# March and July 2009 Population Size Estimates of *Oncorhynchus mykiss* in the Lower Tuolumne River

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## SUMMARY

In both mid-March and mid-July 2009, population size estimates of *Oncorhynchus mykiss* were developed in the lower Tuolumne River in accordance with the 3 April 2008 Delegated Order issued by the Federal Energy Regulatory Commission (FERC) implementing elements of a study plan previously developed in coordination with California Dept. of Fish and Game (CDFG), National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) biologists, and submitted to FERC on 16 July 2007.

Snorkel surveys were conducted during daylight hours from 16 to 25 March and from 9 to 14 July 2009 to estimate *O. mykiss* population size within the Tuolumne River. In addition to snorkel survey observations of *O. mykiss*, data for Chinook salmon (*O. tshawytscha*) and other species was also collected. Snorkel surveys were conducted using a two-phase survey design to sample seven different habitat strata (i.e., riffle, run head, run body, run tail, pool head, pool body, and pool tail) found downstream of La Grange Dam at river mile (RM) 51.8 using habitat typing from that used in the July 2008 surveys. The study reaches extended from RM 51.8 to RM 29.0 in March and from RM 51.8 to RM 41.7 near Turlock Lake State Recreation Area in July. The sampling units were delineated by habitat-typing surveys performed in June 2008 (down to RM 39.5) and March 2009 (from RM 39.5 down to RM 29.0). A total of 66 out of all 340 habitat units were selected for either single pass or multi-pass snorkel surveys in March 2009. A total of 31 of 136 units in the study reach upstream of RM 39.5 were selected for either single pass or multi-pass snorkel surveys in July 2009.

### *O. mykiss population estimates*

Based upon the maximum count obtained over all dive passes in each sampled unit, 5 young-of-the-year (YOY)/juvenile (< 150 mm FL) and 7 adult (> 150 mm FL) (sum total of 12) *O. mykiss* were observed in March 2009, and 641 YOY/juvenile (< 150 mm FL) and 105 adult (> 150 mm FL) (sum total of 746) *O. mykiss* were observed along the study reach in July 2009. For both surveys, most juveniles and adults were found in riffle or pool habitats. Using a bounded counts population estimator (necessarily derived from Chinook salmon data due to low *O. mykiss* counts in multiply-dived sampling units) for the March 2009 survey period, a population estimate of approximately 63 juvenile and 170 adult *O. mykiss* were present within the study reach (RM 51.8–29.0). Using the same estimator (derived from *O. mykiss* counts) for the July 2009 survey period, approximately 3,475 juvenile and 963 adult *O. mykiss* were present within the study reach (RM 51.8–41.7).

The July 2009 *O. mykiss* juvenile population estimate of 3,475 was apparently higher than the July 2008 estimate of 2,472 juveniles, but within the 95% confidence interval (CI) of the estimates in these two years (945–6,004 and 1,263–3,681 juveniles estimated in 2009 and 2008, respectively). The July 2009 *O. mykiss* adult population estimate of 963 was also slightly higher than the July 2008 estimate of 643, with both results within their respective 95% CI in these two years (464–1,461 and 217–1,070 adults estimated in 2009 and 2008, respectively).

### *Chinook salmon population estimates*

For Chinook salmon encountered during the March and July 2009 snorkel surveys, a maximum count of 4,281 juveniles (< 150 mm FL) were observed during March within all habitat types along the study reach and a maximum count of 4,696 juvenile Chinook salmon were observed in all habitat types during the July 2009 survey. This corresponded to bounded count population

estimates of 39,563 Chinook salmon (95%CI: 34,861–44,265) during the March 2009 surveys, and 29,389 (95%CI: 19,068–39,711) during July 2009. By comparison, the July 2009 juvenile population estimate of 29,389 was much higher than the July 2008 estimate of 2,636. There were also 6 adult salmon observed in July 2009 as compared to 2 in July 2008.

***Other species***

A combination of native minnows (hardhead and Sacramento pikeminnow), along with native Sacramento sucker accounted for approximately 90% of observed non-salmonid fish for both the March and July sampling periods, while non-native centrarchid species (largemouth bass, smallmouth bass, bluegill, and green sunfish) accounted for the second largest group of non-salmonids. Most centrarchids occurred toward the downstream end of the study reach where water temperatures were greater, while native minnows and suckers were found throughout the reaches in both sampling periods.

***Relationship between Temperature and O. mykiss habitat use***

To test the hypothesis that the summertime distribution of suitable habitat by observed life stages of *O. mykiss* is related to ambient river water temperature, water temperature data from thermographs deployed in the Tuolumne River were compared to juvenile and adult *O. mykiss* density along the study reach. The data show that temperatures increased in the downstream direction, from 12.6ºC (54.6°F) to 24.8ºC (76.7°F) (maximum weekly average temperature [MWAT]), and that *O. mykiss* density of both adult and juveniles decreased along this same gradient. However, other factors are present that may also explain these relative abundance distributions. Although the longitudinal distribution of *O. mykiss* was similar for both the March and July surveys, the lower number of *O. mykiss* observations in March 2009 coupled with low water temperatures (maximum observed <17.0 °C [62.6 °F]) precluded any meaningful associations with temperature.

***O. Mykiss habitat use at Restoration sites***

A second hypothesis that habitat use by *O. mykiss* juveniles and adults observed in the Tuolumne River occurred at the same density in both restored and nearby reference sites was tested based on observed densities of *O. mykiss* juveniles and adults in habitat types (riffle, run head, and pool head) common to both groups in the July survey. For juveniles, this comparison showed riffle habitat use at upstream restoration sites was slightly greater than that of other riffle habitats. Juvenile habitat use within run head habitats was similar or reduced at the restoration sites in comparison to reference sites, with relatively low use of pool head habitat. For adults, this comparison showed a potential reduction of habitat use of riffle habitat at restoration sites, with similar use of run head habitat, and insufficient data for a comparison of pool head habitats.

***Comparison of June and July 2009 Survey Results***

A comparison was made of *O. mykiss* and juvenile Chinook data collected during the July 2009 survey to routine snorkel survey data collected during June 2009 by TID/MID. The comparison shows a similar longitudinal trend, with overall decreasing densities in the downstream direction for both species. Along the study reach common to both surveys, a total of 112 *O. mykiss* juveniles and 30 adults were observed in the June snorkel survey, while 600 juveniles and 101 adults were observed in the July survey. A total of 1,897 juvenile Chinook were seen in the June survey with 4,423 seen in July 2009.

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# 1 INTRODUCTION

Routine fisheries monitoring surveys for the Don Pedro Project (FERC Project No. 2299) by the Turlock Irrigation District (TID) and Modesto Irrigation District (MID) have long documented the presence of *Oncorhynchus mykiss* in the lower Tuolumne River (TID/MID 2005). Summer snorkel surveys, conducted in most years since 1988, have documented an increased *O. mykiss* presence and relative abundance that is associated with the more consistent and higher summer flows provided since 1997 (TID/MID 2008).

On 19 March 1998, the National Marine Fisheries Service (NMFS) first listed the Central Valley steelhead as threatened under the Endangered Species Act (ESA). After several court challenges, NMFS issued a new final rule relisting the Central Valley steelhead on 5 January 2006 (71 FR 834). In a separate process resulting from terms of the 1996 FERC license amendment for the Project, NMFS staff provided input to a draft limiting factors analysis for Tuolumne River salmonids (Mesick et al. 2007) and included recommendations for developing abundance estimates, habitat use surveys, and anadromy determination of resident *O. mykiss*. These recommendations were conceptually used to develop the Districts' FERC Study Plan (TID/MID 2007), which was the subject of a 3 April 2008 FERC Order. As part of the Order, the Districts were required to conduct population estimate surveys in winter (February/March) and summer (June/July), with the first surveys starting in summer 2008 to determine *O. mykiss* population abundance by habitat type.

The Districts first submitted a detailed *O. mykiss* population estimate study plan (Stillwater Sciences 2008a) to FERC on 3 July 2008 to provide information on the abundance and habitat requirements within the lower Tuolumne River. A report on the July 2008 population size estimate (Stillwater Sciences 2008b) was submitted as part of the Districts' 2008 annual report to FERC (TID/MID 2009). An updated study plan (Stillwater Sciences 2009b) was prepared for the 2009 population estimate surveys, which is attached to this report as Appendix A. In addition to providing data to develop population size estimates under current conditions, the study plan examined the following hypotheses:

> Hypothesis 1: Summertime distribution of suitable habitat by observed life stages of *O. mykiss* is related to ambient river water temperature.
>
> Hypothesis 2: Habitat use by *O. mykiss* juveniles and adults observed in the Tuolumne River occurs at the same density in both restored and nearby reference sites.

The *O. mykiss* snorkel surveys employed a two-phase sampling approach for the development of a reach-wide population estimate (Hankin and Mohr 2001) in the lower Tuolumne River. Survey sites were selected using a stratified random sampling approach, where the strata were major habitat types. In March, the overall sampling "universe" from which sampling strata were delineated extended from near La Grange Dam at river mile (RM) 51.8 to RM 29.5 downstream of Waterford (Figure 1). In July, the survey reach was from RM 51.8 to near Turlock State Recreation Area at RM 41.7, which extended downstream of areas where *O. mykiss* were observed (Riffle 23C at RM 42.3) during the routine June 2009 snorkel surveys (Ford and Kirihara 2009).

The two-phase stratified sampling design involved snorkeling pre-selected habitat units (e.g., riffle, run, pool, etc.) multiple times in order to quantify the variance associated with density and subsequent population estimates. As in a typical Phase I sampling approach, primary snorkel surveys (Edmundson et al. 1968, Hankin and Reeves 1988, McCain 1992, Dolloff et al. 1996) were conducted across a subset of the all habitat units. In Phase II, approximately 20–70% of each habitat type sampled was randomly selected for replicated surveys by repeated dive counts.

The methods presented by Stillwater Sciences (2008) discussed using a combined approach of both repeated dive counts and electrofishing. Current ESA permit restrictions for both NMFS Section 10(a)(1)(A) permit No's 1280 (TID) and 1282 (Stillwater) did not allow sufficient incidental take to conduct the second-phase surveys using electrofishing. Consequently, the surveys utilized only snorkel surveys, as provided for in the 2007 study plan and identified in letters provided by the Districts to FERC dated 3 July 2008 and 31 March 2009.

# 2 METHODS

## 2.1 Habitat Characterization

### 2.1.1 Habitat mapping

We produced habitat maps from an analysis of past habitat surveys, historical and more recent aerial photographs, and recent field surveys superimposed within a geographic information system (GIS). Field maps for the March and July 2009 snorkel surveys were created using an orthorectified aerial photo and accompanying Light Detection and Ranging (LiDAR) topographic data from 21 September 2005 recorded at river flows of 321 cfs. Preliminary sampling unit boundaries of common habitat features (pools, riffles, and runs) were estimated from the LiDAR and bathymetric data between RM 52–38 within GIS by calculating locations corresponding to major water depth transitions (Table 2-1)

**Table 2-1.** Coarse-scale habitat types used during snorkel surveys.

| Habitat type | Description[a] | Approximate depth |
|---|---|---|
| Riffle | Shallow with swift flowing, turbulent water. Partially exposed substrate dominated by cobble or boulder. Gradient moderate (less than 4%). | 0–4 ft |
| Run | Fairly smooth water surface, low gradient, and few flow obstructions. Mean column velocity generally greater than one foot per second ($fts^{-1}$). | 4–10 ft |
| Pool | Slow flowing, tranquil water with mean column water velocity less than 1 $fts^{-1}$. | >10 ft |

[a] Major habitat types determined based upon observed hydraulic conditions (McCain 1992, Thomas and Bovee 1993, Cannon and Kennedy 2003)

As an initial validation of these coarse scale habitat types, we compared the habitat types mapped in July 2008 (Appendix B) with previous habitat type maps (Appendix C) developed by McBain and Trush (2004) between 1999–2001 on a base-layer map corresponding to a wetted perimeter of 622 cfs flown on 20 May 20 1991. Appendix C shows major habitat types (i.e., riffle, run, pool) encountered during the 1999–2001 surveys along with past and planned gravel introduction locations included in the *Tuolumne River Coarse Sediment Management Plan* (McBain and Trush 2004).

In general, habitat typing shown by McBain and Trush (Appendix C) indicates larger proportions of "pool" habitat types than those determined during this effort (Appendix B), which reserved the pool habitat designation for water depths greater than 10 ft. Additionally, because *O. mykiss* tend to congregate at transitions between habitat types, Appendix B shows a further division of pool and run body habitats into smaller, transitional habitat sampling units (pool head, pool tail, run head, and run tail) based upon location of slope channel slope break at the upstream and downstream end of the unit. For the July 2009 surveys, pool tail habitats were consolidated into the pool body habitat. This action was based on low use of the pool tail habitats as discrete sampling units in the prior surveys (July 2008 and March 2009) and results in a reduced number of habitat units having low potential for use by salmonids available for habitat selection, thereby increasing the number of sampling units having a higher potential use, while not eliminating them from the area surveyed (see Section 2.2.1 for a complete description of survey unit selection).

### 2.1.2 Habitat data collection

On 7–8 July 2008 and 10-13 February 2009, float surveys were conducted to further refine and validate the preliminary habitat maps (Appendix B) described above at flows of approximately 106 cfs and 168 cfs, respectively. In addition to refining the locations and sizes of potential habitat sampling units, we collected habitat data (Table 2-2) at several locations within each sampling unit. Starting at upstream end of the study reach just downstream of La Grange Dam (Figure 1), we assigned habitat units a natural sequence order (NSO), a number, beginning with NSO 001, and incremented this identifier at each habitat transition (e.g., NSO 001 pool head, NSO 002 pool body, etc). We located and marked the upstream and downstream end of each unit on field maps, recorded location with a handheld GPS unit, and tied flagging labeled with the date, unit number, and habitat type.

**Table 2-2.** Habitat data collected at each unit.

| Parameter | Method | Metric/Descriptor | Method reporting limit |
|---|---|---|---|
| Natural Sequence Order (NSO – Habitat unit #) | N/A | NSO-1, NSO-2, NSO-3, … | N/A |
| Latitude/Longitude | Handheld GPS receiver | UTM | N/A |
| Habitat type | Visual estimation | See Table 2-1 | N/A |
| Average unit width | Horizontal distance | Meters (feet) (measured at multiple transects) | 0.01 m (0.1 ft) |
| Average unit length | Horizontal distance | Meters (feet) | 0.01 m (0.1 ft) |
| Maximum/minimum depth | Vertical distance | Meters (feet) | 0.15 m (0.5 ft) |
| Bed substrate composition | Visual estimation | Bedrock, boulder, cobble, gravel, organic, sand, silt | 10% |
| Cover type | Visual estimation | None, boulder, cobble, IWM, bedrock ledges, overhead vegetation, aquatic vegetation | 10% |

Note that although the base layer of the 2009 habitat maps corresponds to a 2005 air photo at flows of 321 cfs, in order to provide a more accurate channel edge boundary for the March and

July 2009 surveys, the channel edge of the habitat unit boundaries shown in Appendix B correspond to a wetted perimeter of 96 cfs previously digitized from air photos taken on taken on 19 January 1991. Because the estimated wetted perimeter of the habitat unit boundaries did not vary more than a few feet in most cases at these two flows, the channel edge boundary for 96 cfs was used for both the March and July 2009 surveys. For each habitat unit shown, habitat unit length and width were subsequently determined in GIS. Appendix D shows accompanying field habitat data collected in all habitat units mapped, including maximum depth and average width (usually at 1/3 and 2/3 of the unit's length), bed substrate composition, and instream cover type.

## 2.2 Snorkel Surveys

### 2.2.1 Study design and survey unit selection

After habitat typing and collecting habitat data in all units, a subset of units of each habitat type was selected for single-pass snorkel surveys. The survey units were selected to balance the habitat sampling unit replication, total available number of units to draw from, coverage of at least 10% of the total length of a given habitat type, as well as sampling effort. The selection process involved random selection of one of the most upstream units of each habitat type, followed by a systematic uniform sampling of the remaining units in the study reach. After the first dive pass was completed, a tab was then pulled to determine if the unit was included in the second phase of sampling.

For the March 2009 surveys, a subset of 9 units was selected for each of the 7 habitat types, with the exception of the riffle habitat type for which 12 units were selected to capture habitat use at particular gravel augmentation projects (Table 2-3). In July 2009, a subset of 5–8 sampling units was selected from each of 5 habitat types (Table 2-4). As in the March 2009 surveys, additional units for riffle (2), pool head (1), and run head (1) habitat types were selected to capture habitat use at restoration sites. Habitats were grouped with the pool body and run tail habitats located immediately upstream for the July surveys.

**Table 2-3.** Sample unit selection and survey count for March 2009.

| Habitat | Phase I dives | | Phase II survey | |
|---|---|---|---|---|
| | Initial units | Passes | Repeat units | Passes |
| Riffle | 12 | 1 | 2 | 2 |
| Pool head | 9 | 1 | 2 | 2 |
| Pool body | 9 | 1 | 2 | 2 |
| Pool tail | 9 | 1 | 2 | 2 |
| Run head | 9 | 1 | 2 | 2 |
| Run body | 9 | 1 | 2 | 2 |
| Run tail | 9 | 1 | 2 | 2 |
| **Total** | **66** | | **28** | |

**Table 2-4.** Sample unit selection and survey count for July 2009.

| Habitat | Phase I dives | | Phase II survey | |
|---|---|---|---|---|
| | Initial units | Passes | Repeat units | Passes |
| Riffle | 8 | 1 | 2 | 2 |
| Pool head | 6 | 1 | 2 | 2 |
| Pool body /tail | 5 | 1 | 2 | 2 |
| Run head | 7 | 1 | 2 | 2 |
| Run body /tail | 5 | 1 | 2 | 2 |
| **Total** | **31** | | **20** | |

### 2.2.2 Snorkel data collection

Snorkel surveys were conducted during daylight hours from 16 to 25 March and 9 to 14 July 2008, respectively. A two-phase survey design was used to survey the various riffle, run, and pool strata. For the first phase, single-pass dive surveys were conducted by a four-person team. Sampling units were sampled from downstream to upstream in dive lanes using a zigzag pattern, passing fish and allowing them to escape downstream of the diver. If fish were observed to escape upstream, the diver took care to avoid counting these individuals twice. Divers recorded the type, length, and number of fish (Table 2-5). Total lengths were estimated in 50 mm size ranges (called "bins") using markings on dive slates to correct for underwater size distortion.

**Table 2-5.** Fish data collected within each unit during snorkel surveys.

| Parameter | Method | Metric/Descriptor | Method reporting limit |
|---|---|---|---|
| Date; start and end time | N/A | Day/month/year; hour/minute | N/A |
| Number of individuals | Visual estimation | Number | 1 |
| Fish length | Visual estimation | Millimeter | 50 mm bins |

The second phase of sampling required the collection of fish count and size data during each of two subsequent passes through a selected habitat unit. These data were later used to extrapolate dive counts to total population estimates. The Phase 2 dive pass replication was reduced from 3 passes in July 2008 to 2 passes in March and July 2009. This adjustment was made to reduce sampling effort within particular sampling units while increasing the overall sample unit coverage in 2009. Lastly, occurrence of other non-salmonid native and non-native fish species was recorded as presence/absence and abundance.

## 2.3 Water Quality and Flow

At fish sampling locations, in addition to noting the type, length, and number of fish (Section 2.2), we collected spot measurements of *in situ* water quality data (temperature, dissolved oxygen, and conductivity) using a pre-calibrated multi-probe (YSI 85, Yellow Springs Instruments, Yellow Springs, OH) (Table 2-6). Dissolved oxygen probes were recalibrated each day and checked for accuracy in the laboratory against concentrations measured in aerated tap water. Changes in underwater visibility were monitored horizontally using a Secchi disk oriented both toward and away from the sun. Daily average flow data for each day were obtained from the stream gage below the La Grange powerhouse at RM 51.8 (USGS No. 11289650).

**Table 2-6.** Water quality data collected during snorkel surveys.

| Parameter | Method | Metric/Descriptor | Method reporting limit |
|---|---|---|---|
| Temperature | EPA 170.1 | °C | 0.1 °C |
| Dissolved oxygen | SM 4500-O | mg/L | 0.01 mg/L |
| Conductivity | SM 2510A | umhos/cm | 1.0 umhos/cm |
| Visibility | Secchi depth | meters (feet) | 0.01 m (0.1 ft) |

## 2.4 Water and Air Temperatures

From Spring 1987 to present, TID/MID has collected water temperature data from various locations in the lower Tuolumne River using recording thermographs. These are currently Hobo Pro V2 thermographs (OnSet Computer Corporation, Bourne, MA) housed in protective cases and placed near shore in areas deep enough to avoid dewatering. The thermographs measured and stored water temperature data at one-hour intervals, and these data were historically and are currently downloaded at least twice a year.

Water temperature data collection during July 2009 also included spot measurements taken during snorkel surveys. The measurements were recorded over the course of the day as divers moved further downstream; as such, it was anticipated that these water temperatures would not be as representative as hourly thermograph recordings. The data do provide a general description of relative temperature conditions during dive surveys.

Regional air temperature data were obtained from the National Weather Service (NWS) station at Modesto Airport near RM 18. Water and air temperature data for the June through July 2009 period are presented in this report (Figures 2a and 2b).

## 2.5 Data analysis

### 2.5.1 Bounded counts population estimate

Water quality and fish observation counts were summarized by habitat unit type and initial density estimates were calculated based upon the area searched within each habitat unit sampled. In addition to comparisons of fish density between habitat types, the density estimates and uncertainties were propagated across the unsampled areas for an overall population estimate.

Population estimates were made for each stratum and size class using the general methods of Hankin and Mohr (2001). For units receiving multiple dives, the bounded counts formulae are used to produce an estimate of the unit population and an estimate of the variance of this estimate. Specifically, when there are $r$ passes, and the counts of these are sorted in increasing order as $m_1 \le m_2 \le \ldots \le m_r$, the population is estimated as

$$\tilde{y}_B = m_r + (m_r - m_{r-1}),$$

and the mean squared error of this is estimated as

$$\mathrm{M\tilde{S}E}(\tilde{y}_B) = (m_r - m_{r-1})^2 .$$

The total population of multiply dived units is estimated as the sum of the bounded-counts estimates for the individual units. The total population of the survey region is estimated by expanding this, first to *all* dived units (singly or multiply dived) on the basis of mean dive counts, and then to all units (dived or undived) on the basis of area. An estimator of the variance of this is constructed from estimates of the mean-squared errors of the bounded-counts estimates for the multiply dived individual units, and the variance of the bounded-counts estimates around their common mean. The final formulae are included in Hankin and Mohr (2001). A nominal confidence interval for each stratum and size class was calculated formally as

$\hat{Y} \pm 1.96\sqrt{\hat{V}}$ , where $\hat{Y}$ and $\hat{V}$ are the mean and variance estimates, *except* that the lower bound of this interval was "trimmed" to the number of fish actually observed.

### 2.5.2 Comparisons with June 2009 TID/MID snorkel surveys

Data collected during the July 2009 snorkel surveys (9–14 July) were compared to routine snorkel survey data collected during 16–18 June 2009 (Ford and Kirihara 2009). Although the sampled areas of these surveys differ, these data were collected only a few weeks prior to the data collected for this report, allowing for a general comparison of presence/absence and the relative proportions of larger and smaller size classes of *O. mykiss* and Chinook salmon in habitat units sampled during both surveys. Further, although TID/MID has sampled the same locations since 2001, we limit our comparison to the June 2009 data as these are the most directly comparable. There were no routine snorkel survey data available for comparison with the March 2009 snorkel surveys.

# 3 RESULTS

## 3.1 Habitat Characterization

### 3.1.1 March 2009

For the total reach surveyed in March 2009 (RM 51.8–29.5), riffle and run body habitat types were the most abundant habitat types present; however, the run body habitat type occupied more than half of the total length of channel along the study reach, followed by riffles at 20.9% of the total reach length (Table 3-1). Pool bodies, while less abundant than other habitat types (e.g., run head and tail), occupied the third greatest length of channel. Run heads and tails, despite being abundant, accounted for only 11.3% of the total reach length. Habitat maps and data for the entire study reach are shown in Appendices B and D. The longitudinal distribution of the area of each of the major habitat types within bins of 2 river miles is shown in Figure 3 and Figure 4a presents the distribution of each of the major habitat types sampled in March 2009.

**Table 3-1.** Summary of habitat types from RM 51.8 to 29.0, March 2009.

| Habitat type | Count | % by count | Total length (ft) | Total length (mi) | % reach length | Area ($ft^2$) |
|---|---|---|---|---|---|---|
| Riffle | 76 | 22.4 | 25,272 | 4.8 | 20.9 | 1,998,678 |
| Pool head | 15 | 4.4 | 1,409 | 0.3 | 1.2 | 111,375 |
| Pool body | 22 | 6.5 | 13,824 | 2.6 | 11.4 | 1,667,595 |
| Pool tail | 17 | 5.0 | 2,040 | 0.4 | 1.7 | 180,194 |
| Run head | 69 | 20.3 | 7,214 | 1.4 | 6.0 | 628,214 |
| Run body | 75 | 22.1 | 64,809 | 12.3 | 53.6 | 6,616,752 |
| Run tail | 66 | 19.4 | 6,392 | 1.2 | 5.3 | 600,497 |
| **Total** | **340** | **100** | **120,960** | **22.9** | **100** | **11,803,306** |

### 3.1.2 July 2009

For the total reach surveyed in July 2009 (RM 51.8–41.7), "run body/tail" habitat type was the most abundant and occupied the greatest length of channel along the study reach, followed by riffles (Table 3-2). The "pool body/tail" habitat type, while less abundant than other habitat types (e.g., run head), occupied the third greatest length of channel. Other transitional habitat types (e.g., run head and pool head) accounted for only 4.6 % of the total reach length. Habitat maps and data for the entire study reach are shown in Appendices B and D. The longitudinal distribution of the area of each of the major habitat types within bins of 2 river miles is shown in Figure 3 and Figure 4b presents the distribution of each of the major habitat types sampled in July 2009.

**Table 3-2.** Summary of habitat types from RM 51.8 to 41.7, July 2009.

| Habitat type | Count | % by count | Total length (feet) | Total length (miles) | % reach length | Area ($ft^2$) |
|---|---|---|---|---|---|---|
| Riffle | 30 | 22.1 | 12,678 | 2.4 | 23.7 | 1,109,569 |
| Pool head | 6 | 4.4 | 619 | 0.1 | 1.2 | 51,140 |
| Pool body/tail | 9/6 | 11.0 | 7,522 | 1.4 | 14.0 | 990,349 |
| Run head | 27 | 19.9 | 1,806 | 0.3 | 3.4 | 176,108 |
| Run body/tail | 32/26 | 42.6 | 30,915 | 5.9 | 57.7 | 3,120,036 |
| **Total** | **136** | **100** | **53,540** | **10.1** | **100** | **5,447,202** |

## 3.2 Water Quality and Flow

As water quality data were collected exclusively within units chosen for snorkel survey, data are presented by river mile, rather than by NSO, or summarized for the entire reach (Table 3-3 and Table 3-4). Water quality data for habitat units selected for snorkel surveys are shown in Appendix E.

Because of the strong influence of ambient air temperatures (Sullivan et al. 1990), temperatures of water released from the cold water pool of Don Pedro Reservoir increase in a downstream direction for both the spot measurements (Table 3-4) and in the continuous thermograph record during both the March and July survey periods (Appendix F). Note that the water temperature ranges shown in Table 3-3 and Table 3-4 represent changes over the course of the sampling day, and do not include nighttime temperatures or lows that are shown at representative thermograph locations in Appendix F.

### 3.2.1 March 2009

Daily average flow during the March 2009 survey period ranged from 165–170 cfs. In general, dissolved oxygen concentration was high due to the low water temperatures. Horizontal visibility was much lower at the most downstream location due to local turbidity sources.

**Table 3-3.** Range of water quality data collected at snorkel sites during fish surveys in March 2009.

| River miles | Sample date | Flow (cfs)[1] | Water temp °C [°F] | DO (mg/L) | Horizontal visibility (ft) | Specific conductivity (uS/cm) |
|---|---|---|---|---|---|---|
| 51.6−50.4 | 16 March | 170 | 10.2–11.9 [50.4–53.4] | 10.0−11.7 | 8–10 | 41.9–42.5 |
| 50.1−47.0 | 17 March | 170 | 11.7–14.5 [53.1–58.1] | 9.1−11.1 | 7–12 | 42.0–46.4 |
| 46.9−45.1 | 18 March | 170 | 11.5–13.8 [52.7–56.8] | 10.6−12.1 | 8–9 | 46.0–49.3 |
| 45.0−43.0 | 19 March | 170 | 13.2–15.4 [55.8–59.7] | 11.1−12.3 | 7–13 | 49.3–51.9 |
| 43.2−42.9 | 20 March | 170 | 13.7–15.6 [56.7–60.1] | 10.7−11.9 | 9–11 | 48.3–52.4 |
| 39.6−38.1 | 22 March | 167 | 13.6–14.3 [56.5–57.7] | 9.9−10.7 | 8–10 | 67.9–72.3 |
| 38.1−36.2 | 23 March | 167 | 12.4–14.2 [54.3–57.6] | 11.0−11.5 | 10–11 | 69.9–70.6 |
| 36.8−36.2 | 25 March | 168 | 14.2–14.5 [57.6–58.1] | 11.2−12.1 | 9–10 | 70.6–72.8 |
| 34.0−31.7 | 24 March | 165 | 13.1–15.3 [55.6–59.5] | 11.1−12.5 | 11–12 | 71.4–73.7 |
| 29.5 | 21 March | 170 | 17.3 [63.1] | 10.5 | 5 | 85.2 |

[1] Daily average flow data are measured from the stream gauge below La Grange powerhouse at RM 51.8 (USGS No. 11289650).

### 3.2.2 July 2009

Daily average flow during the July 2009 survey period ranged from 99–110 cfs. In general, dissolved oxygen concentration decreased with increasing temperatures along the same gradient, while specific conductivity increased. Horizontal and vertical visibility also decreased in the downstream direction.

**Table 3-4.** Range of water quality data collected at snorkel sites during fish surveys in July 2009.

| River miles | Sample date | Flow (cfs)[1] | Water temp °C [°F] | DO (mg/L) | Horizontal visibility (ft) | Specific conductivity (uS/cm) |
|---|---|---|---|---|---|---|
| 51.8−51.6 | 11 July | 99 | 11.8–11.8 [53.2–53.2] | 12.0−12.0 | 21–21 | 35.5–35.5 |
| 50.6−50.1 | 9 July | 99 | 12.0–15.6 [53.6–60.1] | 11.8−12.1 | 16–16 | 36.2–37.3 |
| 49.7−48.0 | 10 July | 100 | 14.3–18.0 [57.7–64.4] | 11.4−12.1 | 13–16 | 37.3–38.7 |
| 47.0−45.7 | 12 July | 99 | 16.7–19.5 [62.1–67.1] | 11.1−11.4 | 9–12 | 39.5–40.5 |
| 45.0−44.5 | 13 July | 100 | 19.5–21.5 [67.1–70.7] | 11.1−11.3 | 8–8 | 41.4–42.2 |
| 43.2−41.9 | 14 July | 110 | 21.5–23.1 [70.7–73.6] | 9.9−11.0 | 9–10.5 | 43.7–48.3 |

[1] Daily average flow data are measured from the stream gauge below La Grange powerhouse at RM 51.8 (USGS No. 11289650).

## 3.3 Water and Air Temperature

The daily average water temperature for all thermographs and the daily minimum, maximum, and average air temperature (from the NWS station at the Modesto Airport) are shown in Appendix F. The range of daily averages, instantaneous maximum temperature, maximum weekly average temperature (MWAT), and the seven-day average of daily maximum temperature (7dayMAX) for the 16–25 March and 9–14 July study periods was determined, and all three metrics for both periods showed a similar trend of increasing in the downstream direction. The MWAT is the seven-day rolling average of average daily temperatures, and describes ambient water temperature conditions over the previous week. It is a standard used in water quality studies and total maximum daily load (TMDL) estimations of allowable temperature. The 7dayMAX is the seven-day rolling average of the daily maximum temperatures, and is a potentially more accurate indicator of conditions affecting survival and growth of salmonids (Sullivan et al. 2000, Stillwater Sciences 2002).

### 3.3.1 March 2009

During the March 2009 survey period, water temperature data collected by thermographs followed similar trends to spot temperature data collected during snorkel surveys, showing an increase in the downstream direction (Table 3-5). Along the study reach, the MWAT increased from 11.0°C (51.7°F) at Riffle A7 to 15.1°C (59.1°F) at the Ruddy Gravel site (Table 3-5). The 7dayMAX temperature ranged from 12.0°C (53.5°F) at the Riffle A7 location to 16.4°C (61.4°F) at the Ruddy Gravel site. The hourly, mean weekly average (MWAT), and 7dayMAX water temperatures for Riffle A7 (RM 50.8), Riffle 13B (RM 45.5), Roberts Ferry Bridge (RM 39.6), Ruddy Gravel (RM 36.5), and the Waterford RST (RM29.8) from 1 February to 31 March 2009 are presented graphically in Appendix F.

**Table 3-5.** Maximum weekly average temperature, seven-day average of daily maximum temperatures, and instantaneous maximum temperatures recorded by thermographs in the survey reach of the lower Tuolumne River during March 2009.

| Monitoring location | RM | MWAT ºC [°F] (week ending) | 7dayMAX ºC [°F] (week ending) | Instantaneous maximum ºC [°F] (date) |
|---|---|---|---|---|
| Riffle A7 | 50.8 | 11.0 [51.7] (23 March) | 12.0 [53.5] (21 March) | 12.5 [54.6] (20 March) |
| Riffle 13B | 45.5 | 13.0 [55.5] (22 March) | 14.0 [57.1] (21 March) | 14.5 [50.8] (20 March) |
| Roberts Ferry Bridge | 39.6 | 14.5 [58.1] (22 March) | 15.8 [60.5] (22 March) | 16.6 [61.8] (20 March) |
| Ruddy Gravel | 36.5 | 15.1 [59.1] (22 March) | 16.4 [61.4] (22 March) | 15.4 [59.7] (22 March) |
| Waterford RST[1] | 29.8 | 14.2 [58.0] (17 March) | 15.1 [59.2] (17 March) | 16.8 [62.3] (17 March) |

Note: Thermographs used have a reported error of ±0.2°C.
[1] Waterford RST data available 16-17 March only.

The average daily Modesto Airport air temperatures over the study period ranged from 10.6 to 18.3 ºC (51.0 to 65.0 °F) with a high temperature of 26.1 °C (79.0 °F) (Table 3-6). The warmest day of March occurred just after the study period on 28 March with an average daily temperature of 18.9 °C (66.0 °F) (Figure 2a) and a daily high temperature of 27.2 °C (81 °F).

**Table 3-6.** Daily average, minimum, and maximum air temperature recorded at the NWS station at the Modesto Airport during the March 2009 snorkeling study period.

| Date | Average air temperature ºC [°F] | Minimum air temperature ºC [°F] | Maximum air temperature ºC [°F] |
|---|---|---|---|
| 16 March 2009 | 15.0 [59] | 8.3 [47] | 21.7 [71] |
| 17 March 2009 | 16.1 [61] | 10.0 [50] | 21.7 [71] |
| 18 March 2009 | 16.7 [62] | 10.0 [50] | 22.8 [73] |
| 19 March 2009 | 18.3 [65] | 10.6 [51] | 26.1 [79] |
| 20 March 2009 | 17.8 [64] | 10.6 [51] | 24.4 [76] |
| 21 March 2009 | 13.9 [57] | 8.9 [48] | 18.9 [66] |
| 22 March 2009 | 11.7 [53] | 7.2 [45] | 15.6 [60] |
| 23 March 2009 | 10.6 [51] | 5.0 [41] | 16.1 [61] |
| 24 March 2009 | 12.2 [54] | 2.8 [37] | 21.1 [70] |
| 25 March 2009 | 14.4 [58] | 5.6 [42] | 23.3 [74] |

Hourly water temperature for several monitoring stations along the length of the study reach and daily air temperature from the Modesto Airport station was compared (Figure 2a). With flow being stable throughout period, Figure 2a shows that at the upstream-most monitoring station, water and air temperature are more independent of each other than at thermographs located farther downstream. That is, water temperature becomes more influenced by air temperature in the downstream direction, with water and air temperature peaks and troughs occurring at the same times of day at the downstream monitoring site at Roberts Ferry Bridge (RM 39.6).

### 3.3.2 July 2009

During the July 2009 survey period, water temperature data collected by thermographs followed similar trends to spot temperature data collected during snorkel surveys, which showed a general increase in the downstream direction (Table 3-7). Along the study reach, the MWAT increased from 12.6°C (54.6 °F) at Riffle A7 to 22.3°C (72.2 °F) at Roberts Ferry Bridge (Table 3-7). The 7dayMAX temperature ranged from 14.1°C (57.4 °F) at the Riffle A7 location to 23.9°C (75.1 °F) at the Roberts Ferry Bridge. The hourly, mean weekly average (MWAT), and 7dayMAX water temperatures for Riffle A7 (RM 50.8), Riffle 3B (RM 49.0), Riffle 13B (RM 45.5), Riffle 21 (RM 42.9), and Roberts Ferry Bridge (RM 39.6) from 1 June to 31 July 2009 are presented graphically in Appendix F.

**Table 3-7.** Maximum weekly average temperature, seven-day average of daily maximum temperatures, and instantaneous maximum temperatures recorded by thermographs in the survey reach of the lower Tuolumne River during July 2009.

| Monitoring location | RM | MWAT ºC [°F] (week ending) | 7dayMAX ºC [°F] (week ending) | Instantaneous maximum ºC [°F] (date) |
|---|---|---|---|---|
| Riffle A7 | 50.8 | 12.6 [54.6] (14 July) | 14.1 [57.4] (09 July) | 14.4 [58.0] (13 July) |
| Riffle 3B | 49.0 | 15.2 [59.3] (14 July) | 17.6 [63.7] (14 July) | 18.0 [64.3] (13 July) |
| Riffle 13B | 45.5 | 18.8 [65.8] (14 July) | 20.1 [68.3] (14 July) | 20.8 [69.5] (14 July) |
| Riffle 21 | 42.9 | 20.8 [69.5] (14 July) | 22.4 [72.3] (14 July) | 23.5 [74.2] (14 July) |
| Roberts Ferry Bridge | 39.6 | 22.3 [72.2] (14 July) | 23.9 [75.1] (14 July) | 24.8 [76.7] (14 July) |

Note: Thermographs used have a reported error of ±0.2°C.

The average daily Modesto Airport air temperatures over the study period ranged from 23.3 to 28.3 ºC (74.0 to 83.0 °F) with a high temperature of 38.9 °C (102 °F) (Table 3-8). The warmest day of July occurred just after the study period on 19 July with an average daily temperature of 32.2 °C (90 °F) and a daily high temperature of 41.7 °C (107 °F) (Figure 2b).

**Table 3-8.** Daily average, minimum, and maximum air temperature recorded at the NWS station at the Modesto Airport during the July 2009 snorkeling study period.

| Date | Average air temperature ºC [°F] | Minimum air temperature ºC [°F] | Maximum air temperature ºC [°F] |
|---|---|---|---|
| 9 July 2009 | 24.4 [76.0] | 16.1 [61.0] | 32.2 [90.0] |
| 10 July 2009 | 23.3 [74.0] | 13.9 [57.0] | 32.8 [91.0] |
| 11 July 2009 | 25.6 [78.0] | 18.9 [66.0] | 32.2 [90.0] |
| 12 July 2009 | 26.7 [80.0] | 19.4 [67.0] | 33.9 [93.0] |
| 13 July 2009 | 26.7 [80.0] | 17.2 [63.0] | 36.1 [97.0] |
| 14 July 2009 | 28.3 [83.0] | 17.8 [64.0] | 38.9 [102.0] |

Hourly water temperature for several monitoring stations along the length of the study reach and daily air temperature from the Modesto Airport station was compared (Figure 2b). After flow reductions in mid-June, Figure 2b shows that at the upstream-most monitoring station, water temperature remains low throughout the period and is more independent of air temperatures than at thermographs located farther downstream. That is, water temperature becomes more influenced by ambient air temperature in the downstream direction, with water and air temperature maxima and minima occurring at the same times of day at the site located farthest downstream at Roberts Ferry Bridge (RM 39.6).

## 3.4 Snorkel Surveys

### 3.4.1 March 2009

#### 3.4.1.1 *O. mykiss* observations

During the March 2009 survey period, we observed 12 *O. mykiss* ranging from 0–499 mm (50 mm size bins) based upon maximum counts of all dive passes in each sampling unit (Table 3-9, Table 3-10 and Appendix G). Five of these fish were juveniles in the 50–99 mm size category, and the other 7 observed were in the adult (>150 mm) size classes (Table 3-9 and Table 3-10). The *O. mykiss* were observed in 6 different habitat units (NSOs) from RM 51.5 to RM 43.0, and all fish were observed in riffles with the exception of one adult in the 400–449 size category that was observed in a pool head habitat type (Table 3-9 and Table 3-10). Juveniles were observed in two riffle habitat units at RM 51.5 and RM 43.2. Adults were found in riffle habitat units at RM's 50.6, 48.0, and 43.0 along the pool head habitat unit at RM 49.7. There were no juvenile or adult *O. mykiss* observations made in the 38 habitat units sampled over the lower 14 miles of the study reach.

**Table 3-9.** Maximum count of *O. mykiss* by NSO, March 2009 (data are divided into 50 mm total length size classes).

| RM | Unit ID (NSO) | Habitat | Multiple pass survey (Y/N) | 0-49 mm | 50-99 mm | 100-149 mm | 150-199 mm | 200-249 mm | 250-299 mm | 300-349 mm | 350-399 mm | 400-449 mm | 450-499 mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51.6 | 4 | Pool head | N | | | | | | | | | | |
| 51.6 | 5 | Pool body | N | | | | | | | | | | |
| 51.5 | 6 | Pool tail | N | | | | | | | | | | |
| 51.5 | 7 | Riffle | N | | 2 | | | | | | | | |
| 50.6 | 14 | Riffle | N | | | | | | | 1 | | 3 | |
| 50.6 | 15 | Run head | N | | | | | | | | | | |
| 50.5 | 16 | Run body | N | | | | | | | | | | |
| 50.4 | 17 | Run tail | N | | | | | | | | | | |
| 50.1 | 22 | Riffle | N | | | | | | | | | | |
| 49.7 | 27 | Pool head | N | | | | | | | | | | 1 |
| 49.6 | 28 | Pool body | N | | | | | | | | | | |
| 49.6 | 29 | Pool tail | N | | | | | | | | | | |
| 48.0 | 53 | Riffle | Y | | | | | | | 1 | | | |
| 47.0 | 58 | Run head | Y | | | | | | | | | | |
| 46.9 | 59 | Run body | N | | | | | | | | | | |
| 46.9 | 60 | Run tail | Y | | | | | | | | | | |
| 45.3 | 82 | Run head | N | | | | | | | | | | |
| 45.1 | 83 | Run body | N | | | | | | | | | | |
| 45.1 | 84 | Run tail | Y | | | | | | | | | | |
| 45.0 | 86 | Pool head | N | | | | | | | | | | |
| 44.9 | 87 | Pool body | N | | | | | | | | | | |
| 44.9 | 88 | Pool tail | Y | | | | | | | | | | |
| 44.6 | 97 | Riffle | N | | | | | | | | | | |
| 43.2 | 107 | Riffle | N | | 3 | | | | | | | | |
| 43.2 | 108 | Run head | N | | | | | | | | | | |
| 43.1 | 109 | Run body | N | | | | | | | | | | |
| 43.1 | 110 | Run tail | N | | | | | | | | | | |
| 43.0 | 111 | Riffle | Y | | | | | 1 | | | | | |

| RM | Unit ID (NSO) | Habitat | Multiple pass survey (Y/N) | 0-49 mm | 50-99 mm | 100-149 mm | 150-199 mm | 200-249 mm | 250-299 mm | 300-349 mm | 350-399 mm | 400-449 mm | 450-499 mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43.0 | 112 | Pool head | Y | | | | | | | | | | |
| 43.0 | 113 | Pool body | Y | | | | | | | | | | |
| 43.0 | 114 | Pool tail | N | | | | | | | | | | |
| 42.9 | 118 | Riffle | N | | | | | | | | | | |
| 39.6 | 157 | Run head | N | | | | | | | | | | |
| 39.5 | 158 | Run body | Y | | | | | | | | | | |
| 39.5 | 159 | Run tail | N | | | | | | | | | | |
| 39.4 | 160 | Riffle | N | | | | | | | | | | |
| 38.9 | 168 | Riffle | N | | | | | | | | | | |
| 38.7 | 175 | Riffle | N | | | | | | | | | | |
| 38.1 | 188 | Pool head | N | | | | | | | | | | |
| 38.1 | 189 | Pool body | N | | | | | | | | | | |
| 38.1 | 190 | Pool tail | N | | | | | | | | | | |
| 38.1 | 192 | Pool head | Y | | | | | | | | | | |
| 38.0 | 193 | Pool body | N | | | | | | | | | | |
| 38.0 | 194 | Pool tail | Y | | | | | | | | | | |
| 36.9 | 214 | Pool head | N | | | | | | | | | | |
| 36.9 | 215 | Pool body | N | | | | | | | | | | |
| 36.9 | 216 | Pool tail | N | | | | | | | | | | |
| 36.8 | 218 | Run head | N | | | | | | | | | | |
| 36.6 | 219 | Run body | Y | | | | | | | | | | |
| 36.6 | 220 | Run tail | N | | | | | | | | | | |
| 36.2 | 230 | Pool head | N | | | | | | | | | | |
| 36.2 | 231 | Pool body | Y | | | | | | | | | | |
| 36.2 | 232 | Pool tail | N | | | | | | | | | | |
| 34.0 | 259 | Run head | Y | | | | | | | | | | |
| 34.0 | 260 | Run body | N | | | | | | | | | | |
| 33.9 | 261 | Run tail | N | | | | | | | | | | |
| 33.4 | 271 | Pool head | N | | | | | | | | | | |

| RM | Unit ID (NSO) | Habitat | Multiple pass survey (Y/N) | 0-49 mm | 50-99 mm | 100-149 mm | 150-199 mm | 200-249 mm | 250-299 mm | 300-349 mm | 350-399 mm | 400-449 mm | 450-499 mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33.2 | 272 | Pool body | N | | | | | | | | | | |
| 33.2 | 273 | Pool tail | N | | | | | | | | | | |
| 31.9 | 287 | Run head | N | | | | | | | | | | |
| 31.7 | 288 | Run body | N | | | | | | | | | | |
| 31.7 | 289 | Run tail | N | | | | | | | | | | |
| 29.5 | 324 | Riffle | N | | | | | | | | | | |
| 29.5 | 325 | Run head | N | | | | | | | | | | |
| 29.5 | 326 | Run body | N | | | | | | | | | | |
| 29.5 | 327 | Run tail | N | | | | | | | | | | |
| **Total (maximum unit count of all passes)** | | | | **0** | **5** | **0** | **0** | **1** | **0** | **2** | **0** | **3** | **1** |

**Table 3-10.** Maximum count of *O. mykiss* by habitat type, March 2009 (data are divided into 50 mm total length size classes).

| Habitat | 0-49 mm | 50-99 mm | 100-149 mm | 150-199 mm | 200-249 mm | 250-299 mm | 300-349 mm | 350-399 mm | 400-449 mm | 450-499 mm | Total (max. unit count of all passes) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pool body | | | | | | | | | | | **0** |
| Pool head | | | | | | | | | | 1 | **1** |
| Pool tail | | | | | | | | | | | **0** |
| Riffle | | 5 | | | 1 | | 2 | | 3 | | **11** |
| Run body | | | | | | | | | | | **0** |
| Run head | | | | | | | | | | | **0** |
| Run tail | | | | | | | | | | | **0** |
| **Totals by size class** | **0** | **5** | **0** | **0** | **1** | **0** | **2** | **0** | **3** | **1** | **12** |

#### 3.4.1.2 *O. mykiss* population estimate

Table 3-11 shows the March 2009 *O. mykiss* population estimate for the lower Tuolumne River by length (<150 mm for YOY and juvenile; >150 mm for adults) and habitat type using the method of bounded counts (Hankin and Mohr 2001) for the study reach from RM 51.8 to RM 29.0. From an observed 5 YOY/juveniles and 7 adult *O. mykiss* in March 2009, we estimated a population of 63 YOY/juveniles (no 95% CI available), and 170 adults (with a 95% CI of 12-222), for an overall population estimate of 233 (Table 3-11). Since all *O. mykiss* were observed in riffles with the exception of one adult observed in a pool head; population estimates were only generated for the riffle habitat type. In addition, since the riffle observations for juvenile *O. mykiss* did not include a sufficient number of observations from multiple-pass sites (used to develop an expansion factor), the population estimate for these fish was based on an expansion factor (Hankin and Mohr 2001) developed without a 95% CI by using the variance from corresponding observations of juvenile Chinook salmon within riffle habitat units in the March 2009 surveys.

**Table 3-11.** *O. mykiss* March 2009 bounded count population estimates between RM 51.8 and 29.0 by fish length and habitat type.

| Habitat | ***O. mykiss*** < 150 mm | | | | ***O. mykiss*** ≥ 150 mm | | | |
|---|---|---|---|---|---|---|---|---|
| | **Obs.**[1] | **Est.**[2] | **St. dev.** | **95% CI**[3] | **Obs.**[1] | **Est.**[3] | **St. dev.** | **95% CI**[4] |
| Pool head | 0 | -- | -- | -- | 1 | ≥1 | -- | -- |
| Pool body | 0 | -- | -- | -- | 0 | -- | -- | -- |
| Pool tail | 0 | -- | -- | -- | 0 | -- | -- | -- |
| Riffle | 5 | 63 | -- | -- | 6 | 170 | 86.3 | 6–339 |
| Run head | 0 | -- | -- | -- | 0 | -- | -- | -- |
| Run body | 0 | -- | -- | -- | 0 | -- | -- | -- |
| Run tail | 0 | -- | -- | -- | 0 | -- | -- | -- |
| **Total** | **5** | **63** | **--** | **--** | **7** | **170** | **86.3** | **7–339** |

[1] Largest numbers seen in any single dive pass for each unit, summed over units. Note that because of the potential for the same fish to be assigned to different size classes on subsequent passes, summation of the largest numbers assigned to individual (50 mm) size bins yields may overestimate total fish observed.
[2] Estimate for *O. mykiss* juveniles in riffles based on the expansion used for Chinook juveniles in riffles, no uncertainty data provided.
[3] Estimate for *O. mykiss* adults in pool head not included in overall population estimate due to lack of multiple pass data to develop an expansion factor.
[4] Nominal confidence intervals calculated as + 1.96 standard deviations.

#### 3.4.1.3 Chinook salmon observations

Table 3-12 and Table 3-13 show the number of Chinook salmon observed within the study reach during the March 2009 surveys, based on the maximum count by pass. Most Chinook salmon were YOY and juveniles found within the 0–49 and 50–99 mm size classes. These salmon were seen in 42 different sampling units ranging from RM 51.6 to RM 31.7 (Table 3-12) and all habitat types (Table 3-13).

**Table 3-12.** Maximum counts of juvenile Chinook salmon by size class and sampling unit, March 2009.

| River mile | Sampling unit (NSO) | Habitat type | Multiple pass survey (Y/N) | 0–49 mm | 50–99 mm |
|---|---|---|---|---|---|
| 51.6 | 4 | Pool head | N | 80 | 45 |
| 51.6 | 5 | Pool body | N | | |
| 51.5 | 6 | Pool tail | N | 6 | 4 |
| 51.5 | 7 | Riffle | N | 250 | 119 |
| 50.6 | 14 | Riffle | N | 910 | 505 |
| 50.6 | 15 | Run head | N | 112 | 144 |
| 50.5 | 16 | Run body | N | 149 | 208 |
| 50.4 | 17 | Run tail | N | 71 | 50 |
| 50.1 | 22 | Riffle | N | 32 | 12 |
| 49.7 | 27 | Pool head | N | | 60 |
| 49.6 | 28 | Pool body | N | | |
| 49.6 | 29 | Pool tail | N | | 7 |
| 48.0 | 53 | Riffle | Y | 80 | 110 |
| 47.0 | 58 | Run head | Y | 30 | 15 |
| 46.9 | 59 | Run body | N | 2 | |
| 46.9 | 60 | Run tail | Y | 6 | |
| 45.3 | 82 | Run head | N | | |
| 45.1 | 83 | Run body | N | 2 | 3 |
| 45.1 | 84 | Run tail | Y | | |
| 45.0 | 86 | Pool head | N | | |
| 44.9 | 87 | Pool body | N | | 15 |
| 44.9 | 88 | Pool tail | Y | | 35 |
| 44.6 | 97 | Riffle | N | 31 | 103 |
| 43.2 | 107 | Riffle | N | 65 | 80 |
| 43.2 | 108 | Run head | N | 7 | |
| 43.1 | 109 | Run body | N | 180 | 241 |
| 43.1 | 110 | Run tail | N | | 2 |
| 43.0 | 111 | Riffle | Y | 41 | 42 |
| 43.0 | 112 | Pool head | Y | 26 | 24 |
| 43.0 | 113 | Pool body | Y | | |
| 43.0 | 114 | Pool tail | N | | |
| 42.9 | 118 | Riffle | N | 7 | 14 |
| 39.6 | 157 | Run head | N | | |
| 39.5 | 158 | Run body | Y | | |

| River mile | Sampling unit (NSO) | Habitat type | Multiple pass survey (Y/N) | 0–49 mm | 50–99 mm |
|---|---|---|---|---|---|
| 39.5 | 159 | Run tail | N | | 2 |
| 39.4 | 160 | Riffle | N | | 1 |
| 38.9 | 168 | Riffle | N | 10 | 8 |
| 38.7 | 175 | Riffle | N | 1 | |
| 38.1 | 188 | Pool head | N | | |
| 38.1 | 189 | Pool body | N | | |
| 38.1 | 190 | Pool tail | N | | |
| 38.1 | 192 | Pool head | Y | | |
| 38.0 | 193 | Pool body | N | | 60 |
| 38.0 | 194 | Pool tail | Y | | |
| 36.9 | 214 | Pool head | N | | 1 |
| 36.9 | 215 | Pool body | N | | |
| 36.9 | 216 | Pool tail | N | | |
| 36.8 | 218 | Run head | N | | |
| 36.6 | 219 | Run body | Y | | 9 |
| 36.6 | 220 | Run tail | N | | 10 |
| 36.2 | 230 | Pool head | N | | |
| 36.2 | 231 | Pool body | Y | | |
| 36.2 | 232 | Pool tail | N | | |
| 34.0 | 259 | Run head | Y | 34 | 21 |
| 34.0 | 260 | Run body | N | 3 | 2 |
| 33.9 | 261 | Run tail | N | 17 | 12 |
| 33.4 | 271 | Pool head | N | 8 | |
| 33.2 | 272 | Pool body | N | 7 | |
| 33.2 | 273 | Pool tail | N | 4 | |
| 31.9 | 287 | Run head | N | 55 | 13 |
| 31.7 | 288 | Run body | N | 56 | 18 |
| 31.7 | 289 | Run tail | N | 10 | 5 |
| 29.5 | 324 | Riffle | N | | |
| 29.5 | 325 | Run head | N | | |
| 29.5 | 326 | Run body | N | | |
| 29.5 | 327 | Run tail | N | | |
| **Total (max. unit count of all passes)** | | | | **2,292** | **2,000** |

**Table 3-13.** Maximum counts of juvenile Chinook salmon by size class and habitat type, March 2009.

| Habitat | 0–49 mm | 50–99 mm | Total (maximum unit count of all passes) |
|---|---|---|---|
| Pool body | 7 | 75 | 82 |
| Pool head | 114 | 130 | 244 |
| Pool tail | 10 | 46 | 56 |
| Riffle | 1,427 | 994 | 2,421 |
| Run body | 392 | 481 | 873 |
| Run head | 238 | 193 | 431 |
| Run tail | 104 | 81 | 185 |
| **Totals by size class** | **2,292** | **2,000** | **4,292** |

Divers also observed four adult Chinook salmon (500–850 mm) within the study reach. The adult Chinook salmon observations were made at four separate sampling units between RM 51.5 and RM 36.6. Because the adult salmon were found within single pass dive units within riffle, run body, and pool body habitat units, no expansion was possible using the Hankin and Mohr (2001) methodology. The complete Chinook salmon observation data by pass are shown in Appendix G.

#### 3.4.1.4 Chinook salmon population estimate

Table 3-14 shows the March 2009 Chinook salmon population estimate for the lower Tuolumne River by length (<150 mm for YOY and juvenile; >150 mm for adults) and habitat type using the method of bounded counts (Hankin and Mohr 2001). Out of an estimated 39,563 juveniles, we estimated a 95% confidence interval of 34,861–44,265 (Table 3-14). The data show that the greatest estimated abundance of YOY and juvenile Chinook salmon occurred in riffles (Table 3-14). Although observations of adult Chinook salmon were considered incidental, a population estimate of 126 was developed with a 95% confidence interval of 2–318 (Table 3-14).

**Table 3-14.** Chinook salmon March 2009 bounded count population estimates by fish length and habitat type.

| Habitat | Chinook salmon < 150 mm | | | | Chinook salmon ≥ 150 mm | | | |
|---|---|---|---|---|---|---|---|---|
| | Obs.[1] | Est.[2] | St. dev.[3] | 95% CI[4] | Obs.[1] | Est.[2] | St. dev. | 95% CI[4] |
| Pool head | 244 | 602 | -- | -- | 0 | -- | -- | -- |
| Pool body | 82 | ≥82 | -- | -- | 1 | ≥1 | -- | -- |
| Pool tail | 56 | 160 | 78.0 | 56–313 | 0 | -- | -- | -- |
| Riffle | 2,411 | 30,580 | 1,873.9 | 26,907–34,253 | 1 | ≥1 | -- | -- |
| Run head | 430 | 3,671 | 452.7 | 2,783–4,558 | 0 | -- | -- | -- |
| Run body | 873 | ≥873 | -- | -- | 2 | 126 | 98.1 | 2–318 |
| Run tail | 185 | 4,550 | 1425.8 | 1,756–7,345 | 0 | -- | -- | -- |
| **Total** | **4,281** | **39,563** | **2,399.1** | **34,861–44,265** | **4** | **126** | **98.1** | **2–318** |

[1] Largest numbers seen in any single dive pass for each unit, summed over units. Note that because of the potential for the same fish to be assigned to different size classes on subsequent passes, summation of the largest numbers assigned to individual (50 mm) size bins yields may overestimate total fish observed.

[2] Estimate for pool and run body habitat types for juvenile salmon as well as riffle habitats for adult salmon not included in overall population estimate due to lack of multiple pass data to develop an expansion factor.

[3] Standard deviation and confidence intervals undefined for multiple pass units with identical dive counts.
[4] Nominal confidence intervals calculated as + 1.96 standard deviations.

#### 3.4.1.5 Non-salmonid observations

Several other fish species were observed and counted during the March 2009 survey period (Table 3-15). Most other fish seen within the study reach were native species in the minnow (*Cyprinidae*) and sucker (*Catostomidae*) families. A combination of hardhead and Sacramento pikeminnow, along with Sacramento sucker accounted for 87.7%. Other observed non-salmonid fish included centrarchids (largemouth bass, smallmouth bass, bluegill) (4.1%), sculpin (0.5%), lamprey (0.2%), and unidentified species (7.5%). Most centrarchids occurred toward the downstream end of the study reach where water temperatures were warmer, while native minnows and suckers were found throughout the reach. The complete non-salmonid fish observation data are in Appendix G.

**Table 3-15.** Maximum counts of non-salmonid species by sampling unit (NSO), March 2009.

| RM | Sampling unit (NSO) | Habitat | BG | BASS | LMB | SMB | STP | SC | HH/PM | SS | LAM | UNK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51.6 | 4 | Pool head | | | | | | | | 1 | | |
| 51.5 | 7 | Riffle | | | | | | | | 3 | | |
| 50.6 | 14 | Riffle | | | | | | | | 21 | | |
| 50.6 | 15 | Run head | | | | | | | | 6 | | |
| 50.5 | 16 | Run body | | | | | | | | 30 | | 1 |
| 50.4 | 17 | Run tail | | | | | | | | 2 | | |
| 50.1 | 22 | Riffle | | | | | | | | 7 | | |
| 49.7 | 27 | Pool head | | | | | | | | 3 | | |
| 49.6 | 28 | Pool body | | | | | | | | 15 | | |
| 48.0 | 53 | Riffle | | | | | | 3 | | 10 | | |
| 47.0 | 58 | Run head | | | | | | | | 12 | | |
| 46.9 | 59 | Run body | | | | | | | 2 | 1 | | |
| 45.3 | 82 | Run head | | | 5 | | | | 5 | 9 | | |
| 45.1 | 83 | Run body | | | 1 | | | | 2 | | | |
| 45.0 | 86 | Pool head | | | | | | | 7 | 1 | | |
| 44.9 | 87 | Pool body | | | | | | | 1 | | | |
| 44.9 | 88 | Pool tail | | | 1 | | | | 2 | | | |
| 44.6 | 97 | Riffle | | | | | | | 8 | 9 | | |
| 43.2 | 107 | Riffle | | | | | | | 19 | 4 | | |
| 43.2 | 108 | Run head | | | | | | | 2 | 9 | | |
| 43.1 | 109 | Run body | | | | | | | 117 | 6 | | |
| 43.1 | 110 | Run tail | | | | | | | 3 | 6 | | |
| 43.0 | 111 | Riffle | | | | | | | 4 | 4 | | |
| 43.0 | 112 | Pool head | | | | | | 1 | 7 | 2 | 1 | |
| 43.0 | 113 | Pool body | | | | | | | 81 | 100 | | |
| 43.0 | 114 | Pool tail | | | | | | | 3 | | | |
| 42.9 | 118 | Riffle | | | | | | | | 2 | | |
| 39.6 | 157 | Run head | | | | | | | | 14 | | |
| 39.5 | 158 | Run body | | | 1 | 2 | 1 | | 3 | 53 | | 70 |
| 39.5 | 159 | Run tail | | | | | | | | 20 | | |

| RM | Sampling unit (NSO) | Habitat | BG | BASS | LMB | SMB | STP | SC | HH/PM | SS | LAM | UNK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39.4 | 160 | Riffle | | | 1 | | | | 13 | | | 3 |
| 38.9 | 168 | Riffle | | | | | | 1 | | 6 | | |
| 38.1 | 189 | Pool body | | | 1 | | | | 2 | 4 | | |
| 38.1 | 192 | Pool head | | | | | | | | 1 | | |
| 38.0 | 193 | Pool body | | | 1 | | | | | 17 | | |
| 36.9 | 215 | Pool body | | | | | | | 1 | 35 | | |
| 36.8 | 218 | Run head | | | | | | | | 9 | | |
| 36.6 | 219 | Run body | | 1 | 1 | 2 | | | 1 | 12 | | |
| 36.2 | 231 | Pool body | | | | | | | | 1 | | 1 |
| 34.0 | 259 | Run head | | | | 1 | | | | 30 | | |
| 34.0 | 260 | Run body | | | | 1 | | | 1 | 30 | | |
| 33.9 | 261 | Run tail | | | | | | | | 2 | | |
| 33.4 | 271 | Pool head | | 3 | | | | | | | | |
| 33.2 | 272 | Pool body | | | 1 | | | | | | | |
| 33.2 | 273 | Pool tail | | | | | | | | | 1 | |
| 31.9 | 287 | Run head | | | | | | | 1 | 40 | | |
| 31.7 | 288 | Run body | | | | 1 | | | | 46 | | |
| 31.7 | 289 | Run tail | | | | | | | 1 | | | |
| 29.5 | 324 | Riffle | | | | | | | | 1 | | |
| 29.5 | 325 | Run head | 10 | | | 1 | | | | 4 | | |
| 29.5 | 326 | Run body | 1 | | | | | | | | | |
| 29.5 | 327 | Run tail | 3 | | 1 | | | | | | | |
| **Total (all sampled units)** | | | **14** | **4** | **14** | **8** | **1** | **5** | **286** | **588** | **2** | **75** |

BG = bluegill; BASS = unidentified bass; LMB = largemouth bass; SMB = smallmouth bass; STP = striped bass; SC = sculpin species; HH/PM = hardhead/Sacramento pikeminnow; SS = Sacramento sucker; LAM = lamprey species; UNK = unknown

## 3.4.2 July 2009

### 3.4.2.1 *O. mykiss* observations

During the July 2009 survey period, we observed 796 *O. mykiss* ranging from 0–499 mm (50 mm size bins) based upon maximum counts of all dive passes in each sampling unit (Table 3-16, Table 3-17). The majority of these fish (686) were YOY/juvenile (<150 mm), with a total of 110 adults (>150 mm) observed (Figure 5). Complete fish observation data by NSO and dive pass is presented in Appendix G.

The *O. mykiss* were observed in 23 different habitat units (NSOs) from RM 51.8 to RM 41.9 and in all habitat types (Table 3-16 and Table 3-17). Habitat use and reach-wide distribution of YOY/juvenile and adult *O. mykiss* differed, with the maximum count from dive passes (Figure 6a) and fish densities (Figure 5b) highest in riffle and pool body/tail habitats for juvenile size classes (<150mm) and higher counts and densities of adult size classes (>150 mm) in riffle and pool head habitats. Juvenile size classes were also observed in run head transitional habitat downstream of riffles, with lower densities in run bodies and pool habitats. Adult-size classes were observed in transitional run head habitats as well as within pool and run body/tail habitats in slightly lower numbers and densities (Figure 6a and Figure 6b).

Adult fish habitat use was concentrated at upstream habitat units (above RM 48.0) and primarily occurred at riffle (four NSOs) and transitional pool head (four NSOs) and run head (two NSOs) habitats (Table 3-16 and Figure 7). Juvenile fish habitat use was more uniformly distributed from upstream to downstream and occurred primarily at riffle habitat units, although the highest count was from a single pool body/tail sampling unit (NSO 5/6 at RM 51.6) (Table 3-17 and Figure 8).

**Table 3-16.** Maximum count of *O. mykiss* by NSO, July 2009 (data are divided into 50 mm total length size classes).

| RM | Unit ID (NSO) | Habitat | Multiple pass survey (Y/N) | 0-49 mm | 50-99 mm | 100-149 mm | 150-199 mm | 200-249 mm | 250-299 mm | 300-349 mm | 350-399 mm | 400-449 mm | 450-499 mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51.8 | 1 | Pool head | N | | | | | 2 | | | | 8 | 4 |
| 51.7 | 2/3 | Pool body/tail | N | | | | | | | 1 | 2 | 1 | |
| 51.6 | 4 | Pool head | Y | | | | | | | 2 | 2 | | |
| 51.6 | 5/6 | Pool body/tail | Y | 45 | 188 | 100 | | | 2 | | 2 | | |
| 50.6 | 14 | Riffle | N | | 13 | 35 | 3 | | | | 1 | | |
| 50.6 | 15 | Run head | N | | | 2 | | | | | | | |
| 50.3 | 19 | Run head | N | | | | | | 3 | | 1 | | |
| 50.1 | 20/21 | Run body/tail | Y | | 4 | 1 | | 1 | 3 | 1 | | 1 | |
| 50.1 | 22 | Riffle | Y | 5 | 47 | 43 | | | 2 | 1 | 1 | | |
| 49.7 | 27 | Pool head | N | | 2 | 1 | 1 | | 1 | 2 | | | |
| 49.6 | 28/29 | Pool body/tail | N | | 8 | 2 | 5 | 3 | | | | | |
| 49.2 | 33 | Riffle | N | | 11 | 17 | 6 | 6 | 5 | 3 | | 1 | |
| 49.2 | 34 | Run head | N | | 21 | 5 | 3 | | 1 | 1 | | | |
| 49.1 | 35/36 | Run body/tail | N | | | | | | | | | | |
| 48.2 | 49 | Riffle | N | | 25 | 40 | 2 | 4 | 6 | | 1 | | |
| 48.0 | 54 | Pool head | N | | | | | 1 | | 1 | | | |
| 47.0 | 58 | Run head | Y | | 2 | 5 | 1 | | | | | | |
| 46.9 | 59/60 | Run body/tail | N | | | | | | | | | | |
| 45.7 | 74 | Riffle | N | 2 | 6 | 5 | 1 | | | | | | |
| 45.7 | 75 | Run head | Y | | 1 | | | | | | | | |
| 45.7 | 76/77 | Run body/tail | N | | | | | | | | | | |
| 45.0 | 86 | Pool head | Y | | | | | | | | | | |
| 44.9 | 87/88 | Pool body/tail | N | | | | | | | | | | |
| 44.5 | 101 | Riffle | Y | | 9 | 15 | 3 | | | | | | |
| 43.2 | 108 | Run head | N | | | | | | | | | | |
| 43.1 | 109/110 | Run body/tail | Y | | 5 | 12 | 5 | | | | | | |
| 43.0 | 111 | Riffle | N | | 1 | 6 | 2 | | | | | | |
| 43.0 | 112 | Pool head | N | | 1 | | | | | | | | |

| RM | Unit ID (NSO) | Habitat | Multiple pass survey (Y/N) | 0-49 mm | 50-99 mm | 100-149 mm | 150-199 mm | 200-249 mm | 250-299 mm | 300-349 mm | 350-399 mm | 400-449 mm | 450-499 mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43.0 | 113/114 | Pool body/tail | Y | | | | | | | | | | |
| 41.9 | 132 | Riffle | N | | | 1 | | 1 | | | | | |
| 41.9 | 133 | Run head | N | | | | | | | | | | |
| **Total (maximum unit count of all passes)** | | | | **52** | **344** | **290** | **32** | **18** | **23** | **12** | **10** | **11** | **4** |

**Table 3-17.** Maximum count of *O. mykiss* by habitat type, July 2009 (data are divided into 50 mm total length size classes).

| Habitat | 0-49 mm | 50-99 mm | 100-149 mm | 150-199 mm | 200-249 mm | 250-299 mm | 300-349 mm | 350-399 mm | 400-449 mm | 450-499 mm | Total (max. unit count of all passes) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pool body/tail | 45 | 196 | 102 | 5 | 3 | 2 | 1 | 4 | 1 | | **359** |
| Pool head | | 3 | 1 | 1 | 3 | 1 | 5 | 2 | 8 | 4 | **28** |
| Riffle | 7 | 112 | 162 | 17 | 11 | 13 | 4 | 3 | 1 | | **330** |
| Run body/tail | | 9 | 13 | 5 | 1 | 3 | 1 | | 1 | | **33** |
| Run head | | 24 | 12 | 4 | | 4 | 1 | 1 | | | **46** |
| **Totals by size class** | **52** | **344** | **290** | **32** | **18** | **23** | **12** | **10** | **11** | **4** | **796** |

#### 3.4.2.2 *O. mykiss* population estimate

Table 3-18 shows the July 2009 *O. mykiss* population estimate for the lower Tuolumne River by length (<150 mm for YOY and juvenile; >150 mm for adults) and habitat type using the method of bounded counts (Hankin and Mohr 2001). Out of an estimated 3,475 juveniles and 963 adults *O. mykiss* in July 2009 (an overall population estimate of 4,438), we estimated a 95% confidence interval of 945–6,004 and 464–1,461 for YOY/juvenile and adults, respectively (Table 3-18). As discussed above, the data show that the greatest estimated abundance of YOY and juvenile *O. mykiss* occurred in riffles, despite observing the highest count in the pool body/tail habitat type (Figure 6a).

The relative differences between population estimates and observed fish counts are due to differences in habitat unit areas (e.g., run body/tail habitat units occupying approximately 20 times more habitat area than run head units (Table 3-2). This results in higher population estimates in some habitat types even though the observed counts may be lower than those found in other habitat types. In July 2009, juvenile and adult population estimates were shown to be highest in riffle habitat units (Table 3-18).

**Table 3-18.** *O. mykiss* July 2009 bounded count population estimates by fish length and habitat type.

| Habitat | O. mykiss < 150 mm | | | | O. mykiss ≥ 150 mm | | | |
|---|---|---|---|---|---|---|---|---|
| | Obs.[1] | Est.[2] | St. dev. | 95% CI[3] | Obs.[1] | Est. | St. dev. | 95% CI[3] |
| Pool head | 4 | ≥4 | --- | -- | 23 | 26 | 0.0 | 26–26 |
| Pool body/tail | 304 | 1,382 | 898.2 | 304–3,143 | 16 | 147 | 56.8 | 36–259 |
| Riffle | 279 | 1,528 | 893.5 | 279–3,279 | 48 | 428 | 131.0 | 171–684 |
| Run head | 35 | 265 | 49.8 | 168–363 | 10 | 206 | 123.4 | 10–448 |
| Run body/tail | 19 | 299 | 240.5 | 19–771 | 8 | 156 | 170.6 | 8–490 |
| **Total** | **641** | **3,475** | **1,290.5** | **945–6,004** | **105** | **963** | **254.4** | **464–1,461** |

[1] Largest numbers seen in any single dive pass for each unit, summed over units. Note that because of the potential for the same fish to be assigned to different size classes on subsequent passes, summation of the largest numbers seen assigned to individual (50 mm) size bins may overestimate total fish observed.
[2] Estimate for *O. mykiss* juveniles in pool head habitats not included in overall population estimate due to lack of multiple pass data to develop an expansion factor.
[3] Nominal confidence intervals calculated as + 1.96 standard deviations. Standard deviation and confidence intervals undefined for multiple pass units with identical dive counts.

#### 3.4.2.3 Chinook salmon observations

Divers observed a large number of juvenile Chinook salmon within the study reach during July 2009 as well as small numbers within the adult size classes (>150 mm). Salmon were seen in 25 different sampling units from RM 51.6 to RM 41.9 (Table 3-19) and all habitat types (Table 3-20). Most salmon were juveniles found within the 50–99 mm size class.

**Table 3-19.** Maximum counts of juvenile Chinook salmon by size class and sampling unit, July 2009.

| River mile | Sampling unit (NSO) | Habitat type | Multiple pass survey (Y/N) | 0–49 mm | 50–99 mm | 100–149 mm |
|---|---|---|---|---|---|---|
| 51.8 | 1 | Pool head | N | | | |
| 51.7 | 2/3 | Pool body/tail | N | | | |
| 51.6 | 4 | Pool head | Y | | | |
| 51.6 | 5/6 | Pool body/tail | Y | 250 | 292 | |
| 50.6 | 14 | Riffle | N | 570 | 1,410 | 120 |
| 50.6 | 15 | Run head | N | 30 | 55 | |
| 50.3 | 19 | Run head | N | | 480 | 20 |
| 50.1 | 20/21 | Run body/tail | Y | 116 | 249 | |
| 50.1 | 22 | Riffle | Y | 24 | 139 | |
| 49.7 | 27 | Pool head | N | | 3 | 3 |
| 49.6 | 28/29 | Pool body/tail | N | | 100 | 2 |
| 49.2 | 33 | Riffle | N | | 97 | 6 |
| 49.2 | 34 | Run head | N | 95 | 325 | 5 |
| 49.1 | 35/36 | Run body/tail | N | | | |
| 48.2 | 49 | Riffle | N | 32 | 89 | 7 |
| 48.0 | 54 | Pool head | N | 1 | | |
| 47.0 | 58 | Run head | Y | | 2 | 2 |
| 46.9 | 59/60 | Run body/tail | N | | | |
| 45.7 | 74 | Riffle | N | 3 | 35 | 3 |
| 45.7 | 75 | Run head | Y | | 1 | |
| 45.7 | 76/77 | Run body/tail | N | | 11 | |
| 45.0 | 86 | Pool head | Y | | 4 | |
| 44.9 | 87/88 | Pool body/tail | N | | 3 | |
| 44.5 | 101 | Riffle | Y | 4 | 69 | 18 |
| 43.2 | 108 | Run head | N | | | |
| 43.1 | 109/110 | Run body/tail | Y | | 10 | 2 |
| 43.0 | 111 | Riffle | N | | 1 | |
| 43.0 | 112 | Pool head | N | | 2 | |
| 43.0 | 113/114 | Pool body/tail | Y | | | |
| 41.9 | 132 | Riffle | N | 1 | 19 | 4 |
| 41.9 | 133 | Run head | N | | 2 | |
| **Total (Max. unit count of all passes)** | | | | **1,126** | **3,398** | **192** |

**Table 3-20.** Maximum counts of juvenile Chinook salmon by size class and habitat type, July 2009.

| Habitat | 0–49 mm | 50–99 mm | 100–149 mm | Total (maximum unit count of all passes) |
|---|---|---|---|---|
| Pool body/tail | 250 | 395 | 2 | 647 |
| Pool head | 1 | 9 | 3 | 13 |
| Riffle | 634 | 1859 | 158 | 2,651 |
| Run body/tail | 116 | 270 | 2 | 388 |
| Run head | 125 | 865 | 27 | 1,017 |
| **Totals by size class** | **1,126** | **3,398** | **192** | **4,716** |

Divers observed a total of six adult Chinook salmon at three separate sampling units in the upper portion of the study reach between RM 51.6 and 50.6. A total of four adults were seen in a riffle habitat unit (NSO 14), with one adult each was observed in a pool head (NSO 4) and a pool body/tail (NSO 5/6) habitat unit. The complete Chinook salmon observation data by pass are shown in Appendix G.

#### 3.4.2.4 Chinook salmon population estimate

Table 3-21 shows the July 2009 Chinook salmon population estimate for the lower Tuolumne River by length (<150 mm for YOY and juvenile; >150 mm for adults) and habitat type using the method of bounded counts (Hankin and Mohr 2001). Out of an estimated 29,389 juveniles and 11 adult Chinook salmon in July 2009 (an overall population estimate of 29,400), we estimated a 95% confidence interval of 19,068–39,711 and 6–26 for YOY/juvenile and adults, respectively (Table 3-21). The data show that the greatest estimated abundance of YOY and juvenile Chinook salmon occurred in riffles, with the greatest estimated abundance of adults in the pool body/tail habitat type (Table 3-21).

**Table 3-21.** Chinook salmon July 2009 bounded count population estimates by fish length and habitat type.

| Habitat | Chinook salmon < 150 mm | | | | Chinook salmon ≥ 150 mm | | | |
|---|---|---|---|---|---|---|---|---|
| | Obs.[1] | Est. | St. dev. | 95% CI[2] | Obs.[1] | Est.[2] | St. dev. | 95% CI[3] |
| Pool head | 13 | 62 | 35.8 | 13–132 | 1 | 2 | 1.2 | 1–4 |
| Pool body/tail | 635 | 2,890 | 1,616.2 | 635–6058 | 1 | 9 | 7.7 | 1–24 |
| Riffle | 2,643 | 15,157 | 13,863.8 | 12,445–17,869 | 4 | ≥4 | --- | -- |
| Run head | 1,017 | 5,610 | 0.8 | 5,609–5,612 | 0 | -- | --- | -- |
| Run body/tail | 388 | 5,670 | 4,817 | 388–15111 | 0 | -- | --- | -- |
| **Total** | **4,696** | **29,389** | **5,266.1** | **19,068–39,711** | **6** | **11** | **7.8** | **6–26** |

[1] Largest numbers seen in any single dive pass for each unit, summed over units. Note that because of the potential for the same fish to be assigned to different size classes on subsequent passes, summation of the largest numbers assigned to individual (50 mm) size bins may overestimate total fish observed.
[2] Estimate adult salmon within riffle habitats for adult salmon not included in overall population estimate due to lack of multiple pass data to develop an expansion factor.
[3] Nominal confidence intervals calculated as ± 1.96 standard deviations.

#### 3.4.2.5 Non-salmonid observations

Several other fish species were observed during the July study period (Table 3-22). Most fish seen within the study reach were native species in the minnow (*Cyprinidae*) and sucker (*Catostomidae*) families. A combination of cyprinids (hardhead and Sacramento pikeminnow), along with Sacramento sucker accounted for 91.2% of observed non-salmonid fish, while non-native centrarchids (largemouth bass, smallmouth bass, and unidentified bass) accounted for approximately 7.3%, and sculpin for the remaining 1.5%. Most centrarchids occurred toward the downstream end of the study reach where water temperatures were warmer, while native minnows and suckers were found throughout the reach. The complete non-salmonid fish observation data are in Appendix G.

**Table 3-22.** Maximum counts of non-salmonid species by sampling unit (NSO), July 2009.

| RM | Sampling unit (NSO) | Habitat | BASS | LMB | SMB | SC | HH/PM | SS |
|---|---|---|---|---|---|---|---|---|
| 51.7 | 2/3 | Pool body/tail | | | | | 2 | 4 |
| 51.6 | 5/6 | Pool body/tail | | | | | | 2 |
| 50.6 | 14 | Riffle | | | | 3 | 1 | 22 |
| 50.6 | 15 | Run head | | | | | | 2 |
| 50.3 | 19 | Run head | | | | | | 2 |
| 50.1 | 20/21 | Run body/tail | | | | 9 | 2 | 6 |
| 50.1 | 22 | Riffle | | | | | | 15 |
| 49.7 | 27 | Pool head | | | | | 1 | 3 |
| 49.6 | 28/29 | Pool body/tail | | | | 1 | 1 | 12 |
| 49.2 | 33 | Riffle | | | | | | 1 |
| 49.2 | 34 | Run head | | | | | 5 | 5 |
| 49.1 | 35/36 | Run body/tail | | | | | 2 | 1 |
| 48.2 | 49 | Riffle | | | | | 6 | 17 |
| 48.0 | 54/55 | Pool head/tail | | 6 | 4 | | 9 | 35 |
| 47.0 | 58 | Run head | | | | | 35 | 2 |
| 46.9 | 59/60 | Run body/tail | | 1 | | | 6 | 15 |
| 45.7 | 74 | Riffle | | | | | 2 | |
| 45.7 | 75 | Run head | | 1 | | | 46 | 3 |
| 45.7 | 76/77 | Run body/tail | | | | | 25 | 3 |
| 45.0 | 86 | Pool head | | | | | 7 | 4 |
| 44.9 | 87/88 | Pool body/tail | | | | | 45 | |
| 44.5 | 101 | Riffle | | 1 | 3 | 1 | 17 | 9 |
| 43.2 | 108 | Run head | | 2 | | | 2 | 7 |
| 43.1 | 109/110 | Run body/tail | 13 | 23 | 4 | | 38 | 25 |
| 43.0 | 111 | Riffle | | 1 | | | 31 | 1 |
| 43.0 | 112 | Pool head | | | | | 6 | |
| 43.0 | 113/114 | Pool body/tail | | 6 | 1 | | 62 | 1 |
| 41.9 | 132 | Riffle | | 1 | | | 228 | 15 |
| 41.9 | 133 | Run head | | 2 | | | 66 | 2 |
| **Total (all sampled units)** | | | **13** | **44** | **12** | **14** | **645** | **214** |

BASS = Black bass; LMB = large mouth bass; SMB = small mouth bass;
HH/PM = heardhead/pikeminnow; SS = Sacramento sucker

# 4 DISCUSSION

## 4.1 Bounded Counts Study Assumptions

It should be noted that the bounded counts method was developed for use in smaller stream systems (Hankin and Mohr 2001) and applying the methodology to a larger system such as the Tuolumne River is only feasible provided key assumptions are satisfied. One critical assumption of the bounded counts approach is that all individuals have an equal probability of being observed. As noted above, this assumption may be challenged in locations with large numbers of juvenile Chinook salmon, due to low visibility conditions in deeper pool habitats, as well as low visibility due to light and background turbidity variations within the river between seasons or from upstream to downstream. For these reasons, the resulting population estimates may be low-biased.

A second assumption of the bounded counts method is that observation efficiency is not 100%, so the number of fish seen in any single dive pass is, in general, an underestimate of the true number of fish present. For a closed population where fish do not migrate into or out of the unit between dives, the maximum number of fish seen over multiple passes is a low-biased estimator of the true population. However, because we subsampled larger habitat units at some locations, for run habitat types in particular, the resulting density expansions may have introduced a high-biased estimate of the true population size since fish are able to migrate freely into and out of the searched area due to the lack of habitat boundaries relevant to the sampled fish (e.g., riffle transitions).

## 4.2 Variations in *O. mykiss* Population Estimates

### 4.2.1 March 2009

Overall, the March 2009 population estimate of 44 juvenile *O. mykiss* (< 150 mm) and 117 adults (>150 mm) was low, with very low representation of juvenile size classes relative to adults (Table 3-11). Although the higher numbers of Chinook salmon juveniles observed during the March 2009 surveys (Table 3-13) may have resulted in misidentification of some *O. mykiss* within the same area, the low numbers of juvenile *O. mykiss* observed is consistent with a winter-spring spawning period that begins in February (Moyle 2002). The low number of adult *O. mykiss* observed during March 2009 may be attributed to potential causes such as:

1. Adult *O. mykiss* have a heterogeneous (i.e., “patchy”) distribution and it appears that future winter sampling efforts should be conducted in the same reach as summer surveys, upstream of Roberts Ferry Bridge (RM 39.5), unless other information (e.g., from angling or tracking) identifies whether habitat use is distributed farther downstream.
2. Adult *O. mykiss* may be more furtive in winter, swimming into or occupying deeper portions of pools or out of range of the diver visibility, which is also reduced in winter due to lower light levels and increased turbidity. Nighttime dive surveys could be considered in future surveys, since low light situations tend to reduce the startle reflex of *O. mykiss*.
3. Lastly, adult *O. mykiss* may be altogether absent from the survey reach because they have migrated downstream of RM 29. This could be confirmed by any of: a) catch and release angling outside of the survey reach, b) capture, implantation of acoustic tags and tracking

as provided in the TID/MID (2007) study plan, or c) video observations at the Districts Alaska type counting weir recently deployed at RM 24 in September 2009.

### 4.2.2 July 2009 and July 2008

The July 2009 population estimate of 4,438 fish indicates a relatively high proportion of juvenile *O. mykiss* (3,475) relative to adults (963) (Table 3-18), with these proportions similar to historical June-July routine snorkel surveys conducted by the Districts (Ford and Kirihara 2009). In comparison to the July 2008 results of 2,472 juvenile and 643 adult *O. mykiss* (Stillwater Sciences 2008), the 2009 results indicate a slight increase in population levels at similar flow levels (approximately 100 cfs for sample dates in both July 2008 and July 2009). Juvenile *O. mykiss* population estimates would be expected to vary from year-to-year due to the large number of potential eggs deposited by each additional female spawner. However, the apparent increases in both juvenile and adult populations are within the 95% confidence intervals of the 2008 and 2009 estimates, with 95% CIs for juvenile *O. mykiss* ranging from 945–6,004 and 1,263–3,681, and for adults ranging from 464–1,461 and 217–1,070 in 2009 and 2008, respectively.

## 4.3 *O. mykiss* Distribution in Relation to Water Temperature

### 4.3.1 March 2009

During the March 2009 snorkel surveys, water temperatures remained below 15°C throughout most the study reach and only exceeded 17°C at the lowest sampling unit (RM 29.5) on 21 March 2009. These temperature conditions are not thought to particularly affect the distribution of *O. mykiss*. The few *O. mykiss* observed were found at or upstream of RM 43.0, similar to the 2008–2009 summer surveys. As discussed above in Section 4.2, presence/absence of *O. mykiss* downstream of the study reach could be confirmed by any of: a) catch and release angling outside of the survey reach, b) capture, implantation of acoustic tags and tracking as provided in the TID/MID (2007) study plan, or c) video observations at the Districts Alaska type counting weir recently deployed at RM 24 in September 2009.

### 4.3.2 July 2009

To test Hypothesis #1 that summertime distribution of observed life stages of *O. mykiss* across suitable habitat is related to ambient river water temperature, we compared water temperature data taken from thermographs to fish density in the sampled units. The data show that temperatures increase in the downstream direction (Section 3.3.2, Table 3-7) and that the density of adult *O. mykiss* (>150 mm) decreased along this same gradient (Figure 9). In habitat units where fish were seen, density of adult fish was greatest just downstream of La Grange Dam and decreased markedly in the downstream direction, especially below RM 48.0. Pool heads occupy the least amount of channel area (Table 3-2) and are also more concentrated in upstream locations (Figure 3), so adult fish presence here may indicate a preference for pool head habitats or a preference for cooler water (<21 °C [69.8 °F]). We sampled six pool heads throughout the reach (Appendix G), and found no adult fish (>150 mm) within this habitat type downstream of NSO 54 (RM 48.0), suggesting that water temperature and possibly microhabitat elements such as cover type are a stronger determinant of longitudinal distribution of *O. mykiss* than mesohabitat type. It may also be that spawning activity primarily occurs in upstream areas and may influence the general distribution of both adults and juveniles. Smaller fish were observed in a similar pattern with highest densities upstream of RM 48 and decreasing overall in a downstream direction (Figure 9).

The greatest density of YOY and juvenile *O. mykiss* occurred in pool body/tail and riffle habitats (Figure 6b). The occurrence of juveniles in pool body/tail habitat is somewhat of an anomaly since only one of the five pool body/tail units sampled represented 97% of total observations, and only one other pool body/tail habitat had juveniles present. Juveniles are likely not found in this habitat type at downstream locations for a number of reasons, including predation, territorial exclusion by the larger size classes of *O. mykiss*, lower habitat use preference for rearing (based on depth, velocity, cover, and food supply), as well as increasing thermal conditions. A better indication of juvenile distribution in relation to water temperature is the observations of juveniles in riffle habitats. Juveniles were found in seven out of eight riffle habitats sampled, indicating a strong preference for this habitat type. Juveniles were only excluded at the lower most riffle unit sampled (RM 41.9), however the densities of juveniles decreases further downstream of the dam (Figure 8). When compared with the distribution of adult *O. mykiss*, this may indicate that adults are better able to move upstream toward cooler habitats than YOY and juvenile *O. mykiss*.

## 4.4 Habitat Associations of *O. mykiss* and Chinook salmon Observations

### 4.4.1 March 2009

Table 4-1 and Table 4-2 show the range of cover and substrate components observed during habitat mapping for each habitat type where *O. mykiss* and Chinook salmon were present during the March 2009 surveys. Variations in cover types and amounts were limited in all NSOs, with higher percentages of the "No Cover" class found throughout the reach (Appendix D-2). For this reason, the cover results do not provide a meaningful basis for establishing a relationship with habitat use by juveniles or adults of either species. Chinook salmon juveniles were the most observed salmonid during the surveys and were observed primarily in riffle and transitional pool head and run head habitats where higher percentages of cobble were reported (Table 4-1).

**Table 4-1.** Cover and substrate type found in snorkeled habitat units with *O. mykiss* present during the March 2009 snorkel surveys.

| | Pool body | Pool head | Pool tail | Riffle | Run body | Run head | Run tail |
|---|---|---|---|---|---|---|---|
| **Cover type range (%)** | | | | | | | |
| Boulder | | 0–10 | | 5–10 | | | |
| Wood | | 0–0 | | 0–5 | | | |
| Ledge | | 0–0 | | 0–10 | | | |
| Overhang | | 0–5 | | 5–10 | | | |
| Aquatic vegetation | | 0–0 | | 0–0 | | | |
| No cover | | 85–85 | | 80–95 | | | |
| **Substrate type range (% covering channel bed)** | | | | | | | |
| Bedrock | | 0–20 | | 0–0 | | | |
| Boulder | | 0–20 | | 10–30 | | | |
| Cobble | | 10–60 | | 60–70 | | | |
| Gravel | | 0–40 | | 10–30 | | | |
| Sand | | 0–10 | | 0–10 | | | |
| Silt | | 0–0 | | 0–0 | | | |
| Organic | | 0–0 | | 0–0 | | | |

**Table 4-2**. Cover and substrate type found in snorkeled habitat units with Chinook salmon present during the March 2009 snorkel surveys.

| | Pool body | Pool head | Pool tail | Riffle | Run body | Run head | Run tail |
|---|---|---|---|---|---|---|---|
| **Cover type range (%)** | | | | | | | |
| Boulder | 0–0 | 0–10 | 0–10 | 5–10 | 0–0 | 0–10 | 0–0 |
| Wood | 0–5 | 0–5 | 0–0 | 0–5 | 0–5 | 0–0 | 0–0 |
| Ledge | 0–0 | 0–0 | 0–0 | 0–10 | 0–0 | 0–0 | 0–0 |
| Overhang | 0–5 | 0–5 | 0–5 | 5–10 | 5–10 | 0–5 | 5–10 |
| Aquatic vegetation | 0–30 | 0–30 | 0–5 | 0–5 | 0–50 | 0–0 | 0–20 |
| No cover | 70–90 | 65–100 | 85–100 | 80–100 | 35–100 | 90–100 | 80–100 |
| **Substrate type range (% covering channel bed)** | | | | | | | |
| Bedrock | 10–20 | 20–50 | 10–40 | 0–0 | 0–10 | 0–0 | 0–0 |
| Boulder | 0–0 | 10–20 | 20–30 | 10–30 | 10–20 | 0–10 | 10–20 |
| Cobble | 20–60 | 20–50 | 30–60 | 50–70 | 20–60 | 40–70 | 20–60 |
| Gravel | 20–30 | 10–70 | 10–50 | 10–40 | 10–40 | 20–50 | 20–60 |
| Sand | 20–30 | 10–20 | 10–20 | 0–10 | 10–40 | 0–10 | 20–50 |
| Silt | 0–10 | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 |
| Organic | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 |

### 4.4.2 July 2009

Table 4-3 and Table 4-4 show the range of cover and substrate components observed during habitat mapping for each habitat type where *O. mykiss* and Chinook salmon were present during the July 2009 surveys. As in March 2009, variations of cover types and amounts were limited in all NSOs, with higher percentages of no cover found throughout the reach (Appendix D-2). Therefore cover results do not provide a meaningful basis for establishing a relationship with habitat use by juveniles or adults of either species. The *O. mykiss* and Chinook salmon were observed primarily in riffle and transitional pool head and run head habitats where higher percentages of cobble were reported (Table 4-3).

**Table 4-3.** Cover and substrate type found in snorkeled habitat units with *O. mykiss* present during the July 2009 snorkel surveys.

| | Pool body/tail | Pool head | Riffle | Run body/tail | Run head |
|---|---|---|---|---|---|
| **Cover type range (%)** | | | | | |
| Boulder | 0–10 | 5–10 | 5–10 | 0–0 | 5–10 |
| Wood | 0–0 | 0–5 | 0–0 | 0–0 | 0–0 |
| Ledge | 0–0 | 0–0 | 0–10 | 0–0 | 0–0 |
| Overhang | 0–5 | 0–5 | 5–10 | 0–5 | 0–10 |
| Aquatic vegetation | 10–20 | 10–20 | 0–5 | 0–0 | 0–10 |
| No cover | 80–90 | 65–100 | 80–95 | 95–95 | 85–100 |
| **Substrate type range (% covering channel bed)** | | | | | |
| Bedrock | 20–50 | 10–50 | 0–10 | 0–0 | 0–0 |
| Boulder | 20–40 | 10–50 | 10–20 | 10–20 | 10–20 |
| Cobble | 10–40 | 30–60 | 40–70 | 60–60 | 50–70 |
| Gravel | 0–10 | 5–30 | 20–50 | 20–30 | 20–40 |
| Sand | 5–10 | 5–10 | 0–10 | 0–0 | 0–10 |
| Silt | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 |
| Organic | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 |

**Table 4-4.** Cover and substrate type found in snorkeled habitat units with Chinook salmon present during the July 2009 snorkel surveys.

| | Pool body/tail | Pool head | Riffle | Run body/tail | Run head |
|---|---|---|---|---|---|
| **Cover type range (%)** | | | | | |
| Boulder | 10–10 | 10–10 | 5–10 | 0–0 | 5–10 |
| Wood | 5–5 | 5–5 | 0–0 | 0–0 | 0–0 |
| Ledge | 0–0 | 0–0 | 10–10 | 0–0 | 0–0 |
| Overhang | 5–5 | 5–10 | 5–10 | 5–10 | 5–10 |
| Aquatic vegetation | 10–10 | 30–30 | 5–5 | 0–0 | 10–10 |
| No cover | 85–90 | 65–100 | 80–95 | 90–95 | 85–100 |

| | Pool body/tail | Pool head | Riffle | Run body/tail | Run head |
|---|---|---|---|---|---|
| **Substrate type range (% covering channel bed)** | | | | | |
| Bedrock | 20–50 | 20–50 | 10–10 | 0–0 | 15–15 |
| Boulder | 20–20 | 10–20 | 10–20 | 10–20 | 10–20 |
| Cobble | 25–60 | 30–60 | 40–70 | 60–60 | 45–70 |
| Gravel | 10–20 | 5–30 | 20–50 | 20–30 | 20–40 |
| Sand | 2–20 | 5–10 | 10–10 | 10–10 | 10–10 |
| Silt | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 |
| Organic | 0–0 | 0–0 | 0–0 | 0–0 | 0–0 |

## 4.5 Habitat Use at Restored and Reference Sites by *O. mykiss* and Chinook salmon

Hypothesis #2 states that the density of *O. mykiss* juveniles and adults is the same in restored sites as in nearby reference sites in the Tuolumne River. This hypothesis was originally formulated with the intention of testing habitat use at planned gravel augmentation sites. However, other than the CDFG gravel addition projects near Old La Grange Bridge, completed from 2001–2003, and the joint Tuolumne River Technical Advisory Committee/Friends of the Tuolumne (FOT) gravel augmentation at Bobcat Flat (RM 43) in 2005, no further gravel augmentation projects have been implemented since that time. This has limited the potential sampling replications and statistical power to detect any differences between restored and reference sites.

As a means to evaluate habitat use of these restoration sites, observed densities of *O. mykiss* juveniles and adults were compared at the three habitat types that were sampled within the restoration sites to the same habitat types surveyed elsewhere in July 2009. The low number of *O. mykiss* observations in March 2009 do not allow for meaningful comparisons. Figure 10 shows the *O. mykiss* density of juveniles and adults at pool head, riffle, and run head habitats types sampled in July 2009 from sampling units found at both the restoration sites and from all similar sample units within the study reaches upstream of RM 40.0. For juvenile *O. mykiss* the densities show a relatively high use of riffle habitat at restoration sites when compared with other riffle sampling units; a relatively lower use of run head habitat at the upstream restoration sites; and an overall low density in pool head habitats throughout the reach (Figure 10). For adult *O. mykiss* the density at riffle habitats is potentially reduced at restoration sites, with similar densities at run head habitats, and insufficient data for comparison at pool head habitats.

A similar evaluation was done using juvenile Chinook salmon. Figures 11 and 12 show juvenile Chinook densities as sampled in March 2009 and July 2009, respectively for the same three habitat types. In March 2009, juvenile Chinook densities at the restoration sites were greater in each of the habitat types when compared to the reference sampling units (Figure 11). In July 2009, juvenile Chinook densities either exceeded or were similar to the reference units (Figure 12). Considering the similar habitat preferences for juvenile *O. mykiss* and juvenile Chinook salmon, it appears that salmonid use of restoration sites is similar, or possibly enhanced within riffle habitats, when compared with nearby reference sites. Additional replication through either an increased number of gravel augmentation sites, or an increased number of survey events would be needed to improve the statistical power enough to detect whether significant differences in habitat use exist.

## 4.6 Comparison to June 2009 TID/MID Snorkel Surveys

Results from the July 2009 snorkel data were compared to observations made during the June 2009 TID/MID snorkel survey data (Ford and Kirihara 2009) for the sampled reach common to both surveys and within habitat units surveyed during both sampling events (Table 4-5 and Table **4-6**). July 2009 data are observations from the first pass of the multiple pass bounded count estimation method to allow a direct comparison to June 2009 data (Ford and Kirihara 2009), which came from single pass snorkel surveys that employ catch-per-unit-effort (CPUE) methodology. Note that TID/MID snorkel surveys are not conducted in March, precluding comparison with the March 2009 surveys.

**Table 4-5.** Salmonid observations in June (single pass) and July (first pass) 2009 in the reach sampled during both studies.

| June 2009 snorkel survey | | | | | July 2009 snorkel survey | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Location | RM | <150 mm *O. mykiss* count | >150 mm *O. mykiss* count | <150 mm *O. tshawytscha* count | Habitat Unit (NSO) | RM | <150 mm *O. mykiss* count | >150 mm *O. mykiss* count | <150 mm *O. tshawytscha* count |
| Riffle A7 - R23C | 50.7–42.3 | 112 | 30 | 1,897 | 1–136 | 51.8–41.7 | 600 | 101 | 4,423 |

**Table 4-6.** Salmonid counts and estimated densities in June (single pass) and July (first pass) 2009 for units snorkeled during both dates.

| Location | RM | June 2009 snorkel survey | | | | | | | | | July 2009 snorkel surveys | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Site | Habitat type | Area ($ft^2$) | <150 mm *O. mykiss* | | >150 mm *O. mykiss* | | <150 mm *O. tshawytscha* | | Habitat unit (NSO) | Habitat type | Area ($ft^2$) | <150 mm *O. mykiss* | | >150 mm *O. mykiss* | | <150 mm *O. tshawytscha* | |
| | | | | | # | #/$ft^2$ | # | #/$ft^2$ | # | #/$ft^2$ | | | | # | #/$ft^2$ | # | #/$ft^2$ | # | #/$ft^2$ |
| Riffle A7 | 50.6 | 1 | Riffle | 3,750 | 50 | 0.0133 | 0 | 0 | 700 | 0.186 | 14 | Riffle | 46,670 | 46 | 0.0010 | 4 | 0.0001 | 2,100 | 0.045 |
| | | 2 | Run | 4,000 | 30 | 0.0075 | 0 | 0 | 700 | 0.175 | 15 | Run Head | 13,760 | 2 | 0.0001 | 0 | 0 | 85 | 0.006 |
| Riffle 3B | 49.1 | 1 | Riffle | 4,400 | 6 | 0.0014 | 6 | 0.0014 | 82 | 0.019 | 33 | Riffle | 69,509 | 28 | 0.0004 | 21 | 0.0003 | 105 | 0.002 |
| | | 2 | Run-Riffle | 10,000 | 13 | 0.0013 | 2 | 0.0002 | 250 | 0.025 | 34–36 | Run Head, Body/Tail | 33,758 | 26 | 0.0008 | 5 | 0.0002 | 425 | 0.013 |
| Riffle 7 | 46.9 | 2 | Run | 7,000 | 0 | 0 | 0 | 0 | 0 | 0 | 59/60 | Run Body/Tail | 47,827 | 0 | 0 | 0 | 0 | 0 | 0 |
| Riffle 21 | 42.9 | 1 | Riffle | 5,000 | 0 | 0 | 0 | 0 | 6 | 0.001 | 111 | Riffle | 10,077 | 7 | 0.0007 | 2 | 0.0002 | 1 | 0.0001 |
| | | 2 | Run-Pool | 6,000 | 0 | 0 | 0 | 0 | 1 | 0.0002 | 112–114 | Pool Head, Body/Tail | 36,556 | 1 | 0.0000 | 0 | 0 | 2 | 0.0001 |

### 4.6.1 *O. mykiss* observations

A total of 112 *O. mykiss* juveniles and 30 adults were observed in June 2009, while 600 juveniles and 101 adults were observed in July 2009, a ratio of adults to juveniles of approximately 1:4 and 1:6, respectively for the two surveys. The between-site comparison shows similar longitudinal trends, with juvenile and adult *O. mykiss* density generally decreasing in the downstream direction (Table 4-6), the same trend observed in the July surveys (Table 4-6 and Figure 6). In the June and July surveys, the greatest abundance of *O. mykiss* occurred within riffles near RM 50.6 (Table 4-6). In June, 50 juveniles were observed at the upstream end of Riffle A7 (Site 1, NSO 14) while 46 were observed at this location in July. In June, 30 juveniles were seen in the run habitat below Riffle A7 (Site 2); however, only 2 juveniles were seen in the run head habitat (NSO 15) at this location in the July surveys. Adult *O. mykiss* abundance was similarly low for both time periods within and near the Riffle A7 site and for sites downstream, with 0 fish observed in June and only 4 fish observed in July. For sites within and near Riffles 3B and 21, the counts of juvenile and adult *O. mykiss* were greater in July 2009 than in June 2009. No juvenile or adult *O. mykiss* were observed within the vicinity of Riffle 7 for either the June or July 2009 surveys.

It should be noted that the June 2009 data were collected from sites established in past years and targeted based on prior years' data as likely areas of relatively high *O. mykiss* abundance. The area surveyed during the July surveys was greater (by an order of magnitude in most cases) than in June (Table 4-6). The June survey method, which reoccupies the same habitat units and areas on an annual basis, produces a yearly index with which to evaluate yearly trends, assuming reoccupied habitat units and areas are representative of the entire reach. The method of bounded counts estimation used in July 2009 produces a population estimate, with appropriate confidence intervals, that, due to the incorporation of multiple passes in each unit and greater area searched in each unit and along the reach, can be used to evaluate habitat- and reach-wide distribution patterns.

### 4.6.2 Chinook salmon observations

A total of 1,897 Chinook salmon juveniles were observed June, while 4,423 juveniles observed in July (Table 4-5). Three times as many Chinook salmon juveniles were observed at riffle habitat (Site 1, NSO 14) of Riffle A7 in July than in June; however, a greater number of juveniles were observed at the run habitat (Site 2) in June than in the run head habitat (NSO 15) in July (Table **4-6**). Greater numbers of Chinook salmon juveniles were observed within Sites 1 and 2 of Riffle 3B (NSO 33–35) for July than June. Relatively few juveniles were observed within the vicinity of Riffles 7 and 21 during both the June and July 2009 sampling periods (Table 4-6). Although a stream-type life history strategy is not believed to be common for Chinook salmon in the Tuolumne River, the presence of juveniles in mid-summer indicates that conditions (e.g., water temperature, food availability) in summer 2009 were suitable for survival in upper portions of the reach.

# 5 REFERENCES

Cannon, T.C., and T. Kennedy. 2003. Snorkel survey of the lower American River 2003. Prepared by Fishery Foundation of California, San Francisco for U.S. Fish and Wildlife Service, Central Valley Project Improvement Program, Sacramento, California.

Dolloff, A., J. Kershner, and R. Thurow. 1996. Underwater observations. Pages 533–551 *in* B. R. Murphy and D. W. Willis, editor. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Edmundson, E., F. E. Everest, and D. W. Chapman. 1968. Permanence of station in juvenile Chinook salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 25: 1453–1464.

Ford, T., and S. Kirihara. 2009. 2009 Lower Tuolumne River annual report. Report 2009-5: 2009 snorkel report and summary update. Prepared by Turlock and Modesto Irrigation Districts, California and Stillwater Sciences, Berkeley, California for Federal Energy Regulatory Commission, Washington, D.C. http://tuolumnerivertac.com/Documents/2009Snorkel.pdf

Hankin, D.G. and M. Mohr. 2001. Improved two-phase survey designs for estimation of fish abundance in small streams. Preprint from David G. Hankin, Department of Fisheries Biology, Humboldt State University, Arcata, California.

Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45: 834–844.

McCain, M. E. 1992. Comparison of habitat use and availability for juvenile fall Chinook salmon in a tributary of the Smith River, California. FHR Currents. No. 7. USDA Forest Service, Region 5.

McBain and Trush. 2004. Habitat maps for the upper 15.8 miles of the gravel bedded reach. Appendix D *in* Coarse sediment management plan for the lower Tuolumne River. Revised final report. Prepared by McBain and Trush, Arcata, California for Tuolumne River Technical Advisory Committee, Turlock and Modesto Irrigation Districts, USFWS Anadromous Fish Restoration Program, and CALFED Bay Delta Authority.

Mesick, C., J. McClain, D. Marston, and T. Heyne. 2007. Draft limiting factor analyses & recommended studies for fall-run Chinook salmon and rainbow trout in the Tuolumne River, attachment 2 to USFWS comments on FERC study plan. http://elibrary.FERC.gov/idmws/file_list.asp?accession_num=20070314-0089 [Accessed 10 October 2008].

Moyle, P. B. 2002. Inland fishes of California. Revised edition. University of California Press, Berkeley.

Stillwater Sciences. 2002. Stream temperature indices, thresholds, and standards used to protect coho salmon habitat: a review. Unpublished white paper. Prepared by Stillwater Sciences, Arcata, California for Campbell Timberland Management, Fort Bragg, California.

Stillwater Sciences. 2008a. Population size estimates of resident *O. mykiss* in the lower Tuolumne River. Study plan. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District.

Stillwater Sciences. 2008b. July 2008 population size estimate of *Oncorhynchus mykiss* in the Lower Tuolumne River. Prepared for the Turlock Irrigation District and the Modesto Irrigation District by Stillwater Sciences, Berkeley, CA. October

Stillwater Sciences. 2009. Study Plan for Population Size Estimates of *O. mykiss* in the lower Tuolumne River. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District. January

Sullivan, K., D. J. Martin, R. D. Cardwell, J. E. Toll, and S. Duke. 2000. An analysis of the effects of temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria. Draft report. Prepared for Sustainable Ecosystems Institute, Portland, Oregon.

Sullivan, K. J. J. Tooley, K. Doughty, J. E. Caldwell, P. Knudsen. 1990. Evaluation of prediction models and characterization of stream temperature regimes in Washington. Timber/Fish/Wildlife Report Number TFW-WQ3-90-006. Washington Department of Natural Resources, Olympia, Washington.

Thomas, J. A., and K. D. Bovee. 1993. Application and testing of a procedure to evaluate transferability of habitat suitability criteria. Regulated Rivers: Research and Management 8: 285–294.

TID/MID (Turlock Irrigation District/Modesto Irrigation District). 2005. Ten year summary report of Turlock Irrigation District and Modesto Irrigation District pursuant to Article 58 of the license for the Don Pedro Project, No. 2299. 1 Volume.

TID/MID. 2007. Tuolumne River fisheries study plan - Don Pedro Hydroelectric Project (FERC No. 2299). Prepared by T. Ford, N. Hume, S. Wilcox, and R. Yoshiyama for Turlock Irrigation District and Modesto Irrigation District.
http://elibrary.FERC.gov/idmws/file_list.asp?accession_num=20070718-0082 [Accessed 10 October 2008].

TID/MID. 2008. Report 2007-7: 2007 Rainbow trout data summary report. *In* 2007 report of Turlock Irrigation District and Modesto Irrigation District pursuant to Article 39 of the license for the Don Pedro Project, No. 2299.

TID/MID. 2009. 2008 report of Turlock Irrigation District and Modesto Irrigation District pursuant to Article 39 of the license for the Don Pedro Project, No. 2299.

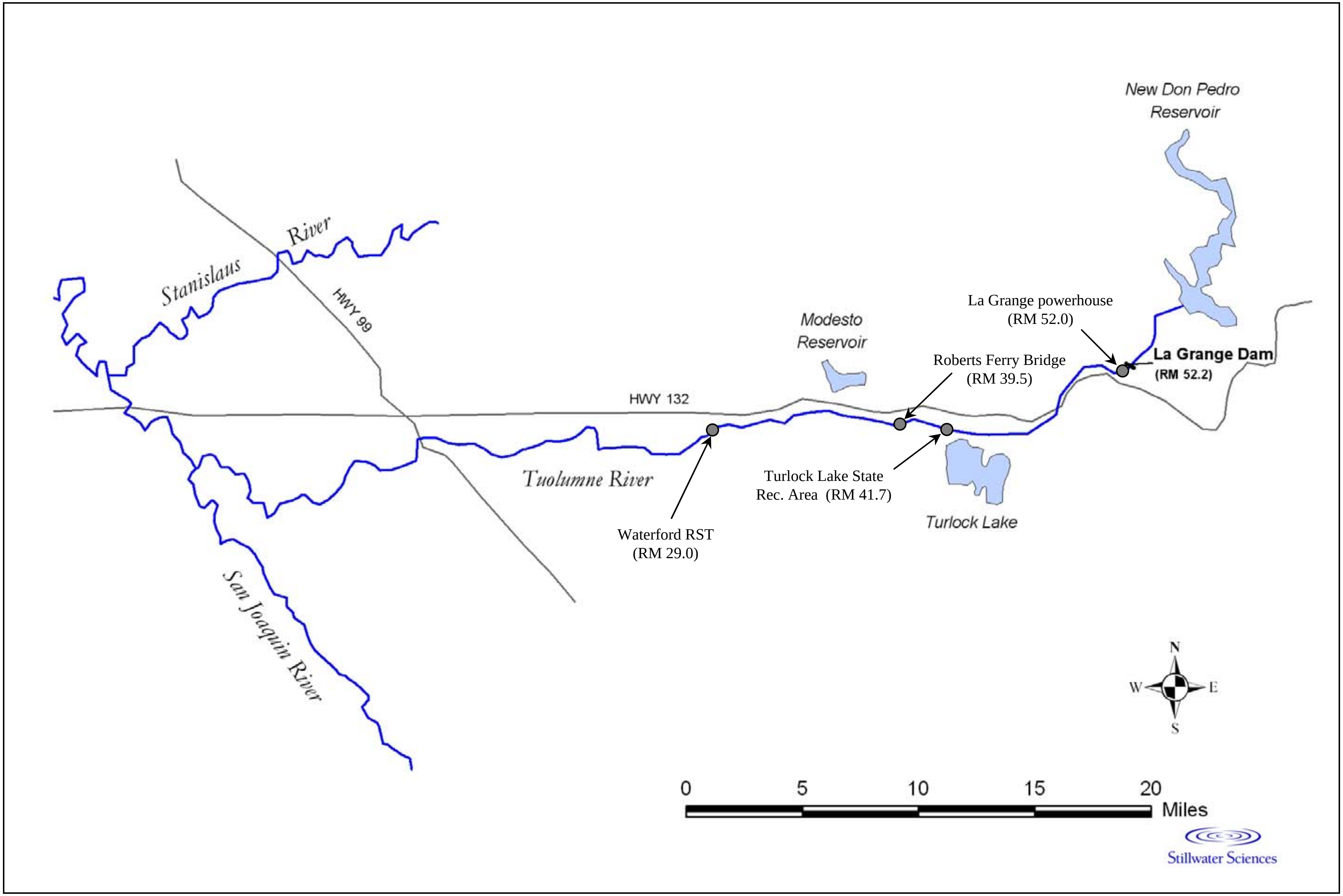


**Figure 1. Survey reach for March and July 2009 *O. mykiss* snorkel surveys in the lower Tuolumne River.**

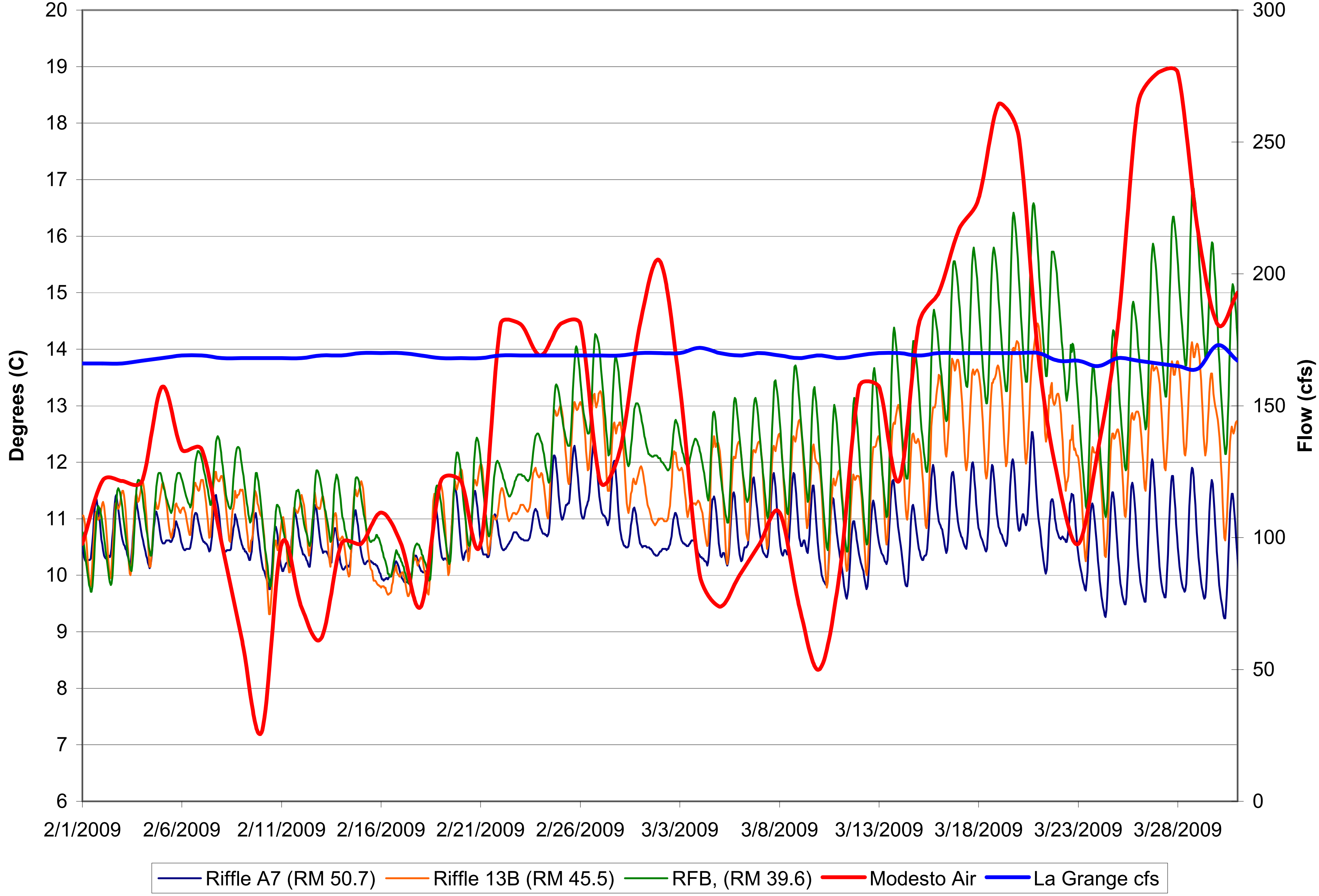


**Figure 2a.** Hourly water temperature, daily average air temperature, and daily average flow for the study reach from 1 February to 31 March 2009.

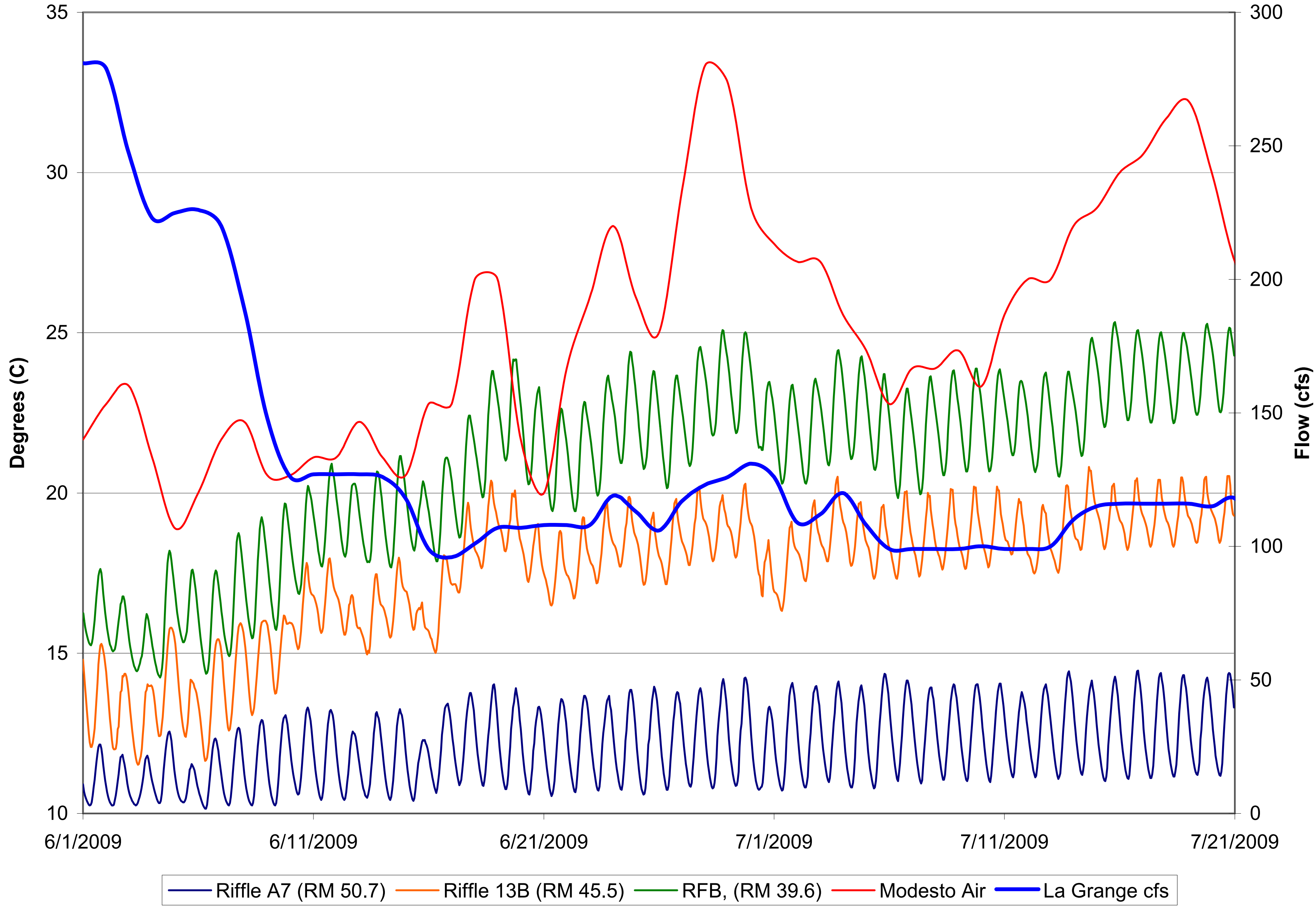


**Figure 2b.** Hourly water temperature, daily average air temperature, and daily average flow for the study reach from 1 June to 21 July 2009.

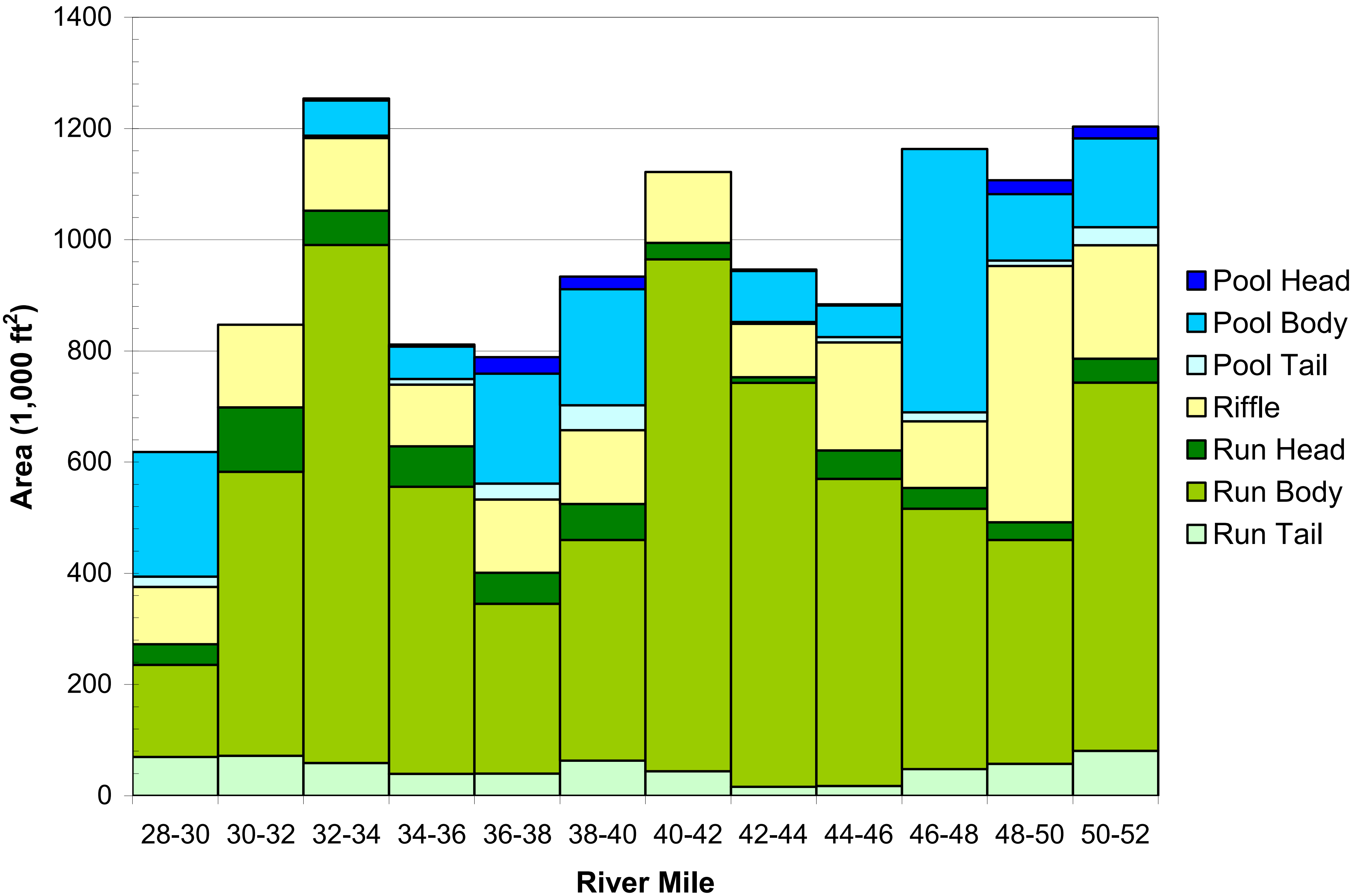


**Figure 3.** Longitudinal distribution of major habitat type areas by river mile in the lower Tuolumne River (RM 52–30) for March and July 2009 surveys.

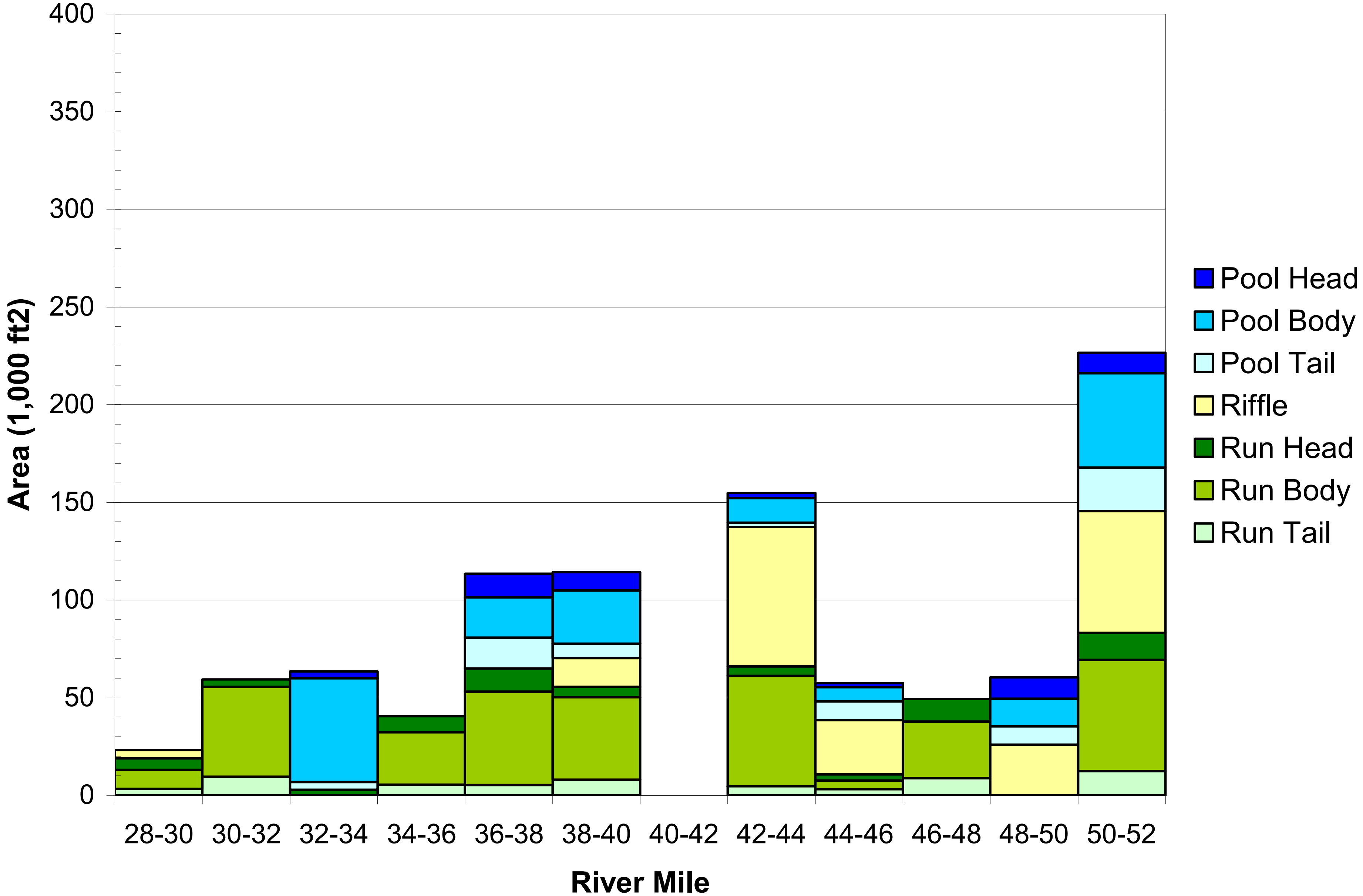


**Figure 4a.** Longitudinal distribution of major habitat type areas sampled by river mile in the lower Tuolumne River (RM 52–30) for March 2009 survey.

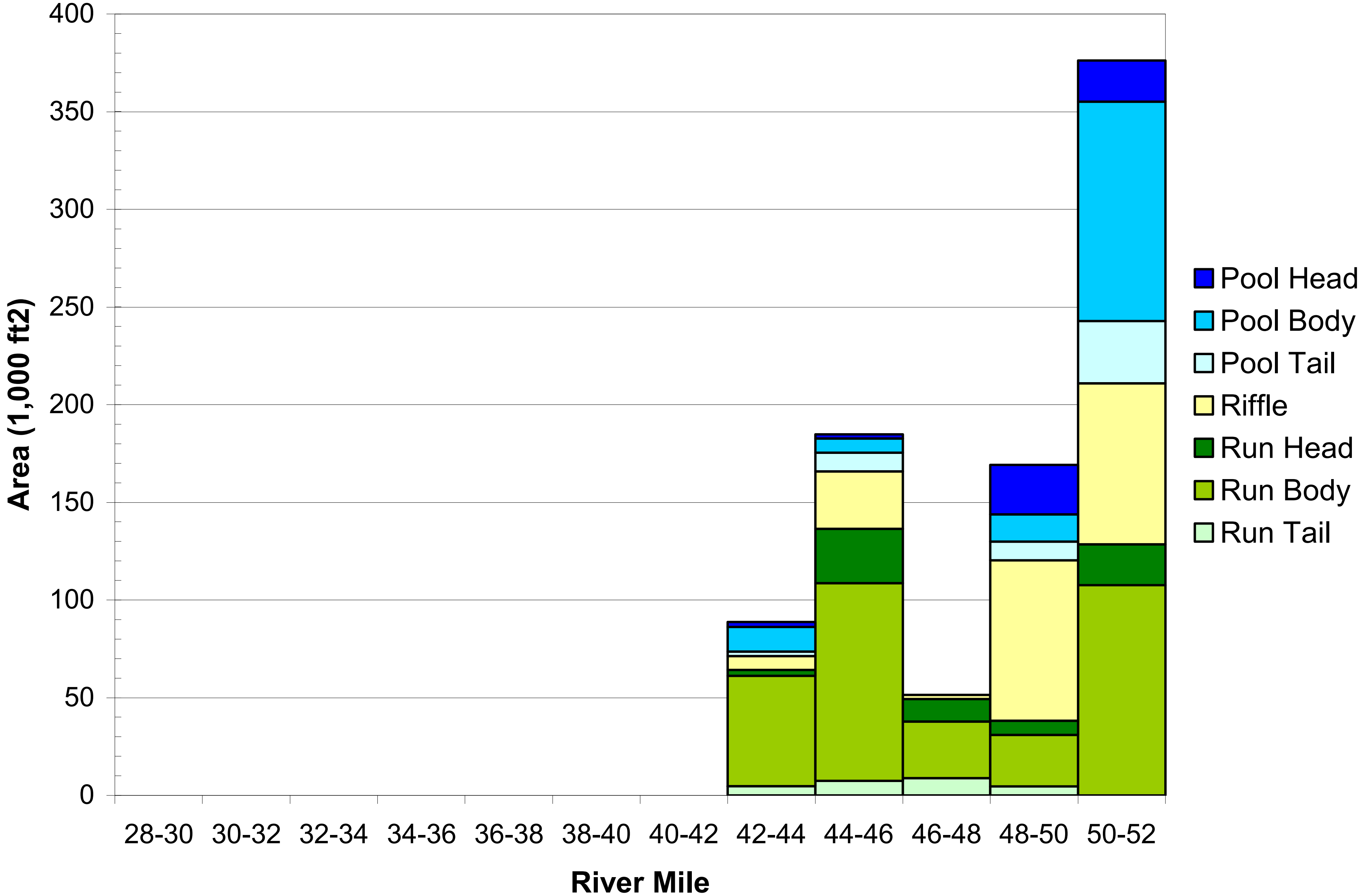


**Figure 4b.** Longitudinal distribution of major habitat type areas sampled by river mile in the lower Tuolumne River (RM 52–30) for July 2009 survey.

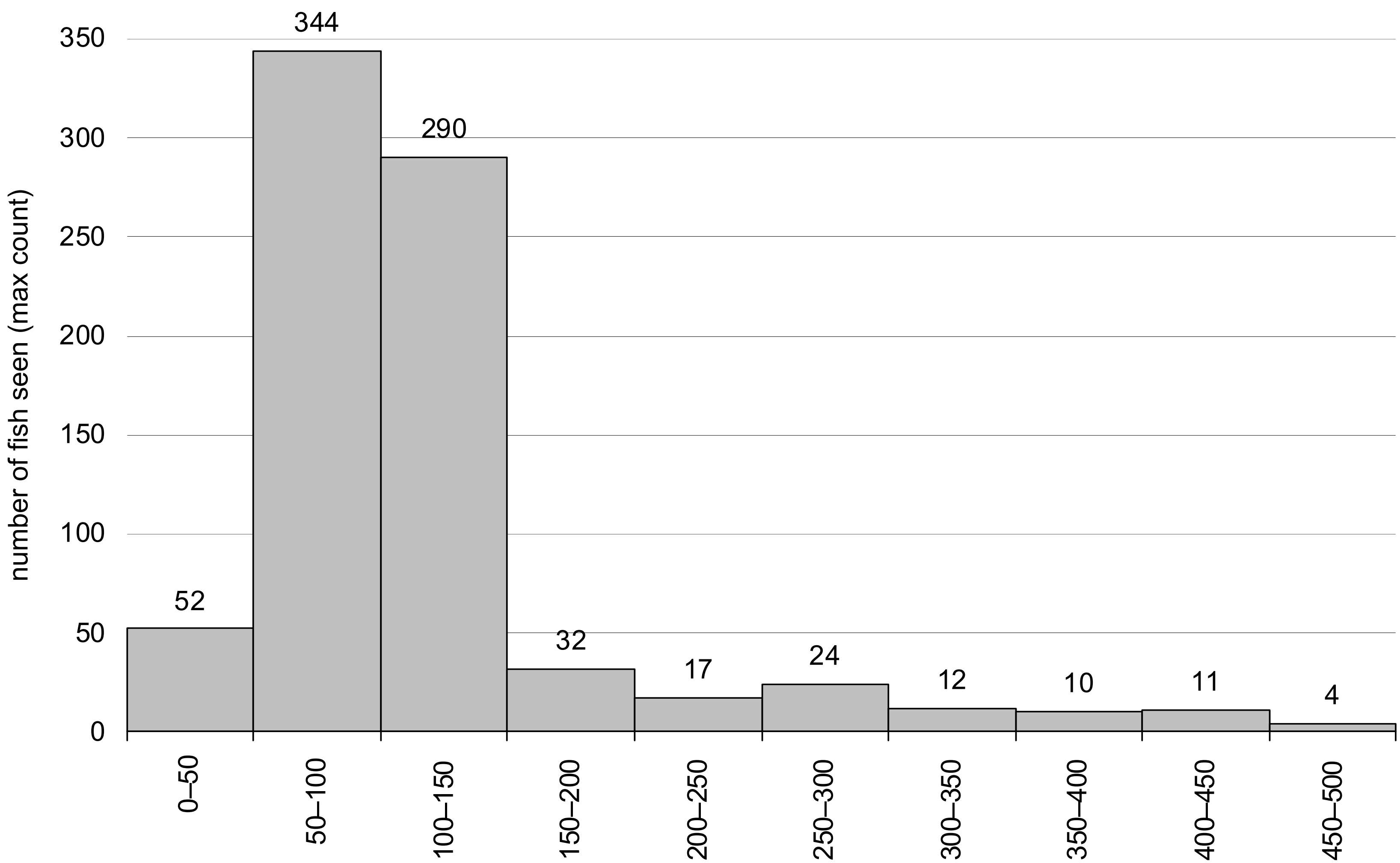


**Figure 5**. Size distribution of *O. mykiss* observed in Tuolumne River snorkel surveys, July 2009. For units receiving multiple passes, the count is from the pass with the largest count for that size class.

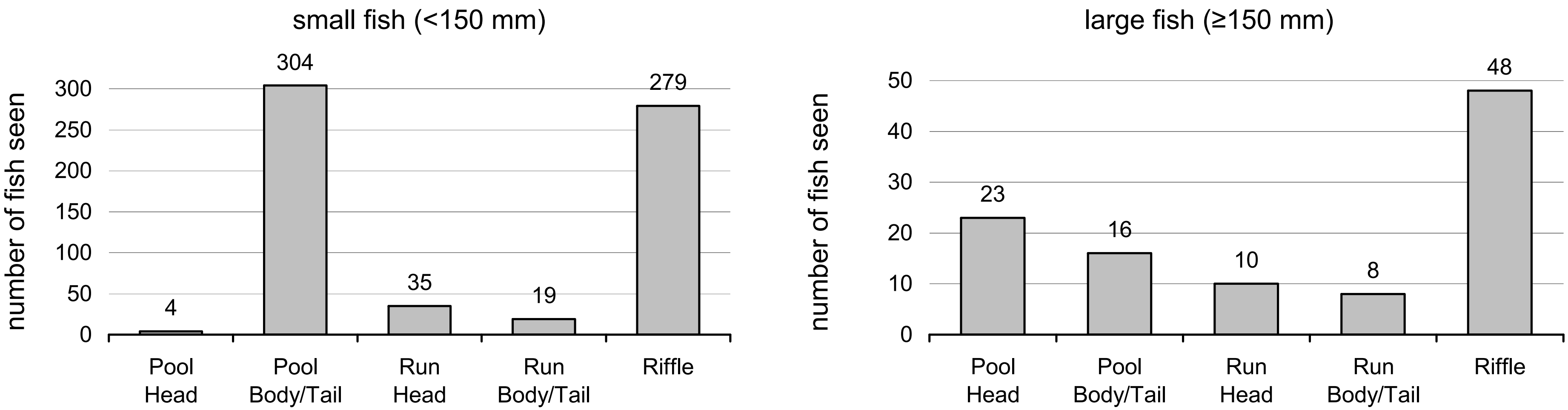


**Figure 6a**. Distribution of observed *O. mykiss* counts among habitat types, by size class. For units receiving multiple passes, the count is from the pass with the largest count.

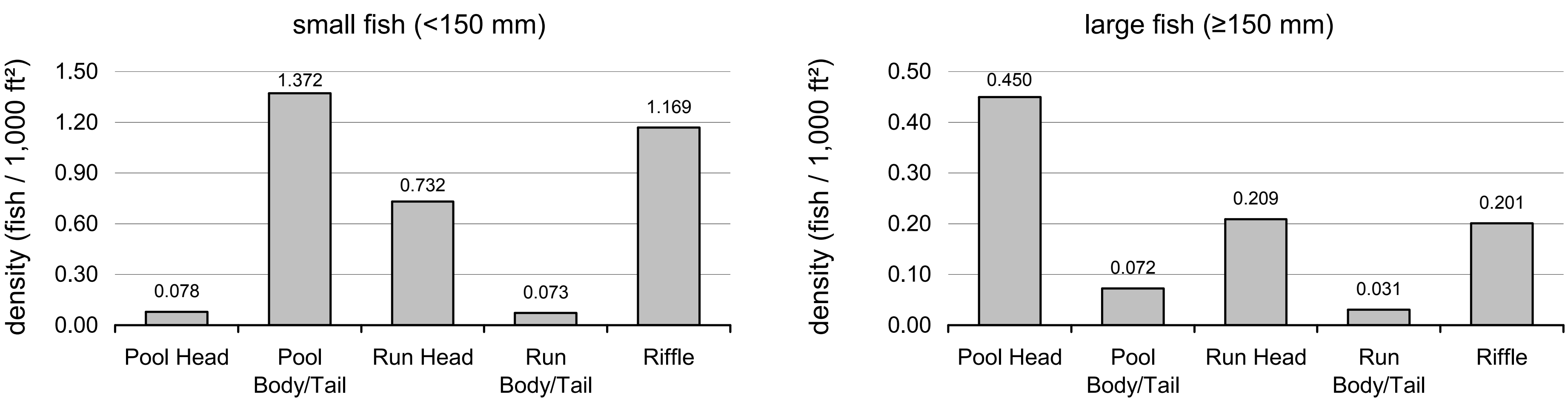


**Figure 6b**. Distribution of observed *O. mykiss* density based on maximum count among habitat types, by size class.

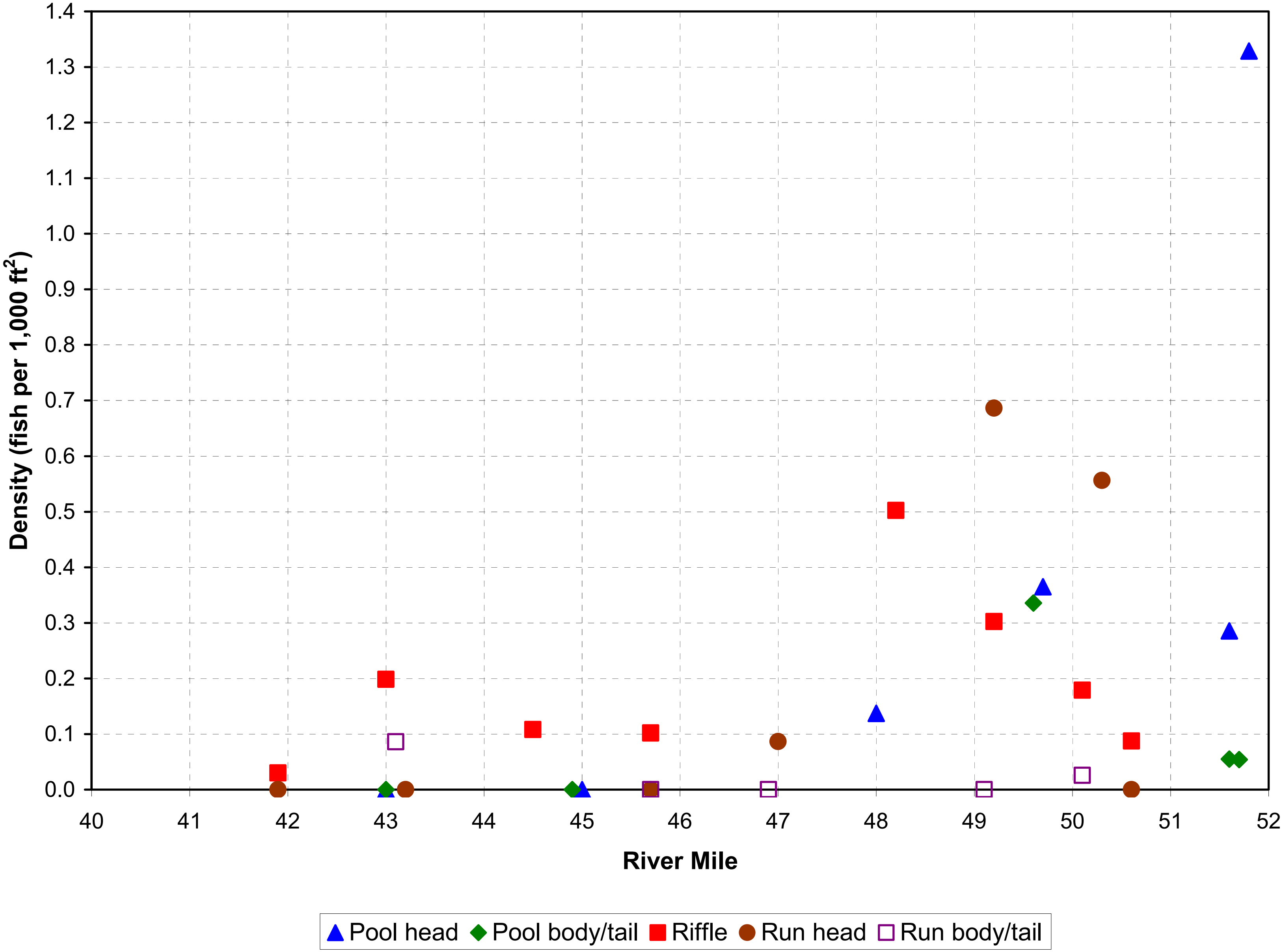


**Figure 7.** July 2009 adult *O. mykiss* density by river mile based upon maximum count in sampling units of each habitat type.

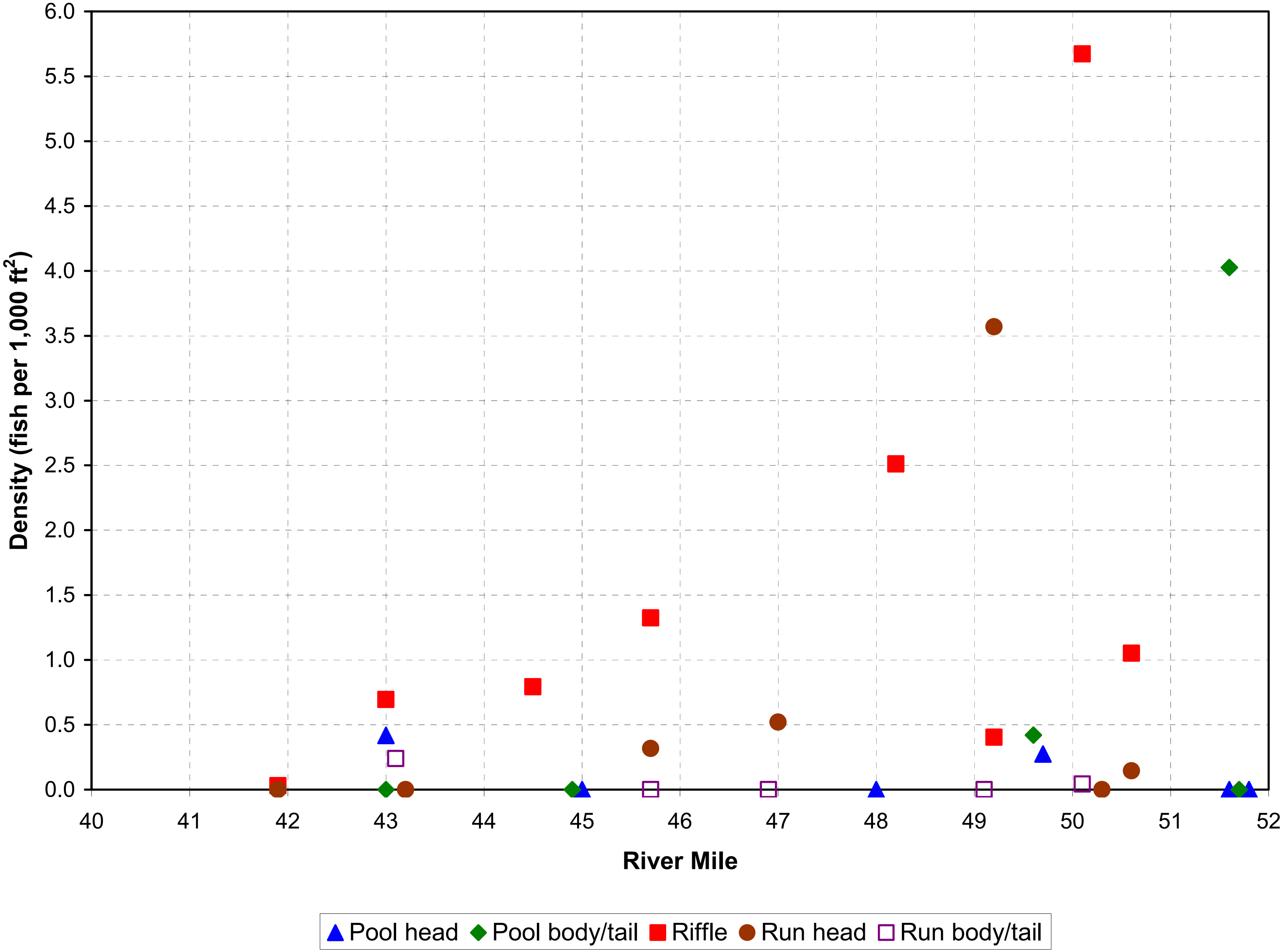


**Figure 8.** July 2009 juvenile *O. mykiss* density by river mile based upon maximum count in sampling units of each habitat type.

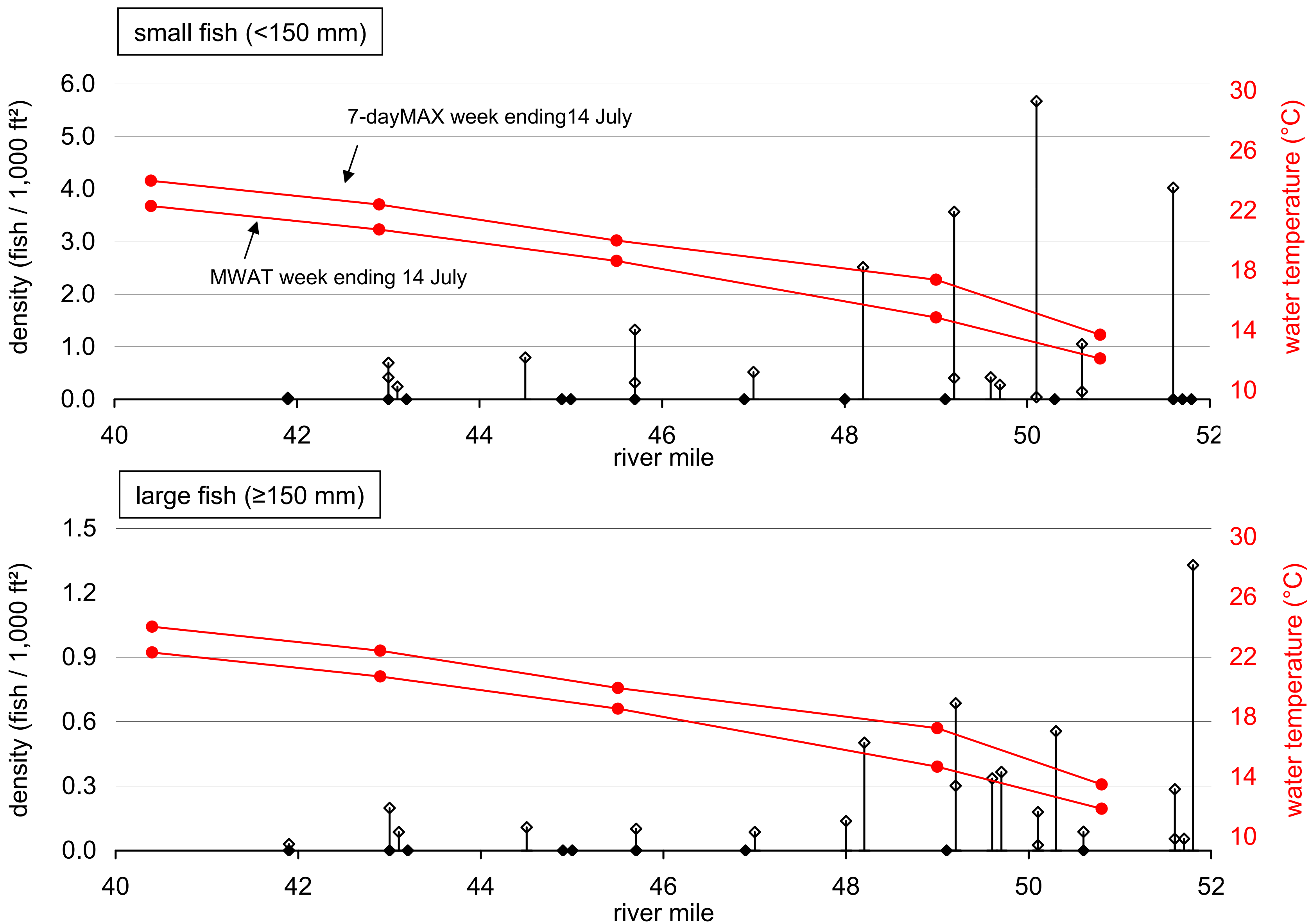


**Figure 9**. Longitudinal distribution of observed *O. mykiss* and water temperature in the lower Tuolumne River, July 2009. Solid diamonds are observed zeros, open diamonds are observed non-zero values.

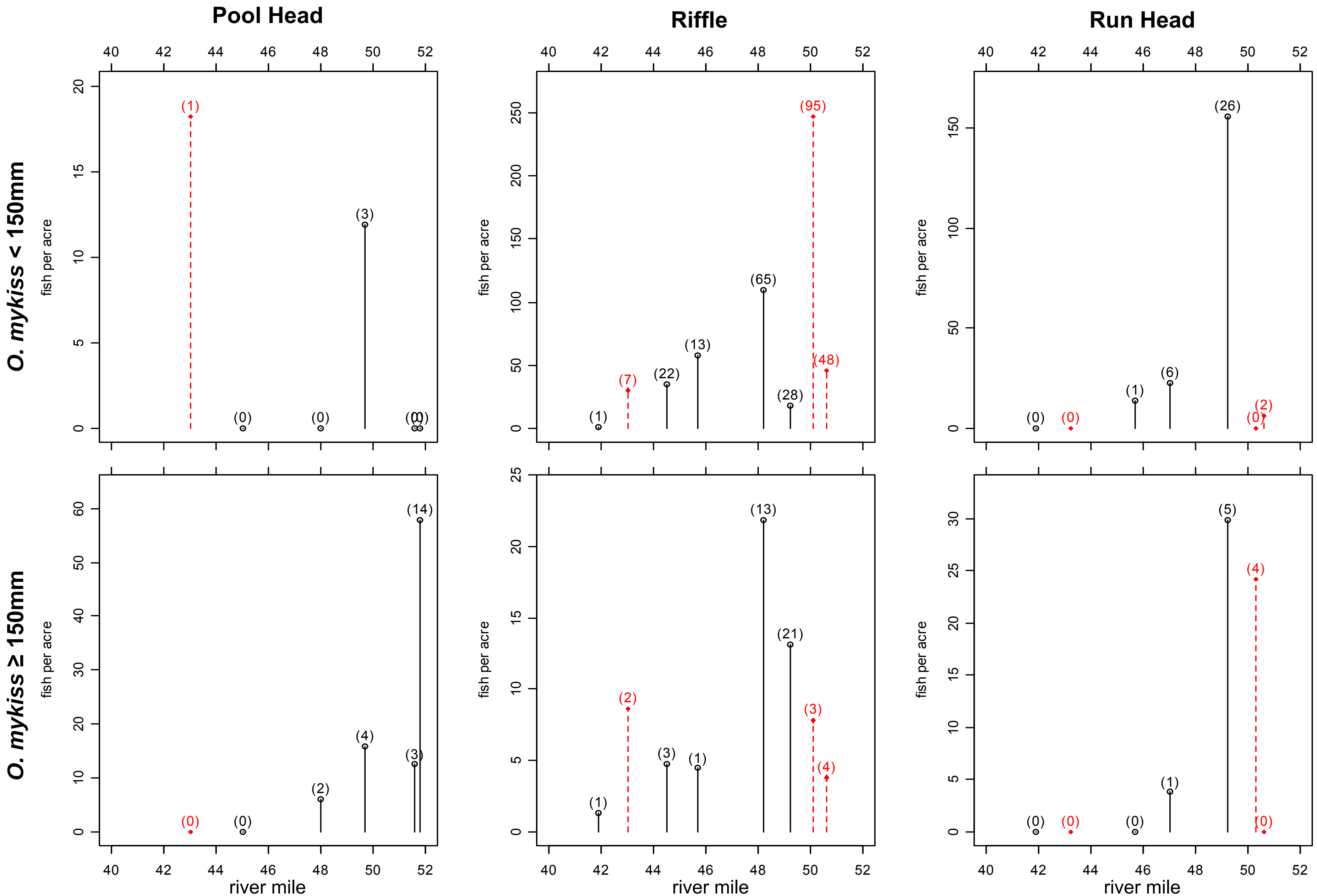


**Figure 10**. Observed densities of *O. mykiss* in individual sampling units in the July 2009 surveys. Densities are maximum dive counts (in parenthesis) divided by the area sampled. Restoration sites are shown with broken lines (FOT [RM 43.0], CDFG 2001 [RM 50.3], CDFG 2003 [RM 50.6]). Non-restoration sites are shown with solid lines.

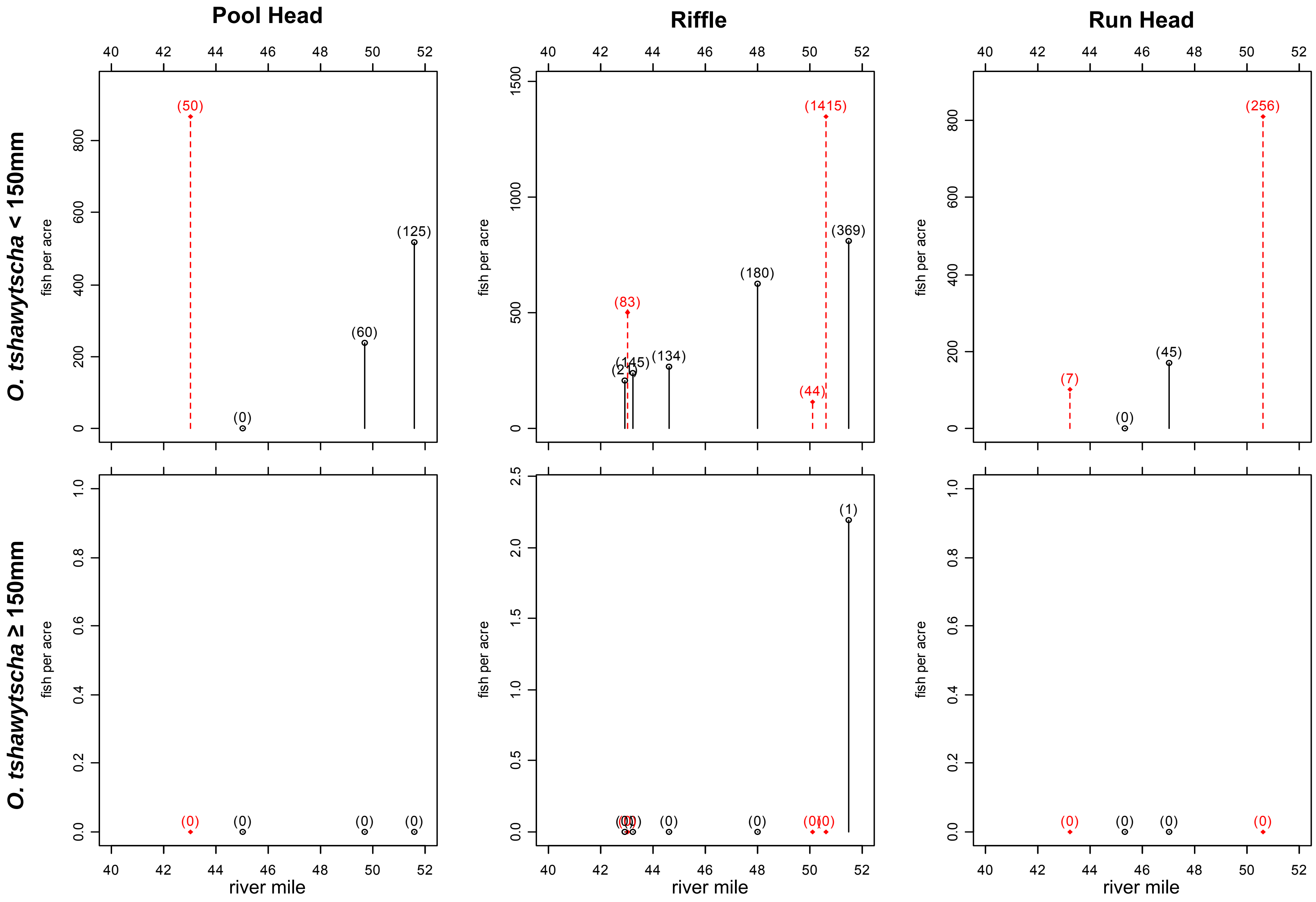


**Figure 11**. Observed densities of *O. tshawytscha* in individual sampling units in the March 2009 surveys. Densities are maximum dive counts (in parenthesis) divided by the area sampled. Restoration sites are shown with broken lines (FOT [RM 43.0], CDFG 2001 [RM 50.3], CDFG 2003 [RM 50.6]). Non-restoration sites are shown with solid lines.

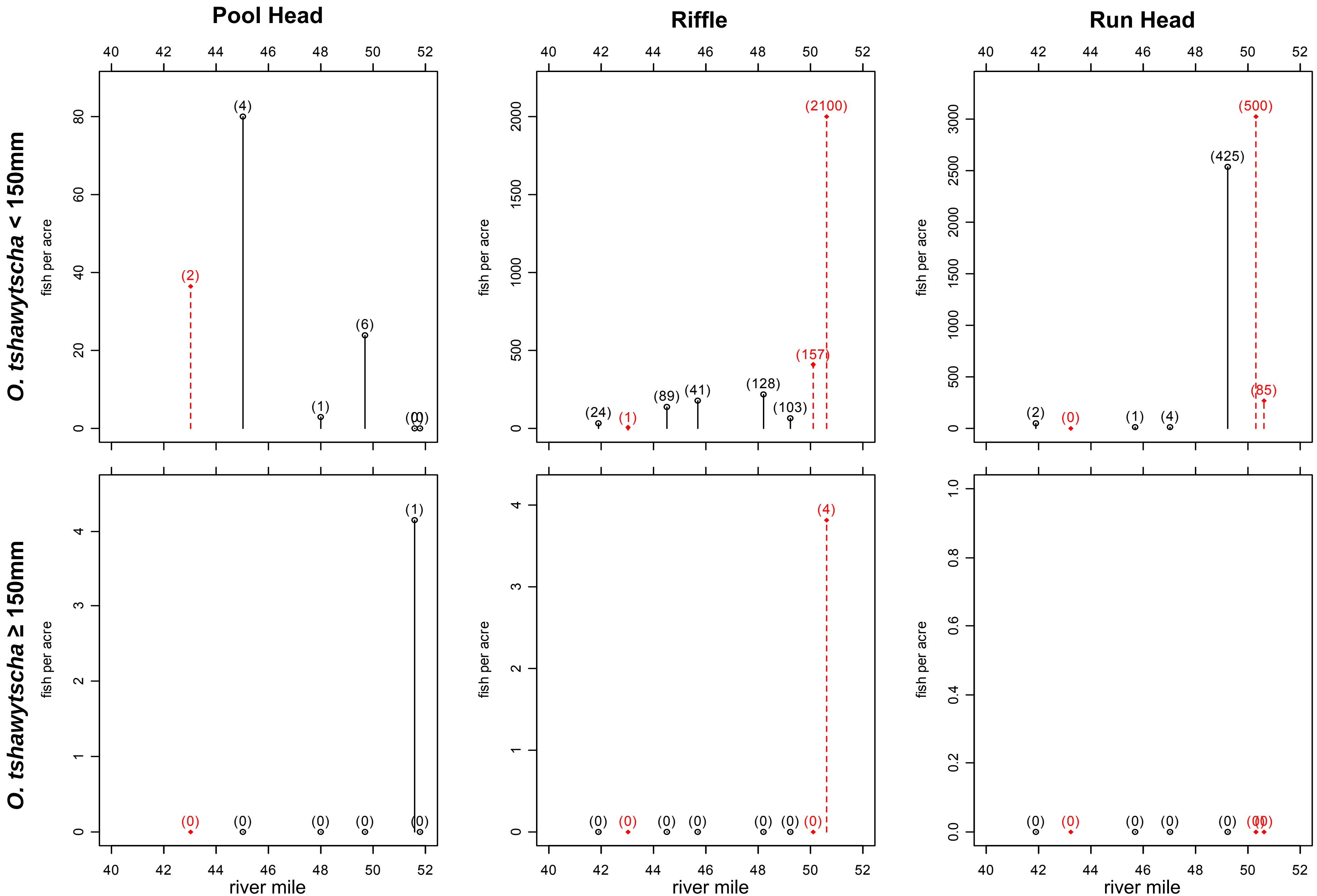


**Figure 12**. Observed densities of *O. tshawytscha* in individual sampling units in the July 2008 surveys. Densities are maximum dive counts (in parenthesis) divided by the area sampled. Restoration sites are shown with broken lines (FOT [RM 43.0], CDFG 2001 [RM 50.3], CDFG 2003 [RM 50.6]). Non-restoration sites are shown with solid lines.