Spring-run Workshop Factsheet

Monitoring of Central Valley spring-run Chinook salmon

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Introduction

Long-term monitoring of Central Valley spring-run Chinook salmon (hereafter CVSC) populations at critical life stages is performed by a variety of state and federal resource agencies. Although this core monitoring might be adequate for quantifying the presence and timing of CVSC populations, it is important to evaluate whether it adequately assesses the influence of water management actions, such as the State and Federal Delta water project operations, on their overall dynamics and persistence. To do so let's first discuss the current state of CVSC population's freshwater monitoring, which we classified into two main categories; adult and juvenile monitoring (Figure 1).

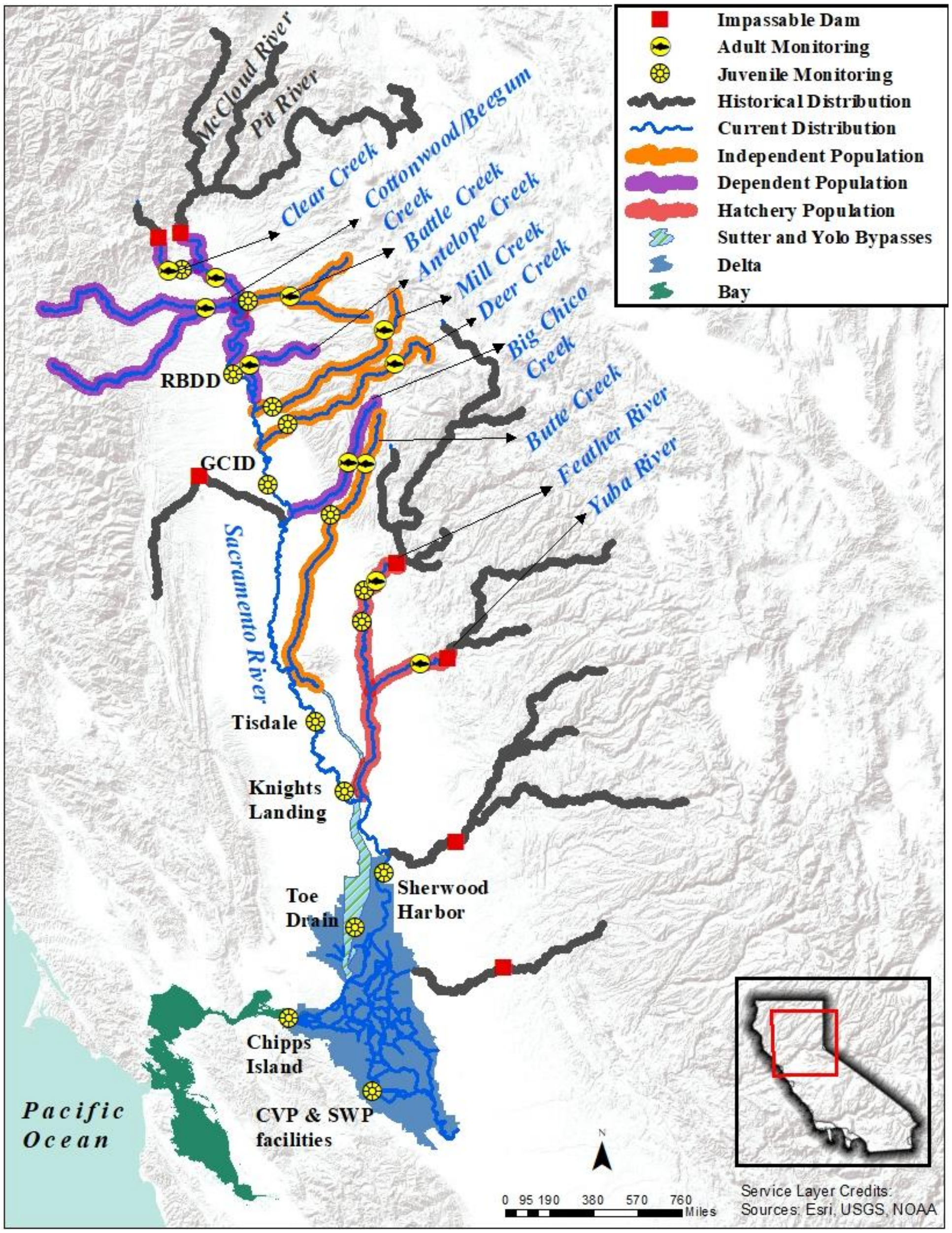

Figure 1. CVSC populations and current CVSC monitoring map. Independent populations correspond to populations that were historically not sustainably altered by exchanges of individuals with other populations, while dependent populations likely would have not persisted without immigration from other streams. This follows the classification proposed by Lindley et al. (2004).

Feather and Yuba River populations were historically independent populations, but are considered here to be hatchery-dominated populations, due to the genetic proximity of Feather River Hatchery adults and natural spawners and the large presence of hatchery fish among in-river spawners (Lindley et al. 2004). Because CVSC likely did not spawn in the mainstem Sacramento River before the construction of Keswick and Shasta dams and it is believed that serious hybridization has occurred with fall-run fish, we consider this population to be dependent.

Adult Monitoring

CVSC adult monitoring has several goals including 1) to quantify the total escapement number, which corresponds to the number of adult returning to the spawning ground, 2) to monitor summer holding and spawning, which includes timing, success and spatial distribution, and 3) to quantify the number of eggs and fry generated per spawner (Table 1). CVSC escapement inventories in the upper Sacramento River basin have been sporadically conducted since the 1940's, but were incomplete, inconsistent and not replicable. Since the early 1990's, there has been an effort to standardize sampling methods to provide consistent and reproducible CVSC adult escapement estimates. However various watershed-specific challenges and uncertainties in adult collection and escapement estimation remain. Overcoming those challenges would improve the accuracy of a CVSC juvenile production estimate (JPE). Below we identify some of those challenges.

Challenge: Lack of adult holding and pre-spawning mortality assessment

Adult holding and pre-spawn mortality during the summer months could be an important driver of CVSC dynamics in certain years and watersheds. However, this source of mortality is not always properly evaluated or accounted for when developing estimates of escapement. For instance, if abundance estimates come only from adult sampling performed during their upstream migration in the spring/early summer (e.g. video monitoring at downstream trap), this could create a discrepancy between escapement and actual spawner numbers, with a potential overestimation of the spawner abundance and further overestimation of the total number of eggs produced. In Butte Creek, where large pre-spawning mortality events have been observed in the past, the estimation of pre-spawning mortality is performed by using a variety of sampling methods; snorkel surveys are conducted early summer, and in conjunction with video monitoring, provide an escapement estimate before any pre-spawn mortality. Additionally, a pre-spawning carcass survey and a subsequent spawning carcass survey are conducted in the summer and early fall to evaluate pre-spawning mortality and to provide an alternative spawner estimate to compare to the snorkel escapement estimate. If extended carcass surveys are challenging to implement, an alternative approach, used in Mill and Battle Creeks for instance, is to complement video monitoring with redd counts in order to provide an additional abundance estimate that only include returning adults that successfully spawned.

Challenge: Inconsistent assessment of sampling efficiency

In most of the CVSC watersheds, adult sampling method efficiency is not assessed and the error in the number of adult spawners observed, related to sampling uncertainty, is not evaluated, potentially creating a bias in the escapement numbers reported. In Mill and Deer Creeks for instance, where both video monitoring and snorkel or redd surveys are performed, the sampling efficiency of each method is not estimated, and the higher count of the two independent methodologies is used to report the final escapement estimate each year. However, there are few examples where the number of CVSC adult spawners recorded is expanded to account for sampling method uncertainty. In Butte Creek, a Cormack-Jolly-Seber model is used to expand the carcass mark-recapture survey's raw adult counts to population production estimates (Garman and McReynolds 2009). In Clear Creek, a Generalized Additive Model (GAM) is sometimes used when escapement is estimated from video monitoring, to derive passage values for days that contain video outages (Bottaro and Chamberlain 2019). In Battle Creek a passage estimate equation is also used to expand adult counts during video monitoring's outages and poor video quality (Bottaro and Earley 2020).

Challenge: Spatio-temporal spawning overlap between spring- and fall-run adults

Extracting and reporting accurate estimates of CVSC escapement numbers is challenging in some watersheds because of overlap between spring- and fall-run spawning in space and time. This is further complicated by the lack of a suitable means of distinguishing between spring- and fall-run adults during the spawning period. In the upper Sacramento River, the traditional process of estimating natural CVSC spawning effort uses the aerial redd data and assigns a spring-run number based on new redds observed in late August through September. There is considerable uncertainty and discussion amongst biologists as to the exact nature of the CVSC population in the Sacramento River (Pipal 2005). In the Feather River, adult CVSC are included in fall-run Chinook counts. The installation of two fish barrier weirs to temporally and spatially separate spring- and fall-run spawners is a proposed action included in DWR's Fish Weir Program (NMFS 2016). In Clear Creek, a segregation weir is installed every year for the same purpose. In the Yuba River, Vaki passage data are used to develop a statistical model that help define a demarcation date between the spawning of the two races upstream of Daguerre Dam. However, model improvements have been suggested and are ongoing to better separate spring- and fall-run adults. Some level of spawning overlap is also sometimes observed in Mill, Deer and Butte Creeks. In Butte Creek, efforts are made to discourage fall run passage at the Parrott-Phelan diversion dam fish ladder, but fall run can ascend the dam and sometimes over the bar rack used for this purpose. Securing reliable funding to collect carcass tissue sample during the entire spawning time period and genetically identify their run origin could help improve CVSC escapement estimations (see "Identifying spring-run" factsheet for additional genetic identification information).

Challenge: Insufficient adult length and sex data

Fish length and sex information is necessary to accurately evaluate the number of eggs produced per spawner each year, and egg production from CVSC streams is required to estimate a fry equivalent production index (used for JPE calculation, see "Developing a juvenile production estimate (JPE) for Central Valley spring-run Chinook salmon" factsheet for more information). However, this type of information can only be accurately collected when carcasses are recovered, which could be challenging in some CVSC streams. This could be in part due to low returning adult numbers in a given year, and/or insufficient monitoring funding. Securing reliable funding for carcass surveys, and/or using fish size and sex ratios from other CVSC streams could be considered to improve CVSC egg production estimates.

Other Considerations

Additional sampling is performed in some CVSC watersheds to obtain biological and environmental information that could also be important for the development of a JPE. For example, carcass otolith sampling is currently ongoing in various CVSC tributaries such as Mill, Deer, Butte, Clear and Battle Creeks, and the Feather River, and isotope analysis can be used to study successful CVSC juvenile rearing and migrating strategy characteristics (Sturrock et al. 2019, Cordoleani et al. In prep, see "Life history variation in Central Valley spring-run Chinook salmon" factsheet for more information). Environmental factors such as water temperature, flow, redd physical data (e.g., substrate used, redd size) are also monitored in some of the CVSC watershed's adult holding and spawning reaches (e.g., Clear and Battle Creeks, Yuba River), to investigate egg incubation's habitat suitability and success. Finally, the CVSC evolutionary significant unit includes Feather River Hatchery (FRH) spring-run production, and the adult tagging and spawning efforts at the hatchery might provide genetic sampling opportunities of hatchery and natural origin CVSC, as well as an opportunity to examine interannual variation of natural versus hatchery and abundance returning to the hatchery.

Table 1. CVSC adult monitoring summary.

Watershed	Monitoring method	Variable measured#	Sampling efficiency estimate	Tissue sampling	Otolith sampling
Upper Sacramento River[1]	Aerial redd survey	Escapement	No	No	No
Clear Creek[2]	Snorkel, redd and carcass surveys, video monitoring	Escapement and successful spawner estimates, summer holding/spawning distribution	Yes (partially)	Yes	Yes
Cottonwood Creek[1]	Snorkel survey and video monitoring	Escapement	No	No	No
Battle Creek[3]	Fish trapping/sorting, video monitoring, snorkel and carcass surveys	Escapement and successful spawner estimates, summer holding/spawning distribution	Yes	Yes	Yes
Antelope Creek[1]	Snorkel survey and video monitoring	Escapement	No	No	No
Mill Creek[1]	Redd survey and video monitoring	Escapement and successful spawner estimates, summer holding/spawning distribution	No	No	Yes
Deer Creek[1]	Snorkel survey and video monitoring	Escapement, summer holding/spawning distribution	No	No	Yes
Big Chico Creek[4]	Snorkel survey	Escapement, summer holding/spawning distribution	No	Yes	Yes
Butte Creek[4,5]	Carcass and snorkel surveys, Vaki Riverwatcher	Escapement and successful spawner estimates, summer holding/spawning distribution	Yes	Yes	Yes

Feather River – Natural*[6]	Carcass Survey, Adult Angling/ Telemetry study	Escapement (combined with fall-run), summer holding/spawning distribution	No	No	Yes
Yuba River[7,8]	Carcass and redd surveys, Vaki Riverwatcher	Escapement, summer holding/spawning distribution	No	No	Yes

[#] The variable "Escapement" corresponds to the number of adults that have returned to the spawning ground. CVSC adult escapement estimates are available here: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=84381&inline

* We only consider here CVSC adults spawning in the river, i.e. Feather River Hatchery production is not included.

[1] Killam D. 2019.
[2] Bottaro and Chamberlain 2020.
[3] Bottaro and Earley 2020.
[4] Garman and McReynolds 2009.
[5] Garman and McReynolds 2012.
[6] DWR 2011.
[7] YRMT 2013.
[8] PSMFC 2015.

Juvenile Monitoring

The goals of CVSC juvenile monitoring include: 1) to assess the relative juvenile abundance, 2) to quantify the total juvenile salmon production (the number of juveniles migrating past a location) and 3) to collect juvenile salmon life history information such as outmigration timing and size distribution (Table 2). Juvenile monitoring is mainly performed using a rotary screw trap(s) (RST) located downstream of the spawning reaches in CVSC tributaries (USFWS 2010), as well as with trawl or beach seine, at key locations along their migratory corridor (e.g. in the Sacramento River and Delta). Currently, very few CVSC watersheds are estimating JPE, due to the difficulties identified below:

Challenge: Lack of sampling efficiency

To expand raw juvenile capture numbers to total abundance values, trap efficiency studies have to be performed throughout the trapping season. However, only a few CVSC watersheds currently conduct trap efficiency trials at the levels necessary to reliably expand estimates because of the frequency of high flow events in these unregulated tributaries (e.g., Butte, Mill and Deer Creeks), and/or access to large fish numbers required for the trials. However, surrogate fish such as hatchery fall- or spring-run juveniles could be used for the trials in some of these streams. Additionally, a similar approach to the one currently implemented to generate accurate trawl efficiency and abundance estimates of juvenile winter-run Chinook at Chipps Island, using paired coded wire (CWTs) and acoustic tagged (AT) hatchery fish, could be developed to estimate trap efficiency at key CVSC monitoring locations.

Challenge: Need for better run identification

In most CVSC watersheds, sampled juveniles are assigned to run based on the length-at-date (LAD) criteria, which have been shown to be inaccurate for CVSC compared to genetic identification (Pyper et al. 2013a). Therefore, in locations where both fall- and spring-run are found (e.g. Sacramento, Feather, Yuba Rivers), CVSC juvenile abundance estimates frequently include fall-run fish and/or exclude misclassified spring-run fish due to overlap in size and outmigration timing. Developing a more robust juvenile fish run identification methodology and securing reliable funding to implement it could improve CVSC juvenile abundance estimations (see "Identifying spring-run" factsheet for additional genetic identification information).

Challenge: Insufficient juvenile survival estimates

Estimation of fry-to-smolt survival and smolt survival from natal streams to the Delta is required to develop a CVSC JPE (see "Developing a juvenile production estimate (JPE) for Central Valley spring-run Chinook salmon" factsheet for more information). However, CVSC fry survival estimates are difficult to obtain due to tracking challenges related to their small size and the absence of large CWT programs in most CVSC streams that could be used to calculate fry survival rates. The Feather River Hatchery is one exception, where spring-run Chinook fry are 100% CWTed at the hatchery before being released in the river. If a large number of tagged juveniles are recovered in the Delta this information could be used to estimate in-stream fry survival. Additionally, the use of passive integrated transponder devices (PIT tags) to mark and track parr-size juveniles (fish > 50mm) in the CVSC streams could help gain insight into fry-to-smolt survival.

With new advances in acoustic tagging technology (smaller tags, longer battery life), biotelemetry has become a well-established tool in estimating CVSC smolt-sized juvenile survival through their migratory corridor (Cordoleani et al 2019, Notch et al. 2020, Singer et al. 2020). However, most of the tagging studies occurred during the last California drought period and likely do not represent the suite of hydrological conditions and water year types CVSC juveniles experienced during the modeled years. Furthermore, because of the small number of tagged fish in some of these studies, Delta smolt survival estimates were associated with large error margins. Therefore, securing reliable funding for the implementation of long-term acoustic tagging studies throughout the Central Valley could help provide better smolt survival estimates to the Delta for CVSC populations.

Other Considerations

Finally, additional monitoring efforts are performed in some CVSC watersheds that could also help the development of an accurate CVSC JPE. As an example, a study on disease prevalence and the impact on juvenile health and outmigration success has been conducted in the Feather River (Foott et al. 2019). Juvenile tracking studies, using CWTs or ATs, of both CVSC wild and hatchery fish can also provide critical information such as 1) movement and presence of juveniles from various size classes (e.g. fry, sub-yearling, yearling) at key locations and time periods (e.g, in the Delta during opened DCC gate period), and 2) sub-yearling migration routes throughout the Central Valley (see "Life history variation in Central Valley spring-run Chinook salmon" factsheet for more information).

Table 2. CVSC juvenile monitoring summary. FL = Fork Length, W = Weight, K = condition factor.

Watershed	Monitoring Method	Years of operation	Season of operation	Variable measured^	Traits measured	Tissue sampling
Clear Creek[9]	RST	1998 - present	November – June	Production, outmigrant size & timing	FL - W - K	Yes

Sacramento River-Balls Ferry	RST	1996 - 1999	October-September	Production, outmigrant size & timing	FL	No
Cottonwood Creek	None					
Battle Creek[10]	RST	1998 - present	November – June. Restarting year round in 2020	Production, outmigrant size & timing	FL - W – K	Yes
Sacramento River - Red Bluff Diversion Dam[11]	RST, telemetry study	1995 - 2000, 2002 - present	January - December	Relative abundance, outmigrant size & timing, smolt survival	FL	Yes (during the fall period)
Antelope Creek	None					
Mill Creek[12]	RST, telemetry study	1996 - 2010	November - June	Relative abundance, outmigrant size & timing, smolt survival	FL	No
Deer Creek[12]	RST, telemetry study	1994 - 2010	November - June	Relative abundance, outmigrant size & timing, smolt survival	FL	No
Sacramento River - GCID Hamilton City[13]	RST	1991-2009, 2013-present	January-December	Relative abundance, outmigrant size & timing	FL	No
Big Chico Creek[14]	RST	1999 - 2003	November - May	Relative abundance, outmigrant size & timing	FL	No
Butte Creek[14]	RST, CWT and telemetry study	1995 - present	October - June	Relative abundance, outmigrant size & timing, smolt survival	FL	No
Sacramento River – Tisdale[15]	RST	2010 - present	October - June	Relative abundance, outmigrant size & timing	FL - K	As needed
Sacramento River - Knights Landing[16]	RST	1995 - present	Aug/Sept - June (since 2015)	Relative abundance, outmigrant size & timing	FL - W	Yes (since 2017)
Feather River[17]	RST, beach seining, snorkel survey,	1998 - present	November/ December - June	Production, outmigrant size & timing, disease	FL	Some

	CWT and telemetry study			monitoring, smolt survival (FRH fish)		
Yuba River[18]	RST	1999 - 2009	October - June	Relative abundance, outmigrant size & timing	FL - W	No
Sacramento River – Sherwood Harbor[19]	Trawl	1988 - present	Year-round since 1994	Relative abundance, outmigrant size & timing	FL	Yes
Yolo Bypass[20]	RST, fyke trap, beach seine, telemetry study	1998 - present	January – June (RST), September – Junes (fyke), year round (seine)	Relative abundance, outmigrant size & timing, spatial distribution, smolt survival	FL	Yes
Delta – various locations (e.g. Chipps Island[19])	Trawl	1976 - present	Year-round since 1996	Relative abundance, outmigrant size & timing	FL	Yes
Delta – various locations[19]	Beach Seine	1970 - present	Year-round since 1995	Spatial distribution	FL	No
Delta – CVP and SWP facilities	Salvage facilities	1968 - present	Year-round	Outmigrant size & timing, fish count	FL	Yes

^ The variable "Production" corresponds to the JPE obtained from the expansion of raw juvenile counts.
[9] Schraml et al 2020.
[10] Schraml and Earley 2020.
[11] Poytress et al. 2014.
[12] Johnson and Merrick 2012.
[13] Coulon 2008.
[14] Garman and McReynolds 2009.
[15] Purdy and Coulon. 2013.
[16] Julienne 2016.
[17] DWR 2019.
[18] YRMT 2013.
[19] Barnard et al. 2015.
[20] Schreier et al. 2018.

Useful Webpages

Useful information and data related to CVSC populations can be found on SacPAS (Central Valley Prediction & Assessment of Salmon), CalFish, Yuba River Management Team, and Environmental Data Initiative (EDI) webpages.

Potential Questions for the Development of a Juvenile Production Estimate (JPE):

1. What are the key monitoring gaps that we would need to develop a JPE?
2. Which necessary information is available or currently missing to apply each JPE approach?
3. What are the trade-offs to filling those data/information gaps?
4. Is a JPE more critical for some populations/locations more than others?

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