NORMANDEAU ASSOCIATES
Environmental Consultants

Memorandum

DATE: 20 September 2018
TO: Roland Sanford, Rich Marovich, and Chris Lee, Solano County Water Agency (SCWA)
FROM: Tim Salamunovich, Normandeau Associates
RE: Late Winter and Spring 2018 Juvenile Chinook Salmon Snorkel Surveys on Lower Putah Creek – Final Report

Background

Part of the May 2000 Settlement and the October 2002 Second Amended Judgement of the Sacramento County Superior Court required releases of late fall supplemental flows to attract anadromous fish into lower Putah Creek to spawn. There are different seasonal (i.e., spring, fall, late-fall or winter) "runs" of Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento basin. These runs are identified on the basis of when the adult fish enter freshwater to begin their spawning migration (Moyle 2002). Freshwater entry and spawning timing are believed to be related to local temperature and water flow regimes. Adult female Chinook will prepare a redd (or nest) in a stream area with suitable gravel size composition, water depth and velocity. Adult female Chinook may deposit eggs in 4 to 5 "nesting pockets" within a single redd. On average, each female salmon typically deposits 5,000-6,000 eggs, with fecundity directly related to fish size. Depending on water temperatures, embryos hatch in 40-60 days and remain in the gravel as alevins for another 30-45 days before emerging as fry, where they typically rear in nearby shallow water, low velocity, and high-density cover margin habitat. As fry grow, they will move into deeper and faster water habitats.

The Los Rios Check Dam is a 3.6-m (12-ft) high concrete box-type structure, fitted with wooden flashboards located in the Yolo Bypass about 1.25 miles upstream of the Toe Drain that prevents salmon migration up the creek until its removal each fall (Figure 1; Plate 1, top). The flashboards are routinely removed after irrigation season, usually by early November, to allow upstream migration of salmon (Plate 1, bottom). In fall of 2017, the flashboard dam in lower Putah Creek was removed on 31 October, three days prior to the supplemental salmon attraction flow release from Putah Diversion Dam (PDD) which occurred on 3-10 November. Adult Chinook salmon were noted in the creek at Winters Putah Creek Park on 4 November, and at the PDD on 9 November (Mark Snyder, SCWA, and Rich Marovich, Putah Creek Streamkeeper, emails). By late November 2017 an estimated 400 adult Chinook salmon had been observed holding and spawning in the creek (Eric Chapman, UC Davis, email), and by January 2018 the total run size was estimated at 700±140 adult salmon (Chapman et al. 2018). The timing of the migration and spawning suggests that the salmon were likely fall-run Chinook. Coded wire tag recoveries indicate that some of the spawning run were stray hatchery fish from the California Department of Fish and Wildlife's Mokelumne, American, and Feather River hatchery propagation programs (Chapman et al. 2018). It is unknown how many, if any, adult salmon that spawn in Putah Creek are native to the basin.

Plate 1. Photographs of the Los Rios Flashboard Check Dam at River Mile 1.25.
Top: view from downstream of dam looking upstream with flash boards installed (October 2005; photo by Tim Salamunovich);
Bottom: view from upstream of dam looking downstream with flash boards removed (19 April 2018; photo by Ken Davis).

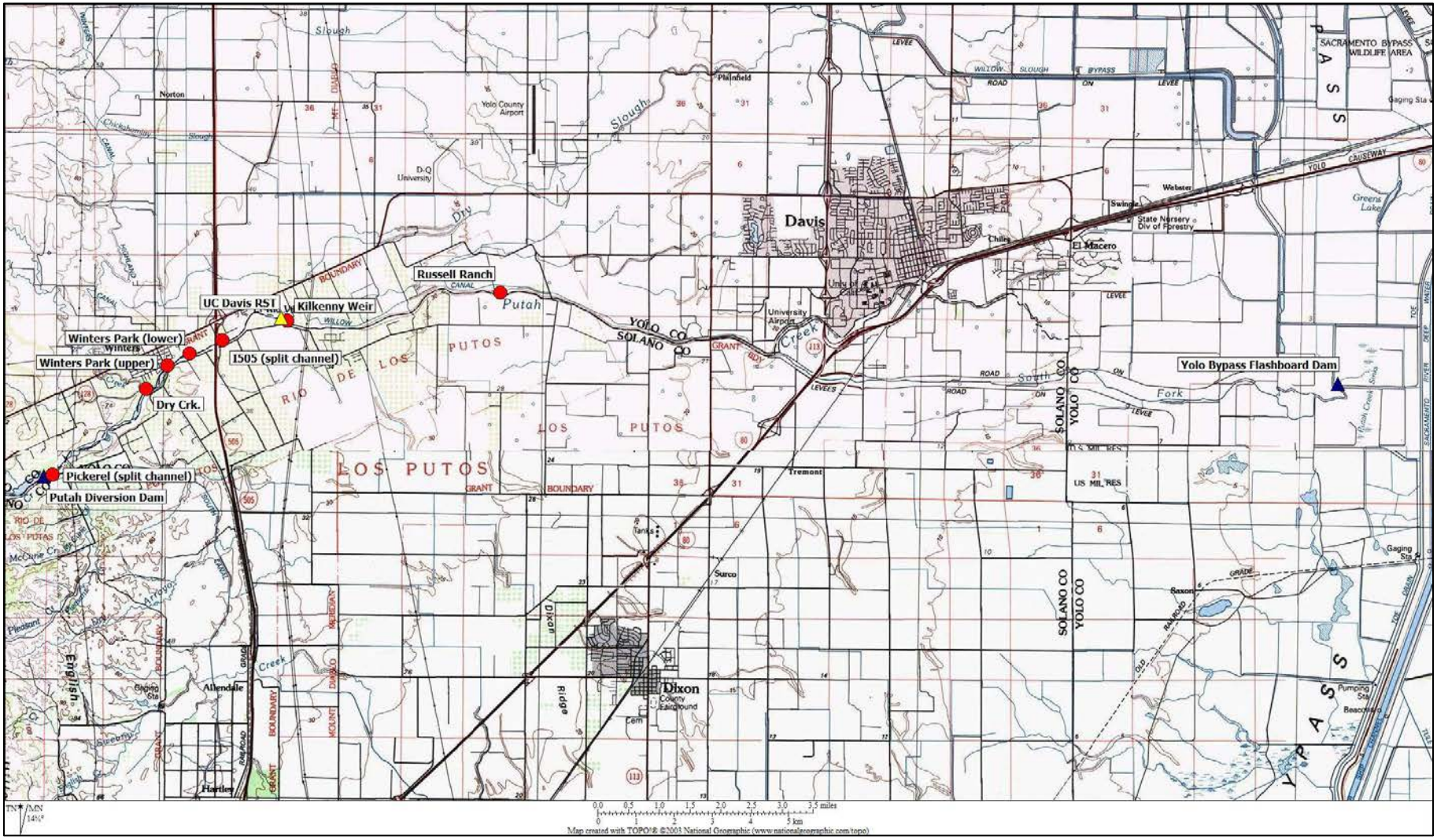

Figure 1. Map showing the lower Putah Creek basin between the Putah Diversion Dam and the Yolo Bypass Flashboard Dam (blue triangles) including the location of the seven Normandeau snorkel survey sites (red circles) snorkeled during the winter and spring of 2018. The location of the location of the UC Davis rotary screw trap (RST) operated over this same time period is denoted by the yellow triangle.

Over the past five years the estimates for Chinook spawners have increased from eight adults in the Fall of 2013, to many hundreds in each of the past four years (Chapman et al. 2018). Recent habitat improvements in lower Putah Creek, including channel modifications to increase shallow-water habitat and improve functional floodplains and side channel, spawning gravel enhancement and scarification programs, erosion control, invasive weed control, native vegetation enhancement, placement of woody debris (especially the tops of alder trees) and trash removal efforts have improved spawning and rearing habitats in lower Putah Creek.

From the large number of spawning salmon reported in Putah Creek following the fall 2017 supplemental flow releases, Solano County Water Agency (SCWA) sponsored periodic snorkel surveys to see if Chinook salmon fry emergence and rearing distributions could be documented. The estimated Chinook spawner abundance of 700 salmon for Fall 2017 was similar to the run size estimate in Fall 2015 prior to the last juvenile Chinook snorkel surveys in the winter and early spring of 2016 (Salamunovich 2017). We contacted Eric Chapman at UC Davis who conducted spawner surveys in November 2017 through January 2018, who indicated that while spawning was observed throughout thirteen miles of lower Putah Creek between PDD and Pedrick Road, most of the spawning occurred in the nine miles of creek upstream of Russell Ranch. From our previous snorkel surveys in 2016, we identified numerous potential sites within this nine mile section of Putah Creek that were near known spawning gravel areas and suitable fry rearing habitat. We (and the Putah Creek streamkeeper) contacted riparian property owners/stewards about granting access for our surveys, and we were able to select seven areas within the principal spawning section that we thought provided the best opportunity for observing newly emergent salmon fry (Figure 1).

Methods

The snorkel surveys consisted of two divers equipped with mask and snorkel swimming and crawling slowly upstream along both banks looking for fish along a six foot wide survey area (narrower in one split channel area). Tally counts for juvenile salmon observed were apportioned into three size categories (<50 millimeters [mm], 50-100 mm, and >100 mm). These tallies were kept on wrist-secured underwater writing slates. Juvenile and adult trout were also identified and counted. Non-salmonid fish were noted, but not counted. Divers were careful to remain calm in the water and to stay adjacent to each other and move at the same speed to minimize disturbing fish and avoid herding fish or their movement toward other bank where they might be double counted. Following each survey, diver counts were recorded on data sheets along with dive start and end times.

Water visibilities were estimated following each snorkel survey by measuring the maximum distance at which a diver could identify the dark parr marks on 52 mm-long trout colored Rapala® fishing lure (Plate 2). Ability to accurately distinguish these parr marks in critical for snorkel counts when mixed species are present. Presence of parr marks are distinctive characteristics for identifying juvenile salmonids and distinguishing them from similarly sized non-salmonids such as suckers and minnows. Differences in

Plate 2. **Top**: photograph of the 52 millimeter-long trout lure used to estimate water visibility during snorkel surveys; **Bottom:** photograph of actual visibility estimate in progress (visibility lure is shown in red circle).

parr mark shape and spacing in conjunction with caudal and dorsal fin spotting, are also used to distinguish between juvenile salmon and juvenile trout. Distances from observers face plate to the lure were measured with a surveyors tape to the nearest 0.1 foot. Visibility measurements were typically made in calm, nearshore, and sunlit locations and thus represent optimal conditions (Plate 2).

Streamflow (measured in cubic feet per second, cfs) and ambient turbidity (side scatter readings measured in Nephelometric Turbidity Units, NTU) levels recorded by SCWA real time recording devices located at the PDD, Interstate 505 Bridge (I505) and Interstate 80 Bridge were noted for the surveys. Water temperatures were also recorded following each survey. Digital photos at each site were taken at the time of the surveys.

Results

Ten separate snorkel surveys were conducted semimonthly over a nineteen week period between 1 February and 7 June 2018 (Table 1). Seven sites were snorkeled during each survey (Figure 1), with two of the sites, I505 and Pickerel, having two separate split channel areas (designated north and south) that were included in each survey, totaling nine snorkel reaches per survey date (Table 1). Snorkel reach lengths ranged from 270 to 530 feet, and averaged 400 feet in length. While the snorkel survey times varied by date and site, surveys averaged about 20 minutes in duration (Table 1). While most surveys included both banks, on two survey dates at several sites, diver availability and time constraints limited surveys to one bank (Table 1). To correct for this discrepancy, a standardized juvenile density estimate was computed, based on total counts divided by actual survey area, or juvenile salmon per acre, for each of the survey dates (Table 1).

During the ten snorkel surveys, over 16,200 juvenile Chinook salmon were counted (Table 1). Other species noted during the surveys included rainbow trout (*O. mykiss*), threespine stickleback (*Gasterosteus aculeatus*), Sacramento pikeminnow (*Ptychocheilus grandis*), Sacramento sucker (*Catostomus occidentalis*), recently hatched pikeminnow/ sucker larvae, tule perch (*Hysterocarpus traskii*), prickly sculpin (*Cottus asper*), western mosquitofish (*Gambusia affinis*), and largemouth bass (*Micropterus salmoides*).

Examination of the survey dates and fry density estimates suggest that the first snorkel survey, conducted on 1 February 2018, began prior to the principal salmon fry emergence from spawning gravels (Table 1). The average fry density for that February survey was about 367 salmon fry per acre, while two weeks later, the average density estimates from the snorkel surveys was 1,614 salmon fry per acre. In fact juvenile Chinook densities continued to climb over the next four weeks, peaking at an estimated 7,856 juvenile salmon per acre. The intermittent snorkel surveys suggest that the peak Chinook fry emergence in lower Putah Creek in 2018 occurred in early to mid-March (Figure 2). Following the mid-March peak, juvenile salmon declined by about 85 percent by the late March survey and remained at relatively stable through mid-May, before showing a marked decline in late-May and the last survey in early June (Figure 2).

Table 1. Winter/Spring 2018 snorkel survey sites, distance below Putah Diversion Dam (PDD), survey reach lengths, and juvenile Chinook salmon counts by survey date. Unless otherwise denoted, both banks were snorkeled during each survey date. Total juvenile salmon counts, average juvenile salmon density and average snorkel survey duration per site, and other fish species observed are also shown by sample date.

Site	Miles below PDD	Reach Length (ft)	Juvenile Chinook Counts 1-Feb	15-Feb	28-Feb	12-Mar	28-Mar	13-Apr	26-Apr	10-May	24-May	7-Jun	Total
Pickerel South	0.1	530	129	527	1,170	2,060	92	254	275	342	212	49	5,110
Pickerel North	0.1	525	185	647	1,592	4,273	264	176	350	337	189	38	8,051
Dry Creek	2.4	452	31	244	327	514	240 [1/]	218	129	52	41	18	1,814
Winters Putah Crk Park Upper	3.0	400	0	3	0	223	23 [1/]	4	20 [1/]	14	8	2	297
Winters Putah Crk Park Lower	3.3	382	0	2	0	6	11 [1/]	3	3 [1/]	0	0	0	25
I505 South	4.0	280	0	68	35	238	51	54	0	6	16	3	471
I505 North	4.0	270	0	53	64	111	5	35	15	10	3	1	297
Kilkenny Weir	4.8	355	0	17	0	79	0 [1/]	0	0 [1/]	0	0	0	96
Russell Ranch	9.2	404	0	0	0	93	0 [1/]	0	0 [1/]	0	1	1	95
Total juvenile salmon count			345	1,561	3,188	7,597	686	744	792	761	470	112	16,256
Juvenile salmon density (#/acre)			367	1,614	3,297	7,856	991	769	1,049	787	487	116	
Average survey duration (min)			15.6	20.4	19.0	18.9	24.7	16.3	25.9	18.3	22.1	19.3	19.8
Rainbow trout								X		X	X	X	
Threespine stickleback			X	X	X	X	X	X	X	X	X	X	
Sacramento pikeminnow			X	X	X	X	X	X	X	X	X	X	
Sacramento sucker			X	X	X	X	X	X	X	X	X	X	
Tule perch					X	X		X	X	X	X	X	
Prickly sculpin				X	X	X	X	X	X	X	X	X	
minnow/sucker fry								X	X	X	X	X	
Mosquitofish			X				X	X					
Largemouth bass												X	

[1/] only one stream bank surveyed

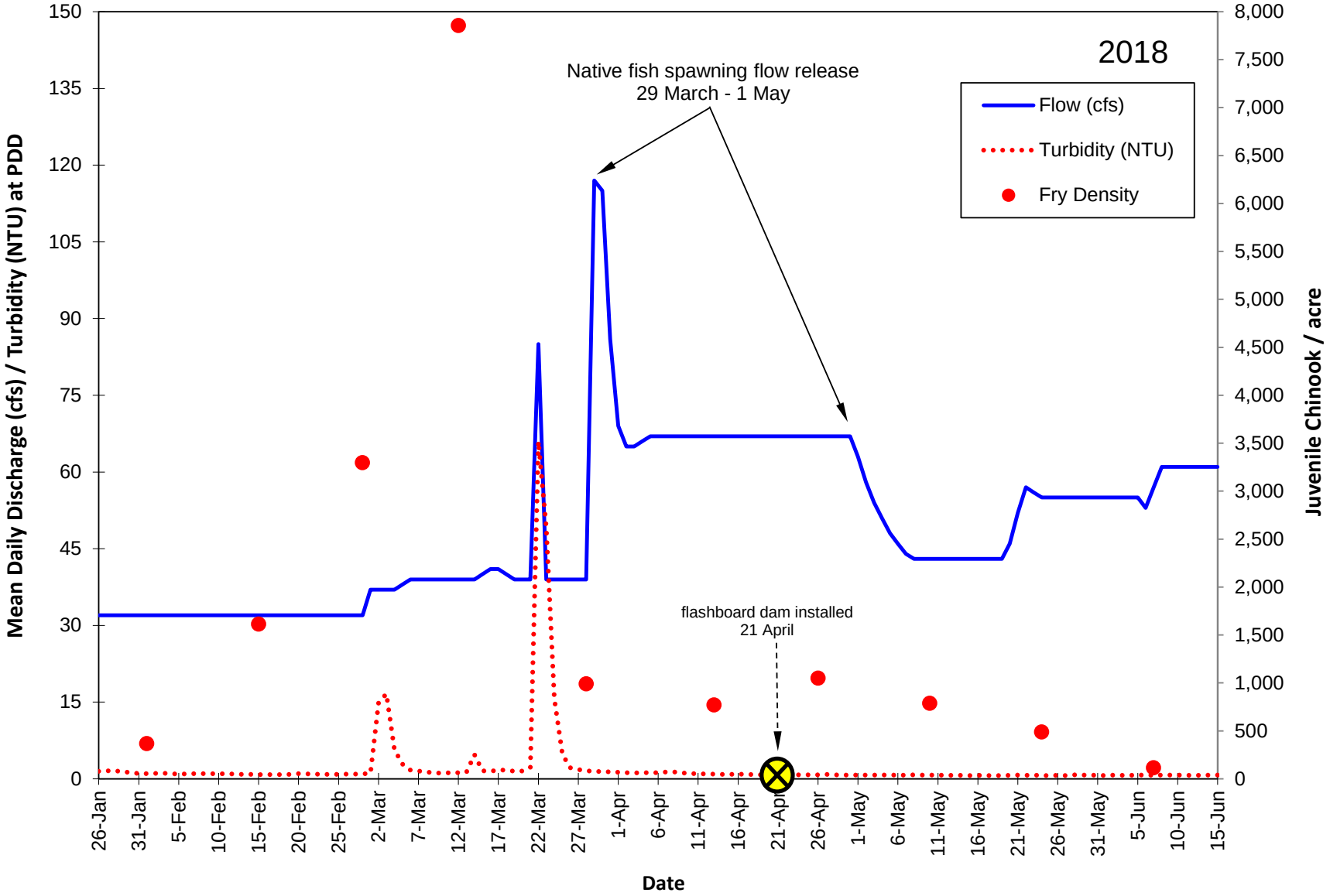

Figure 2. Mean daily flow and mean daily turbidity at Putah Diversion Dam during the late winter and spring of 2018. Red circles denote juvenile Chinook survey dates and mean salmon fry densities observed in lower Putah Creek for that date.

The Los Rios Check Dam was reinstalled on 21 April, about five weeks after the mid-March peak juvenile salmon abundance, but when large numbers of juvenile salmon were still present in Putah Creek (Figure 2). UC Davis operated a rotary screw trap 4.7 miles downstream of the PDD that monitored outmigration from the upstream basin, where most of the salmon spawning occurred. Preliminary data indicated that the trap was still capturing 300-400 Chinook outmigrants per day around the time of the flashboard dam installation (Emily Jacinto, UCD, email).

Juvenile Chinook were observed at most of the sites sometime during the survey period, but the highest counts consistently occurred below the Pickerel weir and at the Dry Creek confluence (Table 1; Plate 3), both of which had been identified as Chinook spawning sites the previous fall. In fact, over the course of the ten snorkel surveys, over 93 percent of the juvenile salmon counted, were observed at the Dry Creek and Pickerel sites. Similar to the previous snorkel survey conducted two years ago (Salamunovich 2017), we noted that until mid-April, most of the salmon fry were only found within a few feet of bank or shallow areas near LWD. It was only later in spring as juveniles grew to larger size, that we started seeing them move toward mid-channel areas and deeper faster water. This microhabitat shift is common for this species (Moyle 2002).

Plate 3. Photograph of juvenile Chinook salmon in the >100 mm size interval below the Pickerel weir on 7 June 2018.

Examination of the salmon size interval distributions collected during the snorkel surveys show that prior to late March, most of the salmon observed and counted were small newly emergent fry less than 50 mm in length (Figure 3). From late March through the end of the survey period most of the juvenile salmon noted had grown and were in the 50 to 100 mm size interval. While large juveniles greater than 100 mm in length were noted by last March, they generally made up less than 5 percent of the counts, until the last survey in early June when over 23 percent of the salmon noted were large juveniles (Plate 3).

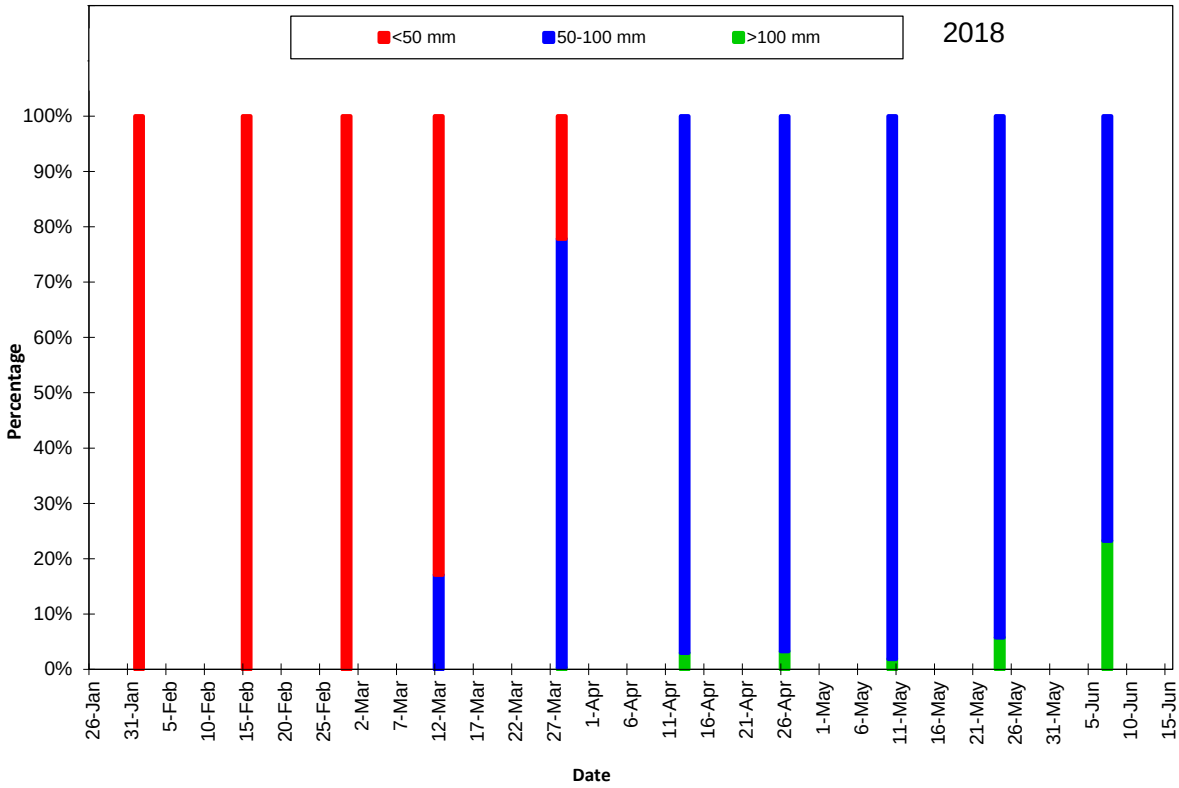

Figure 3. Juvenile Chinook salmon size interval distribution by sample date for the 2018 lower Putah Creek snorkel surveys.

Most of the rainbow trout observed were larger juveniles or adult fish >100 mm in length. Trout fry (<50 mm in length) were noted during the mid-April surveys. This would indicate that trout emergence occurs after the peak salmon fry emergence. If the rainbow trout in lower creek spawn on same schedule as the IDR population, which peaks in mid to late December (Salamunovich 2009), they probably spawn and emerge later than the salmon fry.

Streamflows during the nineteen week survey period were managed by the PDD. The only significant departure was a spike in flow on 22 March in response to a rain event that resulted in an inch of rain in the area (Figure 2). A second extended flow event

occurred in late March and consisted of the managed flow increase for resident native fish spawning flows stipulated in the Putah Creek Settlement Agreement and subsequent Superior Court amended judgement.

Turbidities measured at the PDD were generally low throughout the survey period and only became elevated following infrequent rainfall events. Turbidities at the PDD were low during each of the survey dates (Figure 4). The visibility estimate patterns noted during the surveys consistently shows that visibility worsens with distance downstream (Figure 4). The degraded visibilities downstream likely impact diver ability to see and count non-schooling, individual small salmon fry.

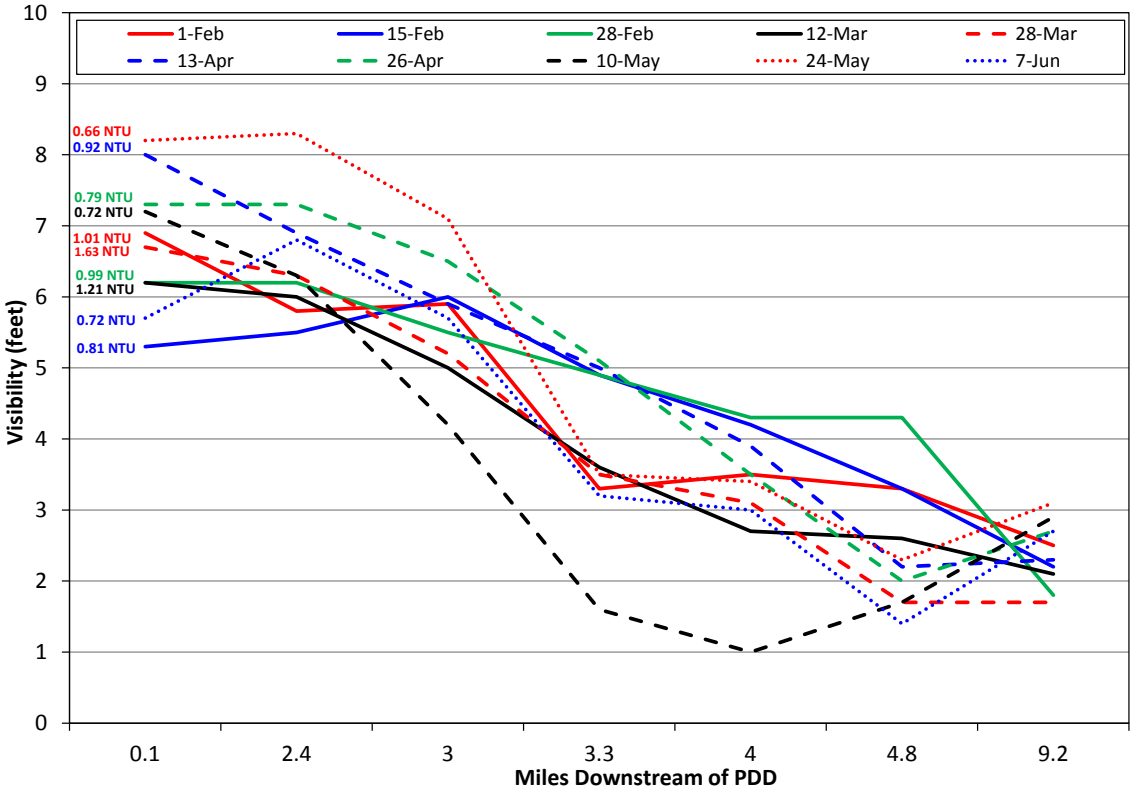

Figure 4. Direct observation visibility estimates (in feet) by survey date and distance downstream of the Putah Diversion Dam (PDD). The ambient PDD turbidity level for the survey date (measured in Nephelometric Turbidity Units or NTU's) is shown to left of each line.

Examination of the visibility estimates for the 10 May survey were noteworthy for their anomalous pattern, where much lower visibilities occurred at the lower Winters Park and I505 sites compared to the Russell Ranch Site located five to six miles downstream (Figure 4). On this date a milky creamy tinge to the flowing water was noted at the downstream sites (Plate 4). We also noted the Willow Canal, which carries Cache Creek water diverted at Capay Dam along the south boundary Yolo County between Winters

Plate 4. Photographs of lower Winters Putah Creek Park Site. **Top:** 12 March 2018; **Bottom:** 10 May 2018. Note milky color of water on 10 May.

and Davis, was transporting very turbid water in late April and throughout May (Plate 5). Flow from the Willow Canal is known to occasionally spill into Putah Creek (Moyle 2011) and likely contributed to the lower visibilities we noted in the middle of the survey reach. It is likely that Willow canal was spilling into Putah Creek and increasing turbidity and reducing visibility.

Through the mid-April surveys, water temperatures tended to decrease with distance downstream from PDD (Figure 5). However, some this apparent decrease may have been a diurnal and not a longitudinal pattern, since surveys began in the early morning at the downstream Russell Ranch Site at mile 9.2 and ended in mid-afternoon below the PDD. Despite this cooling pattern noted for the first six surveys, water temperatures at all sites through late February were typically less than 12° Centigrade ([C], 54° Fahrenheit [F]) and through mid-April were typically less than 15°C (59° F).

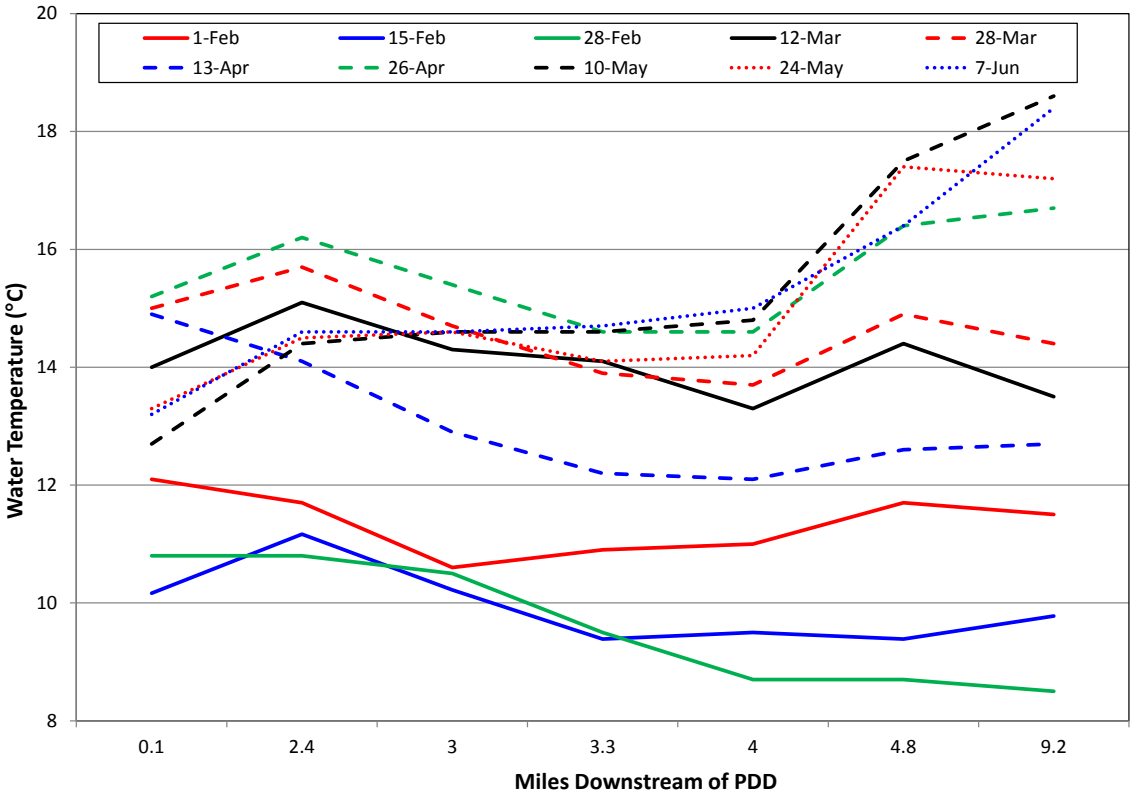

Figure 5. Water temperatures (in degrees Celsius) by date and distance downstream of the Putah Diversion Dam (PDD) for the 2018 juvenile Chinook salmon snorkel surveys.

During the last four surveys between late April and early June, water temperatures tended to increase with distance downstream from PDD (Figure 5), but were typically in the 12° to 18°C (54°-64°F) range, which is considered optimal for juvenile Chinook salmon (Raleigh et al. 1986; Moyle 2002).

Plate 5. Photographs of Willow Canal flow at Russell Ranch, May 2018. Note milky color of water.

During the 2016 snorkel surveys (Salamunovich 2017) we only counted about 1,800 juvenile chinook compared to over 16,000 chinook fry counted in our 2018 surveys. While we conducted more surveys in 2018 compared to 2016 (ten versus seven) and we did not have any high turbidity events in 2018 that limited surveys as we did in 2016, these factors were likely not responsible for the higher counts in 2018 compared to 2016. The two main factors for the higher counts in 2018 were addition of the Pickerel sample site and lack of significant rain events. The Pickerel site, located just below the PDD, is a heavily utilized salmonid spawning area with ample spawning substrates. This site, which had the highest juvenile chinook counts and densities during every sample event in 2018, was not included in the 2016 surveys. Additionally, there were two large rain events in March 2016 that raised both flows (in excess of 450 cfs) and turbidities and may have stimulated chinook fry emigration out of the basin.

One important issue for consideration is the springtime re-installation of the Los Rios irrigation flashboard dam in the Yolo Bypass area of Putah Creek (Plate 6). The boards are typically replaced in early April to create a head of water for irrigation diversion to neighboring agricultural lands (Los Rios Farms) and to flood the permanent wetlands of the Vic Fazio Yolo Wildlife Area (California Department of Water Resources 2005).

Plate 6. Photograph of Putah Creek upstream of the Los Rios Flashboard Check Dam at River Mile 1.25 showing the large ponded habitat upstream of dam. (15 May 2018; photo by Ken Davis).

The Los Rios Check Dam was reinstalled on 21 April 2018. Once installed, the flashboard dam ponds water for irrigation pumps and blocks salmon downstream migration to the Toe Drain and access to the Delta and Pacific Ocean. Once this dam is in place, only a small amount of flow is released downstream through an outflow culvert

and from leakage, effectively preventing emigration of fish downstream. In addition this diversion creates a large ponded deep, slow-water habitat that harbors large predators such as largemouth bass and striped bass (*Morone saxatilis*) that consume salmon and trout fry that are unable to migrate from system. Fry that don't end up feeding the large piscivorous fish in the lower basin will likely perish from high temperatures that exceed their thermal tolerances by mid-May to late May when lower basin water temperatures typically exceed the maximum 22° Centigrade threshold for salmonid growth and survival (Myrick and Cech 2001; Figures 6 through 8).

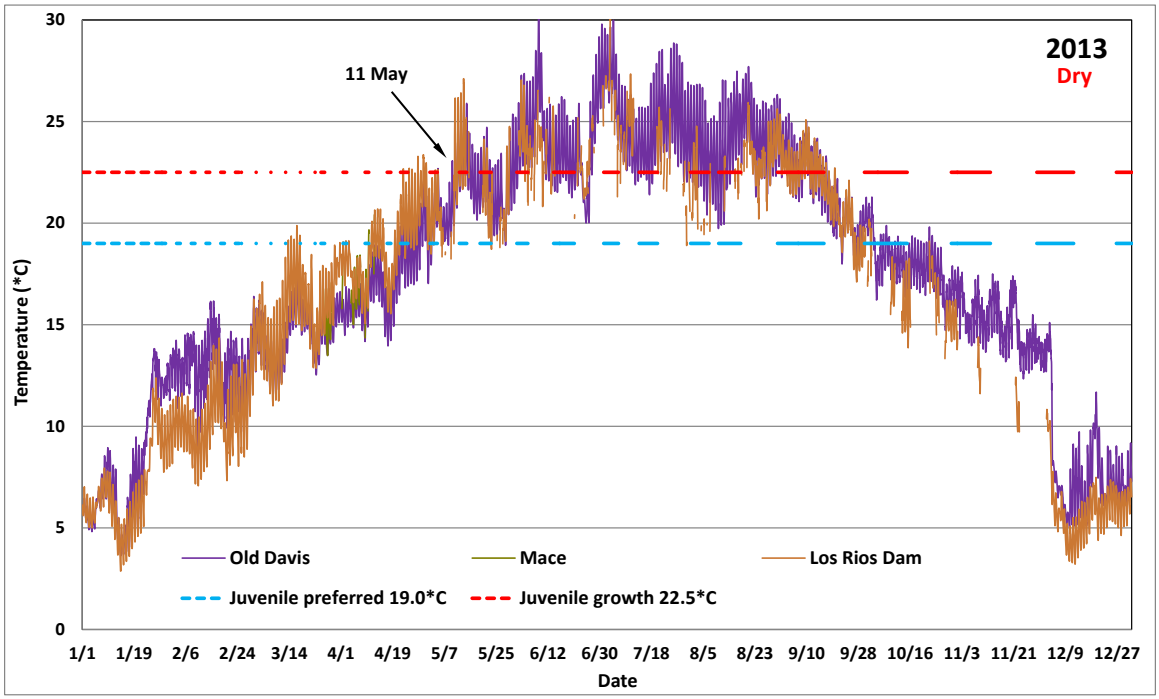

Figure 6. Water temperatures (in degrees Celsius) for lower 8.6 miles of Putah Creek between Davis and Los Rios Dam during 2013, classified by DWR as a dry water year. Dashed lines represent juvenile salmonid thermal tolerance criteria (from Myrick and Cech 2001).

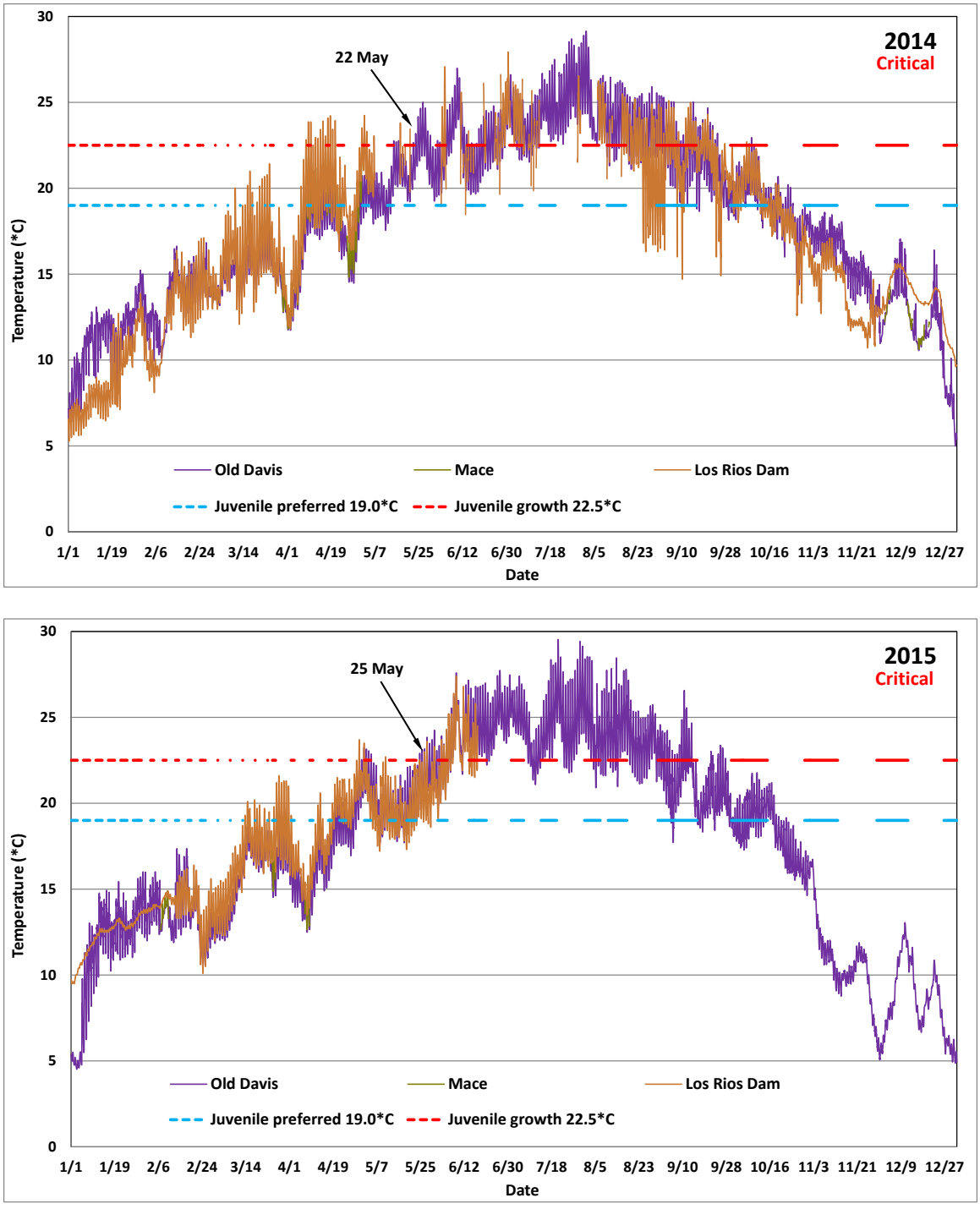

Figure 7. Water temperatures (in degrees Celsius) for lower 8.6 miles of Putah Creek between Davis and Los Rios Dam during 2014 (top) and 2015 (bottom), both classified by DWR as a critical water years. Dashed lines represent juvenile salmonid thermal tolerance criteria (from Myrick and Cech 2001).

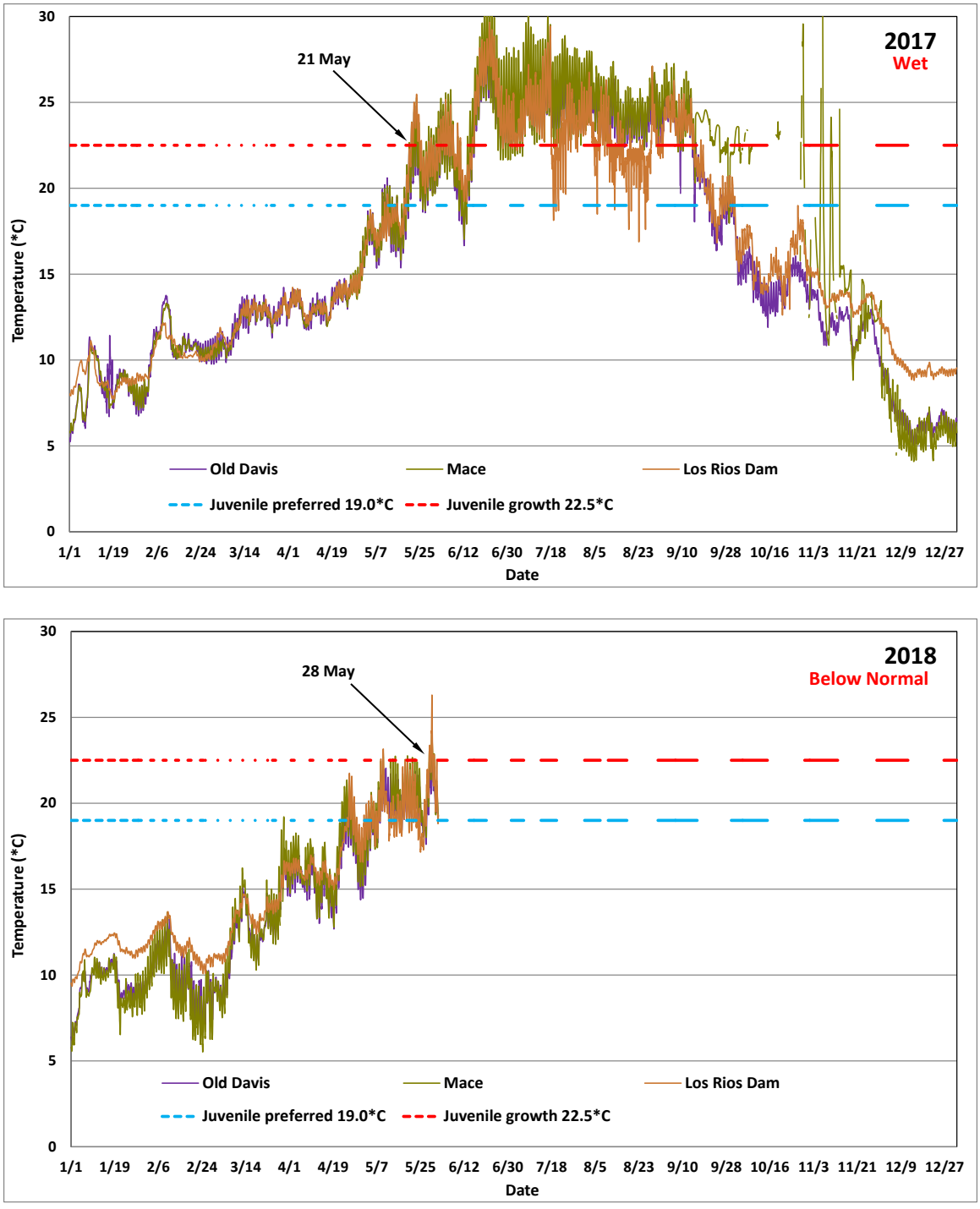

Figure 8. Water temperatures (in degrees Celsius) for lower 8.6 miles of Putah Creek between Davis and Los Rios Dam during 2017 (top) and 2018 (bottom), classified by DWR as wet and below normal water years. Dashed lines represent juvenile salmonid thermal tolerance criteria (from Myrick and Cech 2001).

After flashboard dam installation, it is likely that only salmon that remain in the upper three miles of the basin between the PDD and Winters, where summer water temperatures remain cool enough for salmonid growth and survival, can successfully over summer and have an opportunity to migrate in the late fall or early winter as yearlings (Plate 7). Once the flashboard dam is in place, those juvenile salmon that have not migrated to the Toe Drain, or can over summer upstream of Winters, are trapped and will eventually perish from thermal stress or predators and do not contribute to future salmon production salmon. Delaying the spring re-installation of the Los Rios Check Dam as possible into late April or even mid to late May would provide additional time for more juvenile Chinook still remaining in the lower basin to emigrate to the Toe Drain and the lower Sacramento and Delta. Any delay would extend the period for successful outmigration and presumably enhance Putah Creek salmonid survival and production capacity. The presence of emigrating Chinook smolts in lower Putah Creek basin should be considered in future decision making process when determining the timing of the Los Rios Dam re-installation.

Plate 7. Photograph of 109 millimeter fork length juvenile Chinook salmon parr from Putah Creek near the PDD on 20 October 2016. This juvenile was the progeny of adult salmon that spawned in Putah Creek in November/December 2015 and is an example of an over summering juvenile salmon in Putah Creek.

Planned restoration efforts, scheduled to begin in 2020, will create a new, realigned channel from the existing Putah Creek channel at the Los Rios Check Dam that will connect to tidal channels previously restored by CDFW at the southeast end of the Yolo Bypass Management Area and enter the Toe Drain downstream of Lisbon Weir (Figure 9). The proposed channel design will provide for both upstream and downstream fish passage for salmonids around the flashboard dam, increase wetland habitat subject to tidal influence in the CDFW restored tidal area, and increase floodplain rearing habitat for species of management concern including salmonids (Stillwater Sciences 2011; BOR and DWR 2017).

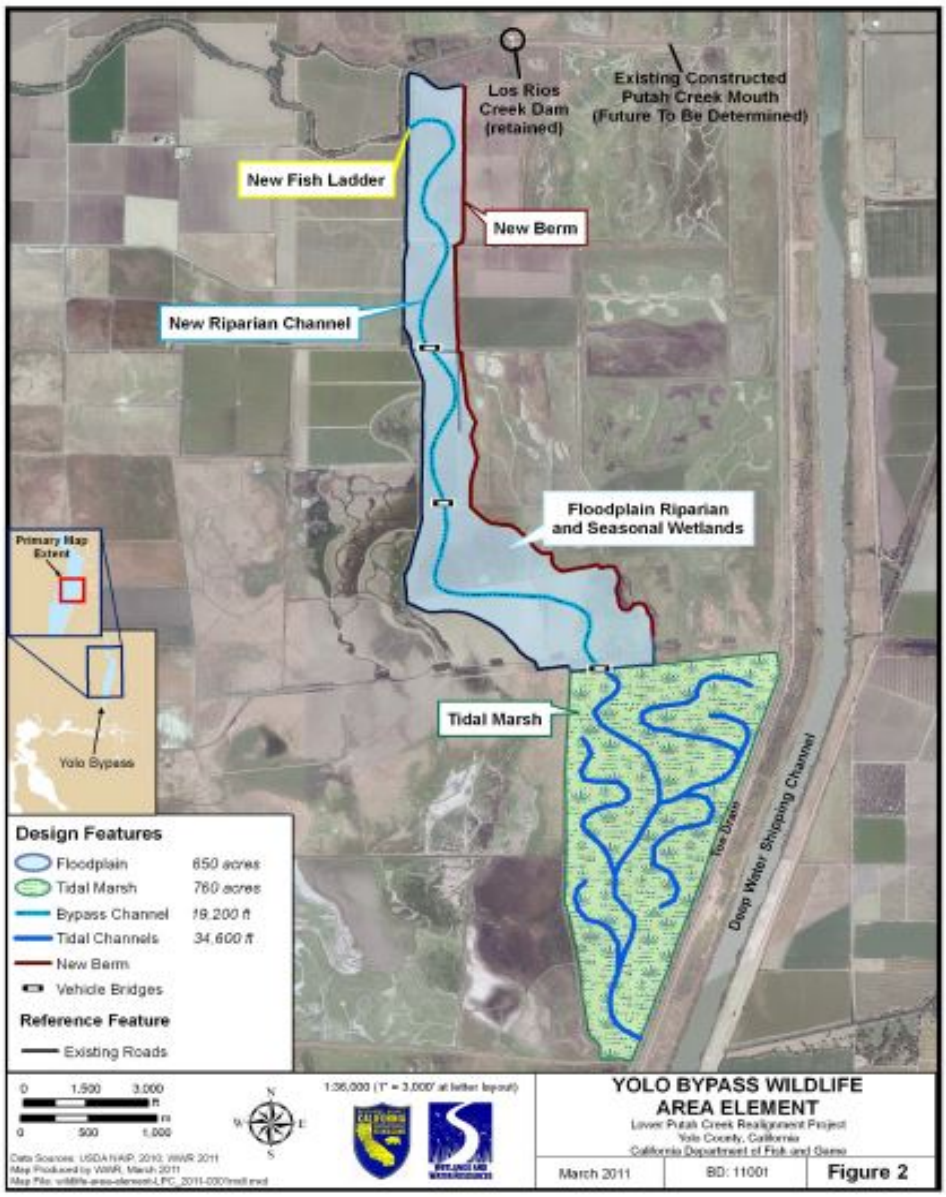

Figure 9. Proposed lower Putah Creek restoration project channels in the Yolo Bypass Management Area (Figure 2 from Stillwater Sciences 2011)

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