Middle and South Yuba Rainbow Trout (*Oncorhynchus mykiss*)
Distribution and Abundance
Dive Counts August 2004
FINAL DRAFT

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Introduction

For the introduction of Chinook salmon (*Oncorhynchus tschawytscha*) and steelhead (*Oncorhynchus mykiss*) into the upper Yuba River to be biologically feasible, suitable habitat conditions must exist for each life-history stage, leading to successful completion of each species' life cycle. In this study, the potential distribution of available rearing habitat in the Middle and South Yuba Rivers was determined for each species by assessing the distribution and abundance of endemic rainbow trout as a surrogate for anadromous salmonids. The relative distribution and abundance of rainbow trout were assessed in the South and Middle Yuba River in August and early September 2004 using direct observation (snorkeling) methodologies. Potential migration barriers and thermal refugia for trout were also investigated. Tributaries and hyporheic flows such as cold-water seeps can create thermal refugia in streams with temperatures otherwise inhospitable for salmonids (Matthews and Berg 1997, Nielsen et al 1994). It was necessary to document the existence of any such refugia for determining the relationship between water temperature and the distribution of salmonid habitat.

The rainbow trout index densities were related to average July stream temperatures for future habitat model calibrations. The distribution and abundance of other fish species were also documented for potential inclusion in ecosystem type models. Rainbow trout index densities observed in the Middle and South Yuba rivers were compared to index densities in other Northern California streams.

The South Yuba River is approximately 40 miles (mi) in length from Lake Spaulding (at 5,000 ft mean sea level [msl]) downstream to Englebright Reservoir (at 600 ft msl). The Middle Yuba River is approximately 45 mi in length from Milton Reservoir (at 5,700 ft msl) downstream to its confluence with the North Yuba River (at 1,200 ft msl) (Figure 1). The average July and August discharge in the South Yuba below Spaulding Reservoir at Langs Crossing of approximately 6 to 7 cubic feet per second (cfs) increases to 120 cfs (July) and 40 cfs (August) in the lower reaches (USGS Data 2005 a and c). The average July and August discharge in the Middle Yuba increases from 4 cfs below Milton Reservoir to 34 cfs (July) and 30 cfs (August) in the lower reaches (USGS Data 2005 b and d). The Middle and South Yuba are high gradient Sierra rivers. Average low flow stream widths in the lower reaches of both rivers are 40 to 50 feet, reducing in the upper reaches to 30 to 40 feet in the South Yuba and 20 to 30 feet in the Middle Yuba (data from this study).

Methods

Distribution and Abundance

The downstream boundary of rainbow trout distribution was established by snorkeling much of the lower portions of each river. The field crew snorkeled downriver while accessing locations selected for trout abundance sampling paying particular attention to any potential thermal refugia. The crew snorkeled a maximum of three to four miles per day between sampling locations if vehicles were located at both upstream and downstream access points.

The relative abundance of rainbow trout was assessed using direct observation dive counts. Semi-quantitative dive counts were made by a team of two or three (depending on stream size) experienced snorkelers in randomly selected run habitats longitudinally distributed throughout each river. Observations were also made in riffle and pool habitats adjacent to each selected run. Run habitats were selected to conduct dive counts for the following biological and logistical reasons:

- In large, warm, main stem rivers, salmonids are frequently restricted to fast-water habitat types (i.e., riffles and runs), whereas they may avoid slow-water habitat types (i.e., pools)
- Trout densities in run habitats are frequently intermediate to densities in riffles and pools, thus run habitats may provide a qualitative measure of mean densities for the remainder of the river (observations based on Thomas R. Payne and Associates (TRPA 1998, 2000, and 2001) data from the Upper Sacramento River, lower North Fork Feather River, and the lower South Fork American River)
- In highly confined, bedrock formed, high gradient rivers, riffles are frequently too complex and/or too hazardous to conduct dive counts with reasonable accuracy and safety (i.e., many riffles contain rapids, falls, or are profuse with large emergent boulders), and many pools are very large and deep, requiring a larger crew and specialized equipment (e.g., scuba) to yield accurate counts; in contrast, runs are typically intermediate in depth, velocity, and cover characteristics, and are thus most amenable to direct observation methodologies

The field crew randomly selected a run habitat from those available in each segment as they progressed downstream or upstream from specific access points. Stream sampling areas or segments were determined according to access points. The estimated total number of habitat units available at a given access point was based on the amount of area which could be covered in the time available (typically 50 habitat units). The total number of units available per segment was multiplied by a random number to determine the sampling location. From the river access point, the dive crew traveled up or downstream, through each segment wearing snorkeling gear and waterproof backpacks for field equipment and personal gear until the selected run habitat was encountered. Care was taken to avoid disturbing the selected run and adjacent pool and riffle habitat units prior to sampling. In order to locate the downstream boundary of trout presence and investigate potential thermal refugia in the lower portion of each river, more area was covered by accessing the river at one point and snorkeling downstream several miles to the egress point. In this case the segment was divided into two sub segments with the boundary about half way between the top and the bottom. Sampling locations were selected from both sub segments. Some stream segments were too confined, too remote, or contained too many hazardous drops to be safely or effectively surveyed.

Once the upper and lower boundaries of the selected run habitat were identified, dive lanes were assigned to each diver based on the physical attributes of the unit. Prior to the count, divers discussed lane assignments in order to minimize missed or double-counted fish. When necessary, divers also communicated during the count in order to verify observed fish and/or assign counts to specific individuals. The dive count commenced with all divers evenly spaced at the downstream end of the unit. The divers then progressed upstream scanning the water for trout. Divers also conducted separate counts along each bank of the run habitats in six-foot wide "fry lanes" in order to focus specifically on small trout fry, which may have been missed in the initial count. All other fish species observed were enumerated on the data forms separately from the trout count data.

All observed trout were counted according to size classes (0-4 inches [in], 4-8 in, 8-14 in and >14 in) by reference to an underwater ruler. All count data were recorded on underwater dive slates during the count, and then transferred to data forms following the dive. Divers carried a wrist-mounted ruler incremented with the size classes, and periodically the divers were tested in size estimation using submerged trout models of various sizes. The length and mean width of each sampled run habitat was measured with a laser range finder following the count. Each sampled run was also photographed, its location determined using hand-held GPS receivers (where coverage permitted), and marked on a topographic map. In addition to the surface area measurements, each run was characterized by dominant/subdominant substrate and cover type using the categories identified in the October 2003 Interim Report on current conditions in the Yuba River Watershed (UYRSP 2003). The lengths of sampled pools and riffles were also measured, however widths, substrate, and cover data were not recorded for those habitat types. Water temperatures were recorded and minimum visibility was estimated by measuring the distance that a diver could clearly identify an artificial trout approximately the size of a large fry.

Thermal Refugia

In order to locate possible thermal refuge areas, water temperatures were measured wherever any unusual clustering of trout were observed, in deep pools where stratification was possible, and above/below all flowing tributary mouths. An AquaCal ClineFinder digital thermometer-depth sounder with a resolution of 0.1^0 Fahrenheit (F) and accuracy of 0.5^0 F was used to measure water column temperature profiles.

Qualitative assessments of all accessible significant tributaries (Oregon Creek, Kanaka Creek, Yellow Jacket Creek, Wolf Creek, Owl Creek, Humbug Creek, Poorman Creek, and McKilligan Creek) were conducted by visually estimating the stream flow, measuring water temperature, photographing, and visually assessing the rearing potential of the lower reaches. Typically the dive crew continued the assessment upstream to an upstream passage barrier or one to two thousand feet if no barriers were encountered. Any migration barriers observed in the lower portion of the tributary were recorded. A cursory dive survey was conducted in the lower reach of the tributary to determine occupancy by trout, and also in the main stem at the confluence to determine if a thermal refuge was indicated. If evidence of a thermal refuge was found, more detailed evaluation of the refuge characteristics (i.e., temperature recordings, additional dive counts, map sketches, etc.) were conducted at that time.

Barriers

All potential barriers to fish migration that were encountered while traveling the stream channel were photographed and qualitatively described, with estimated vertical heights and GPS positions recorded at each site. Additional barriers to fish migration likely exist in the areas not accessed by the dive crew, consequently this description of potential fish barriers is not intended to represent a complete record.

Analysis

The dive counts of trout were converted to index estimates of fish density (#/mile), by size class, for each of the sampled habitat units based on the length of the habitat unit sampled. The index densities were then plotted against location (i.e., river mile [RM]) in order to evaluate longitudinal trends in abundance, and to estimate the area of habitat potentially suitable for rearing by anadromous salmonids. For the Middle and South Yuba rivers, the measurement of river mile began at the confluence with the North Yuba and Yuba rivers respectively. The longitudinal distribution and abundance of trout was also compared to recorded mean July temperature data for both the Middle and South Yuba. In addition, the relative densities of trout in the South and Middle Yuba Rivers were compared to estimated index densities of trout (also based on dive counts) from habitats in other main stem California rivers.

Results

Snorkel counts, refuge assessment, trout distribution, and barrier assessment were conducted on the Middle and South Yuba rivers between 21 August 2004 and 04 September 2004. Measured water temperatures during the survey ranged from 52.7^{o}F to 74.9^{o}F on the Middle Yuba River. On the South Yuba River, temperatures ranged from 63.1^{o}F to 78.5^{o}F. Estimated flows on the Middle Yuba ranged from 8 cfs to 40 cfs, and on the South Yuba flows ranged from 15 cfs to 40 cfs. At the time of this survey, the gaged discharge at Jones Bar on the South Yuba River averaged 40 cfs (38 cfs to 42 cfs) and at Our House Dam on the Middle Yuba River the discharge averaged 25 cfs (23 cfs to 28 cfs) (California Data Exchange Center 2005). Four tributaries to the Middle Yuba and five tributaries to the South Yuba were surveyed for salmonid rearing potential. Water temperature profiles were measured in nine deep pools on the Middle Yuba River and 24 deep pools on the South Yuba River. Four barriers to fish migration were encountered on the Middle Yuba and three were encountered on the South Yuba River.

Fish Distribution

Counts were completed in 14 runs (each with an associated riffle and pool) on the Middle Yuba, and in 18 runs (with riffles and pools) on the South Yuba (Figure 1). Visibility during the survey ranged from 7 feet (ft) to 18 ft on the Middle Yuba, and from 7 ft to 20 ft on the South Yuba, with the highest visibilities occurring in the upper portions of each river. Gold mining reduced visibility below dredging operations and thwarted snorkeling efforts on several occasions. These locations were revisited. Rainbow trout inhabited the entire length of the Middle Yuba River from Milton Dam to the confluence with the North Yuba. In the South Yuba River, rainbow trout were present from approximately 0.5 miles downstream of Owl Creek (RM 4.2) upstream to Spaulding Reservoir; however, densities were very low downstream of Purdon Crossing (RM 12.3).

Other fish species observed included brown trout (*Salmo trutta*), Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow (*Ptychocheilus grandis*), Hardhead (*Mylopharodon conocephalus*), smallmouth bass (*Micropterus dolomieui*), and sunfish (*Lepomis* spp.).

No smallmouth bass, adult pikeminnow, or hardhead were observed upstream of Our House Dam (RM 12.6) on the Middle Yuba River; however, a few minnow fry were observed a short distance upstream of the dam. Sacramento suckers were observed below Our House Dam. Brown Trout were present in the upper reaches of the Middle Yuba River from Milton Dam downstream to RM 37.5.

In the South Yuba River, adult hardhead were observed at RM 3.9, whereas adult pikeminnow were observed at several locations downstream of RM 10.4. Fry and juvenile minnows and Sacramento sucker were observed upstream to RM 28.3. No smallmouth bass or brown trout were observed, but a few sunfish were observed in a shallow backwater pool at RM 5.7.

Figure 1. Locations and river mile of dive count units on the Middle and South Yuba rivers.

Rainbow Trout Density

Estimated index densities of rainbow trout in specific habitats varied between zero and 1,506 rainbow trout per mile on the Middle Yuba and between zero and 1,402 rainbow trout per mile on the South Yuba (Appendix B). Generally trout densities were lower in the warmer, lower reaches of both rivers and higher in the cooler, upstream reaches (Figures 2 and 6). Adult trout densities increased with river mile in both rivers to RM 17.1 in the Middle Yuba and 18.1 in the South Yuba, upstream of which densities showed no apparent trend and averaged 204 trout per mile and 273 trout per mile respectively. Adult rainbow trout observations were more frequent in pools than riffles in both rivers, particularly in the South Yuba (Figures 4, 5, 8, and 9). However, most riffles contained abundant whitewater, fast chutes, and other obstructions, making dive counts difficult and thus observation probabilities were probably lower than in pools. Trout densities in run habitats were intermediate to the lower densities in riffles and higher densities in pools (Figures 3 and 7). In the lower reaches, most of the trout in pools were concentrated at the heads of pools. Trout larger than 14 inches were observed only in runs and pools during the dive counts and only downstream of river miles 31.0 and 28.3 in the Middle and South Yuba rivers, respectively.

The index density of rainbow trout fry was variable, but generally increased upstream to RM 27.5 on both the Middle Yuba the South Yuba where they averaged 343 and 455 trout per mile, respectively (Figures 2 and 6). A spike (1,218 per mile) in the density of fry at RM 39.1 in the Middle Yuba River substantially increased the average density. Excluding that high-density observation, the average fry density in the upper Middle Yuba was 213 trout per mile, approximately one-half of the South Yuba fry density. The most downstream observations of trout fry in the dive counts were at RM 12.6 and RM 15.2 on the Middle and South Yuba, respectively. Trout fry were, however, observed at non-sampling locations in the vicinity of Oregon Creek (RM 4.8) in the Middle Yuba and at Owl Creek (RM 4.2) in the South Yuba. Fry densities were generally highest in riffles as opposed to pools, with runs exhibiting intermediate densities. Fry densities among pools were highest in the cooler upstream reaches (Figures 2-9).

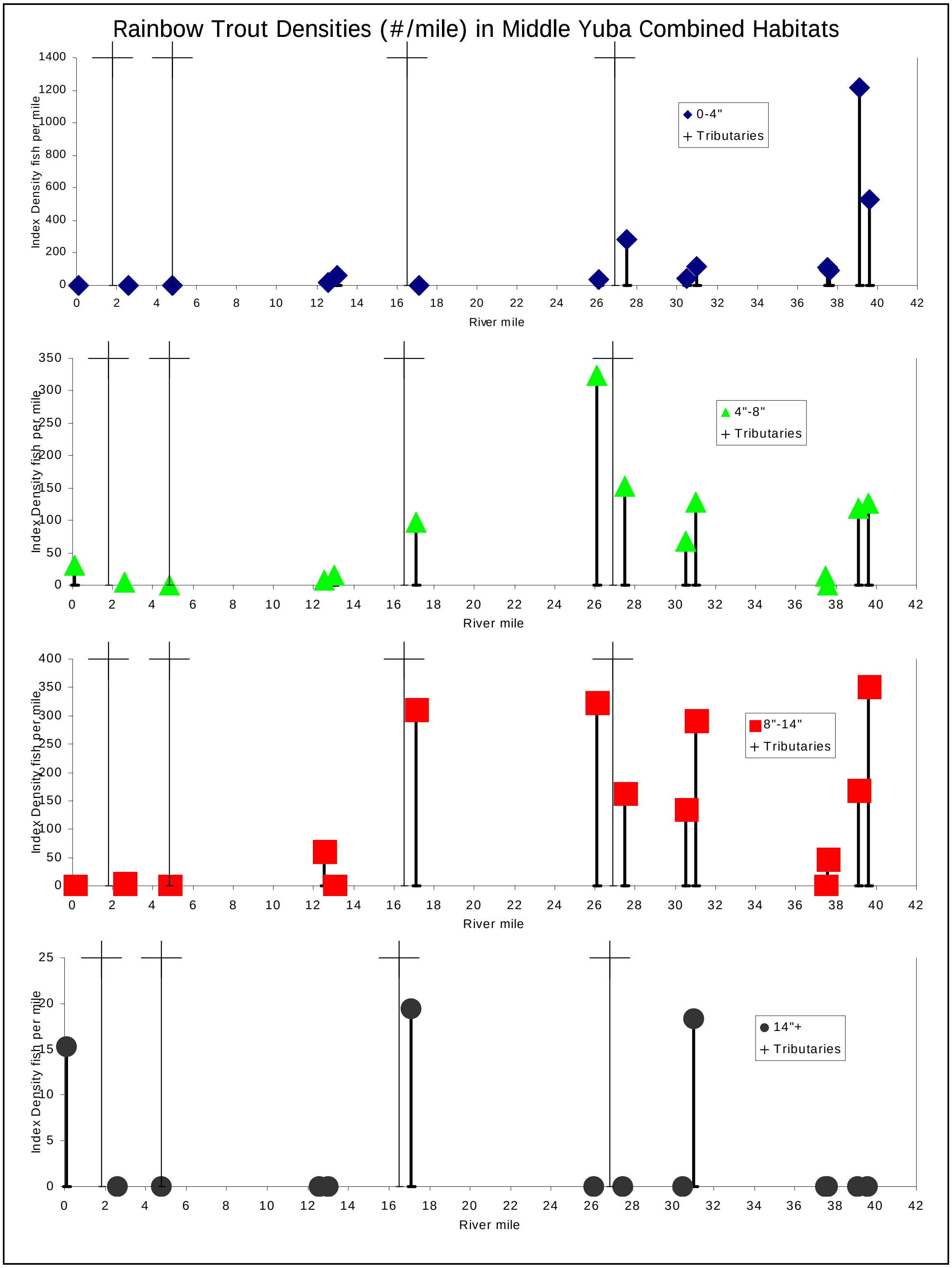

Figure 2. Rainbow trout index densities (#/mile) in sampled run, pool, and riffle habitats (combined) in the Middle Yuba River. The tributaries depicted by the fine vertical lines are: Yellow Jacket Creek (RM 1.8), Oregon Creek (RM 4.8), Kanaka Creek (RM 16.5), and Wolf Creek (RM 26.9).

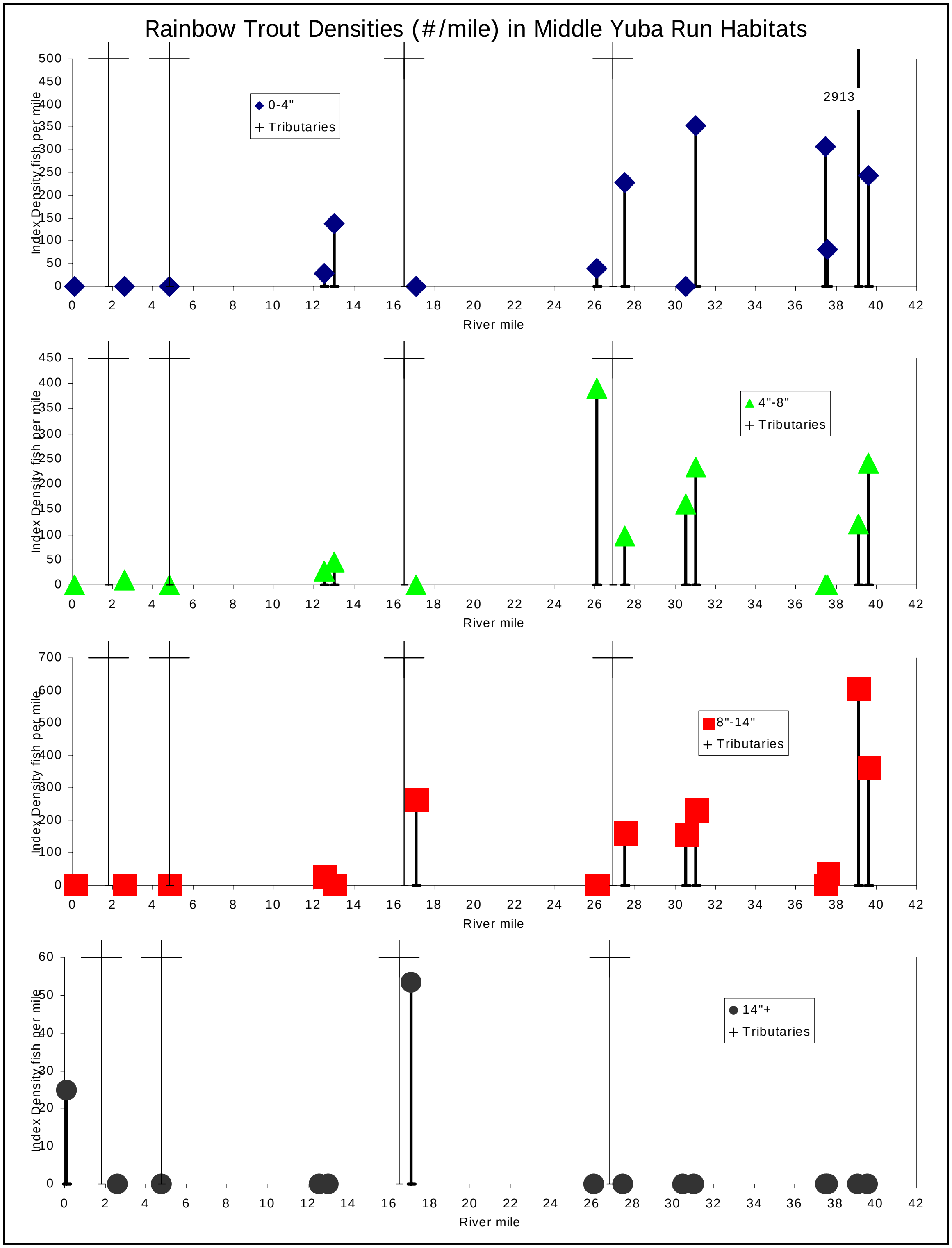

Figure 3. Rainbow trout index densities (#/mile) in sampled run habitats in the Middle Yuba River. The tributaries depicted by the fine vertical lines are: Yellow Jacket Creek (RM 1.8), Oregon Creek (RM 4.8), Kanaka Creek (RM 16.5), and Wolf Creek (RM 26.9). Note that the index density for 0-4 inch rainbow trout at RM 39.1 is 2913 trout/mile, off the chart scale.

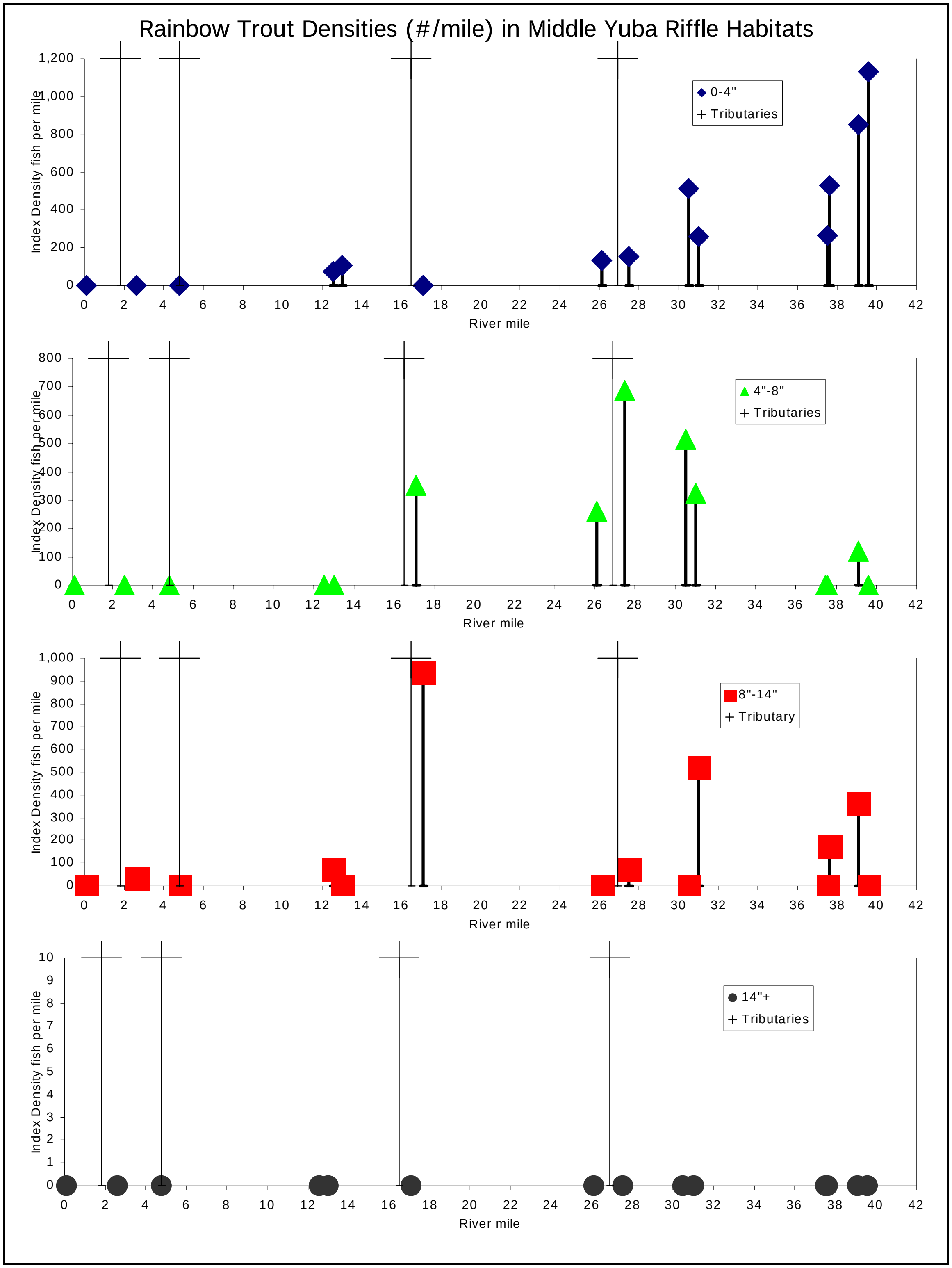

Figure 4. Rainbow trout index densities (#/mile) in sampled riffle habitats in the Middle Yuba River. The tributaries depicted by the fine vertical lines are: Yellow Jacket Creek (RM 1.8), Oregon Creek (RM 4.8), Kanaka Creek (RM 16.5), and Wolf Creek (RM 26.9).

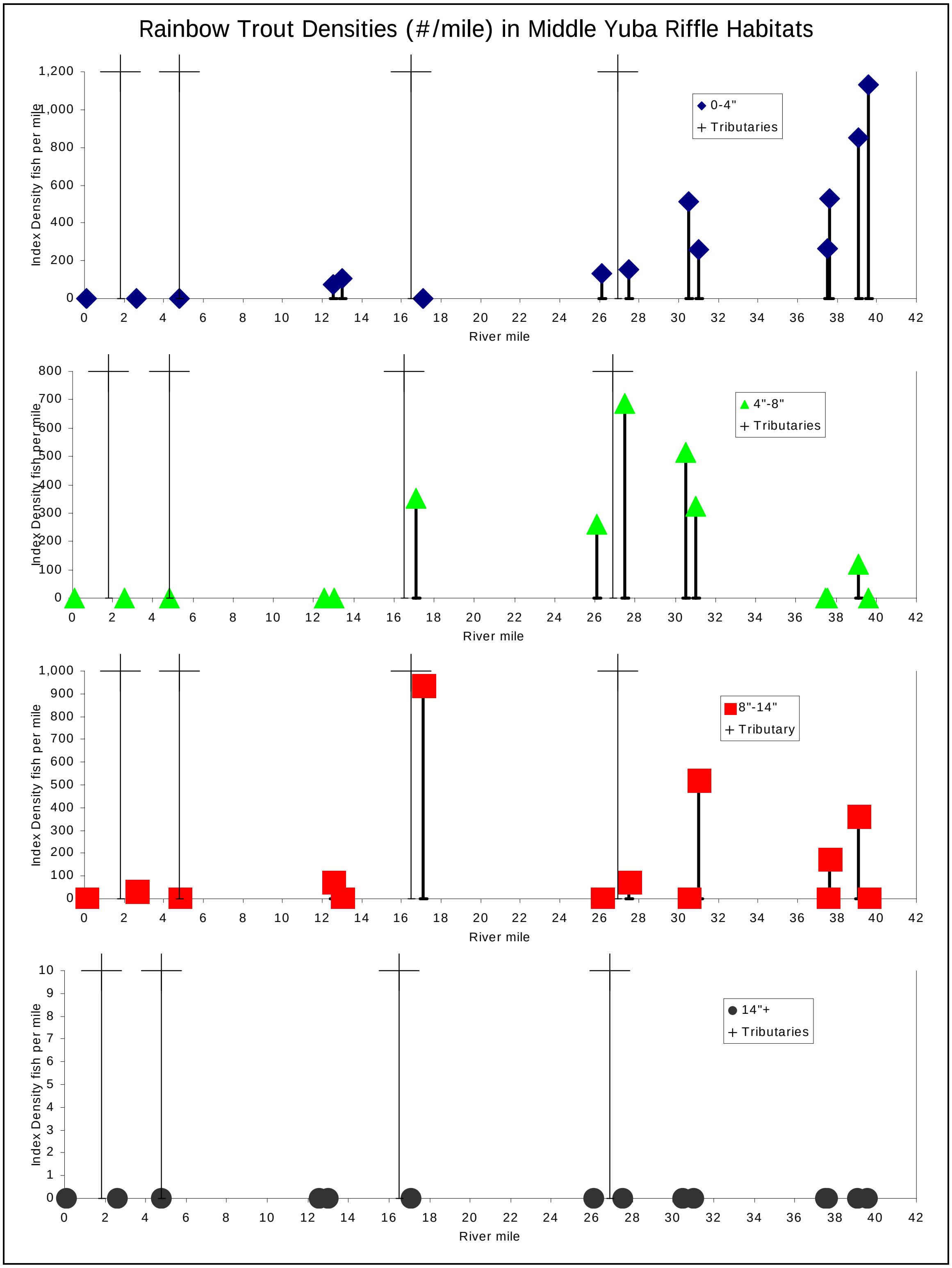

Figure 5. Rainbow trout index densities (#/mile) in sampled pool habitats in the Middle Yuba River. The tributaries depicted by the fine vertical lines are: Yellow Jacket Creek (RM 1.8), Oregon Creek (RM 4.8), Kanaka Creek (RM 16.5), and Wolf Creek (RM 26.9).

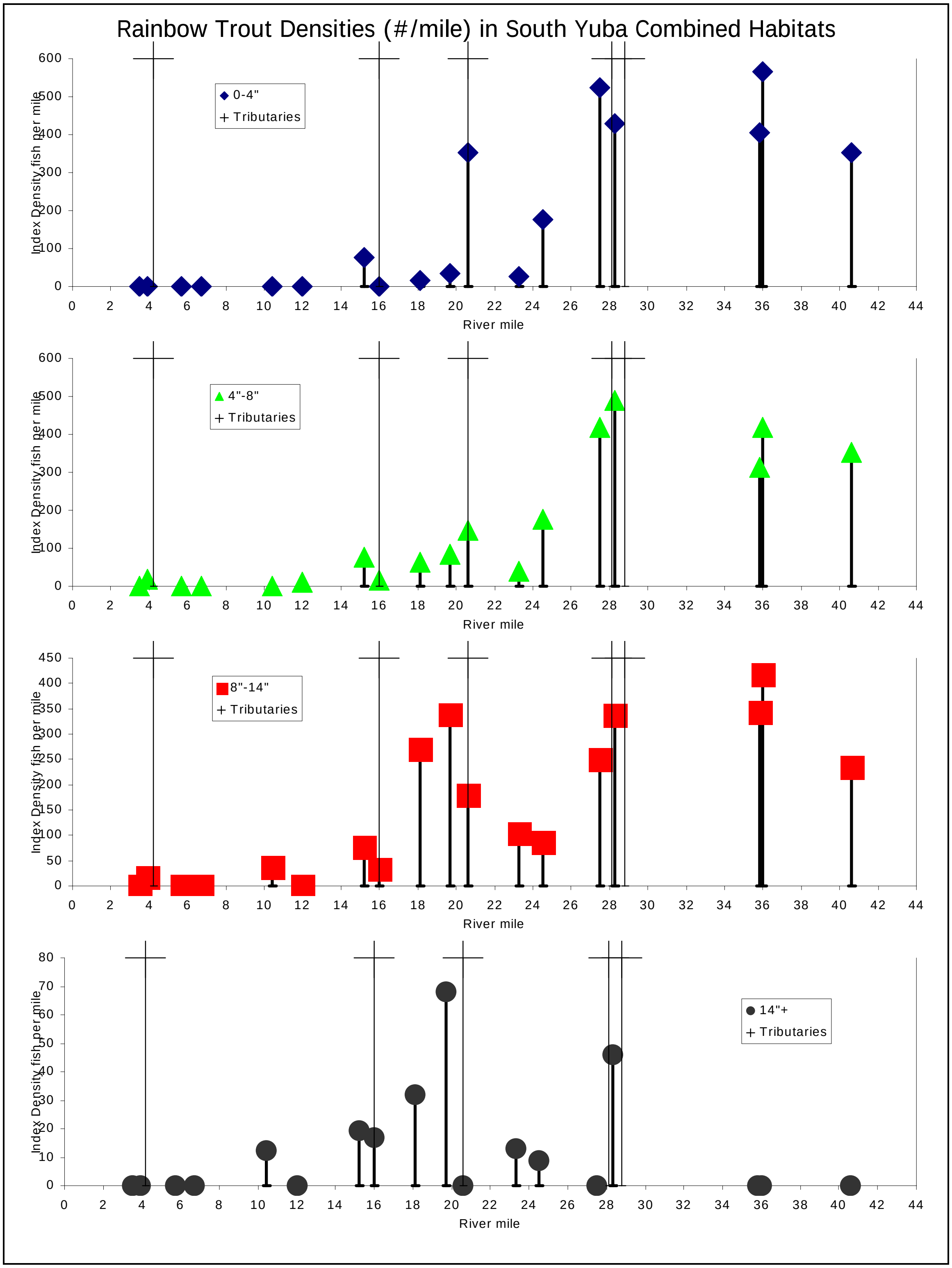

Figure 6. Rainbow trout index densities (#/mile) in sampled run, pool, and riffle habitats (combined) in the South Yuba River. The tributaries depicted by the fine vertical lines are: Owl (RM 4.2), Spring (RM 16), Humbug (RM 20.6), McKilligan (RM 28.1), and Poorman (RM 28.8) creeks.

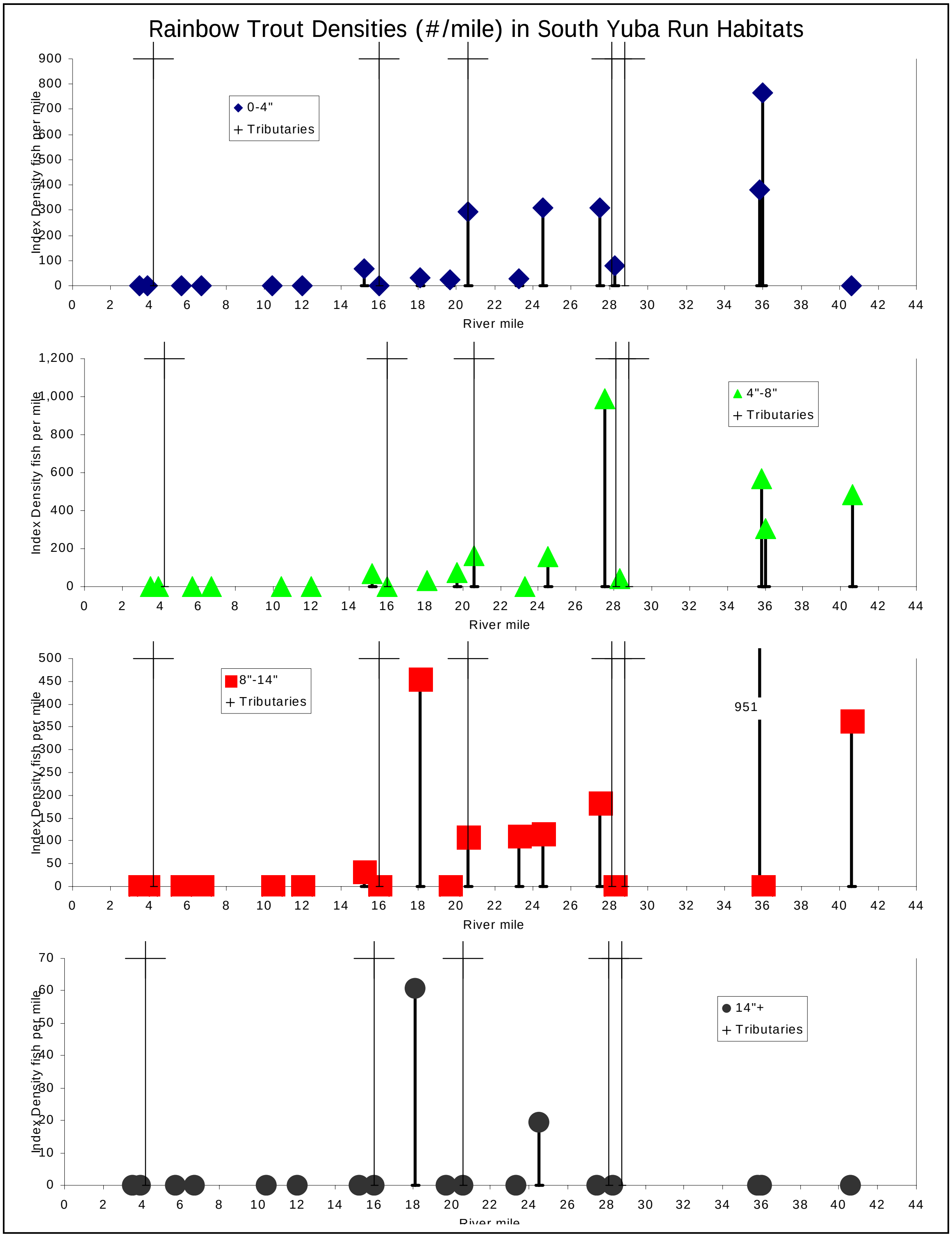

Figure 7. Rainbow trout index densities (#/mile) in sampled run habitats in the South Yuba River. The tributaries depicted by the fine vertical lines are: Owl (RM 4.2), Spring (RM 16), Humbug (RM 20.6), McKilligan (RM 28.1), and Poorman (RM 28.8) creeks. Note that the index density for 8-14 inch rainbow trout at RM 39.1 is 951 trout/mile, off the chart scale.

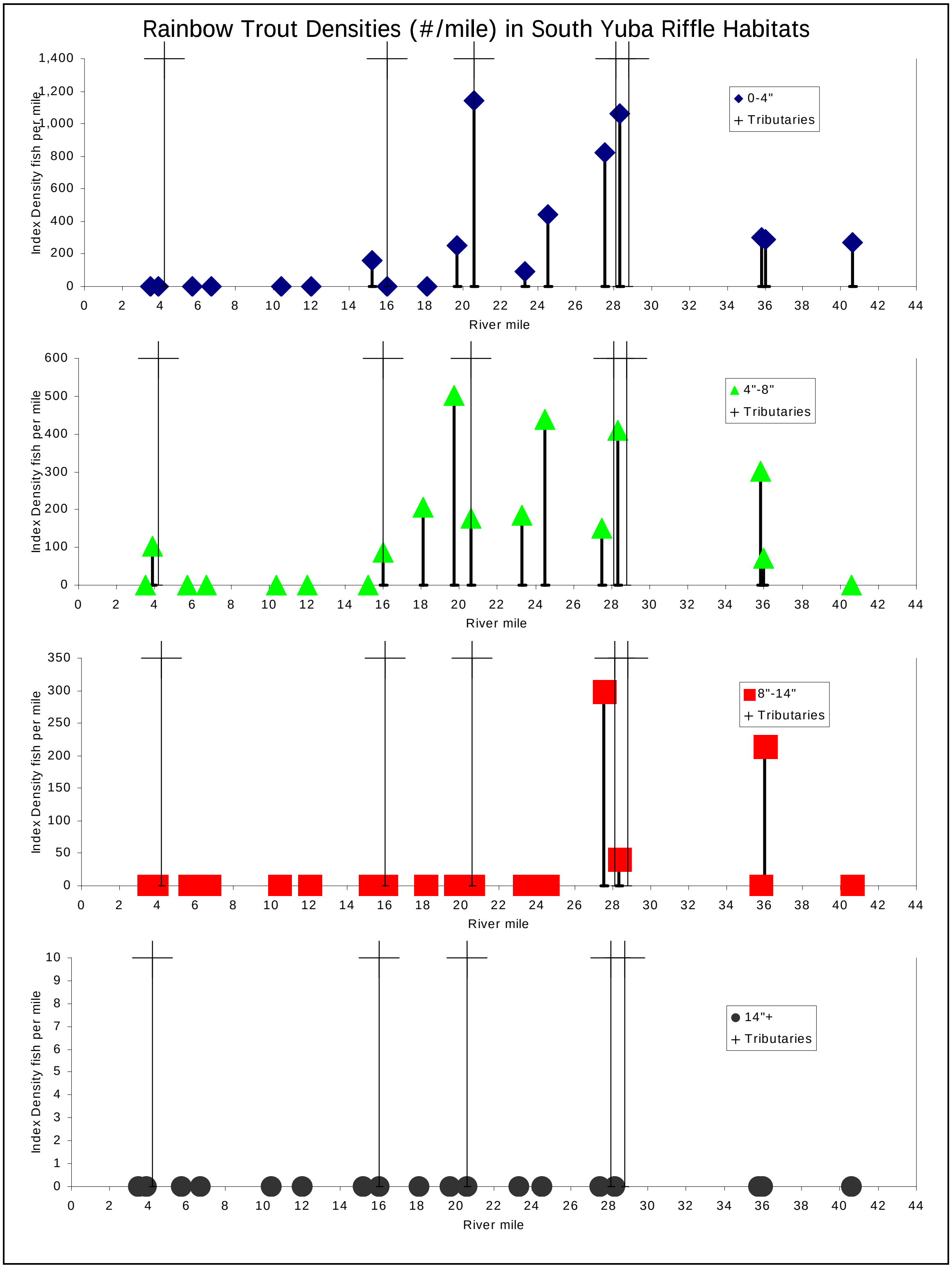

Figure 8. Rainbow trout index densities (#/mile) in sampled riffle habitats in the South Yuba River. The tributaries depicted by the fine vertical lines are: Owl (RM 4.2), Spring (RM 16), Humbug (RM 20.6), McKilligan (RM 28.1), and Poorman (RM 28.8) creeks.

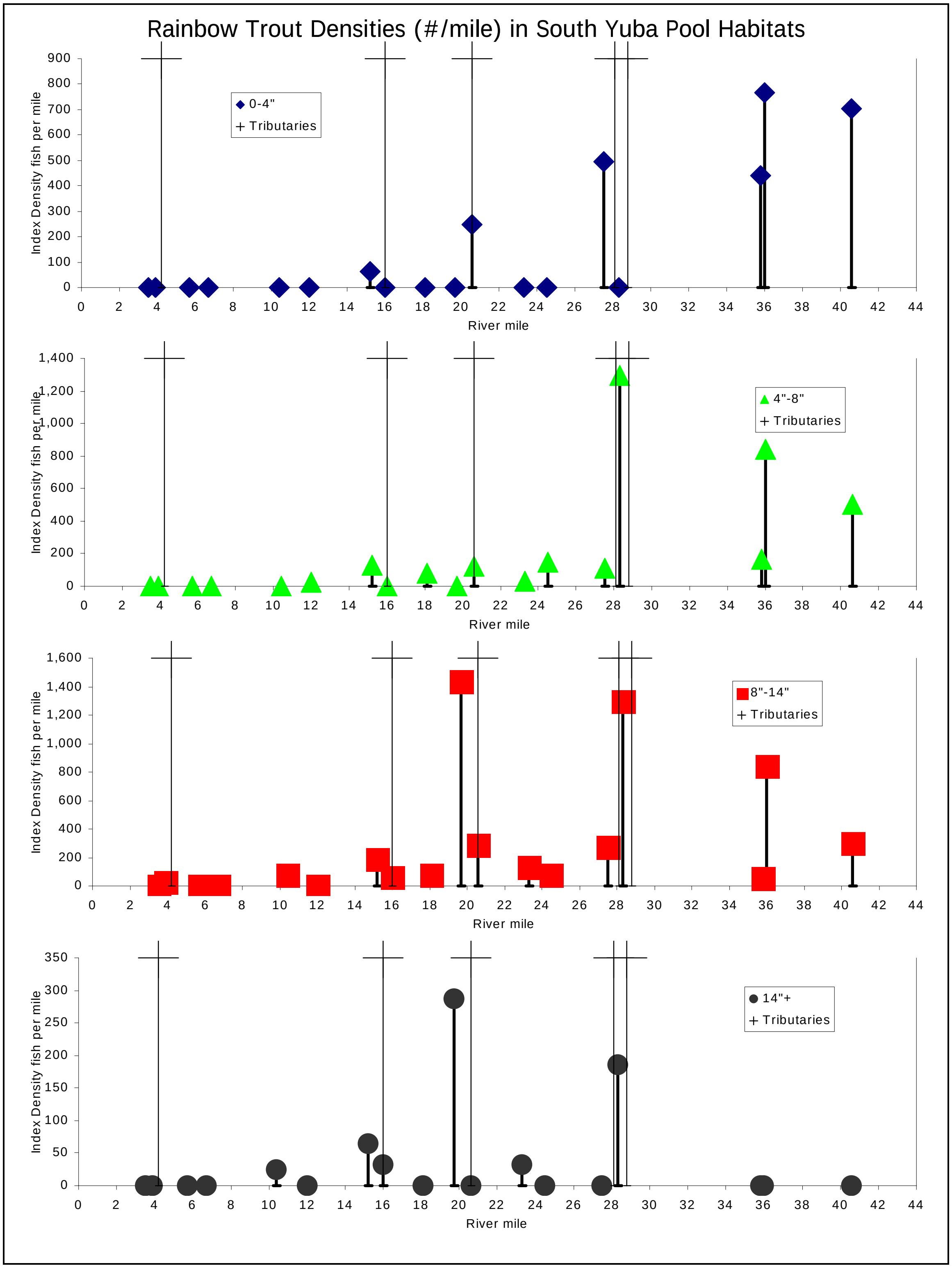

Figure 9. Rainbow trout index densities (#/mile) in sampled pool habitats in the South Yuba River. The tributaries depicted by the fine vertical lines are: Owl (RM 4.2), Spring (RM 16), Humbug (RM 20.6), McKilligan (RM 28.1), and Poorman (RM 28.8) creeks.

Thermal Refugia

Cold-water zones produced by deep pool stratification, tributaries, or hyporheic flows may provide thermal refugia for trout during warm summer periods (Nielsen et al 1994). In this study, however, only one thermal refugia was observed that appeared to be utilized by trout.

Deep Pools

South Yuba

Of the 26 pools in the South Yuba River in which water column temperatures were profiled, only two were thermally stratified (i.e., the difference in bottom and surface temperatures greater than one degree F) (Table 1). The pool at RM 27.5 had a surface temperature of 69.0^{0}F at 13:00 and a bottom temperature of 66.7^{0}F (equal to the morning surface temperature). A steady decline in temperature from the surface to the bottom suggested thermal stratification due to lack of mixing rather than hyporheic flows. No trout were observed in this pool. The 26 foot deep pool at RM 40.5 (Langs Crossing) exhibited the greatest thermal stratification with a bottom temperature of 57.1^{0}F and a surface temperature of 62.5^{0}F. Rainbow and brown trout were observed in this pool; however, they were utilizing the shallow tailout where stratification was not present.

Middle Yuba

Of the nine deep pools surveyed for thermal stratification on the Middle Yuba River, one was stratified with a difference in temperature greater then 1^0 F (Table 1). The 19.5 foot deep pool 0.9 miles upstream of the confluence with the North Yuba had a surface temperature of 73.2^{0}F and a bottom temperature of 69.9^{0}F. The bottom water temperature was warmer than the morning river temperature of 67.4^{0}F. No fish were observed in this pool.

Table 1. Locations and depths of deep pools in which water column temperature profiles were measured on the South and Middle Yuba Rivers. The temperatures were measured at the bottom and surface of the pools.

River Mile	*Depth Feet*	*Bottom*	*Temperature ^{0} F* *Surface*	*Difference*
South Yuba				
4.3	10.0	71.2	71.2	0.0
4.6	18.0	78.0	78.1	-0.1
4.7	14.0	78.0	78.1	-0.1
5.4	14.0	78.5	78.5	0.0
6.0	12.0	75.8	75.8	0.0
6.2	12.0	74.9	74.9	0.0
6.5	15.0	75.0	75.1	-0.1
7.3	12.0	71.2	71.3	-0.1
9.6	10.0	75.5	75.9	-0.4
11.2	16.0	70.6	70.6	0.0
11.5	12.0	70.0	70.2	-0.2
14.8	14.0	73.7	73.8	-0.1
15.2	21.0	72.6	72.7	-0.1
15.3	12.0	71.5	71.6	-0.1
15.9	14.0	71.3	71.8	-0.5
18.0	18.0	75.8	75.8	0.0
19.4	14.0	75.2	75.1	0.1
19.9	13.0	75.3	75.4	-0.1
23.9	11.0	71.7	71.7	0.0
24.1	14.0	71.2	71.4	-0.2
24.6	14.0	69.8	69.8	0.0
27.6	16.5	68.0	68.6	-0.6
27.7	15.0	68.7	68.7	0.0
28.1	15.0	66.7	69.0	-2.3
28.3	12.2	65.9	66.2	-0.3
28.4	11.0	66.6	66.7	-0.1
40.9	26.0	57.1	62.7	-5.6
Middle Yuba				
0.6	14.0	73.7	73.8	-0.1
0.9	19.5	69.9	73.2	-3.3
3.1	12.0	97.1	97.1	0.0
3.4	11.0	67.2	67.2	0.0
12.6	16.0	74.9	74.9	0.0
16.8	18.0	67.6	67.5	0.1
17.0	11.0	69.8	69.8	0.0
17.2	14.0	68.7	68.7	0.0

Tributaries

Tributaries to the main stem, having cooler summertime water temperatures, may provide refuge for salmonids from higher than optimum main stem water temperatures (Table 2). Oregon Creek, Kanaka Creek, and Wolf Creek, tributaries to the Middle Yuba, and Poorman Creek, tributary to the South Yuba, all were cooler than the main stem, appeared to provide good habitat, and are were inhabited by juvenile and adult rainbow trout. The North Yuba River, at the confluence with the Middle Yuba, also provides ample cool-water trout habitat. At the time of observation, water temperature in the North Yuba at the confluence with the Middle Yuba was 65.5^{0}F, 8.3^{0}F less than the Middle Yuba water temperature (73.8^{0}F).

Middle Yuba

- Yellowjacket Creek (confluence with the Middle Yuba at RM 1.8) had an estimated 0.2 cfs flow, steep gradient, and incised channel, and provided very little potential for summer rearing habitat. Creek water temperature was 62.5^{0}F, 10.2^{0}F less than the Middle Yuba.
- Oregon Creek (confluence with Middle Yuba at RM 4.8) had an estimated flow of 2 cfs with a water temperature of 62^{0}F, 7.9^{0}F less than the main stem. The mouth was passable to small fish. Of the 2,088 feet surveyed, no barriers were encountered. Most of the channel was low gradient with holding areas and some spawning gravel.
- Kanaka Creek (confluence with the Middle Yuba at RM 16.5) had an estimated flow of 2 cfs and a water temperature of 65.2^{0}F, 2.3^{0}F less than the main stem. The mouth of the creek is steep and flows over bedrock with a low water fry barrier cascade only 110 feet upstream of the confluence. Rainbow trout adults and fry inhabited the creek both upstream and downstream of this barrier. The creek channel was actively dredged creating dredge pools and spawnable dredge tailings. Four small cascade barriers (approximate four foot drop each) were present below a final eight-foot high barrier 1,748 feet upstream of the confluence (photographs in Appendix C).
- Wolf Creek (confluence with the Middle Yuba at RM 26.9) had an estimated flow of 4 cfs and a water temperature of 59.6^{0}F, 6.1^{0}F less than the main stem. Rainbow trout fry were observed in the 1,004 feet of stream channel surveyed. The gradual channel slope with cobble and small boulder substrate presented good salmonid rearing habitat. Three road crossings and a dredge were recorded in the area surveyed.

South Yuba

- Owl Creek (confluence with the South Yuba at RM 4.7) had an estimated flow of about one cfs. The water temperature in Owl Creek was 65.0^{0}F, 7^{0}F less than the main stem. Although there was no discernable temperature decrease in the main stem due to the Owl Creek accretion, a concentration of rainbow trout was observed at the confluence. In the run and riffle at the confluence one fry and six adult trout were counted. Upstream and downstream of this area zero to two trout per habitat unit were observed. Fry and adult trout inhabited Owl Creek and might represent a source of recruitment to the South Yuba River. Only an estimated 100 feet of Owl Creek is accessible to the first barrier cascade.

- Spring Creek (confluence with the South Yuba at RM 16.0) had an estimated two cfs discharge, and a terminal waterfall at the confluence with the South Yuba preventing upstream migration and utilization as a thermal refuge. The temperature of Spring Creek was 59.7^{0}F, 11.7^{0}F less than the main stem. No discernable decrease in the main stem temperature was evident due to the Spring Creek accretion; however, a concentration of juvenile and adult trout (six juvenile and five adults) was present at the confluence pool. Trout fry were observed in Spring Creek above and below the waterfall, potentially representing a source of recruitment to the South Yuba River.
- Humbug Creek (confluence with the South Yuba at RM 20.6) had a five-foot high cascade barrier to upstream migration approximately 900 feet upstream from the mouth. The channel at the mouth flows through bedrock, cobble, and mine tailings. At the estimated discharge of one cfs, only small fish could pass. Upstream the channel becomes narrow and incised with very little spawning gravel. Adult and juvenile rainbow trout were observed. The temperature in Humbug Creek at the time of the survey was 62.1^{0}F, 9.8^{0}F less than the main stem.
- McKilligan Creek (confluence with the South Yuba at RM 28.2) had an estimated flow of 0.4 cfs and created the only discernable thermal refuge utilized by twenty adult rainbow trout. The creek temperature was 57.1^{0}F at 12:30, 12.1^{0}F less than the main stem (69.2^{0}F). The trout were holding in a mixing area with a temperature of 67.4^{0}F. Earlier in the day (at 09:30) water temperature in the South Yuba was 66.6^{0}F, cooler than the temperature at which the trout were holding. Although trout fry were present upstream in the creek, passage through the cobble at the mouth was not possible due to the low flow.
- Poorman Creek (confluence with the South Yuba at RM 28.8) had an estimated flow of five cfs and no barriers to migration in the 2,148 feet surveyed. The low gradient cobble and boulder substrate channel provided good habitat for the observed rainbow trout. The stream temperature in the morning was 59.5^0 F, 7.1^{0}F less than the main stem. A temperature reading in the afternoon, however, indicated that the stream temperature had risen to 68.4^{0}F, only about one degree less than in the main stem.

Table 2. Tributaries to the Middle and South Yuba assessed for thermal refugia for salmonids. RBT = rainbow trout, SKR = Sacramento sucker, SMB = smallmouth bass.

	Location	Est. flow	Distance feet		Temperature		Fish species	Rearing
Tributary	River Mile	Cfs	Surveyed	Barrier	Tributary	Yuba	Observed	Potential
Yellow jacket Cr.	MY 1.8	0.2	0	0	62.4	72.6		None
Oregon Cr.	MY 4.8	2	2088	Unknown	62.5	70.4	RBT, SKR, SMB	Good
Kanaka Cr.	MY 16.5	2	1748	1748	65.2	67.3	RBT	Good
Wolf Cr.	MY 26.9	4	1004	Unknown	59.6	65.7	RBT	Good
Owl Cr.	SY 4.2	1	100	100	65	72	RBT	Some
Spring Creek	SY 16.0	2	0	0	59.7	71.4	RBT	None
Humbug Cr.	SY 20.6	1	898	898	62.1	71.9	RBT	Poor
McKilligan Cr.	SY 28.2	0.4	0	0	57.1	69.2	RBT	Poor
Poorman Cr.	SY 28.8	5	2148	Unknown	59.5	66.6	RBT	Good

Barriers

Our House Dam at RM 12.7 on the Middle Yuba and the abandoned diversion dam at RM 10.4 on the South Yuba are the two man-made barriers (in the survey area) that currently block upstream fish migration (Table 3). On the South Yuba River, natural barriers at river miles 6.2 and 20.0 may be passable to upstream migrants at higher flows, but they would not be barriers to downstream migration. Likewise on the Middle Yuba, the natural barriers at river miles 0.2 and 3.2 would only be low flow barriers to upstream migration of small fish. The estimated 13 feet high cascade at RM 0.4 on the Middle Yuba, however, represents a major obstacle to upstream migration. Several very large boulders blocking the narrow bedrock channel created this barrier, and sediment has filled in upstream of the boulders forming a dam. Although large fish may be able to pass at certain flows, the height of the cascade and narrowness of the canyon is expected to at least impede passage at all flows. Appendix C contains photographs of the barriers encountered.

Table 3. Location of potential barriers encountered on the Middle and South Yuba Rivers while conducting the rainbow trout distribution and abundance survey.

South Yuba	*River Mile*	*Estimated Height Feet*
	6.2	6
	10.4	Dam
	20.0	6 to 7
Middle Yuba		
	0.2	5
	0.4	13
	3.2	2
	12.7	Dam

Discussion

Relationship Between Water Temperature and Fish Densities

Rainbow Trout

There are numerous and conflicting reports of suitable temperatures for rainbow trout (Cherry et al. 1977, Raleigh et al. 1984, Myrick and Cech 2001, Bratovich et al. 2003). Those temperatures which in the laboratory provide for optimum growth, may not promote the highest abundance in the river. In the laboratory only one variable is altered, temperature, and the resulting growth compared. In reality the temperature affects the entire ecosystem. The abundance, condition, and distribution of trout are controlled by a myriad of variables including complex interactions of food supply, competition, predation, disease, water quality, and physical habitat; the quality, quantity, and robustness of each variable changing with the change in water temperature. Hyporheic flows such as groundwater seeps, tributary accretion, and pool stratification can also provide refuge from lethal or sub lethal water temperatures

(Matthews and Berg 1996, Nielsen et al 1994), and tributaries can provide recruitment to the main stem. Access to the stream and resulting human influences, such as angling and gold dredging, can also substantially alter fish densities. A comparison of water temperatures to trout index densities could reveal trends depicting the optimum temperature with various other undulations reflecting one or more of the other physical, chemical, biological, or human factors.

Stream temperatures for the summer months (CH2MHILL data) were recorded at eight locations on the Middle Yuba and seven locations on the South Yuba. Calculating regression models of average monthly temperature against river mile allows the estimation of average water temperature at each of the locations sampled in the dive counts (Figure 10). This method of determining the average water temperature for each of the sample locations assumes that the stream temperature varies evenly with river mile. Although a perfect relationship is not expected due to accretion, channel morphology, and changes in the riparian canopy, the regression models for both rivers provided a very good representation of the longitudinal stream temperatures (both R^2's exceeded 0.99). Although site-specific stream temperatures were measured at each sample location during the survey period, those temperatures were significantly affected by time of day and short-term meteorological conditions and thus were less representative of the average temperatures occurring at that location. The site-specific temperatures recorded during the survey are included with the raw data in Appendix A.

July average water temperatures were compared to trout densities. Although the survey was conducted in late August and early September when water temperatures were slightly cooler than July, we assumed that July water temperatures were most limiting to the local trout population and that the trout did not substantially redistribute themselves as temperatures decreased in August.

Consideration was also given to other methods of temperature analysis including using average daily maximum water temperatures, monthly mode and median temperatures, and including diurnal fluctuations. Although such methods of analysis are utilized in other studies, the vast majority relate the fish population parameters to mean temperatures. Median temperatures were very close to mean temperatures when unreasonably high values were eliminated form the data set. Also, frequency distributions of monthly temperatures were often bimodal and dependant on the bin sizes specified for the frequency distributions (i.e. 0.1^0, 0.5^0, 1.0^0, etc.), thus the use temperature modes could be misleading. Consequently, mean monthly temperatures are the most universally utilized and are used in this discussion (Figure 11); however, the other values are also presented in Appendix D.

In order to better illustrate trends in the relationship between average July temperatures and rainbow trout index densities, all index densities from locations which had average July temperatures within 2^0F categories were grouped together and averaged prior to plotting (Figure 12).

Middle Yuba

Index densities for adult rainbow trout in the Middle Yuba River were typically low at locations with average July stream temperatures above 71.9^{0}F (Figure 11). Index densities at warmer sites averaged 16 fish/mile (range 0-62 fish/mile), whereas densities at cooler sites averaged 204 fish/mile (range 0-353 fish/mile). Juvenile rainbow trout exhibited similar trends. The index densities for rainbow trout fry in the Middle Yuba were low (average of 17 trout/mile and range of 0 to 63 trout per mile) at locations with average July stream temperatures above 65.8^{0}F. At locations with July average temperatures of or below 65.8^{0}F, the index densities for fry varied between 45 and 1,218 fish per mile. The large variation in trout fry suggest that other environmental factors such as quality and quantity of spawning gravel, tributary recruitment, predation, human influence, or other unidentified factors play an important role in determining fry density.

When index densities were grouped into 2^{0}F categories (Figure 12), the index density for adult trout increased from lows at higher temperatures to the 71^0 to 73^{0}F category, and then declined at cooler temperatures. Similar trends occurred for juvenile trout, except that the index densities peaked at the 65^0 to 67^{0}F category. Fry index densities, except for the unusual peak in the lowest temperature category, also exhibited a similar temperature relationship.

South Yuba

In the South Yuba River, the adult trout index density averaged 273 trout per mile at locations with average July water temperatures less than or equal to 75.2^{0}F (range 96 to 417 fish/mile) (Figure 11). At locations with higher average July stream temperatures, the average adult index density declined to 27 fish per mile, and no adult trout were observed at locations with average July stream temperatures above 76.3^{0}F. Reduced densities of adult rainbow trout occurred in the Humbug Creek to Missouri Bar area with average July temperatures between 73.4^{0}F and 74.7^{0}F. Both fry and juvenile index densities were consistently highest at average July stream temperatures of 71.9^{0}F and cooler. The fry and juvenile index density spike at the location with 72.7^{0}F may have been a result of recruitment from Humbug Creek, which flows into the South Yuba at that point.

Grouping the density data in temperature ranges of 2^{0}F (Figure 12) indicate that index densities of fry, juvenile, and adult rainbow trout reach a plateau in the 71^0 to 73^{0}F category.

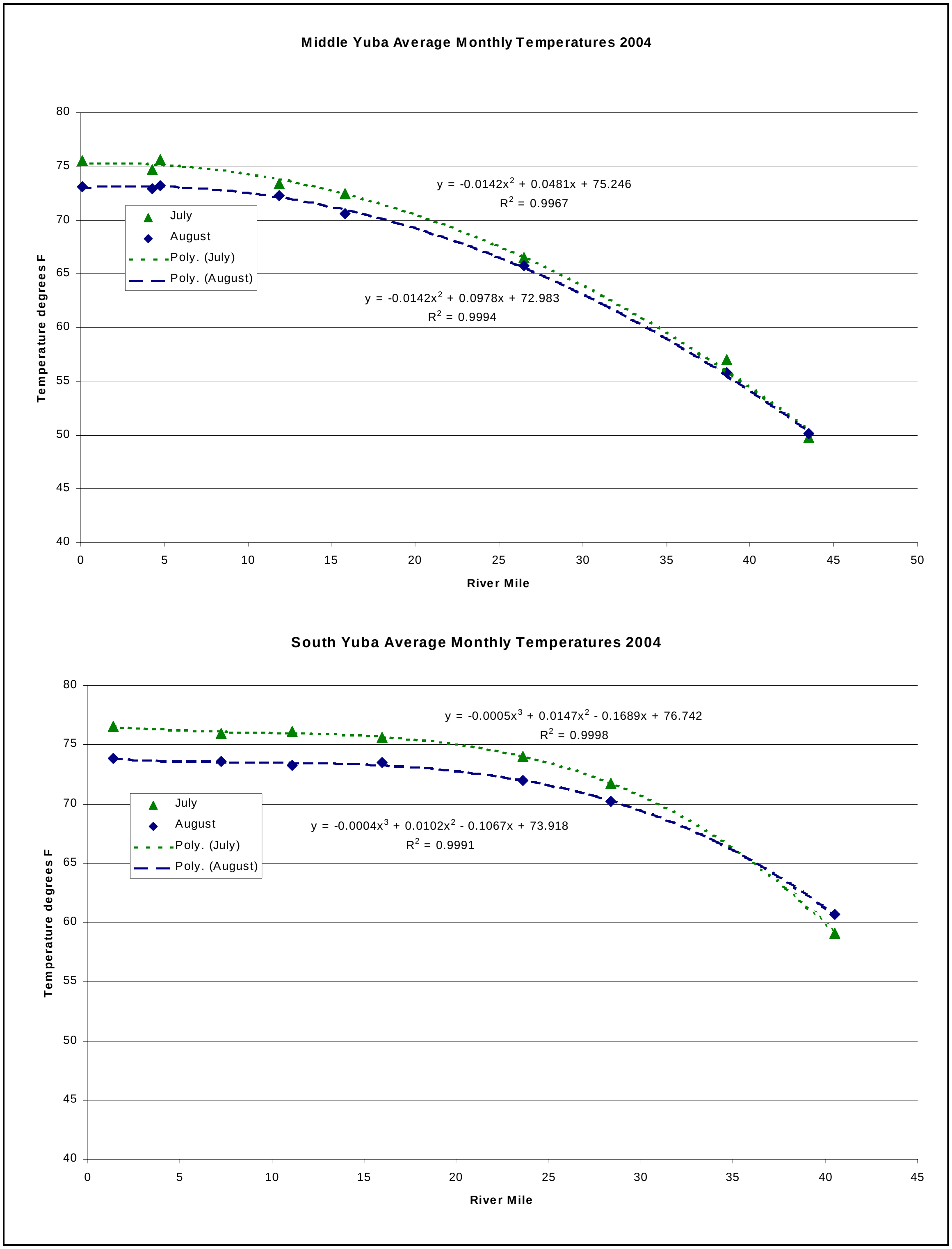

Figure 10. Middle and South Yuba mean July and August recorded temperatures (CH2MHILL data) and regression verses river mile.

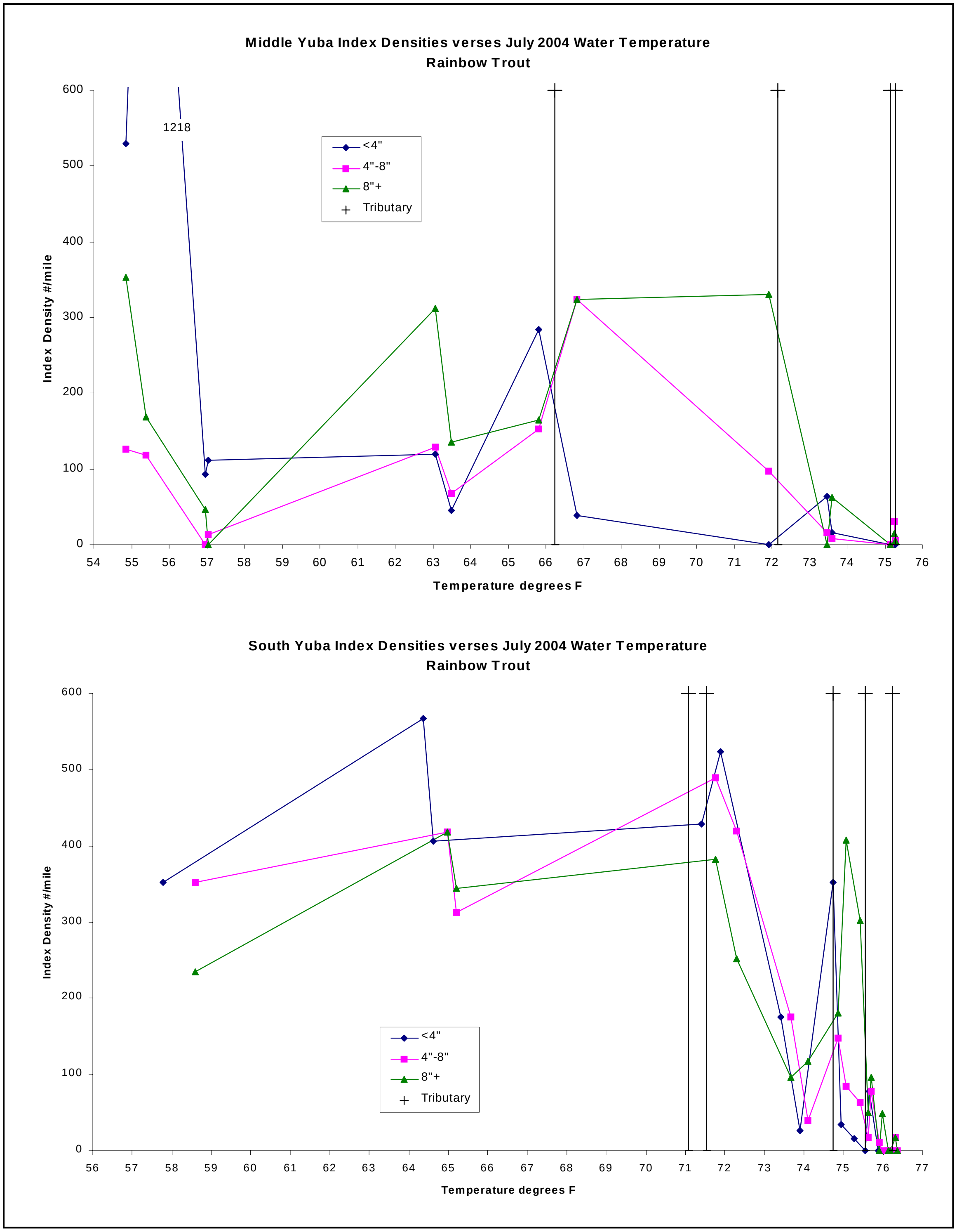

Figure 11. Rainbow trout index densities (three size classes) versus average July water temperature on the Middle and South Yuba rivers. The fine vertical lines show estimated water temperatures at the confluences of Yellowjacket, Oregon, Kanaka, and Wolf creeks on the Middle Yuba and Owl, Spring, Humbug, McKilligan, and Poorman creeks on the South Yuba.

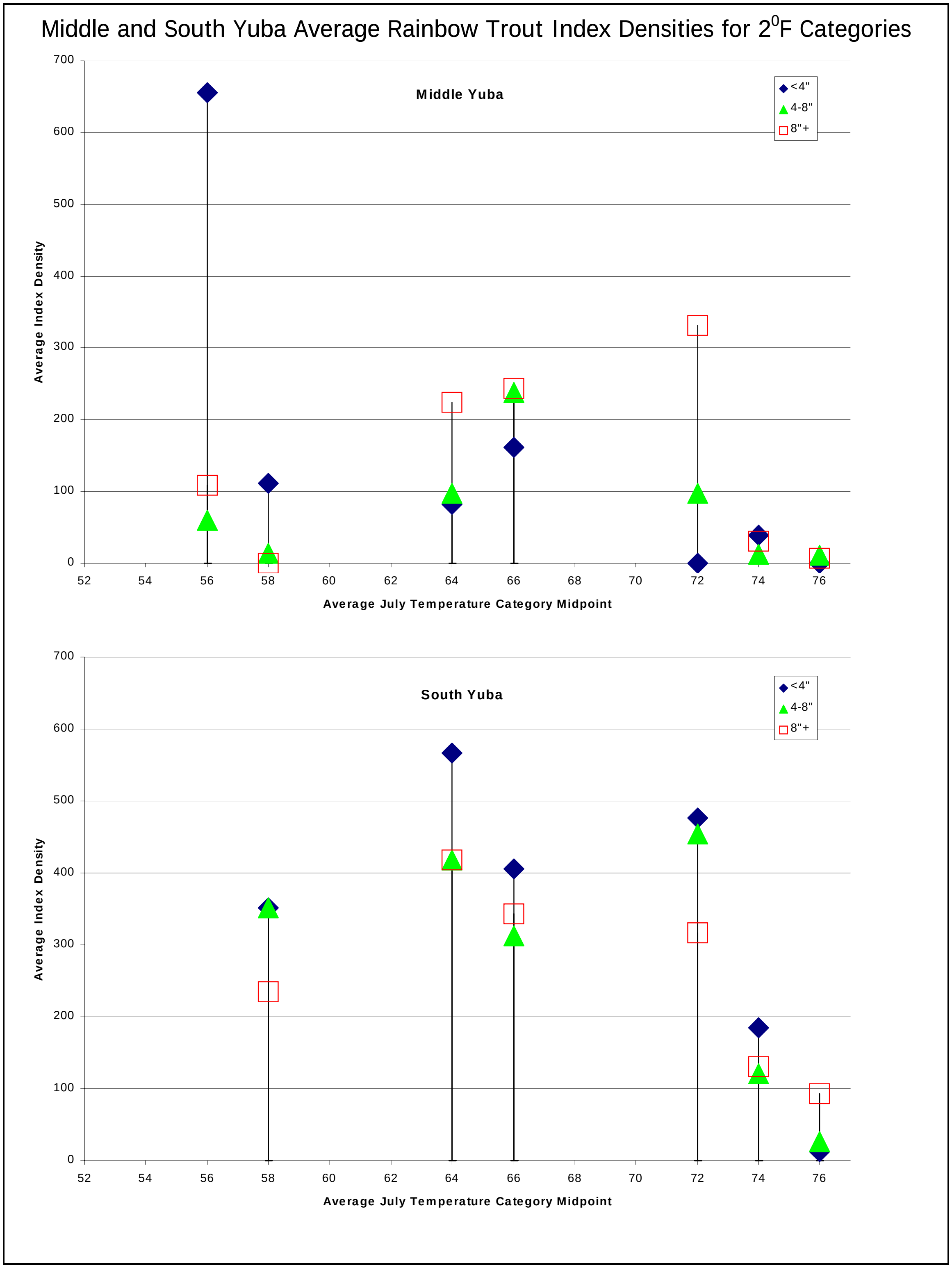

Figure 12. Average rainbow trout index densities (#/mile) by estimated mean daily water temperature in July. All index densities for each location which had an average July temperature within each 2^0F range (midpoint specified on axis) were averaged.

Non-Salmonid Species

Index densities of non-salmonids were variable and, except for Sacramento suckers, confined to the warmer, lower reaches of both rivers. Sacramento suckers were not observed in locations with average July temperatures less than 63.1^{0}F. Smallmouth bass occurred where average July stream temperatures exceeded 73.6^{0}F. Pikeminnow and hardhead were observed in locations with average July temperatures greater than 71.7^{0}F.

Comparison of Rainbow Trout Densities in the Yuba River with Other Northern California Rivers

Index densities of rainbow trout in the South and Middle Yuba rivers were compared to two other northern California rivers in which TRPA has conducted dive counts. For the Middle and South Yuba rivers, the average index densities were calculated from the locations where warm temperatures did not appear to limit trout densities. For the Middle Yuba adult and juvenile rainbow trout, the range used was from RM 17.1 to RM 40, whereas the fry range was from RM 27.5 to RM 40. The South Yuba adult and juvenile index estimate was calculated from dive count data between RM 18.1 and RM 40, whereas the fry index density range was calculated from locations upstream of RM 27.5.

The two rivers to which the Middle and South Yuba rivers are compared are the Upper Sacramento River (TRPA 2001a) and North Fork Feather River (NFFR) (TRPA 2002). The Upper Sacramento River flows approximately 42 miles from Lake Siskiyou to Shasta Lake. The 40 to 50 cfs summer dam release increases to approximately 200 cfs in the lower reach. Stream widths increase from an average of 50 ft in the upper reach to 70 ft in the lower reach. 2001 index densities were available for both the upper and lower reaches (TRPA 2001a). The North Fork Feather River flows between Lake Almanor and Lake Oroville through several hydroelectric diversions. The Seneca Reach extends 17.5 miles from the Canyon Dam (summertime release of 35 cfs) on Lake Almanor to the Belden Fore-bay. The Belden reach extends 15 miles from the Belden Fore-bay (60 to 140 cfs summertime release) to the Belden powerhouse, just upstream of the Rock Creek Fore-bay.

Both the NFFR and the Upper Sacramento River had substantially higher flows than the Middle and South Yuba (Tables 4 and 5). The estimated discharges at the locations used for index density calculations ranged from 15 to 30 cfs in the South Yuba and 8 to 20 cfs in the Middle Yuba. The Seneca Reach of the NFFR had the most comparable discharge, but still approximately twice the South Yuba and four times the Middle Yuba. An area density (#/ft^2) comparison might be better than a longitudinal (#/mile) for these different sized rivers; however, widths were collected only on run habitats at the dive count locations on the Middle and South Yuba rivers. Comparing the Belden and Seneca discharges and index densities demonstrates that even area densities would not have produced comparable densities.

Table 4. Juvenile and adult rainbow trout index densities and range of densities from all habitat types in the Seneca and Belden Reaches of the North Fork Feather River (2001) and the Middle and South Yuba Rivers (2004). Juveniles were classified as 2-6 inches in the North Fork Feather and 4-8 inches in the Yuba River. No data was collected on rainbow trout fry (less than 2 in) in the NFFR.

North Fork Feather River				
Belden Reach	*Juvenile 2-6 in* #/mile (range)	*Adult 6+ in* #/mile (range)	*July*	*August*
			Dam Release - cfs	
Low Gradient	542 (0-3,696)	178 (0-1,848)	140	140
High Gradient	404 (0-1,921)	639 (0-4,000)	140	140
Seneca Reach				
Low Gradient	2178 (0-7,200)	625 (0-4,000)	35	35
High Gradient	2599 (0-9,126)	876 (0-4,107)	35	35
	Juvenile 4-8 in #/mile (range)	*Adult 8+ in* #/mile (range)		
Middle Yuba	114 (0-323)	204 (0-353)	4	4
South Yuba	250 (39-490)	273 (96-418)	6-7	6-7

The Belden Reach of the NFFR had a summertime discharge about twice the lower reach of the Middle Yuba and four to six times the upper reaches. Water temperatures in the Belden Reach averaged about 70^0- 72^0F in August of 2001 (TRPA 2003). Rainbow trout are stocked in the Belden Reach and angler harvest is permitted. With the exception of the adults in the low gradient reach, juvenile and adult trout index densities were substantially higher in the Belden Reach than either the Middle or the South Yuba rivers (Table 4).

The Seneca Reach of the NFFR had a dam release about equal to the discharge in the lower reaches of the South Yuba (approximately five times greater than the upper reaches of the South Yuba) and mean daily stream temperatures between 55^0F and 59^0F in August 2001. Juvenile trout index densities were 8 to 22 times greater than those in the Middle and South Yuba rivers. Adult index densities were about three times greater than the Middle or South Yuba rivers (Table 4).

The Upper Sacramento had a dam release of 40 to 50 cfs giving the upper reach a discharge about 25% higher than the lower South Yuba (approximately seven times the upper reaches). Measured stream temperatures were in the low 50's during the 2001 dive counts. Densities in the upper reach of the Upper Sacramento River were similar or slightly higher than Yuba densities for all size categories except for the trout greater than 14 inches. The upper reach of the Upper Sacramento River had substantially more large trout than the Middle Yuba and about twice as many large trout as the South Yuba. Poor water visibility could have caused under counting in the upper reach of the Upper Sacramento River (Table 5).

The lower reach of the Upper Sacramento had a discharge of about 60 cfs increasing to near 200 cfs at Lake Shasta, about five times the South Yuba. Water temperatures measured during the 2001 dive count varied between 46^0F and 73^0F. Index densities for trout smaller than 14 inches in the Lower Reach were about three to four times greater than those in the Middle and South Yuba. The index densities for trout greater than 14 inches were substantially higher in the lower reach of the Sacramento River (Table 5).

Table 5. Index densities and range of densities for various size categories of rainbow trout in the Upper Sacramento (2001) and Middle and South Yuba (2004) Rivers (all habitat types combined except deep pools which were not sampled on the Upper Sacramento River). The upper reach of the Upper Sacramento River is upstream of the Cantara Loop Bridge while the lower reach extends to the Shasta Reservoir.

	Index Density - # per mile (range)				*Average Dam Release - cfs*	
Upper Sacramento	*RBT4+*	*RBT 4-8 in*	*RBT 8-14 in*	*RBT >14 in*	*July*	*August*
Upper Reach	370 (0-1,610)	438 (0-1,104)	312 (69-690)	37 (0-262)	40-50	40-50
Lower Reach	1123 (0-9,634)	981 (0-4,250)	814 (0-3,670)	168 (0-901)	N/A	N/A
Middle Yuba	343 (45-1,219)	114 (0-323)	200 (0-352)	4 (0-19)	4	4
South Yuba	455 (352-524)	250 (39-490)	257 (88-415)	17 (0-68)	6-7	6-7

Potential Rearing Habitat for Anadromous Salmonids

Steelhead represent the anadromous life form of rainbow trout. The differences between rainbow trout which exhibit anadromy and residency are poorly understood as they often coexist in the same streams (Nielsen et al, 1997, McEwan and Jackson 1996). Offspring from steelhead may become resident trout and offspring from resident trout may become steelhead. Trout may migrate to the ocean after several years of freshwater residency and thus become steelhead. Steelhead populations isolated upstream of migration barriers become resident trout (Nielsen et al, 1997). Resident males may attempt to spawn with anadromous females if not chased away by anadromous adults. In coastal streams in which both resident and anadromous forms exist, the two forms are not taxonomically distinct; however, over 110 years of stocking rainbow trout has complicated the genetic diversity. Relative to the evolution of the Yuba River steelhead stock, the man-made barriers on the Yuba have been in place for a short amount of time. We therefore assume that rearing habitat for the resident and anadromous life history forms will be the same.

Chinook salmon belong to the same genus (*Oncorhynchus*) and share many of same life history patterns as steelhead. There is, however, no resident form of Chinook in the Middle or South Yuba, and most Chinook in California outmigrate as fry within 3-4 months of emergence. Steelhead, in contrast, typically rear in freshwater for 1-3 years prior to outmigration. . Temperature requirements for rearing are similar to steelhead, and reported optimum and suitable temperatures vary substantially (California Department of Water Resources 2003). Chinook salmon and steelhead coexist in many California streams; however, the range for steelhead extends further south suggesting a higher tolerance for warmer water temperatures. In sum, rainbow trout fry are here assumed to be representative of steelhead and Chinook fry, and rainbow juveniles are used to represent steelhead juveniles.

Assuming that rainbow trout is an acceptable surrogate for anadromous salmonids, the 2004 data suggest that summertime habitat in both the Middle and South Yuba main stems is expected to be primarily limited to reaches upstream of RM 17. In the Middle Yuba, juvenile and adult rainbows were observed in the entire study area; however, densities downstream of RM 17 were low and variable. Likewise, in the South Yuba juveniles were observed at RM 3.9, but densities were low and variable downstream of RM 18.1. Although fry were observed at downstream locations, fry densities did not reach consistent densities until RM 27.5. The river miles and elevations are similar in both rivers at the juvenile and fry rearing habitat boundaries; however, the average 2004 July water temperature in the Middle Yuba was lower by 4^0 to 6^0F at those locations. This may be partially related to flow as the South Yuba estimated flow was approximately twice that of the Middle Yuba at those locations. Trout require more food and highly oxygenated water at higher water temperatures (Moyle 2002, Smith and Li 1983) and the higher flows in the South Yuba could allow trout to tolerate higher temperatures.

Our House Dam on the Middle Yuba River (RM 12.7) and the abandoned diversion dam on the South Yuba River (RM 9.7) may block upstream migration to almost all good summertime habitat. The barrier cascade at RM 0.4 on the Middle Yuba is expected to impede upstream migration of adult salmonids to virtually the entire river during most if not all of the year. Oregon Creek (RM 4.8) and Kanaka Creek (RN 16.5) offer additional summertime fry and juvenile habitat downstream of RM 17 in the Middle Yuba drainage. Wolf Creek (RM 26.9), tributary to the Middle Yuba River, and Humbug Creek (RM 20), tributary to the South Yuba River, provide additional summertime fry and juvenile habitat, but converge with the main stem upstream of the identified downstream juvenile habitat boundary. Owl Creek and Spring Creek, tributaries to the South Yuba River, may provide very limited summertime refuge in the lower reach (below RM 18). Poorman Creek (RM 28.8) provides additional habitat, but converges with the South Yuba upstream of the fry and juvenile downstream habitat boundaries.

Because of the limited sample size (units counted) and magnitude of variation in counts, the distribution boundaries at RM 17-18 and 27.5 is not exact and could be several miles downstream. Annual differences in water year type (e.g. consequent discharge) and summertime meteorological conditions may cause the boundaries to vary significantly. For example, Gard (2004) observed no rainbow trout in the South Yuba downstream of Jones Bar (RM 7.0) in 1991 and 1992 surveys, but 16 trout downstream of Starvation Bar (RM 4.2) in 1993. The average July flow at Jones Bar was 107 cfs in 1993, whereas 43 and 68 cfs in 1992 and 1991 respectively, suggesting some flow dependence (USGS 2005c). However, the 2004 average July flow of 51 cfs was similar to the 1991 and 1992 average July flows yet the rainbow trout distribution was similar to 1993 (USGS 2005c). No one variable can explain all the differences in trout population density;

however, knowing the population structure of a watershed is necessary to validate any model simulation of the multitude of interacting variables controlling the populations.

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Appendix A. Raw data collected during the Middle and South Yuba 2004 dive counts.

Separate File.

Appendix B. Index densities of fish observed during the Middle and South Yuba 2004 dive counts.

Separate File.

Appendix C. Photographs of the main stem and tributary barriers to fish passage encountered during the Middle and South Yuba 2004 dive count.

Separate File.

Appendix D. Monthly mean, median, mode, average daily maximum, average daily minimum, and average daily fluctuation of the Middle and South Yuba 2004 July and August stream temperatures.

South Yuba

July

		Monthly					*Average Daily*		
Station	*River Mile*	*Mean*	*Median*	*Mode*	*Maximum*	*Minimum*	*Maximum*	*Minimum*	*Fluctuation*
Bridgeport	1.40	24.75	24.77	26.01	28.42	20.75	26.99	22.55	4.43
abv Rush Creek	7.25	24.42	24.41	24.03	27.26	21.53	25.95	22.96	2.99
abv Rock Creek	11.10	24.51	24.34	23.55	29.09	20.84	27.88	22.22	5.66
abv Spring Creek	16.00	24.21	24.05	22.99	27.95	20.98	26.69	22.13	4.56
Missouri Bar	23.60	23.35	23.45	24.05	26.16	19.96	25.01	21.20	3.82
blw Poorman Crk	28.40	22.08	21.99	20.96	25.65	18.51	24.54	19.91	4.63
blw Spaulding	40.50	15.05	14.96	14.46	17.84	12.32	16.92	13.52	3.40

August

		Monthly					*Average Daily*		
Station	*River Mile*	*Mean*	*Median*	*Mode*	*Maximum*	*Minimum*	*Maximum*	*Minimum*	*Fluctuation*
Bridgeport	1.40	23.23	23.21	22.18	26.82	19.63	25.41	21.19	4.22
abv Rush Creek	7.25	23.10	23.06	22.15	25.74	20.29	24.58	21.72	2.86
abv Rock Creek	11.10	22.90	22.78	21.44	27.97	19.25	26.24	20.66	5.58
abv Spring Creek	16.00	23.03	22.80	22.20	26.30	19.58	25.35	21.11	4.23
Missouri Bar	23.60	22.21	22.27	22.99	25.21	18.99	23.73	20.43	3.30
blw Poorman Crk	28.40	21.21	21.18	20.60	24.77	17.94	23.28	19.31	3.97
blw Spaulding	40.50	15.92	15.84	15.25	18.37	13.52	17.58	14.62	2.96

Middle Yuba

July

				Monthly			*Average Daily*		
Station	*River Mile*	*Mean*	*Median*	*Mode*	*Maximum*	*Minimum*	*Maximum*	*Minimum*	*Fluctuation*
abv NF	0.1	24.18	24.22	23.62	27.01	21.01	25.64	22.53	3.12
blw Oregon Cr	4.3	23.71	23.71	23.86	27.01	20.03	25.83	21.58	4.24
abv Oregon Cr	4.8	24.23	24.27	23.11	27.28	20.77	26.19	22.10	4.09
blw Our House	11.9	23.02	23.00	24.32	26.01	19.98	25.08	21.05	4.03
blw Kanaka Cr	15.8	22.46	22.51	21.32	25.60	18.99	24.56	20.20	4.36
abv Wolf Cr	26.5	19.17	19.01	21.29	22.80	15.27	21.94	16.86	5.08
btwn Boxes	38.6	13.88	13.79	13.33	16.08	11.95	15.39	12.67	2.72
blw Milton	43.5	9.88	10.05	10.22	11.78	7.29	10.82	8.83	1.99

August

				Monthly			*Average Daily*		
Station	*River Mile*	*Mean*	*Median*	*Mode*	*Maximum*	*Minimum*	*Maximum*	*Minimum*	*Fluctuation*
abv NF	0.1	22.86	22.87	23.09	25.53	19.58	19.60	17.14	2.46
blw Oregon Cr	4.3	22.75	22.65	21.56	26.35	19.15	20.08	16.75	3.33
abv Oregon Cr	4.8	22.88	22.85	23.45	26.21	19.51	19.96	17.01	2.95
blw Our House	11.9	22.36	22.30	24.12	24.92	19.41	24.00	20.70	3.30
blw Kanaka Cr	15.8	21.46	21.51	21.18	24.65	18.06	23.25	19.53	3.72
abv Wolf Cr	26.5	18.77	18.70	17.77	21.87	15.80	20.75	16.94	3.82
btwn Boxes	38.6	13.23	13.14	12.85	15.39	11.15	14.63	12.18	2.45
blw Milton	43.5	10.06	10.03	10.03	12.32	8.39	11.40	8.98	2.42