Memorandum

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Department of Water Resources

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Subject: Preliminary SWP Chinook Salmon Survival Estimates for WY 2016

Introduction

In 2009 the National Marine Fisheries Service (NMFS) issued a Biological and Conference Opinion (BiOp) on the Long-term Operations of the Central Valley Project (CVP) and State Water Project (SWP) requiring the Department of Water Resources (DWR) to implement Reasonable and Prudent Alternative (RPA) action (IV 4.2(2)) to reduce pre-screen losses of Endangered Species Act (ESA) protected salmon and steelhead within Clifton Court Forebay (Forebay) to no more than 40 percent (NMFS 2009). Previous studies have shown pre-screen losses (PSL) of federal and State ESA listed salmonids ranging from 63% to 99%.

Since the issuance of this requirement, DWR has undertaken or has planned a number of proposed actions to comply with this pre-screen loss reduction target. Most recently, in WY 2016, DWR implemented a pilot study (Clifton Court Predator Reduction Study) from April 20, 2016 to May 18, 2016 to relocate predatory fishes collected with electrofishing gear in the Forebay to nearby Bethany Reservoir. In tandem with these actions and to evaluate their effectiveness, DWR initiated a mark-recapture study in WY 2013 to evaluate losses of marked salmonids from the SWP intake at the Forebay radial gates to the termination of the fish salvage process at the John E. Skinner Delta Fish Protective Facility (SDFPF). This memorandum describes the preliminary results from the salmonid mark-recapture study for WY2016 to aid in evaluating and refining the continued implementation of the Clifton Court Forebay Predator Reduction - Electrofishing Study (PRES). Final results from this mark-recapture study will be detailed in a future report documenting WY 2016 survival estimates for the SWP including the Forebay and SDFPF.

Methods

Chinook Salmon Stock and Husbandry

During WY 2016, a mark-recapture study was conducted from January through June utilizing Passive Integrated Transponder (PIT) tagging technology. Juvenile late-fall run Chinook Salmon and fall run Chinook Salmon for this study were obtained from the Coleman National Fish Hatchery and Mokelumne River Fish Hatchery, respectively. Late-fall run Chinook Salmon were utilized in releases from January through early-April, while fall-run Chinook Salmon were released from early-April through May. The selection of these runs and their respective size classes was intended to be representative of the general seasonal size distribution of Chinook Salmon salvaged at the SDFPF. Plans to utilize steelhead trout for the WY 2016 study year were cancelled due to study fish being unavailable from area fish hatcheries in large part due to ongoing drought conditions.

Juvenile salmon provided by the hatcheries were transported in two separate events using a 1,700-L insulated fish hauling tank and transferred to the Fish Science Building (FSB) at the SDFPF. Upon arrival at the FSB facility, fish were transferred to 1,362-L and 3,558-L circular, aerated fish holding tanks. These tanks were supplied with either "raw" water from the California Aqueduct (flow through water with minimally treated with UV sterilization and mechanical filtration) or "recirculated" water (filtered, recirculated, and temperature controlled water). Use of the recirculated water system was initiated in March 2016 to prevent fish health problems as a result of temperature fluctuations in the California Aqueduct water source. The salmon were fed a sinking, pelleted feed daily except when fasted for 24 hours before tagging and the 48-72 hour period between tagging and release.

PIT Tagging

Juvenile late-fall run Chinook Salmon selected for PIT tag implantation ranged in fork length from 100 to 241 mm, with a mean of 174 ± 23 mm (mean ± SD). Fall run Chinook Salmon selected for PIT tag implantation ranged in fork length from 45 to 140 mm, with a mean of 102 ± 14 mm (mean ± SD). Salmon were tagged following the general guidelines of the PIT tagging procedure manual prepared by the Columbia Basin Fish and Wildlife Authority PIT Tag Steering Committee (1999). Each juvenile salmon was netted from the holding tank and placed into an 18.9-L anesthesia bath that contained 35 mg/L of Aqui-S 20E. The salmon was left in the bath for 1-3 minutes until anesthetized. Each salmon was measured for length and weight, evaluated for abnormalities or external signs of disease/injury, and the presence of an adipose fin. If the adipose fin was still present, the tagger clipped the fin using dissection scissors to ensure that the salmon was appropriately identified as a study fish if subsequently captured at the SDFPF. A PIT tag implant gun (Biomark, model MK 25) utilizing pre-loaded needles was used to inject the PIT tag (Biomark HPT 12) into the abdominal cavity. The time to PIT tag each fish was less than one minute. Tagged fish were placed into an 18.9-L aerated container and held for observation to ensure recovery. Once recovered, fish were transferred to a 1,362-L tank supplied with raw water and aeration and held for a 48-72 hour recovery period prior to release.

Tagged Fish Releases

To simulate the exposure to high water velocity and turbulence experienced by run of the river fish entrained into the Forebay, small groups of tagged salmon were released immediately upstream of the Forebay radial gates utilizing specially modified 18.9-L buckets (Clark et al 2009). Prior to transportation of tagged salmon to the Forebay radial gate release site, all salmon were checked individually for presence of an operational PIT tag and their tag identification number recorded. Fish with non-operational PIT tags or shed tags were not released, and the total release group size reduced accordingly. Each group of 20 tagged salmon was transported in their 18.9-L release bucket(s), equipped with aeration, to the release site. No more than 5 late-fall Chinook Salmon, or 10 fall run Chinook Salmon were placed in a single bucket to prevent water quality degradation or stress due to overcrowding.

The timing of the releases varied with the daily routine changes in Forebay radial gate operations. Typically, releases were scheduled for the first hour of scheduled water inflows (gate openings) into the Forebay for each day. Notably in WY 2016, for the majority (63 of 66) of releases, releases occurred from 0700-0900 as a result of operational restrictions limiting the openings during night time hours to reduce entrainment of listed fish species. During each fish release, fish were released by lowering the release bucket secured by two lines, one attached to the bucket handle and one attached to the bucket base, to just above the water surface and pulling on the line attached to the bucket base to invert the bucket. PIT tagged salmon releases began on January 10, 2016, and were generally conducted 4 days per week through May 31, 2016 in release groups of 20 fish. Releases of tagged fish ceased at the end of May when daily mean temperatures in the Forebay approached tolerance limits for salmonids. In total, 1,312 PIT tagged salmon in 66 releases were released upstream of the Clifton Court Forebay radial gates with 11, 13, 15, 14, and 13 releases in January, February, March, April, and May, respectively.

Table 1- Chinook Salmon releases conducted during WY 2016 at the Clifton Court Forebay.

	January	February	March	April	May
Late-fall Chinook Salmon	11	13	15	3	
Fall Chinook Salmon				11	13

PIT Tag Detection System

To detect salvaged, PIT tagged salmon released as part of this study, a PIT tag detection system was installed at the two SWP salvage release sites on Sherman Island in the Central Delta. The detection system consisted of three custom made, circular antennae with aluminum shields at the Horseshoe Bend release site (Figure 1) and two custom made, circular antennae at the Curtis Landing release site. Any study fish that were salvaged were trucked to the release sites and released through these pipes outfitted with PIT antennae according to the SDFPF standard operating procedures. All detections of PIT tagged salmon were made post salvage. All PIT tagged salmon detected during the salvage release process were assumed to

have been successfully salvaged and alive[1]. Any PIT tagged salmon encountered during routine counts at the SDFPF were immediately released to a holding tank for subsequent detection on the detection system installed at the salvage release sites. This ensured that all fish were subjected to the entire salvage process through release.

Attached to each antenna was a transceiver/datalogger capable of storing tag detections. The Curtis Landing site was equipped with two types of transceivers/dataloggers; a Destron Fearing FS2001F-ISO and a Biomark HPR+. The antennae at the Horseshoe Bend release site were connected to a series of three Biomark IS1001 transceivers/dataloggers equipped with a battery backup system and remote telemetry. The equipment at the Horseshoe Bend was installed by Biomark and monitored remotely as part of a PIT tagging feasibility study being conducted by the NMFS-Southwest Fisheries Science Center and California Department of Fish and Wildlife in collaboration with DWR as part of a Proposition 1 grant.

Ten tag detection efficiency tests were conducted throughout the study with five at each of the two SDFPF salvage release sites. The efficiency tests utilized groups of either 10 or 40 PIT tagged salmon which were placed directly into the SWP fish hauling truck tank. These fish were subsequently taken to the release site during a routine fish haul and were released through the release pipe outfitted with the PIT tag detection system antennae. Results of the tag detection efficiency test indicated that the efficiency of the two systems was a combined 90.5%.

PIT tag detections and subsequent data analyses were limited to detections occurring on or before June 15, 2016. Therefore, any released (tagged?) fish coming through after that date were not included as part of this analysis. Should any of these fish come through after that date, they would be included as part of a future report documenting final WY 2016 survival estimates for the SWP including the Forebay and SDFPF.

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[1] Striped Bass and other predatory fishes of the size required to consume the PIT tagged salmon are occasionally encountered within the SDFPF fish hauling truck. However, predatory fishes encountered during counts at the SDFPF during experimental salmon releases in 2015 and 2016 were examined for PIT tags and no PIT tags were encountered during these events indicating that predation rates on study fish are likely low.

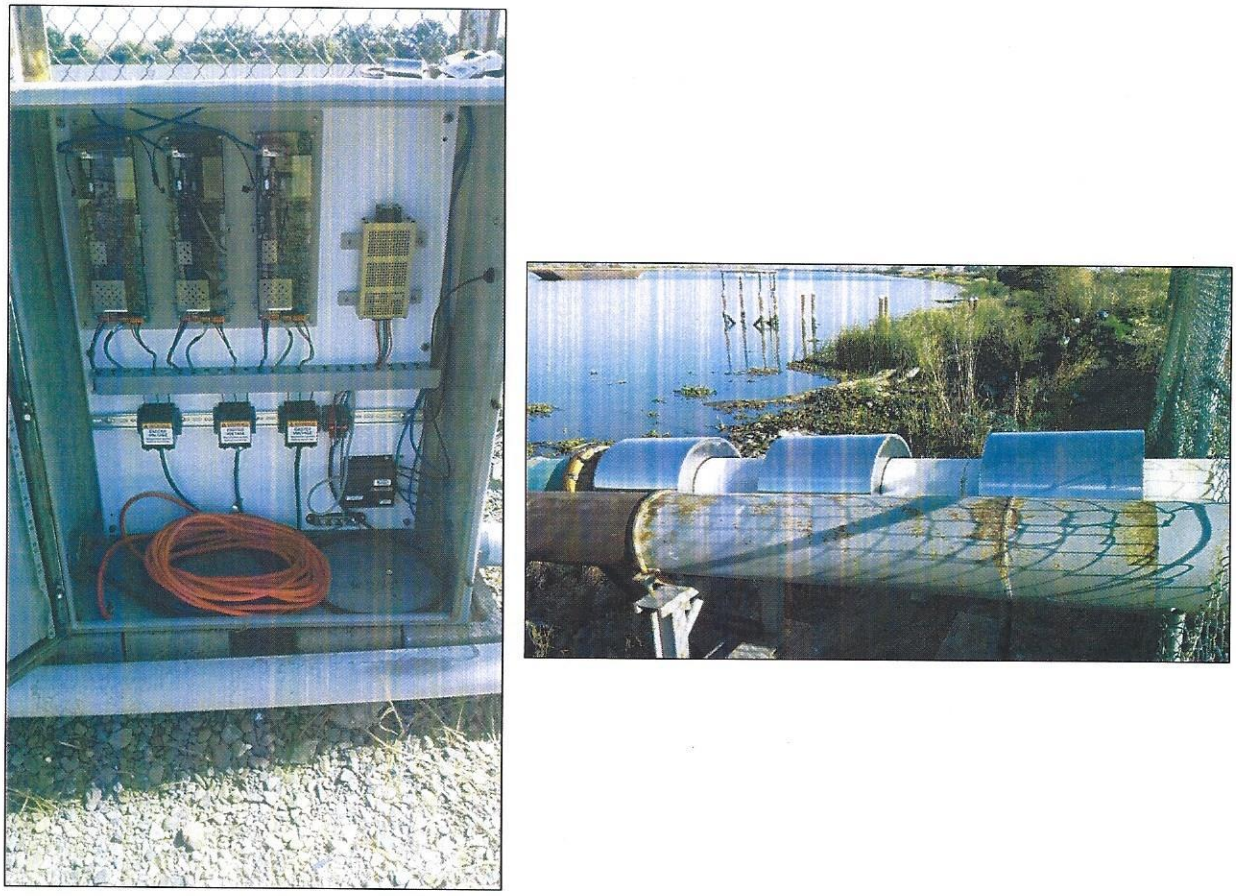

Figure 1- PIT tag detection array installed at the Horseshoe Bend Release Site. Shown are the three Biomark IS1001 transceivers/dataloggers (left) and three custom antennas with their aluminum shields mounted on the salvage release pipe (right).

SWP Water Pumping and Forebay Radial Gate Operations

Forebay hydrodynamics can vary substantially within and among days depending on factors such as water export rates, Forebay radial gate operations, tidal conditions, weather conditions, and water storage within the Forebay (Clark et al 2009). These factors can affect pre-screen loss in the Forebay and salvage at the SDFPF.

Water inflows through the Forebay radial gates were variable during WY 2016, though with marked decreased inflows during April and May. Mean daily inflow ranged from 393 to 4,540 cfs with a season mean of 1,856 cfs (Table 2, Figure 2).

Water exports through Banks Pumping Plant were similar to CCF inflows during WY 2016. Mean daily exports ranged from 0 to 4,528 cfs with a season mean of 1,833 cfs (Table 3).

During the WY 2016 study, atypical Forebay radial gate operations may have also affected pre-screen loss in the Forebay. As indicated earlier, the majority of releases occurred from 0700-0900 as a result of operational restrictions limiting the opening of the gates during nighttime hours to reduce entrainment of listed fish species. While these operations may or may not have affected entrainment into the Forebay, it is notable to point out that historically, under similar seasonal and regulatory conditions, a greater proportion of water would have been exported through the Forebay radial gates during nighttime hours (midnight to 0700). Similarly, some past studies (Clark et al 2009; Wunderlich 2015) conducted the majority of their releases during nighttime hours.

Table 2- Summary statistics for Forebay radial gate water exports from January 1 through June 15, 2016. Data from CDEC.

	January	February	March	April	May	June	Season Total/Mean
Daily CFS min	1,297	1,397	1,164	490	393	1,189	393
Daily CFS max	4,194	2,591	4,540	1,600	1,790	3,992	4,540
Mean	2,224	2,152	2,643	764	957	2,941	1,856

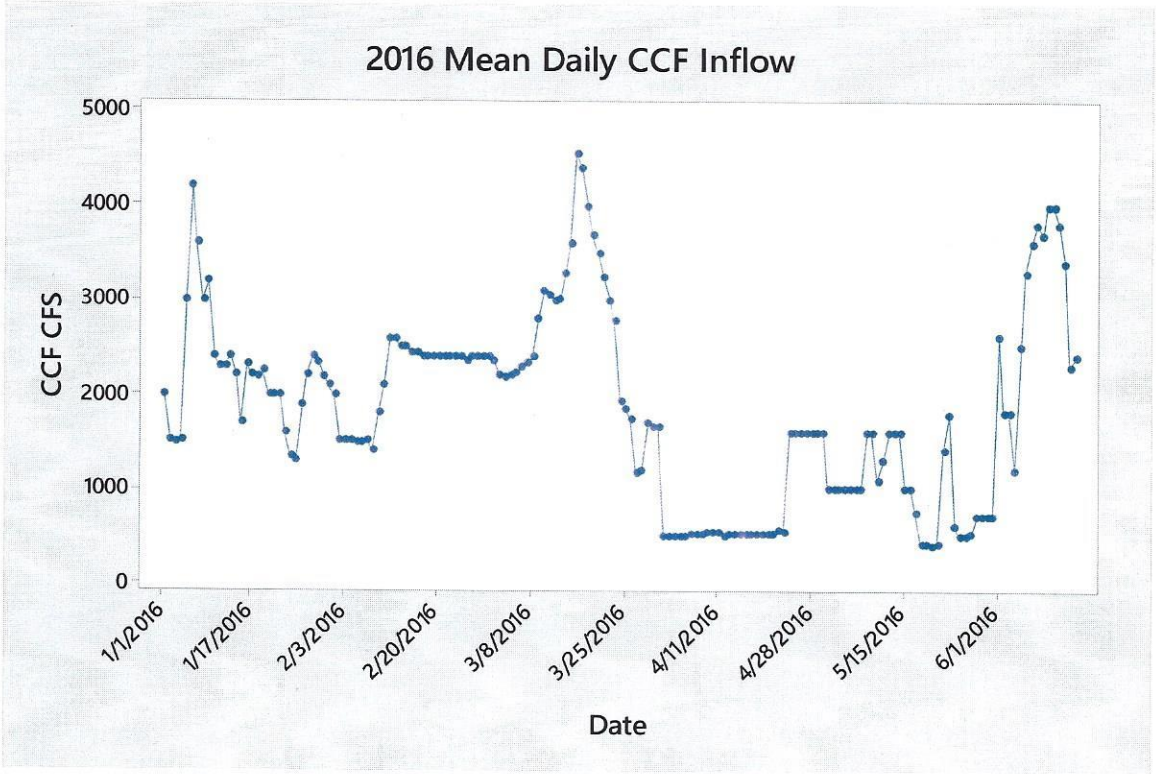

Figure 2- Mean daily inflow (cfs) through the Clifton Court Forebay radial gates from January 1 through June 15, 2016. Data from CDEC.

Table 3- Mean daily exports (cfs) through Banks Pumping Plant from January 1 through June 15, 2016. Data from CDEC.

	January	February	March	April	May	June	Season Total/Mean
Daily CFS min	1,461	1,097	1,276	357	0	729	0
Daily CFS max	4,179	2,782	4,528	1,551	1,707	4,042	4,528
Mean	2,220	2,139	2,633	731	920	2,879	1,833

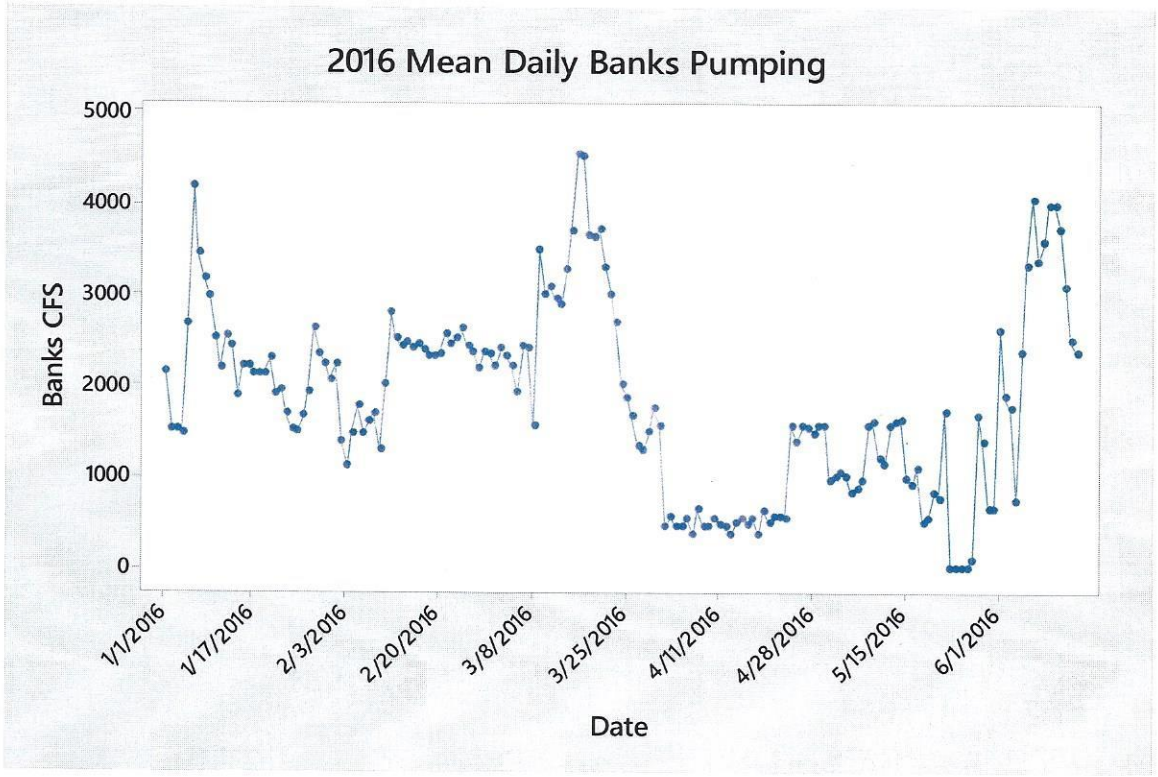

Figure 3- Mean daily water exports (cfs) through Banks Pumping Plant from January 1 through June 15, 2016. Data from CDEC.

Results

Preliminary estimates of Total SWP Loss and Pre-screen Loss (PSL) were calculated using the equations from Clark et al (2009) and Wunderlich (2015) to maintain comparability to prior evaluations. A placeholder value of 78% for SDFPF salvage efficiency was utilized for these analyses (Wunderlich 2015, DWR unpublished data).

Preliminary Total SWP Loss Estimates

Total SWP loss (TL_{SWP}) is defined as the proportion of fish released at the Forebay radial gates that are lost prior to successful salvage at the SDFPF. TL_{SWP} for Chinook Salmon were based upon detections (recaptures) of PIT tagged salmon released at the Forebay radial gates and detected at the SDFPF salvage release sites. TL_{SWP} was calculated for each of the 66 Forebay radial gate release groups as:

$$TL_{SWP} = \left(1 - \left(\frac{Rec_{rg}}{Rel_{rg} \times A}\right)\right) \times 100$$

Rec_{rg} = # PIT tagged Chinook Salmon recovered from Forebay radial gate releases

Rel_{rg} = # PIT tagged Chinook Salmon released at the Forebay radial gates

A = Mean PIT antennae detection efficiency (90.5%)

TL_{SWP} for WY 2016 was estimated to be 93% ± 3% (Mean ± 95% C.I.). TL_{SWP} for each of the 66 release groups ranged from 39% to 100%. Summary statistics for TL_{swp} are shown in Table 4. The percentage of release groups with zero recoveries conducted during WY 2016 ranged from 18% to 77% with a mean of 50% of the releases resulting in 100% loss of the release group (zero recoveries).

Table 4- Summary statistics for Total SWP Loss (TL_{swp}; %) estimates.

	January	February	March	April	May	Annual Total/Mean
No. of Release Groups	11	13	15	14	13	66
TL_{SWP}	80%	90%	96%	97%	98%	93%
S.D.	15%	19%	6%	4%	5%	12%
min	56%	39%	83%	89%	83%	39%
max	100%	100%	100%	100%	100%	100%
% of releases with zero recoveries	18%	54%	53%	50%	77%	50%

Preliminary Pre-screen Loss Estimates

Pre-Screen Loss (PSL) is defined as the proportion of fish released at the Forebay radial gates that were lost within the Forebay prior to the SDFPF trashrack. Due to limitations on the placement of PIT tag detection arrays within the project area, PSL could not be directly determined, but was instead calculated by adjusting the Total SWP loss rate (TL_{swp}) with the SDFPF salvage efficiency rate (E_S).

SDFPF salvage efficiency (E_S) is defined as the proportion of PIT tagged fish released at the head of the primary louver bays that were successfully salvaged and released. E_S is generally calculated as:

$$E_S = \left(1 - \left(\frac{Rec_{tr}}{Rel_{tr} \times A}\right)\right) \times 100$$

Rec_{tr} = # PIT tagged Chinook Salmon recovered from Primary Louver Bay releases

Rel_{rg} = # PIT tagged Chinook Salmon released at the Forebay radial gates

A = Mean PIT antennae detection efficiency

In WY 2016 an evaluation E_S was conducted in tandem with the Total SWP Loss evaluation, however the results of this investigation are still undergoing analysis. In the interim, loss rates for Chinook Salmon developed by Wunderlich (2015; 74%) in WY 2013 were utilized in conjunction with unpublished data collected by DWR in WY 2011 (82%) to establish a place holder value of E_S of 78%. This value is consistent with historical salvage efficiency values established for Chinook Salmon at the SWP (Gingras 1997, Skinner 1974) which range from 65-90%.

PSL was calculated for each of the 66 Forebay radial gate release groups as:

$$PSL = 1 - \left(\left(\frac{Rec_{rg}}{Rel_{rg} \times E_S \times A} \right) \right) \times 100$$

Rec_{rg} = # PIT tagged Chinook Salmon recovered from Forebay radial gate releases

Rel_{rg} = # PIT tagged Chinook Salmon released at the Forebay radial gates

E_S = SDFPF Salvage Efficiency (78%)

A = Mean PIT antennae detection efficiency

Total PSL for WY 2016 was estimated to be 91% ± 4% (Mean ± C.I.). PSL for each of the 66 release groups ranged from 22% to 100%. Summary statistics for PSL are shown in

Table 5. This PSL estimate assumes that all fish released at the Forebay radial gates were entrained into the Forebay and therefore, because this estimate of PSL does not account for emigration into Old River, PSL may be overestimated.

Monthly PSL estimates were determined by taking the calculated PSL for each release group and pooling them by release month. An ANOVA test was used to determine if there was a significant difference in monthly PSL estimates. There was a significant difference ($F=5.05$, $df=65$, $p=0.001$). To determine which months differed, a multiple comparison procedure (Tukey's test) was used. PSL of salmon released at the Forebay radial gates in January was significantly different that for those released in March through May (Figure 4).

Table 5- Summary statistics for Pre-Screen Loss (PSL; %) estimates.

	January	February	March	April	May	Annual Total/Mean
No. of Release Groups	11	13	15	14	13	66
PSL	75%	87%	94%	96%	97%	91%
S.D.	20%	24%	8%	5%	6%	15%
min	43%	22%	79%	86%	79%	22%
max	100%	100%	100%	100%	100%	100%

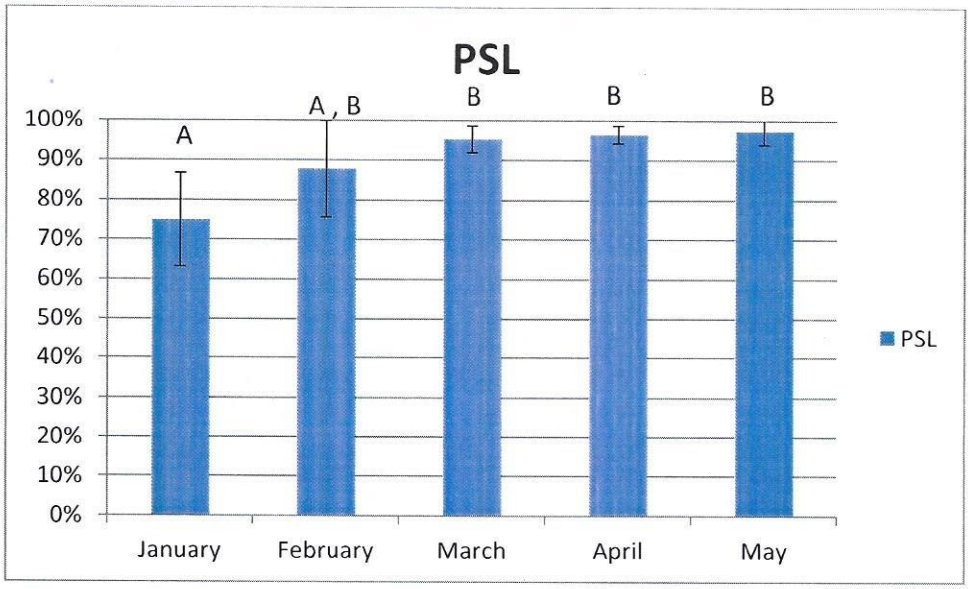

Figure 4- Pre-Screen Loss (PSL) by month in WY 2016. Error bars indicate 95% confidence intervals. Statistically significant groups are indicated by letters above each bar.

Preliminary Time to Salvage for PIT Tagged Chinook Salmon

Time to Salvage (TTS) is defined as the duration of time from the time of release at the Forebay radial gates to the time of detection at the SDFPF. Since all detections at the SDFPF occur post-salvage during the release phase, fish detected at the release sites may have entered the SDFPF from 1-24 hrs prior to the time of detection (note that the SDFPF generally trucks fish every 8, 12, or 24 hours based upon the presence of listed species in the salvage and/or Banks Pumping Plant operations). TTS is a valuable metric for evaluating the effect of Banks Pumping Plant water export on pre-screen losses. A longer TTS likely results in increased exposure of salmonids to predation within the Forebay, and may contribute to increased pre-screen losses.

Mean TTS for WY 2016 was estimated to be 1.9 ± 0.4 days (Mean ± S.D.) TTS ranged from 0.3 to 6.5 days. Summary statistics for TTS are shown in Table 6. Monthly TTS estimates were determined by taking the mean TTS for each release group and pooling them by release month. An ANOVA test was used to determine if there was a significant difference in monthly TTS estimates. There was no significant difference ($F=0.45$, $df=31$, $p=0.774$).

Table 6- Summary Statistics for Time to Salvage (TTS) in days for PIT tagged salmon released at the Forebay radial gates.

	January	February	March	April	May	Annual Total/Mean
TTS (days)	2.5	1.8	1.8	1.9	1.3	1.9

SD	1.8	0.8	1.0	2.1	0.2	0.4
min	0.6	1.1	0.5	0.3	1.0	0.3
max	5.9	3.0	3.3	6.5	1.5	6.5
median	1.8	1.6	1.4	1.0	1.4	1.4

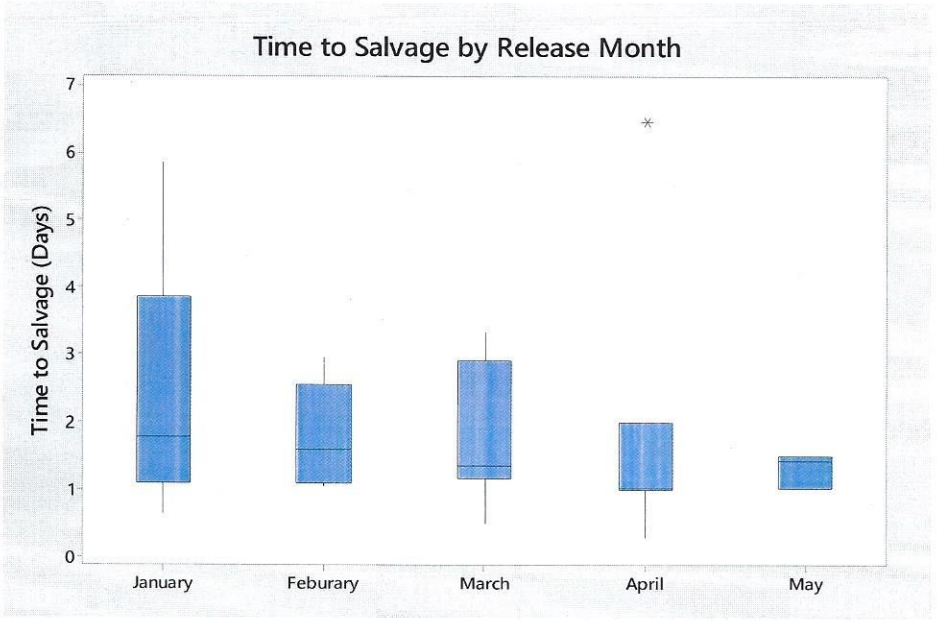

Figure 5- Box plot of Time to Salvage (TTS) by release month. Outliers are denoted by the "*" symbol.

Discussion

Results of the WY 2016 evaluation appear to be consistent with the results of prior studies evaluating losses of salmonids in the Forebay. Chinook Salmon Pre-screen Loss is estimated at 91% which is within the range of loss rates previously documented in the Forebay (63-99%; Gingras, 1997; Clark et al 2009; Wunderlich 2015). Predation by predators, including piscivorous fish, appears to be the primary source of loss and was demonstrated by multiple instances of predators captured with tagged salmon inside of them (V. Wunderlich, Personal Communication). Both this study and Wunderlich (2015) assumed that emigration through the Forebay radial gates was zero, and that all tagged salmon were entrained into the Forebay. Consequently, these estimates of PSL may be biased high if some fish were not entrained or emigrated from the study area. In their 2009 report, Clark et al adjusted their loss estimate to consider possible emigration from the Forebay based upon detections of acoustic tagged steelhead emigrating from the Forebay and a single recovery of a PIT tagged fish at the Tracy Fish Collection Facility. While the likelihood of emigration from the study area is slim, efforts should be taken to document emigration rates during subsequent evaluations, possibly using newly released predation detection tags to differentiate live salmon from predated fish.

The efficacy of predator relocation efforts in WY 2016 was inconclusive based on the preliminary results of this loss monitoring study. No statistically significant differences in loss were detected when comparing the months during the relocation study to the months prior. In addition, there were no statistically significant differences between months for Time to Salvage. One would expect that Time to Salvage would be higher during months with lower total exports (April and May), however this was not observed.

The absence of detectable effects of the WY 2016 predator relocation effort may be due to a variety of reasons. First and foremost, predator relocation efforts in WY 2016 were limited in nature, occurring for only a 3-4 week period at the end of the monitoring season. Tagged salmon released during this period may have encountered unfavorable environmental conditions, including high water temperatures, which may have contributed to mortality. Water temperatures measured in the CA Aqueduct at the Fish Science Building, peaked at 20.6 °C and 22.0°C during April and May respectively, and surface temperatures in the Forebay measured during the predator relocation effort peaked at 21.4°C and 22.4°C during April and May respectively. Furthermore, water temperature in the CA Aqueduct exceeded 24°C in the days following the final release of fish at the Forebay radial gates on 5/31/16. In a laboratory study, Marine and Cech (2004) demonstrated that while Chinook Salmon can grow and survive in temperatures up to 24°C, juveniles reared at 21-24°C experienced significantly decreased, growth rates, impaired smoltification, and higher predation vulnerability compared with fish reared at 13-16°C. Based upon these findings, it is possible that tagged salmon released during April and in particular during May, may have experienced increased mortality rates as a result of temperature stress. This additional mortality could have masked any beneficial effects from a reduction in the predator population, or could have biased the survival of some of the

final release groups as they would have experienced lethal temperatures during part of their migration across the Forebay.

In addition to temperature effects, water export operations may have had an effect on salmon survival during April and May that masked reductions in predation losses due to the predator relocation effort. Forebay inflows and Banks pumping were on average 2.5-3 times higher during January through March than they were in April and May. While this did not result in a statistically significant difference in Time to Salvage, similar studies at the nearby Tracy Fish Collection Facility (C. Karp, Personal Communication) have indicated that lower pumping rates may result in delays in salvage as tagged fish appear to be delayed as they approach the facility trashrack. Such delays, even minor, may result in increased predation losses as fish are exposed to predators at this known predator hot spot.

This study utilized two runs and respective size classes of juvenile Chinook Salmon for tagging and release. As a result, fish (fall run) released during the predator relocation effort in late-April through May were generally smaller than fish (late-fall run) released during most of the period prior to the predator relocation period. In their study, Clark et al (2009) found that losses of juvenile steelhead trout were within the range of reported loss rates for smaller Chinook Salmon. Therefore the results of the steelhead study and of prior studies utilizing Chinook Salmon suggest that we would not expect a significant difference in survival between the fall and late-fall run release groups used for our study.

During this study, the Forebay radial gates were operated differently than they have been historically. Under historical operations, the Forebay radial gates are normally opened at the first available tidal window based on south delta water elevation restrictions ("Priority") after midnight each night and water is drawn into the Forebay until the daily allotment is reached or until the tidal window closes. Consequently, since the water allotment resets each day at midnight, the majority of water drawn in through the gates comes during nighttime hours on most days. During this study year, water operations managers placed a restriction on opening of the gates during nighttime hours. This was in an effort to reduce entrainment of run of the river listed fish including salmonids and smelt. While the efficacy of this effort is unknown as there was no monitoring regimen in place to evaluate the effects on entrainment, it is possible that there may have been effects on PSL. Namely, because the majority of tagged salmonid releases occurred during daylight hours, predation by diurnal feeding activity or more visual predators such as avian predators, may have resulted in higher than expected loss rates. Nevertheless, loss during this study was in the same range as loss during prior studies during historical operations.

While unrelated to the efficacy of the predator relocation effort, we did find a significant difference in survival between tagged salmon released in January and those released in March through April. The cause of this significant difference remains unknown and

will be evaluated further. It does not appear directly related to total exports, as exports were comparable during January and March.

Lastly, half (50%) of all tagged salmon releases conducted in WY 2016 resulted in zero recoveries of live fish at the SDFPF salvage release sites. This finding could not be attributed to problems with the detection array, as concurrent evaluations of salvage efficiency utilizing the same array resulted in "normal" detections, and because the array was tested throughout the study period. Therefore, the large number of non-detections must be attributed to pre-screen losses and emphasizes the magnitude of mortality within the Forebay. Consequently, because this large number of non-detections may limit our ability to resolve changes in pre-screen losses as a result of predator relocation, efforts should be taken to reevaluate the number of releases and release group sizes for subsequent evaluations of pre-screen losses.

Recommendations for Future Work and/or Analyses

Several analyses and study components are recommended for further investigation and for refinement of loss estimation in the Forebay:

1) The sample sizes employed during this study were developed based upon limited available data for Chinook Salmon and with the specific aim of evaluating predation reduction as a result of a different activity (a fishing pier). A revised power and sample size analysis should be conducted prior to initiation of experimental releases in WY 2017 to determine whether a different release scheme would be more effective in detecting changes in pre-screen losses as a result of planned full-scale implementation of the predator relocation (electrofishing) study.

2) Forebay radial gate operations in WY 2016 were constrained to primarily daytime openings beginning in late January. While the data do not appear to directly support the theory that this may have contributed to increased pre-screen loss, further investigation comparing the survival of fish entrained during the day to those entrained at night is warranted. Similarly, an evaluation of entrainment into the Forebay would be valuable in determining whether or not this operational change is actually beneficial for reducing entrainment into the Forebay.

3) The employed PIT tag methodology, while valuable in that it enables the utilization of large sample sizes, limits the amount of information available about the direct source of fish mortality. New and evolving telemetry techniques such as predation indication tags could be used to assess the location of predatory hot spots within the forebay. Such information could be used to refine predator management efforts including electrofishing.

4) These analyses assumed that all tagged salmon released at the Forebay radial gates were entrained into the Forebay and participated in the experiment. However, past studies (Clark et al 2009) have indicated that some fish may be able to emigrate from the study area under certain operational conditions. To asses this factor, releases of acoustic tagged salmonids in tandem with PIT tagged fish could be used to assess the degree of experimental participation.

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Appendices

Appendix 1- Mark-Recapture data, Pre-screen Loss, and TL_{SWP} for each of the 66 releases of Chinook Salmon at the Clifton Court Forebay radial gates in WY 2016.

Release Date	Recaptured	Released	TLswp	PSL
1/10/2016	2	20	89%	86%
1/12/2016	0	20	100%	100%
1/14/2016	1	20	94%	97%
1/15/2016	0	20	100%	100%
1/19/2016	6	19	65%	55%
1/21/2016	6	20	67%	58%
1/22/2016	4	20	78%	72%
1/25/2016	5	19	71%	63%
1/26/2016	8	20	56%	43%
1/28/2016	2	20	89%	86%
1/29/2016	5	20	72%	65%
2/1/2016	11	20	39%	22%
2/2/2016	7	20	61%	50%
2/5/2016	0	20	100%	100%
2/8/2016	1	20	94%	93%
2/9/2016	0	20	100%	100%
2/11/2016	1	20	94%	93%
2/12/2016	3	20	83%	79%
2/15/2016	0	20	100%	100%
2/18/2016		Cancelled		
2/19/2016	0	19	100%	100%
2/22/2016	1	20	94%	93%
2/23/2016	0	20	100%	100%
2/26/2016	0	20	100%	100%
2/29/2016	0	20	100%	100%
3/1/2016	0	20	100%	100%
3/3/2016	0	20	100%	100%
3/4/2016	0	20	100%	100%
3/7/2016	0	20	100%	100%
3/8/2016	0	20	100%	100%
3/10/2016	1	19	94%	93%
3/11/2016	1	20	94%	93%
3/14/2016	2	20	89%	86%
3/15/2016	0	19	100%	100%
3/17/2016	3	20	83%	79%

3/18/2016	0	20	100%	100%
3/21/2016	0	20	100%	100%
3/22/2016	1	20	94%	93%
3/24/2016		Cancelled		
3/25/2016		Cancelled		
3/28/2016	3	20	83%	79%
3/29/2016	1	20	94%	93%
3/31/2016		Cancelled		
4/1/2016		Cancelled		
4/4/2016		Cancelled		
4/5/2016	1	20	94%	93%
4/7/2016	0	20	100%	100%
4/8/2016	0	19	100%	100%
4/11/2016	0	20	100%	100%
4/14/2016	1	20	94%	93%
4/15/2016	1	20	94%	93%
4/18/2016	0	20	100%	100%
4/19/2016	1	20	94%	93%
4/21/2016	0	20	100%	100%
4/22/2016	0	20	100%	100%
4/25/2016	2	20	89%	86%
4/26/2016	0	20	100%	100%
4/28/2016	1	20	94%	93%
4/29/2016	1	19	94%	93%
5/2/2016	0	20	100%	100%
5/3/2016	0	20	100%	100%
5/5/2016	0	20	100%	100%
5/6/2016	0	20	100%	100%
5/9/2016	0	20	100%	100%
5/10/2016	0	20	100%	100%
5/12/2016	0	19	100%	100%
5/13/2016	3	20	83%	79%
5/16/2016	0	20	100%	100%
5/17/2016	1	20	94%	93%
5/19/2016	1	20	94%	93%
5/20/2016	0	20	100%	100%
5/31/2016	0	20	100%	100%