NORMANDEAU ASSOCIATES
Environmental Consultants

Memorandum

DATE: 12 April 2019
TO: Rich Marovich, Roland Sanford, and Chris Lee, Solano County Water Agency (SCWA)
FROM: Tim Salamunovich, TRPA Fish Biologists/Normandeau Associates
RE: Results of October 2018 lower Putah Creek fish surveys

TRPA Fish Biologists/Normandeau Associates Arcata Office staff have been sampling the fish fauna of lower Putah Creek using tote barge electrofishing since August 1991. Students from the University of California at Davis (UCD) have been regularly sampling the creek near campus using a combination of boat/backpack electrofishing, seining, and gill netting each fall since 1978. Following the May 2000 Putah Creek Accord, Normandeau continued surveying multiple sites along the creek each October as part of an annual fish monitoring program under the aegis of the Lower Putah Creek Coordinating Committee. The Accord requires releases of late fall supplemental flows to attract anadromous fish into lower Putah Creek to spawn. Another stipulation requires elevated natural or managed flows in the late winter or spring to enhance native fish spawning opportunities in the lower basin. A database containing all of the raw data (individual fish lengths and weight data by site and survey date) for the entire period of record is regularly updated and managed by TRPA and provided to both SCWA and UCD personnel. The data through 2008 was the focus of a scientific publication that demonstrated the recovery of native fishes in the upper 12.5 miles of the creek (upstream of Pedrick Road [County Road 98]) following the native fish rearing and spawning flows instituted under the Accord (Kiernan et al. 2012).

The TRPA/Normandeau crew sampled nine sites along 19 miles of the lower creek between Putah Diversion Dam (PDD) and Mace Boulevard (County Road 104; Figure 1) on 16-18 October 2018. Two additional sites near the UCD campus (Figure 1) were sampled on 27 October 2018 by a UCD fisheries class, and the results were generously provided for review. This memo report will present the results of these two recent sampling efforts.

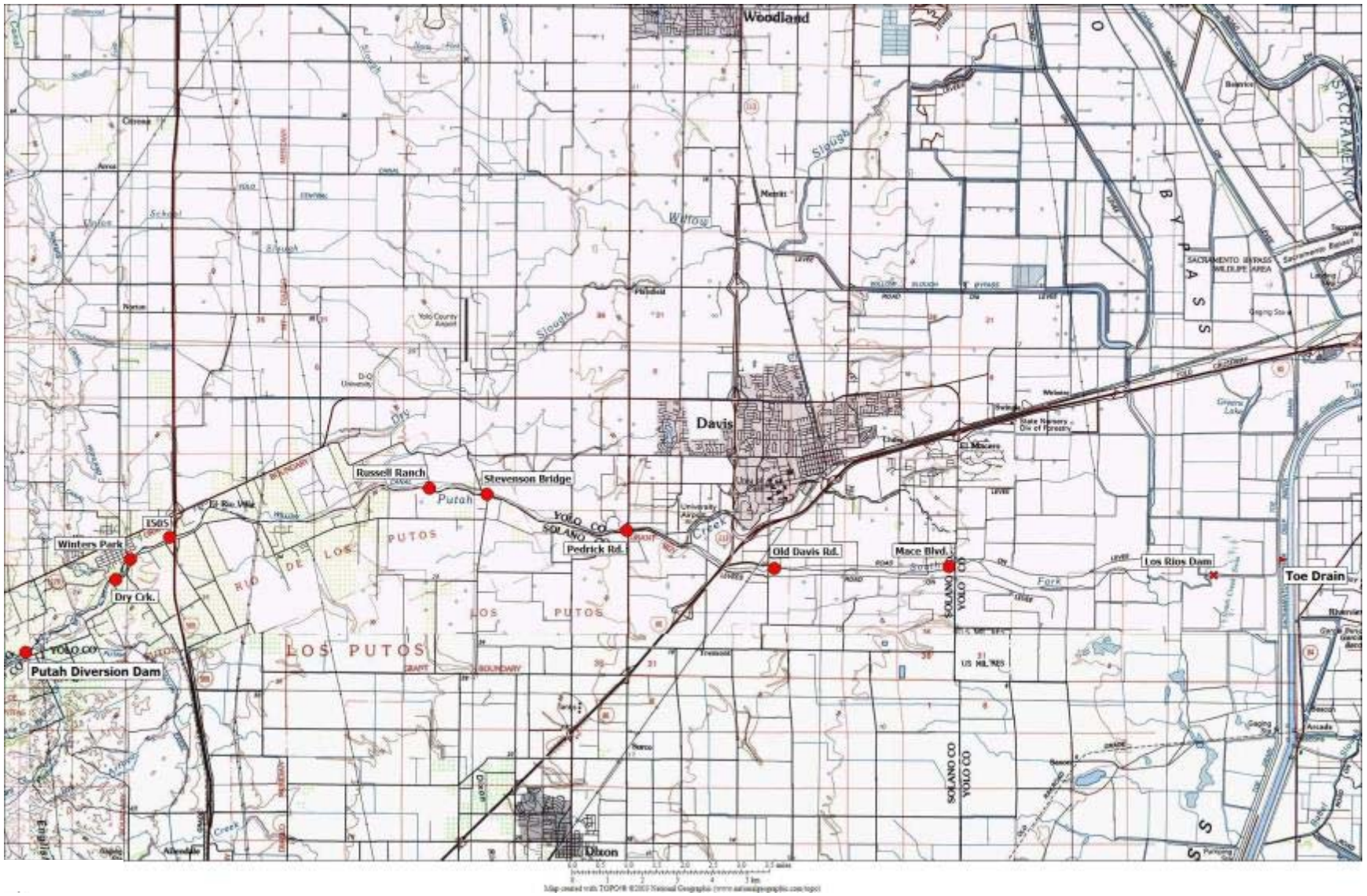


Figure 1. Map showing the nine Normandeau sample sites (red circles) and two UCD sample sites (green triangles) surveyed along lower Putah Creek in October 2018.

The objective of electrofishing surveys is to determine the distribution and relative abundance of fish populations in lower Putah Creek. Biologists captured fish using a Smith-Root gas powered generator and pulsator (model 2.5 GPP) operated out of a small pram. Two biologists wading alongside the pram used electrofishing probes to attract and stun fish. Two additional biologists netted and captured stunned fish and transferred them to buckets located in the front of the pram. A fifth person rowed or pulled the pram and was responsible for shutting off the electric current in the event of a mishap. Sampling effort emphasized the margins of the creek around instream cover and overhead vegetation, and additional effort was allocated to open water portions of the creek. Total effort expended at each site was made approximately equal by a combination of measurements of stream area and shocking seconds. Less effort was expended at the Winters Putah Creek Park site due to extreme depths between riffle habitats. At this site sampling was concentrated at 75-125 feet of shallow water habitats associated with two boulder weir structures.

All stunned fish were netted and held in 5-gallon buckets of creek water equipped with small bait-bucket aerators. Captured fish were periodically transferred to a live cart until the completion of sampling. Fish were identified and measured to the nearest millimeter using either fork length (FL) or total length (TL). A sub-sample of the catch was also weighed to nearest 0.1 gram to determine condition factors (length-weight ratios) prior to release. All rainbow trout captured during the surveys were weighed to evaluate condition factor. The trout were anesthetized in weak CO_2 solution prior to handling to reduce movement and injury during the measurement and weighing process. After handling, all trout were allowed to recover in an aeration bucket until fully mobile prior to their release back into the creek.

Two additional sites (the Alpha Phi Omega [APO] pool and the 1 Kilometer [1 KM] sites) were sampled by students of the UCD Wildlife, Fish, & Conservation Biology class on 27 October 2018 (Figure 1). UCD used a variety of capture gear including beach seines, gillnets, minnow traps and a boat shocker (equipped with a 5.0 GPP) at the APO Site; and backpack electrofishers at the 1 KM Site. All fish were identified, enumerated, and most were measured to standard length (SL) and released.

As specified in the Accord, flows in Putah Creek at Interstate 80 (I80) Bridge near Davis are monitored and dam releases to the lower creek are adjusted to maintain minimum flows of at least 5 cfs (or higher) at the I80 Bridge throughout the year (Table 1). This flow requirement ensures maintenance of a live stream throughout 15.5 miles of the lower basin, even during dry and critically dry water years. In addition, the Accord includes supplemental flow releases into the lower basin to attract anadromous salmonids in the late fall and early spring releases to promote native fish spawning (if they do not occur naturally).

Table 1. Mean daily flow requirements for Putah Creek at Interstate 80.

Month	Minimum Flow Requirement (cfs)
October	5
November	10
December	10
January	15
February	15
March	25
April	30
May	20
June	15
July	15
August	10
September	5

Mean daily flows in lower Putah Creek (measured at the PDD release point) during the 2018 Water Year (WY) is shown in Figure 2. WY 2018, which ended three weeks prior to sampling, was classified as a below normal water year for the Sacramento basin according the Sacramento Valley 40-30-30 Hydrologic Classification Index (DWR California Data Exchange Center, Water Supply Index WSIHIST). WY 2018 was the eighth below normal (or drier) water year in the Sacramento Valley in the last decade and relatively low flows prevailed (Table 2). The mean annual flow in the lower basin was 42.4 cubic feet per second (cfs). The maximum flow during WY 2018 was 117 cfs and it occurred as part of the late March 2018 managed native fish spawning flow (Figure 2). The low flows were the result of a dry winter when only 9.6 inches of rain were recorded between December through March at SCWA's PDO gage [BOR 2018]).

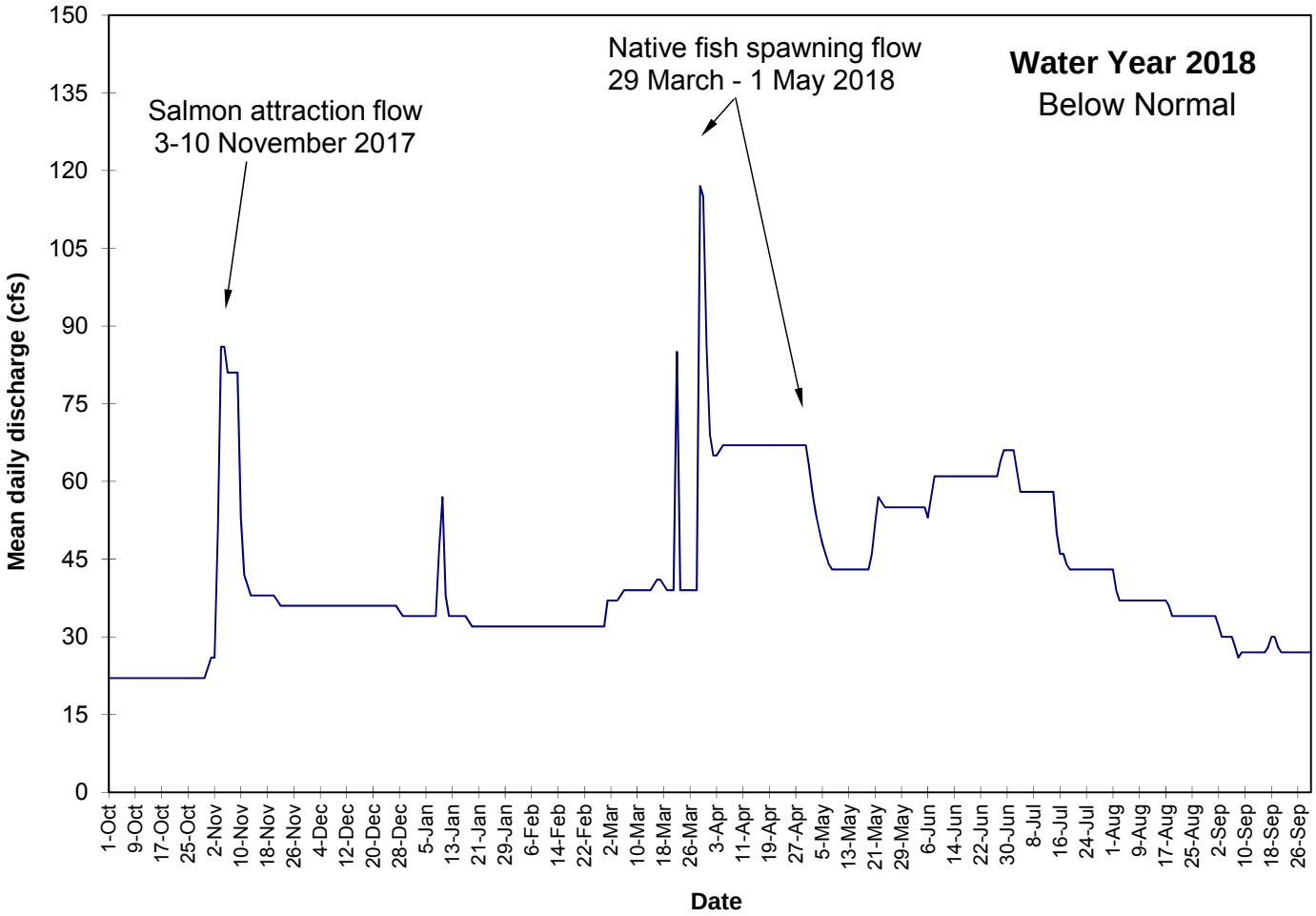


Figure 2. Mean daily discharge released into lower Putah Creek at the Putah Diversion Dam during the 2018 Water Year and prior to the October 2018 survey.

Table 2. Number of days that mean daily releases from Putah Diversion Dam exceeded certain values during the 2018 Water Year (1 October 2017–30 September 2018). Data from USBR Mid-Pacific Region, Central Valley Operations Website.

Exceedance (cubic feet per second)	Number of Days
≥ 150 cfs	0
≥ 100 cfs	2
≥ 75 cfs	10
≥ 50 cfs	103
≥ 25 cfs	335

Stream flows during the October 2018 Normandeau surveys varied and decreased according to distance downstream from the PDD release site, ranging from 22.6 cfs at the Putah Diversion Dam to 7.5 cfs at Mace Boulevard (Table 3). The UCD surveys occurred in late October, immediately prior to the Fall 2018 salmon attraction flows and were around 8 cfs at the I80 gage (Table 3).

Table 3. River mile location, sample date, survey time, stream flow, water temperature, conductivity, and salinity at time of survey for the eleven lower Putah Creek study sites during the October 2018 fish monitoring surveys. River mile notation is based upon distance upstream of the point where creek enters the Toe Drain.

Site	River Mile	Date	Time	Flow [1/] (cfs)	Temp (°C)	DO (mg/L)	Cond (µS/cm)	Salinity (ppt)
Putah Diversion Dam	25.4	10/18/18	1548	29.9	12.9	11.10	253	0.2
Dry Creek confluence	23.0	10/18/18	1014	22.2	11.7	10.12	245	0.2
Winters Park (upper weir)	22.5	10/18/18	1228	22.5	12.4	10.26	249	0.2
Winters Park (lower weir)	22.2	10/18/18	1120	22.5	11.9	9.15	247	0.2
Interstate 505 Bridge (I505)	21.5	10/17/18	1640	22.2	13.7	9.63	259	0.2
Russell Ranch	16.2	10/17/18	1318	18.6	13.7	9.22	261	0.2
Stevenson Road Bridge	15.4	10/17/18	1017	18.7	13.1	9.75	260	0.2
Pedrick Road Bridge	12.6	10/16/18	1718	19.7	16.2	8.55	294	0.2
1 Kilometer Site (1 KM)	12.1	10/27/18	1000	8.1	12.8	9.40	348 [2/]	---
Alpha Phi Omega (APO) Pool	11.8	10/27/18	1000	8.1	13.3	8.2	345 [2/]	---
Old Davis Road Bridge	9.8	10/16/18	1410	9.0	14.6	9.82	284	0.2
Mace Boulevard Bridge	6.4	10/16/18	1034	7.5	14.3	9.29	331	0.2

1/ Flow data provided by Solano County Water Agency
2/ temperature-corrected specific conductivity

Water temperatures measured during the October surveys varied by site as a function of both the time of day and the distance downstream of the Putah Diversion Dam release point (Table 3). The temperatures ranged from 11.7° to 16.2°C (53.1° to 61.2°F). Water conductivity (a measure of total dissolved solids) did not vary in the upper ten miles of the project area, then remained higher (but stable) in the lower nine miles downstream of the Stevenson Road Site. Dissolved oxygen levels were relatively high and exceeded 8.0 mg/L at all the sites.

The Fall 2018 fish surveys of eleven sites along lower Putah Creek captured a total of 2,710 fish representing 21 species (Table 4). Four California native fish species: Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow (*Ptychocheilus grandis*), tule perch (*Hysterocarpus traskii*), and prickly sculpin (*Cottus asper*) made up

Table 4. Capture data for the October/November 2018 fish monitoring surveys on lower Putah Creek.

Fish	PDD	DRY	WPK	I505	RR	STEVE	PED	1KM	APO	OLD	MACE	Total
Native Fishes												
Pacific lamprey (PLR)	1 (142 TL)											1
Sacramento pikeminnow (PKM)	2 (51-52 FL)	6 (42-112 FL)	1 (95 FL)	20 (38-93 FL)	220 (49-310 FL)	214 (46-290 FL)	168 (61-355 FL)	83 (48-282 SL)	3 (175-195 SL)			717
Hitch (HTC)							3 (68-121 FL)	1 (67 SL)		3 (76-83 FL)	9 (74-140 FL)	16
Sacramento sucker (SKR)	6 (39-163 FL)	44 (40-145 FL)	5 (85-223 FL)	14 (42-91 FL)	97 (64-252 FL)	56 (82-342 FL)	62 (81-328 FL)	24 (90-246 SL)	10 (255-400 SL)		1 (151 FL)	319
Rainbow trout (RBT)	61 (127-425 FL)	9 (107-135 FL)	7 (113-284 FL)	4 (96-139 FL)	2 (110-128 FL)							83
Chinook salmon (CHK)	6 (110-140 FL)	1 (116 FL)		4 (90-108 FL)	1 (103 FL)							12
Threespine stickleback (TSB)	33 (15-65 TL)											33
Prickly sculpin (PKS)	70 (37-112 TL)	49 (46-96 TL)	19 (53-87 TL)	26 (50-93 TL)	3 (52-102 TL)	3 (73-81 TL)	5 (57-102 TL)	6 (45-68 SL)	1 (54 SL)	1 (67 TL)	1 (79 TL)	184
Riffle sculpin (RFS)	4 (86-96 TL)											4
Tule perch (TP)		7 (61-93 FL)		2 (49-60 FL)	139 (74-122 FL)	113 (74-120 FL)	11 (87-138 FL)	13 (78-110 SL)				285
Exotic Fishes												
Black bullhead (BLBH)											3 (82-143 TL)	3
White catfish (WCF)											1 (191 FL)	1
Mississippi silverside (MSS)										75 (18-105 FL)	21 (35-90 FL)	96
Western mosquitofish (MSQ)				1 (36 TL)				3 (28-36 SL)	76 (21-44 SL)	2 (28-30 TL)	1 (39 TL)	83
Bluegill (BGS)	8 (55-119 FL)				5 (77-131 FL)			2 (76-96 SL)	54 (56-137 SL)	148 (27-145 FL)	91 (75-132 FL)	308
Redear sunfish (RES)							1 (169 FL)	4 (80-98 SL)	35 (26-235 SL)	11 (79-170 FL)	40 (78-190 FL)	91
Green sunfish (GSF)							1 (117 FL)	9 (46-98 SL)	3 (30-101 SL)	7 (39-115 FL)	7 (56-127 FL)	27
Smallmouth bass (SMB)							6 (79-112 FL)	12 (58-97 SL)	13 (41-141 SL)	1 (172 FL)		32
Spotted bass (SPB)					1 (95 FL)		1 (114 FL)			2 (92-100 FL)	8 (73-114 FL)	12
Largemouth bass (LMB)					6 (62-158 FL)	7 (74-180 FL)	23 (72-331 FL)	59 (45-182 SL)	85 (36-450 SL)	42 (45-346 FL)	159 (63-190 FL)	381
Bigscale logperch (BLP)							1 (112 TL)	1 (98 SL)	4 (62-102 SL)	1 (120 TL)	15 (100-114 TL)	22
Total # Individuals	191	116	32	71	474	393	282	217	284	293	357	2,710
# native fish	183	116	32	70	462	386	249	127	14	4	11	1,654
# exotic fish	8	0	0	1	12	7	33	90	270	289	346	1,056
Total # species	9	6	4	7	9	5	11	12	10	11	13	21
# native species	8	6	4	6	6	4	5	5	3	2	3	10
# exotic species	1	0	0	1	3	1	6	7	7	9	10	11
Shannon's Diversity (ln)	1.542	1.294	1.040	1.530	1.225	1.076	1.254	1.751	1.723	1.358	1.615	2.284
Eveness (H'/Hmax)	0.702	0.722	0.750	0.786	0.558	0.669	0.523	0.705	0.748	0.566	0.630	0.750

over fifty-five percent of the total catch in the lower basin (Figure 4). The most abundant non-native species included largemouth bass (*Micropterus salmoides*), bluegill sunfish (*Lepomis macrochirus*), Mississippi silverside (*Menidia audens*) and redear sunfish (*L. microlophus*), which contributed over thirty-two percent of the total catch.

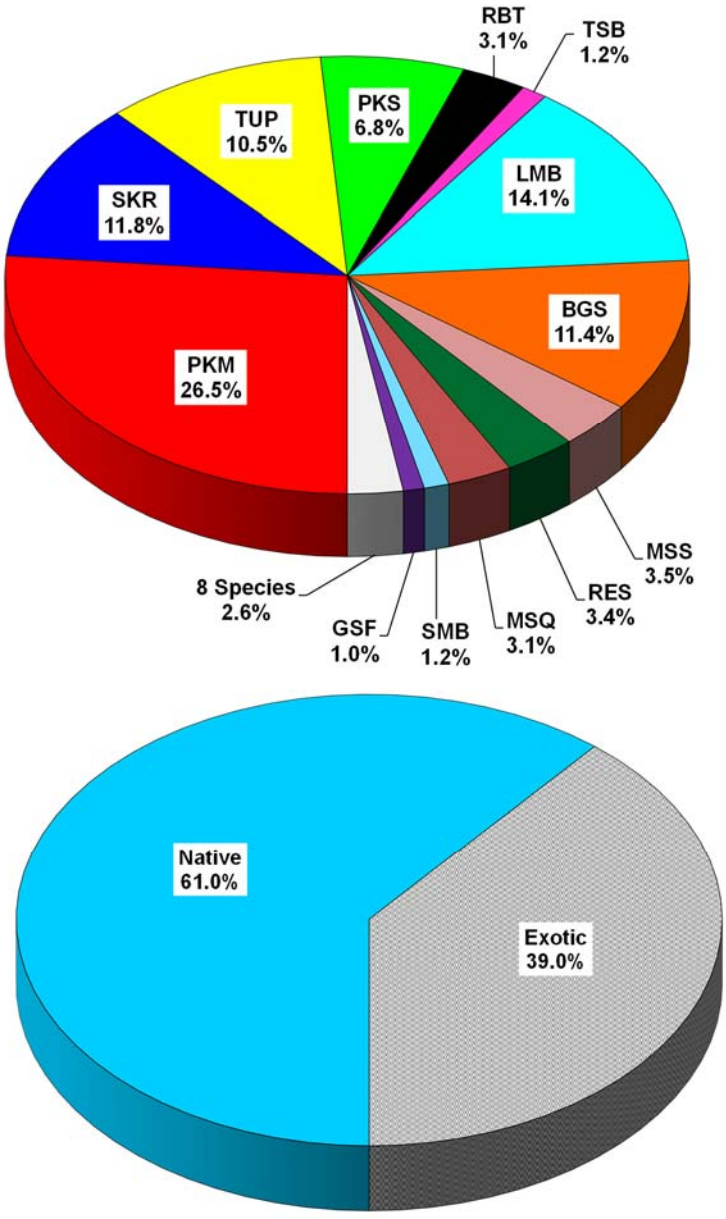


Figure 4. Percentage of total catch by fish species (top) and by native versus non-native (or exotic) species (bottom) for the Fall 2018 lower Putah creek fish surveys. Data includes both Normandeau and UCD survey data.

Eighty-three rainbow trout (*Oncorhynchus mykiss*) were captured in the fall surveys, or just over three percent of the total catch (Table 4; Figure 4). While rainbow trout were most abundant at the most upstream PDD site, they were present at all five sample sites in the upper nine miles of the survey area.

Of the total fish captured in the October 2018 survey, 61 percent (1,654 fish from ten species) were native, or endemic Sacramento River basin fish, while 39 percent (1,056 fish from eleven species were non-native, or exotic fishes (Table 4; Figure 4).

The overall spatial distribution of fishes from the October 2018 survey remains similar to recent prior surveys and continues to demonstrate that lower Putah Creek supports a highly diverse fish fauna. Native fish continue to dominate the 12.7 miles of the lower basin between the PDD at Winters and the Pedrick Road Bridge Site near Davis (Table 4; Figure 5). About 0.5 miles downstream from Pedrick, at the 1KM Site, native and exotic species are more equally abundant. In the twelve miles of creek downstream of the 1KM Site, non-native fish dominate Putah Creek (Figure 5). Despite the prolonged periods of low flow in the Putah Creek basin during 2018, native fish still dominate the fish populations between the diversion dam and Pedrick Road. This consistent pattern for native fish dominance at Pedrick Road and increased abundance of non-native fish dominance about a half mile downstream at the 1KM Site is likely a result some environmental factor such as summer water temperatures that appear to limit the downstream extent of the native fish fauna, which tend to prefer and thrive in cooler water temperatures compared to the non-native fishes, which tend to consist of slow-water pond species that are more tolerant of higher summer water temperatures. The Pedrick and 1 KM sites are at the interface where the native/exotic species meet and interact. The 2018 catch data show that native fish continue to dominate the catch in the upper 12.7 miles of the study area between the PPP and Pedrick Bridge (Table 4). In fact, only eight non-native fish (all bluegill sunfish) were captured in the upper 3.0 miles of the study area and native fish made up over 97 percent of the total catch at the six study sites located in the upper ten miles of the study area from PDD to Stevenson Bridge Road (Table 4).

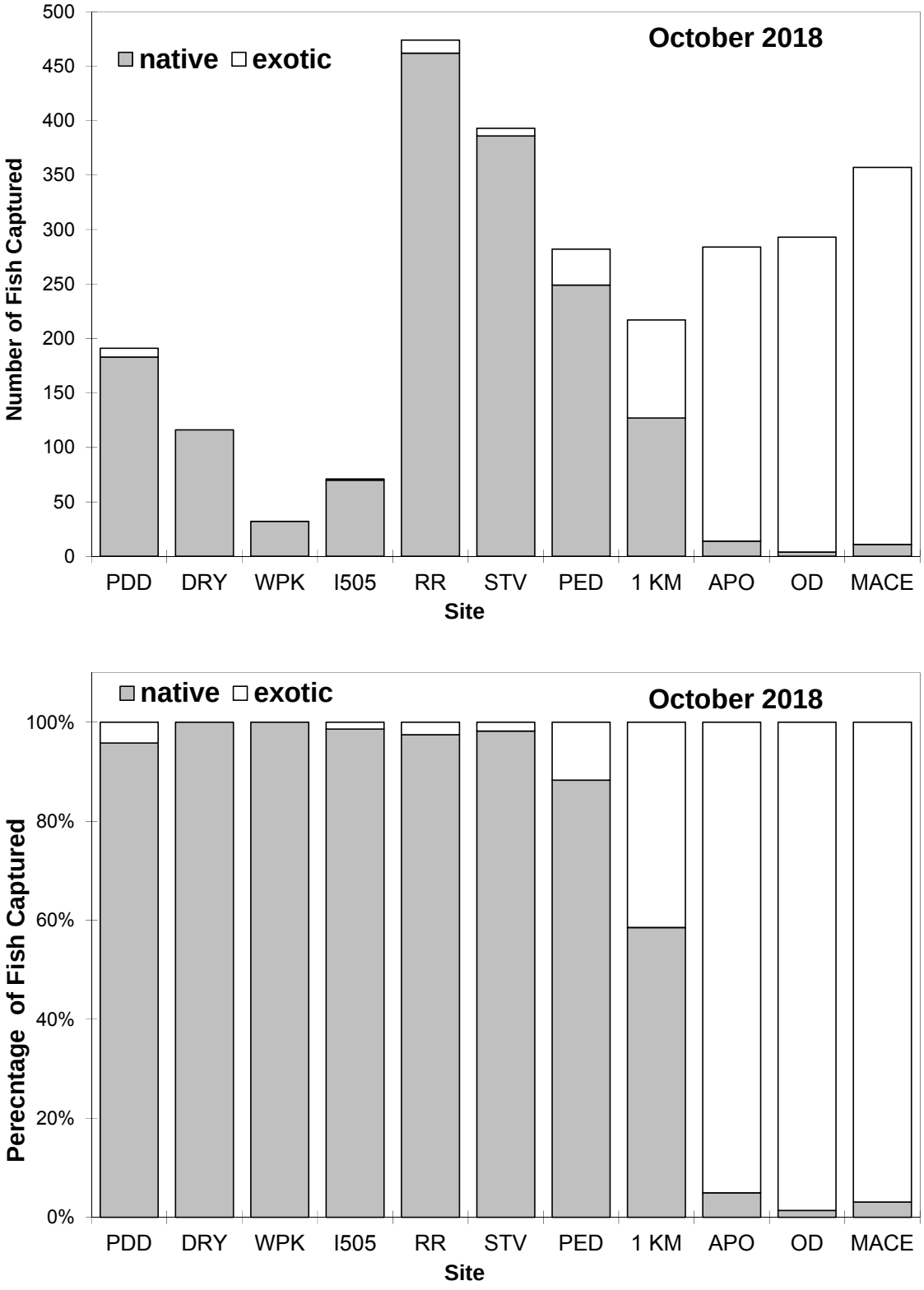


Figure 5. Number (top) and percentage (bottom) of native and exotic fish captured at each lower Putah Creek study site during the October 2018 fish surveys.

Despite the below normal flow conditions during WY 2018 and the prevalent low flows in the basin during winter and spring, the percentage of native fish at Pedrick Road did not change from that noted in 2017 following a very wet WY 2017 (Figure 6, top). In fact, following the below normal WY 2018, native fish abundance actually increased at the 1KM Site over those documented following the wet WY 2017 (Figure 6, bottom).

Of the native species captured during the October survey, some species, such as rainbow trout, threespine stickleback (*Gasterosteus aculeatus*) and Pacific lamprey (*Entosphenus tridentatus*) were limited to the upper half of the study area (Table 4). The native pikeminnow, sucker, prickly sculpin, and tule perch were more widely distributed, and were found throughout the lower basin. Hitch (Lavinia exilicauda), a native minnow), were only found in the lower half of the study area in 2018.

Most Chinook in Putah Creek are classified as fall-run anadromous fish, with adults that spawn soon after entering freshwater in the fall, and juveniles that migrate within several months following emergence (Moyle 2002). Juvenile Chinook salmon were captured at four sites along the upper nine miles of creek as far downstream as Russell Ranch (Table 4). These fish, which successfully over-summered in the cooler water areas of lower Putah Creek, will probably migrate to the Delta and ocean during first rains of the fall and early winter as yearlings. These juveniles were the progeny of the estimated 700+ adult salmon that migrated into and spawned along the lower basin in the fall of 2017 (Chapman et al. 2018a). UCD researchers captured over 33,500 juvenile salmon migrating from the basin between mid-February and mid-June 2018 in a rotary screw trap, located about five miles downstream of PDD (Chapman et al. 2018b). Unfortunately, installation of the Los Rios Check Dam at RM 1.0 (Figure 1) on 21 April 2018 probably blocked juvenile migration from the basin. Once installed, the flashboard dam ponds water for irrigation pumps and blocks salmon downstream migration to the Toe Drain, preventing access to the Delta and Pacific Ocean, where salmon mature. 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

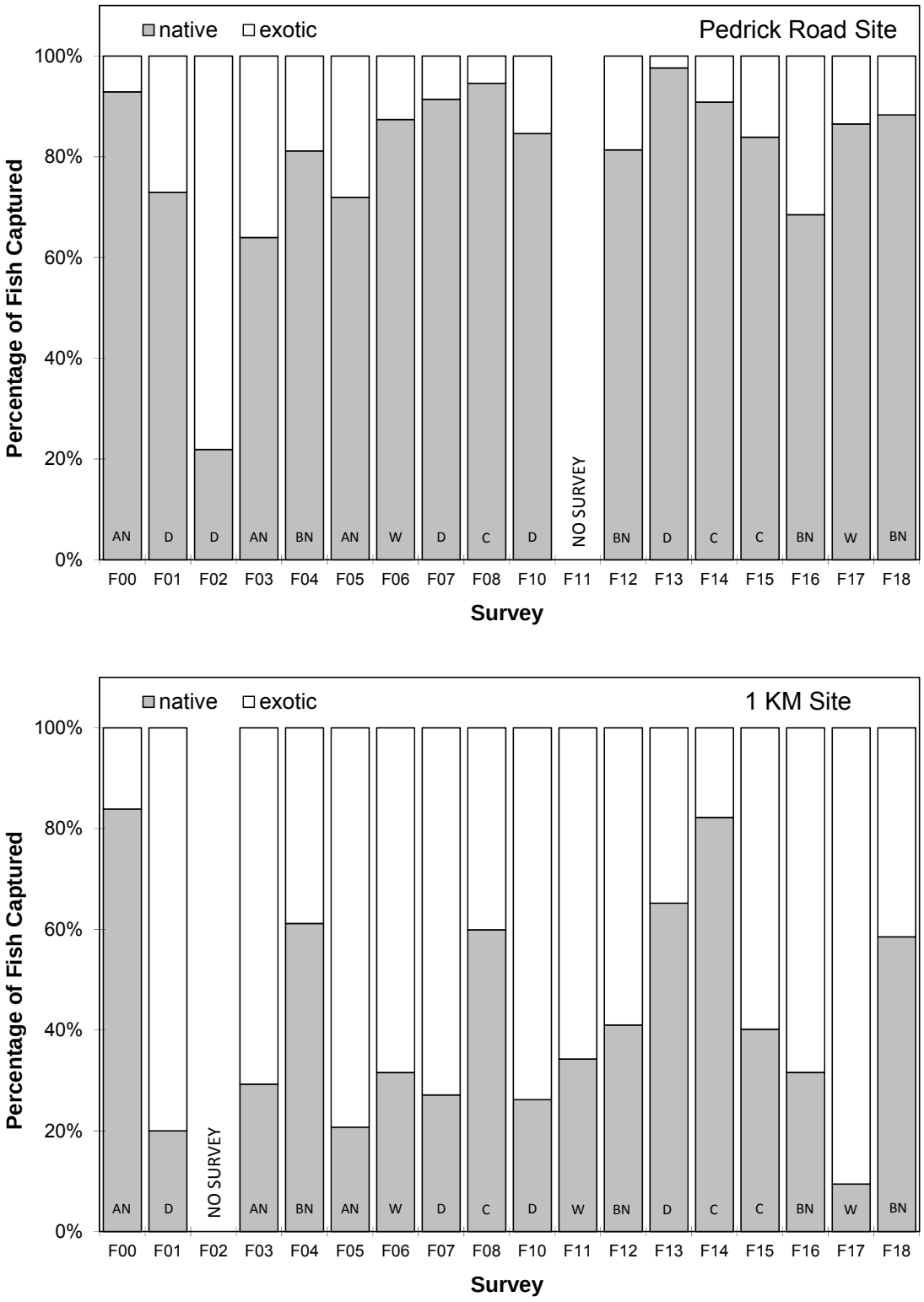
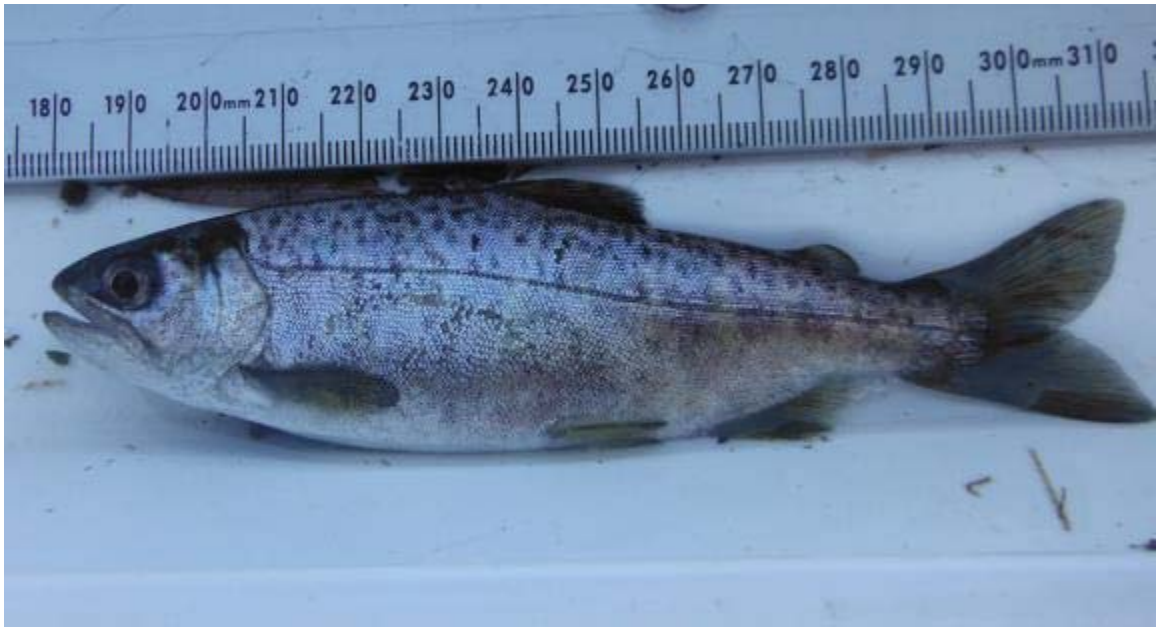


Figure 6. Percentage of native and exotic fish captured at the Pedrick Road Bridge Site (top) and 1 KM Site (bottom) during Fall fish surveys since 2000. Sacramento Valley Water Year Types shown above years: W = wet; AN = above normal; BN = below normal; D = dry; C = critical.

Large piscivorous fish in the lower basin will likely perish from high temperatures that exceed their thermal tolerances by mid to late May when lower basin water temperatures typically exceed the maximum 22° Centigrade threshold for salmonid growth and survival (Myrick and Cech 2001; Salamunovich 2017a). Once the check dam is in place only juvenile salmonids that delay outmigration and remain in the upstream areas where cooler summer water temperatures prevail, and away from warm water areas where large piscivorous bass reside and feed, will survive to the next fall when the dam is removed. Snorkel surveys conducted in the spring of 2018 and after the April dam installation, documented that juvenile Chinook salmon were still present in the upper 2.5 miles even in early June (Salamunovich 2018). It was these residual juvenile Chinook that successfully over-summered in the creek that were captured in the October surveys (Photograph 1).



Photograph1. Juvenile Chinook salmon (120 mm FL / 21.1 grams) captured below the Putah Diversion Dam, 18 October 2018.

The spatial distribution of exotic fishes in the lower basin also varied by species (Table 4). Black bullhead (*Ameiurus melas*) and white catfish (*Ameiurus catus*) were limited to single locations in the lower basin, while Mississippi silversides were documented at only

two sites. Largemouth bass and bluegill sunfish were widely distributed in the 2018 surveys and were captured at six to seven of the eleven survey sites. While these two exotic sunfish had a relatively wide distribution, their highest densities occurred along the lower 5.5 miles of the survey area, at the 1 KM site and downstream (Table 4).

The increasing abundance of non-native "panfish" to the total catch of fish in lower Putah Creek noted in 2017 continued in 2018. This "panfish" group is comprised of the smaller sunfish of the genus *Lepomis* and includes bluegill, green sunfish, redear sunfish, warmouth (*L. gulosus*), and various hybrids forms. Prior to 2010, green sunfish and bluegills were among the most common species of fish found in lower Putah Creek. In the six fall surveys conducted between 2003 and 2008, "lepomids" made up 28.1 percent of the total fish captures, and averaged 1,462 lepomids per survey. In the six complete, basin-wide surveys between 2010 and 2016, lepomids had declined to only 4.4 percent of the total captured fish, and averaged only 199 lepomids per survey. During the 2018 survey, a total of 426 lepomids were captured, or over 15 percent of the total catch (Table 4).

The scarcity of lepomids in 2012 through 2016 is especially surprising since these five water years were all classified as below normal (or drier) in the Sacramento Valley, with few periods of natural high flows that are considered to interfere with sunfish spawning. Non-native sunfish species usually thrive during these low flow and warm water conditions. The increase of sunfish in 2017 was surprising given the higher than normal winter and spring flows which would have been expected to disrupt their spawning. It appears that these sunfish populations are in a cycle of increasing abundance among the Putah creek fish populations.

It is unknown how the presence of black bass in the lower basin may impact the recently-resurgent Chinook fry outmigration during the winter and spring. Adult fall-run Chinook salmon escapement estimates for Putah Creek have ranged from 500-700 adult salmon in the fall of 2015, 1,500-1,700 salmon in the fall of 2016, and 700+ salmon in both the fall of 2017 and 2018 (Chapman et al. 2018a, 2018b). Snorkel surveys conducted in the winter and spring of 2016 and 2018 indicated successful emergence and emigration of fry from upper basin (Salamunovich 2017b, 2018). The annual early

spring placement of the Los Rios irrigation flashboard dam in the Yolo Bypass area of Putah Creek effectively blocks emigration to the Toe drain and subsequent passage movement to the ocean. It also creates large warm deep water pools that harbor large predatory largemouth bass.

The 2018 electrofishing survey included the Winters Putah Creek Nature Park site, which represents a relatively new sample site along lower Putah Creek that has been surveyed only since 2012. In November 2011, a channel realignment and floodplain restoration project (Winters Park Project) was completed along a 3,700 foot-long section of Putah Creek. This project was designed to restore natural channel form and function, enhance habitat of native species and improve public access in a reach that had been mined extensively for gravel and otherwise enlarged, straightened and dammed for flood conveyance and seasonal water storage. This project included removing an historic concrete low flow barrier (Winters Percolation Dam built in 1938 [Sears 2010]), reconfiguring the creek channel to a narrower and shallower meandering form, lowering elevation of the inset floodplain, and replanting native plants along the riparian corridor. Three existing riffles were augmented and 14 new riffles were created at 200 foot intervals by importing 2,000 tons of salmon spawning gravel mix (Rich Marovich, personal communication). It was anticipated that this channel realignment project would eliminate the extensive areas of large deep pool habitat that acted as a heat sink and harbored large predatory non-native basses, and instead create hydraulically diverse and cooler water habitat that would benefit native fish, including salmonids. Fish salvage and relocation efforts conducted in the project area in September 2011 (prior to construction) found only one rainbow trout in this section of Putah Creek (Peter Moyle, personal communication). Since channel restoration, rainbow trout have regularly been captured in this area. During the October 2018 survey seven rainbow trout were captured in this area of Putah Creek (Table 4).

In conclusion, despite a below normal water year and lack of extended high flow, native fish populations continue to thrive in the thirteen miles of Putah Creek from the Putah Diversion Dam to downstream of Pedrick Road and non-native fishes continue to dominate the six miles between Pedrick Road and Mace Boulevard. The WY 2018 low flows did not appear to result in an upstream retreat of the native fish fauna. It appears

that the current Accord flow regime is supporting healthy native fish populations in the Putah Creek basin. Continued fall fish monitoring should indicate how the fish populations respond to the changing water year types and the continuing benefits of the Accord flow regime.

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