TECHNICAL MEMORANDUM ◦ JANUARY 2019

Upper Tuolumne River Ecosystem Program 2017 Fisheries Monitoring

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Cover photo: Aquatic habitat surveys in Cherry Creek, fall 2016

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1 INTRODUCTION AND PURPOSE

Annual monitoring of fish populations in the Upper Tuolumne River serves as a basis for evaluating aquatic habitat conditions and assists in understanding how releases from the San Francisco Public Utilities Commission (SFPUC) Hetch Hetchy Project facilities affect fish habitat and fish populations over time.

The SFPUC conducted annual monitoring of fish populations for the reach between O'Shaughnessy Dam and Kirkwood Powerhouse (the Hetch Hetchy Reach) from 2007 to 2012; no data were collected in 2013 due to the Rim Fire. In 2014, the sampling approach for this reach was refined to be more efficient and effective (see Stillwater Sciences 2016), and sampling was continued in 2015 through 2017. In 2016, reconnaissance-level fisheries monitoring began in the reach immediately upstream of Hetch Hetchy Reservoir (the Above Hetch Hetchy Reservoir Reach).

In 2012, the SFPUC conducted an initial fish population monitoring effort in Cherry Creek from Valley Dam to Holm Powerhouse (the Cherry Creek Reach) and in Eleanor Creek from Lake Eleanor Dam to the confluence with Cherry Creek (the Eleanor Creek Reach). In 2016, the SFPUC reinitiated fish population monitoring in the Cherry Creek Reach using an approach and methods consistent with those used in the Hetch Hetchy Reach since 2014. Sampling in Cherry Creek was continued in 2017 with the addition of two fish population monitoring sites below Holm Powerhouse, extending the Cherry Creek Reach to the confluence with the Tuolumne River. Fish population monitoring was reinitiated in Eleanor Creek in 2017 from Lake Eleanor Dam to the confluence with Cherry Creek (the Eleanor Creek Reach), using an approach and methods consistent with those initiated with the 2014 sampling.

Given the management emphasis of state and federal regulatory agencies on salmonids and sport fishing values, fish population monitoring is focused on evaluating long-term changes in native Rainbow Trout (*Oncorhnychus mykiss*) and non-native Brown Trout (*Salmo trutta*) populations. Other native fish species known to occur in the Upper Tuolumne River include Riffle Sculpin (*Cottus gulosus*), California Roach (*Lavinia symmetricus*), and Sacramento Sucker (*Catostomus occidentalis*). These non-salmonid species are observed infrequently upstream of Preston Falls.

This technical memorandum summarizes the fish population monitoring methods and results for surveys in the Hetch Hetchy Reach, the Above Hetch Hetchy Reservoir Reach, the Cherry Creek Reach, and the Eleanor Creek Reach during 2017. Fisheries monitoring results from previous years are also presented for comparison where appropriate.

2 SAMPLING APPROACH

The sampling approach was designed to monitor Rainbow Trout and Brown Trout populations in sufficient detail to detect meaningful differences over time. The approach focused on locations likely to provide "good" habitat conditions for trout. In this context, "good" habitat refers to habitats having numerous locations where trout would be expected to use and defend bioenergetically profitable feeding locations and where a variety of trout age and size classes would be present. The results are intended to provide an estimate of trout abundance at the sample locations and a reasonable metric of trout abundance within each sub-reach for tracking population trends.

The sampling framework for the Hetch Hetchy Reach used habitat typing by the U.S. Fish and Wildlife Service (USFWS) to describe the distribution and abundance of aquatic habitat in the reach (USFWS 1992). Monitoring sites were selected from within this framework based on criteria developed to meet sampling objectives and key sampling considerations. The primary sampling objective of the revised approach was to incorporate methods that control for statistical bias and allow sample variance and confidence intervals (CI) to be calculated for abundance estimates. These methods improve the ability to detect differences among sites and (sampled) sub-reaches, and changes over time that are statistically significant. Key sampling site considerations included access, efficiency, effectiveness, and repeatability. See Stillwater Sciences (2016) for a detailed discussion.

In 2016, fish population monitoring sites were added in the Above Hetch Hetchy Reservoir Reach to aid in understanding annual variation and long-term trends for a population subject to "natural" unregulated flow conditions. The Above Hetch Hetchy Reservoir Reach differs from the lower three sub-reaches in that habitat quantity and quality are governed by the natural flow regime. Annual monitoring of trout populations in the Above Hetch Hetchy Reservoir Reach will serve as a "control" and increase the ability to understand whether changes in trout populations in reaches downstream from the reservoir are the result of management actions. Although the Above Hetch Hetchy Reservoir Reach is subject to natural flow conditions, fish populations may be influenced by access to Hetch Hetchy Reservoir. In addition, the reach upstream of the reservoir is at a higher elevation compared with reaches downstream, and therefore may be influenced by slightly different climactic conditions.

In Cherry Creek and Eleanor Creek, the sampling framework was based on mesohabitat mapping conducted by McBain Associates in Cherry Creek during summer 2016 (Stillwater 2016) and in Eleanor Creek during summer 2017 (see Section 4.1). Sample sites were selected using similar criteria to those used to select sites in the Hetch Hetchy Reach, with the intent of achieving similar sampling objectives. Sites were selected based on their ease of access, sampling efficiency and repeatability, and their representativeness of the monitoring reach.

In 2017, the Cherry Creek Reach was extended to the confluence with the Tuolumne River to include the Holm Powerhouse sub-reach. During a typical water year, flows in the Holm Powerhouse sub-reach are higher during most of the year compared with the upstream sub-reaches. Due to Cherry Lake being drained in the late summer and early fall to fix a release valve at Cherry Dam, flows in the Holm Powerhouse sub-reach were low enough to conduct fish population monitoring (approximately 40 cubic feet per second [cfs] after October 9, 2017) during the snorkel survey events. Two sites were added in this reach to document fish populations in this reach during abnormally low flows and to assess how fish populations differed downstream of Holm Powerhouse compared with the rest of Cherry Creek because of the sustained higher flows in this reach under normal flow release conditions.

3 ELEANOR CREEK MESOHABITAT MAPPING

Mesohabitat mapping was conducted by McBain Associates with assistance from the SFPUC in Eleanor Creek from Lake Eleanor Dam to the confluence with Cherry Creek in summer 2017. The purpose of mesohabitat mapping was to quantify the amount, location, and type of mesohabitats available to salmonids. Mesohabitat mapping also provides a framework for sample site selection where specific mesohabitat units can be identified for sampling based on habitat-specific attributes as defined by the site selection criteria. The 2017 snorkel survey sites in Eleanor Creek were selected using site selection criteria similar to those used for the Hetch Hetchy Reach.

Mesohabitat mapping for Eleanor Creek was done first by orthorectified aerial photography, then verified using ground-based surveys. The first delineation of mesohabitat units was conducted in the office with a geographic information system (GIS) using polygon coverage, orthorectified aerial photography, and Eleanor Creek "center line" stationing (provided by McBain Associates). Mesohabitat types and boundaries were visually estimated for each unit based on California Department of Fish and Wildlife (CDFW) predetermined mesohabitat classifications (Table 1) and numbered continuously from downstream to upstream. Length, area, and average width of each mesohabitat unit were calculated with GIS using the polygon coverage.

Table 1. Mesohabitat types and descriptions used to characterize the Cherry Creek monitoring reach. Types and descriptions were based on CDFW Level III habitat typing methodology (Flosi et al. 2010), and not all mesohabitat types were observed in the monitoring reach.

Mesohabitat type	Description
Cascade	>10% gradient and boulder
Chute	>10% gradient and bedrock
Deep pool	>6 feet maximum depth
Shallow pool	<6 feet maximum depth
Glide/pool tail	Typically, in the downstream portion of a pool with negative bed slope where converging flow approaches the riffle crest. Wide, shallow, flat bottom with little to no surface agitation. Substrate type is typically smaller than riffle, but coarser than pool, and often provides best salmonid spawning habitat.
Run	Long, smoothly flowing reaches, flat or concave bottom, and deeper than riffles with less surface agitation. Higher velocities than pools.
Boulder garden	Moderate to low gradient riffles, runs, and glides with numerous large boulders/obstructions that create scour pockets and eddies with near zero velocity. Often no clear thalweg present due to multiple flow paths.
High-gradient riffle	>4% and <10% gradient. Substrate is usually large boulder and bedrock (>24 inches).
Low-gradient riffle	<4% gradient. Substrate is usually small boulder and large cobble (6–24 inches).
Side channel	Contains <20% of total flow. Connected at top and bottom to main channel at low flow.
Backwater	Low to zero velocity; only connected to main channel from one end.
Sand-filled pool	Was a pool in 2007 photo, now filled with sand from hillslope erosion (unique to Rim Fire impacts).
Island	In between a split channel (used to enable mesohabitat unit area and width to be adjusted).
Medial bar	Medial gravel bar (used to enable mesohabitat unit area and width to be adjusted).

After office-based surveys were completed, verification was done by an on-ground, reconnaissance-level mesohabitat mapping survey. Survey data included characterization of habitat availability for rearing salmonids including large woody debris counts by size class (Table

2), identification of spawning gravels, and maximum and average depths of pool mesohabitat types. Ground-based mapping was conducted at approximately the same streamflow (29 cfs) at which aerial photos were taken (21 cfs at United States Geological Survey [USGS] gage 11278000 Eleanor Creek near Hetch Hetchy) so that water surface elevations and wetted channel widths would be similar, and verification of office-based mapping would be easier.

Table 2. Large woody debris sizes classes used for tallying wood found in mesohabitat units during reconnaissance-level mesohabitat mapping. Size classes were based on CDFW Level III habitat typing methodology (Flosi et al. 2010), and not all categories were observed in the monitoring reach.

Diameter (inches)	Length (feet)
6–12	3–10
12–24	10–25
24–36	25–50
>36	50–75
	>75

Glide/pool tail-out and sand-filled pool were the only two habitat types not represented in the monitoring reach. The most dominant habitat types identified were deep pool, cascade, high-gradient riffle, and boulder garden, which cumulatively made up 74 percent of total reach length (Table 3). The average depth was 9.1 feet among deep pools and 5.1 feet among shallow pools. Daily average streamflow at the time of the survey was 29 cfs (USGS gage 11278000 Eleanor Creek near Hetch Hetchy).

Table 3. Characterization of habitat types found in Eleanor Creek.

Mesohabitat type	Count of habitat units	Percent of habitat units	Average length (feet)	Average width (feet)	Total area (square feet)	Average maximum depths (feet)
Cascade	29	17%	65.5	32.6	61,271	n/a
Chute	2	1%	31.1	31.6	1,788	n/a
Deep pool	47	28%	104.4	42.0	212,554	9.1
Shallow pool	13	8%	92.4	39.0	49,791	5.1
Run	9	5%	153.7	36.3	51,265	n/a
Boulder garden	24	14%	216.2	48.2	274,703	n/a
High-gradient riffle	25	15%	134.4	35.9	130,981	n/a
Low-gradient riffle	13	8%	171.0	34.1	88,762	n/a
Side channel	2	1%	363.9	17.1	13,436	n/a
Backwater	1	1%	90.5	10.4	944	n/a
Island	1	1%	450.0	98.5	44,327	n/a
Medial bar	3	2%	67.8	172.0	20,215	n/a

n/a = not applicable. Water depths were not measured in these habitat types.

4 MONITORING SITES

Fish population monitoring sites in the Hetch Hetchy Reach of the Upper Tuolumne River were established and surveyed in 2014 and resurveyed in 2015–2017 with minor modifications to the specific sites surveyed. Additional fish population monitoring sites were established and surveyed in Cherry Creek and the Tuolumne River above Hetch Hetchy Reservoir in 2016, and in Eleanor Creek in 2017. Initial surveys of the Cherry Creek and Eleanor Creek reaches were performed in 2012. Monitoring in Cherry Creek was expanded in 2017 to include the Holm Powerhouse sub-reach. Monitoring sites within each surveyed reach represent the dominant habitat types in the reach by length and are distributed to capture longitudinal variability.

4.1 Site Selection

Sixteen monitoring sites were sampled in the Hetch Hetchy Reach during 2017. Monitoring sites sampled in the Hetch Hetchy Reach during 2017 were the same as those sampled in 2016 with one modification, the removal of a deep pool (site 38-DP) in the Early Intake sub-reach.

Four monitoring sites were sampled in the Above Hetch Hetchy Reservoir Reach in 2017. Modifications to the sites sampled in 2016 included adding one pocketwater (site 505-PW) and removing one shallow pool (507-SP).

In 2017, sites in Cherry Creek surveyed in 2016 were modified to include two sites in the Holm Powerhouse sub-reach (sites DP-16 and DP-14) and to eliminate sites where fish densities were low, visibility was poor, and habitat conditions at the site were deemed to be low quality for fish rearing. Sites were selected in three sub-reaches: Upper Cherry, Lower Cherry, and Holm Powerhouse (see Section 4.2.3 for more detail). Modifications to the sites sampled in 2016 included adding two shallow pools (sites 278-SP and 396-SP) in the Upper Cherry sub-reach, adding two deep pools (sites 32-DP and 270-DP) and one shallow pool (site 45-SP) in the Lower Cherry sub-reach, and adding two deep pools (sites 14-DP and 16-DP) in the Holm Powerhouse sub-reach.

In Eleanor Creek, 2012 snorkel survey sites encompassed a sequence of adjacent habitat units and therefore habitat-specific abundance estimates are unavailable, except for site DP-107, which was sampled individually. In 2017, survey sites were modified to encompass only one habitat unit so that trout populations could be compared among habitat types. In addition, one boulder garden site (5-BG) was added to increase the range of habitat types surveyed in Eleanor Creek and was selected from 2017 mesohabitat mapping data based on the site selection criteria.

Site selection and modifications including newly selected sites were based on criteria developed to meet the sampling objectives and were intended to focus effort on sites that can be efficiently and effectively sampled with high repeatability and to reflect the habitat composition within each sub-reach. The monitoring approach focuses on sampling locations that are likely to provide "good" habitat conditions for trout, referring to habitats with numerous locations where trout would be expected to use and defend bioenergetically profitable feeding locations and where a variety of trout age and size classes would be present.

4.2 Surveyed Sites

4.2.1 Hetch Hetchy Reach

A total of 16 monitoring sites in the Hetch Hetchy Reach were sampled in 2017: six in the Early Intake sub-reach, six in the Preston Falls sub-reach, and four in the O'Shaughnessy sub-reach (Table 4, Figure 1). Sites included deep pool, shallow pool, and pocketwater habitat types, which comprise 75 to 90 percent of habitats in the sub-reaches sampled (Table 5). Run, riffle, cascade, and chute habitat types were not included because (1) they did not meet site selection criteria, and/or (2) there was very little representation of these habitat types within the sub-reaches sampled.

The length of each monitoring site was estimated with GIS using a polygon coverage defining upstream and downstream boundaries (provided by the SFPUC), orthorectified aerial photography, and Tuolumne River "center line" stationing. Estimates of surveyed length were used to calculate linear fish density (fish/1,000 feet). Stationing from 2017 is the same as 2016 and reflects an updated downstream boundary (i.e., station 000+00) at the Wards Ferry Bridge (Table 4).

In 2017, sampling coverage by length was 10 percent, 11 percent, and 8 percent for the Early Intake, Preston Falls, and O'Shaughnessy sub-reaches, respectively (Table 6). Within the sub-reaches, 2017 sampling coverages by length for deep pool, shallow pool, and pocketwater habitat types were 7 to 14 percent, 23 to 33 percent, and 4 to 11 percent, respectively (Table 6).

Table 4. 2017 fish population monitoring sites in the Hetch Hetchy Reach with GIS stationing.

Site ID[1]	Habitat type[1]	Longitudinal stationing[2] (feet)		Surveyed length (feet)
		Downstream	Upstream	
Early Intake sub-reach				
11-SP	shallow pool	1483+48	1485+01	153
13-DP	deep pool	1485+98	1487+93	194
18-PW	pocketwater	1512+49	1514+45	197
27-SP	shallow pool	1533+85	1536+59	274
34-DP	deep pool	1556+96	1558+67	170
37-PW	pocketwater	1565+91	1567+24	133
Preston Falls sub-reach				
44-PW	pocketwater	1578+64	1580+33	169
46-DP	deep pool	1580+66	1581+94	129
49-SP	shallow pool	1584+53	1586+10	157
56-DP	deep pool	1593+73	1596+20	246
74-DP	deep pool	1652+21	1654+71	249
76-SP	shallow pool	1656+32	1657+78	146
O'Shaughnessy sub-reach				
223-DP	deep pool	2004+60	2006+96	236
227-DP	deep pool	2009+52	2011+02	150
229-PW	pocketwater	2012+24	2014+40	217
267-SP	shallow pool	2077+05	2079+60	255

1 Based on USFWS habitat typing data. Monitoring site numbers refer to sequential habitat unit numbers from Kirkwood Powerhouse to O'Shaughnessy Dam (data provided to Stillwater Sciences by McBain Associates).
2 Stationing is based on the GIS center line for the Tuolumne River from the Wards Ferry Bridge upstream of Don Pedro Reservoir [river mile (RM) 0] upstream to O'Shaughnessy Dam.

Table 5. Composition of study sub-reaches by habitat type.

Study sub-reach	Habitat type composition by length (percent)						
	Deep pool	Shallow pool	Run	Riffle	Cascade	Pocketwater[1]	Chute
Early Intake	23	12	5	0	0	60	0
Preston Falls	66	12	2	1	2	16	1
O'Shaughnessy	55	11	<1	7	4	16	6

[1] Includes habitats classified as PW (pocketwater) and PW/CA (pocketwater/cascade).

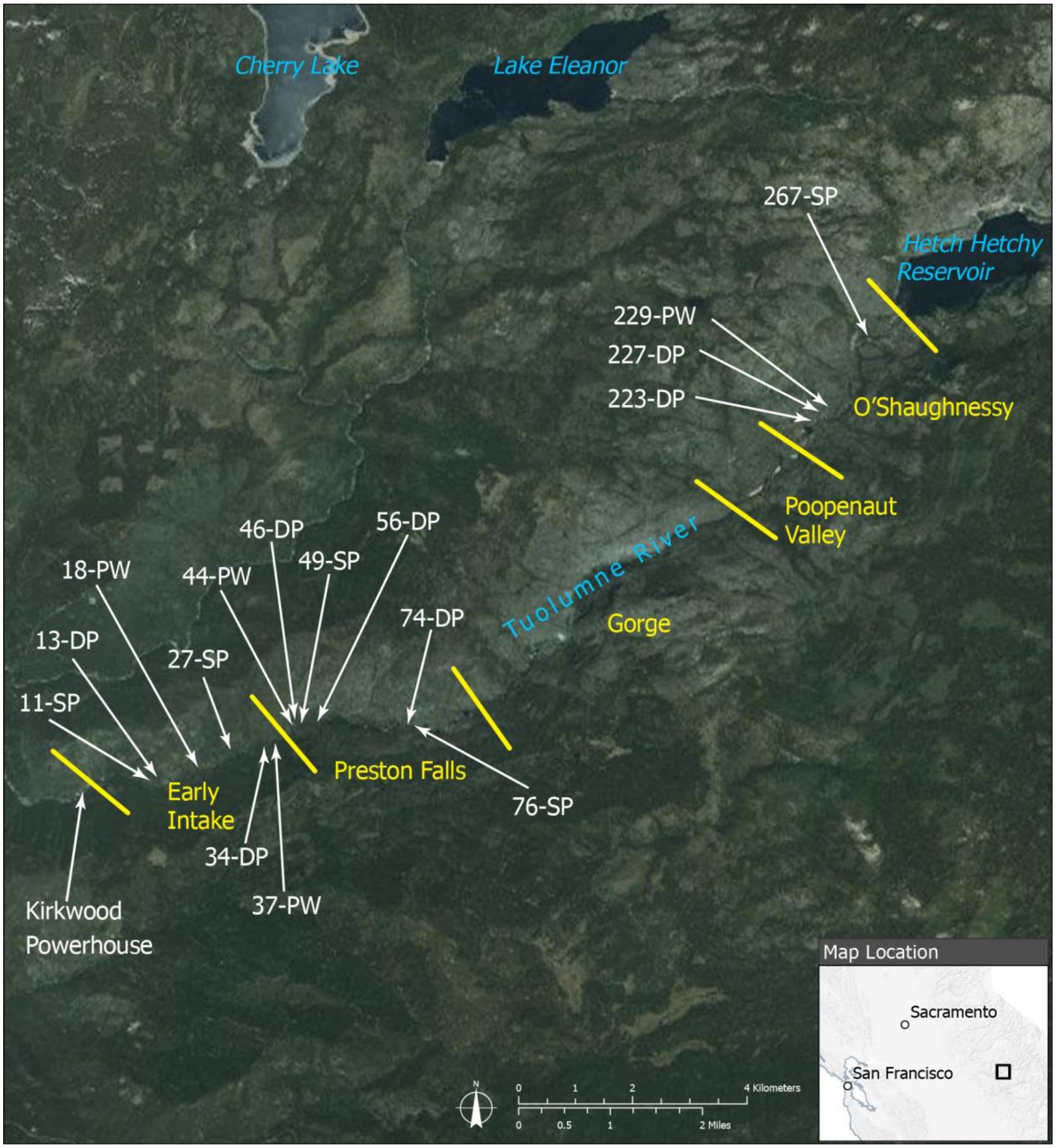

Figure 1. Fish population monitoring site locations in the Hetch Hetchy Reach.

Table 6. Percent length of sub-reaches surveyed by habitat type in the Hetch Hetchy Reach.

Sub-reach	Sub-reach length surveyed by habitat type (percent length)			Total sub-reach length surveyed (percent length)
	Deep pool	Shallow pool	Pocketwater	
Early Intake	14	33	4	10
Preston Falls	10	24	10	11
O'Shaughnessy	7	23	11	8

4.2.2 Above Hetch Hetchy Reservoir Reach

Four monitoring sites were surveyed in the Above Hetch Hetchy Reservoir Reach during 2017: two pocketwaters (505-PW and 510-PW), one shallow pool (511-SP), and one deep pool (514-DP) (Table 7, Figure 2).

Table 7. 2017 fish population monitoring sites in the Above Hetch Hetchy Reservoir Reach with GIS stationing.

Site ID[1]	Habitat type[2]	Longitudinal stationing[3] (feet)		Surveyed length (feet)
		Downstream	Upstream	
505-PW	pocketwater	2540+51	2542+18	168
510-PW	pocketwater	2549+28	2550+32	105
511-SP	shallow pool	2550+33	2551+71	138
514-DP	deep pool	2556+30	2557+76	146

[1] Monitoring site identification numbers refer to sequential habitat unit numbers from Kirkwood Powerhouse to O'Shaughnessy Dam (data provided to Stillwater Sciences by McBain Associates).
[2] Habitat type designations based on USFWS habitat typing data.
[3] Stationing is based on the GIS center line for the Tuolumne River from the Wards Ferry Bridge upstream of Don Pedro Reservoir (RM 0) upstream to O'Shaughnessy Dam.

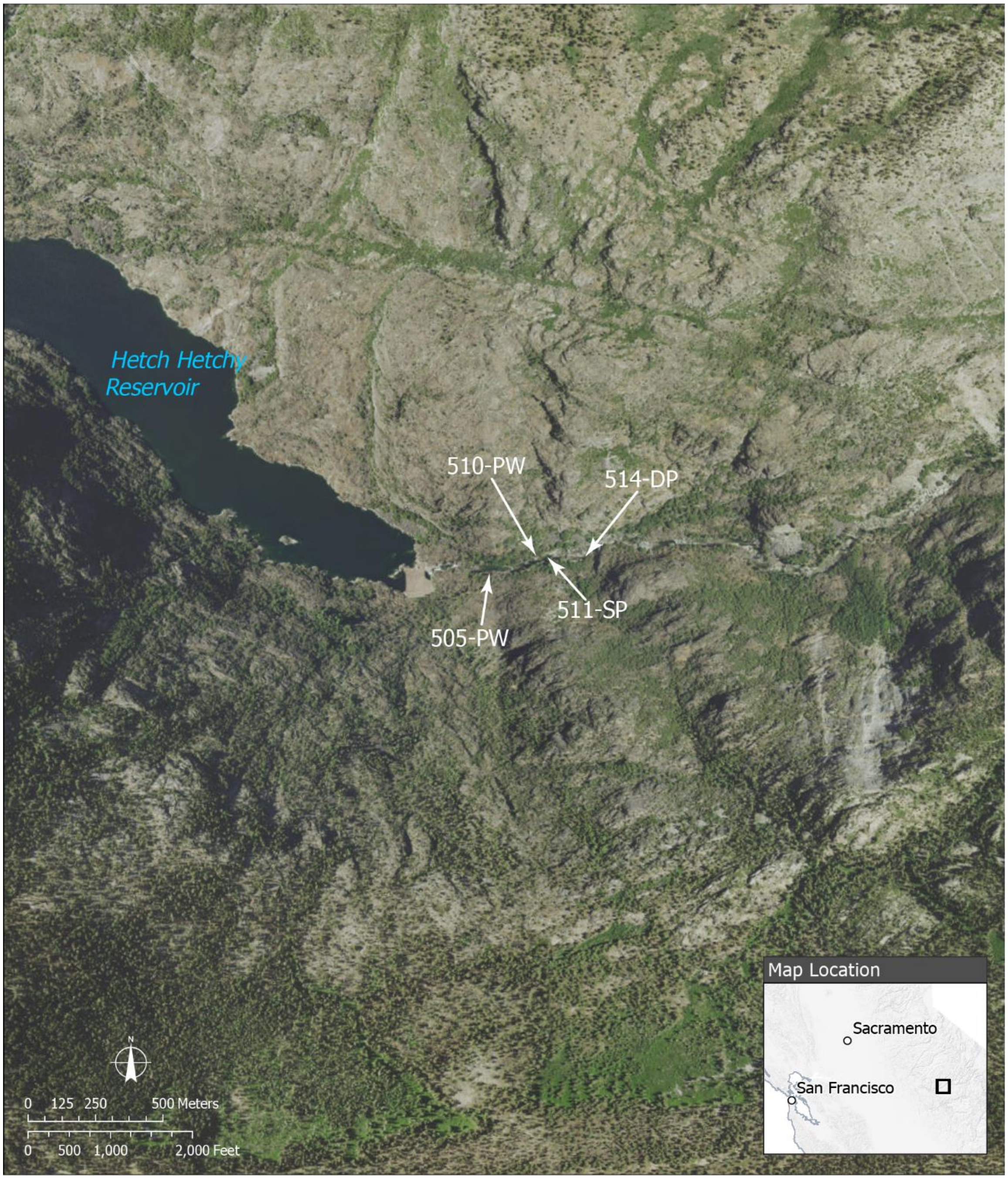

Figure 2. 2017 fish population monitoring site locations in the Above Hetch Hetchy Reservoir Reach.

4.2.3 Cherry Creek and Eleanor Creek Reaches

Snorkel surveys in the Cherry Creek Reach were performed from Valley Dam to the confluence with the Tuolumne River in fall 2017. The Cherry Creek Reach was divided into three sub-reaches: Upper Cherry sub-reach, Lower Cherry sub-reach, and Holm Powerhouse sub-reach (Figure 3). Snorkel surveys in the Eleanor Creek Reach were performed from Lake Eleanor Dam to the confluence with Cherry Creek in fall 2017 (Figure 3). Due to its relatively short length (4 river miles) and lack of any operational inputs (e.g., powerhouses), Eleanor Creek was not separated into sub-reaches like the Hetch Hetchy Reach and Cherry Creek. Monitoring sites were selected based on the same criteria used for the Upper Tuolumne River snorkeling efforts (Stillwater Sciences 2016). A total of 12 monitoring sites were sampled in the Cherry Creek Reach—three in the Upper Cherry sub-reach, seven in the Lower Cherry sub-reach, and two in the Holm Powerhouse sub-reach—while a total of six monitoring sites were selected in Eleanor Creek (Table 8, Figure 3). The length of each monitoring site was estimated with GIS using polygon coverage (.kmz), orthorectified aerial photography, and GIS "center line" stationing (Table 8). The total length surveyed in each sub-reach was 542 feet in the Upper Cherry sub-reach, 1,250 feet in the Lower Cherry sub-reach, 375 feet in the Holm Powerhouse sub-reach, and 589 feet in the Eleanor Creek Reach, which was 2 percent, 4 percent, 10 percent and 3 percent of the total length of each reach, respectively (Table 9). Monitoring sites included shallow pool, deep pool, boulder garden, and run habitat types. These four habitat types represented 71 percent of the total length of the Upper Cherry sub-reach,77 percent of the Lower Cherry sub-reach, 27 percent of the Holm Powerhouse sub-reach, and 70 percent in the Eleanor Creek Reach (Table 10). Monitoring sites did not include riffle, cascade, and chute habitat types because (1) they did not meet site selection criteria (e.g., could not be effectively sampled), and/or (2) there was very little representation of these habitat types within the reaches sampled.

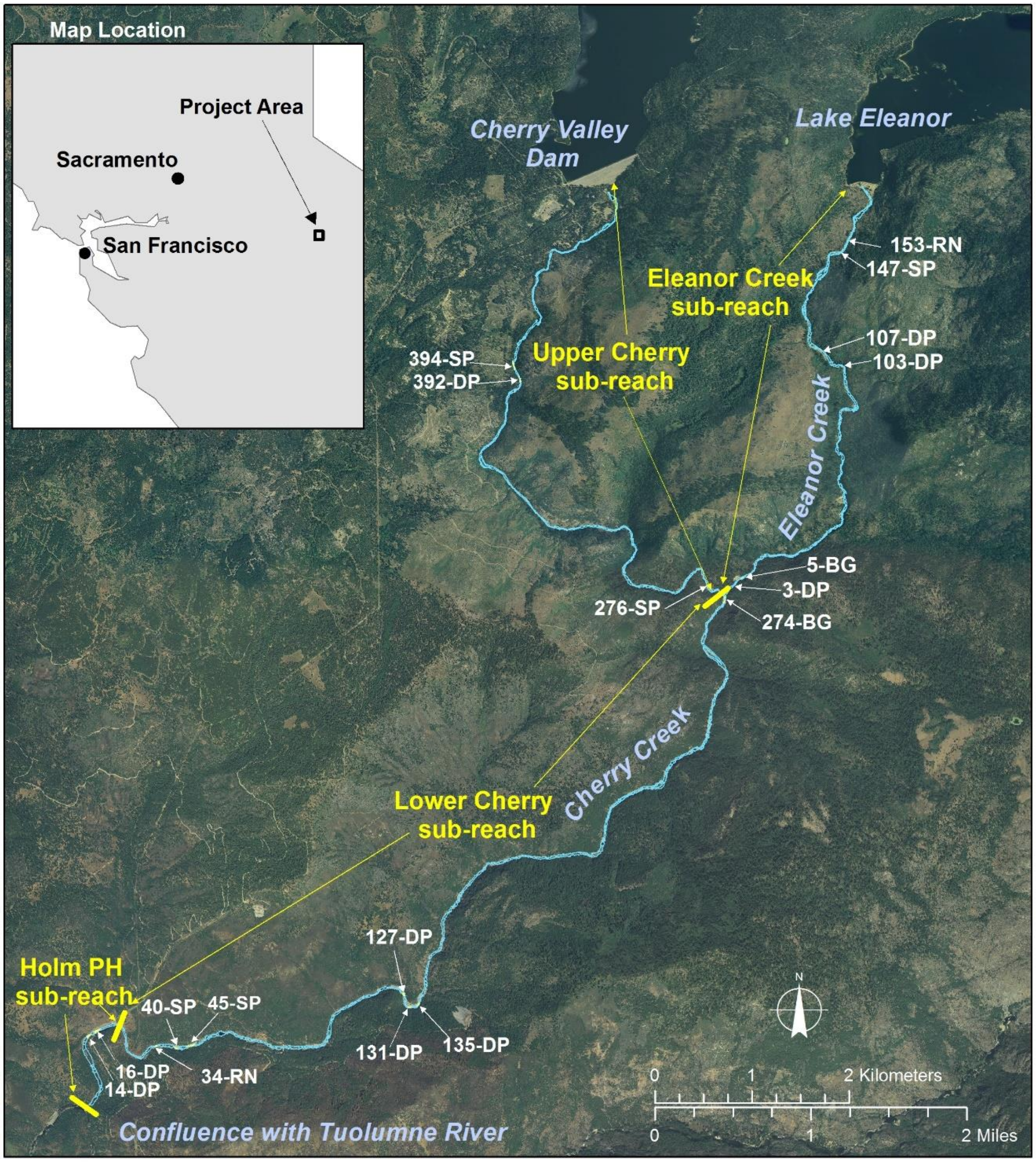

Figure 3. 2017 fish population monitoring site locations in Cherry and Eleanor creeks.

Table 8. Fish population monitoring sites in the Cherry Creek and Eleanor Creek reaches.

Site ID[1]	Habitat type[1]	Stationing[2]		Surveyed length (feet)
		Downstream	Upstream	
Upper Cherry sub-reach				
394-SP[3]	shallow pool	547+90	550+55	265
392-DP	deep pool	543+17	545+36	219
276-SP[3]	shallow pool	383+45	384+03	58
Lower Cherry sub-reach				
274-BG[3]	boulder garden	379+72	382+05	233
135-DP	deep pool	169+12	170+72	160
131-DP[3]	deep pool	165+83	167+32	149
127-DP	deep pool	160+00	161+45	145
45-SP	shallow pool	72+36	75+07	271
40-SP[3]	shallow pool	67+70	69+51	181
34-RN	run	61+06	62+17	111
Holm Powerhouse sub-reach				
16-DP	deep pool	30+93	33+16	223
14-DP	deep pool	27+78	29+30	152
Eleanor Creek Reach				
153-RN	run	172+07	172+70	63
147-SP	shallow pool	167+27	168+37	110
107-DP	deep pool	123+35	124+32	97
103-DP	deep pool	113+96	114+85	89
5-BG	boulder garden	8+92	10+29	137
3-DP	deep pool	5+58	6+51	93

1 Monitoring site numbers refer to sequential habitat unit numbers from the Tuolumne River confluence to Valley Dam.
2 Stationing is based on the GIS center line for Cherry Creek from the Tuolumne River confluence (RM 0) upstream of Valley Dam (RM 11).
3 Monitoring sites surveyed in 2012.

Table 9. Percent length of sub-reaches surveyed by habitat type in the Cherry Creek and Eleanor Creek reaches.

Sub-reach	Sub-reach length surveyed by habitat type (percent length)				Total sub-reach length surveyed (percent length)[1]
	Deep pool	Shallow pool	Boulder garden	Run	
Upper Cherry	5	7	0	0	2
Lower Cherry	5	10	2	7	4
Holm Powerhouse	39	n/a	n/a	n/a	10
Eleanor Creek	6	9	3	5	3

1 Excludes islands, medial bars, and sand filled pools (<1 percent in Cherry Creek).
n/a Habitat type not present in sub-reach

Table 10. Percent length of habitat types in the Cherry Creek Reach. Excludes islands, medial bars, and sand-filled pools (<1 percent in Cherry Creek).

Sub-reach	Habitat type (percent length)										
	Cascade	Chute	Deep pool[1]	Shallow pool[1]	Glide/ Pool tail	Run[1]	Boulder garden[1]	High-gradient riffle	Low-gradient riffle	Side channel	Backwater
Upper Cherry	2	8	16	19	3	7	29	8	5	3	1
Lower Cherry	10	3	27	13	1	4	33	8	0	0	1
Holm Powerhouse	13	0	27	0	0	0	0	53	7	0	0
Eleanor Creek	9	0	23	6	7	25	16	11	3	0	9

1 Habitat types selected for monitoring in Cherry Creek.

5 METHODS

The three-pass snorkel survey method (Routledge 1982) was used to estimate fish population abundance in all reaches and years except on Cherry and Eleanor creeks in 2012. Fewer than three passes were performed at some sites when sampling time was limited. The standardization of snorkel survey methods across reaches and years allows for comparable results and trend assessments. Employing multi-pass snorkel methods allows for variance to be estimated and CI to be calculated, which improves the ability to determine whether changes to fish populations over time are meaningful.

The three-pass method allows abundance estimates and CI to be computed using a bounded counts estimator (Routledge 1982). This method assumes that each fish is observable, that there is a reasonable chance of seeing all fish during a single pass, and that no fish are counted twice during a single pass. There are various ways of deriving the estimator. For this application, the following formula was used:

$$\tilde{y}_B = d_{[m]} + (d_{[m]} - d_{[m-1]})$$

where $d_{[m]}$ is the maximum number of fish counted during any of the passes, and $d_{[m-1]}$ is the second highest count; counts are arranged in ascending order as:

$$d_{[1]} \le d_{[2]} \le d_{[3]} \le \cdots \le d_{[m-1]} \le d_{[m]} .$$

The bounded-counts estimate of the mean squared error is estimated as in Robson and Whitlock 1964 as:

$$\widehat{\text{MSE}} = \left(d_{[m]} - d_{[m-1]}\right)^2$$

This was used as a surrogate for the square of the standard error (SE), for reporting population estimates in the form "Estimate ($\pm$SE)" and calculating nominal confidence intervals as "Estimate 1.96 $\times$ SE".

Abundance estimates were used to calculate linear fish density (i.e., fish/1,000 feet) to normalize for length and allow comparisons of abundance between individual monitoring sites and reaches. Linear density was calculated for each monitoring site by dividing site abundance by site length (resulting in fish abundance per foot of stream), and then multiplying by 1,000 to calculate linear fish density (fish/1,000 feet) for the site. A weighted mean was used for calculating linear density at the reach level.

5.1 Hetch Hetchy Reach

Fish population monitoring surveys in the Hetch Hetchy Reach were performed on August 18–20 and 25–27, 2017. Average daily streamflow during 2017 monitoring surveys was 133 cfs at the upstream end of the reach (USGS gage 11276500 near Hetch Hetchy) and 132 cfs at the downstream end of the reach (USGS gage 11276600 above Early Intake). Sixteen monitoring sites were surveyed in 2017. Three-pass, bounded count snorkel surveys were conducted at all monitoring sites in 2017. Field crews generally consisted of five snorkelers and one shore-based safety/data recorder. For each of the three snorkel passes, snorkelers entered the site from downstream and snorkeled in an upstream direction, each within a designated lane. Snorkelers identified, counted, and visually estimated total length of trout in their own lane while moving upstream at a slow and uniform pace. Dive slates were used to tally fish observed by species and length class, and fish observation data were recorded with a field computer at the end of each pass. General site habitat characteristics and water quality observations were also recorded for each site.

5.2 Above Hetch Hetchy Reservoir Reach

Fish population monitoring surveys in the Above Hetch Hetchy Reservoir Reach were performed on October 5, 2017 when average daily streamflow was 78 cfs (USGS gage 11274790 above Hetch Hetchy). Snorkel surveys were conducted at each of the four monitoring sites using methods similar to those described above for the Hetch Hetchy Reach. Three-pass methods were used at one monitoring site (514-DP), two-pass methods were used at two monitoring sites (510-PW, 511-SP), and one-pass methods were used at one monitoring site (505-PW).

5.3 Cherry Creek and Eleanor Creek Reaches

Fish population monitoring surveys in the Cherry Creek Reach were performed on October 9, 10, and 13, 2017 when daily average streamflow was 14 to 18 cfs at the upstream end of the reach (USGS gage 11277300 below Valley Dam), 30 to 35 cfs above Holm Powerhouse near the downstream end of the reach (USGS gage 11278300 above Holm Powerhouse), and 40 cfs below Holm Powerhouse at the downstream end of the reach (USGS gage 11278400 below Holm Powerhouse) (see Section 6.3 for additional information on stream gages). Snorkel surveys employed the three-pass method using a similar sampling approach with two to three snorkelers and one shore-based safety/data recorder. Due to the change in flow releases from Cherry Valley Dam in the late fall to drain Cherry Lake, turbidity levels in Cherry Creek upstream of the confluence with Eleanor Creek were abnormally high and decreased visibility during snorkeling.

Habitat characteristics were recorded for each monitoring site and included weather, visibility (feet), dominant and subdominant substrate types (silt, sand, gravel, cobble, and boulder), percent instream cover type (boulder, bubble curtain, undercut bank, large woody debris, instream vegetation, bedrock ledge), water temperature (degrees Celsius [ºC]), and maximum depth. In addition, photos and Global Positioning System (GPS) points at the upstream and downstream end of each reach were taken to document the extent of each site.

Fish population monitoring surveys in the Eleanor Creek Reach were performed on October 11 and 12, 2017 when daily average streamflow was 13 cfs (USGS gage 11278000 Eleanor Creek near Hetch Hetchy). Snorkel surveys employed the three-pass method using a similar sampling approach with two to three snorkelers and one shore safety/data recorder. It is important to note that the 2012 Eleanor Creek snorkel surveys only employed a one-pass method, and reported abundances are based on direct enumeration. As a result, CI could not be calculated for the 2012 survey data. In addition, each sample site in 2012 covered multiple habitat types compared with one habitat type per sample site in 2017. For the purpose of reporting, it was only possible to compare linear densities of fish in Eleanor Creek between the 2012 and the 2017 survey, and a comparison of fish abundances by sample sites and habitat types was not possible.

6 RESULTS AND DISCUSSION

Length-frequency data were used to determine a length threshold for differentiating between age-0 and age-1 and older trout in the Hetch Hetchy, Above Hetch Hetchy Reservoir, Cherry Creek, and Eleanor Creek reaches to inform the interpretation of results. Differentiating between these two age classes improves the ability to understand how habitat conditions (e.g., flow and water temperature) influence fish populations in the monitoring reaches, since different environmental pressures influence fish abundance and survival for these age classes. Abundance and linear density were estimated to assess fish populations at the habitat unit, sub-reach, and reach scales, and to evaluate changes and trends in populations over time. Streamflow and water temperature at gages in each of the monitoring reaches provide information on habitat conditions and their influence on trout populations in the monitoring reaches.

6.1 Length and Age

6.1.1 Hetch Hetchy Reach

The length-frequency distributions for Rainbow Trout and Brown Trout in 2017 show different patterns than observed in 2014–2016. The 2017 length-frequency distributions indicate relatively low numbers of Rainbow Trout ≤125 millimeter (mm) and very low numbers of Brown Trout ≤175 mm compared with 2014–2016, suggesting relatively poor age-0 recruitment for both species in 2017 (Figure 4). For Rainbow Trout >125 mm, the length-frequency distribution pattern in 2017 is generally similar to the pattern in 2016. For Brown Trout >125 mm, the length-frequency distribution pattern in 2017 is difficult to interpret due to low overall observation frequency, but it is not inconsistent with the pattern in 2016.

The 2017 length-frequency distributions suggest that age-1 and older Rainbow Trout were mostly >125 mm, and age-1 and older Brown Trout were mostly >175 mm (Figure 4). Age-0 Brown Trout are expected to be slightly larger than Rainbow Trout at the same time of year based on differences in spawning and emergence timing between the two species. By age-1, length differences between the trout species may or may not be evident due to variable growth rates and strongly overlapping length distributions. The 2017 length-frequency data suggest that age-1 Brown Trout were >175 mm at the time of the survey. Minor differences in lengths between the two species may also be masked by using 25-mm length categories to track field observations. Aside from the apparent lack of age-0 Rainbow Trout and Brown Trout in 2017, the length-frequency distributions are not inconsistent with previous years (2014–2016).

Differences in the length-frequency distributions for Rainbow Trout and Brown Trout between 2014 and 2017 are likely the result of variable environmental conditions (e.g., flow and water temperature) and their influence on growth. It is common for length distributions to overlap between age classes because fish emerge at different times and grow at different rates based on competition and environmental conditions. Based on 2014–2017 length-frequency distributions, the length threshold between age-0 and age-1 trout appears to vary between about 125 and 175 mm, depending on the species and year (Figure 4).

For results presented in this document, the 125-mm threshold was used to differentiate between age-0 and age-1 and older trout, for the following reasons:

1. Length-frequency distribution patterns were similar in 2014–2017;
2. The apparent length thresholds differentiating between age-0 and age-1 and older trout were similar for 2014–2017;
3. Using the 125-mm length threshold is consistent with previous annual Fisheries Monitoring Reports (e.g., Stillwater Sciences 2016, Stillwater Sciences and McBain Associates 2017).
4. There is potential for environmental stochasticity to affect individual growth rates and length-frequency data, therefore, minor annual variations are expected and wouldn't necessarily warrant using a different length threshold.

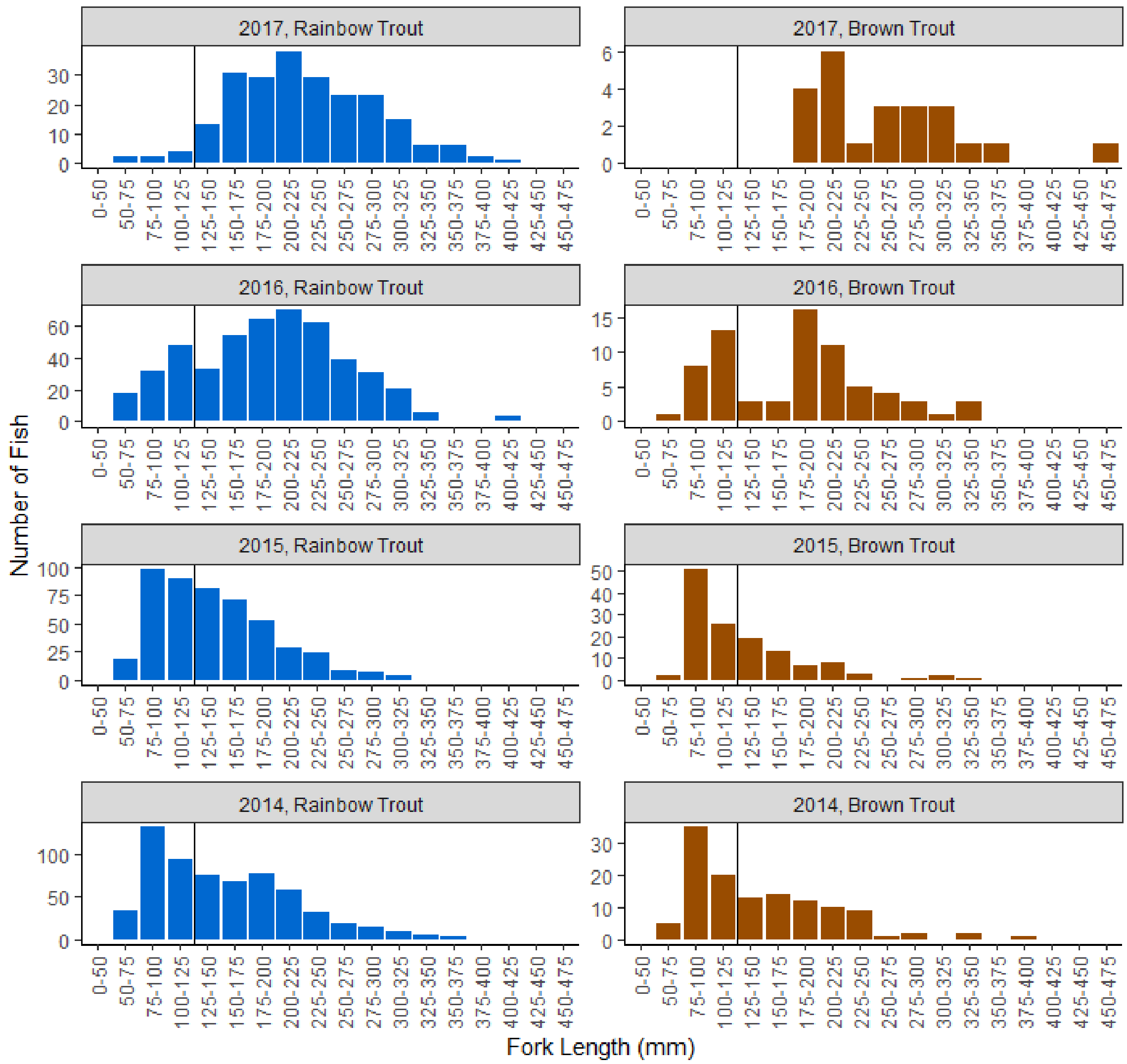

Figure 4. Length-frequency distributions for Rainbow Trout and Brown Trout observed at surveyed sites in the Hetch Hetchy Reach (first pass only). The vertical black line indicates the 125-mm size threshold used to differentiate between age-0 and age-1 and older trout. Note that the y-axis scale is optimized for viewing each data set.

6.1.2 Above Hetch Hetchy Reservoir Reach

Sample sizes of fish length observations in the Above Hetch Hetchy Reservoir Reach were too small to develop meaningful length-frequency distributions to assess trout length-at-age specific to this reach.

6.1.3 Cherry Creek and Eleanor Creek Reaches

During snorkel survey efforts in Cherry Creek in 2017, both Rainbow Trout and Brown Trout were observed, unlike during previous surveys (i.e., 2012 and 2016) when only Rainbow Trout were seen. Due to the limited occurrence of Brown Trout in Cherry Creek and the absence of Brown Trout observations in Eleanor Creek, length-frequency analyses were only performed for

Rainbow Trout. Length-frequency data for Rainbow Trout in the Cherry and Eleanor creeks reaches indicate a length threshold of 125 mm to 150 mm differentiating between age-0 and age-1 and older trout, which is consistent with previous years (2012 and 2016) (Figure 5). The 125-mm length threshold for differentiating between age-0 and age-1 and older trout is consistent with length-frequency data for Rainbow Trout in the Hetch Hetchy Reach during 2014–2017.

Length-frequency data for 2017 generally show similar distribution patterns to 2012 and 2016, with apparently good recruitment of age-0 trout ≤125 mm, and most age-1 fish in the 150–225 mm size range. A greater number of larger trout in the 225–300-mm and >300-mm size ranges were observed in 2017 compared with 2016 and 2012, which was largely due to adding the Holm Powerhouse sub-reach where numerous large trout were observed in 2017. In 2017 and 2016, few Rainbow Trout <50 mm were observed compared with 2012, which is likely explained by the timing of snorkel surveys (i.e., October 2017, September 2016, and August 2012); it is likely that most young-of-the-year Rainbow Trout had grown to >50 mm by September. The inclusion of sampling in the Eleanor Creek Reach in 2017 increased the total number of monitoring sites and the length of stream sampled in 2017 compared with 2016 and 2012.

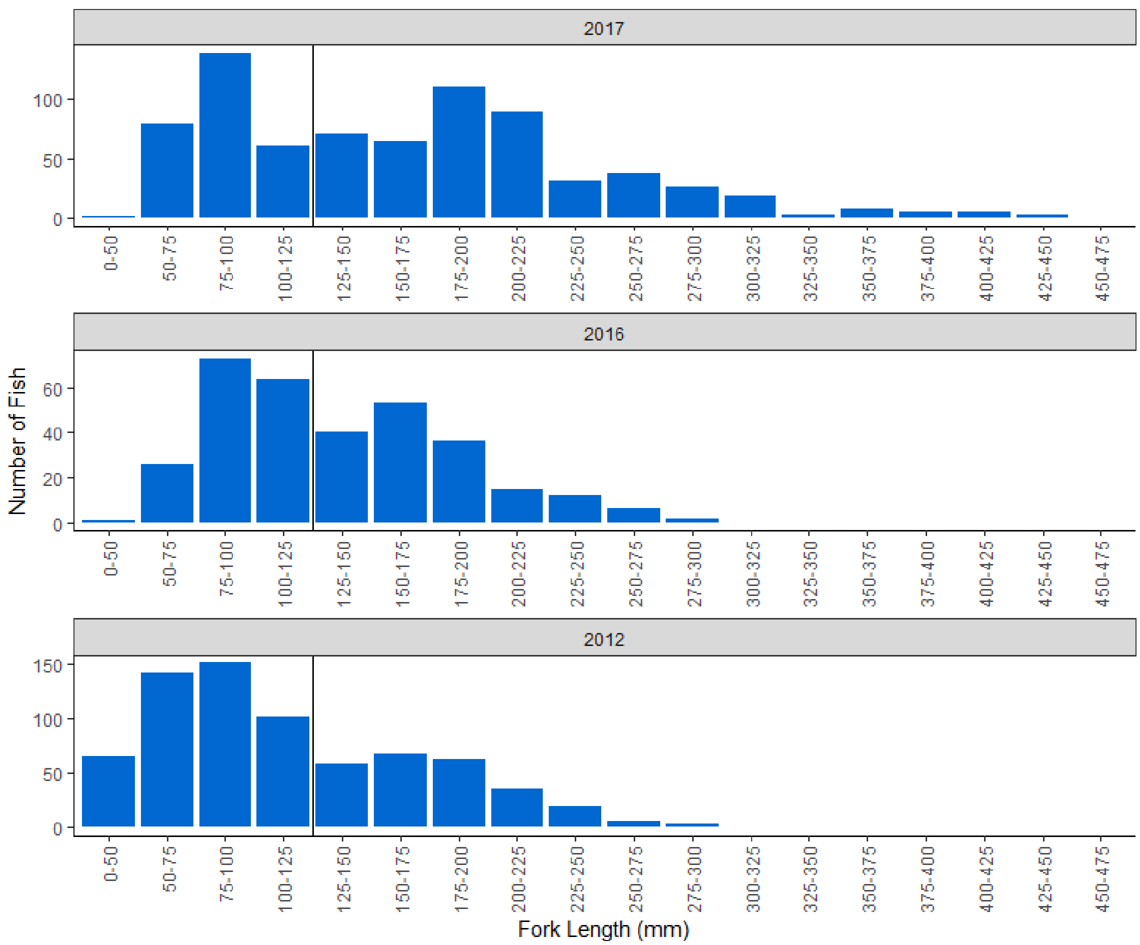

Figure 5. Length-frequency distribution for Rainbow Trout observed at surveyed sites in Cherry and Eleanor creeks during 2017, 2016, and 2012 (first pass only). The line indicates the approximate threshold between age-0 and age-1 and older trout. Note only the Cherry Creek Reach was surveyed in 2016.

6.2 Abundance and Linear Density Estimates

Fry abundance commonly fluctuates from year to year based on spawning and incubation success as well as environmental conditions (e.g., flows) soon after emergence. Age-0 trout (≤125 mm TL) abundance can be a useful indication of potential recruitment to older age classes and can aid in understanding how environmental conditions affect year class success. However, large variations in annual fry numbers can reduce the ability to detect meaningful trends in trout populations; therefore, annual fish population abundance results presented in this document focus on age-1 and older trout (>125 mm total length). In addition, age-1 and older trout have survived through at least one winter and are more likely to contribute to the adult population and reproduce. Within this document, when the length class is not specified, it is referring to trout >125 mm.

6.2.1 Hetch Hetchy Reach

6.2.1.1 2017 Monitoring

Trout >125 mm

The 2017 fish population monitoring results for trout abundance, relative abundance, and density are presented below for trout >125 mm (Tables 11–13, Figures 6–8). Total abundance estimates for all sites combined were 322, 45, and 340 for Rainbow Trout, Brown Trout, and all trout, respectively (Tables 12 and 13). Estimates for "all trout" include unidentified trout that are not included in the species-specific estimates. Rainbow Trout were more abundant than Brown Trout within each site, sub-reach, and habitat type. The ratio of Rainbow Trout to Brown Trout was 7.2:1 for all sites combined and ranged from 5.9:1 for the Preston Falls sub-reach to 8.1:1 for the Early Intake sub-reach. No Brown Trout >125 mm were observed at four of the sixteen sites (sites 37-PW, 44-PW, 49-SP, and 267-SP).

Rainbow Trout density in the Early Intake, Preston Falls, and O'Shaughnessy sub-reaches were 117, 81, and 103 fish/1,000 feet, respectively. Rainbow Trout densities were greatest in deep pools (117 fish/1,000 feet) and pocketwaters (101 fish/1,000 feet), and lowest in shallow pools (76 fish/1,000 feet). Brown Trout densities by sub-reach ranged from 14 to 15 fish/1,000 feet. Brown Trout density was greatest in pocketwaters (21 fish/1,000 feet), followed by deep pools (15 fish/1,000 feet) and shallow pools (7 fish/1,000 feet). Since Rainbow Trout density was substantially greater than Brown Trout density, density patterns for "all trout" generally follow those for Rainbow Trout. Density estimates for all trout >125 mm ranged from 16 fish/1,000 feet at site 267-SP to 235 fish/1,000 feet at site 34-DP. Site 34-DP stood out as having relatively high density in 2017, and site 267-SP as having relatively low density.

Table 11. Abundance estimates for Rainbow Trout and Brown Trout >125 mm by site in the Hetch Hetchy Reach in 2017 (95 percent CI).

Site	Habitat type	Trout >125 mm (age-1 and older)		
		Rainbow Trout	**Brown Trout**	**All trout[1]**
Early Intake sub-reach				
11-SP	shallow pool	14 (±2)	2 (±2)	13 (±0)
13-DP	deep pool	31 (±10)	3 (±2)	31 (±8)
18-PW	pocketwater	16 (±0)	9 (±8)	27 (±10)
27-SP	shallow pool	34 (±6)	2 (±2)	35 (±6)
34-DP	deep pool	38 (±25)	2 (±2)	40 (±27)
37-PW	pocketwater	12 (±4)	0 (±0)	11 (±2)
Preston Falls sub-reach				
44-PW	pocketwater	12 (±2)	0 (±0)	12 (±2)
46-DP	deep pool	20 (±10)	5 (±4)	19 (±6)
49-SP	shallow pool	10 (±6)	0 (±0)	12 (±8)
56-DP	deep pool	17 (±4)	6 (±6)	16 (±0)
74-DP	deep pool	17 (±12)	1 (±0)	19 (±12)
76-SP	shallow pool	13 (±4)	3 (±2)	16 (±4)
O'Shaughnessy sub-reach				
223-DP	deep pool	34 (±10)	4 (±0)	36 (±8)
227-PW	deep pool	18 (±6)	2 (±2)	17 (±4)
229-SP	pocketwater	32 (±10)	6 (±4)	32 (±6)
267-SP	shallow pool	4 (±2)	0 (±0)	4 (±2)

[1] Note that estimates for "all trout" include observations of unidentified trout.

Table 12. Abundance estimates for Rainbow Trout and Brown Trout >125 mm by sub-reach in the Hetch Hetchy Reach in 2017 (95 percent CI).

Sub-reach	Trout >125 mm (age-1 and older)		
	Rainbow Trout	**Brown Trout**	**All trout[1]**
Early Intake	145 (±28)	18 (±9)	157 (±31)
Preston Falls	89 (±17)	15 (±7)	94 (±16)
O'Shaughnessy	88 (±15)	12 (±4)	89 (±11)
Total	**322 (±37)**	**45 (±12)**	**340 (±36)**

[1] Note that estimates for "all trout" include observations of unidentified trout.

Table 13. Abundance estimates for Rainbow Trout and Brown Trout >125 mm by habitat type in the Hetch Hetchy Reach in 2017 (95 percent CI).

Habitat type	Trout >125 mm (age-1 and older)		
	Rainbow Trout	Brown Trout	All trout[1]
Shallow pool	75 (±10)	7 (±3)	80 (±11)
Deep pool	175 (±34)	23 (±8)	178 (±33)
Pocketwater	72 (±11)	15 (±9)	82 (±12)
Total	**322 (±37)**	**45 (±12)**	**340 (±36)**

[1] Note that estimates for "all trout" include observations of unidentified trout.

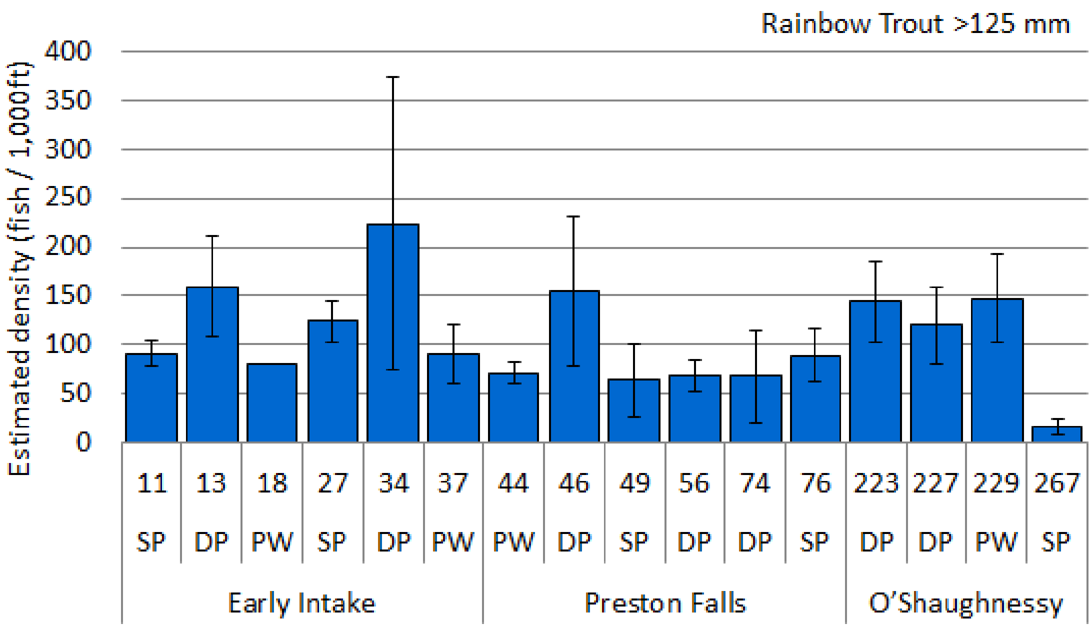

Figure 6. Estimated linear density of Rainbow Trout >125 mm by sub-reach and site in 2017. (Error bars indicate 95 percent CI.) (SP = shallow pool, DP = deep pool, PW = pocketwater.)

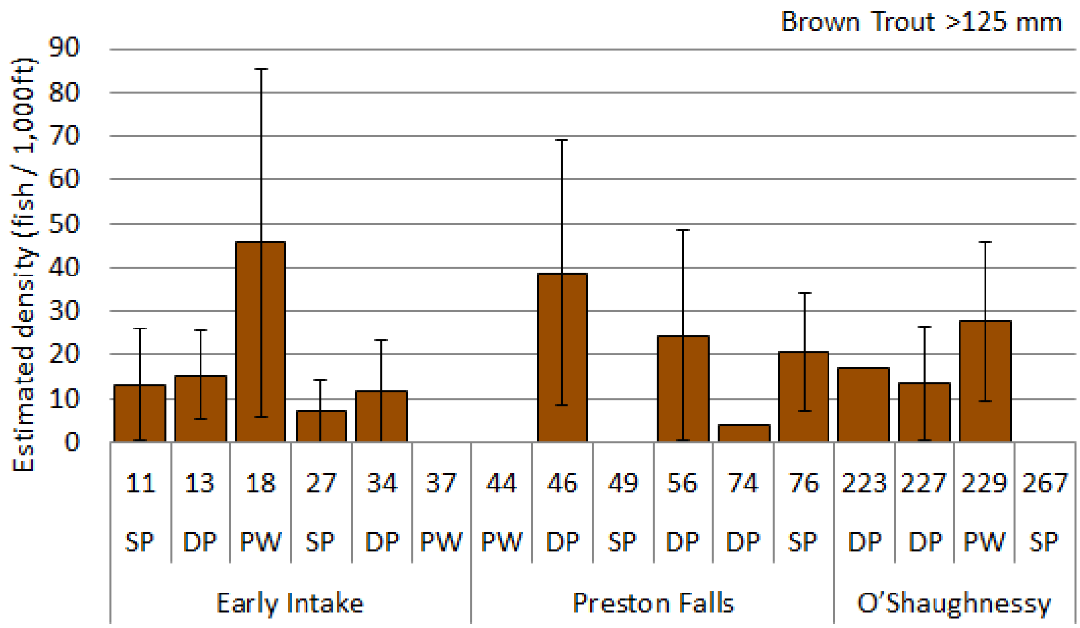

Figure 7. Estimated linear density of Brown Trout >125 mm by sub-reach and site in 2017. (Error bars indicate 95 percent CI.) (SP = shallow pool, DP = deep pool, PW = pocketwater.)

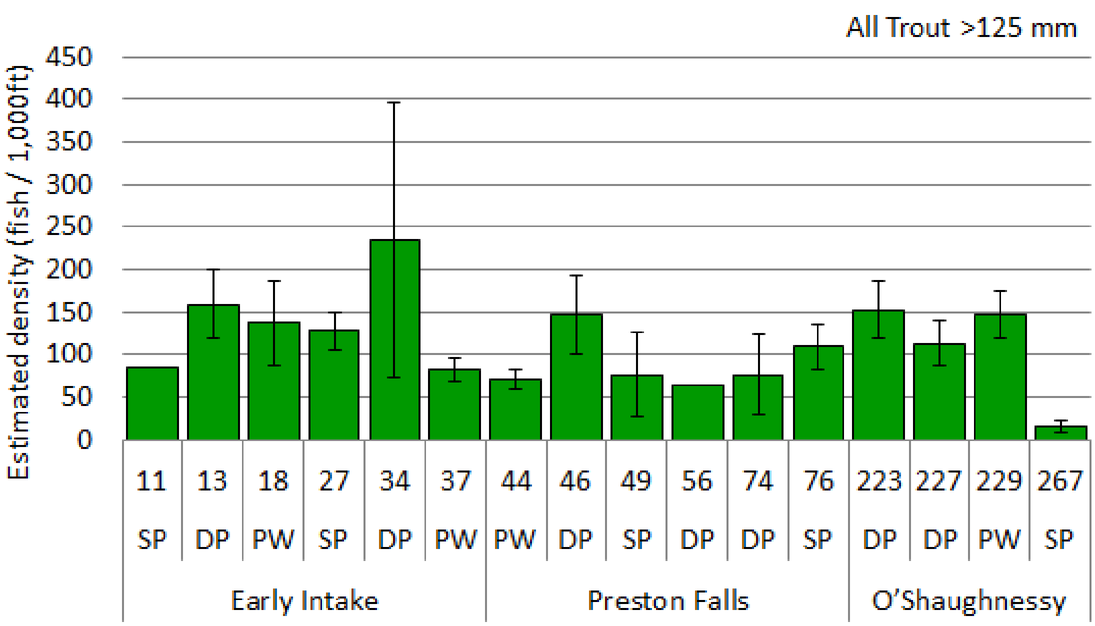

Figure 8. Estimated linear density (fish/1,000 feet) of all trout >125 mm by sub-reach and site in 2017. (Error bars indicate 95 percent CI.) (SP = shallow pool, DP = deep pool, PW = pocketwater.)

Trout ≤125 mm

As described in Section 6.1, trout ≤125 mm are primarily comprised of fish in their first year of life (age-0) and provide an indication of spawning success and age-0 recruitment. The 2017 fish population monitoring results for trout abundance, relative abundance, and density are presented below for trout ≤125 mm (Tables 14–16, Figure 9). The 2017 fish population monitoring results for trout ≤125 mm indicate that age-0 trout abundance was relatively low overall in 2017, with estimated abundance ranging from 1 at sites 13-DP and 44-PW to 5 at sites 27-SP and 229-PW (Table 14). Rainbow Trout ≤125 mm were observed at all monitoring sites except for two sites in the Preston Falls sub-reach; however, two unidentified trout were observed at each of these sites. No Brown Trout ≤125 mm were observed in the Hetch Hetchy Reach in 2017 (Table 14). Estimated densities of Rainbow Trout ≤125 mm ranged from 0 fish/1,000 feet at sites 49-SP and 56-DP to 23 fish/1,000 feet at site 229-PW (Figure 9). The density of Rainbow Trout ≤125 mm was greatest in the O'Shaughnessy sub-reach (15 fish/1,000 feet) and least in the Preston Falls sub-reach (7 fish/1,000 feet). Calculated CI for abundance and density estimates are relatively wide due to the low sample size of Rainbow Trout ≤125 mm in 2017.

Table 14. Abundance estimates for Rainbow Trout and Brown Trout ≤125 mm by site in the Hetch Hetchy Reach in 2017 (95 percent CI).

Site	Habitat type	Trout ≤125 mm (age-0)		
		Rainbow Trout	Brown Trout	All trout [1]
Early Intake sub-reach				
11-SP	shallow pool	3 (±2)	0 (±0)	3 (±2)
13-DP	deep pool	1 (±0)	0 (±0)	1 (±0)
18-PW	pocketwater	2 (±2)	0 (±0)	2 (±2)
27-SP	shallow pool	5 (±4)	0 (±0)	7 (±6)
34-DP	deep pool	2 (±2)	0 (±0)	3 (±2)
37-PW	pocketwater	2 (±0)	0 (±0)	2 (±0)
Preston Falls sub-reach				
44-PW	pocketwater	1 (±0)	0 (±0)	1 (±0)
46-DP	deep pool	2 (±2)	0 (±0)	2 (±2)
49-SP	shallow pool	0 (±0)	0 (±0)	2 (±2)
56-DP	deep pool	0 (±0)	0 (±0)	2 (±2)
74-DP	deep pool	3 (±2)	0 (±0)	3 (±2)
76-SP	shallow pool	2 (±0)	0 (±0)	2 (±0)
O'Shaughnessy sub-reach				
223-DP	deep pool	4 (±4)	0 (±0)	4 (±4)
227-DP	deep pool	2 (±2)	0 (±0)	2 (±2)
229-PW	pocketwater	5 (±4)	0 (±0)	7 (±6)
267-SP	shallow pool	2 (±2)	0 (±0)	2 (±2)

[1] Note that estimates for "all trout" include observations of unidentified trout.

Table 15. Abundance estimates for Rainbow Trout and Brown Trout ≤125 mm by sub-reach in the Hetch Hetchy Reach in 2017 (95 percent CI).

Sub-reach	Trout ≤125 mm (age-0)		
	Rainbow Trout	Brown Trout	All trout[1]
Early Intake	15 (±5)	0 (±0)	18 (±7)
Preston Falls	8 (±3)	0 (±0)	12 (±4)
O'Shaughnessy	13 (±6)	0 (±0)	15 (±8)
Total	**36 (±9)**	**0 (±0)**	**45 (±11)**

[1] Note that estimates for "all trout" include observations of unidentified trout.

Table 16. Abundance estimates for Rainbow Trout and Brown Trout ≤125 mm by habitat type in the Hetch Hetchy Reach in 2017 (95 percent CI).

Habitat type	Trout ≤125 mm (age-0)		
	Rainbow Trout	Brown Trout	All trout[1]
Shallow pool	12 (±5)	0 (±0)	16 (±7)
Deep pool	14 (±6)	0 (±0)	17 (±6)
Pocketwater	10 (±4)	0 (±0)	12 (±6)
Total	**36 (±9)**	**0 (±0)**	**45 (±11)**

[1] Note that estimates for "all trout" include observations of unidentified trout.

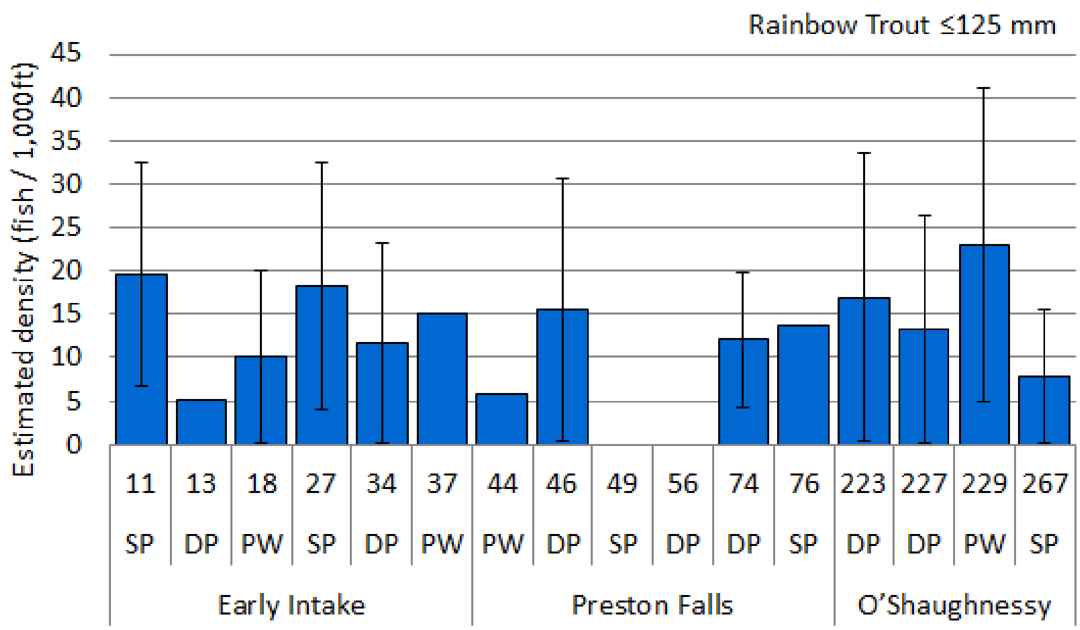

Figure 9. Estimated linear density (fish/1,000 feet) of Rainbow Trout ≤125 mm by sub-reach and site in 2017. (Error bars indicate 95 percent CI.) (SP = shallow pool, DP = deep pool, PW = pocketwater.)

6.2.1.2 Reach-level comparisons of 2014-2017 results in Hetch Hetchy Reach

To assess whether potentially meaningful changes or trends in trout population abundance are evident, comparisons of trout density were evaluated at the sub-reach scale based on 2014–2017 monitoring data. Two-sample t-tests were used to assess whether differences in abundance were statistically significant at a p-value ≤0.05. Site 38-DP was not included in the year-to-year comparisons presented in this section, since it was only surveyed in 2016 and likely will not be monitored in the future.

Trout >125 mm

Rainbow Trout densities in the Early Intake and O'Shaughnessy sub-reaches generally show similar patterns over the 2014–2017 monitoring period, with lowest densities in 2015 and highest densities in 2016 (Figure 10). In 2017, Rainbow Trout densities in the Early Intake and O'Shaughnessy sub-reaches were within the range of densities observed during 2014–2016. Rainbow Trout densities in the Early Intake and O'Shaughnessy sub-reaches were significantly lower in 2015 compared with other years during the 2014–2017 monitoring period. Rainbow Trout density in the Preston Falls sub-reach showed a declining trend from 2014 to 2017. In 2014 and 2015, Rainbow Trout density was significantly higher in the Preston Falls sub-reach compared with the other sub-reaches. In 2017, Rainbow Trout density in the Preston Falls sub-reach was significantly lower compared with the other sub-reaches. Overall, Rainbow Trout density was highest in 2014 and lowest in 2017, which is largely due to the influence of trout densities in the Preston Falls sub-reach.

Brown Trout densities in the Early Intake and O'Shaughnessy sub-reaches during 2017 were within the range of densities observed during 2014–2016 (Figure 11). The lowest densities for Brown Trout in both the Early Intake and O'Shaughnessy sub-reaches occurred in 2015. Brown Trout densities in the O'Shaughnessy sub-reach generally show similar patterns to Rainbow Trout. In contrast, Brown Trout density in the Preston Falls sub-reach was greatest in 2015, which was the highest Brown Trout density observed for a sub-reach during the 2014–2017 monitoring period. Total Brown Trout densities show a similar pattern to the Preston Falls sub-reach. Densities for all trout generally show similar patterns to those for Rainbow Trout, with similar relationships in the Early Intake and O'Shaughnessy sub-reaches and a declining trend over the four-year monitoring period for the Preston Falls sub-reach (Figure 11).

T-test results indicate numerous year-to-year differences that are statistically significant (Table 17) and suggest that trout populations are highly variable annually. The extent to which differences in abundance may be influenced by differences in annual flow conditions (e.g., magnitude, timing, duration), summer water temperature, and recovery from the Rim Fire will be evaluated as more years of monitoring data become available.

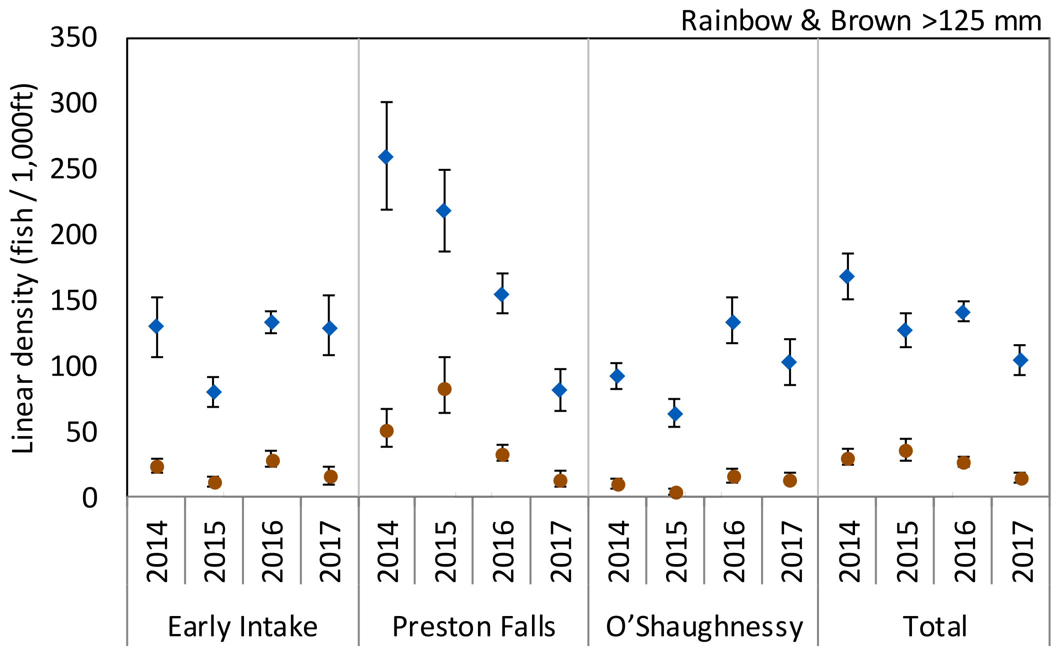

Figure 10. Linear density estimates for Rainbow Trout (blue diamonds) and Brown Trout (brown circles) >125 mm by sub-reach for the 2014–2017 monitoring period. (Error bars indicate 95 percent CI.)

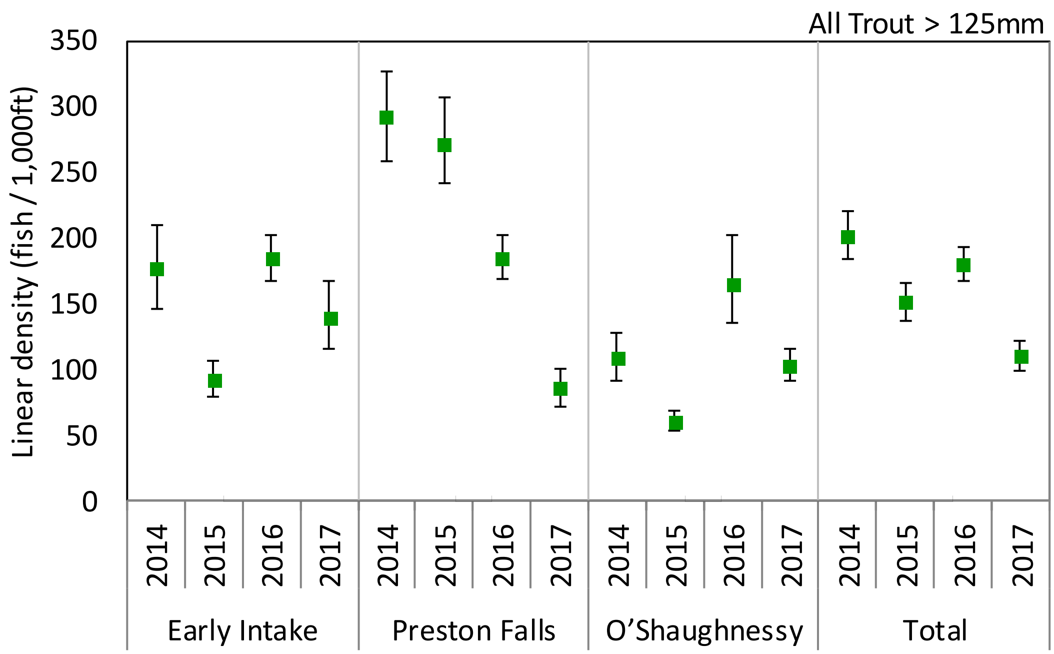

Figure 11. Linear density estimates for Rainbow Trout and Brown Trout combined >125 mm by sub-reach for the 2014–2017 monitoring period. (Error bars indicate 95 percent CI.)

Table 17. T-test results (p-values) comparing 2014–2017 estimated density for Rainbow Trout and Brown Trout >125 mm by sub-reach. Significant values (p-value ≤0.05) are marked with an asterisk (*).

Sub-reach	Comparison	Rainbow Trout	Brown Trout	All trout
Early Intake	2014 vs. 2015	0.0077*	0.0037*	0.0030*
	2014 vs. 2016	0.16	0.49	0.24
	2014 vs. 2017	0.62	0.17	0.25
	2015 vs. 2016	0.0055*	0.016*	0.0013*
	2015 vs. 2017	0.0059*	0.27	0.010*
	2016 vs. 2017	0.085	0.38	0.88
Preston Falls	2014 vs. 2015	0.15	0.053	0.44
	2014 vs. 2016	0.0031*	0.075	<0.001*
	2014 vs. 2017	<0.001*	0.0047*	<0.001*
	2015 vs. 2016	0.0079*	0.0081*	0.0044*
	2015 vs. 2017	<0.001*	0.0021*	<0.001*
	2016 vs. 2017	<0.001*	0.0019*	<0.001*
O'Shaughnessy	2014 vs. 2015	0.0071*	0.067	0.0078*
	2014 vs. 2016	0.031*	0.24	0.084
	2014 vs. 2017	0.22	0.22	1.00
	2015 vs. 2016	0.0036*	0.042*	0.013*
	2015 vs. 2017	0.014*	0.021*	0.0031*
	2016 vs. 2017	0.24	1.00	0.094
Total	2014 vs. 2015	<0.001*	0.31	<0.001*
	2014 vs. 2016	<0.001*	0.083	0.0028*
	2014 vs. 2017	<0.001*	<0.001*	<0.001*
	2015 vs. 2016	0.70	0.017*	0.17
	2015 vs. 2017	0.048*	<0.001*	<0.001*
	2016 vs. 2017	0.0079*	0.0024*	<0.001*

Trout ≤125 mm

The density of trout ≤125 mm provides insight into annual spawning success and recruitment of age-0 Rainbow Trout and Brown Trout. Rainbow Trout and Brown Trout densities in 2017 were the lowest observed during the 2014–2017 monitoring period (Figure 12). For each sub-reach, densities of Rainbow Trout and Brown Trout ≤125 mm show similar patterns of year-to-year relative density over the four-year monitoring period, suggesting that Rainbow Trout and Brown Trout ≤125 mm are responding similarly to environmental pressures within each sub-reach. However, these patterns of relative density are different for each sub-reach, suggesting that there are important differences in habitat quality and/or quantity between the sub-reaches. Rainbow Trout and Brown Trout densities in the Early Intake sub-reach show a declining trend over the four-year monitoring period, with the highest densities in 2014 and lowest in 2017. In the Preston Falls sub-reach, Rainbow Trout and Brown Trout densities were highest in 2015 and lowest in 2017. In 2014 and 2015, Rainbow Trout densities in the Preston Falls sub-reach were significantly higher compared with densities the Early Intake and O'Shaughnessy sub-reaches. Densities of trout ≤125 mm in the O'Shaughnessy sub-reach were highest in 2014 and lowest in 2017.

Total Rainbow Trout and Brown Trout densities in 2017 were significantly lower compared with densities during 2014–2016. Rainbow Trout densities in the Early Intake and Preston Falls sub-reaches were significantly lower compared with densities during 2014–2016. Rainbow Trout density in the O'Shaughnessy sub-reach in 2017 was not significantly different from the density in 2015. No Brown Trout ≤125 mm were observed in the Hetch Hetchy Reach during 2017. These results indicate low overall recruitment of age-0 trout in 2017. The primary factor contributing to low age-0 recruitment in 2017 is likely the effects of high flow conditions during Water Year (WY) 2017 (see Section 6.3.1).

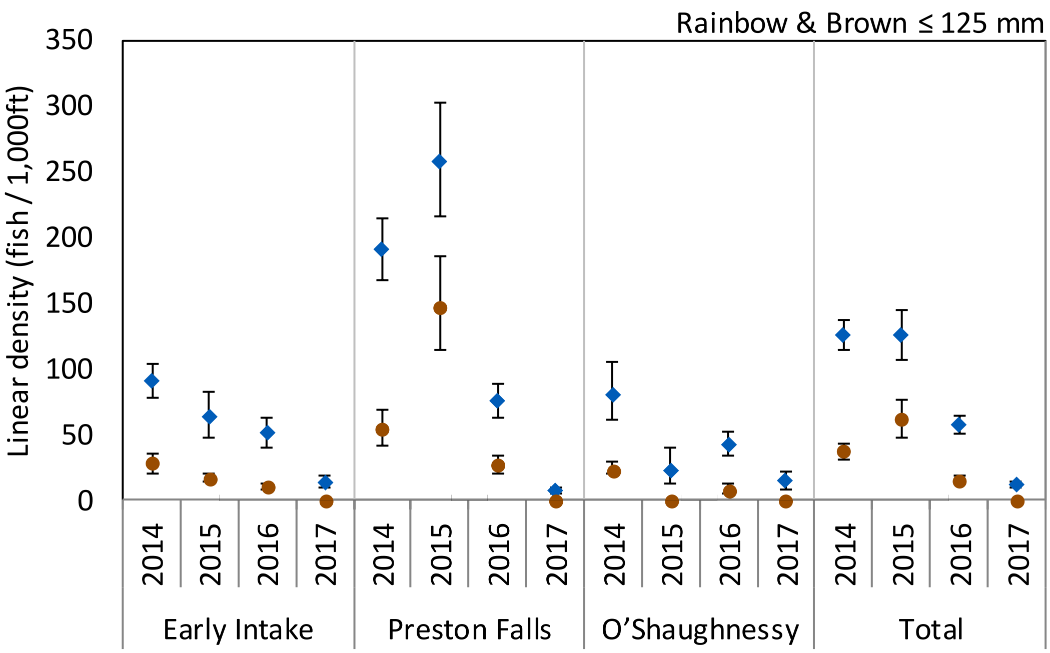

Figure 12. Linear density estimates for Rainbow Trout (blue diamonds) and Brown Trout (brown circles) ≤125 mm by sub-reach for the 2014–2017 monitoring period. (Error bars indicate 95 percent CI.)

6.2.2 Above Hetch Hetchy Reservoir Reach

6.2.2.1 2017 Monitoring

Trout >125 mm

For the Above Hetch Hetchy Reservoir Reach, abundance of Rainbow Trout >125 mm ranged from 0 trout at site 510-PW to 5 trout at site 514-DP (Table 18). Brown Trout >125 mm were observed at one of the four monitoring sites sampled in the Above Hetch Hetchy Reservoir Reach during 2017 with 2 trout observed at site 514-DP. The density of Rainbow Trout >125 mm ranged from 0 to 34 fish/1,000 feet and averaged 15 fish/1,000 feet (Table 19).

Table 18. Abundance estimates for Rainbow Trout and Brown Trout >125 mm by site in the Above Hetch Hetchy Reservoir Reach in 2017 (95 percent CI).

Site	Habitat type	Trout >125 mm (age-1 and older)		
		Rainbow Trout	Brown Trout	All trout[1]
505-PW[2]	pocketwater	2	0	3
510-PW[3]	pocketwater	0	0	0
511-SP[3]	shallow pool	2	0	2
514-DP	deep pool	5 (±2)	2 (±2)	6 (±2)

[1] Note that estimates for "all trout" include observations of unidentified trout.
[2] Habitats sampled with a single pass.
[3] Habitats sampled with two passes.

Table 19. Linear density (fish/1,000 feet) estimates for Rainbow Trout and Brown Trout >125 mm by site in the Above Hetch Hetchy Reservoir Reach in 2017.

Site	Habitat type	Trout >125 mm (age-1 and older)		
		Rainbow Trout	Brown Trout	All trout[1]
505-PW[2]	pocketwater	12	0	18
510-PW[3]	pocketwater	0	0	0
511-SP[3]	shallow pool	14	0	14
514-DP	deep pool	34	14	41

[1] Note that estimates for "all trout" include observations of unidentified trout.
[2] Habitats sampled with a single pass.
[3] Habitats sampled with two passes.

Trout ≤125 mm

No Rainbow Trout or Brown Trout ≤125 mm were observed at the four sites sampled in the Above Hetch Hetchy Reservoir Reach in 2017.

6.2.3 Cherry Creek and Eleanor Creek Reaches

6.2.3.1 2017 Monitoring

Trout >125 mm

The 2017 fish population monitoring results for trout abundance and linear density in the Cherry Creek and Eleanor Creek reaches are presented below for trout >125 mm (Tables 20–22, Figures 13 and 14). Rainbow Trout made up the majority of trout >125 mm observed in the Cherry Creek and Eleanor Creak reaches in 2017. Abundance estimates in 2017 for trout >125 mm for all sites in the Cherry Creek and Eleanor Creek reaches combined were 572 Rainbow Trout and 10 Brown Trout (Tables 21 and 22). Abundance estimates for Rainbow Trout >125 mm ranged from 0 trout at site 127-DP to 130 trout at site 45-SP (Table 20).

In 2017, estimated linear density of Rainbow Trout >125 mm ranged from 0 fish/1,000 feet at site 127-DP to 646 fish/1,000 feet at site 107-DP (Figure 13). Average density of Rainbow Trout

>125 mm by sub-reach was greatest in the Holm Powerhouse sub-reach (408 fish/1,000 feet) and by habitat type was greatest in run habitat (247 fish/1,000 feet) (Figure 13).

Brown Trout >125 mm were observed at three of the 18 sites sampled in 2017: one site (45-SP) in the Lower Cherry sub-reach and both sites (14-DP and 16-DP) in the Holm Powerhouse sub-reach (Table 20). No Brown Trout were observed in Eleanor Creek in 2017. Brown Trout density was greatest at site 14-DP (33 fish/1,000 feet) (Figure 14).

Table 20. Abundance estimates for Rainbow Trout and Brown Trout >125 mm by site in the Cherry Creek and Eleanor Creek reaches in 2017 (95 percent CI).

Site	Habitat type	Trout >125 mm (age-1 and older)		
		Rainbow Trout	Brown Trout	All trout[1]
Upper Cherry sub-reach				
394-SP	shallow pool	4 (±4)	0 (±0)	4 (±4)
392-DP	deep pool	5 (±4)	0 (±0)	5 (±4)
276-SP	shallow pool	2 (±2)	0 (±0)	2 (±2)
Lower Cherry sub-reach				
274-BG	boulder garden	18 (±6)	0 (±0)	18 (±6)
135-DP	deep pool	12 (±6)	0 (±0)	12 (±6)
131-DP	deep pool	15 (±2)	0 (±0)	15 (±2)
127-DP	deep pool	0 (±0)	0 (±0)	0 (±0)
45-SP	shallow pool	130 (±37)	2 (±2)	132 (±39)
40-SP	shallow pool	46 (±6)	0 (±0)	46 (±6)
34-RN	run	24 (±4)	0 (±0)	24 (±4)
Holm Powerhouse sub-reach				
16-DP	deep pool	93 (±0)	3 (±0)	96 (±0)
14-DP	deep pool	60 (±8)	5 (±4)	59 (±4)
Eleanor Creek Reach				
153-RN	run	19 (±10)	0 (±0)	19 (±10)
147-SP	shallow pool	3 (±0)	0 (±0)	3 (±0)
107-DP	deep pool	63 (±25)	0 (±0)	63 (±25)
103-DP	deep pool	36 (±16)	0 (±0)	36 (±16)
5-BG	boulder garden	30 (±24)	0 (±0)	30 (±24)
3-DP	deep pool	12 (±6)	0 (±0)	12 (±6)

[1] Note that estimates for "all trout" include observations of unidentified trout.

Table 21. Abundance estimates for Rainbow Trout and Brown Trout >125 mm by sub-reach in the Cherry Creek and Eleanor Creek reaches in 2017 (95 percent CI).

Sub-reach	Trout >125 mm (age-1 and older)		
	Rainbow Trout	**Brown Trout**	**All trout[1]**
Upper Cherry	11 (±6)	0 (±0)	11 (±6)
Lower Cherry	245 (±39)	2 (±2)	247 (±41)
Holm Powerhouse	153 (±8)	8 (±4)	155 (±4)
Eleanor Creek	163 (±40)	0 (±0)	163 (±40)
Total	**572 (±56)**	**10 (±4)**	**576 (±57)**

[1] Note that estimates for "all trout" include observations of unidentified trout.

Table 22. Abundance estimates for Rainbow Trout and Brown Trout >125 mm by habitat type in the Cherry Creek and Eleanor Creek reaches in 2017 (95 percent CI).

Habitat type	Trout >125 mm (age-1 and older)		
	Rainbow Trout	**Brown Trout**	**All trout[1]**
Shallow pool	185 (±38)	2 (±2)	187 (±40)
Deep pool	296 (±32)	8 (±4)	298 (±32)
Run	43 (±11)	0 (±0)	43 (±11)
Boulder garden	48 (±24)	0 (±0)	48 (±24)
Total	**572 (±56)**	**10 (±4)**	**576 (±52)**

[1] Note that estimates for "all trout" include observations of unidentified trout.

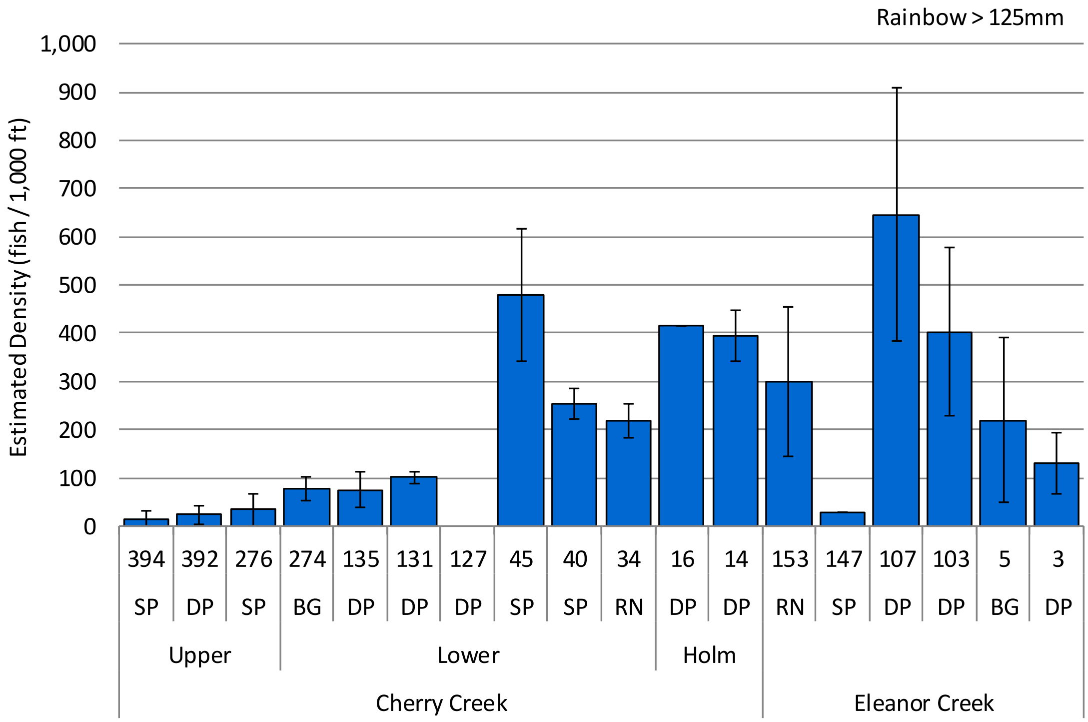

Figure 13. Estimated linear density of Rainbow Trout >125 mm by sub-reach and site in the Cherry Creek and Eleanor Creek reaches in 2017. (Error bars indicate 95 percent CI.) (SP = shallow pool, DP = deep pool, BG = boulder garden, RN = run.)

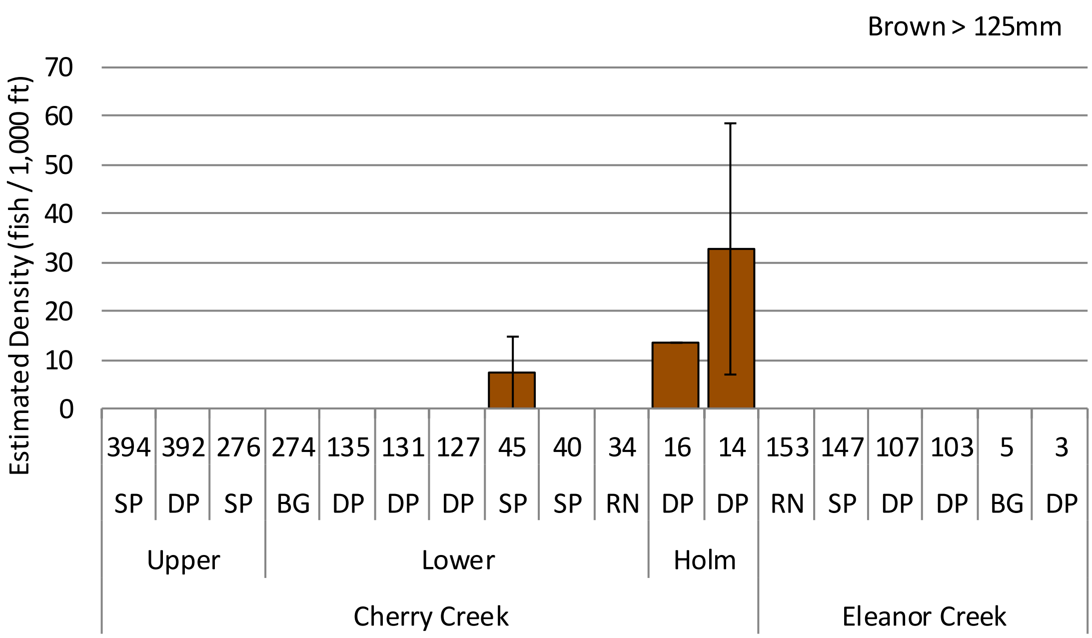

Figure 14. Estimated linear density of Brown Trout >125 mm by sub-reach and site in the Cherry Creek and Eleanor Creek reaches in 2017. (Error bars indicate 95 percent CI.) (SP = shallow pool, DP = deep pool, BG = boulder garden, RN = run.)

Trout ≤125 mm

The 2017 fish population monitoring results for trout abundance and linear density in the Cherry Creek and Eleanor Creek reaches are presented below for trout ≤125 mm (Tables 23–25, Figure 15). Rainbow Trout ≤125 mm were observed at 17 of 18 monitoring sites surveyed in the Cherry Creek and Eleanor Creek reaches in 2017 (Table 23). No Brown Trout ≤125 mm were observed at monitoring sites surveyed in the Cherry Creek and Eleanor Creek reaches in 2017. In 2017, estimated abundance of Rainbow Trout ≤125 mm at all sites in the Cherry Creek and Eleanor Creek reaches combined was 354 (Table 24). Abundance estimates for Rainbow Trout ≤125 mm ranged from 0 trout at site 276-SP to 111 trout at site 107-DP (Table 23).

Estimated linear density for Rainbow Trout ≤125 mm ranged from 0 fish/1,000 feet at site 276-SP to 1,139 fish/1,000 feet at site 107-DP (Figure 15). Average density of Rainbow Trout ≤125 mm by sub-reach was greatest in the Eleanor Creek Reach (414 fish/1,000 feet) and lowest in the Upper Cherry sub-reach (7 fish/1,000 feet). Average density of Rainbow Trout ≤125 mm by habitat type was greatest in run habitat (224 fish/1,000 feet) and least in boulder garden habitat (59 fish/1,000 feet). The four most upstream sites in the Eleanor Creek Reach had significantly higher densities of Rainbow Trout ≤125 mm compared with the other surveyed sites in the Cherry Creek and Eleanor Creek reaches.

Table 23. Abundance estimates for Rainbow Trout ≤125 mm in the Cherry Creek and Eleanor Creek reaches in 2017 (95 percent CI).

Site	Habitat type	Trout ≤125 mm (age-0)
Upper Cherry sub-reach		
394-SP	shallow pool	1 (±0)
392-DP	deep pool	3 (±2)
276-SP	shallow pool	0 (±0)
Lower Cherry sub-reach		
274-BG	boulder garden	11 (±2)
135-DP	deep pool	12 (±4)
131-DP	deep pool	14 (±8)
127-DP	deep pool	2 (±2)
45-SP	shallow pool	15 (±8)
40-SP	shallow pool	30 (±8)
34-RN	run	11 (±4)
Holm Powerhouse sub-reach		
16-DP	deep pool	5 (±2)
14-DP	deep pool	6 (±2)
Eleanor Creek Reach		
153-RN	run	28 (±0)
147-SP	shallow pool	47 (±4)
107-DP	deep pool	111 (±45)
103-DP	deep pool	37 (±0)
5-BG	boulder garden	11 (±8)
3-DP	deep pool	10 (±6)

Table 24. Abundance estimates for Rainbow Trout ≤125 mm by sub-reach in the Cherry Creek and Eleanor Creek reaches in 2017 (95 percent CI).

Sub-reach	Trout ≤125 mm (age-0)
Upper Cherry	4 (±2)
Lower Cherry	95 (±15)
Holm Powerhouse	11 (±3)
Eleanor Creek	244 (±46)
Total	**354 (±49)**

Table 25. Abundance estimates for Rainbow Trout ≤125 mm by habitat type in the Cherry Creek and Eleanor Creek reaches in 2017 (95 percent CI).

Habitat	Trout ≤125 mm (age-0)
Shallow pool	93 (±12)
Deep pool	200 (±46)
Boulder garden	39 (±4)
Run	22 (±8)
Total	**354 (±49)**

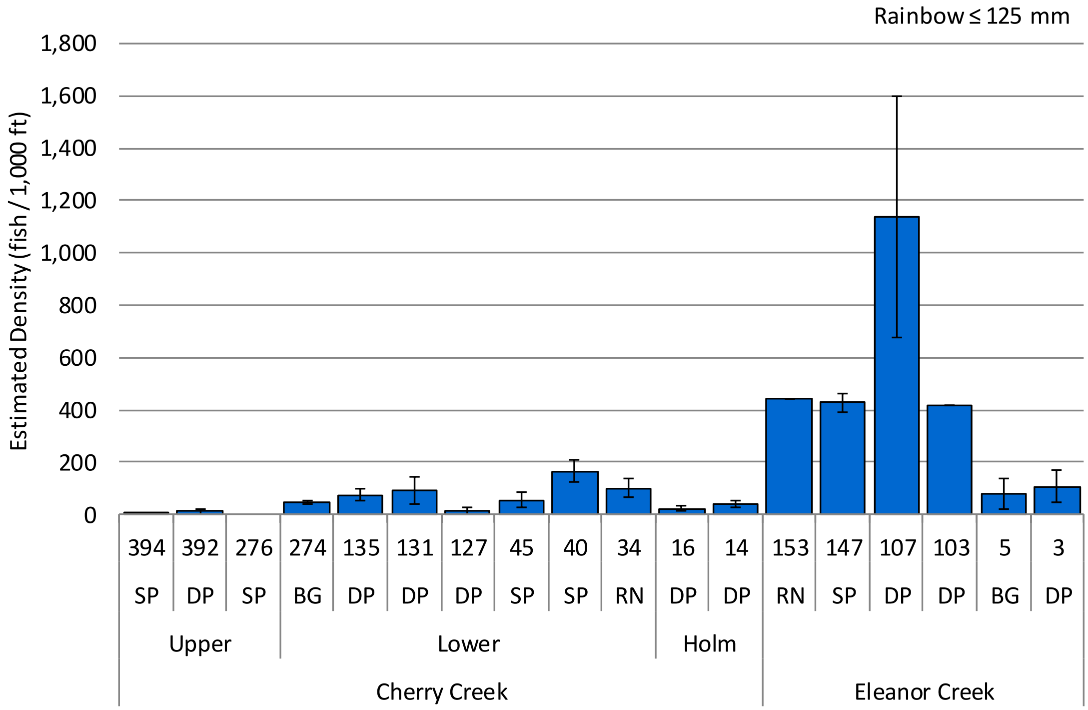

Figure 15. Estimated linear density of Rainbow Trout ≤125 mm by sub-reach and site in the Cherry Creek and Eleanor Creek reaches in 2017. Error bars indicate 95 percent CI. (SP = shallow pool, DP = deep pool, BG = boulder garden, RN = run.)

6.2.3.2 Reach-level Comparisons of Recent Monitoring Results in Cherry Creek

Trout >125 mm

In 2012 and 2017, linear density of Rainbow Trout >125 mm was substantially higher in the Lower Cherry sub-reach compared with the Upper Cherry sub-reach. In 2016, linear densities in the Upper Cherry and Lower Cherry sub-reaches were more similar. In 2017, linear density of Rainbow Trout >125 mm was greatest in the Holm Powerhouse sub-reach, followed by the Eleanor Creek Reach and the Lower Cherry and Upper Cherry sub-reaches (Figure 16). For the Upper Cherry sub-reach, linear density of Rainbow Trout >125 mm was significantly lower in 2017 compared with 2016, and higher than observed in 2012 (Figure 16). For the Lower Cherry sub-reach, linear density of Rainbow Trout >125 mm was significantly higher in 2017 compared with 2016 and slightly lower than observed in 2012 (Figure 16).

The reason for the differing trends observed between the Upper Cherry and Lower Cherry sub-reaches is likely the result of differences in habitat conditions (channel gradient and confinement, habitat complexity) and the influence of flow (magnitude, timing, duration) and water temperature. Flow and water temperature were substantially different between these two sub-reaches during the years monitoring occurred. The Upper Cherry sub-reach is strongly influenced by regulated released from Valley Dam, whereas the Lower Cherry sub-reach has greater influence from natural tributary accretion flow and water temperature regimes.

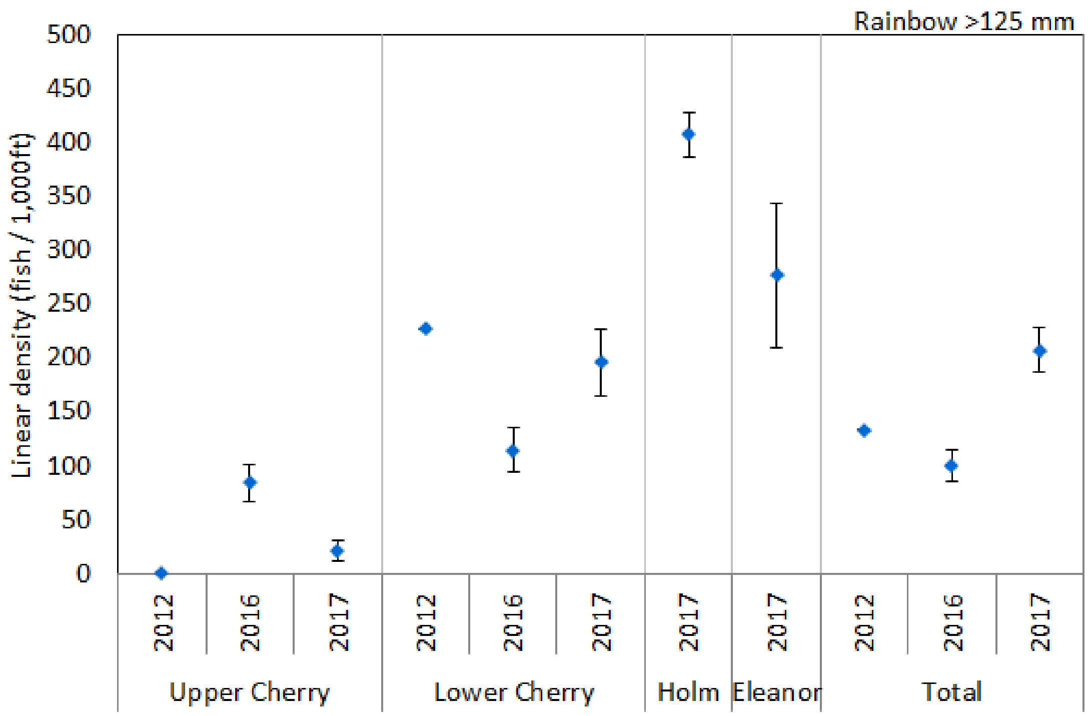

Figure 16. Linear density estimates for Rainbow Trout >125 mm by sub-reach in the Cherry Creek and Eleanor Creek reaches for monitoring years 2012, 2016, and 2017. Error bars indicate 95 percent CI. Note that total linear density for 2017 includes the Holm Powerhouse and Eleanor Creek sub-reaches, which are not included for 2016 or 2012.

Trout ≤125 mm

Linear density of Rainbow Trout ≤125 mm was greater in the Lower Cherry sub-reach compared with the Upper Cherry sub-reach during each of the three years of monitoring. Both the Upper Cherry and Lower Cherry sub-reaches show similar decreasing trends over time based on the three years of monitoring. Linear density of Rainbow Trout ≤125 mm was significantly lower in 2017 compared with 2016 and 2012 for both the Upper Cherry and Lower Cherry sub-reaches (Figure 17). In 2017, linear density of Rainbow Trout ≤125 mm was greatest in the Eleanor Creek Reach.

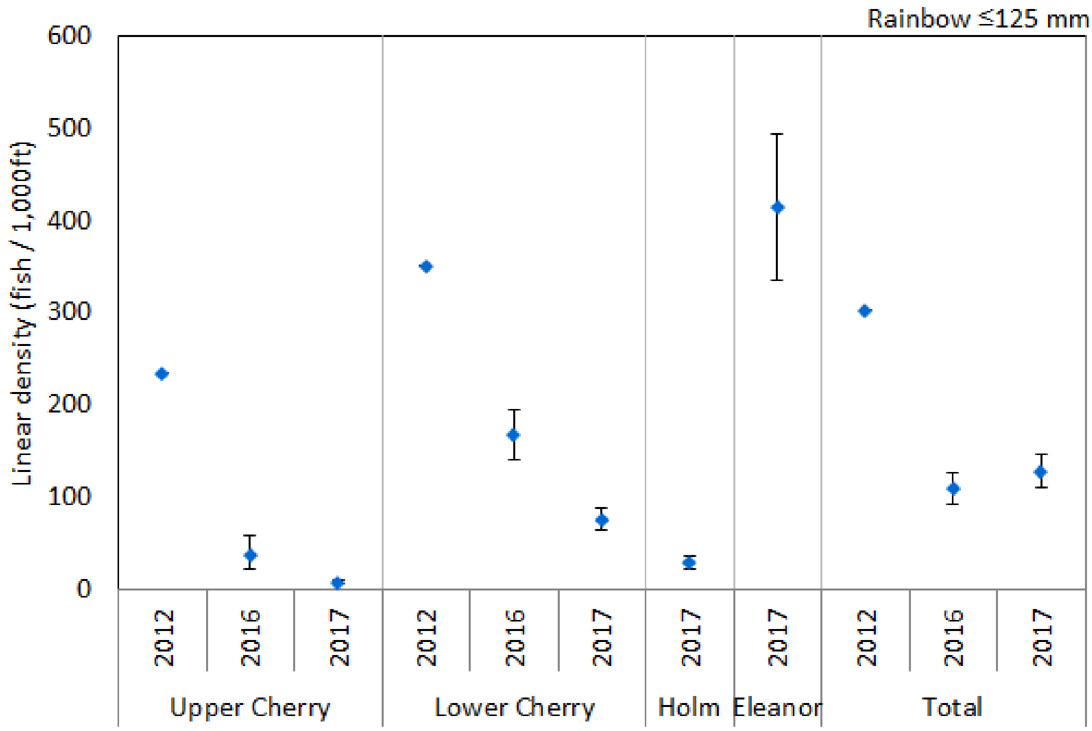

Figure 17. Linear density estimates for Rainbow Trout ≤125 mm by sub-reach in the Cherry Creek and Eleanor Creek reaches for monitoring years 2012, 2016, and 2017. Error bars indicate 95 percent CI. Note that total linear density for 2017 includes the Holm Powerhouse sub-reach and the Eleanor Creek Reach, which are not included for 2016 or 2012.

6.3 Streamflow

6.3.1 Hetch Hetchy Reach

Streamflow in the Hetch Hetchy Reach is derived from (1) required minimum instream baseflow releases from O'Shaughnessy Dam, (2) local accretion from minor tributaries, and (3) snowmelt spill releases from the dam. Two flow monitoring stations in the Hetch Hetchy Reach effectively bracket the survey area: the USGS gage 11276500 near Hetch Hetchy at the upstream end of the reach ("Hetch Hetchy gage"), and the USGS gage 11276600 above Early Intake at the downstream end of the reach ("Above Early Intake gage") (Figure 18). Hydrographs are presented to illustrate conditions in the reach during WY 2017 relative to conditions during the previous decade (2007–2016) (Figures 19–22). During a typical water year (e.g., WY 2009), flows in the Hetch Hetchy Reach are generally high during the spring and early summer snowmelt runoff period (May–July) and low during the fall and winter (September–February). Short-duration, high-flow events occasionally occur during winter. Minimum baseflow releases are designed to provide optimal temperatures for trout during summer and are higher than typical unimpaired summer inflows in most years. See RMC Water and Environment and McBain & Trush, Inc. (2007) for a summary of existing instream flow requirements and hydrology.

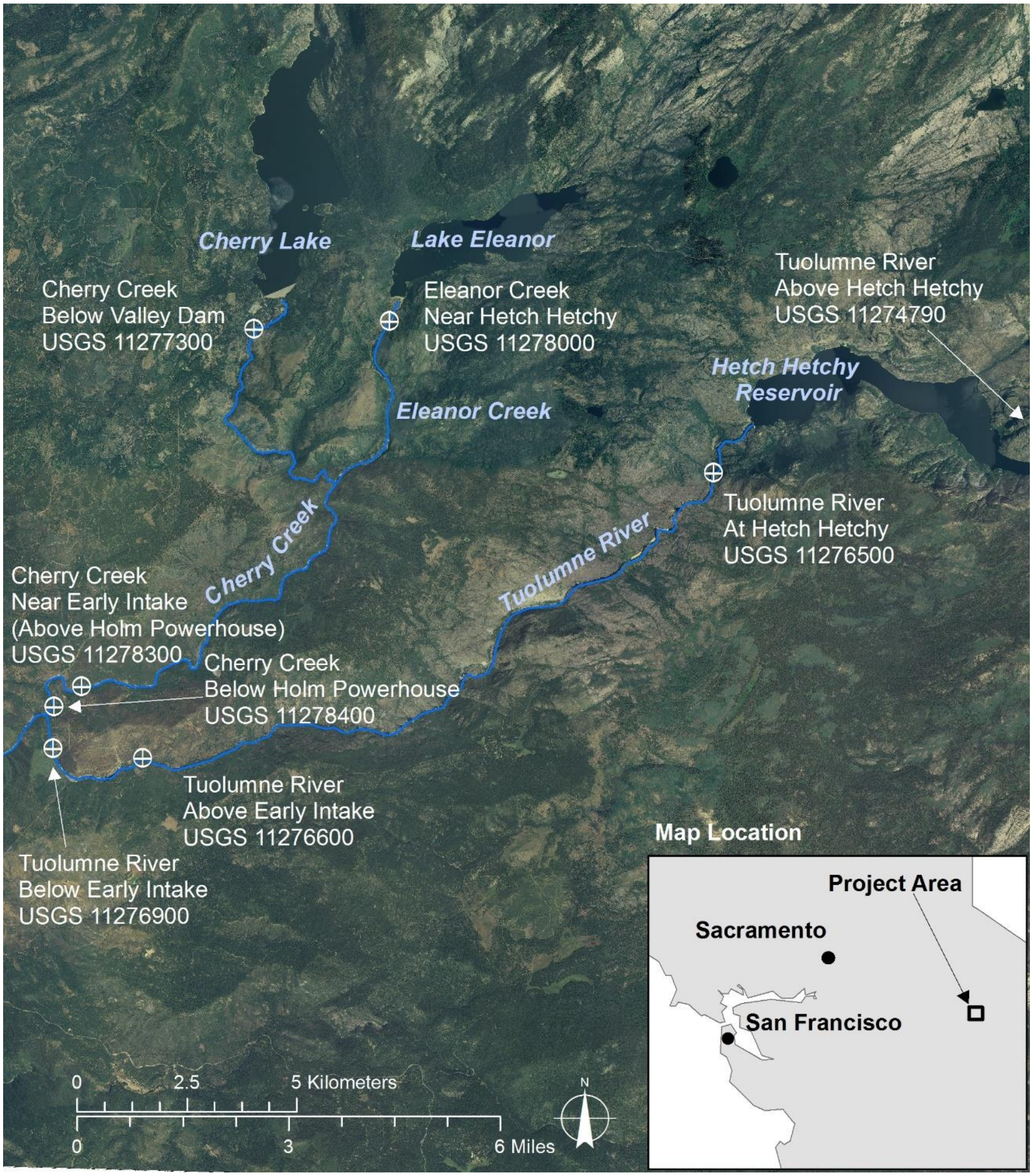

Figure 18. Stream gages in the vicinity of fish monitoring sites in the upper Tuolumne River, Cherry Creek, and Eleanor Creek.

WY 2017 was one of the wettest years on record in recent history, and a dramatic change from the drought conditions experienced during WY 2013–2015. Mean annual flow and average summer flow (May through mid-September) in WY 2017 were the highest recorded in recent years (2007–2017) at both gages in the reach. Average daily flow during October and November were relatively typical, with a few low-magnitude high-flow events evident at Above Early Intake gage. Average daily flows during January and February were particularly high compared with recent years (Figures 19 and 21). Large-magnitude high-flow events occurred multiple times during WY 2017.

Average daily flow in WY 2017 recorded at Hetch Hetchy gage ranged from 51 cfs in December to 9,480 cfs in June (Table 26). During WY 2017 average daily flow at Hetch Hetchy gage was relatively low from October through early December. A series of high-magnitude flow events occurred from mid-December through March, followed by the spring snowmelt runoff, which created sustained high flows from April through July. Average daily flows during WY 2017 were highest in May and June, averaging about 5,850 cfs (Figure 19).

Average daily flow in WY 2017 recorded at Above Early Intake gage ranged from 44 cfs in December to 10,663 cfs in June (Table 26). Average daily flows at Above Early Intake gage during May and June were about 6,360 cfs, indicating that about 510 cfs of accretion occurred in the reach during this period in WY 2017 (Figure 21).

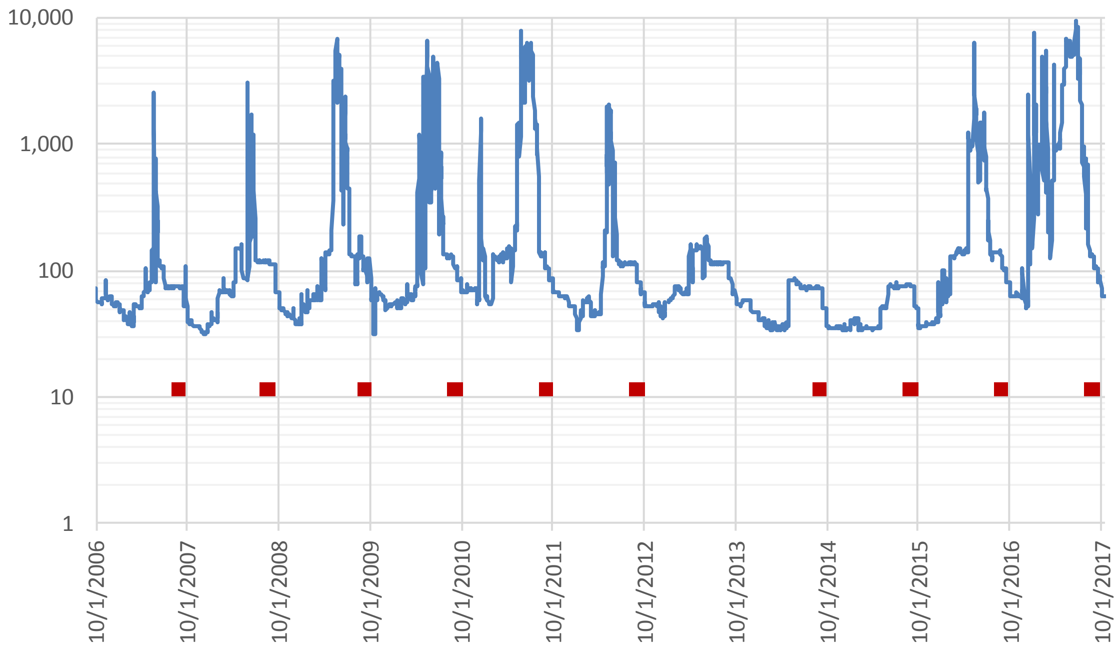

Figure 19. Mean daily streamflow (cfs) in the Tuolumne River at Hetch Hetchy gage (USGS 11276500) for WY 2007–2017. Snorkel surveys performed by the SFPUC in mid-August through late September 2007–2011 and 2014–2017 are identified by red markers.

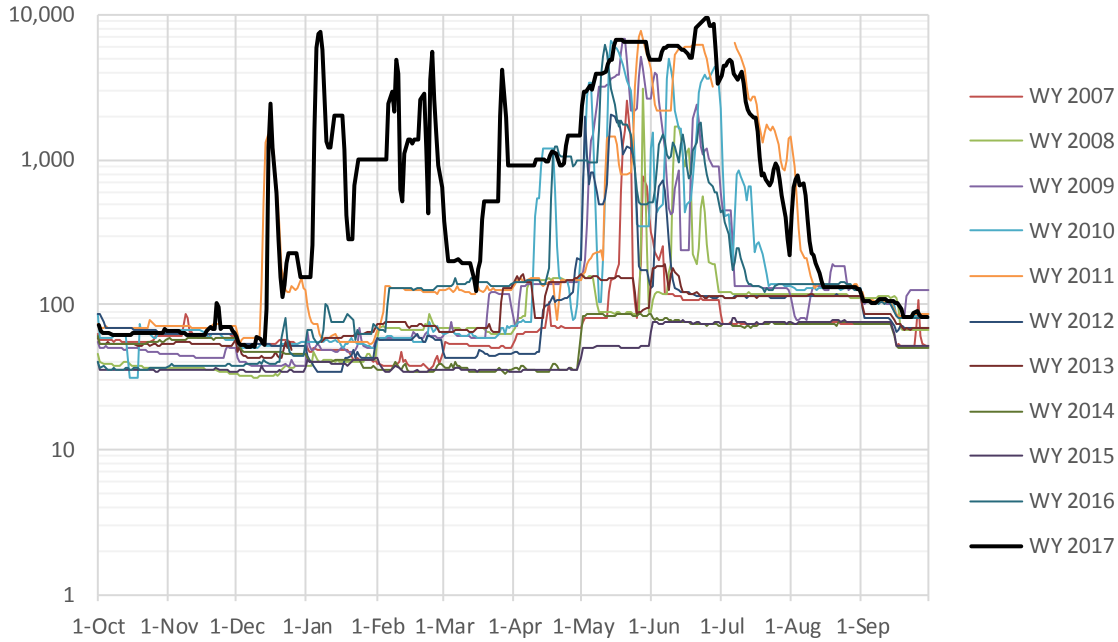

Figure 20. Mean daily streamflow (cfs) in the Tuolumne River at Hetch Hetchy gage (USGS 11276500) for WY 2007–2017, presented individually.

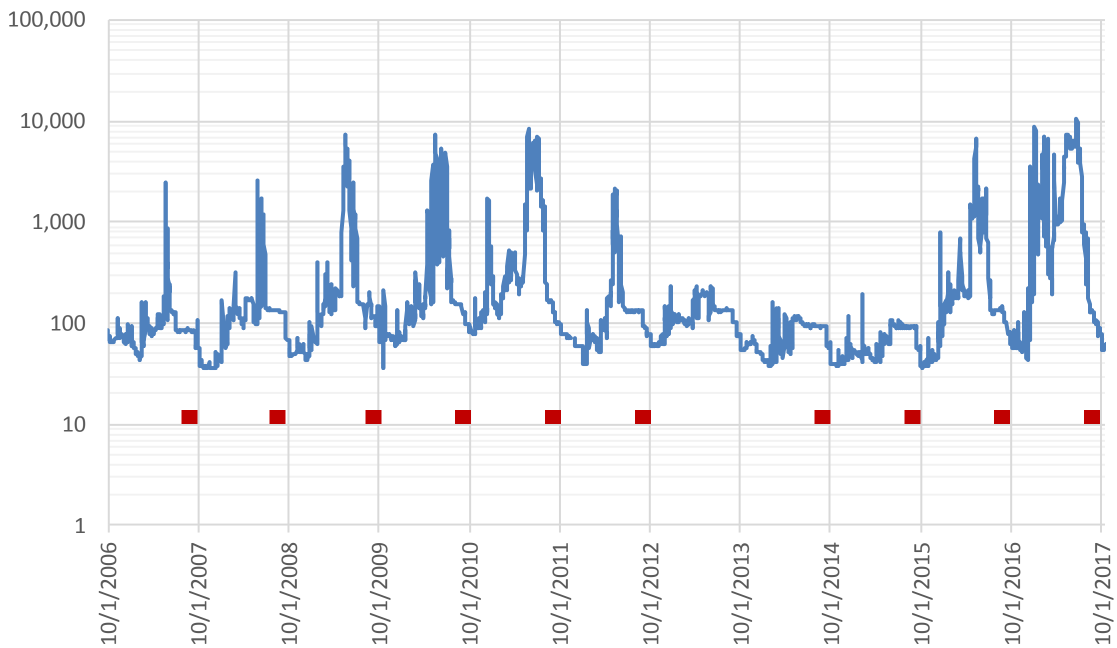

Figure 21. Mean daily streamflow (cfs) in the Tuolumne River at Above Early Intake gage (USGS 11276600) for WY 2007–2017. Snorkel surveys performed by the SFPUC in mid-August through late September 2007–2012 and 2014–2017 are identified by red markers.

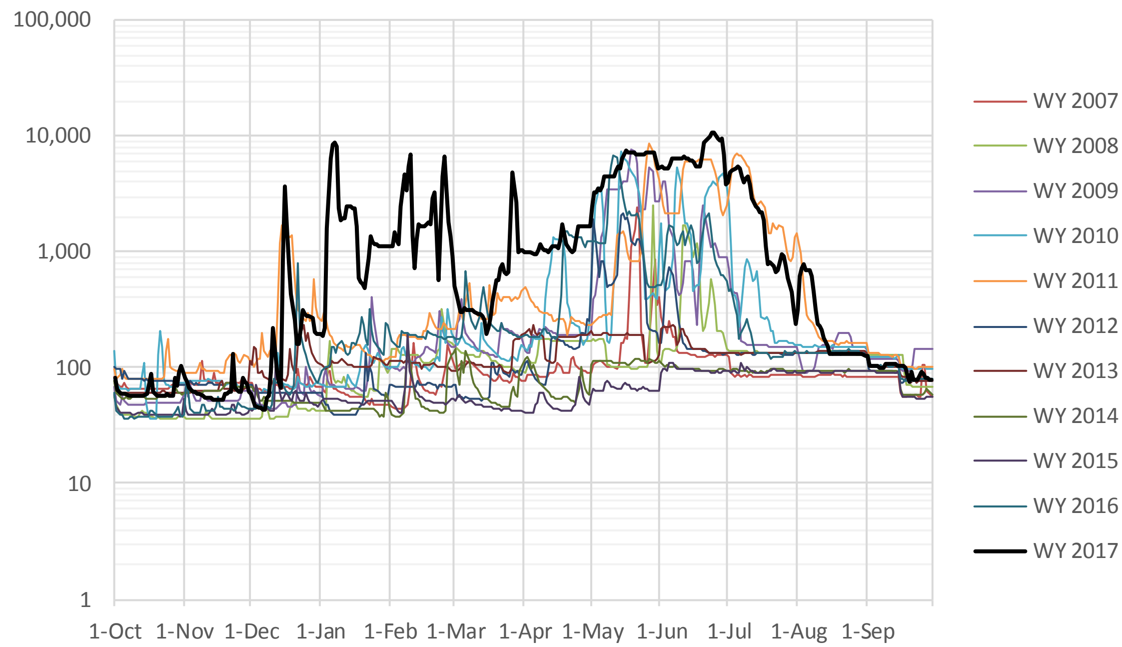

Figure 22. Mean daily streamflow (cfs) in the Tuolumne River at Above Early Intake gage (USGS 11276600) for WY 2007–2017, presented individually.

Table 26. Streamflow metrics (in cfs) for WY 2007–2017 at USGS gages in the Hetch Hetchy Reach.

Flow metric (cfs)	Water year										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Tuolumne River at Hetch Hetchy gage (USGS 11276500)											
Mean daily average	93	121	439	499	793	154	92	57	50	359	1,664
Median daily average	62	69	83	75	127	68	75	54	39	131	587
Minimum daily average	36	31	37	31	54	34	43	34	34	35	51
Maximum daily average	2,549	3,087	6,826	6,725	7,865	2,033	188	87	82	6,273	9,480
Instantaneous maximum (peak)	3,110	6,720	7,010	7,350	8,210	4,340	191	89	91	6,430	9,680
Tuolumne River at Above Early Intake gage (USGS 11276600)											
Mean daily average	111	142	494	554	960	178	121	75	64	434	1,874
Median daily average	84	116	146	141	234	91	112	67	54	150	687
Minimum daily average	44	36	44	36	79	39	60	38	38	36	44
Maximum daily average	2,427	2,571	7,507	7,500	8,508	2,180	234	159	196	6,866	10,663
Instantaneous maximum (peak)	3,310	6,250	7,890	8,270	8,950	4,180	286	235	317	7,260	11,100

6.3.2 Above Hetch Hetchy Reservoir Reach

Streamflow in the Above Hetch Hetchy Reservoir Reach is unregulated. Flow is monitored at USGS gage 11274790 ("Above Hetch Hetchy gage") located near the downstream end of the reach, immediately upstream of Hetch Hetchy Reservoir. Streamflow in the reach is generally lowest in late September and early October. Flows generally increase from October through May or June, and then decrease from June through October (Figures 23 and 24). Average daily flow in WY 2017 recorded at Above Hetch Hetchy gage ranged from 14 cfs in October to 3,720 cfs in June (Figure 24, Table 27). Relatively wet conditions persisted throughout most of WY 2017 and mean annual flow (922 cfs) was the highest recorded in recent years. Despite particularly wet conditions in WY 2017, minimum and maximum daily flows in WY 2017 were within the range observed in recent years (Table 27) and the annual hydrograph for WY 2017 is generally similar to the annual hydrographs during WY 2007–2016. Annual peak flow in WY 2017 was 4,660 cfs, the third highest measured during WY 2007–2017.

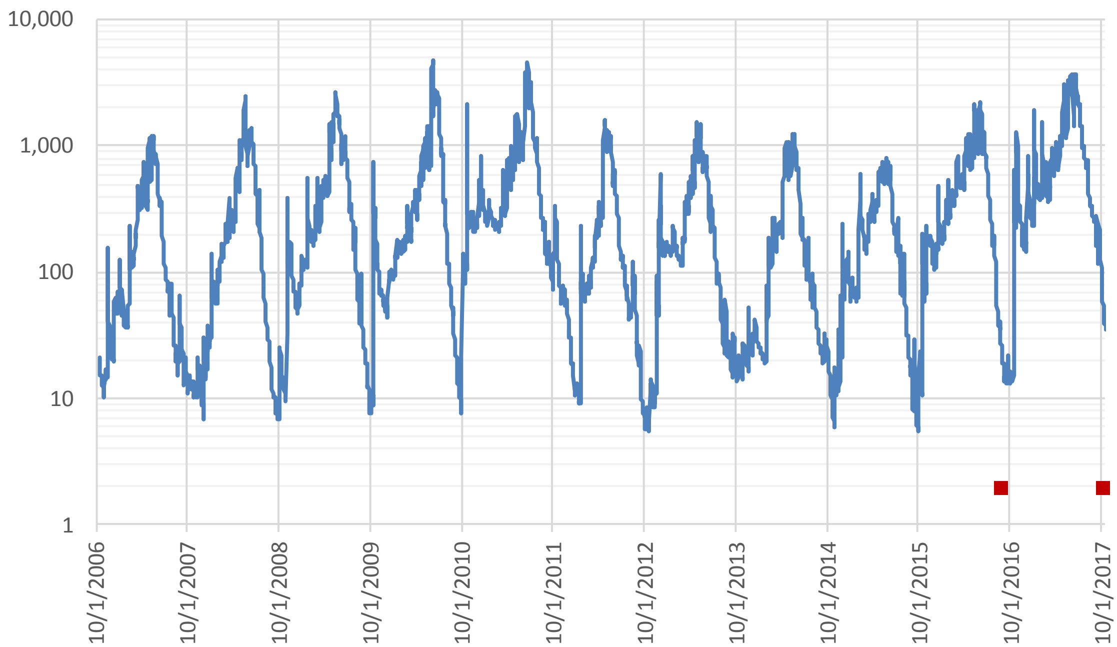

Figure 23. Mean daily streamflow (cfs) in the Tuolumne River at Above Hetch Hetchy gage (USGS 11274790) for WY 2007–2017. Snorkel surveys by the SFPUC in September 2016 and October 2017 are identified by red markers.

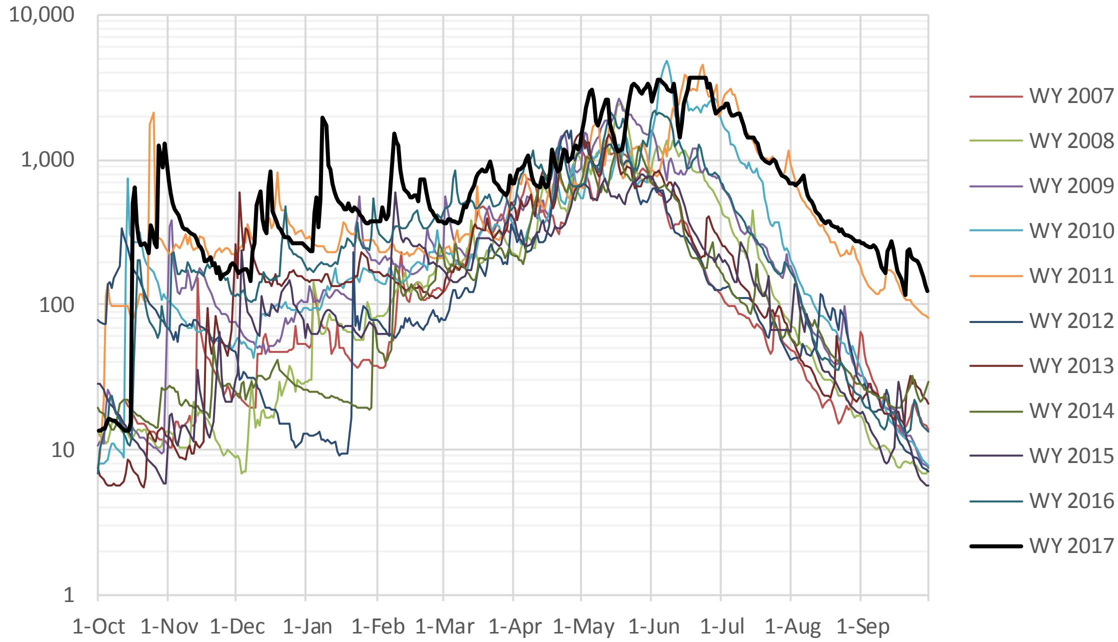

Figure 24. Mean daily streamflow (cfs) in the Tuolumne River at Above Hetch Hetchy gage (USGS 11274790) for WY 2007–2017, presented individually.

Table 27. Streamflow metrics (in cfs) for WY 2007–2017 at the USGS gage in the Above Hetch Hetchy Reservoir Reach.

Flow metric (cfs)	Water year										
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Tuolumne River at Above Hetch Hetchy gage (USGS 11274790)											
Mean daily average	215	292	399	492	682	219	266	204	193	449	922
Median daily average	63	84	181	175	308	80	146	62	98	251	543
Minimum daily average	10	7	8	8	8	7	5	14	6	7	14
Maximum daily average	1,217	2,512	2,653	4,844	4,522	1,591	1,549	1,243	796	2,195	3,720
Instantaneous maximum (peak)	1,420	3,160	3,330	7,060	6,650	1,840	1,780	1,460	986	2,780	4,660

6.3.3 Cherry Creek and Eleanor Creek Reaches

Streamflow in the Cherry Creek Reach was analyzed at three flow monitoring stations: the USGS gage 11277300 below Valley Dam at the upstream end of the reach (“Below Valley Dam gage”), the USGS gage 11278300 above Holm Powerhouse near the downstream end of the reach (“Above Holm Powerhouse gage”), and the USGS gage 11278400 below Holm Powerhouse at the downstream end of the reach (“Below Holm Powerhouse gage”). In addition, streamflow in the Eleanor Creek Reach was analyzed at one flow monitoring station: the USGS gage 11278000 in Eleanor Creek near Hetch Hetchy (“Eleanor Creek gage”). Flows are presented to illustrate conditions in the reach during WY 2017 relative to conditions in previous years (the preceding decade) (Figures 25–32).

Streamflow at Below Valley Dam gage is generally greatest during the peak snowmelt runoff period (May–June) and is low during the fall and winter (September–February) (Figure 26). Short-duration, high-flow events occasionally occur during winter (e.g., WY 2011 and WY 2013) (Figures 25 and 26). During WY 2017, high-magnitude flow events occurred during September, January, and February, and high spring runoff persisted from late March through early August (Figure 26). From the end of August through mid-September, water releases from Valley Dam were increased to drawn down lake levels to prepare for release valve maintenance work scheduled for 2018. Daily average flow at Below Valley Dam gage during WY 2017 ranged from a minimum of 5 cfs in November to a maximum of 3,081 cfs in January. Mean daily average flow for WY 2017 was 549 cfs, the highest flows recorded since WY 2007. Average daily streamflow during 2017 snorkel surveys was approximately 14 to 18 cfs (Figure 26).

Streamflow at Above Holm Powerhouse gage is influenced by flow releases at Valley and Eleanor Creek dams in addition to flow accretion from contributing tributaries in the Upper Cherry and Lower Cherry sub-reaches and the Eleanor Creek Reach. Streamflow at Above Holm Powerhouse gage generally peaks during the snowmelt runoff period (April–July), with occasional precipitation-driven high flow events occurring during fall and winter (September–February) (Figure 28). During WY 2017, numerous high-magnitude flow events occurred during September through February, and sustained high flows occurred during late March through early August (Figure 28, Table 28). Daily average flow at Above Holm Powerhouse gage during WY 2017 ranged from 17 cfs in November to 12,167 cfs in January. Mean daily average flow during WY 2017 was 1,149 cfs. During WY 2017, the mean daily average, maximum daily average, and peak flows were the highest recorded since WY 2007, and substantially higher than flows observed during the 2007–2016 period (Figures 27 and 28, Table 28). Average daily streamflow at Above Holm Powerhouse gage during 2017 snorkel surveys was approximately 30 to 35 cfs (Figure 28).

Streamflow at Below Holm Powerhouse gage is influenced by releases from Holm Powerhouse in addition to flow from Cherry and Eleanor creeks as measured at Above Holm Powerhouse gage. Streamflow at Below Holm Powerhouse gage is generally lowest during October–December, greatest during March–June, and moderate during January–February and July–September. Highly variable powerhouse releases generally dominate streamflow conditions in the Holm Powerhouse sub-reach. As observed elsewhere during WY 2017, streamflow was relatively high compared with recent years (2007–2016). In WY 2017, streamflow at Below Holm Powerhouse gage remained relatively high from January through July, averaging about 2,990 cfs during this period. Average daily streamflow in WY 2017 recorded at Below Holm Powerhouse gage ranged from a minimum of 82 cfs during November to a maximum of 12,744 cfs during January. Average daily streamflow at Below Holm Powerhouse gage during 2017 snorkel surveys was approximately 40 cfs (Figure 30).

Streamflow at Eleanor Creek gage is influenced by releases from Lake Eleanor Dam, which are dominated by natural runoff patterns into Lake Eleanor. Average daily flow in WY 2017 recorded at Eleanor Creek gage ranged from 6 cfs in November to 6,756 cfs in January (Table 28). During WY 2017, average daily flow at Eleanor Creek gage was relatively low from late November through early December, and relatively high from late December through June. WY 2017 streamflow during January through early March was substantially higher compared with conditions during the previous decade (WY 2007–2016). Average daily streamflow at Eleanor Creek gage during 2017 snorkel surveys was approximately 13 cfs (Figure 32).

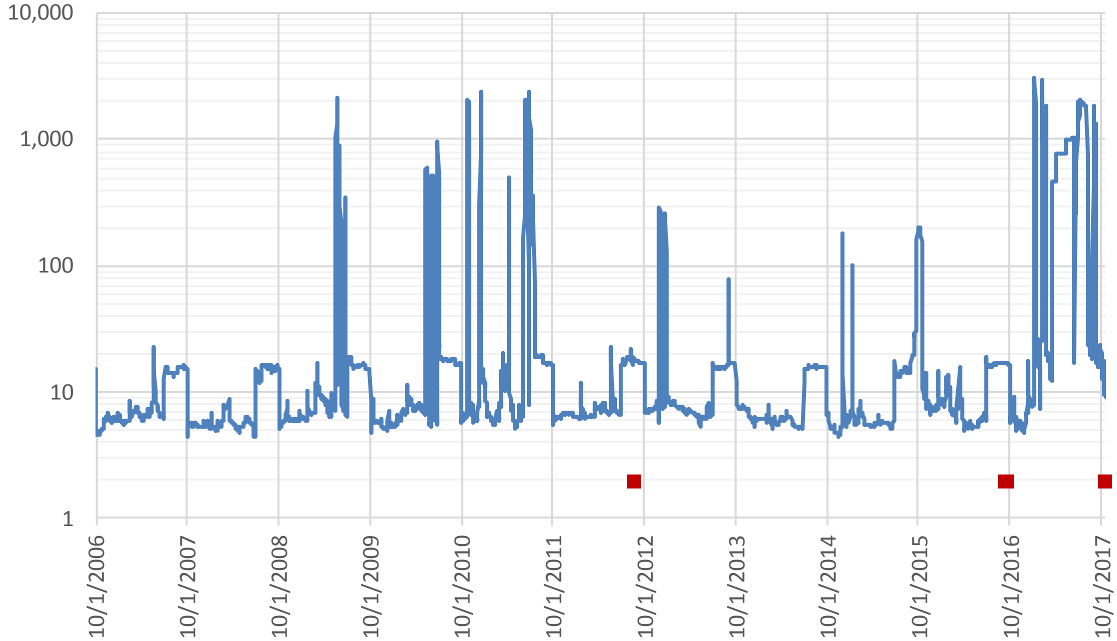

Figure 25. Mean daily streamflow (cfs) in Cherry Creek at Below Valley Dam gage (USGS 11277300) for WY 2007–2017. Snorkel surveys performed in August 2012, September 2016, and October 2017 are identified by red markers.

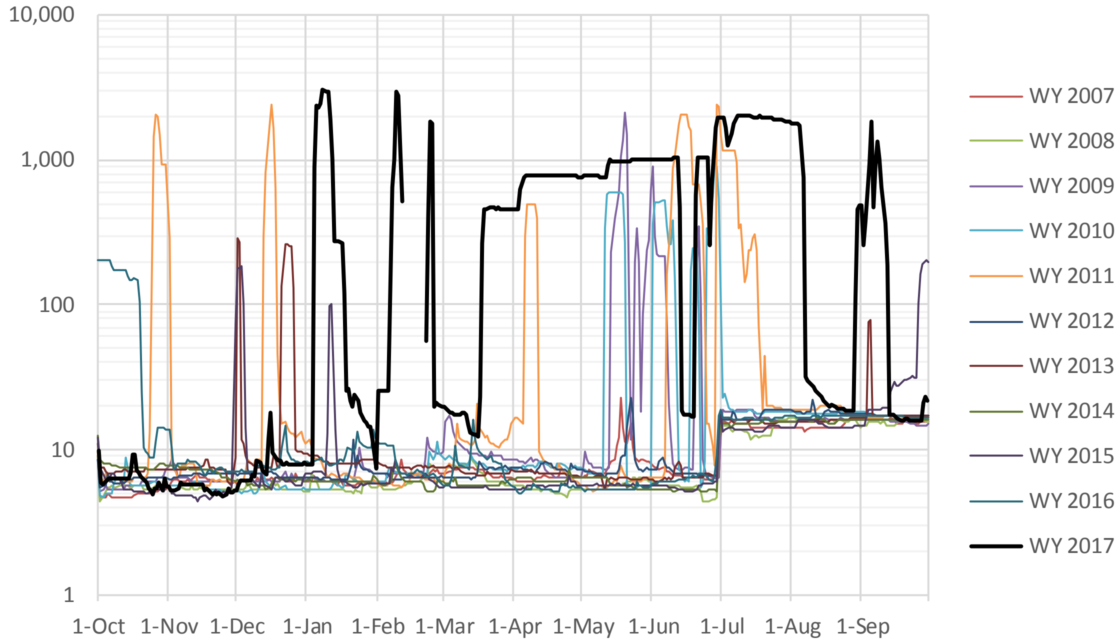

Figure 26. Mean daily streamflow (cfs) in Cherry Creek at Below Valley Dam gage (USGS 11277300) for WY 2007–2017, presented individually.

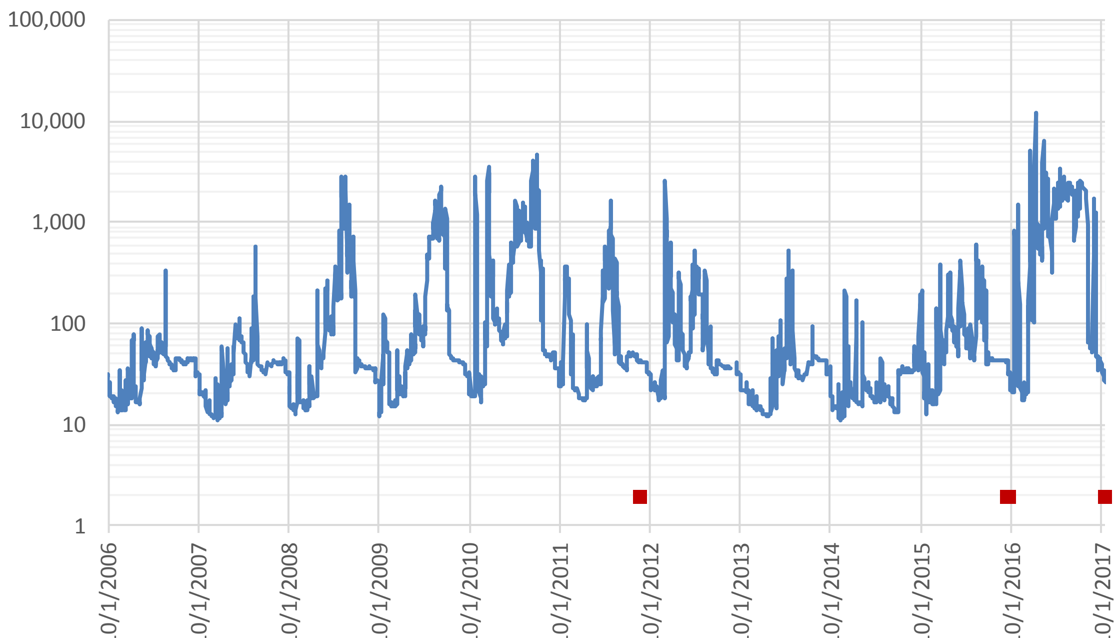

Figure 27. Mean daily streamflow (cfs) in Cherry Creek at Above Holm Powerhouse gage (USGS 11278300) for WY 2007–2017. Snorkel surveys performed in August 2012, September 2016, and October 2017 are identified by red markers.

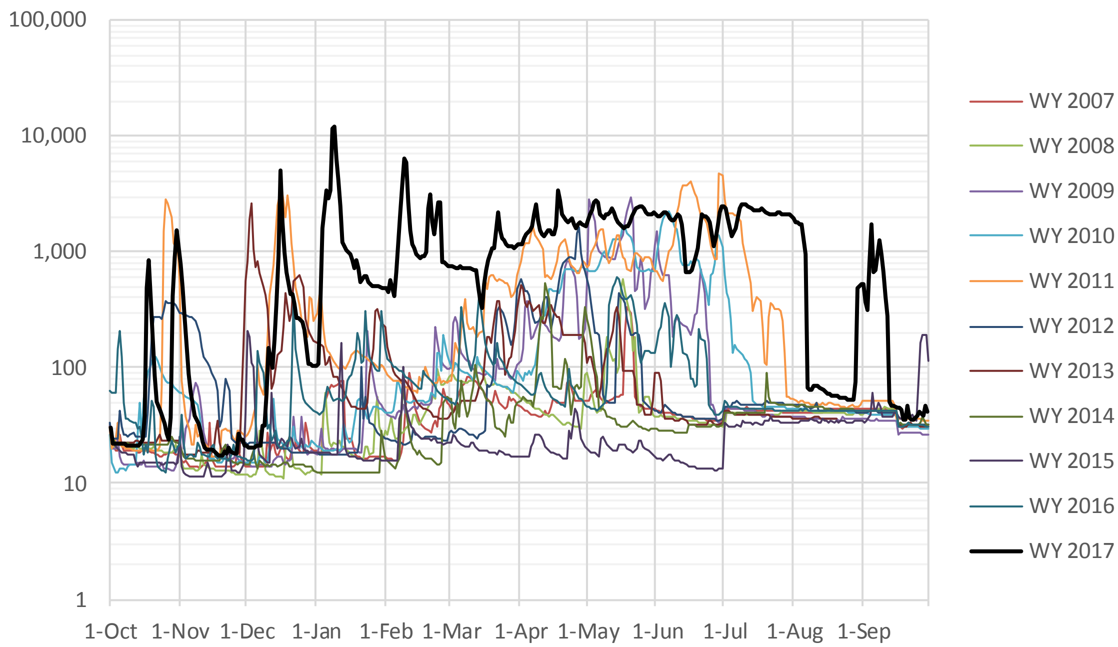

Figure 28. Mean daily streamflow (cfs) in Cherry Creek at Above Holm Powerhouse gage (USGS 11278300) for WY 2007–2017, presented individually.

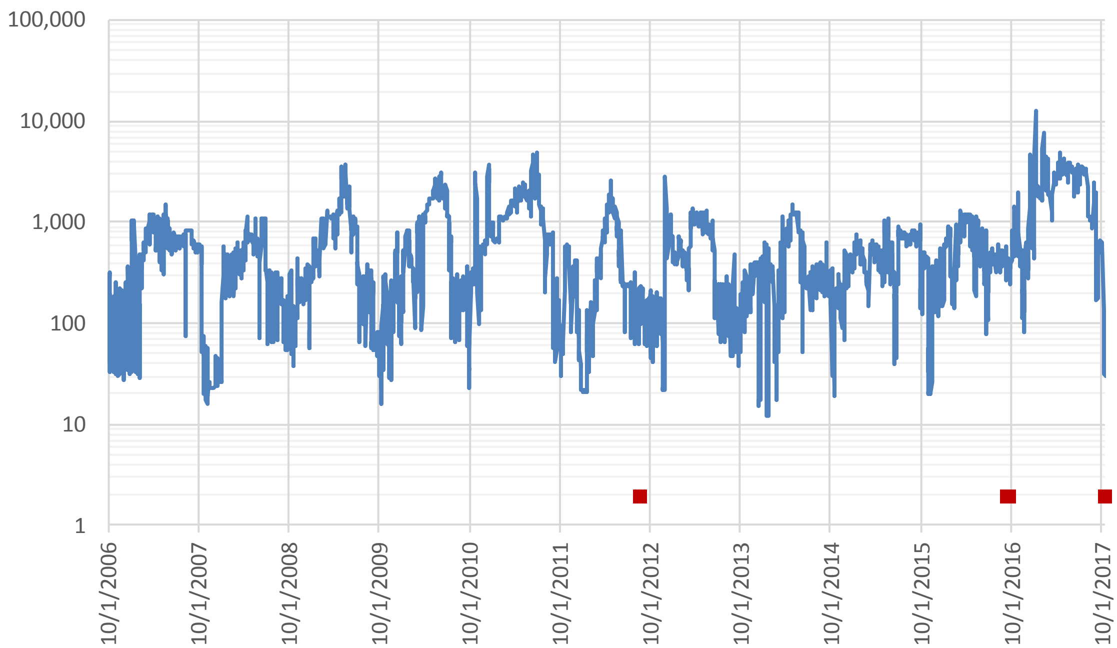

Figure 29. Mean daily streamflow (cfs) in Cherry Creek at Below Holm Powerhouse gage (USGS 11278400) for WY 2007–2017. Snorkel surveys performed in August 2012, September 2016, and October 2017 are identified by red markers.

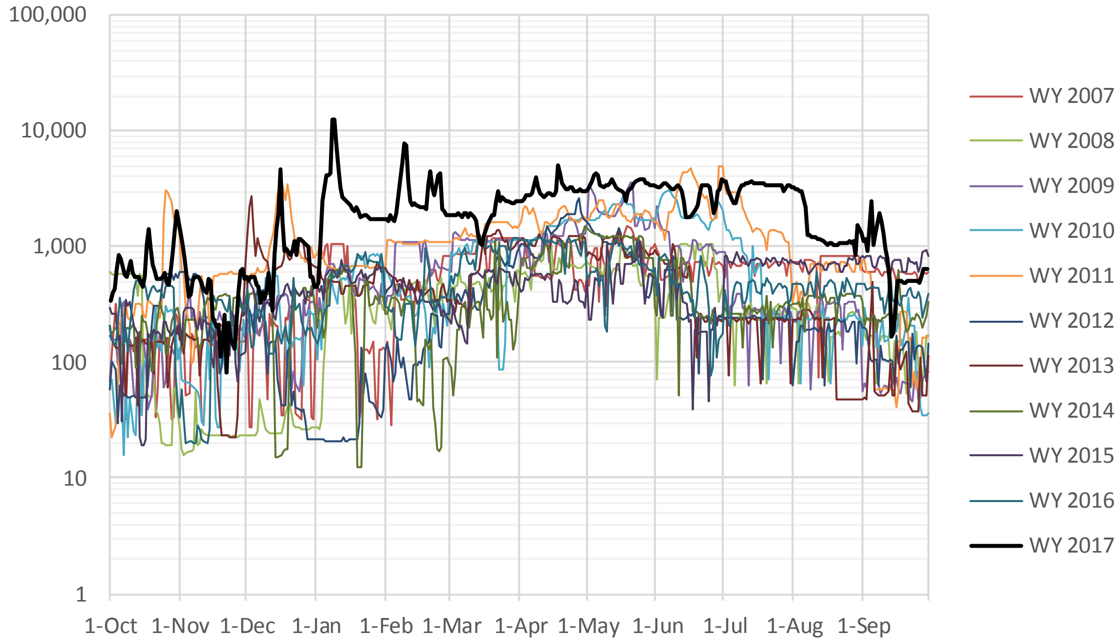

Figure 30. Mean daily streamflow (cfs) in Cherry Creek at Below Holm Powerhouse gage (USGS 11278400) for WY 2007–2017, presented individually.

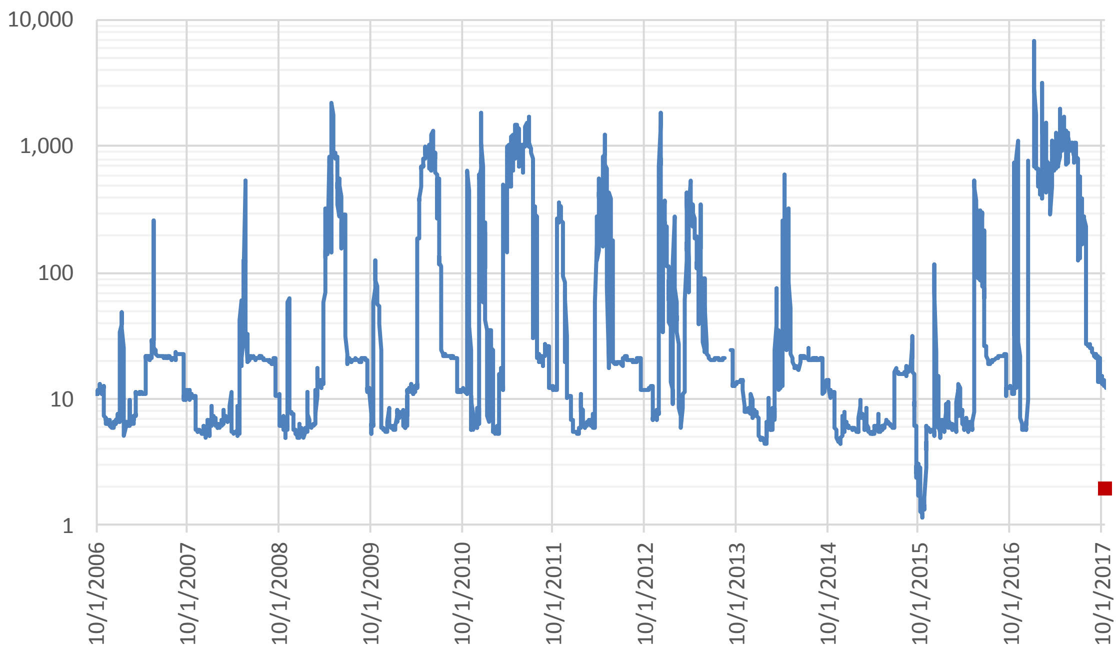

Figure 31. Mean daily streamflow (cfs) in Eleanor Creek at Eleanor Creek gage (USGS 11278000) for WY 2007–2017. Snorkel surveys performed in October 2017 are identified by a red marker.

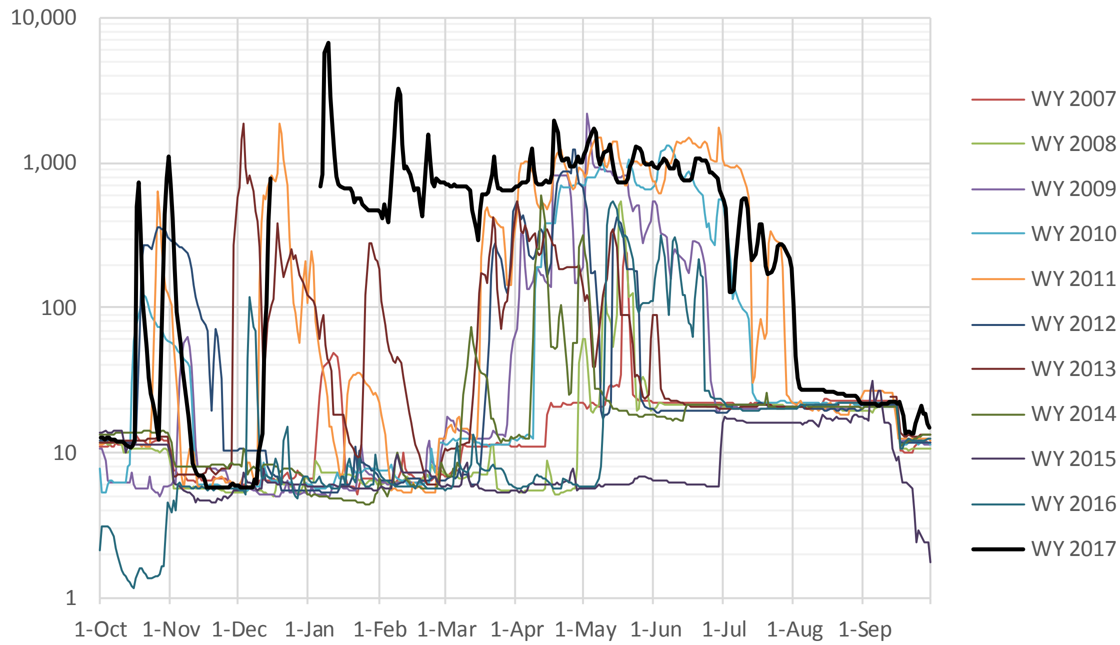

Figure 32. Mean daily streamflow (cfs) in Eleanor Creek at Eleanor Creek gage (USGS 11278000) for WY 2007–2017, presented individually.

Table 28. Streamflow metrics (in cfs) for WY 2007—2017 at USGS gages in the Cherry Creek and Eleanor Creek reaches.

Flow metric (cfs)	Water year										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cherry Creek at Below Valley Dam gage (USGS 11277300)											
Mean daily average	9	8	43	48	162	10	15	9	13	18	549
Median daily average	7	6	8	7	10	7	8	6	6	8	28
Minimum daily average	5	4	5	5	5	6	5	5	4	5	5
Maximum daily average	23	17	2,114	963	2,429	23	288	16	201	202	3,081
Instantaneous maximum (peak)	33	20	2,760	1,230	3,400	44	556	28	205	205	4,520
Cherry Creek at Above Holm Powerhouse gage (USGS 11278300)											
Mean daily average	39	44	187	249	575	118	125	41	27	84	1,149
Median daily average	40	37	38	51	133	42	44	31	20	48	826
Minimum daily average	13	11	13	12	17	18	18	12	11	13	17
Maximum daily average	330	585	2,904	2,234	4,770	1,629	2,602	535	211	610	12,167
Instantaneous maximum (peak)	419	751	3,640	2,390	6,770	2,310	3,980	931	244	652	18,200
Cherry Creek at Below Holm Powerhouse gage (USGS 11278400)											
Mean daily average	577	356	677	746	1,240	392	505	414	481	505	2,106
Median daily average	603	302	372	341	1,081	238	385	310	503	440	1,917
Minimum daily average	27	16	39	16	23	21	22	12	19	20	82
Maximum daily average	1,517	1,145	3,652	3,048	4,998	2,633	2,782	1,487	1,079	1,307	12,744
Instantaneous maximum (peak)	1,610	1,600	4,390	3,200	6,590	3,190	3,890	1,940	1,220	1,620	20,100
Eleanor Creek gage (USGS 11278000)											
Mean daily average	17	20	125	166	354	96	98	26	9	35	545
Median daily average	12	10	16	18	30	20	21	14	6	7	488
Minimum daily average	5	5	5	5	5	5	6	4	2	1	6
Maximum daily average	257	545	2,205	1,336	1,862	1,233	1,882	597	32	543	6,756
Instantaneous maximum (peak)	352	777	2,680	1,500	2,580	1,720	3,230	983	83	602	10,300

6.4 Water Temperature

6.4.1 Hetch Hetchy Reach

Daily average water temperature data for Hetch Hetchy gage and Above Early Intake gage are plotted for WY 2007 through WY 2017, both consecutively (Figures 33 and 35) and individually (Figures 34 and 36) to illustrate annual patterns and compare WY 2017 with conditions during the previous decade. Water temperature metrics based on daily data for WY 2017 are presented in Table 29.

Water temperatures at Hetch Hetchy gage are generally lowest from January through April and highest in June and July, with moderate water temperatures in August through November and transitional periods in December and May (Figure 34). In WY 2017, water temperatures at Hetch Hetchy gage were relatively low from January through mid-June compared with recent years (2007–2016). The highest water temperatures during WY 2017 were relatively high and later than observed in recent years (2007–2016), extending through mid-September.

Above Early Intake gage follows a slightly different pattern compared with Hetch Hetchy gage, with lowest temperatures during December and January, increasing steadily to the highest temperatures in late June to early August, and then steadily decreasing from September through November (Figure 36). In WY 2017, water temperatures at Above Early Intake gage were relatively low from May through mid-July compared with recent years, and the highest water temperatures in WY 2017 were generally shifted later in the year.

The seasonal range of water temperatures at Hetch Hetchy gage is relatively narrow compared with Above Early Intake gage due to the proximity of Hetch Hetchy gage to O'Shaughnessy Dam. During WY 2007–2017, daily average water temperatures at Hetch Hetchy gage ranged from 42.0 degrees Fahrenheit (°F) to 65.7°F, compared with 34.4°F to 73.9°F at Above Early Intake gage. Instantaneous water temperatures at Hetch Hetchy gage and Above Early Intake gage ranged from 39.6°F to 66.9°F and 33.4°F to 79.3°F, respectively (Table 29).

Despite the relatively wet conditions in WY 2017, water temperatures at Hetch Hetchy gage and Above Early Intake gage were not particularly high or low overall. However, water temperatures show relative differences seasonally. Daily average water temperatures at Hetch Hetchy gage in WY 2017 were relatively low in February through June, and relatively high in August and September (Figure 34). Daily average water temperatures at Above Early Intake gage in WY 2017 were relatively low in April through mid-July, and relatively high in late August and early September (Figure 36). Relatively high streamflow during WY 2017 is likely the cause of differences observed between WY 2017 and recent years. Similar conditions were observed during WY 2011, the water year with the next highest flow conditions compared with WY 2017.

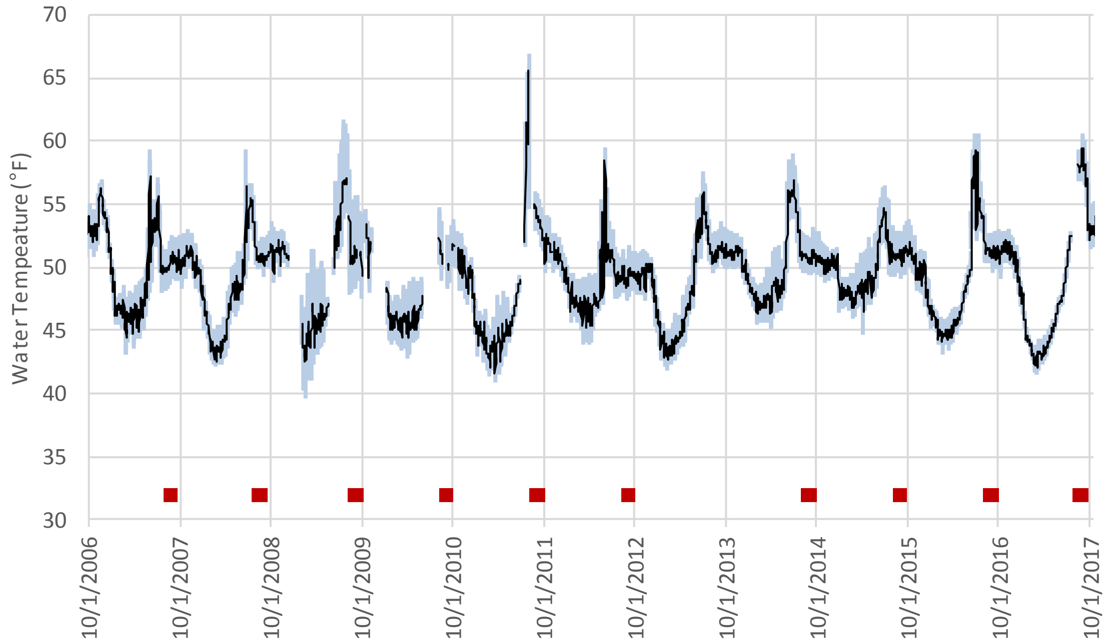

Figure 33. Daily average water temperature (black line) and daily water temperature range (blue lines) in the Tuolumne River at Hetch Hetchy gage (USGS 11276500) for WY 2007–2017. Snorkel surveys performed by the SFPUC in mid-August through September 2007–2012 and 2014–2017 are identified by red markers.

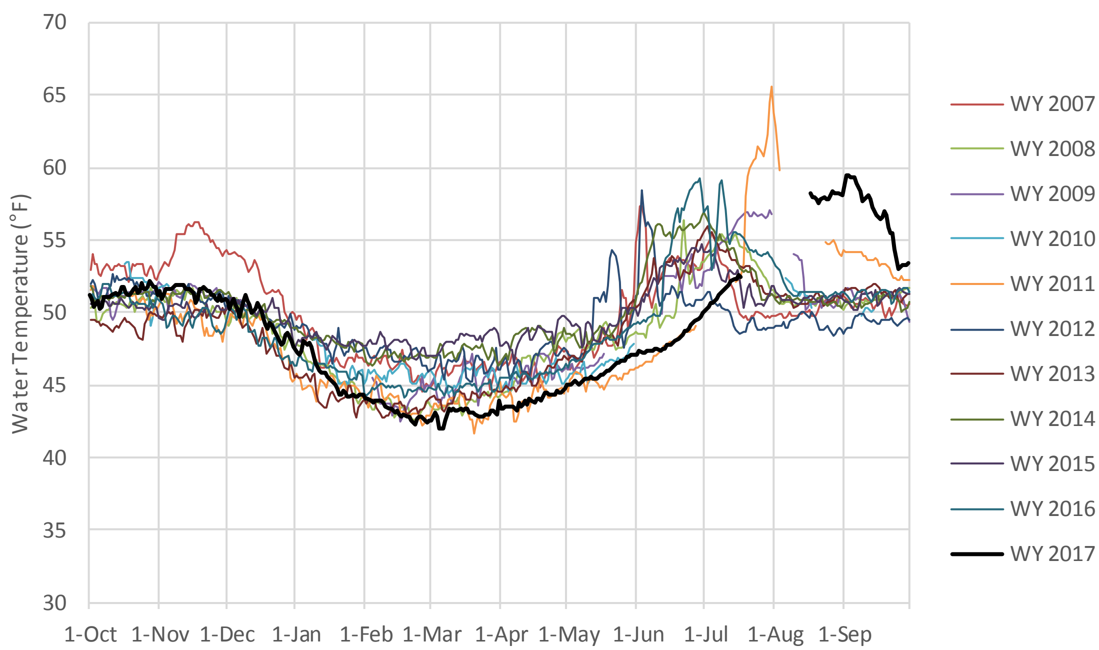

Figure 34. Daily average water temperature in the Tuolumne River at Hetch Hetchy gage (USGS 11276500) for WY 2007–2017, presented individually.

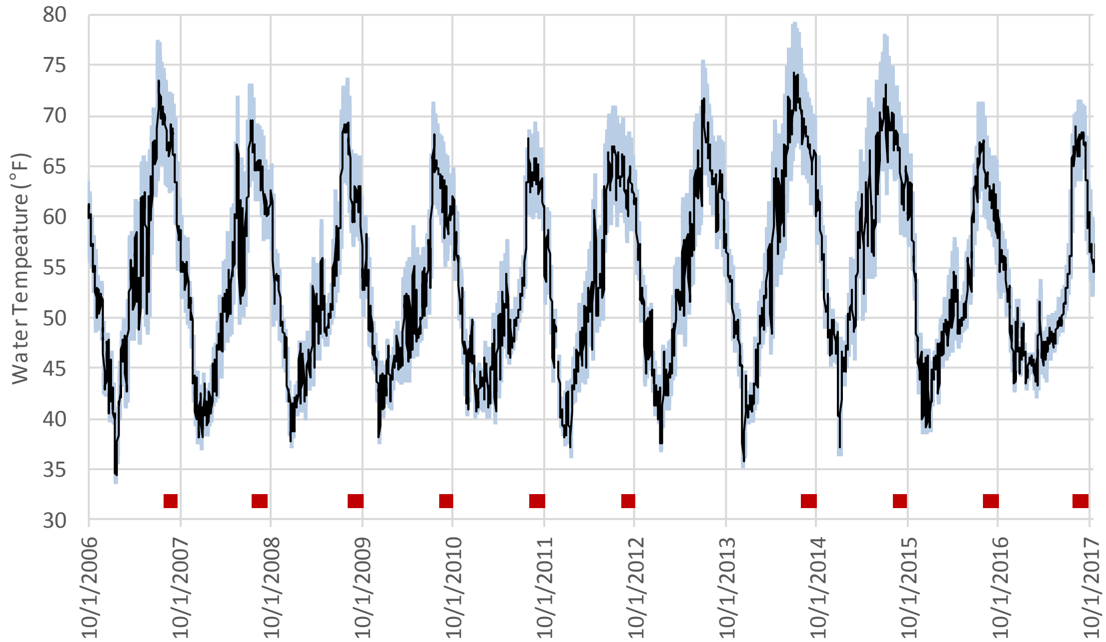

Figure 35. Daily average water temperature (black line) and daily water temperature range (blue lines) in the Tuolumne River at Above Early Intake gage (USGS 11276600) for WY 2007–2017. Snorkel surveys performed by the SFPUC in mid-August through early September 2007–2012 and 2014–2016 are identified by red markers.

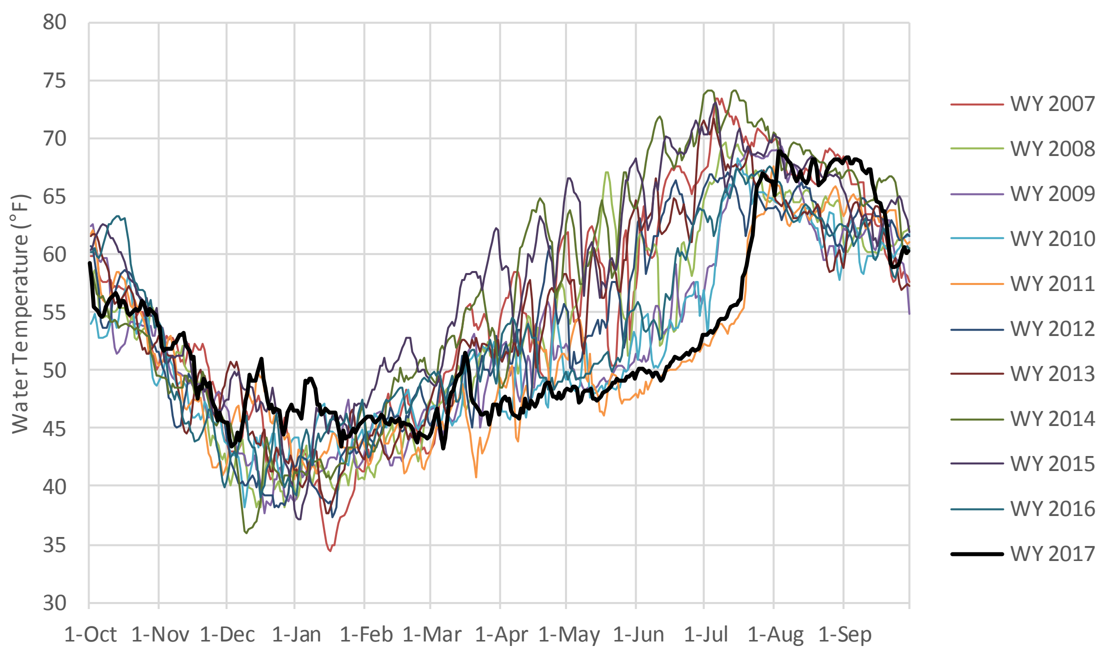

Figure 36. Daily average water temperature in the Tuolumne River at Above Early Intake gage (USGS 11276600) for WY 2007–2017, presented individually.

Table 29. Water temperatures (˚F) for WY 2007–2017 at USGS gages in the Hetch Hetchy Reach.

Temperature metric	Water year										
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Tuolumne River at Hetch Hetchy gage (USGS 11276500)											
Mean daily average	49.9	48.8	49.6	47.1	47.9	49.2	48.5	50.2	50.0	49.2	48.5
Minimum daily average	44.5	42.6	42.5	48.2	50.5	45.2	42.8	46.3	46.6	44.1	42.0
Maximum daily average	57.0	56.5	57.0	53.5	65.7	58.4	56.0	56.9	54.7	59.3	59.4
Minimum daily minimum	43.2	42.1	39.6	42.8	40.8	43.9	41.9	45.1	44.6	43.2	41.5
Maximum daily maximum	59.4	59.4	61.7	64.2	66.9	59.5	57.6	59.0	56.5	60.6	60.6
Tuolumne River at Above Early Intake gage (USGS 11276600)											
Mean daily average	55.3	53.5	52.3	51.9	51.3	53.7	54.6	56.7	58.0	53.3	52.4
Minimum daily average	34.4	38.2	37.7	38.2	40.7	37.3	37.6	36.1	37.1	39.1	43.3
Maximum daily average	73.0	69.7	69.4	68.2	67.7	67.1	71.8	73.9	73.1	67.7	69.0
Minimum daily minimum	33.4	36.9	37.0	37.4	39.4	36.1	36.7	35.1	36.3	38.5	42.1
Maximum daily maximum	77.5	73.2	73.8	71.4	69.4	71.1	75.6	79.3	78.1	71.4	71.6

6.4.2 Above Hetch Hetchy Reservoir Reach

Water temperatures at Above Hetch Hetchy gage are generally lowest in December and January and highest in July and August (Figures 37 and 38). During WY 2007–2017, mean daily average water temperatures at Above Hetch Hetchy gage ranged from 45.2°F to 51.0°F, and instantaneous water temperatures ranged from 32.0°F to 74.1°F (Table 30). For WY 2017, maximum daily average water temperature was 63.2°F, the lowest observed during WY 2007–2017. Daily average water temperatures at Above Hetch Hetchy gage in WY 2017 were relatively low in June through September, and otherwise generally within the range observed during previous years.

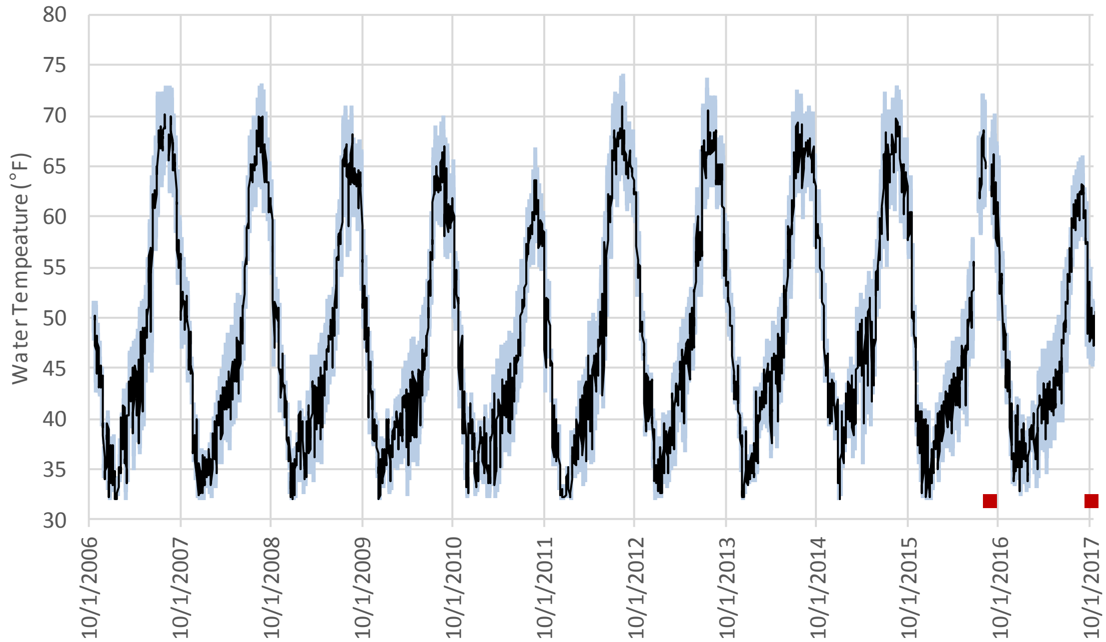

Figure 37. Daily average water temperature (black line) and daily water temperature range (blue lines) in the Tuolumne River at Above Hetch Hetchy gage (USGS 11274790) for WY 2007–2017. Snorkel surveys performed by the SFPUC in late August 2016 and early October 2017 are identified by red markers.

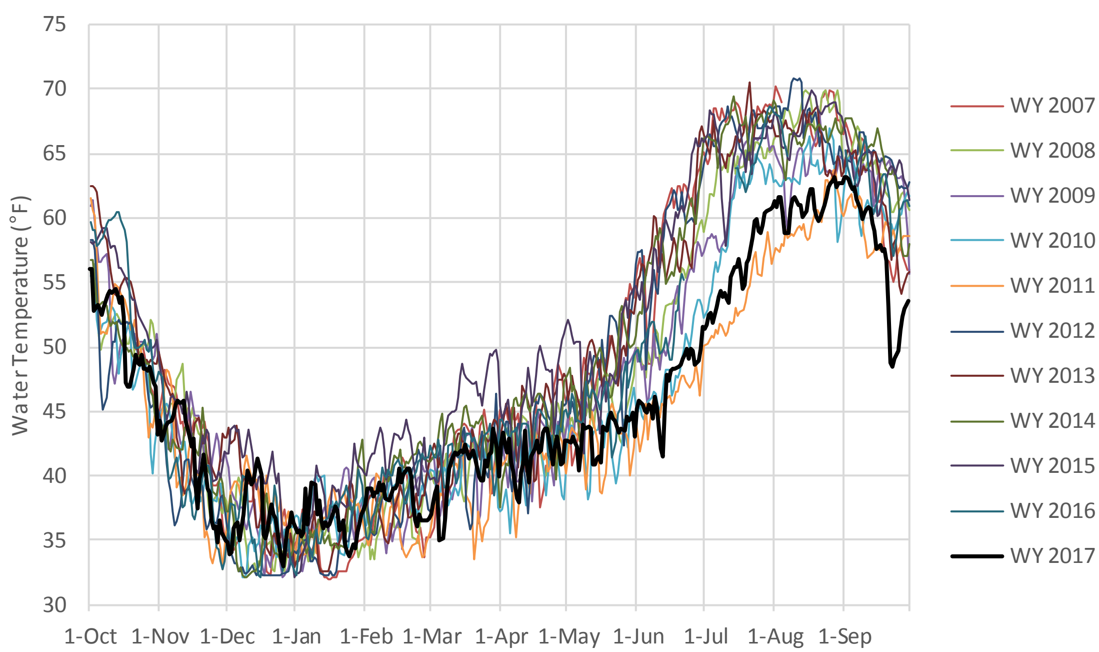

Figure 38. Daily average water temperature in the Tuolumne River at Above Hetch Hetchy gage (USGS 11274790) for WY 2007–2017, presented individually.

Table 30. Water temperatures (˚F) for WY 2007–2017 at the USGS gage in the Above Hetch Hetchy Reservoir Reach.

Temperature metric	Water year										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Tuolumne River at Above Hetch Hetchy gage (USGS 11274790)											
Mean daily average	48.6	48.3	48.1	46.6	45.2	48.7	49.8	49.5	51.0	46.3	45.9
Minimum daily average	32.0	32.5	32.1	32.1	32.7	32.2	32.6	32.2	32.1	32.2	32.9
Maximum daily average	70.1	70.0	68.1	66.9	63.8	70.9	70.5	69.4	69.9	68.6	63.2
Minimum daily minimum	32.0	32.0	32.0	32.0	32.2	32.0	32.0	32.0	32.0	32.0	32.4
Maximum daily maximum	73.0	73.2	71.1	70.2	66.9	74.1	73.8	72.7	73.0	72.3	66.2

6.4.3 Cherry Creek and Eleanor Creek Reaches

Daily water temperature data for Below Valley Dam, Above Holm Powerhouse, Below Holm Powerhouse, and Eleanor Creek gages were plotted for WY 2007 through WY 2017, both consecutively (Figures 39, 41, 43, and 45) and individually (Figures 40, 42, 44, and 46), to illustrate annual patterns and compare WY 2017 to conditions during the previous decade (2007–2016). Water temperature metrics based on daily data for the WY 2007 through WY 2017 period are presented in Table 31.

At Below Valley Dam gage during WY 2008 through WY 2017, average daily water temperatures ranged from 36.4°F to 69.6°F, and daily minimum and maximum temperatures ranged from 33.4°F to 72.5°F (Table 31). Water temperatures at Below Valley Dam gage are generally lowest from December through March and highest in June. Water temperatures generally remain stable from July through August before decreasing at the onset of fall in September (Figure 40). The annual pattern of daily average water temperatures for WY 2017 was different from what typically occurred in previous years; in WY 2017, the highest water temperatures occurred in late August and early September. Maximum water temperatures were also substantially higher in WY 2017 compared with previous years (Figure 40, Table 31). This spike in water temperature corresponded with a flow release from the Cherry Lake epilimnion in late August and early September (Figure 25) in preparation of release valve maintenance work at Valley Dam scheduled in 2018.

At Above Holm Powerhouse gage during WY 2009 through WY 2017, average daily water temperatures ranged from 31.7 °F to 74.9°F, and daily minimum and maximum temperatures ranged from 31.5°F to 79.3°F (Table 31). The annual pattern of daily average water temperatures at Above Holm Powerhouse gage follows a slightly different pattern than Below Valley Dam gage; at Above Holm Powerhouse gage, the lowest temperatures occur during late December and increase steadily to the highest temperatures in late June and July, and then steadily decrease again through fall into winter with no time periods where water temperatures remain stable (Figure 42). Water temperature pattern for WY 2017 generally followed a similar pattern to the other water years evaluated, except in July and early August when an unusual decrease in water temperature occurred (Figure 42). This atypical decrease in water temperature corresponded with a large flow release from Valley Dam (Figure 26).

At Below Holm Powerhouse gage during WY 2007 through WY 2017, average daily water temperatures ranged from 34.5 °F to 71.2°F, and daily minimum and maximum temperatures ranged from 33.3°F to 72.7°F (Table 31). The annual pattern of daily average water temperatures at Below Holm Powerhouse gage follows a slightly different pattern than Above Holm

Powerhouse gage; at Below Holm Powerhouse gage, the lowest temperatures occur during December through March and the highest water temperatures occur in June through September (Figure 44). Water temperatures in June through September are particularly variable. Daily average water temperature in WY 2017 generally followed a similar pattern as previous years, except for the period from early July through early September when daily average water temperatures increased steadily to peak at 71.2°F in early September, the highest maximum daily average temperature by 2.6°F over the 2007–2017 period.

At Eleanor Creek gage during WY 2007 through WY 2017, average daily water temperatures ranged from 36.5 °F to 73.2°F, and daily minimum and maximum temperatures ranged from 34.0°F to 76.5°F (Table 31). The annual pattern of daily average water temperatures at Eleanor Creek gage is relatively consistent, with lowest temperatures occurring during December through February and increasing steadily to the highest temperatures in late July through early September, and then steadily decreasing again through fall into winter with no time periods where water temperatures remain stable (Figure 46). Water temperatures for WY 2017 generally followed a similar pattern to the other water years evaluated.

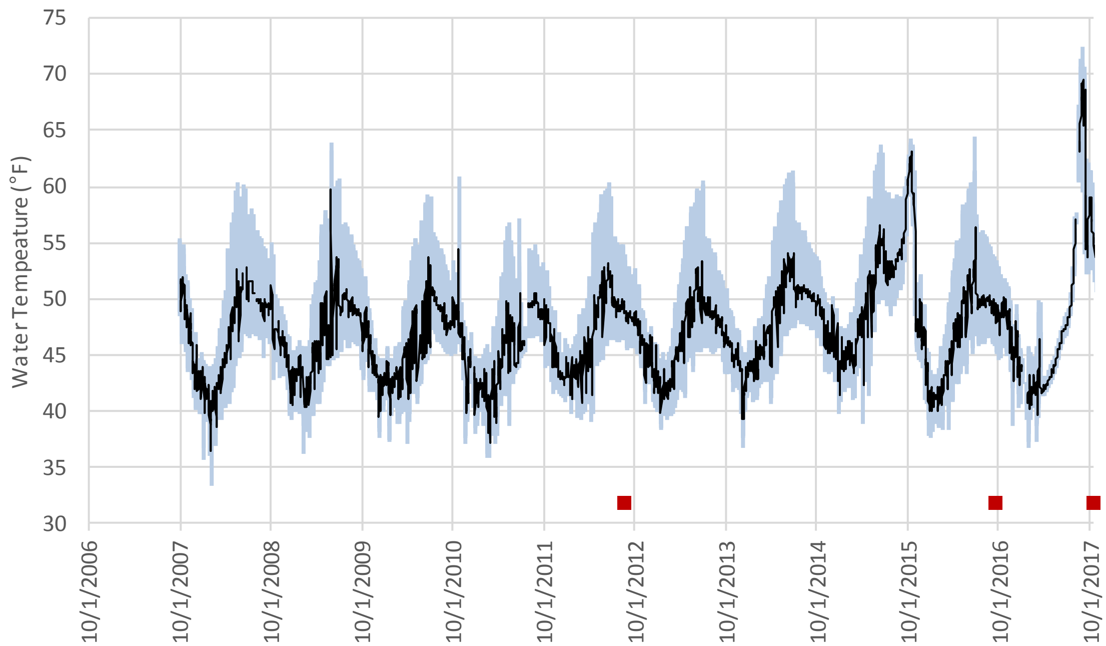

Figure 39. Daily average water temperature (black line) and daily water temperature range (blue lines) in Cherry Creek at Below Valley Dam gage (USGS 11277300) for WY 2007–2017. Snorkel surveys performed in August 2012, September 2016, and October 2017 are identified by red markers.

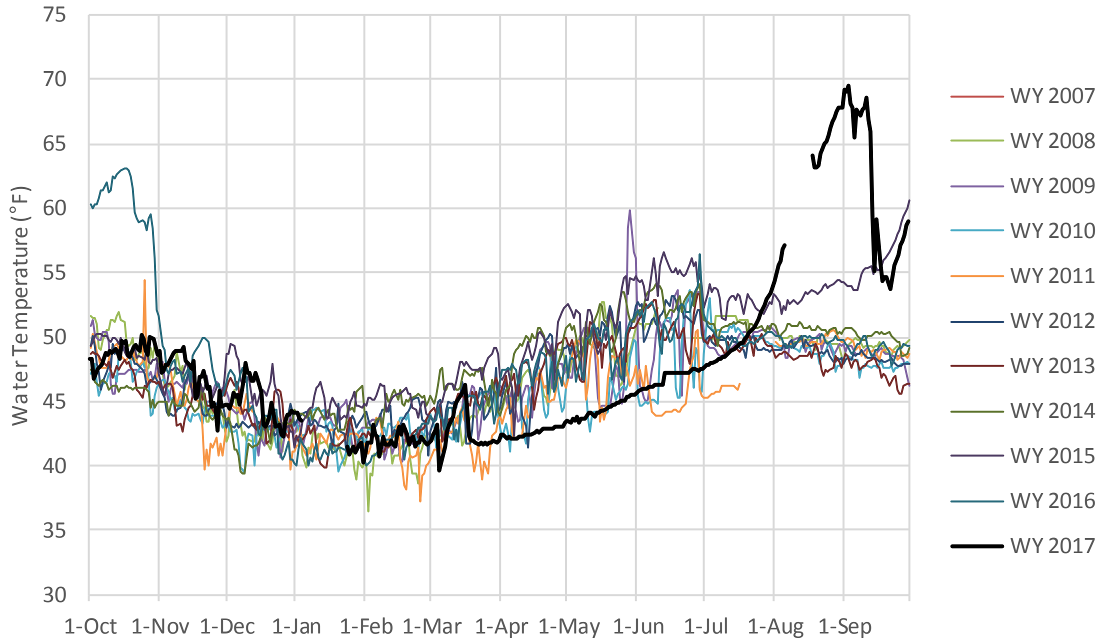

Figure 40. Daily average water temperature in Cherry Creek at Below Valley Dam gage (USGS 11277300) for WY 2007–2017, presented individually.

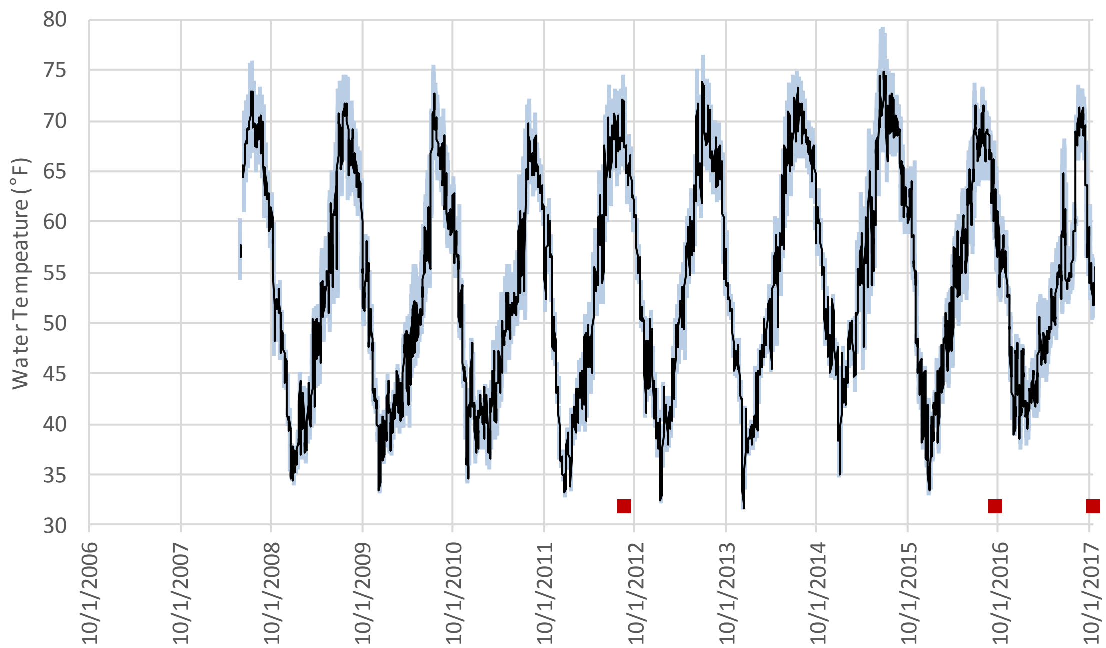

Figure 41. Daily average water temperature (black line) and daily water temperature range (blue lines) in Cherry Creek at Above Holm Powerhouse gage (USGS 11278300) for WY 2007–2017. Snorkel surveys performed in August 2012, September 2016, and October 2017 are identified by red markers.

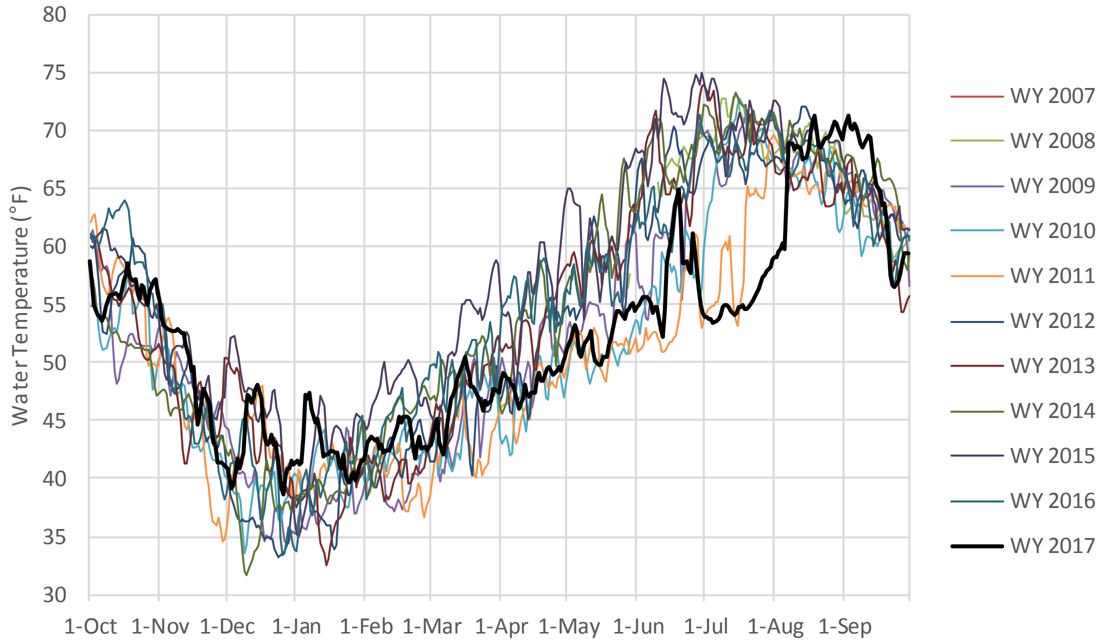

Figure 42. Daily average water temperature in Cherry Creek at Above Holm Powerhouse gage (USGS 11278300) for WY 2007–2017, presented individually.

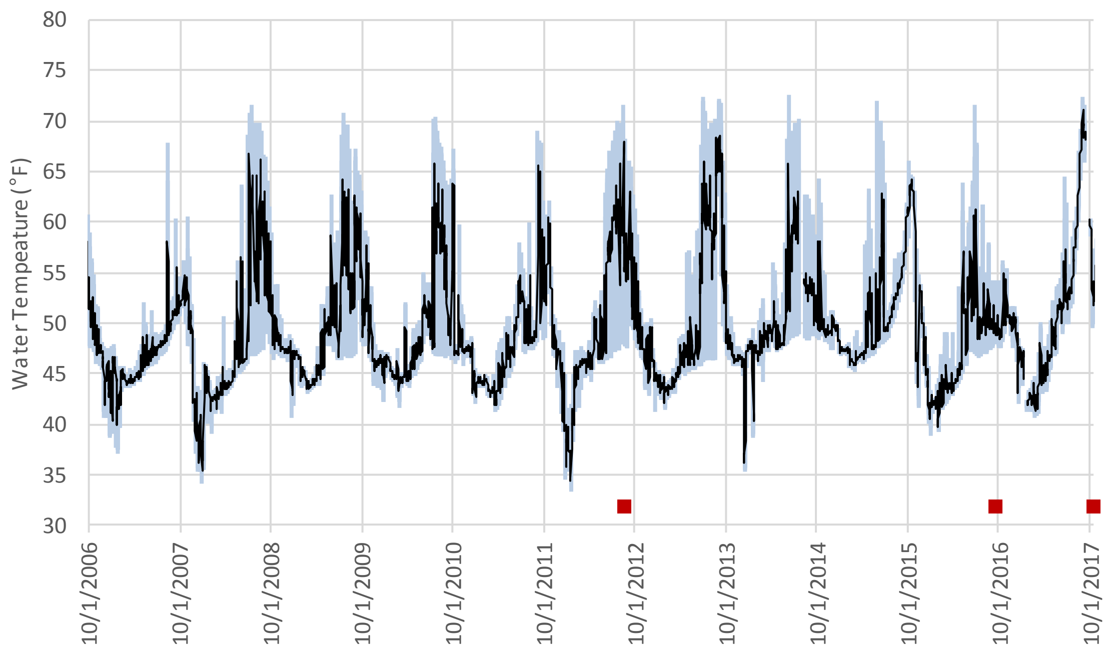

Figure 43. Daily average water temperature (black line) and daily water temperature range (blue lines) in Cherry Creek at Below Holm Powerhouse gage (USGS 11278400) for WY 2007–2017. Snorkel surveys performed in August 2012, September 2016, and October 2017 are identified by red markers.

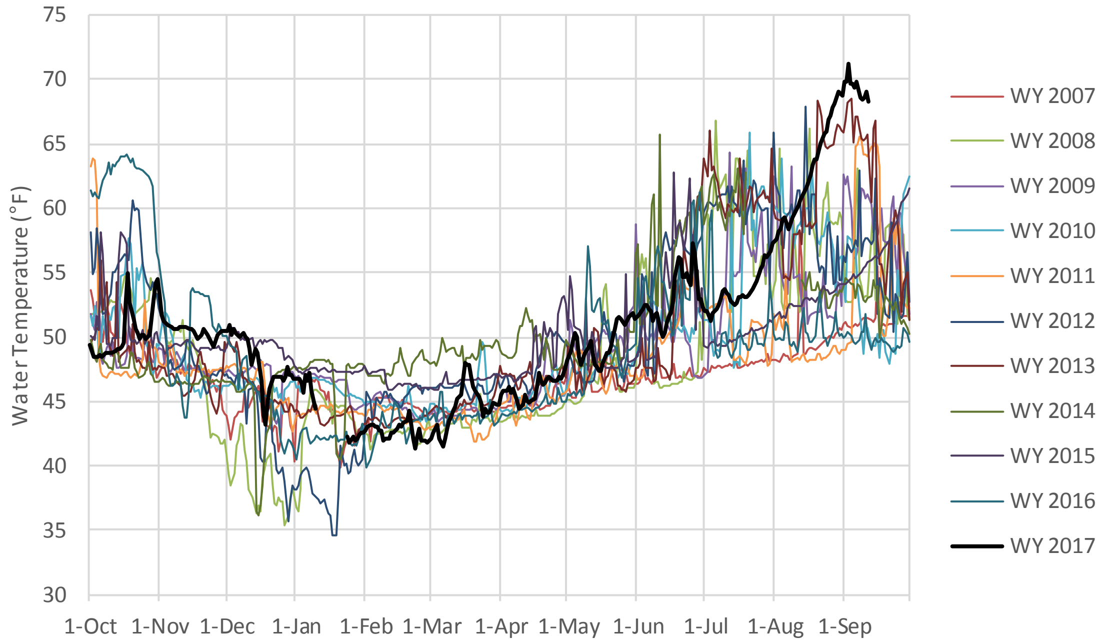

Figure 44. Daily average water temperature in Cherry Creek at Below Holm Powerhouse gage (USGS 11278400) for WY 2007–2017, presented individually.

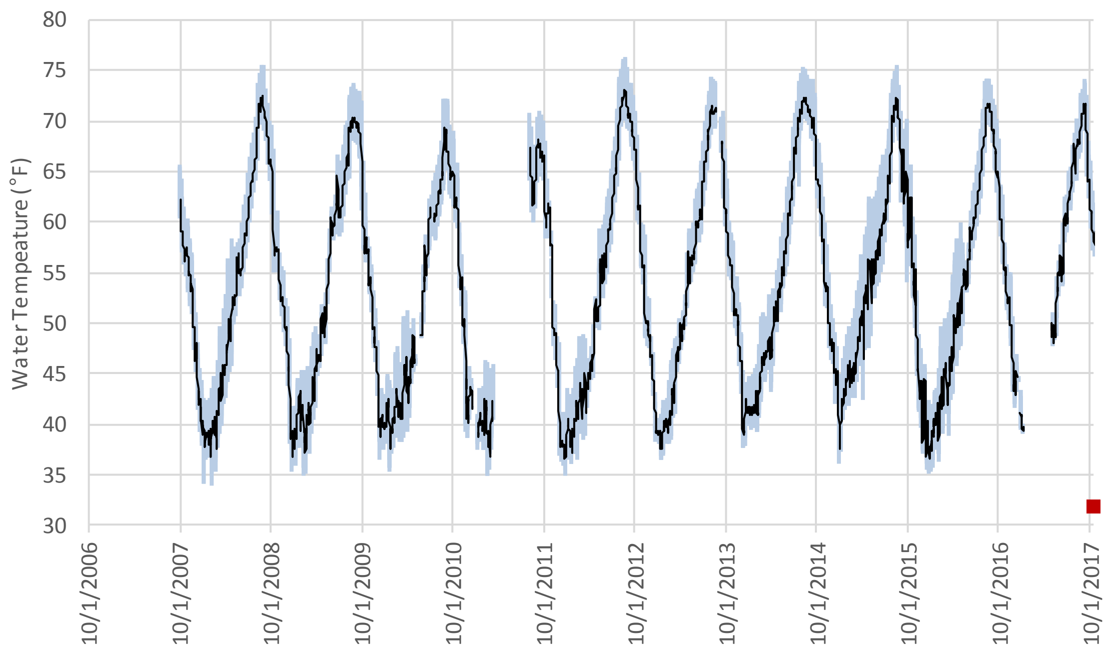

Figure 45. Daily average water temperature (black line) and daily water temperature range (blue lines) in Eleanor Creek at Eleanor Creek gage (USGS 11278000) for WY 2007–2017. Snorkel surveys performed in October 2017 are identified by a red marker.

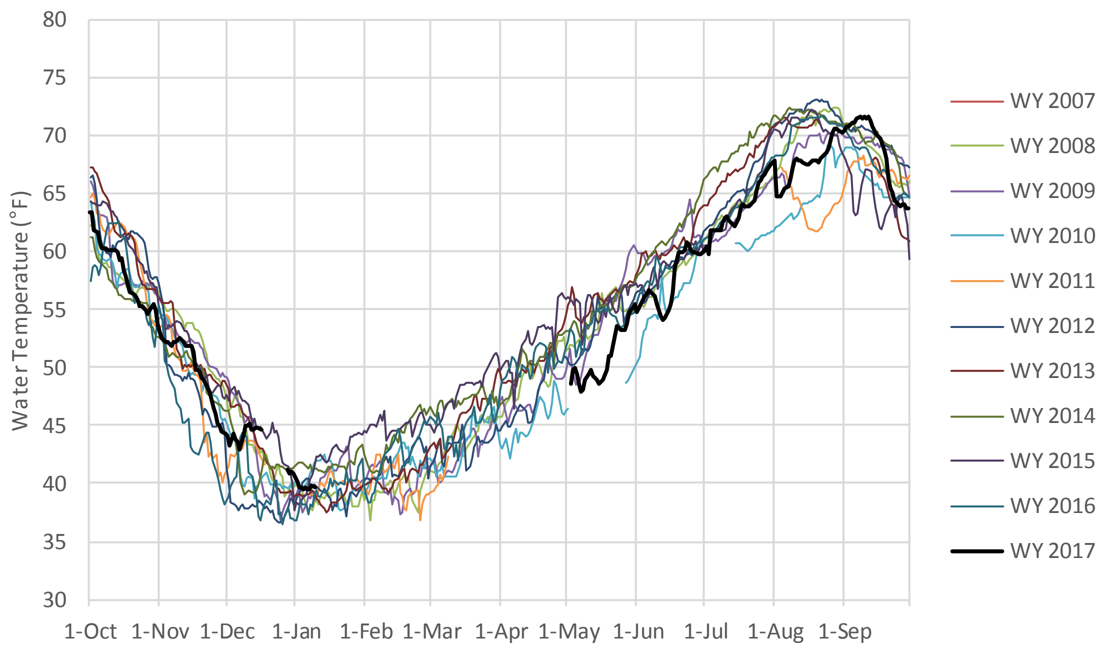

Figure 46. Daily average water temperature in Eleanor Creek at Eleanor Creek gage (USGS 11278000) for WY 2007–2017, presented individually.

Table 31. Water temperatures (°F) for WY 2007–2017 at USGS gages in the Cherry Creek and Eleanor Creek reaches.

Temperature metric	Water year										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Below Valley Dam gage (USGS 11277300)											
Mean daily average	--[a]	46.4	46.7	45.8	45.3	46.9	46.6	47.7	49.6	48.1	47.8
Minimum daily average	--[a]	36.4	40.3	39.4	37.2	40.8	39.9	39.3	41.4	40.0	39.6
Maximum daily average	--[a]	52.8	59.8	53.7	54.4	53.2	53.4	54.1	60.6	63.2	69.6
Minimum daily minimum	--[a]	33.4	36.1	37.0	35.8	39.0	38.3	36.7	38.8	37.6	36.7
Maximum daily maximum	--[a]	60.4	63.9	59.4	61.0	60.4	60.6	61.5	63.7	64.4	72.5
Above Holm Powerhouse gage (USGS 11278300)											
Mean daily average	--[a]	--[a]	52.6	51.3	50.9	53.5	54.1	54.7	57.4	54.7	52.2
Minimum daily average	--[a]	--[a]	34.4	33.5	34.5	33.2	32.5	31.7	35.0	33.4	38.5
Maximum daily average	--[a]	--[a]	71.8	72.8	69.7	72.2	74.0	73.3	74.9	71.5	71.3
Minimum daily minimum	--[a]	--[a]	34.0	33.1	34.2	32.7	32.2	31.5	34.7	32.9	37.6
Maximum daily maximum	--[a]	--[a]	74.7	75.6	72.1	74.7	76.6	75.0	79.3	73.8	73.6
Below Holm Powerhouse gage (USGS 11278400)											
Mean daily average	46.8	48.3	49.4	49.4	48.0	50.2	50.3	49.9	50.2	48.9	50.5
Minimum daily average	39.9	35.3	42.9	43.3	41.9	34.5	42.1	36.2	45.8	39.8	41.4
Maximum daily average	58.2	66.8	64.3	65.8	65.6	68.0	68.6	65.7	62.8	64.2	71.2
Minimum daily minimum	37.0	34.2	40.6	41.7	41.2	33.3	41.2	35.2	45.1	38.8	40.6
Maximum daily maximum	67.8	71.6	70.9	70.5	69.1	71.6	72.5	72.7	72.0	71.6	72.5
Eleanor Creek gage (USGS 11278000)											
Mean daily average	--[a]	53.4	53.4	51.3	52.1 [b]	53.3	53.5	54.8	55.0	52.9	57.5 [c]
Minimum daily average	--[a]	36.9	36.9	37.7	36.8 [b]	36.6	37.6	39.0	37.7	36.5	39.4 [c]
Maximum daily average	--[a]	72.5	70.3	69.4	68.3 [b]	73.2	71.6	72.4	72.4	71.8	71.7 [c]
Minimum daily minimum	--[a]	34.0	34.9	35.2	34.9 [b]	34.9	36.5	37.8	36.1	35.1	39.0 [c]
Maximum daily maximum	--[a]	75.6	73.8	72.3	71.1 [b]	76.5	74.5	75.4	75.6	74.3	74.1 [c]

[a] Water temperature metrics are not reported for water years with particularly large data gaps (>50% of data missing).
[b] Water temperature metrics are based on an incomplete data set. Data gaps during WY 2011 occurred in March through July.
[c] Water temperature metrics are based on an incomplete data set. Data gaps during WY 2017 occurred in December and January through early May.

7 CONCLUSIONS

7.1 Hetch Hetchy Reach

WY 2017 was one of the wettest on record and followed closely after drought conditions in the region during WY 2012–2015 and moderate conditions in WY 2016. Effects from the Rim Fire evidenced by coarse sediment (i.e., sand and small gravel) deposition in pools were substantially reduced in WY 2017 as the result of frequent high flows capable of scouring substantial amounts of sediment remaining stored in the channel during WY 2016. During 2017 fish monitoring surveys, no appreciable pool filling with coarse sediment was observed at monitoring sites where substantial deposition was observed in the past (i.e., sites 44-PW, 46-DP, and 49-SP).

In 2017, the total densities (all sub-reaches) of Rainbow Trout and Brown Trout ≤125 mm were significantly lower than observed during 2014–2016, and no Brown Trout ≤125 mm were observed during 2017 monitoring. Poor recruitment in 2017 is likely due to high flow conditions in 2017. Streamflow in 2017 included numerous short-duration, high-magnitude flow events during December through March, followed by a long period of high flows from April through July (spring snowmelt runoff), and relatively high peak flows (exceeding 10,000 cfs) in late June. In addition to high water velocities that can displace fish, these high flow conditions could result in localized redd scour, or possibly widespread bed mobilization that could significantly reduce availability of high flow refuge habitat provided by interstitial spaces in coarse bed material (cobble and boulder).

Monitoring results for 2017 indicate that Rainbow Trout and Brown Trout densities in the Early Intake and O'Shaughnessy sub-reaches were within the range observed during 2014–2016, and significantly lower in 2017 in the Preston Falls sub-reach compared with 2014–2016. Rainbow Trout and Brown Trout densities in the Preston Falls sub-reach were particularly high in 2014 and 2015 and have decreased significantly each year since 2015. The cause of the decrease in the Preston Falls sub-reach is uncertain but likely (at least in part) the result of relatively wet conditions during 2017 (and moderately wet conditions in 2016) compared with drought conditions in 2014 and 2015. The Preston Falls sub-reach has unique habitat characteristics compared with the other sub-reaches, which may also contribute to the observed differences between sub-reaches.

The densities of Rainbow Trout and Brown Trout >125 mm in the Early Intake and O'Shaughnessy sub-reaches generally show a similar pattern compared with each other for the 2014–2017 period, indicating that similar environmental pressures were likely influencing these populations. It is unclear why Rainbow Trout and Brown Trout densities (>125 mm) in the Preston Falls sub-reach show different patterns compared with the Early Intake and O'Shaughnessy sub-reaches, but habitat conditions are likely an important factor. Fish density at the Early Intake and O'Shaughnessy sub-reaches could be explained by the extended drought conditions in 2015 leading to the observed decrease in density compared with 2014, and then increased flow conditions in 2016 and 2017 leading to a density increase compared with 2015.

For the Preston Falls sub-reach, the density of Rainbow Trout >125 mm shows a steady decline from 2014 to 2017, whereas the density of Brown Trout >125 mm was greatest in 2015 and decreased in 2016, and again in 2017. Since water temperature and flow conditions in the Preston Falls sub-reach are expected to be intermediate to those in the Early Intake and O'Shaughnessy sub-reaches, these factors are not likely influencing trout populations differently in the Preston Falls sub-reach. Therefore, differences in density patterns in the Preston Falls sub-reach are more likely influenced by habitat conditions specific to the sub-reach.

Potentially poor recruitment of Rainbow Trout and Brown Trout ≤125 mm in 2017 suggests that the 2017 year-class may have low abundance, which may be detected in the age-1 population in 2018. Fortunately, densities of Rainbow Trout >125 mm observed in 2017 are likely sufficient to improve recruitment in 2018, if conditions are conducive to spawning and age-0 rearing in WY 2018.

The fish population monitoring approach and sampling framework developed in 2014 and implemented in 2014–2017 continues to detect statistically significant differences in trout population abundance and linear density from one year to the next in key sub-reaches of the Hetch Hetchy Reach of the Tuolumne River.

7.2 Above Hetch Hetchy Reservoir Reach

Monitoring of the Above Hetch Hetchy Reservoir Reach was initiated in WY 2016 and continued in WY 2017. Rainbow Trout densities in the Above Hetch Hetchy Reservoir Reach during WY 2017 were generally lower compared with densities observed in the Hetch Hetchy Reach for trout >125 mm. Two Brown Trout >125 mm were observed at one of the four monitoring sites surveyed in the Above Hetch Hetchy Reservoir Reach in 2017. No Rainbow or Brown Trout ≤125 mm were observed in the Above Hetch Hetchy Reservoir Reach in WY 2017.

Streamflow and water temperature at Above Hetch Hetchy gage are not affected by management and represent natural flow and water temperature regimes. The WY 2017 annual hydrograph generally showed a typical pattern compared with other water years during 2007–2016, although streamflow during WY 2017 was generally higher due to wet conditions. In WY 2016, mean daily streamflow was substantially higher compared with other years during WY 2007–2016. Water temperature during WY 2017 was similar to conditions observed in the past decade, except for a short negative spike in water temperature during September that resulted in relatively low water temperature for a short time.

7.3 Cherry Creek and Eleanor Creek Reaches

In WY 2017, the relatively wet conditions seen in much of California affected flows in Cherry Creek. The creek experienced numerous precipitation-driven high flow events during September and December through February, and persistent high flows during March through early August. The wet conditions seen in 2017 can have a strong influence on current fish populations and habitat conditions over varying time scales. Results from the 2017 monitoring in Cherry Creek indicate that Rainbow Trout densities (>125 mm) decreased in the Upper Cherry sub-reach and increased in the Lower Cherry sub-reach compared with 2016. Although the causes of these differing population responses are uncertain, they likely resulted from a combination of factors related to differences in habitat conditions between sub-reaches, and the effects of high flows during WY 2017. In addition, increased flows from Valley Dam to draw down Cherry Lake caused increased turbidity in the Upper Cherry sub-reach during 2017 field surveys, and reduced underwater visibility may have decreased fish detections. Streamflow from Eleanor Creek ameliorated water clarity downstream of the confluence with Cherry Creek, and a corresponding increase in linear densities of Rainbow Trout was observed in the Lower Cherry sub-reach compared with the Upper Cherry sub-reach. Water temperature may also influence trout density, with relatively low trout density at sites located near Valley Dam where water temperatures typically remain below 55°F throughout the year.

Densities of Rainbow Trout ≤125 mm in both the Upper Cherry and Lower Cherry sub-reaches declined compared with 2016. The decrease in density could be from fish being displaced downstream or caused by scour from high flows during WY 2017. The decrease in density from 2016 to 2017 is a continuation of the declining trend from 2012 to 2016. It is unclear how fish densities fluctuated during 2013–2015, but continued declines (e.g., in 2018) may indicate a population bottleneck.

The fish population monitoring approach and sampling framework for Cherry Creek appear to be effective for efficiently sampling fish populations in key habitat units and for detecting changes in fish population abundance from year to year and trends over longer periods.

8 RECOMMENDATIONS

8.1 Hetch Hetchy Reach

For 2017, minor modifications to the suite of monitoring sites sampled in the Hetch Hetchy Reach were made, including discontinuing sampling site 38-DP in the Early Intake sub-reach as well as discontinuing sampling site 229-PW in the O'Shaughnessy sub-reach. These modifications were intended to include habitats being used by trout and avoid habitats with very low trout density, and to more closely represent the existing relative frequency (by length) of habitat types in each sub-reach.

For 2018, sampling in the Hetch Hetchy Reach should continue in the same monitoring sites that were sampled in 2017.

8.2 Above Hetch Hetchy Reservoir Reach

In 2016, monitoring sites in the Above Hetch Hetchy Reservoir Reach were added to annual fisheries monitoring surveys to include an independent "control" reach to help understand the effects of managed flows on long-term population trends in the Hetch Hetchy Reach. Monitoring in the Above Hetch Hetchy Reservoir Reach continued in 2017 and is recommended to continue in the future. For 2017, minor modifications to the suite of monitoring sites sampled in the Above Hetch Hetchy Reservoir Reach were made, including discontinuing sampling site 507-SP and adding sampling site 505-PW.

The number of sites sampled in the Above Hetch Hetchy Reservoir Reach may be adjusted or expanded in 2018. Any modifications of sampling sites in 2018 should consider the criteria used to select monitoring sites in the Hetch Hetchy, Cherry Creek, and Eleanor Creek reaches.

8.3 Cherry Creek and Eleanor Creek Reaches

Minor modifications to the suite of monitoring sites sampled in Cherry Creek would likely be beneficial for evaluating long-term trends in trout populations. Adding a boulder garden habitat in the Upper Cherry sub-reach would more closely represent the existing frequency of the habitat types by length found in the sub-reach and provide better representation of trout abundance among the sub-reaches. In addition, adding a third snorkeler would be beneficial for boulder garden habitats to better cover the complexity found in this habitat type. Continued sampling of the Holm Powerhouse sub-reach in future years would allow for comparison of Rainbow Trout and Brown Trout densities from year to year and assess whether fish abundances were affected by abnormally low flows in the reach during the early part of WY 2018.

Monitoring sites sampled in the Eleanor Creek Reach in 2017 well represented the frequency of habitat types by length in the reach, and therefore sampling site modifications are not recommended for 2018.

9 REFERENCES

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