Lower Kings River

2019 Fish Population Snorkel Survey

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Introduction

The Kings River Fisheries Management Program (KRFMP) collaboratively developed and implemented by CDFW, KRCD and KRWA, provides support of annual monitoring of the species composition, abundance/density, geographic distribution, and size distribution of resident trout and other fish in the lower river, between Pine Flat Dam and the Green Belt Parkway. The KRFMP has used backpack electroshocking at selected (shallow, wadable) locations annually survey fish abundance. Results from these surveys indicate that few larger trout are collected in electrofishing while anglers report catching larger fish, suggesting that the electrofishing surveys are not necessarily representative of the trout population. It has been hypothesized that resident trout are inhabiting areas of the river where water depth and velocity do not allow backpack electrofishing. To test this hypothesis the program commissioned a snorkel survey during the fall of 2019 to survey larger reaches of the river than the electrofishing surveys with greater habitat diversity (greater depths and velocities) to provide an independent assessment of fish community characteristics. In the fall of 2019, the Kings River Conservation District (KRCD) contracted with FISHBIO to conduct a snorkel survey to characterize fish populations on the lower Kings River, below Pine Flat Reservoir. The survey was intended to provide complimentary information to the annual electrofishing depletion surveys that have been conducted, although the exact methodology of those surveys has varied over time (KRCD 2018).

Among the reasons for conducting a snorkel survey complimentary to the annual depletion estimates was the desire to evaluate trout abundance based on sampling a larger fraction of the available habitat. In order to achieve the desired sampling coverage and account for any longitudinal gradient in fish abundance, a visual survey (direct observation dive count) was chosen. Direct observation dive counts (i.e., snorkel surveys) are a cost-effective, non-invasive means of estimating abundance based on visual counts, which do not require fish handling (Allen and Gast 2007), making this the preferred method for listed or sensitive species.

The main objective of this survey was to characterize the size distribution of trout (<150 mm, 151-300 mm, and >300 mm) and other fish by reach and habitat type, and to estimate abundance of each size class. We believe the visual survey provides useful, complimentary information to guide fishery management on the lower Kings River. The methods and results of the visual surveys are described in this summary report.

Material and Methods

Habitat Mapping and Unit Selection

This survey was focused on the reach of the Kings River below Pine Flat Reservoir, extending from Pine Flat Road Bridge (approximately 0.5 mile downstream of the dam) to just over 11 miles downstream, near the Greenbelt County Park. For purposes of abundance estimation, this reach was subdivided into two sections, above (5.0 river miles) and below (6.2 river miles) the Alta/Cobbles weir. This division was motivated by the different management framework and sportfishing regulations applicable to each section, whereby "General Regulations" (five trout limit, open all year) apply to the river above the Alta/Cobbles Weir, and special regulations (zero trout, artificial lures and barbless hooks only, open all year) are in place below the weir.

In order to obtain an accurate estimate of fish abundance, the whole reach was categorized into distinct habitat units based on a three-category classification (i.e., riffle, run, pool), using high-resolution digital bathymetric data (provided by KRCD) along with Google Earth imagery. Generally, riffles are defined by shallow depth, fast current and turbulent water, runs are characterized by intermediate depths with moderate to fast current, with little or no turbulence. Pools are generally deeper than runs, with slow current velocity. In addition, the length of each unit was remotely estimated in Arcmap by digitizing the centerline of the river and splitting the line using the mapped habitat points. The lengths of each split line section were calculated and joined to the respective habitat points. Within each habitat category conducive to visual surveys (run, riffle, pool; e.g. Figure 1), units were sampled systematically by generating a random number between 1 and 5, and subsequently surveying every k^{th} unit in a downstream direction. Depending on habitat type, approximately one fifth of sampleable units were surveyed (see Table 1). A sub-sample of the surveyed units was randomly selected for calibration of dive counts using the Method of Bounded Counts (MBC), as described in more detail below. The boundaries between units were designated using Global Positioning System (GPS) waypoints to facilitate locating pre-selected habitat units in the field.

Figure 1. Example of riffle habitat near Pine Flat Dam.

Dive Counts

Snorkel surveys were conducted on November 19-21, 2019, at flows ranging from 313 cubic feet per second (cfs) to 367 cfs at Pine Flat Dam (according to U.S. Army Corps of Engineers Sacramento District Water Control Data System; http://www.spk-wc.usace.army.mil/). A standardized protocol was followed to enable comparisons with other surveys and to minimize variation due to sampling error. The number of divers needed for a snorkel survey was dependent on the width of the river, but was chosen to ensure visual coverage of the river cross-section during snorkeling. As all river sections to be surveyed required three or more divers for complete visual coverage of the channel width (channel widths ranged from 10 to 75 feet), parallel dive lanes were established prior to snorkeling. Dive lanes were assigned randomly to divers at each habitat unit surveyed to minimize the effects of diver familiarity with the physical habitat and fish populations on dive counts. Care was taken to minimize disturbance of fish prior to sampling each unit.

Prior to sampling, the length and width of each selected habitat unit was verified with a digital rangefinder. Additional environmental data collected at each site included start time, estimated maximum depth, estimated average depth, and visibility (distance at which a 150 mm fish could be identified).

Divers generally entered the stream at the upstream border of the survey reach and counted fish within their respective dive lanes as they proceeded downstream in unison with the other divers. At the bottom of the unit, two divers proceeded upstream along opposite banks to sample the stream margin. Riffles were generally surveyed in an upstream direction, when depth and velocity allowed. Divers recorded fish counts on a wrist-mounted dive slate and assigned a size category to each observation of rainbow trout and other fish species (less than 150 mm, 150-300 mm, and greater than 300 mm). Divers were equipped with two fishing lures (150 mm and 300 mm in length) to facilitate the correct estimation of fish size and account for underwater size distortion. When approaching the boundary of the survey unit, divers carefully monitored fish holding close to the unit boundary and included fish that crossed the unit boundary. Fish observed moving between lanes were noted immediately after the dive to avoid multiple counts of the same fish.

Obtaining accurate counts of resident rainbow trout was the priority of this survey. Other observed species (and their size categories) were recorded, so long as this did not compromise counts of the focal species.

Fish Abundance

To estimate total abundance of focal fish species, a two-phase estimator was used for each habitat type surveyed (runs, riffles, and pools) to “calibrate” single-pass counts. First phase units were selected for single-pass counts, while a subset of these was selected for second-phase counts (multiple, or “bounded” counts). For each unit selected for a bounded count, individual pass counts were ordered from highest to lowest, and unit abundance was estimated as

$$\mathbf{!}_{!\cdot\cdot} = \%_{\#} + (\%_{\#} - \%_{\#\$\%})$$

where $\hat{y}_k$ = the bounded count estimate of "true" abundance in unit *k*, d_m is the largest of the four counts for the unit, and d_{m-1} is the second largest of the four counts.
The estimate of error, or mean square error (MSE), around the unit abundance estimate was calculated as

$$MSE_k = (d_m - d_{m-1})^2$$

For each stratum in which surveys were conducted, the total stratum abundance ($\hat{Y}_D$) is estimated as

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

where N is the total number of habitat units within stratum *D*, and $\bar{\hat{y}}_D$ is the mean estimated total abundance for all units in stratum *D* for which bounded counts were performed. The last term in the equation is the mean of the first pass counts in habitat units that were dove only once ($\bar{x}_1$) divided by the mean of the first pass counts in habitat units that were dove four times ($\bar{x}_2$). This is an adjustment factor that accounts for the observation probability during the snorkel surveys (i.e., the difference between a unit abundance derived from a single-pass survey versus a four-pass survey). Estimates of error around the total stratum abundance were calculated as

$$V(\hat{Y}_D) = N^2(1-f_1)\frac{s_1^2}{n_1} + N^2(1-f_2)\left(\frac{\bar{x}_1}{\bar{x}_2}\right)^2\frac{s_{2|1}^2}{n_2}$$

where f_1 and f_2 are the sampling fractions for the first and second phases, respectively; n_1 and n_2 are the numbers of units that are sampled in the first and second phases, respectively. The variation in the unit counts in the first phase, s_1^2, was calculated as

$$s_1^2 = \frac{1}{n_2 - 1}\sum_{k=1}^{n_2}\left(\hat{y}_k - \bar{\hat{y}}_D\right)^2$$

where $\hat{y}_k$ is the estimated abundance in the k^{th} second phase sample and $\bar{\hat{y}}_D$ is the mean abundance over all second phase samples in stratum *D*. The conditional variation (i.e., variation that arises from selecting particular second phase samples), $s_{2|1}^2$, was calculated as

$$s_{2|1}^2 = \frac{1}{n_2 - 1}\sum_{k=1}^{n_2}\left[MSE_k + \left(\hat{y}_k - \bar{\hat{y}}_D\frac{x_k}{\bar{x}_2}\right)^2\right]$$

where x_k is the first pass dive count in unit *k*.

Sampling under a stratified design such as the one employed in this study is considered independent across the different habitat strata (run, riffle, pool; *D* = 1, 2, 3), so that estimates of total abundance for each of the habitat types, $\hat{Y}_D$, and their corresponding sampling variances, $V(\hat{Y}_D)$, can be combined across strata (Thompson 2002):

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h$$

and

$$\widehat{var}(\hat{N}) = \sum_{h=1}^{L} \widehat{var}(\hat{N}_h)$$

Notably, though bias of this method is considered negligible at low abundances (less than approximately 30 individuals per unit), special scenarios can lead to a failure of this estimator. More specifically, at very low abundances of the target species, failure to observe the species (or size category) during the first pass of (all) bounded counts in a given stratum results in a zero in the denominator of the count ratio between single- and bounded count units (i.e., $Z_{(}$, see formula for estimation of total stratum abundance). In the vast majority of surveys, random or systematic sampling of a large number of units ensures that this ratio is close to 1, resulting in a slight adjustment to the estimated stratum abundance (i.e., the "bias correction").

However, the chance of estimator failure (or unrealistic estimates) increases with the number of species, size classes and habitat categories for which abundance is to be estimated. In other words, the chance of observing *at least one* individual of a particular species during one or more first-pass MBC counts for a given habitat category is relatively high (given that a sufficiently large number of units are selected for bounded counts). In contrast, the chance of observing individuals belonging to *each* of several size classes is lower, which increases the chance of estimator failure for a given size class and habitat category. As a consequence, no abundance estimates could be generated for some species within the survey reach, including sculpin, largemouth bass, white catfish, bluegill sunfish, California roach, Sacramento pikeminnow, and threespine stickleback. Although suckers, stickleback, and pikeminnow had the highest numbers, the majority of these fish were within relatively few units and many of the sample units had counts of zero. As a consequence, abundance estimates are either associated with large uncertainty (for Sacramento suckers) or could not be generated due to estimator failure (all other species).

Note that the estimates of abundance do include habitat units that were not sampled due to safety concerns, poor visibility, or depth restrictions. These units, although excluded from initial sample selection, were ascribed to particular habitat types (pool, run, riffle), and therefore estimated stratum abundance is expected to be applicable to these units.

Results

Habitat Mapping and Unit Selection

According to our classification, the 11.2 mile long reach of the Kings River between the Greenbelt County Park and the Pine Flat Road Bridge (approximately 0.5 mile downstream of Pine Flat Dam) consists of 120 distinct habitat units (26 pools, 45 riffles, 49 runs; Table 1). Of those, five pools, four riffles and five runs were excluded from sample selection due to safety, visibility or depth concerns. Snorkel surveys were conducted in 7 pools, 12 runs, and 11 riffles. Additionally, 13 of the 30 surveyed units were selected for bounded counts (Figure 2; also identified in Appendix 2). Overall, sampling was conducted in approximately 20% of available habitat types, ranging from 16.2% to 23.8%.

Table 1. Habitat composition and percentage surveyed during snorkel surveys conducted on the Kings River in November, 2019.

Reach	Habitat Type	Count of Type	Sum of Length (ft)	Percent by Length	Units Surveyed	Length Units Surveyed (ft)	Percent of Length Surveyed
Above Weir	Pool	14	12,266	46.1	4	1,991	16.2
	Riffle	19	3,489	13.2	5	971	27.8
	Run	22	10,829	40.7	7	2,105	19.4
	Total	55	26,584	100	16	5,067	19.1
Below Weir	Pool	12	10,062	30.9	3	1,615	16.1
	Riffle	26	10,599	32.5	6	2,388	22.5
	Run	27	11,910	36.6	5	2,214	18.6
	Total	65	32,571	100	14	6,217	19.1
Overall	Pool	26	22,328	37.7	7	3,606	16.2
	Riffle	45	14,088	23.8	11	3,359	23.8
	Run	49	22,739	38.5	12	4,319	19.0
	Total	120	59,155	100	30	11,284	19.1

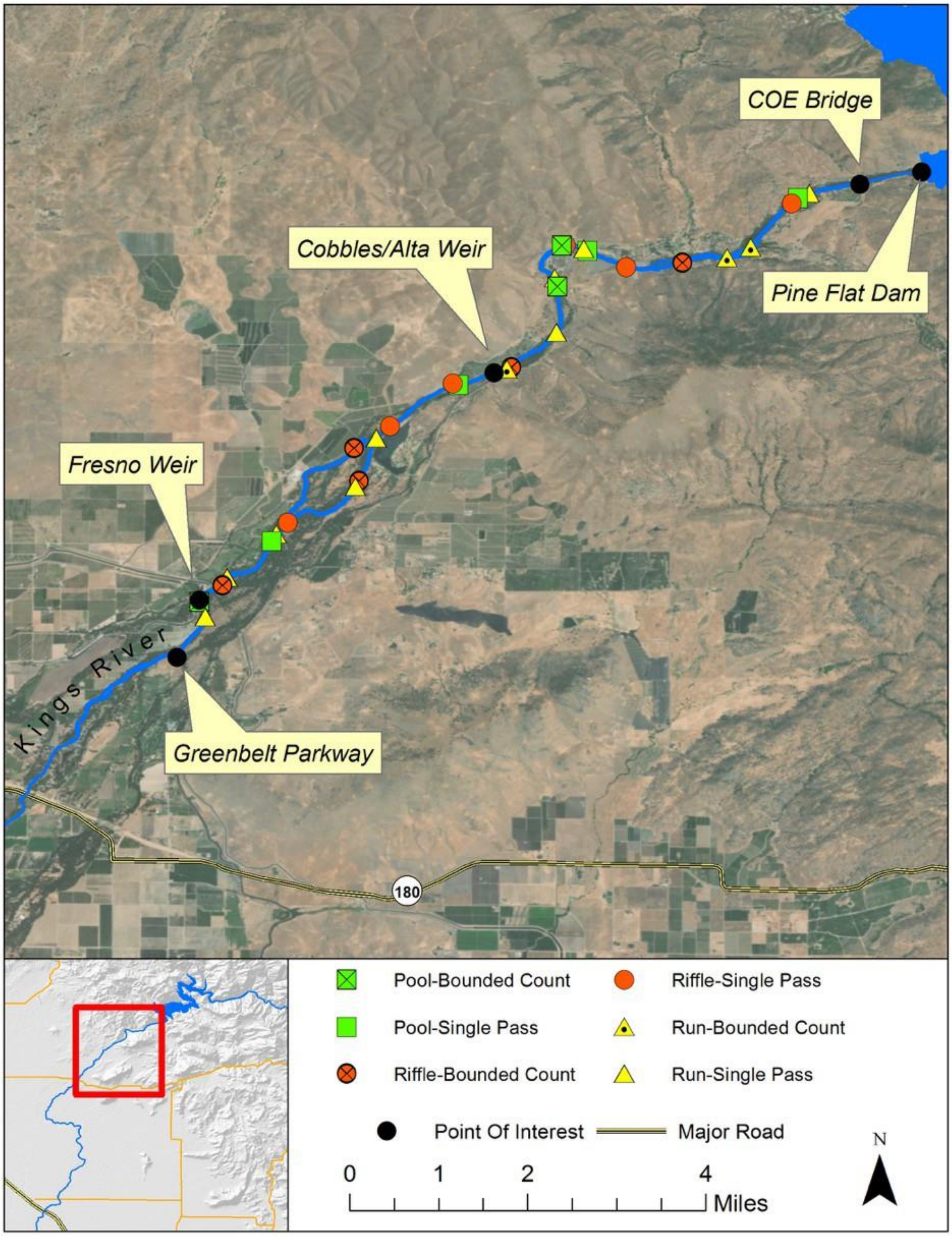

Figure 2. Map of selected sampling units on the Kings River.

Stream Characteristics

Water temperature and visibility

Temperature data were recorded at the downstream end of each unit prior to snorkeling. Instantaneous temperatures ranged from 13.5–16.1°C (56.3–61.0 °F), depending on location and time of day. Visibility was relatively constant throughout the survey, ranging from 3-3.5 ft (distance at which a 150 mm fish could be identified).

Fish Abundance

Overall, nine species of fish were observed during the Kings River snorkel survey, including rainbow trout (*Oncorhynchus mykiss*), Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow *(Ptychocheilus grandis*), California roach (*Hesperoleucus symmetricus*), sculpin (likely riffle sculpin, *Cottus gulosus*), threespine stickleback (*Gasterosteus aculeatus*), white catfish (*Ameiurus catus*), bluegill sunfish (*Lepomis macrochirus*), and black bass (likely largemouth bass, *Micropterus salmoides*; Table 2). Of note, a distinction between California roach and small pikeminnow was not possible during this survey, as individuals belonging to both species were observed in mixed schools. Only large pikeminnow could be identified with certainty, but such observations were rare with 12 adult pikeminnow across five habitat units in first-pass counts (Appendix 2). As a consequence, these two species are not distinguished in this report.

Overall, the observed species composition is nearly identical to that obtained from electrofishing surveys, with the exception of lamprey and mosquitofish. These two species were not detected during the snorkel survey due to their small size (mosquitofish) or habitat preference (in the sediment, lamprey). Abundance estimates could only be calculated for the rainbow trout and Sacramento sucker, as the comparatively low or patchy abundance of other species ("zero" counts in most habitat units/categories; see Appendix 1 and Appendix 2) causes the estimator to fail.

Table 2. Summary of first-pass counts of different species observed, by habitat type, during the snorkel survey.

Species	Size Class	Pool	Riffle	Run	Total
Rainbow trout	<150 mm	1	6	17	24
	150-300mm	5	25	27	57
	>300 mm	3	17	26	46
Threespine stickleback	NA	682	0	41	723
Sacramento sucker	NA	329	11	381	721
Sacramento pikeminnow/ California roach	NA	454	0	41	495
Sculpin (spp.)	NA	3	10	9	22
Bluegill sunfish	NA	4	0	0	4
Largemouth bass	NA	2	0	0	2
White catfish	NA	0	1	1	2

During the first pass of snorkel surveys, 127 rainbow trout were observed (9 in pools, 48 in riffles, 70 in runs; Figure 3). We estimated total abundance of approximately **1,625 rainbow trout** in the study area, or approximately 145 fish per mile (Table 3). A total of 549 trout were estimated above the Alta/Cobbles weir, and 1,076 trout below, corresponding to 109 and 174 trout per mile, respectively.

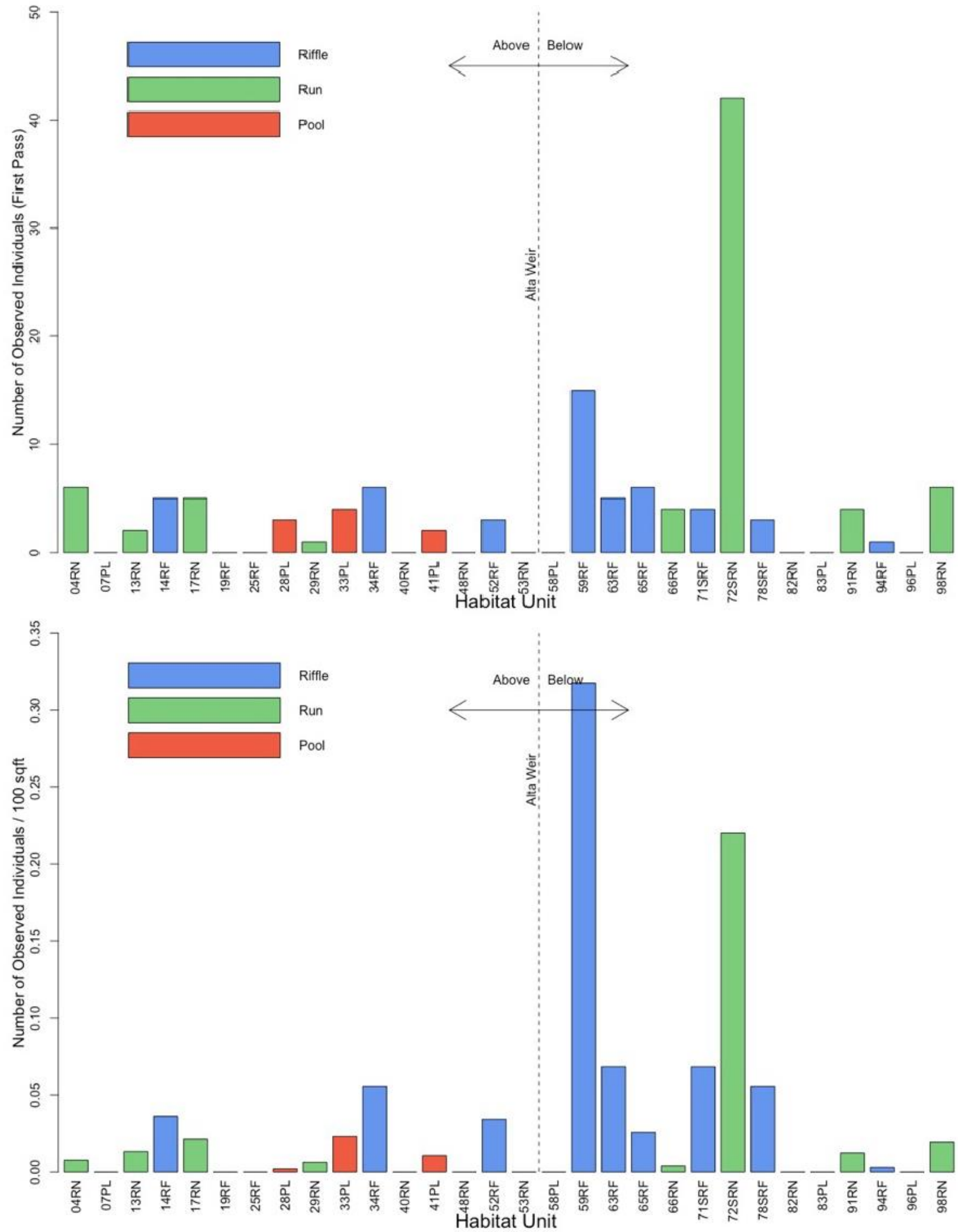

Figure 3. Number (top pane) and densities (bottom pane) of rainbow trout (all size classes combined) observed during the first pass of snorkel surveys conducted on November 19-21, 2019 on the Kings River.

Overall, the majority of rainbow trout were *observed* in runs and riffles (55% and 38%, respectively; note that observation counts do not necessarily correspond to *estimated abundances*). We estimated that there were approximately 830 trout inhabiting riffles, 745 rainbow trout inhabiting runs, and 50 rainbow trout inhabiting pools in the study area (Table 3; Figure 4).

Table 3. Abundance estimates (and standard errors; SE) of rainbow trout, grouped by size class and habitat type, for the lower Kings River above and below the Alta/Cobbles Weir.

Reach	Size Class	Pool	Riffle	Run	Total (SE)
Above Weir	<150 mm	0	36	0	**36** (35)
	150-300mm	33	60	191	**284** (167)
	>300 mm	17	36	176	**229** (113)
Below Weir	<150 mm	0	0	108	**108** (247)
	150-300mm	0	428	162	**590** (513)
	>300 mm	0	270	108	**378** (345)
Total	All	50	830	745	**1,625 (697)**

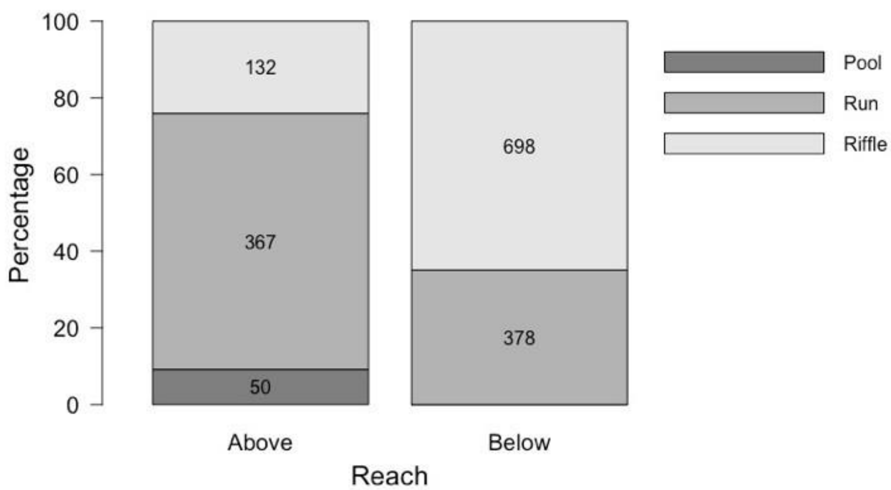

Figure 4. Estimated overall abundance of rainbow trout, above and below the Alta/Cobbles Weir, and habitat type, on the Kings River between Pine Flat Dam and Greenbelt County Park (November 2019). Note that the numbers shown internal to each histogram are the estimated trout abundance by habitat type.

When size classes are combined over the two reaches (upstream and downstream of the Alta/Cobbles Weir), the smallest size class (<150 mm) was estimated to be least abundant (estimated abundance: 144), followed by the largest size class (>300 mm; estimated abundance: 607) and the medium size class (150 – 300 mm; estimated abundance: 874; Figure 5).

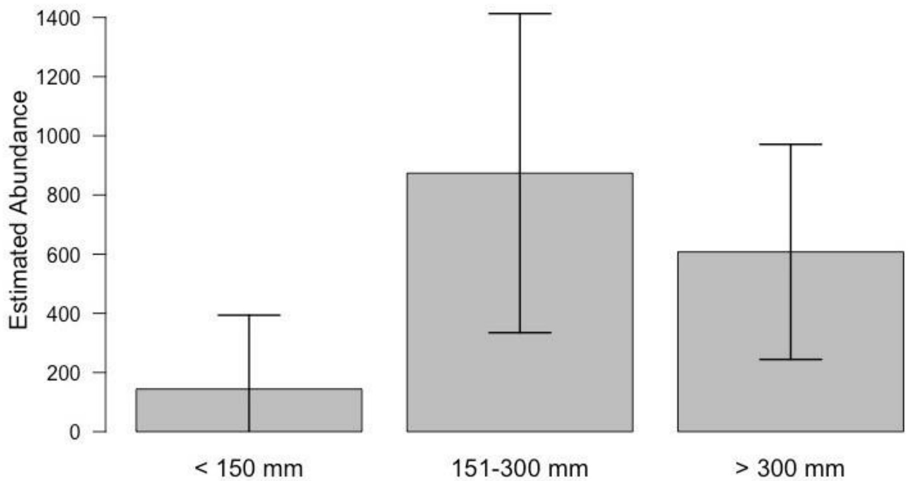

Figure 5. Estimated number of *Oncorhynchus mykiss*, by size category, on the Kings River between Pine Flat Dam and Greenbelt County Park (November 2019). Error bars represent one standard error.

Sacramento sucker were the only other species with a sufficient number and adequate distribution of observations to permit estimation of abundance. The overall abundance of Sacramento suckers was estimated at 4,494, more than twice as high than the estimate of rainbow trout abundance (Table 4). However, this estimate is likely negatively biased due to poor detection probability of this benthic species, particularly small individuals. Previous electrofishing survey reports do not include length information for this species, but we expect that a large fraction of the overall population is smaller than 150 mm. Benthic fish in that size category are difficult to detect during visual surveys, so that the population estimate presented herein should not be used to compare abundances/densities to previous surveys that differed in methodology. The large standard error associated with the estimated abundance of Sacramento sucker is mostly attributable to the highly variable abundance among surveyed units in a habitat category, especially in runs below the Alta Weir. More specifically, units with high abundance were included in the single-pass selection, yet multi-pass units used for calibrating counts had low observed abundance. As a consequence, large uncertainty is associated with the scaling factor, with is reflected in the Standard Error associated with the estimate.

Table 4. Abundance estimates and standard error (SE) of Sacramento sucker (all sizes), grouped by habitat type, for the lower Kings River above and below the Alta/Cobbles Weir.

Reach	Size Class	Pool	Riffle	Run	Total (SE)
Above Weir	All	1089	0	808	**1,897** (176)
Below Weir	All	624	157	1816	**2,597** (4,392)
Total	All	1,713	157	2,624	**4,494** (4,396)

Discussion

In some situations, when water visibility is excellent and conditions are good, snorkeling can provide counts similar to depletion electrofishing (Hankin and Reevves 1988; Mullner et al. 1998). However, visual estimates are typically negatively biased since certain factors can affect fish detectability (e.g., visibility, temperature, time of day, species-specific behaviors and fish size) (Hagen and Baxter 2005, Mullner et al. 1998, Bradford and Higgins 2001, O'Neal 2007, Hagen et al. 2010). Therefore, without estimates of observer bias (which generally require depletion estimates of abundance for a subsample of the reaches under study), single-pass snorkel surveys cannot provide an estimate of absolute abundance. Rather, they provide an unbiased index of abundance with associated confidence intervals. A viable alternative to obtaining accurate population size estimates by traditional methods (such as depletion electrofishing or mark-resighting experiments) is the Method of Bounded Counts. This approach relies on repeated counts of fish from the same unit (generally four passes) and produces nearly unbiased estimates of abundance if fish abundance in respective survey units is relatively low (Mohr and Hankin 2005). As such, this method provides a non-invasive (no fish handling required) alternative to traditional methods that is highly applicable to stream surveys involving species of special concern.

The disadvantages of visual surveys include uncertainty in species identification for closely related taxa that are similar in appearance, particularly for small individuals (e.g. juvenile sucker, pikeminnow, roach). Furthermore, small and/or cryptic species (e.g. sculpin, lamprey) are difficult to detect during visual surveys, which makes this method unsuitable for estimating abundance of these species. Also, detailed evaluation of size composition, condition factors or biological sample collection (scales, tissue) is not possible when visual surveys are used exclusively.

As past fish population surveys were conducted using different methodologies and have reported site-specific abundance estimates (rather than the reach-wide estimates reported herein), the most comparable metric is the "Wild Trout Per Mile" metric reported in KRCD (2016). Although rainbow trout could not be distinguished based on their natal origin (hatchery vs. in-river production), the overall rainbow trout density estimate of 145.1 trout per mile from this survey is higher than the latest available results from depletion electrofishing surveys, which suggest a low density of wild trout (26.4 individuals/mile; KRCD 2018).

However, there remains ambiguity regarding the natal origin of the trout observed during the visual survey. The Kings River in this area is heavily used for sportfishing, and frequently stocked with catchable rainbow trout by CDFW (weekly from late July through November in 2019, according to CDFW's online Fish Planting Schedule), usually in excess of 500 trout per week (presented in Johnson 2017). These practices may help to explain the skewed size distribution of observed trout, wherein fish ranging in size from 150 to 300 mm were most abundant during the survey, followed by larger (>300 mm) fish. In a natural population, the smallest size class is typically numerically dominant, with decreasing abundance as fish size (or age) increases. Such a distribution is generally a result of high reproductive output (i.e. a female rainbow trout can deposit thousands of eggs; highly correlated with fish size), of which only a fraction survives to the fry life stage, and an even smaller percentage survives to age 1. Disease, predation, competition, and other mortality factors continue to reduce the abundance of juveniles, and only a minor fraction of sub-catchable trout survive to reach harvest size. It follows that the skewed size distribution of rainbow trout in the lower Kings River is likely an indication of poor natural recruitment, limited survival of early life stages, or due to increased stocking of larger sized trout.

Given the complex stocking history and practices, wherein the lower Kings River receives plants of fry (resulting from the incubation of purchased eggs; 370,000 in winter 2017/2018; KRFMP), fingerlings (nearly 10,000 in 2017; CDFW), sub-catchable (nearly 30,000 in 2015, none in 2016-2018; CDFW), catchable (over 27,000 individuals in 2018; CDFW), "super-catchable" (almost 1,000 in 2018) and "trophy" rainbow trout (over 1,000 in 2018; CDFW)(KRFMP 2019), the abundance level estimated from the recent survey is relatively low. The most likely explanation for low abundance of trout is high harvest pressure (both, legal and illegal), potentially combined with emigration and/or entrainment from the study reach to the lower river or the various diversions. Past return-to-creel surveys have suggested harvest rates in excess of 50% (from Johnson 2017), and relatively recent evaluations of angler harvest also suggest high levels of exploitation, particularly under consideration of non-reporting or illegal harvest of tagged trout (KRFMP 2012).

Among the benefits of electrofishing depletion surveys are the opportunity to obtain exact lengths and weights of captured individuals, permitting estimates of condition factor, biomass, and accurate evaluation of species composition. However, electrofishing surveys are limited to those areas that can be safely waded, and therefore restricted in the types of habitat that can be sampled effectively. Furthermore, electrofishing surveys generally require a large number of personnel, as each captured fish has to be handled and processed. The large amount of effort required to conduct electrofishing surveys – particularly on larger rivers – often limits the number of habitat units that can be surveyed and therefore introduces uncertainty about the overall (river-wide) fish population. In years past, six sites, totaling 1,800 feet in length, have been surveyed by electrofishing each year, constituting about 2.7% of the river reach between Pine Flat Dam and the Highway 180 Bridge. In 2017, due to above-average discharge from the reservoir, only two sites (0.9% of the river reach) could be sampled (KRCD 2018). Results from past surveys suggest that densities of "wild" rainbow trout (i.e. based on intact fins, diploid blood samples, or likelihood of being planted hatchery brood stock) have ranged from zero (throughout most of the 1990s and in 2014) to 435 fish per mile (in 1984). During the last survey for which data could be obtained (KRCD 2018), the reach-wide estimate was 26 "wild" rainbow trout per mile.

In summary, the results of the visual survey conducted in November of 2019 indicate that the estimated overall abundance level of rainbow trout was higher than electrofishing surveys, which provide detailed insight into spatially very limited sections of river, may suggest. However, under consideration of the extensive history and practices of supplementation of trout in the lower Kings River, the overall density and abundance of rainbow trout is lower than might be expected, potentially attributable to high levels of exploitation. Regardless, this study provides additional insight to the understanding of the trout population and other fish species in the lower Kings River, complementary to electrofishing surveys.

Recommendations

The visual survey provided valuable complimentary information regarding the abundance of rainbow trout and other fish species in the lower Kings River, but could be improved in future years by a more detailed assessment of available habitat. On-the-ground habitat typing would likely result in a greater number of habitat units and higher confidence in habitat classification, which, in turn, would result in the selection of a higher number of survey units (more smaller units, rather than fewer larger units). Increased numbers of survey units are expected to result in greater spatial resolution and reduced variability in abundance estimates to ultimately provide higher confidence in resulting estimates. Such habitat mapping could be conducted by the KRCD, CDFW, or others and is expected to remain applicable for multiple years absent any extreme flow events or large-scale river restoration projects. Of note, habitat surveys should be conducted at flows that mimic expected conditions to accurately represent the habitat and fish distribution within the river during field surveys. If possible, habitat assessment and snorkel surveys should occur at the lowest operational flows that are expected to occur annually/periodically. Observational aquatic surveys are best conducted under conditions that maximize visual coverage of the stream cross-section and detection probability of the target species.

Rainbow trout were observed throughout length of the river surveyed reach, including the sites farthest downstream, near Greenbelt County Park. In the event of future surveys, expanding the study reach from the base of Pine Flat Dam to the Highway 180 Bridge to better and more inclusively capture the distribution of the trout population should be considered. If it is possible to devote additional resources towards such surveys in the future, selecting additional units categorized as “runs” would likely serve to narrow the confidence intervals around the abundance estimates, as most of the variability was found in this habitat category.

To inform the interpretation of survey results obtained using differing methodologies (visual vs. removal surveys), a paired survey that includes both methods on the same habitat units may be conducted in future years. Such a paired survey would serve to “calibrate” the relative efficiency of the different survey types, and provide a mechanism to extrapolate detailed results obtained on a small spatial scale to a reach scale.

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Appendix 1. First-Pass Counts and Densities for Non-Salmonids

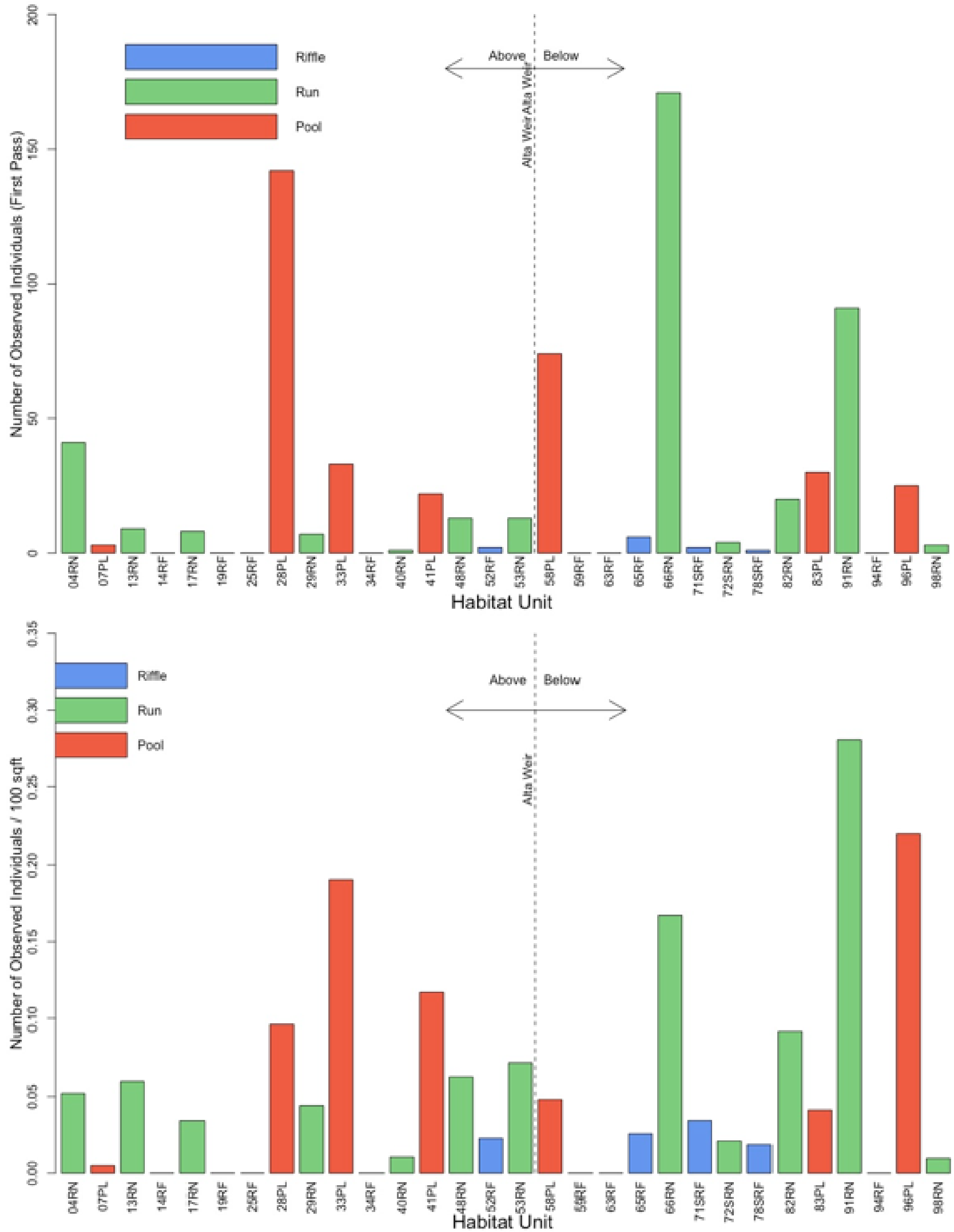

Figure A1. Number (top pane) and densities (bottom pane) of Sacramento sucker (all size classes combined) observed during the first pass of snorkel surveys conducted on November 19-21, 2019 on the Kings River.

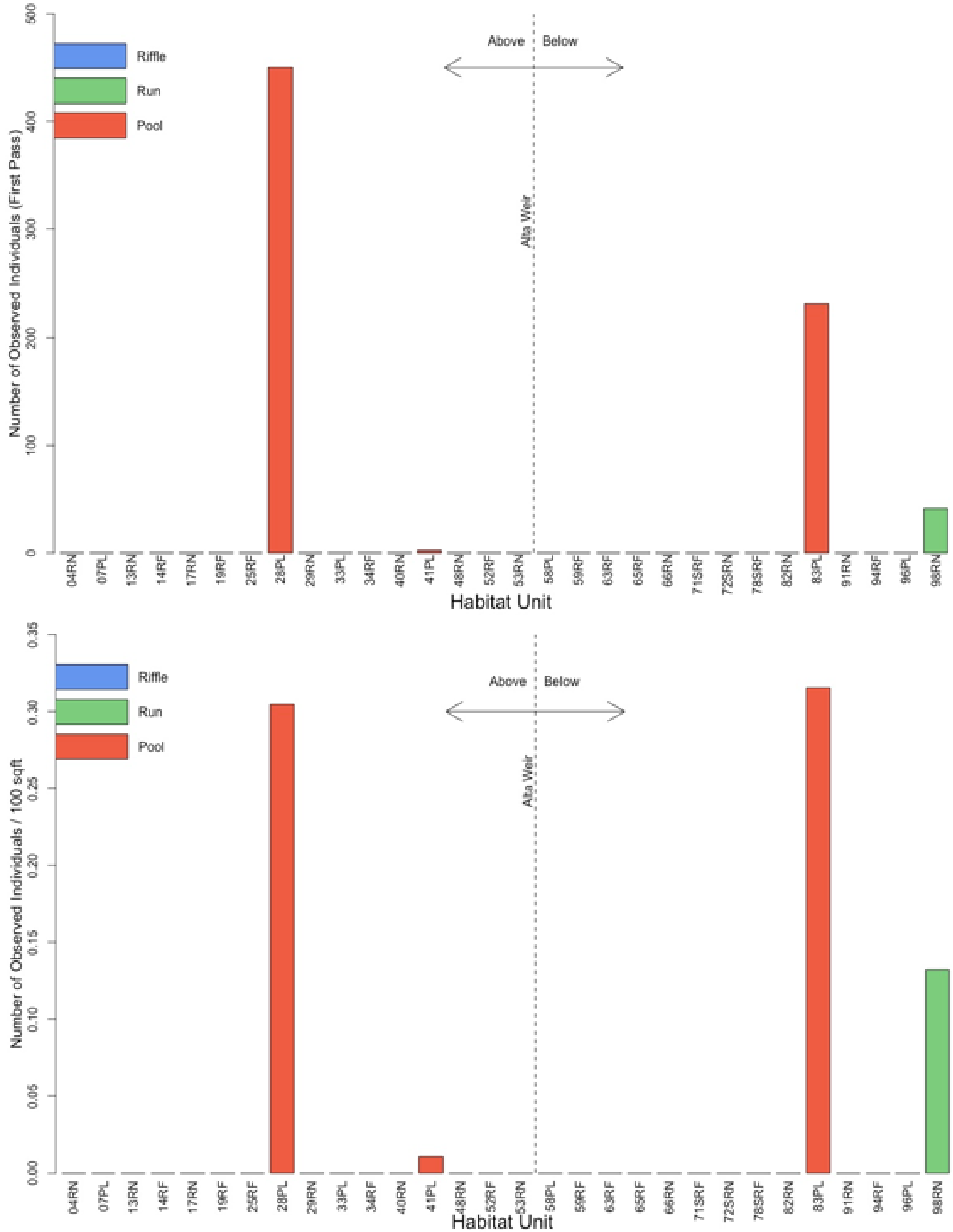

Figure A2. Number (top pane) and densities (bottom pane) of threespine stickleback observed during the first pass of snorkel surveys conducted on November 19-21, 2019 on the Kings River.

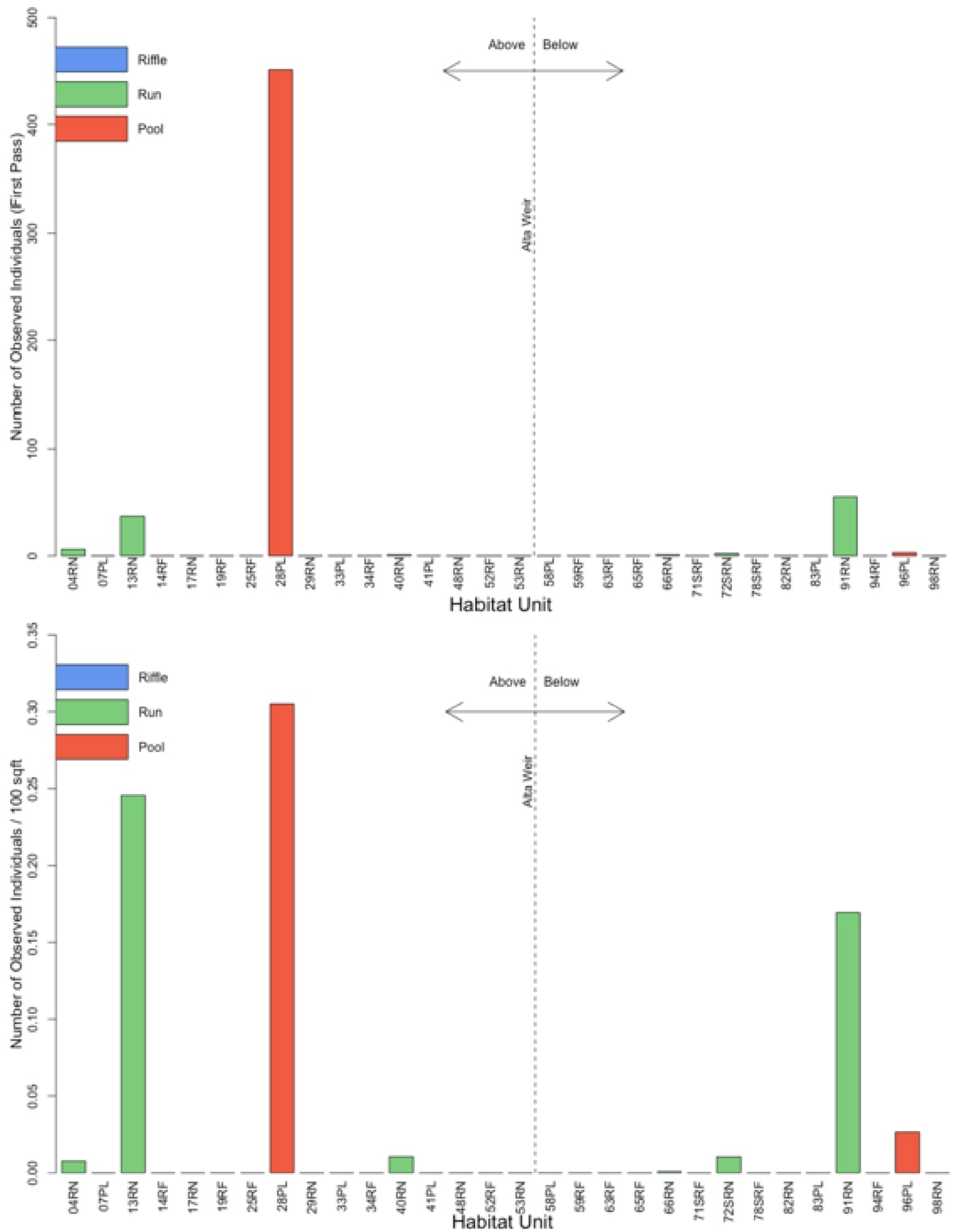

Figure A3. Number (top pane) and densities (bottom pane) of Sacramento pikeminnow (all size classes combined) and California roach (distinction between roach and pikeminnow not possible at small sizes) observed during the first pass of snorkel surveys conducted on November 19-21, 2019 on the Kings River.

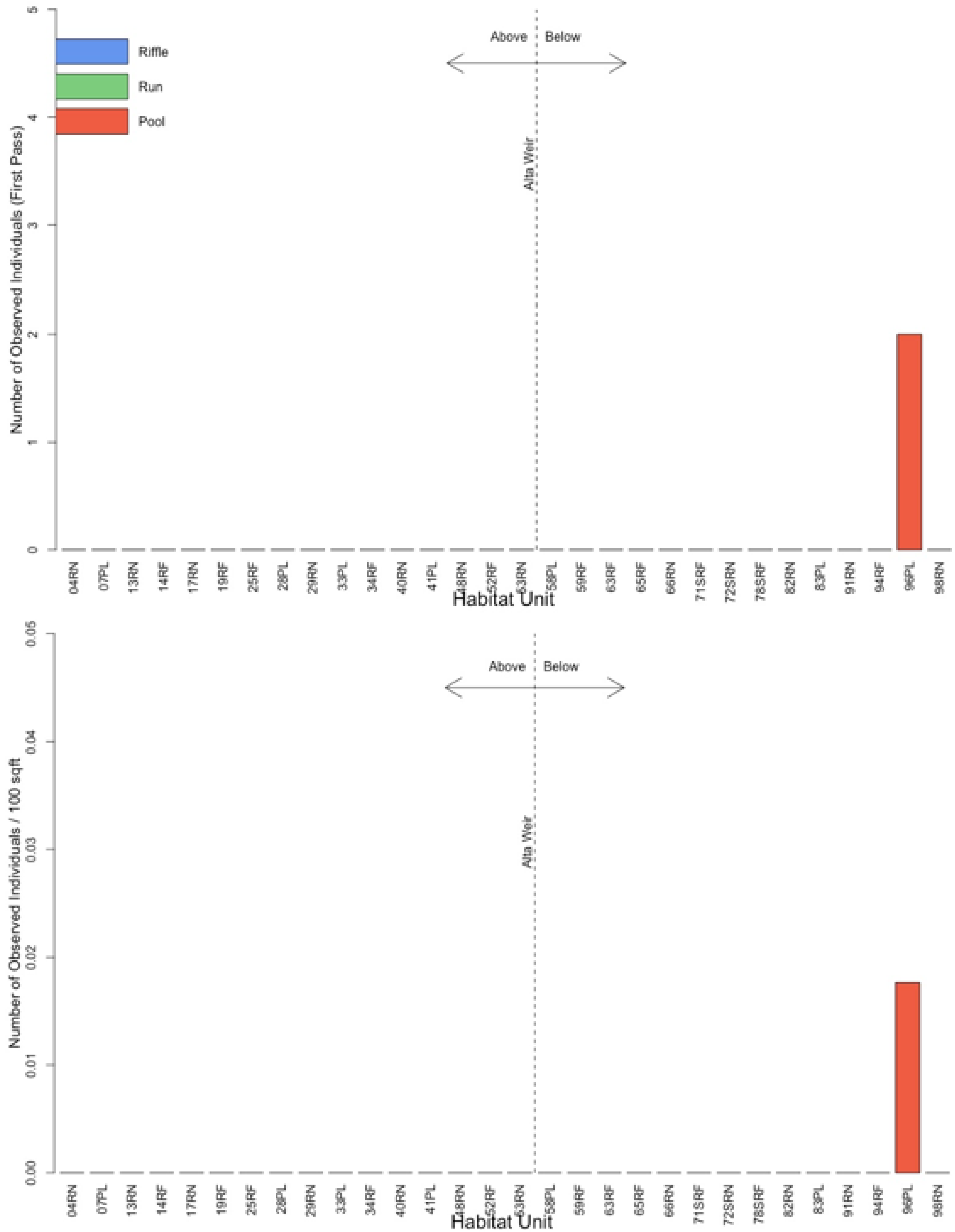

Figure A4. Number (top pane) and densities (bottom pane) of largemouth bass (all size classes combined) observed during the first pass of snorkel surveys conducted on November 19-21, 2019 on the Kings River.

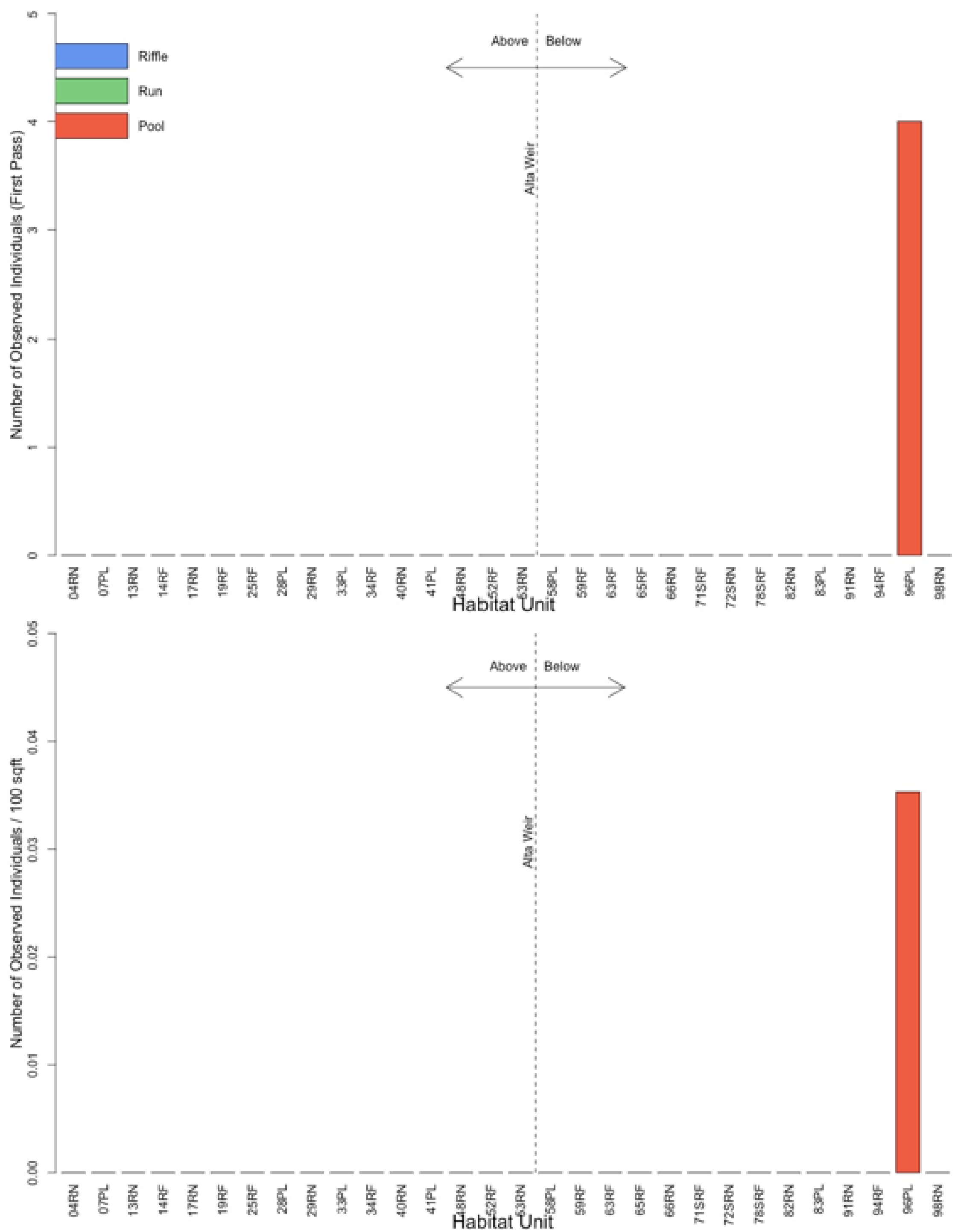

Figure A5. Number (top pane) and densities (bottom pane) of bluegill sunfish observed during the first pass of snorkel surveys conducted on November 19-21, 2019 on the Kings River.

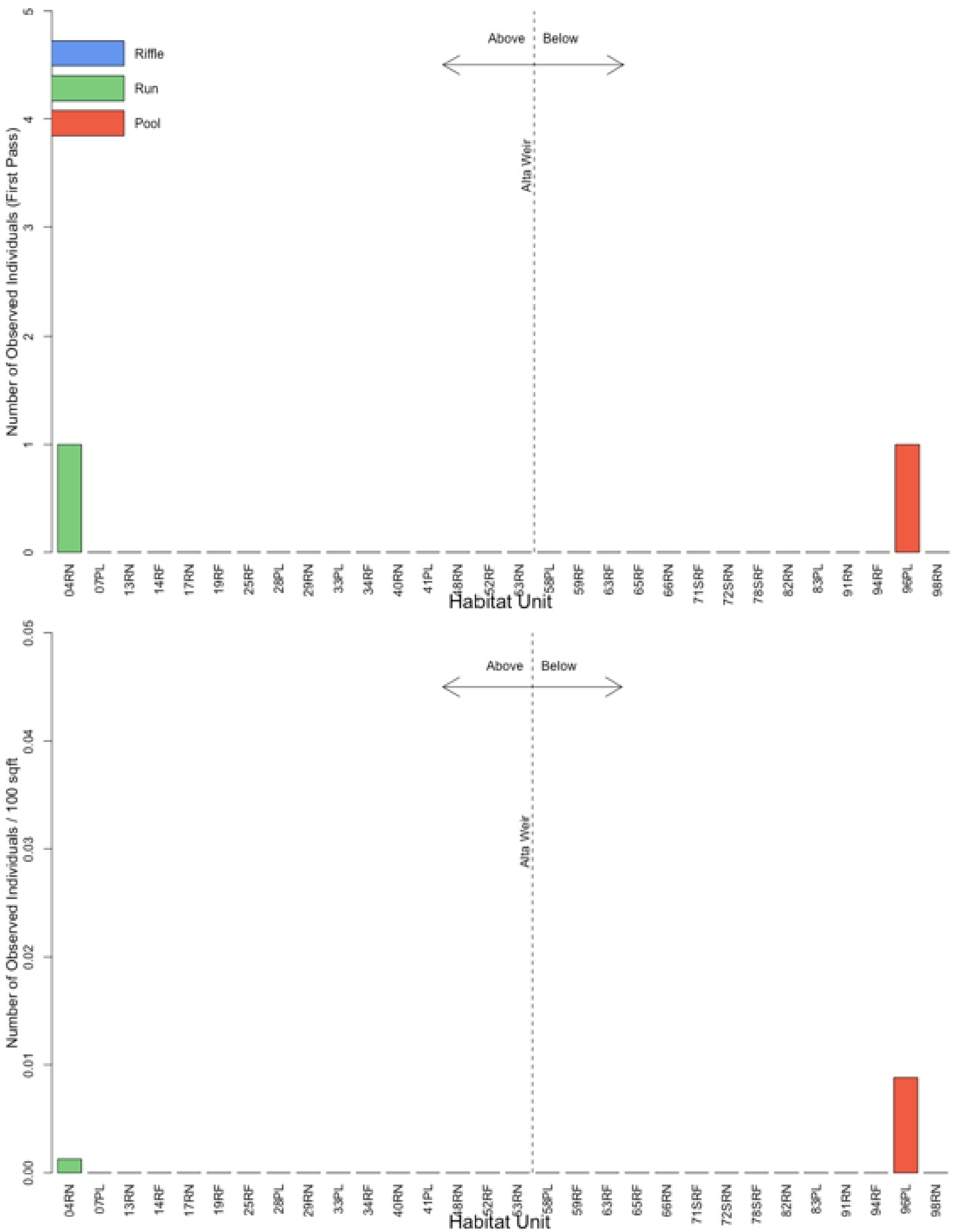

Figure A6. Number (top pane) and densities (bottom pane) of white catfish (all size classes combined) observed during the first pass of snorkel surveys conducted on November 19-21, 2019 on the Kings River.

Appendix 2. Data collected during snorkel surveys conducted on November 19-21, 2019 on the Kings River. See key below for species codes.

Sample Date	Dive Time	Unit #	Water Temp. (F)	Pass #	RBT[1] counts			SASU[1]		SASQ/CAR[1,2]		SCP[1]	TSS[1]	WHC[1]	LMB[1]	BGS[1]	UNID[1]	
					<150mm	150-300mm	>300mm	Juvenile	Adult	Juvenile	Adult			Adult	Adult	Adult	Juvenile	Adult
11/19/19	9:40	4RN	58.1	1	0	2	4		41					1				6
11/19/19	10:00	7RN	58.2	1	0	0	0		3									
11/19/19	10:40	13RN	59.2	1	0	0	2		9	33		1						4
11/19/19	10:40	13RN	59.2	2	0	0	0		7	30								
11/19/19	10:40	13RN	59.2	3	1	0	1		12	45								
11/19/19	10:40	13RN	59.2	4	0	0	2			50								4
11/19/19	11:10	14RF	59.3	1	2	2	1											
11/19/19	11:30	17RN	59.1	1	0	1	3		8			2						
11/19/19	11:30	17RN	59.1	2	0	6	9		13			4						2
11/19/19	11:30	17RN	59.1	3	1	2	1		4			4						6
11/19/19	11:30	17RN	59.1	4	1	3	4		3			4						
11/19/19	13:15	19RF	59.9	1	0	0	0					1						
11/19/19	13:15	19RF	59.9	2	0	0	0					3						
11/19/19	13:15	19RF	59.9	3	0	0	0					3						
11/19/19	14:00	25RF	59.9	1	0	0	0					3						
11/19/19	14:18	28PL	60.2	1	0	2	1	16	126	451			450					
11/19/19	14:20	29RN	60.2	1	0	0	1		7									
11/19/19	15:35	001RF		1	1	3	2											
11/19/19	15:00	33PL	60.8	1	1	3	0		33			2						
11/19/19	15:00	33PL	60.8	2	0	4	1		23									
11/19/19	15:00	33PL	60.8	3	0	1	0		27									
11/19/19	15:00	33PL	60.8	4	0	4	1		30									
11/20/19	9:10	40RN	56.8	1	0	0	0		1									1

Sample Date	Dive Time	Unit #	Water Temp. (F)	Pass #	RBT[1] counts			SASU[1]		SASQ/CAR[1,2]		SCP[1]	TSS[1]	WHC[1]	LMB[1]	BGS[1]	UNID[1]	
					<150mm	150-300mm	>300mm	Juvenile	Adult	Juvenile	Adult			Adult	Adult	Adult	Juvenile	Adult
11/20/19	9:10	40RN	56.8	2	0	0	0					2						
11/20/19	9:10	40RN	56.8	3	0	0	4											1
11/20/19	9:10	40RN	56.8	4	0	1	1											
11/20/19	9:25	41PL	57.2	1	0	0	2		22			1	2					
11/20/19	9:25	41PL	57.2	2	0	0	0	2	19			6						1
11/20/19	9:25	41PL	57.2	3	0	0	0		3			2						
11/20/19	9:25	41PL	57.2	4	0	1	1		3			6						
11/20/19	10:02	48RN	57.2	1	0	0	0		13			1						
11/20/19	11:45	52RF	57.2	1	1	1	1		2			2						
11/20/19	11:45	52RF	57.2	2	0	0	0					2						
11/20/19	11:45	52RF	57.2	3	0	0	0											
11/20/19	11:45	52RF	57.2	4	0	0	0					2						
11/20/19	11:20	53RN	57.2	1	0	0	0		13			3						
11/20/19	11:20	53RN	57.2	2	0	1	0					1						
11/20/19	11:20	53RN	57.2	3	0	0	0	2	2	5	1	1						
11/20/19	11:20	53RN	57.2	4	0	0	0		5			4						
11/20/19	12:44	58PL	57.3	1	0	0	0	1	73									
11/20/19	13:13	59RF	57.2	1	0	6	9					1						
11/20/19	13:35	63RF	58.8	1	2	0	0											
11/20/19	13:35	63RF	58.8	2	1	2	1											
11/20/19	13:35	63RF	58.8	3	1	5	5											
11/20/19	13:35	63RF	58.8	4	1	2	3											
11/20/19	14:05	65RF	58.8	1	0	5	1		6									
11/20/19	14:10	66RN	58.8	1	0	1	3		171		1	1						
11/21/19	9:05	71-S-RF	56.3	1	0	4	0	2				2						

Sample Date	Dive Time	Unit #	Water Temp. (F)	Pass #	RBT[1] counts			SASU[1]		SASQ/CAR[1,2]		SCP[1]	TSS[1]	WHC[1]	LMB[1]	BGS[1]	UNID[1]	
					<150mm	150-300mm	>300mm	Juvenile	Adult	Juvenile	Adult			Adult	Adult	Adult	Juvenile	Adult
11/21/19	9:05	71-S-RF	56.3	2	2	0	1	1										
11/21/19	9:05	71-S-RF	56.3	3	3	0	0	1										
11/21/19	9:05	71-S-RF	56.3	4	4	1	1											
11/21/19	10:50	72-S-RF	58.1	1	10	20	12	2	2		2	1						
11/21/19	10:26	78-S-RF		1	0	3	0	1				1						
11/21/19	11:05	82-RN	58.6	1	0	0	0		20									
11/21/19	11:05	82-RN	58.6	2	0	0	0		8									
11/21/19	11:05	82-RN	58.6	3	0	0	0	1	3									
11/21/19	11:15	83PL	58.6	1	0	0	0		30				230					
11/21/19	12:35	91RN	59.4	1	1	2	1		91		5						50	
11/21/19	12:55	94RF	60.1	1	0	1	0											
11/21/19	12:55	94RF	60.1	2	0	0	0	1				3						
11/21/19	12:55	94RF	60.1	3	0	0	0	1										
11/21/19	13:30	96PL	58.9	1	0	0	0		25		3			1	2	4		
11/21/19	13:30	96PL	58.9	2	0	0	0		20		4				3			
11/21/19	13:30	96PL	58.9	3	0	0	0				1				3	1		
11/21/19	14:04	98RN	61	1	5	1	0		3				41					

[1]BGS- Bluegill, CAR-California roach, LMB- Largemouth bass, RBT- Rainbow trout, SCP- sculpin (spp.), SASQ- Sacramento pikeminnow, SASU- Sacramento sucker, TSS- Three-spined stickleback, UNID- Unidentified fish species, WHC- White catfish

[2] A distinction between California roach and juvenile pikeminnow was not possible during this survey, as individuals belonging to both species were observed in mixed schools.

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Michael Hellmair

Fisheries Biologist

Education

B.S., Fisheries Biology, Freshwater Emphasis
Humboldt State University, Arcata, 2008

M.S., Fisheries Biology, Natural Resources
Humboldt State University, Arcata, 2011

Training and Certifications

First Aid and CPR training. 2016. Red Cross

Radiation Safety and Awareness training. 2014. PG&E

Modeling Patterns and Dynamics of Species Occurrence Course. 2013. Proteus Consulting

Small boat safety and handling. 2009. California Department of Boating and Waterways

Certified Scuba Diver. 2007. NAUI

Tenure in Industry

9 Years

Professional Experience

Michael Hellmair is a fisheries biologist with broad expertise in the application of statistical modeling techniques, analysis, and sampling design to fisheries research, both domestically and internationally. In California, he has evaluated juvenile and adult salmonid habitat use in Central Valley streams, investigated dietary composition of salmonids and piscivorous species, coordinated observational fish abundance assessments, and led environmental DNA (eDNA) species surveys. Michael has participated in several scientific stock evaluation cruises with the National Marine Fisheries Service in Alaska. He has also applied molecular techniques such as microsatellite genotyping for genetic stock identification of Chinook salmon and DNA sequencing for seafood species identification. Michael holds a range-wide Federal Recovery Permit for endangered tidewater goby, *Eucyclogobius newberryi,* and has assessed genetic variation in isolated tidewater goby populations. While working as a fisheries biologist in Austria, he co-chaired a scientific advisory panel to monitor and regulate a large, international inland fishery, and taught courses in fisheries education and electrofishing. He also collaborated on studies to evaluate bird predation, fish passage, and instream flow requirements.

Michael has extensive experience in fisheries field sampling techniques, including electrofishing (backpack and boat), seines, gill-nets, traps, long-lines, trawls, and mark-recapture techniques for abundance estimation (external tags, PIT tags, and chemical/calcein marking). Michael also has expertise in database management, programming, modeling, and graphing (using R software), has taught hands-on university course work in ichthyology and genetics, and leads freshwater fish identification training for FISHBIO staff. He is also familiar with various aspects of hatchery operation, such as broodstock acquisition, spawning and incubating/rearing fish for conservation and fishery supplementation. He has conducted numerous age and growth evaluations for various species using otoliths, scales, vertebrae, spines and opercular bones. His graduate research focused on determining age and growth characteristics of the tidewater goby using otolith microstructural analysis to reveal and quantify daily growth increments.

Education

B.S., Biology-Ecology
California State University, Fresno, 1999

Training and Certifications

Applied Fluvial Geomorphology. 2003. Wildland Hydrology Inc.

Program MARK. 2003. Colorado State University

Incident Command System. 2007. FEMA

Swiftwater Rescue Technician. 2007. Sierra Rescue

Introduction to Electrofishing. 2008. Smith-Root Inc.

FishXing. 2008. Salmonid Restoration Federation

Using Acoustic Tags to Track Fish. 2010. Hydroacoustic Technology, Inc.

Wilderness First Aid. 2014. Sierra Rescue

CPR & First Aid. 2014. American CPR

Tenure in Industry
20 Years

Jason Guignard

Fisheries Biologist

Professional Experience

Jason Guignard is a fisheries biologist with over 20 years of salmonid research, monitoring, and restoration experience. He has supervised and implemented a variety of fish population and passage research projects in San Francisco Bay-Delta watersheds and is experienced in all aspects of field sampling and data analysis, including electrofishing, seining, trawling, rotary screw trap monitoring, spawning surveys, mark-recapture studies, hook-and-line sampling, acoustic telemetry, and DIDSON operation. Jason has been a project lead for multiple fish monitoring and rescue operations in the Sacramento and San Joaquin Basins that have involved potential handling of listed species (Central Valley steelhead, Winter-run Chinook, Spring-run Chinook, and Green sturgeon). He collaboratively planned and implemented multiple floodplain enhancement and restoration projects to augment spawning-size gravel for Chinook salmon and steelhead in the Stanislaus River. As part of these restoration efforts, he obtained various approvals and permits including NEPA, ESA Section 7, and others.

Jason has authored/co-authored multiple technical reports on adult salmon spawning surveys, juvenile outmigration monitoring, smolt survival estimates, and water temperature requirements for Chinook salmon and steelhead. Prior to joining the private sector, Jason was a California Department of Fish and Game Associate Biologist with experience collecting and analyzing fisheries monitoring data on multiple lifestages of Central Valley salmonids. During his time at CDFG, he was the Project Manager for the San Joaquin River Basin-Wide Temperature Monitoring/Modeling Project. This project included collection of reservoir and river temperature data throughout the San Joaquin Basin, as well as development, management, and QA/QC of all temperature data

Education

B.A., Biology
California State University, Stanislaus, 2006

Training and Certifications

First Aid and CPR training. 2014. Sierra Rescue.

Basic/Intermediate GIS for Fisheries Biologists. 2011. American Fisheries Society Workshop

Mapping Aquatic Habitat of Inland Freshwater Systems Using Side-Scan Sonar. 2011. American Fisheries Society Workshop

Surgical Implantation of Acoustic Tags. 2008. UC Davis

River 2d Flow Modeling Training Seminar. 2008, 2009. U.S. Geological Survey

SCUBA certification. 2005. NAUI

California Scientific Collector Permit

Tenure in Industry

14 Years

John Montgomery

Fisheries Biologist

Professional Experience

John Montgomery is a biologist and GIS specialist with 14 years of experience. He has served as a project lead for various biological monitoring projects throughout the Sacramento-San Joaquin Delta and Northern California. John specializes in monitoring freshwater life stages of juvenile and adult salmonids using a variety of methods, including telemetry (using ATS, VEMCO, and HTI technology), electrofishing, rotary screw traps, snorkel surveys, seining, redd surveys, angling surveys, resistance board weirs, and fish identification using image processing and pattern recognition (using Biopar TNT technology). John has tagged more than 900 salmon (using JSATS and VEMCO technology) for projects such as restored levee habitat utilization studies on the Sacramento River, and a Mokelumne River predation and flow study.

John's expertise in fish handling is complemented by a variety of environmental sampling experiences, including measuring river discharge, deploying water pressure loggers, benthic and plankton sampling for invertebrates, large woody debris inventory, water quality testing, habitat typing, and substrate quality analysis (particle size composition, distribution, and permeability). He is also proficient in small watercraft operation. John conducts geo-spatial data collection using Trimble GPS and land survey equipment and performs GIS data management and representation using ArcGIS. He is experienced in data management using Microsoft Excel and Access.

Project Experience

- **Sears Point Restoration Monitoring:** John aided in ARIS camera deployment and boat operations to monitor a restored wetland at Sears Point along the northern portion of San Pablo Bay. This study used an ARIS camera to compare fish abundances to those recorded by traditional seining methods.