California Department of Fish and Wildlife

North Central Region

Colusa Basin Drain and Wallace Weir Fish Trapping and Relocation Efforts November 2013 – June 2014

August 2016

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LIST OF ABBREVIATIONS AND ACRONYMS

CBD	Colusa Basin Drain
CDEC	California Data Exchange Center
CDR	Colusa Drain near Highway 20
cfs	Cubic feet per second
CSC	Cache Slough Complex
cm	Centimeter
CVP	Central Valley Project
CWT	Coded wire tag
Delta	Sacramento-San Joaquin Delta
DFW	Department of Fish & Wildlife
DWR	Department of Water Resources
emt	Electrical metallic tubing
^{o}F	Degrees Fahrenheit
fps	Feet per second
FL	Fork Length
IEP	Interagency Ecological Program
KL	Knights Landing
KLOG	Knights Landing Outfall Gates
KLRC	Knights Landing Ridge Cut
LSNFH	Livingston Stone National Fish Hatchery
mm	Millimeter
NMFS	National Marine Fisheries Service
NTU	Nephelometric Turbidity Units
NWR	National Wildlife Refuge
QAQC	Quality assurance and quality control
USFWS	U.S. Fish and Wildlife Service

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INTRODUCTION

In April 2013, large numbers of adult Chinook salmon (*Oncorhynchus tshawytscha*) were observed within Colusa Basin Drain (CBD) watershed in various agricultural diversions and drainages. Due to concern that these salmon included threatened or endangered runs and would perish in the absence of intervention, the Department of Fish and Wildlife (DFW) implemented multiple rescue efforts in early May 2013. A total of 312 live salmon were recovered during these operations. This included 235 salmon that were tagged with external T-bar anchor tags, 13 of which also received internal acoustic transmitter tags. Tissue samples were collected from a subset (N = 10) for genetic identification.

In the course of rescue operations, numerous fish where identified with clipped adipose fins (ad-clipped) indicating they were of hatchery origin. Eleven ad-clipped Chinook salmon were taken to DFW's Region 2 office, where coded wire tags were extracted to identify the age, run, and production location. A large portion of stranded fish were composed largely of federally endangered winter-run; specifically, 48 adult Chinook salmon were recovered between 20 May and 5 June, 2013, and were sent directly to Livingston Stone National Fish Hatchery (LSNFH) for spawning. An additional 18 mortalities/carcasses were observed during the rescue operations. Based on visual observations by DFW staff, it was speculated that more than a hundred Chinook salmon were not rescued during these efforts and the total number entrained into CBD during 2013 was undetermined. As Central Valley winter and spring-run Chinook salmon are listed as federally endangered and threatened respectively, loss of adults from these races on this scale is very concerning.

A great deal of effort has been put into identifying environmental conditions and water operations which may have caused Chinook salmon entrainment in the CBD during 2013. Stranded anadromous fish species have been documented in the Yolo Bypass (Bypass) on numerous occasions following high flow events that overtop Fremont Weir (CDFG 2011). This is likely a consequence of attraction to the large volume of water that can be conveyed through the bypass during a weir over-topping event. The rescues in spring 2013 occurred during a period of below average flows in the Sacramento River. Stage height in the Sacramento River during this time period was insufficient to result in over-topping the Fremont Weir. This suggests there may be strong attraction cues into the CBD for anadromous species occurring during periods outside of flood conditions.

Following the 2013 rescue, potential entrainment routes for Chinook salmon into the CBD were examined. Possible entry points in the CBD watershed include the Sacramento River through the Knights Landing Outfall Gates (KLOG) and the Knights Landing Ridge Cut (KLRC), which drains into the Tule Canal and subsequently drains into the Cache Slough Complex (CSC) in the northern Sacramento - San Joaquin Delta (Figure 1).

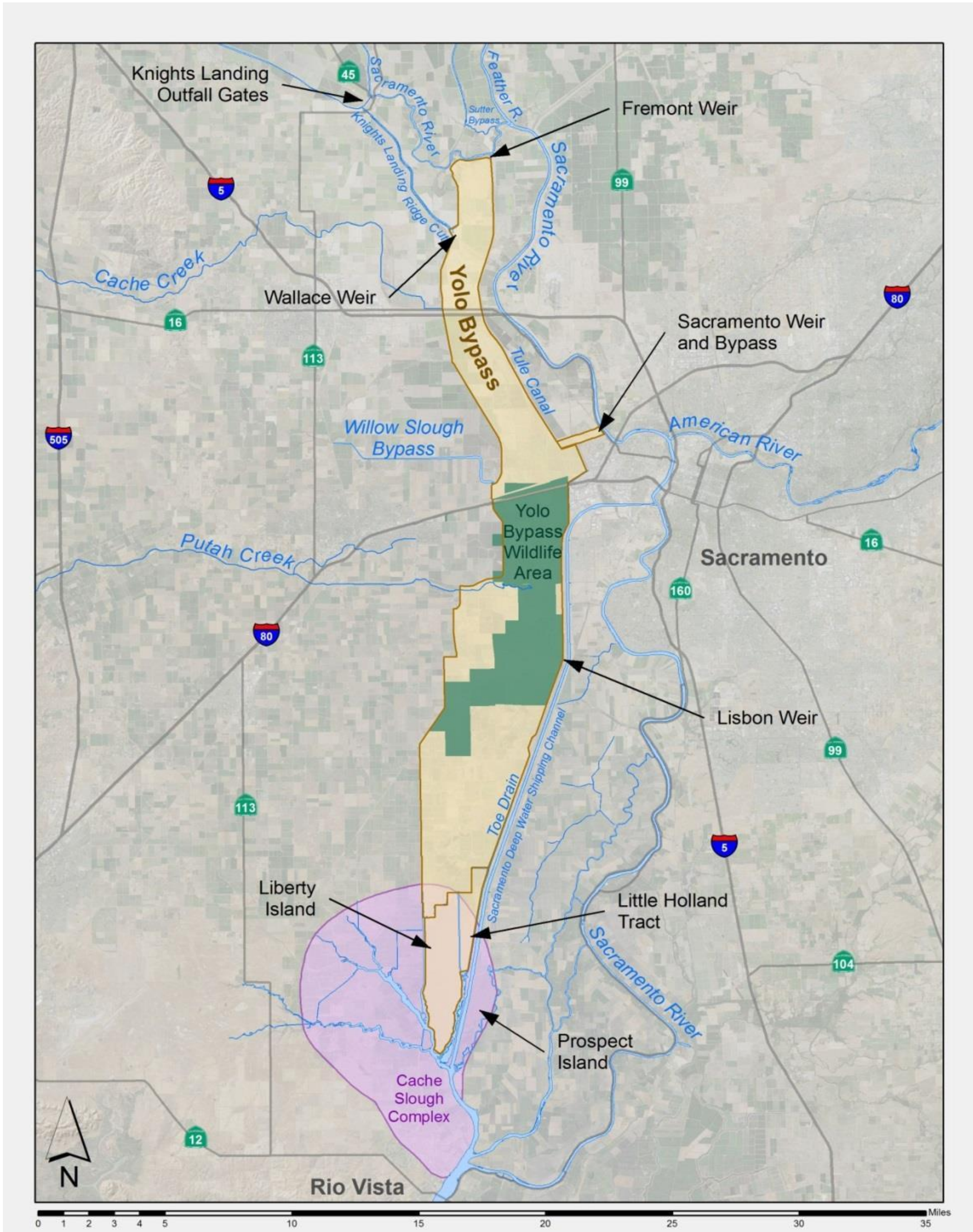

Figure 1. Map of the Yolo Bypass. The Cache Slough Complex extends from approximately Little Holland Tract down to the confluence with Sacramento Deep Water Ship Channel.

To address the issue of anadromous species entrainment in the CBD and to better understand environmental conditions resulting in entrainment, DFW designed and installed a resistance board-style fish weir and an associated fish trap in the CBD approximately 14 miles upstream of the town of Knights Landing in the fall 2013. This location was selected primarily because it could allow fish to be trapped prior to moving further up into the network of agricultural diversions and drainages further upstream in the CBD. The weir was designed to handle the variable flow and debris conditions of the CBD.

To better document utilization of the two entry points for fish into the CBD and increase the ability to capture anadromous species, other locations in Yolo Bypass were evaluated for capturing entrained fish. The DFW, in coordination with the California Department of Water Resources (DWR), installed a 10’ by 20’ fyke trap on 22 January 2014 in the KLRC, downstream from Wallace Weir in the Yolo Bypass. This site was selected to target and rescue fish entering the CBD through the KLRC due to capacity for fish to be captured across a wide range of flow conditions and ease of access for staff. By examining catch at each site independently over time, it was hoped that utilization of entry points to the CBD could be identified for entrained fish.

Primary goals for both rescue efforts:

1. Detect and enumerate the presence of salmonids, sturgeon, and other fish species within the Bypass.
2. Minimize the loss of salmonids with a focus on state and federally listed salmonids and sturgeon through rescue/relocation.
3. Examine the timing, size, and species composition of entrained fish.

Secondary goals:

1. Identify how fish enter the CBD.
2. Identify conditions and operations that result in attracting and entraining fish into the CBD.

In addition to the primary goals the trapping data may allow for inferences to be made into attraction cues for fish during non-flood periods. It was speculated that KLOG operations influence fish entrainment into the CBD as fish can enter the drain directly through KLOG or by regulating attraction flows in the KLRC and subsequently down into the CSC.

BACKGROUND

Historically, Chinook salmon were naturally abundant and widely distributed in almost all major streams of California’s Central Valley (Yoshiyama et al. 2001). Central Valley Chinook salmon numbers have been greatly reduced by anthropogenic changes to the environment from loss of historical spawning habitat through construction of large dams, changes to the natural hydrology of rivers, altering and channelizing rivers and streams, and construction of unscreened diversions. It is well recognized that protection of adult Chinook salmon during their spawning migration is crucial for maintaining Central Valley salmonid stocks.

> *"Adult anadromous fish returning from the ocean and migrating upstream to spawning grounds face a variety of hazards. Protecting adult anadromous fish from time of entry into freshwater until successful reproduction in the upstream spawning habitats is critical. Those adults attaining the reproductive phase are the fewest in number among all the prior life stages. Fish reaching the spawning grounds are the oldest among all prior life stages and have already survived the vast majority of density-independent and density-dependent factors exerting the most influence on the population. Significant changes in the numbers of these adult fish can have resulting profound impacts on subsequent generations. Given the complexity of the anadromous fishes' life cycle, the upstream migrating adult fish should be the easiest to protect."* (Vogel 2011).

Irrigation returns and flood runoff from the west side of the Central Valley drain into the CBD which conveys water to KLOG, where a portion of these flows can be discharged into the Sacramento River under most conditions. The remainder of the water drains into the KLRC. If stage height of the Sacramento River at Knights Landing is greater than approximately 27 feet, then the outfall gates are closed and all flows in the CBD are directed into the KLRC, which ultimately discharges into the north Sacramento-San Joaquin Delta. It is believed that both flow routes have the potential to attract anadromous species into the CBD though KLOG and have been identified as far back as the 1970's as an entry point into the CBD (Figure 2).

> *"Significant numbers of upstream migrant adult Chinook salmon have been known to enter the Colusa Basin Drain Outfall at Knights Landing [KLOG]. Because salmon spawning and rearing habitat in the Drain is essentially non-existent, those fish are lost from Sacramento River production. Salmon runs are presently depressed, stressing the importance of ensuring the safety of those salmon returning to spawn. The California Department of Fish and Game attempted to exclude salmon from entry into the Drain during the 1970s, but failed to do so for a variety of reasons. Presently adult salmon can migrate up into the Drain and many may perish."* (CH2M HILL 1991).

In October 1975, a U.S. Fish and Wildlife Service (USFWS) employee working at Delevan National Wildlife Refuge (NWR) estimated that approximately 200 Chinook salmon were stranded below a refuge-operated canal dam, at least 35 miles upstream from the mouth of the CBD (Lassen, 1975). Inclusive in the memorandum was information from a DFW warden reporting that it was an annual problem, though the magnitude of the loss was unknown; it appeared that the problem was limited to fall-run Chinook salmon during the months of

September through November. Because of the numbers of Chinook salmon regularly observed at the Delavan NWR, it was determined by DFW that significant salmon loss, on the order of 200 to 400 fish per year, must be occurring in the CBD. Preliminary evaluations at the time indicated that an electric barrier immediately downstream of KLOG would be an appropriate method to discourage adult salmonids from entering the CBD. In the fall 1977, DFW installed an electric barrier, however, the device was destroyed during heavy flows through the KLOG in early January 1978 (personal communication, Dave Rose, Senior Supervisor, CDFG) and no physical or behavioral fish barrier has been installed since.

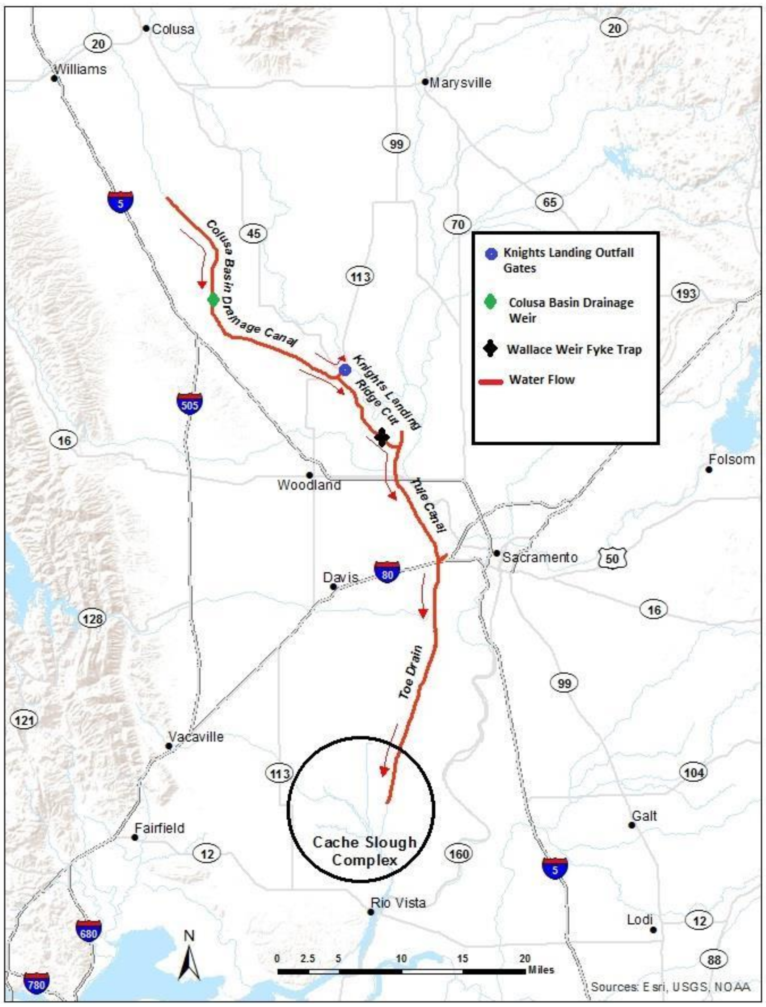

Figure 2. Map depicting the direction in which water flows through the CBD to the KLRC and the RCS.

The problem persisted and correspondence between Reclamation District of Colusa, DFW, DWR, and the California Fish and Game Commission on the entrainment issue continued from the 1960's through the 1990's. In the 1990's, Reclamation District No. 2047 stated that CBD Chinook salmon entrainment had been an issue for at least 20 years. The magnitude of Chinook salmon entrained varied from year to year depending on rainfall and water flows in CBD relative to the Sacramento River. Reclamation District No. 2047 requested fish screens or another electric fish barrier to resolve the issue.

> *"The reasons adult Chinook salmon choose to enter the Drain rather than migrate up the Sacramento River is not entirely understood. … Once at the Drain Outfall [KLOG], salmon are further "enticed" by high velocity water exiting the Outfall Gates. Their attraction to high velocity water is a well-known behavioral trait"* (Bell 1973).

> *"The mechanism for entry at the Outfall Gates occurs when water velocity is sufficient to attract the fish but low enough for the fish to overcome when migrating in an upstream direction. Experience at the Red Bluff Diversion Dam and the Tehama-Colusa Fish Facilities has shown that adult salmon readily swim through flows from hydraulic control structures when the hydraulic head differential between the upstream and downstream water bodies is less than about four feet"* (Vogel et al. 1988).

Reclamation District No. 2047 requested that a fish exclusion device or electric fish barrier be constructed to resolve the issue and that DWR take the lead in preparing and implementing a plan to exclude Chinook salmon from the CBD. However, DWR suggested that DFW take the lead with their technical and potential financial support if a project was developed.

> *"The migration of adult Chinook salmon into the Colusa Basin Drain has been widely reported for many years by personnel of the District [2047], the Glenn-Colusa Irrigation District (GCID), CDFW, DWR [Department of Water Resources], the U.S. Bureau of Reclamation, local farmers, and sportsman groups. The number of adult salmon ascending the Drain appears to vary from year to year and is estimated to range up to thousands of fish in some years; however, no annual counts or comprehensive records of adult salmon in the Drain have been maintained by CDFG."* (personal communications, Paul Ward, Senior Supervisor, CDFG, and Pat O'Brien, CDFG)

> *"Generally, more adult salmon are reported as seen in the Drain during years of high salmon run abundance than during years of low salmon run abundance."* (personal communication Pat O'Brien, Senior Supervisor, CDFG)

Considering the magnitude of adult Chinook salmon loss over the years, the issues of attraction and entrainment into the CBD have major implications on management of threatened and endangered fish populations and commercial and sport fishing opportunities.

Colusa Basin Drain

The CBD is a man-made structure containing multiple canals that drain runoff and irrigation return flows from public and private lands within the Colusa Basin watershed. Farmers built the

CBD in the 1920's as rice production in the Central Valley expanded (Leavenworth, 2004). The CBD was designed to collect and convey flows from agricultural lands and 32 ephemeral streams during the irrigation season and during winter storm water flows. The CBD terminates at two locations: the KLOG, where it empties into the Sacramento River, and at KLRC, a canal that carries excess flood water into the Yolo Bypass. The Colusa Basin watershed, includes both Glenn and Yolo Counties and extends from the Stony Creek watershed in the north to the Cache Creek watershed to the south, and from the Sacramento River in the east to the foothills of the inner Coast Ranges to the west, and covers over one million acres (Colusa County Resources Conservation District, 2012).

Knights Landing Ridge Cut

In 1930, the Army Corps of Engineers partnered with the State of California to construct the KLRC by digging a 7 mile long canal through the Knights Landing Ridge. The purpose of the KLRC is to regulate water flowing to the Sacramento River through KLOG and through KLRC into the Yolo Bypass. The Yolo Bypass conveys water for agricultural needs and flood control. During the irrigation season, water in the Yolo Bypass is controlled and directed by weirs before ultimately draining into the Cache Slough Complex. Two of the more prominent control structures in the Yolo Bypass are Wallace and Lisbon weirs. KLRC runs from the CBD and enters the northwest corner of the Yolo Bypass, downstream of Fremont Weir. Wallace Weir is an earthen berm that is constructed annually at the downstream end of KLRC to allow the retention and regulation of irrigation flows to help meet agricultural needs.

During the irrigation season at low flows, Wallace Weir is in place and KLRC cuts across the Yolo Bypass into the east side toe drain of the Yolo Bypass. At times of high flow, all gates in KLOG are closed and water is diverted through the KLRC where it overtops Wallace Weir and flows into the Yolo Bypass, incidentally allowing unimpeded fish passage into the CBD watershed.

The Knights Landing Outfall Gates

Originally known as Sycamore Slough Outfall Gates, KLOG was constructed around 1914 (Figure 3). The structure was modified again in 1929, 1930, and 1949. The outfall gates were updated most recently in 2012. However, these updates did not include any measures to reduce the likelihood of fish entrainment.

The KLOG structure is operated by the DWR and consists of a concrete barrier wall at the terminus of CBD canal with 10 automated round gated openings. These gates allow water to drain from the CBD to the Sacramento River during river flows up to approximately 27 feet and also prevent water from the Sacramento River from entering the CBD during periods of river flow with stage height greater than 27 feet. During high flows in the Sacramento River (with gates closed), all CBD water is shunted through the KLRC into the Yolo Bypass (Navigant

Consulting, 2004). Eight of the KLOG gate openings are 5.5 feet in diameter and two are 3.5 feet in diameter. All have a centerline elevation of 21 feet and are equipped with automated slide gates on the upstream (canal) side and a flap gate on the downstream (river) side. Automated slide gates allow water level in the canal to be regulated at an elevation above river level and flap gates prevent Sacramento River water from passing into CBD when the river is higher than the water level in the canal. The gate structure has a concrete slab at 17' elevation extending downstream of the gate openings for approximately 40 feet to prevent bed erosion from water discharging through the gates (Heise, 2014). Operations at KLOG also allow for regulation of CBD water elevations for irrigation use in the agricultural lands around the CBD and ridge cut. Stage height is kept at a relatively constant level, approximately 25 feet above the U.S. Army Corps of Engineers geodetic datum upstream in CBD (Yolo Bypass Working Group 2001) (Figure 4).

It is assumed that adult Chinook salmon are attracted to KLOG when water is discharged into the Sacramento River. For entrainment to occur, water elevation over the concrete slab needs to be a sufficient depth, and water velocities through the gates have to be within the burst swimming speed of adult Chinook salmon (≤6 fps). For example, at a river elevation of 20 feet, there would be 3 feet of water over the slab and the bottom of the gate opening would be submerged by 1.7 feet. This condition likely facilitates passage of fish through the gate openings as long as the head differential in CBD does not exceed 6 fps. Discharge velocities greater than 6 fps are assumed to be greater than the burst swimming speed for adult Chinook salmon.

As Sacramento River stage level decreases below 19 feet, the depth over the slab becomes less than 2 feet, decreasing ability for adult Chinook salmon entrainment. Upstream fish passage through KLOG is assumed to be blocked when Sacramento River stage level drops below 17 feet, exposing the concrete slab at KLOG.

Figure 3. Knights Landing outfall gates under construction in 1914.

Figure 4. Knights Landing outfall gates on April 8, 2014. Downstream (top) and upstream (bottom).

Yolo Bypass

The Yolo Bypass is a leveed basin which is designed to convey excess flood flows from the Sacramento Valley, including the Sacramento River, Feather River, Sutter Bypass, and west side streams (Figure 1). The Bypass is considered the primary floodplain of the Delta (Sommer et al., 2001). The 40 mile long floodplain is designed to convey up to 343,000 cfs. Under typical flood conditions, water spills into the Yolo Bypass via Fremont Weir when the stage height of the Sacramento River surpasses 33.5 feet (CDWR 2010). After overtopping the weir, water flows initially along the eastern edge of the Yolo Bypass through the Tule Canal before spreading throughout the floodplain.

At high flows in the Sacramento River, the Sacramento Weir can convey additional water into the Yolo Bypass. In addition, west side streams such as Cache and Putah Creeks are sources of inflow to the Bypass. During the dry season, the Tule Canal and east side toe drain channel remain inundated due to irrigation runoff and tidal action from the north Delta.

Personnel from DWR and DFW have been conducting fish studies in the Yolo Bypass for several years (Sommer et al. 1997; Sommer et al. 2001). Studies by the Interagency Ecological Program (IEP) Yolo Bypass Project Work Team have demonstrated that the shallow water habitat of the Cache slough complex and toe drain support at least 40 fish species including Delta smelt, Sacramento splittail, white and green sturgeon, striped bass, American shad, assorted races of Chinook salmon, and steelhead trout (Sommer et al. 2003).

METHODS

Colusa Basin Drain Resistance Weir and Trap

On 2 November 2013, DFW installed a 125-ft wide resistance board-style weir and associated fish trap in CBD (38°54’10.78”N, 121°54’54.71”W) approximately 14 miles upstream from Knights Landing (Figure 5; Figure 6). This trapping site was operated through 22 May 2014. The site was selected based on security, access, stable bank characteristics, and channel uniformity. Design, construction, and installation of the weir were based on methods developed by the Alaska Department of Fish and Game and the United States Fish and Wildlife Service (Stewart 2002, Stewart 2003, and Tobin 1994). The weir had three major components: panels, an anchored substrate platform, and a fixed picket section (Figure 7).

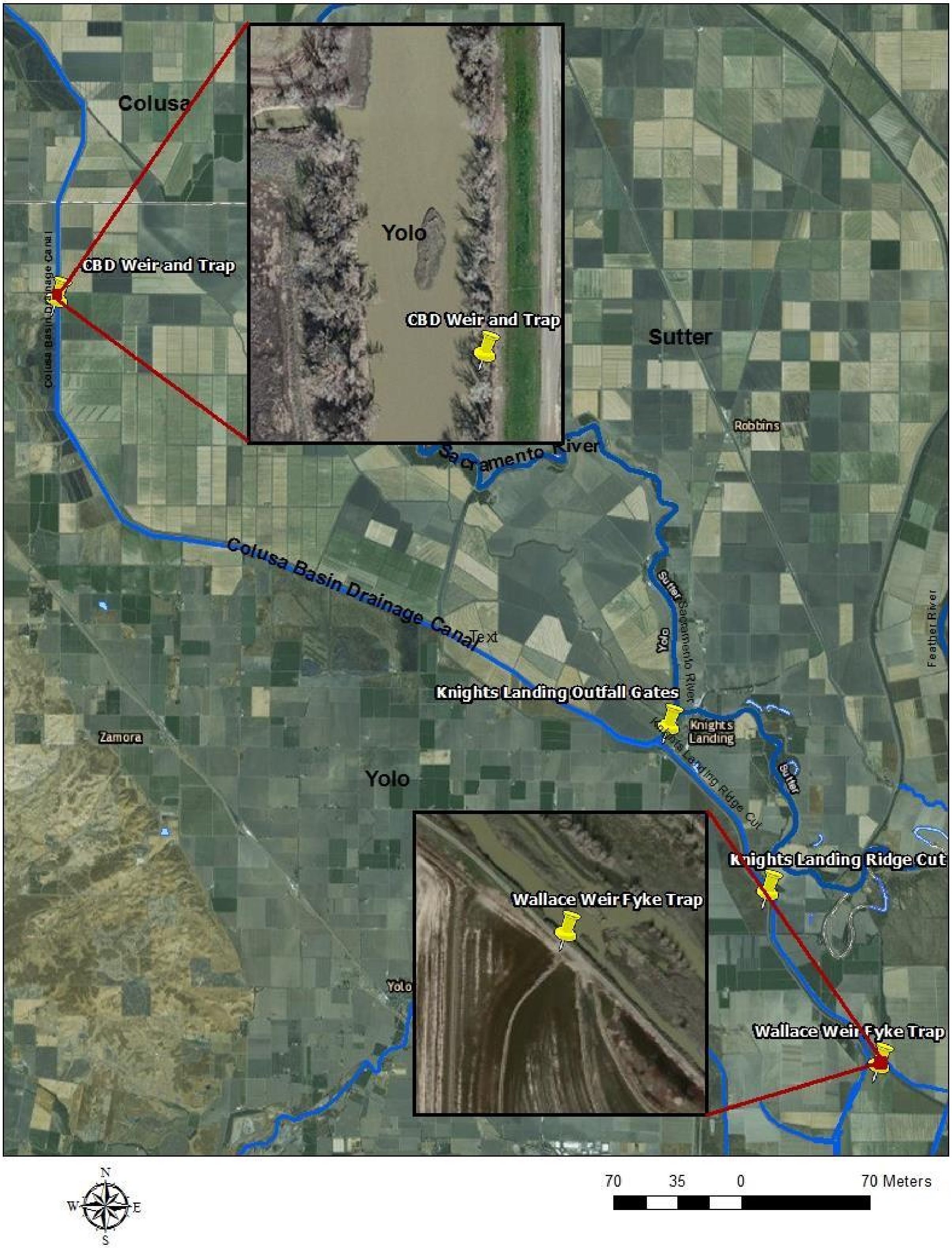

Figure 5. Map of Wallace Weir Fyke Trap Site and Colusa Basin Drain Canal Resistance Weir Site.

Figure 6. Photo of the Colusa Basin Drain weir and trap entrance.

The weir panels were constructed of schedule 40 capped polyvinyl chloride (PVC) irrigation pipe and forty-two panels (3’ X 12’) were linked together to form the weir. Each panel consisted of 11 schedule 40 PVC irrigation pipes (1”x12’) that were held together by 6 ultra-high molecular weight polyethylene plastic stringers (2”x38”). Each stringer had 13 holes that each of the 11 PVC irrigation pipe fit into and one of the pipes from the adjacent panels on either side in order to connect each panel. The panels were connected in this manner until the span of the channel was reached. Boat fenders (10” X 30”) were attached at the top of each panel to provide buoyancy to the upper portion of the panels. A cable anchored to the substrate with earth anchors and t-posts was used to attach the panel bottoms and live trap to the canal bottom.

Approximately 47 feet of fixed-picket weir was used on the west bank, and 31 feet on the east bank (Figure 7). Weir sections were made of ¾ emt conduit placed vertically through holes spaced 2 inches apart in 2” X 4” angle iron and functioned to prevent fish from escaping between the weir and bank.

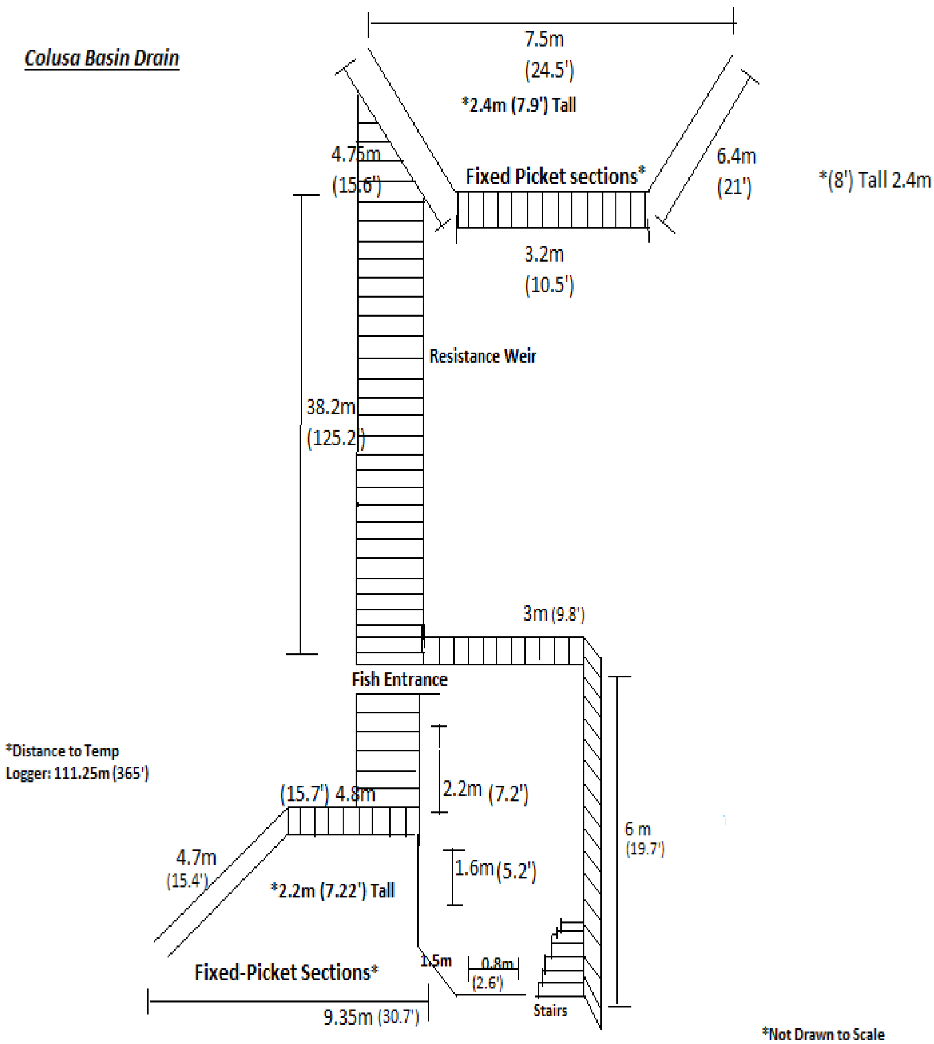

Figure 7. Colusa Basin Drain weir site measurements.

A 10’ x 20’ live trap, also constructed of emt conduit, was attached to the fixed pickets on the east bank. The entrance to the live trap was fitted with a stationary passage chute approximately 15 feet from the east bank made of 5’ X 6’ perforated flat iron and rounded at the top to allow the weir to pivot at various flows and water elevations. The 24” x 8” angle iron had holes to allow ¾ emt conduit placement vertically, completing the fixed picket section. The sections formed a trapezoid-like shape on both banks. A bump rack was constructed at the entrance to the live trap from ¾ emt conduit placed 2 inches apart and individually hinged at the top of 2” x 4” angle iron. It was constructed to allow fish upstream passage by placing a grooved piece of 2” x 4” angle iron affixed to the bottom of the live trap entrance. This allowed for the individual hinged pieces of conduit to recess between the grooves and prevented fish from escaping the live trap.

The weir was checked daily for fish tightness, debris, and catch. Two to four personnel were assigned to check the weir depending upon catch and maintenance needs. All data, including abiotic conditions, catch for the day, and comments, were recorded on water-proof datasheets. Salvaged Chinook salmon were externally marked with anchor tags, which were individually numbered and printed with return information (DFW, Region 2 phone number). Salmonids were sexed if possible and fork length recorded. A genetic sample was collected from all Chinook salmon. Salmonids were then placed in a cradle and carried to a transport trailer for transport to Elkhorn Boat Launch and then released in the Sacramento River. Datasheets were taken to a DFW office and checked for quality assurance and quality control (QAQC). Once all datasheets were checked for QAQC, data were entered into an Excel spreadsheet using the Julian year calendar and again checked for QAQC.

Wallace Weir Fyke Trap

A 10’ x 20’ fyke trap was installed a few hundred yards downstream from Wallace Weir on 22 January 2014 in the KLRC (38°43’4.353”N, 121°39’35.4672”W) (Figure 5; Figure 8). The fyke trap was constructed of 2” x 4” wood cross beams, circular piping, and 2” diameter plastic and wire mesh. The trap was open at one end and contained two funnels which act as behavioral one-way shoots within the trap. Once past the funnels, fish were held in enclosed spaces between the funnels inside the trap. The trap was constructed with three openings covered with strap-on doors which allowed staff to access the holding area to gather catch. The trap was fished with the back, or open end, facing downstream (Figure 8). To increase capture efficiency, the trap was positioned in the KLRC between two wing wall structures that were 33’ x 9’ and constructed from ¼” gauge galvanized steel hog wire paneling with 2” x 4” openings on the downstream end of the trap to prevent fish from bypassing the trap (Figure 9).

Figure 8. Photo of the Wallace Weir fyke trap.

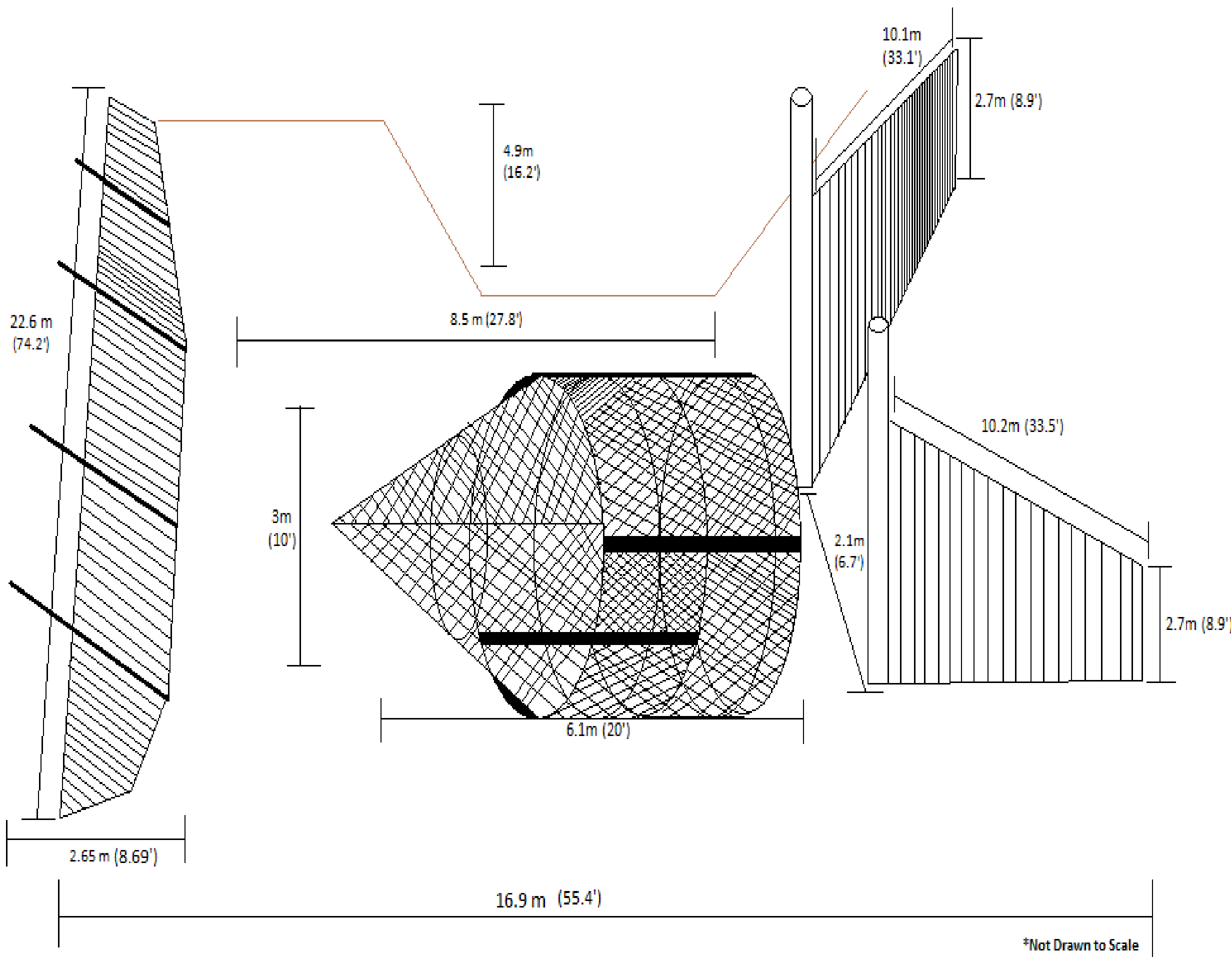

Figure 9. Wallace Weir fyke trap site measurements

Upstream of the fyke trap, a 75' x 9' debris weir was constructed consisting of ¼" gauge galvanized steel hog wire paneling with 2" X 4" openings and ¾" emt conduit to further reduce the chance of fish passing the sampling site.

The fyke trap was secured to shore in three locations with t-bar stakes driven into the levee: a lead at the top end of the trap, a tail at the bottom end, and a centrally located cable for trap retrieval. The central cable was wrapped around the middle of the fyke and during trap service was attached to a truck-mounted winch which allowed the trap to be pulled and rolled onto the side of the levee to check for catch.

Catch was checked by rolling the fyke trap up the side of the levee enough to leave approximately two to three feet of water in the holding area of the fyke. Captured fish were removed from the trap with a dip net and placed in a 250 gallon tub filled with canal water for processing and tagging.

The fyke trap was checked daily to check for fish tightness, debris build up, and catch. Two to four personnel were typically assigned to check the weir for catch and maintenance needs. Data was recorded on water-proof datasheets. Data was recorded and fish were processed in an identical fashion to the CBD weir. Salmonids were placed in a cradle and carried to a transport trailer for transport to the Sacramento River release locations. Datasheets were taken to a DFW office and checked for quality assurance and quality control (QAQC). Once all datasheets were checked for QAQC, data were entered into an Excel spreadsheet using the Julian year calendar and again checked for QAQC. From 22 January through 17 March 2014, DWR operated the Wallace Weir fyke trap Monday through Friday and checked it once daily. On 18 March 2014, DFW began operating the trap, checking it daily seven days a week until 6 June 2014.

Fish Specific Data

All fish captured at both sites were identified to species and enumerated. With the exception of salmonids and sturgeon, fish were released upstream of the trap to minimize recapture. Each captured Chinook salmon received two external, individually-numbered t-bar anchor tags. The tags were placed into the muscle tissue adjacent to the dorsal fin on both sides of the fish prior to transport. Captured sturgeon were measured to the nearest cm total length (TL), but were not externally marked (no anchor tag was applied) and then transported to the release location.

Physical and morphological data (sex, condition, fork length, adipose fin status, tissue samples, and presence of external marks) were collected from all salmonids and sturgeon captured at both sites. Tissue samples were collected from the upper corner of the caudal fin of Chinook salmon and preserved using either the dry or wet tissue sample method (Appendix E). Dry tissue samples were transferred to the DFW Tissue Archive in Sacramento. Wet tissue samples were transferred to the USFWS Abernathy Fish Technology Center in Longview, Washington.

Data specific to the performance of the CBD weir and the Wallace Weir fyke trap were gathered each time personnel visited either site. Data specific to each trapping site included: total hours fished, water velocity entering live trap or fyke trap, and water depth. Water velocity was evaluated using a Global Water flow probe (model FP111) and water depth was read using fixed staff gauges placed in the upper left corner of the CBD live trap (facing upstream) and on the ¾" emt conduit support by the fyke opening at the Wallace Weir site.

Environmental Conditions

Environmental data collected and recorded at each site included: water temperature, water turbidity, and flow rate. Water temperature was evaluated over time using an electronic Onset HOBO temperature logger, and during each trap service an instantaneous temperature was taken with a handheld H-B USA standard liquid thermometer. Two water samples were collected during each site visit and analyzed using a LaMotte 2020 Turbidity Meter. Readings from both water samples were averaged and reported in Nephelometric Turbidity Units (NTU). Flow rate for CBD was obtained from the California Data Exchange Center gauge at Colusa Drain near HWY 20 (CDR) (CDEC 2013-‘15). Wallace Weir fyke trap flow rate was obtained from the California Data Exchange Center gauge at KLRC (RCS) (CDEC, 2013-‘15).

Fish Transport

All salmonids were transported in a trailer-mounted 400 gallon fish transport tank. Transport tanks were specially designed to reduce stress associated with fish handling and transport by outfitting them with an oxygen delivery system to deliver 1.5 pounds per-square-inch pure oxygen, a water circulation system, and a large release gate to facilitate release. Fish were transported and released at either Tisdale Boat Launch or Elkhorn Boat Launch (Figures 10 and 11).

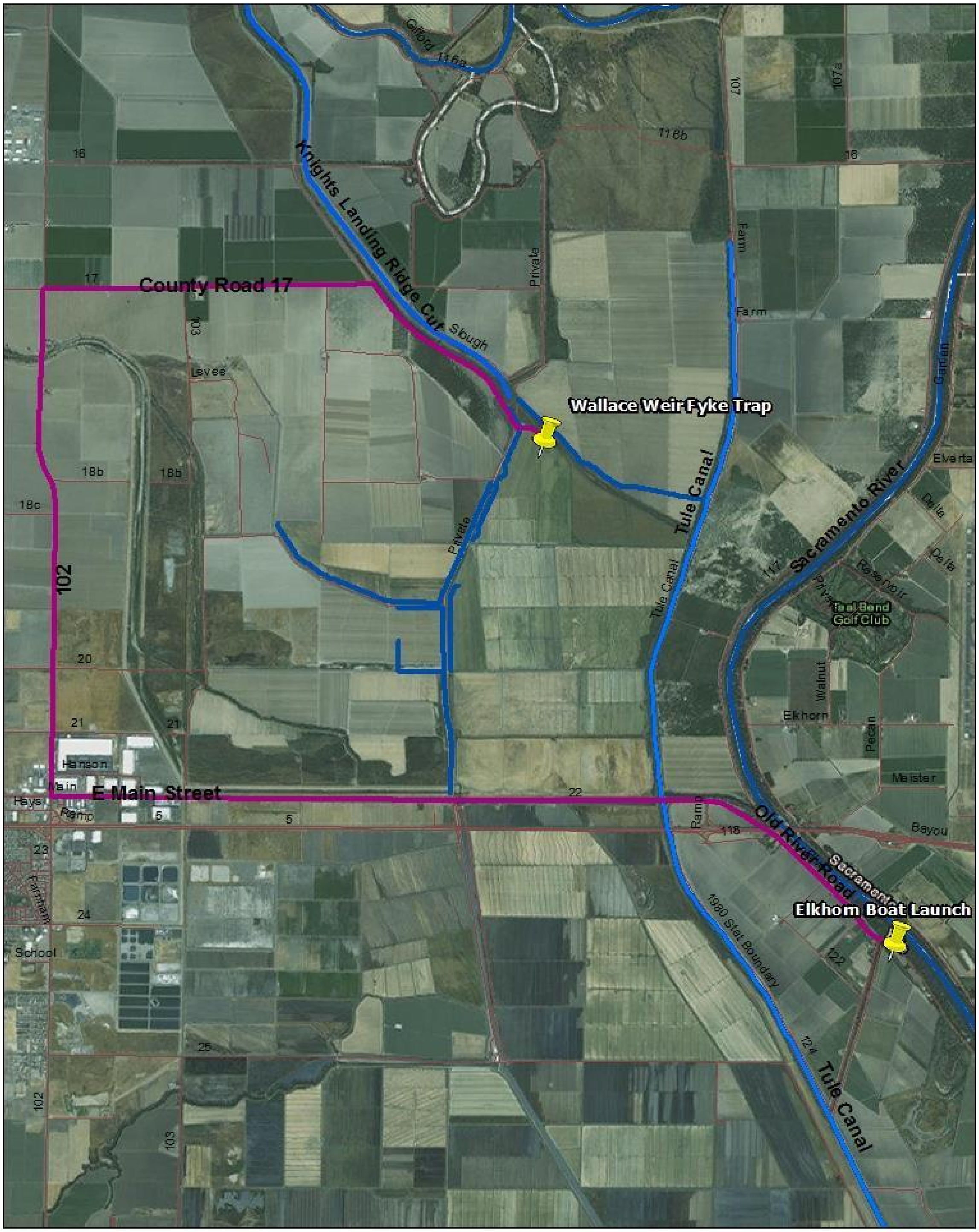

Figure 10. Map of Wallace Weir trap site, with route to the Elkhorn Boat Ramp on the Sacramento River indicated as a purple line.

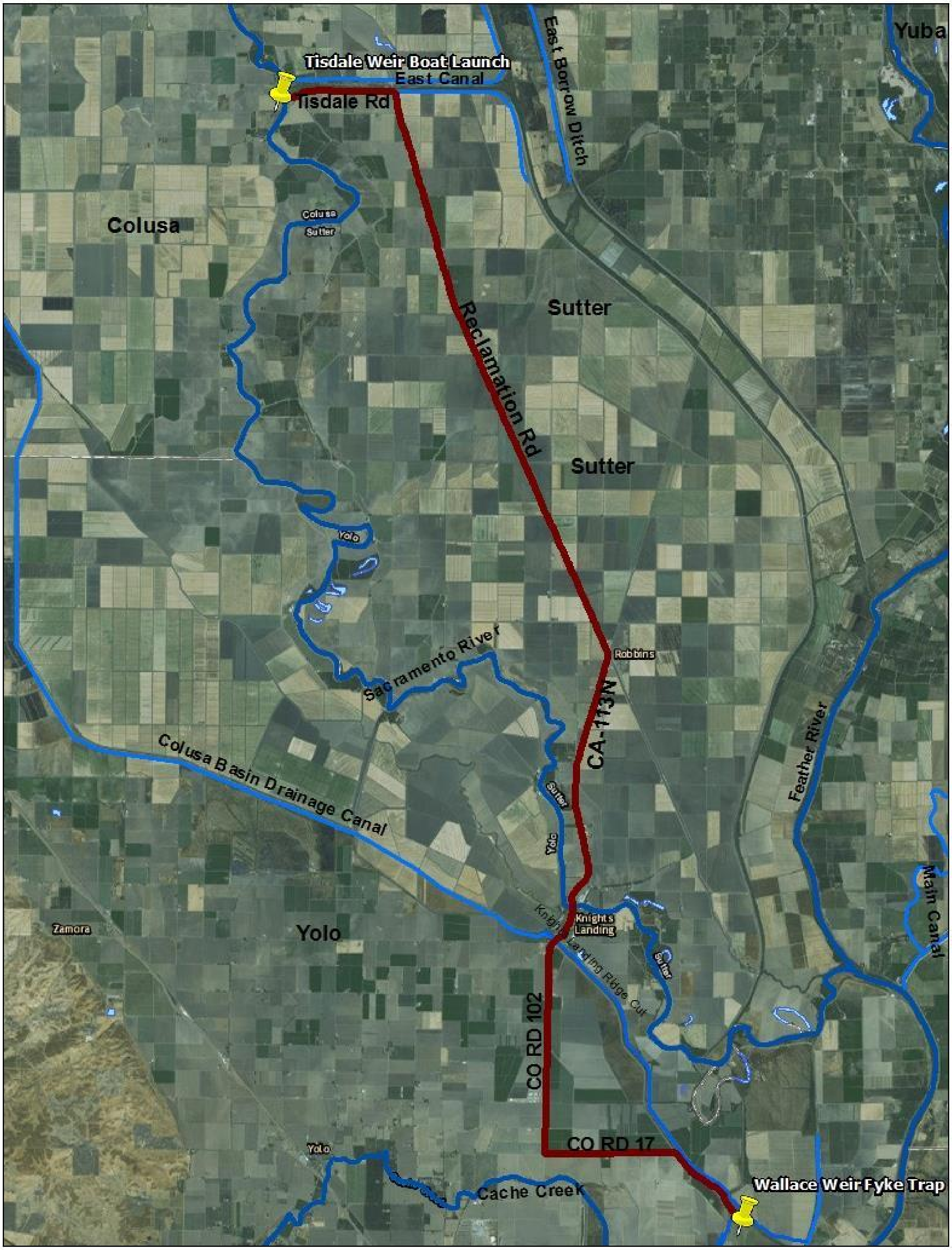

Figure 11. Map of Wallace Weir trap site, with route to the Tisdale Boat Ramp on the Sacramento River indicated as a red line.

To minimize stress to fish, water used in the transport tanks was gathered from the location of fish capture. Once a transport tank was filled with water, an initial water temperature reading was recorded. Water temperatures were re-evaluated every half hour when fish were being held in the transport tank and water temperature was adjusted accordingly by adding water. Prior to use between CBD and Wallace Weir sites, tanks were decontaminated with a heated pressure wash >140˚F to avoid potential spread of aquatic invasive species.

Fish were transported from the trap to the transport tank with a purse-style fish cradle that allowed fish to remain in water during transport. As an operating guideline, DFW personnel were instructed to place no more than 12 fish in a transport tank as per the USFWS recommendation of one fish per 34 gallons (personal communication, Jim Smith, Project Leader, USFWS).

Upon arrival at either release site, water temperature was measured and recorded for both the transport water and the receiving water. When there was a difference greater than two degrees Fahrenheit between the transport and receiving water temperatures, water circulation systems and oxygen delivery systems were shut off and receiving water was transferred into the tank until the transport water was equal to the receiving water temperature.

Once water temperature was equalized between the transport tank and receiving water, the transport trailer was backed down the boat launch to a point where the lift gate could be submerged in the river. The release gate was then opened allowing fish to volitionally swim from the tank to the Sacramento River.

RESULTS

Environmental Conditions Observed at the Colusa Basin Drain

The CBD resistance weir operated for a total of 172 days from 2 November 2013 through 22 May 2014. Mean weekly flow ranged from a high of 674.7 cfs (week 10) to 30.0 cfs (week 44) during the entire trapping period (Figure 12 and Table 1). Peak flow was observed on 1 March 2014, at 1,322 cfs during week 14. Mean weekly water temperature in CBD ranged from 38°F on 12 December 2013 to 72°F on 15 May 2014, and averaged 57°F during the trapping period (Figure 12 and Table 1). Flows in the CBD from 6 May to 22 May 2014 were insufficient for the trap to be operated. During this time of low flows, the trap was still checked for any maintenance needs and to document conditions.

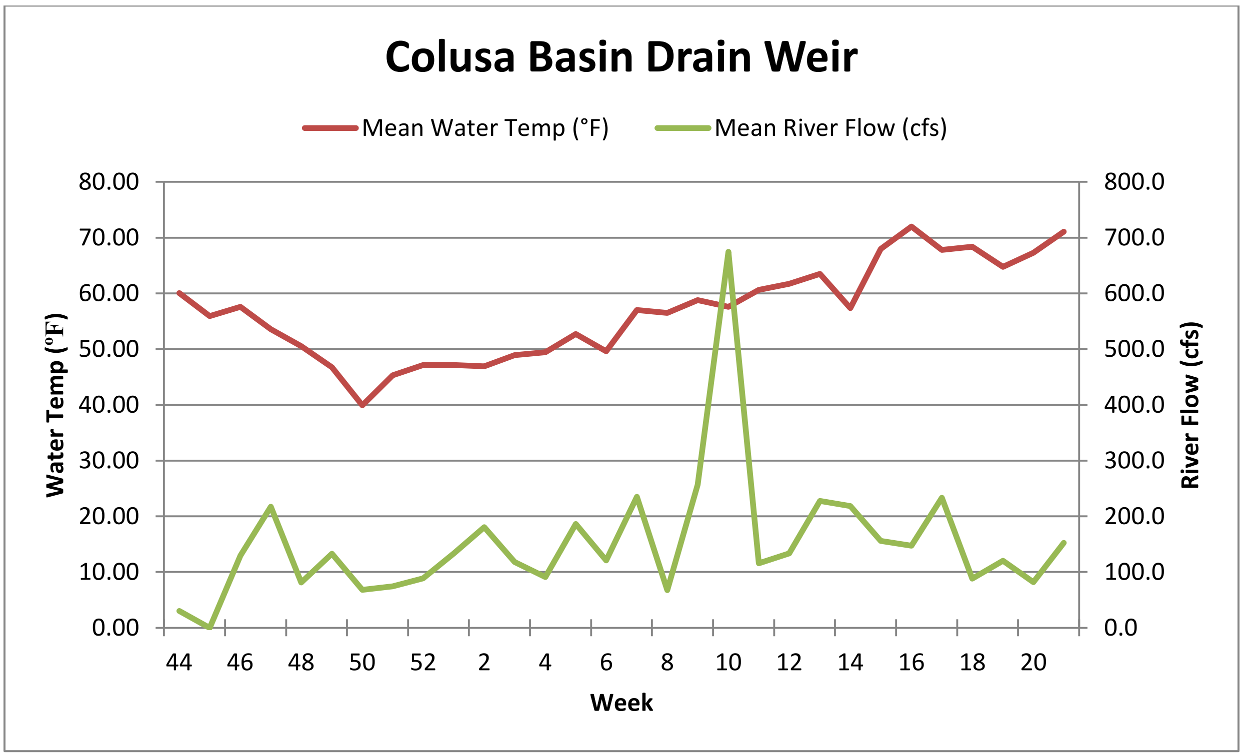

Figure 12. Mean weekly water temperature and mean weekly river flow in the Colusa Basin Drain during the trapping period of 2 November 2013 through 22 May 2014. Water flow was reported by CDEC, Colusa Drain near HWY 20 gauge (CDR).

Table 1. Weekly summaries of environmental conditions recorded for Colusa Basin Drain Weir from 2 November 2013 through 22 May 2014.

Week	Date	Mean Water Temp (°C)	Mean Water Temp (°F)	Mean River Flow (cfs)	Mean Water Turbidity (NTU)
44	10/27/13	15.6	60.08	30.0	N/A
45	11/3/13	13.3	55.94	N/A	N/A
46	11/10/13	14.2	57.56	129.8	N/A
47	11/17/13	12.0	53.60	217.5	N/A
48	11/24/13	10.3	50.54	81.4	N/A
49	12/1/13	8.2	46.76	132.7	39.2
50	12/8/13	4.4	39.92	68.2	15.4
51	12/15/13	7.4	45.32	74.4	19.3
52	12/22/13	8.4	47.12	88.6	25.3
1	12/29/13	8.4	47.12	133.4	15.3
2	1/5/14	8.3	46.94	180.4	25.0
3	1/12/14	9.4	48.92	117.9	21.5
4	1/19/14	9.7	49.46	91.1	31.1
5	1/26/14	11.5	52.70	186.1	32.3
6	2/2/14	9.8	49.64	120.7	33.8
7	2/9/14	13.9	57.02	235.3	52.7
8	2/16/14	13.6	56.48	67.6	52.4
9	2/23/14	14.9	58.82	257.1	44.7
10	3/2/14	14.2	57.56	674.7	118.2
11	3/9/14	15.9	60.62	115.7	47.2
12	3/16/14	16.5	61.70	133.3	41.4
13	3/23/14	17.5	63.50	227.9	31.1
14	3/30/14	14.1	57.38	218.6	53.4
15	4/6/14	20.0	68.00	155.7	34.1
16	4/13/14	22.2	71.96	147.6	33.5
17	4/20/14	19.9	67.82	233.2	28.9
18	4/27/14	20.2	68.36	88.1	28.6
19	5/4/14	18.2	64.76	120.3	31.8
20	5/11/14	19.6	67.28	82.2	23.6
21	5/18/14	21.7	71.06	152.3	35.8

Environmental Conditions Observed at the Wallace Weir Sampling Location

Wallace Weir fyke trap operations were conducted for 136 days from 22 January through 6 June 2014. Mean weekly flow measurements at Wallace Weir ranged from 134.0 cfs (week 22) to 8.5 cfs (week 11) and water temperatures ranged from 48°F on 4 February 2014 to 76°F 5 June 2014 during the trapping period (Figure 13 and Table 2). During weeks 10, 11 and 12 (6 March to 11 March 2014, and 14 March to 17 March 2014) flows at Wallace Weir were high enough to overtop the fyke, upstream debris barrier and wing walls. For crew and equipment safety, trapping operations were stopped during these events. After each event, the fyke, upstream debris barrier and wing walls were re-installed and trapping operations were resumed. During periods when the trap was out, adult Chinook salmon could have passed migrated upstream into the CBD.

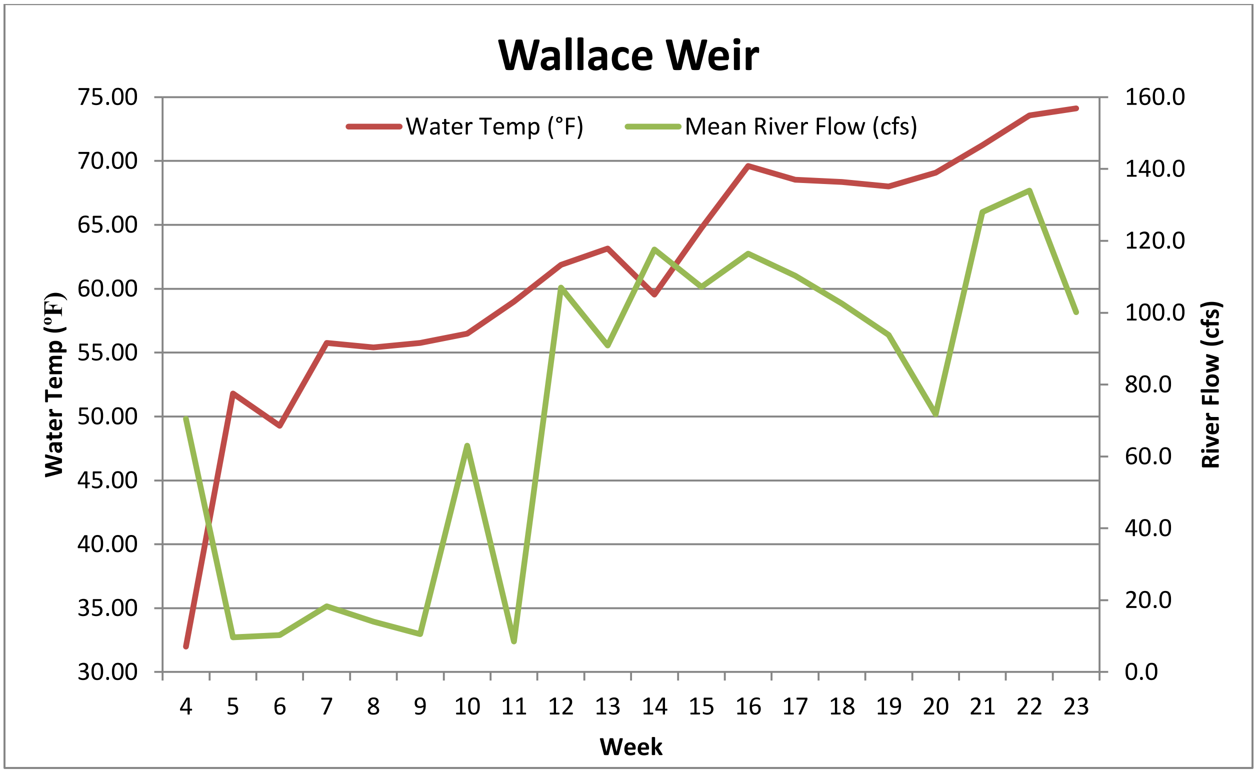

Figure 13. Mean weekly water temperature and mean weekly river flow for the Knights Landing Ridge Cut measured at the Wallace Weir sampling location from 22 January through 6 June 2014 (week 4 through week 23). Water flow was reported by CDEC, Ridge Cut Slough (RCS) gauge and reported in cubic feet per second.

Table 2. Weekly summaries of environmental conditions recorded for Wallace Weir fyke trap from 22 January through 6 June 2014.

Week	Date	Water Temp (°C)	Water Temp (°F)	Mean River Flow (cfs)	Mean Turbidity (NTU)
4	1/19/14	N/A	N/A	70.5	N/A
5	1/26/14	11.0	51.80	9.7	N/A
6	2/2/14	9.6	49.28	10.3	N/A
7	2/9/14	13.2	55.76	18.3	N/A
8	2/16/14	13.0	55.40	14.0	N/A
9	2/23/14	13.2	55.76	10.5	N/A
10	3/2/14	13.6	56.48	63.0	N/A
11	3/9/14	15.0	59.00	8.5	N/A
12	3/16/14	16.6	61.88	107.0	28.6
13	3/23/14	17.3	63.14	90.9	16.0
14	3/30/14	15.3	59.54	117.6	20.8
15	4/6/14	18.2	64.76	107.1	15.0
16	4/13/14	20.9	69.62	116.4	12.8
17	4/20/14	20.3	68.54	110.3	13.6
18	4/27/14	20.2	68.36	102.6	12.5
19	5/4/14	20.0	68.00	93.9	10.3
20	5/11/14	20.6	69.08	71.8	11.1
21	5/18/14	21.8	71.24	128.0	9.9
22	5/25/14	23.1	73.58	134.0	7.5
23	6/1/14	23.4	74.12	100.2	5.9

Summary of Fish Catch

A total of 2,687 fish were captured from both sites during the period of trapping operations (Table 3). Most fish (2,562) were captured at Wallace Weir and the remaining 125 fish from the CBD site. Catch consisted of a total of nineteen species, eight native and eleven non-native species.

Table 3. Summary of fish species recovered from 2 November 2013 through 6 June 2014. *California native fish species.

Common Name	Scientific Name	Number Captured Wallace Weir	Number Captured CBD
Common Carp	*Cyprinus carpio*	2249	111
Sacramento Sucker*	*Catostomus occidentalis*	154	3
Sacramento Pikeminnow*	*Ptychocheilus grandis*	59	0
Channel Catfish	*Ictalurus punctatus*	39	5
Largemouth Bass	*Mirocpterus salmoides*	13	0
Chinook Salmon*	*Oncorhynchus tshawytscha*	**9**	**2**
Striped Bass	*Morone saxatilis*	9	0
Black Crappie	*Pomoxis nigromaculatus*	8	0
Goldfish	*Carassius auratus*	6	1
White Catfish	*Ameiurus catus*	5	1
Sacramento Splittail*	*Pogonichthys macrolepidotus*	4	0
American Shad	*Alosa sapidissima*	2	0
Big Scale Log Perch	*Percina macrolepida*	1	0
Sacramento Blackfish*	*Orthodon microlepidotus*	1	0
Steelhead*	*Oncorhynchus mykiss*	**1**	0
White Crappie	*Pomoxis annularis*	1	0
White Sturgeon*	*Acipenser transmontanus*	**1**	0
Tule Perch*	*Hysterocarpus traskii*	0	1
Western Mosquitofish	*Gambusia affinis*	0	1

A total of nine Chinook salmon were recovered at the Wallace Weir fyke trap and relocated to the Sacramento River. A total of two Chinook salmon were recovered at the CBD weir on 8 November 2013 and 18 March 2014; both were found dead. An upper caudal fin from all collected Chinook salmon was taken for post-hoc genetic based race designation. Results from genetic analysis indicate that of the total recovered from both sites there were 3 fall-run, 3 winter-run, and 5 spring-run Chinook salmon that ascended KLRC and CBD during the sampling period (Table 4). Genetic analysis further indicated that all recoveries were from either upper Sacramento River or Butte Creek.

Table 4. Summary of Chinook salmon trapped and DNA analysis results from both sites; 2 November 2013 through 6 June 2014 (HW = hatchery winter-run; Rsp = spring run)

ID	Sex	Sample Date	Fork Length (mm)	Assignment	PosProb1	Group	Best	AD Clip
CBDC1301	M	11/8/2013	805	Non-winter	1.00	Spring	Upper Sac. Rsp	No
WW1	M	2/4/2014	900	Non-winter	1.00	Fall	Butte Creek	No
WW2	M	2/7/2014	860	Non-winter	1.00	Fall	Butte Creek	No
WW3	F	2/7/2014	870	Winter	0.98	Winter	Upper Sac. HW	Yes
WW4	F	2/28/2014	830	Winter	1.00	Winter	Upper Sac. HW	No
WW5	F	3/4/2014	790	Non-winter	1.00	Spring	Upper Sac Rsp	No
WW6	M	3/5/2014	960	Winter	1.00	Winter	Upper Sac. HW	No
CBCD01	F	3/18/2014	800	Non-winter	1.00	Spring	Upper Sac Rsp	No
WW7	F	3/25/2014	750	Non-winter	1.00	Fall	Butte Creek	No
WW8	F	4/17/2014	810	Non-winter	0.99	Spring	Upper Sac Rsp	No
WW11	M	4/22/2014	770	Non-winter	1.00	Spring	Upper Sac Rsp	No

DISCUSSION

Results from the pilot trapping year indicate that Central Valley Chinook salmon have the ability to migrate into the CBD via the Yolo Bypass or KLOG during non-flood periods. Other native anadromous species such as steelhead and white sturgeon appear to be attracted into and use these canals during non-flood periods as well, though possibly to a lesser extent. The single observations of each species may be a function of smaller population sizes or slightly different migration timing, ability and or attraction cues than those of Chinook salmon.

Observation of non-native anadromous species such as striped bass and American shad at the Wallace Weir site indicates that these migratory species are also attracted into KLRC from the Yolo Bypass during non-flood periods and have access to CBD under some conditions. Other non-native warm water and resident fish species collected at both sites may reside in the trapping locations as they are typically found in various waterbodies throughout the Central Valley.

During spring of 2014, there were three periods from February through April with suitable conditions for Chinook salmon attraction and passage through the KLOG gate structure (Figures 15 and 16). Only one of the two Chinook salmon recovered at the CBD weir overlapped with these periods. Though KLOG cannot conclusively be identified as the entry point for either of the two fish recovered at the CBD trap, the low numbers suggest entrainment through KLOG was minimal during the sampling period. The low numbers of Chinook salmon observed at the CBD weir additionally suggest that few if any fish passed the Wallace Weir trapping location during high flows when trapping operations were suspended.

The critically dry water year during 2013/2014 sampling season may have influenced the numbers of anadromous fish collected at both trapping sites. Drought and low flows may have influenced numbers of anadromous fishes through affecting attraction cues and passage conditions either into the KLRC or through KLOG. Adult Chinook salmon escapement in Sacramento River and tributaries during fall of 2013 and spring of 2014 was lower compared to the previous season. Relative to the number of Chinook salmon recovered in the CBD during early spring of 2013 (312 adult Chinook salmon), the numbers observed in spring of 2014 at the CBD weir were minimal (1 adult Chinook salmon). This suggests in part, that attraction cues into the KLRC and KLOG may have been different between the two consecutive seasons though attraction cues during both seasons were non-flood related. In evaluating attraction cues, factors of interest which occurred when adult Chinook salmon are present in the Delta and Sacramento River include Sacramento River flow, tidal action in the Delta, CBD flows (either flood runoff and irrigation return flows), KLOG operations and KLRC flows.

Also of interest in evaluating attraction cues for recovered fish was that the recoveries at the Wallace Weir trapping site occurred shortly before and after new or full moon phases and associated monthly high tides (Table 5, Figure 16). This suggests an association between tidal fluctuations at the mouth of the Cache Slough complex and fish attraction into the complex and the toe drain during non-flood periods. The mechanism for this is likely the ebb cycle following flood tides magnifying the flow signal of water coming down the toe drain. If water moving through KLRC and Tule Canal is sufficient for fish passage, tidal action may provide greater attraction to these flows for anadromous fish. Low Sacramento River flows most likely amplify this effect by decreasing attraction to the main stem Sacramento River for adults passing through the North Delta. Sacramento River flows were below average in March through June of 2013 overlapping with the adult migration period for winter and spring-run Chinook and coinciding with stranded Chinook salmon found in the CBD. Similarly, Sacramento River flows were below average in winter and early spring of 2014 (Figure 14).

Also of interest in evaluating attraction cues into the CBD are KLOG operations. KLOG operations have a substantial influence on attraction cues to the outfall gates from the Sacramento River and, conversely, in attracting fish into the CBD through KLRC by regulating flows in the KLRC. The extent to which KLOG can influence flows in KLRC was clearly displayed in the hydrograph for the ridge cut (Figure 18). In early March, 2014, flows in the KLRC reversed, then spiked, which suggests that the outfall gates have the capacity to pass large portions of CBD flows to the Sacramento River during some conditions and rapidly change conditions in the KLRC. This has direct implications on attraction cues into KLRC and downstream.

Fish rescue efforts during fall of 2013 and spring of 2014 provided insight into mechanisms resulting in fish entrainment into the CBD. Fish can enter the CBD via two separate routes and entrainment can occur during periods of relatively low Sacramento River flows. As rescues are resource intensive and stressful on fish, it is crucial to further refine our understanding of conditions resulting in fish attraction to both the KLOG and the KLRC. As migratory fish can pass through the Yolo Bypass during high flows when the Fremont Weir is overtopped, finding ways to minimize fish attraction during non-flood periods could largely eliminate the potential for entrainment in the CBD and contribute significantly to protection of listed stocks.

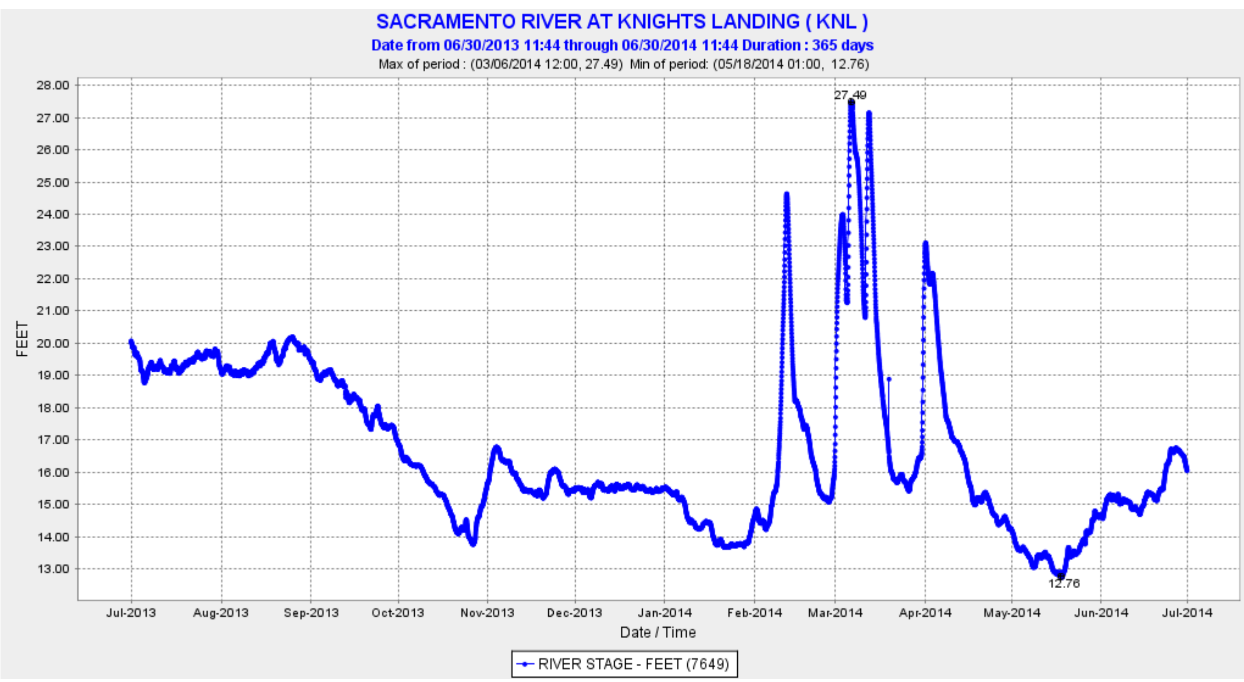

Figure 14. Sacramento River elevations at Knights Landing 1 July 2013 to 30 June 2014. Data source CDEC, accessed 10/24/15.

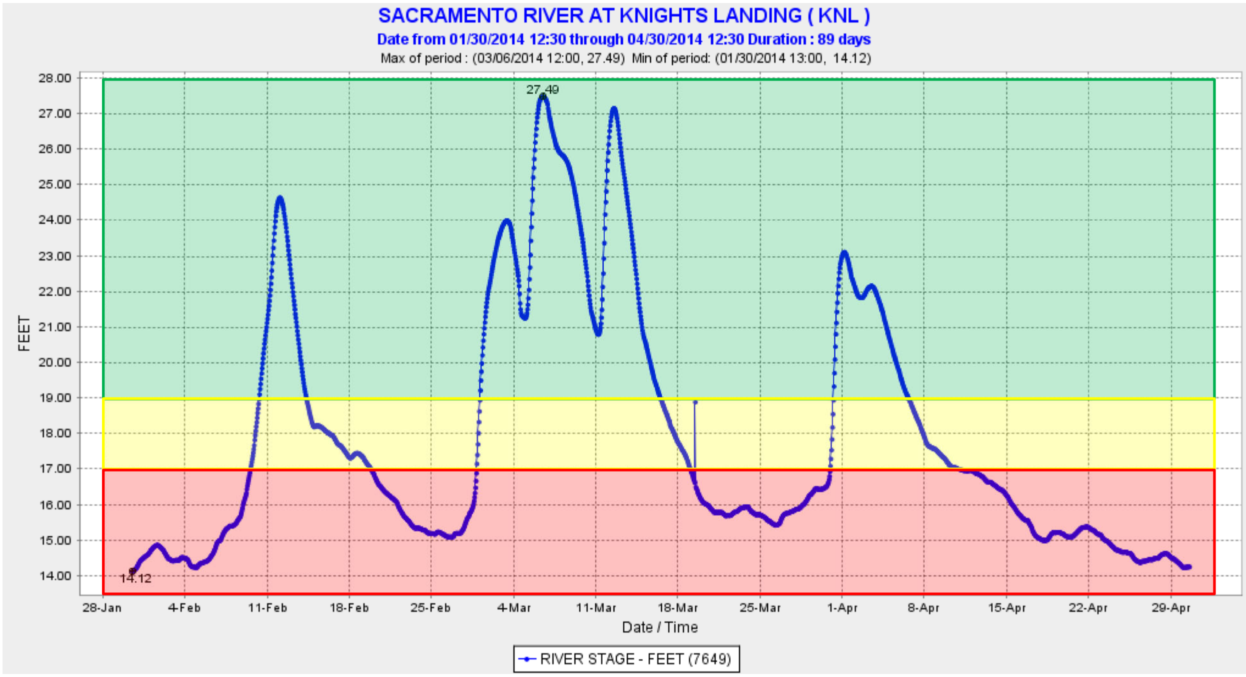

Figure 15. Sacramento River stage height at KL for the period from 1 February to 20 April 2014. Zones have been shaded to indicate the potential of fish passage through the outfall gates based on Sacramento River stage height at Knights Landing. There were three periods that provided suitable conditions for Chinook salmon entrainment from the river into the Colusa Basin Drain through the KLOG gate structure (Heise, 2014). Red indicates no potential for passage; Green and yellow show potential for fish passage. Data source CDEC, accessed 10/24/15.

Table 5. Moon phases in relation to salmon recovered.

Moon Phase	Moon Phase Date	Dates Salmon collected	Sex	Fork Length	Group	Best	AD Clip
New moon	1/30/2014	2/4/2014	M	900	Fall	Butte Creek	No
		2/7/2014	M	860	Fall	Butte Creek	No
		2/7/2014	F	870	Winter	Upper Sac. HW	Yes
New moon	3/1/2014	2/28/2014	F	830	Winter	Upper Sac. HW	No
		3/4/2014	F	790	Spring	Upper Sac Rsp	No
		3/5/2014	M	960	Winter	Upper Sac. HW	No
Full moon	3/16/2014	3/18/2014*	F	800	Spring	Upper Sac Rsp	No
		3/25/2014	F	750	Fall	Butte Creek	No
Full moon	4/15/2014	4/17/2014	F	810	Spring	Upper Sac Rsp	No
		4/22/2014	M	770	Spring	Upper Sac Rsp	No

* Chinook salmon was recovered dead at CBD weir. Exact arrival timing is unknown.

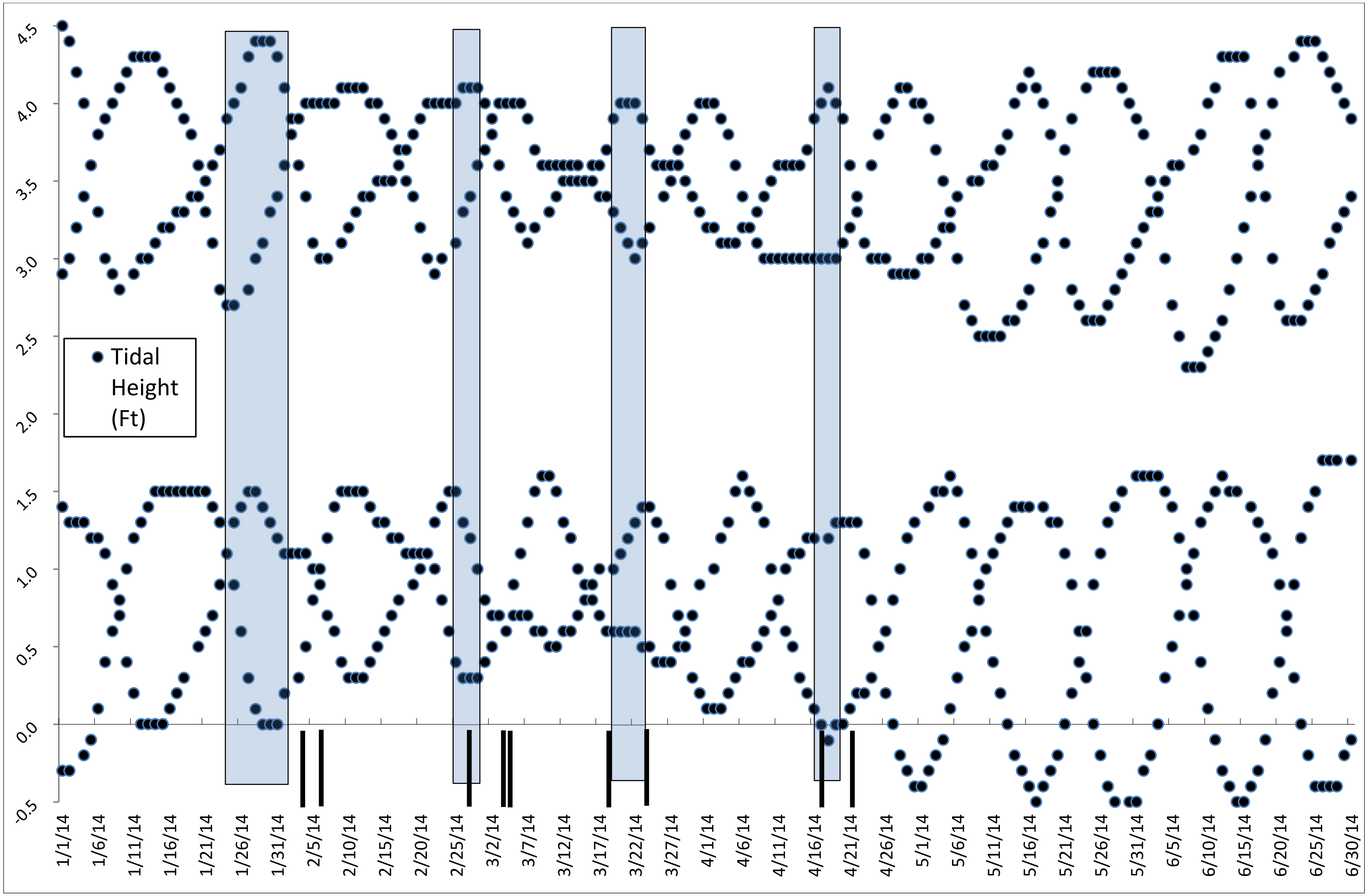

Figure 16. Tide height at Rio Vista. Data downloaded from NOAA Tides & Currents website 10/24/15 for station 9415316. Lines denote Chinook salmon catch. Boxes denote peak high tide periods in relation to observations of Chinook salmon.

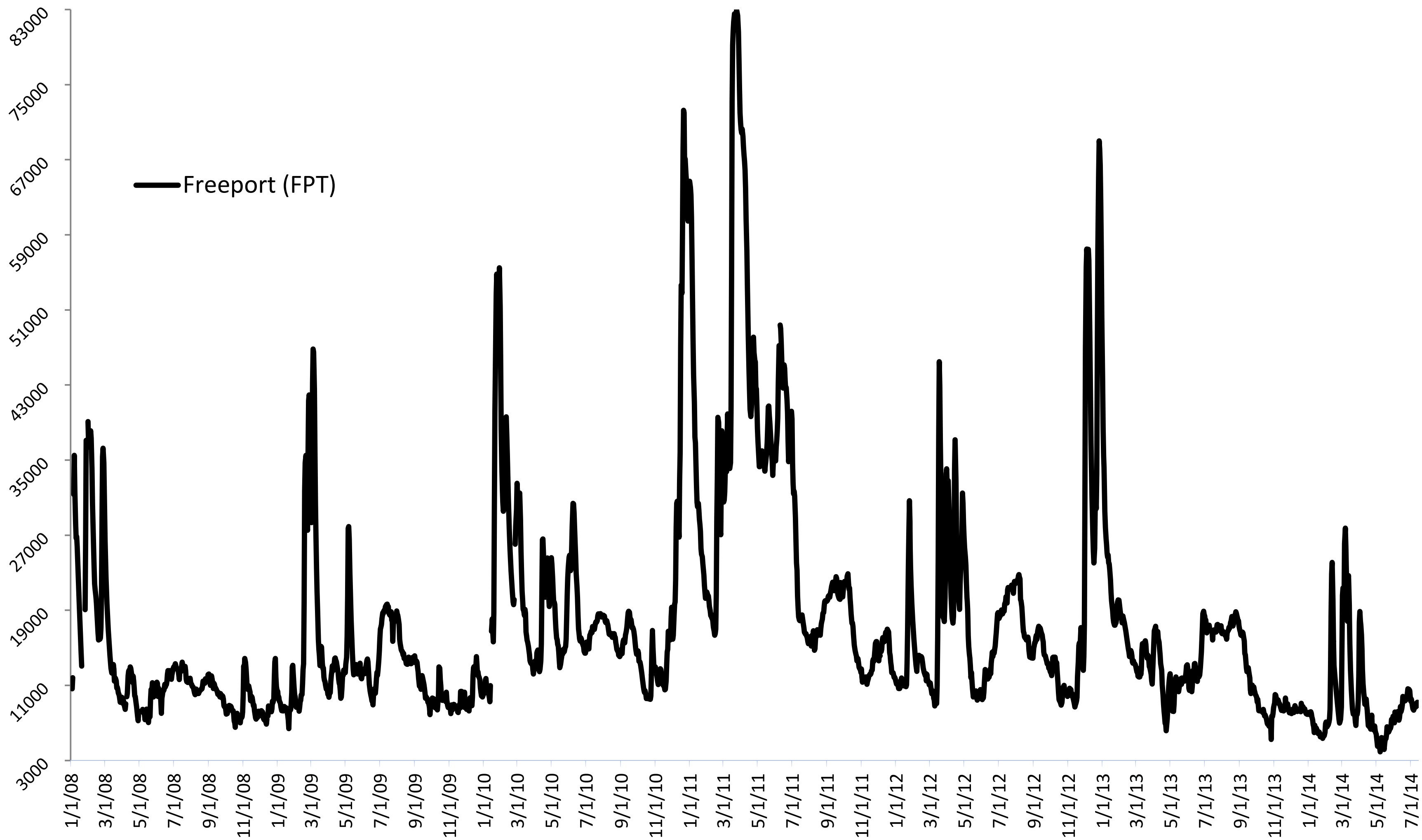

Figure 17. Sacramento River flows in cubic feet per second at Freeport. Data downloaded from California Data Exchange Center. Accessed on 10/24/15

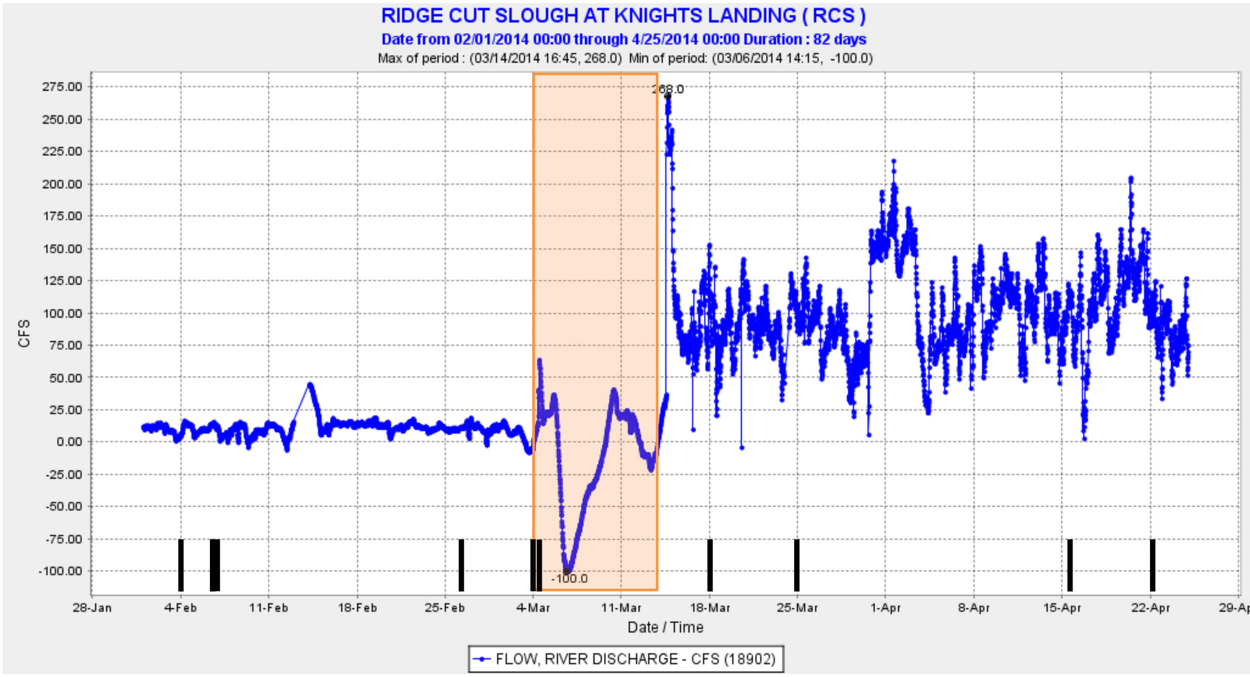

Figure 18. Ridge Cut Slough flow 28 January 2014 to 29 April 2014. The red box highlights the time period where Knights Landing outfall gate operations likely resulted in reverse flows within the ridge cut. Lines denote periods when Chinook salmon were observed at Wallace Weir. Note, fish recovered on 18 March 2014 was from CBD trapping site and was dead. Migration route for this fish in undetermined. Data source CDEC, accessed 10/24/15.

ACKKNOWLEDGEMENTS

The authors would like to express appreciation to both John Brennan and Jacob Katz for providing access and support for the fish rescue efforts at Wallace Weir. The authors would also like to express appreciation to Luis Bair of RD 108 for access and support at the weir site in the CBD. Additionally, we want to acknowledge the support of CDFW staff from the Region 2, Fisheries and Water Branches including Kevin Thomas, Tom Schroyer, Josef Lehr, Chad Dibble, Jason Roberts, and George Heise as well as CDWR staff for their support in rescue efforts at Wallace Weir during the season including Jared Frantzich and James Newcomb. Finally, we want to express our appreciation to Jim Smith and the USFWS for providing the specialized transport tanks required to transport adult fish to release locations.

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Appendix E. Guidelines for sample collection of dry and wet genetic sampling

Protocol for Taking Dry Genetic Samples

I. Select a fresh carcass suitable to obtain a tissue sample. A fresh carcass will have clear eyes (not cloudy) and/or pink gills. **Record all data on the coin envelope**. 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 no smaller than 1 square cm. 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.. 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, repackage tissue into its original, **dry**, envelope and attach to field notes for shipment to our lab. Please make arrangements with the Tissue Archive before shipping. Check all envelopes to ensure that the data is filled out completely and legibly

Protocol for Taking Wet Genetic Samples

Equipment you will need:

1) Screw cap tubes filled with 95% NON-denatured ethanol

2) Surgical scissors and forceps

3) Biological Data Sheet

Procedure:

1) Ensure that tubes are labeled in a way that will not wash off if ethanol leaks (laser-jet printed labels in the tubes work well).

2) To avoid sample contamination keep your hands, sampling instruments and work area clean. Rinse / wash scissors and forceps in fresh water prior to taking each genetic sample.

3) Use the scissors to cut a small piece of tissue off of the caudal fin (approximately 0.5 cm^2 each).

4) Place the tissue sample into the screwcap tube filled with alcohol and tightly screw on the cap (If the cap is not tight, the alcohol will evaporate).

5) Place the sample back in the plastic box. Samples should be stored at room temperature.

6) Contact Christian Smith via e-mail before sending samples to the USFWS genetics repository.

Christian Smith, U.S. Fish and Wildlife Service, Abernathy Fish Technology Center, 1440 Abernathy Creek Rd, Longview, WA 98632, Phone (360) 425-6072, e-mail: Christian_Smith@fws.gov

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