Robbs Peak Powerhouse Fish Entrainment Report

Sacramento Municipal Utility District

Hydro License Implementation • April 2017

Upper American River Project

FERC Project No. 2101

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Acronyms and Abbreviations

Acronym	Definition
ac-ft	acre-feet
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
FERC	Federal Energy Regulatory Commission
FD	full duplex
FL	fork length
fps	feet per second
ft	feet
GPS	Global Positioning System
kHz	kiloHertz
mi	mile
mm	millimeters
MSE	mean squared error
PIT	Passive Integrated Transponder
PG&E	Pacific Gas and Electric Company
SMUD	Sacramento Municipal Utility District
SWRCB	State Water Resources Control Board
UARP	Upper American River Project
USFS	U.S. Department of Agriculture, Forest Service

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1.0 INTRODUCTION AND BACKGROUND

This Fish Entrainment Report (Report) addresses monitoring requirements set forth in Sacramento Municipal Utility District's (SMUD) Fish Entrainment Monitoring Plan (SMUD 2015). The requirements for this Plan are found in State Water Resources Control Board (SWRCB) conditions 8. K and 9.E, and U.S. Forest Service (USFS) 4(e) conditions 31 and 32, located in Attachments A and B, respectively, of the Federal Energy Regulatory Commission's (FERC) Order Issuing New License for the Upper American River Project (UARP), dated July 23, 2014 (FERC 2014). The Plan was developed in consultation with the SWRCB, USFS, California Department of Fish and Wildlife (CDFW), and U.S. Fish and Wildlife Service. The objectives of the Plan are to assess the potential for fish entrainment at Robbs Peak Powerhouse and determine when and at what flow fish migration, and if applicable, entrainment, is occurring. If entrainment is occurring an additional objective of this plan is to determine if that rate of entrainment is having a substantial negative impact on the South Fork Rubicon River fishery. FERC approved the Plan on August 15, 2015. This report presents the results of implementing the Plan in 2015 and 2016.

SMUD owns and operates the UARP which is licensed by FERC. The UARP (FERC Project No. 2101) lies within El Dorado and Sacramento counties, primAprily within lands of the Eldorado National Forest. The UARP consists of three major storage reservoirs: Loon Lake, Union Valley, and Ice House (with a combined capacity of approximately 379,000 acre-feet [ac-ft]), eight smaller regulating or diversion reservoirs, and eight powerhouses. The UARP has an authorized installed capacity of 637.3 megawatts (MW). The UARP also includes recreation facilities containing over 700 campsites, five boat ramps, hiking paths, and bicycle trails at the reservoirs.

The headwaters of the South Fork Rubicon River originate at an elevation of about 8,870 feet (ft) near Tells Peak. The South Fork Rubicon River flows generally westerly to the confluence with the Rubicon River at about elevation 3,850 ft, approximately 13 miles (mi). Gerle Creek is the major tributary of the South Fork Rubicon River, entering the river about 4.8 mi upriver of its mouth. Robbs Peak Forebay (forebay) is a 30 ac-ft impoundment (at maximum water surface elevation of 5,231 ft) created by a 44-ft-high, 320-ft-long concrete gravity overflow structure, with 12 steel bulkhead gates, all 6.2 ft high, on the spillway crest. The development primAprily utilizes water released from the Loon Lake Development via Gerle Canal (an aboveground canal, 22 ft wide and 19 ft deep that extends 1.9 mi from Gerle Creek Reservoir to the Forebay) and the South Fork Rubicon River. The Robbs Peak Powerhouse intake (intake) structure is located within the forebay. Based on prior reports (EA 1980, WESCO 1980, Stillwater Sciences 2004, 2007, 2009; DTA and Stillwater 2005), resident rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta)* are known to occur in the South Fork Rubicon River and the forebay.

2.0 MONITORING PLAN OBJECTIVES

The primary objective of the Robbs Peak Powerhouse Fish Entrainment Monitoring study was to assess the risk to the trout population in the South Fork Rubicon River upstream of Robbs Peak Forebay resulting from entrainment in the Robbs Peak Powerhouse turbines. Results of the monitoring were used to assist in determining if fish are going through the powerhouse, and if so, how to minimize this entrainment. Fish population monitoring was conducted to determine when and at what flow fish migration is occurring, and at what flow entrainment, if any, is occurring. If entrainment is documented to occur, an additional objective was to determine if that rate of entrainment is having a substantial negative impact on the South Fork Rubicon River fishery.

3.0 MONITORING STUDY AREA AND FREQUENCY

The Study Area included Robbs Peak Forebay and a study reach within the South Fork Rubicon River from the confluence with Robbs Peak Forebay, upstream to the first fish passage barrier, a cascade/falls, located approximately 3.1 mi upstream of the forebay (Figure 1). Monitoring occurred over a two-year period to account for seasonal migration patterns of target fish species and seasonal flow variation within the Study Area. Surveys during License implementation Year 1 began in October 2015 and continued through December 2015, and surveys during Year 2 began in January 2016 and continued through December 2016.

Three study index sites were established throughout the study reach to reflect spatial variability by first dividing the study reach into three sub-reaches of approximately equal length, and then selecting a random starting point (except for the lower study index site, where the starting point was selected by CDFW). Study index site lengths were >700 ft for consistency with sites surveyed by CDFW elsewhere in the state. The three study index sites are referred to as lower, middle, and upper study index sites (Figure 1).

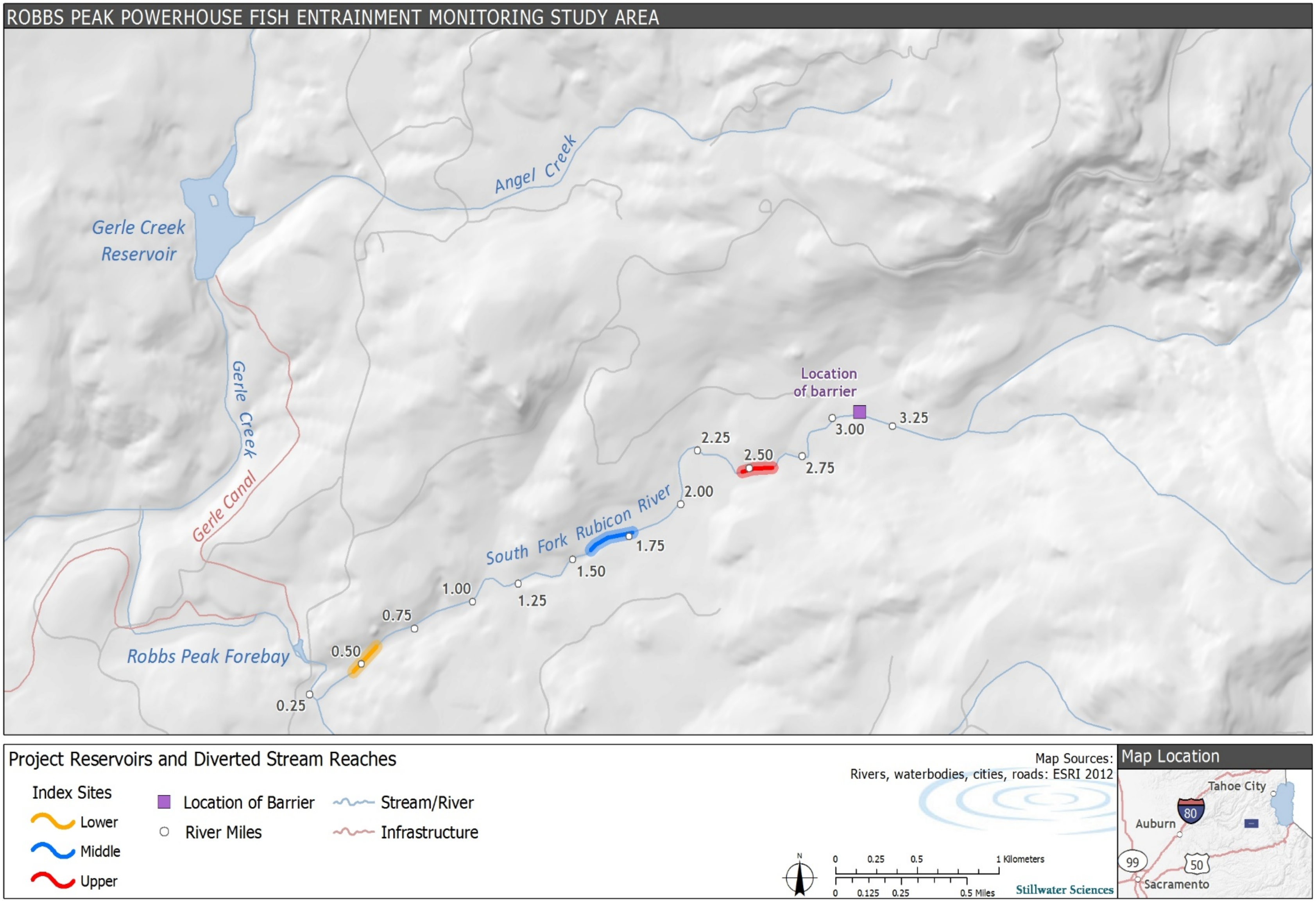

Figure 1. Fish entrainment monitoring Study Area.

4.0 METHODS

The general approach to determining when and at what flow fish migration is occurring near the Robbs Peak Powerhouse intake (Figure 1) included mark-recapture methods on resident trout occurring in South Fork Rubicon River. Individual resident trout were monitored using unique Passive Integrated Transponder (PIT) tags, and fixed antennas to monitor migratory patterns for two migratory seasons. For the purposes of analysis Year 1 was October to December 2015, and Year 2 was January through December 2016. A CDFW sampling permit was obtained to handle and tag 1,000 fish from within the South Fork Rubicon (Figure 1), and during implementation a total of 997 resident trout were captured and tagged. Migration was assessed using a combination of four seasonal mark-recapture efforts as well as stationary PIT tag antennas. During the period of the study, operations of the Robbs Peak Powerhouse were continuously monitored, and flows within the South Fork Rubicon were estimated based on available gages. Details of the approach are described below.

4.1 MARK AND RECAPTURE IN THESOUTH FORK RUBICON RIVER

4.1.1 Habitat Typing

Prior to fish capture, habitat typing was conducted throughout the 3.1-mi study reach. Habitat typing protocols and unit type descriptions generally followed guidelines from the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 2010). Habitat units were classified into distinct habitat types similar to the CDFW Level II unit types (e.g., pool, riffle, flatwater) with some additional sub-unit types based on site-specific conditions (e.g., dry units, bedrock pools, bedrock riffles). Habitat units form the sampling framework used to estimate fish population abundance in fall 2015, and to assess migration among habitat units during recapture efforts.

4.1.2 Fish Capture

The initial fish capture and associated PIT tagging event occurred following the installation of PIT tag antennas (described below) in fall 2015 (Year 1). Initial fish capture within the South Fork Rubicon River was conducted throughout the entire 3.1-mi study reach from the confluence with the forebay, upstream to the first upstream fish passage barrier, and included the three index sites described in Section 3.0 above. The fall 2015 effort was conducted over a period of nine 8 hours-of-effort (or greater) days within all wetted habitat units within the 3.1-mile study reach.

Recapture events were conducted during spring (June), summer (July), and fall (October) of 2016 (Year 2), for a total of four efforts (including the initial tagging). Any fish not tagged (out of the permitted 1,000 fish) during the initial sampling effort in fall 2015 were tagged during the spring and summer 2016 recapture efforts to maximize the number of fish in the sample population. Recapture efforts during 2016 were each conducted over a period of three 8 hours-of-effort days (or greater), and thus less stream area was sampled during each of the recapture efforts than during the fall 2015 nine-day effort. During each recapture effort, a random location was selected within the lower, middle, and upper sections of the study reach, and one day of effort was dedicated to sampling at each location, with surveys ranging from approximately 700 to 1,200 ft in length.

Fish sampling was performed using standard electrofishing methods as described by Reynolds (1996), Meador et al. (2003), and Temple and Pearsons (2007). All habitat units were block netted, unless isolated by dry adjoining habitat units, and units were sampled from downstream to upstream. Backpack electrofishers were initially set at 120 volts (V) and 45 hertz (Hz); voltage was increased after fish showed no response to the 120 V setting. During summer 2016 very low conductivity (<50 microsiemens per centimeter [µS/cm]) was observed in the South Fork Rubicon River, reducing electrofishing effectiveness. Salt blocks were added to the river during the July 2016 effort to increase shocking efficiency (Dunham et al. 2009). Conductivity increased sufficiently by October 2016 to support electrofishing without the use of salt blocks.

Population estimates were developed for the entire study reach during fall 2015, as well as for each of the three index study sites. Over the entire study reach, single-pass electrofishing was performed in all wetted habitat units, and multiple-pass depletion sampling was performed in a subset of randomly selected habitat units (approximately 20%) as well as at the three index study sites. Multiple-pass depletion sampling was performed in all habitat units within the three index study sites to facilitate comparability to other studies. Each habitat unit sampled using multiple-pass depletion methods was block-netted (unless adjoining unit was dry) and evaluated individually such that population estimates were habitat unit-specific. During recapture efforts, multiple-pass depletion was conducted within all sampled habitat units to support comparisons with fall 2015 estimates.

4.1.2.1 Fish Sampling and Processing

Fish were processed immediately after each habitat unit was sampled. All salmonids captured were processed using standard field sampling protocols (e.g., Flosi et al., 2010). Captured fish were placed immediately into containers with cool aerated water. A fish anesthetic (peppermint oil) was used to subdue fish prior to processing to reduce stress and injury. Fish were removed from the anesthetic when sufficiently anesthetized for processing. Processed fish were identified to species and fork length (FL) measured to nearest millimeter (mm).

Each fish of sufficient size (>60mm) was tagged using methods similar to those outlined in the PIT Tag Marking Procedures Manual prepared by the Columbia Basin Fish and Wildlife Authority (CBFWA 1999). Fish 60–124 mm FL were tagged using 12.5-mm 134.2 kiloHertz (kHz) full-duplex (FD) tags which allow for tagging smaller fish but have a smaller detection range than larger tags. For all fish ≥125 mm FL, 23-mm 134.2 kHz

FD tags were used to take advantage of the larger tag detection range. PIT tags were inserted into the abdominal cavity anterior to the pelvic fin on fish <125 mm FL using a 12-gauge hypodermic needle and syringe; on fish ≥125 mm FL a scalpel was used to make an incision which the tag was inserted into and the incision was sealed with a quick drying adhesive. All fish were allowed to fully recover and displayed normal swimming and escape behavior (typically fewer than 20 minutes) in a well-oxygenated recovery container before being returned to the habitat unit from which they were captured.

4.1.3 PIT Tag Antennas

A series of full-duplex (FDX) PIT tag antennas were installed within the forebay at four locations: (1) South Fork Rubicon River at the confluence with the forebay, (2) lower Gerle Canal, (3) in the forebay at the trash rack in front of the intake, and (4) in the forebay at the intake (Figure 2). Monitoring was conducted continuously from October 2015 through December 2016 with data downloaded regularly. Antenna function was periodically assessed during site visits over the course of the study.

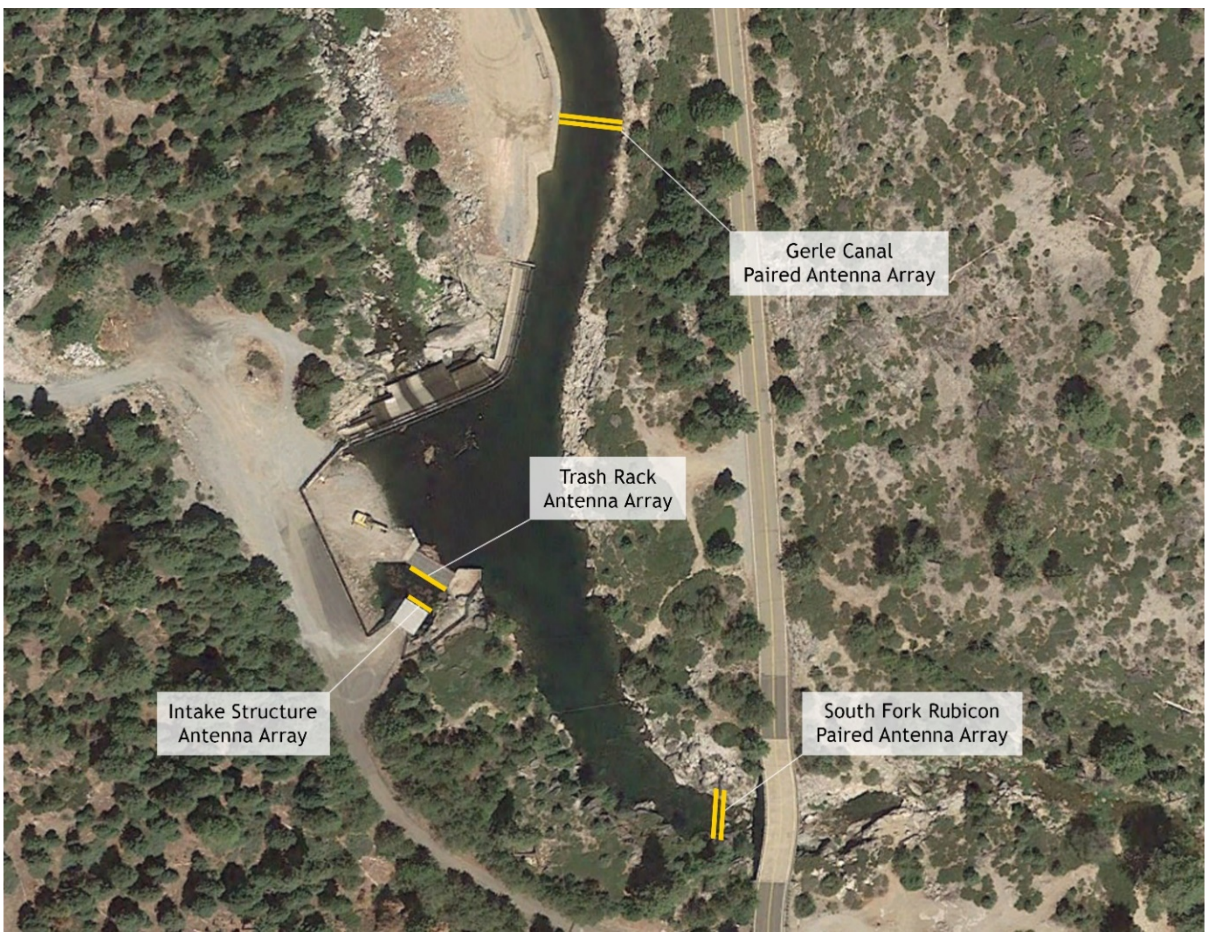

Figure 2. Antenna configuration in Robbs Peak Forebay.

The paired antennas (i.e., two antennas installed in parallel across the river near each other) in the South Fork Rubicon River were installed near the confluence with the forebay where the creek is narrow and flow is approximately laminar (Figure 3). Paired antennas were used to increase the detection probability of tagged fish. This site was established to monitor the migration of fish between the South Fork Rubicon River and the forebay. Each antenna consisted of a single loop of antenna wire running from the tuner unit into the water, along the bottom of the channel, then back along a steel cable spanning the channel above the water surface, to an antenna tuner box which allowed for a full channel-width antenna. The antennas were spaced approximately 5 feet apart.

Figure 3. Installation of the paired antenna area in the South Fork Rubicon at the confluence with Robbs Peak Forebay.

Paired antennas were constructed in lower Gerle Canal using a similar approach as described above. This site was established to monitor the potential migration of fish upstream within Gerle Canal. Antenna wires were placed along the canal substrate and water surface to form a loop so that all fish swimming through the loop within the read-range would be detected.

At the Robbs Peak Powerhouse intake an array consisting of three antennas was constructed to cover the intake and a second similar array was constructed to cover the trash rack (Figure 4). The array at the trash rack was used to provide information on potential milling behavior of fish in the forebay and to assess the entrainment probability of fish detected at the powerhouse intake array. For example, fish detected at the intake, and subsequently detected at the trash rack array, were assumed to have not been entrained at the intake.

Figure 4. Vertical antenna group prepared for deployment at Robbs Peak Forebay trash rack.

Electrical power was supplied by SMUD for all four locations. Regular visits occurred throughout the monitoring period to check antenna function and make antenna adjustments as necessary. The read-range of the antennas was measured by obtaining an average of the farthest distance that a PIT tag was readable from the horizontal plane of the antenna loop. Vertical read-range were determined by placing a PIT tag on the bottom antenna wire and measuring the read-range while the tag was slowly moved up within the antenna, along a vertical plane. The antennas were initially shop tested and tuned, and later adjusted after installation to maximize the read-range of each antenna. At all locations where a PIT-tagged fish passed within the antennas read-range, the unique tag number, the antenna ID, and the date and time of passage was recorded on the data logger.

The operational efficiency goal of antenna arrays was 80% detection. Initial and regular calibrations were conducted at each antenna using test PIT tags to tune equipment for maximum read-range. All equipment was repaired and upgraded as appropriate following periods of high flow or other disturbances to the antennas.

4.1.4 Flow Monitoring

Flows in the Study Area were monitored using a combination of the Gerle Canal gage flows, Robbs Peak Powerhouse flows, and Gerle Creek gage flows. These sources were used to in a water balance equation to estimate the South Fork Rubicon flows upstream of the forebay. Flows and operations that occurred during the period of monitoring were compared with fish migration patterns and entrainment observations, as described in “Analysis” below.

4.2 ANALYSIS

4.2.1 Fish Migration and Movement

Analysis focused on determining correlations between stream flow, powerhouse operations, and fish migration as well as correlations between fish entrainment and flow based on assessing detections from mark-recapture efforts and PIT tag antenna detections. The locations of all fish detected at antennas or recaptured during fish mark-recapture efforts were assessed to determine:

- distance moved,
- direction of movement,
- timing of movement,
- relationship to season and flows,
- whether they were entrained, and
- initial size.

Because of the tendency of fish to exhibit “milling” behavior and feed from within the higher water velocities that occur near the intake antennas, they can be detected multiple times without being entrained. Therefore, potential entrainment was defined as fish detected at the intake antennas during periods of powerhouse operation that were not subsequently detected at another location upstream of the intake. Based on the number of fish observed as entrained while the antennas were operational, an average daily entrainment rate was calculated (Section 4.1.3). This average daily entrainment rate was extrapolated to estimate total entrainment for the period of study. The total entrainment for the period of study was then used to estimate an annual entrainment rate.

Based on this analysis, the percentage of fish PIT tagged in the South Fork Rubicon River that were entrained was calculated. The data from all entrained fish were analyzed to describe patterns, including flows, timing, species, size, tagging location, and distance upstream from forebay. Data from the general migratory patterns of resident trout were also described with specific emphasis on flows, fish length, and timing of the use of habitat in the forebay.

4.2.2 Growth Analysis

Growth rate was quantitatively analyzed for fish observed between October 2015 and October 2016 based on measured individual growth rates of recaptured PIT tagged individuals. Growth rate was calculated for all fish that were PIT tagged and subsequently recaptured between 2015 and 2016 for the following periods:

- October to October (annual growth),
- October to June/July (winter/spring growth), and
- June/July to October (summer growth).

Growth analysis of individually PIT tagged fish was based on “intrinsic growth rate”, which expresses growth relative to body size as mm-per-mm-per-day (mm/mm/d) (Busacker et al. 1990). Intrinsic growth rate (often referred to as “g” in the literature) is calculated here as:

$$G = \frac{\ln l_2 - \ln l_1}{t_2 - t_1}$$

Where $l_1$and l_2 are the starting and ending fork lengths and $t_2 - t_1$ is the time in days between measurements.

Intrinsic growth rates were compared with initial sizes of fish, season, location (distance upstream) within South Fork Rubicon River, and movement (distanced migrated) within the study area. In addition, the size distribution (expressed as fork length frequency) of all captured fish was compared among sampling visits.

4.2.3 Fish Abundance Estimate (October 2015)

Population estimates were developed for the three index study sites, and for the entire 3.1-mi study reach during the October 2015 sampling effort. The methods employed provide a “robust” estimate (i.e., a relatively precise estimate that is unlikely to change significantly with repeat measurements) of the existing trout population, and allow estimates of variance to be calculated for making quantitative comparisons and assessing trends.

A two-phase survey design (Särndal et al. 1992, Hankin 1999) was used. In this design, some of the habitat units making up the region of interest are sampled with a “low-intensity” method (i.e., single pass electrofishing), which yields a simple “index” of abundance for each sampled unit, and a subset of these are sampled with a “high-intensity” (i.e., multiple pass electrofishing) method which yields data from which an estimate of actual abundance can be made together with a variance or mean squared error (MSE) (Figure 5). These are referred to as the Phase I (i.e., low-intensity) and Phase II (i.e., high-intensity) sampling data, respectively. In practice, Phase I and Phase II sampling data are collected during the same field effort. Two-phase sampling is a common approach for making population estimates across an area too large or too sensitive to sample exhaustively using high-intensity methods. Similar applications for assessing salmonid abundance using a two-phase survey design have been applied elsewhere in California, including by CDFW (e.g., Voight 2006, McLeod and Howard 2010, Duffy 2011, Ricker and Anderson 2011).

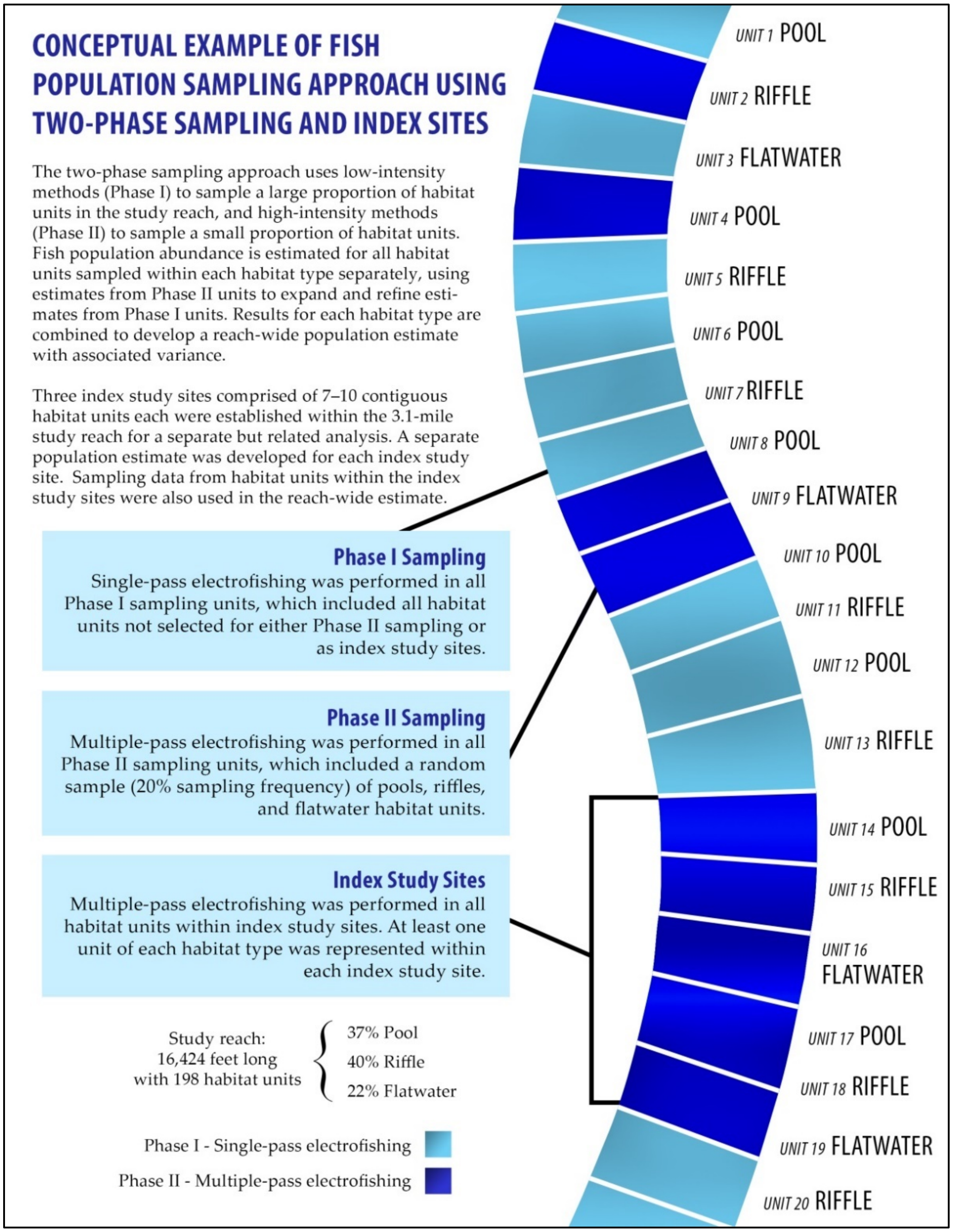

Figure 5. Sampling design.

This design includes stratification of the reach by habitat type, and separate estimates of abundance are made for the “pool”, “riffle”, and “flatwater” strata of the study reach (Figure 5). This is done both to account for intrinsic differences between habitat types, since trout use different habitat types in different ways and/or at different densities, and to reduce the variance in the final reach-wide estimate. If the variability among units of the same stratum is comparable to the variability among units from all strata, this process yields an estimate with a broad confidence interval, gaining nothing. If, however, the within-stratum variability is smaller than the between-stratum variability, stratification can produce a narrower confidence interval. The implication is that stratification may yield a better estimate of overall abundance, provided that the strata tend to be used differently by the population of interest, and that there are a reasonable number of units in each stratum. This generally means that the number of different strata should be kept small, and that the strata should be distinct.

The strengths of the two-phase approach include:

1. A high proportion of habitat units were sampled during Phase I (100%) and Phase II (20%).
2. Within-strata variability was relatively low compared with variability overall, such that stratification improved the estimates and reduced the associated confidence interval.
3. Random sampling design strengthens the ability to draw conclusions from results.
4. Concepts are well-supported in literature and application.

In addition to the two-phase approach, benefits of also establishing index sites are that (1) they can be sampled with the same high-intensity methods (reducing the influence of statistical uncertainty so that changes in actual abundance at these sites from year to year can be seen more clearly); (2) they do not risk adverse sampling effects on the entire trout population; (3) they allow better comparability to other estimates that use this same, common method. A disadvantage of an index-site approach is that it is not always clear what year-to-year changes at a fixed site mean for the population of interest. For example, it is not possible to discern if changes in abundance are simply random fluctuations in the spatial *distribution* of a stable population (a particularly relevant point in an intermittently flowing stream), or if results indicate changes in a variable population. For this study, collecting data at both site and reach scales helped clarify such issues.

4.2.3.1 Estimating Abundance at Individual Units from Depletion-Sampling Data

The Phase II “high-intensity” sampling and the index site sampling used multiple-pass depletion electrofishing (described above). Population abundance for high-intensity sampling sites was calculated as follows:

Let y be the true population of a particular habitat unit, and suppose r electrofishing passes are made, with m_k fish recovered in the kth pass, $1 \leq k \leq r$. The jackknife estimator (Pollock and Otto 1983) for y is:

$$\tilde{y} = \sum_{k=1}^{r-1} m_k + r m_r$$

The variance of this estimator is estimated as:

$$\hat{V}(\tilde{y}) = r(r-1)m_r$$

4.2.3.2 Estimating Total Abundance for the Study Sites

Since all the habitat units making up each of the three study sites were sampled with multiple-pass electrofishing, estimates for the total populations of these sites and their variances are calculated by simply adding up the estimates and variances of their constituent units.

That is, if the study site consists of units numbered 1 to N, and the population estimate for the ith unit is $\left(\tilde{y}_i, \hat{V}(\tilde{y}_i)\right)$, then the population estimate for the study site is:

$$\tilde{Y} = \sum_{i=1}^{N} \tilde{y}_i$$

with the estimated variance:

$$\hat{V}(\tilde{Y}) = \sum_{i=1}^{N} \hat{V}(\tilde{y}_i)$$

4.2.3.3 Estimating Total Abundance for the Study Reach

As explained above, a two-phase design was used to estimate total population for (each stratum of) the entire study reach:

Of the N sites making up (a stratum of) the study reach, a subset $I \subseteq \{1, \ldots, N\}$ were sampled with single-pass electrofishing and yielded trout counts $\{x_i\}_{i \in I}$. A subset of these, $II \subseteq I$ were sampled with multiple-pass electrofishing and yielded trout population estimates $\left\{\left(\tilde{y}_i, \hat{V}(\tilde{y}_i)\right)\right\}_{i \in II}$

In this situation, the reach-wide estimate from survey-sampling theory (Särndal et al. 1992) is:

$$\tilde{Y} = N\bar{\tilde{y}}_2 \frac{\bar{x}_1}{\bar{x}_2}$$

where n_1 and n_2 are the number of units sampled in Phase I and Phase II respectively, and:

$$\bar{x}_1 = \frac{1}{n_1}\sum_{i \in I} x_i\,,\ \bar{x}_2 = \frac{1}{n_2}\sum_{i \in II} x_i\,, \bar{\tilde{y}}_2 = \frac{1}{n_2}\sum_{i \in II} \tilde{y}_i$$

The variance of $\tilde{Y}$ is estimated as:

$$\hat{V}(\tilde{Y}) = N^2\left(1 - \frac{n_1}{N}\right)\frac{s_{\tilde{y}}^2}{n_1} + N^2\left(1 - \frac{n_2}{n_1}\right)\left(\frac{\bar{x}_1}{\bar{x}_2}\right)^2 \frac{s_{\tilde{y}|x}^2}{n_2}$$

where

$$s_{\tilde{y}}^2 = \frac{1}{n_2 - 1}\sum_{i \in II} (\tilde{y}_i - \bar{\tilde{y}}_2)^2$$

$$s_{\tilde{y}|x}^2 = \frac{1}{n_2 - 1}\sum_{i \in II}\left[\left(\tilde{y}_i - \bar{\tilde{y}}_2\frac{x_i}{\bar{x}_2}\right)^2 + \hat{V}(\tilde{y}_i)\right]$$

The calculations were simplified when applied to data collected from the South Fork Rubicon River because all units received at least Phase I sampling, so that $n_1 = N$ and the first term of $\hat{V}(\tilde{Y})$ vanishes.

4.2.4 Trend Analysis

Although a complete population estimate was only conducted in October 2015, all habitat units that were re-visited during 2016 recapture efforts were sampled consistent with Phase II high-intensity multiple-pass electrofishing methods, as described above. For all habitat units that were sampled in multiple efforts, population estimates were compared over time to assess the trend in population abundance.

5.0 RESULTS AND DISCUSSION

5.1 HABITAT TYPING

Habitat typing was conducted in early September 2015. A total of 198 habitat units were identified within the 3.1-mi study reach from the forebay to the first apparent barrier (Figure 1). Of these, 184 habitat units were wetted during the habitat survey, and the remaining habitat units were dry (775 ft, 4.7% of study reach). Habitat length was comprised mostly of riffle (40%), followed by pool (37%) and flatwater (22%) habitat types (Table 1).

Table 1. Habitat Frequency within the South Fork Rubicon River Study Reach.

Habitat type	Number of units	Length (ft)	% of reach length
Pool	78	6,150	37.4
Riffle	77	6,594	40.1
Flatwater	43	3,680	22.4
Totals	**198**	**16,424**	**100***

*Sum does not equal 100.0 due to rounding error.

Three index study sites were established within the study reach, each over 700 ft in length (range 718–1,213 ft). The location of the first index site was selected by CDFW in the lower third of the study reach, and the other two sites were randomly selected from the middle and upper thirds of the study reach. In combination, the three index sites comprise about 17% of the total reach length. Habitat type composition within index study sites varied by site. Flatwater habitat was most abundant in the lower site, riffle habitat in the middle site, and pool habitat in the upper site (Table 2).

Table 2. Habitat Unit Type Composition for Index Study Sites within the South Fork Rubicon River Study Reach.

Study site	Lower			Middle			Upper			All sites		
Habitat type	Number of units	Length (ft)	% of site length	Number of units	Length (ft)	% of site length	Number of units	Length (ft)	% of site length	Number of units	Length (ft)	% of length (all sites)
Pool	2	301	38	2	202	17	4	369	51	8	872	32
Riffle	2	89	11	5	946	78	4	207	29	11	1,242	45
Flatwater	3	409	51	1	65	5	2	142	20	6	616	23
Totals	**7**	**799**	**100**	**8**	**1,213**	**100**	**10**	**718**	**100**	**25**	**2,730**	**100**

Habitat conditions appear generally suitable for rainbow trout. Even during the drought of 2015 there were deep pools with habitat complexity and cover. Spawning gravel is common, and observed abundant aquatic invertebrates indicated food availability from frequent, productive riffles. General conditions within each reach during June 2016 are photo-documented in Figure 6.

Figure 6. Habitat conditions in the South Fork Rubicon River from a) the lower reach, b) middle reach, and c) the upper reach during June 2016.

5.2 FISH POPULATION IN THE SOUTH FORK RUBICON RIVER

5.2.1 Population Abundance

5.2.1.1 Abundance Estimate (October 2015)

Multiple-pass depletion electrofishing was conducted for eight days during mid-October 2015 within all wetted habitat units following methods described above (Section 4.1). Overall, 1,103 rainbow trout and one brown trout were captured in October 2015.

The length frequency of captured fish was used to evaluate length-at-age and estimate age classes within the trout population. Based on the length-frequency histogram for rainbow trout, together with a two-component normal mixture model[1], two distinct age classes were observed: age-0+ (fish in their first growing season), and age-1+ (fish that have gone through one growing season). Based on this assessment the length threshold between age-0+ and age-1+ trout was defined as age-0+ less than 80 mm (Figure 7), with age-1+ fish defined as less than 160 mm. Because growth rates begin to slow as fish age, it can be difficult to distinguish between older age classes; however, a third age class may be present indicating fish that are age-2+ or older with lengths ≥160 mm.

Age-0+ trout abundance is not typically a strong indicator of habitat conditions or population health because it can comprise a relatively large component of the population (based on numbers of individuals) and fluctuates substantially from year-to-year, obscuring the ability to detect meaningful trends over time (Elliott and Hurley 1998). Because age-1+ and older trout have likely experienced habitat limitations during at least one of their life stages, abundance of fish age-1+ and older is generally a better indicator of habitat conditions and population trends over time. Therefore, estimates are reported for all ages combined and for age-1+ and older, considering only rainbow trout.

[1] R package "mclust" (Fraley et al. 2012) was used in this analysis.

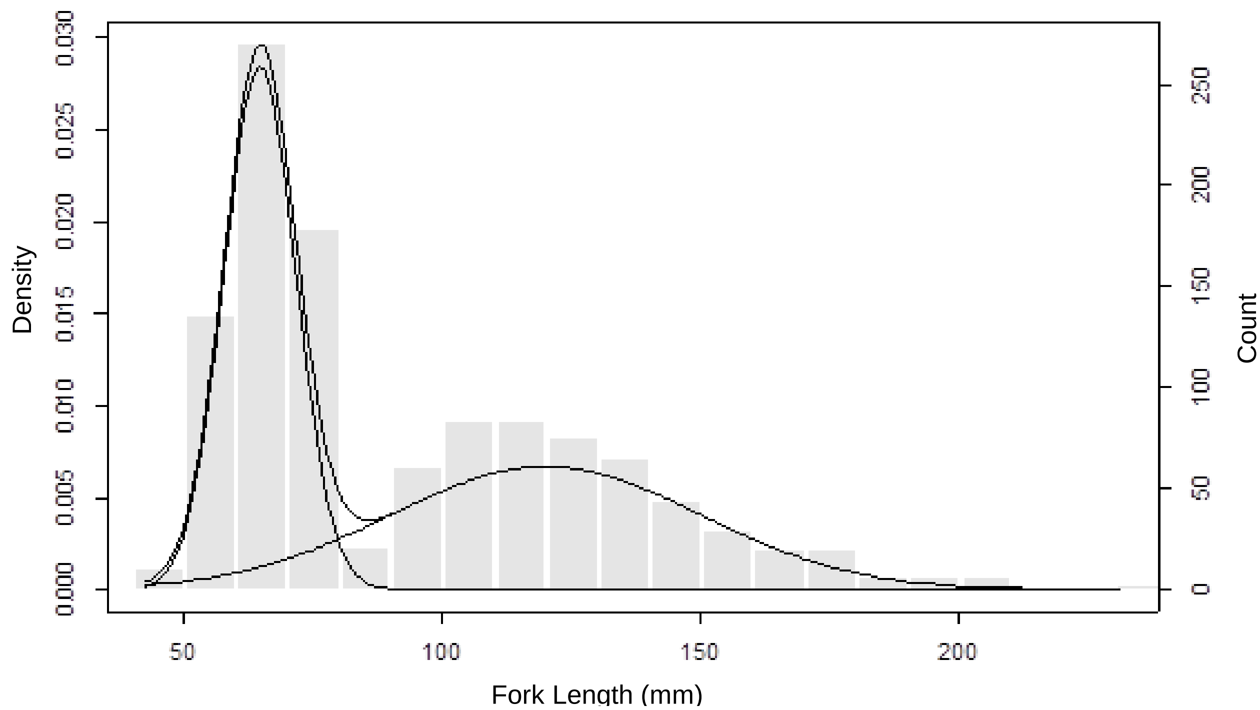

Figure 7. Length frequency of rainbow trout captures in the study reach in October 2015 (lines indicate potential age-class components using a two-component normal mixture model).

Abundance estimates were calculated for each of the three study sites, and the entire 3.1-mi study reach. The estimated population of rainbow trout in the study reach was 2,110 (±256), with the population of age-1+ and older trout estimated at 878 (±150) (Table 3). Most age-1+ and older trout in the study reach were found in pools (73%), followed by flatwaters (17%) and riffles (10%).

Table 3. Population Abundance Estimates within the South Fork Rubicon Study Reach, Fall 2015.

Habitat type (length, ft)	Total trout abundance (95% Confidence Interval)		
	Age-0+	Age-1+ and older	All trout
Pool (6,150 ft)	632 (±125)	639 (±129)	1,304 (±210)
Riffle (6,594 ft)	261 (±73)	92 (±28)	353 (±75)
Flatwater (3,680 ft)	293 (±89)	147 (±72)	452 (±126)
Total (16,424 ft)	**1,186 (±170)**	**878 (±150)**	**2,110 (±256)**

Among study sites, the middle site had the greatest estimated abundance of trout for all age classes, whereas the upper site had the lowest estimated abundance of trout for all age classes (Table 4, and see Attachment C for a map of fish distribution).

Table 4. Abundance Estimates within Index Study Sites, Fall 2015.

Index Study Site (length, ft)	Total trout abundance (95% Confidence Interval)		
	Age-0+	Age-1+ and older	All trout
Lower (799 ft)	40 (±11)	10 (±6)	50 (±12)
Middle (1,213 ft)	55 (±7)	44 (±8)	99 (±11)
Upper (773 ft)	36 (±5)	7 (±0)	43 (±5)

5.2.1.2 Trout Density (October 2015)

Trout density in the study reach was greatest in pool habitats, followed by flatwater and riffle habitats, respectively (Table 5). Age-1+ and older trout density in the study reach was about twice as high in pools compared with flatwaters, and more than six times as high in pools compared with riffles. There was a high variability in fish density between habitat units, including a high frequency of very shallow sampling locations where no fish were observed (including multiple units in both the lower and upper index study sites; see attached fish distribution maps). The random selection of Index Study Sites happened to include a significant number of locations with lower fish densities than the remainder of the Study Reach. Therefore, trout density in the index study sites was relatively low compared with average density for the entire study reach (Tables 5 and 6). For age-1+ and older trout, densities were substantially higher in the middle study site compared with the lower and upper study sites. Density in the middle study site was strongly influenced by relatively high densities within two of the seven habitat units sampled (pool unit 104, and flatwater unit 108), and only one habitat unit where no fish were observed.

Table 5. Density of Rainbow Trout Within the South Fork Rubicon River Study Reach, Fall 2015.

Habitat type (length, ft)	Density (fish/mile)*		
	Age-0+	Age-1+ and older	All trout
Pool (6,150 ft)	543	549	1,119
Riffle (6,594 ft)	234	83	318
Flatwater (3,680 ft)	430	216	664
Total (16,424 ft)	**401**	**297**	**713**

* Based on wetted habitat unit lengths

Table 6. Density of Rainbow Trout at Index Study Sites, Fall 2015.

Index Study Site (length, ft)	Density (fish/mile)*		
	Age-0+	Age-1+ and older	All trout
Lower (799 ft)	264	66	330
Middle (1,213 ft)	239	192	431
Upper (773 ft)	265	51	316

* Based on wetted habitat unit lengths

5.2.1.3 Trout Biomass (October 2015)

Trout biomass in 2015 was estimated based on abundance estimates, combined with length-weight relationship data from 2003 and 2005 (since, per the sampling protocol, trout weights were not collected during fall 2015 sampling at all the sites). Trout biomass in the study reach was 8.05 pounds (lb)/acre for rainbow trout (all ages), and 6.65 lb/acre for trout age-1+ and older (Table 7). Trout biomass at the lower and upper study sites was relatively low compared with average biomass estimated for the entire study reach (Tables 7 and 8). Biomass at the middle study sites was higher than average trout biomass estimated for the entire study reach for all age classes.

Table 7. Rainbow Trout Biomass within the South Fork Rubicon River Study Reach, Fall 2015.

Habitat type	Biomass (pound [lb]/acre)*		
	Age-0+	Age-1+ and older	All trout
Pool	1.32	9.55	10.97
Riffle	1.10	2.69	3.80
Flatwater	1.48	3.76	5.37
Total	**1.30**	**6.65**	**8.05**

* Based on wetted habitat unit areas

Table 8. Rainbow Trout Biomass at Index Study Sites, Fall 2015.

Index Study Site	Biomass (pound [lb]/acre)*		
	Age-0+	Age-1+ and older	All trout
Lower	0.55	1.80	2.35
Middle	1.57	8.36	9.93
Upper	0.88	1.77	2.65

* Based on wetted habitat unit areas

5.2.2 Annual Abundance Fluctuations

There were 55 habitat units that were sampled in both October 2015 and 2016. The abundance of rainbow trout from within these units was compared as an assessment of fluctuations in annual trout abundance. The abundance of trout between October of 2015 and 2016 went down in 37 units, up in 13 units, and was zero in five units in both years (Figure 8). Overall, the populations of most units were generally lower in October 2016 than in October 2015, and the reach-wide estimate of the total population (based on the 55 habitat units in common between years) was lower in 2016 than in 2015 (Figure 9).

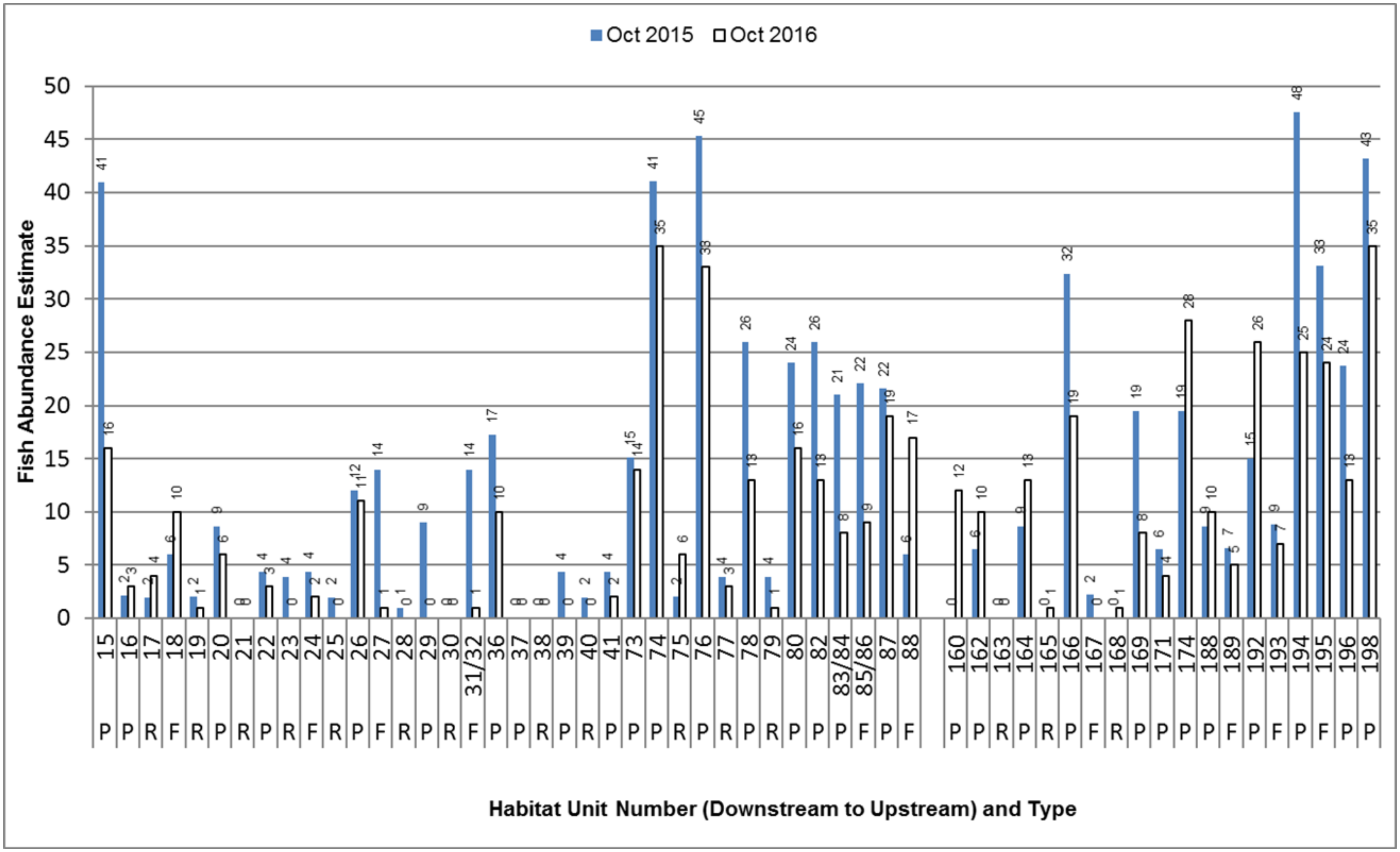

Figure 8. Rainbow trout population estimates in 55 habitat units surveyed in both October 2015 and October 2016 in the South Fork Rubicon River. (P=pool, R=riffle, F=flatwater).

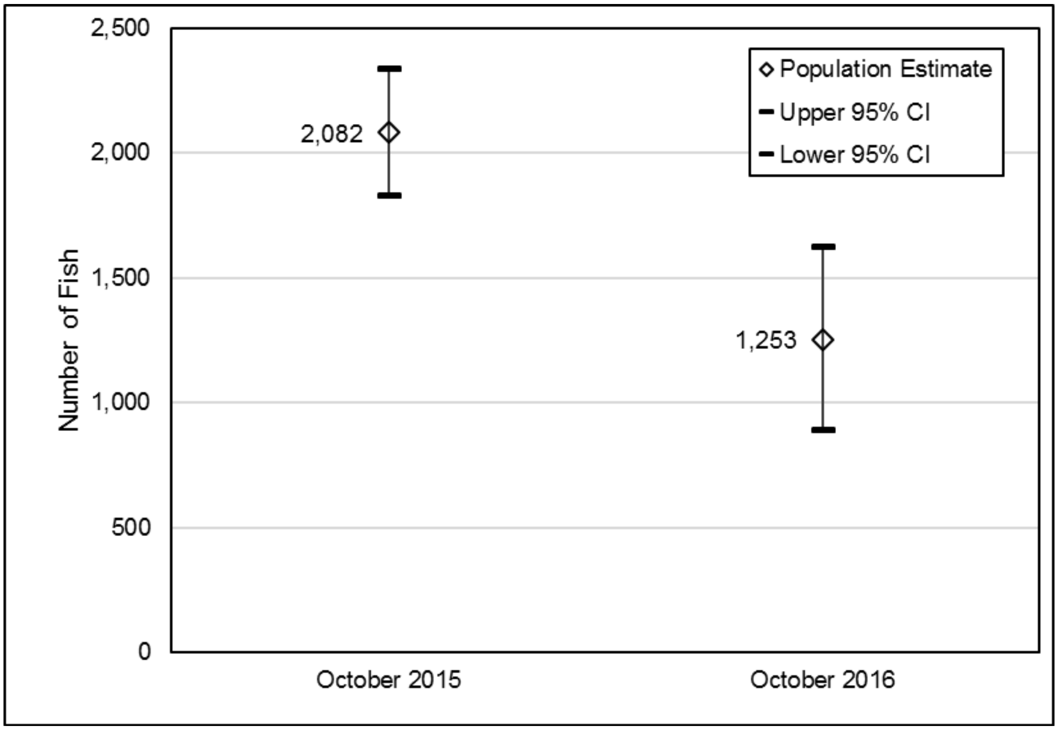

Figure 9. Rainbow trout population estimates (with 95% upper and lower Confidence Intervals) for the South Fork Rubicon River, based on 55 habitat units surveyed in both October 2015 and October 2016.

5.2.3 Comparison with Historical Data

The October 2015 population estimates were compared with previous surveys to evaluate trends in abundance. Gerstung (1968) sampled 132 ft of channel, captured 63 trout, and estimated 3,600 fish/mi. There is no record of how that 132 ft of channel was selected, what the flows were like that year, or any mention of if multiple-pass depletion or other sampling techniques were used. Similarly, EA (1980) reports results from 1979 of 31 fish captured within 1,660 ft of channel and estimated 3,490 fish/mi without reporting site selection, sampling methods, flows, or other comparable information. In 2003 and 2005 two different sites located approximately 0.50 miles and 0.75 miles upstream of the forebay were sampled using multiple-pass depletion electrofishing (DTA and Stillwater Sciences 2005, Stillwater Sciences 2006). The site sampled in 2003 was located near the lower index study site, was approximately 307 ft long, and resulted in an estimate of 175 fish/mi while the site sampled in 2005 was located slightly upstream of the lower index study site (near unit 44), was 170 ft long, and resulted in an estimate of 985 fish/mi. The October 2015 results reported here estimated 713 fish/mi based on sampling over 16,000 ft of channel. The more recent results from 2005, 2006, and 2015 are substantially lower than estimates in the 1960s and 70s. However, the October 2015 population estimate is the first population estimate conducted in the South Fork Rubicon River to include all the habitat downstream of the fish passage barrier, and involved substantially greater sampling effort than any prior study. Because the South Fork Rubicon River is a small stream with disconnected flow at times, and habitat is not uniformly distributed, the trout population could either appear very large or very small depending on where sampling is conducted, and this high variance is likely reflected in the range of historical results. For example, in Figure 8 (and Attachment A), it is evident that if a short section of the middle reach was specifically or randomly selected for sampling, the population would appear much larger than if the same length of the lower reach were selected. Because of this, the October 2015 population estimate is likely the most accurate and precise estimate to date for the South Fork Rubicon River.

5.3 FISH CAPTURE AND DETECTION SUMMARY

PIT tag antennas were constructed at four locations in October 2015 and operated through December 2016. High flows and ice damaged the antennas for periods of time. Overall the antennas were operational for nearly the entire period of monitoring, and at least one array was operational for the entire period of monitoring (Figure 10, Attachment B). Most the cross-sectional area of the South Fork Rubicon, trash rack, and intake were covered by their respective antennas, and read-ranges of the antennas were from 24 to 72 inches (Attachment B).

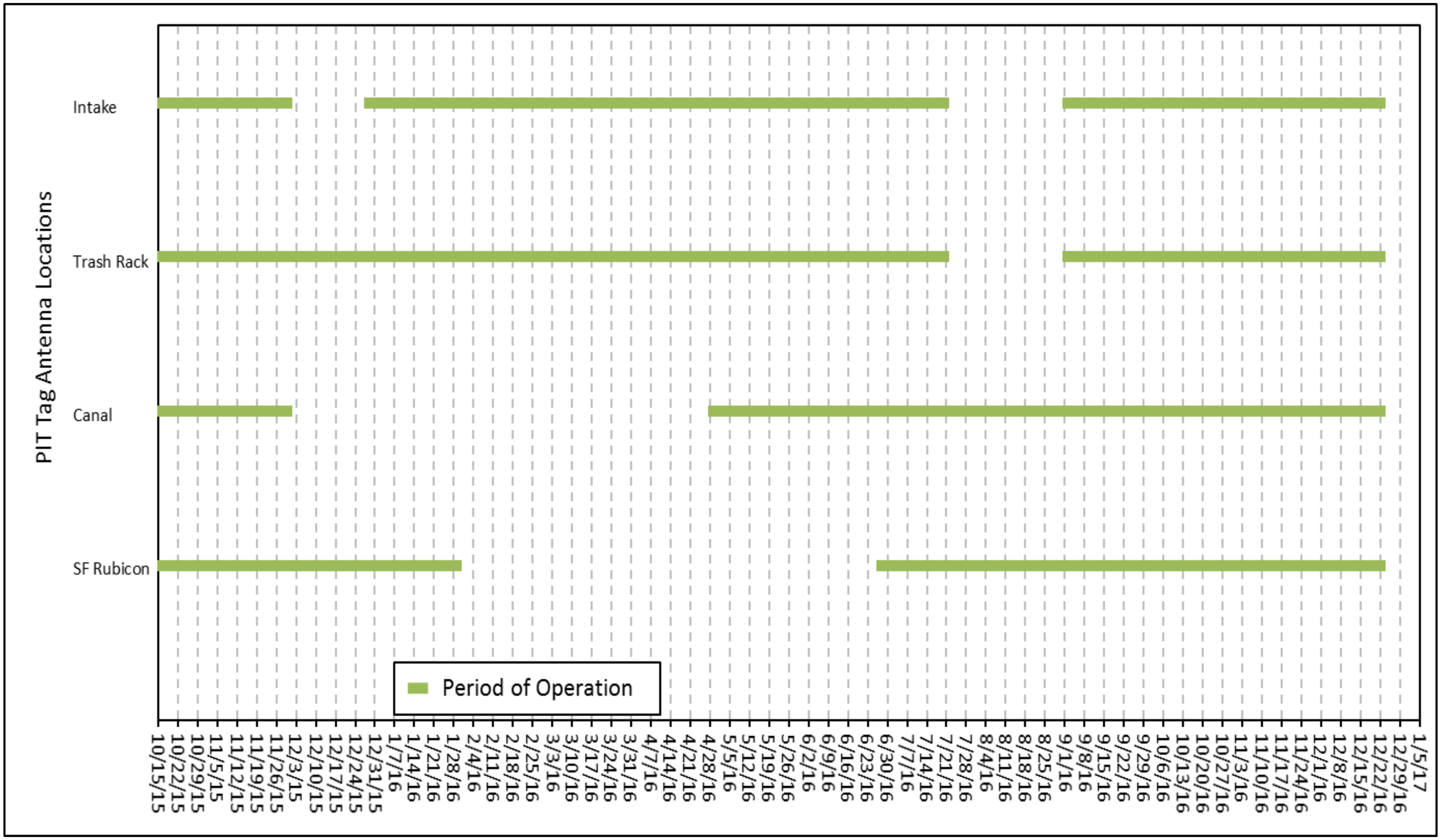

Figure 10. Antenna period of operation in Robbs Peak Forebay, October 2015 through December 2016.

A total of 1,794 rainbow trout and two brown trout were captured during sampling efforts (Table 9). Overall, 997 captured rainbow trout were tagged with full duplex PIT tags. A total of 148 trout were recaptured at least once, and 33 trout were detected at one or more PIT tag antennas (Table 9). During October 2015 one brown trout was captured and PIT tagged, and during October 2016 one brown trout was captured and not PIT tagged; no other brown trout were captured during this study. Due to small sample sizes of brown trout, no detailed analysis was conducted on this species.

Table 9. Summary of Rainbow Trout Mark and Recaptures in the South Fork Rubicon River.

Sampling effort	Captured fish	PIT tagged fish	Recaptured fish
October 2015	1,103	942	na
June 2016	74	23	32
July 2016	149	32	37
October 2016	469	na	84
Total	**1,794**	**997**	**148**

na = not applicable

Of the 997-trout tagged, 181 were either recaptured, or re-detected at a PIT tag antenna. There were over 43,000 detections at the PIT tag antennas, from a total of 33 different rainbow trout (Table 10). Fish milling behavior, where individuals feed and hold in a small area for a long duration, was observed at all antennas and resulted in many more detections than would have been expected for 33 individual fish. Most milling behavior was observed by the trash rack and Robbs Peak Powerhouse intake antennas (Table 10), which are located at the deepest part of the forebay pool, and regularly have positive water velocities (into the intake) providing feeding opportunities.

Table 10. Summary of Rainbow Trout Detections at Antennas in Robbs Peak Forebay.

PIT Tag antenna	Total detections	Unique tags detected
South Fork Rubicon	2,155	5
Gerle Canal	2,468	7
Trash Rack	19,683	12
Robbs Peak Powerhouse intake	19,121	9
Total	**43,427**	**33**

5.4 GROWTH ANALYSIS

5.4.1 Age Distribution

Fork length frequency was compared between October 2015 and October 2016 to compare the age distribution of the population over time. In general, the length frequency pattern of the population was similar, with at least two distinct age classes (age-0+ and age-1+), and a group of fish likely to be age-2+ or older (Figure 11). However, in a more precise comparison of the size classes between 2015 and 2016, it is apparent that the population during October 2016 included a higher proportion of the age-1+ and older rainbow trout compared to the population during October 2015 (Figure

12). Based on kernel smoothing and a non-parametric test for equality of distributions, the size distributions of the population in October 2015 and October 2016 were dissimilar, with the fish in October 2016 being larger than the fish in 2015 (Figure 12). Therefore, although the population declined in abundance from 2015 to 2016, the individuals within the population were older and larger, suggesting a population that fluctuates on an annual basis, but is stable and healthy.

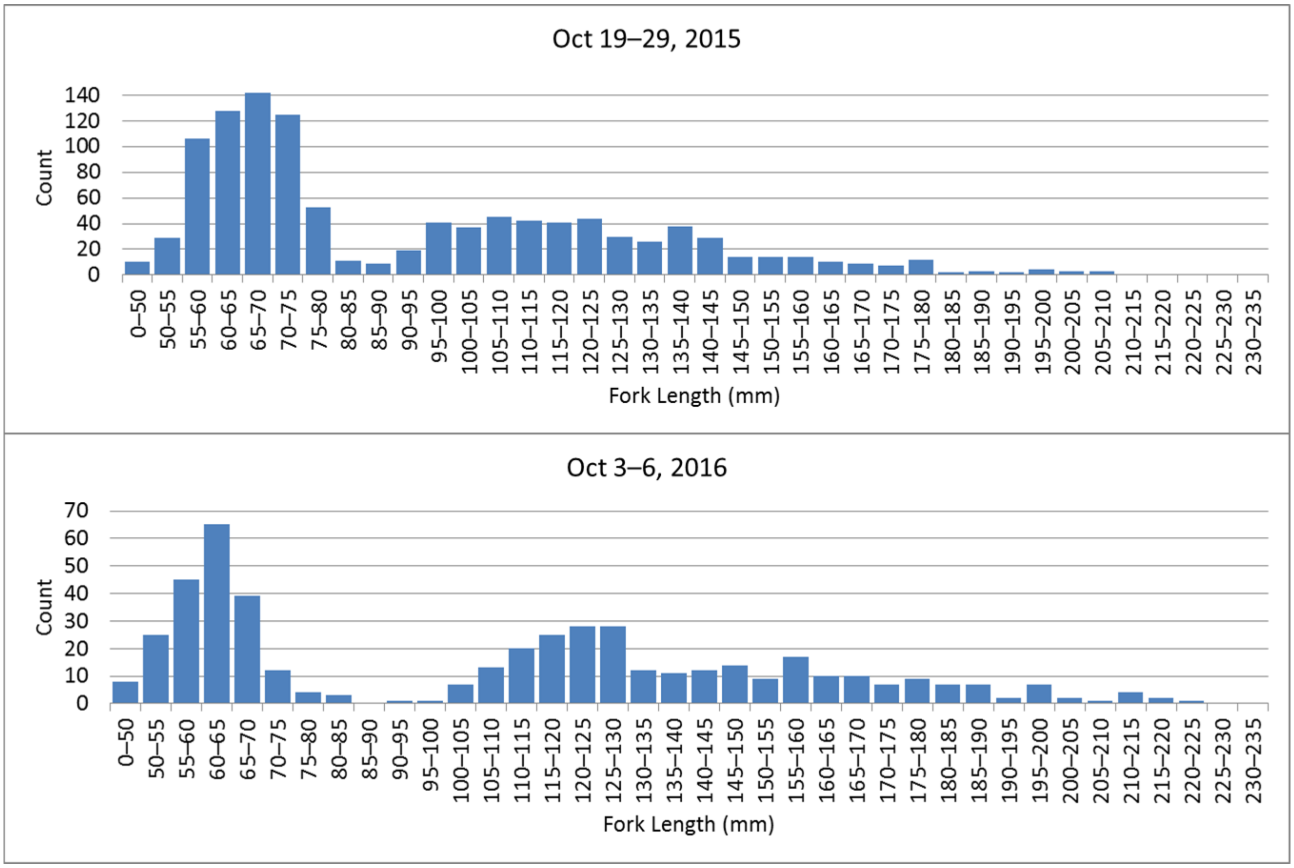

Figure 11. Length frequency of rainbow trout captured in the study reach in October 2015 and 2016.

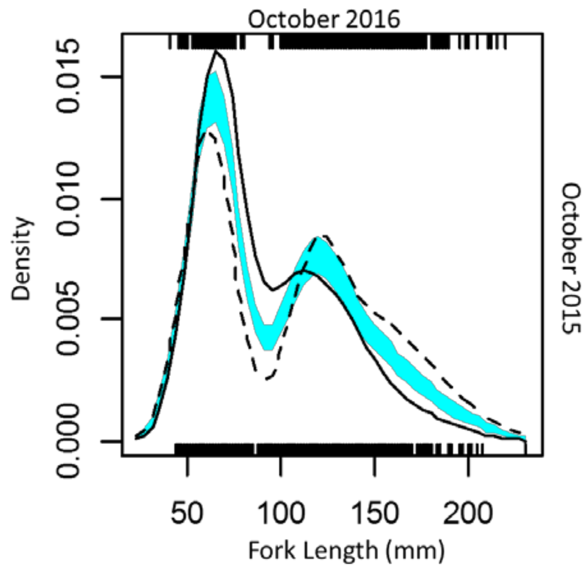

Figure 12. Estimates of the fork length size distributions of rainbow trout in the South Fork Rubicon River obtained by kernel smoothing (the solid line is the estimate for October 2015, the dashed line is the estimate for the October 2016 survey, the cyan band encodes a non-parametric test for equality of distributions; if both distributions are not within this band it indicates significant differences).

5.4.2 Individual Growth Rates

The size of all fish captured, PIT tagged, and recaptured was evaluated to measure growth patterns. By examining the trajectory of the fork length of all observed fish depicted in Figure 13, general patterns are evident. The slope of each line is an indicator of growth in this figure, such that high growth appears as a “steep” line connecting individual fish observations between periods. It is evident in this figure that growth is occurring during all seasons, and throughout the life of each fish. It is also clear that small fish grow at faster rates than larger fish. These patterns are further explored in more detailed analysis of intrinsic growth rates below.

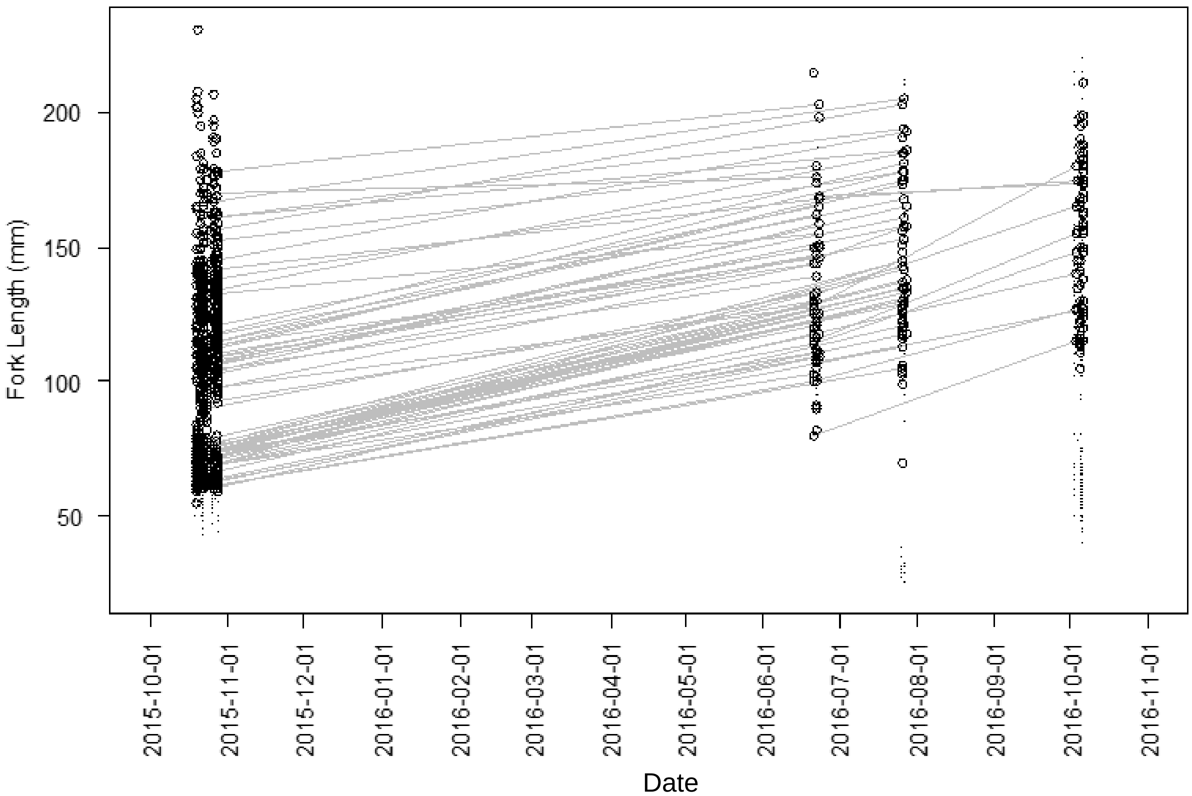

Figure 13. Fork length of all captured rainbow trout in the South Fork Rubicon. Grey lines connect recoveries of the same individual in fall-to-summer, summer to summer, and summer-to-fall intervals. Every measurement of a tagged fish is indicated with a circle and a dot. Fish that were captured but not tagged are shown as dots only.

Intrinsic growth rate was calculated for all recaptured fish and summarized to assess annual growth (October 2015 to October 2016), winter/spring growth (October 2015 to June/July 2016), and summer growth (June/July to October 2016). Growth rates appeared highest during summer (Figure 14), likely in association with warmer water temperatures and greater food availability. Growth rate was also observed to be strongly dependent on initial size (Figure 14), and fish greater than about 170 mm appeared to grow very little. Notably, very few fish were observed at sizes larger than 200 mm. Although trout smaller than 200 mm can prey on both invertebrates or small fish, once stream-dwelling salmonids reach around 270 mm they must be predominantly piscivorous to grow larger (Keeley and Grant 2001). With only minor exceptions, the only two fish prey sources for mature trout in South Fork Rubicon River are either smaller *O. mykiss*, or brown trout (especially young-of-year). The observed number of young-of-year following fry emergence during spring (< 50) was very low, and typically below the level needed to maintain the bioenergetic demands of a mature resident trout (Beauchamp 1990). Therefore, the infrequent observations of rainbow trout larger than about 200 mm is likely related to low prey abundance.

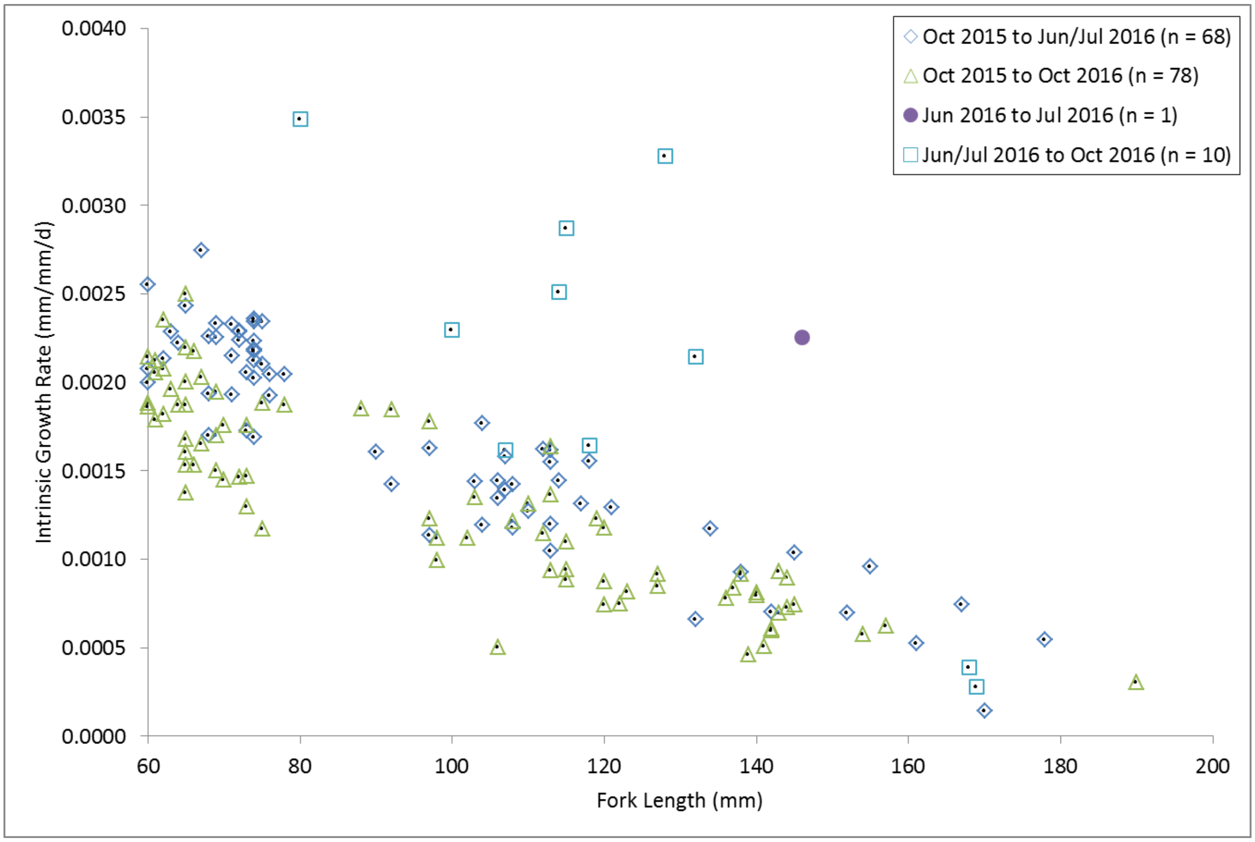

Figure 14. Intrinsic growth rate (mm/mm/d) based on successive captures of individually PIT tagged rainbow trout in relation to initial fork length.

5.5 FISH MIGRATION

5.5.1 South Fork Rubicon River

Most rainbow trout monitored during the period of study remained in the South Fork Rubicon River, and few migrated downstream to the forebay. Of the trout PIT tagged from within the habitat units surveyed in both 2015 and 2016 (586 rainbow trout), 148 (25.3%) were recaptured and documented to have remained in the South Fork Rubicon, compared with the 33 (3.3%) of the total tagged population that were detected migrating to the forebay. No fish were observed migrating from the forebay upstream into the river. Of all the 997 fish PIT tagged, most were re-captured near the location where they were originally captured (Figure 15). Overall, 62 fish (47.3%) were in the same location; 37 (28.2%) were observed in locations downstream of their original unit, and 32 (24.4%) were detected in habitat units upstream of their original location. There appeared to be a pattern of greater movement during the fall to summer period, and a slight pattern of upstream migration in the summer to fall period (Figure 16). Fish originating within the lower reach were more likely to migrate downstream to the forebay than fish from the middle or upper reach (Figure 16). Overall, migration was limited, with most fish remaining in their original habitat unit, few moving downstream, and even fewer migrating to the forebay.

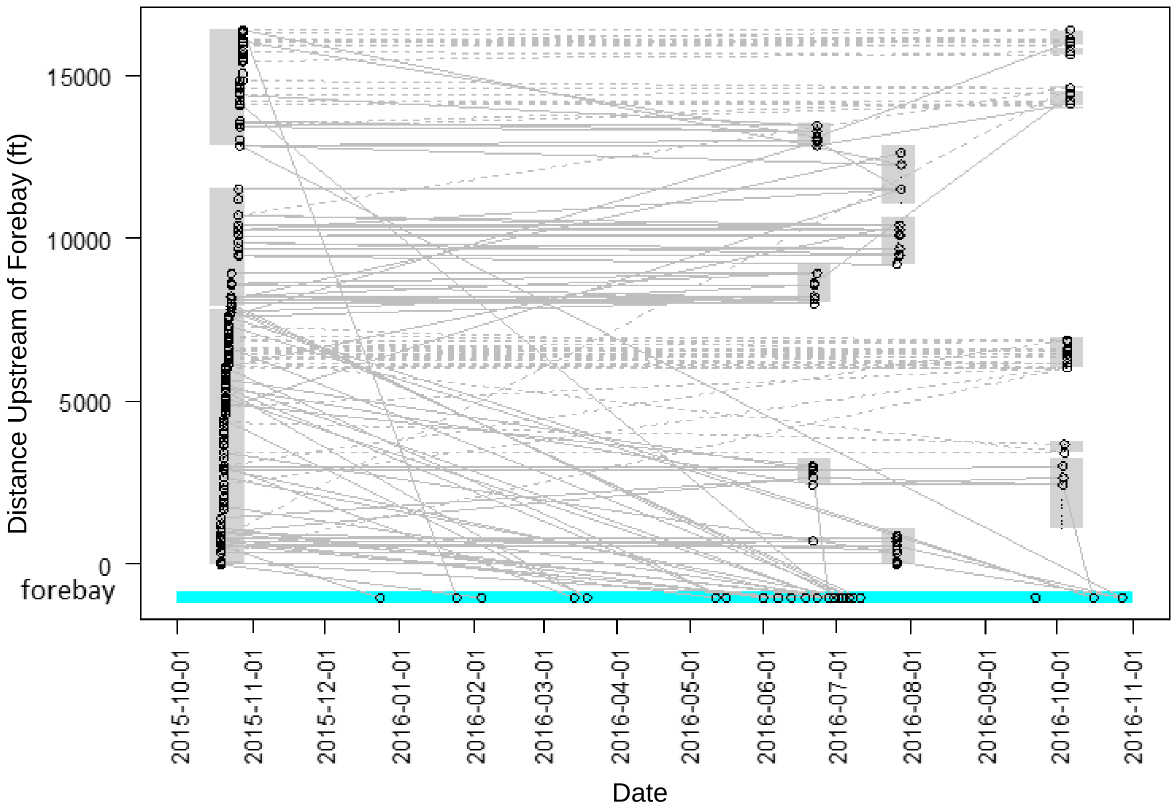

Figure 15. Location (ft upstream from forebay) of all recaptured rainbow trout in South Fork Rubicon in 2015 and 2016. Grey lines connect recoveries of the same individual during all sampling periods, and antenna detections in the forebay. Dashed gray lines show fish detected in both October 2015 and October 2016. Shaded boxes show which habitat units were sampled in each survey. Every location of a tagged fish is indicated with a circle and a dot. Fish that were captured but not tagged are shown as dots only.

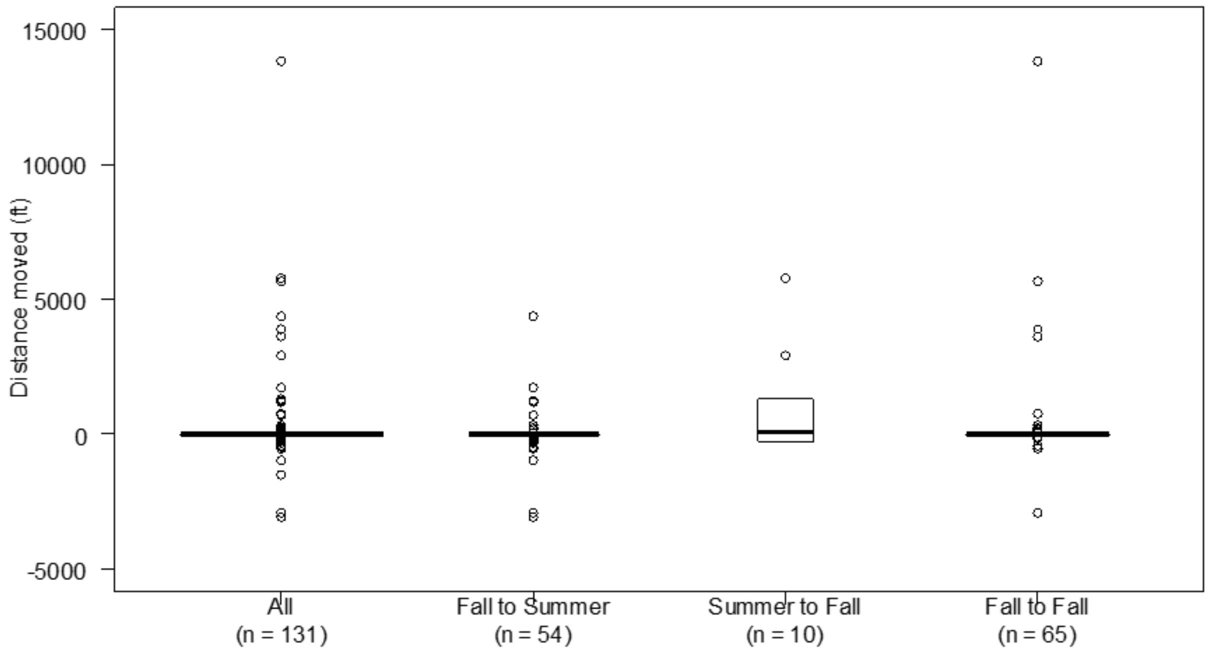

Figure 16. Boxplots showing distance moved (ft) of PIT tagged rainbow trout in the South Fork Rubicon River in 2015 and 2016.

5.5.2 Downstream Migration into Forebay

Of the 997-rainbow trout PIT tagged, 33 (3.3%) were detected migrating into Robbs Peak Forebay. Of the 33 fish that migrated into the forebay, 25 were detected numerous times, at two or more antennas. The multiple detections (> 43,000) indicate that the antennas were effective at detecting migrating fish, and suggests that most fish moving into the forebay were detected. Migration occurred year-round, and was generally correlated to instream flows in the South Fork Rubicon River (Figure 17). Notably, no detections were observed during the very low flows of fall 2015, nor when flows declined in late summer 2016. Spikes in detections occurred during winter flow events, although cold water temperatures may have suppressed additional migration during winter and early spring. The largest downstream migration into the forebay occurred during late spring 2016, coinciding with the falling limb of the snow-melt hydrograph and warming water temperatures.

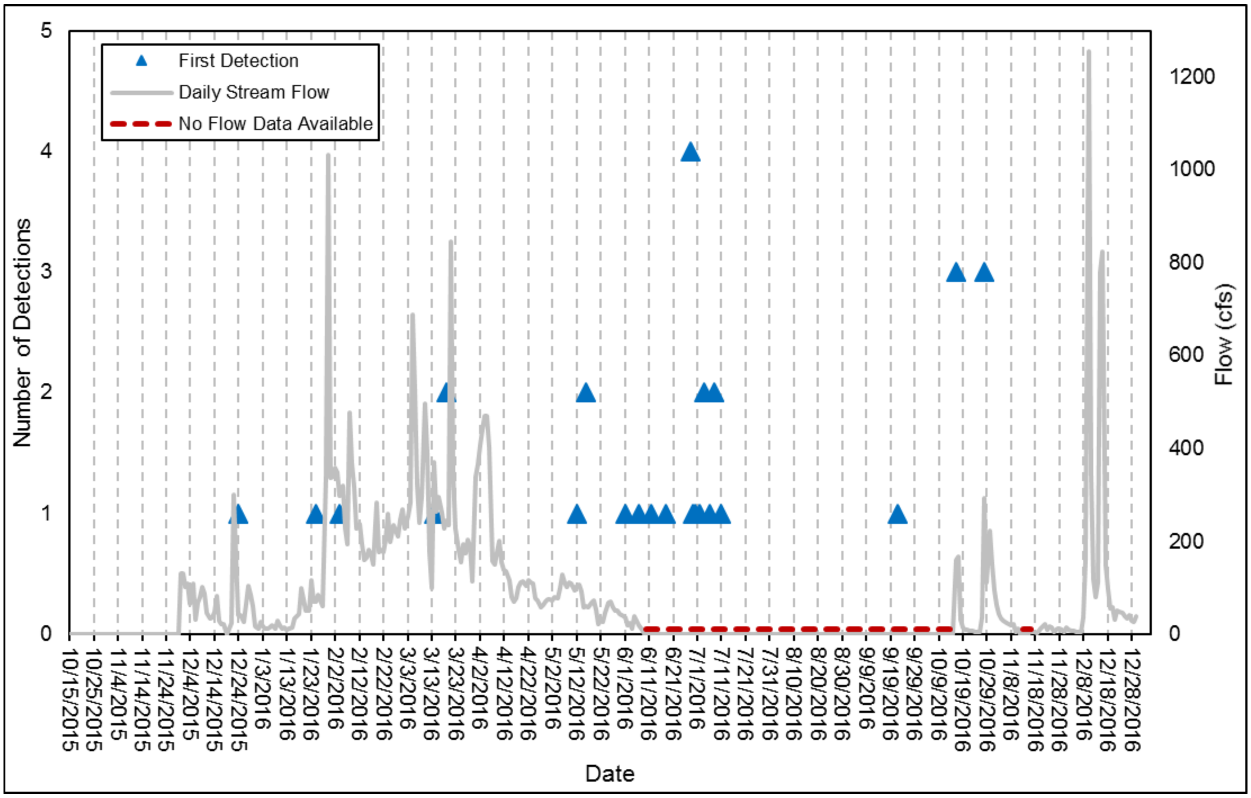

Figure 17. Mean daily flow in the South Fork Rubicon during the study period (October 2015 through December 2016), and number of unique first detections in Robbs Peak Forebay.

5.5.3 Fish Entrainment

Entrainment was defined for this study as PIT tagged trout detected at the intake antennas during periods of powerhouse operation that were not subsequently detected at another location. Based on this definition, of the 997 PIT tagged fish in the South Fork Rubicon, 9 were observed as entrained during the 345 days that the intake antenna was operational, with an extrapolated annual entrainment rate of 9.5 fish per year (of the 997-tagged trout). This equates to an estimated annual entrainment rate of 0.95%.

The 3.3% of trout that were detected migrating to the forebay were substantially smaller (at time of tagging) than fish that remained in the South Fork Rubicon River (Figure 18), and on average fish that were entrained were smaller than all other fish monitored (entrained fish averaged 70 mm FL and all other fish averaged 94 mm; two-sample t-test $p<0.01$), and most likely all age-0+. This equates to a total annual mortality rate for age-0+ rainbow trout from entrainment of less than 1%.

Entrainment was observed in all seasons, and was generally related to periods of high intake flows into the Robbs Peak penstock (Figures 19). Throughout the monitoring period fish were often detected milling near the intake, and then days or weeks later detected elsewhere in the forebay (Figure 19).

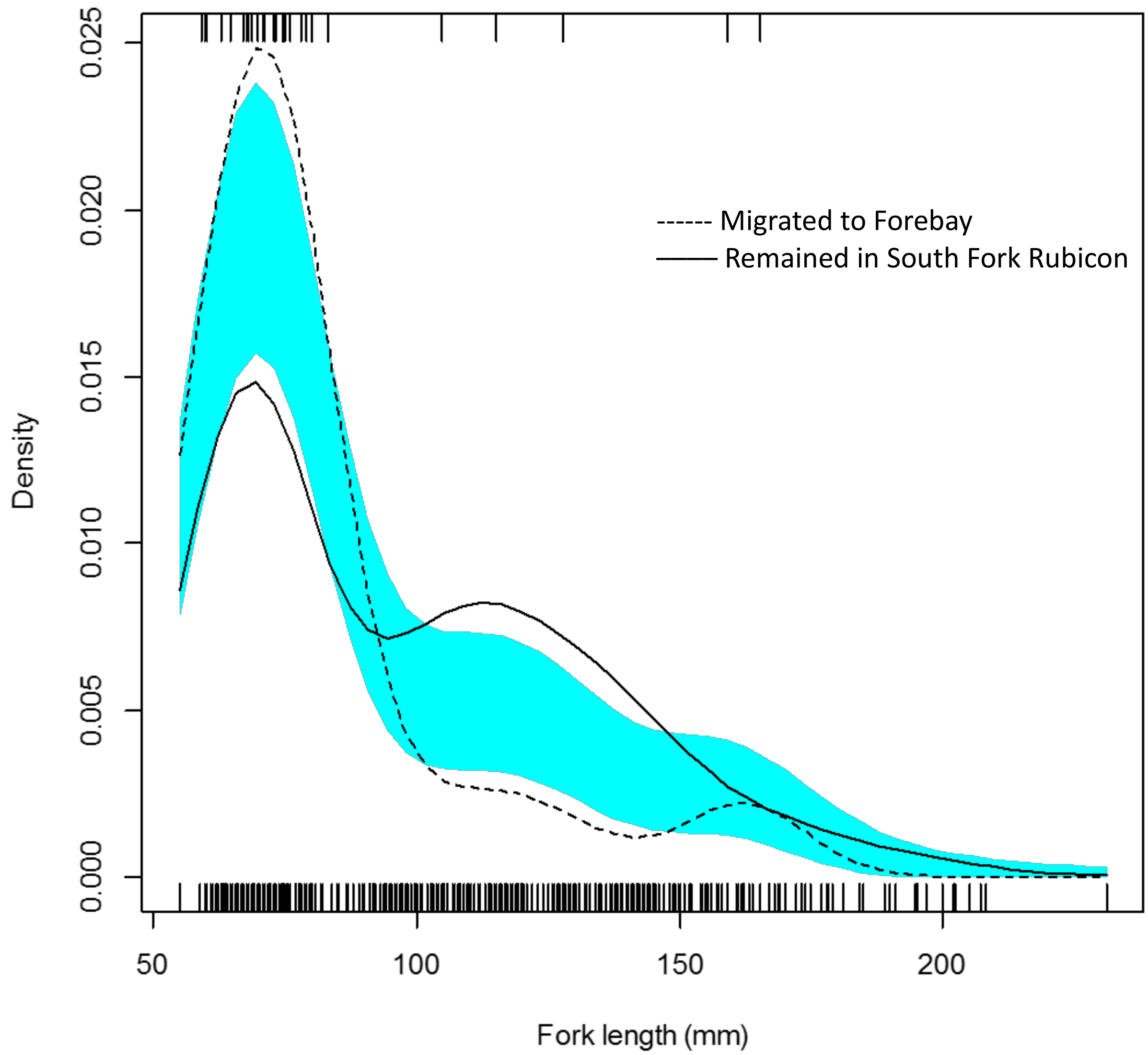

Figure 18. Initial size (October 2015) of PIT tagged rainbow trout in the South Fork Rubicon that were detected having either migrated downstream to the forebay (dashed line), or remained in the South Fork Rubicon River (solid line). The cyan band encodes a non-parametric test for equality of distributions; if both distributions are not within this band it indicates significant differences.

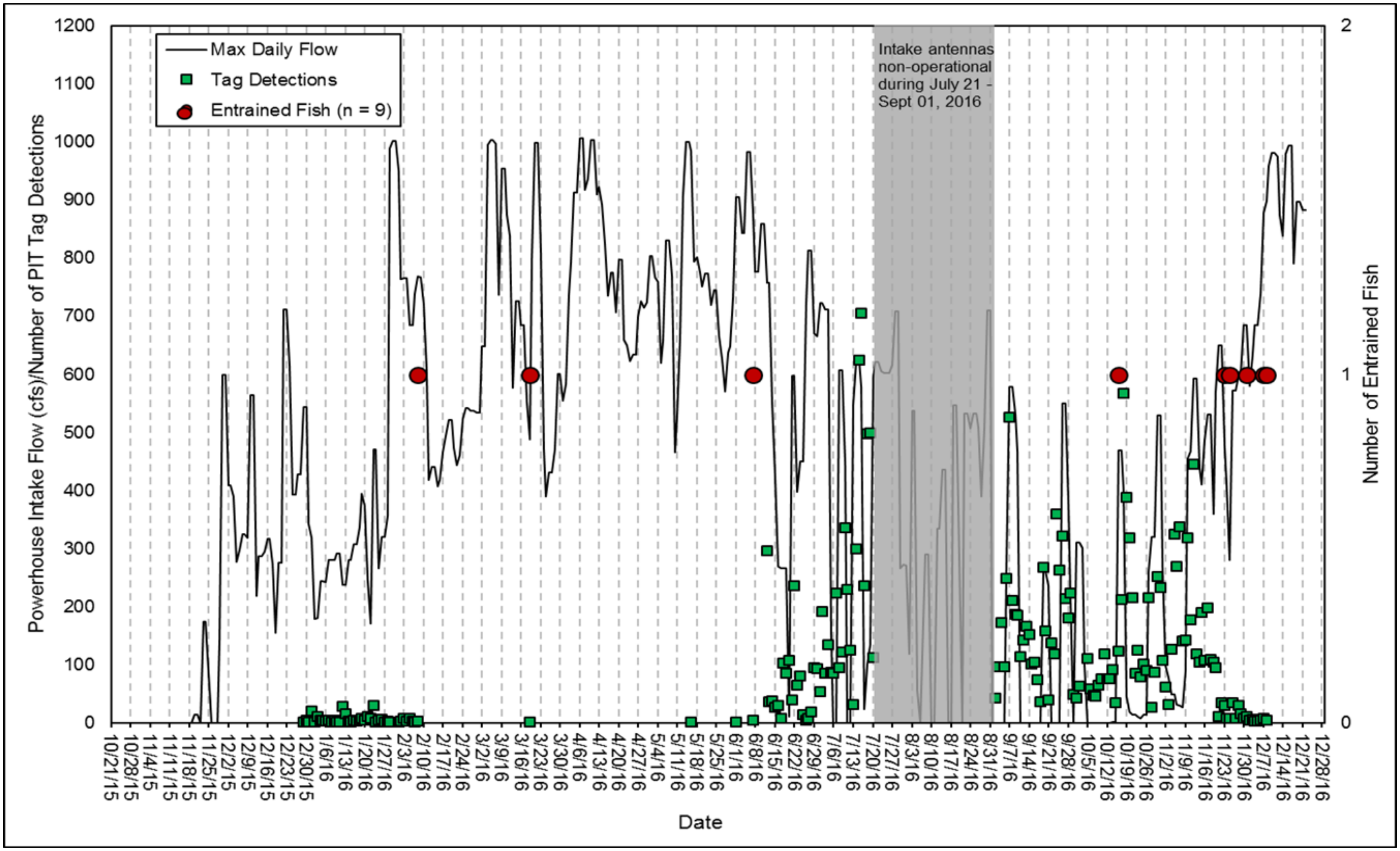

Figure 19. Robbs Peak Powerhouse intake flow (cfs), PIT tag detections at the intake, and entrained PIT tagged fish.

Powerhouse flows during periods of operation throughout the study period averaged 365 cubic feet per second (cfs) and reached a maximum of 1,006 cfs, which equates to velocities at the intake of 0.96 feet per second (fps) and 2.65 fps, respectively. Fish entrainment occurred over intake flows ranging from 275 cfs to 975 cfs. However, many more fish were detected at the same range of intake flows and were not entrained than were entrained (Figure 20). This is likely related in part to the size of the fish that were entrained. PIT tagged fish that were detected as entrained averaged 70 mm FL, with sustained swimming speeds calculated to be 0.92 fps, and burst swimming speeds of 2.30 fps (Table 11). The average fish observed in the South Fork Rubicon River (94 mm FL) is expected to outswim intake velocities under most conditions observed during the study, based on calculated sustained swimming speed of 1.23 fps and a burst speed of 3.08 fps. Fish greater than 200 mm FL are expected to outswim the intake velocities under all conditions observed during the study period.

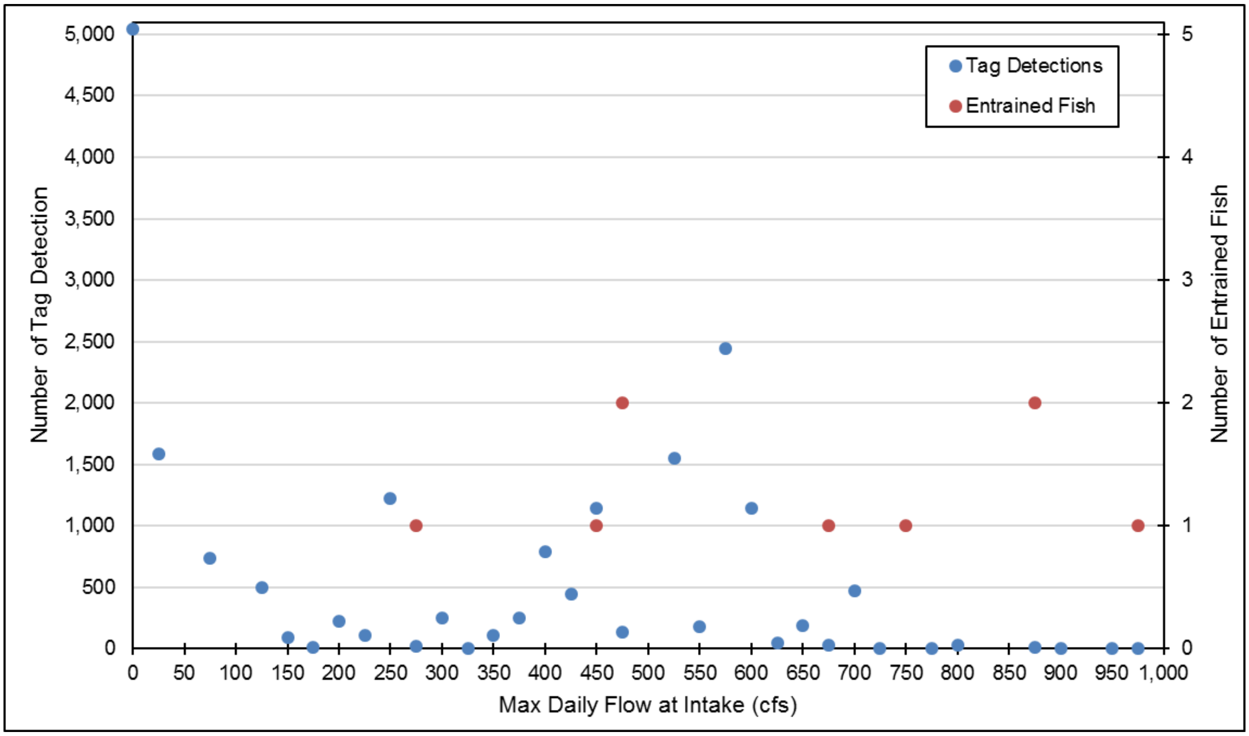

Figure 20. Robbs Peak Powerhouse intake flow (cfs), PIT tag detections, and entrained PIT tagged fish. Detections that appear on the X-axis correspond to low detection numbers, not "0" detections.

Table 11. Fish Swim Speeds and Intake Water Velocity During the Study Period (October 2015–December 2016).

Fish fork length (mm)	Sustained swim speed (fps)[1]	Burst swim speed (fps)[1]	Mean approach velocity (fps)[2]	Max approach velocity (fps)[3]	Approach velocity (fps) at maximum capacity (1,250 cfs)[4]
70	0.92	2.30	0.96	2.65	3.29
94	1.23	3.08			
200	2.63	6.58			

Notes: fps = feet per second
ft = feet
mm = millimeter
[1] Swim speed calculations based on Alexander (1967)
[2] Mean approach velocity based on average intake flow of 365 cfs
[3] Max approach velocity based on maximum intake flow of 1,006 cfs
[4] Maximum intake capacity is 1,250 cfs but was not observed during the study period.

6.0 CONCLUSIONS

Few fish migrate from the South Fork Rubicon River to the Robbs Peak Forebay. Nearly 1,000 rainbow trout were PIT tagged in 2015 and 2016 in the South Fork Rubicon River, and most fish that were detected or recaptured remained within the river (154 fish, 15.4% of all tagged fish), while only 33 (3.3%) of the tagged population migrated to the forebay. The fish detected moving downstream into the forebay were substantially smaller (age-0+ based on fork length) than fish that remained in the river, consistent with the tendency of smaller rainbow trout being the most likely to migrate or be displaced (Stauffer 1970, Hiss 1982). Overall, it appears that there is not a strong pattern of downstream migration from the South Fork Rubicon River into the forebay.

The observed annual entrainment rate (0.95%) was low in comparison with natural sources of mortality. In a natural river environment, the physical habitat requirements for different age classes of trout are relatively similar, except that as fish age and grow they require more space for foraging and cover (Bjornn and Reiser 1991). Therefore, rivers can typically support far fewer older and larger age-1+ trout than age-0+ trout, resulting in a large mortality of age-0+ during their first year of life as habitat limitations constrain the number of older fish that can be supported (Elliott and Hurley 1998). In addition, density independent natural sources of mortality for rainbow trout are high (especially for smaller fish), and include avian and terrestrial predation, piscivorous predation, angling, poor condition, and disease. For age-0+ *O. mykiss* mortality during their first summer is typically 25% or higher (Engle 2005, Korman 2009, Korman et al. 2011, Grantham et al. 2012), with even higher rates of mortality (~40%) during their first winter (Justice 2007). Annual mortality rates for resident trout are typically variable, and can be 50 to 80% (Hume and Parkinson 1988, Christopher et al. 2009, Benjamin et al. 2013). In contrast, less than 1% of the PIT tagged population in the South Fork Rubicon was detected as entrained. Based on this proportion of PIT tagged fish that were entrained, around 19 of the 2,110-rainbow trout estimated in October 2015 are expected to have been entrained, and all were apparently age-0+. The risk of mortality attributable to entrainment is very low relative to other sources within the environment, and there is a low probability that the few (<20) age-0+ fish entrained at the intake would have ever have contributed to the South Fork Rubicon rainbow trout population.

It does not appear that the measured low annual rate (0.95%) of mortality from entrainment at the intake has a substantial effect on the population in the South Fork Rubicon. If substantial mortality of rainbow trout at the intake were influencing the population, the population of age-1+ and older adult rainbow trout in the South Fork Rubicon would be in low abundance and/or in decline. This could occur if either, a) age-1+ and older trout were more likely to migrate downstream and be entrained, or b) if dramatically high levels of age-0+ mortality at the intake were limiting the recruitment of age-0+ into the age-1+ and older population. However, there is strong evidence that neither of these is occurring. First, it is the smaller and younger age-0+ that are migrating downstream into the forebay and risk entrainment, and secondly, the proportion of fish entrained is very low relative to other sources of mortality. Most importantly, the age-1+ and older population in the South Fork Rubicon appears stable. Based on revisiting the study reach in 2015 and 2016, individuals are growing during all seasons, can locate suitable habitat, and the overall age structure is maintained year-to-year. Although the population likely fluctuates on an annual basis, the abundance, growth, and age structure of the population indicate it is healthy and stable.

The central focus of this study was to determine if entrainment is occurring, and if it is having a substantial effect on the population in the South Fork Rubicon River. The results indicate that entrainment of age-0+ rainbow trout is occurring at very low levels, and is unlikely to influence the population in the South Fork Rubicon River. Reducing entrainment at the Robbs Peak Powerhouse intake is unlikely to result in an increase in the South Fork Rubicon population, since, a) few fish are migrating downstream into the forebay, b) the ones that are migrating are small age-0+, and c) the probability of entrainment is minimal.

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Attachment A
Map of Fish Distribution in the South Fork Rubicon River, October 2015

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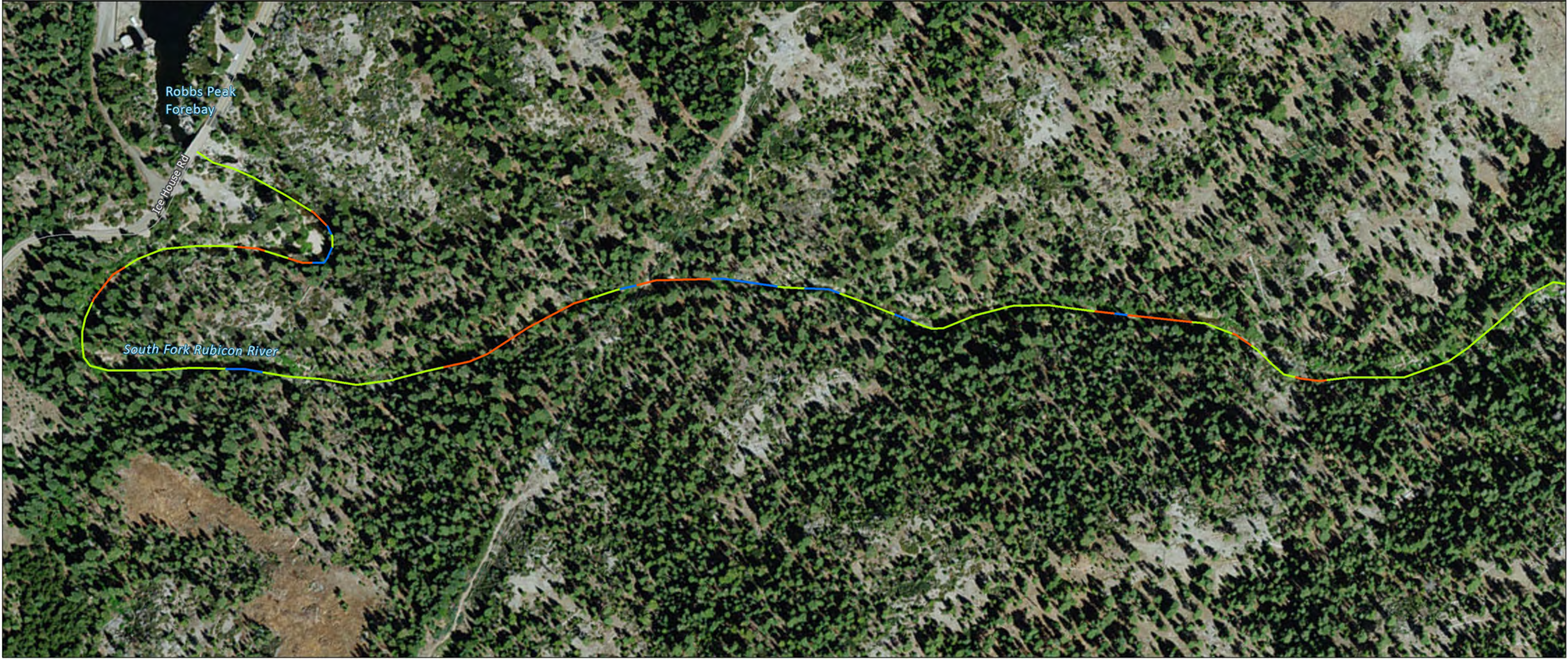
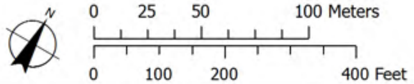


Estimated Fish Abundance
- 0
- 1 - 10
- 11 - 41

☐ Fish passage barrier



Map Sources:
Imagery: ESRI World Mapping Service

Stillwater Sciences

Map Location

Estimated Fish Abundance

- 0
- 1 - 10
- 11 - 41

□ Fish passage barrier

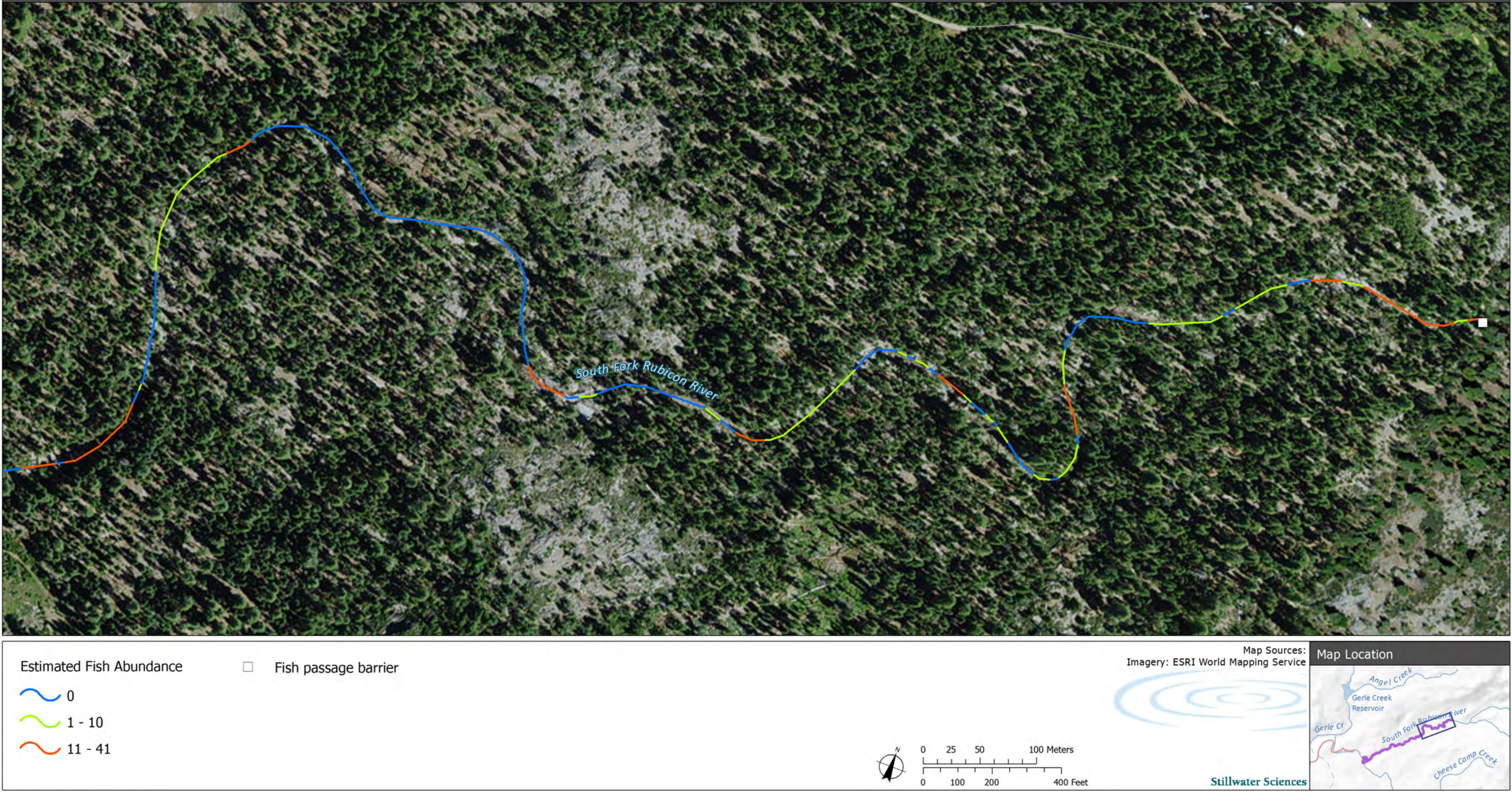
0 25 50 100 Meters

0 100 200 400 Feet

Map Sources:
Imagery: ESRI World Mapping Service

Stillwater Sciences

Map Location


South Fork Rubicon River
Estimated Fish Abundance
0
1 - 10
11 - 41
Fish passage barrier
0 25 50 100 Meters
0 100 200 400 Feet
N
Map Sources:
Imagery: ESRI World Mapping Service
Stillwater Sciences
Map Location
Angel Creek
Gerle Creek Reservoir
Gerle Cr
South Fork Rubicon River
Cheese Camp Creek

Attachment B
PIT tag antenna operational details

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Table B-1. PIT Tag Antenna Operational Details.

<table>
<tr><th>PIT Tag Array</th><th>Period of Operation</th><th>Read Range</th><th>Cross-Section Coverage</th><th>Notes</th></tr>
<tr><td>South Fork Rubicon at Forebay</td><td>10/15/2015 to 1/29/16
6/28/16 to 12/22/16</td><td>24 inches</td><td>100%</td><td rowspan="2">The antenna groups spanned the channel; however, at high flows when the forebay was at full operational levels, the antennas were under several feet of water so any fish on or within several feet of the water surface would not have been detected</td></tr>
<tr><td>Gerle Canal at Forebay</td><td>10/15/2015 to 11/30/15
4/29/16 to 12/22/16</td><td>44–48 inches for the initial antennas
72 inches for the replacement antennas</td><td>100%</td></tr>
<tr><td>Trash Rack</td><td>10/15/2015 to 7/20/16
09/02/16 to 12/22/16</td><td>42–48 inches</td><td>70–75%</td><td>Approximately 70–75% of the cross-sectional area of the trash rack was covered during system operations.</td></tr>
<tr><td>Intake Structure</td><td>10/15/2015 to 11/30/15
12/28/15 to 7/20/16
09/02/16 to 12/22/16</td><td>42–48 inches</td><td>75-80%</td><td>Intake rack antennas covered the face of the intake completely and also extended in a straight line beyond the angled sides, with approximately 75–80% coverage of the cross-section of the intake opening</td></tr>
</table>

FEDERAL ENERGY REGULATORY COMMISSION
Washington D.C. 20426

OFFICE OF ENERGY PROJECTS

Project No. 2101-106 and 114 -- California
Upper American River Hydroelectric Project
Sacramento Municipal Utility District

June 27, 2017

Jon Bertolino
Sacramento Municipal Utility District
P.O. Box 1500
Pollock Pines, CA 95726

Subject: Robbs Peak Powerhouse entrainment study report and Gerle Creek fish passage plan report- Articles 402 and 401(a)

Dear Mr. Bertolino:

This letter acknowledges receipt of your Gerle Creek fish passage plan report (fish passage report) and Robbs Peak Powerhouse entrainment study report (entrainment study report), filed with the Commission on April 10 and 20, 2017, respectively, pursuant to Articles 402 and 401(a) of the Upper American River Project license FERC No. 2101.[1] The report is also required by the Commission's August 5, 2015 Order Modifying and Approving Gerle Creek Fish Passage Plan (Fish Passage Plan)[2] and July 30, 2015 Order Modifying and Approving Robbs Peak Powerhouse Entrainment Monitoring Plan (Entrainment Monitoring Plan).[3]

According to your Fish Passage Plan, you are to file a final report upon conducting three studies/analyses to understand the potential for depth barriers that impede upstream fish passage through the Gerle Creek Delta from August through October when brown trout migration is occurring. One study included conducting a topographic survey to establish baseline data on the Delta's geomorphology. Following this, you conducted a critical riffle analysis under three flow regimes, in order to establish current passage

[1] Order Issuing New License. 148 FERC ¶ 62,070 (issued July 23, 2014).

[2] 152 FERC ¶ 62,089

[3] 152 FERC ¶ 62,072

conditions that are independent of backwater influence from Gerle Creek Reservoir in the Delta and ultimately identify passage flow and passage depth. Finally, upon determining passage flow, you compared it to the minimum instream flow requirement from the August to October period to determine whether a change in the Gerle Creek Reservoir surface elevation is necessary to maintain passage. From these studies/analyses, you concluded in your April 10th report that there is no barrier to brown trout passage out of Gerle Creek Reservoir into Gerle Creek at any of the streamflows or reservoir elevations required by the license during the August-October spawning period. You also used the model to simulate morphological changes to the Delta, assuming potential aggradation and degradation scenarios in the future. You also concluded from the studies that there weren't any conditions that should impede brown trout passage upstream during the spawning period. Therefore, you deemed the development of a reservoir operations plan and nomograph, as referenced in your Fish Passage Plan as a potential follow-up action pending the results of the study, unnecessary and did not pursue it further.

You provided the results of your studies/analyses to the U.S. Forest Service (Forest Service), California State Water Control Board (Control Board), California Department of Fish and Wildlife (California DFW), and the U.S. Fish and Wildlife Service (FWS) on March 1, 2017 for review and comment. One comment was provided by California DFW, which requested that you perform additional analysis to determine whether downstream riffles not originaly classified as "critical" could become passage impediments to brown trout at the lowest reservoir level. You completed the analyses as requested and ultimately determined that the riffles in question were of sufficient depth and width to accommodate brown trout passage under the lowest reservoir level conditions. California DFW concurred with your determination that no further action is needed.

Your Entrainment Monitoring Plan requires you to conduct a study to determine at which flows fish migration is occurring and whether fish are being entrained at Robbs Peak Powerhouse, and if the entrainment is occurring, whether it's substantially impacting the South Fork Rubicon River fishery. In the event that entrainment is found to occur and it is negatively impacting the South Fork Rubicon River fishery, you must consult with the resource agencies identified in the Entrainment Monitoring Plan to develop adaptive management measures described in the water quality certification and Forest Service 4(e) conditions for the project license.

According to your April 20th report, you concluded that approximately 3.3 percent of fish are migrating from the South Fork Rubicon River into the forebay at Robbs Peak Powerhouse. These are typically younger fish, aged at 0+ years, based on fork length. You determined that that there is not a strong pattern of downstream migration from the South Fork Rubicon River into the forebay. Of the 1,000 individuals tagged, only nine fish were entrained. You extrapolated this data to estimate an annual entrainment rate of less than 1 percent in the South Fork Rubicon River fishery, which is substantially lower than the natural mortality for this age class that would be considered compensatory. From this, you concluded that there is no substantial negative impact to the South Fork Rubicon River fishery from entrainment, and thus, no need for adaptive management measures.

You provided the report to Forest Service, FWS, California DFW, and the Control Board for review and comment on March 1, 2017 and then further discussed the results of the study at an annual meeting with these agencies on March 23, 2017. No outstanding comments remain.

Your April 10th and 20th reports fulfill the reporting requirements referenced here within. Thank you for your cooperation. If you have any questions regarding this letter, please contact me at (202) 502-6760.

Sincerely,

Joy M. Kurtz
Aquatic Ecologist
Division of Hydropower Administration and
Compliance

cc: Mr. Darold Perry
Sacramento Municipal Utility District
P.O. Box 1500
Pollock Pines, CA 95726