmonids. Assessing viability requires abundance of adult returns, the percentage of hatchery fish among the returning adults, and routine collection of genetics to examine effective population size, detect population bottlenecks, and introgression. Abundance estimates of returning adults should have measures of uncertainty (e.g., standard error or confidence intervals) and statistical power to detect trends.

The NMFS Northwest Region developed a guidance document for monitoring the recovery of salmon and steelhead listed under the Endangered Species Act in Idaho, Oregon, and Washington (Crawford and Rumsy 2009). The guidance document is in draft form and is subject to change, but provides recommendations for data collection needed for monitoring VSP status/trends for each VSP parameter (i.e., abundance, productivity, diversity, and spatial structure). Adult spawner abundance (the number of fish that actually spawned) was ranked as the highest monitoring priority, because spawner abundance is used to examine multiple questions for each VSP parameter. For abundance the key monitoring components include: (1) the status/trend of natural origin adult spawners for each population, (2) the proportion of hatchery origin fish on the spawning grounds for each population, (3) the age structure and cohort structure for each population, and (4) the harvest mortalities in fisheries throughout the fish's range. Abundance estimates must have measures of uncertainty, bias and statistical power to detect trends. Adult productivity is measured as adult to adult productivity, which is the measure of the viability of natural salmon populations based upon the number of adult fish that returned to spawn from the parents of the returning fish. Adult to adult ratios are used because the measure provides the best information when juvenile data are not available. Information needed to examine the annual productivity of natural-origin spawners include: (1) adult spawner abundance by cohort and origin, (2) sex ratio of spawners, and (3) percent of spawners of hatchery origin. A population's spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution (McElhany et al. 2000). A key question is how has the distribution of spawners within a population changed? Diversity is measured through behavioral, morphological, and genetic traits. Traditional diversity indicators include run timing, sex ratios, age at maturity, spawn timing, and DNA.

Additional Monitoring Needs – Recommendations for monitoring CV Chinook salmon runs, were also made by Williams et al. (2007), Williams (2006) and biologists at a CV salmonid monitoring workshop (Brown and Bellmer 2006). Their recommendations include monitoring for population viability as described by Lindley et al. (2007). Additional recommendations by Williams et al. (2007) include (1) estimate inland harvest, examine the age structure and analyze genetics of harvested fish; and (2) examine the age-structure, size distribution, and estimate fecundity of the returning adult

Chinook salmon. At the workshop, escapement monitoring needs identified included monitoring for population viability, inland harvest, and ocean fisheries management.

Historic and Current Chinook Salmon Escapement Monitoring

Escapement monitoring programs have evolved over the years and are summarized by Low (2007) and Pipal (2005). In addition, current programs' data collection and analysis methods are described here (Chapters 6-9). The length of the data record varies from run to run, but, in general, data for several runs are available from the early 1950s and in some cases from the 1940s. Historic CV Chinook salmon escapement estimates were based on a variety of techniques, including carcass surveys, visual counts of live fish (e.g., Red Bluff Diversion Dam), extrapolation based on spatial or temporal subsets of an entire run, and expert judgment/guess. For some older data, documentation of sampling and estimation methods does not exist. Mark-recapture carcass surveys are now widely used in the CV as a technique to estimate Chinook salmon escapement. In recent years, the use of device counters (i.e., traditional video cameras, Vaki Riverwatcher System, and dual-identification frequency sonar) to estimate Chinook salmon escapement in CV rivers has increased. Snorkel surveys and redd surveys are also used in some watersheds to provide an index of Chinook salmon escapement, especially for spring-run Chinook.

Until this plan, Chinook salmon escapement estimates in the CV were reported without measures of precision, and there has been no evaluation of potential biases in the methods used. Therefore, determining trends with statistical confidence is not possible. NMFS recovery planning guidance (NMFS 2000) states that a common failing of monitoring and evaluation efforts under the ESA is lack of statistical power. Lack of statistical power means that the intensity of data collected may be too low, given sampling error and environmental variability, to determine trends and effects with reasonable statistical confidence that are useful for feedback into management actions.

Existing CV monitoring programs have changed over time for several reasons. These include accommodating available resources (reduce survey frequency, survey area, or effort) or implementing new survey methods as they became available (e.g., changing from a mark-recapture carcass survey to a fish device counter), and using new data analysis techniques (e.g., changing from a Petersen or modified-Schaefer to a Jolly-Seber mark-recapture estimator). Implementing a new survey or analysis method can be slightly uncomfortable, especially when considering that field crews may have to be retrained, and biologists may have to learn new statistical analyses. Some biologists in the CV have voiced their concern that changing a monitoring program might make it difficult to compare future escapement estimates to historical data, as historical estimates were made using different protocol and analysis methods. We caution against relying on the idea that consistency in data collection and analysis methods provide cleaner comparisons and better estimates of trends. Multiple factors can influence a survey and result in different biases and loss of precision. For example, closed-population mark-recapture analyses are not appropriate for estimating Chinook salmon escapement and such methods result in different amounts of bias depending on the degree to which the closure assumption is violated (as discussed in Chapter 3).

Currently, data management and reporting of Central Valley escapement data are conducted on a project-by-project basis. A standardized database is not available for data storage and retrieval. Most projects prepare an annual report of survey results; however, escapement data and reports are not readily accessible to managers, other researchers, stakeholders, or the public.

Goal and Objectives

The goal of this monitoring plan is to provide recommendations for obtaining and managing Chinook salmon escapement data in California Central Valley streams for improved fisheries management and assessing the recovery and restoration of Chinook salmon populations and ESUs in a comprehensive and coordinated way. The focus of this monitoring plan is for winter-run, spring-run, fall-run, and late fall-run Chinook salmon escapement in CV streams. Programs that monitor escapement at CV hatcheries were not reviewed, because they are the focus of other ongoing review programs including the California Hatchery Review Project and with the development of hatchery genetic management plans (HGMPs). This plan is not a comprehensive management plan for CV Chinook salmon.

The objectives of this plan are to:

1. Recommend Chinook salmon in-river escapement monitoring programs that when implemented will collect data to examine the following for each population monitored:
    - Annual escapement estimates with measures of uncertainty and evaluation of bias
    - Trends in annual escapement estimates
    - Proportion of natural-origin and hatchery-origin fish in a population
    - Proportion of females that spawned
    - Age and cohort structure
    - Sex ratios
    - Size structure

2. Review the Central Valley Angler Survey Program and provide recommendations for improvement of inland harvest estimates for Chinook salmon.

Many of the recommended monitoring programs will also collect data to examine run timing, spawning timing, spawning distribution and spring-run Chinook salmon holding distribution. Collecting genetic tissue samples and otoliths requires some additional effort, but can provide valuable information. Biologists are recommended to collect these samples if possible or collect the data if there is a request by researchers that can provide additional resource support.

Many CV monitoring programs already collect data to satisfy some of these objectives,. Some programs may need to be modified or changed to improve escapement estimates and collect all of the recommended data. In addition to escapement monitoring, several related programs provide critical data for CV Chinook salmon management. In 2007, CDFG initiated a constant fractional marking (CFM) program where 25% of all CV hatchery fall-run Chinook salmon production releases are adipose fin-clipped (ad-clipped) and tagged with a CWT (Buttars 2010). All CV hatchery winter-run, late fall-run, and spring-run Chinook are tagged with a CWT and ad-clipped (Williams 2006). In 2006, CDFG initiated a CV-wide Chinook salmon aging program. CDFG maintains a genetics tissue archive for CV Chinook salmon, and the NMFS Southwest Science Center has started developing a genetics library for Chinook salmon.

Approach for Plan Development

First, the goal and objectives of the monitoring plan were developed based on Chinook salmon escapement monitoring needs. The major impetus for the development of this Plan was a need for escapement estimates to be accurate with estimates of precision and bias for examining population trends and status in a statistically valid manner. Additional reasons for the development of this monitoring plan included a need for: (1) CWT recovery for the CFM Program; (2) scale collection for CDFG's Scale Age Program; (3) review of the Angler Survey Program regarding harvest estimates; and (4) coordinated and consistent data management, analysis and reporting. Additional Chinook salmon escapement monitoring data collection needs were identified through meetings with escapement monitoring program project leads, a meeting with CDFG and NMFS Ocean Fisheries Management and reviewing multiple reports regarding CV escapement monitoring needs or assessing the recovery of listed salmon

Second, each of the existing Chinook salmon escapement monitoring programs was documented to understand how field data are collected and how data are analyzed to estimate escapement. Meetings were held with each project lead(s) to discuss their monitoring program(s) and participate in some field surveys. Project leads provided annual reports and additional information (e.g., protocols and procedures, answered questions) for documentation of their program(s). In addition, each project lead(s) reviewed the documentation of their program(s).

Third, the most appropriate survey method (i.e., mark-recapture carcass surveys, redd surveys, snorkel surveys, and fish device counters) was identified for each watershed. Fish device counters, when used appropriately, can be an efficient method for estimating total escapement with high precision. Wherever possible, a fish device counter was recommended for monitoring escapement. Snorkel surveys are recommended to continue for some streams where escapement numbers have been too small for a mark-recapture carcass survey and too small to justify the cost of a fish device counter and weir. Mark-recapture carcass surveys are recommended for the remaining watersheds. Most of these streams are too large for installation of a weir and device counter. Recommended procedures were developed for estimating Chinook salmon with a fish device counter and with a mark-recapture carcass survey were developed. Details of these recommendations are contained in subsequent chapters.

Unlike mark-recapture carcass surveys, fish device counters cannot be used to obtain all of the escapement data needed to meet objectives of this plan. Some fish device counters measure or approximate length and the images of Chinook salmon can be reviewed to identify sex and the presence of an adipose fin. However, carcass sampling surveys are needed to collect biological data (i.e., sex, length, female spawning status, scales, genetic tissue, and otoliths) and recover CWTs. These carcass sampling surveys do not have a mark and recapture component since they are not used for estimating escapement. Procedures for carcass sampling surveys were developed. The protocol for collecting biological data collection and CWT recovery for mark-recapture carcass surveys are the same as those developed for a carcass sampling survey, but carcasses are also marked and recaptured using recommended mark-recapture carcass survey procedures.

The recommended monitoring programs are organized by NMFS diversity groups, watershed, and Chinook salmon run (Figures 1 and 2). The NMFS Recovery Plan (2009) divides the CV into six eco-regions or diversity groups based on differences in climatological, hydrological, and geological conditions (Lindley et al. 2007). Recommended monitoring programs are within four of these diversity groups, which include the Basalt and Porous Lava group, the Northwestern California group, the Northern Sierra Nevada group, and the Southern Sierra Nevada group. The use of these diversity groups in the plan are for organizational purposes.

A spatial sampling design is not necessary for identifying where Chinook salmon escapement monitoring should occur in the CV. Chinook salmon escapement monitoring currently occurs in most CV watersheds that support Chinook spawning. While most of the recommended monitoring programs are already in place; we have identified some additional monitoring needs and improvements for estimating escapement. Existing programs were summarized and reviewed (Chapters 6-9). Reviews were based on our recommended procedures for estimating escapement using a fish device counter (Chapter 2) or mark-recapture carcass survey (Chapter 3) and recovering CWTs and collecting biological data (Chapter 4). Following the review of each program is our recommendations for monitoring Chinook salmon escapement.

The CDFG Angler Survey program was reviewed and recommendations are provided for improved data collection and angler harvest estimation (see Chapter 5).

Data Management recommendations are provided, including the development of a centralized database management system and for centralized data reporting (see Chapter 10).

Approximate cost estimates for the recommended monitoring programs were identified (Chapter 11).

Finally, implementation of this Plan and adaptive management is discussed in Chapter 12 with some recommendations to improve the implementation process.

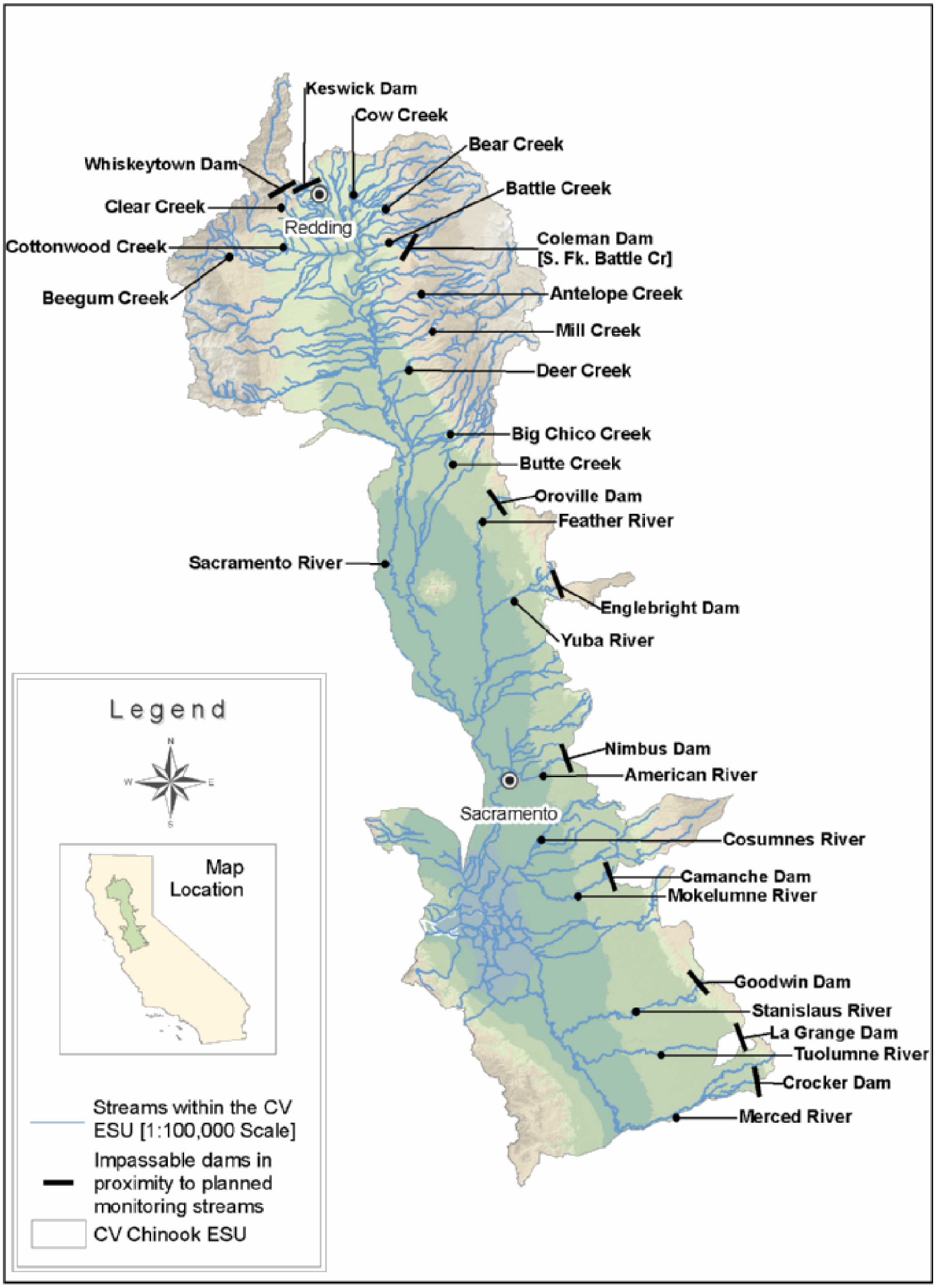


Figure 1. Major California Central Valley (CV) streams within the NOAA National Marine Fisheries Service's CV Evolutionarily Significant Unit (ESU). Labeled streams are those with Chinook salmon escapement monitoring.

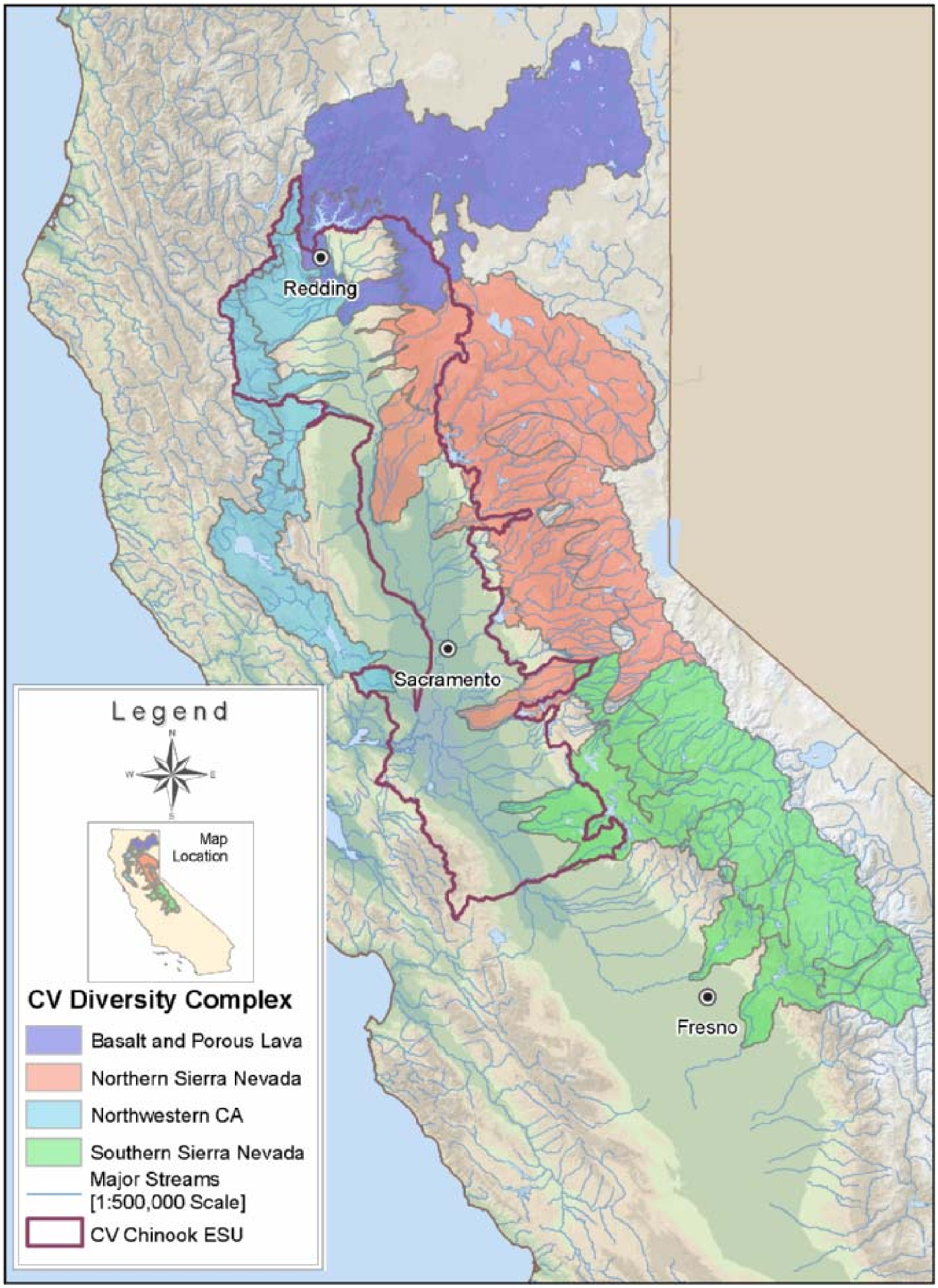


Figure 2. California Central Valley (CV) streams within the NOAA National Marine Fisheries Service's CV Chinook salmon Evolutionarily Significant Unit (ESU) and approximate boundaries for four of NOAA's Chinook salmon diversity groups or eco-regions where watersheds are recommended for escapement monitoring.

CHAPTER 2

ESTIMATING CHINOOK SALMON ESCAPEMENT USING FISH DEVICE COUNTERS

Fish device counters (i.e., optical cameras, dual-frequency identification sonar, or infrared-imaging technology) have been used to monitor salmon escapement in Alaska (Estensen and Cartusciello 2005; Otis et al. 2010; Maxwell and Gove 2007), Idaho (Faurot and Kucera 2002; Kucera and Orme 2007), Washington (Hatch and Schwartzberg 1991; Hatch et al. 1995), California (Anderson et al. 2007; Workman 2005; Killam 2006b, 2008a, 2008b; Killam and Johnson 2008; Johnson et al. 2006; Massa et al. 2008; Pipal et al. 2010); British Columbia (Holmes et al. 2006), and many other places throughout the world.

Fish device counters have several advantages over other traditional survey methods for estimating total escapement: they provide a fairly accurate and consistent count, they can function year-round, and they can operate with minimal impact on individual fish (an important consideration for threatened or endangered runs) (Mackey 2005). Moreover, a permanent record is obtained for fish passage that can be reviewed and corrected for error and used for training personnel to process the images. Some disadvantages include: device counters may be expensive to buy and install, are vulnerable to vandalism and theft, are vulnerable to damage during flood flows, and must be installed at an appropriate in-river structure. In addition, they require regular monitoring, maintenance and servicing to maintain reliable operation and to insure high quality data.

Data from all survey methods may be compromised during high flow and high turbidity periods; however some fish device counters (i.e., Vaki Riverwatcher and DIDSON) can be used to monitor fish populations more accurately under these conditions compared to traditional methods (i.e., mark-recapture carcass survey, redd survey, and snorkel survey). In the CV, spring, fall, and late fall-run Chinook salmon may immigrate during high flow and turbid water periods. In addition, some rivers are naturally turbid under low flow conditions.

Escapement estimates from device counters can be more accurate and precise than those from other traditional techniques, such as mark-recapture carcass surveys, snorkel surveys, and redd surveys. If a device counter is placed below all spawning habitat and every fish can be detected by the device counter, all immigrating fish can be counted. However, device counters are not perfect and counting errors can occur. Multiple types of counting errors are identified in this chapter (see below) and recommended procedures are provided to account for these potential errors in the total escapement estimate.

Fish device counters are recommended for estimating Chinook salmon escapement in many CV streams (Chapters 6-9). Some of these streams already have a device counter; escapement estimates for these streams could be improved by examining the potential for counting errors (described below). Each of the existing monitoring programs is described in Chapters 6-9 followed by recommendations for improved monitoring. Device counters are recommended to improve escapement estimates over the current survey method (mark-recapture carcass survey, redd survey, or snorkel survey) for one or more of the following reasons: (1) all Chinook salmon spawning habitat cannot be surveyed; (2) the survey area is too large and remote for more than one survey therefore total escapement with estimates of precision and bias are not possible; (3) predation on carcasses is high; (4) an index of escapement and not an estimate of total escapement can be produced; and (5) installation and operation of a device counter is feasible. Fish device counters are also recommended by Eilers et al. (2010) to estimate abundance of steelhead in many CV streams; the same equipment and personnel could also be used for Chinook salmon escapement monitoring. Other traditional survey techniques are needed when fish device counters are not effective, cannot be used because a river is too large or flashy for installation of a weir, landowner access to the river is not allowed, or the cost of a device counter is not warranted due to lack of information about Chinook salmon in a stream.

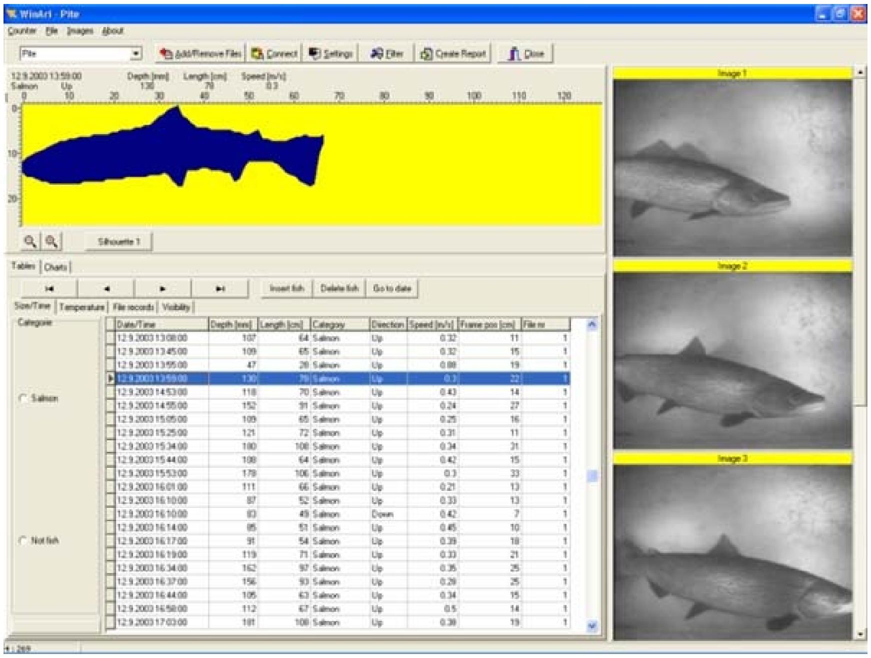
While a fish device counter can provide an accurate and precise escapement estimate, most biological and spawning distribution data cannot be obtained. This information is important for fisheries management, therefore a carcass sampling survey is recommended for streams with a device counter. Recommended procedures for a carcass sampling survey are described in Chapter 4.

Three types of fish device counters are currently used in the Central Valley (CV) to monitor instream escapement of Chinook salmon and steelhead. These device counters include Vaki Riverwatcher®, a Dual-frequency Identification Sonar (DIDSON), and traditional optical video cameras. These device counters are described below.

Vaki Riverwatcher Systems

The Vaki Riverwatcher system uses a linear sensory array to measure the height (ventral-dorsal) of a fish breaking infrared light beams emitted from a series of diodes positioned opposite a series of sensors. From the height of the fish and the fish's speed between the two arrays, the Vaki Riverwatcher system is able to reconstruct an outline of the fish. This outline is then digitally stored for validation by the operator (Mackey 2005, Figure 3). A digital video camera system add-on is available for the Vaki Riverwatcher system to limit the rate of counting errors (Figure 3). In the lower Yuba River, the Vaki Riverwatcher system with a digital video camera system add-on was found to improve the ability to identify *O. mykiss* from other species (i.e., Chinook salmon, northern pike minnow, hardhead), detect the presence of an adipose fin, reduce double counting fish due to fall-back, and reduce missed counts when multiple fish passed the sensors at the same time (R. Greathouse, PSMFC, pers. comm., 2010). Therefore Vaki Riverwatcher systems used in the CV should have a digital video camera system add-on feature. The system measures the body depth of the fish. A predefined body depth to length ratio for a species will need to be applied to the height or body depth to approximate the length of a fish. On the Stanislaus River from 2002-2006, estimated lengths from a Riverwatcher system were found to be greater than 95% accurate when fish were trapped in conjunction with Riverwatcher monitoring (J. Anderson, Cramer Fish Sciences, pers. comm., 2010).

Vaki Riverwatcher systems require fish to be directed through a relatively narrow opening (45 cm; 17.7 in) to pass the series of sensors compared to the opening of a weir needed with optical video cameras (see below). The best system for each stream will need to be determined based on specific stream conditions. For example, if the width of the Vaki Riverwatcher opening would prevent passage for a particular species then an optical camera and DIDSON should be used (see below). Vaki Riverwatcher systems in the CV are installed in Alaskan style resistance board weirs (Figure 4) or within a fish ladder. An Alaskan style weir remains operational at a wide range of stream discharges, and fish can be directed into the Vaki Riverwatcher system. The upper discharge limit is somewhat site-specific and dependent on the overall size of the weir, channel characteristics, and debris loads/types. At stream discharges above this limit, the weir folds down. When flows decrease, the weir self-rights, providing that debris does not prevent the weir from righting. The benefit of using existing fish ladders at diversion dams may include no additional costs for weir structures and structural integrity over a relatively wide range of flows. There is anecdotal evidence that fish may be able to jump over the resistance panels of a weir and avoid the counting chamber (Tim Heyne, CDFG, pers. comm., 2008). In any weir operation it is essential to determine daily if the weir is fish tight; fish are not passing under or over the weir.



Date/Time	Depth [mm]	Length [cm]	Category	Direction	Speed [m/s]	Frame pos [cm]	File nr
12.9.2003 13:08:00	107	64	Salmon	Up	0.32	11	1
12.9.2003 13:45:00	109	65	Salmon	Up	0.32	15	1
12.9.2003 13:55:00	47	28	Salmon	Up	0.08	19	1
12.9.2003 13:59:00	130	79	Salmon	Up	0.3	22	1
12.9.2003 14:53:00	118	70	Salmon	Up	0.43	14	1
12.9.2003 14:55:00	152	91	Salmon	Up	0.24	27	1
12.9.2003 15:05:00	109	65	Salmon	Up	0.25	16	1
12.9.2003 15:25:00	121	72	Salmon	Up	0.31	11	1
12.9.2003 15:34:00	180	108	Salmon	Up	0.34	31	1
12.9.2003 15:44:00	108	64	Salmon	Up	0.42	15	1
12.9.2003 15:53:00	179	106	Salmon	Up	0.3	33	1
12.9.2003 16:01:00	111	66	Salmon	Up	0.21	13	1
12.9.2003 16:10:00	87	52	Salmon	Up	0.33	13	1
12.9.2003 16:10:00	83	49	Salmon	Down	0.42	7	1
12.9.2003 16:14:00	85	51	Salmon	Up	0.45	10	1
12.9.2003 16:17:00	91	54	Salmon	Up	0.39	18	1
12.9.2003 16:19:00	119	71	Salmon	Up	0.33	21	1
12.9.2003 16:34:00	162	97	Salmon	Up	0.35	25	1
12.9.2003 16:37:00	156	93	Salmon	Up	0.28	25	1
12.9.2003 16:44:00	105	63	Salmon	Up	0.34	15	1
12.9.2003 16:58:00	112	67	Salmon	Up	0.5	14	1
12.9.2003 17:03:00	181	108	Salmon	Up	0.38	19	1

Figure 3. The Vaki Riverwatcher can be equipped with a digital camera system to record video or still images of fish passing through the scanner. The scanner triggers the camera to capture 1 to 5 digital photos or a short video clip of each fish. The computer then automatically links the digital images to the other information in the database for that individual fish such as size, passing hour, speed, silhouette image, temperature etc. Image taken from Vaki, Inc. website: http://www.vaki.is/Products/RiverwatcherFishCounter/CameraRW/.

Figure 4. Resistance board weir (Alaskan style) with a Vaki Riverwatcher System on the Stanislaus River, CA. Photo credit: David Hu, USFWS.

Dual-frequency Identification Sonar

DIDSON uses high (1.8MHz) or low (1.1 MHz) frequency sound waves to produce high resolution underwater images. Originally DIDSON was designed for use by the Navy to help identify mines and divers underwater. This technology has now expanded into fisheries science. DIDSON has proved to be an effective tool for monitoring salmonid run size in several rivers in Alaska (Maxwell and Gove 2004 and 2007; Burwen et al. 2007), the Methow River, Washington (Galbreath and Barber 2005), the Secesh River, Idaho (Kucera 2009) and the San Lorenzo River, Big Creek, Scott Creek, and Mill Creek in California (Pipal et al. 2010; Johnson et al. 2006). DIDSON not only provides count data, but also data on fish size, shape, behavior, and swimming motion. Since DIDSON uses sound waves to produce images of fish, it can be used in turbid water conditions. In addition, DIDSON does not require fish to pass through a narrow location to capture an image. However, DIDSON does require specific physical features in a stream to allow survey of the entire cross section.

DIDSON is recommended to be paired with optical video cameras to monitor steelhead in CV rivers when water becomes too turbid to enumerate fish (Eilers et al. 2010). DIDSON monitoring will also be needed to monitor Chinook salmon escapement during turbid water conditions. In particular, spring, fall, and late fall-run Chinook salmon may immigrate during high flow and turbid water periods. In addition, some rivers are naturally turbid under low flow conditions.

Pipal et al. (2010) developed guidelines for using DIDSON to monitor steelhead in coastal streams in central California, based on evaluating its performance on three streams (San Lorenzo River, Santa Cruz County; Big Creek, Monterey County; and Scott Creek, Santa Cruz County). They provide guidelines for equipment and logistics, site selection, data collection and analysis methods, costs and species identification. Many of their guidelines and recommendations also apply to monitoring Chinook salmon escapement.

Distinguishing Chinook salmon from steelhead and other species may be difficult with DIDSON technology. Pipal et al. (2010) found that distinguishing between steelhead and Coho salmon (*O. kisutch*) and possibly Sacramento suckers (*Castostomous occidentalis*) was difficult in three coastal streams. Differences in fish size and migration timing allow for differentiating fish species with similar shape and size. Research is currently focused on improving species identification using patterns of echograms related to tail-beat patterns of fish. Muller et al. (2010) examined the echograms of DIDSON and found that tail-beat frequency has the potential to differentiate Chinook salmon and sockeye salmon (O. *nerka*) in the Kenai River, Alaska. In the CV, video readers use paired images from video cameras and DIDSON to identify the different movement patterns and morphological features of fish to distinguish Chinook salmon from other species (D. Killam, CDFG, pers. comm., 2010).

Optical Video Cameras

Video cameras need good visibility conditions (low to moderate flows with relatively clear water conditions) to produce a reliable image of a fish. Video cameras have been used to monitor Chinook salmon and steelhead in several CV streams including Bear Creek, Cow Creek, Cottonwood Creek, Mill Creek, Antelope Creek, Battle Creek, the Mokelumne River, and the Sacramento River at Red Bluff Diversion Dam. Fish can be identified to species when good images are available. In addition to count data, fish length can be approximated, and run timing, presence of an adipose fin, sex (fall-run only) and fish behavior can be examined.

Fish need to be directed past video monitoring equipment to be detected and counted. Partial horizontal bar weirs have been used in Bear, Cow, Cottonwood, Mill, Antelope, and Battle creeks to direct fish through the center of the weir where the underwater and overhead video cameras are located (up to 16 cameras could be used; Figures 5 and 6). The center opening in the weir is much larger (10-15 ft) than the size needed for the Vaki Riverwatcher to produce reliable images of fish. Benefits of a horizontal bar weir include: they can be made fish tight, debris can easily pass through them, they can withstand relatively high flow conditions, and they are relatively inexpensive to build and install. An Alaskan style resistance board weir could also be used to direct fish past the video equipment, but has not been used so far with traditional video cameras in the CV. Video equipment is also located in the vault of fish ladders of Woodbridge Dam on the Mokelumne River and in the fish ladder at the Coleman National Fish Hatchery barrier weir on Battle Creek. The vault is a weather-proof room with a viewing widow built into the fish ladder. In some cases modifications at the viewing window may be needed to channel fish closer to the window for video monitoring. Video equipment is installed at the top of a fish ladder in Mill Creek, so fish are counted as they leave the fish ladder.

Video cameras alone are a less powerful tool than using both a video camera paired with a DIDSON. Fish cannot be observed in turbid water using a video camera. A DIDSON or similar device is needed in conjunction with each site to enumerate fish when water is too turbid for the video camera alone. Video cameras are needed to identify fish to species; species identification with a DIDSON is possible if the fish species has identifying features (described above).

Figure 5. An example of a partial horizontal bar weir currently in use in the Upper Sacramento River Basin (Cottonwood Creek), operated to monitor fall-run Chinook salmon. The weir directs fish through the central opening where they are filmed by overhead and underwater cameras. Photo credit: Doug Killam, CDFG.

Figure 6. An example of favorable conditions for optical video cameras. The image shows an adult fall-run Chinook salmon (approximately 91 cm in length) passing the Battle Creek weir. Photo credit: Doug Killam, CDFG.

Recommended Procedures for Estimating Chinook Salmon Escapement

An appropriate type of device counter must be selected for each stream location. The device must be installed in an optimal place in the stream where fish are confined to pass within the detection range of the device during normal operating conditions. Optimal device settings and setup are imperative for maximum counting accuracy and precision.

Multiple sources of error and variability may affect estimates of total escapement when using fish device counters. Six types of counting errors are possible:

1) **Missed counts**: A missed count occurs when a fish passes the device counter but is not recognized. The fish may pass the device too quickly for an image to be recorded or turbidity may cause the sensors to fail. A missed count may also occur when two fish cross the device counter but only one fish is recorded. Periods when the device counter is malfunctioning or inoperative will result in missed counts.

2) **False counts**: A false count occurs when another object is mistaken for a fish (e.g., waterfowl, muskrats, leaves, sticks, or bubbles).

3) **Mixed counts**: A mixed count can occur when a species other than the target species is recorded and is not correctly identified.

4) **By-passed counts:** By-passed counts are the result of the target fish swimming around the device counter and never passing within the range of device detection. This type of error can occur during high water events or when the device counter has not been installed in a constricted enough area to allow detection of all fish migrating through the weir opening. The range of accurate counts will depend on correct installation for a given bottom topography, depth and stream width.

5) **Double counts**: Double counts occur when fish are counted once, drop back below the device counter, and then enter the range of the device counter for a second time.

6) **Observer or technician errors**: Errors can be made by the individual(s) processing the images or device counter data. For example, a file may become corrupted or lost, or the observer may under- or over-count fish. Both within and between observer errors are possible.

The type of counting errors observed and the effect on total escapement will depend on specific stream conditions (i.e., type of device counter, river, and installation setup). Potential counting errors will need to be identified for each stream, and validation and calibration trials conducted. This work will be needed to ensure more accurate and precise estimates of total escapement using fish device counters.

Appendix A describes in detail recommended field and statistical analysis methods to correct for each of the six types of counting errors and to estimate total escapement with measures of precision and bias. We recommend hiring or contracting with a biostatistician to provide technical assistance during implementation (as described in Chapter 12).

CHAPTER 3

ESTIMATING CHINOOK SALMON ESCAPEMENT USING MARK-RECAPTURE CARCASS SURVEYS

Since the mid-1950s, Chinook salmon mark-recapture carcass surveys have been widely used in the Central Valley (CV) to estimate in-river escapement. Data collection and analysis methods have varied both within and between CV monitoring programs. Various population models have been used to estimate escapement, but measures of precision are usually not reported. There is a wealth of literature describing mark-recapture methods (see Amstrup et al. 2008 for a review). However, a carcass-based mark-recapture study has a few unusual characteristics that prevent the use of standard techniques for estimating Chinook salmon escapement. The objective of this chapter is to recommend statistically sound methods for using mark-recapture carcass survey data to obtain unbiased estimates of Chinook salmon escapement, along with measures of precision (e.g., 90% confidence intervals). Recommendations are based on a review of mark-recapture methods and results of a simulation model comparing four estimators: pooled Petersen, modified Schaefer, Jolly-Seber and the Cormack-Jolly-Seber. We begin this chapter with a description of the general sampling situation for a mark-recapture carcass survey. Then we describe the difficulties of a mark-recapture carcass survey using common techniques historically employed in the CV, followed by some results of a computer simulation designed to compare different mark-recapture estimators. Finally, we provide recommended sampling procedures and data analysis methods for estimating Chinook salmon escapement using mark-recapture carcass surveys. An example protocol and procedures was developed to assist biologists with implementation (Appendix B).

Sampling Situation

Chinook salmon are an anadromous species – as adults they return from the ocean to their natal freshwater streams to spawn and then die. The spawning season can range from several weeks to several months depending on the race (e.g., fall, winter or spring), size of run, and ocean and stream conditions. In most cases, Chinook salmon die close to where they spawn or at least within the same stream, with the possible exception of males or jacks (precocious males). After death, a carcass is exposed to scavengers, natural decay, and the hydrology of the system. This means that once spawning in a stream begins, new carcasses enter the system on a daily basis and may be removed at any time by scavengers or be swept out of the system by hydrological events. In addition, decay of a carcass can reduce the chance that it is detected by even the most skilled biologist and can reach a point where the carcass literally becomes a mushy, unrecognizable mass or a skeleton of bones.

Mark-recapture carcass surveys usually begin around the time the first spawners appear in the system and continue until the time no fresh carcasses can be found. Teams of biologists make frequent passes through the system, usually on a systematic schedule with frequency depending on the survey area and the expected number of carcasses.

Typically, all observed carcasses are checked for marks. Unmarked carcasses are given a mark (e.g., a disc tag or colored flagging on a wire ring attached through the snout or lower jaw) and released. Previously marked carcasses that are found again are noted and records are kept on the number of carcasses marked and released, the number of previously marked carcasses detected, and the total number of carcasses handled during each survey event.

Some biologists in the CV have modified the general mark-recapture approach described above. These adjustments were either attempts to reduce work-loads and improve efficiency or were based on the assumption that not all carcasses in the system had the same probability of detection or survival rate. For example, in many surveys only ‘fresh’ carcasses are being marked and released back into the system. Non-fresh carcasses are checked for tags and then chopped in half using a machete as a way of removing the carcass from the population. Thus, non-fresh carcasses are never marked. The definition of what constitutes a fresh carcass varies across survey protocols but generally involves an examination of the clarity of the eyes, firmness of the body or color of the gills.

Using language common to mark-recapture studies, a ‘birth’ into the carcass population occurs when a fish dies, and a ‘death’ occurs when a carcass leaves the system via scavengers, hydrological transport, or decays to an unrecognizable state. When a carcass is removed from the population via chopping in half this is called ‘death on capture’.

Common Mark-Recapture Analyses and the Superpopulation Model

Common Mark-Recapture Analyses – Closed-population mark-recapture models assume no births or unknown deaths during the survey period. Known removals (i.e., deaths on capture) are allowed. Some closed-population models may be more robust to unknown deaths compared to others, provided the marked and unmarked individuals die at similar rates. However, none of the closed-population models can account for births into the population as births yield unmarked individuals only. Petersen-type estimators, including the well known Lincoln-Petersen, stratified Petersen, and pooled Petersen are closed-population models. Modifications to the Petersen estimators made by Chapman (1951) also only apply to closed populations. The Schaefer estimator (Schaefer 1951) generally requires the same conditions as the Petersen (e.g., closed-population) and has the same expected performance (Schwarz et al. 2002). The modified Schaefer (Boydstun 1994), which includes an adjustment for sampling with replacement, still only applies to closed populations.

Open-population models allow for births and deaths during the survey period. The two most common open-population models are the Jolly-Seber (JS; Seber 1982) and the Cormack-Jolly-Seber (CJS; Cormack 1964). The JS allows for direct maximum likelihood estimates (MLE) of the total population size, N_j, during each survey period j. For the JS to be unbiased, the following assumptions must hold:

1) marks must be retained and individuals must be correctly identified as being marked or unmarked

2) every individual in the population at a given survey time j has an equal chance of being captured (p_j) in that sample;
3) every individual in the population just after survey time j has an equal chance of survival (ϕ_j) until the next survey occasion;
4) survey periods are nearly instantaneous (i.e., no births or deaths during the survey); and
5) emigration from the population is permanent.

Pollock et al. (1990) identified that heterogeneity in the capture probabilities across individuals can result in population size estimates that are negatively biased.

The CJS model does not directly result in estimates of N_j, but they can be obtained using the MLE of the p_j and a Horvitz and Thompson approach (Nichols 2008). The assumptions required for the CJS model includes (1), (4) and (5) above, but not (2) or (3), since the model conditions on the first capture (Nichols 2008). Conditioning on first capture means that estimates of p_j and ϕ_j come only from those animals marked and released back into the population. Thus, equal survival and capture probabilities for both marked and unmarked animals are not necessary to obtain unbiased estimates, provided the proper covariates related to survival and capture probabilities are included in the analysis (*see below*). Following initial marking, equal survival and catchability is not necessarily required because the CJS model can accommodate inclusion of external covariates, thus allowing heterogeneity (variation among individuals) in the population. For example, if larger carcasses have a higher probability of capture and measurements on individual carcasses are recorded, this source of heterogeneity can be modeled and does not cause negative bias in the final estimates of the N_j.

The Superpopulation model – The standard method for estimating total population size during the survey period using the JS and CJS models is to average the N_j values to obtain an ‘average population size’ during the study period. This approach is not expected to work well when many individuals enter and leave the system as if on a conveyor belt (think of a long spawning season and the births and deaths of carcasses). Fortunately, Crosbie and Manly (1985) and Schwarz et al. (1993) have studied this problem and reparameterized the JS model by focusing attention to a new parameter, N, representing the size of the total number of unique individuals that ever entered the system. This ‘superpopulation’ approach involves estimating the total number of births (new carcasses) that occurred during the survey. Although the superpopulation approach was originally applied to the JS model, this approach can just as easily be applied to the CJS model.

To describe the superpopulation approach, the following definitions are needed:

Let

S = the number of survey periods;

p_j = the probability of capture in period j;

ϕ_j = the probability of a carcass surviving in the system from period *j* to period *j* + 1;

M_j = the marked population size just before period *j;*

N_j = the population size in period *j*;

B_j = the number of new carcasses (births) in the interval from period *j* to period *j* + 1;

m_j= the number of carcasses captured at sampling occasion j that are marked;

n_j= the total number of carcasses captured (and checked for marks) at sampling occasion j;

R_j= the total number of carcasses at sampling occasion j that are released with marks;

r_j= the number of members of the Rj captured again on some later occasion; and

z_j= the number of carcasses in the marked population not captured at sampling occasion j that are captured again later. Note that the number of marked individuals not captured at occasion j is ($M_j - m_j$)

The superpopulation modification to the JS first computes two slightly different estimates of the total marked population size just before period *j*:

$$\tilde{M}_j = m_j + \frac{(R_j+1)z_j}{r_j+1} \quad [1]$$

and

$$\hat{M}_j = m_j + \frac{(R_j)z_j}{r_j} . \quad [2]$$

for *j* = 2, 3, …, *S*-1. Then, an estimate of the probability of a carcass surviving in the system from period *j* to period *j* + 1 (*j* = 1, 3, …, *S*-2) is estimated using

$$\tilde{\phi}_j = \frac{\tilde{M}_{j+1}}{\hat{M}_j + R_j - m_j} . \quad [3]$$

The total number of individual carcasses in the system during each period *j* (*j* = 2, 3, …, *S*-1) is then estimated using

$$\tilde{N}_j = \frac{\tilde{M}_j(n_j+1)}{m_j+1} , \quad [4]$$

and the total number of births for each period *j* (*j* = 2, 3, …, *S*-2) is estimated as

$$\tilde{B}_j = \tilde{N}_{j+1} - \tilde{\phi}_j\left[\tilde{N}_j - (n_j - R_j)\right] . \quad [5]$$

The number of births is then adjusted for those that entered the system between periods *j* and *j*+1 but did not survive to period *j*+1:

$$B^*_j = \tilde{B}_j \frac{\ln(\tilde{\phi}_j)}{\tilde{\phi}_j - 1} . \quad [6]$$

This adjustment assumes that carcasses leave the system uniformly between periods *j* and *j*+ 1 (Crosbie and Manly 1985). Other distributions can be used (see Schwarz et al.

1993), but a uniform seems most appropriate for Chinook salmon carcasses and a systematic survey schedule.

Finally, an estimate of total escapement can be obtained using

$$\hat{N}_{escapement} = \tilde{N}_2 \frac{\ln\left(\tilde{\phi}_1\right)}{\tilde{\phi}_1 - 1} + B_2^* + B_3^* + \ldots + B_{S-2}^* \quad . \qquad [7]$$

To apply the superpopulation modification to the CJS model, the parameters ϕ_j and p_j are estimated via maximizing the CJS likelihood using numerical optimization (i.e., via Maximum Likelihood), and then estimating $\tilde{N}_j$ using the Horvitz-Thompson (1952) population estimator. Total escapement is then estimated using equations [5] – [7] above.

Comparison of Models – For a simple comparison of the pooled Petersen (Chapman 1951), modified Schaefer (Boydstun 1994), and the superpopulation modifications to the JS (Crosbie and Manly 1985) and CJS (this document) a computer simulation was conducted with a population of 5000 individuals entering the system over an 11 week time period according to the distribution shown in Figure 7. A survey was conducted every week in the simulation. The probability of a carcass surviving from period *j* to period *j*+1 was set at $\phi_j = 0.6$ and the probability of capture for each period *j* was $p_j = 0.4$. These rates are similar to historic rates seen in the CV. Only fresh carcasses (≤ 2 weeks old) were marked, and all non-fresh and recaptured marked carcasses were removed from the system (i.e., chopped). Although the parameters ϕ_j and p_j in the CJS model can be related to a suite of covariates potentially related to survival and capture probabilities using a logistic function, this simulation assumed these parameters could change over time but were not related to other carcass characteristics. A total of 1000 replications were performed for each simulation.

Simulation results indicated that both the pooled Petersen and modified Schaefer estimators had large positive bias (Figure 8). One interesting note is that the difference between the average estimated population sizes from the pooled Petersen and modified Schaefer estimators was approximately equal to the number of carcasses marked and released back into the system after the first survey period, which is the modification of the original Schaefer estimator.

A closer inspection of the superpopulation modification to the JS and CJS models was conducted considering population sizes of 5000, 500 and 250 with capture rates of 0.4 or 0.3. Results of these simulations (Table 1) indicated the superpopulation modification to the JS and CJS models had little bias and acceptable levels of precision even for extremely small population sizes and lower capture probabilities.

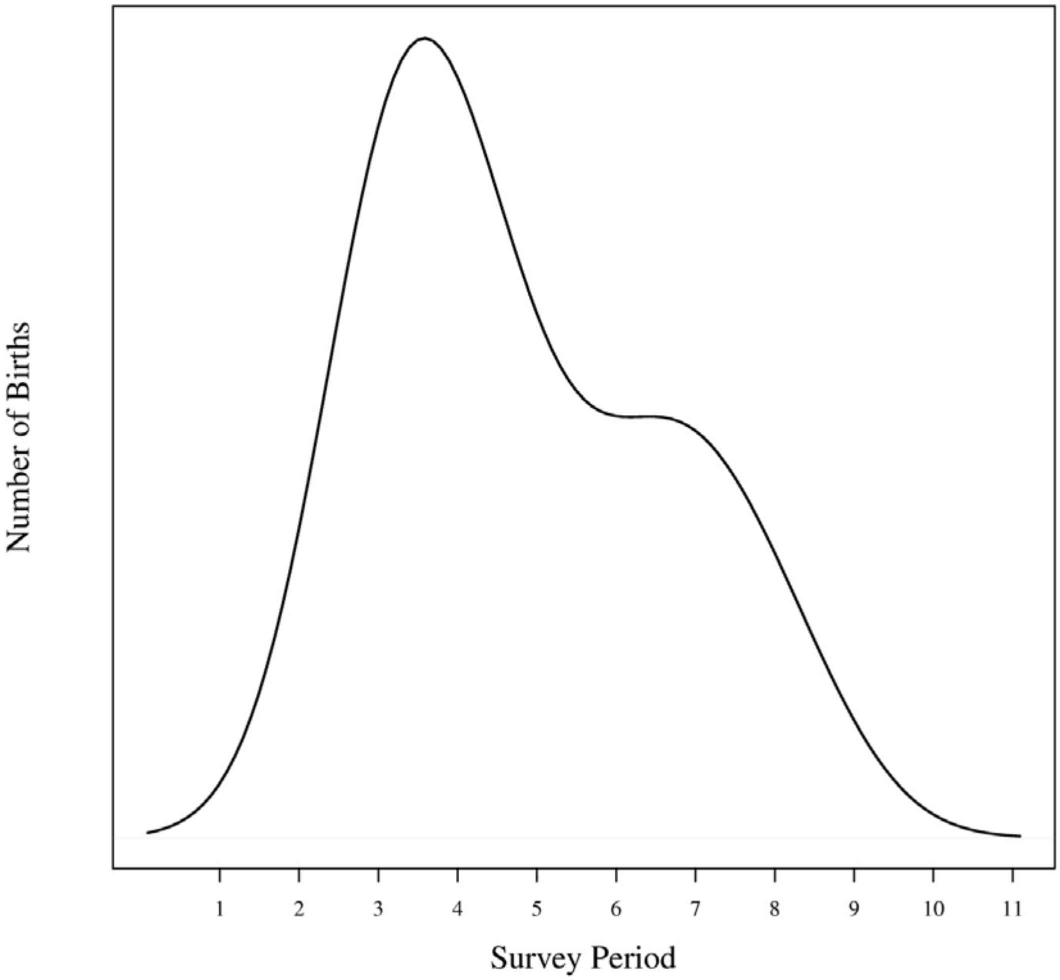


Figure 7. Simulated distribution of the number of new carcasses ('births') entering the system during an 11-week survey.

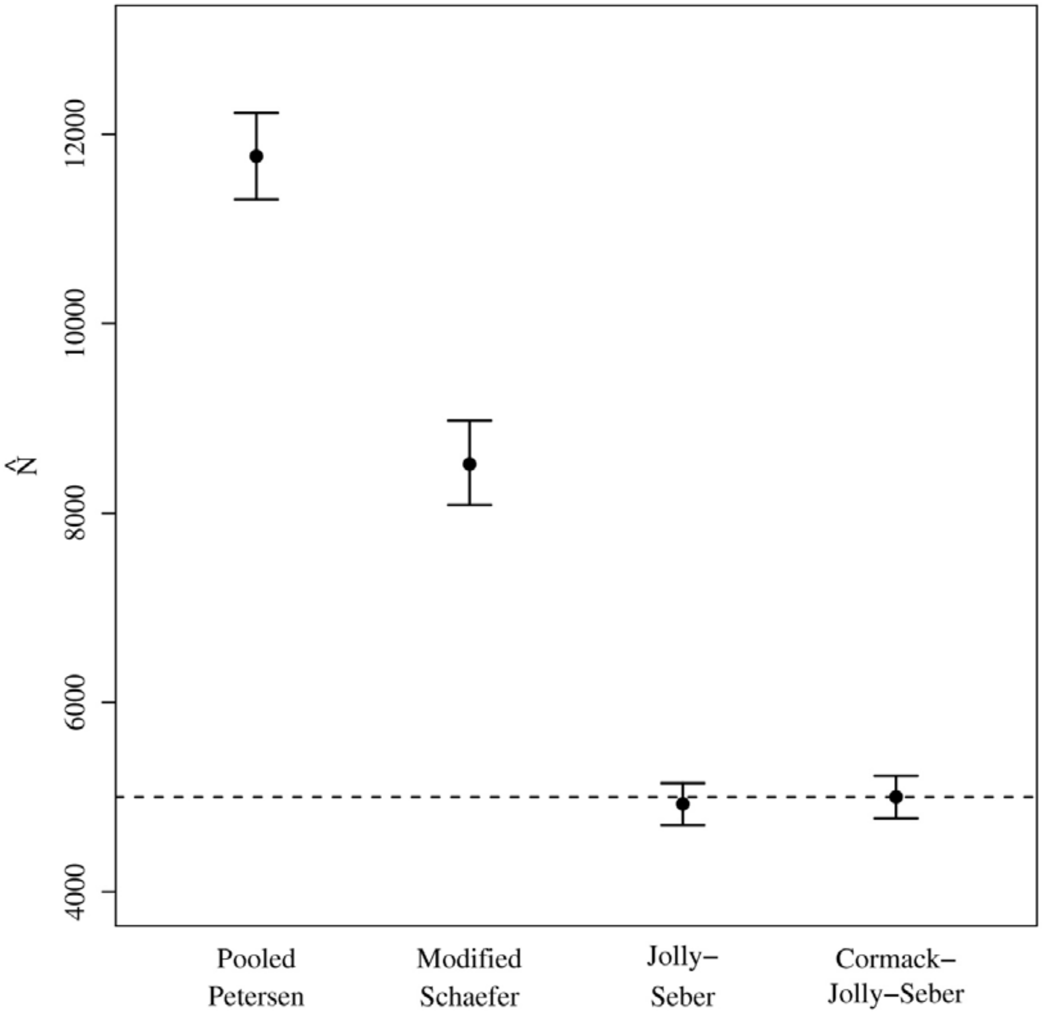


Figure 8. Simulation results for an open population mark-recapture study with a population size of 5000, 11 survey periods with births following the distribution shown in Figure 1, probability of capture = 0.4, and probability of survival = 0.6. Only fresh carcasses (≤ 2 weeks old) were marked and all recaptures and non-fresh carcasses were chopped. Points represent mean estimates of total population size and vertical bars represent the upper and lower bounds of the central 90% of the simulation results.

In order to demonstrate the effect that heterogeneity in capture rates can have on the JS and CJS models an additional simulation was conducted similar in nature to the previous. This simulation considered a population size of 5000, 500 and 250 carcasses and a survival rate of $\phi_j = 0.6$. However, capture probabilities varied from carcass to carcass based on a uniform distribution with a lower limit of $p_j = 0.15$ and an upper limit of $p_j = 0.45$. Results of this simulation confirm that unmodeled heterogeneity in capture rates will result in negatively biased estimates of *N* using either the JS or CJS estimator (Table 2).

Table 1. Percent bias and coefficient of variation of escapement estimates from the superpopulation modificiation to the Jolly-Seber and Cormack-Jolly-Seber estimators based on computer simulations (1000 replications). A survival rate of 0.6 was used in all simulations mimicking a sampling scenario that focused on marking fresh carcasses only and chopping all non-fresh carcasses and marked carcasses after 1st recapture.

		Jolly-Seber		Cormack-Jolly-Seber	
N	Probability of Capture	% Bias	CV	% Bias	CV
5000	0.4	-1.44%	0.03	0.04%	0.03
	0.3	-1.08%	0.04	0.54%	0.04
500	0.4	-0.40%	0.12	1.14%	0.09
	0.3	1.40%	0.18	1.16%	0.13
250	0.4	2.98%	0.21	2.73%	0.14
	0.3	4.18%	0.39	3.03%	0.27

Table 2. Percent bias and coefficient of variation of escapement estimates from the superpopulation modificiation to the Jolly-Seber and Cormack-Jolly-Seber estimators based on computer simulations (1000 replications) with heterogeneous capture probabilities sampled from a uniform distribution with a minimum of 0.15 and a maximum of 0.45. A survival rate of 0.6 was used in all simulations mimicking a sampling scenario that focused on marking fresh carcasses only and chopping all non-fresh carcasses and marked carcasses after 1st recapture.

	Jolly-Seber		Cormack-Jolly-Seber	
N	% Bias	CV	% Bias	CV
5000	-5.52%	0.04	-4.50%	0.04
500	-5.56%	0.18	-4.84%	0.15
250	-7.70%	0.33	-6.38%	0.25

Discussion and Recommendations for Estimating Chinook Salmon Escapement Using Mark-Recapture Carcass Surveys

In general, preference is given to a sampling situation that involves marking all fresh carcasses with unique identification numbers and returning all recaptured carcasses into the system for possible future recoveries. However, in order to better mimic historical carcass surveys in the CV the simulation did not include returning recaptured carcasses to the system. If recaptured carcasses were returned to the system, the performance of the superpopulation JS and CJS procedures are anticipated to equal or exceed the performances demonstrated here due to an increase in sample sizes and information related to survival and recapture. Results of the simulation (Figure 8) illustrate the difficulty in estimating abundance for an open population using methods designed for closed populations. Since closed population models are not appropriate for Chinook carcass mark-recaptures surveys in the CV no further discussion on these methods is warranted. Differences in estimates between the JS, pooled Petersen and modified Schaefer estimators will likely vary according to the survival and capture probabilities, number of survey periods, the rate of death on capture and the distribution of birth rates.

The simulation results indicated the CJS was generally more robust (i.e., lower bias and higher precision) than the JS. In addition, the ability of the CJS to handle covariates related to heterogeneity in the population and the relaxed assumptions of equal catchability and survival between marked and unmarked fish make the CJS the method of choice for Chinook salmon carcass mark-recapture surveys. Some biologists in the CV have expressed concern about the effect of high-flow events that have the potential to wash out a majority of carcasses in the system. The CJS estimates of survival and capture probabilities should be lower during these events. Of course, frequent flushing of a system can drastically reduce sample sizes which may occasionally complicate estimation of escapement. However, such events only strengthen arguments for using an open-population model like the CJS that can allow for time-varying survival and capture probabilities.

The simulation study was conducted to illustrate the differences between the pooled-Petersen, modified Schaefer, JS and CJS models under somewhat simple conditions using realistic survival and capture probabilities. More simulations are recommended following a few years of data collection under the CJS approach in order to better understand the effect of sample sizes (number of carcasses) and the number of survey periods necessary for acceptable levels of precision for each survey section.

The superpopulation modification of the Cormack-Jolly-Seber model is recommended to be used to estimate Chinook salmon escapement with mark-recapture carcass surveys. Below are recommended sampling procedures and data analyses for a mark-recapture carcass survey using the superpopoulation modification of the Cormack-Jolly-Seber model.

Field Methods

The mark-recapture carcass survey must begin before any new carcasses are lost from the system, and the survey area should either encompass all known Chinook salmon spawning habitat or a random sample of spawning locations. Equally as important is to maintain the surveys throughout the spawning period until well after no new carcasses are found. Violation of this survey schedule is expected to result in population estimates that are biased low. Thus, the interval between mark-recapture carcass surveys should not exceed seven days.

The definition of what constitutes a fresh carcass in the CV varies across survey protocols but generally involves an examination of the clarity of the eyes, firmness of the body or color of the gills. A standard definition for a fresh carcass in the CV is not necessary and can change over time. However, whatever definition a biologist uses must be consistent and maintained throughout a mark-recapture study season.

All carcasses should be tagged with a uniquely numbered disc-tag in the lower jaw. Tagging in the lower jaw will allow for larger sample sizes in streams with a relatively large number of marked hatchery fish, as the snouts from these carcasses should be removed for CWT recovery. However, systems experiencing large numbers of returns and lower proportions of ad-clipped fish can tag carcasses in the upper jaw and chop ad-clipped carcasses on first capture to reduce survey effort. Again, analysis of future data collected for CJS estimation will allow for evaluating the potential violation of the CJS assumptions and assessing the sample size requirements in various streams.

Covariates (e.g., fork length, sex, fresh or non-fresh, ad-clip or unclipped, otoliths taken) are recommended to be used to examine if capture and survival probabilities of carcasses are homogenous. To include covariates in the analysis, an individual capture history needs to be recorded for each tagged carcass. Thus uniquely numbered disc-tags should be used for marking. All carcasses should be tagged on the lower jaw with a numbered disc tag because of the need to recover the snout/upper head from all adipose-fin clipped carcasses encountered. Central Valley hatcheries currently mark (ad-clip) and coded-wire tag (CWT) 100% of spring, winter, and late fall-run juveniles released into the system. Hatcheries have operated with a target goal of tagging production releases of fall-run Chinook salmon since 2007 at a minimum rate of 25%. CWT recoveries in the escapement are a critical component of these tagging programs. Recommended sampling procedures for biological data and CWTs are described in Chapter 4.

In systems where the number of carcasses encountered is expected to be low (e.g., <500), every carcass encountered should be tagged, including non-fresh carcasses provided the carcass will not further deteriorate upon handling and biological data (e.g., sex, length) can be measured reliably. This will increase the sample size available for estimating escapement with the recommended model and improve the model’s precision and accuracy, particularly when covariates (e.g., fresh or non-fresh, length, sex) related to capture and survival probabilities are included to account for potential heterogeneity in the carcasses.

In systems where the number of carcasses is expected to be high, biologists can chose to mark all carcasses or mark only the fresh carcasses. The amount of resources available will likely determine what carcasses are tagged. Whatever decision is made, the marking strategy must remain consistent during a survey period.

In some systems escapement may be very high in some years making it difficult to handle every fresh carcass encountered. If resources do not permit this level of effort, we recommended systematically sub-sampling carcasses in these situations. For example, inspect (but do not chop) and tag every third carcass encountered, regardless of whether every third carcass is considered to be fresh. This sampling situation will result in lower sample sizes and lower capture probabilities, but will not otherwise bias results. Another option is to inspect every carcass but only mark every N^{th} carcass (provided it is not already marked).

If resources are available, all recaptured carcasses should be returned into the system for possible future recoveries. If a carcass is recaptured more than once and becomes very deteriorated the biologist can remove the carcass from the system by chopping the carcass in half. However if resources are not available for this level of effort recaptures should be chopped in half to reduce survey effort for subsequent surveys. The unique tag number should be recorded for each recapture event and if the carcass was removed from the system (chopped in half). At some time, a carcass will decay to the point where it is not possible to handle and mark, reliably measure length or determine the sex of the fish, or accurately identify whether the fish was ad-clipped. At this stage, the carcass should be inspected for a disc tag and chopped.

Data Analysis Methods

The superpopulation modification of the Cormack-Jolly-Seber model (described above) is recommended to be used to estimate Chinook salmon escapement. In addition, until homogeneity of capture and survival probabilities can be demonstrated, the appropriate covariates (e.g., fork length, sex, fresh or non-fresh, ad-clip or unclipped, otoliths taken) potentially related to these probabilities should be recorded and included in the analysis. An information theoretic approach such as the small sample variant of Akiake's Information Criterion (AICc; Burnham and Anderson 2002) should be used to compare models with different combinations of covariates. AICc is calculated as $-2\log(Likelihood) + 2kn/(n-k-1)$, where k is the number of parameters in the model (including intercept terms), n is the number of observations used to fit the model, *Likelihood* is the value of the logistic likelihood evaluated at the maximum likelihood estimates, and 'log' is the natural logarithm. The model with the lowest AICc value is generally chosen as 'best' and used to make final inferences. The small sample variant of AIC eventually converges and agrees with the larger-sample version (AIC) once sample sizes become large enough.

Implementation of the CJS model has been made relatively easy in the **mra** contributed package (McDonald 2010) for R (R Development Core Team 2010). R is free-ware and is becoming the standard software around the world for statistical analysis and graphics. Required input to the **mra** function for estimating the CJS model includes a matrix of capture histories, with one row for each individual encountered during the surveys. The matrix should be of size *nXs*, where *n* is the total number of unique carcasses handled and *s* is the number of survey events, or periods. When a carcass enters the marked population or is found marked and released back into the population, a 1 is entered into the appropriate cell of the capture history matrix to indicate “capture”. A value of 2 in the matrix represents when a carcass is removed from the marked population (death on capture; e.g., chopped). All other cells in the matrix receive a value of 0, indicating the carcass was not handled. For example, if three carcasses are handled during a survey with 5 repeated sweeps of the stream, the matrix might look like

$$\begin{matrix} 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 2 & 0 & 0 \\ 0 & 0 & 0 & 2 & 0 \end{matrix}$$

In this example carcass #1 was caught and marked in period 2, then not captured again until period 4 when it was released back into the population. Carcass #2 was first captured and marked in period 1, recaptured in period 2 and released back into the population, and then recaptured again in period 3 but chopped and removed from the population. Carcass #3 was first captured in period 4 and chopped on first capture.

In addition to the capture history matrix described above, an additional data frame with measured values for each handled carcass is required for including covariates related to probability of capture or survival in the CJS model. This data frame should have the same number of rows (*n*) as the capture history matrix, and match the rows and columns of the capture history matrix 1 to 1 (i.e., row 1 in covariate matrix represents the same carcass as row 1 in the capture history matrix).

In the simulations the CJS model failed to converge on Maximum Likelihood estimates in a small proportion of the replications when the population size was low (250 individuals). In other words, the numerical optimization routine used to estimate survival and capture probabilities failed to return valid estimates. If the CJS numerical optimization routine fails to converge during analysis of real data biologists are recommended to resort to the JS as there is a closed form solution to the estimator which cannot suffer from convergence problems. However, convergence problems for the CJS model may also result from using (or ignoring) incorrect (or important) covariates related to capture and/or survival probabilities.

Given the complexity of the superpopulation modification to the CJS, a nonparametric bootstrap (Manly 2007) is recommended to be used to estimate standard errors (SE) and 90% confidence intervals (CI) for total escapement. Confidence intervals and SEs for other parameters such as capture and survival probabilities can be obtained through the Fisher Information Matrix, and are standard output from the **F.cjs.estim** function in the **mra** package.

CHAPTER 4

RECOVERING CODED-WIRE TAGS AND COLLECTING BIOLOGICAL DATA

The primary objective of this plan is to improve estimates of the total number of Chinook salmon that return to streams in the Central Valley (CV) to spawn (escapement). However, additional biological data (e.g., sex ratios, age and length distributions) and coded-wire tag (CWT) recovery can enhance understanding of the life history, status and health of each stock, and are critical to improved management. This chapter describes the need for CWT recovery and collection of biological data, and recommends procedures for obtaining a representative sample (i.e., unbiased) of the spawning population. An example protocol and procedures was developed to assist biologists with implementation (Appendix B).

Need for Data Collection

Coded-Wire Tags (CWT) – CWTs need to be recovered in an unbiased manner to examine the contribution of hatchery and natural origin Chinook salmon on the spawning grounds, and determine the stray rates of various stocks (M. Palmer-Zwahlen, CDFG, pers.comm., 2010). In addition, CWT data can be used to monitor the recovery of listed runs (Crawford and Rumsy 2009) and evaluate CV hatchery operations.

Over 32 million fall-run Chinook salmon are produced annually at five hatcheries in the CV (Buttars 2010). In 2007, a CV Constant Fractional Marking (CFM) Program was initiated, targeting the marking (adipose fin clip) and coded-wire tagging of a minimum of 25% of the production releases of fall-run Chinook salmon from hatcheries in the CV. In addition, 100% of the CV hatchery releases of winter, spring, and late fall-run Chinook salmon are marked and coded-wire tagged.

CDFG calculates the number of hatchery fish in a population based on the escapement estimate, a ‘production factor expansion’, a ‘catch sample expansion’ and adjustments for shed tags and other anomalies. Unique CWT codes are used by hatcheries in the CV to identify release groups of fish. Each release group may not have the same proportion marked; therefore a ‘production factor expansion’ is calculated for each release group. The ‘production factor expansion’ is the total number of fish released divided by the total marked. Multiplying the number of tags for a release group observed in the sample of carcasses with the release group’s ‘production factor expansion’ gives the total number of carcasses in the sample that are from that release group. A ‘catch sample expansion factor’, which is the escapement estimate divided by the number of carcasses in the sample, is multiplied by the number of hatchery carcasses in the sample to estimate the number of hatchery fish in the population.

The CFM program requests that all carcasses (fresh and non-fresh carcasses) observed be examined for an adipose fin clip to recover CWTs. However, subsampling may be needed if it is not possible to examine all carcasses for an adipose fin clip. Sampling all fresh carcasses or systematically sampling every N^{th} carcass would provide a representative sample of the spawning population. Knowing the number of carcasses examined for an adipose fin (sample size) is important for calculating the 'catch sample expansion'. Carcasses that are decayed to point where the presence or absence of an adipose fin cannot be determined should not be included in the sample, but chopped in half and not recorded on the data sheet. The sample size will then depend on the sampling frequency for carcasses (i.e., all carcasses, all fresh carcasses, or every N^{th} carcass). For example, if all fresh carcasses are being sampled the sample size would be the total number of fresh carcasses observed and examined for an adipose fin. If every 2nd carcass is examined for an adipose fin clip, the sample size would be the total number of carcasses examined (every 2nd carcass) where an adipose fin clip could be detected.

Scale samples, sex, fork length measurements, survey period, and survey reach need to be collected for every sampled ad-clipped carcass. This information and a unique ID number needs to be recorded on the datasheet or PDA and the head tag which is attached to the collected head.

Scale Samples – Age data are important for improved CV salmon management. Harvest rates for Central Valley fall-run Chinook salmon stocks are now established based on the unrefined Sacramento Index, a relationship between 2-year-old and older fish. Age and race-specific Chinook salmon escapement data in the Central Valley, as in the Klamath River basin, will allow development of more accurate models for ocean harvest management, and development of a full life cycle model for each Chinook run.

Age information may also be needed to assess the recovery of listed Chinook salmon runs. The age and cohort structure of spawners (fish that actually spawned) and the age-structure of returning adults is important for assessing the VSP abundance parameter (Crawford and Rumsy 2009; Williams et al. 2007). Adult spawner abundance by cohort and origin (hatchery or natural) is needed to examine annual productivity (Crawford and Rumsy 2009). The VSP diversity parameter is measured through behavioral traits including age-at-maturity (Crawford and Rumsy 2009).

In 2007, a CV-wide scale aging program was initiated to examine the age-composition of the Chinook salmon spawning run. The program has a minimum sample size target of 550 scale samples per run for each tributary (Kormos 2007). Scales should be collected in an unbiased manner from the entire spawning run (which includes ad-clipped carcasses). Scales collected from ad-clipped carcasses are not only used to examine the age composition of the run, but are also used with CWT information for reader bias correction. If carcass numbers are low (fewer than 550 carcasses expected in an annual survey), scale samples should be collected from all carcasses observed. If carcass numbers are high, scale samples should be collected from all fresh carcasses or a systematic subsample (every N^{th}) of carcasses. Similar to the CWT recovery protocol, sex and fork length measurements are needed from every sampled carcass, and a unique ID number used to link these measurements to the scale data.

Length Measurements – Length data are used for examining the size structure of populations, examining changes in size over time, and paired with age data can be used to examine growth. The VSP diversity parameter is measured through morphological characteristics including size.

Sex Determination – Sex ratios are an important population parameter, used to evaluate fecundity rates (Williams et al. 2007) and the VSP productivity parameter (Crawford and Rumsy 2009).

Spawning Status – Spawning status can be used to monitor the recovery of listed Chinook salmon. Crawford and Rumsy's (2009) guidelines for monitoring the recovery of ESA listed salmonids is based on evaluating the VSP parameters (abundance, diversity, productivity, and spatial structure) of spawners (fish that actually spawned) and not escapement (fish that returned to spawn).

Genetic Tissue Samples – Genetics research can be used to examine the VSP diversity parameter (Lindley et al. 2007 and Crawford and Rumsy 2009). In addition, genetic tissue samples may be needed for future research or NMFS's efforts in development of standard GSI and PBT for Chinook salmon.

Otoliths – Fish ear stones, otoliths, provide a wealth of information about the life-history of individual fish including origin, movement, age, and growth. Otoliths are formed by the accretion of calcium carbonate deposited on a protein matrix, where otoliths accrete new crystalline and protein material on their exterior surface forming a pattern of concentric daily layers (Elsdon et al. 2008). Unlike other hard structures (scales and bones), otoliths have not been found to undergo resorption under stress conditions; therefore the otolith is a permanent record of their life-history (Jones 1992). Minor and trace elements are incorporated into accreted layers and several of these elements and isotope ratios may reflect environmental parameters. Otoliths therefore provide a chemical chronology of the entire life of the fish that serves as a natural tag to examine natal origin and tracers for determining fish movement.

In the CV, otolith microchemistry has been used to determine the natal river of origin of Chinook salmon (Barnett-Johnson et al. 2008). In addition, otolith microstructure has been used to identify the origin (hatchery or natural) of CV Chinook salmon in the ocean fishery (Barnett-Johnson et al. 2007).

Otolith microchemistry could help track the recovery of listed Chinook salmon and restoration efforts. Tracking the natal source and life-history of Chinook salmon is important for understanding the status and trends of stocks and provides information that helps understand how processes occurring in freshwater, estuarine, and marine environments influence growth, survival, and reproductive success (Barnett-Johnson et al. 2008). While CWTs allow for the examination of the contribution of hatchery fish to a population and straying of hatchery fish, CWTs cannot be used to examine straying of wild fish from their natal river. Trends in population abundance in specific streams may be masked if wild fish stray.

Recommendations for Collecting Biological Data and Recovering CWTs

1) Carcasses should be sampled to obtain a representative sample (i.e., unbiased) of the Chinook salmon spawning population using recommended sampling procedures described below.

2) Scales should be sampled from Chinook salmon carcasses to meet a minimum target goal of 550 carcasses per run established by CDFG Ocean Salmon Project.

3) Heads should be collected from all adipose fin-clipped Chinook salmon carcasses for CWT recovery.

4) Fork length should be measured for Chinook salmon carcasses. Fork length is currently the standard measurement of length for Chinook salmon carcasses in all CV watersheds. Fork length refers to the length from the tip of the snout to the end of the middle of the caudal fin rays.

5) Female carcasses should be examined for spawning status. Spawning status should at a minimum be classified as ‘spawned’ (few or no eggs remaining) or ‘unspawned’ (many eggs remaining in the body).

6) If possible biologists should collect otoliths; suggested methods for otolith collection and archive are described in Appendix B.

7) If possible biologists should collect genetic tissues; suggested methods for tissue collection and archive are described in Appendix B.

Data Collection in Mark-Recapture Carcass Surveys

In systems where mark-recapture carcass surveys will be conducted, all observed carcasses should be subjected to tagging, biological sampling and CWT recovery unless the carcass will deteriorate upon handling or biological data cannot be measured reliably. If a carcass is too decayed to detect an adipose fin, the carcass should be chopped in half and not included in the sample. Only the snout/upper head of ad-clipped carcass will be collected for CWT recovery and the bottom jaw will remain intact for tagging, unless escapement numbers are high then the entire head can be collected. When biologists anticipate that handling all carcasses will not be feasible, then the biologists should modify the protocol where the minimum scale sample size goal of 550 will be achieved. If escapement numbers are high in systems and handling all carcasses will not be possible, all fresh carcasses should be tagged and subject to collection of biological data and CWT recovery. In systems where sampling all fresh carcasses is not feasible, carcasses should be sampled in a systematic manner (i.e., every N^{th} carcass). Non-systematic sampling of carcasses (e.g., the first 50 in every reach) may result in a biased sample of biological data. For example, if a total of 1,100 carcasses are encountered during a spawning season and biological data are only collected on the first 550, there is potential for the data to be biased in space or time if spawners arriving earlier in the season are dissimilar to those arriving later in the season. Similarly, fish spawning lower in a system may not be similar to those spawning at higher elevations. A better approach in this example would be to collect biological data on every 2nd carcass encountered.

Biological data collected are recommended to be used as covariates in the superpopulation modification of the Cormack-Jolly-Seber model to estimate Chinook salmon escapement (see Chapter 3). If otoliths are to be collected from carcasses a covariate for ‘otolith sample taken’ should be considered when estimating abundance using the Cormack-Jolly-Seber model. Additional covariates that are recommended to be considered include sex, fork length, and ad-clip status. These covariates will allow for investigation into potential differences in survival and capture probabilities for carcasses of different size, sex, origin or those that have had their otoliths or snout/upper head removed.

Data Collection in Carcass Sampling Surveys

In systems where mark-recapture studies will not be conducted (i.e., systems with fish device counters), carcass sampling surveys are recommended for collection of biological data and recovery of CWTs. These carcass sampling surveys should be performed in a similar manner to the mark-recapture surveys as described above. Unlike mark-recapture carcass surveys, carcasses do not need to be tagged and all sampled carcasses can be chopped in half to reduce future survey efforts. Carcass sampling surveys should be conducted on a regular basis (i.e., weekly) and span all spawning habitat or a random or systematic sample of reaches available for spawning. Again, the biological data collected should represent Chinook salmon in the system, both in terms of spawning location (e.g., upper vs. lower) and timing (e.g., early vs. late). All observed carcasses should be subjected to biological sampling and CWT recovery unless the carcass biological data cannot be measured reliably. If a carcass is too decayed to detect an adipose fin, the carcass should be chopped and not included in the sample. When biologists anticipate that handling all carcasses will not be feasible, then the biologist should modify the protocol where the minimum scale sample size goal of 550 will be achieved. If handling all carcasses will not be possible, all fresh carcasses should be subject to collection of biological data and CWT recovery or all carcasses should be sampled in a systematic manner (i.e., every N^{th} carcass).

CHAPTER 5

RECOMMENDATIONS FOR ESTIMATING TOTAL ANGLER HARVEST AND ANGLER EFFORT WITH THE CENTRAL VALLEY ANGLER SURVEY

Inland sport harvest of Chinook salmon in California's Central Valley (CV) streams comprises a significant proportion of the total escapement. The CV angler harvest survey, reinitiated in 2007, is a long-term monitoring program designed to develop annual estimates of total angler effort and in-river harvest of sport fish in the Sacramento River and major tributaries. In addition to Chinook salmon, the survey includes a number of other species considered to have recreational value. As described in Titus et al. (2009), the key objectives of the CV angler survey specific to Chinook salmon are:

1. Analysis and reporting of angler effort and harvest,
2. Estimating the contribution of hatchery Chinook in the CV sport harvest, and
3. Estimating the age structure of Chinook salmon and steelhead in the CV sport harvest.

Estimates of Chinook salmon harvest in the inland fishery are used by the Pacific Fishery Management Council to help determine ocean harvest quotas off the coasts of California, Oregon and Washington (Titus et al. 2009).

This chapter reviews the existing angler survey design and analysis techniques used in the CV for estimating Chinook salmon angler effort and harvest (Titus et al. 2009). After describing the current angler survey protocol, we provide recommendations for future surveys and analyses of those survey data. The recommended methods will allow for estimation of precision (e.g., confidence interval [CI]), and are expected to reduce bias and improve precision of estimates of Chinook salmon angler effort and harvest in the CV.

Current Methods

Survey Design

The CV angler survey is based on a stratified sampling design developed for the Sacramento River Sport Fish Inventory (Wixom et al. 1995) and the Upper Sacramento River Sport Fishery (Smith 1950). Physical strata (river sections) have been identified, and a stratified allocation of effort is used to survey river sections each month. A total of 21 river sections ranging from 1 to 56 miles in length were surveyed in 2008 – 2009 (Titus et al. 2009). We assume that stratification of river sections is based on a combination of physical/geographic features, angler and surveyor access to the river, and unique features of the fishery (e.g., estimated historic harvest levels). In 2008 – 2009, each section was surveyed on eight randomly selected days per month: four weekdays and four weekend days. Relatively more effort was given to weekend days since angling effort during these times is typically greater.

Surveys are conducted using a method similar to what is called a 'roving-roving' survey, in combination with access point interviews. Roving-roving surveys involve a survey team traveling the entire river section at least once to count the number of anglers, and then traveling the river section again to interview anglers. Given two or more random roving (or progressive) count surveys, angler effort and total harvest can be calculated for that day, along with estimates of precision (Pollock et al. 1994). Estimates of harvest are calculated by multiplying an estimate of the amount of angler effort (e.g., number of angler-hours) by an estimate of total harvest-per-unit-effort (*hpue*; e.g., how many fish were caught by the average angler, per hour).

Only one roving count is conducted for each section, each survey, which precludes estimation of precision. This single count is combined with data from an effort distribution model (EDM) to estimate the number of angler-hours. The EDM represents an estimate of the proportion of a day's total angler-hours that occur over any period of time. For example, the EDM may identify that 12% of all angler-hours occur between 6 and 7 am on weekend days during August on a particular river section. If a roving count conducted during the same period resulted in a total count of 10 anglers, we would estimate that 83 anglers $(10 / 0.12 = 83.3)$ fished that section of river that day.

The first EDMs for the CV were developed using access interviews (Wixom et al. 1995). Access interviews occur at a representative sample of river access locations and target anglers that have completed their fishing experience for that day. Although access interviews were conducted in 2008 – 2009, development of EDMs for 2008 – 2009 based on those interviews was incomplete. Thus, the historical EDMs developed by Wixom et al. (1995) were used by Titus et al. (2009). Although historical EDMs have been compared to more recent data (Rob Titus, personal communication), no statistical comparisons were presented in Titus et al. (2009).

Roving counts and access interviews provide information regarding the number of anglers present and the total number of angler-hours during a day. In addition, for each interview all harvested fish are subject to biological data collection and coded-wire tag recovery (if adipose fin clipped), which is used for management purposes. While access interviews allow collection of completed trip information at access sites, roving interviews intercept anglers while they are still fishing. Angler success and the number of fish harvested are estimated from access point interviews and roving interviews. If time permits, every angling party in the section during the roving survey is interviewed. Otherwise, every N^{th} party is interviewed, where N is determined by field personnel and based on the time of day, number of anglers present, and field logistics.

Surveys of river sections begin at sample start times and launch locations. For each section, a survey start time is determined by randomly selecting the beginning, middle, or final 1/3 of the sample day. Actual start times within a selected period (early, middle or late) vary according to length of the survey and logistics. If a river section can be surveyed using a motorboat, a launch location (upstream or downstream) is randomly sampled for each survey. Surveys along river sections traveled by kayak or drift boat, due to available boat access and/or water depth, always begin upstream.

Estimation of Angler Effort and Harvest of Chinook Salmon

The procedures used to estimate total angler effort and harvest of Chinook salmon follow those described in Wixom et al. (1995). Three survey parameters are estimated for each river section on each survey day: (1) total effort in angler-hours (E), (2) harvest per unit of effort (*hpue*) measured as the number of Chinook salmon harvested per angler per hour, and (3) total Chinook harvest (H). Daily estimates are then expanded to provide monthly estimates. Months were chosen as the time interval for survey periods because historical CV angler surveys (e.g., Wixom et al. 1995, Murphy et al. 1999) focused on monthly estimates of angler effort and harvest.

To describe the estimators used for each parameter, the following definitions are needed:

Let b = time required to conduct a roving (roving) count pass through the section;
E = total angling hours for all species;
$E_{Chinook}$ = total angling hours for Chinook salmon;
e = length (hours) of a fishing experience for an interviewed angler;
H = total harvest in numbers of Chinook salmon kept (or released) by anglers;
h = total numbers of fish kept (or released) during a fishing trip by an interviewed angler;
P = proportion of anglers present during a given period of day (based on EDM);
$P_{Chinook}$ = proportion of angler-hours targeting Chinook salmon (based on interviews);

Estimates of total angler effort for all species for a particular day is calculated by dividing the roving angler count (n) by the estimated average proportion of individual anglers present in the section for the period during which the count was made:

$$\hat{E} = \frac{n}{P}, \tag{1}$$

where P is based on the EDM and time period when the roving count was conducted.

Estimates of angler effort specific to fishing for Chinook salmon are calculated for each sampled day, using

$$\hat{E}_{Chinook} = \hat{E} \times P_{Chinook} . \tag{2}$$

The average daily *hpue* is estimated by dividing a sample day's average number of Chinook salmon harvested by the average number of hours fished for Chinook by the anglers interviewed (i.e., a ratio of means):

$$\overline{hpue} = \frac{\bar{h}}{\bar{e}} . \tag{3}$$

Harvest is estimated sample day in the CV angler survey by multiplying an estimate of $\overline{hpue}$ (equation [3]) by an independent estimate of effort for that sample day:

$$\hat{H} = \hat{E}_{Chinook} \times \overline{hpue}. \tag{4}$$

Separate estimates are made for kept and released fish, and total harvest is calculated as the sum of harvests over days, months and or river sections of the survey. No variance estimates or confidence intervals are available for estimates of angler effort (equations [1] and [2]) or total harvest (equation [4]), since only one roving count is conducted for each river section, each survey.

Recommendations

Separate EDMs have been developed for various river sections in the CV (Wixom et al. 1995), but not for all 21 river sections surveyed in 2008 – 2009 (Titus et al. 2009). In addition, the EDM method used for estimating angler effort assumes that the distribution of hourly effort throughout each day is constant for all days regardless of the date or year (and possibly section) of the survey. We believe this tenuous assumption is not met in many situations (e.g., holidays, inclement weather). In addition, as mentioned above, using only one roving count per survey day precludes estimation of precision for both angler effort and total harvest, which is critical for trend monitoring and effective management of the fishery. Thus, we recommend that the current angler survey be continued, but with some modification.

We recommend roving-roving surveys include two or more roving counts of anglers at random times during the day, with a randomized direction of travel (when practical). These counts can then be used for calculation of total angler-hours for a sampled day. This approach follows several angler survey designs described in the literature (e.g., Wade et al. 1991, Pollock et al. 1994, Bernard et al. 1998), and if implemented correctly, can be expected to produce accurate estimates of harvest and effort (Hoenig et al.1993). We describe one possible method of implementing the multiple roving count approach below. In addition, formulas for estimating total harvest based on access interviews or a combination of roving and access interviews are provided in Appendix C, which is the full report completed by WEST Inc. with the review and formulas. Currently, data is collected for each angling party interviewed. However, future surveys should involve collecting data at the level of individual anglers to permit proper variance estimation.

Implementing Two or More Roving Counts

There are many ways in which two or more roving counts can be conducted, but all methods assume that a random start time, and possibly a random direction of travel (upstream or downstream) can be selected for each count. We envision the simplest approach, which is to conduct only two roving counts for a river section within a survey day, with one occurring either before or after a roving interview survey, and the other occurring during the roving interview.

If a roving count is expected to take b hours, then divide the fishing day into B blocks of length b, and randomly select one of the blocks for the roving count. For example, if the fishing day is 14 hours long, and a roving count would require b=1 hour, the survey day would be divided into B=14 blocks of time. A random sample of the 14 blocks would determine when the roving count was conducted, and a coin-flip would determine whether the roving interview was conducted prior to, or following the roving count. If a sampled block is near the beginning (end) of the day and a roving interview cannot be conducted (before) after the roving count, the roving interview can be conducted after (before), as long as the randomly selected start time for the roving count is maintained. It is important to randomly select the starting time for the first roving count each sampled day for each river section.

If *b* hours were required to complete a roving count, an unbiased estimate of the fishing effort in any particular *b* block of time is calculated as

$$\hat{E}_b = x \times b \,, \qquad [5]$$

where *x* is the number of anglers counted. When a roving count of anglers is conducted using a random start time and direction of travel, the count can be considered an unbiased estimate of the mean number of anglers fishing during any block of time of that duration (Hoenig et al. 1993, Robson 1961). Thus, if the fishing day contains *B* *b*-hour blocks, an unbiased estimate of the total fishing effort in angler-hours for the day is estimated using (Hoenig et al. 1993)

$$\hat{E} = x \times b \times B \ . \qquad [6]$$

The second roving count during a survey can either take place at a random time (same methods described above), or during the roving interview. Since a count of anglers during the interview process may result in a substantial underestimate of fishing effort due to length-of-stay bias (Wade et al. 1991, Pollock et al. 1994:244, Bernard et al. 1998), we recommend including adjustments in the survey protocol involving scheduled checkpoint locations (Wade et al. 1991). Length-of-stay bias exists when the amount of time an angler spends on the river depends on his or her fishing success.

The checkpoint method insures that anglers are counted evenly along the entire survey section through the sampling period. A time schedule is followed so the survey team reaches specific checkpoints at designated times along the survey. Although fewer angler interviews may be conducted using the checkpoint method because some anglers may need to be skipped in order for the survey to stay on schedule, the resulting estimate of effort is expected to be accurate. Total angler-hours using the checkpoint method can be calculated using equation [6].

Using two roving counts to obtain two estimates of angler effort (equation [6]), the average angler effort for the survey day should then be used as the final estimate of total angler-hours:

$$\hat{E} = \frac{\hat{E}_1 + \hat{E}_2}{2} \ . \qquad [7]$$

Anglers are usually classified by harvest type, i.e. whether they will (are) going to keep or release any Chinook caught. The proportion of anglers determined to be targeting Chinook is multiplied by the roving total count of anglers to obtain the number of Chinook anglers. The number of sample day hours determined to belong to each harvest category (kept or released) is the product of the number of hours in the day and the proportion of total hours fished by harvest type. This allows for partitioning of estimates of Chinook angler effort and harvest by harvest type.

We recommend that information on angler-trips of less than 0.5 hours not be used in $\overline{hpue}$ calculations based on the roving-roving survey due to the fact that the angler(s) was likely interviewed prior to completion of their 'angling trip'. This tends to stabilize the variance of the estimates of angler effort and harvest, while not contributing appreciable bias (Pollock et al. 1997).

Estimation of $\overline{hpue}$ and total harvest using the roving-roving survey design with at least two roving counts follows equations [3] and [4], with details in Appendix C. Variance estimates for angler effort and harvest for a survey day are also presented in Appendix C. In addition, we present formulas for estimating angler effort and harvest using a combination of roving and access point interviews.

Conclusions

The CV Angler Survey uses a stratified random roving-roving design in which access interview data is also sometimes used in combination with roving interviews to estimate angler effort and harvest of Chinook salmon. However, a historical EDM is used in place of two or more random roving counts. Use of the historical EDM requires tenuous assumptions, and precludes estimation of CIs for total harvest. A modification of the current approach would improve estimates (reduce bias and improve precision), and allow for calculation of CIs. This modification involves conducting multiple (two or more) roving counts of the number of anglers each survey day, where one of the counts can be conducted simultaneously with the roving interview survey.

CHAPTER 6

RECOMMENDED CHINOOK SALMON ESCAPEMENT MONITORING FOR THE BASALT AND POROUS LAVA DIVERSITY GROUP

1 MAINSTEM SACRAMENTO RIVER

1.1 WINTER-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

A mark-recapture carcass survey and aerial redd survey are used to estimate winter-run Chinook salmon escapement in the mainstem Sacramento River. In addition, sex ratio data are obtained from trapping below Keswick Dam by the Livingston Stone National Fish Hatchery (LSNFS) program (Killam 2006a). The aerial redd survey is conducted to account for winter-run Chinook salmon spawning downstream of the mark-recapture carcass survey area. The winter-run Chinook salmon escapement estimate is the official number reported to CDFG ocean fisheries management.

Mark-Recapture Carcass Survey – The mark-recapture carcass survey begins before spawning (end of April) and extends until the end of spawning (beginning of September). The survey area extends from Keswick Dam downstream to Balls Ferry Bridge and is divided into four survey reaches. Each reach is surveyed every four days. Crew members are instructed to search all areas with visible river bottom to avoid pre-determined search patterns based on prior experiences finding carcasses. Typically, two jet boats each with two crew members are used to search the river zigzagging from right to left in an upstream direction. During peak carcass periods up to five boats are used to ensure complete coverage of the river.

Each carcass observed is examined and data are recorded for an adipose fin (missing, present, unknown), fork length, sex (male or female), fresh (recently died with one clear eye or red/pink gills) or non-fresh, location (river mile and GPS waypoint), scale samples, genetic tissue samples, and tagged or chopped status.. Fork length is measured and scales are sampled from most fresh carcasses and some non-fresh carcasses. Carcasses are systematically sub-sampled for genetic tissue. Female carcasses are examined for spawning status (spawned or unspawned). Spawned is defined as a female carcass having a worn caudal fin and few eggs remaining in the body. Unspawned is defined as a female carcass having an unworn caudal fin with many eggs in the body cavity. Otoliths are collected upon request for research studies. Heads are removed for CWT recovery from all ad-clipped or unknown ad-clipped and the remaining carcass is chopped in half. Carcasses with an adipose fin (unclipped) that are new encounters (untagged) are tagged in the upper jaw if fresh and lower jaw if non-fresh. Hog-ring tags with a unique color for the tagging period are used. A disc tag bearing a unique identification number is used for all fresh carcasses. Carcasses that are too decayed for tagging are chopped in half. Recovered carcasses with a disc tag from a previous tagging period are released for potential multiple recaptures or chopped if too decayed for recapture during a following survey period. Recovered carcasses with only a hog ring tag from a previous tagging period are chopped in half.

Data from large and small Chinook salmon (> or ≤609 mm.) are used to calculate large female, small female, large male, small male and total escapement estimates. Unclipped large female carcass data are used in a superpopulation modification of the Jolly-Seber model (Schwarz et al. 1993; Crosbie and Manly 1985) to estimate in-river escapement of unclipped large females. Total escapement is estimated using expansions to account for: (1) ad-clipped large female Chinook salmon carcasses that were recovered for CWTs; (2) large female Chinook salmon spawning outside of the carcass study area; (3) large male Chinook salmon based on Keswick Dam trap data; (4) small male and small female Chinook salmon; and (5) winter-run Chinook salmon taken for brood stock for the Livingston Stone National Fish Hatchery (LSNFH) supplementation program.

After total escapement is estimated, the size structure of the population is examined using length frequency histograms to establish cut-off lengths for grilse and adults. The proportion of adult carcasses examined and the proportion of grilse carcasses examined is applied to the total escapement estimate to estimate escapement of adults and grilse.

<u>Unclipped large female in-river escapement</u> – The unclipped large female carcass data (fresh and non-fresh carcasses) are used to estimate unclipped large female escapement using a superpopulation modification of the Jolly-Seber model (Schwarz et al. 1993; Crosbie and Manly 1985).

The Jolly-Seber superpopulation model requires information on the number of carcasses that are marked, the number examined for marks, and the number recaptured each survey period. Marked carcasses are the tagged large unclipped female carcasses. Recaptures are previously tagged large unclipped females. The carcasses examined for marks include recaptures of previously tagged carcasses and non-fresh unclipped large females (subsequently chopped). In addition, any fresh unclipped large female carcasses that are chopped in half are considered examined for marks; due to the short survey period, these carcasses could be observed as fresh in more than one survey period (D. Killam, CDFG, pers. comm., 2008).

<u>Large female in-river escapement</u> – Large female in-river Chinook salmon escapement is the number of large females that are unclipped and ad-clipped. The unclipped large female Chinook salmon escapement estimate (described above) is adjusted to account for ad-clipped large female Chinook salmon:

$$E_{LF} = \frac{F_L}{F_{LN}} * E \;;$$

where E_{LF} is large female escapement, F_L is the count of all fresh large females observed, F_{LN} is the number of fresh large unclipped females, and E is the unclipped large female Chinook salmon escapement estimate described above.

Total large female in-river escapement – The large female in-river escapement estimate (described above) is adjusted to account for large females outside of the survey area using aerial redd data (described below):

$$E_{TLF} = \frac{R}{r} * \left(E_{LF}\right);$$

where E_{TLF} is total large female escapement, R is the total number of redds observed during the aerial redd surveys, r is the number of redds observed in the carcass survey's survey area, and E_{LF} is large female escapement described above.

Total female (large and small) in-river escapement –The total large female Chinook salmon escapement estimate (described above) is adjusted for the number of small female carcasses observed:

$$E_F = \frac{F}{F_L} * E_{TLF};$$

where E_F is total female in-river escapement, F is the total number of fresh females observed, F_L is the count of all fresh large females observed and E_{TLF} is total large female escapement (described above).

Adult female Chinook salmon in-river escapement –Adult female in-river escapement is estimated as:

$$E_{AF} = E_F * \frac{F_A}{F};$$

where E_{AF} is in-river adult female Chinook salmon escapement, E_F is described above, F_A is the number of fresh adult female carcasses (FL > 599mm), and F is described above. Length cut-offs for female Chinook salmon adults and grilse is determined from a length frequency histogram of the fresh female carcass data.

Female grilse in-river escapement – Female grilse Chinook salmon in-river escapement is estimated as:

$$E_{FG} = E_F - E_{AF};$$

where E_{FG} is female grilse Chinook salmon escapement, and E_F and E_{AF} are described above.

Large male in-river escapement – Large male Chinook salmon in-river escapement is estimated using the LSNFH winter-run trapping data and the large female Chinook salmon in-river escapement estimate:

$$E_{LM} = \frac{M_T}{F_T} * E_{TLF} ;$$

where E_{LM} is large male Chinook salmon escapement, M_T is the number of large males captured in the LSNFH trap, F_T is the number of large females captured in the LSNFH trap, and E_{TLF} is described above. An adjustment factor for males spawning outside of study area is not needed because these males are accounted for in the total large female estimate.

Total male Chinook salmon in-river escapement – Total male Chinook salmon escapement accounts for small males:

$$E_M = E_{LM} * \frac{M}{M_L} ;$$

where E_M is total male Chinook salmon escapement, E_{LM} is described above, M is the total number of fresh male carcasses observed, and M_L is the total number of fresh large male carcasses observed.

Adult male Chinook salmon escapement – Adult male Chinook salmon escapement is estimated as:

$$E_{AM} = E_M * \frac{M_A}{M} ;$$

where E_{AM} adult male Chinook salmon escapement, E_M and M are described above and M_A is the number of fresh adult males (FL > 669 mm) observed. Length cut-off for male adults and grilse is determined from a length frequency histogram of fresh male carcass data.

Male grilse escapement – Male grilse Chinook salmon escapement is estimated:

$$E_{GM} = E_M - E_{AM} ;$$

where E_{GM} is male grilse Chinook salmon escapement, E_M and E_{AM} are described above.

Total winter-run in-river escapement in the mainstem Sacramento River – Winter-run Chinook salmon in-river escapement in the mainstem Sacramento River is the sum of the female escapement estimate (E_F) and male escapement estimate (E_M).

Total winter-run escapement in the mainstem Sacramento River – Total winter-run Chinook salmon escapement in the mainstem Sacramento River is the sum of the total winter-run Chinook salmon in-river escapement estimate and the number of winter-run Chinook salmon collected by the LSNFH.

Redd Survey – Since 1981, the aerial redd survey has been conducted by CDFG on the mainstem Sacramento River to collect data on the spatial and temporal distribution of spawning winter-run Chinook salmon. In addition, the redd surveys are used to expand the mark-recapture carcass survey escapement estimate to include Chinook salmon spawning downstream of the mark-recapture carcass survey area (described above). Aerial redd surveys do not provide complete counts of redds due to variability in turbidity, water depth, riparian vegetation, weather, wind, and redd superimposition which affect the ability of the observer to count redds. Temporal and spatial distribution of spawning is examined using the redd survey data. Data are compared to the historic data available (1981-2008) to determine temporal changes in spawning distribution.

The redd survey is conducted by helicopter or fixed wing plane from Keswick Dam to Woodson Bridge. The survey area is divided into 10 reaches: (1) Keswick Dam to ACID; (2) ACID to the Highway 44 Bridge; (3) Highway 44 Bridge to Airport Rd Bridge; (4) Airport Rd Bridge to Balls Ferry Bridge; (5) Balls Ferry Bridge to Battle Creek; (6) Battle Creek to Jellys Ferry Bridge; (7) Jellys Ferry Bridge to Bend Bridge; (8) Bend Bridge to Red Bluff Diversion Dam (RBDD); (9) RBDD to Tehama Bridge; and (10) Tehama Bridge to Woodson Bridge. Redd maps are made to document spawning distribution throughout the 10 reaches.

Data are used to expand winter-run escapement estimates from the mark-recapture carcass survey (described above), but are not used independently to estimate total escapement.

REVIEW OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey – Most of the winter-run spawning areas in the mainstem Sacramento River are surveyed. In addition, the survey encompasses the entire winter-run Chinook salmon spawning period. The survey frequency (every four days) is appropriate for a mark-recapture carcass survey.

A superpopulation modification of the Jolly-Seber (JS) model is used to estimate escapement of large female Chinook salmon without estimates of precision or bias. Unlike the Cormack-Jolly-Seber (CJS) model, the model requires the assumption of complete mixing of marked carcasses in the population.

Large female carcass data are used in the mark-recapture model and various expansions are used to account for additional subpopulations (i.e., ad-clipped carcasses, small unclipped females, small and large unclipped males). These subpopulations are not included in the mark-recapture model because they likely have different probabilities of detection and survival. Due to the several expansions used to get a total in-river escapement estimate and unknown error for each expansion, estimates of precision and bias are not made.

Compared to the JS model, incorporating covariates (e.g., length and sex) into the CJS is relatively easy to account for potential difference in the survival and capture probabilities of carcasses. For example, sex or length may be related to capture probability. The CJS model with the covariates (e.g., sex, size, ad-clip status, fresh or non-fresh) may account for differences in probability of detection and survival of those carcasses. If substantial differences (aka heterogeneity) are not accounted for, both the JS and CJS models are expected to be biased low. The CJS model, with or without covariates, can be used to estimate total escapement and level of precision. Bias of the CJS can be estimated for various situations using computer simulation.

Redd count data from the aerial redd survey are used to account for winter-run Chinook salmon spawning downstream of the mark-recapture carcass survey area. The assumption is made that the detection rates of redds are similar between the carcass survey area and the area downstream. The mark-recapture survey includes most spawning areas; very few winter-run redds are observed downstream of the carcass survey area.

Most fresh and some non-fresh carcasses are sampled for scales and measured for fork length. Sex is identified for all carcasses. Spawning status (spawned or unspawned) is examined for all female carcasses. Genetic tissue samples are collected from carcasses using a systematic subsampling approach. Otoliths are collected upon request. Heads are removed from all ad-clipped and unknown ad-clipped carcasses for CWT recovery.

Redd Survey – The aerial redd survey provides a count of winter-run redds downstream of the mark-recapture carcass survey area, and provides information about the spatial and temporal distribution of winter-run spawning. The survey is not intended to provide total counts for an escapement estimate. The proportion of redds found within and downstream of the mark-recapture carcass survey area are used to expand the escapement estimate to account for fish spawning downstream of the mark-recapture carcass survey area. All of the winter-run spawning area in the mainstem Sacramento River is surveyed. Survey effort can vary annually due to weather, funding or aircraft availability. In addition, the helicopter is the preferred method for the survey but due to lack of funding a fixed-wing airplane is often used.

RECOMMENDED MONITORING

1) Continue the mark-recapture carcass survey to estimate escapement of winter-run Chinook salmon and collect biological data using procedures described in Chapters 3 and 4.

2) Use the CJS model and investigate use of covariates related to survival and capture probabilities to reduce bias and improve precision of the escapement estimate as described in Chapter 3.

3) Continue the aerial redd survey to account for Chinook salmon spawning downstream of the mark-recapture carcass survey area. The survey should be conducted at least bi-weekly to account for potential differences in the temporal distribution of redds within and downstream of the carcass survey area.

a. Historically, total escapement for the river (E_{total}) has been estimated by multiplying an expansion factor (c) to $\hat{E}_1$. This expansion factor comes from repeated aerial redd surveys over both sections of the river. Thus,

$$\hat{E}_{total} = (\overline{1 + R_2 / R_1}) \times \hat{E}_1, \qquad [1]$$

where $\overline{1 + R_2 / R_1} = c$ is the average ratio of redds counted in the downstream section to the redds counted upstream.

b. Assuming independence between the expansion factor (c) and total escapement in the upper section of the river, the $\mathrm{var}(\hat{E}_{total})$ can be estimated using the following:

$$\widehat{var}(E_{total}) = [[c]^2 \times \widehat{var}(E_1)] + \left[([\widehat{E_1})]^2 \times \widehat{var}\left(1 + \frac{R_2}{R_1}\right)\right] - \left[\widehat{var}(E_1) \times \widehat{var}\left(1 + \frac{R_2}{R_1}\right)\right]$$

c. where $\widehat{var}(E_1)$ is the estimated variance for the total escapement in the upper section, which is obtained via bootstrapping and the superpopulation CJS model, and

$\widehat{var}\left(1 + \frac{R_2}{R_1}\right)$ is the estimated variance of the expansion factor (c) from multiple aerial surveys.

d. Equation [1] provides an estimate of total escapement for the portion of river (upper and lower sections) surveyed. Assumptions that are necessary for equation [1] to produce unbiased estimates of total escapement are: (1) productivity (number of redds per fish) is the same in the upper and lower river sections; (2) probability of redd detection is similar in both the upper and lower sections; and (3) the same survey protocol, including flight path and effort, is used during all repeated aerial surveys within a spawning season.

Upper and lower confidence intervals (CI) can be calculated for the total escapement estimate for the system as:

$$\text{Upper Limit} = \hat{E}_{total} \pm \text{Critical Value} \times \hat{\mathrm{var}}(E_{total}),$$

where the critical value is chosen based on the CI desired (e.g., 90% CI = 1.645), and $\hat{\mathrm{var}}(E_{total})$ and $\hat{E}_{total}$ are described above.

e. As detection rates of redds may differ within and downstream of the mark-recapture carcass survey area testing for differences in detection rates between the two areas is recommended using the methods described in Royle (2004). This method adjusts counts for missed detections using independent surveys when the study area is closed (i.e., no net loss or increase in the number of redds between surveys). Thus, redd counts within and downstream of the mark-recapture surveys are adjusted for different probabilities of detection, and these adjusted counts are used in the equations given above. In this situation, bootstrapping is recommended to estimate variances and CIs for total escapement. The bootstrap procedure should include new estimates of probabilities of detection using the methods described in Royle (2004) and the final estimate of total escapement.

4) If there is evidence that the mark-recapture carcass survey is not a reliable method for estimating the number of males in the mainstem Sacramento River because the males leave the survey area before death directly after spawning then the following procedures are recommended to estimate total escapement.

   a. Historically, total escapement for both males and females (E_{total}) has been estimated by multiplying an expansion factor (r) to the estimated total escapement of females, $\hat{E}_f$. This expansion factor comes from an estimate of the ratio of males to females in the system,

$$\hat{r} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i}, \qquad [1]$$

where a sample of n fish is examined, and $y_i = 1$ if fish i is a male (0 otherwise), and $x_i = 1$ if fish i is a female (0 otherwise). Based on the ratio estimator (equation [1]), total escapement for both males and females can be estimated as

$$\hat{E}_{total} = (1 + \hat{r}) \times \hat{E}_f, \qquad [2]$$

The variance of the expanded estimate can be estimated using

$$\widehat{var}(E_{total}) = \left[(1 + \hat{r})^2 \times \widehat{var}(E_f)\right] + \left[\hat{E}_f^2 \times \widehat{var}(r)\right] - \left[\widehat{var}(E_f) \times \widehat{var}(r)\right], \qquad [3]$$

where $\widehat{var}(E_f)$, is the estimated variance for the total escapement of females, which is obtained via bootstrapping and the superpopulation Cormak-Jolly-Seber model, and

$$\widehat{var}(r) = \frac{1}{n-1} \sum_{i=1}^{n} (y_i - \hat{r} x_i)^2 \qquad [4]$$

is the estimated variance of the expansion factor (r).

1.2 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Fall-run Chinook salmon have been monitored in the mainstem Sacramento River using video monitoring and trapping, aerial redd surveys and mark-recapture carcass surveys. Video monitoring and trapping at Red Bluff Diversion Dam (RBDD) has been used in past years but will be discontinued in 2012 due to a change in gate operations. An aerial redd survey is used to examine the spatial and temporal distribution of Chinook salmon spawning and expand the mark-recapture carcass survey escapement estimate for fall-run spawning downstream of the survey area.

Mark-Recapture Carcass Survey – Since 1996, the CDFG has conducted a mark-recapture carcass survey to monitor fall-run escapement in the mainstem Sacramento River. Beginning in 2001, the official fall-run escapement estimate was generated from this survey (Killam and Harvey-Arrison 2001). Over the past 13 years, the mark-recapture carcass survey protocol has changed to refine data collection efforts (Killam, CDFG, pers. comm., 2008). Adaptive management is used to improve each successive year's survey and improve data collection for management.

The mark-recapture carcass survey is conducted on 13.2 miles of the mainstem Sacramento River from Keswick dam (RM 302) to the power lines just downstream of the mouth of Clear Creek (RM 288.8). The study area is divided into three sampling reaches: (1) Keswick Dam to ACID; (2) ACID to RM 294; and (3) RM 294 to the Clear Creek Power lines. If funding is available, sampling reach 3 is extended downstream to Balls Ferry (an additional 12.8 miles).

The survey is conducted weekly from September to January. The dates can vary annually and are determined based on observation of an increase in fresh carcasses. Sampling reaches are designed for one full day of work, where Reach 3, 2, and 1 are surveyed the first, second and third day respectively (in an upstream direction).

Each observed carcass is examined and data are recorded for an adipose fin (missing, present, unknown), fork length, size category (large:>609 mm or small: ≤ 609 mm), sex (male or female), fresh (recently died with one clear eye or red/pink gills) or non-fresh, location (river mile and GPS waypoint), scale samples, genetic samples, and tagged or chopped status. Most fresh and some non-fresh carcasses are sampled for scales and measured for fork length. Carcasses are systematically sub-sampled for genetic tissues. Female carcasses are examined for spawning status (spawned or unspawned). Spawned is defined as a female carcass having a worn caudal fin and few eggs remaining in the body. Unspawned is defined as a female carcass having an unworn caudal fin with many eggs in the body cavity. Otoliths are collected upon request for research studies. Heads are removed for coded-wire tag (CWT) recovery from all adipose fin clipped (ad-clipped) or unknown ad-clipped fish and the remaining carcass is chopped in half. Carcasses with an adipose fin (unclipped) that are new encounters (untagged) are tagged in the upper jaw if fresh and lower jaw if non-fresh. Hog-ring tags with a unique color for the tagging period are used. A disc tag bearing a unique identification number is also used for all fresh carcasses. Carcasses that are too decayed for tagging are chopped in half. Recovered carcasses with a disc tag from a previous tagging period are released for potential multiple recaptures or chopped in half if too decayed for recapture during a subsequent survey period. Recovered carcasses with only a hog ring tag from a previous survey period are chopped in half. If the carcass has a disc tag, the disc tag number is recorded. Recovered tagged carcasses from previous survey periods are recorded as a recovery with the associated location (for disc tagged fish-GPS waypoint, and river mile) and examined for sex, size category (large or small), tag color, and tag location (upper or lower jaw).

Large and small Chinook salmon data are used to estimate large female, small female, large male, small male and total escapement estimates. Unclipped large female carcass data are used in a superpopulation modification of the Jolly-Seber model (Schwarz et al. 1993; Crosbie and Manly 1985) to estimate unclipped large female Chinook salmon in-river escapement. Total escapement is estimated using expansions to account for: (1) ad-clipped large female Chinook salmon carcasses that were recovered for CWTs; (2) large female Chinook salmon spawning outside of the carcass study area; (3) large male Chinook salmon based on Coleman National Fish Hatchery data; and (4) small male and small female Chinook salmon.

After total escapement is estimated, the size structure of the population is examined using length frequency histograms to establish cut-off lengths for grilse and adults. The proportion of adult and grilse carcasses examined is applied to the total escapement estimate to calculate escapement of adults and grilse.

<u>Unclipped large female in-river escapement</u> – The unclipped large female carcass (fresh and non-fresh carcasses) data are used to estimate unclipped large female escapement with a superpopulation modification of the Jolly-Seber (JS) model (Schwarz et al. 1993; Crosbie and Manly 1985).

This model requires information on the number of carcasses that are marked, the number examined for marks, and the number recaptured each survey period. Marked carcasses are unclipped large female carcasses (fresh and non-fresh) tagged in a survey period. A recaptured carcass is an unclipped large female Chinook salmon carcass that was previously tagged and was recaptured in a subsequent survey. The carcasses examined for marks include the recaptures of previous tagged unclipped large female Chinook salmon carcasses, and non-fresh unclipped large female carcasses (chopped after first capture).

<u>Large female in-river escapement</u> – The large female escapement estimate is adjusted to account for ad-clipped large female carcasses:

$$E_{LF} = \frac{F_L}{F_{LN}} * E \ ;$$

where E_{LF} is large female escapement, F_L is the count of all fresh large female Chinook salmon carcasses observed, F_{LN} is the number of fresh large unclipped female Chinook salmon carcasses, and E is the unclipped large female Chinook salmon escapement estimate described above.

<u>Total large female in-river escapement</u> – The large female in-river escapement estimate is adjusted to account for large female Chinook salmon outside of the study area using aerial redd survey data (described above):

$$E_{TLF} = \frac{R}{r} * \left(E_{LF}\right);$$

where E_{TLF} is total large female Chinook salmon escapement, R is the number of total redds observed during the aerial redd surveys, r is the number of redds observed in the carcass survey area, and E_{LF} is described above.

Total female in-river escapement – The total large female escapement estimate is adjusted for the number of small female Chinook salmon carcasses observed:

$$E_F = \frac{F}{F_L} * E_{TLF};$$

where E_F is total female Chinook salmon in-river escapement, F is the total number of fresh female Chinook salmon carcasses observed, F_L and E_{TLF} are described above.

Adult female Chinook salmon in-river escapement – Adult female Chinook salmon escapement is estimated as:

$$E_{AF} = E_F * \frac{F_A}{F};$$

where E_{AF} is in-river adult female Chinook salmon escapement, E_F is described above, F_A is the number of fresh adult female Chinook salmon carcasses (FL > 599mm), and F is described above. Length cut-offs for adult and grilse female Chinook salmon is determined from a length frequency histogram of the fresh Chinook salmon carcass data.

Female grilse Chinook salmon in-river escapement – Female grilse Chinook salmon escapement is estimated as:

$$E_{FG} = E_F - E_{AF};$$

where E_{FG} is female grilse Chinook salmon escapement, and E_F and E_{AF} are described above.

Large male in-river escapement –Prior to 2008, RBDD trapping data was used to calculate sex ratios. In 2008, the sample size of fish captured at RBDD was too small to determine a sex ratio. The sex ratio for fish collected at the Coleman National Fish Hatchery (CNFH) on Battle Creek is assumed to represent fall-run on the mainstem Sacramento River. Large male escapement is estimated using the sex ratio and the large female in-river escapement estimate:

$$E_{LM} = \frac{M_T}{F_T} * E_{TLF};$$

where E_{LM} is large male escapement, M_T is the number of large males captured at the CNFH, F_T is the number of large females captured at the CNFH, and E_{TLF} is described above. An adjustment factor for males spawning outside of study area is not needed because these males are accounted for in the total large female estimate.

Total male in-river escapement – Total male escapement accounts for small males:

$$E_M = E_{LM} * \frac{M}{M_L};$$

where E_M is total male escapement, E_{LM} is described above, M is the total number of fresh male carcasses observed, and M_L is the total number of fresh large male carcasses observed.

Adult male escapement – Adult male escapement is estimated as:

$$E_{AM} = E_M * \frac{M_A}{M};$$

where E_{AM} adult male escapement, E_M and M are described above and M_A is the number of fresh adult male carcasses (FL > 669 mm) observed. Length cut-offs for adult and grilse male Chinook salmon is determined from a length frequency histogram of fresh carcass data.

Male grilse escapement – Male grilse Chinook salmon escapement is estimated:

$$E_{GM} = E_M - E_{AM};$$

where E_{GM} is male grilse escapement, E_M and E_{AM} are described above.

Total fall-run in-river escapement in the mainstem Sacramento River – Fall-run Chinook salmon in-river escapement in the mainstem Sacramento River is the sum of the female escapement estimate (E_F) and male escapement estimate (E_M).

Redd Survey – Since 1981, an aerial redd survey has been conducted on the mainstem Sacramento River to collect data on the spatial and temporal distribution of spawning fall-run Chinook salmon. In addition, the redd surveys are used to expand fall-run Chinook salmon escapement estimates to include salmon spawning downstream of the mark-recapture carcass survey area. Aerial redd surveys do not provide complete counts of redds due to variability in turbidity, water depth, riparian vegetation, weather, wind, and redd superimposition which affect the ability of the observer to count redds. Temporal and spatial distribution of Chinook salmon spawning is examined using the redd survey data. Data are compared to the historic data available (1981-2008) to determine temporal changes in Chinook salmon spawning distribution.

The survey area is divided into 13 reaches: (1) Keswick Dam to Anderson-Cottonwood Irrigation District Dam (ACID); (2) ACID to the Highway 44 Bridge; (3) Highway 44 Bridge to Airport Rd Bridge; (4) Airport Rd Bridge to Balls Ferry Bridge; (5)Balls Ferry Bridge to Battle Creek; (6) Battle Creek to Jellys Ferry Bridge; (7) Jellys Ferry Bridge to Bend Bridge; (8) Bend Bridge to Red Bluff Diversion Dam (RBDD); (9) RBDD to Tehama Bridge; (10) Tehama Bridge to Woodson Bridge; (11) Woodson Bridge to Hamilton City Bridge; (12) Hamilton City Bridge to Ord Ferry Bridge; and (13) Ord Ferry Bridge to Princeton Ferry.

Aerial redd surveys using a fixed wing airplane are conducted bi-weekly or opportunistically depending on aircraft availability in October and November. Redds are counted throughout the 13 sampling reaches.

REVIEW OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey –The survey encompasses the entire fall-run Chinook salmon spawning season. In addition, the survey frequency (weekly) is appropriate for a mark-recapture carcass survey.

The survey area does not include all fall-run Chinook salmon spawning habitat in the mainstem Sacramento River. An aerial redd survey is used develop an expansion factor to account for fish spawning downstream of the survey area. Based on aerial redd survey data from 1969-2006, the average percentage of redds observed from Keswick Dam downstream to Balls Ferry (mark-recapture carcass survey area) was 45.1% (unpublished data, CDFG).

A superpopulation modification of the JS model is used to estimate escapement of large female Chinook salmon without estimates of precision or bias. Unlike the Cormack-Jolly Seber (CJS) model, the model requires the assumption of complete mixing of the marked carcasses in the population.

Large female carcass data are used in the JS model and various expansions are used to account for additional subpopulations (i.e., ad-clipped carcasses, small unclipped females, small and large unclipped males). These subpopulations of carcasses are not included in the JS model because they likely have different probabilities of detection and survival. Due to the multiple expansions used to get a total escapement estimate and unknown error for each expansion, estimates of precision and bias are not made.

Compared to the JS model, incorporating covariates (e.g., length and sex) into the CJS is relatively easy to account for potential difference in the survival and capture probabilities of carcasses. For example, sex or length may be related to capture probability. The CJS model with the covariates (e.g., sex, size, ad-clip status, fresh or non-fresh) may account for differences in probability of detection and survival of those carcasses. If substantial differences (aka heterogeneity) are not accounted for, both the JS and CJS models are expected to be biased low. The CJS model, with or without covariates, produces a total escapement estimate with estimates of precision. Bias of the CJS can be estimated for various situations using computer simulation.

Redd count data from the aerial redd survey are used to account for fall-run Chinook salmon spawning downstream of the mark-recapture carcass survey area. Assumptions are made that the detection rates of redds are similar between the mark-recapture carcass survey area and the area downstream.

Most fresh and some non-fresh carcasses are sampled for scales and measured for fork length. Sex is identified for all carcasses. Spawning status (spawned or unspawned) is examined for all female carcasses. Genetic tissue samples are collected from carcasses using a systematic subsampling approach. Otoliths are collected upon request. Heads are removed from all ad-clipped and unknown ad-clipped carcasses for CWT recovery.

Redd Survey – The aerial redd survey provides a count of fall-run Chinook salmon redds downstream and within the mark-recapture carcass survey area, and provides information about the spatial and temporal distribution of fall-run Chinook salmon spawning. The survey is not intended to provide total counts for an escapement estimate. The proportion of redds found within and downstream of the mark-recapture carcass survey area are used to expand the escapement estimate to account for fish spawning downstream of the carcass survey area. All of the fall-run Chinook salmon spawning area in the mainstem Sacramento River is surveyed. Survey effort can vary annually due to weather, funding or aircraft availability.

RECOMMENDED MONITORING

1) Continue the mark-recapture carcass survey to estimate escapement of winter-run Chinook salmon and collect biological data using procedures described in Chapters 3 and 4.

2) Use the CJS model and investigate use of covariates related to survival and capture probabilities to reduce bias and improve precision as described in Chapter 3.

3) Continue the aerial redd survey to account for Chinook salmon spawning downstream of the mark-recapture carcass survey area. The survey should be conducted at least bi-weekly to account for potential differences in the temporal distribution of redds within and downstream of the carcass survey area.

    a. Historically, total escapement for the river (E_{total}) has been estimated by multiplying an expansion factor (c) to $\hat{E}_1$. This expansion factor comes from repeated aerial redd surveys over both sections of the river. Thus,

$$\hat{E}_{total} = (\overline{1 + R_2 / R_1}) \times \hat{E}_1, \qquad [1]$$

    where $\overline{1 + R_2 / R_1} = c$ is the average ratio of redds counted in the downstream section to the redds counted upstream.

b. Assuming independence between the expansion factor (c) and total escapement in the upper section of the river, the $\text{var}\left(\hat{E}_{total}\right)$ can be estimated using the following:

$$\widehat{var}(E_{total}) = [[c]^2 \times \widehat{var}(E_1)] + \left[\left([\hat{E}_1]\right)^2 \times \widehat{var}\left(1 + \frac{R_2}{R_1}\right)\right] - \left[\widehat{var}(E_1) \times \widehat{var}\left(1 + \frac{R_2}{R_1}\right)\right]$$

c. where $\widehat{var}(E_1)$ is the estimated variance for the total escapement in the upper section, which is obtained via bootstrapping and the superpopulation CJS model, and

$\widehat{var}\left(1 + \frac{R_2}{R_1}\right)$ is the estimated variance of the expansion factor (c) from multiple aerial surveys.

d. Equation [1] provides an estimate of total escapement for the portion of river (upper and lower sections) surveyed. Assumptions that are necessary for equation [1] to produce unbiased estimates of total escapement are: (1) productivity (number of redds per fish) is the same in the upper and lower river sections; (2) probability of redd detection is similar in both the upper and lower sections; and (3) the same survey protocol, including flight path and effort, is used during all repeated aerial surveys within a spawning season.

Upper and lower confidence intervals (CI) can be calculated for the total escapement estimate for the system as:

$$\text{Upper Limit} = \hat{E}_{total} \pm \text{Critical Value} \times \hat{\text{var}}(E_{total}),$$

where the critical value is chosen based on the CI desired (e.g., 90% CI = 1.645), and $\hat{\text{var}}(E_{total})$ and $\hat{E}_{total}$ are described above.

e. If detection rates of redds may differ within and downstream of the mark-recapture carcass survey area testing for differences in detection rates between the two areas is recommended using the methods described in Royle (2004). This method adjusts counts for missed detections using independent surveys when the study area is closed (i.e., no net loss or increase in the number of redds between surveys). Thus, redd counts within and downstream of the mark-recapture surveys are adjusted for different probabilities of detection, and these adjusted counts are used in the equations given above. In this situation, bootstrapping is recommended to estimate variances and CIs for total escapement. The bootstrap procedure should account include new estimates of probabilities of detection using the methods described in Royle (2004) and the final estimate of total escapement.

4) If there is evidence that the mark-recapture carcass survey is not a reliable method for estimating the number of males in the mainstem Sacramento River, then the following procedures are recommended to estimate total escapement.

   b. Historically, total escapement for both males and females (E_{total}) has been estimated by multiplying an expansion factor (r) to the estimated total escapement of females, $\hat{E}_f$. This expansion factor comes from an estimate of the ratio of males to females in the system,

$$\hat{r} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i}, \qquad [1]$$

   where a sample of n fish is examined, and $y_i = 1$ if fish i is a male (0 otherwise), and $x_i = 1$ if fish i is a female (0 otherwise). Based on the ratio estimator (equation [1]), total escapement for both males and females can be estimated as

$$\hat{E}_{total} - (1 + \hat{r}) \times \hat{E}_f, \qquad [2]$$

   The variance of the expanded estimate can be estimated using

$$\widehat{var}(E_{total}) = \left[(1 + \hat{r})^2 \times \widehat{var}(E_f)\right] + \left[\hat{E}_f^2 \times \widehat{var}(r)\right] - \left[\widehat{var}(E_f) \times \widehat{var}(r)\right], \qquad [3]$$

   where $\widehat{var}(E_f)$, is the estimated variance for the total escapement of females, which is obtained via bootstrapping and the superpopulation Cormak-Jolly-Seber model, and

$$\widehat{var}(r) = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \hat{r}x_i)^2 \qquad [4]$$

   is the estimated variance of the expansion factor (r).

1.3 LATE FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

CDFG conducts an aerial redd survey and mark-recapture carcass survey to monitor late fall-run Chinook salmon in the mainstem Sacramento River. The aerial redd survey is used to examine the spatial and temporal distribution of late fall-run spawning. In addition, the redd survey is used to expand the mark-recapture carcass survey escapement estimate for Chinook salmon spawning downstream of the survey area.

Mark-Recapture Carcass Survey – The mark-recapture carcass survey methods are the same as those described above for fall-run Chinook salmon (Section 1.2). Professional judgment is used to differentiate Chinook salmon runs in the mainstem Sacramento River. Late fall-run surveys are typically conducted from December through the beginning of May.

Redd Survey – The aerial redd survey methods are the same as those described for fall-run Chinook salmon above (Section 1.2). Data for late fall-run Chinook salmon are collected in mid-December through May.

REVIEW OF EXISTING PROGRAM(S)
Review of the aerial redd survey and the mark-recapture carcass survey is the same as described for fall-run Chinook salmon (Section 1.2).

RECOMMENDED MONITORING
Recommended monitoring for late fall-run Chinook salmon is the same as that described for fall-run Chinook salmon (Section 1.2). Professional judgment is used to differentiate runs based on spawning time and appearance of carcasses.

2 COW CREEK

2.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)
Since 2006, fall-run Chinook salmon have been monitored in Cow Creek using traditional optical video cameras and a partial horizontal bar weir (Killam 2008a). Methodology for video monitoring continues to evolve over time as new technology becomes available and affordable.

The weir is located approximately 1.3 miles upstream from the mouth of Cow Creek. Site characteristics chosen for weir placement are: (1) limited public access to avoid vandalism and poaching; (2) a close power source; (3) near the mouth of the river so most salmonids travel past the site; (4) permission from landowner to construct and access the site daily; and (5) suitable stream geology to place the weir (shallow and even stream bottom). The weir is placed in a “V” shape facing upstream to guide fish to a center opening. In the center opening, white high density polyethylene sheets are staked into the stream bottom to better view fish passage. In addition, a measurement device is placed on the white sheets to estimate length of fish and aid in identification of fish species based on length criteria. The site has three monochrome video cameras, one overhead video camera at the center opening and two underwater cameras. Equipment is operated 24 hours per day and is checked daily from late-September through December.

Chinook salmon can spawn downstream of the weir, therefore redds are enumerated in this area.

Fall-run Chinook salmon escapement is estimated using the counts of adult Chinook salmon passing up and downstream of the video system. Twenty-four hour fish passage counts are tallied in one-half hour increments (48 increments total). Handheld tally counters are used to count salmon moving up and downstream. Salmon moving downstream are subtracted from the total number passing upstream for each video increment to calculate total passage. Chinook salmon total passage is adjusted to account for quality control (QC) of fish counts. QC checks are completed for fish counts in the 48 one-half hour video increments. QC is completed for all video increments with fish passage counts greater than 9. If counts differ between the first and second count, a third count is made to get a final count for that video increment. For video increments with 9 or fewer salmon counted, the increments are stratified by reader and by count type. Video increments are classified as Count Type 0 and Count Type 1. Count Type 0 is used for video increments with counts of one or no salmon. Count Type 1 is used for video increments with counts of 2-9 salmon. A random subsample of video increments is chosen from each stratum (reader and Count Type) and reviewed. An adjustment factor is created for each stratum (reader and count type) from a random sub sample of strata and applied to all Type 0 and Type 1 counts. The adjustment factor is the percent difference between the sum of the total stratum QC counts and the sum of the total stratum original counts (within the subsample). The adjustment factor and original counts are multiplied (for each stratum) to get the adjusted QC count. Adjusted counts for each video increment in each stratum are summed to get a total adjusted count. The QC counts are summed to calculate the total salmon passage for the station.

Chinook passage estimates are further adjusted for video taping malfunction, turbid water, and redd counts. Interpolation is used to account for missing data. Redds observed downstream of the weir are multiplied by two, assuming a 1:1 sex ratio.

REVIEW OF EXISTING PROGRAM(S)

The video station is located downstream from most fall-run Chinook salmon spawning habitat and is operated for the entire immigration period. Therefore, most immigrating Chinook salmon should pass the video monitoring station for enumeration. Interpolation is used to account for missing data and quality control procedures are in place to account for reader error.

Fall-run Chinook salmon spawning downstream of the fish device counter is very limited. In 2006 no spawning fall-run Chinook salmon were found downstream of the weir (Killam 2007). In 2007, six fall-run Chinook salmon spawners were observed downstream of the weir (Killam 2008a). While the redd survey downstream of the weir does not incorporate error in the redd count, accounting for error may not be worth the effort due to the very limited spawning activity.

Biological data are not collected and coded-wire tags are not recovered.

RECOMMENDED MONITORING

1) Continue monitoring with the fish device counter to estimate fall-run Chinook salmon escapement in Cow Creek, incorporating recommended procedures to estimate precision and bias as described in Chapter 2. These recommended procedures include accounting for reader error and missing data.

2) Continue the redd survey to enumerate fall-run Chinook salmon downstream of the weir.

3) Collect biological data and recover coded-wire tags as described in Chapter 4.

3 BEAR CREEK

3.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

In 2007, traditional optical video cameras and a partial horizontal bar weir were installed in Bear Creek, Shasta County to monitor fall-run Chinook salmon. The project is operated cooperatively by the Red Bluff Sacramento River Salmon and Steelhead Assessment Project of the California Department of Fish and Game (CDFG), the Western Shasta Resource Conservation District (WSRCD), the Cottonwood Creek Watershed Group (CCWG) and the Red Bluff Fish and Wildlife Office of the U.S. Fish and Wildlife Service (USFWS) (Chichester 2008). The site is located approximately 1.5 miles upstream from the confluence with the Sacramento River and was chosen based on the following criteria: (1) limited public access to avoid vandalism and poaching; (2) close to a power source; (3) near the mouth of Bear Creek so most salmonids would travel past the site; (4) permission from landowner to construct and access the site daily; (5) suitable stream geology to place weir (shallow and even stream bottom).

The weir is placed in a “V” shape facing upstream to guide fish to a center opening. In the center opening, white high density polyethylene sheets are staked into the stream bottom to better view fish passage. In addition, a measurement device is on the white sheets to estimate length of fish and aid in identification of fish species based on length criteria. The site has three monochrome video cameras, one overhead video camera at the center opening and two underwater cameras. Equipment is operated 24 hours per day and is checked daily from late September through at least May.

Fall-run Chinook salmon escapement is estimated using the counts of Chinook salmon passing upstream and downstream of the video system. Videotapes are processed using a digital video recorder (DVR) to reduce the viewing footage by recording only sections of the video where motion is detected during periods of clear water. Twenty-four hour fish passage counts are tallied in one-half hour increments (48 increments total). Handheld tally counters are used to count salmon moving upstream and downstream. Salmon moving downstream are subtracted from the total passing upstream for each video to calculate total passage.

Total passage is adjusted to account for quality control (QC) of fish counts. QC checks are completed for fish counts in 48 one-half hour video increments with fish passage counts greater than nine. If counts differ between the first and second count, a third count is made to get a final count for that video increment. For video increments with nine or fewer salmon counted, the increments are stratified by reader and by count type. Video increments are classified as Count Type 0 and Count Type 1. Count Type 0 is used for video increments with counts of one or no salmon. Count Type 1 is used for video increments with counts of 2-9 salmon. A random subsample of video increments is chosen from each stratum (reader and Count Type) and reviewed by personnel. An adjustment factor is created for each stratum (reader and count type) from a random subsample of strata and applied to all video increments’ Type 0 and Type 1 counts. The adjustment factor is the percent difference between the sum of the total stratum QC counts and the sum of the total stratum original counts (within the sub sample). The adjustment factor and original counts are multiplied (for each stratum) to get the adjusted QC count. Adjusted counts for each video increment in each stratum are summed to get a total adjusted count. The QC counts are summed to calculate the total salmon passage for the station.

Chinook passage estimates are further adjusted for missing data (video tape malfunction, turbid water) and redd counts downstream of the weir. Redd counts are multiplied by two; a female to male sex ratio of 1:1 is assumed. Interpolation is used to account for missing data.

REVIEW OF EXISTING PROGRAM(S)

The video station is located downstream from most fall-run Chinook salmon spawning habitat and is operated for the entire fall-run Chinook salmon immigration period. Therefore, most immigrating Chinook salmon should pass the video monitoring station for enumeration. Interpolation is used to account for missing data and a quality control procedure is in place to account for reader error.

Fall-run Chinook salmon spawning downstream of the fish device counter is very limited. In 2007 two fall-run Chinook salmon redds were observed downstream of the weir (Chichester 2008). While the redd survey downstream of the weir does not account for error into the redd count, accounting for error would not be worth the effort due to the very limited spawning activity.

Biological data are not collected and coded-wire tags are not recovered.

RECOMMENDED MONITORING

1) Continue monitoring with the fish device counter to estimate fall-run Chinook salmon escapement in Bear Creek. Incorporate recommended procedures to estimate escapement, precision and bias as described in Chapter 2.

2) Continue the redd survey to enumerate fall-run Chinook salmon spawning downstream of the weir.

3) Collect biological data and recover coded-wire tags as described in Chapter 4.

3.2 LATE FALL-RUN CHINOOK SALMON

Currently late fall-run Chinook salmon are not monitored in Bear Creek. The device counter and weir used to monitor fall-run (Section 3.2) could be used to monitor late fall-run. In addition, a device counter is recommended to be used to monitor steelhead in Bear Creek (Eilers et al. 2010), which would encompass the immigration period for late fall-run.

RECOMMENDED MONITORING

1) Use a fish device counter and weir to monitor late fall-run Chinook salmon escapement in Bear Creek. The period of operation of the fish device counter

used for fall-run Chinook salmon (Section 3.2) would need to be extended to encompass the late fall-run immigration period (January-March). Incorporate recommended procedures for fish device counters to estimate escapement, precision and bias as described in Chapter 2.

2) Collect biological data and recover coded-wire tags as described in Chapter 4.

4 BATTLE CREEK

4.1 WINTER-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Trapping and Fish Device Counter – Since 1995, Chinook salmon have been monitored using a live trap and video monitoring at the Coleman National Fish Hatchery (CNFH) on Battle Creek (Newton et al. 2007 and Brown and Alston 2007; J. Newton, USFWS, pers. comm., 2008, 2010). A barrier weir on Battle Creek at CNFH (River Mile 5.8) blocks upstream passage of fish from the beginning of August through the beginning of March. Upstream passage is allowed and monitored from March through July. Live trapping occurs throughout this time period when water temperatures do not exceed 60° F. Once water temperature exceeds 60° F the trap is closed and a traditional optical video camera is used to monitor fish passage upstream of the CNFH barrier weir. After the construction of a new fish ladder in 2009, the video camera is located within a vault (weather proof room) adjacent to the fish ladder. The fish ladder has a viewing window to observe fish passage. Tissue samples collected from Chinook salmon trapped and from Chinook salmon carcasses collected during a snorkel survey (described below) are genetically analyzed to distinguish winter-run, spring-run, fall-run, and late fall-run Chinook salmon. Escapement estimates for each run of salmon are calculated using the count data from trapping, the fish device counter, and from the results of the genetic analysis.

The fish trap is operated approximately 8 hours/day, 7 days/week. When water temperature exceeds 60ºF, trapping for the day is terminated to reduce effects of handling. During hours when the trap is not operated, the exit on the trap is blocked to allow fish to enter the trap but not pass. Each morning the trap is cleaned before operating. In the 8-hour period, the trap is checked every 30 minutes and fish are removed. Fish are netted from the trap and immediately transferred to a large water tank. Water temperatures are maintained to within 2ºF of the stream water temperature. All salmonids are measured (fork length in mm), examined for scars and tissue damage, examined for the presence or absence of a mark (adipose fin-clip or floy tag), and sex is identified if possible. All adipose fin-clipped (ad-clipped) Chinook salmon are sacrificed for recovery of coded-wire tags (CWTs). Personnel use a dip net to release unclipped salmonids upstream of the fish trap.

The video camera is used to estimate Chinook salmon passage in Battle Creek, beginning when water temperatures exceed 60ºF for the majority of the day and ending August 1. A lighting system allows for 24 hour monitoring. A digital video recorder (DVR) records fish passage. Data are stored each night to a terabyte external hard drive. A secondary

DVR also records and temporarily stores a few days of video data and is used as back-up to the primary DVR.

Digital video data is recorded on two channels of the primary DVR: one channel records continuous video data (24-hr/d) and one channel records 10-second clips whenever motion is detected. The backup DVR records only continuous video data. The "motion detection" video record is viewed to identify the species and the presence or absence of an adipose fin. The certainty of the identification is rated as good, fair, or poor. A good rating suggests complete confidence in identifying species and the presence or absence of an adipose fin. A fair rating suggests confidence in identifying species and the presence of an adipose fin with additional review. A poor rating suggests uncertainty in identifying species and the presence of an adipose fin. For quality control, five-second clips of all salmonids observed on the video are recorded and reviewed by more experienced personnel to confirm species and presence of an adipose fin. Personnel record the total numbers of ad-clipped, unclipped, and unknown adipose fin-clip. Additionally, personnel log the number of hours of possible fish passage and the hours of video-recorded passage. For quality control of the DVR's motion detection capabilities, the continuous video record is reviewed every third day.

Picture quality affects the ability to identify species and the presence or absence of an adipose fin. Picture quality is rated as good, fair, and poor. A good rating for picture quality signifies a clear picture, a fair rating signifies that the objects were discernable but extra review is needed, a poor rating indicates that the objects are indiscernible. Passage estimates during periods of poor picture quality are estimated using the passage rate estimates during adjacent time periods with fair and good picture quality.

<u>Chinook salmon escapement estimation by trapping</u> – Passage estimates are made for ad-clipped and unclipped Chinook salmon at the barrier weir fish ladder. The number of unknown adipose fin-clipped Chinook salmon is estimated by the proportion of ad-clipped and unclipped fish passing the weir during the same week salmon with unknown adipose fin status was observed. Passage is estimated for ad-clipped and unclipped Chinook salmon by:

$$P_{tu} = \sum_{i=1}^{n} \left(\left[\frac{u_i}{c_i + u_i} \cdot unk_i \right] + u_i \right)$$

and

$$P_{tc} = \sum_{i=1}^{n} \left(\frac{c_i}{c_i + u_i} \cdot unk_i \right);$$

where P_{tu} is the passage estimate for unclipped Chinook salmon during barrier weir trap operation, P_{tc} is the passage estimate for ad-clipped Chinook salmon during barrier weir trap operation, c_i is the actual number of ad-clipped Chinook salmon captured in the barrier weir during week i (not passed upstream), u_i is the actual number of unclipped Chinook salmon observed passing the barrier weir during week i, and unk_i is the actual number of unknown adipose fin-clip status Chinook salmon observed passing the barrier weir during week *i*.

Chinook salmon escapement estimation with video monitoring – Passage estimates are made for ad-clipped and unclipped Chinook salmon for each week of video monitoring. Total passage is estimated by apportioning any unknown adipose fin-clip status Chinook salmon and then expanding observed counts according to the amount of time passage was allowed but not recorded due to poor video picture quality or equipment malfunction. Passage is estimated for ad-clipped and unclipped Chinook salmon using video monitoring by:

$$\mathrm{P_{vu}} = \sum_{\mathrm{i=1}}^{\mathrm{n}} \left(\left[\frac{\mathrm{u_i}}{\mathrm{c_i + u_i}} \cdot \mathrm{unk_i} \right] + \mathrm{u_i} \right) \cdot \left(\frac{\mathrm{T_i}}{\mathrm{V_i}} \right)$$

and

$$P_{vc} = \sum_{i=1}^{n} \left(\left[\frac{c_i}{c_i + u_i} \cdot unk_i \right] + c_i \right) \cdot \left(\frac{T_i}{V_i} \right);$$

where P_{vu} is the passage estimate for unclipped Chinook salmon during barrier weir video monitoring, P_{vc} is the passage estimate for ad-clipped Chinook salmon during barrier weir video monitoring, c_i is the actual number of ad-clipped Chinook salmon observed passing the barrier weir during week *i*, u_i is the actual number of unclipped Chinook salmon observed passing the barrier weir during week *i*, unk_i is the actual number of unknown clip status Chinook observed passing the barrier weir during week *i*, T_i is the number of hours of unrestricted fish passage at the barrier weir during week *i*, and V_i is the number of hours of actual good and fair video recorded fish passage at the barrier weir during week *i*.

Total Chinook salmon escapement estimation – Total Chinook salmon escapement estimates of ad-clipped and unclipped Chinook salmon are estimated by summing weekly passage estimates at the barrier weir and the number of ad-clipped and unclipped Chinook released into upper Battle Creek by CNFH prior to trapping (beginning of March):

$$P = P_{tu} + P_{tc} + P_{vu} + P_{vc} + H;$$

where *P* is total passage of Chinook salmon at the barrier weir, P_{tu}, P_{tc}, P_{vu}, P_{vc} are described above, and *H* is the number of Chinook salmon released into upper Battle Creek prior to trapping.

Chinook salmon escapement estimation by run – Genetic analyses from tissue samples collected from Chinook salmon during trapping and a snorkel survey (describe below) are used in conjunction with migration timing to develop run-specific escapement estimates for winter-run, spring-run, fall-run, and late fall-run Chinook salmon.

Three pieces of tissue for each unclipped Chinook salmon trapped or unclipped Chinook salmon carcass observed during the snorkel survey are stored in small vials containing ethanol (live fish) or an envelope (carcass). One sample is sent to Hatfield Marine Science Center, Oregon State University, for analysis by Dr. Michael Banks. The other samples are archived at the Red Bluff Fish and Wildlife Service Office (RBFWO). In 2004, the genetic analysis changed and now individual fish are classified by run (i.e., spring-run, winter-run, fall-run, or late fall-run Chinook salmon). Each run assignment has an associated confidence probability. Genetic results are used in conjunction with migration timing to develop run-specific escapement estimates for each run of Chinook salmon.

Snorkel and Redd Survey – In 2001, the U.S. Fish and Wildlife Service Red Bluff Office initiated a snorkel and redd survey in Battle Creek to monitor salmonid spawning (Newton et al. 2007; J. Newton, USFWS, pers. comm., 2008). The objectives of the survey are to determine the location and timing of spawning, evaluate relationships between spawning and habitat conditions, and collect biological information. The survey is not used to estimate escapement of adult Chinook salmon. However, the tissue samples collected from Chinook salmon carcasses are used to genetically differentiate the runs in order to estimate escapement for individual runs in Battle Creek (Section 4.1).

The 18.6 mile survey area is divided into six sampling reaches: (1) North Fork – Eagle Canyon Dam to Wildcat Dam; (2) North Fork – Wildcat Dam to Confluence; (3) South Fork – Coleman Diversion Dam to Confluence; (4) Mainstem – Confluence of Forks to Barn Beat; (5) Mainstem – Barn Beat to Spring Branch; and (6) Mainstem – Spring Branch to CNFH Barrier Weir.

Prior to 2009, surveys were conducted in Battle Creek between late-April to mid-November to collect biological data and habitat information and determine the spatial and temporal distribution of Chinook salmon. Since 2009, surveys are only conducted in September and October mainly due to funding. Therefore this data would no longer be of value for monitoring winter-run Chinook salmon. Sampling occurs one or two times per month. Surveys take approximately four days to complete, depending on personnel availability and stream flow. Surveys are scheduled on consecutive weekdays beginning in the uppermost reaches and working downstream.

For the snorkel surveys, three samplers snorkel and count live Chinook salmon, carcasses, and redds. Samplers snorkel adjacent to each other and move in a line perpendicular to the flow, trying to stay three abreast for consistent data collection. Each person is responsible for surveying a section of the river: river right, river left, or river center. Side channels are surveyed. If the channel narrows, one person will walk the shore and look for washed up carcasses. To survey a pool, one person portages around the pool and enters the pool from the downstream end, while the other person enters the upstream end of the pool. For large pools, one person with polarized glasses will count salmon from the top of a rock. When groups of fish are encountered, samplers confer with each other to ensure fish were not missed or double counted.

Chinook salmon spawning areas are located and examined to determine habitat suitability and the timing of spawning. For each reach, redds are counted, redd dimensions are measured, redds are flagged with a unique identification number, and GPS coordinates are recorded for each redd observed.

All Chinook salmon carcasses observed during the survey are sampled for biological data. Scales, genetic tissue samples, and otoliths are collected. All carcasses are measured (fork length), examined for sex, and all females are examined for spawning status (egg retention). Heads from all ad-clipped carcasses and those with unknown clip status are removed for CWT recovery.

REVIEW OF EXISTING PROGRAM(S)

Trapping and a fish device counter in conjunction with genetic analyses are used to estimate escapement of winter-run Chinook salmon.

Biological data are collected and CWTs are recovered during the snorkel and redd survey. All carcasses observed are sampled for scales, otoliths, and genetic tissue. In addition, all observed carcasses are measured (fork length), examined for sex, and all female carcasses are examined for spawning status.

RECOMMENDED MONITORING

1) Continue monitoring with a fish device counter and trap to estimate winter-run Chinook salmon escapement. Recommended procedures to estimate escapement with measures of precision and bias using a fish device counter are described in Chapter 2.

2) Continue the snorkel and redd survey to collect biological data and recover CWTs using methods described in Chapter 4.

4.2 SPRING-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Trapping and Fish Device Counter – This is the same program as described for winter-run Chinook salmon (Section 4.1).

Snorkel Survey – This is the same program as described for winter-run Chinook salmon (Section 4.1).

REVIEW OF EXISTING PROGRAM(S)

Review is the same as for winter-run Chinook salmon (Section 4.1)

RECOMMENDED MONITORING

Recommendations are the same as for winter-run Chinook salmon (Section 4.1).

4.3 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

A video monitoring weir was installed on lower Battle Creek in 2003 to monitor escapement of fall-run Chinook salmon (Killam 2006b). The weir is operated cooperatively by the CDFG and USFWS. Each year of operation, changes have been made to improve the operation of the weir and data collection. The official fall-run Chinook salmon escapement estimate is from this monitoring.

The weir is located between the mouth of the stream at the Sacramento River and the Coleman National Fish Hatchery barrier weir, downstream of the primary spawning areas of fall-run Chinook. The site was chosen based on the following criteria: (1) limited public access to avoid vandalism and poaching; (2) access to a power source; (3) proximity to the mouth of Battle Creek so most salmonids would travel past the site; (4) permission from landowner to construct and access site daily; (5) suitable stream geology to place weir (shallow and even stream bottom).

The video monitoring methodology used in this program has continually evolved as new technology has become affordable/available. Methods have changed from year to year, but the overall method has remained the same. A partial horizontal bar weir is used to channel fish into the traditional optical video cameras' view. The site has three underwater cameras and one overhead camera. Lighting for the cameras are provided by compact fluorescent spotlights. White galvanized metal sheets are staked into the stream bottom to aid viewing of fish passage. In addition, a measuring device is placed on the white sheet to approximate fish length.

Equipment is operated 24 hours per day and is checked daily from mid-September through the beginning of December. Video footage is saved to a digital video recorder (DVR). Daily activities include: 1) changing the DVR, 2) checking power levels and operation of equipment, 3) cleaning the weir and white sheets of algae and debris, and 4) recording comments and time of visit in a logbook. The DVR with recorded images are brought back to the office and stored until viewing.

Escapement is estimated from the total count of Chinook salmon migrating upstream of the video monitoring station. The escapement estimate is adjusted for quality control, missing footage, the number of fish in the stream prior to video weir operation, the number of fish spawning downstream of the video weir, and grilse. In some years, snorkel survey counts are used to enumerate the number of fish upstream of the weir prior to the video weir operation. A grilse-to-adult ratio estimated from data collected at the Coleman National Fish Hatchery is used to account for grilse.

Biological data are collected and coded-wire tags (CWTs) are recovered at the Coleman National Fish Hatchery. A three-year study found that the ratio of ad-clipped Chinook salmon collected at the hatchery was not different from the ratio found for in-river spawners in two of the three years (Null et al. 2003).

REVIEW OF EXISTING PROGRAM(S)

The video station is located below Chinook salmon spawning habitat and is operated for the entire fall-run Chinook salmon immigration period. Therefore, all immigrating Chinook salmon should pass the video monitoring station for enumeration. Biological data collected at Coleman National Fish Hatchery is representative of the in-river spawners.

RECOMMENDED MONITORING

1) Continue monitoring with a fish device counter and weir to estimate fall-run Chinook salmon escapement in Battle Creek. Recommended procedures to estimate escapement with measures of precision and bias using a fish device counter are described in Chapter 2.

2) Continue to collect biological data and recover CWTs at the Coleman National Fish Hatchery as described in Chapter 4.

4.4 LATE FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Trapping and Fish Device Counter – The fish trap and device counter as described for winter-run Chinook salmon (Section 4.1) are not used for the entire late fall-run immigration period. Fish are handled at the Coleman National Fish Hatchery until trapping begins. All adipose fin clipped fish are sacrificed for CWT recovery.

RECOMMENDED MONITORING

1) Continue monitoring with a fish device counter and trap to estimate late fall-run Chinook salmon escapement in Battle Creek. Recommended procedures to estimate escapement with measures of precision and bias using a fish device counter are described in Chapter 2.

2) Continue to collect biological data and recover CWTs at the trap and Coleman National Fish Hatchery, as described in Chapter 4.

CHAPTER 7

RECOMMENDED CHINOOK SALMON ESCAPEMENT MONITORING FOR THE NORTHERN SIERRA NEVADA DIVERSITY GROUP

5 ANTELOPE CREEK

5.1 SPRING-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1992, the CDFG has conducted a snorkel survey and walking survey on Antelope Creek to monitor adult spring-run Chinook escapement (Harvey-Arrison 2007). In July, a snorkel survey is conducted to enumerate spring-run Chinook salmon in their holding habitat to get the official escapement number. In October, the walking survey is conducted to enumerate spring-run Chinook salmon that spawned, collect biological data, and examine spawning distribution. Surveying Antelope Creek is difficult due to the remote location, rough terrain, and limited access points.

A 14-mile reach is divided into six survey reaches, and the reaches are surveyed the same time of month every year by personnel familiar with underwater fish counting and the entry and exit sites for the stream. The snorkel survey is used to count live spring-run Chinook salmon in holding habitat, and occurs near the end of July approximately 10 weeks prior to spawning. The survey is completed in one day to minimize harassment to holding fish and minimize the chance of fish movement. A crew of 2-3 samplers snorkels downstream to count and record the location of live spring-run Chinook salmon and carcasses. The highest count between samplers is recorded. The official spring-run Chinook salmon escapement count is the sum of all holding Chinook salmon counted during the July snorkel survey.

A walking survey is used to enumerate the number of Chinook salmon that spawned and examine their spawning distribution. The survey is completed in the first two weeks of October after peak spawning. The stream is walked in a downstream manner. Samplers count and record the number and location of complete redds, partial redds, live Chinook salmon, and Chinook salmon carcasses.

All spring-run Chinook salmon carcasses observed in July and October surveys are measured (fork length) and examined for sex and an adipose fin; genetic tissue samples, otoliths, and scales are collected only if time and funding permits or upon request. Scale re-absorption makes scale collection difficult or impossible. Heads are collected from all carcasses missing an adipose fin.

REVIEW OF EXISTING PROGRAM(S)

All known spring-run Chinook salmon holding and spawning habitats are surveyed.

The official escapement number is an index, the count from the July snorkel survey. The survey is not designed to estimate escapement with measures of precision or bias. Redd counts are commonly used for monitoring annual trends in the abundance of spawning salmonids. However, if redds are not detected with 100 percent accuracy, counting errors may obscure important population trends (Maxell 1999). In addition, in order to estimate escapement using redd counts corrected for observer error, the number of females per redd and the ratio of females to males in the population must be estimated. The redd survey would need to span the entire spawning season and be conducted more frequently.

The survey frequency may not be sufficient to obtain biological data representative of the population; however, increasing sampling effort may not be worth the additional cost. Population estimates since 1998 have ranged from 0 to 154 fish (CDFG 2010); in many years, no fish are observed. Finding additional carcasses after the one-time survey would likely be difficult over the 14-mile survey reach. In addition, scavengers could remove carcasses between additional survey events making the chances of finding carcasses even more unlikely.

All observed carcasses are measured (fork length) and are cut open to determine sex. If an ad-clipped carcass is observed, the head is removed for coded-wire tag (CWT) recovery. If time and funding permits or upon request, genetic tissue samples and otoliths are collected. Scales are collected if possible; however scale re-absorption makes scale collection difficult or impossible. Female carcasses are examined for spawning status.

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Antelope Creek to monitor spring-run Chinook salmon escapement. Recommended methods for estimating escapement using a fish device counter are described in Chapter 2. This monitoring technique is also recommended for fall-run and late fall-run Chinook salmon (Sections 5.2 and 5.3) and steelhead (Eilers et al. 2010) in Antelope Creek.

2) Continue the July snorkel survey for examining the spatial distribution of holding spring-run Chinook salmon. Until a fish device counter is installed, continue to use the July snorkel survey to provide an index of escapement.

3) Continue the October survey to count the number of spawners and examine the spatial distribution of spawning Chinook salmon, and collect biological data and recover CWTs as described in Chapter 4.

5.2 FALL-RUN CHINOOK SALMON

Currently fall-run Chinook salmon are not monitored in Antelope Creek. Antelope Creek is made up of four distributaries. A recent hydrological survey identified the potential for fall-run spawning in these distributaries under favorable flow conditions (C. Harvey-Arrison, CDFG, pers. comm., 2011).

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Antelope Creek to monitor fall-run Chinook salmon escapement. Recommended methods for estimating escapement using a fish device counter are described in Chapter 2. This survey method is also recommended for spring-run and late fall-run Chinook salmon (Sections 5.1 and 5.3) and steelhead (Eilers et al. 2010) in Antelope Creek.

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

5.3 LATE FALL-RUN CHINOOK SALMON

Currently late fall-run Chinook salmon are not monitored in Antelope Creek.

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Antelope Creek to monitor late fall-run Chinook salmon escapement. Recommended methods for estimating escapement using a fish device counter are described in Chapter 2. This survey method is also recommended for spring-run and fall-run Chinook salmon (Sections 5.1 and 5.2) and steelhead (Eilers et al. 2010) in Antelope Creek.

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

6 MILL CREEK

6.1 SPRING-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

A redd survey and fish device counter (weir and video cameras) are currently used to monitor spring-run Chinook salmon in Mill Creek. The redd survey has been conducted by CDFG since 1997 to estimate escapement, examine the spawning distribution, and collect biological data. In 2007, CDFG installed a fish device counter in Mill Creek to monitor Chinook salmon and steelhead.

Redd Survey – Conducting the redd survey is difficult due to the remoteness of Mill Creek, rough terrain, and limited access to the river. A redd survey is conducted instead of a snorkel survey because the natural turbidity of the river precludes direct counts.

Forty-one miles of spring-run Chinook salmon spawning habitat are surveyed, from two miles upstream of the Highway 36 Bridge downstream to the Steel Tower Transmission Lines (Harvey-Arrison 2007). The stream is divided into 14 sampling reaches. The survey is conducted over a two-week period in the beginning of October (peak spawning period). The survey starts in the sampling reach of highest elevation which has the earliest spawning and progresses downstream. A team of two people walk downstream on opposite sides of the stream channel and count carcasses, redds, and live Chinook salmon. In the most remote reaches, an aircraft (helicopter or fixed-wing depending on funding) is used to count redds from Blackrock to Buckhom Gultch (10.7 miles) to obtain a ground survey to aerial survey ratio of redds, and apply this factor to aerial redd counts downstream of Buckhom Gultch.

Redds are identified as "complete" or "practice". A "complete" redd consists of a shallow depression in the gravel with a mound of clean gravel at the downstream end (tail spill). A "practice" redd is any area of clean gravel that appears to have been turned over by a fish, but lacks a pit and a tail spill.

The spring-run Chinook escapement estimate is calculated by multiplying the total count of complete redds by two. An assumption is made that each female constructs one redd and the population has a 1:1 female-to-male sex ratio. In the most remote reaches, an aircraft is used to count redds from Blackrock to Buckhom Gultch (10.7 miles) to obtain a ground survey to aerial survey ratio of redds, and apply this factor to aerial redd counts downstream of Buckhom Gultch.

All spring-run Chinook salmon carcasses observed are collected and measured (fork length), cut open to determine sex, and examined for an adipose fin clip. Genetic tissue samples, otoliths and scales are collected only if time and funding permits or upon request. Re-absorption makes scale collection difficult or impossible for spring-run Chinook salmon. Heads are collected from all carcasses missing an adipose fin.

Fish Device Counter – In 2006, a partial horizontal bar weir and video equipment were located in the town of Los Molinos near the Sherwood Road Bridge, approximately 1.8 miles upstream from the mouth of Mill Creek (Killam and Johnson 2008). In the fall of 2008, the video equipment was moved and is currently located at the top of the Ward Dam fish ladder, about two miles upstream from the former site.

The video monitoring methods used in this program have continually evolved as new technology has become affordable/available. Methods have changed from year to year, but the overall method has remained the same. At the top of the fish ladder, white high density polyethylene sheets are staked into the stream bottom to better view fish passage. A measurement device is mounted to the white sheets to estimate lengths of fish as they pass and aid in identification of fish species based on length criteria. The site has 2-3 monochrome video cameras, one overhead video camera at the center opening and 1-2 underwater camera(s). Compact fluorescent spotlights mounted overhead provide lighting for the cameras from dusk until dawn. Equipment is operated 24 hours per day and is checked daily from the beginning of October through June. Video footage is saved to a digital video recorder (DVR).

Video footage is processed using the DVR by selecting only sections of the video where motion is detected. Large blocks of time exist where no fish pass upstream; the DVR therefore significantly reduces the time required to analyze video footage. The DVR recording is stored on a hard drive.

In the office, video footage is viewed on a computer monitor; fish are counted and identified to species. Due to limited resources, each period is viewed only once. Fish passage counts are tallied in one-half hour increments (48 increments total). Fish are counted if they move upstream and exit the upper portion of the white sheets. Handheld tally counters are used to count fish that move upstream and downstream.

Historical trapping data at the Red Bluff Diversion Dam showed that almost all (99.8%) salmon returning to spawn in the Upper Sacramento River Basin are larger than 16 inches. In addition, CDFG considers any *Oncorhynchus mykiss* greater than 16 inches present in anadromous waters to be the steelhead form and not the resident rainbow trout form. The measuring device on the white board is used by reviewers for estimating the relative length of each fish that passes. The viewer's judgment is used to identify a fish greater than 16 inches as a steelhead or Chinook salmon. Viewers provide comments on all fish less than 24 inches that are counted on the datasheets. Most non-salmonid species in Mill Creek are less than 24 inches. Carp (*Cyprinus carpio*), hardhead (*Mylopharodon conocephalus*), Sacramento pikeminnow (*Pytchoceilus grandis*), and Sacramento suckers (*Catostomus occidentalis*) rarely grow longer than 24 inches in the watershed. Viewers differentiate between salmonids and non-salmonids based on body form, shape and posture of the pectoral fins, and swimming behavior.

Spring-run Chinook salmon escapement is estimated from the counts of Chinook salmon passing upstream. Interpolation is used for missing video footage.

REVIEW OF EXISTING PROGRAM(S)

Redd Survey – All known spawning habitat is surveyed. The spring-run Chinook salmon escapement estimate based on the redd survey is considered an index of abundance. The redd survey is not designed to estimate error; therefore escapement is estimated without measures of precision or bias. The survey is conducted only once and assumptions are made that each female makes one redd and the sex ratio is one female to one male. Redd counts are commonly used for monitoring annual trends in the abundance of spawning salmonids. However, if redds are not detected with 100 percent accuracy, counting errors may obscure important population trends (Maxell 1999). In addition, in order to estimate escapement using redd counts corrected for observer error, the number of females per redd and the ratio of females to males in the population must be estimated. The redd survey would need to span the entire spawning season and be conducted more frequently.

The survey frequency may not be sufficient to obtain biological data representative of the population. Population numbers since 1998 have ranged from 140-1594 fish (CDFG 2010). Observing additional carcasses after the one time survey would likely be difficult over the 41-mile survey reach. In addition, scavengers could remove carcasses between additional survey events making the chances of finding carcasses even more unlikely.

All observed carcasses are measured (fork length) and cut open to determine sex. If an ad-clipped carcass is observed, the head is removed for coded-wire tag (CWT) recovery. If time and funding permits or upon request, genetic tissue samples and otoliths are collected. Scales are collected if possible; however, re-absorption makes scale collection difficult or impossible. Female carcasses are examined for spawning status (spawned or unspawned).

Fish device counter – The video station is located at Ward Dam; all of the spring-run Chinook salmon spawning habitat is located upstream. The station is operated for the entire immigration period. Therefore, all immigrating spring-run should pass the video monitoring station for enumeration.

RECOMMENDED MONITORING

1) Use the fish device counter to estimate spring-run Chinook salmon escapement with measures of precision and bias using recommended procedures in Chapter 2.

2) Continue the redd survey to monitor the distribution of spawning spring-run Chinook salmon, collect biological data and recover CWTs as described in Chapter 4 (carcass sampling survey).

6.2 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1988, the CDFG has used a mark-recapture carcass survey to monitor fall-run Chinook salmon escapement in Mill Creek. The fall-run escapement estimate for Mill Creek is based on data from this survey.

An eight-mile reach of Mill Creek is surveyed from the canyon mouth (upstream of Los Molinos Mutual's Upper Diversion Dam) to the confluence with the Sacramento River (Harvey-Arrison 2007). If redds are counted near the most upstream point, the mark-recapture carcass survey is extended farther upstream to the limit of spawning. The survey area is divided into three survey reaches.

The mark-recapture carcass survey is conducted weekly for six weeks, as long as carcasses are available, between late October and early December. Two samplers walk each survey reach in a downstream manner examining all carcasses encountered and counting redds.

For fresh Chinook salmon carcasses (at least one clear eye, red gills, firm "bright" body) with an adipose fin (unclipped), the upper jaw is tagged with a color-coded hog ring, recorded under the appropriate size class (grilse or adult) and sex, then the carcass is released into running water. If running water is not nearby, the fresh unclipped carcass is chopped in half and recorded as a chop under the appropriate size class and sex. In addition, during weeks of peak carcass recovery the biologist may make the decision to reduce the number of new tagged fresh carcasses and chop them in half. These chopped carcasses are recorded as a chop under the appropriate size class and sex.

Chinook salmon carcasses with a jaw tag from a previous survey week are chopped in half and recorded as a recovery by tag color. Non-fresh Chinook salmon carcasses are chopped in half and recorded as a chop under the appropriate size class (adult or grilse) and sex. Adipose fin-clipped (ad-clipped) carcasses are examined for sex, measured for fork length, and the head is removed and placed in a bag with an information tag for coded-wire tag (CWT) recovery. These carcasses are chopped in half and are recorded as a chop under the appropriate size class (adult or grilse) and sex.

The modified Schaefer (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994), or the Petersen (Ricker 1975) mark-recapture models are used to estimate escapement. The Petersen estimator is used when recapture rates are low. Both estimators require information on the number of carcasses that are marked, the number examined for marks, and the number recaptured. Fresh unclipped adult and grilse carcasses that were tagged during the survey period are considered marked. Carcasses examined for marks are those that were previously tagged, recaptured, or were chopped in half at first encounter. All subpopulations of carcasses are considered examined for marks (fresh, non-fresh, unclipped, ad-clipped, male, female, adults, and grilse).

If recapture rates cannot be calculated due to low carcass numbers, redd data are used to provide an index of escapement. The total count of redds is multiplied by two. An assumption is made that each female builds one redd and the female to male sex ratio is 1:1.

REVIEW OF EXISTING PROGRAM(S)

Escapement is estimated using a closed-population mark-recapture model, and precision and bias are not estimated. Closed-population mark-recapture models are not recommended for estimating Chinook salmon escapement with mark-recapture carcass surveys as discussed in Chapter 3.

The carcass survey is conducted throughout the entire spawning season, includes all spawning habitat in Mill Creek, and has an appropriate survey frequency (weekly).

All carcasses are measured (fork length) and cut open to determine sex. In addition, heads from all ad-clipped carcasses are collected for CWT recovery. Genetic tissue samples, scales, and otoliths are collected if time and funding permits or upon request. Female carcasses are examined for spawning status (spawned or unspawned).

Redd counts are sometimes used to index escapement. Assumptions are made that one female makes one redd and the sex ratio is one female to one male. Redd counts are commonly used for monitoring annual trends in the abundance of spawning salmonids. However, if redds are not detected with 100 percent accuracy, counting errors may obscure important population trends (Maxell 1999). In addition, in order to estimate escapement using redd counts corrected for observer error, the number of females per redd and the ratio of females to males in the population must be estimated.

RECOMMENDED MONITORING

1) Use the fish device counter at Ward Dam to estimate fall-run Chinook salmon escapement. Recommended procedures to estimate escapement with levels of precision and bias using a fish device counter are described in Chapter 2. Monitoring should be year-round to estimate escapement of fall-run, late fall-run, spring-run Chinook salmon and steelhead in Mill Creek (as recommended in Sections 6.1 and 6.3 and Eilers et al. 2010).

2) Two miles of fall-run Chinook salmon spawning habitat is located downstream of Ward Dam, therefore redds should be counted downstream.

3) Conduct a carcass sampling survey to collect biological data and recover CWTs as described in Chapter 4. The current mark-recapture carcass survey's area, survey period, and sampling frequency are appropriate for biological data collection and CWT recovery.

6.3 LATE FALL-RUN CHINOOK SALMON

Late fall-run Chinook salmon are currently not monitored in Mill Creek.

RECOMMENDED MONITORING

1) Use the fish device counter at Ward Dam to estimate late fall-run Chinook salmon escapement. Recommended procedures to estimate escapement with levels of precision and bias using a fish device counter are described in Chapter 2. Monitoring would be year-round to estimate escapement of fall-run, late fall-run, spring-run Chinook salmon and steelhead in Mill Creek (as recommended in Sections 6.1 and 6.3 and Eilers et al. 2010).

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

7 DEER CREEK

7.1 SPRING-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1992, the CDFG has conducted snorkel surveys to monitor adult spring-run Chinook salmon escapement in Deer Creek (Harvey-Arrison 2007). The first survey takes place in August to count salmon in their holding habitat and provide an index of escapement. A walking survey takes place in October to count the number of Chinook salmon that spawned. Surveys are completed during the same Julian week every year using personnel familiar with underwater fish counting and the entry and exit sites on the stream. Surveying Deer Creek is difficult due to remoteness, rough terrain, and limited access points.

Twenty-four miles of Deer Creek are surveyed from the Upper Deer Creek Falls downstream to within two miles of Dillon Cove. This reach encompasses the known holding and spawning habitat of adult spring-run Chinook salmon in Deer Creek.

The snorkel survey, is conducted around the first week in August. The survey is completed in one day to minimize harassment to holding Chinook salmon and minimize the chance of Chinook salmon movement. A crew of 2-3 samplers snorkels downstream. Personnel count live fish and carcasses observed. The highest count of live Chinook between the 2-3 samplers is recorded. The escapement estimate is the sum of all holding Chinook salmon counted during the snorkel survey.

The walking survey is used to enumerate the number of spawning spring-run Chinook salmon and their spawning distribution. The survey is completed in October after the peak of spawning. The survey begins at the highest elevation (earliest spawners) and progresses in a downstream direction. Personnel count complete Chinook salmon redds, partial redds, live fish, and carcasses.

All spring-run Chinook salmon carcasses collected are measured (fork length), cut open to determine sex, and examined for the presence of an adipose fin. Genetic tissue samples, otoliths and scales are collected only if time and funding permits or upon request. Re-absorption makes scale collection difficult or impossible for spring-run Chinook salmon. Heads are collected from all carcasses missing an adipose fin. Female carcasses are examined for spawning status (spawned or unspawned).

REVIEW OF EXISTING PROGRAM(S)

All known spring-run Chinook salmon holding and spawning habitat is surveyed.

The total count of Chinook salmon from the August snorkel survey is an index of escapement. The survey is not designed to estimate escapement with levels of precision or bias.

The survey frequency for biological data may not be sufficient to obtain samples representative of the population; however, increasing effort to sample more carcasses may not be worth the additional cost. Population numbers since 1998 have ranged from 140 to 2759 fish (CDFG 2010). Finding additional carcasses after the one time survey would likely be difficult over the 24-mile survey reach. In addition, scavengers could remove carcasses between additional survey events making the chances of finding carcasses more unlikely.

All observed carcasses are measured (fork length) and examined for sex. If an ad-clipped carcass is observed, the head is removed for coded-wire tag (CWT) recovery. If time and funding permits or upon request by others, genetic tissue samples and otoliths are collected. Scales are collected if possible; however re-absorption makes scale collection difficult or impossible. Female carcasses are examined for spawning status (spawned or unspawned).

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Deer Creek to monitor spring-run Chinook salmon escapement. Recommended methods for estimating escapement with levels of precision and bias using fish device counters are described in Chapter 2. This monitoring technique is also being recommended to monitor fall-run and late fall-run Chinook salmon escapement (Sections 7.2 and 7.3) and steelhead (Eilers et al. 2010) in Mill Creek.

2) Continue the August snorkel survey to monitor the holding distribution of spring-run Chinook salmon in Deer Creek. Use the snorkel survey data to provide an index of escapement until a fish device counter is installed.

3) Continue the October walking survey to monitor the spawning distribution of spring-run Chinook salmon, enumerate the number of spawners and redds, collect biological data and recover CWTs. Recommended sampling procedures for collecting biological data and recovering CWTs are described in Chapter 4. If possible, the survey frequency should be increased to sample more carcasses, especially during years with high spring-run numbers.

7.2 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1989, the CDFG has used mark-recapture carcass surveys to monitor fall-run Chinook salmon escapement in Deer Creek. The fall-run escapement estimate is based on data from this survey.

The survey is conducted from the USGS gauge, located upstream of the Deer Creek Irrigation District's upper diversion dam, to the Highway 99 bridge crossing (Harvey-Arrison 2007). If redds are counted near the upstream point, the mark-recapture carcass survey is extended to the upstream limit of spawning. The survey area is divided into three sampling reaches.

The survey is conducted weekly for seven weeks from mid-October through December. Two personnel walk each reach in a downstream direction. All carcasses encountered are examined. In addition, all Chinook salmon redds are counted and their locations recorded (coordinates from a Global Positioning System).

Carcasses are checked for a jaw tag, floy tag, radio tag, and an adipose fin. In addition, fork length is measured (cm) and sex is determined. Carcasses are recorded as a grilse (< 61 cm) or an adult (≥ 61 cm).

For all Chinook salmon carcasses missing an adipose fin (ad-clipped), sex is determined, fork length (cm) is measured and the head is removed and placed in a bag with an information tag for coded-wire tag (CWT) recovery. The carcass is chopped and recorded as a chop under the appropriate size class and sex. Non-fresh (opaque eye, white gills, body is not firm) Chinook salmon carcasses are chopped in half and recorded as chop under the appropriate size class and sex.

For fresh carcasses (at least one clear eye, red gills, firm "bright" body) with an adipose fin (unclipped), the upper jaw is tagged with a hog-ring tag with a unique color for the tagging period, recorded under the appropriate size class (adult or grilse) and sex. The tagged carcass is released into running water. If running water is not nearby, the fresh carcass is chopped in-half and recorded as a chop under the appropriate size class and sex. In addition, during weeks of peak carcass recovery the biologist may make the decision to reduce the number of newly tagged fresh carcasses and chop them in-half. These carcasses are recorded as a chop under the appropriate size class and sex.

Chinook salmon carcasses with a jaw tag from a previous survey week are chopped and recorded as a recovery by tag color.

The modified Schaefer (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994), or the Petersen (Ricker 1975) mark-recapture models are used to estimate escapement. The Petersen estimator is used when recapture rates are low. Both estimators require information on the number of carcasses that are marked, the number examined for marks, and the number recaptured each survey period. Fresh unclipped adult and grilse carcasses that were tagged during the survey period are considered marked. Carcasses examined for marks are those that were previously tagged, recaptured, or were chopped in half at first encounter. All subpopulations of carcasses are considered examined for marks (fresh, non-fresh, unclipped, ad-clipped, male, female, adults, and grilse).

If weekly recapture rates cannot be calculated due to low carcass numbers, a redd expansion is used to estimate Chinook salmon escapement. The total count of redds is multiplied by two to calculate total escapement. An assumption is made that one female builds one redd and the female-to-male sex ratio is 1:1.

REVIEW OF EXISTING PROGRAM(S)

Escapement is estimated using a closed-population mark-recapture model; precision and bias are not estimated. Closed-population mark-recapture models are not recommended for estimating Chinook salmon escapement with mark-recapture carcass survey data as discussed in Chapter 3. In years when carcass numbers are low, the redd survey escapement estimate is an index and does not have measures of precision or bias.

The survey period encompasses the entire fall-run spawning period. The sampling frequency (weekly) is appropriate and most fall-run Chinook salmon spawning habitat is surveyed in Deer Creek.

All observed carcasses are measured (fork length) and examined for sex. If an ad-clipped carcass is observed, the head is removed for CWT recovery. If time and funding permits or upon request, genetic tissue samples and otoliths are collected. Scales are collected if possible; however re-absorption makes scale collection difficult or impossible. Female carcasses are not examined for spawning status.

Redd counts are sometimes used to index escapement. Assumptions are made that each female makes one redd and the sex ratio is one female to one male. Redd counts are commonly used for monitoring annual trends in the abundance of spawning salmonids. However, if redds are not detected with 100 percent accuracy, counting errors may obscure important population trends (Maxell 1999). In addition, in order to estimate escapement using redd counts corrected for observer error, the number of females per redd and the ratio of females to males in the population must be estimated.

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Deer Creek to monitor fall-run Chinook salmon escapement. Recommended methods for estimating escapement with levels of precision and bias with fish device counters are described in Chapter 2. This technique is also recommended to monitor spring-run and late fall-run

Chinook salmon escapement (Sections 7.1 and 7.3) and steelhead (Eilers et al. 2010) in Mill Creek.

2) Until a device counter is installed, continue to estimate Chinook salmon escapement with a mark-recapture carcass survey using recommended procedures in Chapter 3.

3) Conduct a carcass sampling survey to collect biological data and recover CWTs as described in Chapter 4. The current mark-recapture carcass survey area, survey period, and sampling frequency are appropriate for biological data collection and CWT recovery.

7.3 LATE FALL-RUN CHINOOK SALMON

Late fall-run Chinook salmon are currently not monitored in Deer Creek.

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Deer Creek to monitor late fall-run Chinook salmon escapement. Recommended methods for estimating escapement with levels of precision and bias with fish device counters are described in Chapter 2. This technique is also recommended to monitor spring-run and fall-run Chinook salmon escapement (Sections 7.1 and 7.2) and steelhead (Eilers et al. 2010) in Mill Creek.

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

8 BIG CHICO CREEK

8.1 SPRING-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1995, the CDFG has conducted snorkel surveys on Big Chico Creek to monitor adult escapement (Garman and McReynolds 2008). The spring-run escapement estimate is based on data from this survey.

The snorkel survey extends from Higgins Hole to Iron Canyon. This reach includes all spring-run Chinook salmon holding habitat in Big Chico Creek. The survey area is divided into three sampling reaches.

In mid-July, a one-day snorkel survey is conducted to estimate adult spring-run Chinook salmon escapement. The survey takes place prior to Chinook salmon spawning and the occurrence of pre-spawning mortalities. Up to four experienced personnel survey from the upstream end to the downstream end of each sampling reach. Each pool is surveyed once by each person and counts are recorded independently.

Snorkel survey data are reviewed and used to estimate adult Chinook salmon escapement in Big Chico Creek. All of the data are examined for outliers. After removal of outliers, individual counts are averaged for each sampling reach. Total escapement is calculated by summing the average counts for all the sampling reaches. A range is calculated for total escapement using the counts from the multiple independent observations.

Biological data and coded-wire tags (CWTs) are not recovered because the survey takes place prior to spawning.

REVIEW OF EXISTING PROGRAM(S)

The spring-run Chinook salmon escapement estimate is an index of abundance without estimates of precision and bias.

Biological data are not collected and CWTs are not recovered because the survey is conducted during the spring-run Chinook salmon holding period.

Finding spring-run Chinook salmon carcasses would be difficult. Escapement estimates in Big Chico Creek have ranged from 0-369 fish from 1998-2009 (CDFG 2010). Excluding two years with relatively large numbers, the average number of spring-run Chinook salmon has been 19 fish.

RECOMMENDED MONITORING

1) Install a fish device counter in Big Chico Creek to monitor spring-run Chinook salmon escapement using recommended procedures in Chapter 2. The Pacific Gas and Electric Company and the California Department of Water Resource's (2009) draft Habitat Expansion Plan recommends improvement of spring-run Chinook salmon and steelhead passage in Big Chico Creek by repairing the Iron Canyon Fish Ladder. If this action is implemented, spring-run Chinook salmon escapement and steelhead (Eilers et al. 2010) should be monitored using a fish device counter in the Iron Canyon fish ladder.

2) Until a fish device counter is installed in Big Chico Creek, continue the snorkel survey to provide an index of escapement.

3) Conduct a carcass sampling survey to collect biological data and recover CWTs as recommended in Chapter 4.

9 BUTTE CREEK

9.1 SPRING-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Snorkel Survey - Since 1995, the CDFG has conducted snorkel surveys on Butte Creek to monitor Chinook salmon escapement. The spring-run Chinook salmon escapement estimate is based on data from this survey.

The snorkel survey extends from Quartz Bowl Pool (QBP) to the Parrott-Phelan Diversion Dam (PPDD). The survey area is divided into three distinct sampling reaches. All adult salmon are assumed to be in their holding habitat during the survey. The survey is conducted over a three-day period in July prior to spawning and observance of pre-spawning mortalities. Each day, a distinct sampling reach is surveyed. Up to four experienced samplers survey from the upstream end to the downstream end of each reach. A pair swims downstream side-by-side. After the first pair surveys a pool, the next pair follows. Each person records an independent count.

Snorkel survey count data are reviewed and used to estimate Chinook salmon escapement. The count data are examined for outliers. After removal of outliers, individual counts are averaged for each of the sampling reaches. Total escapement is calculated by summing the average counts for all the sampling reaches. A range is calculated for total escapement using the multiple independent observations.

Mark-Recapture Carcass Survey – Since 2001, the CDFG has used mark-recapture carcass surveys to monitor spring-run Chinook salmon escapement in Butte Creek (Garman and McReynolds 2008). The mark-recapture carcass surveys are used to estimate Chinook salmon pre-spawning mortalities, escapement, and collect coded-wire tags (CWTs), both from natural Chinook salmon juveniles tagged in the river and strays from hatcheries. The escapement estimate from the mark-recapture carcass survey is compared to the estimate based on the snorkel survey.

The mark-recapture carcass survey extends from Quartz Bowl Pool (QBP) to the Centerville Covered Bridge (CCB). The 17.7 km (11 mi) stream section is divided into five sampling reaches. Each sampling reach is divided into sub-reaches. (Reach A) QBP to Whiskey Flat (sub-reaches 1-5); (Reach B) Whiskey Flat to Helltown (sub-reaches 1-8); (Reach C) Helltown to Quail Run Bridge (sub-reaches 1-12); (Reach D) Quail Run Bridge to Cable Bridge (sub-reaches 1-8); and (Reach E) Cable Bridge to CCB (sub-reaches 1-7).

The survey is conducted from June through November. Each sampling reach is surveyed once per week. Two to four samplers walk downstream searching both sides of the stream and any side channels for Chinook salmon carcasses.

All Chinook salmon carcasses are examined for the presence of an adipose fin, tags, and freshness. All fresh carcasses (at least one clear eye and firm flesh) with an adipose fin (unclipped) that do not have a tag are tagged in the lower jaw with a hog-ring tag with a unique color for the tagging period, are measured for fork length (mm), sampled for scales, and sex determined. Genetic tissue samples are collected from the first 10 fresh unmarked (i.e., unclipped and no tag) in each reach each week. These carcasses are recorded as tagged with the appropriate tag color for that survey week. Carcasses that are collected with a jaw tag from a previous survey week are chopped in half and recorded as a recovery with the appropriate tag color. Carcasses that have an adipose fin missing (ad-clipped) are measured for fork length (mm), sexed, and head removed for CWT recovery. Otoliths from the heads of these carcasses are later removed in the lab. The remaining carcass is chopped in half and recorded as a chop with the appropriate sex. Carcasses that are non-fresh (more than one week old or both eyes missing) and do not have a jaw tag or ad-clipped are chopped in half, and then it is recorded as an adult chop. All tagged carcasses and chopped carcasses are released back into the river near the location of collection.

During October, many Chinook salmon are observed downstream of the survey area from CCB to Parrott-Phelan Diversion Dam (PPDD). The mark-recapture carcass survey is not funded for a mark-recapture effort in this stream reach. A weekly survey is conducted in this stream reach to only count and chop carcasses.

Data collected in the mark-recapture carcass survey from June through mid-September are used to estimate pre-spawning mortality with the modified Schaefer estimator (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994). The estimator requires information on the number of carcasses that are marked, the number examined for marks, and the number recaptured each survey period. Marked carcasses are the fresh unclipped carcasses (adults and grilse) that are tagged during the carcass survey. Recaptured carcasses are those that were previously tagged and are recovered during a subsequent survey. Carcasses examined for marks are carcasses that were either tagged, recovered, or were chopped in half at first encounter. All sub-populations of carcasses (fresh, non-fresh, unclipped, ad-clipped, adults (females and males), and grilse) are considered examined for marks.

The modified-Schaefer estimator is not used to estimate pre-spawning mortality if recapture rates of the tagged carcasses are too low. If recapture rates are low, the number of adult Chinook salmon pre-spawning mortalities is estimated using carcass counts from June through mid-September and an expansion factor:

$$E_M = C * F \; ;$$

where E_M is the number of adult Chinook salmon pre-spawning mortalities, C is the number of Chinook salmon carcasses examined, and F is an expansion factor developed using data collected from mid-September through the beginning of November as described below.

Data collected in the mark-recapture carcass survey from mid-September through the beginning of November are used to estimate Chinook salmon spawning escapement (the number of Chinook salmon that spawned) with the modified-Schafer model. The estimator requires information on the number of carcasses that are marked, the number examined for marks, and the number recaptured. Marked carcasses are the fresh unclipped carcasses (adults and grilse) that are tagged during the carcass survey. Recaptured carcasses are those that were previously tagged and are recaptured during a subsequent survey. Carcasses examined for marks are carcasses that were either tagged, recaptured, or were chopped in half at first encounter. All sub-populations of carcasses (fresh, non-fresh, unclipped, ad-clipped, adults (females and males), and grilse) are considered examined for marks.

An expansion factor is used to account for Chinook salmon carcasses in reaches with an incomplete survey:

$$F = \frac{E}{(C+T)};$$

where F is an expansion factor, E is the Chinook salmon spawning escapement as described above, C is the total number of untagged carcasses chopped for surveyed reaches:

$$C = \left(\sum_{j=1}^{n} C_j - \sum_{i=1}^{n} R_i \right) + C_i;$$

where C_j are carcasses counted during the j^{th} recovery week, R_i are the number of tagged carcasses recovered during i^{th} week of tagging, and C_i are carcasses chopped during the first period, and T is the total number of tagged carcasses in the survey.

Total Chinook salmon spawning escapement is estimated as:

$$E_T = E + F * N;$$

where E_T is total Chinook salmon spawning escapement, E is the Chinook salmon spawning escapement estimate as described above, F is expansion factor described above, and N are the number of carcasses observed during incomplete surveys (i.e., the number of chops from Covered Bridge to PPDD).

Total adult Chinook salmon escapement is the sum of the total Chinook salmon spawning escapement estimate (E_T) and the number of pre-spawning mortalities (E_M).

REVIEW OF EXISTING PROGRAM(S)

Escapement is estimated using a closed-population mark-recapture model, and measures of precision and bias are not estimated. Closed-population mark-recapture models are not recommended for estimating Chinook salmon escapement from mark-recapture carcass survey data as discussed in Chapter 3.

The entire spring-run Chinook salmon spawning area is not included in the mark-recapture carcass survey. An expansion is used for the reach downstream of the survey area from CCB to Parrott-Phelan Diversion Dam (PPDD). The accuracy and precision of this expansion is unknown.

The carcass survey's frequency (weekly) is appropriate and the survey is conducted over the entire spawning season.

The mark-recapture carcass survey (June-mid-September) or expansion used to estimate pre-spawning mortalities may not be appropriate. The mark-recapture carcass survey used to estimate total escapement should begin before carcasses enter the system. The Cormack-Jolly-Seber model can account for survey weeks with low carcass numbers, therefore total escapement could potentially be estimated using data collected during the entire survey period (June-November). However, if carcass numbers are too low the model would need to use data starting at a later date (e.g., late-August versus June). In the past the numbers of carcasses observed during the pre-spawning mortality survey have been low; accounting for a very small percentage of the population may not be worth the additional effort to estimate total spring-run Chinook salmon escapement.

All observed fresh unclipped and all ad-clipped spring-run Chinook salmon carcasses are examined for sex, measured for fork length, and sampled for scales. Genetic tissue samples are collected from the first 10 fresh unmarked fish (i.e., unclipped and no tag) in each reach each week. Female spawning status is not examined. Heads are collected from all ad-clipped Chinook salmon. Otoliths are removed from these heads; however, otoliths are not collected from unclipped Chinook salmon carcasses.

RECOMMENDED MONITORING

1) Install a fish device counter to monitor the escapement of spring-run Chinook salmon in Butte Creek. Recommended methods to estimate escapement with levels of precision and bias are described in Chapter 2. This technique has also been recommended for monitoring steelhead in Butte Creek (Eilers et al. 2010).

2) Conduct a carcass sampling survey to collect biological data and recover CWTs using procedures recommended in Chapter 4. The survey area should extend from Quartz Bowl Pool to PPDD to include all spawning habitat.

9.2 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1995, the CDFG has conducted mark-recapture carcass surveys to estimate fall-run Chinook salmon escapement in Butte Creek (Garman and McReynolds 2008). The fall-run escapement estimate is based on data from this survey.

The survey area extends from Parrott-Phelan Diversion Dam (PPDD) to Gorrill Ranch Dam. In addition, a 0.8 km (0.5 mi) section near the Western Canal Siphon is surveyed. The 15.3 km (9.5 mi) of stream surveyed is divided into four sampling reaches.

The survey is conducted weekly from mid-November through mid-December. Two to four samplers search for fall-run Chinook salmon carcasses by walking downstream covering both sides of the stream and any side channels.

All fall-run Chinook salmon carcasses collected are examined for an adipose fin, tags, and freshness. All fresh carcasses (at least one clear eye and firm flesh) that do not have a tag and have an adipose fin (unclipped) are tagged with a hog-ring tag in the lower jaw with the unique tag color for that survey period. Carcasses that have a jaw tag from a previous survey week are chopped in half and recorded as a recapture by the appropriate tag color. Carcasses that have an adipose fin missing (ad-clipped) are measured (fork length in mm), sexed, and head removed for coded-wire tag (CWT) recovery. The remaining carcass is chopped in half and recorded as a chop by the appropriate sex. Untagged non-fresh unclipped carcasses are chopped in half and recorded as a chop. All tagged and chopped carcasses are released back into the river near the location of collection.

All fresh carcasses and all ad-clipped carcasses are measured for fork length (mm) and sexed. Scales are not collected. Genetic tissue samples are collected upon request. Heads are removed from all ad-clipped carcasses for coded-wire tag recovery. Otoliths are removed from these heads.

The modified Schaefer (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994) or the Petersen (Ricker 1975) population estimators are used to estimate escapement. The Petersen estimator is used when recapture rates are low. Both estimators require information on the number of carcasses that are marked, the number examined for marks, and the number recaptured. Marked carcasses are the fresh unclipped carcasses (adults and grilse) that are tagged during the carcass survey. Recaptured carcasses are those that were previously tagged and are recaptured during a subsequent survey. Carcasses examined for marks are carcasses that were either tagged, recaptured, or were chopped in half at first encounter. All sub-populations of carcasses (fresh, non-fresh, unclipped, ad-clipped, adults (females and males), and grilse) are considered examined for marks.

REVIEW OF EXISTING PROGRAM(S)

Escapement is estimated using a closed-population mark-recapture model, and measures of precision and bias are not estimated. Closed-population mark-recapture models are not recommended for estimating Chinook salmon escapement from mark-recapture carcass survey data as discussed in Chapter 3.

The survey period encompasses the entire fall-run Chinook salmon spawning period. Most spawning habitat is surveyed and the survey frequency (weekly) is appropriate for a mark-recapture carcass survey.

All observed fresh unclipped and all ad-clipped fall-run Chinook salmon carcasses are examined for sex and measured for fork length. Heads are collected from all ad-clipped Chinook salmon carcasses. Scale samples and genetic tissue samples are not collected. Female spawning status is not examined. Otoliths are removed from ad-clipped carcass heads, but are not collected from unclipped carcasses.

RECOMMENDED MONITORING

1) Continue the mark-recapture carcass survey to estimate escapement of fall-run Chinook salmon, collect biological data and recover coded-wire tags using procedures described in Chapters 3 and 4. The fish device counter recommended for spring-run Chinook salmon monitoring (Section 9.1) cannot be used to estimate fall-run escapement. Installing a weir and device counter downstream of fall-run Chinook salmon spawning habitat would be difficult due to land access issues (C. Garman, CDFG, pers. comm., 2010). However, if the device counter can be installed downstream of fall-run Chinook salmon spawning habitat, a

device counter is recommended over the mark-recapture carcass survey as described in Chapter 2.

2) Use the Cormack-Jolly-Seber model to estimate escapement, and investigate use of covariates related to survival and capture probabilities to reduce bias and improve precision as described in Chapter 3.

10 FEATHER RIVER

10.1 SPRING-RUN CHINOOK SALMON

Escapement is not estimated for spring-run Chinook salmon in the Feather River because spring-run and fall-run Chinook salmon spawning overlaps temporally and spatially. A mark-recapture carcass survey is currently conducted to estimate Chinook salmon escapement and is reported as fall-run Chinook salmon (Section 10.2). A segregation weir is being proposed by the California Department of Water Resources (CDWR) to be installed in the Feather River to prevent the spatial overlap in spring-run and fall-run Chinook salmon spawning. The proposed weir will have a fish device counter to estimate spring-run Chinook salmon escapement.

<u>RECOMMENDED MONITORING</u>

1) Monitor spring-run Chinook salmon escapement using the proposed segregation weir with a fish device counter. Recommended procedures for estimating escapement with estimates of precision and bias with a fish device counter are described in Chapter 2.

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

10.2 FALL-RUN CHINOOK SALMON

<u>SUMMARY OF EXISTING PROGRAM(S)</u>

Since 2000, the CDWR has conducted a mark-recapture carcass survey to estimate Chinook salmon escapement (Low 2007). Both fall-run and spring-run Chinook salmon spawn in the Feather River. Spawning of the runs overlaps both spatially and temporally, therefore escapement cannot be estimated separately by run. The mark-recapture carcass survey escapement estimate is reported as fall-run.

Separate spawning escapement estimates are prepared for the "low flow channel" (LFC), from the Fish Barrier Dam to the Thermalito Afterbay Outlet, and "high flow channel" (HFC), from the Thermalito Afterbay Outlet to Gridley. Separate estimates are also made for adults and grilse.

The Feather River mark-recapture carcass survey takes place from the Fish Barrier Dam to the East Gridley Bridge (CDWR 2002). The survey area is divided into sections. These sections have been adjusted over the years; currently there are 38 sections (LFC sections 1-21; HFC sections 22-38). Each river section corresponds to a riffle-pool complex. Each river section is subdivided into three parts of the channel: left, middle, and right. The river sections and subsections help ensure the entire spawning reach is surveyed. In addition, river sections are used to provide information on the distribution of spawning. Sampling for coded-wire tags, scales, and otoliths begins at Table Mountain Bridge and continues downstream through each section of the survey area. Equal sampling effort is used in the LFC and HFC.

The mark-recapture carcass survey begins the Tuesday immediately after Labor Day. A field crew strives to survey all river sections completely. Crew members consult with river section maps to verify location and boundaries of each section. All possible areas of the river are surveyed, including deep pools and shallow back waters. A boat is used to survey each section. In addition, crew members walk shorelines. Guidelines are provided to the crew on the level of effort to spend in each of the river sections. The crew strives to survey the entire area in four 10-hour days; however this is sometimes exceeded. Each of the 38 river sections receive no more than 90 boat minutes of sampling effort each week during a year with heavy spawning. The crew may spend over 90 minutes each week in a heavily used spawning section during in a slow year. Boat minutes are equivalent to the effort of a full three to four person crew (with or without the boat). For example, if two crews are surveying one river section at the same time, each crew can only spend 45 minutes in the section. If two crews are surveying together, they work closely to minimize duplication of effort. The amount of sampling effort (boat minutes) used among the sub-sections is at the discretion of the field crew. In general, sub-sections are searched relative to the number of carcasses present in each sub-section. All sub-sections must be searched completely. If carcasses are dense in the river section, crew members try to systematically sub-sample from the available carcasses and search the entire river section rather than skipping parts of the river because of insufficient time. Time spent sampling each sub-section is recorded.

Crew members use a decision process for each salmon carcass collected to obtain data. A Chinook salmon carcass is first assessed for condition of “taggable” (recently deceased salmon where the carcass is firmer and may have a clear eye or pinkish gills) or non-“taggable”. If a Chinook salmon carcass is “taggable”, the carcass is recorded as a male or female, fork length is measured, and egg retention (females) are recorded. The “taggable” carcass is then examined for a weekly survey tag (hog nose ring) from the previous weeks. If the carcass has a tag from a previous survey week, the carcass is chopped in half and recorded as a chop by tag color. A “taggable” carcass that has no tags is tagged with a predetermined unique tag color for the survey period. Four different colors are used for weekly tags as previous surveys have revealed that carcasses generally decompose fully before four weeks have passed. Carcasses that are non-“taggable” are examined for a tag from a previous survey week, tallied (by tag color if tag is present) and chopped. Non-“taggable” carcasses are not measured for length or examined for sex. Chopped and tagged carcasses are returned to the river near the location they were originally collected.

Sampling for coded-wire tags, scales, and otoliths is conducted weekly for 2-4 days per week by a two or three-person crew independently of the mark-recapture carcass survey. Sampling is conducted using a jet boat in the HFC and a jet boat or canoe in the LFC.

The crew works ahead of the carcass survey. In each river section, the crew checks the first 25 (years with high escapement) or 50 (years with low escapement) "taggable" carcasses encountered per section. Searching ceases when the first 25 or 50 "taggable" carcasses are found or the entire river section has been searched, regardless of time elapsed.

Crew members use a decision process for each observed Chinook salmon carcass to obtain biological data. When a carcass is encountered, crew members must determine immediately if the carcass is non-"taggable" or "taggable" to reduce potential for sampling bias. Once a fish is determined as "taggable", the carcass must be sampled, even if closer examination reveals the carcass is in poorer condition than originally thought. If the carcass is non-"taggable", the carcass is ignored. If the carcass is "taggable", the carcass is examined for a carcass survey tag. A "taggable" carcass is ignored if a tag is present. If a tag is not present, the "taggable" carcass is examined for an adipose fin. Heads are removed from carcasses that are ad-clipped for coded-wire tag recovery. Each head is stored in a plastic bag with a unique label. The remaining carcass is chopped in half. "Taggable" carcasses that have an adipose fin (unclipped) and lack a hog ring tag are tagged with the same tag color used by the carcass survey crew and recorded. For each carcass sampled, fork length, sex, egg retention (females), adipose fin presence, and coded-wire tag head tag number (if applicable) are recorded on the coded-wire tag sampling datasheet. Data collected for tagged and chopped carcasses is used in the escapement estimate. All chopped and tagged carcasses are released back into the river where they first were collected.

The modified Schaefer (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994), or the Petersen (Ricker 1975) population estimators are used to estimate escapement. The Petersen estimator is used when recapture rates are low. Both estimators require information on the number of carcasses that are marked, the number examined for marks, and the number recaptured. Fresh unclipped adult and grilse carcasses that were tagged during the survey period are considered marked. Carcasses examined for marks are those that were previously tagged, recaptured, or were chopped in-half at first encounter. All sub-populations of carcasses are considered examined for marks ("taggable", "non-taggable", unclipped, ad-clipped, male, female, adults, and grilse).

REVIEW OF EXISTING PROGRAM(S)

Escapement is estimated using a closed-population mark-recapture model, and measures of precision and bias are not estimated. Closed-population mark-recapture models are not recommended for estimating Chinook salmon escapement with mark-recapture carcass survey data as discussed in Chapter 3.

Biological data collection and coded-wire tag recovery efforts are currently independent of the mark-recapture carcass survey. The recommended superpopulation modification of the Cormack-Jolly-Seber model requires carcasses to be tagged with unique numbers and for covariate data to be collected for each marked carcass, such as origin (hatchery or natural), size, sex, etc (Chapter 3).

The survey period encompasses the entire fall-run Chinook salmon spawning period and the survey frequency (weekly) is appropriate for a mark-recapture carcass survey. In addition, the survey covers all Chinook salmon spawning habitat.

A sub-sampling approach (first 50 "taggable" carcasses) is used for biological data collection and coded-wire tag recovery. For the first 50 "taggable" carcasses fork length is measured, sex and female spawning status are examined, and scale and otolith samples are collected. Genetic tissue samples are not collected.

RECOMMENDED MONITORING

1) Continue the mark-recapture carcass survey to estimate escapement of fall-run Chinook salmon, collect biological data and recover coded-wire tags using procedures described in Chapters 3 and 4.

2) Use the Cormack-Jolly-Seber model and investigate use of covariates related to survival and capture probabilities to reduce bias and improve precision as described in Chapter 3.

11 LOWER YUBA RIVER

11.1 FALL-RUN CHINOOK SALMON

In the lower Yuba River there are early returning Chinook salmon with the phenotypic expression of spring-run Chinook salmon. Separate escapement estimates are not made for these spring-run Chinook salmon because spawning overlaps both temporally and spatially and spawners cannot be differentiated by run. Efforts are being made to collect genetic tissue samples to determine if fall-run and spring-run Chinook salmon can be differentiated, and if possible use genetic results to estimate escapement for both runs. In addition, Chinook salmon passage upstream of Daguerre Point Dam (DPD) is monitored using Vaki Riverwatcher systems and the temporal modalities of passage are examined to try to differentiate the runs upstream of DPD. Currently the Chinook salmon escapement estimate in the lower Yuba River is based on mark-recapture carcass survey data and is reported as fall-run Chinook salmon.

SUMMARY OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey – The lower Yuba River extends 38.6 km (24 mi) from Englebright Dam, the first impassible fish barrier on the river, downstream to the confluence with the Feather River near Marysville, CA The lower Yuba River mark-recapture carcass survey is conducted from the Narrows pool downstream to the Simpson Lane Bridge (Massa 2007). The 32 kilometer (20 river mile) survey reach is divided into three reaches: (Reach 1) bottom of Narrows pool to State Route 20 Bridge (4 miles); (Reach 2) State Route 20 Bridge to Daguerre Point Dam (6 miles); and (Reach 3) Daguerre Point Dam to Simpson Lane Bridge (10 miles).

The survey is conducted weekly from the beginning of September through the beginning of January using two jet boats and a crew of five to six personnel. The start date of the carcass survey varied in the past. Beginning in 2009, reconnaissance redd surveys are used to initiate the start of the survey. Field crews begin reconnaissance redd surveys in mid-August. The first mark-recapture carcass survey period begins 10-14 days after the first redd is observed.

Field crew members examine carcasses for freshness, presence of adipose fins, and hog ring tags. Fresh carcasses (one clear eye and pink gills) that have an adipose fin (unclipped) and do not have a tag are tagged with a hog-ring tag. Tags have a unique color for each survey period and are attached on the upper jaw for adults and the lower jaw for grilse. The fork length cutoff for grilse is 65 cm. The CDFG Ocean Salmon Project indicates that 65 cm is an appropriate cutoff length in most years based on the analysis of Central Valley Chinook salmon metadata (mark and recapture data in the Regional Mark Processing Center's RMIS database; D. Massa, PSMFC, pers. comm., 2010). The carcass is returned to flowing water to disperse for possible recapture in subsequent weeks.

All recaptured carcasses tagged during previous surveys are recorded by the appropriate tag color and size (grilse or adult), and then chopped in half.

If a fresh carcass is missing an adipose fin (ad-clipped) or the presence of the fin is unknown, the head is removed for coded-wire tag recovery. Heads are labeled with information on fork length, sex, species, method of take, date and a tag code. The remaining carcass is chopped in half and recorded as a fresh chop.

All observed non-fresh carcasses are counted and chopped in half with a machete to prevent recounting during subsequent surveys. These chopped carcasses are recorded as a non-fresh chop by the appropriate size class (grilse or adult).

All fresh carcasses are measured for fork length and sexed. In addition, scales, genetic tissue samples, and otoliths are collected. Spawning status of fresh female carcasses is recorded as spawned or unspawned. Heads are removed from all fresh ad-clipped carcasses for coded-wire tag recovery.

The modified Schaefer model (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994) is used to estimate escapement. The estimator requires information on the number of carcasses that are marked, number examined for marks, and number recaptured each survey period. Fresh unclipped adult carcasses that were tagged during the survey period are considered marked. Recaptured carcasses are those adult carcasses that were previously tagged and recaptured during a subsequent survey. Carcasses examined for marks are all adult Chinook salmon carcasses tagged, chopped on first capture, or recaptured in a survey period. All sub-populations of adult carcasses are considered examined for marks (male, female, fresh, non-fresh, unclipped, and ad-clipped).

If the mark-recapture data for grilse is sufficient, the data are used to estimate grilse escapement with the modified-Schaefer model. Otherwise, grilse escapement is estimated by multiplying the adult escapement estimate by the proportion of fresh adult to fresh grilse carcasses observed during the survey:

$$N_G = N \times \frac{G}{A};$$

where N is the adult estimate from the modified-Schaefer model, G is the number of fresh grilse carcasses observed and A are the number of fresh adult carcasses observed.

Total fall-run Chinook salmon escapement is the sum of the adult and grilse escapement estimates.

Fish Device Counter – Since 2003, the CDFG has used Vaki Riverwatcher Systems to monitor adult spring-run, fall-run, and late fall-run Chinook salmon passage at Daguerre Point Dam (DPD) on the lower Yuba River (D. Massa, CDFG, pers. comm., 2008). A Vaki Riverwatcher System is installed in the north and south fish ladders at DPD. The Vaki Riverwatcher Systems are automated fish counters that consist of infra-red imaging to create silhouettes of fish passing and a camera that takes still images or short video clips of the fish passing. This monitoring program is currently not used to develop an adult Chinook salmon escapement estimate for the lower Yuba River. The Vaki Riverwatcher Systems provide passage counts and migration timing of Chinook salmon that pass upstream of DPD. Temporal modalities are examined to potentially separate runs (i.e., spring-run, fall-run and late fall-run). In addition, Chinook salmon are examined for the presence of an adipose fin and length is approximated. Spawning habitat is located below DPD, therefore total Chinook salmon escapement for the lower Yuba River cannot be determined using the Vaki Riverwatcher Systems alone.

In 2010, the River Management Team of the lower Yuba River Accord (RMT) used River Management Funds (RMF) to build structures to house computers to prevent overheating and protect them during high flow events. In addition, the RMF was used to purchase new Vaki Riverwatcher Systems for both fish ladders. Vaki technology has improved to enhance the ability to identify fish species and determine the presence of an adipose fin.

Restoration funds from the USFWS Anadromous Fish Restoration Program were used to purchase new solar panels and batteries to power both Vaki Riverwatcher Systems to help prevent power outages during the winter months.

Net passage of Chinook salmon upstream of DPD is calculated. Net upstream passage is the total number of Chinook salmon that passed upstream of DPD minus the number of Chinook salmon that moved downstream of DPD.

Redd Survey - The lower Yuba River Accord's RMT conducted a 2008-2009 pilot Chinook salmon and steelhead redd survey to assist in the development a long-term redd survey. The RMT developed an extensive area redd survey for long-term monitoring and conducted the first survey in 2009-2010. The goals of the extensive area redd surveys include: (1) evaluate and compare the spatial and temporal distribution of redds and redd superimposition for Chinook salmon runs and steelhead spawning in the lower Yuba River; (2) compare the magnitude (and seasonal trends) of lower Yuba River flows and water temperatures with the spatial and temporal distribution of redds; (3) estimate the annual abundance of adult Chinook salmon (potentially by run in conjunction with Vaki Riverwatcher System fish passage data and steelhead; and (4) establish a long-term data set to evaluate habitat utilization by Chinook salmon and steelhead in the lower Yuba River.

The lower Yuba River extends 38.6 km (24 mi) from Englebright Dam, the first impassible fish barrier on the river, downstream to the confluence with the Feather River near Marysville, CA. Approximately 33.6 km (20.9 mi) of the 38.6 km (24 mi) of the lower Yuba River is surveyed. About 1.1 km (0.7 mi) of the lower Yuba River located immediately below the first set if riffles downstream of Deer Creek to the bottom of Narrows Pool is not surveyed due to rugged and dangerous conditions in the steep canyon known as the Narrows. Additionally, a 3.2 km (2 mi) reach of the river from Simpson Lane Bridge is not regularly surveyed because redds have not been observed in past surveys. This reach is surveyed once during peak spawning. The area surveyed for redds is divided into four sampling reaches: (1) Englebright Dam to the first set of riffles below Deer creek (1.4 km; 0.9 mi); (2) Narrows Pool to SR 20 Bridge (6.4 km; 4.0 mi); (3) SR 20 Bridge to Daguerre Point Dam (9.7 km; 6.0 mi); and (4) Daguerre Point Dam to Simpson Lane Bridge (16.1 km; 10.0 mi).

Reconnaissance-level redd surveys begin on or about August 1 to document the initiation of Chinook salmon and steelhead spawning activity in the lower Yuba River. The survey area is examined using a jet boat or walking along the shore. Survey weeks with zero redds are documented. Extensive area redd surveys begin the first week after a redd is first observed during the reconnaissance-level redd survey and extends until May 1 (or until newly constructed redds are no longer observed). This period encompasses the spawning seasons of spring-run, fall-run, and late fall-run Chinook salmon, and steelhead.

The extensive area redd surveys are conducted weekly beginning the week after the first redd is observed through the majority of the Chinook spawning season. From the 2008-2009 pilot redd survey data, a weekly sampling frequency was found to result in the most precise and accurate (least biased) estimates of spawning activity. Therefore, the extensive area surveys are conducted weekly through December. After December the redd survey may be conducted bi-weekly to obtain required data in a most cost-effective manner. For 2010, the surveys were conducted weekly for this period.

The extensive area redd survey is conducted using four kayaks (2009-2010) or pontoon boats (2010-2011) and 1-2 survey crews, with two personnel each. Each person scans the river from the shore to the middle of the river, working downstream. Side channels in the survey area may require walking. Each redd observed is consecutively numbered and measurements are taken for every 17th redd. For each new redd observed throughout the sampling season, the following data are recorded: (1) a GPS (Trimble GeoExplorer XT) location taken at the center of the redd's pit with a unique identifying number (i.e., Date + redd number; e.g., 082908-001); (2) total dimensional area for areas appearing to contain multiple redds with no clear boundaries (i.e., redds superimposed on each other); (3) habitat type (i.e., pool, riffle, run, or glide); (4) substrate composition of ambient habitat based on substrate size immediately upstream of the pit; (5) redd species identification; (6) number of fish observed on the redd; (7) location information (i.e., side-channel or main-channel); (8) comments regarding observable redd superimposition (i.e., redd overlap); and (9) any additional comments. The GPS with data dictionary and marking each redd at the pit with a painted rock is used to ensure redds counted during previous survey weeks are not double-counted.

Currently, an established redd size criterion is used to distinguish Chinook salmon and steelhead redds. A redd that is less than 1.56 m long and less than 1.37 m wide is considered a steelhead redd, redds larger than this length and width are considered Chinook salmon redds. This size criterion was used to classify 129 Chinook salmon redds with 96% accuracy and 28 steelhead redds with 53% accuracy in the lower Yuba River (USFWS 2008). Uncertainty regarding species-specific redd identification using the size criterion initially is addressed by examining the timing of spawning, gravel size, and location of the redd in the river channel.

Chinook salmon and steelhead redds are enumerated above and below DPD. Total redd counts are compared to the mark-recapture carcass survey escapement estimate. In addition, total redd count above DPD is compared to the total net passage observed with the Vaki Riverwatcher System.

REVIEW OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey – Escapement is estimated using a closed-population mark-recapture model, and measures of precision and bias are not estimated. Closed-population mark-recapture models are not recommended for estimating Chinook salmon escapement with mark-recapture carcass survey data as discussed in Chapter 3.

The survey period encompasses the entire Chinook salmon spawning period and the survey frequency (weekly) is appropriate for a mark-recapture carcass survey (Chapter 3).

The mark-recapture survey covers most, but not all known spawning habitat in the lower Yuba River. The reach from Englebright Dam downstream to Narrows Pool is not surveyed.

All fresh carcasses are examined for an adipose fin clip, sex, and spawning status (females only), measured for fork length, and sampled for otoliths, genetic tissue samples and scales.

Fish Device Counter – Fish device counters could have potential counting errors as described in Chapter 2. Potential counting errors with the device counters should be identified and accounted to improve the Chinook salmon passage count for above DPD.

Redd Survey – Redd counts are commonly used for monitoring annual trends in the abundance of spawning salmonids. However, if redds are not detected with 100 percent accuracy, counting errors may obscure important population trends (Maxell 1999). In addition, to estimate escapement using redd counts corrected for observer error, an estimate must be made of the number of females per redd and the ratio of females to males in the population. Counting errors and probability of detection of redds are not incorporated into the redd survey. Redd counts are not expanded for males.

The RMT completed a pilot study to determine the best survey methods, survey frequency and sampling frequency for redd attribute data to obtain the most accurate and precise redd count and attribute data in the lower Yuba River. All Chinook salmon spawning habitat is surveyed, and the survey encompasses the entire spawning season.

RECOMMENDED MONITORING

1) Use the Vaki Riverwatcher Systems to estimate escapement of Chinook salmon upstream of DPD. Recommended methods for using a fish device counter to estimate escapement with levels of precision and bias are described in Chapter 2.

2) Conduct a carcass sampling survey upstream of DPD to collect biological data and recover coded-wire tags using procedures described in Chapter 4.

3) Continue the mark-recapture carcass survey downstream of DPD to estimate escapement of Chinook salmon, collect biological data, and recover coded-wire tags using procedures described in Chapters 3 and 4.

4) Use the Cormack-Jolly-Seber model to estimate escapement downstream of DPD. Investigate the use of covariates related to survival and capture probabilities to reduce bias and improve precision as described in Chapter 3.

5) Continue the redd survey to monitor the temporal and spatial distribution of spawning. The redd survey is also recommended by Eilers et al. (2010) to estimate steelhead abundance downstream of DPD. Recommended methods in Appendix C of Eilers et al. (2010) should be used to correct for counting errors and probability of redd detection.

12 AMERICAN RIVER

12.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1976, the CDFG has conducted mark-recapture carcass surveys on the lower American River to estimate escapement of fall-run Chinook salmon.

The survey area includes the Nimbus weir downstream to the Watt Avenue Bridge (12.9 river miles) (Healey 2005). Chinook salmon spawning occurs within an 18-mile stretch from Paradise Beach to Nimbus Dam. However, most spawning occurs in the uppermost 3 miles. The 12.9-mile reach surveyed is divided into three reaches: (1) Sailor Bar to

Elmanto Access (3.4 mi); (2) Elmanto Access to Goethe Park Footbridge (3.5 mi); and (3) Goethe Park Footbridge to Watt Avenue Bridge (6.0 mi).

The mark-recapture carcass survey takes place from mid-October through mid-January. A crew of 6-7 crew members surveys each reach once per week. The weekly survey takes three or four days to complete. All carcasses are examined for freshness, tags, and the presence of an adipose fin.

All fresh (either one clear eye or pink gills) carcasses that have an adipose fin present (unclipped), are tagged with a color-coded hog ring tag. Hog rings are affixed to the upper jaw on adults (≥68 cm FL) and lower jaw of grilse (<68 cm FL). A unique tag color is used each week to identify carcasses to a specific tagging week. Tagged carcasses are returned to flowing water for dispersal. However, all adult fresh Chinook salmon carcasses below Gristmill Fishing Access are chopped in half (not tagged) due to the likelihood of these carcasses floating out of the study area.

All non-fresh carcasses lacking a hog ring tag are counted, sex and age (i.e., adult or grilse) recorded, and chopped in half.

Carcasses that are collected with a tag from a previous survey period are counted, recorded by tag color, and chopped in half.

All fresh carcasses are measured for fork length (cm), sexed, and aged (i.e., adult or grilse). In addition, scales are collected. Spawning status is examined for both adult and grilse females. Females are recorded as ‘spawned’ if < 30% of eggs are retained, ‘partially spawned’ if 30-70% of eggs are retained, and ‘unspawned’ if >70% of eggs are retained. Genetic tissue samples and otoliths are not collected.

Heads are removed from fresh carcasses that have an adipose fin missing (ad-clipped) for coded-wire tag recovery. Heads are tagged with a jaw tag for identification. The remaining carcass is chopped in half and recorded as a fresh carcass chop.

The modified Schaefer model (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994) is used to estimate escapement. This estimator requires information on the number of carcasses that are marked, number examined for marks, and number recaptured each survey period. Fresh unclipped adult carcasses that were tagged during the survey period are considered marked. Carcasses examined for marks are adult Chinook salmon carcasses tagged, chopped on first capture, or recaptured in a survey period. All sub-populations of adult carcasses are considered examined for marks (male, female, fresh, non-fresh, unclipped, and ad-clipped).

Grilse escapement is estimated by multiplying the adult escapement estimate by the proportion of fresh adult to grilse carcasses observed during the survey:

$$N_G = N \times \frac{G}{A};$$

where N is the adult estimate from the modified-Schaefer model, G is the number of fresh grilse carcasses observed and A are the number of fresh adult carcasses observed. Total escapement is the sum of the adult and the grilse escapement estimate.

REVIEW OF EXISTING PROGRAM(S)

Escapement is estimated using a closed-population mark-recapture model, and measures of precision and bias are not estimated. Closed-population mark-recapture models are not recommended for estimating Chinook salmon escapement with mark-recapture carcass survey data as discussed in Chapter 3.

The survey period encompasses the entire Chinook salmon spawning period and the survey frequency (weekly) is appropriate for a mark-recapture carcass survey (Chapter 3).

The mark-recapture survey covers most, but not all known Chinook salmon spawning habitat in the American River. Of the 18 miles of Chinook salmon spawning habitat 12.9 miles of habitat are surveyed.

All fresh Chinook salmon carcasses are sampled for fork length, sex, age (i.e., adults and grilse), and scales, but are not sampled for genetic tissues or otoliths. Female spawning status is examined for all fresh female carcasses.

Heads are removed from all fresh ad-clipped carcasses for coded-wire tag recovery.

RECOMMENDED MONITORING

1) Continue the mark-recapture carcass survey to estimate in-river escapement of fall-run Chinook salmon, collect biological data, and recover coded-wire tags using procedures described in Chapters 3 and 4.

2) Use the Cormack-Jolly-Seber model to estimate escapement as described in Chapter 3. Investigate use of covariates related to survival and capture probabilities to reduce bias and improve precision.

13 COSUMNES RIVER

13.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 2002, the Fishery Foundation of California (Fishery Foundation) has conducted mark-recapture carcass surveys and redd surveys to estimate Chinook salmon escapement in the Cosumnes River, a tributary of the lower Mokelumne River. In addition, live fish counts are completed.

Twenty miles of the Cosumnes River are surveyed from Latrobe Falls downstream to Twin Cities. This area encompasses all known spawning habitat in the river. The survey area is divided into seven survey reaches. Each reach is surveyed weekly during the immigration and spawning periods (beginning of November through mid-December) by foot or canoe. Survey period and frequency for reaches downstream of Hwy 16 can vary annually due to a lack of fall flows to connect the upper reach with the tidewater; the river channel downstream of Hwy 16 dewaters.

Mark-Recapture Carcass Survey – Mark-recapture of carcasses is conducted in the survey reaches with the most spawning activity (e.g., Meiss Road upstream to Michigan Bar) which can change annually. Mark-recapture carcass survey escapement estimates are calculated each week for each reach; therefore each reach is surveyed twice per week on consecutive days. For example, one reach would be surveyed on Monday and Tuesday and that data used to calculate weekly escapement. Weekly mark-recapture surveys are conducted to minimize the bias associated with violating assumptions of the Petersen model used to estimate escapement.

All observed carcasses are tagged with a unique identification jaw tag unless the carcass is too decayed for tagging. Carcasses too decayed for tagging are chopped in half for removal from the system; these carcasses are not used for estimating escapement. Adipose fin-clipped (ad-clipped) carcasses are tagged in the lower jaw and the upper head is removed for coded-wire tag recovery. Recaptured carcasses are released for multiple recapture events or chopped in half if they are too decayed for subsequent recapture events.

All fresh carcasses are measured (fork length), examined for sex and females are examined for spawning status (spawned or unspawned). If requested by outside researchers, genetic tissue samples and otoliths are collected.

Weekly Chinook salmon escapement is estimated for each reach using the mark-recapture data and the adjusted Petersen model (Ricker 1975). This model requires information on the number of carcasses marked, number examined for marks, and number recaptured in each survey period. Sub-populations of carcasses marked include: adults, grilse, females, males, fresh, non-fresh, unclipped, and ad-clipped. Recaptured carcasses are those carcasses that were previously tagged and are recaptured during a subsequent survey. The number of carcasses examined for marks are the carcasses tagged and the number of recaptured carcasses in a survey period. Standard error and confidence intervals are estimated for total escapement.

The mark-recapture escapement estimate is expanded for fish upstream and downstream of the survey reaches. Redd counts, carcass counts, and unspawned carcass count data are used to expand the escapement estimate to include fish outside of the mark-recapture survey area.

Redd, Live Fish, and Carcass Count Survey – All 20-miles of the survey area are surveyed weekly. All newly constructed redds and live fish are documented using a GPS.

In addition, all carcasses are counted if not included in the reaches with mark-recapture carcass surveys (e.g., carcasses found stranded in pools after fall flows are reduced).

All fresh carcasses counted are measured (fork length), examined for sex and females are examined for spawning status (spawned or unspawned). If requested by outside researchers, genetic tissue samples and otoliths are collected.

Redd counts are used to estimate escapement in survey reaches where carcasses were not marked and recaptured, or if there were too few carcasses for a mark-recapture estimate due to low numbers or high predation. The total redd count in these reaches are expanded by a factor of 2.5, which is the long-term observed average number of fish per redd in the Mokelumne River.

REVIEW OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey – The mark-recapture carcass survey encompasses the entire spawning period and spawning areas of fall-run Chinook salmon in the Cosumnes River. All carcasses that are not too decayed for tagging are disc tagged with a unique identification number. In addition, carcasses are released for multiple recaptures.

Mark-recapture data are analyzed using a closed-population estimator (adjusted Petersen model), and not the recommended superpopulation modification of the Cormack-Jolly-Seber model. Closed-population estimators are not recommended for estimating Chinook salmon escapement as discussed in Chapter 3.

Fork length is measured and sex is examined for all carcasses collected. Spawning status is examined for all female carcasses. Scales are collected from all carcasses. Genetic tissue samples and otoliths are collected upon request. Heads of all ad-clipped carcasses are collected for coded-wire tag recovery.

The spatial and temporal distribution of spawning is examined using carcass survey data.

Redd, Live Fish, and Carcass Count Survey – Redd counts are commonly used for monitoring annual trends in the abundance of spawning salmonids. However, if redds are not detected with 100 percent accuracy, counting errors may obscure important population trends (Maxell 1999). In addition, in order to estimate escapement using redd counts corrected for observer error, the number of females per redd and the ratio of females to males in the population must be estimated. Counting errors and probability of detection of redds are not incorporated into the redd survey. The sex ratio for redd count expansion to include males is based on a long-term data set from the Mokelumne River. The redd survey spans the entire fall-run Chinook salmon spawning period and reach and is conducted frequently.

RECOMMENDED MONITORING

1) Install a fish device counter in the Cosumnes River to monitor Chinook salmon escapement, using procedures recommended in Chapter 2. The Fishery Foundation is currently seeking funds for a device counter.

2) Conduct carcass sampling surveys using recommended procedures in Chapter 4.

3) If a device counter is not installed, continue the mark-recapture carcass survey to estimate in-river escapement of fall-run Chinook salmon, collect biological data, and recover coded-wire tags using procedures described in Chapters 3 and 4.

4) Use the Cormack-Jolly-Seber model to estimate escapement as described in Chapter 3. Investigate use of covariates related to survival and capture probabilities to reduce bias and improve precision.

5) Continue the redd survey to provide information to address the objectives established by the Fishery Foundation or, if needed, estimate Chinook salmon escapement downstream of the mark-recapture survey area. If this survey is needed for the Chinook salmon escapement estimate, counting errors and the detection rates should be accounted for in the estimate. Recommended methods to correct for counting errors and probability of detection of redds are described in Appendix C of Eilers et al. (2010).

14 MOKELUMNE RIVER

14.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Fish Device Counter – From 1990-2006, East Bay Municipal Utility District (EBMUD) conducted video monitoring and trapping on the Mokelumne River at the Woodbridge Irrigation District (WID) Dam to monitor escapement of fall-run Chinook salmon (Workman et al. 2008). Beginning in 2006, year-round video monitoring was not possible due to the reconstruction of WID's dam, fish ladders, and fish screening facilities. EBMUD anticipated that video monitoring was not going to be feasible and developed a mark-recapture carcass survey to monitor escapement beginning in 2003. After a few years of paired data with video monitoring and the mark-recapture carcass survey, they determined that the mark-recapture carcass survey was appropriate. The mark-recapture carcass survey was conducted from 2003-2010. In 2011, video monitoring resumed at the WID dam for the entire fall-run Chinook salmon immigration period.

The WID dam is located at RKM 64 on the Mokelumne River. Video monitoring is conducted 24 hrs per day, 7 days per week until WID lowers their bladder dam and drains Lake Lodi, which in 2011 occurred after the fall-run immigration period. The WID dam has a high-flow and low-flow fish ladder. Next to the high flow fish ladder is a vault with a viewing window built into the fish ladder. Honeywell video monitoring equipment is contained in the vault to monitor fish passage through the viewing window. A white board with a measuring tool is mounted to the side of the ladder to improve fish viewing and approximating fish length. Data are downloaded to a digital video recorder and also streamed live to a server at the EBMUD office in Lodi, CA.

Video footage is examined to identify adult and grilse passage, measure length, identify sex, and determine fish origin by examining adipose fin presence or absence.

Mark-Recapture Carcass Survey – In 2003, EBMUD implemented a mark-recapture carcass survey on the Mokelumne River to estimate fall-run Chinook salmon escapement (Workman et al. 2008). A biometrician was contracted to develop the mark-recapture carcass survey techniques (M. Workman, EBMUB, pers. comm., 2008). EBMUD collected two years of comparable video monitoring and mark-recapture carcass survey data and found the mark-recapture carcass survey escapement estimates were appropriate (Workman et al. 2008).

The mark-recapture carcass survey on the Mokelumne River begins at the base of the Camanche Dam and extends downstream for nine miles (Workman et al. 2008). The study area is divided into three sampling reaches designated as Reach 6a, 6b, and 5. Reach 6a, the upstream most reach, begins at a fish guidance fence below Camanche Dam at river mile (RM) 64 and continues downstream to Highway 88 (RM 61). Reach 6b begins at Highway 88 (RM 61) and extends downstream to Mackville Road (RM 59). Reach 5 begins at Mackville Road (RM 59) and extends downstream to two and one half river miles upstream of Elliott Road (RM 54).

The survey period varies between years. Generally, the survey is conducted twice a week starting in October and ending in January. The survey is initiated with the first Chinook salmon observed in the video monitoring at Woodbridge Dam. Each week, a three-person crew surveys the entire study area in one day. The survey is conducted using a drift boat and by foot. All observed carcasses are collected with a gaff and examined for condition, sex, fork length, presence of an adipose fin, tag or mark. Female carcasses are cut open and examined for spawning status (completely spawned, partially spawned, or unspawned).

Carcasses are classified as fresh (at least one clear eye and presence of blood in the gills), non-fresh (cloudy eyes and no presence of blood in the gills), and skeleton (condition ranges from fungus covered, falling apart, actual skeleton/bones). All fresh and non-fresh carcasses are tagged with a uniquely numbered tag in the lower jaw and colored flagging to denote the week of the survey. All carcasses are checked for an adipose fin. If the adipose fin is missing (ad-clipped), a handheld wand coded-wire tag detector is used to detect the presence of a coded-wire tag. If no coded-wire tag is detected, the carcass is tagged for the mark-recapture carcass survey and released. If a coded-wire tag is detected, the upper portion of the head is removed and the remaining lower jaw is tagged for the mark-recapture carcass survey and released. Tagged carcasses recovered from previous weeks are recorded by the unique tag number and returned to the river for subsequent recapture. The location of all tagged and recovered carcasses is recorded using GPS coordinates. Skeletons are enumerated, the jaws are removed, and the entire skeleton is placed outside of the survey area. The jaws are removed to prevent recounting if scavengers bring the skeleton back into the study area. A percentage of the carcasses are sampled for scales; genetic tissues and otoliths are sampled upon request or for program needs.

From the first week of November through the third week of December, tagged fresh hatchery carcasses are released throughout the reach above and below Highway 88. These carcasses are used to increase sample size for statistical analysis. The number of hatchery carcasses released depends on run size and carcass availability at the hatchery.

Mark-recapture carcass survey data are used to estimate escapement using a Jolly-Dickson open population estimator (Schwarz et al. 1993; Schwarz and Arnason 1996) with the POPAN 5 statistical package (Arnason et al. 1998; http://www.cs.umanitoba.ca/~popan/).

The estimator requires information on the number of carcasses marked, the number examined for marks, and the number recaptured for each survey period. Sub-populations of tagged carcasses include: adult (female and male), grilse, fresh, non-fresh, unclipped, and ad-clipped. Carcasses examined for marks are all subpopulations of carcasses observed in a survey period. The number of recaptured carcasses is the number of tagged carcasses recovered from a previous survey period. The Jolly-Dickson model allows for multiple recaptures, injections of hatchery fish (used to increase sample size), and enumeration of loss on captures (skeletons). The Jolly-Dickson model estimates precision (95% confidence interval) of the escapement estimate based on the variance of recapture probabilities from week to week. Any fish considered being a 'loss on capture', or skeleton, is incorporated into the Jolly-Dickson estimate.

To estimate the number of grilse and adults, the observed ratio of adult-to-grilse in observed carcasses is applied to the total escapement estimate.

Redd Survey – Since 1990, EBMUD has conducted redd surveys on the Mokelumne River to enumerate fall-run Chinook salmon redds (Del Real and Rible 2009). In 1998, EBMUD began counting *O. mykiss* redds as well. Other objectives of the redd surveys are to map the location of individual redds, enumerate redds impacted by superimposition, and determine the use of gravel enhancement areas. When Chinook salmon carcass numbers are extremely low and prevent the generation of an escapement estimate from the mark-recapture carcass survey, the redd survey is used to estimate spawning escapement.

The redd surveys are conducted from Camanche Dam downstream to Elliot Road (Del Real and Rible 2009) and are completed in conjunction with the carcass survey. This survey area includes the majority of spawning habitat in the Mokelumne River. The 9.8-mile survey section is divided into two survey reaches.

Weekly redd surveys are conducted from the beginning of October through March. Both reaches are surveyed each week.

Surveys consist of two to three-person crews walking abreast downstream in the river and searching for redds. A canoe or drift boat is used to transport crews between spawning areas.

Redd locations are recorded using two GPS units (Trimble Geo XH). The GPS units record accurate positions (< 1 meter) and display data from previous surveys preventing redds from being double counted. The location of each redd is recorded at the downstream end of the redd at the tailspill. A minimum of 10 points are recorded for each redd and point files are stored in the GPS using Terrasync software. After field data are collected, information is downloaded and processed using GPS Pathfinder Office 3.10 software. Once data are downloaded, the geographic positions are corrected using the nearest base data provider. The point data files are then imported to an ArcMAP 9.3 (ESRI) database.

Depth and superimposition status for each redd is recorded. Crews determine if previously detected redds are superimposed based on the length of time elapsed since the redd was first recorded and the amount of silt or algae within each redd. In some years, a subset of depth and velocity measurements are recorded just above the nose of Chinook salmon and *O. mykiss* redds. Depth measurements are recorded to the nearest centimeter using a top-setting velocity rod. Velocity measurements are taken using a Flo-Mate™ portable velocity meter (Marsh McBirney, Inc.) at 60% of the depth.

Escapement is estimated by multiplying the total redd count by a long-term average of the number of fish per redd based on historic data collected on the Mokelumne River. The redd survey data is used to estimate escapement of fall-run Chinook salmon when the mark-recapture carcass survey data cannot be used due to low carcass numbers.

REVIEW OF EXISTING PROGRAM(S)

Fish Device Counter – Operation of the fish device counter currently encompasses the entire fall-run Chinook salmon immigration period. The fish device counter is located downstream of the spawning reach, therefore all immigrating Chinook salmon are likely counted.
Fish device counters have multiple types of counting errors as described in Chapter 2. These counting errors are not accounted for in the escapement estimate.

Mark-Recapture Carcass Survey – Currently the superpopulation modification of the Jolly-Seber model is used with an additional modification that adjusts for the injection of hatchery carcasses into the population. Unlike the Jolly-Seber model, the Cormack-Jolly-Seber model does not include the assumption that marked carcasses need complete mixing in the population. 'Jolly-Dixon' is not referenced in current mark-recapture literature, but the term likely includes the name of the person (Dixon) who developed software for the model. Adding hatchery carcasses is a good approach to improve the precision of the escapement estimate if carcass numbers are low. Currently a modification for the injection of hatchery carcasses into the population does not exist for the Cormack-Jolly-Seber model, but this modification could be made.

Compared to the Jolly-Seber model, the Cormack-Jolly-Seber model can easily incorporate covariates (e.g., length, sex) to account for potential differences in survival and capture probabilities of carcasses. Adding covariates to the Jolly-Seber model in the POPAN5 software could be difficult. If substantial differences in survival or capture probabilities (aka heterogeneity) are not accounted for, both the Jolly-Seber and Cormack-Jolly-Seber models are expected to be biased low. However, if the number of carcasses is very low, incorporating covariates into the models may make only a small difference in the escapement estimate.

All carcasses are examined for sex, female spawning status, and measured (fork length). Genetics samples and otoliths are collected upon request. Scales are collected from a subsample of carcasses.

Redd Survey – Redd counts are commonly used for monitoring annual trends in the abundance of spawning salmonids. However, if redds are not detected with 100 percent accuracy, counting errors may obscure important population trends (Maxell 1999). In addition, in order to estimate escapement using redd counts corrected for observer error, the number of females per redd and the ratio of females to males in the population must be estimated. Counting errors and probability of detection of redds are not incorporated into the redd survey. The sex ratio for redd count expansion is based on a long-term data set. The redd survey spans the entire fall-run Chinook salmon spawning period and reach and is conducted frequently.

RECOMMENDED MONITORING

1) Continue to monitor fall-run Chinook salmon escapement with the fish device counter. Recommended methods for using a fish device counter to estimate escapement with levels of precision and bias are described in Chapter 2.

2) Conduct a carcass sampling survey for biological data collection and coded-wire tag recovery as described in Chapter 4.

3) If a mark-recapture carcass survey is used to estimate fall-run Chinook salmon escapement, data should be analyzed using the model currently used and the recommended Cormack-Jolly-Seber model (Chapter 3). Data collected from the hatchery injected carcasses will need to be removed from the dataset for the Cormack-Jolly-Seber model. Removal of these data should be relatively easy since all carcasses are uniquely tagged.

   Use the Cormack-Jolly-Seber model to investigate use of covariates related to survival and capture probabilities to reduce bias and improve precision of the escapement estimate.

4) Continue the redd survey to address the objectives established by EBMUD. In addition, this survey is recommended by Eilers et al. (2010) to estimate steelhead abundance if the device counter cannot be operated over the entire steelhead immigration period. If this survey is needed for the Chinook salmon escapement estimate, counting errors and detection rates should be accounted for in the estimate, as for estimating steelhead abundance. Recommended methods to correct for counting errors and probability of detection of redds are described in Appendix C of Eilers et al. (2010).

CHAPTER 8

RECOMMENDED CHINOOK SALMON ESCAPEMENT MONITORING FOR THE NORTHWESTERN CALIFORNIA DIVERSITY GROUP

15 COTTONWOOD CREEK

15.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 2007, the CDFG has operated a partial horizontal bar weir with a fish device counter (traditional optical video cameras; video station) to monitor adult fall-run Chinook salmon escapement in Cottonwood Creek (Killam 2008b). The video station is located approximately 1.2 miles upstream from the mouth of Cottonwood Creek at the Sacramento River and is operated from mid-September through the beginning of December. The site was chosen based on these criteria: (1) limited public access to avoid vandalism and poaching, (2) a close power source, (3) proximity to the mouth of Cottonwood Creek so most salmonids would migrate past the site, (4) permission from landowner to construct and access site daily, and (5) suitable stream geology to place weir (shallow and even stream bottom). Chinook salmon may spawn below the station; therefore, redds are counted in the 1.2 mile reach from the station to the mouth of Cottonwood Creek.

Video station methodology has continually evolved as new technology becomes affordable and available; however, the method has remained basically the same. A partial horizontal bar weir is placed in a “V” shape facing upstream to guide fish to a center opening. In the center opening, white high density polyethylene sheets are staked into the stream bottom to better view fish passage. In addition, a measurement device is placed on the white sheets to estimate length of fish and aid in identification of fish species based on length criteria. Fish are guided across the HDPE sheets using two guidance weir panels. Monochrome (black and white) weatherproof cameras (PC88WR) are used to produce images of fish under various lighting conditions. A camera with remote lighting and other wiring hookups is placed in a “camera box” and suspended about 15 feet over the creek to get an overhead image of fish. At least one underwater camera is used to identify the species of fish observed and examine salmon for adipose fin clips. A DVR records video footage 24 hours per day. In the office, personnel view video footage on a computer monitor to count fish, determine fish species, and if possible determine sex.

Chinook salmon escapement is estimated using the counts of Chinook salmon passing upstream of the video monitoring station. Twenty-four hour fish passage counts are tallied in one-half hour increments (48 increments total). Downstream moving Chinook salmon are subtracted from the total number of upstream passing Chinook salmon for each video increment to get a total passage estimate. The Chinook salmon total passage estimate is adjusted to account for quality control (QC) of fish counts. QC checks are completed for fish counts in the 48 one-half hour video increments. QC is completed for all video increments with fish passage counts greater than 9. If counts differ between the first and second count, a third count is made to determine the final count for that video increment. For video increments with 9 or fewer salmon counted, the increments are stratified by reader and by count type. Video increments are classified as Count Type 0 and Count Type 1. Count Type 0 is used for video increments with counts of one or no salmon. Count Type 1 is used for video increments with counts of 2-9 salmon. A random subsample of video increments is chosen from each stratum (reader and Count Type) and reviewed by personnel. The adjustment factor is created for each stratum (reader and count type) from a random subsample of strata and applied to all video increments' Type 0 and Type 1 counts. The adjustment factor is the percent difference between the sum of the total stratum QC counts and the sum of the total stratum original counts (within the subsample). The adjustment factor and original counts are multiplied (for each stratum) to determine the adjusted QC count. The adjusted counts for each video increment in each stratum are summed to get a total adjusted count. The QC counts are summed to calculate the total salmon passage for the station.

Chinook salmon passage estimates are further adjusted for video tape malfunction, water clarity, and redds observed downstream of the weir. Interpolation is used when fish cannot be counted. The redd count below the weir is multiplied by two. An assumption is made that one female builds one redd and there is a 1:1 female-to-male sex ratio.

REVIEW OF EXISTING PROGRAM(S)

The video station is located below most Chinook spawning and is operated during the entire fall-run Chinook salmon immigration period; therefore most Chinook salmon returning to Cottonwood Creek pass the video station. Interpolation is used to account for missing data and a quality control procedure is completed to account for reader error.

Very few Chinook salmon spawn below the weir and are enumerated using a redd survey In 2007 18 redds (36 fish expansion) were found downstream of the weir (Killiam 2008b). While the redd survey does not incorporate error into the redd count, accounting for error may not be worth the additional effort due to the very limited spawning activity.

Beginning in 2010, video footage from underwater cameras was examined to approximate fish length, ad-clip status, and sex.

RECOMMENDED MONITORING

1) Continue to monitor fall-run Chinook salmon escapement with the fish device counter. Recommended methods for using a fish device counter to estimate escapement with levels of precision and bias are described in Chapter 2. In addition, this technique is being recommended to monitor steelhead in Cottonwood Creek (Eilers et al. 2010).

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

16 BEEGUM CREEK

16.1 SPRING-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1973, the CDFG has conducted snorkel surveys on Beegum Creek to monitor escapement of adult spring-run Chinook salmon (Killam 2007). Beegum Creek is one of the few tributaries to the Sacramento River without a dam. In addition, the creek is on the west side of the Sacramento Valley with a drier and hotter climate than east side tributaries. Salmon travel the farthest distance to hold and spawn in Beegum Creek compared to any other watershed in the Central Valley (387 miles from the Golden Gate Bridge). The stream is remote and access to spring-run Chinook salmon holding habitat is difficult.

The survey area of Beegum Creek is accessed using a trail leading to the North Fork. The North Fork is surveyed from the trail access point to the confluence with the South Fork. The confluence joins the two forks and is the upper end of the mainstem creek. The mainstem is surveyed downstream to an old water ditch located upstream of the Highway 36 Bridge. A total of 7.5 miles is surveyed with an elevation drop of 698 ft.

Typically, one or two surveys are conducted from March through September. Surveys are conducted sporadically due to lack of funding, personnel availability, and poor weather conditions. Sampling early (March and June) helps identify when Chinook salmon arrive. A crew of 1-3 experienced people walks and snorkels the entire survey area in one day. Personnel count all live Chinook salmon and carcasses.

All carcasses are sampled for genetic tissues, otoliths, and scales; heads are collected from all adipose fin-clipped fish.

The escapement estimate reported includes the total count of live fish and carcasses observed.

REVIEW OF EXISTING PROGRAM(S)

All potential holding habitat for spring-run Chinook salmon is surveyed in Beegum Creek during their holding period; therefore all fish may be available for counting and collection of biological data. However, due to lack of resources (funding and personnel) the survey may be conducted prior to the arrival of all immigrating Chinook salmon. Therefore, escapement may be underestimated.

The survey is not designed to estimate escapement with levels of precision or bias; the escapement estimate is considered an index.

Collecting biological data and coded-wire tags would require field crews to survey during the spawning period (likely September); however, resources are not always available to conduct the surveys. When spawning surveys are conducted, otoliths, scales, and genetic tissue samples are collected from all carcasses. Length is not measured and sex and female spawning status are not examined. Heads are collected from all adipose fin clipped carcasses.

RECOMMENDED MONITORING

1) Install a fish device counter and weir to monitor spring-run Chinook salmon escapement. Recommended procedures for estimating escapement with levels of precision and bias using fish device counters are described in Chapter 2. This technique was also recommended for monitoring steelhead in Cottonwood Creek (Eilers et al. 2010), but will probably need to be placed higher in the watershed for steelhead monitoring due to high flows during the immigration period (Killam, CDFG, pers. comm., 2010).

2) Continue the snorkel survey to monitor the spatial distribution of spring-run Chinook salmon during their holding and spawning periods, and to collect biological data and coded-wire tags as described in Chapter 4.

3) Until the fish device counter is installed in Beegum Creek, continue the snorkel survey to provide an index of spawning escapement.

17 CLEAR CREEK

17.1 SPRING-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

The U.S. Fish and Wildlife Service (USFWS) has used snorkel surveys to monitor spring-run Chinook salmon escapement in Clear Creek since 1999 (Newton and Brown 2005). Clear Creek, Shasta County, is a westside tributary to the Upper Sacramento River and enters the mainstem at river mile (RM) 289. The purpose of this monitoring program is to examine adult spring-run Chinook salmon population status and trends, spatial and temporal distribution, and evaluate the effectiveness of stream and habitat restoration actions.

The snorkel survey is conducted from below Whiskeytown Dam (RM 18.1) to the USFWS rotary screw trap (RM 1.7) from April through November. In May and June, the survey has been used to evaluate Chinook salmon immigration during scheduled pulse flows. One survey is used in August to count adult Chinook salmon, which is the official index of escapement. Surveys are conducted every two weeks in September and October to count redds and collect carcasses. The survey area is divided into six sampling reaches. Surveys terminate in the lowermost reach (Reach 6) in late September or early October due to the presence of fall-run Chinook salmon. Crews begin the survey at the upper most reach (Reach 1) and snorkel downstream with the current and abreast to each other in a line perpendicular to flow. Each person counts the fish in their lane and, as needed, crew members confer to avoid missing or double counting fish. Crews sum their counts of live fish observed. In addition, a GPS is used to record the location of observed spring-run Chinook salmon.

All observed carcasses are sampled for biological data, and the head is collected from adipose fin clipped carcasses and carcasses with unknown clip status for coded-wire tag recovery. All carcasses are sampled for genetic tissues, scales, otoliths, measured for fork length, and examined for sex and female spawning status (presence of eggs).

Redds are examined to determine Chinook salmon spawn timing, spatial distribution, and success of gravel supplementation projects. All redds are flagged by marking nearby vegetation to prevent recounting. Redds are documented if they have a clearly defined pit and tailspill. "Practice" or "test" redds lacking clear form are not counted. GPS coordinates are recorded for all redds. Spring-run Chinook salmon redd dimensions, depths, water velocities, and dominate substrate size are measured. Redd dimensions include maximum length and maximum width. Area of each redd is calculated using the equation for an ellipse (area = $\pi * \frac{1}{2}$ width * ½ length). Depth measurements include maximum depth (redd pit), minimum depth (redd tailspill), and pre-redd depth (measured immediately upstream of redd). Redd size, depth, and water velocity measurements are compared to ranges reported for stream type (spring-run) Chinook by Healey (1991). Substrate type used to construct redds is recorded as: (1) native, (2) supplementation gravel, (3) mixture of native and supplementation gravel, and (4) unknown gravel type. Supplementation gravel is identified by tracer rock (chert not native to Clear Creek), size (2-4 inches), and shape (round edges).

A temporary weir is installed near the top of Reach 5 in late-August (RM 7.4) before fall-run Chinook salmon enter Clear Creek (beginning of September) to prevent hybridization of fall-run and spring-run Chinook salmon. The weir is checked a minimum of three times per week (with increased monitoring based on environmental conditions) to ensure that the weir is fish tight, remove debris, detect vandalism, and biologically sample Chinook salmon carcasses (Giovannetti and Brown 2009). Since weir monitoring occurs at the same time as the snorkel survey, spring-run Chinook salmon carcass and redd counts are included in the dataset for Reach 5.

StowAway® temperature loggers are deployed to evaluate water temperatures for Chinook salmon eggs incubating in redds. Minimum days of exposure to high water temperature was based on the following criteria: (1) 1,600 Daily Temperature Units are required for egg incubation to time of emergence (Piper et al. 1982); and (2) the redds were constructed the day following the preceding survey (April-July) or the day preceding the current survey (August-November).

The escapement estimate for spring-run Chinook salmon in Clear Creek is the August count of observed live Chinook salmon (an index). Monthly counts and summary statistics of observed live Chinook salmon, carcasses, and redds are included in an annual report.

REVIEW OF EXISTING PROGRAM(S)

Almost the entire migratory corridor and all spring-run Chinook salmon holding and spawning habitat is surveyed in Clear Creek. The survey encompasses the immigration, holding and spawning periods.

The escapement estimate is an index; the survey is not designed to estimate escapement with levels of precision or bias.

Typically the survey is conducted bi-weekly during the spawning period (September and October); therefore, newly spawned carcasses should be available for sampling.

All observed spring-run carcasses are sampled for biological data, and the head is collected from adipose fin clipped carcasses and carcasses with unknown clip status for coded-wire tag recovery. All carcasses are sampled for genetic tissues, scales, otoliths, measured for fork length, and examined for sex and female spawning status (presence of eggs).

The survey collects data to examine the spatial and temporal distribution of spring-run Chinook salmon during their holding and spawning periods. In addition, the survey collects data to evaluate the effectiveness of stream and habitat restoration actions.

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Clear Creek to estimate spring-run Chinook salmon escapement. Recommended procedures for estimating escapement with levels of precision and bias using fish device counters are described in Chapter 2. This technique is also recommended for monitoring steelhead from September through June (Eilers et al. 2010) and fall and late fall-run (Sections 19.2 and 19.3). Monitoring should be year-round for these runs of Chinook salmon and steelhead.

2) Continue the snorkel redd survey to collect biological data and recover coded-wire tags as described in Chapter 4. In addition, continue to monitor the segregation weir including sampling carcasses for biological data and recovering CWTs. Continuation of this survey would provide information on the spatial and temporal distribution of spring-run Chinook salmon during their immigration, holding, and spawning periods and evaluate the effectiveness of stream and habitat restoration actions. In addition, the survey should continue to provide an index of escapement until a device counter is installed.

17.2 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Since 1988, the CDFG in collaboration with USFWS has used a mark-recapture carcass survey to monitor fall-run Chinook salmon escapement in Clear Creek. The fall-run escapement estimate for Clear Creek is based on data from this survey (Harvey-Arrison 2007).

The mark-recapture carcass survey is conducted weekly from the second week in October through December over a 4.2-mile reach downstream of the former McCormick-Saeltzer Dam site. The survey area is divided into two reaches. Two to three-person crews walk each reach in a downstream direction searching for carcasses. All carcasses observed are collected, measured for fork length (cm), recorded as a grilse (< 61 cm) or an adult (≥ 61 cm), examined for ad-clips and sexed. The head is collected from all ad-clipped carcasses for coded-wire tag recovery and chopped in half. All non-fresh (opaque eye, white gills, body not firm) carcasses are chopped and recorded as a chop under the appropriate size class (grilse or adult) and sex.

For fresh Chinook salmon carcasses (at least one clear eye, red gills, firm "bright" body) with an adipose fin (unclipped), the upper jaw is tagged with a color-coded hog ring, recorded under the appropriate size class (grilse or adult) and sex, and the carcass is released into running water. If running water is not nearby, the fresh unclipped carcass is chopped in half and recorded as a chop under the appropriate size class and sex. In addition, during weeks of peak carcass recovery, the biologist may make the decision to reduce the number of new tagged fresh carcasses and chop them in-half. These chopped carcasses are recorded as a chop under the appropriate size class and sex.

Chinook salmon carcasses with a jaw tag from a previous survey week are chopped in-half and recorded as a recovery by tag color.

The modified Schaefer (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994) or the Petersen (Ricker 1975) models are used to estimate fall-run Chinook salmon escapement. The Petersen estimator is used when recapture rates are low. Both estimators require information on the number of carcasses marked, number examined for marks, and number recaptured each survey period. Fresh unclipped adult and grilse carcasses that were tagged during the survey period are marked. Carcasses examined for marks are those that were previously tagged, recaptured, or were chopped in half at first encounter. All sub-populations of carcasses are considered examined for marks (fresh, non-fresh, unclipped, ad-clipped, male, female, adults, and grilse).

REVIEW OF EXISTING PROGRAM(S)

Escapement is estimated using a closed-population mark-recapture model, and measures of precision and bias are not estimated. Closed-population mark-recapture models are not recommended for estimating Chinook salmon escapement with mark-recapture carcass surveys as discussed in Chapter 3.

The survey period encompasses the entire Chinook salmon spawning period and the survey frequency (weekly) is appropriate for a mark-recapture carcass survey. In addition, the survey covers all spawning habitat.

All carcasses are examined for sex and fork length is measured. Genetic tissues, scales, and otoliths are only collected if requested and if time and funding permits. Heads from all observed ad-clipped carcasses are collected for CWT recovery.

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Clear Creek to estimate fall-run Chinook salmon escapement. Recommended procedures for estimating escapement with levels of precision and bias using fish device counters are described in Chapter 2. This technique is also recommended for monitoring steelhead from September through June (Eilers et al. 2010) and for spring-run and late fall-run Chinook salmon (Sections 19.1 and 19.3). Monitoring should be year-round to monitor these runs of Chinook salmon and steelhead.

2) Conduct carcass sampling surveys to collect biological data and recover coded-wire tags as described in Chapter 4. The existing program's survey area, period, and frequency are appropriate for the carcass sampling survey.

3) Until a fish device counter is installed, continue to use a mark-recapture carcass survey to estimate escapement using recommended procedures in Chapter 3.

17.3 LATE FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

The USFWS conducts a redd survey to monitor late fall-run Chinook salmon and steelhead spawning. The escapement estimate for late fall-run Chinook salmon in Clear Creek is an index of escapement.

The redd survey extends from below Whiskeytown Dam (impassible barrier) at river mile (RM) 18.1 downstream to RM 1.7, and is divided into six sampling reaches. To attempt to count as many redds as possible, surveys are scheduled every two weeks from January to April, and are carried out depending on environmental conditions (Giovannetti and Brown 2007). Surveys are not conducted during rain events or if flow is greater than 500 cfs due to poor water clarity and high velocities that limit the visibility of redds. The number of complete creek surveys varies each year due to weather and staff availability.

Redd surveys are conducted by kayak on all of the sampling reaches (Giovannetti and Brown 2007). Each crew consists of two experienced crew members (completed at least one season of surveying) and one member trained in the office and in the field for a full day. Three kayaks are distributed across the width of the stream evenly for complete coverage. Crew members kneel on the pontoons or stand in the bottom of boats to get the best vantage point. Polarized sunglasses and caps with visors are worn to increase visibility into the water. When searching for redds, the crew stops at places in the stream where gravel is clean, sorted, or contrasted with the surrounding substrate. A snorkel and mask are used to examine redds more thoroughly. In stretches of fast moving water, kayaks are parked and crew members snorkel or walk to search for redds.

Redds are identified by fish species (Giovannetti and Brown 2007). During the survey, three species build redds: (1) non-migratory (resident rainbow trout) and migratory *O. mykiss* (anadromous steelhead and potadromous rainbow trout from the Sacramento River), (2) late fall-run Chinook salmon, and (3) Pacific lamprey. Redd characteristics differ between species. The following criteria are used to identify the species: (1)

observing a fish on the redd or (2) redd size, location, and substrate type. Redds of anadromous and non-anadromous rainbow trout cannot be differentiated. On Clear Creek, *O. mykiss* redds are typically smaller than Chinook redds, constructed using smaller substrates, and often built closer to the shoreline or near structure. Lamprey redds are circular in appearance and tailings are found on all sides of the pit. A redd is defined as having a pit and a tail. Incomplete redds are not counted, but are marked as test redds and flagged for checking on the next survey.

Physical characteristics (velocity, substrate, size) of redds are measured to gain a better understanding of the spawning habitat being used. All redds are measured when they are first encountered unless a fish is present or time is limiting.

Individual redds are tracked throughout the spawning season to prevent counting redds more than once and to examine redd distribution (Giovannetti and Brown 2007). To track redds, coordinates are recorded using a GPS and a flag is tied to the nearest tree branch or vegetation located upstream of the pit on the side of the stream closest to the redd. Each redd is given an identification number that includes date, reach number, and number for the survey day.

Redds are aged to determine how long the redd lasts and if a redd was missed on a previous survey. Redd detection decreases with time because algal growth and flattening of redds due to fine sediment accumulation reduces the contrast of the redd from the surrounding substrate. Age is defined by the visibility of the redd: (1) Age 2 redds are clearly visible and clean; (2) Age 3 redds are older and the tail split is flat or pit has fines or algal growth; (3) Age 4 redds are old and hard to discern; and (4) Age 5 redds no longer exist, only the flag. A tracking study in 2003-2005 found that without high flows, redds may be visible for 4 weeks and flows above 3,000 cfs may scour redds in Clear Creek. Currently, redds are only aged in their first encounter.

During the redd survey, observations of live steelhead, late fall-run Chinook salmon, and lamprey on redds are recorded. In addition, all live late fall-run Chinook are counted throughout the entire survey. All Chinook salmon carcasses are measured for fork length, examined for sex and an adipose fin. Scales, genetic tissues, and otoliths are collected. In addition, heads are removed from all ad-clipped carcasses for coded-wire tag recovery. Carcasses are marked to prevent double counting.

The Chinook salmon escapement estimate is an index. Escapement reported is the total count of redds from the kayak survey (Giovannetti and Brown 2007). However, total counts of live late fall-run Chinook and total carcass counts are also reported.

REVIEW OF EXISTING PROGRAM(S)

The Chinook salmon escapement estimate is considered an index and is currently estimated without measures of precision or bias. Survey frequency can vary annually due to weather conditions.

The redd survey encompasses all known spawning habitat in Clear Creek and is conducted throughout the spawning season.

All observed late fall-run Chinook salmon carcasses are sampled for biological data, and the head is collected from adipose fin clipped carcasses and carcasses with unknown clip status for coded-wire tag recovery. All carcasses are sampled for genetic tissues, scales, otoliths, measured for fork length, and examined for sex and female spawning status (presence of eggs).

RECOMMENDED MONITORING

1) Install a fish device counter and weir in Clear Creek to estimate late fall-run Chinook salmon escapement. Recommended procedures for estimating escapement with levels of precision and bias using fish device counters are described in Chapter 2. This technique is also recommended for monitoring steelhead from September through June (Eilers et al. 2010) and for spring-run and fall-run Chinook salmon (Sections 19.1 and 19.2). Monitoring should be year-round for these runs of Chinook salmon and steelhead.

2) Continue the redd survey to collect biological data and recover coded-wire tags as recommended in Chapter 4. The survey would continue to examine the spatial and temporal distribution of late fall-run Chinook salmon spawning and evaluate the effectiveness of stream and habitat restoration actions. In addition, the survey should continue to provide an index of escapement until a device counter is installed.

CHAPTER 9

RECOMMENDED CHINOOK SALMON ESCAPEMENT MONITORING FOR THE SOUTHERN SIERRA NEVADA DIVERSITY GROUP

18 STANISLAUS RIVER

18.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey – Mark-recapture carcass surveys have been used by the CDFG since 1971 to estimate escapement of fall-run Chinook salmon in the Stanislaus River (Guignard 2008).

Mark-recapture carcass surveys are conducted weekly from the first week of October through December. The survey covers a 25-mile reach from river mile (RM) 58 downstream to RM 33 near Riverbank. The survey reach is divided into four sections. All riffles in the study reach are geo-referenced in ArcView with unique identification based on sequential letter/number designations for river mile and riffle (e.g., A1-C1 are in Section 1). The mark-recapture carcass survey is conducted in sections 2, 3, and 4 using a drift boat.

A 2-3 person crew with a drift boat surveys from upstream to downstream and collects all visible carcasses from each riffle and pool complex. Multiple passes are made through each pool and riffle to ensure the entire area is surveyed. Carcasses are classified as fresh (at least one clear eye and presence of blood in the gills), non-fresh (cloudy eyes), or skeleton (condition ranges from fungus covered to actual skeleton). All fresh and non-fresh carcasses are marked by attaching a uniquely numbered aluminum tag to the lower jaw. Scale samples and otoliths are collected from all carcasses when the number of carcasses is low, or systematically (i.e., every third carcass) when carcass numbers are high. Fork length (0.5 cm) is measured and sex recorded for all carcasses tagged. In addition, all fresh female carcasses are examined for spawning status (fully spawned, partially spawned, and unspawned). Heads are collected from adipose fin clipped fish for coded-wire tag recovery; the lower jaw is left intact and tagged. Newly tagged carcasses are returned to moving water at the tail end of the riffle or above the pool where the carcasses were collected. Returned tagged carcasses are available for recapture during subsequent weeks. Recovered carcasses from previous survey weeks are recorded by the unique tag number and returned to the river for potential recapture during subsequent weeks. (Prior to 2008, recovered carcasses were chopped.) All skeletons are chopped and returned to the river.

Live fish and redds are counted during the survey. Crews use tally counters to count live fish and redds as they float over riffles and pools in the drift boat. Counts are taken for each riffle and pool with the unique riffle identification numbers.

Section 1 is too dangerous to survey by drift boat, so this section is surveyed by foot. A two-person crew walks the accessible pool and riffle combination areas that are known to aggregate carcasses. Mark-recapture is not used in this section. Carcasses are collected, enumerated, chopped, and returned to the river. Chopping is used to prevent duplicate counting.

Carcass survey data in sections 2, 3, and 4 are used to estimate escapement using the Jolly-Seber model (Seber 1982), the modified Schaefer model (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994), or the Adjusted Petersen model (Ricker 1975). Model selection depends on the number of tagged and recaptured carcasses. The Jolly-Seber model is a better estimator if the number of tagged and recovered carcasses is greater than 10 for each survey week (Schwartz et al. 1993). If the number of tagged and recaptured carcasses is low, the Schaefer model overestimates escapement (Law 1994). These models require information on the number of carcasses marked, number examined for marks, and number recaptured in each survey period. However, the multiple-recapture data are not used for estimating escapement. Only the first recapture event is used for estimating escapement. Sub-populations of carcasses tagged include: adults, grilse, females, males, fresh, non-fresh, unclipped, and ad-clipped. Recaptured carcasses are those carcasses that were previously tagged and are recaptured during a subsequent survey. The number of carcasses examined for marks are the carcasses tagged and the number of first time recaptured carcasses in a survey period.

Escapement in section 1 is estimated by applying a ratio of 2.74 salmon to each redd to the total number of redds counted. The ratio is based on 15 years of salmon counts at a weir and redd counts on the Mokelumne River (Workman 2007 as cited by Guignard 2008).

Total Chinook salmon escapement is the sum of the mark-recapture estimate and redd survey estimate.

Fish Device Counter – Since 2002, a resistance board weir (weir) and Vaki Riverwatcher System (Vaki) has been used to monitor Chinook salmon escapement on the Stanislaus River (Cramer Fish Sciences 2002-2007 and FISHBIO Environmental, LLC 2007-present).

The weir and Vaki are located at river kilometer (RKM) 50.6 and are operated from the beginning of September through June (Anderson et al. 2007). The site is downstream of the lowest spawning area and has the characteristics necessary for operation and maintenance of the weir and Vaki. The weir is checked daily when flows are above 500 cfs, otherwise every other day. The Vaki collects image data (i.e., silhouettes and digital photos) and direction of passage (i.e., up or downstream) for all objects greater than 40 mm.

For each fish passage event, corresponding photos are reviewed. Morphometrics are used to aid in fish identification when viewing the silhouettes; however, the best image data are from the photos. Digital photos improve identification of fish, and are used to distinguish sex and the presence of an adipose fin. The Vaki silhouette measures the depth of each object and approximates total length based on a predefined length-to-depth ratio. For each record, silhouette quality (poor or good) and photo quality (poor, fair, or good) are recorded. In addition, identification certainty (positive, very likely, or likely) is recorded for each fish identified.

The escapement estimate for fall-run Chinook salmon is the total count of identified Chinook salmon passing upstream.

Live traps at the weir are operated on a '2-day on' and '2-day off' pattern from November to early December during low flows (600 cfs). When traps are operated, they are checked twice a day. Scales (10 per fish) are collected from the scale pocket of each Chinook salmon. Fork length (mm), total length (mm), and depth measurements (mm, maximum girth measured immediately anterior to the dorsal fin insertion point) are made for each Chinook salmon captured.

REVIEW OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey – The mark-recapture carcass survey encompasses the entire spawning period of fall-run Chinook salmon in the Stanislaus River, but not all of the spawning area. Due to dangerous conditions in the uppermost section (survey section 1) only accessible riffle-pool combinations are surveyed for redds and carcasses are counted.

Escapement is estimated without levels of precision and bias using mark-recapture carcass data (collected in sections 2-4) and redd survey data (section 1). Escapement in section 1 is estimated as the maximum number of redds counted multiplied by 2.74 fish per redd. The entire area of section 1 is not surveyed, therefore redds are likely missed. In addition, errors in redd counts are not accounted for since the probability to detect redds and redd life is not incorporated into the estimate.

The mark-recapture carcass survey methods for marking, tagging, recapturing and collecting covariate data for each carcass are as recommended in Chapter 3. Mark-recapture data are analyzed using a closed-population estimator (adjusted Petersen or modified Schaefer model) or the Jolly-Seber model, and not the recommended superpopulation modification of the Cormack Jolly Seber model. Closed population estimators are not recommended as discussed in Chapter 3. Compared to the Jolly-Seber model, the recommended Cormack Jolly Seber model does not have the assumption of complete mixing of marked carcasses into the population. In addition, the Cormack Jolly Seber model can easily have covariates (e.g., length, sex) incorporated to account for potential differences in survival and capture probabilities of carcasses.

Fork length is measured and sex is examined for all carcasses collected. Spawning status is examined for all fresh female carcasses. Scales and otoliths are collected from all carcasses when numbers are low, but systematically when numbers are high. Genetic tissue samples are not collected. Heads of all ad-clipped carcasses are collected for coded-wire tag recovery.

The spatial and temporal distribution of spawning is examined using carcass survey data.

Fish Device Counter – The weir and Vaki Riverwatcher system is located downstream of fall-run Chinook spawning and is operated over the entire immigration period. However, the weir may not be fish tight; a fish was observed to pass over the top of the weir (Tim Heyne, pers. comm.., CDFG, 2008).

Escapement is estimated without levels of precision and bias. Counting errors with fish device counters are not examined and accounted for in the escapement estimate.

Some biological data (sex, length and scale samples) are collected and fish are examined for the presence of an adipose fin. Length from the Vaki Riverwatcher is estimated based on a depth measurement and a predefined depth-to-length ratio. Length is measured for all fish caught in the live trap. All fish recorded by the Vaki Riverwatcher and fish caught in the live trap are examined for the presence of an adipose fin clip. Scales are sampled for all fish caught in the live trap. CWT recovery and otolith collection is not possible since fish are sampled alive, and spawning status cannot be examined since fish are immigrating. Genetic tissue samples are not collected.

Run timing is examined using the Vaki Riverwatcher data.

RECOMMENDED MONITORING

1) Use the Vaki Riverwatcher System to estimate fall-run Chinook salmon escapement. With corrections made for potential counting errors, the fish device counter is expected to yield more accurate estimates of total escapement than the mark-recapture carcass survey. Recommended procedures for using a fish device counter to estimate escapement with levels of precision and bias are described in Chapter 2. This technique is also recommended for monitoring steelhead (Eilers et al. 2010).

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

19 TUOLUMNE RIVER

19.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey – Mark-recapture carcass surveys have been used by the CDFG since 1971 to estimate escapement of fall-run Chinook salmon in the Tuolumne River (Blakeman 2008).

Mark-recapture carcass surveys are conducted weekly from the first week of October through December. The survey covers a 26.5 mile reach from river mile (RM) 52 near

La Grange Dam downstream to RM 24.1. The survey reach is divided into five sections. All riffles in the study reach are geo-referenced in ArcView with unique identification based on sequential letter/number designations for river mile and riffle (e.g., A1-E1 are in Section 1).

A 2-3 person crew with a drift boat surveys from upstream to downstream and collects all visible carcasses from each riffle and pool complex. Multiple passes are made through each pool and riffle to ensure the entire area is surveyed. Carcasses are classified as fresh (at least one clear eye and presence of blood in the gills), non-fresh (cloudy eyes), or skeleton (condition ranges from fungus covered to actual skeleton). All fresh and non-fresh carcasses are marked by attaching a uniquely numbered aluminum tag to the lower jaw. Scale samples and otoliths are collected from all carcasses when the number of carcasses is low, or systematically (i.e., every third carcass) when carcass numbers are high. Fork length (0.5 cm) is measured and sex recorded for all carcasses tagged. In addition, all fresh female carcasses are examined for spawning status (fully spawned, partially spawned, and unspawned). Heads are collected from adipose fin clipped fish for coded-wire tag recovery; the lower jaw is left intact and tagged. Newly tagged carcasses are returned to moving water at the tail end of the riffle or above the pool where the carcasses were collected. Returned tagged carcasses are available for recapture during subsequent weeks. Recovered carcasses from previous survey weeks are recorded by the unique tag number and returned to the river for potential recapture during subsequent weeks. (Prior to 2008, recovered carcasses were chopped.) All skeletons are chopped and returned to the river.

Live fish and redds are counted during the survey. Crews use tally counters to count live fish and redds as they float over riffles and pools in the drift boat. Counts are taken for each riffle and pool with the unique riffle identification numbers.

Carcass survey data are used to estimate escapement using the modified Schaefer model (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994) or the adjusted Petersen model (Ricker 1975). Model selection depends on the number of tagged and recaptured carcasses. If the number of tagged and recaptured carcasses is low, the Schaefer model overestimates escapement (Law 1994). The adjusted Petersen model is used to estimate escapement for surveys with low numbers of tagged and recaptured carcasses. These models require information on the number of carcasses marked, number examined for marks, and number recaptured in each survey period. However, the multiple-recapture data are not used for estimating escapement. Only the first recapture event is used for estimating escapement. Sub-populations of carcasses tagged include: adults, grilse, females, males, fresh, non-fresh, unclipped, and ad-clipped. Recaptured carcasses are those carcasses that were previously tagged and are recaptured during a subsequent survey. The number of carcasses examined for marks are the carcasses tagged and the number of first time recaptured carcasses in a survey period.

Fish Device Counter – Since 2009, FISHBIO Environmental, LLC has installed and operated an Alaskan style resistance board weir and Vaki Riverwatcher System to monitor fall-run Chinook salmon escapement on the Tuolumne River. The program is a joint effort funded by the Turlock Irrigation District, Modesto Irrigation District, and the City and County of San Francisco (Cuthbert et al. 2010).

The Vaki Riverwatcher System is operated from the beginning of September through June to monitor adult fall-run Chinook salmon escapement and steelhead (Cuthbert et al. 2010). Silhouettes and video or digital photos are used together to identify each passing object. Video or photos are needed to distinguish salmonid species; a silhouette alone cannot be used to distinguish species. In addition, video and photos are used to aid in determining sex, total length, the presence of an adipose fin, and fish condition. When turbidity exceeds 3.0 NTU or the Vaki malfunctions, all fish are trapped at the weir to collect data. Each image is judged as good, fair or poor quality.

Estimated escapement is the total number of fish that passed upstream of the weir.

REVIEW OF EXISTING PROGRAM(S)

Mark-Recapture Carcass Survey – The carcass survey encompasses the entire spawning period and spawning areas for Chinook salmon in the Tuolumne River.

Escapement is estimated without levels of precision and bias. Also, closed-population models are not recommended for estimating Chinook salmon escapement with mark-recapture carcass data.

The mark-recapture carcass survey methods for marking, tagging, recapturing and collecting covariate data for each carcass are as recommended in Chapter 3. Mark-recapture data are analyzed using a closed-population estimator (adjusted Petersen or modified Schaefer model) or the Jolly-Seber model, and not the recommended superpopulation modification of the Cormack Jolly Seber model. Closed population estimators are not recommended as discussed in Chapter 3. Compared to the Jolly-Seber model, the recommended Cormack Jolly Seber model does not have the assumption of complete mixing of marked carcasses into the population. In addition, the Cormack Jolly Seber model can easily have covariates (e.g., length, sex) incorporated to account for potential differences in survival and capture probabilities of carcasses.

Fork length is measured and sex is examined for all carcasses collected. Spawning status is examined for all fresh female carcasses. Scales and otoliths are collected from all carcasses when numbers are low, but systematically when numbers are high. Genetic tissue samples are not collected. Heads of all ad-clipped carcasses are collected for coded-wire tag recovery.

The spatial and temporal distributions of spawning are examined using carcass data.

Fish Device Counter – The resistance board weir and Vaki Riverwatcher system is located downstream of Chinook spawning habitat and is operated over the entire fall-run Chinook salmon immigration period.

Escapement is currently estimated without levels of precision or bias. Potential sources of error with fish device counters (discussed in Chapter 2) are not examined and accounted for in the escapement estimate.

Some biological data (sex, and length and scale samples) are collected and fish are examined for the presence of an adipose fin. Length from the Vaki Riverwatcher is an estimate based on a depth measurement and a predefined depth-to-length ratio. Length is measured for all fish caught in the live trap. All fish recorded by the Vaki Riverwatcher and those fish caught in the live trap are examined for the presence of an adipose fin. Scales are sampled for fish caught in the live trap.

Run timing is examined using the Vaki Riverwatcher data.

RECOMMENDED MONITORING

1) Use the Vaki Riverwatcher System to estimate fall-run Chinook salmon spawning escapement. With corrections made for potential counting errors, the fish device counter is expected to yield more accurate estimates of total escapement than the mark-recapture carcass survey. Recommended procedures for using a fish device counter to estimate escapement with levels of precision and bias are described in Chapter 2. This technique is also recommended for monitoring steelhead (Eilers et al. 2010).

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

20 MERCED RIVER

20.1 FALL-RUN CHINOOK SALMON

SUMMARY OF EXISTING PROGRAM

Mark-recapture carcass surveys have been conducted CDFG since 1971 to estimate in-river fall-run Chinook salmon escapement for the Merced River (Tsao 2008).

Mark-recapture carcass surveys are conducted weekly from the beginning of October through December. The survey covers a 24.7-mile reach from river mile (RM) 51.9 below the Crocker-Huffman Dam downstream to RM 27.1 at Santa Fe Road near Cressey, CA. The survey reach is divided into four sections. All riffles in the survey area are geo-referenced in Arc View and are uniquely identified (e.g., riffles A1-F2 are in section 1).

A 2-3 person crew with a drift boat surveys from upstream to downstream and collects all visible carcasses from each riffle and pool complex. Multiple passes are made through each pool and riffle to ensure the entire area is surveyed. Carcasses are classified as fresh (at least one clear eye and presence of blood in the gills), non-fresh (cloudy eyes), or skeleton (condition ranges from fungus covered to actual skeleton). All fresh and non-fresh carcasses are marked by attaching a uniquely numbered aluminum tag to the lower jaw. Scale samples and otoliths are collected from all carcasses when the number of carcasses is low, or systematically (i.e., every third carcass) when carcass numbers are high. Fork length (0.5 cm) is measured and sex recorded for all carcasses tagged. In addition, all fresh female carcasses are examined for spawning status (fully spawned, partially spawned, and unspawned). Heads are collected from adipose fin clipped fish for coded-wire tag recovery; the lower jaw is left intact and tagged. Newly tagged carcasses are returned to moving water at the tail end of the riffle or above the pool where the carcasses were collected. Returned tagged carcasses are available for recapture during subsequent weeks. Recovered carcasses from previous survey weeks are recorded by the unique tag number and returned to the river for potential recapture during subsequent weeks. (Prior to 2008, recovered carcasses were chopped.) All skeletons are chopped and returned to the river.

Carcass survey data are used to estimate escapement using the Jolly-Seber model (Seber 1982), the modified Schaefer model (subtraction of tagged carcasses from the second survey period to the last from the escapement estimate; Boydstun 1994) or the adjusted Petersen model (Ricker 1975). Model selection depends on the number of tagged and recaptured carcasses. The Jolly-Seber model is a better estimator if the number of tagged and recovered carcasses is greater than 10 for each survey week (Schwartz et al. 1993). If the number of tagged and recaptured carcasses is low, the Schaefer model overestimates escapement (Law 1994). The adjusted Petersen model is used to estimate escapement for surveys with low numbers of tagged and recaptured carcasses. These models require information on the number of carcasses marked, number examined for marks, and number recaptured in each survey period. However, the multiple-recapture data are not used for estimating escapement. Only the first recapture event is used for estimating escapement. Sub-populations of carcasses tagged include: adults, grilse, females, males, fresh, non-fresh, unclipped, and ad-clipped. Recaptured carcasses are those carcasses that were previously tagged and are recaptured during a subsequent survey. The number of carcasses examined for marks are the carcasses tagged and the number of first time recaptured carcasses in a survey period.

REVIEW OF EXISTING PROGRAM(S)

The mark-recapture carcass survey encompasses the entire spawning period and spawning areas of fall-run Chinook salmon in the Merced River.

The mark-recapture carcass survey methods for marking, tagging, recapturing and collecting covariate data for each carcass are as recommended in Chapter 3. Mark-recapture data are analyzed using a closed-population estimator (adjusted Petersen or modified Schaefer model) or the Jolly-Seber model, and not the recommended superpopulation modification of the Cormack Jolly Seber model. Closed population estimators are not recommended as discussed in Chapter 3. Compared to the Jolly-Seber model, the recommended Cormack Jolly Seber model does not have the assumption of complete mixing of marked carcasses into the population. In addition, the Cormack Jolly Seber model can easily have covariates (e.g., length, sex) incorporated to account for potential differences in survival and capture probabilities of carcasses.

Fork length is measured and sex is examined for all carcasses collected. Spawning status is examined for all fresh female carcasses. Scales and otoliths are collected from all carcasses when numbers are low, but systematically when numbers are high. Genetic tissue samples are not collected. Heads of all ad-clipped carcasses are colleted for coded-wire tag recovery.

The spatial and temporal distribution of spawning is examined using carcass survey data.

RECOMMENDED MONITORING

1) Install a fish device counter and weir (e.g., Vaki Riverwatcher System and Alaskan Style Resistance Board Weir) to estimate fall-run Chinook salmon escapement. With corrections made for potential counting errors, the fish device counter is expected to yield more accurate estimates of total escapement than the mark-recapture carcass survey. Recommended procedures for using a fish device counter to estimate escapement with levels of precision and bias are described in Chapter 2. This technique is also recommended for monitoring steelhead (Eilers et al. 2010).

2) Conduct a carcass sampling survey to collect biological data and recover coded-wire tags as described in Chapter 4.

3) Until a fish device counter is installed, continue the mark-recapture carcass survey to estimate escapement using procedures recommended in Chapter 3.

CHAPTER 10

DATA MANAGEMENT AND REPORTING

Many stakeholders and the general public are interested in the data collected in CV Chinook salmon escapement surveys. In January of each year, CDFG compiles a spreadsheet, Grandtab, summarizing the annual escapement estimates for CV Chinook salmon in the previous year. While GrandTab provides a quick way to see past and current escapement estimates for each watershed monitored, the table does not include a description of data collection methods or other biological data collected during the surveys (e.g., sex ratios, ad-clipped rations, coded-wire tag recovery, size structure, etc.). Annual escapement reports often provide this information, but can be difficult to obtain. Some programs make reports available upon request, post to individual websites, email to specific individuals, or submit to the CalFish program. CalFish is a cooperative web-based program involving a growing number of agency and organization partners. CalFish's mission is to create, maintain, and enhance high quality, consistent data that are directly applicable to policy, planning, management, research, and the recovery of anadromous fish and related aquatic resources in California. CalFish also provides data and information services in a timely manner in formats that meet the needs of the end users.

CalFish includes an Abundance Database that is the result of the efforts by multiple agencies to collect, archive, and enter the information generated by fisheries surveys into standardized database formats, including CV Chinook salmon escapement estimates. The database format is nearly identical to the StreamNet database format. StreamNet is a cooperative information management and data dissemination project focused on fisheries and aquatic data and data-related services in the Pacific Northwest. Efforts to establish the CalFish Abundance Database began in 1998. The database now includes historic Chinook salmon escapement estimates dating as far back as the 1940's; however, funding has been inadequate to maintain the database and make annual updates.

The Abundance Database provides enough detail to convey the relative accuracy of each abundance record. In addition, spatial datasets are created and published to map viewers hosted by CDFG and CalFish. These spatial datasets summarize each trend or index of Chinook salmon escapement and provide a way to view the survey location and access the detailed tabular data. These spatial data are specifically designed for use in California and enable spatial queries of the data via the CalFish map viewer. Abundance data in the database can also be directly accessed from the Calfish online database application via the CalFish Tabular Data Query. For those interested in additional details on the calculation of abundance estimates, the database offers hyperlinks to digital copies of the original documents used to record the information. In this way the database serves as an information hub directing the user to supporting information. Many reports also include additional data collected (e.g., sex ratios, age structure, status, etc.) for each population.

In 2010, as part of the development of this plan, the CalFish Salmonid Abundance Database was reorganized and updated to provide a centralized location for sharing CV

Chinook salmon escapement estimates and annual monitoring reports. Annual Chinook salmon in-river escapement estimates and indices for all programs are now updated though 2009. In some cases, multiple datasets were consolidated into a single, more comprehensive, dataset to more closely reflect the way data are reported in GrandTab. All annual Chinook salmon escapement reports used to update the database were digitized. These digital copies were uploaded to the CDFG Digital Document Library and are available to CalFish users through hyperlinks provided in the Abundance Database.

Other updates and improvements are planned to the Abundance Database. For example, work is currently underway to update the CV Chinook hatchery return datasets. Digitizing hatchery reports and making them available directly from the CDFG Digital Document Library through the hyperlinks in CalFish is also planned.

While stakeholders often use data in a summarized or analyzed form, storing and maintaining data in raw or primary form allows data to be readily retrieved in the future for data users to verify analyses, perform data analyses on long-term datasets, synthesize data on a regional scale, and account for variance in the data for analyses and modeling. However, obtaining raw field data for CV Chinook salmon and steelhead has been reported to be difficult (Williams et al. 2007; Kimmerer et al. 2001). The lack of a centralized data system and accompanying descriptions of methodologies has hindered fisheries evaluations, including assessing the recovery of listed species (Pipal 2005) and assessing the effectiveness of restoration actions designed to increase the natural production of Chinook salmon and steelhead (D. Threloff, USFWS, pers. comm., 2010).

Data management for the existing Chinook salmon escapement monitoring programs varies between agencies and for individual programs within agencies. Data are maintained in a variety of ways. Some programs retain paper data sheets and only summaries of the data are recorded digitally, some enter all or most field data to spreadsheets (e.g. Microsoft Excel) or database applications (e.g. Microsoft Access, Oracle). Availability of metadata or documentation of the data collected by each program is unknown. Data quality assurance and control (QA/QC) procedures are often not reported, which makes evaluating the quality of the data difficult. Data QA/QC procedures should occur at multiple levels of data management including field data collection and data entry. Biologists need to make sure field crew members are trained and that they implement established protocols and procedures. Crews needs to implement established QA/QC procedures in the field when collecting data and recording data. During data entry established QA/ QC procedures need to be completed by the data entry person and database architect.

This plan would not be complete without addressing the need for managing all of the data collected from the recommended Chinook salmon escapement monitoring programs. Monitoring programs collect essential data for management and monitoring of Chinook salmon and requires a great deal of effort and expense; the data collected should be valued and protected.

Development of a Data Management System

The goal of a data management system is to maintain, in perpetuity, data that results from monitoring programs (NPS 2008) to ensure high quality data standards. Standards include accuracy, security, longevity, and usability. Data management is complex and requires a carefully conceived design. An example of a comprehensive data management system is one developed by the National Park Service (NPS 2008) for their Inventory and Monitoring Program. In addition, SteamNet (2009) developed an outline for the components needed in a data management plan (outline provided in Appendix D). The NPS data management guidance document (NPS 2008) describes in detail their objectives, laws and policies, and details for multiple topics that should be addressed for a data management system. These topics include: infrastructure (computers, servers, and hardware), architecture (applications, database systems, etc.), project management and the data life cycle (e.g., data collection, data entry, data archival, data reporting, etc), data management roles and responsibilities (e.g., biologists, agencies, and database architect), databases, quality assurance and quality control, data documentation, data ownership and sharing, data dissemination, records management, archiving, and implementation. Many of these components are also in the StreamNet (2009) outline. Discussions of some of these components are described below. A well developed data management plan will help ensure that all of the components are addressed and that data management strategies are sound and well documented. Such a plan will guide development of a centralized data management system, or platform, for CV monitoring data.

Estimating the cost to develop a data management system is beyond the scope of this plan. Costs will include the database architect (~$70,689 annually). Additional costs will include the development a centralized database management system. Costs could vary based on the type of system chosen (e.g., highly centralized or distributed type system described below) or if an existing database structure can be used. Cost estimates are provided from some existing database systems described in Appendix D (e.g., WDNR database costs about $250,000 annually to maintain and improve). The recommended data management plan is expected to develop cost estimates and identify potential funding sources for the data system.

Data Capture

Paper data sheets are traditionally used to capture fisheries data in the field; however the use of electronic devices is becoming more common and has many benefits compared to paper data sheets. Electronic devices, such as a rugged tablet Personal Computer (PC) or a Personal Digital Assistant (PDA), improve the efficiency and quality of data recording, data quality control checking, and data entry (Appendix D). Applications can be developed for the electronic devices to efficiently record data, such as drop down menus and check boxes. In addition, quality control of the data can occur while recording data, where the application has established validation rules (e.g. length limits for different fish species and alerting data recorders to missing values). With a paper data sheet, these errors may not be noticed until data entry in the office.

Data from electronic devices are easily imported into a database. Whereas, entering data on paper data sheets into a database is very time consuming. Proofing the data that was entered into the database is also time consuming and standard protocols for proofing methods may not exist. Proofing is essential for improving the quality of the data. Basic quality checks still need to be completed for data that was uploaded from an electronic device into a database; however these checks can be completed using automated routines designed in a database application. Overall, electronic devices are more cost effective than paper data sheets (Appendix D). While there are upfront costs to purchase the devices and setup costs, there are cost savings for data entry and proofing. In addition, the devices allow data to be available immediately for analysis and report writing.

We recommend examining the feasibility of using electronic devices to capture data in the field for the recommended CV Chinook salmon escapement monitoring programs.

Centralized Database Management Systems

Archiving field data sheets is important for all programs; however an archived field data sheet is not recommended as the primary data storage method. Some of the problems associated with field data sheets as the primary data storage method include: 1) data stored on datasheets does not allow analyses to be easily replicated and verified or additional analyses to be completed, 2) sharing data or responding to data requests is not efficient and may not be possible for large datasets, and 3) individual paper datasheets within a large collection may become difficult to locate.

While spreadsheets like Microsoft Excel are often used to complete data analyses, spreadsheets used for storing and archiving raw field data have underlying problems and are not recommended. Use of spreadsheets does not guarantee that data are managed consistently overtime. For example, a new spreadsheet may be developed for each new field season. Over time, the design of the spreadsheet may change slightly or dramatically, so the spreadsheet from the first monitoring season may bear little resemblance to the most recent season. Spreadsheets often do not include documentation or metadata needed to understand them. Data are likely not easy to pool across years nor are they easy to pool with similar data from other projects. Therefore data become difficult and very time consuming to use. Data quality control is time consuming and data can become unknowingly erroneous if sorting functions of the software are used incorrectly.

Microsoft Access or similar software can be used to develop and manage a relational database. A relational database is a collection of data items organized as a set of formally-described tables from which data can be accessed or reassembled in many different ways without having to reorganize the database tables. Therefore efficiency and protection of the data is provided. Relational databases are easy to extend; a new data category can be added to a table without modifying all existing applications. Another advantage of developing a database in Microsoft Access or another similar program is the ability to easily query data to look for data outside of expected ranges (e.g. length limits for a species) and set value limits for fields (e.g. length) that would flag unacceptable values. Microsoft Access allows an individual to query data into a format to export to

Microsoft Excel or other software programs for analysis, and also has capabilities to perform analyses itself.

A centralized database system accommodates data from many separate locations, pooling the data into a relational database at a single location. There are a variety of ways to create a centralized database system. In a highly centralized database, raw field data may be entered directly to the central server database. In this case, data do not reside on personal computers. Another type of centralized database system includes the central database, and stand alone applications (e.g. Microsoft Access databases) distributed for use on personal computers. These distributed databases communicate with the central server database periodically to share data. Uploads to the central server may or may not be automated. If uploads are not automated then upload deadlines need to be established in a data management plan. There are advantages and disadvantages to each configuration and some of these are presented in Appendix D; however, recommending one type of centralized configuration over the other is beyond the scope of this plan.

Benefits of a centralized database system include (FAO 2000): (1) ensure data conforms to standard classifications; (2) ensure the validity of the data; (3) ensure the data integrity and internal consistency; (4) secure and maintain raw data; (5) allow easy access to raw data; (6) process the data efficiently; and (7) allow different datasets to be integrated, thereby increasing their overall utility. A centralized database in the CV for Chinook salmon escapement data may foster peer review and discussion leading to collaboration, new research, additional analysis, and improved management decisions. Data collected incidentally for non-target species will also be readily available. These data are often not reported formally. These data include redds observed during Chinook salmon escapement surveys. They also include lamprey, sturgeon, and many other species observed from fish device counters.

We recommend that a centralized database system be created for and used by the Chinook salmon escapement monitoring programs throughout the CV. In addition, we recommend that those who design the centralized database consider the recommendations received from database developers/managers of existing centralized databases (Appendix D). Similar recommendations were made in the CV Steelhead Monitoring Plan. Field data collected for both species should be included in a single database. This is appropriate since similar methods are recommended to be used to monitor both species. Some monitoring programs will collect data for both species. The front end applications will enable the user to identify information for each species and having a database with both species will save database development and maintenance costs.

This plan has not attempted to estimate costs for development, implementation, and maintenance for a centralized database system. Cost information for a few of the example databases are provided in Appendix D. Likely, costs are higher for the distributed system. Costs may be minimized if the distributed databases are identical or nearly identical (i.e., few if any modifications) to the central database.

The database architect hired to create a centralized database system will need to work with biologists from multiple agencies and entities. They will need to determine which database type works best to meet the needs of the biologists and management. The database application should be designed specifically to capture the raw field data collected from the CV Chinook salmon escapement monitoring programs. Data fields will need to be identified for each survey method (potential fields are described in Appendix D). The application should be built to ease data entry and data management tasks. Additional functionality can be added to address summary, analysis, and reporting needs (potential data analysis and reporting needs are described in Appendix D). The database does not need to be made available to the general public although developing access is feasible. Data access and security should be identified in the data management plan. Other options for sharing data with the public are provided in the section below, "Data Sharing."

Annual reporting

Annually biologists must in a timely manner report escapement estimates, coded-wire tag (CWT) data, catch/sample data (number of carcasses examined for a CWT), and other biological data collected to Ocean Management, which is used by the Pacific Fisheries Management Council and reported in their associated management reports. Some improvements have been made to obtain this information from biologists, including development of an online tool that can be used by biologists to submit their escapement estimates and modify estimates when needed. The catch/sample data is essential for determining the number of hatchery fish in a system and must be submitted to the Regional Mark Processing Center (RMIS database) along with uploading CWT recovery data. However, there has been confusion about what is the catch/sample data. Along, with this plan and development of a centralized data management system would improve reporting escapement data to Ocean Management, by clarifying data needs, standardizing data reporting, improving data quality, and increasing the efficiency of the data reporting process.

Annual program reports and a summary report are essential for documenting and sharing results of the CV Chinook salmon escapement monitoring programs. Annual reports are currently produced for each CV Chinook salmon escapement monitoring program. In addition, the CDFG produces a summary of CV Chinook salmon monitoring activities (e.g., Annual Report Chinook Salmon Spawner Stocks in the California's Central Valley, 2004). This report has been produced annually since 1961. The report is a summary of the annual reports produced by the individual CV programs. There has been difficulty getting annual summarized reports for Chinook salmon escapement monitoring programs published within a year or two of the field season. For example, the most recent CV summary report is for the 2004-2005 season. Because this report compiles the annual reports from multiple programs, finishing reports is often delayed because one or more of the individual reports have not been finalized (J. Azat, CDFG, pers. comm., 2010). With funding shortfalls these delays will likely continue. Report writing often remains unfinished because report writing is secondary to collection of field data. (J. Azat, CDFG, pers. comm., 2010).

This plan recommends that all CV Chinook salmon escapement monitoring reports be posted to a common location for easy access by the stakeholders and the general public. The use of CalFish is recommended to provide the means to centralize and organize these data. Currently, annual reports for Chinook salmon escapement monitoring in the upper Sacramento River Basin are published on CalFish. Additionally, CalFish is working to develop a new digital library component that will organize and offer a wide range of fisheries information (R. Carlson, PSMFC, pers. comm., 2010). Funding would need to be acquired and maintained in order for this reporting approach to be successful in the long term.

Data Sharing

The CalFish Salmonid Abundance Database is recommended for developing, maintaining, and standardizing Chinook salmon escapement estimates and hatchery return data for access by the public.

The RMIS database formats are recommended for use to develop, maintain, and standardize hatchery release, recovery, and catch/sample data. While use of the RMIS formats will ensure that CV data are retained in standardized formats and will enable public access to these data via the RMIS website, the RMIS query system is outdated and difficult to master. Users would benefit from development of a new database query system to interface with RMIS standard data formats and present data in a user-friendly format. Technical assistance would be needed to develop this new web application.

Conclusions

Improved data management and reporting are essential to improve fisheries management and monitoring of Chinook salmon. In addition, large amounts of resources (i.e., time, money, and personnel) are used annually to monitor Chinook salmon escapement. Therefore additional resources are needed to develop a high quality data management system to protect, store, and report escapement data; otherwise the full utility of the data will not be realized. Our recommendations include:

1) Develop a data management system for Chinook salmon escapement data.

2) Develop a data management plan that includes all of the components of a data management system to document decisions made for each component (i.e., infrastructure, architecture, project management and the data life cycle, data management roles and responsibilities, databases, quality assurance and quality control, data documentation, data ownership and sharing, data dissemination, records management, archiving, and implementation).

3) Develop a centralized database system to manage all of the raw/primary Chinook salmon escapement data.

4) Sufficient resources should be available for completing annual program and summary reports. This may require a dedicated position to compile and produce the annual summary report.

5) Maintain and standardize reporting of Chinook salmon escapement data, hatchery return data, and angler survey data using the CalFish Salmonid Abundance Database.

6) Continue to use the RMIS database formats to develop, maintain, and standardize hatchery release, recovery, and catch/sample data. In addition, make the database more user friendly.

7) Examine the potential of using electronic devices to capture data in the field to potentially improve the efficiency of data collection, efficiency of data reporting, and improve data quality.

8) Hire a database architect(s)/data management specialist(s) to implement these recommendations. We recommend that this person(s) considers the recommendations we received from other data management specialists. All of those specialists said the key is to work with the biologists from the very beginning and include them through the entire process. This will likely involve multiple workshops and working with individual biologists.

CHAPTER 11

COST ESTIMATES FOR RECOMMENDED CHINOOK SALMON ESCAPEMENT MONITORING PROGRAMS

Costs were estimated for each of the escapement monitoring programs recommended in this plan. For existing programs, the costs reported in Low (2007) were used; the lead biologist(s) were consulted to verify the estimates or recommend changes. For new programs, cost estimates were based on similar monitoring programs already in place or through consultation with the lead biologist(s). For some new programs, cost estimates were based on the Pacific States Marine Fisheries Commission's (PSMFC) average personnel and overhead rates. Estimating changes in project costs based on recommended changes to the surveys in the plan would be difficult. In many cases work loads and project costs are not expected to change substantially. For example, the only difference between a mark-recapture carcass survey and a carcass sampling survey is the tagging and recapture component. Personnel still need to travel to the survey site, survey the entire spawning habitat, and handle carcasses. This chapter describes the cost of each program followed by a summary table of all program costs (Table 1). These costs should be considered approximate or 'ball-park' estimates for general planning purposes. Detailed program budgets will need to be developed for new programs as they are funded and implemented.

1. MAINSTEM SACRAMENTO RIVER

***Mainstem Sacramento River** – Winter-run, Fall-run, and Late fall-run*
(Basalt and Porous Lava Diversity Group)

This plan recommends continuation of the mark-recapture carcass surveys to estimate escapement of winter-run, fall-run and late fall-run Chinook salmon in the mainstem Sacramento River. The total cost of these surveys is approximately $440,000 annually. Details of these costs can be obtained from the CDFG office in Red Bluff, CA.

USFWS participates in the winter-run mark-recapture carcass survey. Costs vary annually with run-size; more resources are needed with high run sizes. The cost ranges from $76,000 (in low abundance years) to $190,000 (high abundance years). Details of these costs can be obtained from the USFWS in Red Bluff, CA.

This plan recommends continuation of the aerial redd survey to estimate escapement of Chinook salmon spawning downstream of the mark-recapture carcass survey study area and to examine the spawning distribution of all runs in the mainstem Sacramento River. The aerial redd survey costs approximately $30,000 annually. Details of these costs can be obtained from the CDFG office in Red Bluff, CA.

The total estimated annual cost for escapement monitoring in the mainstem Sacramento River is $660,000.

2. COTTONWOOD, COW, BEAR, BATTLE, ANTELOPE, MILL, AND DEER CREEKS

Cottonwood Creek *– Fall-run (Northwestern California Diversity Group)*
Cow Creek *– Fall-run and Late fall-run (Basalt and Porous Lava Diversity Group)*
Bear Creek *– Fall-run and Late fall- run*
(Basalt and Porous Lava Diversity Group)
Battle Creek *– Fall-run (Basalt and Porous Lava Diversity Group)*
Antelope, Mill, and Deer Creeks *– Spring-run, Fall-run, and Late fall- run*
(Northern Sierra Nevada Diversity Group)

A dedicated crew is recommended for monitoring Chinook salmon escapement in Cottonwood, Cow, Bear, Battle (fall-run only), Antelope, Mill, and Deer creeks using fish device counters. One crew can effectively and efficiently monitor Chinook salmon escapement in these streams. If separate crews were used, costs would increase due to a need for additional personnel, training, equipment and operating expenses. Device counters will be operated during Chinook salmon immigration period(s) for the run(s) being monitored (fall-run: September through December; late-fall run: January through July; and spring-run: April through July/August). Responsibilities of crew members include: installing and removing equipment and weirs, operating and maintaining video equipment and weirs, reading video images, ordering equipment, managing the project, analyzing data, and writing reports.

The labor needed for the tasks described above for the seven monitoring programs is based on experience from the project leads (Harvey Arrison and Killam, CDFG, pers. comm., 2010). A cost estimate for labor was developed using rates established by the PSMFC and is approximately $468,000.

Labor –Video Monitoring	*Personnel Needs*
Field work	12 months, 4 Technicians
Video analysis, Data Management, Reporting	12 months, 4 Technicians
Project Lead and Reporting	12 months, 1 Biologist

Partial horizontal bar weirs and fish device counters (video cameras) are already in place in Cottonwood, Cow, Bear, and Battle creeks, but not in Antelope and Deer creeks. Video equipment and the partial horizontal bar weirs for the existing programs are old and should be replaced (Killam, CDFG, pers. comm., 2010). Video cameras are currently installed at the top of the Ward Dam fish ladder in Mill Creek, and only a few weir panels are needed to improve fish passage past the video cameras. There is also interest in replacing the partial horizontal bar weirs with Alaskan style resistance board weirs (Berry, CDFG, pers. comm., 2010). The design of the Alaskan style resistance board weir might better withstand high flow events. None of the programs currently have the recommended DIDSON unit.

Permission to access to private lands is an issue that needs to be addressed annually, where changes in site location can affect the size or need of a weir and power source.

Currently all programs in place except Battle Creek have access to a 120 volt power supply. Solar panels are used on Battle Creek. Therefore due to possible land access issues in the future, cost estimates for each program include solar power and weir materials as a contingency. Potentially land access agreements can be developed with the land owners to negate these issues. This plan does not include costs for obtaining land access from property owners.

Equipment cost estimates presented below include the construction of one video monitoring station. To help prevent underestimating costs the following assumptions were made for each program: the Alaskan style resistance board weir is used ($52,000/weir; Berry, CDFG, pers. comm., 2010); solar power is used; and a DIDSON unit is needed. Total equipment costs for each monitoring site are estimated to be $162,000. Therefore the total startup costs for seven monitoring sires are estimated to be $1,134,000.

Operating and equipment costs are described below. Costs include purchasing vehicles, renting an office and garage space (will house crew and a separate crew for carcass sampling surveys as described below), vehicle and trailer maintenance, video analysis equipment, computers, training, trailer, miscellaneous equipment (e.g. welding equipment for building weirs, waders, cables), and unforeseen project costs. In addition, these costs include vehicle fuel. These monitoring stations will be located in remote locations, therefore require extensive travel for maintenance.

Overhead costs are estimated to be $94,000 using a PSMFC rate of 13 percent (does not apply to equipment or weirs).

Costs for each video/sonar monitoring station

Weir	*Cost*
Alaskan style resistance board weir	52,000
White plates	1,000
Overhead cables (support power, coaxial cables, lights, cameras)	-
Camera frames and attachments	-
Overhead lighting	-
Subtotal	**53,000**
Video/Sonar Monitoring Equipment for Weir	
DIDSON	100,000
Solar Power Panels (10)	5,000
Coaxial cables	4,000
Underwater cameras (3)	-
Overhead camera	-
Power cables	-
Digital video recorders + Storage hard drives (3)	-
Security cabinet	-
Back-up power supply (Batteries; 12)	-
Subtotal	**109,000**
Total each monitoring station	**162,000**

Operating and Equipment Costs to operate 7 weirs	
Equipment	
Vehicles (4x4,3/4 ton, 1 short bed, 1 long bed, crew cab pickups, with caps) (3)	90,000
Video analysis equipment (3)	39,000
Utility trailer (1)	3,000
Operating	
Rent – Office and garage space	40,000
Supplies (waders, vehicle fuel, safety equip., tools, computers, misc.)	105,000
Services (training, management, insurance)	53,000

Summary of Costs

	Year 1	**Year 2**
Personnel	$468,000	$468,000
Seven monitoring stations	$1,134,000	
Equipment	$132,000	
Operating	$198,000	$198,000
Overhead	$94,000	$94,000
Total	$2,026,000	$760,000

In addition to the video monitoring crew, a separate crew is recommended to conduct carcass sampling surveys to collect biological data and recover coded-wire tags for each run monitored. Some of the recommend carcass sampling surveys are already in place (mark-recapture carcass surveys, snorkel surveys or redd surveys), while other surveys will be new.

Extensive travel will be required to conduct all recommended carcass sampling surveys in Mill, Deer, Antelope, Cottonwood, Cow, and Bear creeks. Data for fall-run Chinook salmon in Battle Creek are collected at the Coleman National Fish Hatchery. Four pickup trucks will be required. Cost estimates were based on $30,000 per truck, gasoline costs of $0.59/mile, and 75 miles/day per truck. The total cost for four trucks was estimated to be $120,000. The cost for travel was estimated to be $4,500.

Carcass sampling surveys are recommended for the following monitoring programs:

***Cottonwood Creek** – Fall-run (Northwestern California Diversity Group)*
***Cow Creek** – Fall-run (Basalt and Porous Lava Diversity Group)*
***Bear Creek** – Fall-run and Late fall-run (Basalt and Porous Lava Diversity Group)*
***Antelope Creek** – Fall-run and Late fall-run (Northern Sierra Nevada Diversity Group)*
***Mill Creek** – Late fall-run (Northern Sierra Nevada Diversity Group)*
***Deer Creek** – Late fall-run (Northern Sierra Nevada Diversity Group)*

Based on the counts of Chinook salmon observed with the fish device counters, biologists will need to use their judgment on the level of survey effort needed for the carcass sampling surveys. For example, during the fall-run spawning period (October through December) it is expected that two additional full-time seasonal fishery technicians will be needed to conduct carcass sampling in Cottonwood, Cow, Bear and Antelope creeks when the video monitoring technicians are fully involved with their duties. For the other Chinook salmon runs the video technicians would be able to conduct both video monitoring and carcass sampling in these streams (Killam, CDFG, pers. comm., 2010). The cost for two seasonal fisheries technicians for four months (including training) is estimated to be $33,000 using PSMFC rates. Equipment and supplies are approximated at $2,000.

***Antelope Creek** – Spring-run (Northern Sierra Nevada Diversity Group)*
This plan recommends continuation of the July and October snorkel/walking surveys in Antelope Creek to recover coded-wire tags and collect biological data from carcasses, and monitor the number and distribution of holding and spawning spring-run Chinook salmon. The surveys cost approximately $52,000 annually, which does not include travel costs.

***Mill Creek** – Spring-run (Northern Sierra Nevada Diversity Group)*
This plan recommends continuation of the redd survey in Mill Creek to recover coded-wire tags and collect biological data from carcasses, and monitor the number and distribution of holding and spawning spring-run Chinook salmon. The redd survey costs approximately $52,000 annually, which does not include travel costs.

***Mill Creek** – Fall-run (Northern Sierra Nevada Diversity Group)*
This plan recommends conducting a carcass sampling survey for fall-run Chinook salmon in Mill Creek. A mark-recapture carcass survey has been used in the past. The estimated cost for the carcass sampling survey is approximately $52,000 annually, which does not include travel costs.

***Deer Creek** – Spring-run (Northern Sierra Nevada Diversity Group)*
This plan recommends continuation of the snorkel surveys in Deer Creek to recover coded-wire tags and collect biological data from carcasses, and monitor the number and distribution of holding and spawning spring-run Chinook salmon. The surveys cost approximately $52,000 annually, which does not include travel costs.

***Deer Creek** – Fall-run (Northern Sierra Nevada Diversity Group)*
This plan recommends conducting a carcass sampling survey for fall-run Chinook salmon in Deer Creek. A mark-recapture carcass survey has been used in the past. The estimated cost for the carcass sampling survey is approximately $52,000 annually, which does not include travel costs.

Summary of Costs

	Year 1	**Year 2**
Personnel (additional)	$33,000	$33,000
Existing Programs	$260,000	$260,000
Equipment (additional)	$2,000	$2,000
Travel	$4,500	$4,500
Trucks (4)	$120,000	
Total	$419,500	$299,500

Total costs for monitoring programs:

Summary of Costs

	Year 1	**Year 2**
Video Monitoring	$2,026,000	$760,000
Carcass Sampling Surveys	$419,500	$299,500
Total	$2,445,500	$1,059,500

3. CLEAR CREEK

***Clear Creek** – Spring-run, Fall-run, and Late fall-run*
(Northwestern California Diversity Group)

This plan recommends monitoring escapement of Chinook salmon in Clear Creek with a fish device counter and weir. Monitoring with a Vaki Riverwatcher System and Alaskan style resistance board weir is being considered by the USFWS in Clear Creek. The type of weir and fish device counter that will work best for Clear Creek may change, but cost estimates presented below are for a Vaki Riverwatcher System and Alaskan style resistance board weir. Cost estimates for the weir were obtained from USFWS (M. Brown, USFWS, pers. comm., 2010). Personnel costs are a rough estimate for using USFWS employees to operate the fish device counter year-round and manage the project (M. Brown, USFWS, pers. comm., 2010). Existing USFWS trucks can be used, therefore gasoline costs were based on the USFWS rate ($0.18/mile) and traveling 80 miles per day. Costs are described below.

Fish Device Counter Monitoring Clear Creek	*Costs USD*
Personnel costs	150,000
Alaskan Style Weir	105,000
Vaki Riverwatcher System with digital cameras	50,000
Equipment (solar panels, security box, batteries, etc)	10,000
Contingency costs	15,000
Gasoline costs	5,256

Summary of Costs

	Year 1	**Year 2**
Personnel	$150,000	$150,000
Video station	$165,000	
Operating	$20,256	$20,256
Total	$335,256	$170,256

***Clear Creek** – Spring-run (Northwestern California Diversity Group)*

This plan recommends continuation of the snorkel survey for spring-run Chinook salmon in Clear Creek to recover coded-wire tags and collect biological data from carcasses, and monitor the number and distribution of holding and spawning spring-run Chinook salmon. This snorkel survey costs approximately $133,000 annually; details can be obtained from the USFWS office in Red Bluff, CA.

***Clear Creek** – Fall-run (Northwestern California Diversity Group)*

This plan recommends a carcass sampling survey for fall-run Chinook salmon in Clear Creek. A mark-recapture carcass survey has been used in the past. The estimated cost for the carcass sampling survey is $52,000 annually, which does not include travel costs. Two trucks are needed for 10 days costing approximately $900 (Same trucks and rates are described in Section 2).

***Clear Creek** – Late fall-run (Northwestern California Diversity Group)*

This plan recommends continuation of the redd survey for late fall-run Chinook salmon in Clear Creek to recover coded-wire tags and collect biological data from carcasses, and monitor the number and distribution of holding and spawning fish. This redd survey costs approximately $53,000 annually; details can be obtained from the USFWS office in Red Bluff, CA.

Total costs for monitoring programs:

Summary of Costs

	Year 1	**Year 2**
Video Monitoring	$335,256	$170,256
Carcass Sampling Surveys	$238,000	$238,000
Total	$573,256	$408,256

4. BEEGUM CREEK

***Beegum Creek** – Spring-run (Northwestern California Diversity Group)*
The snorkel survey in Beegum Creek is an existing program that costs $5,000 annually. Details of the costs can be obtained from the CDFG office in Red Bluff, CA.

5. BIG CHICO CREEK

***Big Chico Creek** – Spring-run (Northern Sierra Nevada Diversity Group)*
The snorkel survey in Big Chico Creek is an existing program to monitor the holding distribution and count the number of spring-run Chinook salmon. This program costs $10,000 annually. This cost also includes the spring-run Chinook salmon snorkel survey in Butte Creek. Details of the costs can be obtained from the CDFG office in Chico, CA.

6. BUTTE CREEK

***Butte Creek** – Spring-run (Northern Sierra Nevada Diversity Group)*
This plan recommends monitoring spring-run Chinook salmon escapement in Butte Creek using a fish device counter. Personnel needs are described below and costs are estimated to be $91,000.

Labor - Video Monitoring Butte Creek	*Personnel Needs*
Weir installation	3 days, 4 Technicians
Weir removal	1 day, 4 Technicians
Repair, Daily Maintenance, Video Analysis, and QC	5 months, 1 Technician
Planning and Reporting	2 months, 1 Technician
Supervisor	6 months, 1 Biologist

To prevent underestimating the cost of this program, assumptions were made that a weir, solar power, Vaki Riverwatcher, and DIDSON will be needed since it is uncertain which equipment will be needed. Costs would be reduced substantially if fish device counters were placed in the fish ladder at Durham Mutual Diversion Dam (DMDD), the power grid at DMDD were used, or a less expensive fish device counter were used.

The weir, Vaki Riverwatcher system, and solar panels for the Tuolumne River cost approximately $145,000 (C. Sonke, FishBio, pers. comm., 2010). A DIDSON unit with extra components costs approximately $100,000. One truck will be needed ($30,000) and there will be other operating costs (gas, computer, maintenance, etc.; $15,000).

Overhead costs are estimated to be $14,500.

Summary of Costs

	Year 1	**Year 2**
Personnel	$91,000	$91,000
Equipment	$245,000	
Operating	$15,000	$15,000
Overhead	$14,500	$14,500
Truck	$30,000	
Total	$395,500	$120,500

***Butte Creek** – Snorkel Survey for Spring-run (Northern Sierra Nevada Diversity Group)*
This plan recommends continuation of the snorkel survey in Butte Creek to monitor the holding distribution of spring-run. Program costs are included in the spring-run Chinook salmon snorkel survey in Big Chico Creek. Details of the costs can be obtained from the CDFG office in Chico, CA.

***Butte Creek** – Fall-run and Spring-run (Northern Sierra Nevada Diversity Group)*
This plan recommends continuation of the mark-recapture carcass survey to estimate escapement of fall-run Chinook salmon in Butte Creek and recover coded-wire tags and collect biological data from carcasses. The approximate cost for the mark-recapture survey and for collecting biological data and recovering coded-wire tags for spring-run Chinook salmon is $80,000 annually. Details of the costs for the survey can be obtained from the CDFG office in Chico, CA.

7. BATTLE CREEK

***Battle Creek** – Spring-run, Late fall-run and Winter-run*
(Basalt and Porous Lava Group)
This plan recommends continuing to use a fish device counter (video monitoring) and trapping to estimate escapement of spring-run, late-fall, and winter-run Chinook salmon and collect biological data. Video monitoring and trapping costs approximately $130,000 annually. A detailed cost estimate for this program is available from the USFWS Red Bluff office.

This plan recommends continuation of the snorkel survey to recover coded-wire tags and collect biological data from carcasses. In addition, this survey examines the holding (spring-run) and spawning distribution of Chinook salmon in Battle Creek. Genetic tissue samples collected from fish captured in the traps and from carcasses in the snorkel surveys are used with passage data to estimate escapement for each run. The snorkel survey costs approximately $228,800 annually. A detailed estimate of costs is available from the USFWS Red Bluff office.

Total estimated annual costs for monitoring programs in Battle Creek are $358,800.

8. FEATHER RIVER

***Feather River** – Spring-run (Northern Sierra Nevada Diversity Group)*

This plan recommends using a weir and fish device counter in the Feather River to estimate spring-run Chinook salmon escapement. The cost to build and install all necessary operating equipment is estimated to be between $350,000 and $375,000 (J. Kindopp, CDWR, pers. comm., 2010). The weir will include PIT tag readers. Electricity will be connected to the site, and a field office and bunker will be built. Operating costs and data reporting are estimated to be $160,000 annually. A detailed estimate of costs for this monitoring program is available from the CDWR Oroville office.

This plan recommends a carcass sampling survey to recover coded-wire tags and collect biological data from carcasses. The cost for this survey is included in the cost of the mark-recapture carcass survey for fall-run Chinook salmon.

***Feather River** – Fall-run (Northern Sierra Nevada Diversity Group)*

This plan recommends continuation of the mark-recapture carcass survey to estimate escapement of fall-run Chinook salmon in the Feather River. In addition, this survey will recover coded-wire tags and collect biological data from fall-run and spring-run Chinook salmon carcasses. This survey costs approximately $300,000 annually. Details of the costs can be obtained from the CDWR office in Oroville, CA.

Summary of Costs

	Year 1	**Year 2**
Video Monitoring	$535,000	$160,000
Carcass Sampling Survey	$300,000	$300,000
Total	$835,000	$460,000

9. LOWER YUBA RIVER

***Lower Yuba River** – Spring-run, Fall-run, and Late fall-run*
(Northern Sierra Nevada Diversity Group)
This plan recommends estimating Chinook salmon escapement upstream of Daguerre Point Dam (DPD) in the lower Yuba River using the Vaki Riverwatcher systems in the north and south fish ladders. This program costs approximately $75,000 annually. A detailed estimate of costs for this program is available from the YCWA office in Marysville.

This plan also recommends continuation of the mark-recapture carcass survey to estimate spring-run and fall-run Chinook salmon escapement downstream of DPD, and continue the survey to recover coded-wire tags and collect biological data from carcasses both up and downstream of DPD. This survey costs approximately $98,000 annually. Costs are not expected to change significantly with the elimination of the mark-recapture component of this survey upstream of DPD.

Total estimated annual costs for monitoring programs in the lower Yuba River are $173,000.

10. AMERICAN RIVER

***American River** – Fall-run (Northern Sierra Nevada Diversity Group)*
This plan recommends continuation of a mark-recapture carcass survey to estimate fall-run Chinook salmon in the American River, and recover coded-wire tags and collect biological data from carcasses. This program costs approximately $100,000 annually. Details of the costs can be obtained from the CDFG office in Rancho Cordova, CA.

11. COSUMNES RIVER

Cosumnes River – This plan recommends estimating escapement of fall-run Chinook salmon in the Cosumnes River using a weir and fish device counter. Assuming the same type and size of system is used on the Tuolumne River, the weir, Vaki Riverwatcher system, and solar panels would cost approximately $145,000 (C. Sonke, FishBio, pers. comm., 2010). Annual monitoring costs could be as high as the cost of the monitoring program on the Stanislaus River described below, $100,000, but could be less depending on how many days the river is connected to tidewater allowing fish to immigrate upstream.

A carcass sampling survey is also recommended (without the mark-recapture component) to recover coded-wire tags, collect biological data, and examine spawning distribution. The cost estimate is $75,000 annually; which is the cost of the current mark-recapture carcass survey. Details can be obtained from the Fisheries Foundation.

12. MOKELUMNE RIVER

***Mokelumne River** – Fall-run (Northern Sierra Nevada Diversity Group)*
This plan recommends using the fish device counter at Woodbridge Dam to estimate escapement of fall-run Chinook salmon in the Mokelumne River. This program costs $270,000 annually. In addition, this plan recommends conducting a carcass sapling survey to collect biological data and recover coded-wire tags. The cost estimate of the existing carcass/redd survey is $75,000. Total annual cost for monitoring is $345,000. Details for the cost estimate can be obtained from the East Bay Municipal Utility District in Lodi, CA.

13. STANISLAUS RIVER

***Stanislaus River** – Fall-run (Southern Sierra Nevada Diversity Group)*
This plan recommends estimating escapement of fall-run Chinook salmon in the Stanislaus River using the existing Alaskan style resistance board weir and Vaki Riverwatcher system. Monitoring costs from September through December are approximately $20,000 per month during periods of normal flow/debris loads, and $30,000 per month during periods of high flow/debris loads (C. Sonke, FishBio, pers. comm., 2010). Assuming an average of $25,000 per month, total annual monitoring costs are about $100,000. Detailed estimates of cost for this monitoring program are available from the FishBio office in Oakdale, CA.

A fish device counter is recommended to estimate spawning escapement; however, a carcass sampling survey is also recommended (without the mark-recapture component) to recover coded-wire tags, collect biological data, and to examine spawning distribution. The cost estimate for the carcass sampling survey is $78,000 annually; details can be obtained from the CDFG office in La Grange, CA.

Total estimated annual costs for monitoring in the Stanislaus River are $178,000.

14. TUOLUMNE RIVER

***Tuolumne River** – Fall-run (Southern Sierra Nevada Diversity Group)*
This plan recommends estimating escapement of fall-run Chinook salmon in the Tuolumne River using the existing Alaskan style resistance board weir and Vaki Riverwatcher system. Annual monitoring costs are similar to the program on the Stanislaus River described above, $100,000. Detailed cost estimates are available from the FishBio office in Oakdale, CA.

A fish device counter is recommended to estimate spawning escapement; however, a carcass sampling survey is also recommended (without the mark-recapture component) to recover coded-wire tags, collect biological data, and examine spawning distribution. The cost estimate for the carcass survey is $78,000 annually; details can be obtained from the CDFG office in La Grange, CA.

Total estimated annual costs for monitoring in the Tuolumne River are $178,000.

15. MERCED RIVER

***Merced River** – Fall-run (Southern Sierra Nevada Diversity Group)*

This plan recommends estimating escapement of fall-run Chinook salmon in the Merced River using a weir and fish device counter. Assuming the same type and size of system is used on the Merced as on the Tuolumne River, the weir, Vaki Riverwatcher system, and solar panels would cost approximately $145,000 (C. Sonke, FishBio, pers. comm., 2010). Annual monitoring costs would likely be similar to the monitoring programs on the Tuolumne and Stanislaus rivers described above, $100,000.

A carcass sampling survey is also recommended (without the mark-recapture component) to recover coded-wire tags, collect biological data, and examine spawning distribution. The cost estimate is $78,000 annually; details can be obtained from the CDFG office in La Grange, CA.

Summary of Costs

	Year 1	**Year 2**
Video Monitoring	$245,000	$100,000
Carcass Sampling Survey	$78,000	$78,000
Total	$323,000	$178,000

16. IMPLEMENTATION STAFF

A full-time database architect, plan coordinator, and statistician are recommended for implementation of the monitoring plan (Chapter 12). Annual costs are described below.

$70,689	Database Architect
$86,030	Biologist/Plan Coordinator
$102,180	Statistician
$258,899	TOTAL

17. TOTAL COST

Total cost includes the cost of monitoring programs (described above and listed in Table 3) and implementation staff.

Summary of Costs

	Year 1	**Year 2**
Total	$7,100,581	$4,748,661

Table 3. Total cost estimates (bolded) for recommended escapement monitoring programs in California's Central Valley.

Stream	Target Run	Monitoring Method(s)	Variable(s) Measured			Agency	Year 1 Total Cost (Personnel/Equip/Operating)	Year 2 Total Cost (Personnel/Equip/O
			Escapement	CWT Recovery & Biological Data	Distribution			
Main. Sacramento R.	F, LF, W	Aerial Redd Survey	X		X	CDFG	$30,000	$30,000
		Mark-Recapture Carcass Survey	X	X	X	CDFG	$629,696	$629,696
						USFWS	**$659,696**	**$659,696**
Up. Sacramento Basin Tributaries:								
Cottonwood Creek	F	Fish Device Counter	X			CDFG	**$2,023,717**	**$760,797**
Battle Creek	F	-	X			CDFG	-	-
Cow Creek	F, LF	-	X			CDFG	-	-
Bear Creek	F,LF	-	X			CDFG	-	-
Antelope Creek	F, LF, S	-	X			CDFG	-	-
Mill Creek	F, LF, S	-	X			CDFG	-	-
Deer Creek	F, LF, S	-	X			CDFG	-	-
Cottonwood Creek	F	Carcass Sampling Survey		X	X	CDFG	**$419,789**	**$299,789**
Cow Creek	F, LF	-		X	X	CDFG	-	-
Bear Creek	F,LF	-		X	X	CDFG	-	-
Antelope Creek	F, LF, S	-		X	X	CDFG	-	-
Mill Creek	F, LF, S	-		X	X	CDFG	-	-
Deer Creek	F, LF, S	-		X	X	CDFG	-	-
Clear Creek	F, LF, S	Fish Device Counter	X			USFWS	$335,256	$170,256
	S	Carcass Sampling Survey		X	X	USFWS	$133,000	$133,000
	F	Carcass Sampling Survey		X	X	CDFG	$52,000	$52,000
	LF	Carcass Sampling Survey		X	X	USFWS	$53,000	$53,000
							$573,256	**$408,256**
Beegum	S	Snorkel Survey	X	X	X	CDFG	**$5,000**	**$5,000**
Big Chico Creek	S	Snorkel Survey	X	X	X	CDFG	**$10,000**	**$10,000**
Butte Creek	S	Fish Device Counter	X			CDFG	$404,424	$120,424
	S	Snorkel Survey		X	X	CDFG	Included w/Big Chico Ck.	-
	F	Mark-Recapture Carcass Survey	X	X	X	CDFG	$80,000	$80,000
	S	Carcass Sampling Survey		X	X	CDFG	Included w/Fall-run	-
							$484,424	**$200,424**
Battle Creek	LF, W, S	Fish Device Counter/Trapping	X	X		USFWS	$130,000	$130,000
	LF, W, S	Snorkel & Redd Survey		X	X	-	$228,800	$228,800
							$358,800	**$358,800**
Feather River	S	Fish Device Counter	X			CDWR	$535,000	$160,000
	F	Mark-Recapture Carcass Survey	X	X	X	CDWR	$300,000	$300,000
	S	Carcass Sampling Survey		X	X	CDWR	-	-
							$835,000	**$460,000**
Lower Yuba River	F, LF, S	Fish Device Counter	X			CDFG	$75,000	$75,000
	F, S	Mark-Recapture Carcass Survey	X	X	X	CDFG	$98,000	$98,000
	F, S	Carcass Sampling Survey		X	X	CDFG	-	-
							$173,000	**$173,000**
American River	F	Mark-Recapture Carcass Survey	X	X	X	CDFG	**$100,000**	**$100,000**
Cosumnes River	F	Fish Device Counter	X	X	X	FF	$245,000	$100,000
		Carcass Sampling Survey					$75,000	$75,000
							$320,000	**$175,000**
Mokelumne River	F	Fish Device Counter	X			EBMUD	$270,000	$270,000
	F	Carcass Sampling Survey		X	X	EBMUD	$75,000	$75,000
							$345,000	**$345,000**
Stanislaus River	F	Fish Device Counter	X			FISH BIO	$100,000	$100,000
	F	Carcass Sampling Survey		X	X	CDFG	$78,000	$78,000
							$178,000	**$178,000**
Tuolumne River	F	Fish Device Counter	X			FISH BIO	$100,000	$100,000
	F	Carcass Sampling Survey		X	X	CDFG	$78,000	$78,000
							$178,000	**$178,000**
Merced River	F	Fish Device Counter	X			Unkown	$100,000	$100,000
	F	Carcass Sampling Survey		X	X	CDFG	$78,000	$78,000
							$178,000	**$178,000**
					Total Cost		**$6,841,682**	**$4,489,762**

CHAPTER 12

IMPLEMENTATION AND ADAPTIVE MANAGEMENT

This monitoring plan provides recommendations for in-river Chinook salmon escapement monitoring in California's Central Valley (CV) for improved fisheries management and assessing the recovery and restoration of Chinook salmon populations. Many of the recommended monitoring programs are already in place, but this plan has recommended changes to improve Chinook salmon escapement estimates, biological data collection, coded-wire tag recovery, and data management. Successful implementation of this monitoring plan will not be possible without the continuation of the collaborative and dedicated efforts of biologists from multiple agencies and entities throughout the CV.

Full implementation of the recommendations in this plan will require additional funding. We recommend that biologists begin implementing the recommendations as soon as possible, based on availability of resources. We envision the entire plan will be implemented in phases as funding opportunities arise.

Dedicated funding is essential for in-river Chinook salmon escapement monitoring. Due to lack of dedicated funding in the past, programs were either temporarily terminated or monitoring was compromised because effort (survey area, number of personnel, and amount of equipment) to estimate escapement, collect biological data and recover coded-wire tags was reduced. Many of the existing escapement monitoring programs do not have stable dedicated funding. We did not identify current funding status of programs, nor did we prioritize monitoring programs.

Device counters are recommended for monitoring Chinook salmon escapement in many streams that currently use mark-recapture carcass surveys, snorkel surveys or redd surveys to estimate or index escapement. Again, additional funding will be needed to install and operate device counters in these systems. Installation and refinement of the use of a device counter in a stream may take time; therefore the current survey method would need to continue until a device counter is in place and considered reliable.

There are many constraints to implementing the recommended monitoring programs such as natural factors (e.g. environmental conditions) and institutional factors (e.g. limited funding, permitting, and land access permission). High flows and high turbidity affect all survey methods (i.e., fish device counters, mark-recapture carcass surveys); however this plan includes recommendations for addressing these events when estimating escapement. Land access issues may also prevent the implementation of some recommended programs that use a fish device counter or conduct carcass sampling surveys. Access to the stream is required to install and maintain a weir and device counter, install a device counter in an existing structure, or conduct the carcass sampling surveys.

This monitoring plan should be considered dynamic; the plan and individual monitoring programs should have on-going evaluation and refinement. Adaptive management needs to be incorporated as part of implementing the recommended changes to existing programs or new recommendations. Adaptive management allows managers to adjust, refine, or modify the plan and monitoring activities based on new information and changing needs for fisheries management. After each monitoring program is implemented, results should be used to evaluate achievement of the objectives and goals of the plan. If successful, a monitoring program will continue. If changes are warranted, decisions will need to be made for future monitoring, including: (1) modify the monitoring program (e.g. survey period, survey frequency, and study location); (2) continue with status quo; (3) implement a new monitoring program; or (4) terminate the monitoring program. Research and management could provide information to evaluate the monitoring programs, implement decisions described above (e.g. new monitoring technique), and modify the plan if additional data needs or additional objectives are identified (e.g., sample size requirements for CWT recovery or mark-recapture carcass surveys).

We recommend evaluation of sample sizes in the mark-recapture carcass survey estimates after the first few years of data collection to determine if the sampling strategy needs to be modified in future years. In addition, we recommend examination of statistical power to detect trends in escapement over time.

We recommend that the existing Interagency Ecological Program (IEP) Central Valley Salmonid Project Work Team (PWT) provide guidance during the implementation phase. The Salmonid PWT has established technical subteams including Escapement Monitoring, Salmon DNA, Upper Sacramento River Basin, and Winter-run Chinook salmon PWTs. These technical subteams encourage, facilitate, and coordinate applicable monitoring, research, and information dissemination, and provide a technical forum for topics of interest at meetings. Team members include project leaders and professionals from various agencies and entities.

We envision that a dedicated team of biologists, statisticians, and database developers/managers will be available during implementation of this plan. We have recommended hiring a plan coordinator and database architect to work with the multiple agencies and entities involved in Chinook salmon escapement monitoring through the IEP Salmonid Escapement PWT and on an individual basis. Duties of the staff could include: (1) assist with logistics for implementing programs (e.g., permits, land access permission, etc.); (2) develop a data management plan with identified resources (i.e., money, time, and personnel) needed for implementation; (3) oversee posting of all annual reports to an established central location; (4) prepare an annual summary report for all CV Chinook salmon escapement monitoring; (5) assist with acquiring funds for monitoring programs and the data management system; and (6) assist with adaptive management of the programs.

Biologists will need technical assistance for completing the recommended monitoring programs and data analyses described in this plan. We also recommend hiring or contracting a statistician to assist with the implementation of the plan. The statistician would provide technical assistance at an annual workshop and throughout the year to individual biologists to implement recommended monitoring procedures and analyze data. The annual workshop would be an interactive meeting for the statistician to assist and train biologists in data analysis and address questions regarding data collection/study design for future years.

Some of the recommended Chinook salmon escapement monitoring programs, data management recommendations, and recommended implementation staff (plan coordinator, database architect, and statistician) were also recommended in the CV steelhead monitoring plan (Eilers et al. 2010). There are likely multiple opportunities for cost sharing between the two programs.

LITERATURE CITED

Amstrup, S. C., T. L. McDonald, and B. F. J. Manly (editors). 2008. *Handbook of capture-recapture analysis*. Princeton University Press, Princeton, New Jersey, USA.

Anderson, J.T., C. B. Watry and A. Gray. 2007. Upstream fish passage at a resistance board weir using infrared and digital technology in the lower Stanislaus River, California. Cramer Fish Sciences. Gresham, Oregon.

Arnason, A.N., C.J. Schwarz, and G. Boyer. 1998. POPAN-5: A data maintenance and analysis system for mark-recapture data. Scientific Report, Department of Computer Science,University of Manitoba, Winnipeg.

Barnett-Johnson, R., T. E. Pearson, F. C. Ramos, C. B. Grimes, and R. B. MacFarlane. 2008. Tracking the natal origins of salmon using isotopes, otoliths, and landscape ecology. Limnol. Oceanogr. 53(4):1633-1642.

Barnett-Johnson, R., C. B. Grimes, C. F. Royer, and C. J. Donohoe. 2007. Identifying the contribution of wild and hatchery Chinook salmon (*Oncorhynchus tshawytscha*) to the ocean fishery using otolith microstructure as natural tags. Can. J. Fish. Aquat. Sci. 64:1683-1692.

Bernard R. B., A. E. Bingham, and M. Alexandersdottir. 1998. Robust harvest estimates from on-site roving-access creel surveys. Transactions of the American Fisheries Society 127:481-495.

Blakeman, D. 2008. 2007 Tuolumne River fall Chinook salmon escapement survey. California Department of Fish and Game.

Boydstun, L. B. 1994. Analysis of two mark-recapture methods to estimate the fall Chinook salmon (*Onchorynchus tshawytscha*) spawning run in Bogus Creek, California. *Calif. Fish and Game* 80: 1 – 13.

Brown, M. R. and N. O. Alston. 2007. Monitoring adult Chinook salmon, rainbow trout, and steelhead in Battle Creek, California, from November 2002 through November 2003. United States Fish and Wildlife Report. Red Bluff, California.

Brown, R. and R. Bellmer. 2006. A summary of the August 23-25, 2005 Central Valley salmonid monitoring workshop. USFWS and CDFG.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Burwen, D. L., S. J. Fleischman, and J. D. Miller. 2007. Evaluation of a dual-frequency imaging sonar for detecting and estimating the size of migrating salmon. Alaska Department of Fish and Game, Divisions of Sport Fish and Commercial Fisheries, Fishery Data Series 07-44, Anchorage.

Buttars, B. 2010. Constant fractional marking/tagging program for Central Valley fall-run Chinook salmon , 2010 marking season. Pacific States Marine Fisheries Commission.

[CDFG] California Department of Fish and Game. 2010. GrandTab. Available at: http://www.calfish.org/LinkClick.aspx?fileticket=m%2BQf7Cx2i9Y%3D&tabid=104&mid=524

[CDWR] California Department of Water Resources. 2002. Feather River carcass survey: methods and sampling procedures. CDWR, Oroville.

Chapman, D. H. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1:131 – 160.

Chichester, J. 2008. Results of the 2007 Bear Creek Video Station fall-run Chinook salmon escapement. 35-31 Project Report. Western Shasta Resource Conservation District. Anderson, CA.

Cormack, R. M. 1964. Estimates of survival from the sightings of marked animals. Biometrika 51:429 – 438.

Crawford, B. A. and S. Rumsey. 2009. Draft: Guidance for monitoring the recovery of salmon and steelhead listed under the federal Endangered Species Act (Idaho, Oregon, and Washington). June 12, 2009.

Crosbie, S. F., and B. F. J. Manly. 1985. Parsimonious modeling of capture-mark-recapture studies. Biometrics 41:385 – 398.

Cuthbert, R., A. Fuller, and S. Snider. 2010. Fall/winter migration monitoring at the Tuolumne River weir. 2009/10 annual report. FISHBIO Environmenta, LLC. Oakdale, CA.

Del Real, S. C. and E. Rible. 2009. Fall-run Chinook salmon and winter-run steelhead redd survey report: October 2008 through March 2009. East Bay Municipal Utility District, Lodi, CA.

Eilers, C., J. Bergman, and R. Nielson. 2010. A comprehensive monitoring plan for steelhead (*Oncorhynchus mykiss*) in the California Central Valley. California Department of Fish and Game Fisheries Branch, Administrative Report Number 2010-2.

Elsdon, T. S., B. K. Wells, S. E. Campana, B. M. Gillanders, C. M. Jones, K. E. Limburg, D. H. Secor, S. R. Thorrold, and B. D. Walther. 2008. Otolith chemistry to describe movements and life-history parameters of fishes: hypotheses, assumptions, limitations and inferences. Oceanography and Marine Biology: An Annual Review 46:297-330.

Estensen, J. L., and M. Cartusciello. 2005. Salmon enumeration in the Nome River using video technology, 2004.

FAO. 1999. Guidelines for the routine collection of capture fisheries data. FAO Fisheries Technical Paper No. 382. Rome, FAO. Available at: [ftp://ftp.fao.org/docrep/fao/003/x2465e/x2465e00.pdf]

Fisher, F. W. 1994. Past and present status of Central Valley Chinook salmon. Conservation Biology 8:870–873.

Galbreath, P. F. and P. E. Barber. 2005. Validation of a long-range dual frequency identification sonar (DIDSON_LR) for fish passage enumeration in the Methow River. Columbia River Inter-Tribal Fish Commission Technical Report 05-4. Portland, Oregon.

Garman, C. E. and T. R. McReynolds. 2008. Butte Creek and Big Chico Creeks spring-run Chinook salmon, Oncoryhnchus Tshawytscha, life history investigation 2006-2007. Report 2008-1. California Department of Fish and Game, Chico.

Garza, J. C., S. M. Blankenship, C. Lemaire, and G. Charrier. 2008. Genetic population structure of Chinook salmon (Oncorhynchus tshawytscha) in California's Central Valley. Draft Final Report for CalFed Project "Comprehensive Evaluation of Population Structure and Diversity for Central Valley Chinook Salmon".

Giovannetti, S. and M. R. Brown. 2009. Adult spring Chinook salmon monitoring in Clear Creek, California, 2008 annual report. USFWS Report. U.S., Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Giovannetti, S. L. and M. R. Brown. 2007. Central Valley steelhead and late fall-run Chinook salmon redd surveys on Clear Creek, California 2007. U.S. Fish and Wildlife Service. Red Bluff, California.

Guignard, J. 2008. Stanislaus River fall Chinook salmon escapement survey 2007. California Department of Fish and Game.

Hatch, D. R., D. R. Pederson, J. K. Fryer, and M. Schwartzberg. 1995. Wenatchee River salmon escapement estimates using video tape technology in 1994. Columbia River Inter-Tribal Fish Commission. Technical Report 95-3.

Hatch, D. R. and M. Schwartzberg. 1991. Wenatchee River salmon escapement estimates using video tape technology in 1990. Columbia River Inter-Tribal Fish Commission. Technical Report 91-3.

Harvey-Arrison, C. 2007. Chinook salmon monitoring in Clear, Antelope, Mill and Deer Creeks for 2006. Sport Fish Restoration Annual Report.

Healey, M. 2005. Lower American River Chinook salmon escapement survey October-December 2005. California Department of Fish and Game. Rancho Cordova, CA.

Healey, M. C. 1991. Life history of Chinook salmon. Pages 313-393 in C. Groot and C. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver, BC.

Holmes, J. A., G. M. W. Cronkite, H. J. Enzenhofer, and T. J. Mulligan. 2006. Accuracy and precision of fish-count data from a "dual-frequency identification sonar" (DIDSON) imaging system. ICES Journal of Marine Science 63: 543 – 555.

Hoenig, J. M., D. S. Robson, C. M. Jones, C. M., and K. H. Pollock. 1993. Scheduling counts in the instantaneous and progressive count methods for estimating sport-fishing effort. North American Journal of Fisheries Management 13:723-736.

Horvitz, D. G., and D. J. Thompson. 1952. A generalization of sampling without replacement from a finite universe. Journal of the American Statistical Association 47:663 – 685.

Johnson, P., B. Nass, D. Degan, J. Dawson, M. Johnson, B. Olson, and C. Harvey-Arrison. 2006. Assessing Chinook salmon escapement in Mill Creek using acoustic technologies in 2006. Report submitted to USFWS Anadromous Fish Restoration Program.

Jones, C. M. 1992. Development and application of the otolith increment technique, p 1-11. *In* D. K. Stevenson and S. E. Campana [ed.] Otolith microstructure examination and analysis. Can. Spec. Publ. Fish. Aquat. Sci. 117.

Killam, D. and M. Johnson. 2008. The 2007 Mill Creek Video Station steelhead and spring-run Chinook salmon counts. SRSSAP Technical Report No. 08-01.

Killam, D. 2008a. Results of the 2007 Cow Creek Video Station fall-run Chinook salmon escapement. SRSSAP Technical Report No. 08-02.

Killam, D. 2008b. Results of the 2007 Cottonwood Creek Video Station fall-run Chinook salmon escapement. SRSSAP Technical Report No. 08-03.

Killam, D. 2007. Beegum Creek survey notes. Unpublished document. California Department of Fish and Game. Red Bluff, CA.

Killam, D. 2006a. Sacramento River winter-run Chinook salmon carcass survey summary report for years 1996-2006. SRSSAP Technical Report No. 06-4.

Killam, D. 2006b. Results of the experimental video station for fall-run Chinook salmon escapement into Battle Creek for years 2003-2005. SRSSAP Technical Report No. 06-01.

Killam, D. and C. Harvey-Arrison. 2001. Chinook salmon spawner populations for the Upper Sacramento River System, 2001. California Department of Natural Resources. Red Bluff, California.

Kimmerer, W., B. Mitchell, and A. Hamilton. 2001. Building models and gathering data: can we do this better? California Department of Fish and Game Contributions to the Biology of Central Valley Salmonids, Volume 2, Fish Bulletin 179:305.

Kormos, B. 2007. Escapement survey sampling, scale aging field sampling – standard operation procedures. Version 1.0. California Department of Fish and Game. Santa Rosa, CA.

Kucera, P.A. 2009. Use of dual frequency sonar to determine adult Chinook salmon (*Oncorhynchus tshawytscha*) escapement in the Secesh River, Idaho in 2007-2008. Nez Perce Tribe Department of Fisheries Resources Management, Lapwai, ID.

Kucera, P. A. and R. W. Orme. 2007. Chinook salmon (*Oncorhynchus tshawytscha*) adult escapement monitoring in Lake Creek and Secesh River, Idaho in 2006. Nez Perce Tribe Department of Fisheries Resources Management, Lapwai, ID.

Law, P. M. W. 1994. Simulation study of salmon carcass survey capture-recapture methods. California Department of Fish and Game 80(1):14-28.

Lindley, S. T., R. S. Schick, E. Mora, P. B. Adams, J. J. Anderson, S. Green, C. Hanson, B. P. May, D. R. McEwan, R. B. MacFarlane, C. Swanson, J. G. Williams. 2007. Framework for assessing the viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin Basin. San Francisco Estuary and Watershed Science. Vol. 5, Issue 1, Article 4.

Low, A. 2007. Existing program summary, Central Valley salmon and steelhead monitoring programs. California Department of Fish and Game. Sacramento, CA.

Mackey, E. 2005. Trends in Atlantic salmon: the role of automatic fish counter data in their recording. Scottish Natural Heritage Commissioned Report No. 100.

Manly, B. F. J. 2007. Randomization, bootstrap, and Monte carlo methods in biology. 3rd ed. Chapman and Hall, Boca Raton, Florida, USA.

Massa, D. 2007. Lower Yuba River salmon escapement survey. California Department of Fish and Game.

Massa, D., J. Bergman, and R. Greathouse. 2008. Lower Yuba River Accord Monitoring and Evaluation Plan annual Vaki Riverwatcher report, March 1, 2007-February 29, 2008. Available at: http://www.yubaaccordrmt.com/.

Maxell, B. A. 1999. A prospective power analysis on the monitoring of bulltrout stocks using redd counts. North American Journal of Fisheries Management 19:860 – 866.

Maxwell, S. L., and N. E. Gove. 2004. The Feasibility of estimating migrating salmon passage rates in turbid rivers using a dual frequency identification sonar (DIDSON). Regional Information Report No. 2A04-05, Alaska Department of Fish and Game.

Maxwell, S. L., and N. E. Gove. 2007. Assessing a dual-frequency identification sonars' fish-counting accuracy, precision, and turbid river range capability. J. Acoust. Soc. Am. 122(3): 3364-3377.

McDonald, T. L. 2010. mra: Analysis of mark-recapture data. R package version 2.7. http://CRAN.R-project.org/package=mra .

McElhany P., M. H. Rucklelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. NOAA Technical Memorandum NMFS-NWFSC-42.

Moyle, P. 2002. Inland fishes of California, 2nd Edition. University of California Press, Berkley.

Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. Salmon, steelhead, and trout in California: status of an emblematic fauna. Report commissioned by California Trout. University of California at Davis Center for Watershed Sciences.

Mueller, A., D. L. Burwen, K. M. Boswell, and T. Mulligan. 2010. Tail-beat patterns in dual-frequency identification sonar ecograms and their potential use for species identification and bioenergetics studies. Transactions of the American Fisheries Society 139:900-910.

Murphy, K. L. Hanson, M. Harris, and T. Schroyer. 1999. Central Valley Salmon and Steellhead harvest monitoring project, 1998 angler survey. California Department of Fish and Game, Sacramento Valley – Central Sierra Region.

Myers, J. M., R. G. Kope, G. J. Bryant, et al. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. US Dept. Commerc., NOAA Tech. Memo. NMFS-NWFSC-35, 443 p.

Newton, J. M., N. O. Alston, and M. R. Brown. 2007. Monitoring adult Chinook salmon, rainbow trout, and steelhead in Battle Creek, California, from March through November 2006. United States Fish and Wildlife Report. Red Bluff, California.

Newton, J. M. and M. R. Brown. 2005. Adult spring Chinook salmon monitoring in Clear Creek, California 2003-2004. U.S. Fish and Wildlife Service. Red Bluff, California.

Nichols, J. D. 2008. Modern open-population capture-recapture models. Pages 88 – 123 in Amstrup, S. C., T. L. McDonald, and B. F. J. Manly, editors. Handbook of capture-recapture analysis. Princeton University Press, Princeton, New Jersey, USA.

[NMFS] National Marine Fisheries Service. 2009. Public draft recovery plan for the evolutionarily significant units of Sacramento winter-run Chinook salmon and Central Valley spring-run Chinook salmon and the distinct population segment of Central Valley steelhead. Sacramento Protected Resources Division. October 2009.

[NMFS] National Marine Fisheries Service. 2000. Draft recovery planning guidance for technical recovery teams. September 1, 2000.

[NPS] National Park Service. 2008. Data management guidelines for inventory and monitoring networks. Natural Resources Report NPS/NRPC/NRR – 2008/035. National Park Service, Fort Collins, Colorado.

Null, R. E., L. McLaughlin, and K. S. Niemela. 2003. Comparison of methods used to estimate the proportions of marked fall Chinook salmon returning to Battle Creek, Anderson, California. USFWS Red Bluff, CA.

Otis, E. O., N. J. Szarzi, L. F. Fair, and J. W. Erickson. 2010. A review of escapement goals for salmon stocks in Lower Cook Inlet, Alaska, 2010. Alaska Department of Fish and Game. Fishery Manuscript No. 10-07.

Pipal, K. A. 2005. Summary of monitoring activities for ESA-listed salmonids in California's Central Valley. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-373.

Pipal, K., M. Jessop, G. Holt, and P. Adams. 2010. Operation of dual-frequency identification sonar (DIDSON) to monitor adult steelhead (*Oncorhynchus mykiss*) in the central California coast. NOAA-TM-NMFS-SWFC-454.

Piper, P. G., and five coauthors. 1982. Fish Hatchery Management. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D. C.

Pollock, K. H. J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs 107:1 – 97.

Pollock, K. H., Jones, C. M., and T. L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society Special Publication 25.

Pollock, K. H., J. M. Hoenig, C. M. Jones, D. S. Robson, and C. J. Greene. 1997. Harvest rate estimation for roving and access point surveys. North American Journal of Fisheries Management 17:11-19.

R Development Core Team. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org .

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin 191of the Fisheries Research of Canada, Ottawa, Ontario.

Robson, D. S. 1961. On the statistical theory of a roving creel census. Biometrics 17:19-24.

Royle, J. A. 2004. N-mixture models for estimating population size from spatially replicated counts. *Biometrics* 60:108-115.

Schaefer, M. B. 1951. Estimation of the size of animal populations by marking experiments. U.S. Fish and Wildlife Service Fisheries Bulletin 69:191 – 203.

Schwarz, C. J., A. N. Arnason, and C. W. Kirby. 2002. The siren song of the Schaefer estimator – no better than a pooled Petersen. Unpublished manuscript available at: http://www.stat.sfu.ca/~cschwarz/papers/2002/Schaefer/

Schwarz, C.J. and A.N. Arnason. 1996. A general methodology for the analysis of capture-recapture experiments in open populations. Biometrics. 52:860-873.

Schwarz, C. J., R. E. Bailey, J. R. Irvine, and F. C. Dalziel. 1993. Estimating spawning escapement using capture-recapture methods. Can. J. Fish. Aquat. Sci. Vol 50:1181-1197.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd ed. Chapman, London, England and Macmillan, New York, New York, USA.

Smith, S. H. 1950. Upper Sacramento River sport fishery. Special Scientific Report No. 34, United States Department of the Interior, U. S. Fish and Wildlife Service.

StreamNet. 2009. Considerations for regional data collection, sharing, and exchange. White paper. Bruce Schmidt.

Titus, R., M. Brown, J. Phillips, J. Lyons, and E. Collins. 2009. Annual performance report – Central Valley angler survey; project number F-119-R; report period July 1, 2008 to June 30, 2009. California Department of Fish and Game.

Tsao, S. 2008. 2007 Merced River fall Chinook salmon escapement survey. California Department of Fish and Game.

[USFWS] U.S. Fish and Wildlife Service. 2008. Flow-Habitat Relationships for Spring and Fall-run Chinook Salmon and Steelhead/Rainbow Trout Spawning in the Yuba River. Prepared by personnel of the Energy Planning and Instream Flow Branch. Sacramento, California.

Wade, D. L., C. M. Jones, D. S. Robson, and K. H. Pollock. 1991. Computer simulation techniques to access bias in the roving-creel-survey estimator. American Fisheries Society Symposium 12:40-46.

Waples, R. S. 1991. Definition of ‘‘species’’ under the Endangered Species Act: application to Pacific salmon. NOAA Technical Memorandum NMFS F/ NWC-194.

Williams, J. 2006. Chapter fifteen: monitoring. San Francisco Estuary and Watershed Science. Vol 4, Iss. 3, Art. 23.

Williams, J. G., and 10 coauthors. 2007. Monitoring and research needed to manage the recovery of threatened and endangered Chinook and steelhead in the Sacramento-San Joaquin basin. NOAA Technical Memorandum NMSF-SWFSC-399.

Wixom, L. H., J. Pisciotto, and C. Lake. 1995. Sacramento River system sport fish harvest inventory. Federal Aid Project F-51-R-7, U.S. Fish and Wildlife Service.

Workman, M. L. 2005. Lower Mokelumne River upstream fish migration monitoring conducted at the Woodbridge Irrigation District Dam, August 2004 through July 2005. East Bay Municipal Utility District. Lodi, CA.

Workman, M. L., E. T. Rible, and J. L. Shillam. 2008. Lower Mokelumne River fall-run Chinook salmon escapement report, October 2007 through January 2008. East Bay Municipal Utility District. Lodi, California.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 1998. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Fish Bulletin 179, Volume 1.

PERSONAL COMMUNICATION

Anderson, J., Cramer Fish Sciences, pers. comm., Stanislaus River Vaki Riverwatcher data, 2010.

Azat, J., CDFG, pers. comm., Central Valley Chinook salmon escapement monitoring summary reports and Grand Tab, 2010.

Brown, M., USFWS, pers. comm., Weir and fish device counter for Clear Creek, 2010.

Carlson, R., PSMFC, pers. comm., CalFish, 2010.

[CDFG] California Department of Fish and Game and [NMFS] National Marine Fisheries Service Ocean Fisheries Management, pers. comm.., Chinook salmon escapement monitoring needs for fisheries management, 2008.

Garman, C., CDFG, pers. comm., Video monitoring in Big Chico and Butte Creeks, 2010.

Greathouse, R., PSMFC, pers. comm., Vaki Riverwatcher systems on the lower Yuba River, 2010.

Harvey-Arrison, C., CDFG, pers. comm., Monitoring in Clear, Antelope, Mill, and Deer Creeks, 2010 and 2011.

Heyne, T., CDFG, pers. comm., Stanislaus River monitoring, 2008.

Killam, D., CDFG, pers. comm., Video monitoring in the upper Sacramento River basin and cost estimates, 2010.

Killam, D., CDFG, pers. comm., Upper Sacramento River monitoring, 2010.

Killam, D., CDFG, pers. comm., Upper Sacramento River monitoring, 2008.

Kindopp, J., CDWR, pers. comm., Proposed weir for the Feather River, 2010.

Massa, D., Pacific States Marine Fisheries Commission (PSMFC), pers. comm., Yuba River, 2010.

Massa, D. California Department of Fish and Game (CDFG), pers. comm., Yuba River, 2008.

Newton, J., USFWS, pers. comm., Battle Creek monitoring, 2010.

Newton, J., USFWS, pers. comm., Battle Creek monitoring, 2008.

Palmer-Zwahlen, M., CDFG, pers. comm., Ocean Salmon Project – age scale program and coded-wire tag recovery, 2010.

Sonke, C., FISHBIO Environmental, LLC, pers. comm., Weir and Vaki Riverwatcher system on the Stanislaus and Tuolumne Rivers, 2010.

Threloff, D., USFW, pers. comm., CAMP program and data management, 2010.

Workman, M., EBMUD, pers. comm., Mokelumne River monitoring, 2008.

APPENDIX A

ESTIMATING CHINOOK SALMON ESCAPEMENT USING DEVICE COUNTERS

By
Western EcoSystems Technology
2003 Central Avenue, Cheyenne, WY 82001
Phone: 307-634-1756 Fax: 307-637-6981

Jim Griswold
jgriswold@west-inc.com

Ryan Nielson
rnielson@west-inc.com

December 31, 2010

INTRODUCTION

We describe methods for estimating the accuracy and precision of three fish device counters that could be used to estimate total escapement within a watershed or stream: the Vaki Riverwatcher®, the dual frequency identification sonar (DIDSON), and traditional optical video cameras. These devices provide enumeration data which are subject to a number of sources of error. The objective of the report is to describe procedures by which these errors can be quantified and incorporated into estimates of total escapement.

The Vaki Riverwatcher, DIDSON and video fish counters have advantages and disadvantages over traditional methods of collecting data to be used for estimating total fish escapement. The devices are expensive to buy and install, are vulnerable to vandalism and theft, and must be installed at an appropriate in-river structure (Mackey 2005). The devices require regular monitoring, maintenance and servicing to maintain reliable operation and to insure that the data are of high quality. Damage by flooding of the in-river structure is always a possibility. Nevertheless, these devices have a number of strengths: they provide a fairly accurate and consistent count, they can function all year round, and they can operate with minimal impact on individual fish which is an important consideration when the status of the population is threatened or endangered. Moreover, a permanent record is obtained for fish passage which can be reviewed and corrected for error and used for future training personnel that process the images.

The Vaki Riverwatcher uses a linear sensory array to measure the height (ventral-dorsal) of a fish breaking infrared light beams emitted from a series of diodes positioned opposite a series of sensors. As a fish swims in a linear fashion (e.g., upstream or downstream) it breaks a second array of infra-red light beams. From the height of the fish and the rate it moves between the two arrays the counter is able to reconstruct an outline of the fish. This outline is then stored to be validated by the operator (Mackey 2005, Figure 1).

A video camera add-on is available for the Vaki Riverwatcher (Figure 2) to limit the rate of false counts. The Vaki Riverwatcher has the advantage of being less costly than the DIDSON. However, the DIDSON forms near-video-quality images based on sound instead of light and has the advantage of being able to collect images in near zero-visibility water (Maxwell and Gove 2004, Tiffan and Rondorf 2004). The range of imaging for the DIDSON depends on the frequency used. The traditional video camera is the least expensive of the three devices but probably the least accurate when visibility is poor. When water clarity is high a traditional video camera has the advantage of being able to identify fish by species and origin (wild vs. hatchery) (Gates and Boersma 2009, Figure 3).

This report describes methods which will be used to quantify uncertainty in Vaki Riverwatcher, DIDSON, and traditional video count data and obtain estimates of total escapement from the device counts. Hereafter the three device counters will be referred to generally as “device counter”, since each of the three devices will be subjected to the same methodology for error measurement, except when noted otherwise.

Types of Counting Errors

There are at least six types of counting errors that may affect estimates of the number of fish passing by a device counter:

7) **Missed counts**: A missed count occurs when a fish passes the device counter but is not recognized. The fish may pass the device too quickly for an image to be recorded or turbidity may cause the sensors to fail. A missed count may also occur when two fish cross the device counter but only one fish is recorded. Periods when the device counter is malfunctioning or inoperative will result in missed counts.

8) **False counts**: A false count occurs when another object is mistaken for a fish (e.g., waterfowl, muskrats, leaves, sticks, or bubbles).

9) **Mixed counts**: A mixed count can occur when a species other than the target species is recorded and is not correctly identified.

10) **By-passed counts:** By-passed counts are the result of the target fish swimming around the device counter and are never in the range within which the fish can be recorded. This type of error can occur during high water events or when the device counter has not been installed in a constricted enough area and the range of the counter is not adequate to detect all fish which migrate past the device. The range of accurate counts will depend on correct installation and aiming the device counter at the correct tilt angle for a given bottom topography, depth and stream width.

11) **Double counts**: Double counts occur when fish which have been counted once drop back below the device counter, and then again enter the range of the device counter and are counted for a second time.

12) **Observer or technician errors**: Errors can be made by the individual(s) processing the images or device counter data. For example, a file may become corrupted or lost, or the observer may under- or over-count fish. Both within and between observer errors are possible.

Three methods are recommended to assess the accuracy and variability of the device counter data. The biologist(s) responsible for estimating escapement should determine the most appropriate method for their system. The first methods relies on comparing device counts to paired visual counts from a counting tower, using groups of fish allowed to pass through a weir (Holmes et al. 2006). The second method relies on comparing device counts to paired visual counts from a counting tower using unconstrained Chinook salmon (*Oncorhynchus tshawytscha*), Holmes et al. 2006, Figure 4). The third method for assessing device counter accuracy and variability involves the use of artificial targets or tethered fish that can be passed across the recording field at measured turbidity, temperature, depths and distances from the device in order to evaluate the error rate (see Burwen et al. 2003 as an example). Alternatively, a DIDSON unit could be paired with another device counter for a certain number of trials (Maxwell and Gove 2007). Since the

DIDSON is not limited by the range of turbidity expected for Central Valley streams the counts from the two devices can be compared, using the DIDSON count as truth. Staging trials in which target-species and non-target species, either free or tethered, are released through the range of a video camera will be used to assess video performance in recognizing the target species and presence/absence of an adipose fin.

FIELD METHODS

When passage can be constrained using an enumeration fence, weir or trap (e.g., Cousens et al. 1982) just downstream from the device counter, timed releases of fish will be used to test the device counter. An observer will be positioned on a counting tower to monitor and visually count fish through the period of time when all fish have moved upstream of the device counter. Counts from the device counter recordings will be compared to the visual counts (e.g., the number of fish released from the weir).

When fish passage cannot be constrained, timed comparisons of visual and device counts will be made by stationing an observer on an observation tower overlooking the counter site. A visual marker will be placed on the bottom of the river to mark the device counter’s maximum fish recording distance, if this distance is less than the entire stream width. Care should be taken to insure that the visual marker does not disturb fish and prevent them from entering the device counter range. The observer will count all fish passing between the distance reference and the near bank over a pre-specified time period. Counts from the device counter recordings can be compared to the visual counts, which will be considered ‘truth’.

Some streams may experience extreme environmental effects which cannot be corrected by simultaneous visual counts of live fish. These include situations during extreme turbidity and high flow. Monitoring on the Thorsa River (Iceland) suggested that the Vaki Riverwatcher is expected to provide correct counts up to a secchi depth of at least 4 inches (Vaki-DNG 2000). Maxwell and Gove (2004) found that in DIDSON images a plastic target sphere roughly the volume of a sockeye salmon was visible within 17 m at turbidity levels of 800 NTU’s (Figure 5), while in clear water (secchi 4.0 -5.5 m) the plastic sphere was visible at 26 m. For almost all conditions in Central Valley Chinook salmon streams the DIDSON’s ability to provide accurate counts is not expected to be limited by turbidity. If the Vaki Riverwatcher® or a traditional optical video camera will be used during periods of high turbidity the device counter should be paired with a DIDSON to obtain estimates of error rates during those conditions. By constraining fish passage immediately below device site and using staged releases of fish (known numbers) for passage through the device we could compare the known numbers to the device counts. Here the DIDSON would be assumed to provide the true count. Alternatively, fish could be towed through the counting site during various conditions.

Measurements of environmental conditions (e.g., flow, turbidity, lighting conditions, device operator ID) will be made during the validation tests as well as for every day of the migration period. These potential explanatory covariates will be used during modeling and prediction (see below) to account for variations in error rates.

All fish counting towers will be covered and include a light source beside the gate to the upstream barrier so that continuous counts can be made regardless of weather or time of day. Fish which fall back below the device counter range during validation tests will be noted as having been possibly double counted by the device. Fish that are clearly moving upstream but have not disappeared from the field of view when the device film/files have ended will be included in the upstream count. These ‘event’ based approaches are necessary to assess the accuracy and precision of the device counter over a range of fish densities and water visibility conditions (Maxwell and Gove 2004, Holmes et al. 2006).

The decision as to which streams are to be tested depends on the frequency and extent to environmental conditions are expected to change. These field methods just described represent the minimum field tests that are necessary to produce valid estimates of total escapement. However, more field testing will be necessary if other conditions exist. For instance, if species misidentification is a potential issue or the device counter is not operational for an extended period of time. These additional protocols are described below.

STATISTICAL ANALYSIS

Estimating Detection Rates for a Device Counter

As mentioned above, error rates for a device counter could involve missed detections or false detections. Normal linear regression (Kutner et al. 2005) will be used to estimate the probability of detection for each device counter over the range of environmental conditions when the visual/DIDSON counts are obtained during the trials were considered to have been made without error. The data taken from each validation trial will consist of a series of paired counts from the counting towers, tethered fish or DIDSON counts, and the estimates from the device counter being tested. Each set of paired counts correspond to one validation trial and will have a set of covariate information (e.g., flow, turbidity, lighting conditions, device operator ID). The response values in the model will be the number of device counts for each trial divided by what is considered the true count (i.e., visual or DIDSON count) for that trial. The normal linear regression modeling may require identification of a suitable transformation of the proportion of counts to meet the model assumptions. This method allows for estimating adjustment terms that incorporate for missed counts, false counts, mixed counts, and double-counts. Here the estimated detection rates will be specific to each covariate combination.

Identification of the best covariates for modeling detection rates will be carried out using the small sample version of Akaike’s information criterion (AICc, Burnham and Anderson 2002). The use of covariates for counting conditions will provide information on river conditions affecting accuracy and precision of counts. The observer ID covariate will allow for an estimate of the importance of variation between individual device counter operators.

Sample Sizes for Estimating Detection Rates

In order to estimate the error rates of device counters at acceptable levels of precision an adequate number of paired trials will need to be conducted. Sample sizes required for given levels of effect size (difference between visual counts and device counts), statistical significance (alpha), and statistical power can be estimated via linear regression analysis of the device counts versus visual/DIDSON counts as paired trials are being conducted. The method proceeds as follows. The variance of the regression slope (*b*) of device count versus visual/DIDSON counts is given by

$$s_b^2 = \frac{MSE}{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2} \tag{1}$$

where MSE is the mean square error estimated from the linear regression of device counts on visual/DIDSON counts, X_i is the visual/DIDSON count for the i^{th} paired trial, and *n* is the number of paired events (sample size) during which X_i fish were counted. Power ($1-\beta$) where β is the probability of a type II error, can be calculated using

$$t_{1-\beta} = t_\alpha + \frac{\delta}{s_b}, \tag{2}$$

and

$$Power = 1 - \beta = P\left(t \geq t_{1-\beta}\right), \tag{3}$$

where δ is the detectible effect size or difference between the Vaki count and the true count. Sample sizes which provide power of at least 0.80 are recommended. Gamma (δ) should be set so that $\frac{\delta}{MSE} \leq 0.10$. This will insure that there is minimal sampling variability contributed by estimated detection rate.

Estimating Daily Escapement

Assuming either flow, turbidity or both are selected as important variables in explaining the variation in detection rates, the estimated expected values of those detection rates will be used to adjust the device counts. Recall that detection rates ($\hat{p}$) are estimated from linear regression analysis and can be less than 1 or greater than 1, depending if under-counting or over-counting dominates during certain environmental conditions. For the case where both flow and turbidity are included as explanatory covariates in the final linear regression model for detection rates, the adjusted count for the i^{th} day of the counter enumeration which experienced flow level *j* and the turbidity level *k* is

$$\hat{C}_i = \frac{C_{i,flow_j,turbidity_k}}{\hat{p}_{flow_j,turbidity_k}}. \tag{4}$$

Bootstrapping (Davison and Hinkley 1996) will be used to estimate the standard error (SE) and a 90% confidence interval (CI) for total escapement within a day. Two thousand bootstrap samples will provide 2000 additional estimates of total escapement for each day. The standard deviation (SD) of the 2000 estimates for each day will be used as an estimate of the SE, and the 5th and 95th percentiles of the *B* = 2000 estimates will be used for the lower and upper 90% confidence interval limits, respectively. The bootstrap algorithm proceeds as follows:

1. For each bootstrap replicate, indexed $b = 1, \dots, B$:

   (a) Generate bootstrap sample $X^{*(b)} = \begin{pmatrix} y_1^* & x^*_{11} & \cdots & x^*_{1p} \\ \vdots & \vdots & & \vdots \\ y_n^* & x^*_{n1} & \cdots & x^*_{np} \end{pmatrix}$ by sampling with replacement from the n rows of the observed dataset for the selected detection rate model.

   (b) Compute the b^{th} replicate estimates of $\overline{p}^{(b)}$ from the b^{th} bootstrap sample in (a).

2. Calculate the b^{th} replicate estimates of the daily estimated escapements, $\hat{C}_i^b$ using (4).

3. The SE is the sample standard deviation of the replicates $\hat{C}_i^{(1)},...,\hat{C}_i^{(B)}$. The bootstrap 90% confidence interval is the 5th and 95th percentiles of the replicates $\hat{C}_i^{(1)},...,\hat{C}_i^{(B)}$.

Estimating Seasonal Escapement

The total escapement for the spawning migration period will be estimated using the sum of the n daily escapement estimates

$$\hat{E}_{total} = \sum_{i=1}^{n} \hat{C}_i \,. \tag{5}$$

With the assumption of independence of adjusted counts over all days of the spawning migration period the variance of the total escapement can be estimated as the sum of the variances of the individual daily adjusted counts

$$\hat{\mathrm{var}}\left(\hat{E}_{total}\right) = \sum_{i=1}^{n} SE\left(\hat{C}_i\right). \tag{6}$$

An approximate 90% asymptotic confidence interval for the total escapement over the entire t days of the spawning migration is

$$CI = \hat{E}_{total} \pm 1.65 \times \sqrt{\hat{\mathrm{var}}\left(\hat{E}_{total}\right)}. \tag{7}$$

Estimating Error in Species and Stock of Origin

If species other than Chinook salmon (e.g., steelhead, resident rainbow trout, pikeminnow) are expected to result in false counts, or it is necessary to estimate escapement by stock of origin (wild or hatchery), it will be necessary to estimate detection rates for target species and/or origin group for each location where a device counter is used. Both the Vaki Riverwatcher and the DIDSON may have low reliability for correctly identifying adipose fins, fish length, or species identification (Holden and Struthers 1997, Miller et al. 2003, Stanislaus weir email summary 2005, Baumgartner 2010) (Figures 1, and 5 – 7). However, Vaki Riverwatcher and DIDSON have been shown to be both accurate and precise with accuracy in the range of mid to high 90th percentile for fish passage rates generally encountered in the Central Valley, and can operate at a greater detection range than a video device counter (Holmes et al. 2006, Maxell and Gove 2007). When completely submersed in a plexi-glass box of clear water video device counters have been shown to give good discrimination of species and adipose fin recognition (Gates and Boersma 2009). If video camera images have acceptably high discriminatory ability, video cameras will be paired with the Vaki Riverwatcher or DIDSON when non-target species (or origin) are present and at random intervals throughout the migration period. This will allow for independent estimates of the proportions of the target species (or origin) during each temporal segment of the spawning migration period. To assess video reliability in identifying target species and presence or absence of an adipose fin, video counts will be used to estimate the ratio of the target species to the rest of the fish in the stream across a range of environmental conditions (e.g., turbidity and flow).

If species other than Chinook salmon result in false counts, or it is necessary to estimate escapement by stock of origin, the escapement estimation procedure described above will need to be modified as follows:

1. Carry out calibration trials to obtain the best device settings for the video for optimal discrimination of the target species and adipose fin recognition.
2. Estimate the video detection rate of the target species, $\bar{\hat{R}}_{jk}$ (equation [8] below) and the rate of fish identified as wild (adipose fin recognition) using trials with known targets.
3. Calculate the proportion of total video fish that are the target fish using a video device counter across a range of days during the migration period and a range of environmental conditions, $\hat{P}_{video_{jk}}$ (equation [9] below).
4. Estimate escapement of the target species (and origin) for a survey day from paired video and device survey counts for a given set of environmental conditions. This is done by estimating the number of target fish comprising the device counts by multiplying the device counts adjusted for detection rate, $\hat{C}_i$ (equation [4] above), by the proportion ($\hat{P}_{video_{jk}}$) of target fish counted in the video images. Finally, obtain the corrected estimate of escapement, $\hat{E}_{ijk}$ (equation [10] below), by dividing the estimated number of target fish by the estimated video detection rate ($\bar{\hat{R}}_{jk}$) obtained in step 2.

In order to calibrate the video and train image processing personnel to minimize false counts, calibration trials in which pikeminnow, Chinook salmon and steelhead (the latter two with and without adipose fins) can be allowed to pass through the recording range of the counting device. Target fish will be presented at a range of distances from the video over a range of water depths, turbidity and flow conditions to obtain video settings and installation setup which allow for optimal discrimination of target species and origin groups (Maxell and Gove 2004). Those video settings giving the highest proportion of correct counts by species and origin group will be used for all escapement estimates. If fish cannot be tethered or manipulated to pass by the device counter, it could be assumed that during clear water conditions the video camera could provide 'true' estimates and be used to calibrate the DIDSON.

The second step in the process involves a series of trials used to estimate the rate of target fish counts by releasing through the imaging field of the video individual fish of known species/origin over river conditions having a range of flow and turbidity levels. For the case in which the trials use only Chinook salmon and steelhead, the estimated rate of Chinook salmon discrimination is the ratio of the count of fish identified as Chinook salmon in the video image to the true number of Chinook salmon in the trials for the given environmental conditions. The mean ratio over *n* trials with varying turbidity and flow levels is

$$\bar{\hat{R}}_{jk} = \frac{1}{n}\sum_{i=1}^{n}\frac{C_{video,ijk}}{C_{Chinook,ijk}} ; \tag{8}$$

where $C_{video,ijk}$ and $C_{Chinook,ijk}$ are the counts of fish identified as Chinook salmon in the video and counts of the true number of Chinook salmon for the i^{th} trial during turbidity level *j* and flow level *k* respectively.

The estimated proportion of target fish counted in the video for the i^{th} day of the survey when the video camera is paired with the device (Vaki or DIDSON) is

$$\hat{P}_{video,ijk} = \frac{C_{video(Chinook),ijk}}{C_{video(total),ijk}} , \tag{9}$$

where $C_{video(Chinook),ijk}$ is the count of Chinook salmon for turbidity level *j* and flow level *k*, and $C_{video(total),ijk}$ is the total fish count for the video for turbidity level *j* and flow level *k* when the video camera is paired with the device (Vaki or DIDSON) on the i^{th} day of the survey.

Estimated escapement for the i^{th} survey day during the j^{th} turbidity level and k^{th} flow level is estimated in the third step as

$$\hat{C}_i' = \frac{\hat{P}_{video,ijk}}{\bar{\hat{R}}_{jk}} \times \hat{C}_i , \tag{10}$$

where $\hat{C}_i$ was estimated using equation (4) above, and $\hat{C}_i'$ is the new adjusted estimate.

Standard errors for the daily total escapement estimates adjusted for species or origin misidentification can be calculated using the bootstrap method described above. However, the bootstrap procedure will need to be amended to include new bootstrap estimates for equations (8) and (9). Following the bootstrap, new estimates of the total escapement during the migration period, along with a 90% confidence interval, can be obtained using equations (5) – (7) above (recognizing the need to switch from $\hat{C}_i$ to $\hat{C}'_i$ in those equations).

False identification of steelhead as Chinook salmon will depend on the degree of overlap in the migration of the two species. The period and extent to which both Chinook salmon and steelhead are expected to be migrating past a site will vary by river but should be minimal (Hannon and Deason 2005, Pagliughi 2008). However, this time may extend for as long as a month in some waters (Hannon and Deason 2005). Intensive sampling using fyke nets or weirs set downstream or upstream from the device counter will be used to provide an independent estimate of the true proportions and run-timing of target species, non-target species and origin groups.

Imputation of Missing Data: Extended Periods of Missing Data

Missing data can occur for a number of reasons. We expect that the test analyses and regression results described above will provide unbiased estimates of escapement at a range of turbidity and flow conditions when the device counter is in operation. However, extreme high water, excessive turbidity or malfunctioning of equipment may result in a device counter being non-operational for extended periods from several hours to several days. These are considered to be missing at random. Missing data due to malfunctioning of equipment is the condition of data missing completely at random. That is the condition of being missing is not dependent on the number of fish present on any day and not dependent on any other variable. While device counts will be dependent on turbidity levels, actual fish passage or the true count may not be dependent on turbidity or high flow events. The exception to this would be when fish are staging at a downstream location due to lower than normal flows or behind a partial barrier just before a high flow event. Data from Clear Creek, Mokelumne River and the American River do not indicate a general relationship between fish passage rate and discharge (Hannon and Deason 2005, Giovannetti and Brown 2007, Pagliughi 2008).

Generalized additive regression models (GAM) using either spline fitting (LOESS) or locally weighted regression (LOWESS; Hastie and Tibshirani 1990, Zanobettie et al. 2000, Woods 2006) will be used to predict missing counts during these extended periods. Standard errors and 90 % confidence intervals will be computed for the predictions. The autocovariance function will be computed for the GAM model to test for autocorrelation in the counts. Distributed lag terms will be included in the model according to the method described in Zanobettie et al. (2000) if autocorrelation is found to be significant at the alpha = 0.1 level (equivalent to a 90% CI).

A second Bayesian method is also recommended. This method involves estimating a posterior predictive distribution from which the missing values are predicted (Gelman et al. 2004, Ntzoufras 2009). Variances and 90% credible intervals of the counts for the missing days can be computed by sampling from the posterior predictive distribution. Which of these two methods is best to use may depend on the degree to which prior information exists on the correct distribution of the data.

Both recommendations described above provide methods to impute the missing data for each period of time, along with methods for calculating variances for those imputations. If data imputation is necessary, simply include those imputed escapement estimates in and their estimated variances in equations (5) – (7) to obtain a total escapement estimate and 90% for the spawning migration period.

Generalized Additive Modeling (GAM) of Missing Values

Likely distributions for the count data can be Poisson, binomial, negative binomial or approximately Gaussian if the counts are large (say median count > 25). The day of the missed count is used as an explanatory covariate potentially along with other covariates if these are found to be related to the period of missing data. Then, a generalized additive model (GAM) can be used to predict the missing count data using splines or locally weighted regression.

The additive model applied on the estimated daily escapement (response variable Y_i) and day (explanatory variable X_i) variable is

$$Y_i = \alpha + f\left(X_i\right) + \varepsilon_i\,, \tag{20}$$

where $\varepsilon_i \sim N\left(0, \sigma^2\right)$.

Writing $f\left(x_i\right)$ as a linear regression model in terms of basis functions $b_j\left(X_i\right)$ we get

$$f\left(X_i\right) = \sum_{j=1}^{p} \beta_j \times b_j\left(X_i\right). \tag{21}$$

Suppose that p = 4. This gives

$$f\left(X_i\right) = \beta_1 \times b_1\left(X_i\right) + \beta_2 \times b_2\left(X_i\right) + \beta_3 \times b_3\left(X_i\right) + \beta_4 \times b_4\left(X_i\right). \tag{22}$$

For a cubic polynomial where

$$b_1\left(X_i\right) = 1, b_2\left(X_i\right) = X_i, b_3\left(X_i\right) = X_i^2\ , b_2\left(X_i\right) = X_i^3$$

we have

$$f\left(X_i\right) = \beta_1 + \beta_2 \times X_i + \beta_3 \times X_i^2 + \beta_3 \times X_i^3\,, \tag{23}$$

which can give a wide range of possible shapes, depending on the values of the coefficients (Zuur et al. 2009).

Models with more than one explanatory variable can also be fitted:

$$Y_i = \alpha + f_1\left(X_i\right) + f_2\left(Z_i\right) + \varepsilon_i \tag{24}$$

where $\varepsilon_i \sim N\left(0, \sigma^2\right)$, where $f_1\left(X_i\right)$ and $f_1\left(Z_i\right)$ are functions of covariates. In this case *Z* could represent sex, water temperature or discharge if these were expected to be implicated in run timing.

Since the LOESS smoother and the polynomial and cubic regression splines are local regression models they can be written in the same form as the linear regression model:

$$\hat{Y} = S \times Y \quad and \quad \operatorname{var}\left(\hat{Y}\right) = \sigma^2 \times S \times S\,', \tag{25}$$

where S is analogous to the hat matrix, $X\left(X'X\right)^{-1}X'$ in multiple linear regression where X is the design matrix of 1's and covariates and σ^2 is the variance of the response (counts) and the expressions $\hat{Y}, Y, X, and\ S$ are vectors and matrices.

An estimated standard error for the i^{th} missing value is given by:

$$s\hat{e}\left\{\hat{Y}_i\right\} = \sqrt{\hat{\sigma}^2\left(1 + x_i^{'}S\left(S'S\right)^{-1}S'x_i\right)}, \tag{26}$$

where x_i is the $p\times 1$ vector of i^{th} row (i^{th} observation) of the design matrix X containing the covariate values. A 90% confidence interval for the i^{th} predicted value is

$$\hat{Y}_i \pm t_{n-p-1,\alpha/2}\cdot s\hat{e}\left\{\hat{Y}_i\right\}. \tag{27}$$

Estimating Missing Values Within a Bayesian Framework

Estimates of missing values are based on predictive distributions, or the distribution of the data averaged over all possible parameter values (Gelman et al. 2004, Ntzoufras 2009). Distributions may be Gaussian, Poisson, negative binomial or binomial. The choice of which distribution to use will depend on goodness of fit tests and posterior predictive checking and sensitivity analyses (Gelman et al. 2003, pgs 157–176). Therefore, when say, Gaussian data *y* (estimated daily escapement), (substitute summations for integrals for discrete data) have not been observed yet, predictions are based on the marginal likelihood

$$f\left(y\right) = \int f\left(y\,|\,\theta\right)f\left(\theta\right)d\theta, \tag{28}$$

which is the likelihood averaged over all parameter values backed up by our prior beliefs. In this example $f\left(y\right)$ is also called the prior predictive distribution. After having observed data *y*, we can find the prediction of missing data y'. We then compute the posterior predictive distribution

$$f\left(y'\,|\,y\right) = \int f\left(y'\,|\,\theta\right)f\left(\theta\,|\,y\right)d\theta, \tag{29}$$

which is the likelihood of the future data averaged over the posterior distribution $f\left(\theta\,|\,y\right)$. Another way to view missing data y' is as additional parameters under estimation for which the joint posterior distribution is given by $f\left(y',\theta\,|\,y\right)$. Inference on the future observations y' can be based on the marginal posterior distribution $f\left(y'\,|\,y\right)$ by integrating out all nuisance parameters. One such nuisance parameter is the parameter vector θ. Now, the predictive distribution is given by

$$f\left(y'\,|\,y\right) = \int f\left(y',\theta\,|\,y\right)d\theta = \int f\left(y',\theta\,|\,\theta,y\right)f\left(\theta\,|\,y\right)d\theta, \tag{30}$$

since known and missing observations ($y\ and\ y'$ respectively) are conditionally independent given the parameter vector θ (Ntzoufras 2009).

The Poisson regression model assumes that y (daily count data) is Poisson with mean μ (and therefore variance μ). The link function is typically chosen to be the logarithm, so that $\log \mu = X\beta$. The distribution for count data $y = \left(y_{1,\ldots,}y_n\right)$ is therefore

$$p\left(y \mid \beta\right) = \prod_{i=i}^{n} \frac{1}{y_i!} e^{\exp(\eta_i)} \left(\exp\left(\eta_i\right)\right)^{y_i}, \tag{31}$$

where $\eta_i = \left(X\beta\right)_i$ is the linear predictor for the i^{th} case (McCullagh and Nelder 1989). The initial one covariate model will have the following structure:

$$\begin{aligned} &count_i \sim Poisson\left(\lambda_i\right) \\ &\log \lambda_i = \beta_1 + \beta_2 day_i \quad for\ i = 1, 2, \ldots, n. \end{aligned} \tag{32}$$

The prior distributions for the β 's are

$$\begin{aligned} &\beta_1 \sim N\left(0, 0.0001\right) \\ &\beta_2 \sim N\left(0, 0.0001\right). \end{aligned} \tag{33}$$

If we consider a missing observation Y_i with known covariate value x_i then we can estimate its expected value $E\left(Y_i \mid y, x_i\right)$ using the predictive distribution

$$p\left(y_i \mid \underline{y}, x\right) = \sum p\left(y_{i|} \mid \beta, x_i\right) p\left(\beta \mid \underline{y}\right), \tag{34}$$

and Y_i can be considered as an additional parameter under estimation. Therefore, it can be generated within an MCMC algorithm from the conditional posterior distribution and we can generate y_i in the iteration of the algorithm by

$$\overset{(t)}{y_i} \sim P\left(\overset{(t)}{\log}\left(\lambda\right)_i\right) with \overset{(t)}{\log} \lambda_i = E\left(Y_i \mid \overset{(t)}{\log} \lambda_i, x_i\right) = \beta_1^t + \beta_2 x_i^{(t)}. \tag{35}$$

In WinBUGS (Lunn et al. 2000) we can define an additional stochastic node ynew (y_i)

$$\begin{aligned} &ynew \sim dnorm(munew) \\ &munew < -\, beta1 + inprod(beta[], xnew[]) \end{aligned}, \tag{36}$$

where xnew[] is the vector with element(s) of the explanatory value(s) for the missing (to-be-estimated) response. It is important to note that we need to specify *xnew* in the data of the WinBUGS model code. We also need to specify that the value of *ynew* (missing value for a given day) is not available by setting *ynew*=NA in the list data format. *Ynew* is treated in a way similar to that used for parameters that are to be estimated. Otherwise we substitute specific missing count data elements with NA values in the list format. After compiling and running the model, posterior summaries of y will provide standard errors and credible intervals for the missing (i.e., stochastic) counts of the vector *ynew*.

Estimating Within- and Between-observer Variability

Within-observer (device operator) variability consists of individual-specific observer errors in the assignment of counts to device images. This includes all activities undertaken by the observer which affect a given count. Within-observer variability can be minimized by extensive observer training and conducting test trials prior to analysis of the device counter images. If results from the test trials indicate unacceptable levels of variability, either within- or between-observers, additional training and testing will be conducted prior to analysis the current season's device counter images.

Test trials will involve each observer processing the same sample of device counter images/files multiple times. We recommend using a sample of 10 images/files from previous years. Each sample will consist of 20 minutes of device counter operation. The sample of images/files will be chosen so as to best represent the variable environmental conditions and fish passage rates. Each observer will view each of the 10 files 5 times.

The coefficient of variation for an individual observer *i* for file *j* is a measure of within-observer precision (Jones et al. 1998)

$$CV_{W-O,ij} = \frac{\sqrt{\sum_{k=1}^{n_k}\left(X_{ijk}-\overline{X}_{ij}\right)^2 / \left(n_k-1\right)}}{\overline{X}_{ij}}, \qquad (37)$$

where X_{ijk} is the k^{th} replicate count for observer *i* viewing file *j*, n_k is the number of replicate counts for the i^{th} recording (we recommend a minimum of 5), and is the mean count for observer *i* across the replicate counts for file *j*. An average of the coefficient of variation estimates for an individual observer across the sample of image files will be used as the measure of within-observer variability for each individual. As a general rule of thumb, a coefficient of variation greater than 0.10 will be cause for concern as larger values can be expected to result in substantial errors in escapement estimates.

Another source of error that is often overlooked in escapement estimation of all types is the variability of counts among observers (Cousins et al. 1982, Symons and Waldichuk 1984, Jones et al. 1998). The variability between observers will also be assessed using the same methods described above (i.e., replicate viewings of 10 files by each observer). An assessment of the device counts among observers who process the data, stratified by file, can be accomplished using the coefficient of variation (CV) and the average percent error (APE), where

$$CV_j = \frac{\sqrt{\sum_{i=1}^{R_j}\left(\overline{X}_{ij}-\overline{X}_j\right)^2 / \left(R_j-1\right)}}{\overline{X}_j}, \qquad (38)$$

R is the number of observers that viewed file *j*, $\overline{X}_{ij}$ is the average count by observer *i* for file *j*, and $\overline{X}_j$ is the average count for file *j* across observers. Here the CV is a measure of the precision of counts from different observers for a particular file. Again, these estimates can be averaged across the sample of files to get an overall assessment across various environmental conditions and fish passage rates. If the CV exceeds 0.10 additional training should be provided until observer variability is at or below 10%.

DISCUSSION

Estimating total escapement using fish enumeration counters requires identifying and accounting for a number of sources of error and variability which may be dependent on a variety of factors involving the river environment, the device itself, the species present in the spawning run and the observers who process the recorded count data. We assume in this report that the proper device counter is chosen for each stream location and that the device is installed in an optimal place in the stream where fish are confined to pass within the recording range of the device during normal operating conditions. It is also imperative that the device settings are optimal for maximum counting accuracy and precision again given the specific geometries of the location, bottom profile, depth etc. Methods available for validating and assessing the accuracy of device counters are relatively new in the fisheries literature and not well tested over a full range of field conditions. Thus, some considerable experimentation, exploration and resources may be required to carry out the validation and calibration trials described above as each stream's field location and river parameters are different. However, this work will be justified since the reward will be more accurate and precise estimates of total escapement necessary for effectively monitoring trends and abundance of Central Valley Chinook salmon.

LITERATURE CITED

Baumgartner, L., M. Bettanin, J. McPherson, M. Jones, B. Zampatti and K. Beyer. 2010. Assessment of an infrared fish counter (Vaki Riverwatcher) to quantify fish migrations in the Muray-Darling Basin. Industry & Investment NSW-Fisheries Final Report Series, No. 116.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Burwen, D. L., S. J. Fleischman, J. D. Miller, and M. E. Jensen. 2003. Time-based signal characteristics as predictors of fish size and species for a side-looking hydroacoustic application in a river. ICES Journal of Marine Science 60:662 – 668.

Cousens, N. B. F., G. A. Thomas, C. G. Swann, and M. C. Healey. 1982. A review of salmon-escapement estimation techniques. Canadian Technical Report of Fisheries and Aquatic Sciences: 1108.

Davison, A. C., and D. V. Hinkley. 1996. Bootstrap methods and their application. Cambridge University Press, Cambridge, New York, USA.

Gates, K. S., and J. K. Boersma. 2009. Abundance and run timing of adult Chinook salmon and steelhead in the Funny River, Kenai Peninsula, Alaska, 2009. Alaska Fisheries Data Series Number 2009-16, U.S. Fish and Wildlife Service.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2004. Bayesian data analysis. Chapman & Hall/CRC, Boca Raton, Florida, USA.

Giovannetti, S. L., and M. R. Brown. 2007. Central Valley steelhead and late fall Chinook salmon redd surveys on Clear Creek, California. U.S. Fish and Wildlife Service; Red Bluff Fish and Wildlife Office.

Hannon, J., and B. Deason. 2005. American River steelhead (*Oncorhynchus mykiss*) spawning 2001 – 2005. Central Valley Project, American River, California, Mid-Pacific Region.

Hastie, T. J., and R. J. Tibshirani. 1990. Generalized additive models. Chapman & Hall/CRC, Boca Raton, Florida, USA.

Holden, A. V., and G. Struthers. 1997. Fish counters seminar: proceedings of a one-day seminar held at A K Bell Library, Perth. The Atlantic Salmon Trust and The Institute of Fisheries Management (Scottish Branch).

Holmes, J. A., G. M. W. Cronkite, H. J. Enzenhofer, and T. J. Mulligan. 2006. Accuracy and precision of fish-count data from a "dual-frequency identification sonar" (DIDSON) imaging system. ICES Journal of Marine Science 63: 543 – 555.

Jones, E. L., III, T. J. Quinn, II, and B. W. Van Alen. 1998. Observer accuracy and precision in aerial and foot survey counts of pink salmon in a southeast Alaska stream. North American Journal of Fisheries Management 18:832–846.

Kutner, M. H., C. J. Nachtsheim, J. Neter, and W. Li. 2005. Applied linear statistical models. McGraw-Hill, Boston, Massachusetts, USA.

Lauver, E.D. 2007. Priest Rapids project video fish-counting program annual report 2007. Public Utility District No. 2 of Grant County, Ephrata, WA 98823. Page 2 of Appendix C.

Lunn, D.J., A. Thomas, N. Best, and D. Spiegelhalter. 2000. WinBUGS - a Bayesian modelling framework: concepts, structure, and extensibility. Statistics and Computing **10**:325 – 337.

Mackey, E. 2005. Trends in Atlantic salmon: the role of automatic fish counter data in their recording. Scottish Natural Heritage Commissioned Report No. 100.

Maxwell, S. L., and N. E. Gove. 2007. Assessing a dual-frequency identification sonars' fish-counting accuracy, precision, and turbid river range capability. Acoustical Society of America 122(6): 3364 – 3377.

Maxwell, S. L., and N. E. Gove. 2004. The Feasibility of estimating migrating salmon passage rates in turbid rivers using a dual frequency identification sonar (DIDSON). Regional Information Report No. 2A04-05, Alaska Department of Fish and Game.

McCullagh, P., and J. A. Nelder. 1989. Generalized linear models. Second edition. Chapman & Hall, Boca Raton, Florida, USA.

Miller, J. D., D. L. Burwen and S. J. Fleischman. 2003. Estimates of Chinook salmon abundance in the Kenai River using split-beam sonar, 2001. Alaska Fishery Data Series No. 03-03.

Ntzoufras, I. 2009. Bayesian modeling using WinBUGS. Wiley & Sons, New York, New York, USA.

Pagliughi, S.W. 2008. Fall-run Chinook salmon and winter-run steelhead redd survey report: October 2007 through March 2008. East Bay Municipal District, 1 Windemasters Way, Lodi, CA 95240.

Santos, J. M., P. J. Pinheiro, P. J. Ferreira, and J. Bochechas. 2008. Monitoing fish passes using infrared beaming: a case study in an Iberian river. Journal of Applied Ichthyology 24:26 – 30.

Stanislaus weir email summary 2005. http://www.sanjoaquinbasin.com/resources/stanweir_archives/Postcards04/postcard8.htm

Symons, P. E. K., and M. Waldichuck, editors. 1984. Proceedings of the workshop on stream indexing for salmon escapement estimation, West Vancouver, B.C. Canadian Technical Report of Fisheries and Aquatic Science 1326.

Tiffan, K., F., and D. W. Rondorf. 2004. Imaging fall Chinook salmon redds in the Columbia River with a dual-frequency identification sonar. North American Journal of Fisheries Management 24:1421 – 1426.

Woods, S. N. 2006. Generalized additive models: an introduction with R. Chapman & Hall/CRC, Boca Raton, Florida, USA.

Vaki-DNG Ltd. 2000. Letter from B. Traustason (Vaki-DNG Ltd.) to T. McCarthy (Water Management Technologies) regarding turbidity levels. December 13, 2000. Quoted from Biological Opinion – Authorization from the construction and future operation of the Robles diversion Fish Passage Facility.

Zanobetti, A., M. P. Wand, J. Schwartz, L. M. Rayan. 2000. Generalized additive distributed lag models: quantifying mortality displacement. Biostatistics 1: 279 – 292.

Zuur, A. F., E. N. Ieno, N. J. Walker, A. A. Saveliev, and G. M. Smith. 2009. Mixed effect models and extensions in ecology with R. Springer, New York, New York, USA.

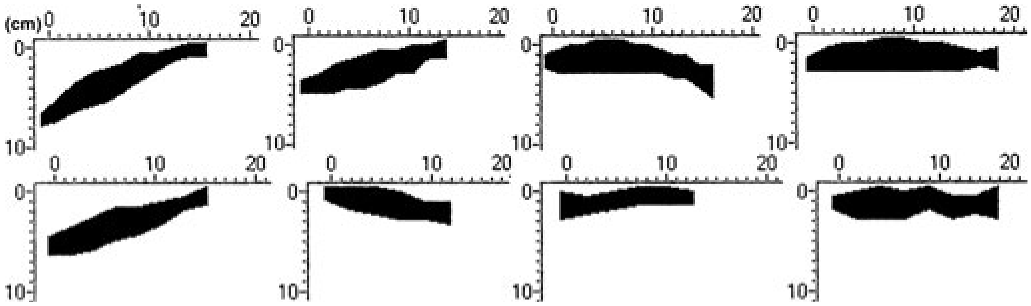
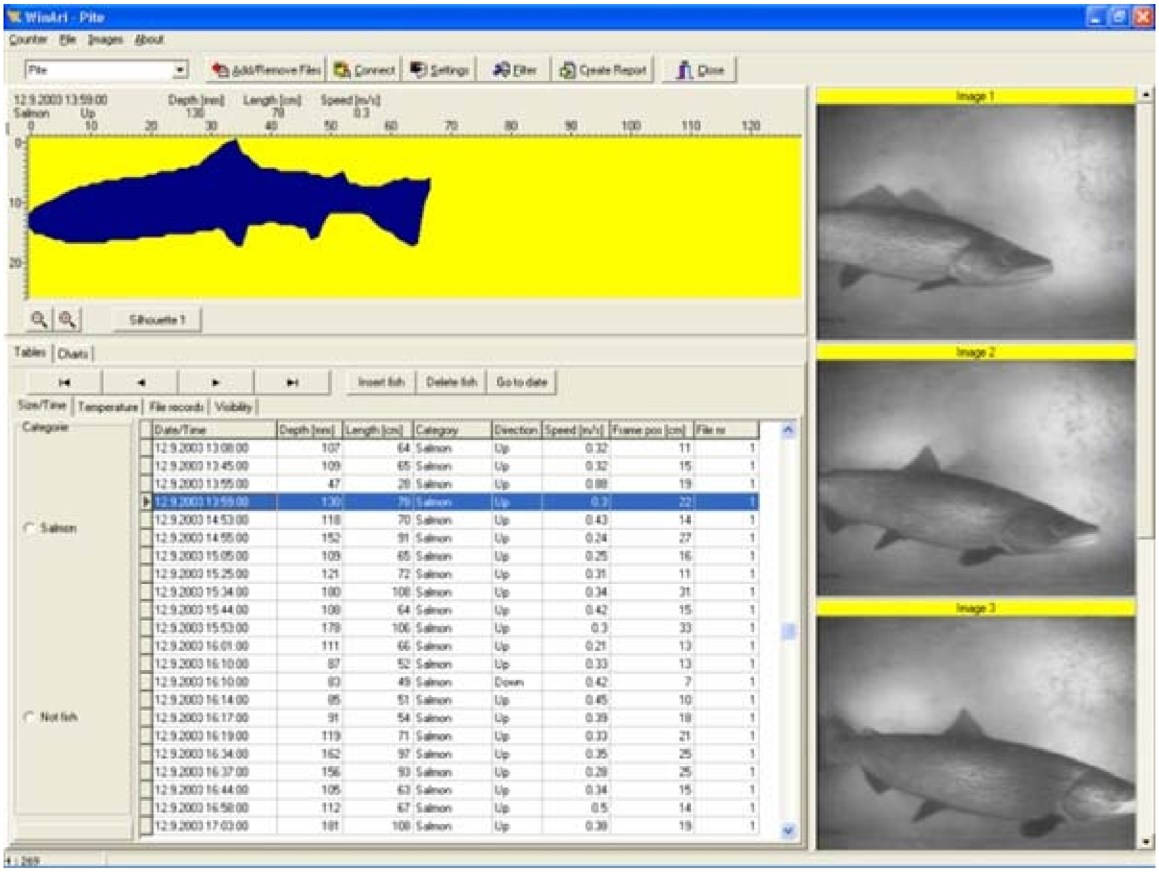


Figure 1. Silhouette examples recorded by the Vaki River-Watcher system (from Santos et al. 2007). Note the lack of defining characteristics, including dorsal and anal fin.



12.9.2003 13:59:00 Salmon Up

Depth [mm]	Length [cm]	Speed [m/s]
130	79	0.3

Date/Time	Depth [mm]	Length [cm]	Category	Direction	Speed [m/s]	Frame pos [cm]	File nr
12.9.2003 13:08:00	107	64	Salmon	Up	0.32	11	1
12.9.2003 13:45:00	109	65	Salmon	Up	0.32	15	1
12.9.2003 13:55:00	47	28	Salmon	Up	0.88	19	1
12.9.2003 13:59:00	130	79	Salmon	Up	0.3	22	1
12.9.2003 14:53:00	118	70	Salmon	Up	0.43	14	1
12.9.2003 14:55:00	152	91	Salmon	Up	0.24	27	1
12.9.2003 15:05:00	109	65	Salmon	Up	0.25	16	1
12.9.2003 15:25:00	121	72	Salmon	Up	0.31	11	1
12.9.2003 15:34:00	180	108	Salmon	Up	0.34	31	1
12.9.2003 15:44:00	108	64	Salmon	Up	0.42	15	1
12.9.2003 15:53:00	178	106	Salmon	Up	0.3	33	1
12.9.2003 16:01:00	111	66	Salmon	Up	0.21	13	1
12.9.2003 16:10:00	87	52	Salmon	Up	0.33	13	1
12.9.2003 16:10:00	83	49	Salmon	Down	0.42	7	1
12.9.2003 16:14:00	85	51	Salmon	Up	0.45	10	1
12.9.2003 16:17:00	91	54	Salmon	Up	0.39	18	1
12.9.2003 16:19:00	119	71	Salmon	Up	0.33	21	1
12.9.2003 16:34:00	162	97	Salmon	Up	0.35	25	1
12.9.2003 16:37:00	156	93	Salmon	Up	0.28	25	1
12.9.2003 16:44:00	105	63	Salmon	Up	0.34	15	1
12.9.2003 16:50:00	112	67	Salmon	Up	0.5	14	1
12.9.2003 17:03:00	181	108	Salmon	Up	0.38	19	1

Figure 2. The Riverwatcher can be supplied with a digital camera system to record video or still images of fish passing through the scanner. The scanner triggers the camera to capture between 1 and 5 digital photos or a short video clip of each fish. The computer then automatically links the digital images to the other information contained in the database for that individual fish such as size, passing hour, speed, silhouette image, temperature etc. Image taken from Vaki, Inc. website:

http://www.vaki.is/Products/RiverwatcherFishCounter/CameraRW/.

Figure 3. Example of an image from the video fish counter system at Priest Rapids on the Columbia River, taken from Lauver (2007).

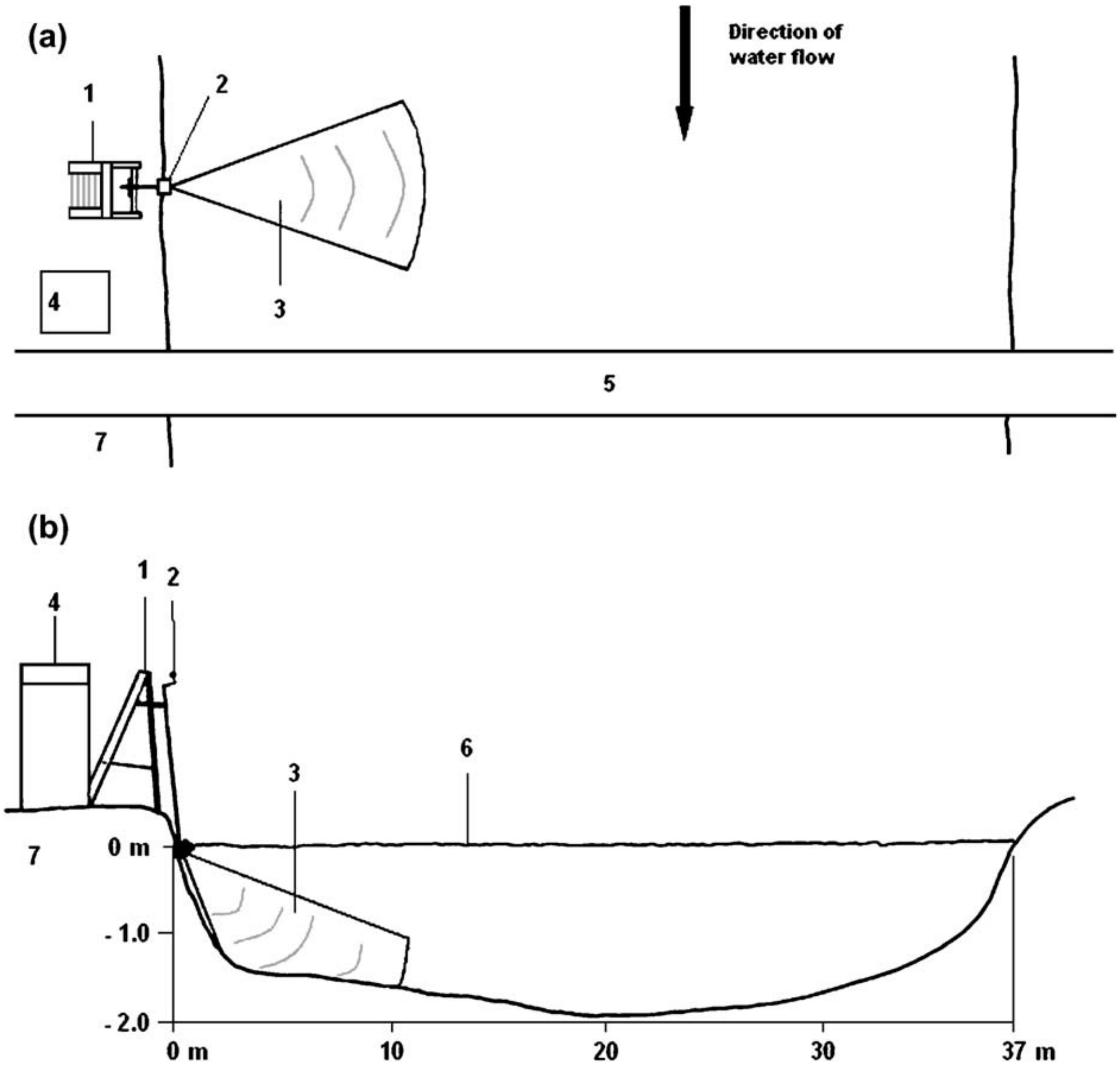


Figure 4. A schematic overhead (a) and side view (b) of a study area showing the deployment of the DIDSON imaging system and the water volume ensonified by the beams using a 1, counting tower; 2, DIDSON transducer mounted to adjustable pole mount; 3, ensonified water volume; 4, topside equipment shed; 5, bridge deck; 6, water surface; 7, right river bank. Note that the vertical and horizontal scales differ. River banks are labelled right and left relative to an observer facing downstream. Image taken from Holmes (2006).

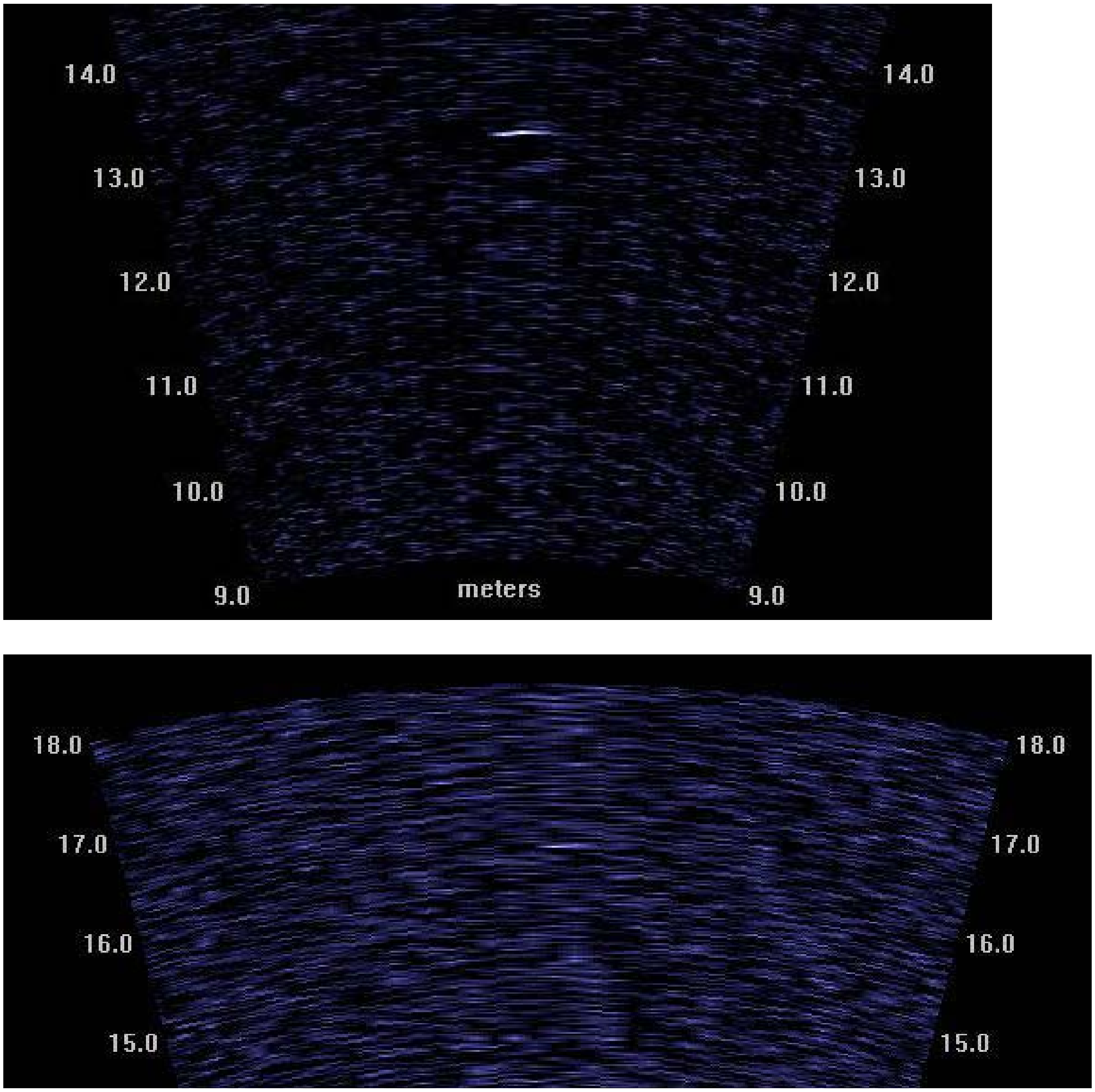


Figure 5. DIDSON image of the 10.16 cm plastic sphere shown at 13 m (top) and at 16.5 m (bottom) in turbid water. Image taken from Maxwell and Gove (2004).

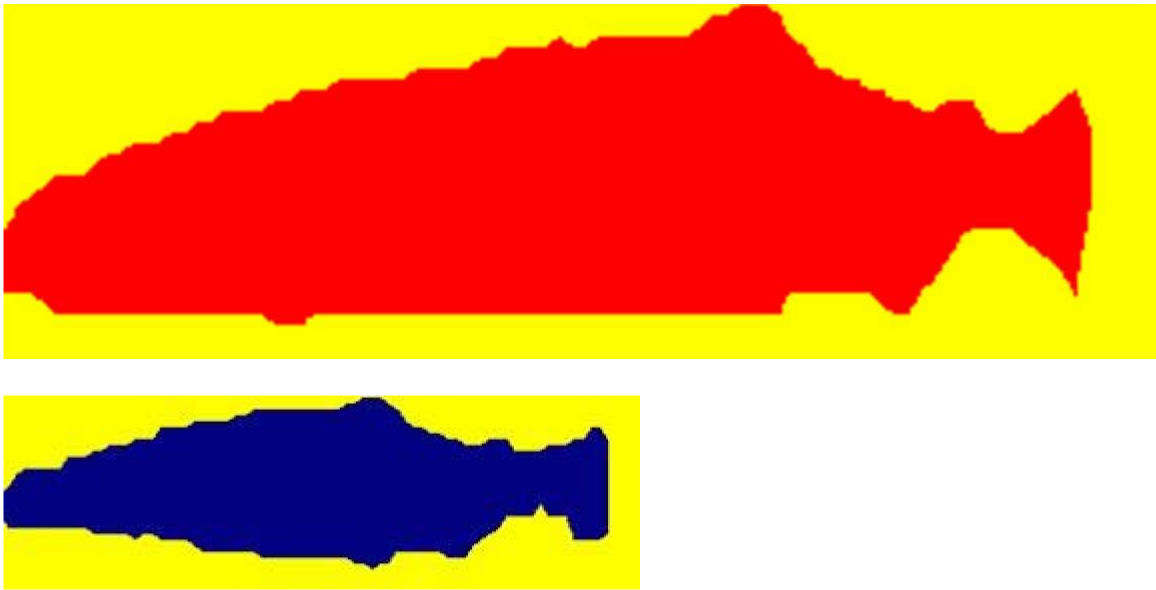


Figure 6. Infrared silhouettes created from the *O. mykiss* as it passed through the Vaki scanner and into the trap. These silhouettes are very similar to the Chinook silhouettes and without a digital photograph could have easily been mistaken for a Chinook. Images obtained from Stanislaus weir e-mail summary (2005).

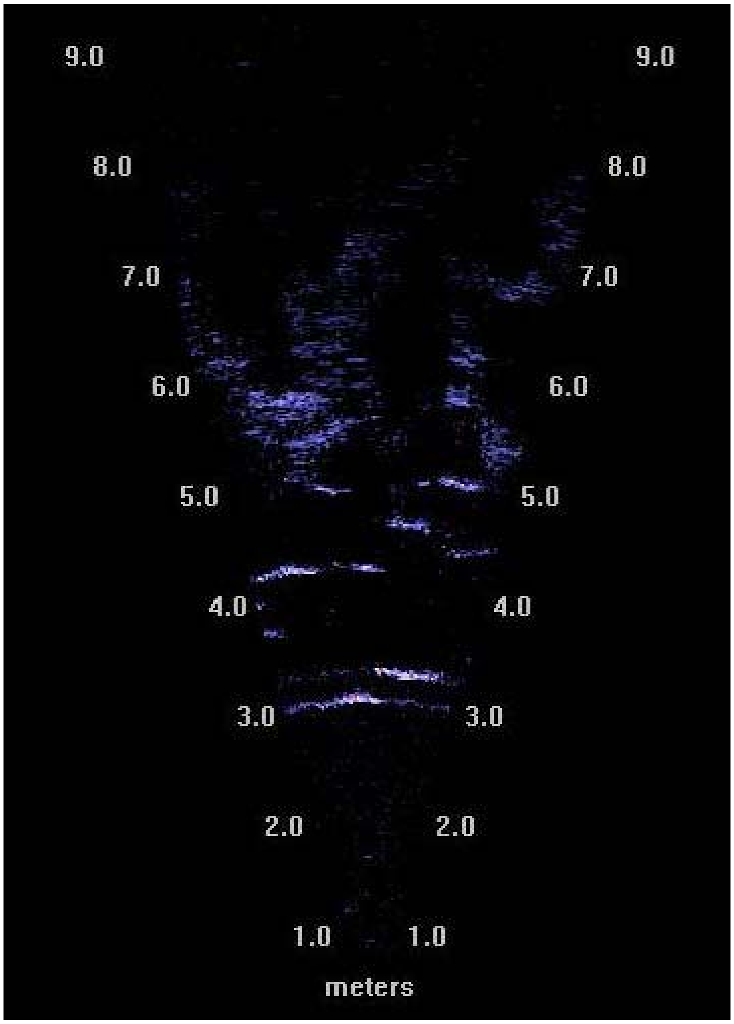


Figure 7. DIDSON image of migrating sockeye salmon with the salmon images outlined. The remaining signal comes from a combination of river bottom and volume reverberation, Wood River, July 2, 2002. Image was taken from Maxell and Gove (2004).

APPENDIX B
PROTOCOLS AND PROCEDURES FOR

CHINOOK SALMON MARK-RECAPTURE AND CARCASS SAMPLING SURVEYS

These protocols and procedures were developed for mark-recapture carcass surveys for estimating Chinook salmon escapement, collecting biological data and recovering coded-wire tags. In addition, they were developed for carcass sampling surveys when a fish device counter is used to estimate escapement.

1 SURVEY LOCATION

The survey location is a description of the stream and demarcation of survey reaches. Mark-recapture carcass surveys should encompass all known spawning habitat, unless the survey takes place in a closed survey reach. For carcass sampling surveys, either all known spawning habitat or a random or systematic sample of reaches available for spawning should be surveyed. Maps and location markers should be used to help field crew identify survey reaches.

2 SURVEY PERIOD

Surveys should be conducted to obtain a representative sample (i.e., unbiased) of the spawning population. Therefore, surveys should encompass the entire spawning season and represent the spawning population both spatially and temporally. Surveys should commence immediately after detection of the first carcass. This is to ensure that all fish are available to be sampled during the survey. It is equally as important to maintain the surveys throughout the spawning season until well after no new carcasses are found. Violation of this survey approach is expected to result in escapement estimates that are biased low and potentially a biased sample of biological data and CWTs (i.e., unrepresentative of the spawning population).

3 SURVEY FREQUENCY

The interval between mark-recapture carcass surveys and carcass sampling surveys should not exceed seven days. Again, biological data collection and coded-wire tag (CWT) recovery should be representative of Chinook salmon spawning in the system, both in terms of spawning location (e.g., upper vs. lower) and timing (e.g., early vs. late).

4 SAMPLING STRATEGY

The size of the Chinook salmon run and available resources will likely determine the sampling strategy for the mark-recapture carcass survey and carcass sampling surveys. Target goals have been established for CWT recovery and scale sampling for the Constant Fractional Marking (CFM) Program and Age Scale Program, respectively. At a minimum, scales should be collected from 550 Chinook salmon carcasses per run at the tributary level for which Chinook salmon escapement is estimated. Heads should be collected from all adipose fin-clipped (ad-clipped) Chinook salmon carcasses observed for CWT recovery. Fork length, sex, and female spawning status should be recorded and scales collected for every carcass sampled.

A sampling strategy can be adjusted as necessary, but must be remain constant within a survey period (e.g., week). For example, in survey period 1 every second carcasses is examined, but in survey period 2 every third carcass is examined. Changes to a sampling strategy need to be documented, so that statistical analyses can include appropriate adjustments.

Mark-Recapture Carcass Survey

The best sampling strategy, especially for systems where the number of carcasses encountered is expected to be low (e.g., <500), subjects every carcass encountered to tagging provided the carcass will not further deteriorate upon handling and biological data (e.g., sex, length) can be measured reliably. This will increase the sample sizes for estimating escapement and improve the model's precision and accuracy, particularly when covariates (e.g., fresh or non-fresh, length, sex) related to capture and survival probabilities are included to account for potential heterogeneity in the population. In systems where the number of carcasses is expected to be high, biologists can chose to mark all carcasses or mark all fresh carcasses[2]. If a carcass is deteriorated to the point that the status of the adipose fin cannot be determined, the carcass should be chopped in half with a machete or other tool to remove it from the population. Carcasses in this state are no longer considered a carcass (dead) and data should not be recorded.

In some rivers the number of carcasses may be very high in some years making it difficult to handle every carcass encountered. If resources do not permit this level of effort, biologists should systematically sub-sample carcasses. For example, every third carcass encountered should be inspected, regardless of the condition of the carcass (fresh or non-fresh). This sampling situation will result in lower sample sizes and lower capture probabilities, but will not otherwise bias results. Chopping the first two of every three carcasses and only marking every third carcass encountered requires the unrealistic assumption that every carcass in the system is detected and inspected for tags. The two intervening carcasses need to be ignored and they will have the potential to be sampled during a later survey.

Carcass Sampling Survey

All observed carcasses should be subjected to biological sampling and CWT recovery unless the biological data cannot be measured reliably. If a carcass is deteriorated to the point that the status of the adipose fin cannot be determined, the carcass should be chopped in half with a machete or other tool to remove it from the population. Carcasses in this state are no longer considered a carcass (dead) and data should not be recorded. If handling all carcasses is not feasible, all fresh carcasses should be subject to collection of biological data and CWT recovery or all carcasses should be sampled in a systematic

---

[2] The definition of what constitutes a fresh carcass in the CV varies across survey protocols but generally involves the examination of the clarity of the eyes, firmness of the body, or color of the gills. A standard definition for a fresh carcass is not necessary and can change over time. However, whatever definition a biologist uses must be consistent and maintained throughout a spawning season.

manner (i.e., every N^{th} carcass). Sampling strategies should target collection of the minimum scale sample size of 550.

5 DATA COLLECTION AND SAMPLING TECHNIQUES

Biologists may identify additional data needed to examine spawning distribution, spawning habitat, movement of carcasses, etc. that are not described in these protocols and procedures.

5.1 Planning Activities

1. The lead biologist will determine the sampling strategy for the survey based on the anticipated run size and available resources (i.e., personnel, money, and equipment).

2. The lead biologist will need to ensure the field crew is trained, logistics of the survey are organized, equipment is available and necessary permits are obtained. Training the field crew is essential to ensure data are collected and recorded according to the protocols and procedure. The field crew is more likely to collect data according to protocols and procedures if they understand why it is necessary. Therefore, training should also include the importance of data collection, why data needs to be collected and recorded a certain way, and how data are used for analysis. For example, if systematic sampling is used (i.e., every N^{th} carcass) they should understand the rationale of the sampling approach and how targeting an intervening carcass would bias the sample.

5.2 Processing Carcasses

5.2.1 Carcass Survey Sampling Survey

1. Record on each datasheet the sampling strategy and pertinent survey data
2. Collect observed carcasses using a gaff or spear pole according the predetermined sampling strategy
3. Determine if the carcass can be sampled or if it should be chopped in half
4. If the carcass can be sampled, collect biological data and examine the carcass for an adipose fin to recover CWTs
5. Chop the carcass in half after sampled or if it cannot be sampled

Processing carcasses during carcass sampling surveys should be performed in a similar manner to the mark-recapture surveys as described in more detail below (Sections 5.2.2.1, 5.2.2.2, 5.2.2.5, 5.2.2.6). Unlike mark-recapture carcass surveys, carcasses do not need to be tagged and all sampled carcasses can be chopped in half to reduce future survey efforts.

Each sampled carcass will need to be given a unique identification number to relate biological data to that carcass. This unique number could be the disc tag (mark-recapture survey) or scale sample number (if all carcasses are sampled). A database application or PDA can be developed to give each carcass a unique identification number during data entry or recording, respectively. If otoliths or genetic tissue samples are collected, a suggested ID number is the date and carcass number or scale sample number (if collected). For example, 101011-001 is the first carcass that was observed on 10 October 2011. If multiple crews are out on a particular day, one crew can use ID numbers 1-499 and the second crew use numbers 500-999.

5.2.2 Mark-Recapture Carcass Survey

1. Record on each datasheet the sampling strategy and pertinent survey data
2. Collect observed carcasses using a gaff or spear pole according the predetermined sampling frequency
3. Examine the carcass for a disc tag (recapture)
4. If the carcass is a recapture, record the disc tag number and either release it back into the system or chop it in half
5. If the carcass is not a recapture, determine if it should be tagged or chopped, and if it should be sampled for biological and examined for an adipose fin to recover CWTs
6. Release marked carcasses into the river for possible future recoveries

5.2.2.1 Survey data

Survey data includes: date, survey period, sampling strategy, survey location, survey reach, crew members, data recorder, begin and end time, weather, streamflow, water clarity (secchi disk depth), comments, etc.

5.2.2.2 Collection of Carcasses

Use the method (e.g., drift boat, jet boat, walking/hiking, snorkeling) that is best suited for the river. Collect carcasses by implementing the sampling strategy (Section 4) that was predetermined for the survey.

5.2.2.3 Examine the Carcass for a Disc Tag

Inspect and roll the carcass using a gaff or spear pole. Examine the lower or upper jaw for a disc tag from previous survey periods. Crew members should be instructed to examine carcasses for other marks (e.g., floy tags, hall print tags, etc.) for other CV studies. If the carcass has a disc tag, determine if the carcass should be released or chopped in half (Section 5.2.2.4). If the carcass does not have a disc tag the crew should determine if the carcass can should be tagged or chopped in half (Section 5.2.2.5).

5.2.2.4 Recaptured Carcass – Release or Chop

The mark-recapture population estimator (superpopulation modification of the Cormack-Jolly-Seber model) requires the capture history of individual carcasses. If a carcass is a recapture from a previous survey period, the following must be recorded: (1) disc tag number; (2) if the carcass was removed from the system (chopped in half); and (3) date that the carcass was recaptured.

It is recommended that the carcass should be returned to the system for possible future recoveries. Unless a recaptured carcass is deteriorated to the point that the status of the adipose fin can no longer be determined, the carcass should be chopped in half. If a river has low carcass numbers the biologist should allow for multiple recaptures. If resources are not available for this level of effort, recaptures can be chopped in half on the first recapture event to reduce effort in subsequent surveys.

The level of effort (multiple recaptures or chop on first recapture) should be maintained throughout the survey season. However, the sampling strategy can be adjusted as necessary. For example, in survey period 1 every 2nd carcasses is examined, but in survey period 2 every 3rd carcass is examined. Again, changes in sampling strategy need to be documented for proper analysis

5.2.2.5 Determine if the Carcass Should be Tagged or Chopped

Tag a Carcass

If a carcass is deteriorated to the point that the status of the adipose fin cannot be determined, the carcass should be chopped in half with a machete or other tool to remove it from the population. Carcasses in this state are no longer considered a carcass (dead) and data should not be recorded.

A carcass should be tagged if it is not a recapture from a previous survey week and covariate data (i.e., sex, fork length, ad-clip status) can be measured reliably. In addition, the carcass must be included in the sub-population of carcasses predetermined to be tagged in the sampling strategy (i.e., all carcasses, all fresh carcasses, and every N^{th} carcass).

The mark-recapture population estimator (superpopulation modification of the Cormack-Jolly-Seber model) requires individual carcass information. Therefore carcasses must be tagged with a uniquely numbered disc tag. In addition, covariate data (i.e., sex, fork length, ad-clip status, otoliths removed, etc.) must be recorded for each individual.

The best situation is to tag all carcasses; however ad-clipped carcasses can be chopped in half on first capture (see below). Ad-clipped carcass should be tagged if carcass numbers are low or if the numbers of ad-clipped carcasses are high and tagging only unclipped carcass will result in a low sample size.

If the sampling strategy is to tag all carcasses, including ad-clipped carcasses, carcasses should be tagged in the lower jaw with a disc tag. Tagging the lower jaw will be necessary to remove the upper head of ad-clipped carcasses for CWT recovery. However, if ad-clipped carcasses are chopped on first capture the upper jaw of unclipped carcasses can be tagged. Tagging is recommended to be kept consistent among carcasses[3].

All biological data needs to be measured for each tagged carcass and the upper head collected from tagged ad-clipped carcasses (Section 5.2.2.6).

---

[3] In the past, some CV biologists have tagged adult carcasses in the upper jaw and grilse carcasses in the lower jaw. Since each carcass is recommended to be tagged with a unique disc tag, all carcasses can be tagged in the same jaw (i.e., upper or lower) and data can be post processed by adult or grilse if desired.

Chop a Carcass

If a carcass is deteriorated to the point that the status of the adipose fin cannot be determined, the carcass should be chopped in half with a machete or other tool to remove it from the population. Carcasses in this state are no longer considered a carcass (dead) and data should not be recorded.

If the sampling strategy is to tag all fresh carcasses, non-fresh carcasses (after examination for a disc tag) should be chopped in half. Covariate data (i.e., sex, fork length) should be recorded for these chops on first capture if the data can be measured reliably. If covariate data cannot be measured reliably, chops on first capture should be tallied with the status of the adipose fin (i.e., ad-clipped, unclipped or unknown).

If the sampling strategy is to chop all ad-clipped carcasses on first capture, covariate data should be recorded and the head collected for CWT recovery.

If the sampling strategy is to examine every N^{th} carcass, carcasses that are not tagged but are chopped on first capture should be tallied with adipose fin status (i.e., ad-clipped, unclipped, unknown). If covariate data can be measured reliably for a carcass chopped on first capture and resources (i.e., time, money, personnel) allow for data collection, these data are recommended to be collected.

5.2.2.6 Collecting Biological Data and Recovering CWTs

For each examined carcass where covariate data can be measured reliably the following biological data should be recorded (with the disc tag number if tagged) : (1) fork length; (2) sex; (3) ad-clip status; (4) female spawning status; (5) fresh or non-fresh; (6) scale sample identification number; and (7) head tag number (if CWT recovery is required). In addition, otolith or genetic tissue sample collection should be recorded.

5.2.2.6.1 Fork Length

Fork length refers to the length from the tip of the snout to fork of the caudal fin. A standardized unit of length among programs in the CV is not required.

5.2.2.6.2 Sex

Male carcasses typically have a longer hooked jaw, large canine teeth, and a less rounded body than females. In addition, they are typically larger than females and can have red coloration.

Female carcasses typically have a symmetrical upper and lower jaws, may appear more plump or rounded than males, will often have eroded tails and vents from recent redd construction and egg deposition.

If the sex of the carcass is not apparent, the ventral side of the carcass can be rubbed to see if eggs or milt are released from the body cavity. Otherwise, a small incision can be made on the ventral side to observe eggs, milt, or sex organs.

5.2.2.6.3 Adipose Fin Clip Status and CWT Recovery

A carcass should be sampled if included in the sub-population of carcasses predetermined for sampling (i.e., all carcasses, all fresh carcasses, and every N^{th} carcass; Section 4). The presence of the adipose fin should be recorded: unclipped, ad-clipped, or unknown.

If the carcass is ad-clipped, the upper head should be removed for CWT recovery. If the adipose fin status is unknown, a CWT wand should be used to detect the presence of a CWT in the head; if present, the upper head should be removed. When a wand is not available, the upper head should be removed. A head tag (provided by CDFG Ocean Salmon Project) must be completed and attached to the head of the carcass. The head with tag should be placed into a Ziploc freezer bag. The unique head tag number must be recorded on the data sheet with associated information for that carcass. Recovered heads should be frozen at the end of each survey day.

5.2.2.6.4 Female Spawning Status

All female carcasses should be visually inspected for spawning status. Spawning status should be defined as unspawned (many eggs remaining in the body) or spawned (few or no eggs remaining). An unspawned female can be identified as being gravid and will inject eggs from the vent when lifted. A spawned female will appear emanciated, the visceral cavity will seem evacuated, and folds of skin can be visible on the ventral side.

A biologist can choose to increase the number of categories (e.g., spawned, partially spawned or unspawned) to define spawning.

5.2.2.6.5 Freshness of a Carcass

Each carcass should be recorded as fresh or non-fresh. If only fresh carcasses are being sampled, this can be recorded once with other survey data (Section 5.2.1.2). The definition of a fresh carcass varies in the CV, but is typically defined using clarity of the eye(s), color of the gills, or firmness of the body. A standard definition for the CV is not needed and can change over time. However, the biologist must ensure that the definition used is consistent throughout the entire survey period. All crew members must be trained in the definition.

5.2.2.6.6 Scale Sample Collection

Kormos (2007) developed the following standard protocol for CV scale sample collection:

(1) Lay the fish on the ground or boat so that the left side of the fish faces up. Next, record the sex, fork length, presence or absence of an ad-clip, head tag number (if needed), river, and run type on the envelope. A sample can now be collected.

(2) To collect a sample, locate the correct area for retrieving scale samples. The correct area will have the best quality scales and will allow for consistency in the sampling method. First, locate the posterior insertion of the dorsal fin. Next, follow the diagonal row of scales from this point down and back to just above the lateral line. This area of the fish is the correct area to collect a scale sample (Figure1). Before

collecting a sample from this area, wipe away any mucous or dirt that may interfere with collecting a quality sample. Using a fillet knife, gently slide the edge of the knife just under the skin and peel away a portion of the skin approximately 3-4 cm square. Be careful to eliminate as much muscle and fat as possible while removing the skin patch. This will achieve better sample quality once the samples are dried and mounted. Once the skin patch is removed from the fish, wrap it in the small square of wax paper from within the envelope and slide it off of the knife blade and into the envelope. Once a sample has been collected, remove the head if necessary. To avoid cross contamination of samples, the knife and hands need to be carefully cleaned between samples. Additionally, it should be noted here that special care should be given to the overall sampling process. The quality of samples and their associated data dictates the degree of success of the scale aging project as a whole.

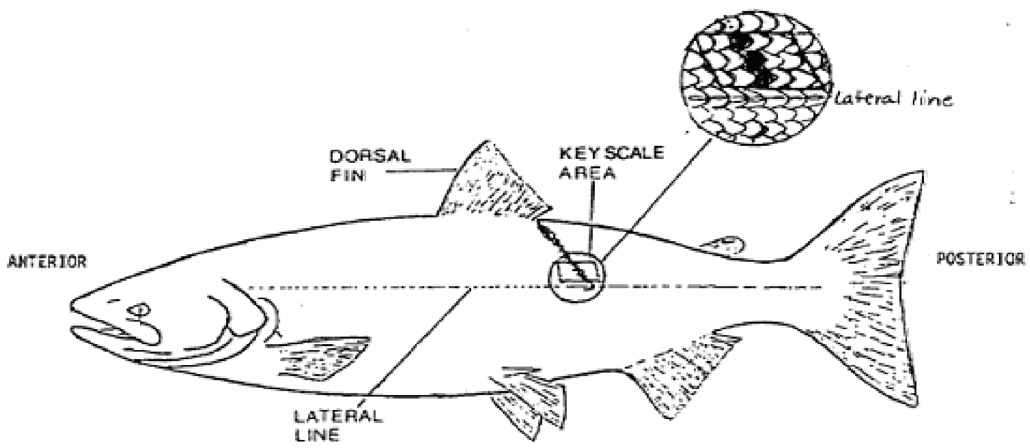


Figure 1. Correct location for scale sample collection (key scale area).

Once the samples have been collected, place them into a clean dry container. Regardless of the container choice, the samples must be stored free from any possibility of damage and can be easily transported to a drying location.

Drying the scale samples is another important part of the process that can greatly affect the quality and eventual usefulness of the samples. Drying should take place immediately after collection to prevent deterioration of the samples. Place the samples on a clean dry surface in a well ventilated area that is kept approximately at room temperature. The samples should be laid out individually without any overlapping or stacking of the envelopes. Drying should take about 24 hours to complete. Attempting to dry them faster by raising the temperature, using a dehydrator, etc. will result in poor quality samples. Deviation from the drying protocol is not recommended.

(3) When the samples are dry, they can be entered into the project database and boxed for storage and eventual mounting. When boxing the samples, keep them organized numerically and temporally. This will ease further processing.

5.2.2.6.7 Removing Otoliths

If biologists collect otoliths, two methods are recommended to remove otoliths from Chinook salmon carcasses.

A high quality serrated knife or bread knife is needed to make clean cuts. Otoliths can be stored in vials or coin envelopes. Wearing cotton or neoprene gloves helps hold the carcass while making the cuts. Each otolith sample must have a unique identification number to relate the otolith information to other data collected for that fish and survey (e.g., scales, genetics, length, sex, and river).

One quick and efficient method to remove otoliths is called the "open hatch' or"flip top" approach described below (Scarnecchia 1987):

1) Make the first cut vertically starting on the top of a fish between the eyes and the extension of the gill cover, and end above the extension of the eye (Figure 2; photo 1)

2) Make a second cut horizontally starting at between the eyes and the nose on the anterior of salmon and toward the first cut

3) The cranial cavity will be exposed when two cuts meet with each other (Figure 2, photo 2)

4) Extract otoliths using forceps and place the otoliths in uniquely labeled vials or coin envelopes.

5) Record the vial or coin envelope number on the data sheet.

A second method is simply cutting the head down the middle perpendicular to the tip of the snout (Figure 3). The head can be split open and the otoliths can be found in the brain cavity. Depending on the cut, otoliths can be located in one side of the head or one otolith can be located in each side of the head. The bottom jaw remains intact for tagging.


Photo 1

Photo 2

Figure 2. The “open hatch” approached used to extract otoliths from a Chinook salmon carcass. (Photo Credit: Tim Heyne, CDFG, 2011).

Figure 3. The process of removing otoliths from a Chinook salmon carcass with an intact adipose fin. Otoliths are removed by cutting down the center of the head perpendicular to the snout and taking otoliths from the brain cavity. The bottom jaw is left intact for tagging. If the carcass was adipose fin-clipped, the upper head would be removed leaving the bottom jaw for tagging. The head and pieces cut would be placed in a bag with a head tag for coded-wire tag recovery. (Photo credit: Leslie Alber, PSMFC, 2010)

5.2.2.6.8 Genetic Tissue Sample Collection

When genetic tissue samples are collected or requested by researchers, protocols and procedures developed by CDFG (2006) should be followed for sampling and storage. Samples should be recorded with the disc tag number.

I. Select a fresh carcass suitable to obtain a tissue sample. A fresh carcass will have clear eyes (not cloudy) and/or pink gills. **<u>Record all data on the coin envelope</u>**. Use only one envelope per fish. If the envelope is not pre-stamped, include the following data: date, location with landmarks, sample ID number GPS coordinates (if available), fork length (mm), sex of fish, collector's name, fin which sample was taken from, species of fish, adipose fin present or absent, and any other information pertaining to the sample.

II. From each fish, choose a fin (caudal, pectoral, dorsal, etc.) in the best condition. Take a fin-clip from the base of the fin. Do not take tissue from the adipose fin as there is little DNA provided in that sample.

III. Place the tissue sample on one piece of filter paper and fold paper over to cover the sample. Place filter paper into the coin envelope.

IV. Vigorously agitate scissors in water between samples to prevent cross contamination.

V. Cut open each fish and examine the gonad tissue to confirm the sex of the fish. Write any remarks concerning the sample in the notes section of the data sheet (e.g. the fish looks like a male, but has female gonads).

VI. Either in the field after collection, or in the office immediately upon return from the field, air-dry all samples on the same filter paper. The samples are dry when all mucous and moisture has evaporated and the tissue feels dry to the touch. Sun drying in the field works best and can be done quickly. Drying fins indoors usually takes 24 hours.

VII. Record the appropriate field and lab preservation methods (both will normally be noted in the "other" column as "air dried") on the data sheet.

VIII. When completely dry, repacking the tissue into its original, dry, envelop and attach to field notes for shipment to DFG genetics archive. Check all envelopes to ensure data are filled out completely and legibly.

Genetic Tissue Collection Data

Collection Date_________________

Collection Location (County, River, Exact Location on River)____

Collection Name___________________________ Collector Affiliation/Phone____________________________________

Sample ID Number	Species	Tissue Type	Fish Condition	Fork Length (mm)	Sex (M, F or Unk)	Adipose Fin Clip? (Y or N)	Tag? (Y or N)	Notes/ Comments

DFG Salmonid Genetic Tissue Repository

Sacramento, CA

6 DATA MANAGEMENT

Data management includes at least data collection, data storage and archive, and quality assurance and quality control (QA/QC) procedures. Data should be recorded on a datasheet designed for the recommended data collection (see example data sheet). All data should undergo quality assurance and quality control (QA/QC) procedures both in the field and office. In the field, the data recorder is responsible to ensure all data are collected and recorded accurately and legibly. In the office, the data entry technician is responsible for QA/QC of the data entered into a database. Data recorded on the datasheets or in an electronic device should be entered or uploaded into the database on a weekly basis to identify potential data collection or data recording errors, which will promote prompt changes to improve data quality. In addition, entering data into the database on a weekly basis will help the biologists meet tight deadlines for producing escapement estimates for Ocean Management. Copies of field data sheets or backup electronic files should be archived. The California CV Chinook Salmon In-River Escapement Monitoring Plan recommends development of a data management plan including a centralized relational database for managing data from all programs. In addition, the plan recommends the use of PDAs for improved efficiency in data entry and reducing errors in data transfer. An example mark-recapture database and a PDA application were developed to manage mark-recapture data recommended in this example protocol and in the plan. This database can be modified to meet the needs of biologists.

LITERATURE CITED

[CDFG] California Department of Fish and Game. 2006. CDFG Central Valley Salmonid Tissue Archive Operations Manual.

Kormos, B. 2007. Escapement survey sampling, scale aging field sampling – standard operation procedures. Version 1.0. California Department of Fish and Game. Santa Rosa, CA.

Scarnecchia, D. L. 1987. Rapid removal of otoliths from salmonids. North American Journal of Fisheries Management 7:312-313.

Mark-Recapture Carcass Survey Data Sheet: Front Side

Date:	**Water Temp:**	**Crew:**	**Comments:**
Survey Reach:	**Water Clarity:**	**Sampling Frequency:**	
Survey Period:	**Weather:**	**Boat ID:**	

Marking & Biological Data

	DISC Tag #	Adipose Fin	Sex	Fork (unit)	Fresh?	Spawned?	RM	Sample Taken?	Scale #	CWT Head Tag #	Floy #	Comment
1		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
2		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
3		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
4		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
5		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
6		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
7		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
8		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
9		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
10		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
11		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
12		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
13		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
14		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
15		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
16		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
17		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
18		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
19		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
20		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
21		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
22		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
23		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
24		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
25		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
26		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
27		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
28		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
29		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
30		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				

Chops on First Capture With Covariate Data

1		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
2		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
3		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
4		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
5		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
6		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
7		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
8		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
9		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
10		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
11		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				
12		Y N Unk	F M		Y N	Y N		Tis Hd Sc Ot				

Chops on First Capture Without Covariate Data

Adipose Fin-Clipped Chops	Non-Adipose Fin-Clipped Chops	Unkown Adipose Fin-Clipped Chops

Mark-Recapture Carcass Survey Data Sheet: Back Side

Date:	Survey Reach:	Boat ID:

Disc Tag Recaptures

	DISC Tag #	Release or Chop?	RM		DISC Tag #	Release or Chop?	RM		DISC Tag #	Release or Chop?	RM
1		R C		51		R C		101		R C	
2		R C		52		R C		102		R C	
3		R C		53		R C		103		R C	
4		R C		54		R C		104		R C	
5		R C		55		R C		105		R C	
6		R C		56		R C		106		R C	
7		R C		57		R C		107		R C	
8		R C		58		R C		108		R C	
9		R C		59		R C		109		R C	
10		R C		60		R C		110		R C	
11		R C		61		R C		111		R C	
12		R C		62		R C		112		R C	
13		R C		63		R C		113		R C	
14		R C		64		R C		114		R C	
15		R C		65		R C		115		R C	
16		R C		66		R C		116		R C	
17		R C		67		R C		117		R C	
18		R C		68		R C		118		R C	
19		R C		69		R C		119		R C	
20		R C		70		R C		120		R C	
21		R C		71		R C		121		R C	
22		R C		72		R C		122		R C	
23		R C		73		R C		123		R C	
24		R C		74		R C		124		R C	
25		R C		75		R C		125		R C	
26		R C		76		R C		126		R C	
27		R C		77		R C		127		R C	
28		R C		78		R C		128		R C	
29		R C		79		R C		129		R C	
30		R C		80		R C		130		R C	
31		R C		81		R C		131		R C	
32		R C		82		R C		132		R C	
33		R C		83		R C		133		R C	
34		R C		84		R C		134		R C	
35		R C		85		R C		135		R C	
36		R C		86		R C		136		R C	
37		R C		87		R C		137		R C	
38		R C		88		R C		138		R C	
39		R C		89		R C		139		R C	
40		R C		90		R C		140		R C	
41		R C		91		R C		141		R C	
42		R C		92		R C		142		R C	
43		R C		93		R C		143		R C	
44		R C		94		R C		144		R C	
45		R C		95		R C		145		R C	
46		R C		96		R C		146		R C	
47		R C		97		R C		147		R C	
48		R C		98		R C		148		R C	
49		R C		99		R C		149		R C	
50		R C		100		R C		150		R C	

Comments:

APPENDIX C

REVIEW OF THE CENTRAL VALLEY ANGLER SURVEY

By

Western EcoSystems Technology
2003 Central Avenue, Cheyenne, WY 82001
Phone: 307-634-1756 Fax: 307-637-6981

Jim Griswold
jgriswold@west-inc.com

Ryan Nielson
rnielson@west-inc.com

May 13, 2011

INTRODUCTION

Inland sport harvest of Chinook salmon in California's Central Valley (CV) streams comprises a significant proportion of the total escapement. The CV angler harvest survey, reinitiated in 2007, is a long-term monitoring program designed to develop annual estimates of total angler effort and in-river harvest of sport fish from the Sacramento River and major tributaries. In addition to Chinook salmon, the survey includes a number of other species considered to have recreational value. As described in Titus et al. (2009), the key objectives of the CV angler survey specific to Chinook salmon are:

1. Analysis and reporting of angler effort and harvest,
2. Estimating the contribution of hatchery Chinook in the CV sport harvest, and
3. Estimating the age structure of Chinook salmon and steelhead in the CV sport harvest.

Estimates of Chinook salmon harvest in the inland fishery are used by the Pacific Fishery Management Council to help determine ocean harvest quotas off the coasts of California, Oregon and Washington (Titus et al. 2009).

This document reviews the existing angler survey design and analysis techniques used in the CV for estimating Chinook salmon angler effort and harvest (Titus et al. 2009). After describing the current angler survey protocol, we provide recommendations for future surveys and analyses of those survey data. The recommended methods will allow for estimation of precision (e.g., confidence interval [CI]), and are expected to reduce bias and improve precision of estimates of Chinook salmon angler effort and harvest in the CV.

CURRENT METHODS

Survey Design

The CV angler survey is based on a stratified sampling design developed for the Sacramento River Sport Fish Inventory (Wixom et al. 1995) and the Upper Sacramento River Sport Fishery (Smith 1950). Physical strata (river sections) have been identified, and a stratified allocation of effort is used to survey river sections each month. A total of 21 river sections ranging from 1 to 56 miles in length were surveyed in 2008 – 2009 (Titus et al. 2009). We assume that stratification of river sections is based on a combination of physical/geographic features, angler and surveyor access to the river, and unique features of the fishery (e.g., estimated historic harvest levels). In 2008 – 2009, each section was surveyed on eight randomly selected days per month: four weekdays and four weekend days. Relatively more effort was given to weekend days since angling effort during these times is typically greater.

Surveys are conducted using a method similar to what is called a 'roving-roving' survey, in combination with access point interviews. Roving-roving surveys involve a survey team traveling the entire river section at least once to count the number of anglers, and then traveling the river section again to interview anglers. Given two or more random roving (or progressive) count surveys, angler effort and total harvest can be calculated for that day, along with estimates of precision (Pollock et al. 1994). Estimates of harvest are calculated by multiplying an estimate of the amount of angler effort (e.g., number of angler-hours) by an estimate of total harvest-per-unit-effort (*hpue*; e.g., how many fish were caught by the average angler, per hour).

Only one roving count is conducted for each section, each survey, which precludes estimation of precision. This single count is combined with data from an effort distribution model (EDM) to estimate the number of angler-hours. The EDM represents an estimate of the proportion of a day's total angler-hours that occur over any period of time. For example, the EDM may identify that 12% of all angler-hours occur between 6 and 7 am on weekend days during August on a particular river section. If a roving count conducted during the same period resulted in a total count of 10 anglers, we would estimate that 83 anglers $(10/0.12 = 83.3)$ fished that section of river that day.

The first EDMs for the CV were developed using access interviews (Wixom et al. 1995). Access interviews occur at a representative sample of river access locations and target anglers that have completed their fishing experience for that day. Although access interviews were conducted in 2008 – 2009, development of EDMs for 2008 – 2009 based on those interviews was incomplete. Thus, the historical EDMs developed by Wixom et al. (1995) were used by Titus et al. (2009). Although historical EDMs have been compared to more recent data (Rob Titus, personal communication), no statistical comparisons were presented in Titus et al. (2009).

Roving counts and access interviews provide information regarding the number of anglers present and the total number of angler-hours during a day. While access interviews allow collection of completed trip information at access sites, roving interviews intercept anglers while they are still fishing. Angler success and the number of fish harvested are estimated from access point interviews and roving interviews. If time permits, every angling party in the section during the roving survey is interviewed. Otherwise, every N^{th} party is interviewed, where N is determined by field personnel and based on the time of day, number of anglers present, and field logistics.

Surveys of river sections begin at sample start times and launch locations. For each section, a survey start time is determined by randomly selecting the beginning, middle, or final 1/3 of the sample day. Actual start times within a selected period (early, middle or late) vary according to length of the survey and logistics. If a river section can be surveyed using a motorboat, a launch location (upstream or downstream) is randomly sampled for each survey. Surveys along river sections traveled by kayak or drift boat, due to available boat access and/or water depth, always begin upstream.

Estimation of Angler Effort and Harvest of Chinook Salmon

The procedures used to estimate total angler effort and harvest of Chinook salmon follow those described in Wixom et al. (1995). Three survey parameters are estimated for each river section on each survey day: (1) total effort in angler-hours (E), (2) harvest per unit of effort ($hpue$) measured as the number of Chinook salmon harvested per angler per hour, and (3) total Chinook harvest (H). Daily estimates are then expanded to provide monthly estimates. Months were chosen as the time interval for survey periods because historical CV angler surveys (e.g., Wixom et al. 1995, Murphy et al. 1999) focused on monthly estimates of angler effort and harvest.

To describe the estimators used for each parameter, the following definitions are needed:

Let b = time required to conduct a roving (roving) count pass through the section;

E = total angling hours for all species;
$E_{Chinook}$ = total angling hours for Chinook salmon;
e = length (hours) of a fishing experience for an interviewed angler;
H = total harvest in numbers of Chinook salmon kept (or released) by anglers;
h = total numbers of fish kept (or released) during a fishing trip by an interviewed angler;
P = proportion of anglers present during a given period of day (based on EDM);
$P_{Chinook}$ = proportion of angler-hours targeting Chinook salmon (based on interviews);

Estimates of total angler effort for all species for a particular day is calculated by dividing the roving angler count (n) by the estimated average proportion of individual anglers present in the section for the period during which the count was made:

$$\hat{E} = \frac{n}{P} \ , \tag{1}$$

where P is based on the EDM and time period when the roving count was conducted.

Estimates of angler effort specific to fishing for Chinook salmon are calculated for each sampled day, using

$$\hat{E}_{Chinook} = \hat{E} \times P_{Chinook} \ . \tag{2}$$

The average daily *hpue* is estimated by dividing a sample day's average number of Chinook salmon harvested by the average number of hours fished for Chinook by the anglers interviewed (i.e., a ratio of means):

$$\overline{hpue} = \frac{\overline{h}}{\overline{e}} . \tag{3}$$

Harvest is estimated sample day in the CV angler survey by multiplying an estimate of $\overline{hpue}$ (equation [3]) by an independent estimate of effort for that sample day:

$$\hat{H} = \hat{E}_{Chinook} \times \overline{hpue}. \tag{4}$$

Separate estimates are made for kept and released fish, and total harvest is calculated as the sum of harvests over days, months and or river sections of the survey. No variance estimates or confidence intervals are available for estimates of angler effort (equations [1] and [2]) or total harvest (equation [4]), since only one roving count is conducted for each river section, each survey.

RECOMMENDATIONS

Separate EDMs have been developed for various river sections in the CV (Wixom et al. 1995), but not for all 21 river sections surveyed in 2008 – 2009 (Titus et al. 2009). In addition, the EDM method used for estimating angler effort assumes that the distribution of hourly effort throughout each day is constant for all days regardless of the date or year (and possibly section) of the survey. We believe this tenuous assumption is not met in many situations (e.g., holidays, inclement weather). In addition, as mentioned above, using only one roving count per survey day precludes estimation of precision for both angler effort and total harvest, which is critical for trend monitoring and effective management of the fishery. Thus, we recommend that the current angler survey be continued, but with some modification.

We recommend roving-roving surveys include two or more roving counts of anglers at random times during the day, with a randomized direction of travel (when practical). These counts can then be used for calculation of total angler-hours for a sampled day. This approach follows several angler survey designs described in the literature (e.g., Wade et al. 1991, Pollock et al. 1994, Bernard et al. 1998), and if implemented correctly, can be expected to produce accurate estimates of harvest and effort (Hoenig et al. 1993). We describe one possible method of implementing the multiple roving count approach below. In addition, formulas for estimating total harvest based on access interviews or a combination of roving and access interviews are provided in the Appendix. Currently, data are collected for each angling party interviewed. However, future surveys should involve collecting data at the level of individual anglers to permit proper variance estimation.

Implementing Two or More Roving Counts

There are many ways in which two or more roving counts can be conducted, but all methods assume that a random start time, and possibly a random direction of travel (upstream or downstream) can be selected for each count. We envision the simplest approach, which is to conduct only two roving counts for a river section within a survey day, with one occurring either before or after a roving interview survey, and the other occurring during the roving interview.

If a roving count is expected to take *b* hours, then divide the fishing day into *B* blocks of length *b*, and randomly select one of the blocks for the roving count. For example, if the fishing day is 14 hours long, and a roving count would require *b*=1 hour, the survey day would be divided into *B*=14 blocks of time. A random sample of the 14 blocks would determine when the roving count was conducted, and a coin-flip would determine whether the roving interview was conducted prior to, or following the roving count. If a sampled block is near the beginning (end) of the day and a roving interview cannot be conducted (before) after the roving count, the roving interview can be conducted after (before), as long as the randomly selected start time for the roving count is maintained. It is important to randomly select the starting time for the first roving count each sampled day for each river section.

If *b* hours were required to complete a roving count, an unbiased estimate of the fishing effort in any particular *b* block of time is calculated as

$$\hat{E}_b = x \times b, \qquad [5]$$

where *x* is the number of anglers counted. When a roving count of anglers is conducted using a random start time and direction of travel, the count can be considered an unbiased estimate of the mean number of anglers fishing during any block of time of that duration (Hoenig et al. 1993, Robson 1961). Thus, if the fishing day contains *B* *b*-hour blocks, an unbiased estimate of the total fishing effort in angler-hours for the day is estimated using (Hoenig et al. 1993)

$$\hat{E} = x \times b \times B \ . \qquad [6]$$

The second roving count during a survey can either take place at a random time (same methods described above), or during the roving interview. Since a count of anglers during the interview process may result in a substantial underestimate of fishing effort due to length-of-stay bias (Wade et al. 1991, Pollock et al. 1994:244, Bernard et al. 1998), we recommend including adjustments in the survey protocol involving scheduled checkpoint locations (Wade et al. 1991). Length-of-stay bias exists when the amount of time an angler spends on the river depends on his or her fishing success.

The checkpoint method insures that anglers are counted evenly along the entire survey section through the sampling period. A time schedule is followed so the survey team reaches specific checkpoints at designated times along the survey. Although fewer angler interviews may be conducted using the checkpoint method because some anglers may need to be skipped in order for the survey to stay on schedule, the resulting estimate of effort is expected to be accurate. Total angler-hours using the checkpoint method can be calculated using equation [6].

Using two roving counts to obtain two estimates of angler effort (equation [6]), the average angler effort for the survey day should then be used as the final estimate of total angler-hours:

$$\hat{E} = \frac{\hat{E}_1 + \hat{E}_2}{2} \;. \qquad [7]$$

Anglers are usually classified by harvest type, i.e. whether they will (are) going to keep or release any Chinook caught. The proportion of anglers determined to be targeting Chinook is multiplied by the roving total count of anglers to obtain the number of Chinook anglers. The number of sample day hours determined to belong to each harvest category (kept or released) is the product of the number of hours in the day and the proportion of total hours fished by harvest type. This allows for partitioning of estimates of Chinook angler effort and harvest by harvest type.

We recommend that information on angler-trips of less than 0.5 hours not be used in $\overline{hpue}$ calculations based on the roving-roving survey due to the fact that the angler(s) was likely interviewed prior to completion of their ‘angling trip’. This tends to stabilize the variance of the estimates of angler effort and harvest, while not contributing appreciable bias (Pollock et al. 1997).

Estimation of $\overline{hpue}$ and total harvest using the roving-roving survey design with at least two roving counts follows equations [3] and [4], with details in the Appendix. Variance estimates for angler effort and harvest for a survey day are also presented in the Appendix. In addition, we present formulas for estimating angler effort and harvest using a combination of roving and access point interviews.

CONCLUSIONS

The CV Angler Survey uses a stratified random roving-roving design in which access interview data is also sometimes used in combination with roving interviews to estimate angler effort and harvest of Chinook salmon. However, a historical EDM is used in place of two or more random roving counts. Use of the historical EDM requires tenuous assumptions, and precludes estimation of CIs for total harvest. A modification of the current approach would improve estimates (reduce bias and improve precision), and allow for calculation of CIs. This modification involves conducting multiple (two or more) roving counts of the number of anglers each survey day, where one of the counts can be conducted simultaneously with the roving interview survey.

LITERATURE CITED

Bernard R. B., A. E. Bingham, and M. Alexandersdottir. 1998. Robust harvest estimates from on-site roving-access creel surveys. Transactions of the American Fisheries Society 127:481-495.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Hayne, D. W. 1991. The access point survey: procedures and comparison with the roving-clerk creel survey. American Fisheries Society Symposium 12:123-138.

Hoenig, J. M., D. S. Robson, C. M. Jones, C. M., and K. H. Pollock. 1993. Scheduling counts in the instantaneous and progressive count methods for estimating sport-fishing effort. North American Journal of Fisheries Management 13:723-736.

Hoenig, J. M., C. M. Jones, K. H. Pollock, D. S. Robson, and D. L. Wade. 1997. Calculation of harvest rate and total harvest in a roving survey of anglers. Biometrics, Vol. 53, 1:306-317.

Jones, C. M., D. S. Robson, H. D. Lakkis, and J. Kressel. 1995. Properties of harvest rates used in analysis of angler surveys. Transactions of the American Fisheries Society 124:911-928.

Manly, B. F. J. 1997. Randomization, bootstrap and Monte Carlo methods in biology. Second edition. Chapman and Hall, London.

Murphy, K. L. Hanson, M. Harris, and T. Schroyer. 1999. Central Valley Salmon and Steellhead harvest monitoring project, 1998 angler survey. California Department of Fish and Game, Sacramento Valley – Central Sierra Region.

Pollock, K. H., Jones, C. M., and T. L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society Special Publication 25.

Pollock, K. H., J. M. Hoenig, C. M. Jones, D. S. Robson, and C. J. Greene. 1997. Harvest rate estimation for roving and access point surveys. North American Journal of Fisheries Management 17:11-19.

Robson, D. S. 1961. On the statistical theory of a roving creel census. Biometrics 17:19-24.

Smith, S. H. 1950. Upper Sacramento River sport fishery. Special Scientific Report No. 34, United States Department of the Interior, U. S. Fish and Wildlife Service.

Thompson, S. K. 2002. Sampling. Wiley. New York, New York.

Titus, R., M. Brown, J. Phillips, J. Lyons, and E. Collins. 2009. Annual performance report – Central Valley angler survey; project number F-119-R; report period July 1, 2008 to June 30, 2009. California Department of Fish and Game.

Wade, D. L., C. M. Jones, D. S. Robson, and K. H. Pollock. 1991. Computer simulation techniques to access bias in the roving-creel-survey estimator. American Fisheries Society Symposium 12:40-46.

Wixom, L. H., J. Pisciotto, and C. Lake. 1995. Sacramento River system sport fish harvest inventory. Federal Aid Project F-51-R-7, U.S. Fish and Wildlife Service.

Wolter, K. M. 2007. Introduction to variance estimation. Springer. New York, N.Y.

APPENDIX C-1

Harvest-per-unit-effort Using a Roving-Roving Survey

Angler effort and $\overline{hpue}$ are estimated separately for each river section, survey day and harvest type. Subscripts in the formula presented below only represent an individual harvest type, though they are not specific to kept or released fish.

Since interviewed anglers in a roving-roving survey have not completed their fishing trips, the mean of ratios of harvest to effort for individual interviewed anglers is the least biased estimate of $\overline{hpue}$ (Jones et al. 1995, Hoenig et al. 1997, Pollock et al. 1994). An estimate of the $\overline{hpue}$ for sample day *i* is calculated using a mean of ratios:

$$\overline{hpue}_i = \frac{1}{m_i} \sum_{k=1}^{m_i} \frac{h_{ik}}{e_{ik}} \quad , \qquad [8]$$

with an estimated variance of

$$v\left(\overline{hpue}_i\right) = \frac{\sum_{k=1}^{m_i} \left(hpue_{ik} - \overline{hpue}_i\right)^2}{m_i\left(m_i - 1\right)} \quad , \qquad [9]$$

where m_i is the number of anglers interviewed, h_{ik} is the harvest of the k^{th} angler, e_{ik} is the effort (in hours) up to the time of interview for the k^{th} angler, and $hpue_{ik}$ is the harvest-per-hour for the k^{th} angler.

If m_i anglers are interviewed systematically (every N^{th} angler) the following variance formula should be used (Wolter 2007, pg 300):

$$v\left(\overline{hpue}_i\right) = \frac{\sum_{k=2}^{m_i} \left(hpue_{ik} - hpue_{i(k-1)}\right)^2}{m_i(2)\left(m_i - 1\right)} \quad . \qquad [10]$$

Angler Effort

An estimate of monthly effort for a given river section and day-type is calculated using equation [7] and

$$\hat{E} = \frac{D}{d} \sum_{i=1}^{d} \hat{E}_i \quad , \qquad [11]$$

where *D* is the number of days of that day-type (weekday or weekend day) in a given month, and *d* is the number of sampled days (currently 4) of a given day-type within the month.

Using two or more roving counts of *x* anglers based on random start times for the surveys, variance for a sample day is calculated as (Pollock et al. 1994, pg 248)

$$v\left(\hat{E}_i\right) = T^2 \frac{\sum_{t=1}^{r} \left(x_{it} - \bar{x}_i\right)^2}{r\left(r - 1\right)} \quad , \qquad [12]$$

where T is the number of hours in the fishing day, x_{it} is the number of anglers counted during the t^{th} daily roving count, and $\bar{x}_t$ is the mean of the r roving counts. The variance for angler effort for a given day-type within a month is estimated using

$$v\left(\hat{E}\right) = \frac{D(D-d)}{d} \frac{\sum_{i=1}^{d}\left(\hat{E}_i - \overline{\hat{E}}\right)^2}{d-1} + \frac{D}{d}\sum_{i=1}^{d} v\left(\hat{E}_i\right). \qquad [13]$$

Estimating Total Harvest

Estimated harvest for sample day i on a river section is calculated as

$$\hat{H}_i = \hat{E}_i \overline{hpue}_i. \qquad [14]$$

The daily estimated harvest is then expanded over all available days (weekdays or weekend days) to estimate the total number of fish harvested ($\hat{H}$) for a specific month and river section by day-type:

$$\hat{H} = D\frac{\sum_{i=1}^{d} \hat{H}_i}{d}, \qquad [15]$$

and D is the number of weekdays (or weekend days) in the month, and d is the number of days sampled (4).

An approximate variance formula for estimated total harvest in a sample day was derived by Goodman (1960) as,

$$v\left(\hat{H}_i\right) = \hat{E}_i^2 v\left(\overline{hpue}_i\right) + \overline{hpue}_i^{\,2} v\left(\hat{E}_i\right) - v(\overline{hpue}_i) v\left(\hat{E}_i\right). \qquad [16]$$

However, a bootstrap procedure (Manly 1997) may provide a better method for estimating variance in harvest when coefficients of variation (CV) are large (say ≥ 0.25).

Variance for a harvest estimate for a particular stratum (e.g., month, river section, type of day) is consistent with a stratified random sampling design (Thompson 1992, pgs 119 and 134):

$$v\left(\hat{H}\right) = D(D-d)\frac{s_1^2}{d} + \frac{D}{d}\sum_{i=1}^{d} v\left(\hat{H}_i\right), \qquad [17]$$

$$s_1^2 = \frac{\sum_{i=1}^{d}\left(\hat{H}_i - \overline{\hat{H}}\right)^2}{d-1}, \qquad [18]$$

and $\overline{\hat{H}} = \left(\sum_{i=1}^{d} \hat{H}_i\right)/d$. If sample days are chosen systematically to obtain a more even distribution of harvest and effort over the available days in the month (Pollock et al. 1994), an approximation of s_1^2 (Wolter 2007, pg 300) is

$$s_1^2 = \frac{\sum_{i=2}^{d}\left(\hat{H}_i - \hat{H}_{i-1}\right)^2}{2(d-1)}. \qquad [19]$$

The systematic method may be preferred over random sampling when it is known that there is a temporal trend in harvest, as may be the case with migratory salmon fisheries.

Angler Effort and Harvest Using a Roving-access Survey

The roving-access survey method interviews anglers as they exit the fishery having completed their fishing trips (Hayne 1991). For some sample days the angler survey may involve both roving interviews and access point interviews so that the survey becomes a combination of roving-roving and roving-access survey types. For the roving-access method, the total angler count is obtained by roving counts. An advantage to the roving-access survey is the elimination of "length-of-stay" bias, where an angler's harvest influences the length of his or her fishing trip (Pollock et al. 1994, pg 179). Another advantage is the assumption that each angler experiences a constant harvest rate throughout the day is not necessary. This condition is a necessary assumption for minimal bias in estimates of $\overline{hpue}$ using roving interviews (Pollock et al. 1997, pg 13). However, access points to a river section may be too numerous, too sparse or too inaccessible to allow enough anglers to be interviewed to achieve acceptable estimates of $\overline{hpue}$ given limited personnel (Pollock et al. 1994, pg 160).

When a moderately large number of interviews can be obtained, the roving-access survey is preferred since bias in harvest per unit of efforts will in general be lower than those estimated from roving interviews (Bernard et al. 1998). Access sites must be chosen in a probabilistic manner. If the section has multiple access sites, one or more sites should be selected at random from a list of available access sites. Precision can be maximized if access sites are chosen randomly with weights in proportion to the fishing effort occurring at those sites (Pollock et al. 1994, pg 142). If access point interviews are used, the best method for estimating mean sample day $\overline{hpue}$ is the ratio of means (Jones et al. 1995, pg 921; Hoenig et al. 1997):

$$\overline{hpue}_i = \frac{\sum_{k=1}^{m_i} h_{ik}}{\sum_{k=1}^{m_i} e_{ik}}. \qquad [20]$$

The variance can be calculated using (Thompson 1992, pg 60)

$$v\left(\overline{hpue}_i\right) = \frac{\sum_{k=1}^{m_i}\left(h_{ik} - e_{ik}\overline{hpue}_i\right)^2}{\bar{e}_i m_i \left(m_i - 1\right)}, \qquad [21]$$

where $\bar{e}_i = \frac{1}{m_i}\sum_{k=1}^{m_i} e_{ik}$, and m_i is the number of anglers interviewed during sample day *i*.

Using A Combination of Roving and Access Interviews

When both roving interviews and access interviews are used to estimate $\overline{hpue}$ for a river section, the following weighted average should be used:

$$\overline{hpue}_{wi} = \frac{\overline{hpue}_{Ai} m_{Ai} + \overline{hpue}_{Ri} m_{Ri}}{m_{Ai} + m_{Ri}} \quad , \qquad [22]$$

with a variance estimated as

$$v\left(\overline{hpue}_{wi}\right) = \frac{v\left(\overline{hpue}_{Ai}\right) + v\left(\overline{hpue}_{Ri}\right)}{\left(m_{Ai} + m_{Ri}\right)^2} \quad , \qquad [23]$$

where m_{Ai} is the number of access interviews, m_{Ri} is the number of roving interviews, $\overline{hpue}_{Ai}$ is the estimated harvest rate based on the access interviews (equation [20]), $\overline{hpue}_{Ri}$ is the estimated harvest rate based on roving interviews (equation [10]), $v\left(\overline{hpue}_{Ai}\right)$ is the estimated variance for the access interviews (equation [21]), and $v\left(\overline{hpue}_{Ri}\right)$ is the estimated variance for the roving interviews (equations [11] or [12]).

Cumulative Estimates for Season and Strata

When strata are established according to time and location of anglers, all anglers within such stratum belong by definition to that stratum. Thus sample sizes for basic units are fixed (Thompson 1992: 109). Unbiased estimates of harvest, effort and their sample variances are then independent for each stratum. Since days are scheduled independently across time-space strata, adding stratified estimates of harvest and their sample variances across any combination of such strata will produce unbiased, cumulative estimates (Thompson 1992:102, Bernard et al. 1998). For example a total season estimate of harvest which would include both kept and released fish with its estimated variance would be calculated as

$$\hat{H}_{season} = \sum_{i=1}^{I} \sum_{j=1}^{21} \sum_{k=1}^{2} \sum_{l=1}^{2} \hat{H}_{ijkl}, \qquad [24]$$

$$v\left(\hat{H}_{season}\right) = \sum_{i=1}^{I} \sum_{j=1}^{21} \sum_{k=1}^{2} \sum_{l=1}^{2} v\left(\hat{H}_{ijkl}\right) , \qquad [25]$$

where *i* indexes sampled months of the survey season, *j* indexes river section (e.g., 21 sections in current survey), *k* indexes type of day (weekday or weekend day) and *l* indexes harvest type (kept or released). Stratum estimates and their variances follow equations [14] and [16], respectively.

An approximate asymptotic 90% confidence interval for total seasonal harvest can be calculated as

$$\hat{H}_{season} \pm Z_{0.05} \sqrt{v\left(\hat{H}_{season}\right)}, \qquad [26]$$

where $Z_{0.05}$ is the upper 0.95 tail value of the standard normal distribution.

APPENDIX D

DATA MANAGEMENT OUTLINE, DATA CAPTURE, CENTRALIZED DATABASES, POTENTIAL DATA FIELDS AND REPORTING FUNCTIONS

Data Management Plan

This plan recommends that a detailed data management plan be developed in conjunction with a database to assure that all people involved in entering or using a data set understand how the data are managed. StreamNet (2009) developed an outline for the components needed in a data management plan. Development of a data management system for managing Chinook salmon escapement data will need to address at least these components for a data management system (StreamNet 2009):

1. Project Description
    - 1.1. Title
    - 1.2. General description
2. Contacts
    - 2.1. Project leader
    - 2.2. Person(s) responsible for collecting data in the field
    - 2.3. Person(s) responsible for entering the data
    - 2.4. Person(s) responsible for managing (maintaining, changing, updating, correcting, disseminating) the data after collection and entry
3. Data
    - 3.1. General description
    - 3.2. Collection methods description.
    - 3.3. Data capture (e.g., paper data sheets or electronic tools)
    - 3.4. Standards for data management (e.g., standard coding schemes, formats, etc.)
    - 3.5. Data dictionary (e.g., data definitions, codes, units, data is optional or required)
    - 3.6. Data quality control and assurance procedures to be employed
    - 3.7. Data storage process and format (e.g., backup procedures, database structure)
    - 3.8. Where data is stored (e.g., centralized or distributed type database)
    - 3.9. Data "ownership" or control
    - 3.10. Data analysis (how data is analyzed)
    - 3.11. Access to data (who has access to the data)
    - 3.12. Sensitive data (how will this be handled)
    - 3.13. Long term data storage and dissemination
4. Schedules
    - 4.1. Description of data pathway and operations
    - 4.2. Schedule for data flow (flow diagram of data)
    - 4.3. Methods for tracking data status
    - 4.4. How and when will data be made available to others
5. Metadata
    - 5.1. Provide metadata

5.2. Describe who will develop metadata and where and when will the metadata be available.

Data Capture

This plan recommends investigating the feasibility of using an electronic device to improve the efficiency of data recording, data entry and data quality checking. Two examples are the rugged tablet Personal Computer (PC) and the rugged Personal Digital Assistant (PDA) device.
One example of using the rugged tablet PC is with the Minnesota Department of Natural Resources (MNDNR). They changed from using paper field data sheets to a PC to collect fisheries and habitat data from their lake surveys (Xploretech 2007). Prior to the PC, entering data into dozens of distributed databases across the state of Minnesota, methodically analyzing databases for entry errors, and consolidating all of the databases into one central database took months. To overhaul their data management system, MNDNR implemented a project that took three years with 40 staff to develop a new data management system. Dozens of field hardware options were examined to capture data, and MNDNR chose Xplore X104C2 rugged tablets. The application of technology significantly improved efficiency for capturing fisheries data, speed of data retrieval, and quality of data stored. A Java client database application was developed and is used on rugged tablets and desktop workstations over the MNDNR intranet to provide statewide access to a single database and dozens of reports. The rugged tablets have eliminated 27 separate copies of the database that previously required weeks of data consolidation annually. The application improves data quality by providing validation when the fish is still in-hand instead of during data entry from paper datasheets over the winter when the fish was no longer available to recheck. Quick upload of the data from the PC to the central database provides immediate reporting. Since data entry occurs directly onto the rugged tablets while in the field, approximately 8,875 hours of in-office data entry is eliminated. These hours save the Department $195,250 annually. Overall, estimated cost benefits from implementing the application is $216,170 each year. The estimated base price for each tablet PC is USA $2,800.00.

The PDA offers many of the same advantages of a tablet PC and may prove to be a viable option. The PDA is being used successfully to record fisheries field data in California. These devices can increase the accuracy of data capture and provide a significant time savings when compared to paper datasheets like the PC. Since data are entered from the PDA directly into the database, less handling is required resulting in fewer data entry errors. Some quality control can be built into the PDA application. Once data are loaded to the main database back at the office, the data can be subjected to a wider range of automated quality control checks.

The PDA recommended by CDFG Northern Region is the Meazura Rugged Digital Assistant (Aceeca MEZ1000 RDA Handheld). The Meazura RDA is less expensive than the tablet PC. The device has a monochrome screen with adjustable backlighting to allow use in a wide range of lighting conditions. In addition, the device can be adapted to include GPS functionality by connecting to a Garmin Global Positioning Unit (GPS) via Blue Tooth wireless or may be wired to any GPS. The units are stable, reliable, waterproof, and extremely durable. Starting cost for the Meazura RDA is $400.00. The Northern Region also recommends Pendragon Forms 5.1 (Pendragon Software Corporation) for simple field form development although there are more sophisticated options. This software will create forms from access database tables or queries.

The forms need modification if pick lists and other options are desired. Software is $300.00 for the first license and $100.00 for additional licenses. In addition to the CDFG Northern Region, in 2010 the River Management Team of the lower Yuba River Accord used a PDA to capture data for their Chinook salmon mark-recapture carcass survey on the lower Yuba River. Use of the PDA was found to be easy and extremely efficient in the field. Data was uploaded to a relational database and available for analysis immediately. The PDA had some error checking to flag the data recorder for missing fields. The crew had paper data sheets on hand if the PDA malfunctioned, but that only happened occasionally and the crew learned how to trouble shoot the problem.

Johnson et al. (2009) has suggested that for most common fisheries estimates, a single entry of data or single entry using a PDA is sufficient and further that the use of automated error checking in both the PDA and a main database helps to ensure an acceptable level of data quality without the time and expense of more traditional error-checking methods such as double data entry and read-aloud proofing (Johnson et al. 2009). Initial startup costs of a PDA are offset by time saved entering data from paper datasheets to a digital format. Additional time savings result from automating error checking. Johnson et al. (2009) noted some difficulties with the PDA including small screen size, poor system navigation, and data loss. However, these difficulties were not reported by CDFG Northern Region.

Centralized Database Management Systems

Highly Centralized Database Management System

Example 1. California Department of Fish and Game Central Valley GrandTab Application

An online database application was created in December, 2009 for the reporting of Chinook salmon escapement estimates in California's Central Valley to GrandTab (J. Azat, CDFG, pers. comm. 2010). The GrandTab online database application is an example of a centralized database system, however the purpose of this system is to maintain summarized data and not raw or primary data. Biologists from multiple agencies including: California Department of Fish and Game (CDFG), California Department of Water Resources (CDWR), United States Fish and Wildlife Service (USFWS), and East Bay Municipal District (EBMUD) enter escapement numbers for adult, grilse, and total (adult and grilse) Chinook salmon for the stream(s) they monitor. Before this online database application was developed, biologists would have to call in their preliminary escapement Chinook salmon escapement numbers, and call in any changes or the final escapement numbers.

Quality control of the data in the GrandTab database application occurs at different levels. With this application, each biologist is given a username and password to enter data into the database (J. Azat, CDFG, pers. comm., 2010). Only the biologists entering data and some managers can access the data. Only biologists can edit the data they entered; to edit the data the line must be first deleted, and once the data is finalized the data cannot be changed without contacting the database specialist. The database is constrained to allow for only one instance of any run/area/survey/year. Data entry validation rules include data entry requirements for some fields and formatting rules.

The GrandTab online database application is in an initial stage. The application was created by a biologis/database specialist, who is currently hosting the application on GoDaddy.com. for $5 per month (J. Azat, CDFG, pers. comm. 2010). One of the reasons for this effort was to demonstrate the usefulness of on-line data entry. More resources and support are needed to continue development and improvement of the application and keep it running. The application is demonstrating that the use of this technology to improve data reporting.

Example 2. Wisconsin Department of Natural Resources

An example of a highly centralized database is the Wisconsin Department of Natural Resources (WDNR), Bureau of Fisheries Management Biology Database. The database was developed to manage fisheries and habitat field data collected statewide in Wisconsin lakes and streams (J. Griffin, WDNR, pers. comm., 2010). In 2001, the database was implemented and biologists are mandated to enter all data from annual fish and habitat surveys. Since 2001, the database has grown to include data from fish kills, fishing tournaments, and propagation quota and stocking. Currently, the amount of data in the database is extensive. The database contains 13,826 fish surveys conducted at 8,880 sites in 2,917 streams; 7,542 fish surveys conducted at 1,447 sites in 1,226 lakes; and 1,328 fish survey conducted at 457 sites in 109 rivers. Efforts are also under way to include data from the WDNR's Statewide Paradox Database, containing data from 1938-1992. These historic data will provide access to data collected during 18,000 surveys. The Paradox Database was the result of an initiative by WDNR to enter historic data into a centralized database and warehouse (basically a crew of 2-4 data entry specialists traveled to field offices with laptop computers and entered fisheries data (stored on paper field sheets) into a standardized data entry system).

Fish and habitat monitoring surveys by WDNR are conducted using standardized protocols (developed by the Central Office) with data recorded on standardized datasheets (J. Griffin, WDNR, pers. comm., 2010). Forms in the database were developed for easy data entry. When the database was first implemented, data entry was a slow process. However, over time problems were addressed to speed the data entry process. Recently a utility was added to allow biologists to enter data into a spreadsheet template directly into the database, which has resulted in a faster data entry process. Additionally, WDNR is planning a pilot study to examine the feasibility of using tablet or PDA devices to capture data in the field which would also speed data entry. The digital PDA data would be uploaded to the central database automatically.

The database is secured; biologists and database coordinators each have a username and password. The WDNR has strict rules about allowing individuals outside of the Department to have access to the database.

Data quality and control is handled at a couple of different levels for the WDNR database (J. Griffin, WDNR, pers. comm., 2010). Guidelines for quality control of data were developed by the Central Office and distributed to biologists. Survey data quality control status (i.e., data entry not complete; data entry complete not proofed; and data entry complete and proofed) is reported by biologists in the database. The database has built in quality control checks such as bounds for fish lengths and weights. These prompt the user if measures are outside of reasonable limits. They have also developed some error checking programs that flag records that appear to contain errors. While the flags identify records that need to be verified, they can be also be used to exclude questionable data when summary reports are developed.

WDNR biologists can easily retrieve the data they enter into the database. The database has a program to query data and download data into an Excel spreadsheet (J. Griffin, WDNR, pers. comm., 2010). In addition, WDNR uses Oracle Business Intelligence Discoverer, software, to allow biologists to set criteria and generate a custom summary report for mark- recapture data, length frequencies, length-at-age, relative weight, size structure (i.e., proportional stock density and relative stock density), catch-per-unit of effort, and more.

WDNR has contracts with the United States Geological Survey (USGS) in Middleton, Wisconsin to house and maintain the server and database; and has dedicated staff for the database (J. Griffin, WDNR, pers. comm., 2010). In addition, USGS developed the database. The program is currently operating with minimal staff. Additional staff would be used to improve the database. The WDNR pays for one full-time and two part-time programmers at USGS, and one part-time contractor and a full-time database coordinator at the WDNR. The programmers at USGS house, maintain, and make improvements to the database. The contractor assists with relaying needs by the WDNR to USGS. The database coordinator functions as a liaison between the biologists and the programmers, and fills custom data requests for statewide data. However, the biologists fill outside data requests for the water bodies they manage.

WDNR includes the database in their annual budget. Contract costs with USGS are about $200,000 per year. Original development costs were not specified. Costs for the 2001 implementation year were around $250,000. Costs tend to go up over time as salaries increase; however less time is needed for database development each year.

While the WDNR's database is not perfect, they continue to improve the application. The application is currently functional and is used extensively (J Griffin, WDNR, pers. comm., 2010).

Distributed Type Centralized Database System

Example 3. California Department of Fish and Game, Northern Region Field Data Collection Databases

The databases being developed by CDFG Northern Region to capture field data from several CDFG monitoring programs in the Northern Region are all developed with a goal of standardization (D. Burch, CDFG, pers. comm., 2010). While the applications may seem quite different, all of the data within them can be uploaded to a common database. The concept is to base the structure and formatting on a centralized database schema (entity diagram) that, at this point, only exists on paper. The purpose of the database application is to streamline data entry, data management, provide analysis tools, and ease reporting requirements. The distributed type database system is designed to be flexible so that new columns can be added or selected for use. The applications are currently designed to capture data for creel surveys, carcass surveys, and redd surveys. The central database schema was designed to easily add additional survey types (e.g., RST, snorkel surveys, video monitoring).

The database schema is very similar to the CDFG Information Technology Branch's BIOS database schema. The BIOS database schema was developed to capture a broader range of information and is largely in the development stages. There are currently no examples of fisheries monitoring applications in the BIOS Database (P. Gaul, CDFG, pers. comm., 2010). The Northern Region database applications have been modified so that data can be uploaded to the BIOS database at some point in the future (i.e. they are BIOS compliant).

The databases were developed in Microsoft Access, some "front end" user interfaces with built in forms and pre-built queries and standardized reports are also in Access. Other user interfaces were developed for use with a PDA. Both the front and back end databases are distributed for installation on the local computer and PDA equipment. Individuals control the data and upload and export the data as needed. There are plans to develop a utility to upload data periodically for archive in a "central data store" most likely an intranet site.

Currently, the Northern Region Database Applications are supported and maintained by one programmer analyst (D. Burch, CDFG, pers. comm., 2010). The database applications are developed for biologists that request database/programming assistance. The distributed databases have been in use for over five years, but they are still in the development phase. The spawner survey database, a PDA application, is currently being used by Seth Ricker and Sean Gallagher, CDFG Northern Region fisheries biologists.

As is currently the case in the Central Valley, each biologist establishes protocols and standards for their project and databases must be flexible (include additional columns and code), to accommodate variations in field protocol and personal preference. This requires intensive programmer time.

Example 4. Interagency Ecological Program Rotary Screw Trap Database Applications with centralized Bay Delta and Tributary Database (BDAT)

The Bay Delta and Tributaries database (BDAT), including the Rotary Screw Trap (RST) component was created to meet the needs of the Interagency Ecological Program (IEP) (R. Breuer, CDWR, pers. comm., 2010). A database specialist with the California Department of Water Resources (CDWR) developed a "one size fits all" database template to capture all RST data and prepare the data for upload into the BDAT. The RST database is a distributed type database where copies of the database were shared with various agencies and programs in the CV. Use of the database and submission of data for upload into BDAT was voluntary. CDWR provided support to local CDWR offices and if other agencies requested assistance, but there was never a plan to maintain databases for all agencies. Dedicated funds were not provided to CDWR to create and maintain the databases or upload data to BDAT. CDWR is not mandated to collect RST data and it is not a priority. The IEP's focus is in the Delta and most of the RSTs are further upstream so most of the RST data is not a priority for the IEP. Providing the IEP- type databases and hosting RST data to BDAT was a service that CDWR provided. The service was not being utilized and so other avenues for sharing data are being explored. The CDWR intends to focus IEP funding toward data collection of a higher priority for the IEP.

Example 5. Idaho Department of Fish and Game's Stream Database

The Idaho Department of Fish and Game (IDFG) developed a collection of databases (IFWIS group) to hold raw field data collected from hatcheries (HDMS database), adult salmonid spawning surveys (SGS database), and stream surveys that collect fish (multiple species) and habitat data (SSS database) throughout Idaho (Harrington and Butterfield; IDFG; pers. comm., 2010). Originally, the effort was established to collect standardized data for the regional StreamNet database, but it has evolved over time. The hatchery release database was started 11 years ago and is being re-created with additional functionality to include genetics information that is now being used to identify eggs up to release from the hatchery and salmon that move throughout the Snake River basin. The hatchery trapping database was developed 4-5 years ago, the SSS database is older than 4 years old, and the SGS started 4 years ago and was just implemented in the summer of 2009. This database is used by many individuals within multiple agencies including IDFG, two Native American Tribes, United States Forest Service (USFS), and the USFWS.

The IFWIS group consists of a centralized database and several other distributed-type databases (Harrington and Butterfield; IDFG; pers. comm., 2010). All databases are hosted on an SQL server. Biologists enter stream survey data online directly into the SSS database on the SQL server. The other databases (HDMS and SGS) are a distributed type, where the databases are distributed in two formats in a Microsoft Windows environment to the field offices and data coordinators. The distributed databases are flexible enough to allow for a variety of installations. The field databases may not even resemble the SQL server database. A database is installed on an individual's computer. After an individual enters data into a field database, the database is periodically uploaded and exported to a coordinator database for review. Data are then uploaded from the coordinator database to the SQL server database. Conversion of formats happens automatically when data is uploaded from a field database to the SQL server database.

Data quality control is implemented for the IFWIS group. For the SGS distributed databases, individuals are instructed to make edits in their own data and then re-submit the data to the coordinator database (Harrington and Butterfield, IDFG, pers. comm., 2010). In some cases, established dates are set for the data to be finalized and submitted to the coordinator database or SQL server. Data coordinators also do some quality control procedures on the data prior to upload to the SQL server, where data errors can be tracked.

IDFG plans to continue to maintain and develop these databases. IDFG accepted responsibility for costs, but this program is being managed by mitigation funding (C. Harrington, IDFG, pers. comm., 2010). The cost to house and maintain the database was not provided. IDFG has one of the largest IT Departments in the state of Idaho, and the program is wrapped into the IT Department. Staff includes a program manager, one database assistant, three programmer analysts, and at least three data coordinators. They believe that once the programs are completed and people get used to data entry, staffing will decrease to one programmer for a variety of databases. Costs are being lowered by dropping their five physical servers and using virtual servers, where cost savings are in power, maintenance and upgrades. In addition, the costs of the virtual servers will be shared across the Department.

Summary of Recommendations for Creating and Implementing a Standardized Database System

The managers that were interviewed for the databases described above were asked to share their recommendations for designing and implementing a standardized data management system in the CV for steelhead and Chinook salmon monitoring programs. These recommendations are their opinions based on their experiences with the database applications they work on. Lessons they learned from their experiences may provide useful information in the development and implementation of a standardized data management system for CV steelhead and Chinook salmon monitoring programs.

Unanimously, everyone interviewed agreed that biologists must be included in the development of the database (J. Azat, CDFG, M. Banach, PSMFC, D. Burch, CDFG, R. J. Griffin, WDNR, C. Harrington, IDFG, R. Breuer, CDWR, pers. comm., 2010). Biologists need to be included to help identify what they need and want from the database system. Biologists should provide input as to what fields need to be in the database, what reports are needed, and they should be comfortable with the data entry forms, and other functions of the database. Biologists should be asked to test and critique data forms and reports developed prior to production, which will help improve the utility of the database (J. Azat, CDFG, J. Griffin, WDNR, pers. comm., 2010). Biologists should not be asked to input data into a database until they can effectively access, query, and export or download their own data (J. Griffin, WDNR, pers. comm., 2010). Problems and questions need to be addressed quickly; this builds a trust between the database managers, biologists and database users. The biologists must be confident that they will be supported in order for this effort to be successful (D. Burch, CDFG, pers. comm., 2010).

Recommendations were given regarding development of the database. Before a database is created, the desired outputs need to be well defined, such as queries, reports. The database system needs to accommodate data entry at a variety of levels (e.g., PDA, desktop database, online entry) (D. Burch, CDFG, pers. comm., 2010) and allow for fast entry (J. Griffin, WDNR, pers. comm., 2010). The more there is agreement on standardize units of measure and other codes the better, however standardization of units and measure is not necessary. The WDNR and the CDFG Northern Region have worked around dissimilarities by providing descriptive fields. For example one program collects length in inches and another in centimeters. An adjacent field describes the unit of measure. Prior to summary these measures must be converted so that they are reported in a similar unit. The more dissimilar the data, the more complex and difficult the data are to manage (J. Griffin, WDNR, D. Burch, CDFG, pers. comm., 2010).

A few managers emphasized the importance of selecting the right database programmers and developers (C. Harrington, IDFG, pers. comm., 2010). Programmers with a fisheries or other scientific background will have an advantage because they understand the data and how data are collected (J. Azat, CDFG, J. Griffin WDNR, pers. comm., 2010). In the 1980s, IDFG hired two contractors at different times and at least one IDFG programmer was assigned to develop a hatchery release database, but nothing resulted from those efforts. A biologist working at the hatchery saw a need and developed the hatchery release database that was implemented and is still in use. The majority of the programmers working with the example database systems described were trained in fisheries or some other natural resource science.

Strong advocacy is also important, the Idaho team is using power point to help convey concepts and new products planned for development (C. Harrington, IDFG, pers. comm., 2010). It is much easier to gain support when stakeholders can envision the product. Similar advice was noted by other managers. Stakeholders must be able to envision the finished product if they are to understand and support the effort.

Some managers advised not to try to do too much too quickly; start small and build on success (M. Banach, PSMFC, H. Rook, CDWR, pers. comm., 2010). The core structure of the database must be able to accommodate the evolution of new monitoring methods or changes to the methods, and therefore this core structure needs to be well thought out (D. Burch, CDFG, pers. comm., 2010). All of the fields should be identified before the creation of the database, and the database must support the various data collection techniques (J. Azat, CDFG, D. Burch CDFG, J.Griffin, WDNR, pers. comm., 2010). Adding fields to a table in a database later can make the database structure complex or difficult for upload (D. Burch, CDFG, J. Griffin, WDNR, pers. comm., 2010). Watch out for “feature creep”. Feature creep is a tendency for product or project requirements to increase during development beyond those originally foreseen, leading to features that weren’t originally planned and resulting risk to product quality or schedule. Feature creep may be driven by a client’s growing “wish list” or by developers themselves as they see opportunity for improving the product (http://sawaal.ibibo.com/computers-and-technology) (H. Rook, CDWR, pers. comm., 2010).

A successful database program is always based on adequate funding and support (R. Breuer, CDWR, pers. comm., 2010). This group recommended attending the CV Project Work Team meetings regularly and meeting with the participants individually to garner support. Stable long-term funding sources need to be identified.

Potential Fields for a CV Chinook Salmon Monitoring Database

Potential fields were identified that may be included in a centralized database system for the Chinook salmon escapement monitoring programs. The list of fields for fish device counters (Table 1), mark-recapture carcass surveys (Table 2), and carcass surveys (Table 3), should be used for discussion purposes between a database architect and biologists, when determining fields needed in the database for each monitoring program. Additional fields may be identified or fields listed could be excluded from the database. Biologists through meetings will need to identify if certain fields (e.g., length) can be standardized regarding units, or if additional fields will be necessary to accommodate different units of measure (e.g., Unit field with options for inches, centimeters, etc.) or definitions (e.g., female spawning status).

Table 1. Potential fields for fish device counters for inclusion in a centralized database system.

Survey	Fish Device Counter
Survey ID	Survey ID
River	Survey Sequence ID
Survey Type	Device Counter Type
Year	Hours Operated
Comments	Fish ID
	Fish Species
	Direction of Passage
	Date
	Time
	Length
	Depth
	Speed
	Position in Frame
	Comments

Table 2. Potential fields for mark-recapture carcass surveys for inclusion into a centralized database system.

Survey	Collection	Tagging	Recoveries	Chops
Survey ID	Survey ID	Survey Sequence ID	Survey Sequence ID	Number of Ad-clips
River	Survey Sequence ID	Unique Fish ID/Tag	Unique Fish ID/Tag	Number of Non-clipped
Survey Type	Date	River Mile	Chop (Y or N)	Number of Unknown
Year	Survey Week	Ad-clip Status	Release (Y or N)	
Comments	Survey Reach	Fork Length	River Mile	
	Weather	Fresh or Decayed		
	Secchi Disk	Sex		
	Mean Flow	Female Spawning		
	Time of Arrival	CDFG Head Tag Number		
	Time of Departure	CDFG Scale Sample Number		
	Samplers	Genetics Collect (Y or N)		
	Data Recorder(s)	Otoliths Collected (Y or N)		
	Comments	Comments		

Table 3. Potential fields for carcass sampling surveys for inclusion into a centralized database system.

Survey	Collection	Carcass Sampling
Survey ID	Survey ID	Survey Sequence ID
River	Survey Sequence ID	River Mile
Survey Type	Date	Ad-clip Status
Year	Survey Week	Fork Length
Comments	Survey Reach	Fresh or Decayed
	Weather	Sex
	Secchi Disk	Female Spawning
	Mean Flow	CDFG Head Tag Number
	Time of Arrival	CDFG Scale Sample Number
	Time of Departure	Genetics Collect (Y or N)
	Samplers	Otoliths Collected (Y or N)
	Data Recorder(s)	Comments
	Comments	

Reporting Functions for a Database System for CV Chinook Salmon Monitoring Data

Potential reporting functions that could be developed into the front end of the centralized database system (Table 4). Biologists and database architect can use these identified functions as a start to discussing what biologists need from the reporting functions.

Table 5. Potential reporting functions of a centralized database system for data collected from Chinook salmon monitoring programs.

Capture History Matrix
Covariate Table
Chops on First Capture Table
Descriptive Statistics
Length Frequency Histograms

LITERATURE CITED

Johnson, C. L, G. M. Temple, T. N. Pearsons, and T. D. Webster. 2009. An evaluation of data entry error and proofing methods for fisheries data. Transactions of the American Fisheries Society 138:3, 593-601. Available: http://afsjournals.org/doi/abs/10.1577/T08-075.1. (March 2010)

StreamNet. 2009. Considerations for regional data collection, sharing, and exchange. White paper. Bruce Schmidt.

Xploretech, Xplore Technologies Corporation of America [internet], Case Study Field Service Minnesota Department of Natural Resources' Division of Fish and Wildlife, 2007. Xplore Technologies. Available: http://www.xploretech.com/AboutUsSubPages/cspdfs/fieldservicescs/mnndrcs.pdf (March 2010).

PERSONAL COMMUNICATION

Azat, J., CDFG, pers. comm., Central Valley Chinook salmon escapement monitoring summary reports and Grand Tab, 2010.

Banach, M., PSMFC, pers. comm., StreamNet, 2009

Breuer, R., CDWR, pers. comm., BDAT data system and associated Interagency Ecological Program's rotary screw trap database., 2010.

Burch, D. CDFG, pers. comm., Distributed Access database developed for monitoring programs in CDFG Region 4, 2010.

Harrington, C. and B. Butterfield. IDFG, pers. comm., Idaho Department of Fish and Game's Stream database, 2010.

Harrington, C. IDFG, pers. comm., Idaho Department of Fish and Game's Stream database, 2010.

Gaul, P., CDFG, pers. comm., California Department of Fish and Game BIOS program, 2010.

Griffin, J., WDNR, pers. comm., Wisconsin Department of Natural Resources Statewide Fish and Habitat database, 2010.

Rook, H., CDWR, pers. comm., BDAT data system and associated Interagency Ecological Program's rotary screw trap database., 2010.