Technical Report 2018-3-FINAL

EVALUATION OF ADULT CHINOOK SALMON BEHAVIOR AT THE FOSTER DAM ADULT FISH FACILITY AND IN FOSTER DAM RESERVOIR ON THE SOUTH SANTIAM RIVER, 2017

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Department of Fish and Wildlife Sciences
University of Idaho, Moscow, Idaho 83844-1136

For

U.S. Army Corps of Engineers
Portland District

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Acknowledgements

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Executive Summary

Low Chinook salmon collection efficiency at the Foster adult fish facility (AFF), prolonged adult holding in the Foster Dam tailrace, spawning of hatchery-origin salmon in the wild, and prespawn mortality (PSM) have been ongoing concerns for fish managers in the South Santiam River basin. In 2017, we used radiotelemetry, photo and video monitoring, and river environment monitoring to address several objectives related to Chinook salmon behavior in the Foster tailrace and fishway and regarding adult collection efficacy at the Foster Trap. We also used radiotelemetry combined with archival temperature and depth loggers to assess the behavior and temperature exposure for presumed wild-origin (i.e., unclipped) Chinook salmon collected at the Foster Trap and outplanted into Foster reservoir, a trap-and-haul operation that would reduce transport time and distance and allow salmon to behaviorally thermoregulate in the reservoir before moving to spawning sites.

River environment

Water temperatures in the Foster Dam tailrace and fishway were affected by conditions in Foster Reservoir and source water (Middle and South Santiam rivers). Large temperature gradients (4-5 °C) were recorded in the Foster tailrace during periods of spill, with warmer reservoir surface water near the south side of the tailrace and colder water from the powerhouse and AFF. Foster AFF water temperatures continued to be ~1-2 °C cooler than the Foster tailrace after spill stopped in June. Importantly, Foster tailrace and AFF temperatures were routinely 8-10 °C lower than – and occasionally ~15°C lower than – the natural thermal regime of the South Santiam River upstream from the reservoir. Dissolved oxygen levels were slightly higher and specific conductivity was slightly lower inside the AFF than in the tailrace.

To test whether fishway entrance velocity affected salmon attraction and entry into the AFF, the main AFF entrance weir gate was manipulated in 2017 from mid-June to mid-September. A randomized-block schedule alternated between low-velocity (~1.2-1.5 m/s) and high-velocity (~4.5 m/s) treatments; blocks ranged from 1-13 d (*mean* =6.3 d).

Lebanon Dam adult trap installation and operation

We designed and built a removable adult salmonid trap in winter 2016-2017 that was installed in the middle fishway of the Lebanon Dam south-shore fishway in June 2017. The trap was fully functional starting on 6 July and was operated intermittently from 10-28 July, after the peak of the South Santiam Chinook salmon run. We collected and radio-tagged 16 hatchery-origin Chinook salmon at the Lebanon Trap during 67.2 h of effort (total CPUE = 0.24 fish/h).

Chinook salmon radio-tagged at Lebanon Trap

The 16 salmon tagged at Lebanon Dam quickly (*median* = 1.6 d) migrated the 19 km to the Foster tailrace. Fifteen salmon (94% of 16 released) were eventually detected inside the AFF fishway and 14 (88%) were detected near the Foster pre-sort pool. Time from first tailrace detection to first fishway entry was 10.3 d, on median, but several fish spent more than a month in the tailrace area before entering the fishway. The median passage time from fishway entry to

the pre-sort pool weir was 15.7 h, but several fish spent more than a week between first entry and detection near the pre-sort pool. Several fish also entered and exited the fishway multiple times.

Ultimately, just 7 of the 16 (44%) Chinook salmon radio-tagged at Lebanon were collected at the Foster AFF Trap. The salmon that were not captured at the trap had longer tailrace residence and fishway passage times, entered and exited the fishway more frequently, and were slightly smaller, on average, than the collected fish. Radio-tagged salmon entered the fishway during both fishway velocity treatments, but proportionately more entry events occurred during the low-velocity condition, consistent with previous sonar study results. Statistical tests of velocity treatment effects were inconclusive, but results from this and previous studies suggest that hydraulic or structural features are unlikely to be the primary factor limiting salmon collection rates at the Foster AFF Trap.

Temperature loggers from recaptured salmon indicated that fish body temperatures were ~15 °C in the South Santiam River downstream from Foster Dam, ~12 °C in the Foster tailrace, and ~10 °C inside the AFF fishway. Water temperatures in the tailrace and in the AFF varied little over the time that tagged salmon were present, precluding statistical evaluation of temperature effects.

Video monitoring at the Foster Trap entrance weir

We used video to monitor adult Chinook salmon and steelhead behavior at the weir immediately downstream from the Foster AFF pre-sort pool. We reviewed 309 randomly-selected 10-min video clips from 26 June to 15 September, with a minimum of 30 min reviewed each day. The video results were consistent with the radiotelemetry results in that many fish approached the AFF pre-sort pool but failed to enter. We observed 219 successful adult salmonid ascents into the pre-sort pool, 1,744 failed attempts, and 30 fallback events from the pool back into the fishway. Season-long estimates of behavioral metrics were 4.3 ascents/h, 38.1 attempts/h, 0.6 fallbacks/h and 9.0 attempts/ascent. Adult fallback out of the pre-sort pool was unexpected and mostly occurred while the fish crowder was operated and water elevation in the pre-sort pool was high.

Salmonid activity at the pre-sort pool weir largely paralleled adult collection at the AFF trap, indicating that the video data were a good index of salmon and steelhead presence. Salmonid activity was higher, on average, during the high-velocity fishway entrance treatment, but treatment effects were statistically complicated by interactions with diel and seasonal patterns. Low adult passage rates at the weir indicate that this is a problem area for adults, although the specific factors limiting collection remain uncertain.

Photo surveys of salmon holding in the Foster tailrace

We tested the feasibility of using optical cameras to systematically enumerate adult salmonids in the Foster tailrace. Six cameras were deployed at five locations adjacent to the powerhouse and one location above the spillway. The spillway deployment provided the widest field of view and highest quality images. We enumerated salmon visible in photos of the spillway tailrace 2 d/week from 30 June to 28 September. Mean daily minimum estimates of adult abundance in the spillway portion of the tailrace ranged from 24-114 fish/d in July, and were <15 fish/d in August and September. In a less formal review of photos from the powerhouse tailrace, fish were frequently in the attraction plume from the AFF fishway entrance and intermittently grouped in other locations, including in shaded areas during mid-day and afternoon. Better imagery of fish in the powerhouse tailrace is likely possible, but would require mounting cameras at a higher elevation than was feasible in 2017.

Chinook salmon radio-tagged at Foster Trap and released upstream

We radio-tagged adult Chinook salmon at the Foster AFF and then released 19 into the Foster reservoir and 5 into the South Santiam River above the reservoir. About 84% (n =16 of 19) of the reservoir-released fish eventually entered the South Santiam River and ~11% (n = 2) fell back past Foster Dam. Salmon residence times in the reservoir were highly variable, with a median time of 4.9 d but a maximum of 95.1 d. Most of the reservoir-released fish also moved between the South and Middle Santiam rivers, a behavior that may have been related to searching for natal sites or thermoregulation.

Archived data were recovered from 13 salmon, including nine released into the reservoir and four released in the South Santiam River. Daily Chinook salmon body temperatures in the river averaged 15.8 °C, which was warmer than those in the reservoir (13.8 °C) and much warmer than those that were temporarily in the Middle Santiam River (8.5 °C). Fish in the reservoir were often 4-6 °C cooler than those in the river from mid-July to mid-August, the period when the South Santiam River was near seasonal peak temperatures. Salmon depths in the reservoir were concentrated around 5-7 m, but fish were occasionally as deep as 25 m.

Consistent with results in previous study years, reservoir-released Chinook salmon had lower acute and cumulative temperature exposure, on average, than river-released fish. The reservoir release strategy may therefore reduce the risk of prespawn mortality in Chinook salmon in the South Santiam River trap-and-haul program. Furthermore, a single reservoir-released salmon was last detected in the Middle Santiam River in 2017, suggesting that reservoir release may give adults the opportunity to locate and use natal tributaries. We note, however, that natal origin was unknown for all radio-tagged fish, the risk of fallback may differ between salmon with above- and below-dam natal origin, and thus the benefit vs. risk of reservoir-release may differ between origin groups.

Introduction

The Foster adult fish facility (AFF) was reconfigured in the winter of 2013-2014 with significant structural modifications. The rebuild aimed to address several objectives, including more efficient collection and sorting of adult migrants, reduced fish handling, and improved ability to sort, hold and transport fish to hatchery facilities and trap-and-haul outplant sites upstream from Foster Dam. In spring and summer of 2014, Oregon Department of Fish and Wildlife (ODFW) hatchery personnel observed that many adult Chinook salmon (*Oncorhynchus tshawytscha*) were congregating in the Foster tailrace, but that few were being collected in the AFF trap facility; this behavior continued in 2015-2017. Adult holding in the Foster tailrace is not simply a function of the new AFF because similar behavior was observed in some years prior to the new configuration (Brett Boyd, ODFW, *personal communication*). A radiotelemetry study in 2011-2014 also showed that both hatchery and natural-origin salmon tagged at Willamette Falls spent 25-52 d, on median, in the Foster tailrace, and that the behavior was similar before and after the AFF modifications (Jepson et al. 2015). Adult salmon holding in the tailrace continues to be a concern for managers because: (1) it may delay broodstock collection; (2) delayed collection may compromise trap-and-haul of natural-origin fish to upstream release sites; and (3) failure to collect hatchery fish may result in increased proportion hatchery-origin salmon (pHOS) straying and inter-breeding with natural-origin Chinook salmon at downstream sites.

Several hypotheses for the perceived low AFF collection rates have been suggested. Possible hydraulic explanations include poor attraction to fishway openings or false attraction to non-collection sites such as the spillway, turbine, or hatchery effluent outlets. However, operational modifications that included modifying flow from the auxiliary water supply (AWS) and closing the side fishway entrance weir had relatively weak effects on behavior and trapping rate. It is also possible that differences in water temperature or water chemistry contribute to the observed Chinook salmon behaviors in the tailrace. Specifically, water for the adult fish facility is drawn only from the reservoir hypolimnion whereas water entering the tailrace is from several locations (i.e., spillway, powerhouse, hatchery effluent, etc.) so large water temperature gradients have been observed between the tailrace and fishway (Clabough et al. 2017). Notably, cool water in the AFF ladder and pre-sort pool is sourced from a deep-water inlet on the forebay face of the dam and thus is colder than at many tailrace sites and much colder during summer than in unregulated reaches of the South Santiam River upstream from Foster Dam. Temperature differences between the ladder and tailrace may affect fishway entry. Temperatures gradients inside fishways have been shown to slow passage and affect body temperature in Chinook salmon at Snake River dams, where fishways are often warmer than the tailrace (Caudill et al. 2013); we note that this is the converse of the conditions observed at Foster Dam. The water sources that strongly affect AFF temperatures may also result in different chemical signatures, including the composition of dissolved free amino acids (DFAAs), which are among the most important compounds used by salmon for imprinting and homing (Ueda et al. 2011).

In 2015, we started a series of studies at Foster Dam to investigate factors that may have contributed to the apparent low collection efficiency of adult Chinook salmon at the AFF (Clabough et al. 2017). These studies included extensive water temperature monitoring and water chemistry monitoring. We also conducted randomized block studies of altered hydraulic head (vis à vis water velocity) in one of the two Foster fishway openings in relation to AFF adult salmon collection rates (2015) and in relation to adult fish behaviors assessed using optical and acoustic cameras (2016). Overall, the results from the 2015-2016 studies indicated that adult salmonids frequently held near the main AFF fishway entrance and that the low-head, low-velocity treatment increased fish entry rates. However, substantial holding, milling, fishway exiting, and fish turnarounds in the fishway as far upstream as the base of the upper ladder limited salmon collection rate at the AFF trap. In both years, significant numbers of adult fish were observed holding in the tailrace throughout the experimental period, indicating low effective AFF collection rates. Examination of environmental data revealed strong temperature gradients within the tailrace during periods of spill with cooler water in the fishway. Temperatures encountered by adult salmon in the powerhouse tailrace and fishway were much cooler (mostly 11-12 °C) than in the South Santiam River above Foster reservoir, which were mostly > 15 °C. Low temperatures at the fishway entrance may have affected adult salmon behavior by reducing swimming rate and or stimuli for upstream movement. The studies were limited to observation of unmarked adults and thus individual behavior, passage time, passage success to the trap and overall system collection efficiency could not be estimated.

The 2017 Foster AFF research objectives addressed in this report were built on previous study results. To better understand how individual Chinook salmon behaved in the tailrace and AFF, including residency times and AFF collection rates, we radio-tagged adult Chinook salmon collected at a new, removable adult trap at Lebanon Dam (~30 rkm downstream from Foster Dam). We also used optical cameras to enumerate adults holding in the Foster tailrace and to evaluate their behaviors at the final weir below the AFF pre-sort collection pool, near where milling and turnaround behavior was previously documented (Clabough et al. 2017). Behaviors were related to operations in a randomized block fishway velocity experiment that paralleled previous experiments, and to water temperatures in the Foster tailrace and AFF.

In a separate research objective related to the South Santiam River trap-and-haul program, we radio-tagged adult Chinook salmon at the Foster AFF and released them in either Foster reservoir or the South Santiam River upstream from the reservoir. Reservoir release is currently an experimental approach to reduce adult transport times and distances and to reduce prespawn mortality of outplanted Chinook salmon (Keefer et al. 2010; Naughton et al. 2016; DeWeber et al. 2017) in the Willamette River tributaries. The strategy is premised on allowing salmon to behaviorally thermoregulate in the relatively cool water of reservoirs prior to spawning (Naughton et al. 2016, *in press*). Release into Foster reservoir also has the potential to improve homing to the South versus Middle Santiam rivers, as natal sites are often unknown for naturally-produced adult fish in the trap-and-haul program (Evans et al. 2016). Foster-tagged salmon released upstream in 2017 had temperature and depth sensors integrated into radio transmitters to better evaluate how salmon used reservoir habitats.

1. River and reservoir environment monitoring

Water temperature

In 2017, temperature loggers (HOBO V2 Pro, Onset, Inc., Bourne, MA) were installed at the Foster Adult Fish Facility, in the Foster tailrace, and upstream in the Middle Santiam and South Santiam rivers. Temperature data were also obtained from the USACE temperature string (0.2 to 24.4 m) located in Foster Reservoir (http://www.nwd-wc.usace.army.mil/ftppub/water_quality/tempstrings/). In the Middle Santiam, three temperature recorders were deployed with one near the mouth at Sunnyside (at river kilometer [rkm] 426.8 from the Columbia River mouth) and two in the middle section of the river (~3.2 rkm upstream from the mouth) (Figure 1). The site in the Green Peter tailrace (rkm 429.2) was not deployed in 2017, but temperature data were available and downloaded from the U. S. Geological Survey (USGS) site 14186200 (https://waterdata.usgs.gov/nwis/uv?site_no=14186200). Five temperature loggers were deployed in the South Santiam River: two at Menear's Bend (rkm 425.5), one at River Bend (rkm 428.3), one at Cascadia (rkm 437.3) and one at Gordon Rd (rkm 445.1; Figure 1). Fifteen temperature loggers were installed at Foster Dam fishway and tailrace (Figure 2). All recorders were deployed from ~2 May until 31 October.

Figure 1. Location of temperature loggers in the Middle and South Santiam rivers in 2017. Note Green Peter tailrace site is the approximate location of the USGS monitoring location (Site 14186200). Source: Google maps.

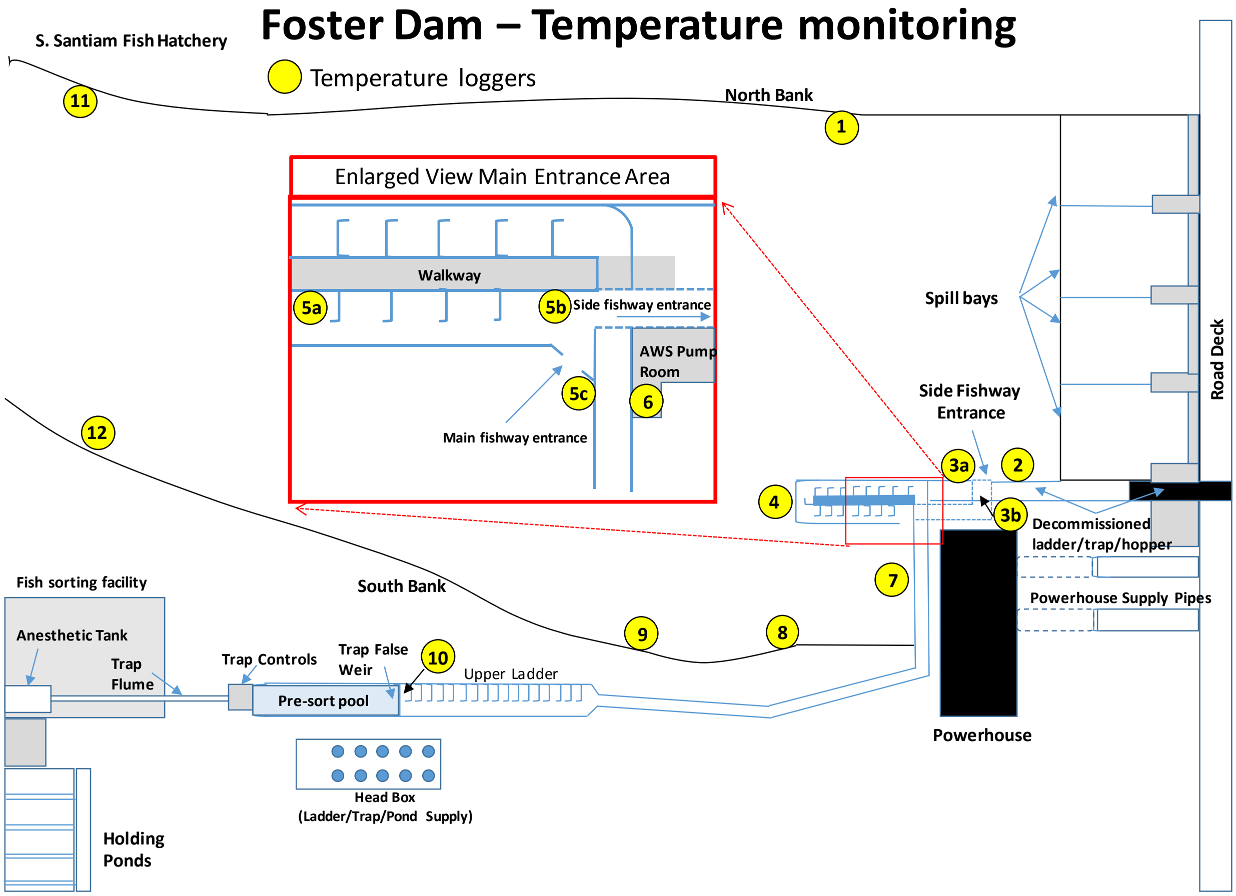

Figure 2. Map of the Foster Dam tailrace study area with water temperature logger locations (numbered circles) monitored in 2017. Logger sites: 1) North shore; 2) spill bay; 3a) side fishway entrance (outside); 3b) side fishway entrance (inside); 4) outside ladder wall; 5a) ladder 5th pool; 5b) main entrance (inside); 5c) main entrance (outside); 6) auxiliary water supply; 7) powerhouse wall; 8) turbine wall; 9) tailrace; 10) pre-sort pool, 11) downstream north, and 12) downstream south.

Water temperatures in Foster reservoir were stratified with warm water in the upper layers, reflecting surface warming of the reservoir but also input of relatively warm water from the South Santiam River and subduction of cooler water from the Middle Santiam River (Green Peter Dam releases) to depth. Mean daily water temperature in the Middle Santiam River during the 2017 study period (1 June to 1 October) was 8.4 °C, with a peak of 9.5 °C on 27 September (Figure 3); influence of reservoir water was apparent at the confluence site (Sunnyside). Water temperatures in the South Santiam River (Menear's Bend) were approximately 9.1 °C warmer (*mean* = 17.5 °C) than in the Middle Santiam River with a maximum mean daily water temperature of 22.5 °C on 7 August (Figure 4). Mean daily water temperatures in the South Santiam ranged from 17.5 °C at Menear's Bend to 15.0 °C at Gordon Rd. (Figure 4). In Foster reservoir, mean daily water temperatures collected by the U.S. Army Corps of Engineers (USACE) at 11 depths, ranged from 24.4 °C at 0.2 m (0.5 ft) from the surface to approximately 7.7 °C at 24.4 m (80 ft) (Figure 5). The thermocline was at approximately 4.6-6.1 m (15-20 ft) and water deeper than 6.1 m (20 ft) generally remained ≤15 °C throughout the summer.

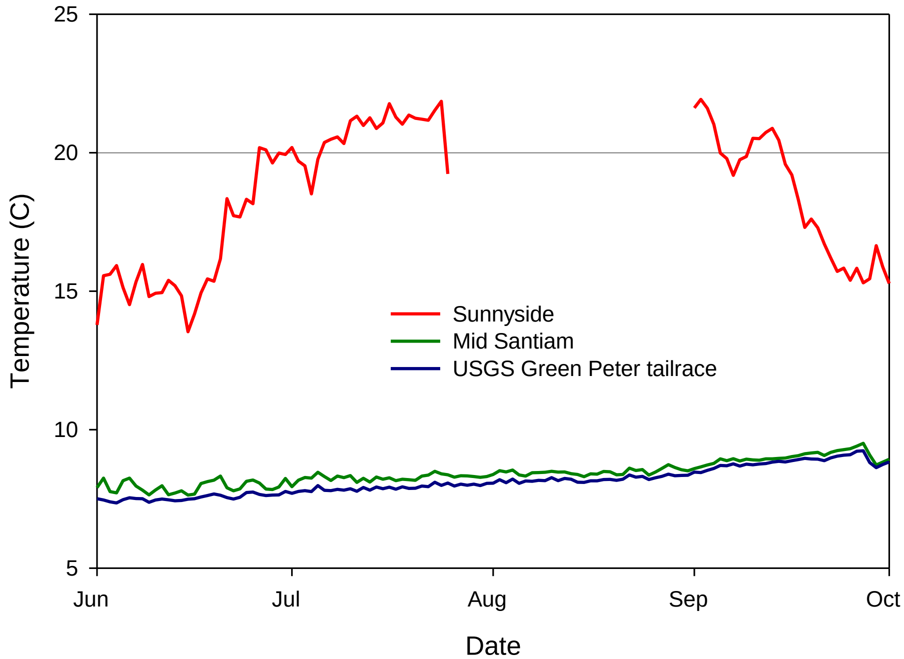

Figure 3. Daily mean water temperatures in 2017 in the Middle Santiam River. The loggers represent a progression upstream starting near the mouth at Sunnyside (rkm 426.8), to the Middle Santiam (rkm 430.0), and at the USGS site just downstream of Green Peter Dam (432.8 rkm). Solid line at 20 °C represents a threshold temperature considered to be physiologically stressful for adult salmonids.

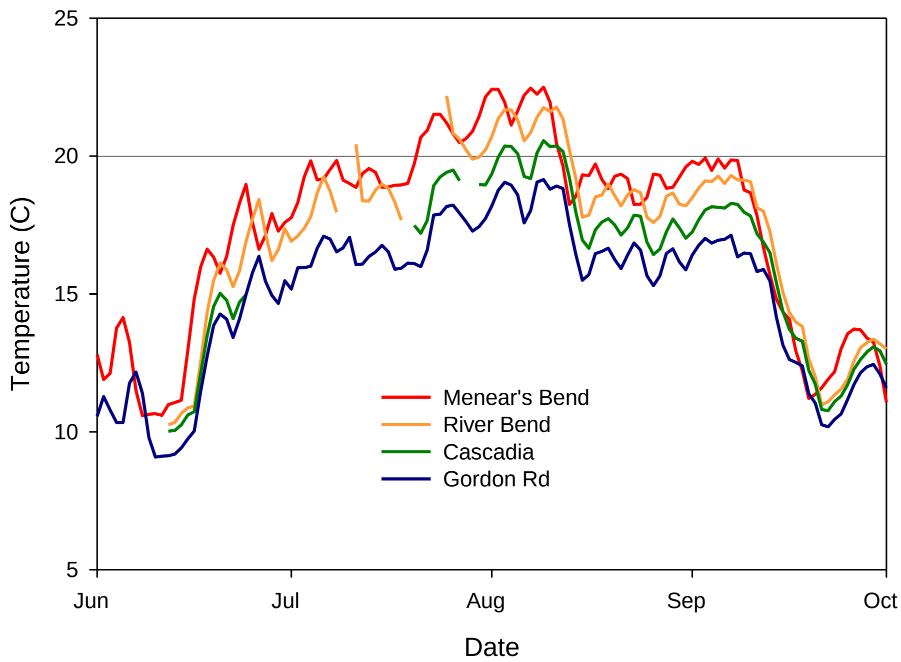

Figure 4. Daily mean water temperatures in 2017 in the South Santiam River. The loggers in the South Santiam represent a progression upstream from Menear's Bend (rkm 425.5) to the Gordon Road release site (rkm 444.7). Solid line at 20 °C represents a threshold temperature considered to be physiologically stressful for adult salmonids.

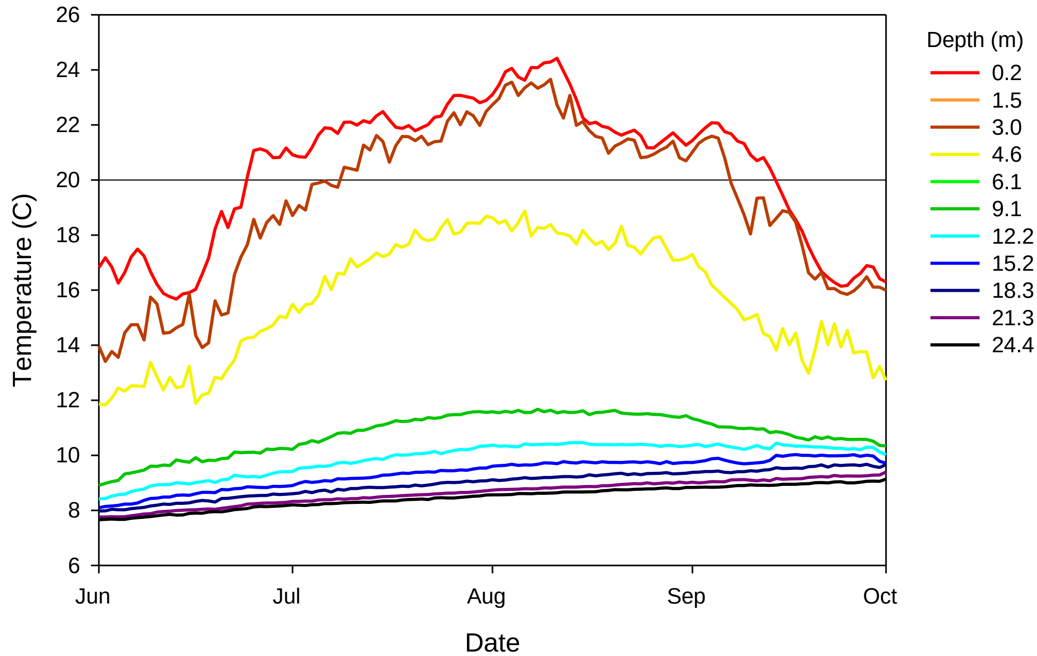

Figure 5. Foster Reservoir mean daily water temperatures collected at 11 depths between 1 June and 1 October 2017 (Source: U.S. Army Corps of Engineers). Note data for the 1.5 and 6.1 m depths of the temperature string were not available in 2017. Data are preliminary because an apparent logger naming error complicated interpretation of depths (Tina Lundell, Corps CENWP-EC-HR, *personal communication*). Solid line at 20 °C represents a threshold temperature considered to be physiologically stressful for adult salmonids.

Water temperatures in the Foster Dam tailrace and fishway were affected by conditions in Foster Reservoir and source water (Middle and South Santiam rivers). Warm South Santiam water stays near the surface of Foster Reservoir and the temperature signal is detected at Foster Dam during spill in June at the spill entrance outside, north shore, and downstream north temperature monitoring locations (Figures 6-7). Spill during this time was from the juvenile fish weir and a spillbay (Fenton Khan, USACE, *personal communication*). Cool water from Green Peter Dam in the Middle Santiam River is evident deep in Foster Reservoir and is observed in the fishway (ladder 5th pool and pre-sort pool) at Foster Dam (Figures 6-7).

Temperature gradients were observed within and among monitoring sites at the Foster AFF and tailrace in 2017. Water temperatures measured outside the side fishway entrance were ~3.3 °C warmer on average in June during spill than after spill stopped on 26 June (Figure 8). Temperatures in the tailrace were >1 °C warmer than the pre-sort pool after spill ended. Large temperature differences (4-8 °C) were observed between the side fishway entrance and the ladder wall. Lateral temperature gradients were also observed during spill, with water near the south shore tailrace site being much (4-5 °C) cooler than water near the north shore (Figure 8). Overall, the Foster tailrace was warmer than the AFF fishway, and both were generally cooler than the unregulated reaches of the South Santiam River upstream of the reservoir (Figures 6-8).

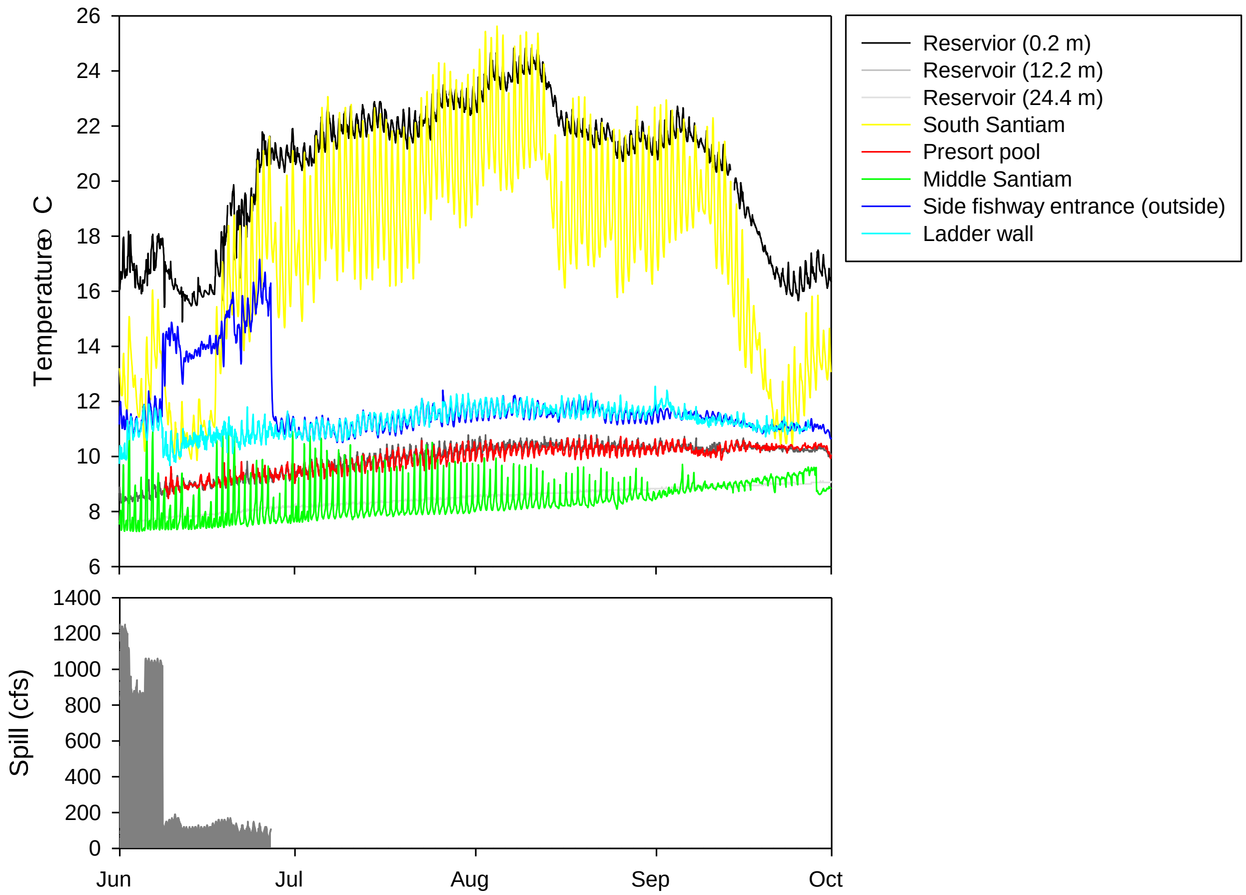

Figure 6. Foster Reservoir, South Santiam (Menear's Bend), Middle Santiam (Sunnyside), and Foster Dam mean hourly water temperatures (top panel) and spill (bottom panel) between 1 June and 1 October 2017. Spill and juvenile fish weir operations were stopped on 26 June.

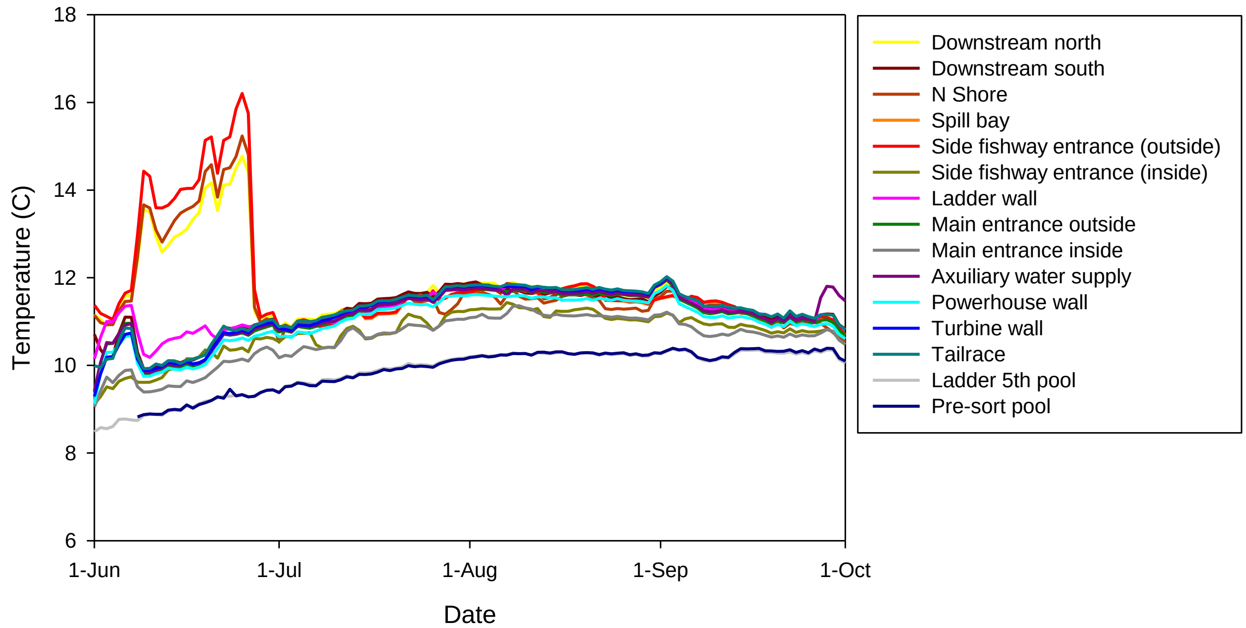

Figure 7. Mean daily water temperatures at the 15 Foster AFF fishway and tailrace monitoring locations in 2017 (see Figure 2 for locations).

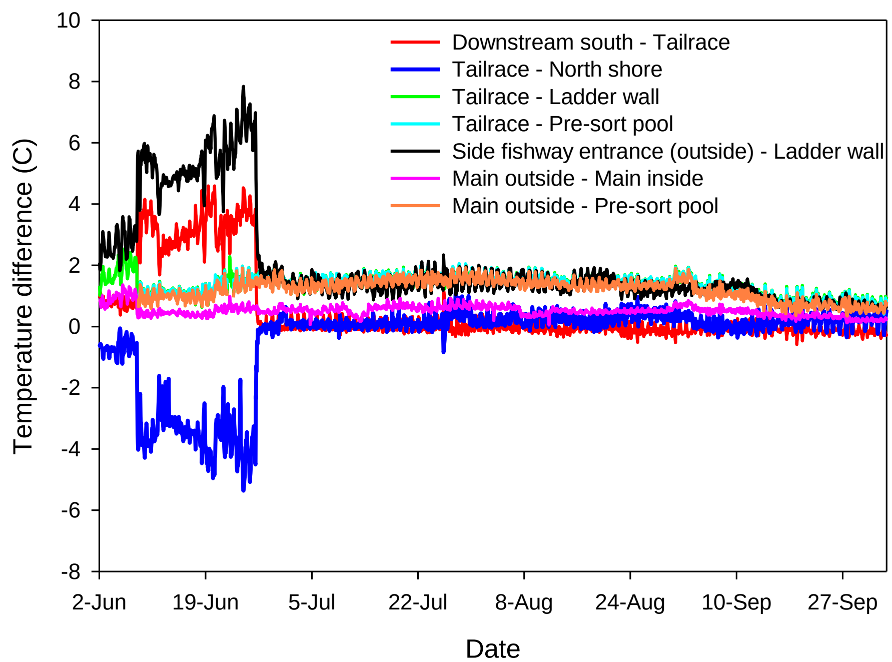

Figure 8. Pairwise differences in mean hourly water temperatures calculated from data collected at Foster AFF fishway and tailrace sites between 2 June and 3 October 2017. Site numbers as referenced in Figure A: Downstream south (12), Tailrace (9), North shore (1), Ladder wall (4), Pre-sort pool (10), Side fishway entrance outside (3a), Main outside (5c) and Main inside (5b).

Water chemistry

We monitored water chemistry parameters (pH, dissolved oxygen [DO], conductivity) in the fishway and tailrace of the Foster AFF in 2017. Two Hydrolab (Hach HL4 Sonde, Loveland, CO) units were deployed from ~24 May until 31 October. One Hydrolab unit was inside a PVC pipe mounted on a T-post in the tailrace (Figure 9; site 2) and the other was mounted to the I-beam in the turn pool (Figure 9; site 1). Results were corrected for differences between units. Due to inconsistent and possibly inaccurate pH recordings, pH results were not reported.

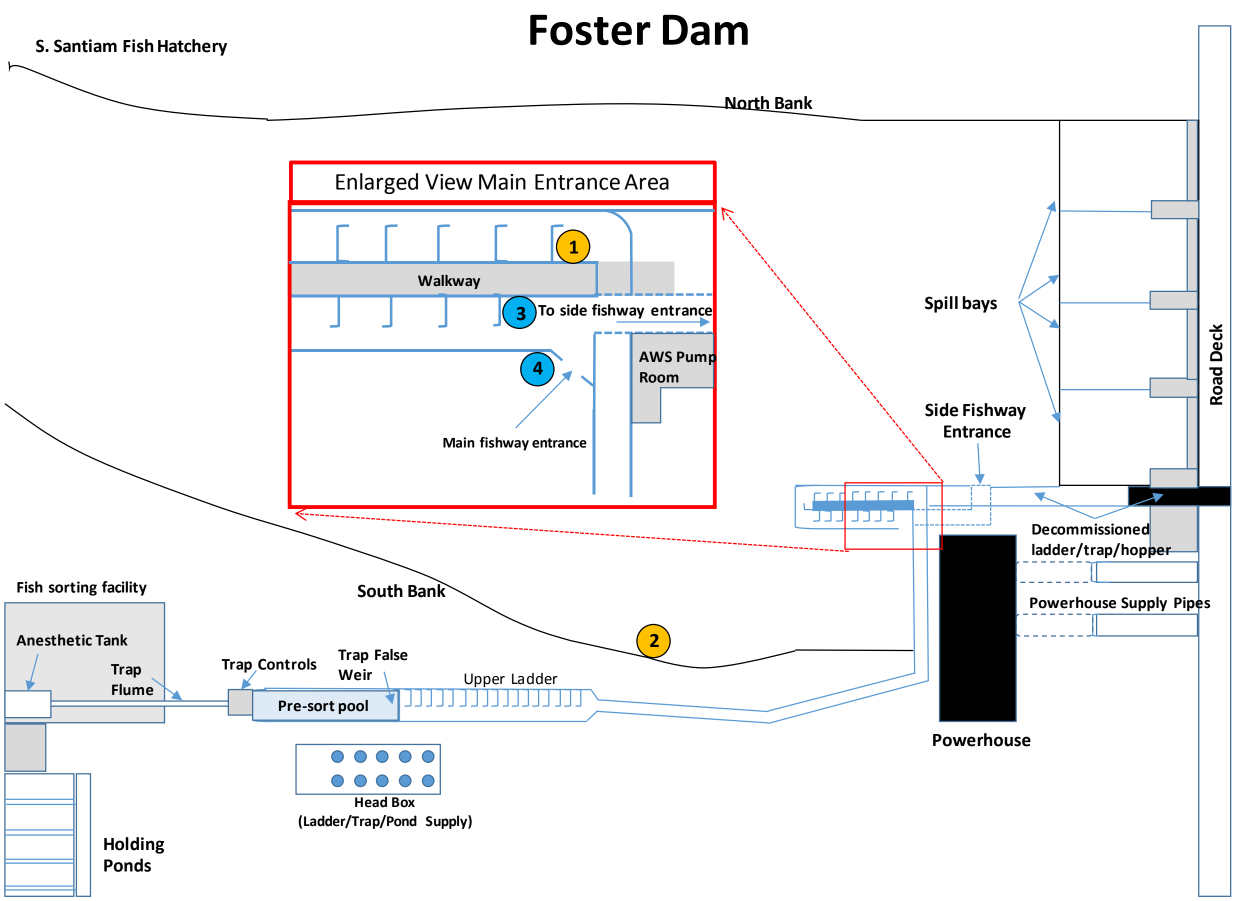

Figure 9. Map of the Foster Dam tailrace study area with location of hydrolabs (orange numbered circles) and water level loggers blue numbered circles in 2017. Hydrolabs: 1) ladder turn pool and 2) tailrace near south shore. Water level loggers: 3) inside the main entrance and 4) outside the main entrance.

Dissolved oxygen percent saturation (DO %) and dissolved oxygen (DO) were both higher in the fishway than in the tailrace during the 2017 study period (Figure 10). Fishway water is oxygenated at the head box and via turbulence and entrained air during movement down the weired section of the fishway. Thus, differences in DO between tailrace and fishways sites resulted from a combination of potential differences in source water DO and exchange rate with atmospheric gases. Specific conductivity (µs/cm) was generally lower in the fishway than in the tailrace, but differences were small.

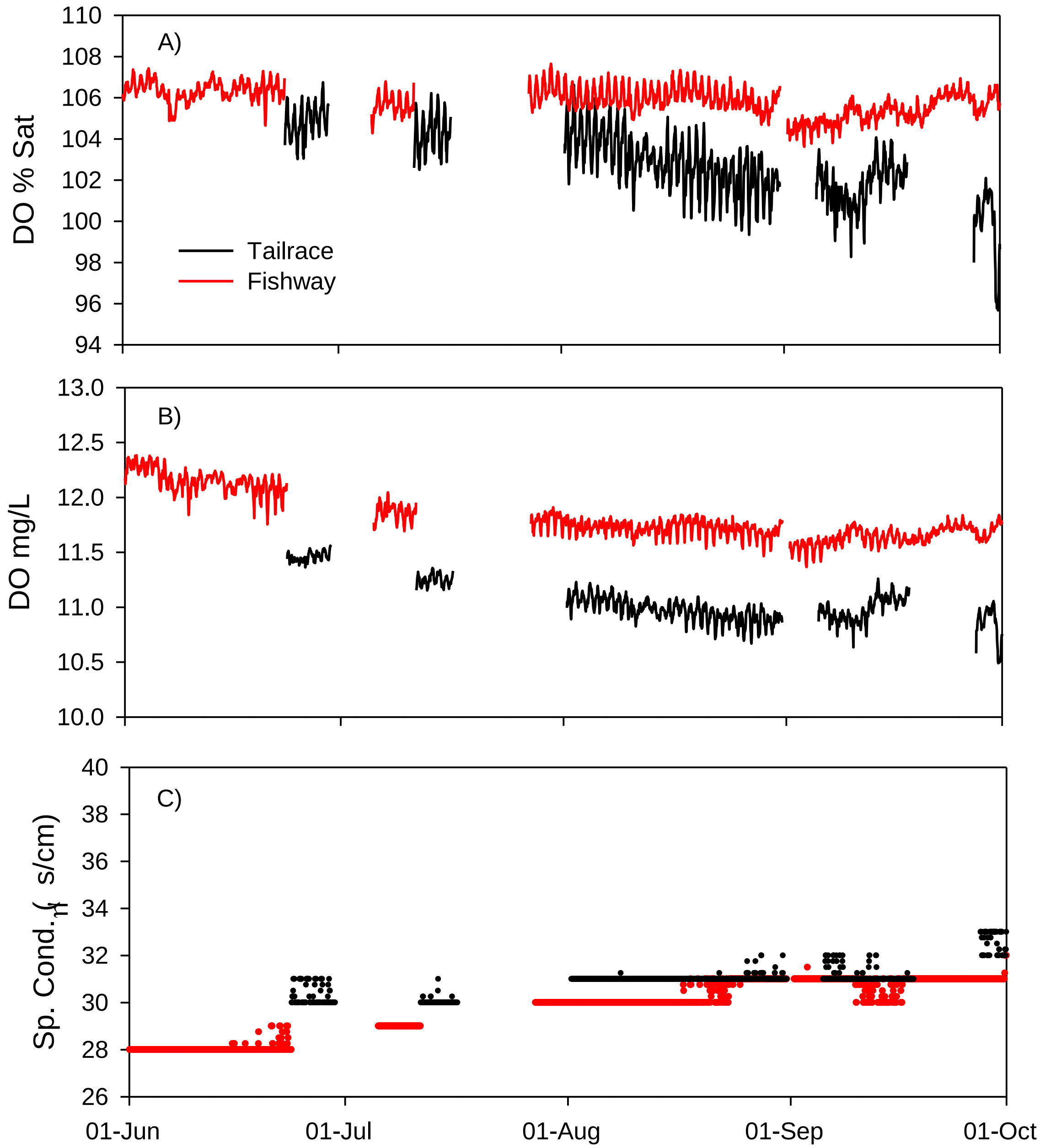

Figure 10. Water chemistry parameters collected in the Foster AFF fishway and tailrace: A) dissolved oxygen percent saturation (DO % Sat), B) dissolved oxygen (DO), and C) specific conductivity (Sp. Cond.) in 2017.

Foster Dam operations

Peak flow and spill at Foster Dam during May through October occurred on 18 May at 202 cms (7,140 cfs) and 195 cms (6,890 cfs), respectively. Mean daily spill from May 1 until the end of the spill period on 26 June was 46.4 cms (1,640 cfs). After spill stopped, daily flow averaged 38.2 cms (1,350 cfs) from 27 June to 1 October (Figure 11).

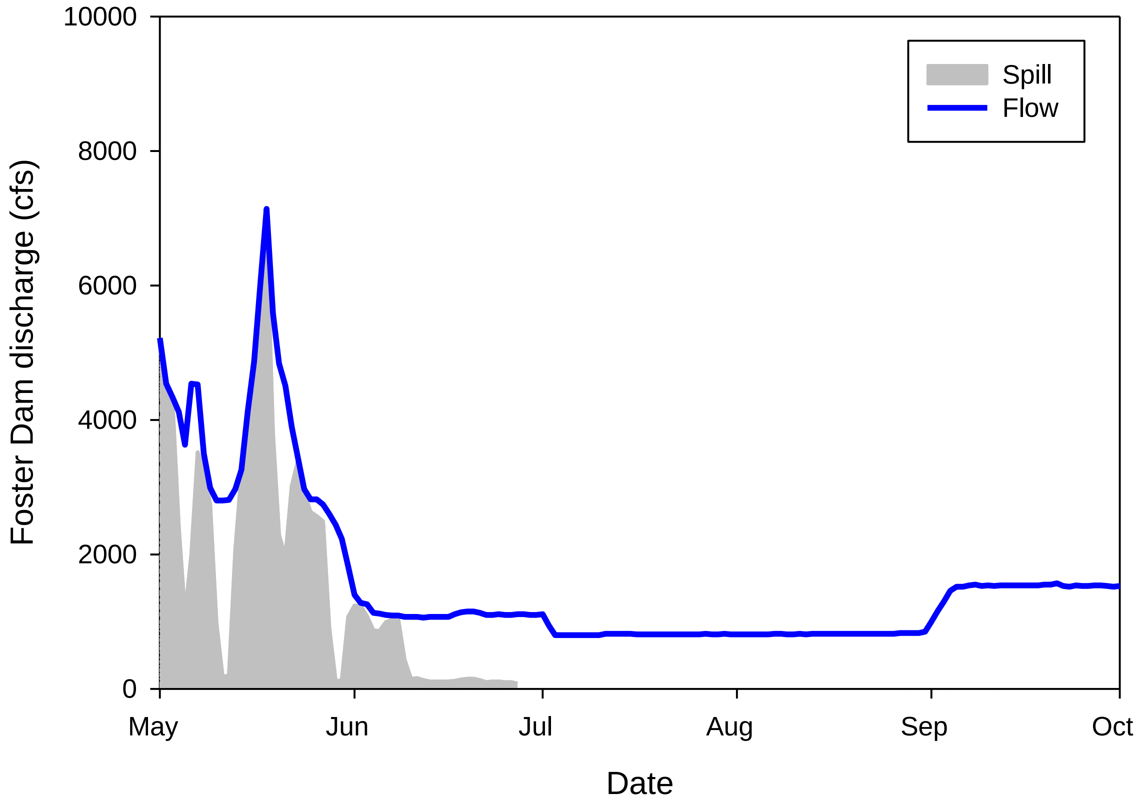

Figure 11. Mean daily flow and spill (cfs) at the Foster AFF in 2017.

Foster fishway entrance water velocity experiment

Entrance velocities at the Foster Dam AFF are controlled by a complex combination of discharge from the ladder (fixed), auxiliary water supply (AWS) water pumped into the fish collection channel / junction pool inside the fishway from intakes outside the main fishway entrance, forebay water supplied to the side entrance, and by altering the height of fishway entrance and transport channel weirs. AWS discharge is provided by up to four pumps, and the number of pumps operating increases discharge from the fishway as tailwater elevation increases. A forebay water supply valve increases discharge, in four increments, to the side fishway entrance at the same tailwater level set points that trigger the four AWS pumps (Steve Schlenker, USACE Portland District, 26 January 2017, *personal communication*).

In 2017, the main entrance weir gate was manipulated in either the ‘Open’ treatment position, with the gate completely lowered, or in the ‘Auto’ position, with the gate partially raised. Seven randomized treatment blocks were evaluated during the experimental period from 19 June until 15 September (Table 1). Entrance weir gate settings were altered between the ‘Auto’ and ‘Open’ treatments approximately every 6.3 d, on average, during the experimental period, although blocks were as short as 1 d and as long as 13 d (Figure 12).

We deployed two water level loggers (Hobo water level logger U20-001-02) at the main entrance (one inside and one outside the entrance) to assess water level differences during the experimental period. The Auto treatment increased hydraulic head by approximately 0.3 m (1 ft) compared to the Open treatment (see Figure 12). Pump operations data for 2017 were not archived and we assumed higher water velocity at the fishway opening was produced in the Auto treatment, on average, because tailwater elevation did not systematically change with treatment during the experimental period. Main entrance velocities were estimated to be ~1.2-1.5 m/s (~4-5 ft/s) during the ‘Open’ treatment and ~2.7-3.0 m/s (~9 to 10 ft/s) during the ‘Auto’ treatment based on head and estimated cross-sectional area of the fishway entrance (Steve Schlenker, USACE Portland District, 26 January, 2017, *personal communication*).

Table 1. Main entrance experimental design used in 2017 to test for effects of open versus automatically-controlled entrance gates at the Foster Dam AFF. Note variable duration of each block.

Start date	End date	Block	Treatment
19-Jun	27-Jun	1	Auto
27-Jun	30-Jun	1	Open
30-Jun	5-Jul	2	Auto
5-Jul	7-Ju1	2	Open
7-Jul	11-Jul	3	Auto
11-Jul	14-Jul	3	Open
14-Jul	21-Ju1	4	Auto
21-Jul	25-Jul	4	Open
25-Jul	7-Aug	5	Auto
7-Aug	8-Aug	5	Open
8-Aug	15-Aug	6	Auto
15-Aug	22-Aug	6	Open
22-Aug	3-Sep	7	Auto
3-Sep	15-Sep	7	Open

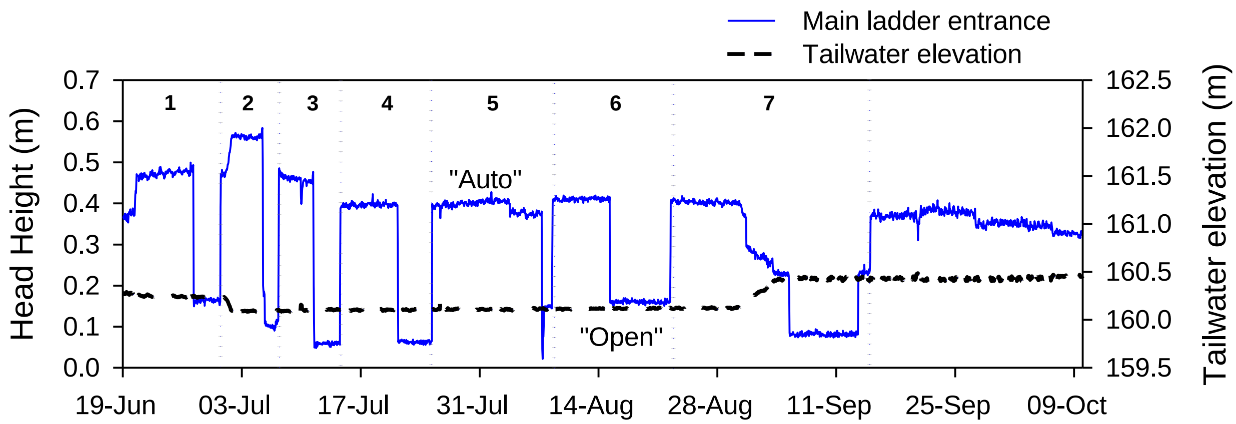

Figure 12. Head height (hourly) at the main entrance ladder in 2017 indicating 'Auto' when the weir gate was partially raised (head ~0.46 m [~1.5 ft] and 'Open' treatments (head ~0.15 m [~0.5 ft]) when the weir gate was lowered completely during the treatment period (19 June until 25 September). Dotted vertical lines and numbers represent the 7 treatment blocks during the study period. Tailwater elevation referenced to NGVD 29.

Water Temperature Monitoring: Summary

In both 2016 and 2017, we observed large differences in absolute temperatures from different water sources, strong early-season temperature gradients in the Foster tailrace, and notable temperature differences between the AFF fishway and tailrace. During the spill period, temperature differences in the tailrace were likely the result of warm water in near-surface layers of the Foster reservoir (potentially from the South Santiam River) and cooler water in the lower reservoir layers that was from the Middle Santiam River via hypolimnetic water from Green Peter reservoir.

In 2017, water in the upper sections of the AFF fishway and in the pre-sort pool was consistently 1-2 °C cooler than water in the powerhouse tailrace. The temperature gradients across the tailrace and from the tailrace through the AFF fishway have been hypothesized to deter adult Chinook salmon and steelhead from efficiently entering the Foster Trap (Clabough et al. 2017).

2. Lebanon Dam trap installation and operation

The Lebanon hydroelectric project located on the South Santiam River is owned and operated by the City of Albany, Oregon. The project is located ~226 rkm upstream from the Willamette River–Columbia River confluence and ~389 rkm from the Pacific Ocean. The project consists of Lebanon Dam, a 137.2-m (450-ft) long, 1.8-m (6-ft) high concrete gravity weir diversion dam with 0.6 m (2 ft) of flashboards and the Albany-Santiam canal, which carries diverted water ~30 km (18 mi) to the Calapooia River at the city of Albany. Fish ladders are located on the north and south shores of the South Santiam River. The north-shore ladder has one ladder exit and the south shore ladder (high volume pool and chute) has three parallel exits.

Trap design

The Lebanon trap was designed and constructed in collaboration with BJ Schenk, James Mader, Jordan McCutcheon, and James Kirk at the University of Idaho Machine Shop. The trap consists of two primary components: (1) a rectangular rail assembly that fits into existing channels on the middle fishway bulkhead; and (2) the trap box (Figures 13 and 15). The trap box measured 152 cm (60 in) long, 122 cm (48 in) wide and 91 cm (36 in) high with a two-door 61-cm (24-in) gate at each end. Each gate was constructed of square aluminum bar stock with four 2.54 cm (1 in) diameter aluminum tubes on the outside edge and six 1-cm (3/8-in) diameter surgical tubes on the interior of the to reduce the risk of injuring fish. The top of the trap box was constructed of square aluminum bar stock and tubing with a door to access the interior. A tapered aluminum sanctuary pan (10-15 cm, 4-6 in deep) was attached to bottom of the trap to keep fish in the water (~230 L; 60 gal) when the trap was raised (Figure 15). A work platform made of aluminum bar grating was also installed over the fishway next to the south retaining wall. The trap was designed to be raised and lowered according to water levels and pinned above the water when not in use. The design allows selective trapping of individual fish, and transfer of adults to anesthetic without direct handling.

Trap installation and operation

The Lebanon Dam trap was installed with an overhead crane (Forslund Crane, 30-ton boom truck #230) on 16 June 2017 but was not fully operational until 6 July. The trap was installed in ~4.5 h in the middle fishway at the top of the Lebanon Dam south-shore ladder (Figures 13-15). The inner and outer fishways were blocked with aluminum bar screens to prevent fish from bypassing the trap. A bar screen that fluctuated with the trap height was also attached to the bottom of the trap box to prevent fish from swimming under the trap. The trap was lowered and raised with an electric winch (Warn Industrial Hoist, Part number 63899, DC2000 MF, 12-V) powered by a deep cycle marine battery. Trap gates were activated by an air compressor (Kobalt, 8-gallon, model 0300841, 120V, 4 CFM @ 90 PSI, 150 max PSI, 1.8 HP running) connected to a console that opened and closed the front and rear gates (see Appendix A for additional technical drawings and a more complete description of equipment).

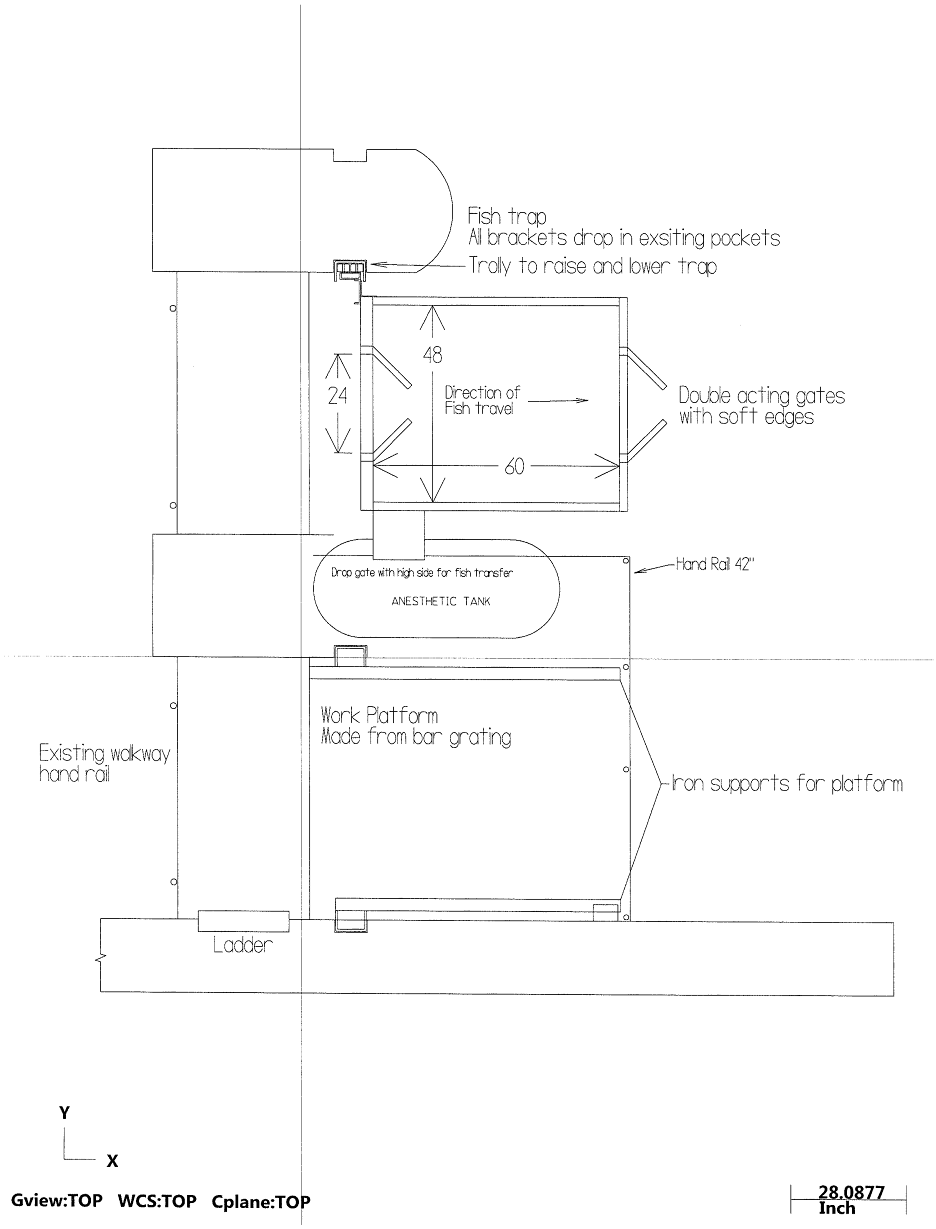

Figure 13. Plan view schematic of the new Lebanon Dam adult fish trap. Measurements in inches.

The trap and decking were removed with the 30-ton boom truck on 15 August 2017 (~2.5 h), placed on a flatbed semi-truck trailer and transported to the City of Albany facility near the dam. The trap and decking were placed on treated wood blocks and covered with a tarp. The winch and all hoses and cables except for those attached to the pneumatic gate actuators were removed from the trap and stored in a cool, dry place. Recommended future improvements include construction of a small aluminum bar screen (approximately 61 cm (24 in) × 122 cm (48 in) wide) for the bulkhead brackets on the downstream end of the work platform to increase the safety of trap users. A winch housing for weather protection and to prevent theft was constructed after the trapping season and is ready for future deployments.

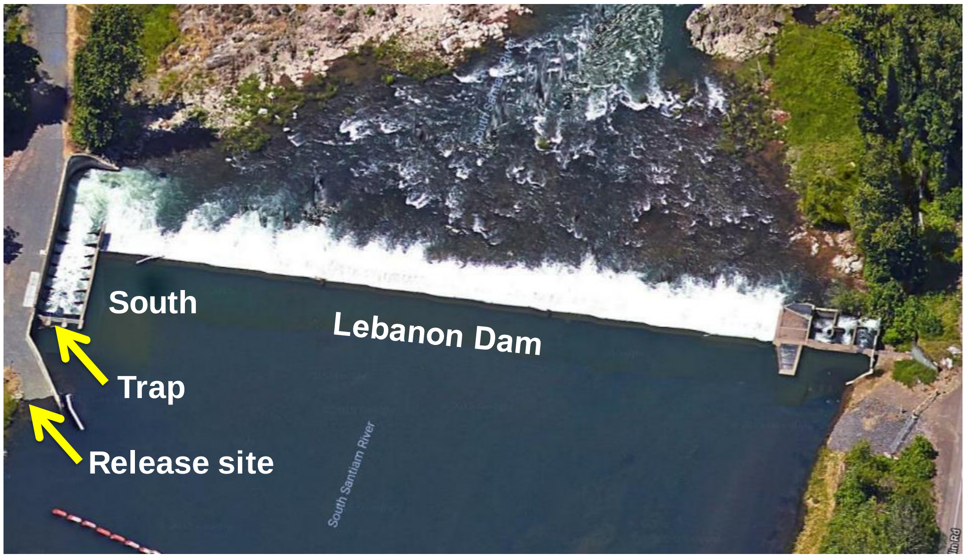

Figure 14. Overhead view of Lebanon Dam with location of the fish trap and release site in 2017.

Figure 15. Installation of the Lebanon adult fish trap deck (A & B), photo of the initial trap installation (C) and photo of the pneumatic trap lines and fish capture (D) in 2017 at Lebanon Dam.

Adult Chinook salmon collection and tagging

The trap was operated by two University of Idaho employees. One person watched for fish entering the trap and the other controlled the trap gate. During operation, the trap was lowered into position with the downstream gate opened and the upstream gate was closed. If an adult salmon entered the trap, a signal was given to close the downstream gate. After the rear gate was closed and we confirmed capture, the trap was raised until the drop-gate on the right side of the trap was level with the top of the anesthetic tank (283 L, 75 gal). Once level, the side drop-gate was opened and the fish, along with water from the sanctuary pan (approximately 150 L, 40 gal), was released into the anesthetic tank containing 10 ml of AQUI-S 20E (Aquatactics Fish Health, Kirkland, WA) resulting in a dosage of approximately 7 mg/L and ensuring that the anesthetic water was the same temperature as the river. The anesthetic tank was covered with mesh netting to prevent fish from escaping before they were fully anesthetized.

Captured Chinook salmon were fully anesthetized prior to handling at the Lebanon trap. Fish were PIT tagged (Biomark, Boise Idaho; model HPT12) in the dorsal sinus, near the back of the dorsal fin in an effort to increase tag retention on scavenged carcasses. Fish were then intragastrically radio-tagged with a 3-V transmitter that recorded temperature (+/- 0.8°C resolution) every eight minutes (Lotek Wireless Inc., New Market, Ontario; MCFT3-3A-T-L, 58 mm × 16 mm, 20 g in air). A silicone band was placed on each transmitter to reduce regurgitation (Keefer et al. 2004).

While anesthetized, fish were measured for fork length (nearest 0.5 cm), assigned an estimated sex based on morphological characteristics, inspected for fin clips or markings, and assessed for condition (see Keefer et al. 2004; Naughton et al. 2016 for description of methods). We also collected four morphological measures previously used by Mann et al. (2010) to estimate energetic status (Figure 16). Mid-eye to hypural length was defined as the distance along the lateral line from the middle of the eye to the end of the scales on the hypural plate on the caudal peduncle. Hump height was the distance from the anterior origin of the dorsal fin to the lateral line, perpendicular to the lateral line. Depth at anus was the total depth of the fish perpendicular to the lateral line at the anal opening. Breadth at anus was the width of the fish at the intersection of the lateral line and a line perpendicular to the lateral line at the anus. Morphometric measurements were taken using calipers and recorded to the nearest mm. Fish weights (to the nearest decagram) were collected using a flat table scale (Ohaus Defender bench scale, Ohaus Corp., Pine Brook, NJ). Following tagging the fish was placed in rubber inner tube and transferred to perforated recovery tank tethered in the river where they were allowed to recover and exit volitionally (typically about 6 min). Fish were released from the south shore in the Lebanon Dam forebay, just upstream from the trap (rkm 389.1; Figure 14).

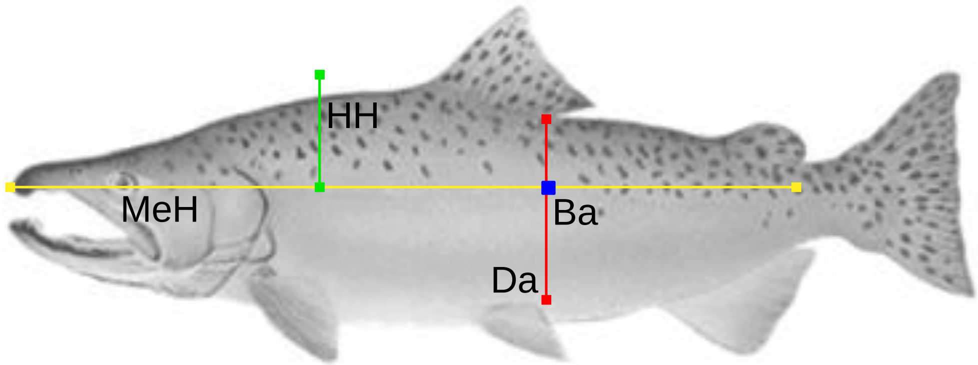

Figure 16. Diagram of morphometrics collected. MeH = Mid-eye to hypural length, HH = Hump height, Da = Depth at anus, Ba = Breadth at anus.

3. Behaviors of Chinook salmon radio-tagged at Lebanon Trap

Methods

Salmon collection and tagging

We collected and radio-tagged 16 adult Chinook salmon at the Lebanon adult fish trap, which was operated intermittently from 10-28 July 2017. Sampling was after the peak of the Chinook salmon run, as enumerated at the Foster Trap (see Figure 19), and the end date was associated with very low salmon abundance and an interruption of trap operations caused by a large log jammed at the fishway exit. All tagged fish were presumed hatchery origin based on clipped adipose fins. Overall, the trap was operated (in-water time) for 67.2 hours for a CPUE of 0.24 fish/h (*range* = 0.0-0.4 fish/h). On average, tagged salmon weighed 4.73 kg (*sd* = 1.15 cm, *range* = 3.12 – 7.34 kg), had a fork length of 72.3 cm (*sd* = 4.6 cm, *range* = 65.0 – 81.0 cm), and had a Distell fatmeter score of 3.3% (*sd* = 2.25%, *range* = 1.0 – 9.4%) (Table 2). The mean condition index score was 2.3 (*sd* = 0.6) and 15 of the tagged fish (94%) were estimated to be females. None of the tagged fish had marine mammal marks, head injuries, or head burns at the time of tagging. Tagged salmon had mean mid-eye to hypural length, depth at anus, breadth at anus, and hump height measurements of 60.03 (*sd* = 3.65 mm), 11.57 (*sd* = 1.12 mm), 6.28 (*sd* = 0.65 mm), and 8.14 (*sd* = 0.87 mm), respectively.

Table 2. List of release date, fork length, estimated sex, weight, fat content, condition, mid-eye to hypural length (MeH), depth at anus (Da), breadth at anus (Ba), and hump height (HH) for adult Chinook salmon radio-tagged and released at Lebanon Dam in 2017.

Fish ID	Release date	FL (cm)	Est. Sex	Wt. (kg)	Fat (%)	Condition	MeH (mm)	Da (mm)	Ba (mm)	HH (mm)
97	10 July	66.5	F	3.12	1.0	2	54.0	10.0	5.4	6.9
100	10 July	65.0	F	3.21	1.3	2	55.0	9.8	5.4	6.7
96	12 July	78.5	M	5.28	5.5	2	64.0	12.3	6.4	8.6
90	13 July	69.0	F	3.84	3.4	3	56.5	10.9	6.0	7.8
92	13 July	76.0	F	5.68	5.1	3	64.0	11.9	7.0	9.1
95	13 July	73.5	F	5.27	2.8	2	60.5	11.5	6.5	8.5
93	14 July	72.0	F	4.00	9.4	1	62.0	10.6	5.6	7.2
94	14 July	65.5	F	3.44	2.0	3	55.5	10.1	5.4	7.3
79	17 July	71.0	F	4.96	2.9	3	58.5	12.0	6.9	9.0
84	17 July	71.5	F	4.48	3.9	2	59.5	12.2	6.2	8.1
86	19 July	70.0	F	4.00	2.2	2	58.5	10.6	5.8	7.2
91	20 July	81.0	F	7.34	1.5	2	66.5	13.5	7.0	9.0
87	24 July	75.7	F	5.42	2.1	2	63.5	12.0	6.6	8.5
82	25 July	72.0	F	4.10	1.8	2	58.5	13.2	6.0	9.4
83	25 July	74.5	F	5.48	4.9	3	61.5	12.3	6.9	8.1
85	28 July	76.0	F	6.02	3.1	2	62.5	12.2	7.4	8.9
Mean	17 July	72.3	-	4.73	3.3	2.3	60.0	11.6	6.3	8.1
sd	-	4.6	-	1.15	2.1	0.6	3.7	1.12	0.7	0.9

Monitoring sites

We deployed 14 radio receivers to monitor the movements of tagged salmon after their release into the Lebanon Dam forebay (Table 3 and Figure 17). Monitoring efforts also included opportunistic mobile tracking via truck during spawning ground surveys by UI personnel. There was no reward offered for the return of transmitters used in 2017.

Table 3. List of radio receivers amd antennas deployed in the South Santiam River in 2017, site name abbreviations, and river kilometer (rkm) from the Columbia River mouth.

Monitoring site	Site code	rkm	Antenna Type
Downstream from Lebanon Dam	1LB	382.7	Yagi
Lebanon Dam forebay (release site)	-	389.1	-
Upstream from Lebanon Dam	BBF	399.2	Yagi
Foster Dam			
Tailrace	1FS	416.6	Yagi
Tailrace	2FS	418.2	Yagi
Outside side fishway entrance	ZFS	418.2	Underwater
Inside side fishway entrance	CFS	418.2	Underwater
Outside powerhouse (main) entrance	EFS	418.2	Underwater
Inside powerhouse (main) entrance	HFS	418.2	Underwater
Lower fishway	AFS	418.2	Underwater
Upper fishway	BFS	418.2	Underwater
Lower transport channel	GFS	418.2	Underwater
Upper transport channel	DFS	418.2	Underwater
Upper fish ladder	FFS	418.2	Underwater
Pre-sort pool weir (immediately downstream)	TFS	418.2	Underwater

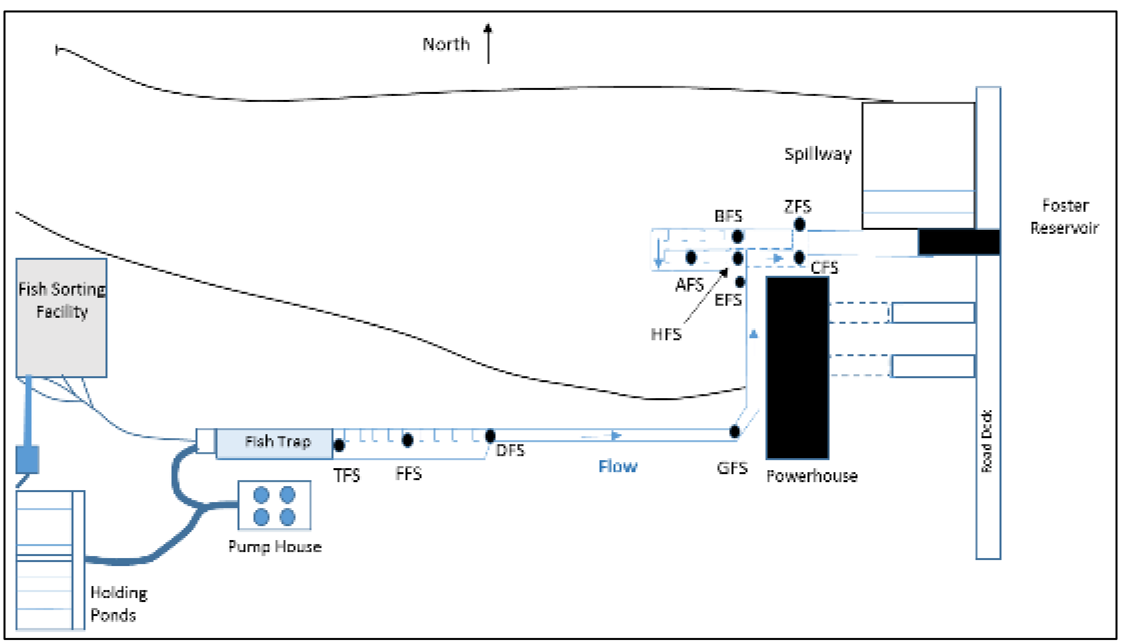

Figure 17. Generalized map of radio receiver deployments at Foster Dam in 2017 (not to scale).

Results

Salmon migration from Lebanon Dam to Foster Dam

All 16 tagged salmon released into the forebay of Lebanon Dam were detected in the Foster Dam tailrace, ~27.5 rkm upstream from the release site (Table 4; also see Appendix B). Migration times from release to their first detection in the Foster tailrace ranged from 35.2 to 112.7 h (*median* = 38.9 h [1.62 d]). No tagged fish were detected moving downstream from Lebanon Dam after release.

Final distribution of salmon radio-tagged at Lebanon Trap

Seven of the 16 (44%) tagged salmon released at Lebanon Dam were ultimately recaptured at the Foster Dam Trap (Table 4). The remaining nine (56%) were last detected downstream from Foster Dam, including one salmon recaptured in the Foster Dam tailrace by an angler, one last detected in Wiley Creek, and one salmon carcass recovered in Little Wiley Creek during spawning ground surveys. Tagged salmon last detected downstream from Foster Dam may have spawned naturally below the dam, died before spawning, or may have been harvested prior to spawning without being reported.

Salmon behaviors in Foster tailrace and at the Foster adult fish facility

Tagged salmon typically approached one of the two fishway openings less than 8 h after being detected in the Foster Dam tailrace (n = 16, *median* = 5.2 h; Table 4). The distribution of first fishway approaches favored the side opening (n = 10) versus the main opening (n = 6). Fifteen of the 16 (94%) salmon detected in the tailrace were detected entering the fishway. Tailrace to first fishway entry times varied widely, ranging from 0.22 – 60.06 d. Most of the tagged salmon that entered the fishway did so ~10 d after being detected in the tailrace (*median* = 10.25 d) but four of the fifteen tagged salmon did not enter the fishway until ~32 d (*3rd quartile* = 28.53 d) or more after being detected in the tailrace. The number of first fishway entries was similar at the main fishway opening (n = 8) and the side fishway opening (n = 7).

Of the 15 tagged salmon detected entering the fishway, 14 (93%) were detected near the Foster AFF pre-sort pool. Times from first tailrace detection and first fishway approach to first detection at the pre-sort pool antenna (site TFS) also ranged widely, with median times of 669.8 h and 665.7 h (~28 d), respectively. The median time from first fishway entry to first pre-sort pool detection was 15.7 h, but five of the 14 (36%) salmon detected near the pre-sort pool took ~11 d or more to reach the pool after their first fishway entry. Nine of the 14 (64%) salmon detected at the pre-sort pool were subsequently detected in the tailrace (i.e., they exited the fishway back to the tailrace). The other five were recaptured by hatchery personnel within a day or two of their initial detection at the pre-sort pool antenna. Of the nine salmon detected in the tailrace after being detected near the pre-sort pool, two were recaptured at the trap shortly after their second detections there. The remaining seven salmon returned to the pre-sort pool from the tailrace but were never recaptured by hatchery personnel; these fish moved between the tailrace and pre-sort pool up to six times per fish. The fish that were never captured at the trap entered and exited the fishway 6 times, on median (Table 4, see Appendix B for individual histories).

Table 4. Times that adult Chinook salmon radio-tagged at Lebanon Dam used to swim from: (a) release in the Lebanon Dam forebay to the Foster Dam (FST) tailrace, (b) the FST tailrace to first fishway approach, (c) the FST tailrace to first fishway entry, (d) the FST tailrace to first detection near the FST pre-sort pool (PSP), (e) first fishway approach to first detection at the PSP, and (f) first fishway entry to first detection at the pre-sort pool. Table organized by fish that were or were not collected at the FST Trap. Lower rows include minimum, 1^{st} quartile (Q1), median, 3^{rd} quartile (Q3), maximum, and sample size values for all fish. Also included are details on whether salmon were detected at the PSP, whether they exited to the FST tailrace, and how many exits were detected after being detected at the PSP, and how many entries and exits were detected in total. Recapture site and type are listed where applicable as is the last detection site of each tagged salmon.

	Passage time (d)								Number (*n*)					
FishID	Rel. to Foster tailrace	Tailrace to 1^{st} approach	Tailrace to 1^{st} entry	Tailrace to PSP	1^{st} approach to PSP	1^{st} entry to PSP	Detected at PSP?	Exit to tailrace	Exits after PSP	Total entries	Total Exits	Recapture Site	Recapture Type	Last Site
79	1.52	0.26	5.25	35.62	35.36	30.37	Yes	Yes	1	10	9	Trap	Hatchery	Trap
82	1.69	0.11	2.19	2.31	2.20	0.12	Yes	No	0	1	0	Trap	Hatchery	Trap
85	1.62	0.15	19.36	30.34	30.19	10.98	Yes	No	0	3	2	Trap	Hatchery	Trap
87	1.63	0.19	13.16	25.47	25.28	12.31	Yes	Yes	1	29	28	Trap	Hatchery	Trap
92	1.58	0.11	1.57	1.66	1.55	0.09	Yes	No	0	1	0	Trap	Hatchery	Trap
94	1.91	0.20	0.22	0.32	0.12	0.10	Yes	No	0	1	0	Trap	Hatchery	Trap
95	1.63	0.21	2.55	2.72	2.50	0.17	Yes	No	0	1	0	Trap	Hatchery	Trap
Median	**1.63**	**0.19**	**2.55**	**2.72**	**2.50**	**0.17**			**0**	**1**	**0**			
83	1.56	0.22	44.66	44.79	44.57	0.13	Yes	Yes	5	5	5			< FST
84	1.47	0.69					No			-	-			< FST
86	1.59	0.17	60.06	60.34	60.17	0.28	Yes	Yes	1	1	1	L Wiley	Carcass	< FST
90	1.62	0.22	7.24	9.88	9.66	2.64	Yes	Yes	1	3	3	Tailrace	Angler	< FST
91	2.48	1.05	24.86	47.57	46.52	22.71	Yes	Yes	1	7	7			< FST
93	4.70	0.28	32.20	32.35	32.07	0.15	Yes	Yes	4	6	6			< FST
96	1.65	0.54	34.18	52.72	52.19	18.54	Yes	Yes	6	15	15			< FST
97	1.51	0.25	4.61	5.63	5.39	1.02	Yes	Yes	4	10	10			< FST
100	2.57	0.33	10.25				No			1	1			< FST
Median	**1.62**	**0.28**	**28.53**	**44.79**	**44.57**	**1.02**			**4**	**6**	**6**			
All fish														
n	*16*	*16*	*15*	*14*	*14*	*14*								
Min	*1.47*	*0.11*	*0.22*	*0.32*	*0.12*	*0.09*								
Q1	*1.57*	*0.18*	*3.58*	*3.45*	*3.22*	*0.14*								
Median	***1.62***	***0.22***	***10.25***	***27.91***	***27.74***	***0.65***								
Q3	*1.74*	*0.29*	*28.53*	*42.50*	*42.27*	*11.98*								
Max	*4.70*	*1.05*	*60.06*	*60.34*	*60.17*	*30.37*								

There were notable differences in most passage time metrics between groups of salmon that were and were not recaptured at the AFF trap (Table 4). The median times the two groups used to swim from their release near Lebanon to the Foster tailrace were almost identical (~1.6 d) but the median passage times for fish not recaptured at the trap were higher than those for trap-recaptured salmon in other passage segments, sometimes by a factor of >16. We found that trap-recaptured salmon were only modestly longer, heavier, and rounder (based on morphometrics), on average, than salmon with fates downstream from Foster Dam (Table 5). Mean hump height differed significantly (P = 0.026, t-test) between trapped and non-trapped fish.

Salmon entry into the main AFF fishway in relation to velocity treatment

Radio-tagged salmon entered the AFF fishway an estimated 94 times between 16 July and 19 September, with a majority of events between 15 August and 15 September (Figure 18). Nineteen events occurred at the side fishway opening and 75 occurred at the main fishway opening. During the full range of dates when fish were recorded entering the main fishway, the fishway velocity treatment was high-velocity Auto 65% of the time and low-velocity Open 35% of the time. Ten unique tagged salmon entered during the Auto treatment and 11 unique salmon entered during the Open treatment. However, proportionately more entry events occurred during the Open treatment (n = 59, 63%) than during the Auto treatment (n = 35, 37%); this was driven, in part, by multiple entry and exit events per fish by several individuals during the Open treatment in early September.

Table 5. Mean and standard deviation fork length (FL), weight, and morphometric values of groups of adult radio-tagged Chinook salmon that were recaptured at the Foster Trap and those with fates downstream from Foster Dam (<FST) in 2017. The last two rows include t-statistics and associated probabilities of mean morphology metrics differing (α = 0.05).

Last site	Statistic	Tag Date	FL (cm)	Wt. (kg)	MeH (cm)	Da (cm)	Ba (cm)	HH (cm)
Foster trap	*Mean*	19 July	72.79	4.984	60.43	11.84	6.54	8.67
(n = 7)	*sd*	-	3.77	0.912	3.11	0.93	0.67	0.68
< FST	*Mean*	15 July	72.00	4.528	59.72	11.36	6.08	7.73
(n =9)	*sd*	-	5.27	1.329	4.18	1.26	0.60	0.79
	t value	1.26	0.33	0.77	0.37	0.86	1.47	2.50
	$P > \|t\|$	0.229	0.744	0.451	0.715	0.407	0.165	0.026

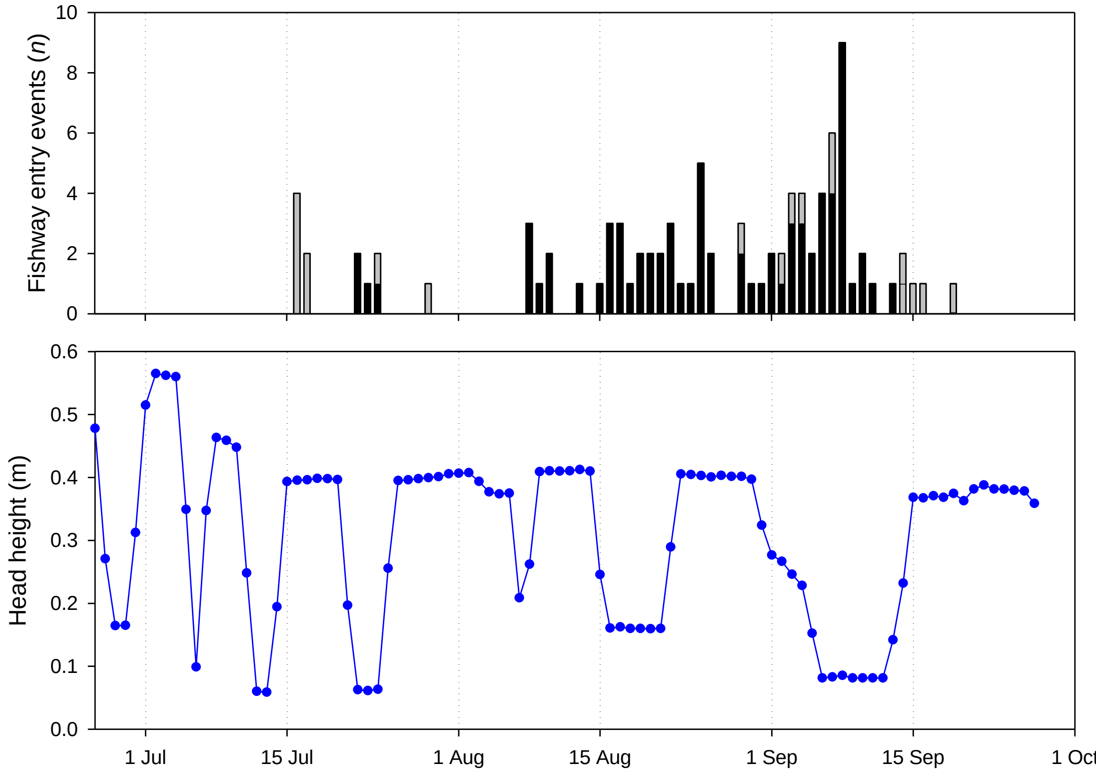

Figure 18. Daily numbers of fishway entry events recorded for radio-tagged adult Chinook salmon at the main fishway opening (black bars, top) and side fishway opening (gray bars, top) and mean daily fishway head height (bottom) in 2017. (See Figure 12 for hourly head height data.)

Salmon body temperatures in the Foster tailrace and fishway

Seven salmon with archived body temperatures were recovered. Five were recaptured in the Foster Trap, one was recovered in Foster tailrace, and one was recovered in Little Wiley Creek. Body temperatures of all salmon were approximately 15 °C at the time of release at Lebanon Dam. Body temperatures declined to <12 °C in the Foster tailrace and to <10 °C for the five that were collected at the trap (Appendix B). The fish recaptured in the tailrace entered the tailrace at 11-12 °C and then ascended to the AFF pre-sort pool at ~10 °C, before exiting back to the tailrace. The fish recovered in Little Wiley Creek was 11-12 °C in the Foster tailrace and ~10 °C inside the fishway; its body temperature dropped to ~8-10 °C after entering Little Wiley Creek.

Conclusions

The new, removable adult trap at Lebanon Dam was designed and constructed in winter 2016-2017. An accelerated timeline from conception to deployment allowed trapping during the tail end of the 2017 Chinook salmon run in the South Santiam River. Given the late timing and small sample size (n = 16), the effort should be considered as a 'proof of concept' or pilot-study. The trap CPUE was < 0.5 fish/h, but we expect the capture rate would be higher during peak migration periods. All 16 radio-tagged salmon were detected at Foster Dam within 4.7 d of release (*median* = 1.6 d), which suggests that there were limited negative effects associated with collection and tagging at the new trap.

Behaviors of the radio-tagged salmon in the Foster Dam tailrace and at the AFF largely confirmed previous observational results. Most fish rapidly approached the AFF fishway, but most took days to several weeks to enter the fishway and be detected near the AFF pre-sort pool. Fewer than half of the tagged fish were collected at the AFF trap, although all had adipose fin clips and presumably originated from the hatchery. An unanticipated result was the association between behavior in the tailrace and fishway and eventual fate. Fish that were eventually trapped at Foster first entered the AFF fishway much faster (*median* = 2.6 d) than the group that was not trapped (*median* = 28.5 d), but there were few clear differences among the two groups that could explain the behavioral difference. The fish that were collected at the trap were slightly larger than those that were not trapped, but we think the small differences were not likely to have affected the likelihood of recapture at the AFF trap, particularly when seven of the nine fish with fates downstream from Foster Dam were detected at the pre-sort pool at least once. Importantly, several of the fish that were not captured at the trap entered and exited the AFF fishway multiple times, consistent with the milling and exiting behaviors observed in previous DIDSON and optical camera evaluations (Clabough et al. 2017) and in our 2017 video monitoring (see below).

The late timing of the radio-tagged sample resulted in no fish encountering spill at Foster Dam or the strong lateral temperature gradients that spill produced in the tailrace. Instead, tagged salmon encountered very stable temperature and flow conditions in the tailrace and this precluded analysis of how tailrace conditions may have affected behavior. Salmon did encounter several fishway velocity treatment blocks in July-September, but behaviors with respect to treatment were equivocal. Similar numbers of unique salmon entered the fishway during the Auto and Open treatments, though proportionately more entry events occurred during the Open treatment. Regardless, all fish encountered cooling temperatures from the time of tagging (~15 °C) to the tailrace (~12 °C) to the fishway and trap (<10 °C). The decrease in temperature may have affected motivation of fish to move upstream, as movement rates are typically slower in cooler waters.

In an exploratory analysis, we used Cox proportional hazards regression to test for associations between fishway velocity and the time tagged Chinook salmon used to enter the Foster fishway and to their last detection before entering the trap. The model results indicated no statistically significant ($P > 0.05$) treatment effect after controlling for date and time of day. However, the small sample size limited the inferential power of the tests; a more rigorous statistical evaluation would require more tagged individuals.

Overall, the results suggest a substantial proportion of the adult salmon, including hatchery origin salmon, were not stimulated to or lacked motivation to enter the fishway and trap. The trap design and operational criteria are widely used with high success throughout the region and a subset of adults rapidly (<3 hours) moved through the fishway to the pre-sort pool after entering the fishway. Thus, poor hydraulic or structural features seem unlikely to be the primary factor causing the slow entry rates, high turnaround, and relatively low overall collection efficiency. The apparent low motivation displayed by some individuals may be related to rapidly declining water temperatures encountered by adults as they enter the Foster Dam tailrace and fishway. While salmon normally encounter declining temperatures as they travel from main stem to headwaters, the South Santiam River below Foster Dam, the tailrace, and fishway were routinely 8-10 °C and sometimes ~15°C cooler than the natural thermal regime in the South Santiam River (see Figure 6).

Inappropriate natal cues may also contribute to declining attraction or motivation because much of the source water for the fishway originates from the Middle Santiam River (based on thermal signature). The majority of unclipped fish from above Foster Dam are thought to originate from the South Santiam River, which, based on stratification in the reservoir, does not readily mix with deeper waters sourcing the fishway. Similarly, the fishway water source may lack cues expected by adult hatchery-origin fish that were reared at the ODFW facility on the north side of the river and which has a separate water supply. We note that water samples were collected at several locations in 2016 to evaluate the presence of chemicals potentially related to salmon olfaction and homing (i.e., dissolved free amino acids, or DFAAs). These samples were sent to the University of Texas-Galveston but were not processed due to problems at the receiving laboratory.

Recommendations

Future studies with larger radio-tagged sample sizes could evaluate: (1) the consistency of the overall collection efficiency of the facility through the full migration season; (2) whether unclipped salmon exhibit similar patterns as clipped salmon;(3) whether holding in the tailrace and slow passage are consistently associated with non-collection; (4) whether salmon are attracted to the hatchery outfall on the north side of the Foster tailrace; and (5) the distribution and potential spawning of salmon downstream from the dam. In particular, experimental manipulation of temperature at the Adult Fish Facility and the hatchery effluent would disentangle the relative roles of temperature vs. olfactory cues as mechanisms affecting collection efficiency of adult salmonids.

If the Lebanon trap is operated in future years, we recommend that genetic samples be collected that could be used to evaluate if adult salmon were the progeny of adults from the hatchery, from adults outplanted upstream from Foster Dam, or of natural spawners downstream from Foster Dam. Similarly, inclusion of hatchery broodstock to a pedigree would allow identification of offspring from hatchery-origin adults which spawned downstream of Foster Dam and would not require operation of the Lebanon trap.

Potential operational experiments that may help resolve the Foster collection efficiency issue include: (1) manipulation of water temperatures at the facility, specifically including use of warmer water that reduces thermal gradients between the tailrace, fishway and trap, and better matches temperatures of the South Santiam River upstream from Foster Dam; (2) manipulation of water source for the facility (i.e., drawing water from a different location in the reservoir or tailrace); (3) manipulation of chemical cues at the facility, potentially including some source water from the hatchery or from specific reservoir layers. We also recommend that water chemistry analyses that test for differences in dissolved free amino acids (DFAAs) among potential facility source waters be reconsidered in light of the laboratory failure for samples collected in 2016; and (4) manipulation of the hatchery effluent on the north shore of the tailrace to determine the effects on adult behavior.

4. Video monitoring at the Foster Trap pre-sort pool weir

Methods

Video monitoring

We monitored adult salmonid behavior at the weir below the Foster AFF pre-sort pool using an optical video camera mounted over the last fishway pool before the trap weir (Figure 19). The camera (Swann Model SWPRO-T890CAM, Victoria, Australia) was connected to a digital video recorder (Model SWDVJ-8HD5MP4) that stored video data. To assess video quality, we initially tested video collected at rates ranging from 480×240 pixels to 2,592×1,944 pixels (5 Mp). After review, we selected the 960×480 pixel and 10 frames/sec settings, which were used for the duration of the study.

Figure 19. Screenshot of the area monitored using optical video at the weir at the downstream end of the Foster Trap pre-sort pool.

The video camera was operated nearly continuously from 26 June to 31 October, with a single ~3-d outage in early August. Over this date range, we collected ~1,400 video files of varying duration. To standardize video review and scoring, we watched 10-min video segments that were randomly selected from daylight hours primarily starting on the hour or half hour (e.g., 9:00-9:10, 14:30-14:40). The random video review was structured so that we scored a minimum of three 10-min segments for each day from 26 June to 15 September, after which salmon activity was considerably diminished. Review effort was reduced for the second half of September and no video was reviewed from October. During the early stages of our review, we observed adult salmon falling back out of the pre-sort pool, shortly after crowding operations and water elevation changes in the pool (see Results). In an effort to better quantify this behavior, we watched additional randomly-selected 10-min video segments from trap operation days. As a potential test of whether fish density in the trap affected behavior at the weir, we watched additional random segments on the days immediately before fish were processed (when abundance in the pool was relatively high) and the day after fish were processed (when abundance was relatively low).

Video data processing and analyses

In the video, adult Chinook salmon (and steelhead, *O. mykiss*) were observable at the weir only when they jumped out of the water or when their heads or backs broke the water surface. While reviewing video, we scored all fish observations in each 10-min segment into three categories: (1) successful ascent, when a fish passed over the weir into the pre-sort pool; (2) failed attempt, when a fish jumped or otherwise broke the water surface at the weir, but failed to enter the pool; and (3) fallback, when a fish exited the pool over the weir and re-entered the fishway channel. We note that failed attempts included a variety of behaviors, including jumps that failed when fish hit the weir or a wall, jumps with insufficient forward progress, lateral movements in the hydraulic jump at the base of the weir (‘surfing’), and non-jumping emergence through the water surface (e.g., heads and backs) that we interpreted as searching or testing behavior.

For each observed event, we recorded the behavior category, the time, and the approximate fish location along the weir (left, center, right). We also noted any unusual behaviors, issues with image quality (e.g., near darkness), or evidence of operational changes (e.g., pre-sort pool water elevation changes or crowder operations). Scored events were used to calculate several behavioral metrics, including:

*Attempts/h = (successful ascents + failed attempts) / ((segments observed*10)/60),*

*Ascents/h = (successful ascents) / ((segments observed*10)/60),*

*Fallbacks/h = (fallbacks) / ((segments observed*10)/60)*

Attempts/Ascent = (successful ascents + failed attempts) / (successful ascents)

These metrics were calculated with data aggregated across data subsets to address specific research questions. For example, metrics were calculated for each date (i.e., all segments from each day) to create behavioral time series, and for time of day (in 2-h blocks) to assess diel patterns. We also combined segments across the dates between each adult sorting operation at the Foster pre-sort pool, which varied from 2-15 d across the video monitoring period (Figure 25, top), to assess whether fish abundance inside the pool was associated with behavior at the weir. To test for potential effects of fish density in the pre-sort pool plus effects of operating the crowder, we combined segments across dates that were either the day before trapping, day of trapping, or day after trapping.

During the video monitoring period, the velocity manipulation at the Powerhouse fishway entrance resulted in approximately 15 treatment changes (Figure 20, bottom). The ‘Open’ treatment, which was characterized by low head inside the fishway, occurred for 1-2 d periods in the first half of July, and the rapid changes resulted in days with intermediate mean head levels. Daily salmon activity metrics at the weir were therefore potentially misleading with regards to fishway velocity treatment so we instead used data from individual 10-min video segments where each segment was assigned the head level at the start of the respective hour. We used general linear modeling (PROC GLM in SAS) to assess the relative effects of date, time of day, and fishway head on salmon activity metrics. Initial models included the main effects plus each 1-way interaction term. Importantly, our evaluation of fishway velocity effects was only indirect, as the time that each fish entered the fishway, the fishway opening used, and the entrance velocity treatment (i.e., head) they encountered was unknown for all fish. The hypothesis was that differences in entrance velocity might affect fishway entry rates and subsequently activity rate at the pre-sort pool.

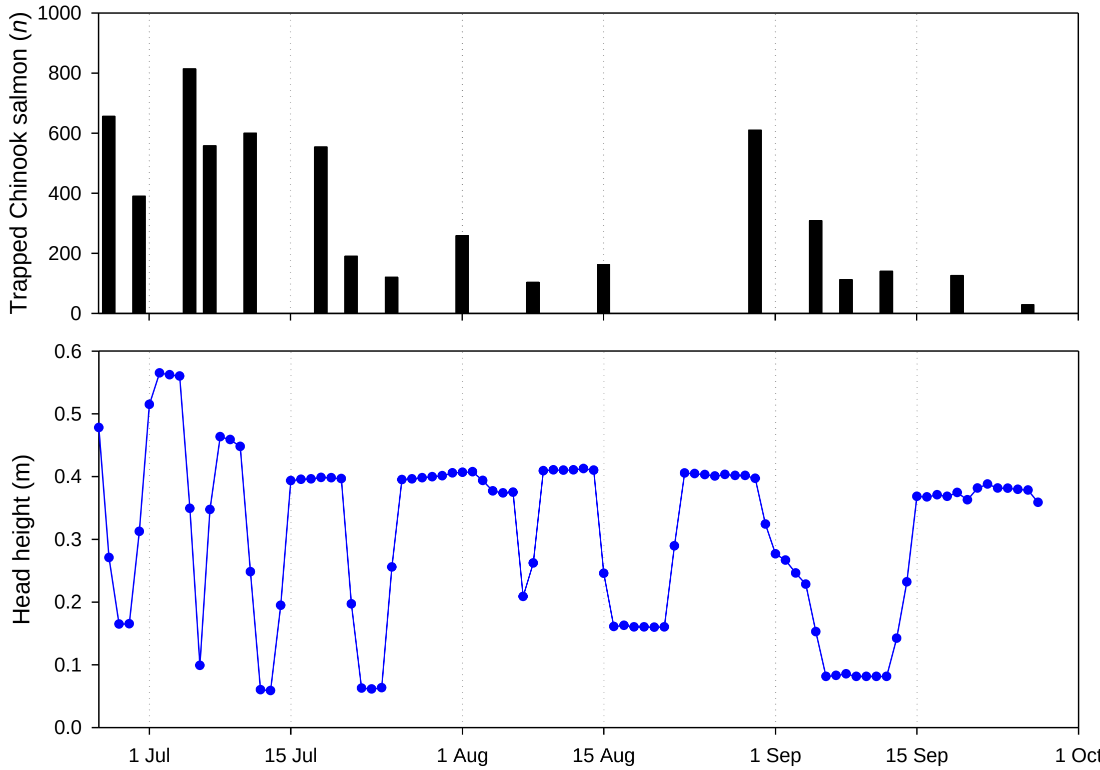

Figure 20. Daily numbers of adult Chinook salmon processed at the Foster Trap (top) and mean daily fishway head height (bottom) during the optical video evaluation in 2017 (26 June to 1 October). See Figure 12 for hourly head height data.

Results

We reviewed a total of 309 10-min video segments (51.5 h) during the study period, averaging 3.4 segments per day. Across all dates, 1,993 adult salmon (and steelhead) events were identified, including 219 successful ascents, 1,744 failed attempts, and 30 fallbacks. Adults identified as potential steelhead accounted for <2% of all events although ~350 steelhead were trapped during the video monitoring period (ODFW data). Season-long behavior metric estimates were 4.3 ascents/h, 38.1 attempts/h, 0.6 fallbacks/h, and 9.0 attempts/ascent.

Seasonal and diel patterns

Adult salmon activity at the weir was highest during the first half of July, steadily declined into mid-August, and then increased in late August until mid-September (Figure 21). Daily attempt rate was positively correlated (r^2 =0.65, n = 90 d) with ascent rate (Figure 22). Daily fallback rate was not correlated with either attempt rate or ascent rate ($r^2 < 0.10$).

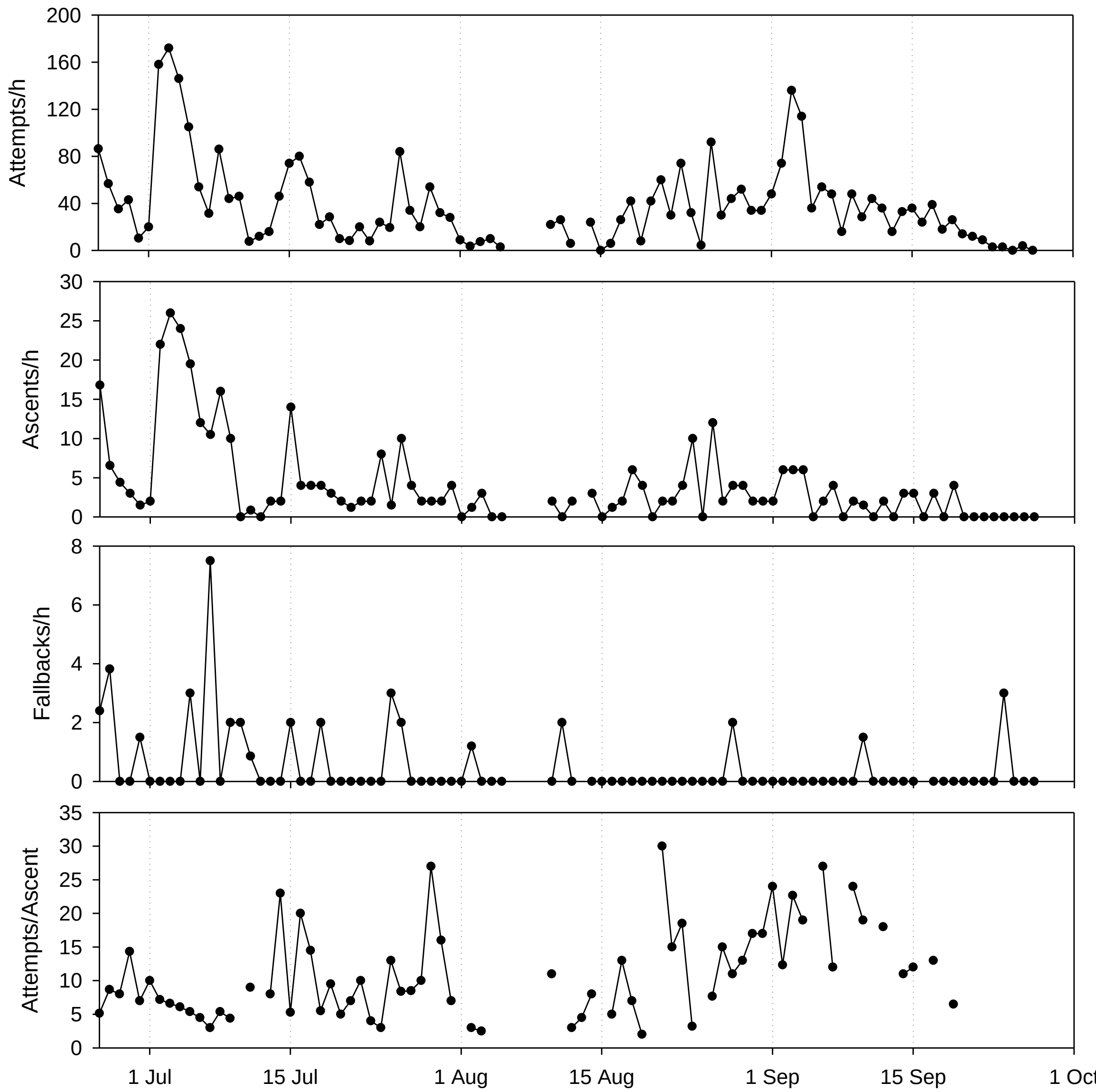

Figure 21. Daily adult salmon and steelhead behavior metrics calculated from optical video data collected at the weir at the downstream end of the Foster AFF pre-sort pool in 2017.

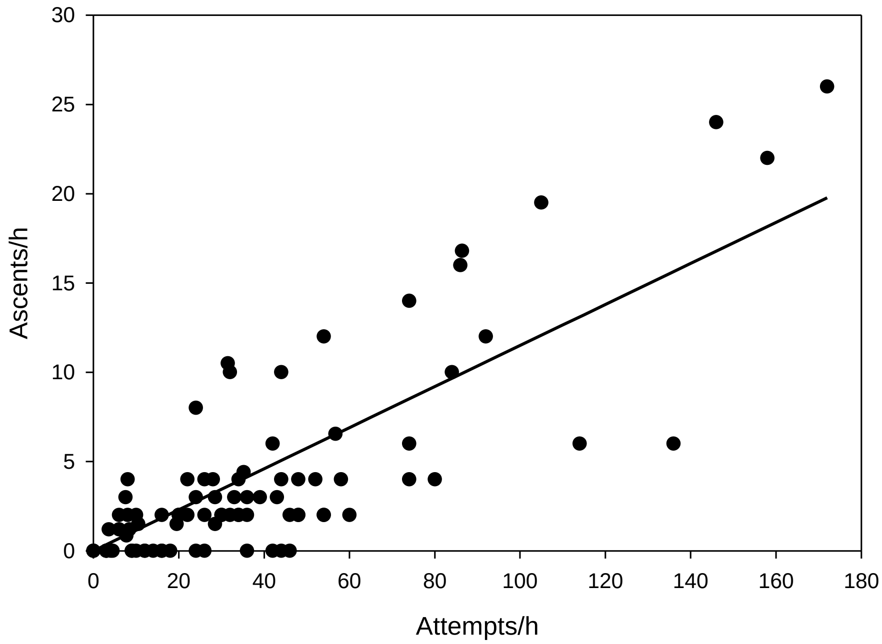

Figure 22. Relationship between the daily attempt and ascent rates (hourly) calculated for adult salmonids at the pre-sort pool weir in 2017. Line is linear regression, forced through the origin.

Salmon activity at the weir steadily increased through the day (Figure 23). Attempt rates over the monitoring period were ~10-20/h early in the morning and ~40-60/h in late afternoon and evening. Successful ascent rates followed a similar pattern, with ~2/h in the morning and ~6-10/h later in the day.

Fallback rates were more variable through the day, with the highest estimates in mid-morning (~1.5/h) and near dusk (~1.9/h). The higher morning fallback was at least partially associated with crowding operations in the pre-sort pool, which also tended to occur in the morning and was sometimes accompanied with an increase in pool water elevation. The attempts/ascent metric was highest in mid-day and slowly declined in the afternoon and evening, but showed less overall variation than the other metrics (Figure 24).

Relationship with salmon collection

Activity at the weir generally followed the pattern of adult salmon collection at the Foster Trap. The number of adult Chinook salmon processed at the trap over 2-15 d intervals was positively correlated with attempts/h (r^2 = 0.53-0.59), ascents/h (r^2 = 0.64-0.66), and fallbacks/h (r^2 = 0.25-0.26) and negatively correlated with attempts/ascent (r^2 = 0.16-0.19) (Figure 24).

About 60% of the events scored occurred on dates when salmon were processed or on the dates immediately before or after processing (Table 6). Attempt and ascent rates were higher by a factor of ~1.4 to ~1.7 on the day before the trap was operated (50.4/h and 6.1/h, respectively) than rates on the days before or after the trap was operated. In contrast, fallback rates were higher by a factor of ~5.6-8.5 on trapping days (1.7/h) than on the days before or after (0.2-0.3/h), indicating that trap operations affected fallback. On some dates when the crowder was operated and fish were processed, we observed that water elevation in the pre-sort pool increased by an estimated ~30 cm and that water flowed over the weir. This condition was associated with many, but not all, of the detected fallback events. To what degree fallback affected overall collection is unknown. While fallback events were ~1.5% of the total events observed, the 30 fallback event represented 13.7% of the 219 successful ascents, suggesting the potential that more than one in eight adults exited the trap after entering and may (or may not) have been eventually collected.

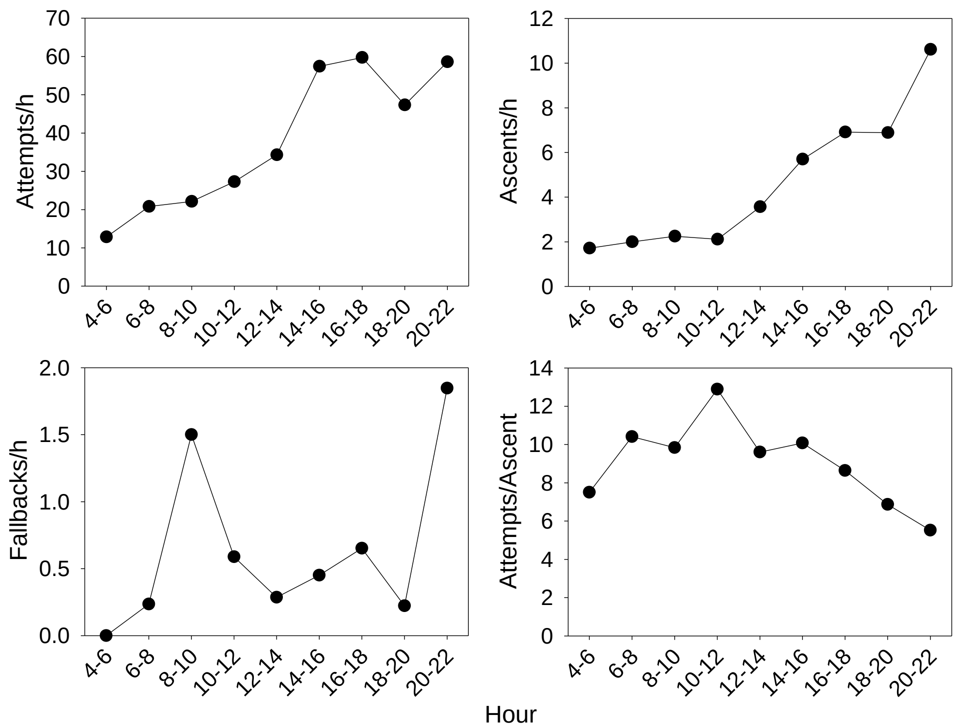

Figure 23. Salmon behavior metrics calculated from optical video data, binned by 2-h intervals over the monitoring period in 2017.

GLM model results

The initial GLMs for salmon attempts and ascents at the weir included 309 video segments with the covariates date, time of day, fishway head, date×time, date×head, and time×head. The time×head term was not statistically significant ($P > 0.05$) for either attempts or ascents and was removed. All remaining terms were included in the reduced models (Table 6).

The attempts model results indicated that the number of attempts per video segment decreased through the monitoring period, increased with time of day, and was higher during the high-head ‘auto’ fishway treatment. However, the date×time and date×head interactions were also statistically significant, indicating some complex relationships associated with the bimodal distribution in activity at the weir. The date×head interaction indicated relatively higher numbers of attempts during the high-head Auto treatment in summer but also during the low-head Open treatment during the peak of activity in July and again later in the fall (Figure 25). The date×time interaction showed that some video segments had low numbers of attempts both early and late in the monitoring period but also low numbers of attempts early in the day in some summer segments. The ascents model results were broadly similar to those for the attempts model (Figure 26).

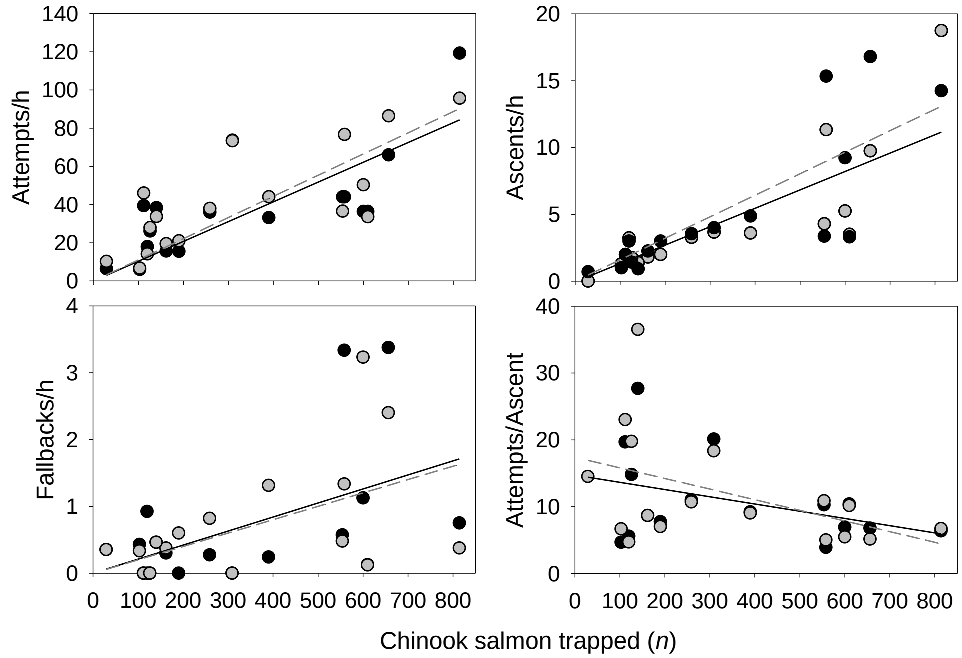

Figure 24. Relationships between the number of Chinook salmon processed at the Foster AFF and the behavior metrics calculated from optical video data collected at the pre-sort pool weir in 2017. Black and gray circles are estimates where the processing date was the final day or first day in each block, respectively. Lines are linear regressions forced through the origin for the hourly metrics.

Table 6. Number of events observed at the pre-sort pool weir and the behavior metrics across the season on the day before trapping, day of trapping, or day after trapping.

		Behavior metrics			
	Events (*n*)	Attempts/h	Ascents/h	Fallbacks/h	Attempts/Ascent
Day before	473	50.4	6.1	0.3	8.3
Trap operation	343	28.6	3.7	1.7	7.7
Day after	356	34.3	4.2	0.2	8.2

Table 7. Results of general linear models (GLMs) used to test for effects of date, time, fishway head, and interaction terms on the number of salmon attempts and successful ascents observed in optical video at the pre-sort pool weir in 2017.

	Attempts			Ascents		
Covariate	Type III SS	F	*P*	Type III SS	F	*P*
Date	377.9	7.7	0.006	6.6	5.4	0.021
Time	407.8	8.4	0.004	20.3	16.6	<0.001
Head	751.7	15.4	<0.001	9.6	7.8	0.006
Date×Time	219.1	4.5	0.035	13.3	10.9	0.001
Date×Head	663.8	13.6	<0.001	7.0	5.7	0.017
Time×Head	--	--	--	--	--	--

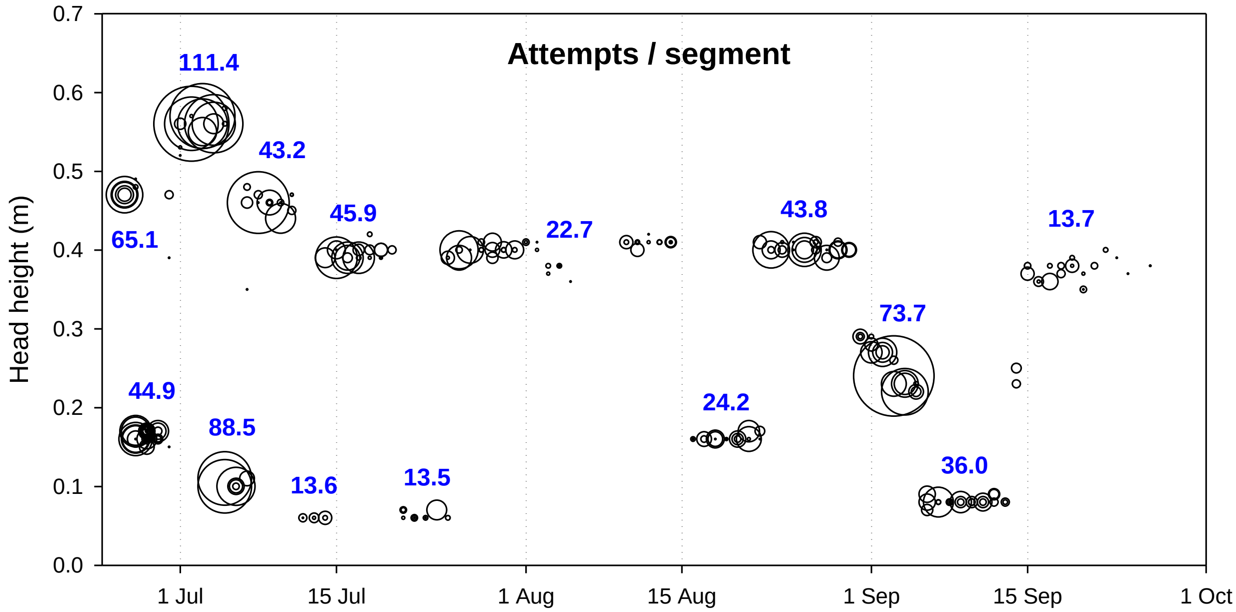

Figure 25. Bubble plot showing the relationships among the number of attempts at the pre-sort pool weir (bubbles scaled to show relative number of events), date, and fishway head (m) in 2017. Blue numbers show the attempts/h for groups of days with similar head treatment.

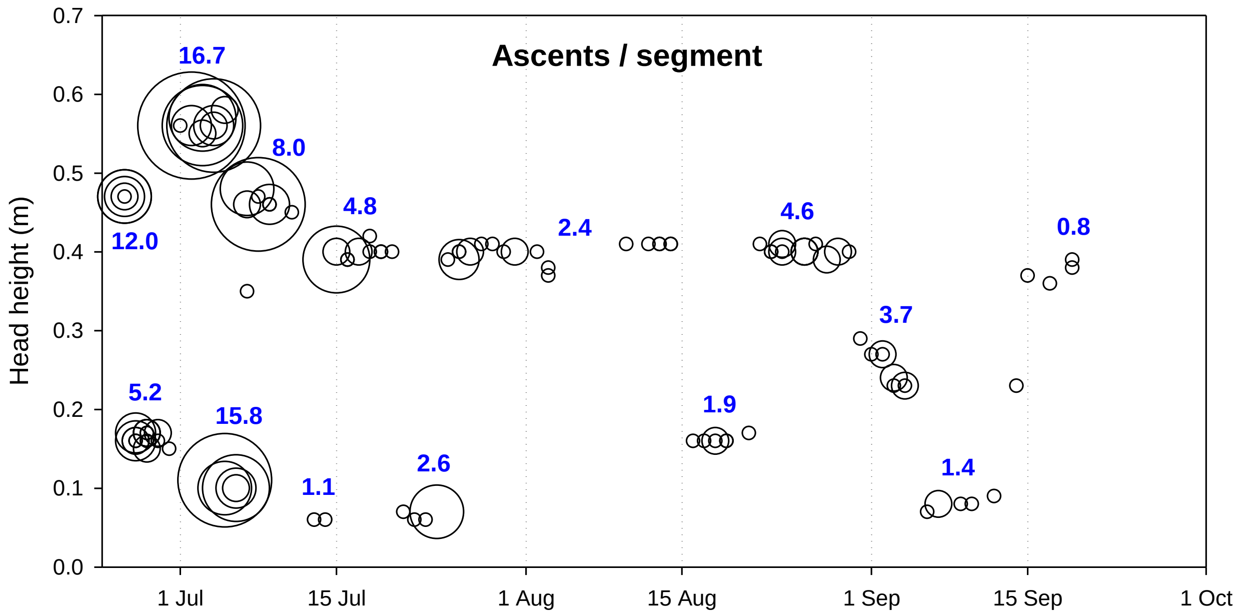

Figure 26. Bubble plot showing the relationships among the number of ascents at the pre-sort pool weir (bubbles scaled to show relative number), date, and fishway head (m) in 2017. Blue numbers show the ascents/h for groups of days with similar head treatment.

Conclusions

Optical video provided a useful index of adult salmonid daytime activity at the weir below the Foster AFF pre-sort pool in 2017. We observed nearly 2,000 jumping or surface-breaking events during the study period. Fish activity in the video was clearly correlated with adult salmon collection rate at the trap, suggesting that the video reasonably indexed adult salmon activity and abundance at the monitoring site.

Four basic conclusions from the video analysis were: (1) there were far more attempts to enter the pre-sort pool than there were successful ascents, with a season-long estimate of 9.0 attempts per ascent; (2) activity at the weir varied substantially over the course of a day, with considerably more activity in late afternoon and evening than in the morning; (3) some adults fell back out of the pre-sort pool into the fishway, mainly when pool water elevation neared the weir crest during fish crowding and sorting operations; and (4) fish activity was higher during the high-head, high-velocity Auto treatment, but statistically significant date, time-of-day, and interaction effects indicated that relationships between velocity treatment and fish behavior were complicated.

The 2017 results provide an interesting complement to passive monitoring results from 2015 and 2016. The 2016 DIDSON study showed that adult salmonids frequently moved into the AFF fishway, but also frequently exited back into the tailrace. Similarly, the underwater optical camera data from 2016 showed that there was considerable adult salmon movement (upstream and downstream) and milling inside the fishway, and that total activity peaked late in the day;

these findings were very consistent with our video observations in 2017. The radiotelemetry results from 2017 also clearly demonstrated that individual Chinook salmon entered the AFF fishway multiple times and several repeatedly moved between an entrance area and the pre-sort pool (see Table 4 and Appendix B). Collectively, these results indicated that low collection rates at the Foster AFF trap were not simply a function of a failure or inability by salmon to locate or enter the fishway. Fish holding in the tailrace, AFF entry and exit rates, and pre-sort pool entry rates may be inter-related. Specific mechanisms for failed trap entry attempts and the broader mechanisms affecting fish behaviors in the tailrace and AFF remain uncertain as noted above.

The experimental results from the fishway velocity treatments demonstrate some of the behavioral complexity of adult salmon at the Foster tailrace and AFF. Operation in the low-head, low-velocity Open position appeared to increase salmon entry rates into the fishway (2016) and trap collection rates (2015). However, the Open treatment was also associated with higher rates of salmon exit from the fishway into the tailrace and more downstream movements inside the fishway channel (Clabough et al. 2017). The 2017 radiotelemetry results also indicated more fishway entry events during the Open treatment. In contrast, the 2017 video monitoring at the pre-sort pool weir showed more salmon activity during the high-head, high-velocity Auto treatment overall, but relatively high activity also occurred during the Open treatment during the July peak in activity and again later in the fall (see Figure 25). Interpretation of the video data was complicated, of course, by our inability to differentiate among individual salmon as multiple attempts by some fish would inflate activity estimates and because of time-lags between treatment conditions fish experienced at the fishway entrance and the time they reached the pre-sort pool weir.

Our tentative conclusion is that manipulations of fishway velocity at the entrances has an effect on salmon behavior in the fishway entrance area, but that milling and holding behaviors inside the fishway and at the base of the pre-sort pool contribute to low overall AFF adult collection efficiency. Hypothetically, treatment condition at the main entrance should have relatively limited effects on adults once they enter the weir-and-pool sections of the fishway upstream from the velocity manipulation. Potential on-going factors limiting collection at the trap include the gradient of cooling water temperature moving from the tailrace to the AFF trap, a fishway water source composed primarily of water from a non-natal upstream tributary (Middle Santiam River), and perhaps reduced migration stimuli associated with substantially cooler than ‘natural’ temperatures in the tailrace.

We did not expect to see adult salmon fall back out of the pre-sort pool. This behavior was largely limited to periods when the fish crowder was operated and pool elevation increased. However, not all trap operations included the water elevation change and not all fallback events occurred while fish were being processed. Periods of high pool water elevation were relatively short in duration in the video we observed, and we think it is unlikely that large numbers of fish fell out of the pool over the course of the season. Reducing or preventing fallback should be straightforward, either by adding a physical barrier at the weir when the trap is operated, or by limiting the pool elevation changes that allowed fish to easily move downstream.

Recommendations

An important limitation of video monitoring is the inability to differentiate individual fish and therefore to assess repeated attempts to enter the pre-sort pool and the eventual 'fate' of fish that reach the trapping facility. Telemetry studies with either active (e.g., radio) or passive (e.g., PIT) tags would provide additional information on fish behaviors and the efficacy of the fishway and trap.

Additional steps that could be taken to isolate the potential factors that affect ladder ascent and pre-sort pool entry include: (1) manipulation of water temperatures at the facility, specifically including use of warmer water that better matches temperatures of the South Santiam River upstream from Foster Dam; (2) manipulation of water source for the facility (i.e., drawing water from a different location in the reservoir or tailrace); (3) manipulation of chemical cues at the facility, potentially including some source water from the hatchery or from specific reservoir layers; (4) operations modifications at either Green Peter or Foster dams that would alter the temperature and/or chemical composition of water in the facility; or (5) changes to hatchery operations to minimize false attraction to the north side of the river.

To prevent or reduce adult fallback out of the pre-sort pool, we recommend either: (1) maintaining pool water elevations below the weir crest; and/or (2) installing temporary netting or other blocking devices above the weir during crowding and sorting operations. More substantive structural or operational modification may be warranted if the above prove ineffective.

5. Aerial photo and video surveys of salmon holding in the Foster tailrace

Methods

Camera deployments

In 2017, we tested the feasibility of using optical cameras to provide minimum estimates of the number of adult salmonids in the Foster Dam tailrace. Recognizing that the observations were limited because adults at depth, out of the field of view, or otherwise not detectable by imagery would not be included, the estimates provided a quantitative index of the minimum number of adult holding in the tailrace. We deployed six fixed-site cameras at five locations adjacent to the powerhouse section of the tailrace and one location above the spillway section of the tailrace (Figure 27, Table 8). Fourteen camera angles were used among the five powerhouse tailrace locations in attempts to obtain the best quality imagery (e.g. minimum surface glare, optimal fields of view and increased visibility of fish). The digital cameras included two Reconyx (Model PC900 Hyperfire, Holmen, WI), two GoPros (Models Hero3+ and Hero4, San Mateo, CA) continuously charged by a deep cycle marine battery, a Nikon DSLR (Model D3200, Tokyo, Japan) with an intervalometer, and a Swann digital video camera and recorder (Camera Model SWPRO-T890CAM and DVR Model SWDVK-8HD5MP4, Victoria, Australia). The Reconyx and Nikon cameras were programmed to take photos at 15-min intervals and the GoPros were set at 1-min intervals.

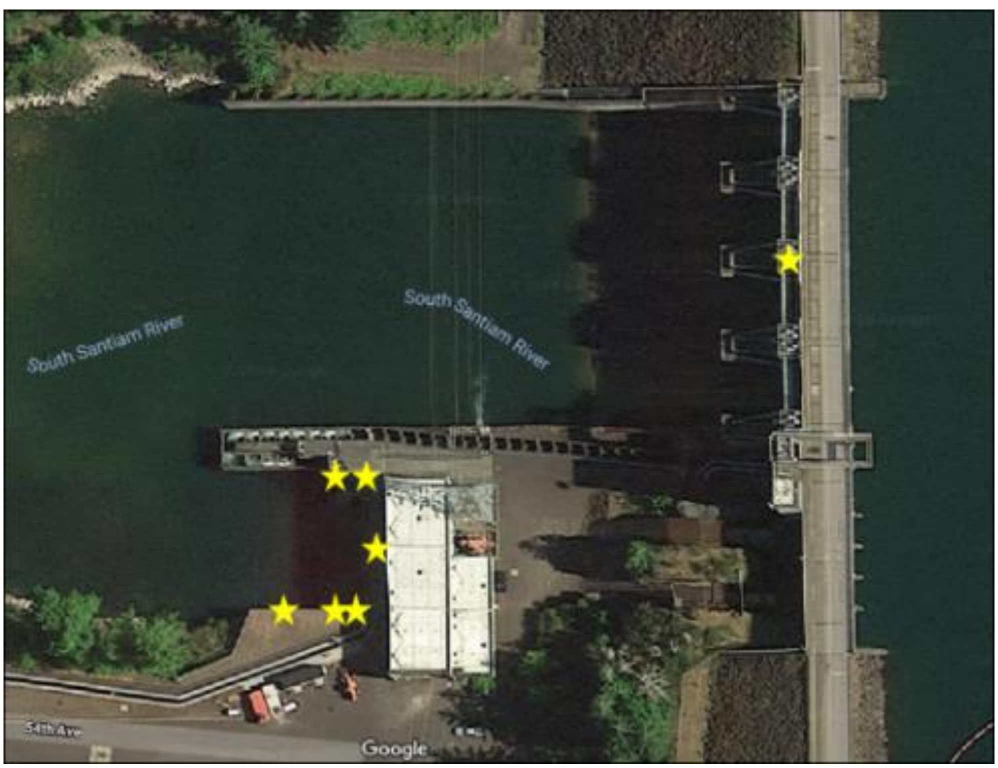

Figure 27. Google Earth photo of Foster Dam and tailrace; stars show where optical cameras were deployed in an effort to enumerate adult Chinook salmon holding in the tailrace. See Table 8 for deployment details.

Table 8. Summary of optical camera deployments used to monitor the Foster Dam tailrace in 2017. All imagery has been archived for potential future review.

Camera	Location	Angle	Date range	Comments
Reconyx	Spillway	RCNX Spill	29 June – 20 October	Most consistent images, with fish clearly visible when lighting suitable
Reconyx	Powerhouse	RCNX1	29-30 June	Decent imagery. No scoring effort.
Reconyx	Powerhouse	RCNX2	3-11 July	Decent imagery with no fish.
Reconyx	Powerhouse	RCNX3	11 July – 7 August	Glare, fish are not visible or present.
Reconyx	Powerhouse	RCNX4	7-16 August	Glare was an issue and no fish were viewed.
Reconyx	Powerhouse	RCNX5	16-22 August	Fish were seen with glare present.
Reconyx	Powerhouse	RCNX6	22 August – 3 September	Glare was an issue with few fish viewed.
GoPro3	Powerhouse	GP3B	22-31 August	Many fish visible when glare is not present.
GoPro3	Powerhouse	GP3D	8-20 September	No visible fish with lens condensation issues.
GoPro3	Powerhouse	GP3D	27 September – 17 October	No scoring effort.
GoPro4	Powerhouse	GP4A	27 July	No fish observed
GoPro4	Powerhouse	GP4A	10 August	One fish observed.
GoPro4	Powerhouse	GP4C	31 August – 27 September	No fish observed. Many issues with lighting and lens condensation.
Nikon	Powerhouse	DSLR Angle	14 September – 14 October	Most images were compromised with improper focus, blurriness, condensation and lighting. No scoring effort.
Swann (video)	Powerhouse	Video Angle	16 August – 17 October	Good imagery, but excerpted still photos degraded and were difficult to score

Image review and processing

Photos and video from all deployments were assessed for image quality and suitability for locating adult salmonids in the tailrace. Among the still photo deployments, the Reconyx images of the spillway tailrace were the most consistent, with fish visible on many dates. This location at the top of the spillway (~36 m [120 ft] above the water surface) created a wide field of view that captured much of the tailrace closest to the spillway and the AFF side fishway entrance adjacent to the spillway. The highest quality images were concentrated in mid-day, when there was less reflection (glare) off the water surface. All the powerhouse tailrace deployments (Table 8) were from ground-level railing 6-8 m (20-25 ft) above the water surface, which led to narrow fields of view at most of the angles tested. Although some fish were visible in the still photos, glare (despite the use of polarized lenses), shadows, and surface turbulence frequently reduced image quality. At all sites, rain, fog, and occasional condensation on the camera lens also reduced quality. After considerable review, we decided that it was unlikely that an informative time series of photos could be derived from the powerhouse tailrace cameras and instead focused our evaluation on the spillway tailrace.

For the summary presented here, we reviewed photos from the spillway tailrace (Reconyx camera) collected from 29 June through 20 October 2017. Estimates of adult salmon abundance in the photos were derived using an enumeration tool in ImageJ, an open-source image processing software (National Institutes of Health, https://imagej.nih.gov/ij/). This tool allowed us to magnify each photo, mark individual fish (Figure 33), and enumerate the total number of marks per photo. We reviewed five photos collected at 15 m intervals from 12:00 through 13:00 hrs on each Monday and Thursday during the monitoring period. Salmon abundance estimates from the five images each day were used to calculate daily mean estimates of minimum abundance.

Results

Photos of the spillway tailrace were reviewed for a total of 27 dates from 30 June through 28 September (Figure 29). There were 14 days when we could confidently score photos and estimate adult salmonid abundance. Image quality was best during seven days in July, when mean daily estimates of salmon abundance in the spillway tailrace ranged from 24-114 fish (Figure 29). Visible adult fish abundance was estimated to be <15 fish each day (n = 4 d with fish counted) in August and <4 fish each day (n = 2 d) in September.

Figure 28. Aerial photos of the Foster spillway tailrace taken on 6, 13, 24, and 27 July, 2017 between 12:00 and 13:00. Small yellow dots indicate locations of individual adult salmonids that were identified under magnification and enumerated using ImageJ software.

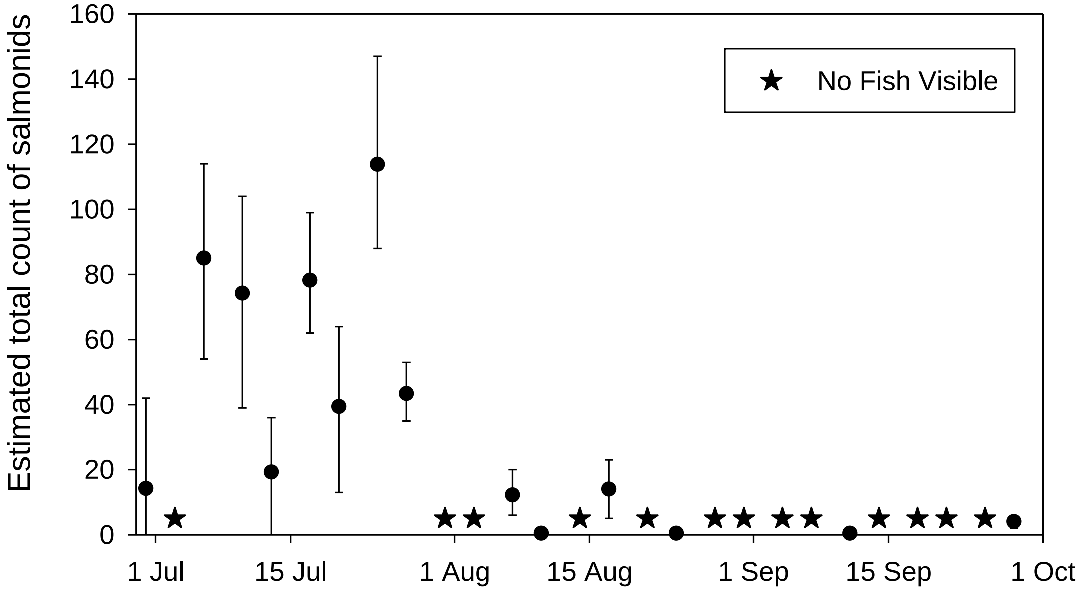

Figure 29. Estimated mean daily counts (black circles) of adult salmonids observed in the Foster Dam tailrace on Mondays and Thursdays during the monitoring period in 2017. Whiskers denote the minimum and maximum daily estimates from five scored photos taken each day between 12:00 and 13:00. Some days with no visible fish had reduced image quality due to weather or other factors.

Conclusions

Monitoring of the Foster tailrace with fixed-location optical cameras was moderately successful. The spillway deployment provided fairly consistent images of adult salmonids holding in the tailrace, with 10s to more than 150 fish per image for most of July, coincident with relatively high Chinook salmon collection rates at the AFF trap. Few fish were observed in photos from August or September despite a second peak in salmon collection at the trap. Fish in the spillway tailrace images tended to be concentrated within several meters of the spillway concrete, and were most often oriented to the south, where there was discharge from the side fishway entrance adjacent to the spillway. It was not possible to assess fish depth from the photos, but fish deeper than ~1-2 m likely could not be detected. All estimates of abundance should be considered minimums because many fish were observed in deeper water during on-site observations.

Adult salmon were also observed in photos of the powerhouse tailrace, but these images were of much lower quality overall and we elected not to make a systematic review. That said, in our preliminary screening we observed that fish were frequently in the attraction plume from the main fishway entrance and in various other locations in groups throughout the imaged area. Fish distribution in the powerhouse tailrace also appeared to change throughout the day, with many individuals moving into shaded areas in mid-day and afternoon, including near the channel adjacent to the powerhouse. Image quality was likely diminished by constraints on where cameras could be placed at the powerhouse, which resulted in low camera angles and limited fields of view. If camera monitoring is considered in future studies, we recommend deployment sites that are much higher, perhaps with cameras mounted on the powerhouse. Regardless, the quantitative estimates were consistent with past qualitative observations of holding by large numbers of adults in the tailrace and with 2017 radiotelemetry results. Similar methods could be employed in future years as a low-cost index of in-season collection efficiency.

6. Chinook salmon radio-tagged at Foster Trap and released upstream

Methods

Study area and fish collection

Adult Chinook salmon were collected and tagged from June-September 2017 at the Foster Dam Adult Fish Facility (AFF) on the South Santiam River (Figure 30). The AFF was operated by ODFW to collect fish for hatchery broodstock and for the adult trap-and-haul operation. Sampled fish were provided for this study as part of routine operations. The Foster fishway consists of a lower ladder, transport channel, upper ladder, and pre-sort pool (see Figure 2). After sorting by ODFW personnel, the fish were anesthetized (AQUI-S 20E at 15-20 mg/l; AquaTactics Fish Health, Kirkland, WA) in a primary tank and then transferred to a secondary tank containing a 5 mg/l concentration of AQUI-S 20E. While anesthetized, fish were measured for fork length (nearest 0.5 cm), assigned a sex based on morphological characteristics, inspected for fin clips or markings, and assessed for condition (see Keefer et al. 2004; Naughton et al. 2016 for description of methods). Fish were then PIT tagged in the dorsal sinus and gastrically implanted with a 3-volt radio-transmitter that recorded temperature (+/- 0.8 C resolution) and pressure (+/- 1 PSI [or 0.01 meters] resolution) every eight minutes (Lotek Wireless Inc., New Market, Ontario; model MCFT3-3A-TP-L, 61 mm × 16 mm diameter, 23 g in air). A silicone band was placed on each transmitter to reduce regurgitation. After tagging, fish were loaded into a transport truck and then released into Foster Reservoir near the Calkins Park boat launch (rkm 421.7) or into the South Santiam River at Gordon Road (rkm 444.7). All of the released fish had intact adipose fins suggesting natural-origin.

Telemetry monitoring

We used fixed-site radiotelemetry antennas (4 or 6 element yagi) to evaluate whether radio-tagged adult salmon exited Foster Reservoir into an upstream tributary or fell back downstream of the dam (Figure 31). The antenna sites were located near the mouth of the Middle Santiam River (MSR, rkm 424.1), in the South Santiam River upstream of the reservoir release site (SFR, rkm 422.0) and at River Bend (RVB, rkm 427.6), and in the Foster Dam forebay (QFS, rkm 418.2) and tailrace (2FS, rkm 418.2 and 1FS, 416.6).

Sample summary

We collected and radio-tagged 25 adult Chinook salmon at the Foster Dam adult fish facility between 27 June and 26 September 2017 (Figure 30). On average, tagged salmon weighed 5.05 kg (*sd* = 1.5 cm, *range* = 3.38 – 7.08 kg), had a fork length of 77.1 cm (*sd* = 5.2 cm, *range* = 65.0 – 87.0 cm), and had a fatmeter value of 1.9% (*sd* = 1.7%, *range* = 1.5 – 4.4%). The mean condition score was 2.5. Nineteen fish were released in the reservoir, five fish were released in the South Santiam River at Gordon Road, and one fish regurgitated its radio transmitter in the transport truck prior to release into the reservoir.

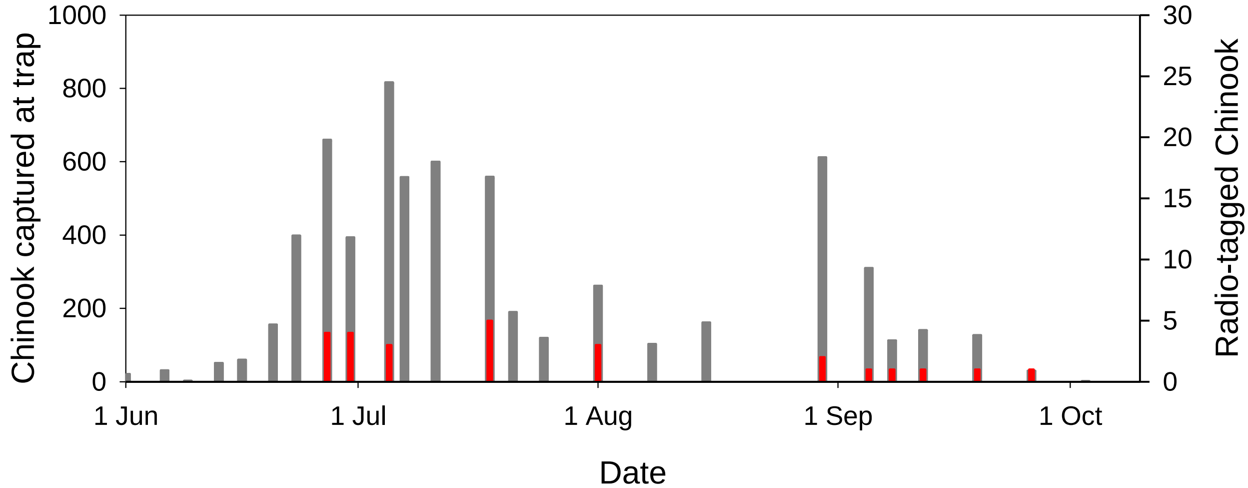

Figure 30. Distribution of Chinook salmon (hatchery and natural-origin) captured in Foster Trap (*n* = 6,455, gray bars) and the number of trapped Chinook salmon that were radio-tagged (*n* = 25, red bars) in 2017.

Results

Salmon recovery rates

The overall recovery rate for radio-tagged fish (or their transmitters) released in the reservoir was 47.4% (9/19), including 7 (36.8%) that were recovered on the spawning grounds and 2 (10.5%) that fell back past Foster Dam and were recovered downstream. The sample recovered on South Santiam River spawning grounds was distributed between Menear's Bend (rkm 425) and the Soda Fork (rkm 456.3). Four of the five (80%) fish released into the South Santiam River were also recovered, all on the spawning grounds.

Salmon behaviors in Foster reservoir

All 19 radio-tagged salmon released into Foster Reservoir were recorded at receivers upstream from the Calkins release site. Of the 19, 16 (84.2%) entered the South Santiam river, 2 (10.5%) fell back at Foster dam and were last recorded downstream, and 1 (5.3%) entered the Middle Santiam River. The 16 salmon that eventually entered the South Santiam River had a median reservoir residence time (including time in the lower reaches of the Middle Santiam River) of 4.9 d (*range* = 0.6-95.1 d). The two fish that fell back after release spent 2.4 and 28.4 d in the reservoir, and the single salmon that was last detected in the Middle Santiam River spent 9 d in the reservoir.

The 16 reservoir-released salmon that eventually entered the South Santiam included ten that were also recorded at the Middle Santiam receiver site. At least five of these fish moved between the South Santiam and Middle Santiam antennas multiple times. It is not known whether these movements were associated with homing, behavioral thermoregulation, or other factors.

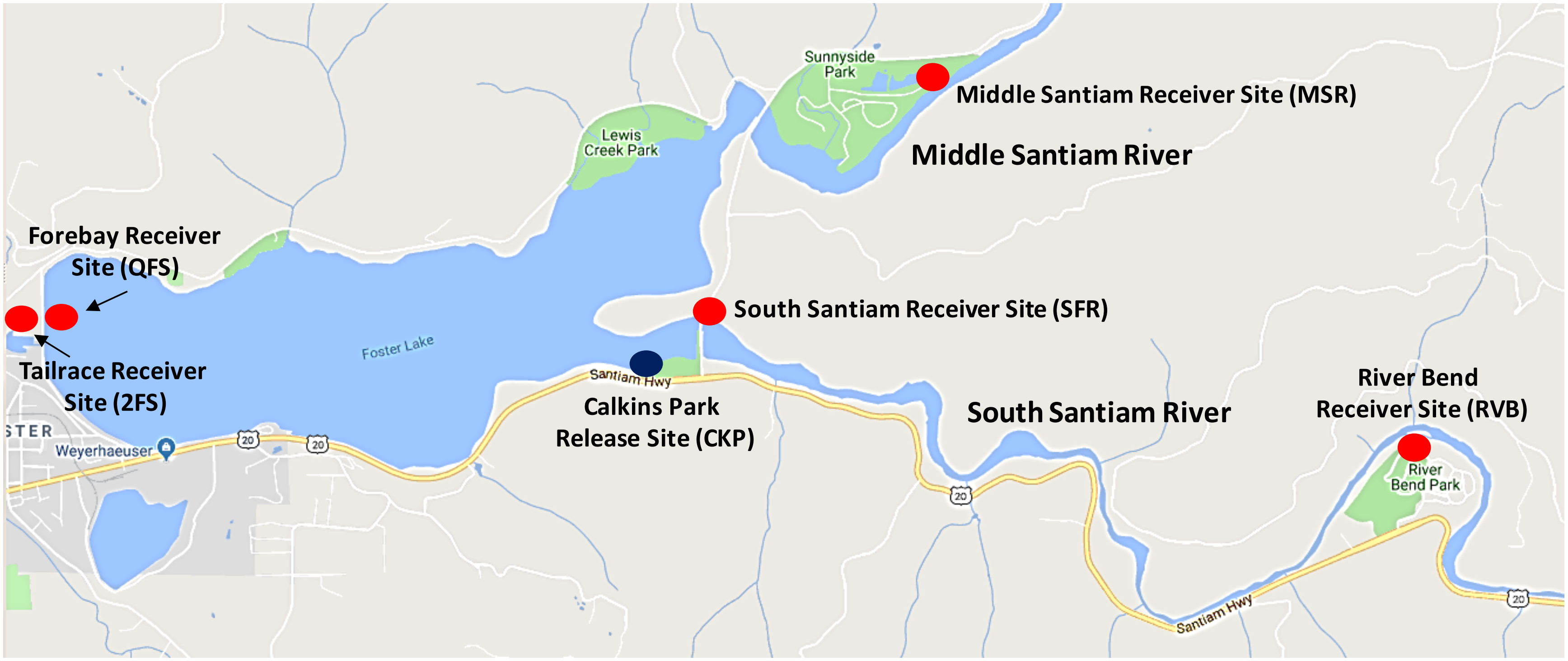

Figure 31. Map of Foster Reservoir including South and Middle Santiam rivers, radiotelemetry monitoring antennas (●) in the Middle Santiam River (MSR, rkm 424.1), in the South Santiam River (SFR, rkm 422.0 and RVB, rkm 427.6) in the forebay (QFS, rkm 418.2) and tailrace (2FS, rkm 418.2 and 1FS, rkm 416.6) of Foster Dam. Chinook salmon release sites (●) were at Calkins Park (CKP, 421.7 rkm) and Gordon Road (GDR, 444.7 rkm). The Gordon Road release site is approximately 17.1 rkm upstream of the River Bend receiver site and is not shown.

Temperature and depth histories from archival transmitters

Archival transmitters from 13 Chinook salmon were recovered that had viable temperature and depth records. Nine of the 13 fish had been released into Foster reservoir and the other four had been released at Gordon Road in the South Santiam River. Five fish that were released into the reservoir spent time in the reservoir (2.4-26.1 d) and intermittently entered the Middle Santiam River (range 0.9-13.1 d) before entering the South Santiam River (Table 9; Figure 32 shows an example and Appendix C includes complete data for all recovered transmitters). Chinook salmon were cooler, on average, in Foster reservoir (individual means = 13.8 °C, n = 9) than in the South Santiam River (15.8 °C, n = 11). Fish were considerably colder while in the Middle Santiam River (8.5 °C, n = 5; e.g., Figure 32).

Salmon were recorded at a wide range of depths in Foster reservoir, from near the surface to > 25 m deep (Table 9). Individual mean depths in the reservoir were mostly in the 5-7 m range. Mean depths in the Middle Santiam River were mostly ~2-4 m, which included time fish likely spent in the inundated lower section of the river. Fish were shallowest in the South Santiam River, where individual means ranged from ~0.5-2.5 m (Table 9).

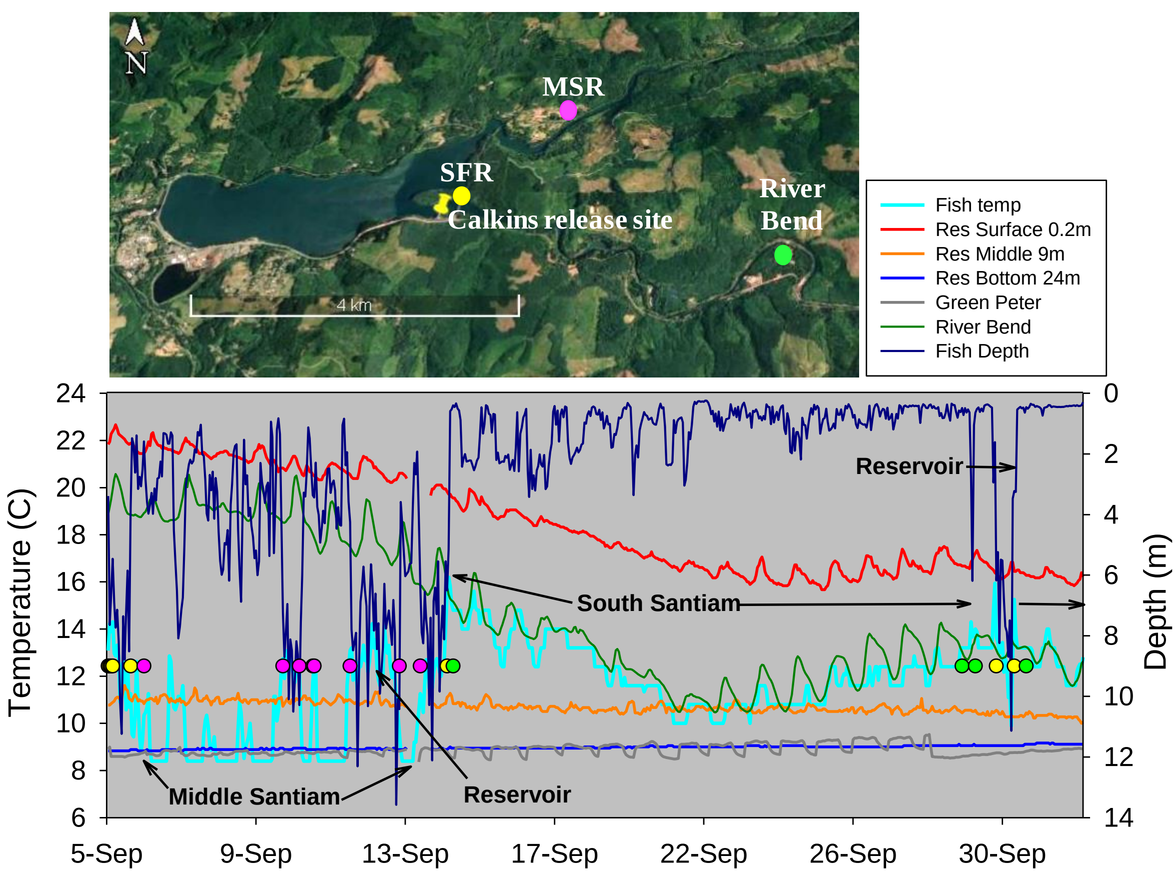

Figure 32. Chinook salmon 19-161 released into Foster reservoir and last detected in the South Santiam River above the reservoir. Lines show hourly fish temperature, fish depth, reservoir (Res) surface, middle and bottom temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend. Dots on graph correspond to antenna sites in map.

Table 9. Estimated time that Chinook salmon with recovered sensor tags spent in Foster reservoir and in the Middle and South Santiam rivers, with the mean, standard deviation (SD), and range (max-min) recorded temperature and depth records in 2017. Note that first record dates give approximate start times because several salmon moved in and out of the river and reservoir habitats.

		First		Temperature (C)			Depth (m)		
Location	FishID	record date	Time (d)	Mean	SD	Range	Mean	SD	Range
Reservoir	19-152	27-Jun-17	13.4	13.1	1.5	10.4	6.8	1.9	23.7
	19-151	30-Jun-17	0.6	16.3	1.2	5.6	-	-	-
	19-197[1]	5-Jul-17	17.3	13.6	1.9	13.6	6.5	2.6	30.1
	19-172	5-Jul-17	13.4	13.4	1.2	10.4	7.2	1.4	18.0
	19-157	18-Jul-17	26.1	12.7	1.5	10.4	6.9	2.4	25.5
	19-159[1]	30-Aug-17	2.4	14.9	1.1	7.2	7.1	2.5	25.6
	19-160	30-Aug-17	2.4	13.7	1.5	8.8	6.4	3.4	22.7
	19-161	5-Sep-17	5.5	12.3	1.6	8.8	6.4	4.1	27.0
	19-165	19-Sep-17	0.3	13.8	0.7	2.4	5.4	2.3	9.5
Middle Santiam	19-152	30-Jun-17	0.9	9.3	1.9	8.0	5.2	2.0	10.9
	19-197[1]	7-Jul-17	10.7	7.7	0.3	2.4	2.6	2.1	8.3
	19-157	20-Jul-17	13.1	8.4	0.6	4.0	3.4	1.5	8.6
	19-160	30-Aug-17	11.2	8.4	0.2	3.2	1.9	1.6	10.7
	19-161	6-Sep-17	4.8	8.7	0.7	4.0	3.4	1.9	11.3
South Santiam	19-155[2]	30-Jun-17	44.5	17.0	2.1	12.8	1.9	0.7	3.6
	19-171[2]	30-Jun-17	51.9	16.5	1.7	10.4	0.6	0.5	4.4
	19-151	1-Jul-17	81.9	16.9	1.5	8.0	-	-	-
	19-152	11-Jul-17	64.1	17.7	1.5	6.4	2.1	0.9	5.5
	19-172	18-Jul-17	5.1	17.6	1.6	6.4	2.5	1.2	5.6
	19-162[2]	1-Aug-17	51.2	14.8	2.5	16.8	1.2	0.7	4.0
	19-174[2]	1-Aug-17	12.5	18.3	1.3	7.2	0.7	0.6	3.5
	19-157	26-Aug-17	19.2	16.4	1.3	6.4	1.5	1.2	9.0
	19-160	13-Sep-17	16.9	14.0	1.5	5.6	0.9	0.7	7.0
	19-161	15-Sep-17	16.9	12.2	1.3	5.6	1.0	0.9	8.5
	19-165	20-Sep-17	12.9	11.9	1.0	4.0	1.3	1.2	8.1

[1] Fell back and last recorded below Foster Dam
[2] Fish were released in the South Santiam River at Gordon Rd.

Potential thermal benefits from reservoir release

Data recovered from 13 archival transmitters indicated that salmon in the reservoir were typically 2-8 °C cooler than the fish in the South Santiam River on most days (Figure 33). Several of the fish that were last recorded in the South Santiam also used lower reaches of the Middle Santiam River, where salmon body temperatures were mostly 8-10 °C, or 6-10 °C cooler than those in the South Santiam River. Using a 3-d moving average of the temperature difference between fish in the South Santiam River versus the cooler reservoir and Middle Santiam River sites, we estimated that reservoir-released salmon were at least 2 °C cooler on almost all dates from early July through mid-September (Figure 34).

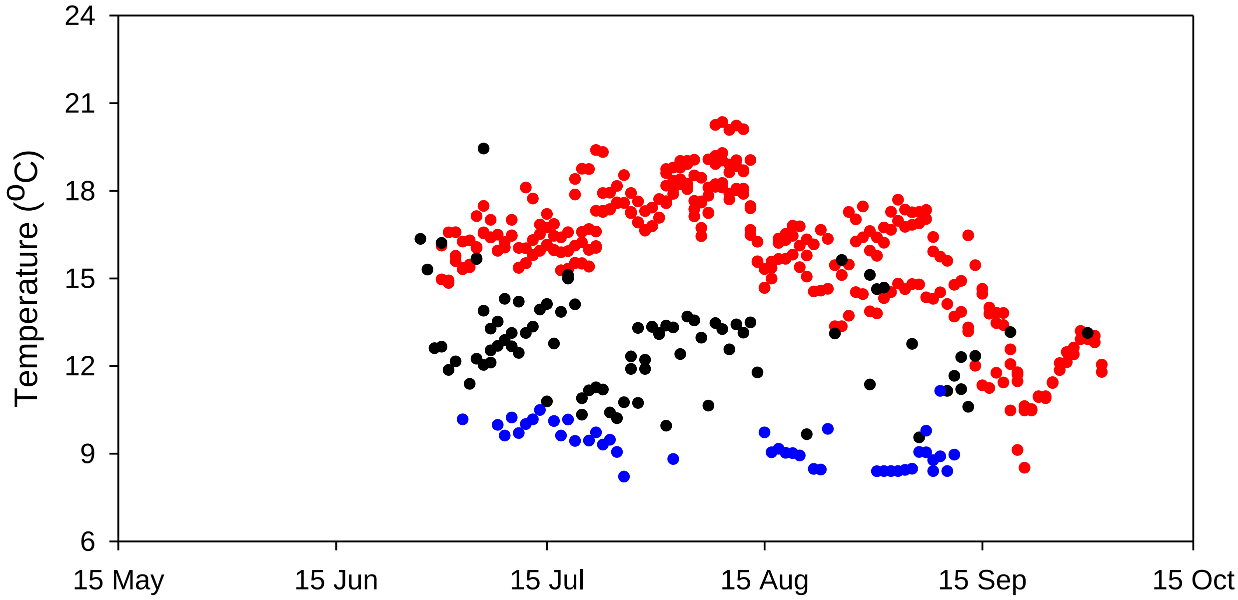

Figure 33. Mean daily body temperatures of 13 adult Chinook salmon tagged with archival radio transmitters. Symbols are for dates when salmon were in the Foster reservoir (black), South Santiam River upstream from the reservoir (red), or the Middle Santiam River upstream from the reservoir (blue). All fish were last detected in the South Santiam River.

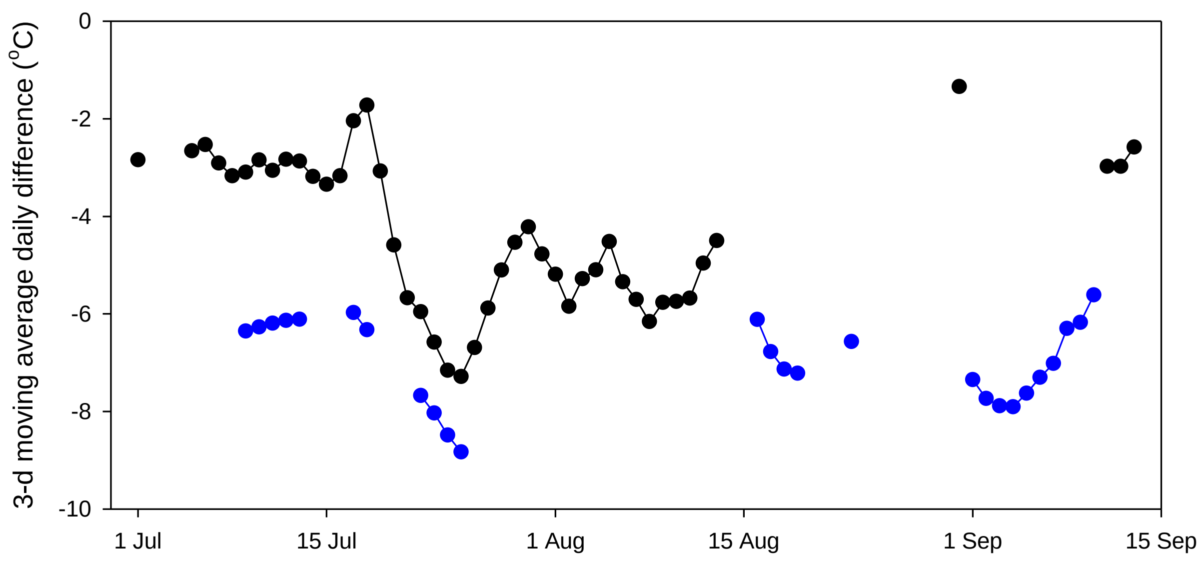

Figure 34. 3-d moving average of the mean differences in the body temperatures of individual archival-tagged salmon that were in the Foster reservoir (black dots) or Middle Santiam River (blue dots) versus in the South Santiam River. Calculations were restricted to dates with at least one fish each in the reservoir (*range* = 1-3 fish per day) or Middle Santiam (*range* = 1-2 fish per day) and in the river (*range* = 2-5 fish per day).

Conclusions

The Chinook salmon released into Foster reservoir in 2017 were the first in the series of reservoir-release studies that had depth sensors in addition to temperature sensors integrated with radio transmitters. The recovered depth data indicated that salmon used a variety of strata in the reservoir, but mostly selected for temperatures between 11-16 °C, corresponding to depths of 5-7 m. Those that temporarily used the Middle Santiam River were shallower in the water column, but in colder water. Several adult salmon studies have shown that maturing adults will select thermal conditions that optimize physiological processes, including maturation and metabolism, during prespawn holding or staging (Berman and Quinn 1991; Newell and Quinn 2005; Mathes et al. 2010; Minke-Martin et al. 2018). The recorded Chinook salmon behaviors in Foster reservoir presumably reflected similar selection for preferred thermal conditions and we note that preferences have been fairly consistent across five study years (Naughton et al. 2016, *in press*). Cold and cool water deep in the reservoir provides a clear opportunity for managers of the trap-and-haul program to reduce temperature exposure during the final stages of migration.

The cumulative thermal benefit of reservoir release is strongly dependent on how long salmon remain in the reservoir and the difference between selected temperatures in the reservoir and available temperature in the South Santiam River upstream. Across study years, we have estimated that reservoir-released fish were exposed to ~3-6 fewer degree days (DD) per day than fish released directly into the South Santiam River. The average thermal benefit across years has been ~65 DD per fish and has ranged as high as 392 DD; the cumulative benefit is more strongly affected by the duration of reservoir residence than the difference in temperature between habitats (Naughton et al. 2016, *in press*). Reducing cumulative exposure may help reduce prespawn mortality in the South Santiam River because exposure increases the risk of lethal and sublethal effects from bacterial and fungal infections and pathogens in salmon (e.g., Kocan *et al.* 2004; Bradford *et al*. 2010; Kent *et al*. 2013). Before being collected at Foster Dam, adult Chinook salmon can accumulate several hundred to >1,000 DD during their migration through the Willamette and South Santiam rivers (Keefer *et al*. 2015). Consequently, many fish have very high pathogen loads before they are collected (Benda et al. 2015), and this almost certainly contributes to some degree to the high mortality in trap-and-haul fish (Naughton et al. 2016; DeWeber et al. 2017).

About 11% of reservoir-released salmon fell back at Foster Dam in 2017, which was in the middle of the range (6-23%) of annual fallback estimates from previous study years. Fallback estimates at Foster Dam were similar to those of Kock *et al*. (2016), who found that 19% of adult Chinook salmon released in the reservoir upstream from Cowlitz Falls Dam (Washington) fell back, as did 15% of those released in the Cowlitz River above the reservoir. It is unclear why reservoir-released salmon fell back at Foster Dam, but one hypothesis is that their natal site was downstream from the dam and fallback was related to homing or orientation. In a genetic parentage study, Evans *et al*. (2016) found that up to 35% of Chinook salmon adults in the South Santiam River trap-and-haul program were not produced upstream from Foster Dam. Reservoir-released fish that originated downstream may actively search for natal sites and, lacking familiar olfactory cues, some may eventually find downstream routes at the dam and fall back (e.g., Keefer et al. 2008). Distinguishing between volitional fallback by adults attempting to return to downstream natal sites versus incidental fallback via entrainment is an important information gap in the South Santiam River trap-and-haul program.

Lastly, one reservoir-released Chinook salmon was last detected in the Middle Santiam River in 2017, consistent with previous results showing some salmon use of this tributary (Naughton et al. *in press*). Natal locations were unknown for all tagged fish and so we do not know whether salmon in the Middle Santiam River indicates homing or local-scale straying. However, one of the potential benefits of release into the reservoir is the opportunity for adults to select among spawning sites.

Recommendations

Genetic parentage analyses (e.g. Evans et al. 2016) could help resolve several questions associated with the adult outplanting program, including: (1) whether adults collected at Foster originated upstream from the dam; (2) if upstream origin is likely, whether fish should be released into the South Santiam River or Middle Santiam River; (3) whether fallback at Foster Dam by outplanted fish is associated with fish origin location. Furthermore, if adult release into the reservoir continues as a temperature-mitigating tactic, parentage information may provide some insight regarding the time fish spend in the reservoir before entering spawning areas. A pedigree study should sample hatchery broodstock, carcasses from natural-origin spawners below Foster Dam and outplanted adults given the potential for spawning by hatchery-origin adults below the facility.

Adult Chinook salmon have been last detected in the Middle Santiam River in many study years, but it remains uncertain whether spawning or successful reproduction occurs there. We recommend that either spawning ground surveys or smolt collection studies be considered for this reach to better inform outplanting operations (e.g., release of adults into tributaries versus into the reservoir).

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Appendix A

Technical drawings and parts list for the portable adult trap installed at Lebanon Dam in 2017.

Lebanon trap technical drawings

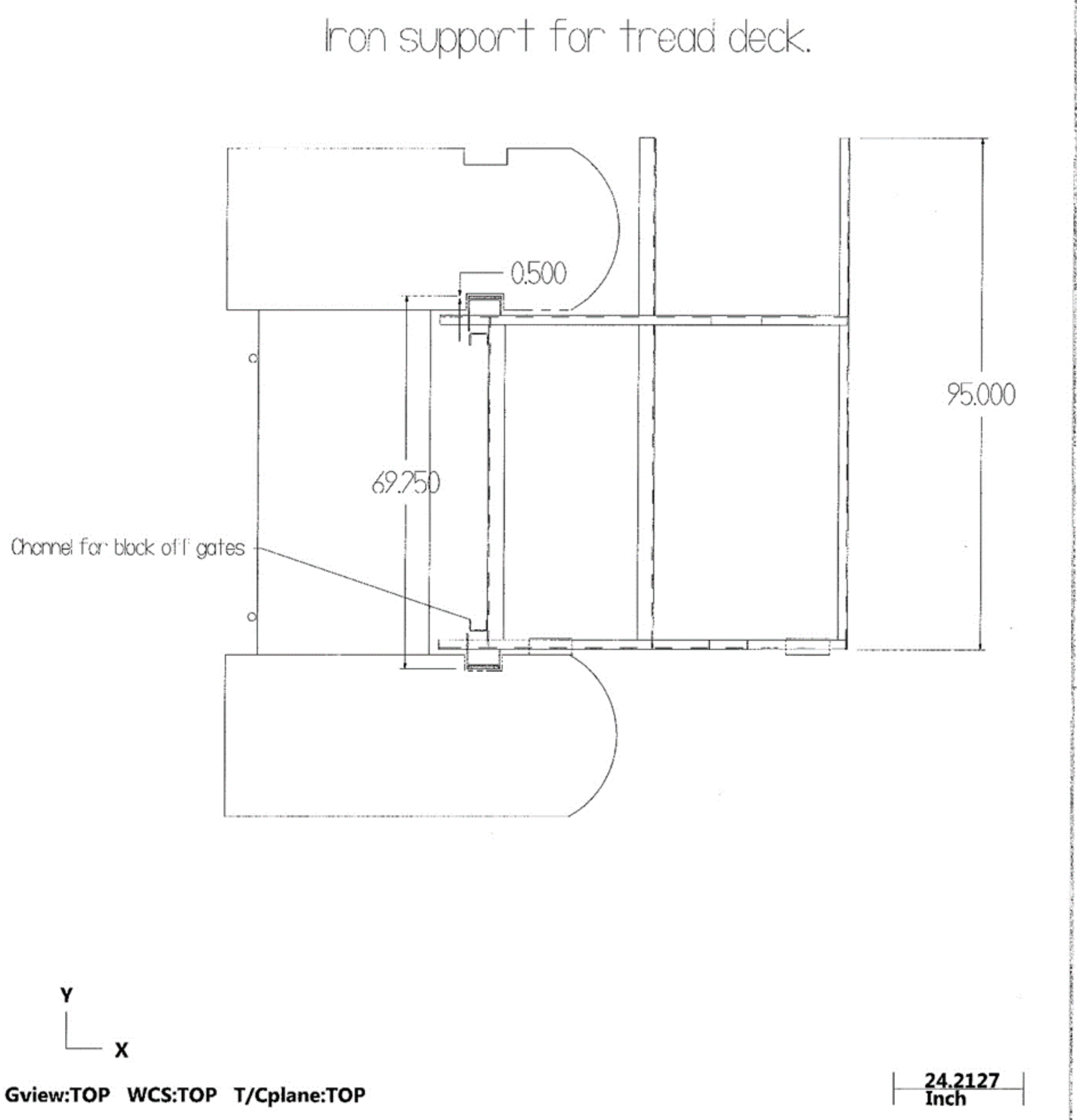


Figure A1. Iron support for tread decking.

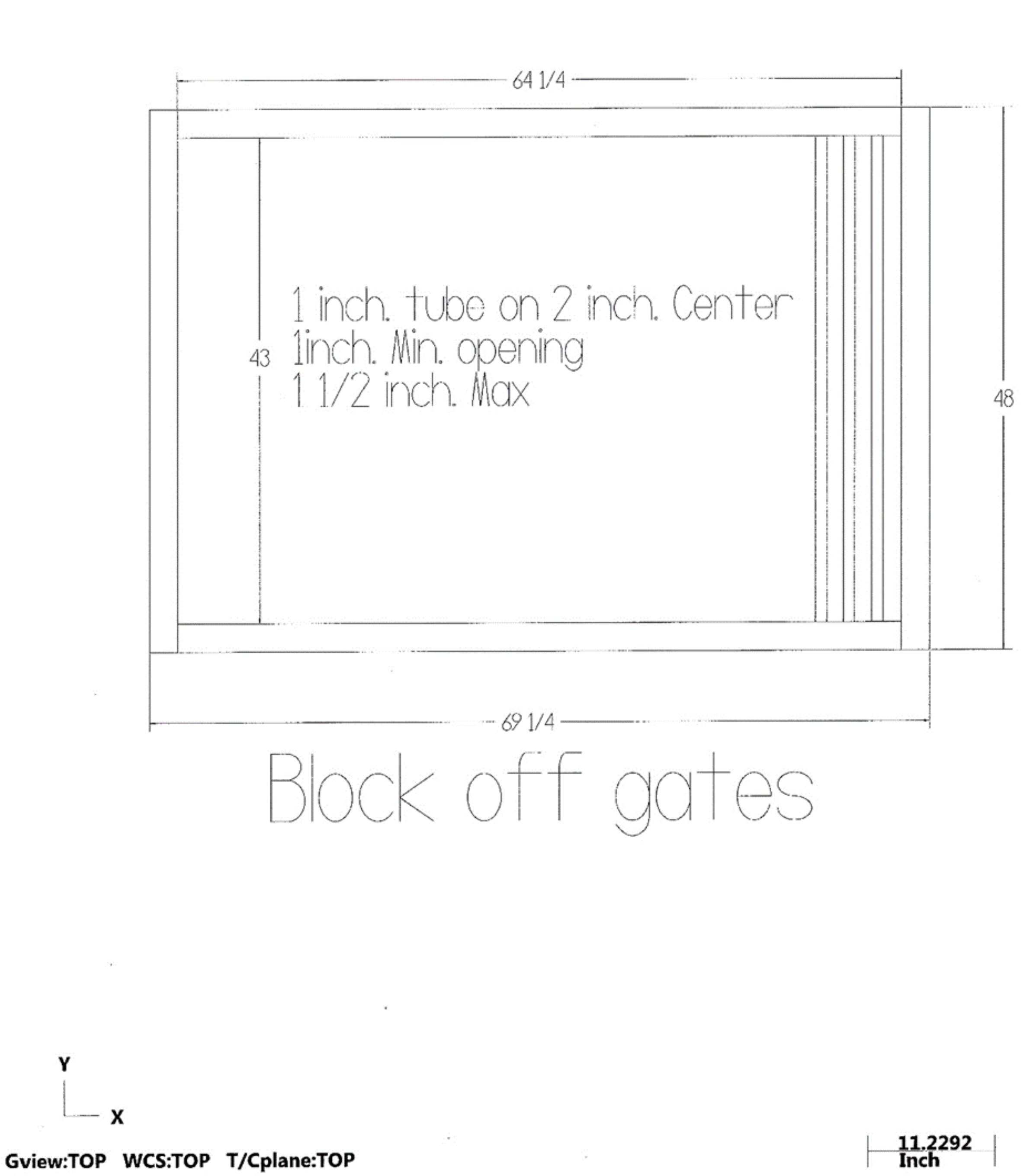


Figure A2. Aluminum block off gate (bar screens)

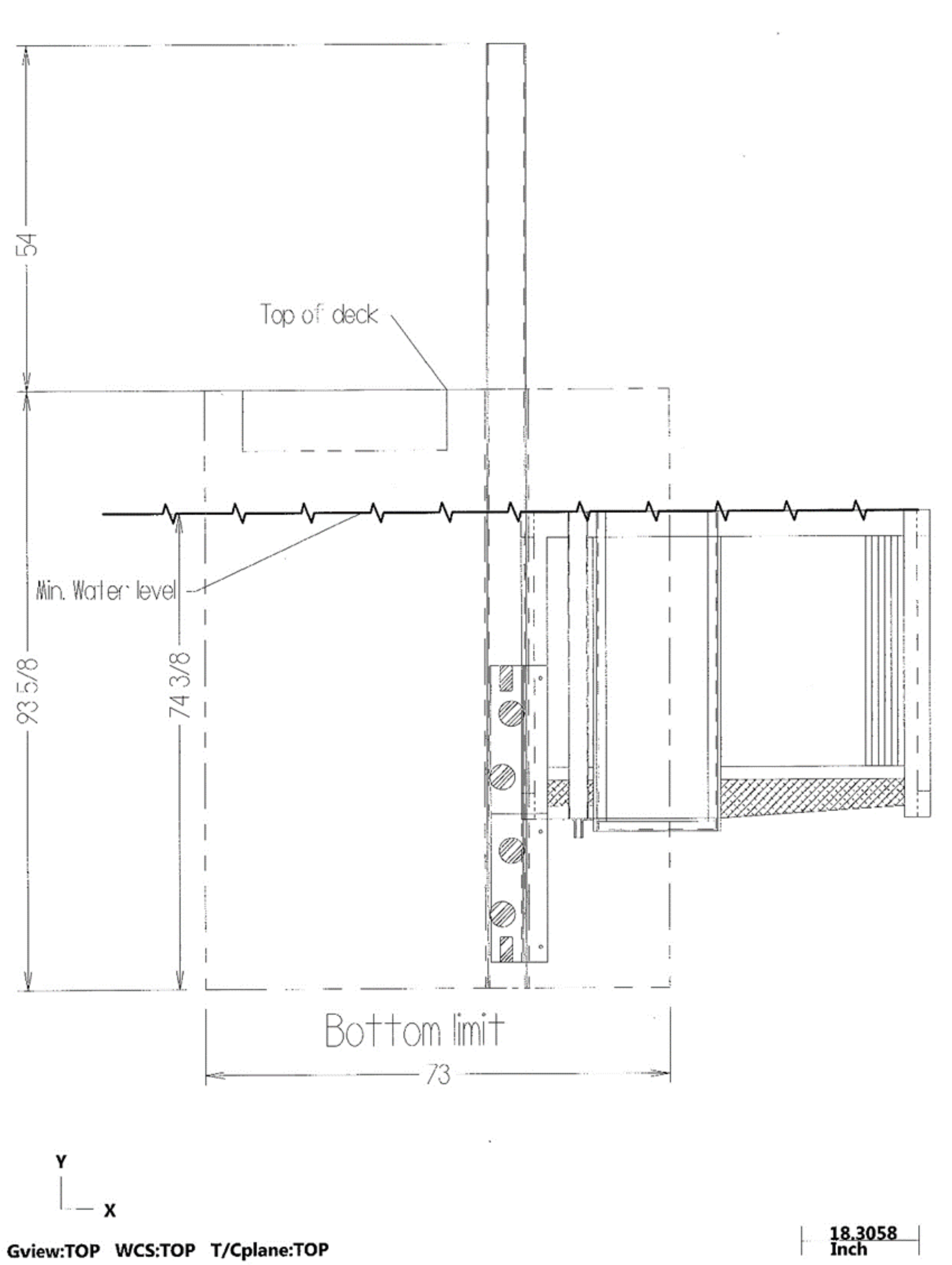


Figure A3. Trap deployed at minimum estimated water level (one inch = 32.1 inches).

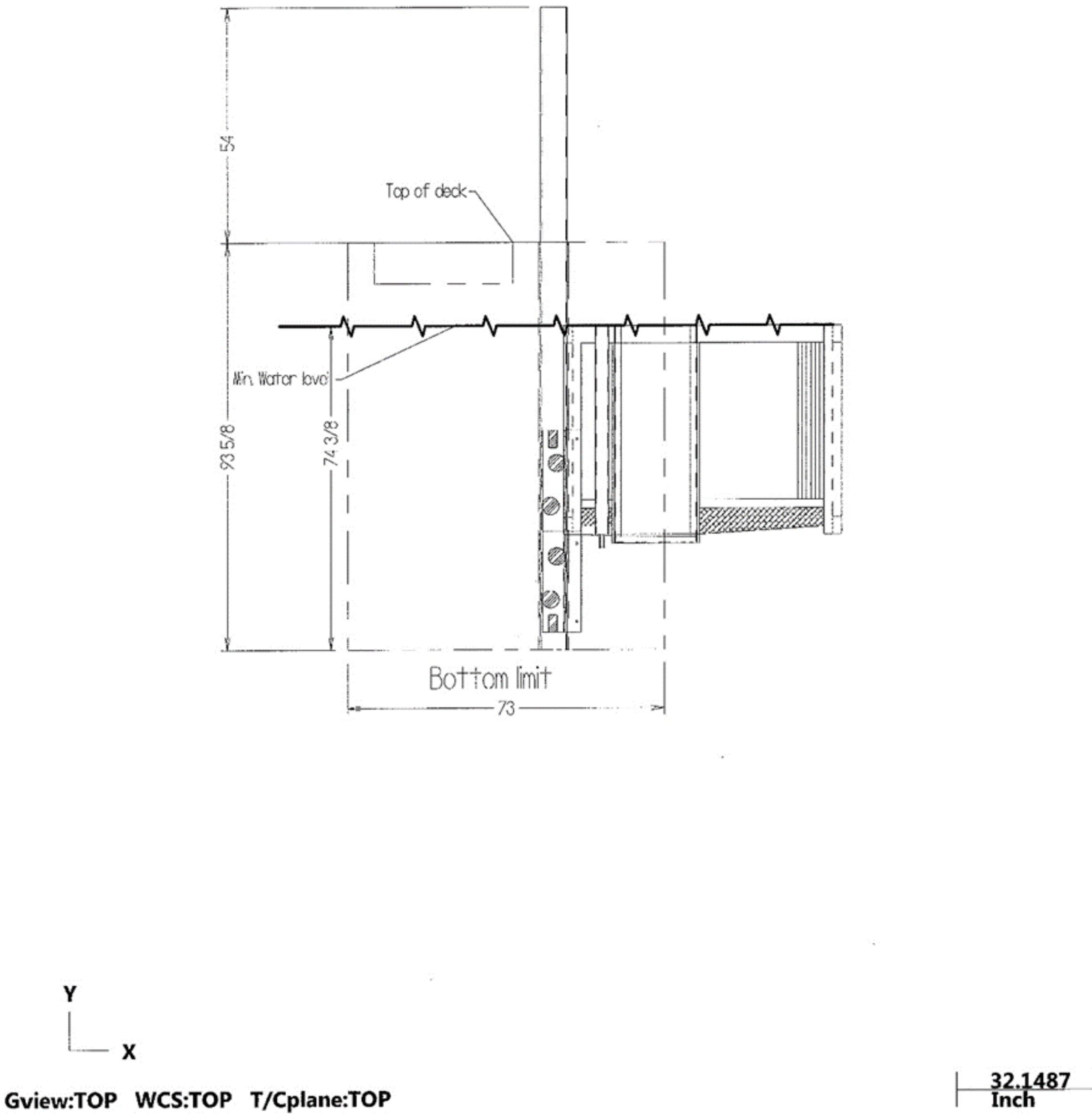


Figure A4. Trap deployed at minimum estimated water level (one inch = 18.32 inches).

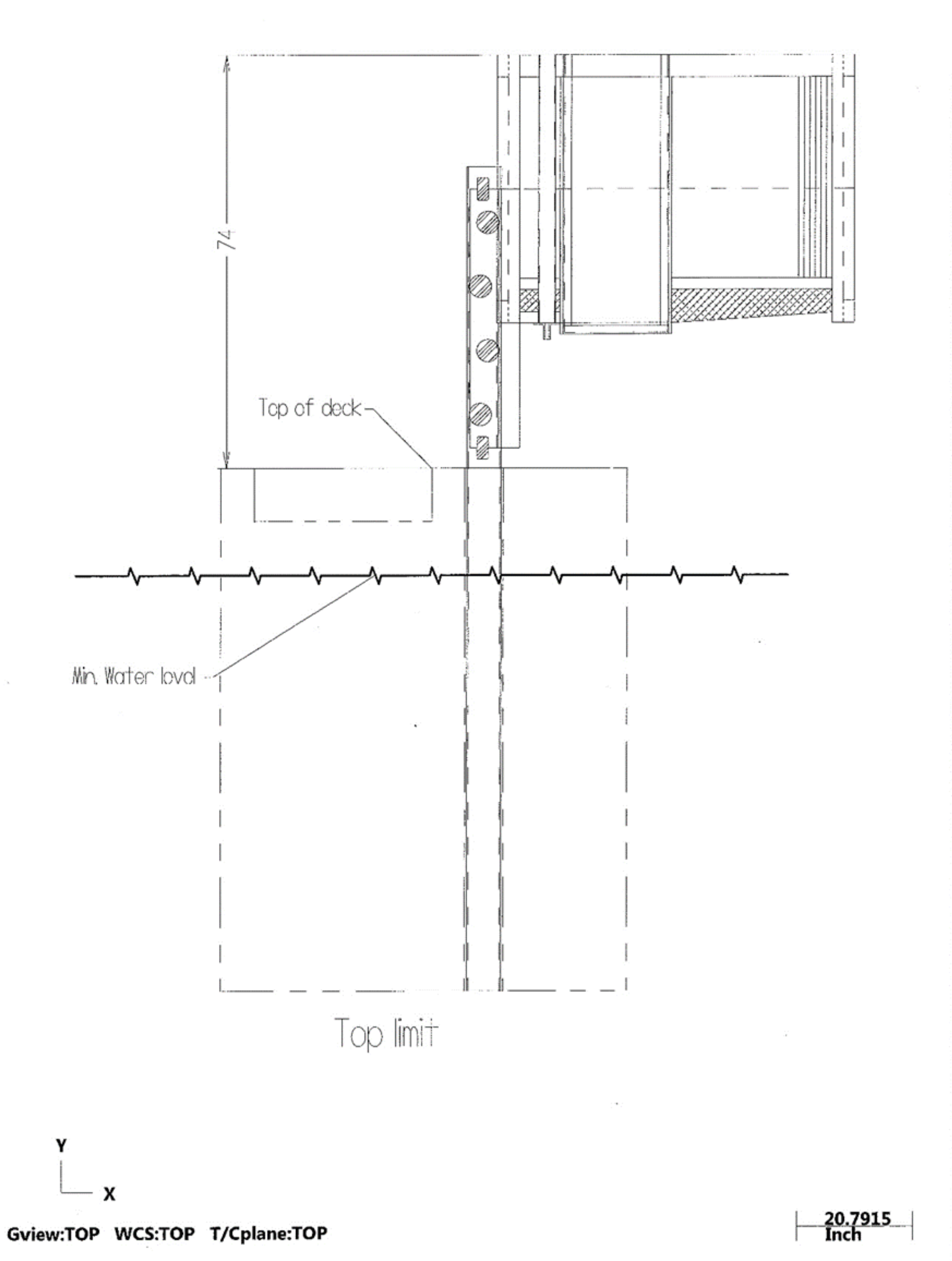


Figure A5. Trap raised to maximum height.

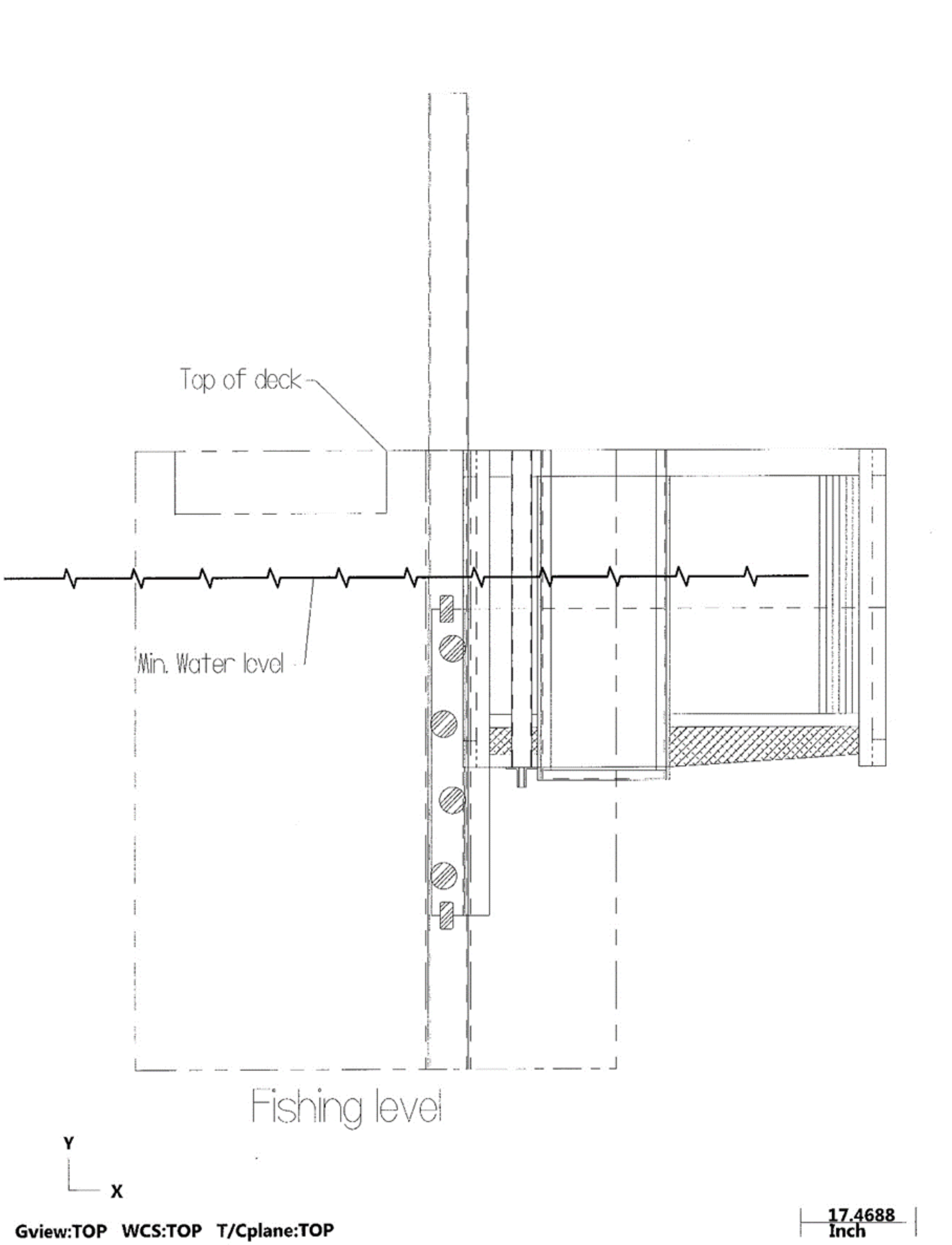


Figure A6. Trap deployed at fishing level.

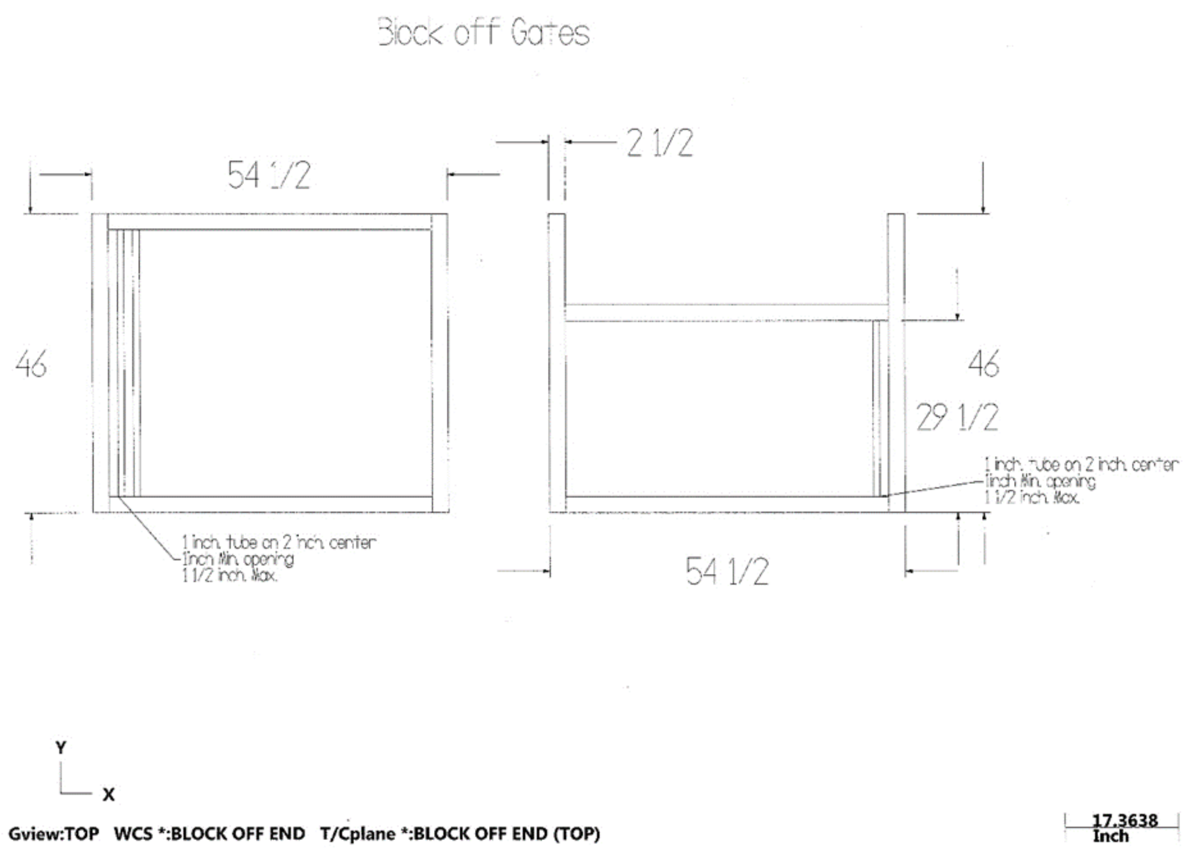


Figure A7. Block off gate dimensions.

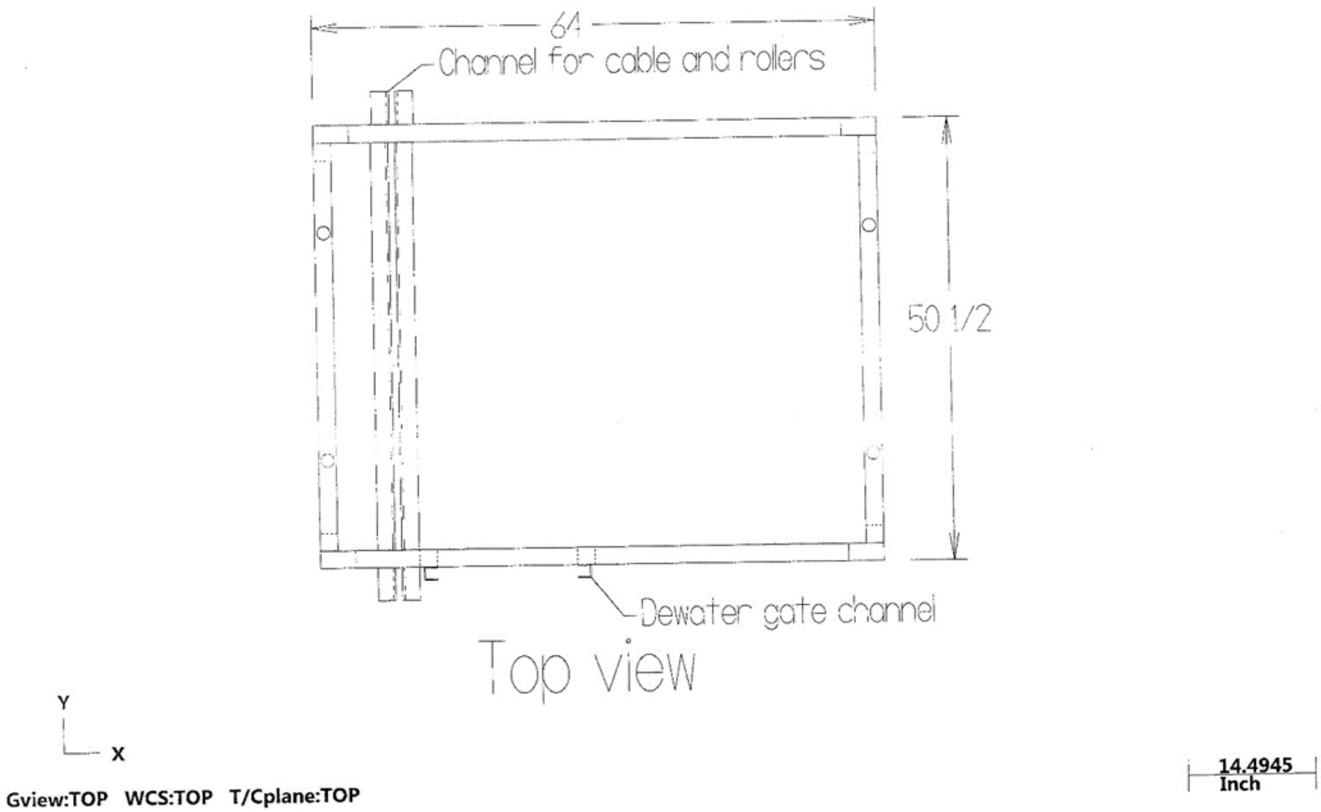


Figure A8. Top view showing dewater gate channel and cable roller channels.

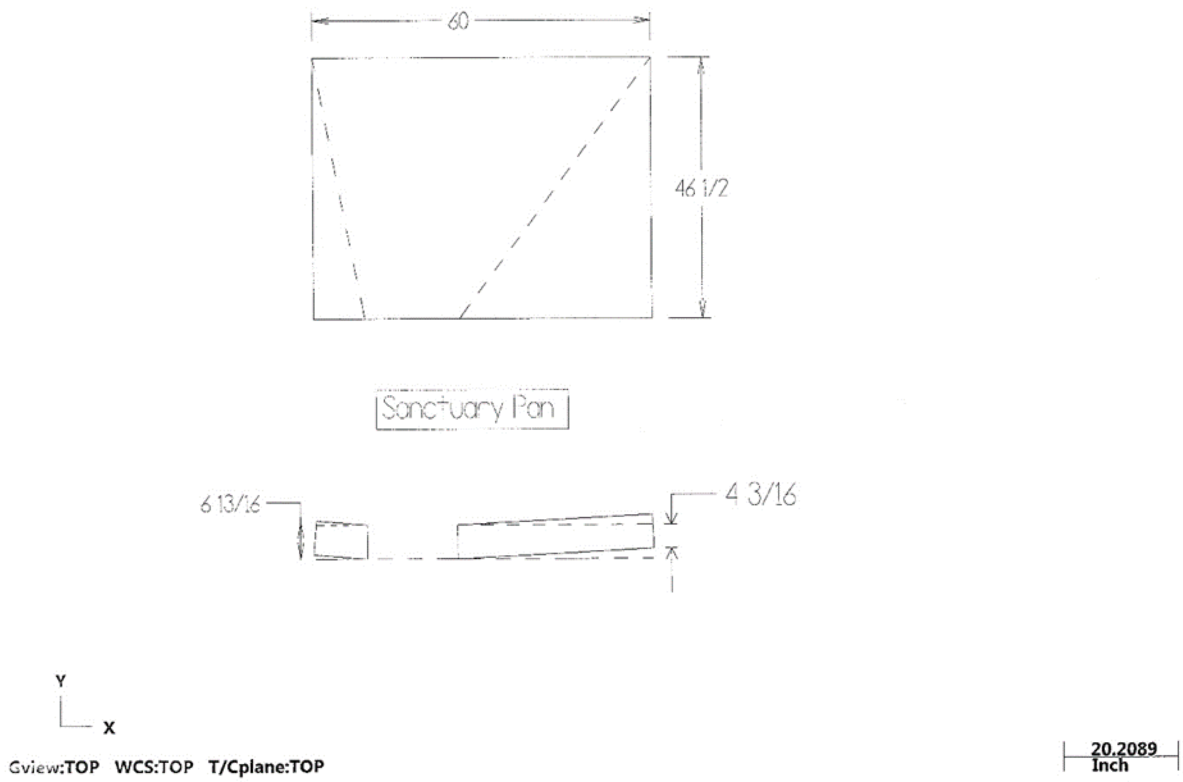


Figure A9. Sanctuary pan dimensions.

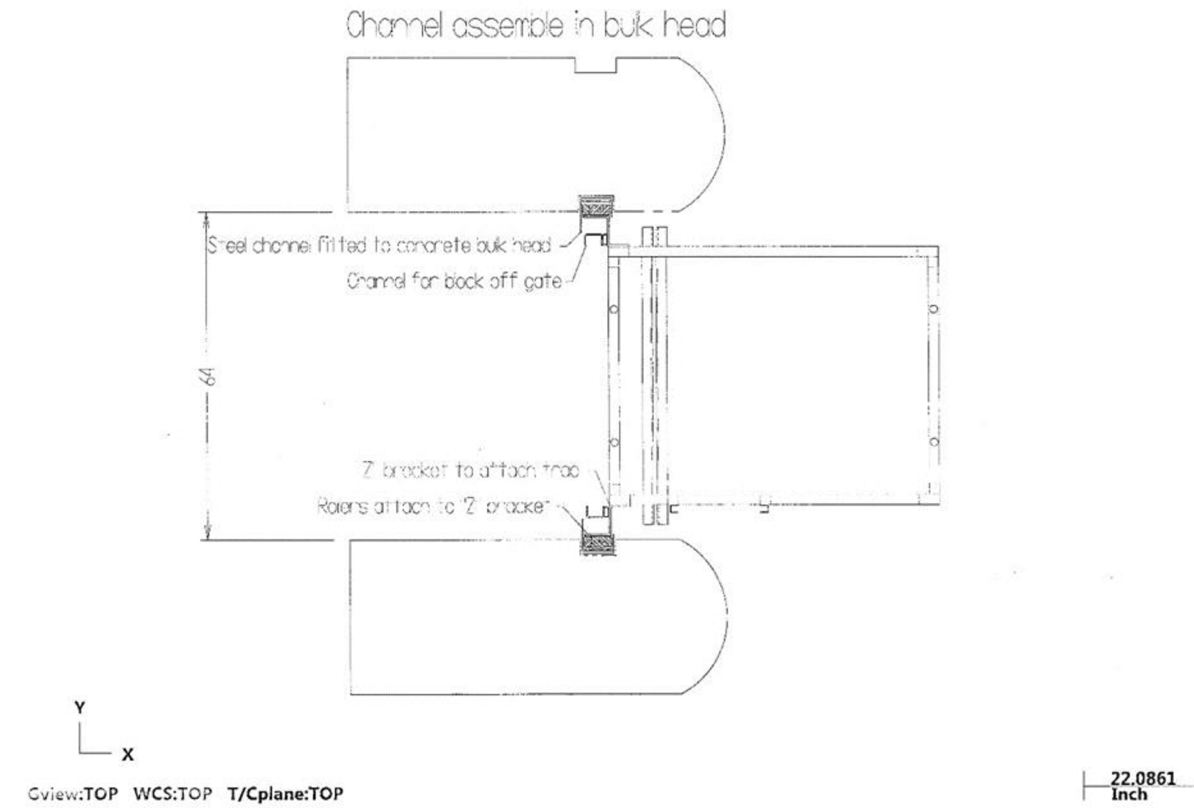


Figure A10. Channel assembly in fishway bulkhead.

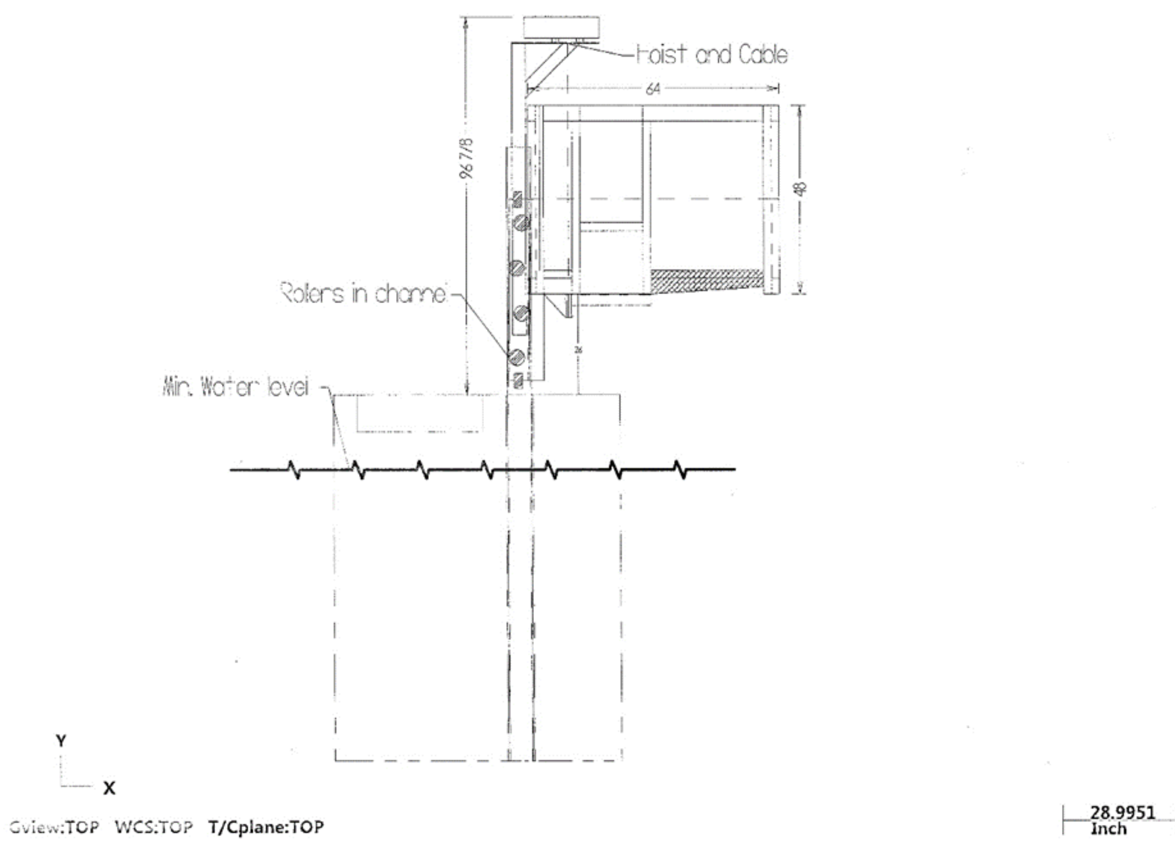


Figure A11. Rollers in channel and hoist and cable.

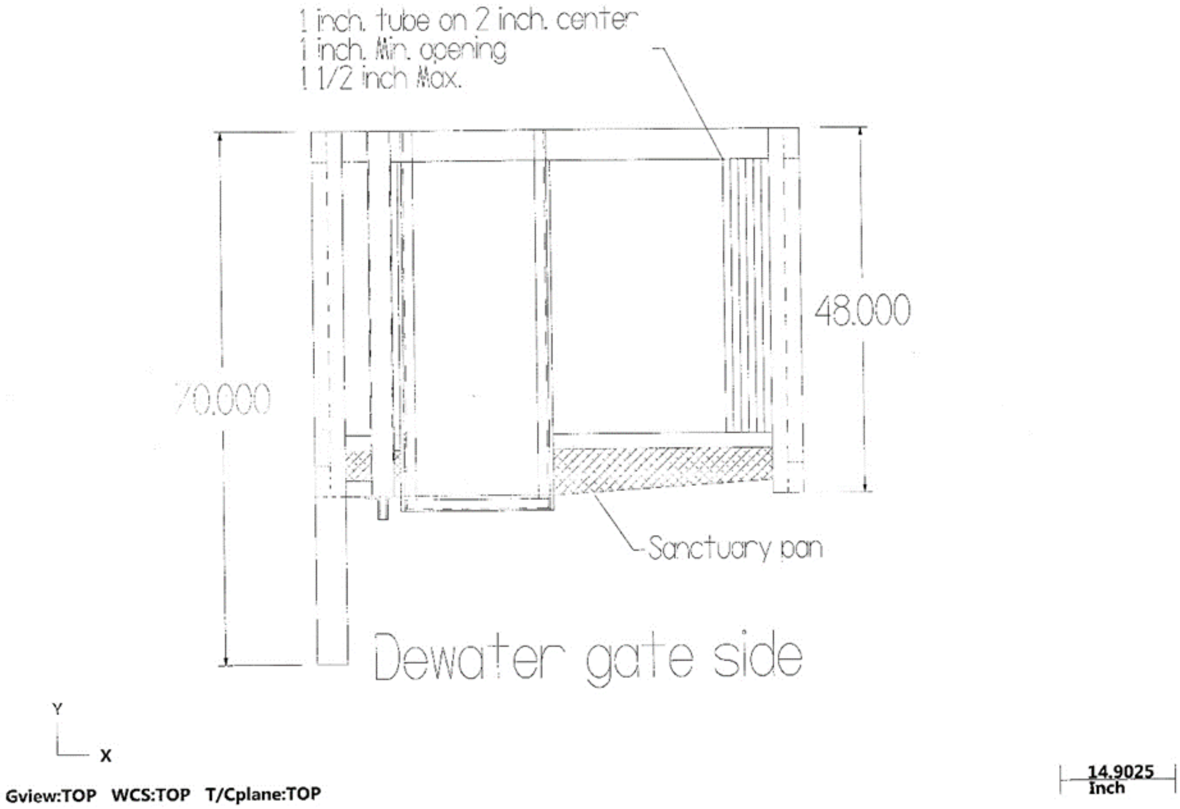


Figure A12. Dewater gate side view.

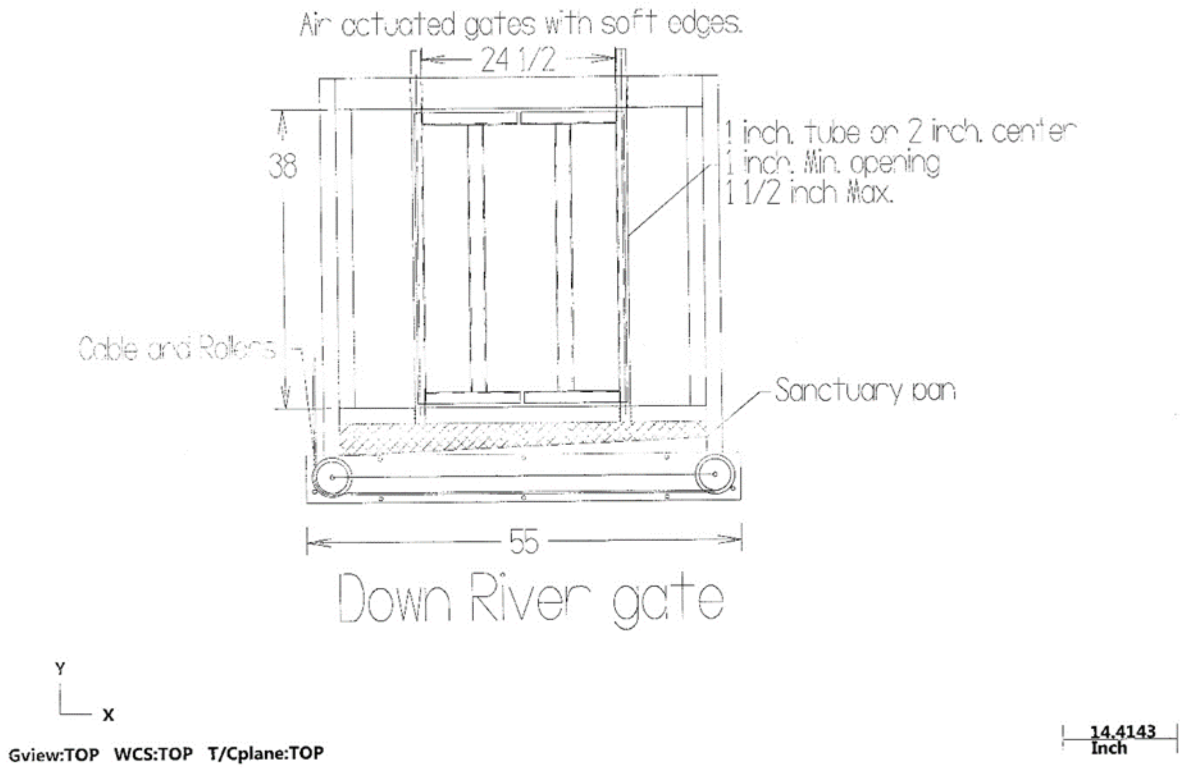


Figure A13. Downriver (downstream) gate.

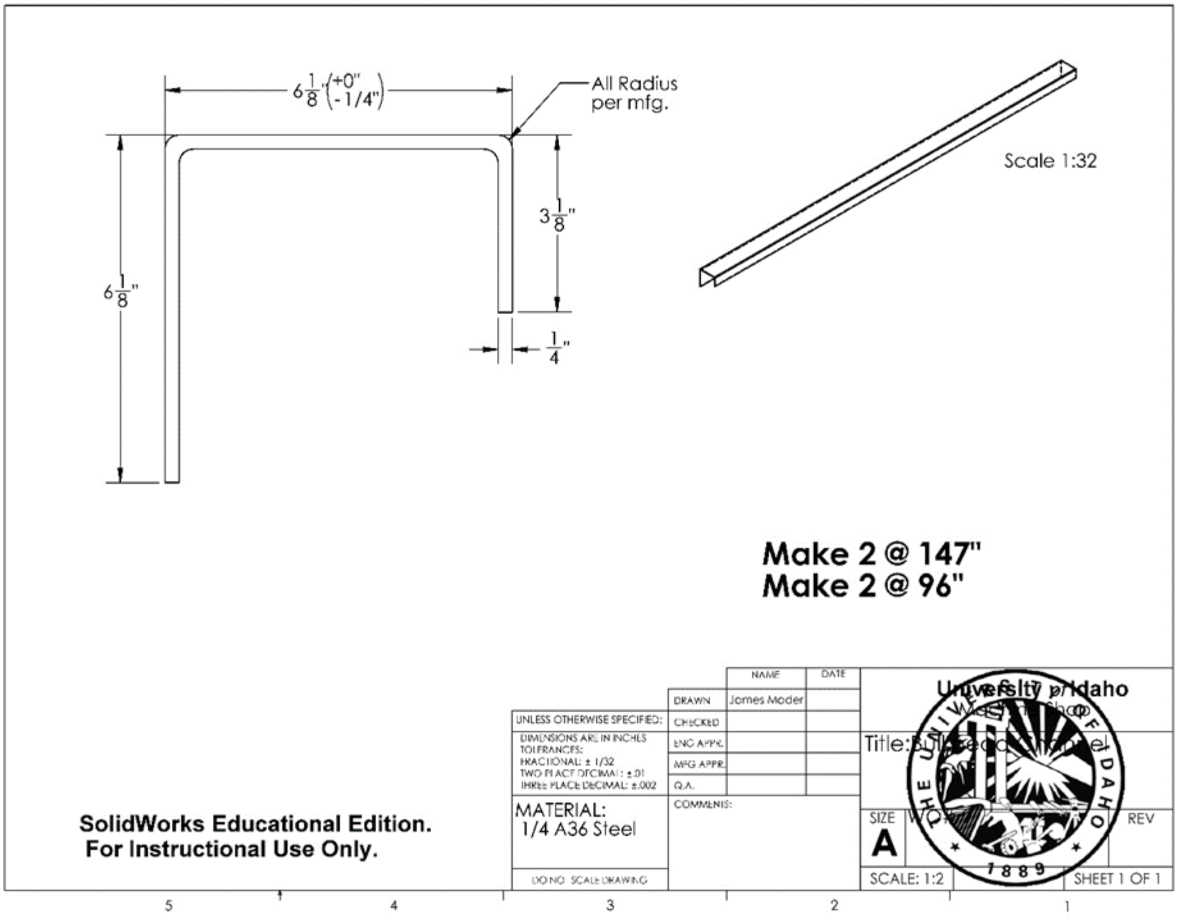


Figure A14. Bulkhead channel.

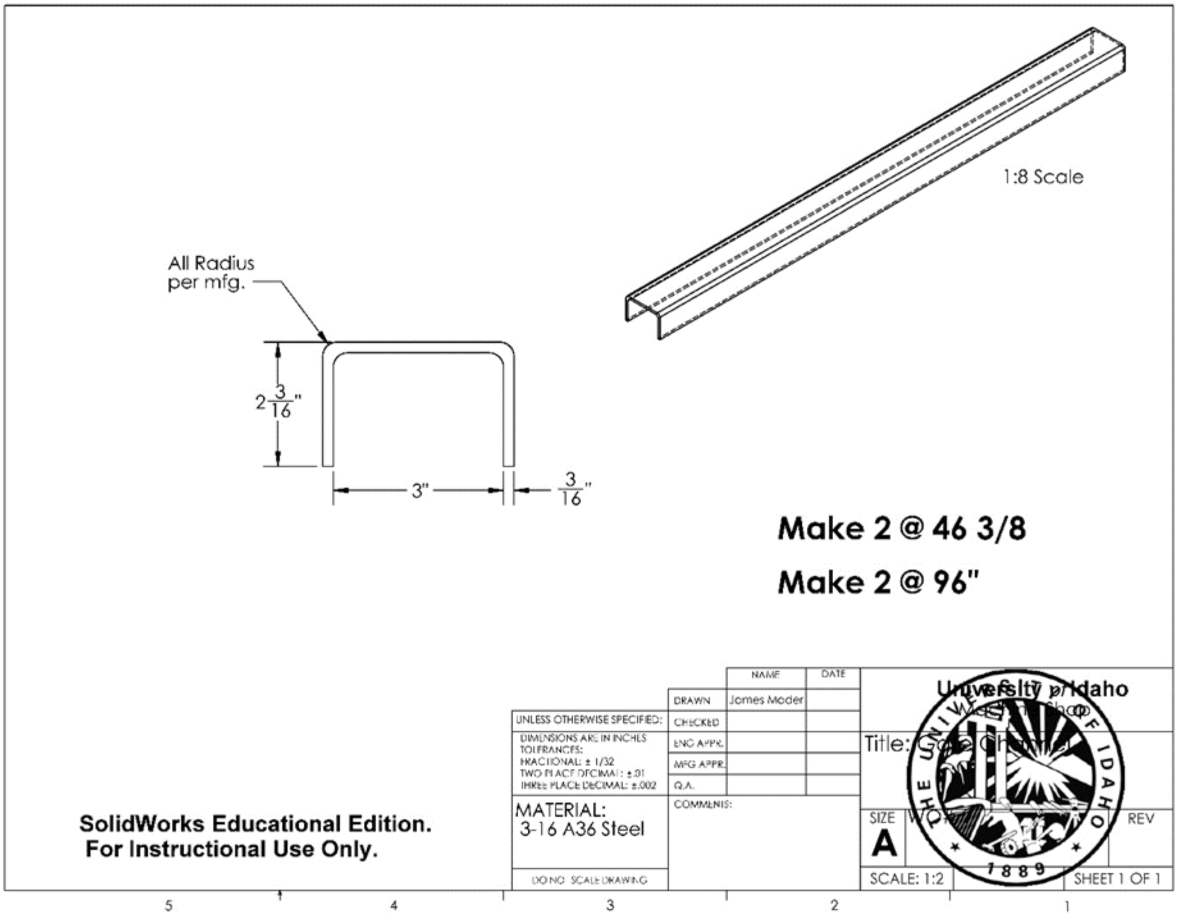


Figure A15. Trap gate channel.

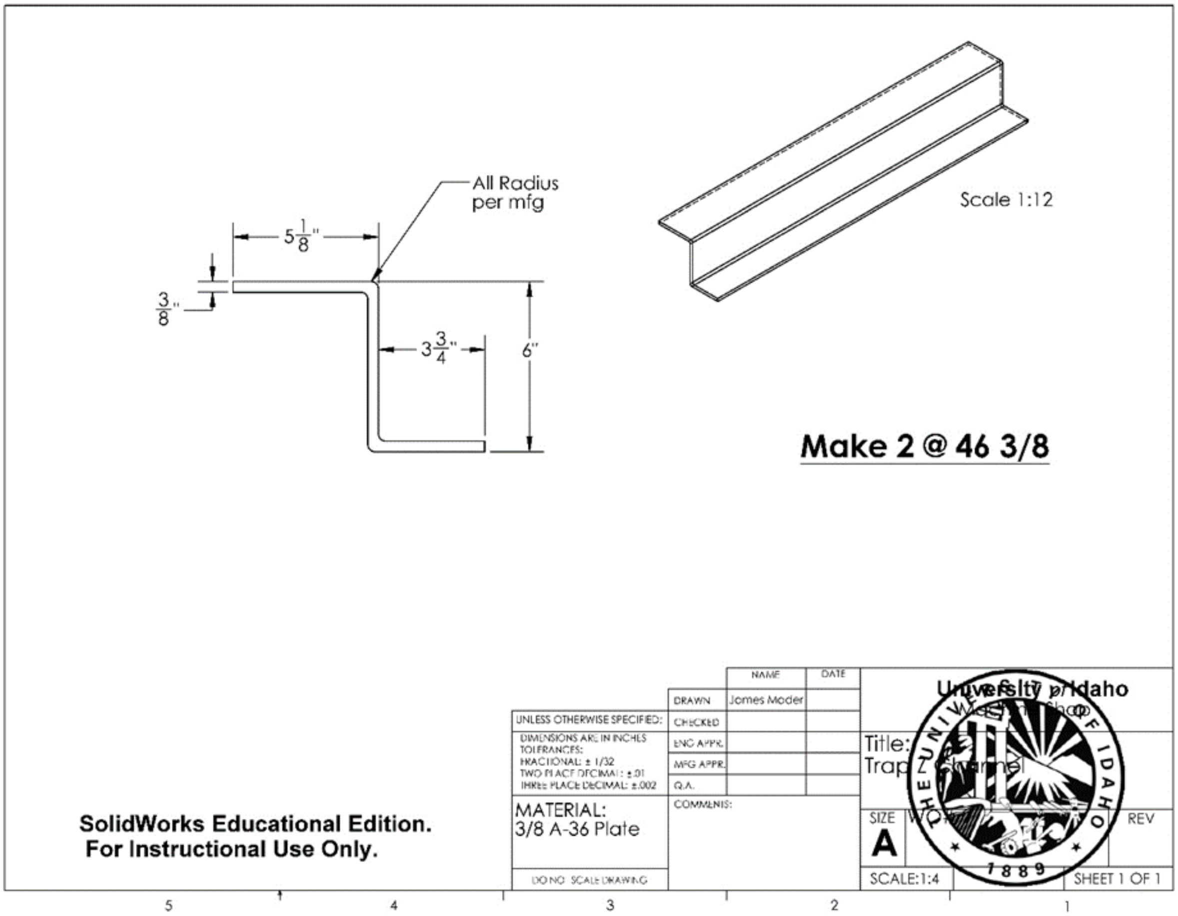


Figure A16. Trap Z channel.

Lebanon trap parts list

Winch system
Winch: Warn Series Wound power winch (Model 83145, 12V)
Winch controller: Carol 18AWG water resistant (Model SV00W CS/L)???
Winch cable: #2 ToughFlex heavy duty welding cable (600V, -50 °C to -105 °C),
Power source: 12V battery

Trap gate activator
Kobalt 8-gallon compressor (Model 0300841, 120V, 4 CFM @ 90 PSI, 150 max PSI, 1.8 HP running).
Flexible PVC compressor hose (Husky 50 ft. AG200, 3/8" ID).
Gate controller: Parker PL37HP, 250 maximum PSI. Two levers connected to four pneumatic actuators (one each for opening and closing the front and rear doors on the trap)
Pneumatic actuators (Bimba, Inc.) connected to the gate controller by four 50-foot Husky 3/8" diameter hoses.

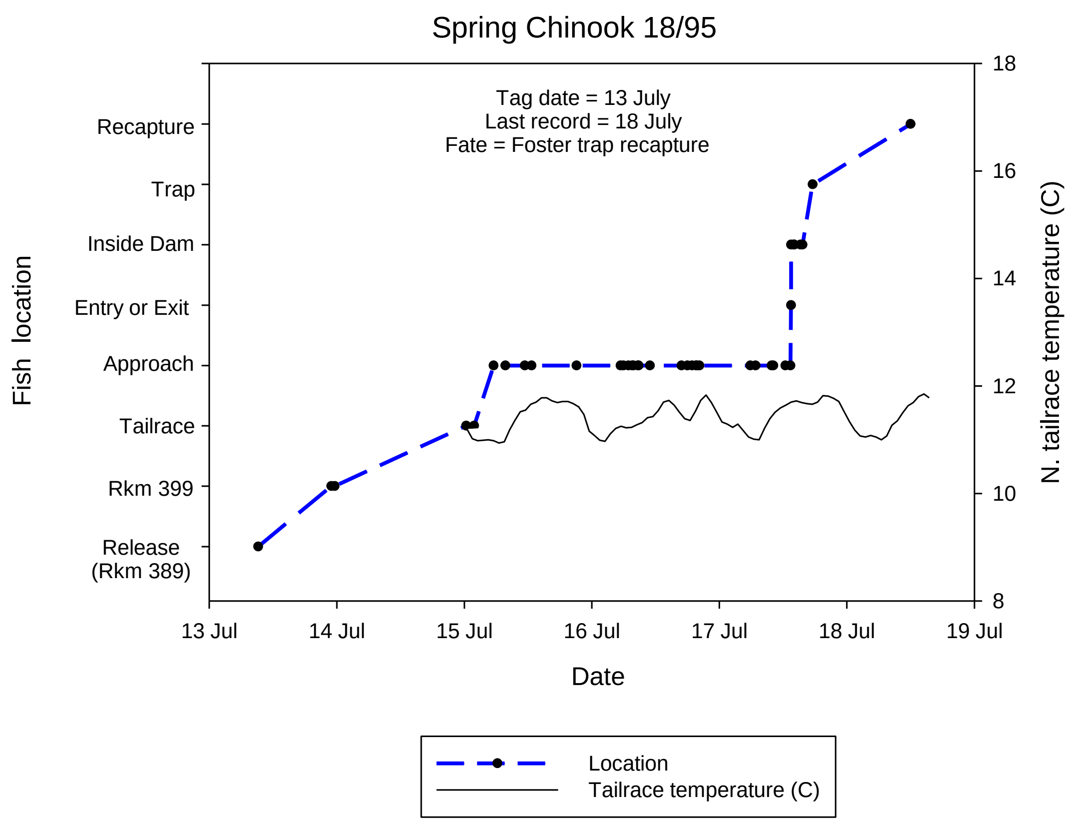
Appendix B

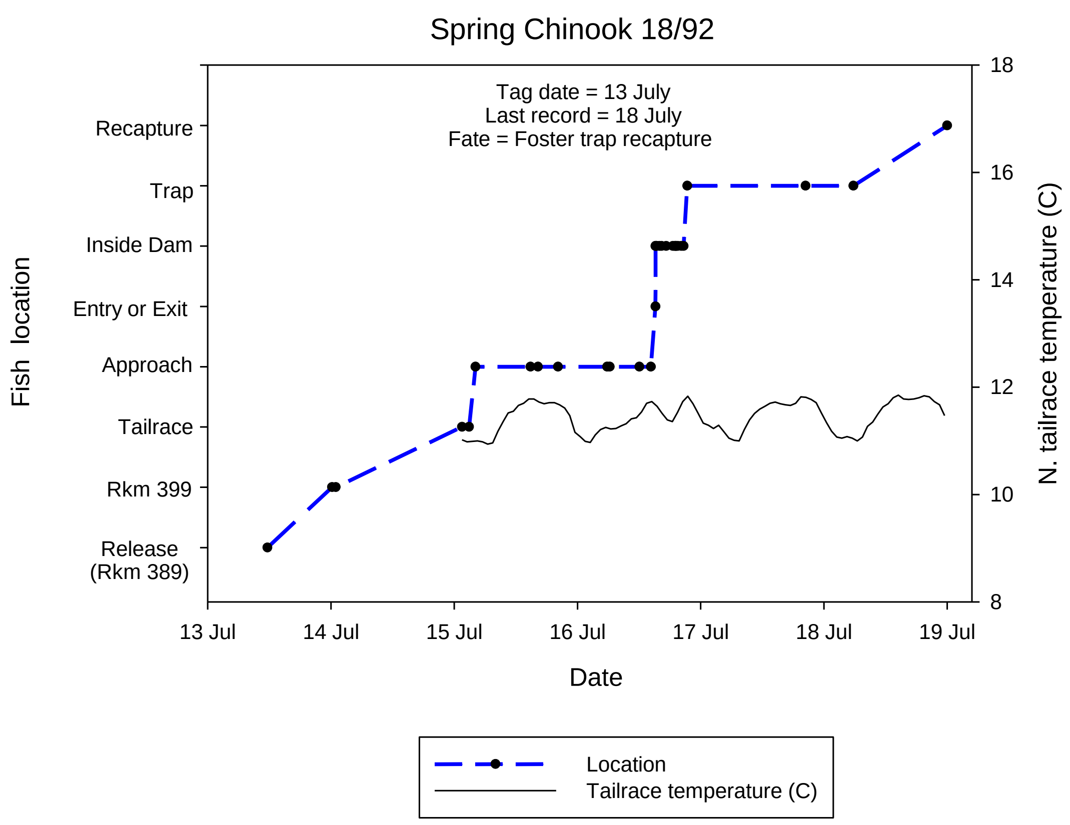
Chronological detection histories of adult Chinook salmon that were radio-tagged at Lebanon Dam and monitored in the Foster tailrace and the AFF fishway in 2017.

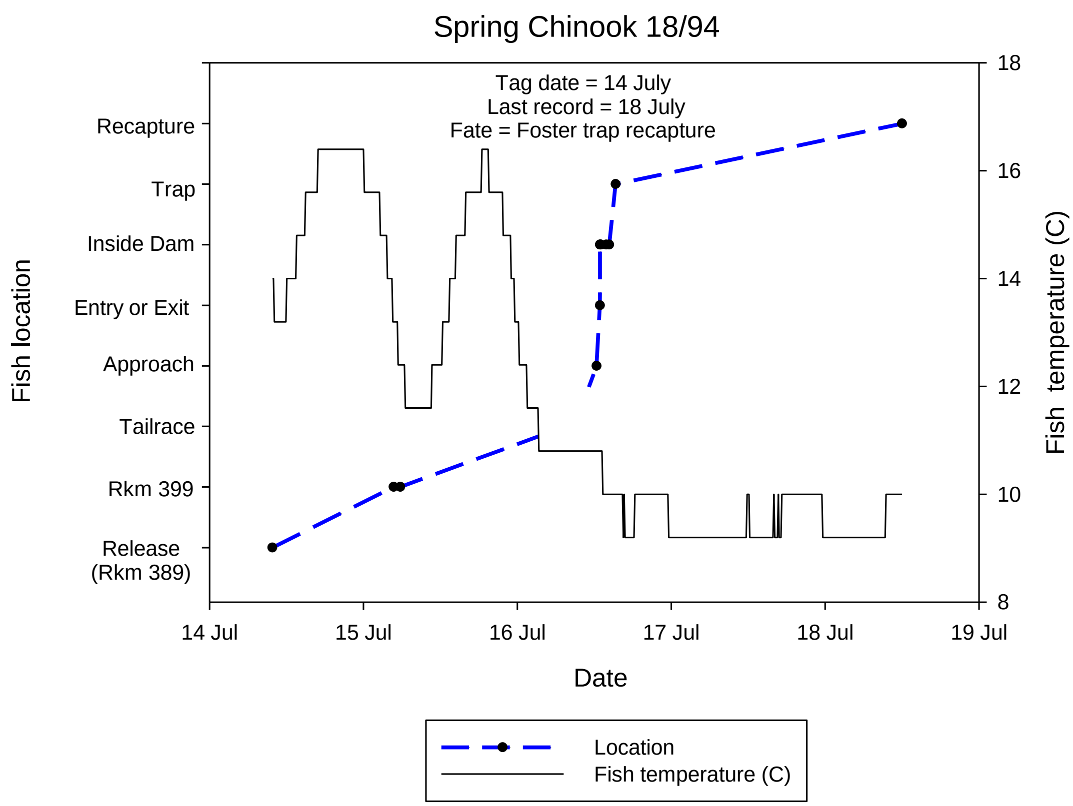
Table B1. Summary of the last detection or recapture dates and locations for 16 adult Chinook salmon that were radio-tagged at Lebanon Dam in 2017.

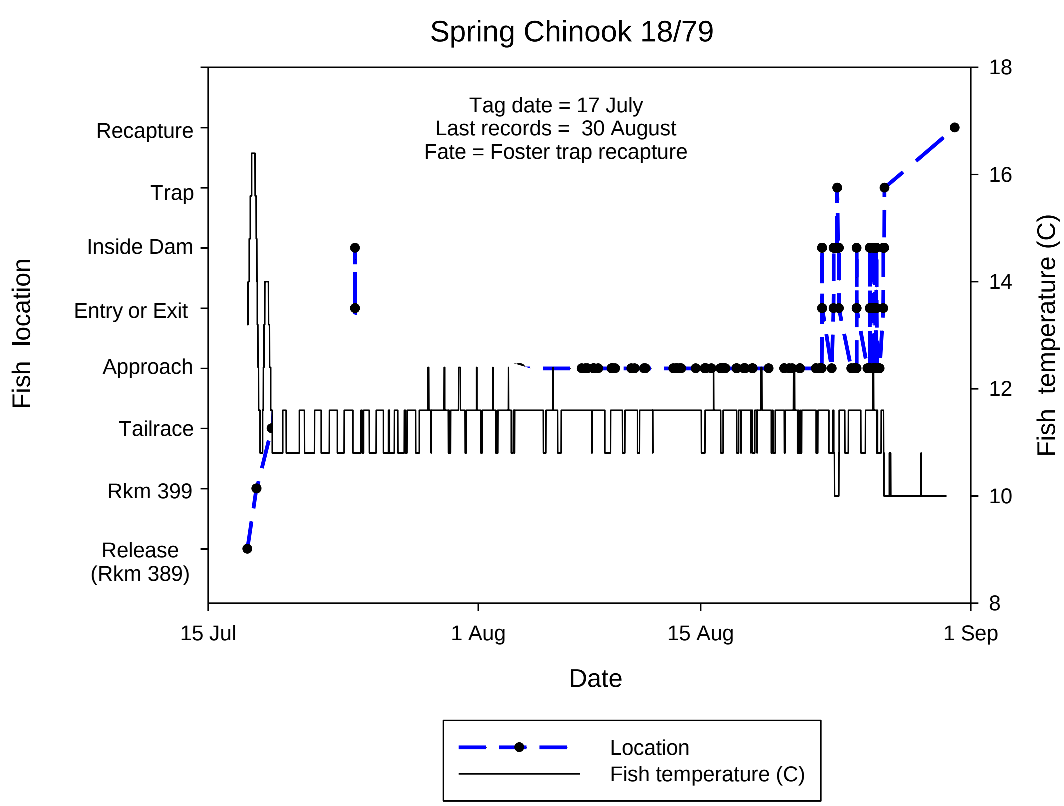
Fish ID	Tag date	Recapture date	Recapture or last location
95[1]	13 July	18 July	Foster Trap
92[1]	13 July	18 July	Foster Trap
94	14 July	18 July	Foster Trap
79	17 July	30 August	Foster Trap
87	24 July	12 September	Foster Trap
82	25 July	1 August	Foster Trap
85	28 July	30 August	Foster Trap
97	10 July	-	Foster tailrace
100	10 July	-	Foster tailrace
96	12 July	-	Foster tailrace
90	13 July	1 August	Foster tailrace
93	14 July	-	Wiley Creek
84	17 July	-	Foster tailrace
86	19 July	9 October	L. Wiley Creek
91	20 July	-	Foster tailrace
83	25 July	-	Foster tailrace

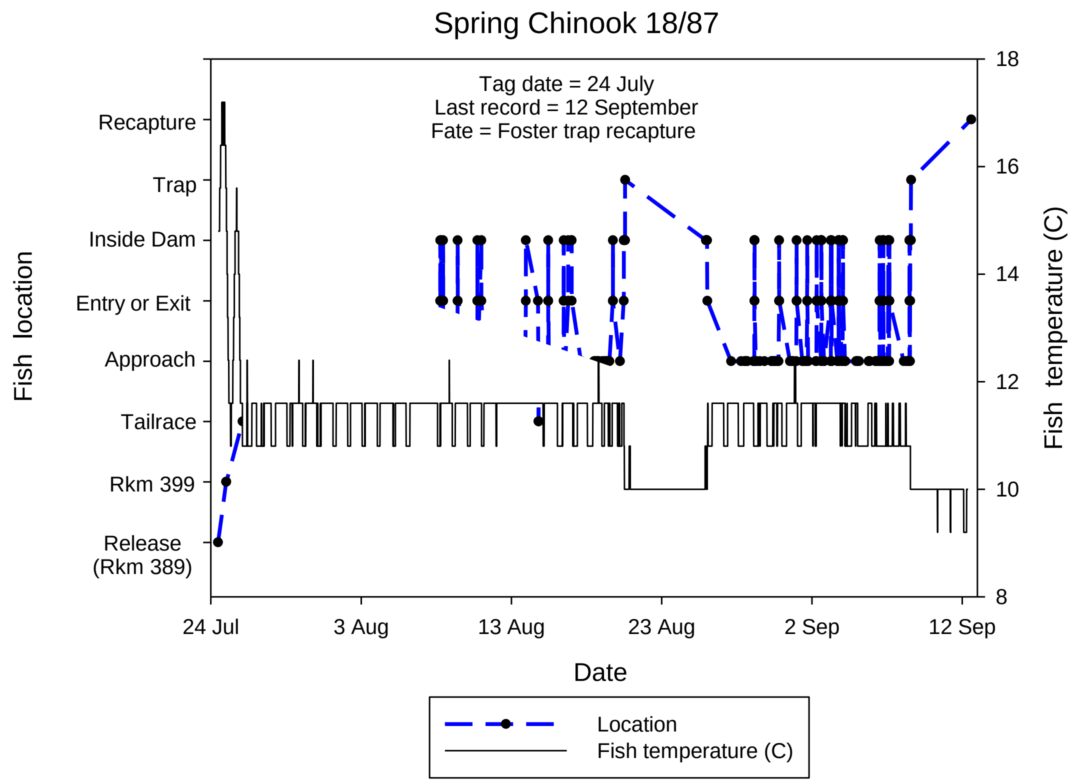
[1] Recovered transmitter, but unable to download data

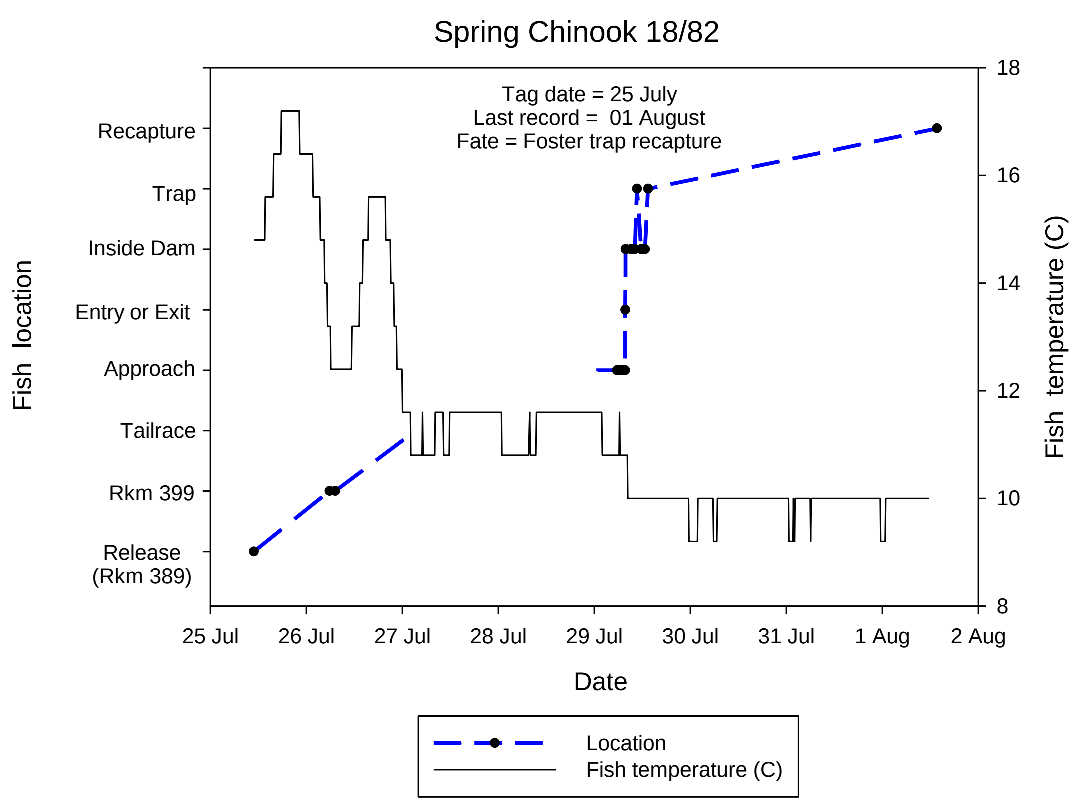

Spring Chinook 18/95
Tag date = 13 July
Last record = 18 July
Fate = Foster trap recapture
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
N. tailrace temperature (C)
18
16
14
12
10
8
13 Jul
14 Jul
15 Jul
16 Jul
17 Jul
18 Jul
19 Jul
Date
Location
Tailrace temperature (C)

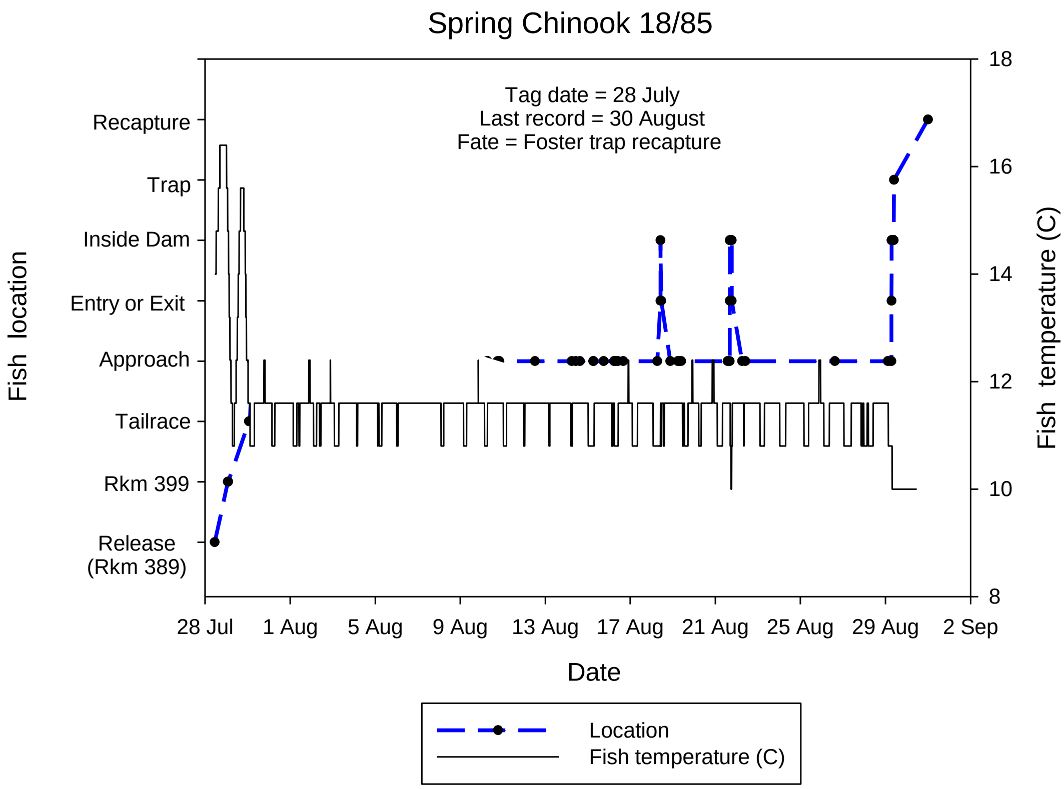

Spring Chinook 18/92
Tag date = 13 July
Last record = 18 July
Fate = Foster trap recapture
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
N. tailrace temperature (C)
18
16
14
12
10
8
13 Jul
14 Jul
15 Jul
16 Jul
17 Jul
18 Jul
19 Jul
Date
Location
Tailrace temperature (C)

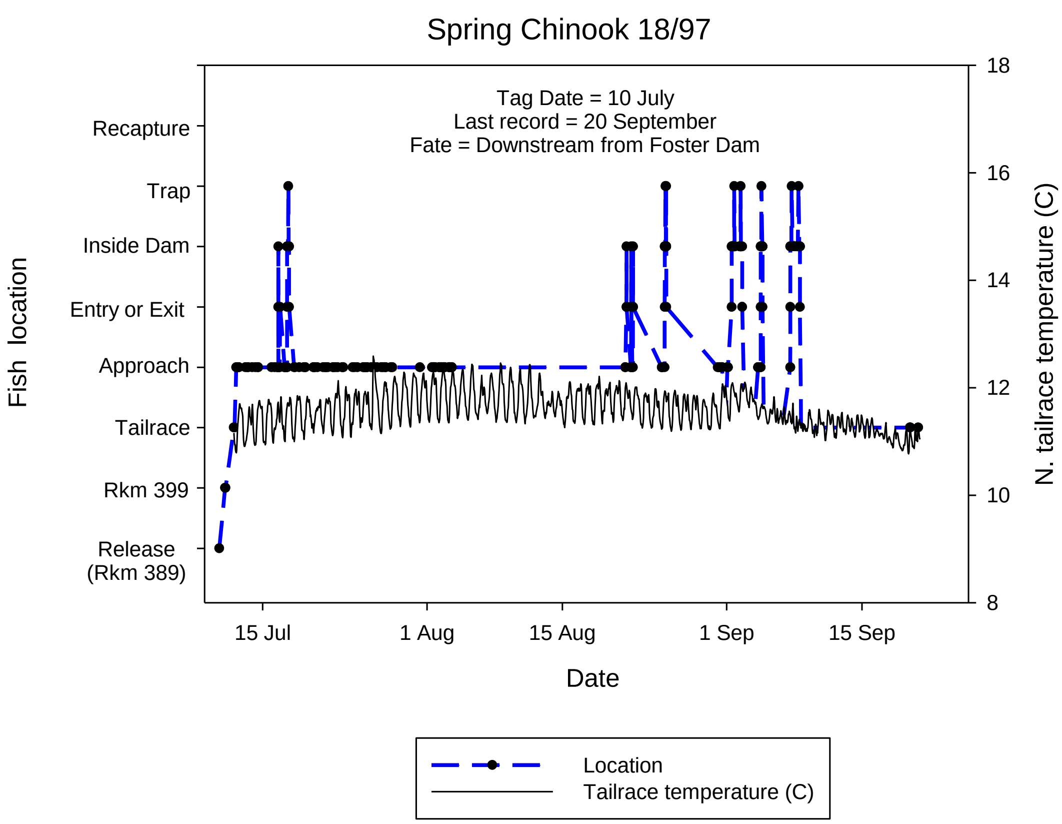

Spring Chinook 18/94
Tag date = 14 July
Last record = 18 July
Fate = Foster trap recapture
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish temperature (C)
18
16
14
12
10
8
14 Jul
15 Jul
16 Jul
17 Jul
18 Jul
19 Jul
Date
Location
Fish temperature (C)

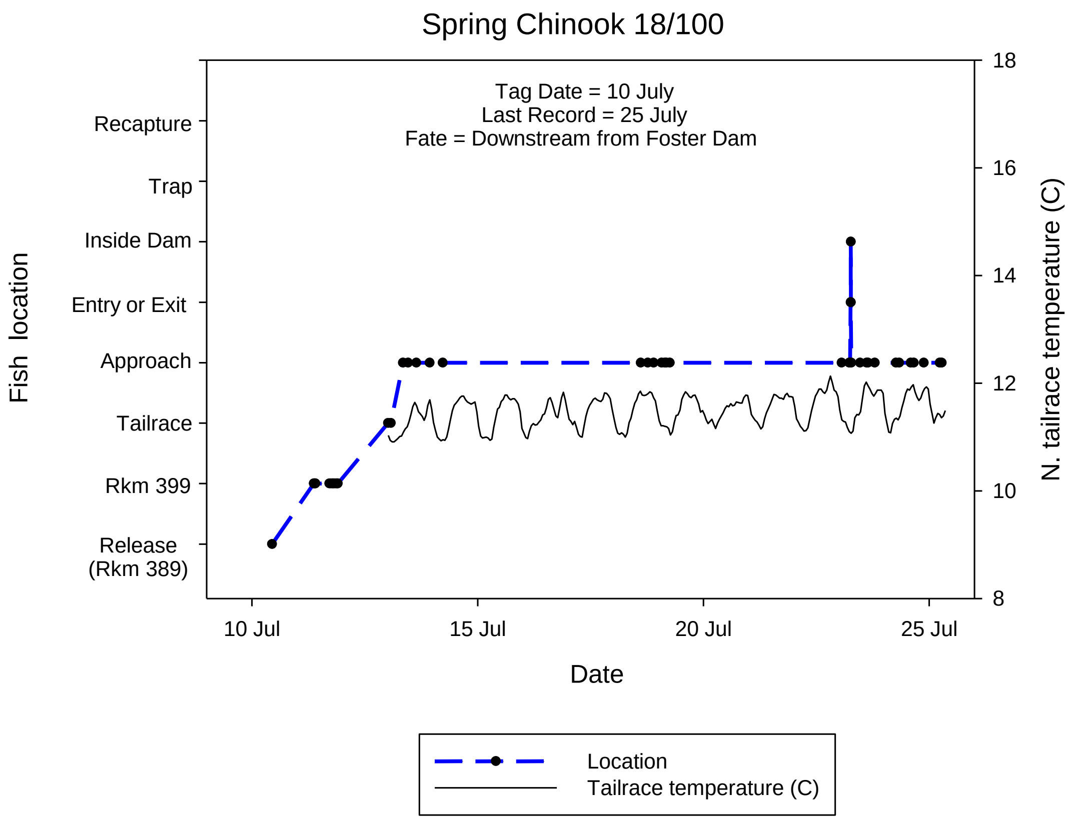

Spring Chinook 18/79
Tag date = 17 July
Last records = 30 August
Fate = Foster trap recapture
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish temperature (C)
18
16
14
12
10
8
15 Jul
1 Aug
15 Aug
1 Sep
Date
Location
Fish temperature (C)

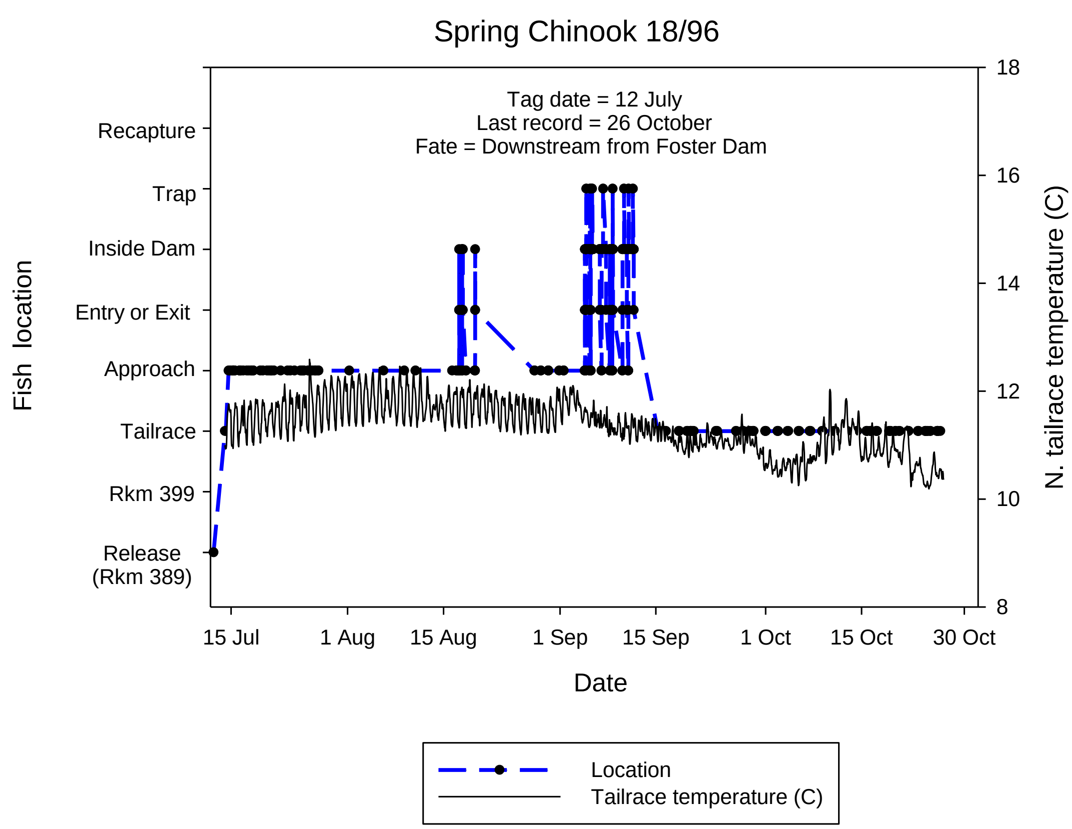

Spring Chinook 18/87
Tag date = 24 July
Last record = 12 September
Fate = Foster trap recapture
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish temperature (C)
8
10
12
14
16
18
24 Jul
3 Aug
13 Aug
23 Aug
2 Sep
12 Sep
Date
Location
Fish temperature (C)

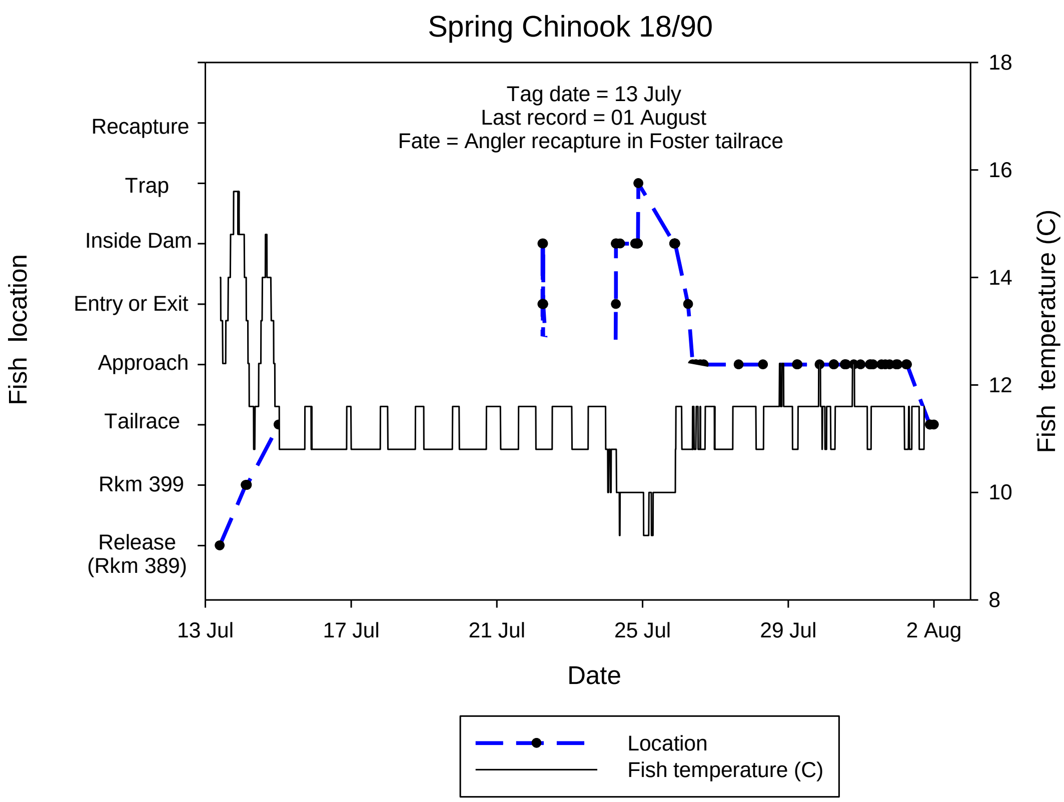

Spring Chinook 18/82
Tag date = 25 July
Last record = 01 August
Fate = Foster trap recapture
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish temperature (C)
8
10
12
14
16
18
25 Jul
26 Jul
27 Jul
28 Jul
29 Jul
30 Jul
31 Jul
1 Aug
2 Aug
Date
Location
Fish temperature (C)


Spring Chinook 18/85
Tag date = 28 July
Last record = 30 August
Fate = Foster trap recapture
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish temperature (C)
18
16
14
12
10
8
28 Jul
1 Aug
5 Aug
9 Aug
13 Aug
17 Aug
21 Aug
25 Aug
29 Aug
2 Sep
Date
Location
Fish temperature (C)

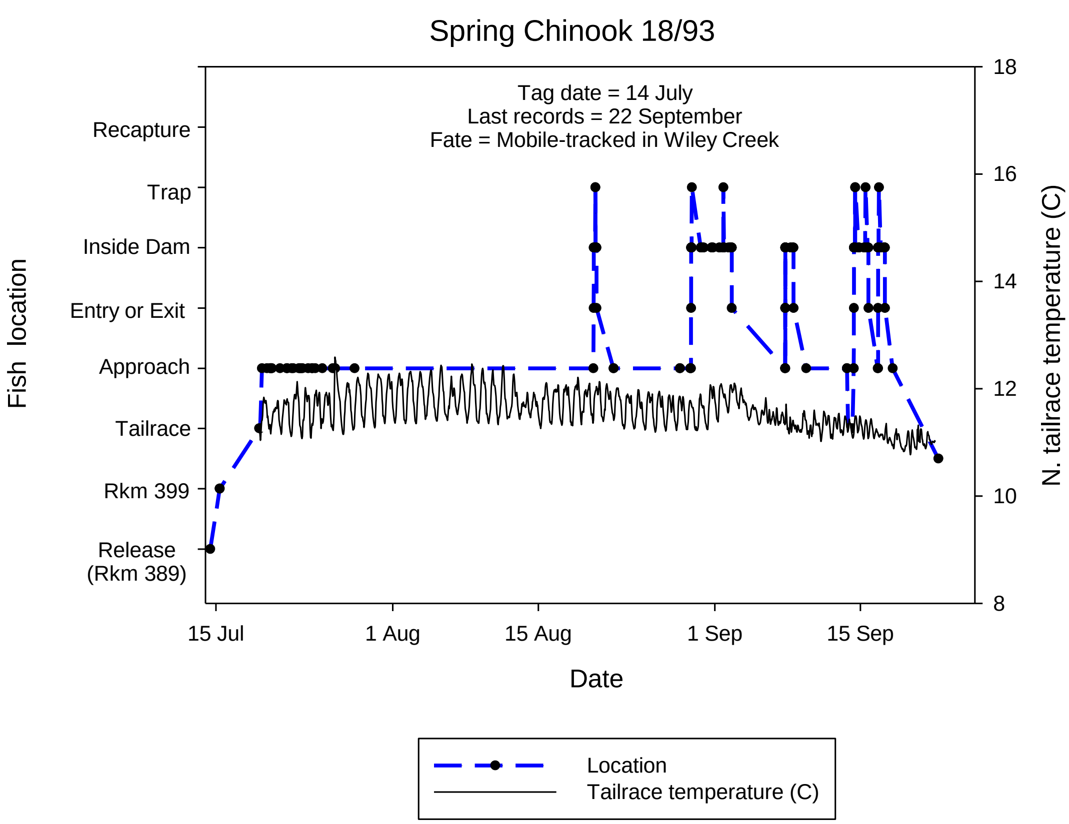

Spring Chinook 18/97
Tag Date = 10 July
Last record = 20 September
Fate = Downstream from Foster Dam
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
N. tailrace temperature (C)
18
16
14
12
10
8
15 Jul
1 Aug
15 Aug
1 Sep
15 Sep
Date
Location
Tailrace temperature (C)


Spring Chinook 18/100
Tag Date = 10 July
Last Record = 25 July
Fate = Downstream from Foster Dam
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish location
18
16
14
12
10
8
N. tailrace temperature (C)
10 Jul
15 Jul
20 Jul
25 Jul
Date
Location
Tailrace temperature (C)

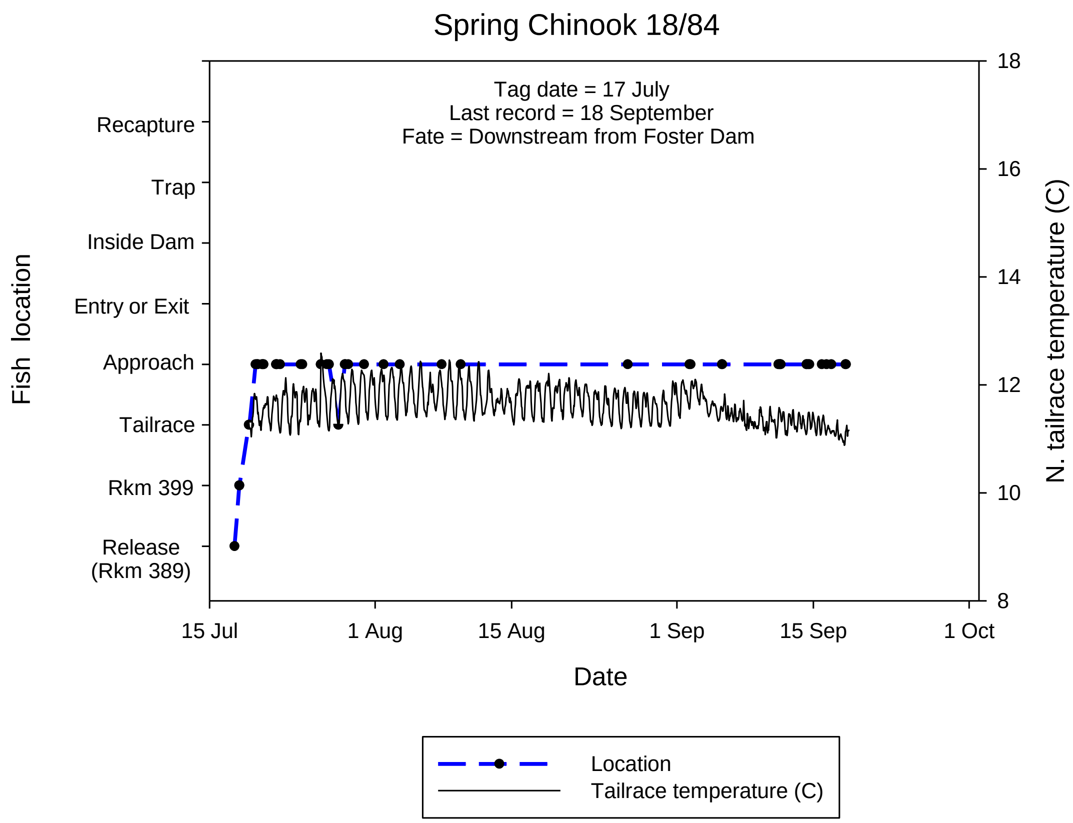

Spring Chinook 18/96
Tag date = 12 July
Last record = 26 October
Fate = Downstream from Foster Dam
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish location
18
16
14
12
10
8
N. tailrace temperature (C)
15 Jul
1 Aug
15 Aug
1 Sep
15 Sep
1 Oct
15 Oct
30 Oct
Date
Location
Tailrace temperature (C)

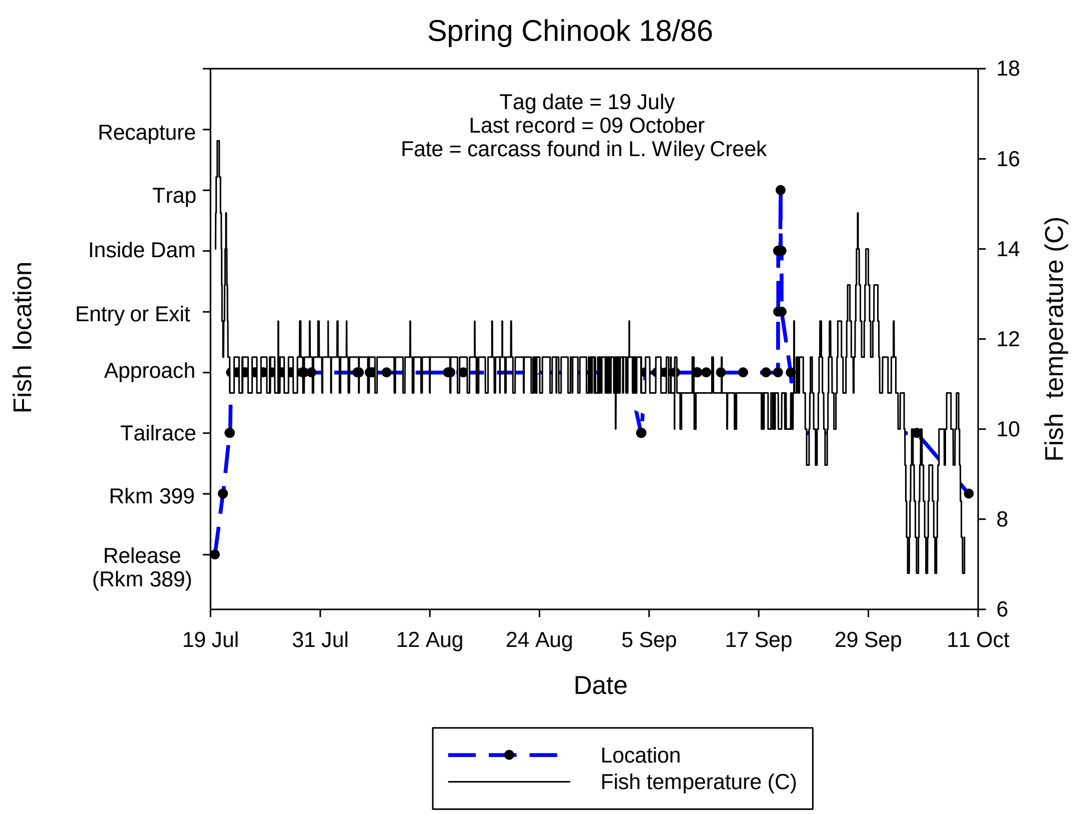


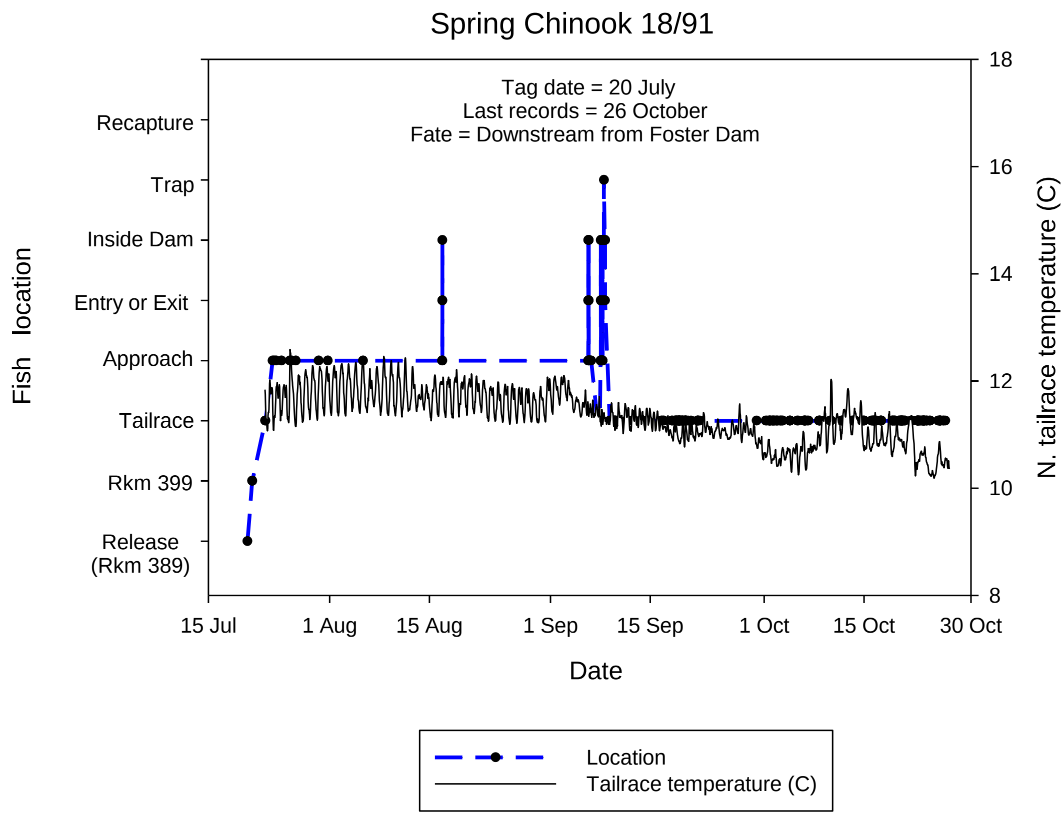
Spring Chinook 18/90
Tag date = 13 July
Last record = 01 August
Fate = Angler recapture in Foster tailrace
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish location
18
16
14
12
10
8
Fish temperature (C)
13 Jul
17 Jul
21 Jul
25 Jul
29 Jul
2 Aug
Date
Location
Fish temperature (C)

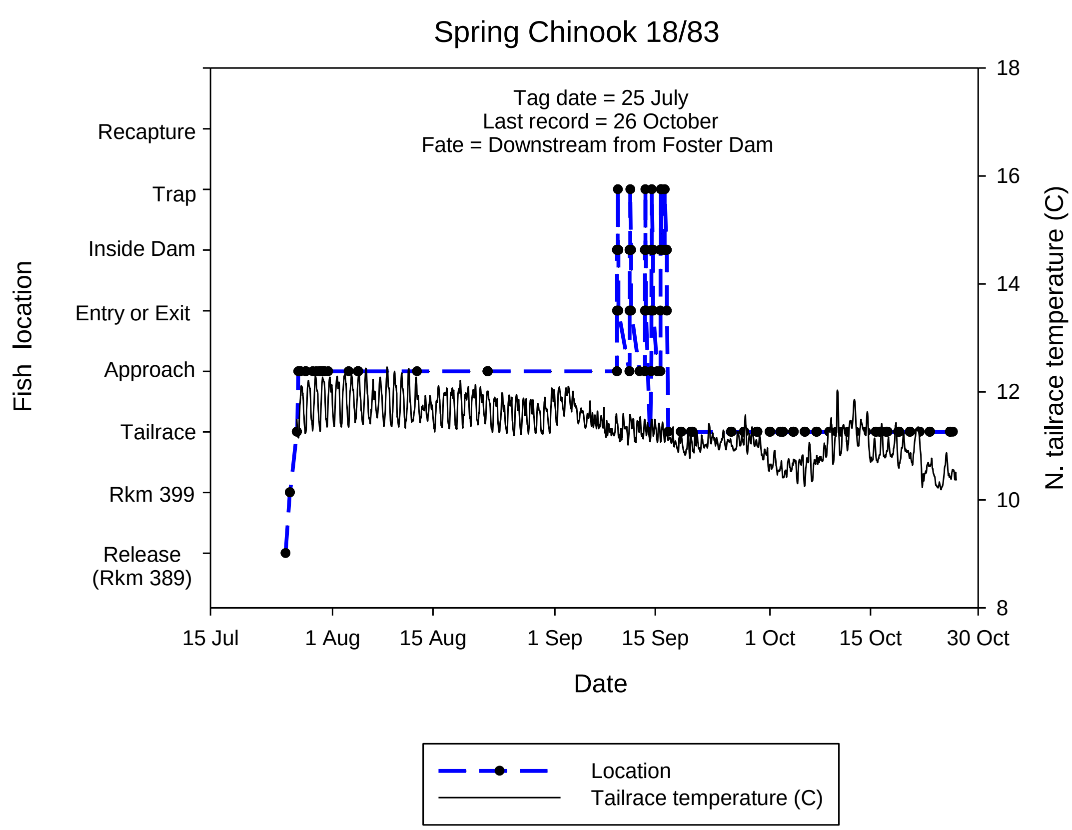


Spring Chinook 18/93
Tag date = 14 July
Last records = 22 September
Fate = Mobile-tracked in Wiley Creek
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish location
18
16
14
12
10
8
N. tailrace temperature (C)
15 Jul
1 Aug
15 Aug
1 Sep
15 Sep
Date
Location
Tailrace temperature (C)


Spring Chinook 18/84
Tag date = 17 July
Last record = 18 September
Fate = Downstream from Foster Dam
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
N. tailrace temperature (C)
18
16
14
12
10
8
15 Jul
1 Aug
15 Aug
1 Sep
15 Sep
1 Oct
Date
Location
Tailrace temperature (C)


Spring Chinook 18/86
Tag date = 19 July
Last record = 09 October
Fate = carcass found in L. Wiley Creek
Fish location
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish temperature (C)
18
16
14
12
10
8
6
19 Jul
31 Jul
12 Aug
24 Aug
5 Sep
17 Sep
29 Sep
11 Oct
Date
Location
Fish temperature (C)


Spring Chinook 18/91
Tag date = 20 July
Last records = 26 October
Fate = Downstream from Foster Dam
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish location
N. tailrace temperature (C)
18
16
14
12
10
8
15 Jul
1 Aug
15 Aug
1 Sep
15 Sep
1 Oct
15 Oct
30 Oct
Date
Location
Tailrace temperature (C)


Spring Chinook 18/83
Tag date = 25 July
Last record = 26 October
Fate = Downstream from Foster Dam
Recapture
Trap
Inside Dam
Entry or Exit
Approach
Tailrace
Rkm 399
Release
(Rkm 389)
Fish location
N. tailrace temperature (C)
18
16
14
12
10
8
15 Jul
1 Aug
15 Aug
1 Sep
15 Sep
1 Oct
15 Oct
30 Oct
Date
Location
Tailrace temperature (C)

Appendix C

Archival temperature and depth plots of 12 Chinook salmon released into Foster Reservoir or the South Santiam River in 2017 whose transmitters were recovered with usable data.

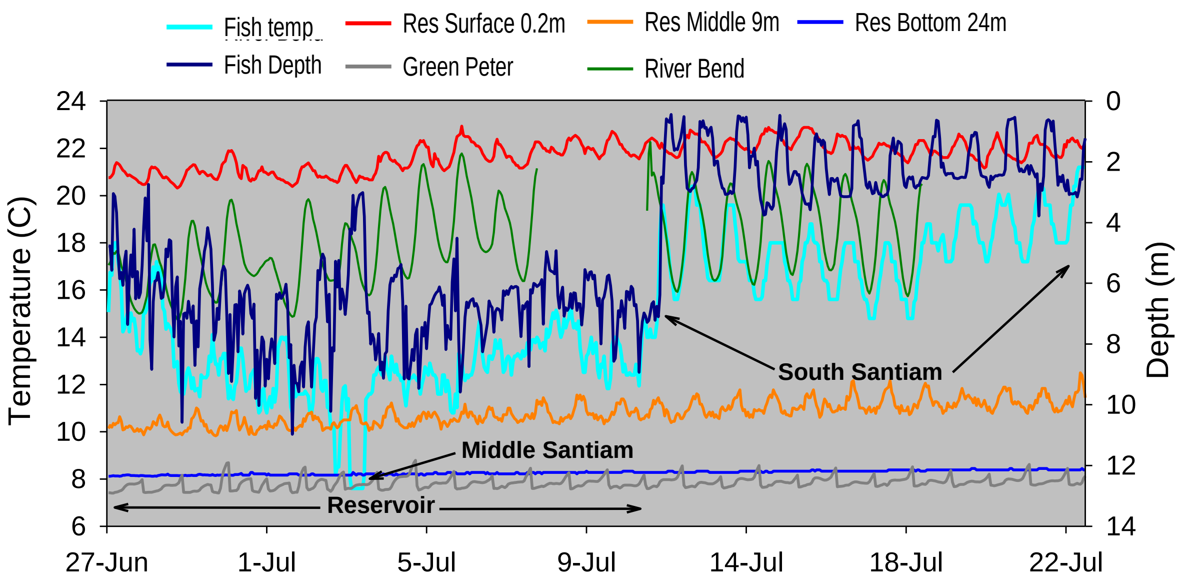


Figure C1. Chinook salmon 19-152 released into Foster reservoir and last detected in the South Santiam River above the reservoir. Lines show mean hourly fish temperature, fish depth, reservoir (Res) surface, 9 m, and 24 m temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend.

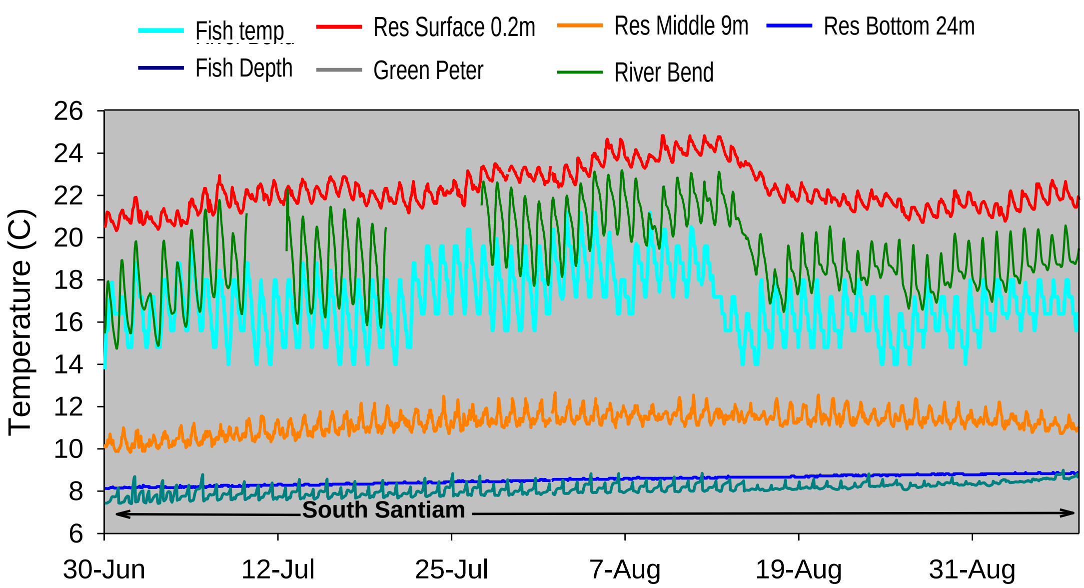


Figure C2. Chinook salmon 19-151 released into Foster reservoir and last detected in the South Santiam River above the reservoir. Lines show mean hourly fish temperature, reservoir (Res) surface, 9 m, and 24 m temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend.

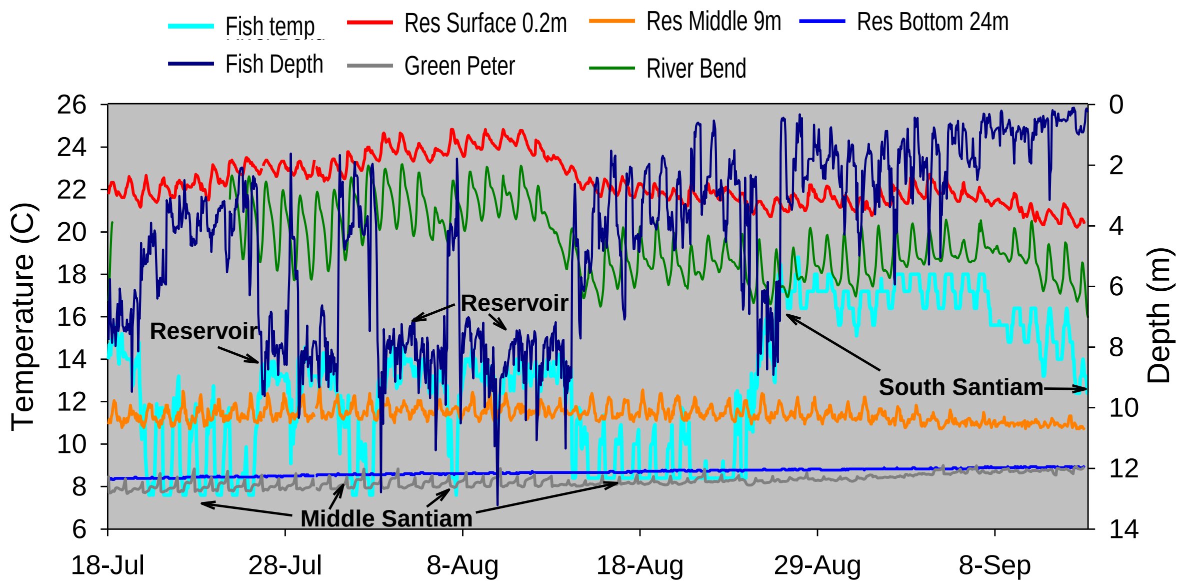


Figure C3. Chinook salmon 19-157 released into Foster reservoir and last detected in the South Santiam River above the reservoir. Lines show mean hourly fish temperature, fish depth, reservoir (Res) surface, 9 m, and 24 m temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend.

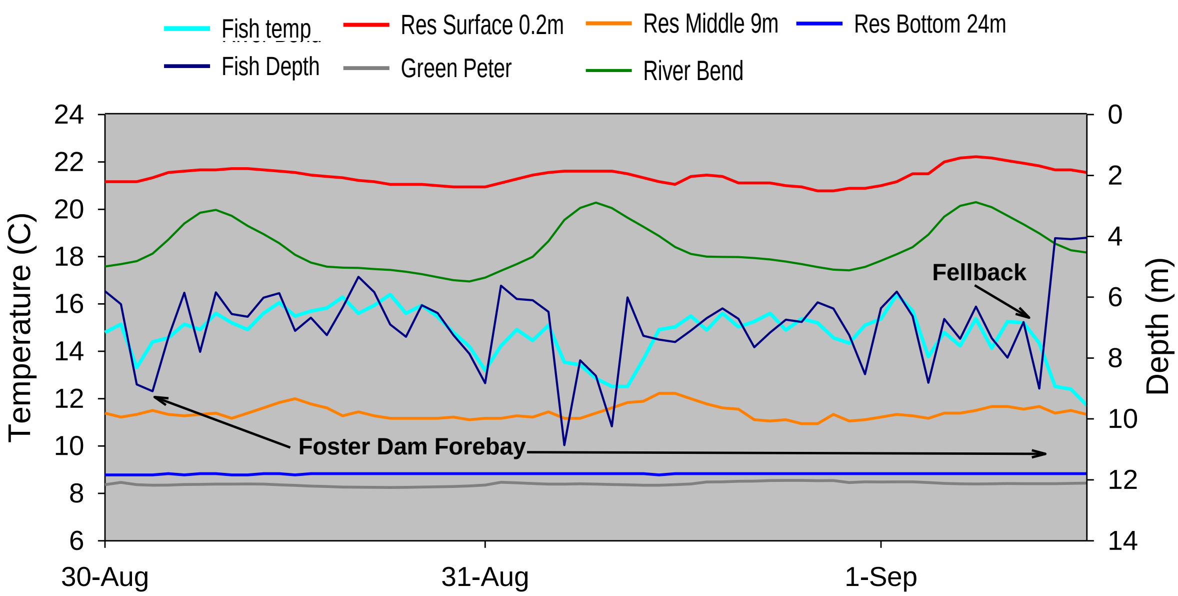


Figure C4. Chinook salmon 19-159 released into Foster reservoir and last detected below the reservoir in Foster tailrace. Lines show mean hourly fish temperature, fish depth, reservoir (Res) surface, 9 m, and 24 m temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend.

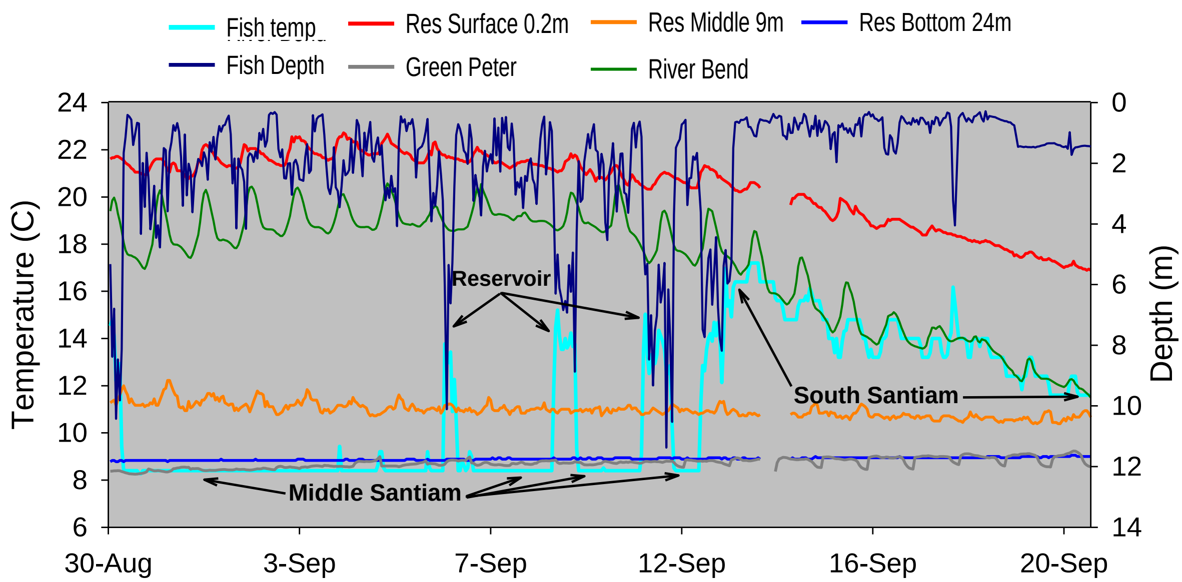


Figure C5. Chinook salmon 19-160 released into Foster reservoir and last detected in the South Santiam River above the reservoir. Lines show mean hourly fish temperature, fish depth, reservoir (Res) surface, 9 m, and 24 m temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend.

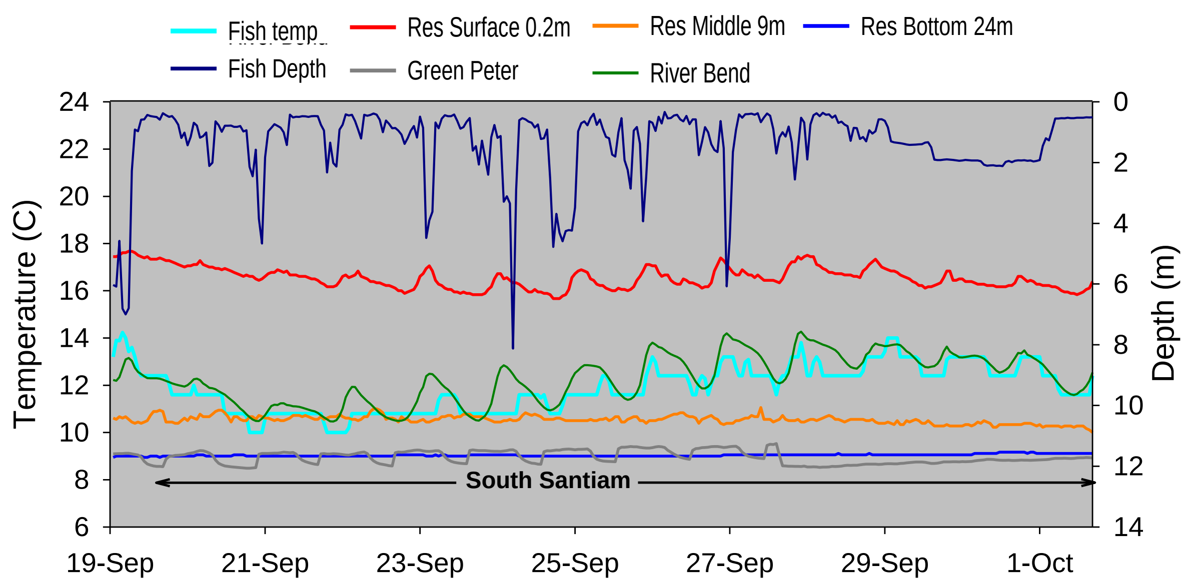


Figure C6. Chinook salmon 19-165 released into Foster reservoir and last detected in the South Santiam River above the reservoir. Lines show mean hourly fish temperature, fish depth, reservoir (Res) surface, 9 m, and 24 m temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend.

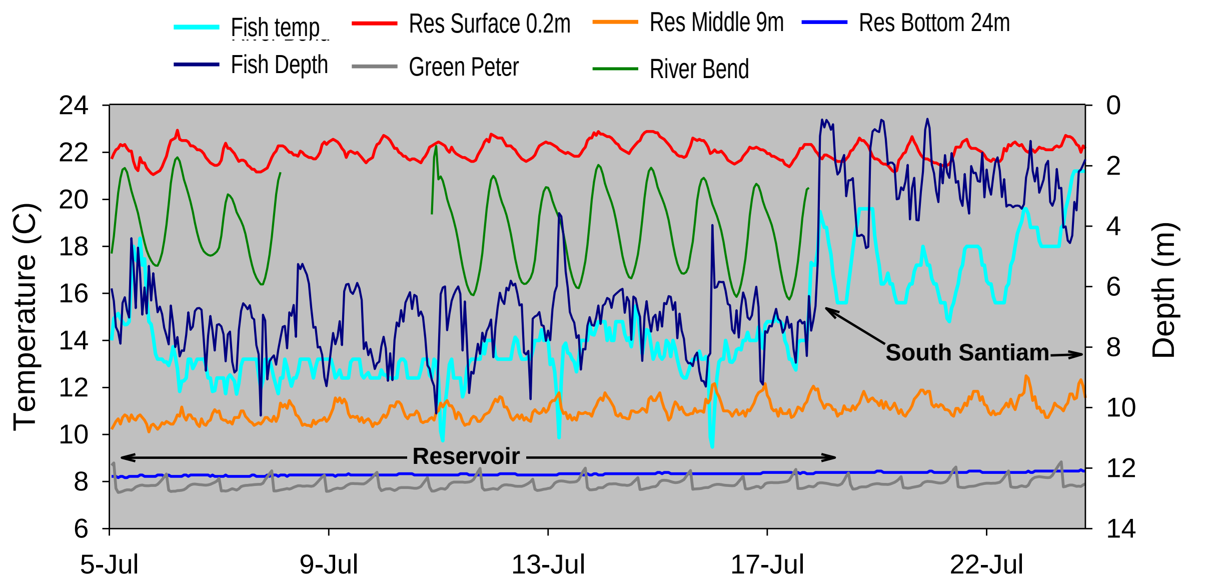


Figure C7. Chinook salmon 19-172 released into Foster reservoir and last detected in the South Santiam River above the reservoir. Lines show mean hourly fish temperature, fish depth, reservoir (Res) surface, 9 m, and 24 m temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend.

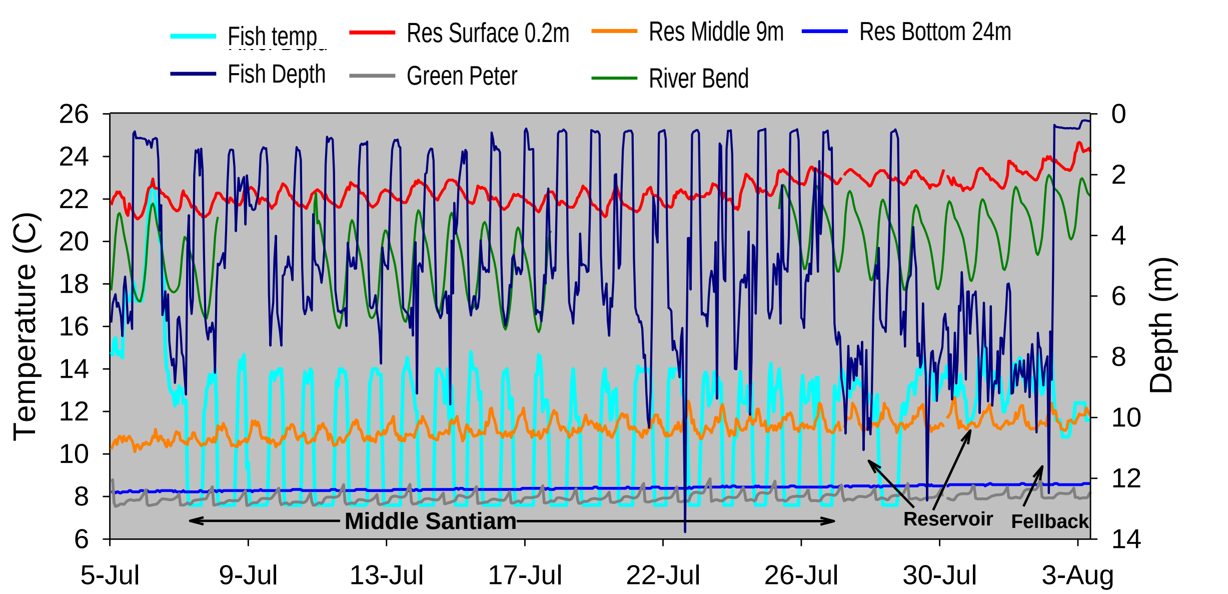


Figure C8. Chinook salmon 19-197 released into Foster reservoir and last detected below the reservoir in Foster tailrace. Lines show mean hourly fish temperature, fish depth, reservoir (Res) surface, 9 m, and 24 m temperatures, Middle Santiam temperature in Green Peter tailrace, and South Santiam temperature at River Bend.

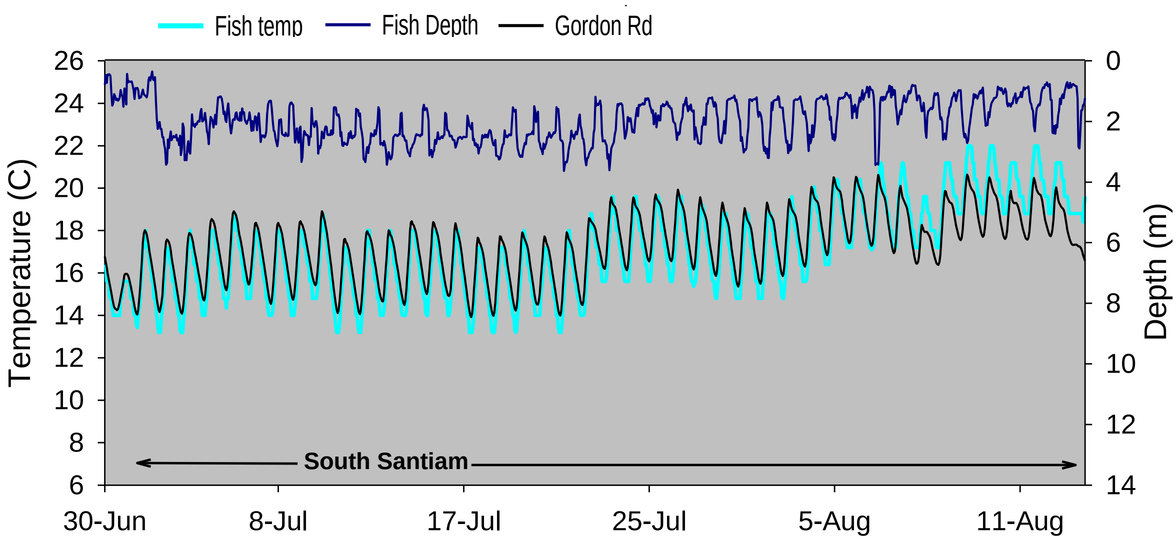


Figure C9. Chinook salmon 19-155 released into the South Santiam River at Gordon Rd (rkm 444.7) and last detected in the South Santiam above Soda Fork (rkm 457.3). Lines show mean hourly fish temperature, fish depth, and South Santiam River temperature at Gordon Rd.

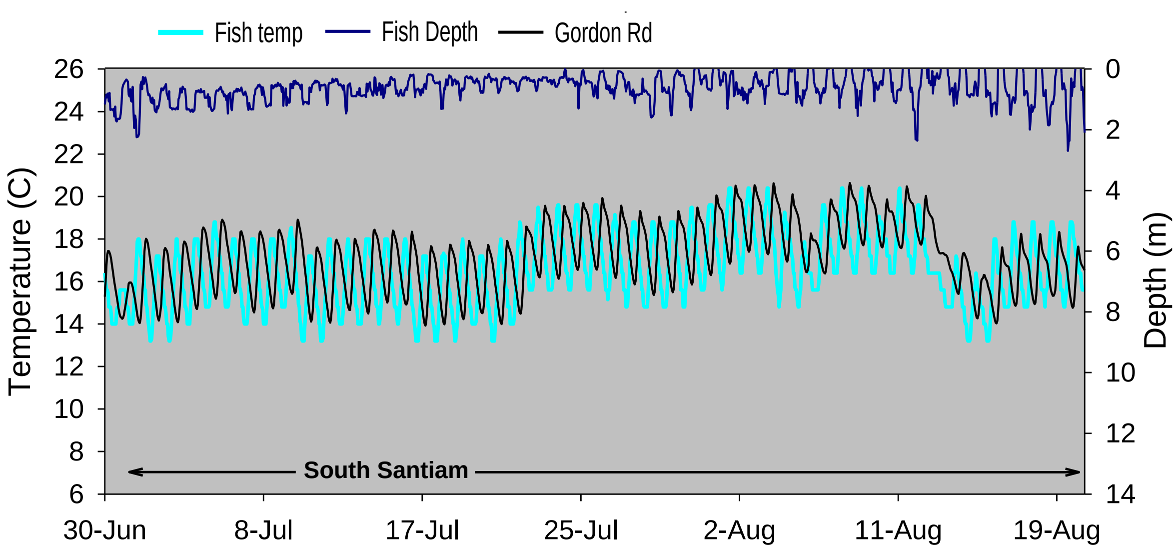


Figure C10. Chinook salmon 19-171 released into the South Santiam River at Gordon Rd (rkm 444.7) and last detected in the South Santiam near Trout Creek (rkm 452.3). Lines show mean hourly fish temperature, fish depth, and South Santiam River temperature at Gordon Rd.

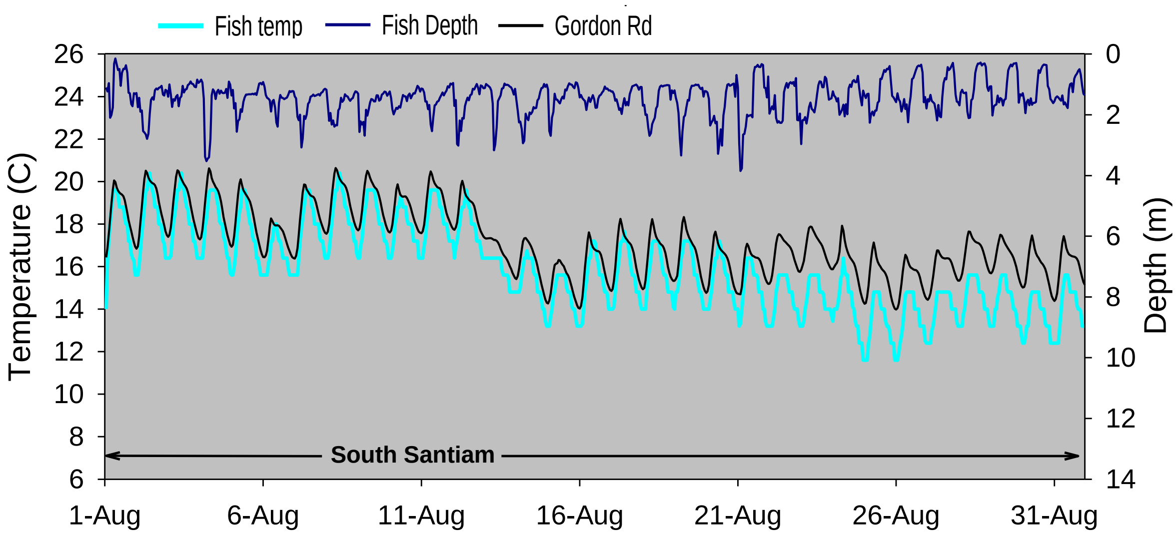


Figure C11. Chinook salmon 19-162 released into the South Santiam River at Gordon Rd (rkm 444.7) and last detected in the South Santiam near Trout Creek (rkm 453.3). Lines show mean hourly fish temperature, fish depth, and South Santiam River temperature at Gordon Rd.

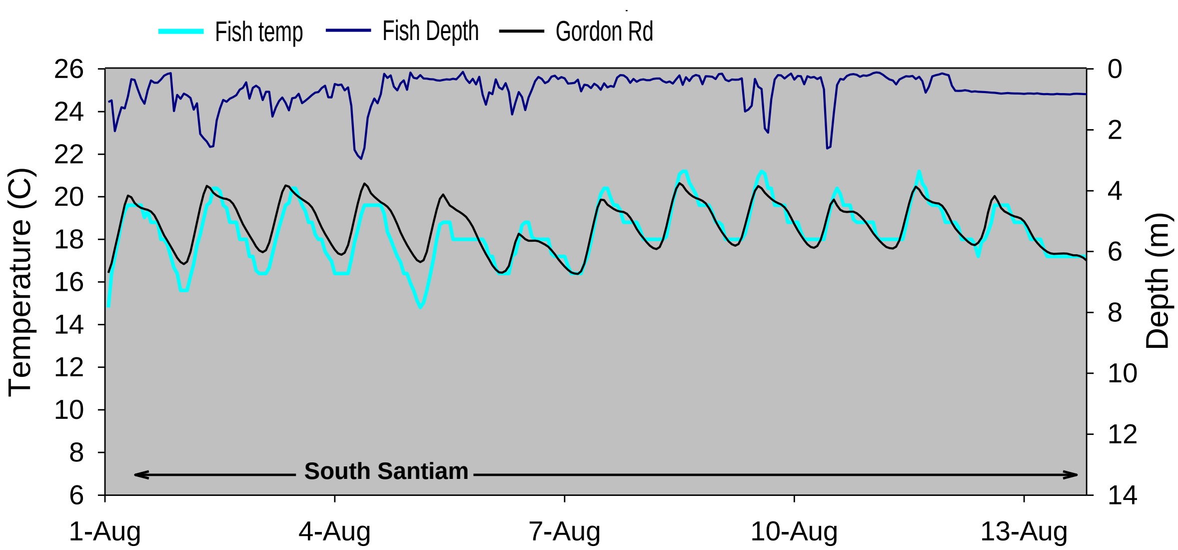


Figure C12. Chinook salmon 19-174 released into the South Santiam River at Gordon Rd (rkm 444.7) and last detected in the South Santiam above Monster Falls (rkm 443.9). Lines show mean hourly fish temperature, fish depth, and South Santiam River temperature at Gordon Rd.