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BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Turlock Irrigation District	)	
	)	
and	)	Project No. 2299
	)	
Modesto Irrigation District	)	

2009 LOWER TUOLUMNE RIVER ANNUAL REPORT

Report 2009-7

2009 Aquatic Invertebrate Monitoring and Summary Update

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2009 Benthic Macroinvertebrate Monitoring and Summary Update

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1 INTRODUCTION

Hydroelectric projects may affect stream flow, resulting in the potential for changes in physical habitat that could affect benthic macroinvertebrate (BMI) communities (Rehn et al 2007). Generally, most river ecosystems are dominated by larval aquatic insects, but BMI communities also include mollusks, crustaceans, worms, leeches, and other invertebrate organisms. The "health" of a riverine system can be indicated by the presence or absence of these organisms (Plafkin et al. 1989, Barbour et al. 1999, Mebane 2001). In 1999, the EPA published a revised version of the "rapid bioassessment protocol" (RBP), which provides a cost-effective, rapid, and standardized method of assessing the BMI community and physical habitat within a stream. The California Department of Fish and Game (CDFG) adopted a variation of the EPA's RBP known as the California Stream Bioassessment Protocol (CSBP) (CDFG 1999). In 2007, the CDFG developed an updated protocol in conjunction with the State Water Resource Control Board's Surface Water Ambient Monitoring Program (SWAMP). This protocol, which is based on the BMI collection and physical habitat assessment methods outlined by the EPA's Environmental Monitoring and Assessment Program (Ode 2007), has been designated as the California Monitoring and Assessment Program (CMAP) since 2004 and generally replaces the earlier CSBP versions.

1.1 Project Background

BMI community monitoring on the lower Tuolumne River began in 1987 as part of fishery studies and other programs associated with the Don Pedro Project (Table 1). The initial studies assessed the effects of flow magnitude on wetted areas and food supply for the resident fish community in the lower Tuolumne. The results of the initial sampling efforts were presented in TID/MID (1991) and FERC Report 1996-4 (TID/MID 1997) included the results of Summer Flow Invertebrate studies for 1989–1993. In 1996, the FERC ordered increased minimum summer flows to 50 cfs or greater in the Tuolumne River in accordance with the 1995 FERC Settlement Agreement (FSA) (TID/MID 1996). Since that time, the Turlock and Modesto irrigation districts (Districts) have continued with summer BMI collection as a means of documenting long-term conditions in the physical habitat and aquatic ecosystem health downstream of the Don Pedro Project. Analysis of monitoring data collected in 1994, 1996, 1997, 2000, 2001, and 2002 (Tables 1 and 2) was presented in FERC Report 2002-8 (TID/MID 2003). The results of monitoring during 2003 and 2004 are presented in FERC Report 2004-9 (TID/MID 2005). The results of monitoring during 2005–2008 are presented in FERC Report 2008-7 (TID/MID 2009). No samples were collected in 1999 and in the high flow years of 1995, 1998, and 2006.

Table 1. BMI sampling site, locations (RM), dates, methods, and quantities of samples collected (1987–2000).

		Sampling Location									
		Riffle 4A			Riffle 5	Charles Rd.		McClesky			
		RM 48.8			RM 48.0	RM 24.9		RM 6.0			
		Sampling Methodology									
Year	**Month**	Hess	Kick	Drift	Kick	Kick	Drift	Hess	Drift	Ponar	**Notes**
1987	MAY	28 (32)		17		16	22 (24)	20	12 (24)	8 (9)	Collected near fry rearing observations
	SEP	11 (12)		8 (36)		11 (12)	8 (27)	5	6 (27)	12	
1988	FEB	20		20 (30)		18 (20)	10 (30)	20	10 (30)	0 (9)	Summer flow study baseline
	MAY	12	1		1						Summer flow studies (TID/MID 1991, 1997)
	SEP	12			1						
1989	APR	12	2 (2)								
	MAY	12									
	SEP	12									
1990	MAY	12									
	OCT	12									
1991	JUN	12									
	SEP	12									
1992	MAY	6 (12)									
	SEP	6 (12)									
1993	MAY	6 (12)									
	OCT	6 (12)									
1994	AUG	6 (12)									Interim Riffle 4A monitoring (see TID/MID 2003)
1996	AUG	6 (12)									
1997	JUL	6 (12)									
2000	JUL	6 (12)									

Note: quantities of samples analyzed shown, followed by quantities collected in parentheses.

Table 2. BMI sampling site, locations (RM), dates, methods, and quantities of samples collected (2001–2009).

		Sampling Location														
		Riffle A4	Riffle 4A		Riffle 7	Riffle 13B	Riffle 17	Riffle 20C	Riffle 21	Riffle 23C		Riffle 31	Riffle 33	Riffle 57	Riffle 72	
		RM 51.6	RM 48.8		RM 46.9	RM 45.5	RM 44.2	RM 43.2	RM 42.9	RM 42.3		RM 38.1	RM 37.7	RM 31.5	RM 25.4	
		Sampling Methodology														
Year	**Month**	Kick	Hess	Kick	Kick	Kick	Kick	Kick	Kick	Hess	Kick	Kick	Kick	Kick	Kick	**Notes**
2001	JUL	1	6						1	6				1		River-wide CSBP/ CMAP monitoring (TID/MID 2003, 2005, 2009; McBain & Trush 2008)
2002	JUL	1	6	6						3	3		1	1	1	
2003	JUL	1	3	1						3	1	1		1	1	
2004	JUL	1	3	2						3	1	1		1	1	
2005	AUG	1	6	1						6	1	1		1	1	
2007	JUL	1	6	1						6	1	1		1	1	
2008	MAY				3	3	3	3			3					
	JUL	1	6	1						6	1	1		1	1	
2009	JUL	1	6	1						6	1	1		1	1	

Note: all samples analyzed.

1.2 Purpose and Goals

The report provides a summary and analysis of BMI monitoring for the lower Tuolumne River conducted in 2009 by Stillwater Sciences on behalf of the Districts using the standard level of taxonomic identification established by the California Aquatic Bioassessment Laboratory Network (CAMLnet). The goals of the collection and analyses of BMI samples from the lower Tuolumne River are as follows:

1. Assess the BMI community of the Tuolumne River for 2009 using metrics outlined by the current CMAP.
2. Provide a summary update of long-term trends derived from data collected from 1988–2009 at specific locations along the Tuolumne, with regard to effects of water year type and changes in instream flows.

2 METHODS

The field and laboratory methods for invertebrate collection and processing employed in this study were based on standard protocols (CDFG 1999, Merritt and Cummins 1996). Sampling site selection, habitat characterization, collection methods, and analysis methods are presented below.

2.1 Site Selection

Benthic macroinvertebrates have been collected with a Hess sampler at Riffle 4A (RM 48.8, approximately 3.5 miles downstream of La Grange Dam) since the inception of BMI monitoring on the lower Tuolumne River (Table 1). Consequently, Riffle 4A has become a reference site for BMI sampling. BMI collections were expanded to 5 sites in 2001 and to 6 sites starting in 2002 with additional Hess sample collections added at Riffle 23C (RM 42.3) and other sampling sites within RM 25.4-51.6 added (Figure 1) to provide a longitudinal gradient of sampling conditions for use with kick-net (D-shape) net sample collections under the CSBP. In 2004, deeper water and coarser substrate at Riffle 4A necessitated its relocation 250 ft. downstream. Also in 2004, due to gravel deposits at the head of the riffle, Riffle 23C was moved to a location 450 ft upstream.

Table 3. Location descriptions for aquatic invertebrate monitoring sites on the lower Tuolumne River in 2009.

Site	River mile	Latitude	Longitude	Ecological subregion[1]
Riffle A4	51.6	37° 39' 90" N	120° 26' 69" W	Lower Foothills Metamorphic Belt
Riffle 4A	48.4	37° 39' 39" N	120° 29' 02" W	Camanche Terraces
Riffle 21	42.9	37° 37' 41" N	120° 32' 29" W	Camanche Terraces
Riffle 23C	42.3	37° 37' 46" N	120° 33' 29" W	Camanche Terraces
Riffle 31	38.1	37° 38' 03" N	120° 38' 02" W	Camanche Terraces
Riffle 33	37.3	37° 38' 20" N	120° 38' 29" W	Camanche Terraces
Riffle 57	31.5	37° 38' 09" N	120° 45' 34" W	Camanche Terraces
Riffle 72	25.4	37° 37' 02" N	120° 51' 09" W	Manteca - Merced Alluvium

1. Information on ecoregions (Miles and Goudey 1997) provided for use in developing future comparisons with representative multi-metric assessments.

The sites sampled 2009 are shown in Table 3 and Figure 1. Sampling sites, months, location (RM), method, and quantities of samples collected are shown in Table 1 and Table 2. The sampling took place in late July (July 29–31, 2009) to provide comparable data from year to year and avoid short-term community shifts due to variable insect emergence timing**.**

2.2 Site Characterization and Physical Habitat Data

Since 2001, sampling sites have been characterized by physical habitat measures (Appendix B), with recent efforts conforming to the main cross-sectional transect measures included in the current CMAP (Ode 2007). The average wetted width, average gradient, and total length (horizontal distance) were measured or estimated at each monitoring site. Water quality parameters, including temperature, dissolved oxygen, specific conductance, or conductivity, and pH were recorded at one transect along each sample reach using a calibrated YSI multiprobe.

Percent canopy cover was estimated along each transect along with relative percent composition of substrate size, fixed organic matter and macrophytes. In addition, at the sample point along each transect, water velocity and depth were recorded using a flow meter (Marsh-McBirney Flowmate 2000) and a top-setting rod. Substrate was classified as fine (< 2 mm), gravel (> 2–16 mm), cobble (> 64–250 mm), boulder (> 250–4,000 mm), or bedrock (> 4,000 mm). All sites sampled since 2001 are riffle habitats with gravel and cobble substrates.

2.3 Sample Collection and Preservation

2.3.1 Sampling methods

2.3.1.1 Kick-net sampling

Benthic macroinvertebrates were collected using a D-frame net (Frost et al. 1971) at selected riffle habitats from RM 51.6–25.4. Kick-net sampling was conducted in general accordance to the Targeted Riffle Composite Procedure in the CMAP (Ode 2007). At each riffle, a transect was randomly selected in the upper third of the riffle. Kick net samples were taken at three locations along the transect: near the stream margins and in the center. These three samples were composited to create a single sample for each site. At each location, larger rocks were scrubbed by hand to dislodge caddises and attached invertebrates, with the remaining substrate agitated by foot over a 1-ft by 2-ft area for two minutes directly upstream of the net.

2.3.1.2 Hess Sampling

In addition to kick net samples, Hess samples were taken at Riffle 4A and Riffle 23C using a 0.10 m^2 Hess sampler (Hess 1941, Jacobi 1978). At both locations, samples were collected at randomly spaced transects along the riffle. At Riffle 4A, samples were taken within the 250 ft of the upstream end of the riffle due to the relatively long length of the riffle. At both sites, samples were taken near the channel margin and at the center of each transect.

Hess samples were collected by first placing the frame into the substrate with the net portion trailing downstream. Larger rocks found in the sampler were removed from the cylinder to a bucket where they were examined on shore by hand to collect any attached organisms. After all larger rocks were removed; the substrate was agitated using a hand trowel to a depth of 5–10 cm for five minutes. Samples at downstream transects were collected first to avoid disturbing the upstream stations. The location of each station was measured along each transect and the transect location within the riffle measured relative to a reference location (e.g., tree, rebar pin, etc.).

2.3.2 Sample preservation

Samples were preserved in the field using a 95% ethanol solution with the sample bottle labeled with the location, date, sampling technique, and replicate number. After collection, the samples were stored at ambient temperature until processing.

2.4 Sample Processing

Sample picking, sorting, and identification was performed by Aquatic Biology Associates, Inc. (Corvallis, OR) using the methods described in the CMAP and outlined by the CAMLnet (Ode 2007).

2.4.1 Subsampling

In order to save processing time, samples with large numbers of individuals are subsampled. To do this, the sample was quantitatively reduced using the following procedure. First, the contents of the full sample were spread evenly over a gridded tray. A grid cell (or section) was randomly selected and the organisms within it were picked and counted. The process was repeated with additional grid cells picked and counted until a total of 500 organisms had been reached. The number of organisms in the sample can be extrapolated using the subsample count and the number of grid cells counted (Caton 1991, Carter and Resh 2001). Organisms picked from the last grid cell in excess of 500 were retained to supplement potentially discarded or misidentified organism during identification. Typically, the original sample was spread over 30 grid cells, but in cases where the organism density was low, a coarser grid of 4–8 grid cells was employed.

2.4.2 Invertebrate identification

Taxonomic identification was performed to the standard level of taxonomic effort described by CAMLnet (i.e., family, genus, or species). Revisions to the taxonomic effort may affect the ability to directly compare results in this report to previous years, although many of the metrics would be largely unaffected unless the taxon in question was very abundant.

2.4.3 Quality assurance

The CMAP describes Quality Assurance (QA) procedures for sample handling and custody, sub-sampling, taxonomic identification and enumeration, organism recovery, and taxonomic validation. All archived samples were well preserved in jars labeled with river name, sample date and time, location, and sample ID number. Tally sheets for each sample include counts of organisms, grid information, and notes about discarded organisms. Sample remnants were inspected to ensure that fewer than 10% of the organisms counted (e.g., 50 for a 500 count sample) remained.

2.5 Data Analysis

A large number of metrics have been developed in the original CSBP (CDFG 1999), with additional metrics described in Plafkin et al. (1989) and Barbour et al. (1999) while the functional feeding group concept is discussed in Cummins (1973) and Merritt and Cummins (1996). Due to differing taxonomic effort requirements for many of these metrics, not all metrics are comparable to previous years or between individual taxonomists. Commonly used metrics for each sampling location are presented (Table 4) in the following four categories:

- Richness Measures (number of distinct taxa)
- Composition measures (distribution of individuals among taxonomic groups and measures of diversity)
- Tolerance measures (reflects the relative sensitivity of organisms to disturbance or pollution)
- Feeding Measures (shows balance of feeding groups within the BMI community)
- Quantitative measures (abundance and density of aquatic insects)

A short explanation of some of the metrics is below.

Shannon Diversity Index. Shannon's diversity Index (Shannon and Weaver 1963) is based on information theory and represents the amount of information gained by common or rare organisms within a sample. Essentially, this index demonstrates the uncertainty in predicting what taxon an organism will belong to when chosen at random. The index is calculated by:

$$H = - \sum p_i \ln p_i$$

Where p_i = is the proportion of individuals in the *i* th species compared to the total number of species in a community. The Shannon Diversity values can range from 0.2–3.3 (natural log scale), with increasing diversity from additional unique species present, or by having a greater species evenness. Higher diversity is generally indicative of higher water and habitat quality.

EPT Index. This is the percentage of all organisms that are in the orders Ephemoptera mayflies), Plectoptera (stoneflies), and Trichoptera (caddisflies). This metric will generally decrease with biological impairment.

Percent Chironomid. This metric is the percentage of organisms that are in Chironomidae, a family that is regarded as mainly consisting of tolerant organisms.

EPT/ Chironomid Ratio. This metric employs the ratio of these two groups as an indicator of community balance and health. A healthier stream would have substantially more EPT organisms. Sites with higher numbers of generally tolerant chironomids compared to the more sensitive taxa may indicate disturbance (Ferrington 1987).

The application of many of these metrics relies substantially on the consistency and reliability of the taxonomic identification. As a result of changing taxonomic standards and differences among taxonomists, the amount of information gained from recent sampling efforts may differ from samples collected and processed prior to 2003.

Data from Hess sampling that was conducted between 1988–2009 at Riffle 4A (RM 48.8) were also compiled in order to examine long term effects of the FERC-mandated minimum summer flows that began in 1996. Data for percent EPT and percent chironomids were grouped by pre-1996 and post-1996 categories and treated as two populations before and after the adoption of increased summer flows.

Table 4. Metrics used for BMI data analysis (Ode 2007)

BMI Metrics	Description	Predicted Response to Impairment
Richness Measures		
Taxonomic Richness	Total number of individual taxa	Decrease
No. EPT taxa	Number of taxa in the insect orders Ephemeroptera, Plecoptera, and Trichoptera	Decrease
Ephemeroptera taxa	Number of mayfly taxa	Decrease
Plecoptera taxa	Number of stonefly taxa	Decrease
Trichoptera taxa	Number of caddisfly taxa	Decrease
Composition Measures		
% EPT	Percent of the composite of mayfly, stonefly, and caddisfly larvae	Decrease
Percent Insects	Percent insects in sample	Variable
% Chironomidae	Percent of midge larvae	Increase
% Baetidae	Percent of baetid mayfly larvae	Decrease
% Hydropsychidae	Percent of netspinner caddisfly larvae	Decrease
EPT/ Chironomid ratio	Ratio of EPT larvae to midge larvae	Decrease
Shannon Diversity index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	Decrease
Tolerance/Intolerance Measures		
California Tolerance Value (CTV)	CTVs between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) and intolerant (lower values).	Increase
% Intolerant Organisms	Percent organisms with Tolerance Values of 0, 1, or 2.	Decrease
% Tolerant Organisms	Percent of organisms with Tolerance Values of 8, 9, or 10.	Increase
% Dominant Taxon	Measures the dominance of the single most abundant taxon.	Increase
Sensitive EPT	Number of mayfly, stonefly, and caddisfly taxa with Tolerance Value of 0, 1, or 2.	Decrease
Feeding Measures		
% Collector-Gatherers	Percent of macroinvertebrates that collect or gather material	Increase
% Collector-Filterers	Percent of macroinvertebrates that filter suspended material from the water column	Increase
% Scrapers	Percent of macroinvertebrates that graze upon periphyton	Variable
% Predators	Percent of macroinvertebrates that prey on living organisms	Decrease
% Shredders	Percent of macroinvertebrates that shred leaf litter	Decrease
Quantitative Measures		
Abundance	Total number of organism in sample	Variable
Density	Number of organisms per m^2	Variable

3 RESULTS

3.1 Environmental Conditions and Physical Habitat Data

The annual hydrograph (Water Year 2009) of the lower Tuolumne River below La Grange Dam (USGS 11289650) is included in Appendix A. The 30-day average flow prior to sampling was approximately 110 cfs. Daily average flow at the time of sampling was approximately 98 cfs. Other physical habitat data described in the CMAP were collected at the sampling sites and are included in Appendix B. Exploratory analyses found no significant relationships between computed BMI metrics (Table 4) and sampled habitat parameters (Appendix B), largely due to the fact that many of the physical habitat data, other than water temperature, do not vary greatly throughout the sampled reach of the lower Tuolumne River.

3.2 Benthic Macroinvertebrate Data

CMAP metrics for kick net samples at all sampling sites for 2001–2008 are presented in Table 5, with results for recent kick-net samples collected in 2009 shown in Table 6. Figures 2–5 show the variation by riffle of selected metrics in the lower Tuolumne River for the 2009 sampling. Taxonomic richness was generally similar throughout study area, ranging from 27 to 33 (Figure 2). The EPT index was highest at Riffle 23C [RM 42.3] and lowest at Riffle 72 [RM 25.4] (Figure 3). The EPT/Chironomid ratio was highest in the middle reaches (Figure 4) where the percentage of chironomids was lowest (Figure 5).

3.3 Hess Data for Riffle 4A (1988-2009)

Table 7 presents metrics from Hess sampling at Riffles 4A from 1988–2009 as well as more recent data (2001–2009) from Riffle 23C. Figure 6 shows box and whisker plots of data collected at Riffle 4A before and since 1996, representing the periods before and after the 1995 FSA flows. The percentages of EPT at Riffle 4A since 1996 were significantly higher than those before 1996 (Figure 6; t-test, $p=0.0001$). The percentages of chironomids since 1996 were lower than before 1996, but did not differ significantly (Figure 6; t-test, $p=0.25$). The EPT/Chironomid ratio increased since 1996, but not significantly (Table 7; t-test, $p=0.09$).

The density of organisms measured in Riffle 4A Hess samples decreased slightly in post-FSA years, along with the Shannon Diversity Index, reflecting an increase also in the percentage of the dominant taxon. The Shannon Diversity Index did not change significantly between pre-and post-FSA years (Table 7; t-test, $p=0.55$). Regression of the Shannon Diversity Index with Water Year Type Index , however, suggests some decrease in overall diversity with increasing basin-wide flows ($r^2=0.64$ over 1994–2009 period). The percentage of insects in the Hess samples was significantly higher since 1996 (Table 7; t-test, $p=0.001$). The dominant taxon percentage increased since 1996 (Table 7; t-test, $p=0.11$), with variations partly explained by Water Year Type Index ($r^2=0.55$ over 1994–2009 period).

Table 5. CMAP metrics for historical Kick Net samples by river mile (2001–2008)

Year	**2001**			**2002**					**2003**					
Riffle	**A4**	**21**	**57**	**A4**	**4A**	**23C**	**57**	**72**	**A4**	**4A**	**23C**	**31**	**57**	**72**
River Mile	**51.6**	**42.9**	**31.5**	**51.6**	**48.8**	**42.3**	**31.5**	**25.4**	**51.6**	**48.8**	**42.3**	**38.1**	**31.5**	**25.4**
Richness Measures														
Taxonomic Richness	25	21	25	20	22	20	25	23	25	33	21	21	30	22
EPT Taxa	8	6	7	5	7	5	8	5	7	8	9	7	10	7
Ephemeroptera Taxa	2	4	3	1	3	2	5	4	3	3	5	5	6	3
Plecoptera Taxa	1	0	0	1	0	0	0	0	1	0	0	0	0	0
Trichoptera Taxa	5	2	4	3	4	3	3	1	3	5	4	2	4	4
Composition Measures														
EPT Index	55	75	47	31	62	24	34	38	41	39	85	77	52	17
Percent Insects	91	91	70	88	86	53	70	55	73	83	90	85	70	48
Percent Chironomid	22	6	14	9	24	12	25	15	22	43	1	5	7	24
Percent Baetidae	29	17	3	25	4	6	13	1	31	2	35	22	23	4
Percent Hydropsychidae	12	51	42	5	2	16	13	2	4	0	36	48	26	6
EPT/Chironomid Ratio	2	12	3	3	3	2	1	2	2	1	91	15	7	1
Shannon Diversity	2.48	1.8	2.09	1.7	2	2.3	2.7	2.2	2.42	2.52	1.9	1.86	2.34	2.44
Tolerance Measures														
Tolerance Value	5	4	5	6	5	5	5	5	6	5	5	4	4	5
Percent Intolerant Organisms	9	3	1	1	4	2	3	2	3	0	1	5	2	1
Percent Tolerant Organisms	14	1	1	10	8	14	2	21	24	4	1	1	1	1
Percent Dominant Taxon	29	51	42	46	47	29	16	33	31	26	36	48	26	30
Sensitive EPT Index	4	1	1	1	5	2	2	2	2	4	1	5	2	2
Feeding Measures														
Percent Collector-Gatherers	43	22	18	41	79	34	46	63	62	59	48	29	33	30
Percent Collector-Filterers	25	53	44	51	2	15	13	2	19	13	37	51	29	14
Percent Scrapers	8	16	11	1	6	20	13	3	2	2	5	9	12	9
Percent Predators	3	3	15	6	8	31	26	32	2	2	5	3	10	9
Percent Shredders	1	0	0	0	0	0	0	0	2	0	0	0	0	0
Percent Others	21	6	13	0	4	0	1	0	14	24	4	9	16	39
Quantitative Measures														
Abundance (total in sample)	1,307	835	1,642	6,680	833	310	1,642	944	3,554	7,548	1,611	943	1,110	335
Density (No./m^2)	6,873	3,655	8,634	35,953	4,482	1,668	8,634	5,079	6,231	13,234	2,825	1,654	1,946	587

Table 5 (cont.).

Year	2004						2005						2007					
Riffle	**A4**	**4A**	**23C**	**31**	**57**	**72**	**A4**	**4A**	**23C**	**31**	**57**	**72**	**A4**	**4A**	**23C**	**31**	**57**	**72**
River mile	**51.6**	**48.8**	**42.3**	**38.1**	**31.5**	**25.4**	**51.6**	**48.8**	**42.3**	**38.1**	**31.5**	**25.4**	**51.6**	**48.8**	**42.3**	**38.1**	**31.5**	**25.4**
Richness Measures																		
Taxonomic Richness	28	23	20	25	27	26	31	33	37	23	20	16	25	28	28	17	23	22
EPT Taxa	8	9	7	10	11	8	7	10	7	5	4	5	9	8	9	6	11	8
Ephemeroptera Taxa	4	4	5	7	7	4	3	5	5	3	3	3	5	5	5	4	6	4
Plecoptera Taxa	1	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0
Trichoptera Taxa	3	5	2	3	4	4	3	4	2	1	1	2	4	3	4	2	5	4
Composition Measures																		
EPT Index	33	77	82	77	68	24	58	66	94	90	92	83	61	65	86	53	59	35
Percent Insects	85	90	85	85	76	41	85	95	95	97	98	98	97	87	91	62	84	48
Percent Chironomid	21	13	2	1	4	16	10	11	6	3	3	14	33	20	3	0	4	7
Percent Baetidae	26	1	11	8	21	1	49	45	57	54	46	78	31	35	9	2	3	1
Percent Hydropsychidae	2	1	56	51	29	8	2	19	33	31	29	3	1	22	59	35	39	23
EPT/Chironomid Ratio	2	6	51	108	16	1	5	6	29	28	34	6	2	3	33	130	14	5
Shannon Diversity	2.2	1.6	1.68	1.92	2.45	2.21	1.84	1.89	1.22	1.64	1.61	1.56	2.09	2.34	1.73	1.83	2.13	2.38
Tolerance Measures																		
Tolerance Value	6	5	4	4	4	5	6	6	5	5	5	5	6	5	4	4	4	5
Percent Intolerant Organisms	3	1	1	4	12	7	6	1	2	1	0	0	3	3	5	0	12	5
Percent Tolerant Organisms	15	1	0	1	1	2	6	2	0	0	0	0	10	5	0	2	0	13
Percent Dominant Taxon	31	53	56	51	29	40	49	44	57	41	38	45	29	33	59	35	39	23
Sensitive EPT Index	3	1	1	4	12	7	4	5	3	2	0	1	3	2	2	0	4	2
Feeding Measures																		
Percent Collector-Gatherers	42	62	23	26	43	57	66	53	59	57	48	83	38	54	15	14	17	26
Percent Collector-Filterers	41	9	57	51	29	12	18	38	33	32	32	4	22	26	60	35	39	34
Percent Scrapers	4	1	7	12	13	10	6	2	4	8	17	3	2	2	19	17	32	10
Percent Predators	1	1	9	6	6	2	2	2	1	2	0	6	1	4	3	32	4	17
Percent Shredders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percent Others	12	27	4	6	9	19	8	6	3	2	2	5	38	13	3	2	7	13
Quantitative Measures																		
Abundance (total in sample)	3,519	3,468	2,749	2,232	813	659	1,057	1,031	463	1,201	513	273	306	522	388	247	428	240
Density (No./m^2)	6,169	6,081	4,820	3,913	4,276	3,466	1,853	1,808	812	2,106	899	479	537	915	680	433	750	421

Table 6. CMAP metrics for Kick Net samples collected in 2009 by river mile

Year	2008						2009					
Riffle	**A4**	**4A**	**23C**	**31**	**57**	**72**	**A4**	**4A**	**23C**	**31**	**57**	**72**
River mile	**51.6**	**48.8**	**42.3**	**38.1**	**31.5**	**25.4**	**51.6**	**48.8**	**42.3**	**38.1**	**31.5**	**25.4**
Richness Measures												
Taxonomic Richness	24	30	16	16	23	27	27	33	27	27	30	29
EPT Taxa	7	10	9	9	7	7	5	9	9	11	10	8
Ephemeroptera Taxa	3	6	7	6	4	2	2	5	6	6	6	4
Plecoptera Taxa	0	1	0	0	0	0	0	1	0	0	0	0
Trichoptera Taxa	4	3	2	3	3	5	3	3	3	5	4	4
Composition Measures												
EPT Index	37	68	79	35	39	25	38	67	77	38	32	18
Percent Insects	97	85	83	63	59	40	95	86	86	63	52	39
Percent Chironomid	52	16	1	1	10	8	19	17	2	1	10	19
Percent Baetidae	27	30	15	4	7	0	34	20	18	2	3	1
Percent Hydropsychidae	1	24	49	24	23	11	1	26	54	28	7	7
EPT/Chironomid Ratio	1	4	109	65	4	3	2	4	50	68	3	1
Shannon Diversity	2.42	2.39	1.82	2.05	2.45	2.25	1.88	2.54	1.77	2.2	2.5	2.29
Tolerance Measures												
Tolerance Value	6	5	4	5	4	5	6	4	5	5	5	5
Percent Intolerant Organisms	2	7	1	6	6	5	2	14	1	2	1	2
Percent Tolerant Organisms	9	0	0	0	0	1	6	1	2	1	3	6
Percent Dominant Taxon	27	27	49	24	23	31	38	26	54	28	21	38
Sensitive EPT Index	2	4	1	1	1	1	2	14	1	2	1	2
Feeding Measures												
Percent Collector-Gatherers	38	56	22	14	42	40	43	42	25	14	17	18
Percent Collector-Filterers	33	24	49	24	25	12	45	28	57	30	9	23
Percent Scrapers	1	6	13	28	10	13	3	15	8	26	18	10
Percent Predators	7	2	11	9	10	7	2	5	3	16	20	38
Percent Shredders	0	0	0	0	0	0	0	0	0	0	0	0
Percent Others	21	12	4	26	14	28	7	9	6	14	37	11
Quantitative Measures												
Abundance (total in sample)	296	360	275	185	118	345	4,720	1,507	2,146	882	428	1,189
Density (No./m^2)	520	632	483	324	207	606	8,280	2,643	3,765	1,547	750	2,086

Table 7. BMI community metrics for long-term Hess sampling sites at riffles R4A (RM 48.8) and R23C (RM 42.3) (1988–2009).

Year	San Joaquin Valley Water Year Index[a]	Summer Flow (cfs)[b]	30-days prior flow (cfs)	Sampling Location	EPT Index (%)	EPT/Chironomid Ratio	Shannon Diversity	Percent Chironomid	Percent Insects	Percent Dominant Taxon	Density [No./m^2]
1988	1.48 (C)	16	16	R4A	9	0.52	2.28	29	53	19	33,700
1989	1.96 (C)	47	45	R4A	35	0.94	2.4	38	81	24	34,400
1990	1.51 (C)	21	26	R4A	14	0.26	2.13	53	81	33	52,658
1991	1.96 (C)	25	22	R4A	26	1.05	2.64	25	60	19	35,047
1992	1.56 (C)	20	23	R4A	14	0.28	2.13	60	76	38	23,272
1993	4.2 (W)	466	464	R4A	15	0.38	1.77	44	66	41	24,813
1994	2.05 (C)	23	23	R4A	22	1.73	2.62	17	42	22	3,897
1996	4.12 (W)	335	189	R4A	84	11.09	1.59	8	93	47	22,987
1997	4.13 (W)	283	290	R4A	28	0.45	1.31	63	94	62	20,780
2000	3.38 (AN)	459	305	R4A	52	2.57	2.13	25	79	33	28,832
2001	2.2 (D)	91	89	R4A	44	1.44	2.7	30	30	25	17,037
				R23C	48	2.17	2.43	22	75	30	15,528
2002	2.34 (D)	85	87	R4A	49	1.52	2.0	34	84	40	24,798
				R23C	11	0.38	2.26	32	59	31	11,649
2003	2.82 (BN)	241	240	R4A	41	0.85	2.32	48	90	32	23,547
				R23C	51	8.16	2.37	8	65	28	11,767
2004	2.21 (D)	113	114	R4A	68	3.18	1.92	21	90	52	28,994
				R23C	79	26.86	1.79	3	84	48	19,120
2005	4.75 (W)	1706	803	R4A	76	7.52	1.56	10	95	64	27,440
				R23C	85	15.34	1.42	3	98	66	6,710
2007	1.96 (C)	110	118	R4A	58	1.91	2.73	30	90	26	10,040
				R23C	80	15.95	1.84	5	89	59	4,143
2008	2.07 (C)	96	102	R4A	61	0.88	2.58	18	80	28	4,733
				R23C	68	23.28	2.12	3	86	48	2,762
2009	2.73 (BN)	116	110	R4A	50	1.82	2.79	28	79	19	28,516
				R23C	49	12.99	2.33	4	71	36	23,917

[a] San Joaquin Valley WY Index (C= Critical; W= Wet; D= Dry; AN= Above Normal; BN= Below Normal). Downloaded from CDEC http://cdec.water.ca.gov/cgi-progs/iodir/wsihist

[b] Jun 1–Sept 30 mean discharge (cfs) for Tuolumne River at La Grange (USGS 11289650).

4 DISCUSSION

4.1 2009 Results

RBP indices use presence/absence and abundance of taxa with different tolerance levels as indicators of environmental stress (Jackson and Resh 1988). Environmental stressors can include habitat degradation, pollution, and organic enrichment. The impact of the environmental stress can be evidenced by (1) absence of relatively intolerant organisms, especially the EPT taxa, such as Ephemeroptera (mayflies), Trichoptera (caddisflies), and Plecoptera (stoneflies); (2) high proportion of tolerant taxa, such as Chironomidae (midges); (3) low number of individual taxa (richness); (4) other perceptible differences in community structure relative to the reference condition. For 2009, the invertebrate sampling on the lower Tuolumne River focused on these differences along the longitudinal gradients in riffle habitats.

In 2009, the percentages of EPT organisms were generally higher upstream of Riffles 23C (RM 42.8) and generally decreased with distance downstream (Table 6 and Figure 3). However, the EPT/chironomid ratio was greatest along the middle reaches of the study area (Table 6 and Figure 4) as found in previous studies (Table 5). These findings typically indicate a decrease in sediment impairment and it is important to note that the high EPT/Chironomid ratio is associated with a lower Shannon Diversity index, primarily as a result of Hydropsyche caddisfly (Trichoptera) dominance (Table 4).

4.2 Summary Update

Although long-term comparisons of historical data collected prior to water year 2000 are somewhat confounded by differences in invertebrate emergence timing as well as sampling methodology, Table 7 provides a long-term comparison of Hess samples collected at Riffles 4A (RM 48.4) and 23C (RM 42.3). Since the adoption of RBP sampling in 2001–2002, the resulting CSBP/CMAP metrics from kick-net samples collected at lower Tuolumne River sites exhibit a pattern of generally decreasing habitat quality from upstream (high) to downstream (low), likely due to increases in higher average temperatures and increases in fine sediments with increasing distance from La Grange dam (Table 5 and Table 6).

We do not present absolute multi-metric scores on the historical invertebrate data in the current Summary Update, primarily because available multimetrics (Karr 1999, Rehn et al. 2007; and Rehn 2008) were not developed for valley floor aquatic communities in the California's Central Valley. For example, Markiewicz et al. (2003) initiated the development of a regional biotic index for Central Valley waterways in 2002, yet were only able to assess relative metric response due to a lack of suitable undisturbed reference sites. Future summary update reports will evaluate historical data using multi-metrics as they are adopted by the CAMLnet.

Analysis of Hess sampling data gathered from 1988–2009 at Riffle 4A (RM 48.8) continue to support the observations that increased summer flows have resulted in beneficial shifts in food supply for fishes and improved instream conditions (Table 7). Although overall invertebrate abundances in Riffle 4A samples declined slightly in the post-FSA period (1996 to the present), community composition shifted away from pollution-tolerant organisms and towards those with higher food value for fish (TID/MID 2003), suggesting improved instream conditions for resident fish species in the lower Tuolumne River as a result of higher flow schedules since adoption of the 1996 FERC order (TID/MID 2005). In addition to the increased occurrence in stoneflies relative to past studies, the abundance and species richness of Ephemeroptera generally increased in the post-FSA sampling period (TID/MID 2003, 2005, 2009). Chironomids generally declined in the post-FSA period and EPT species increased (TID/MID 2003, 2005, 2009). The present study, summarizing data from 2009, continues to illustrate these trends.

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Figures

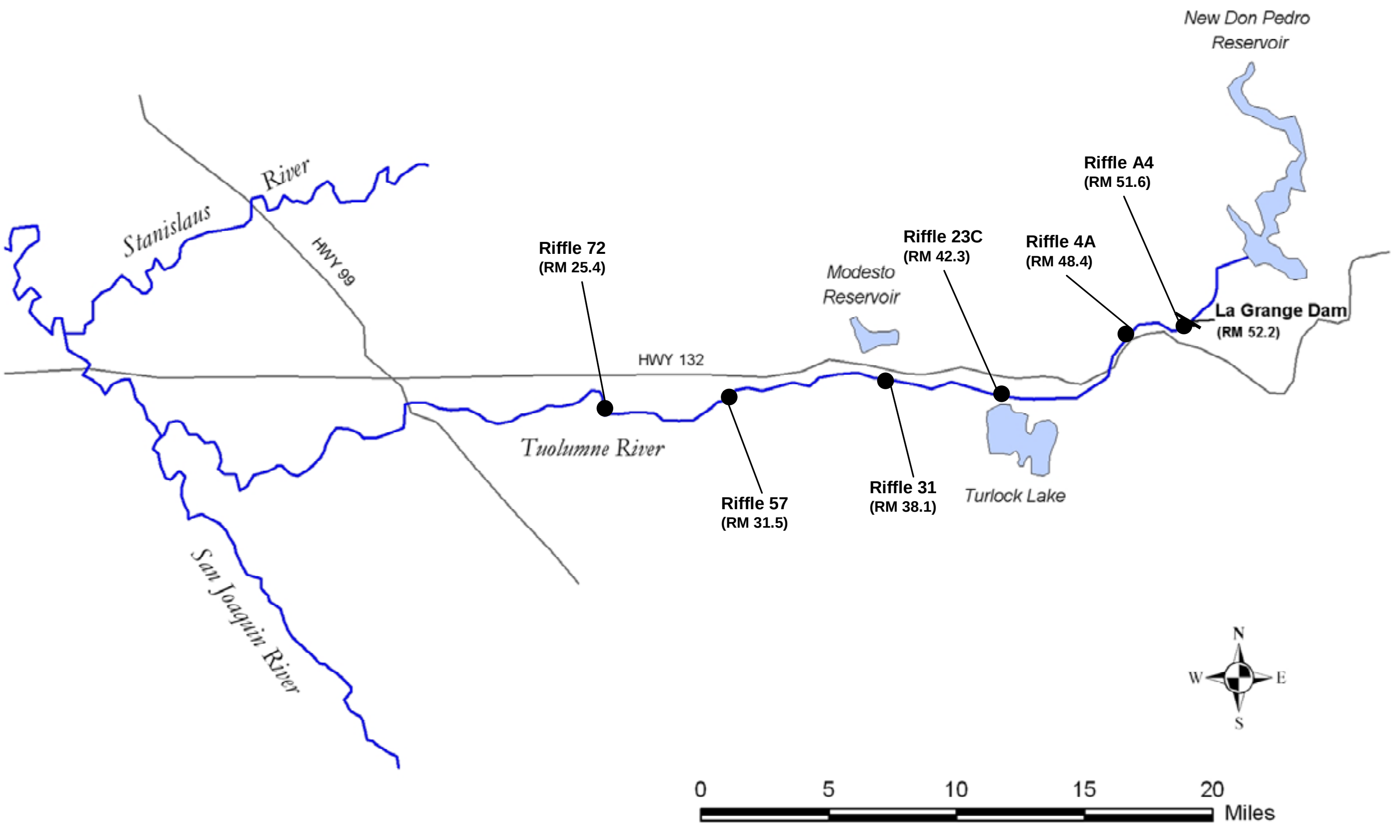

Figure 1. Locations of invertebrate sampling sites on the lower Tuolumne River, 2009.

Stillwater Sciences

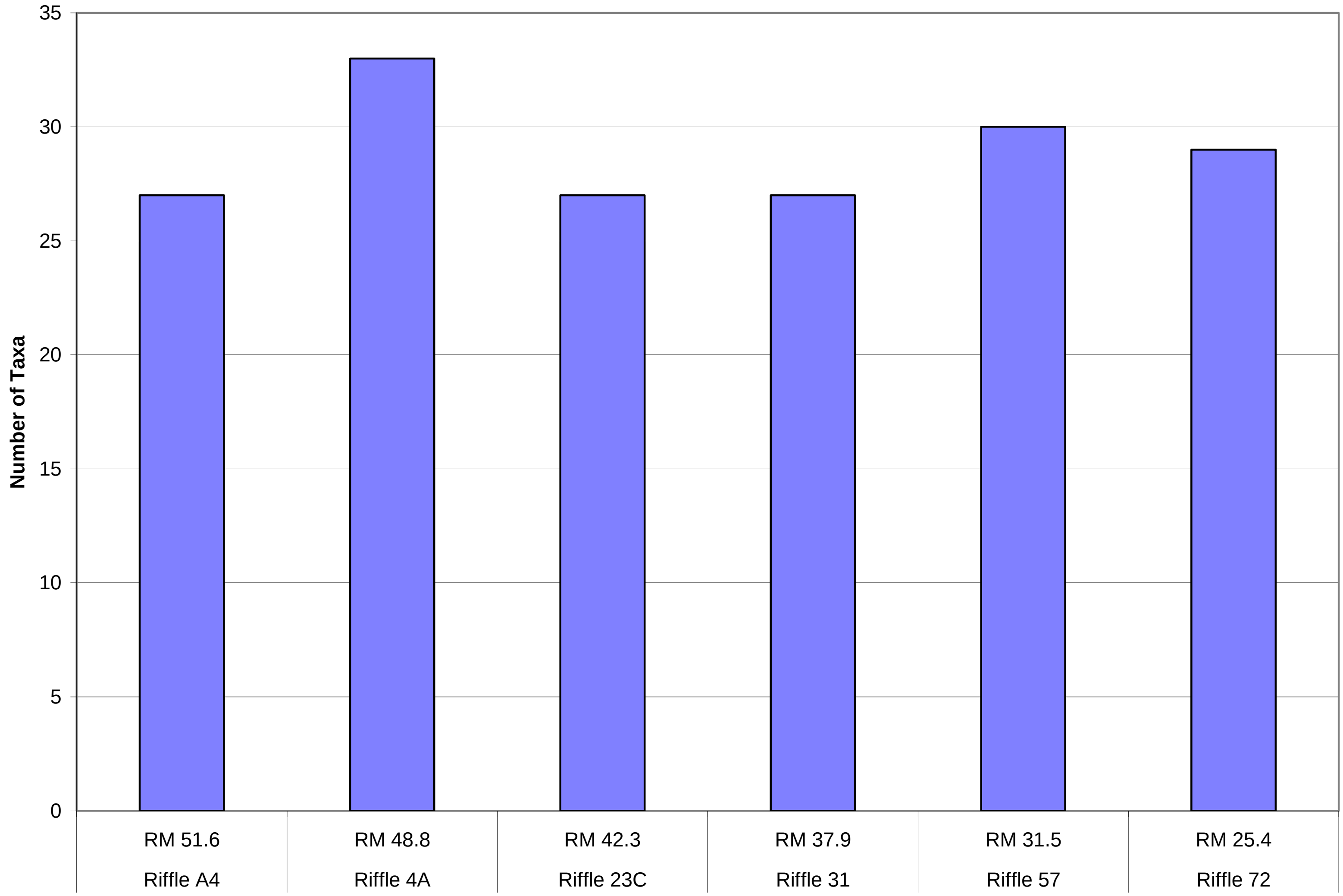

Figure 2. Taxonomic richness by site for 2009.

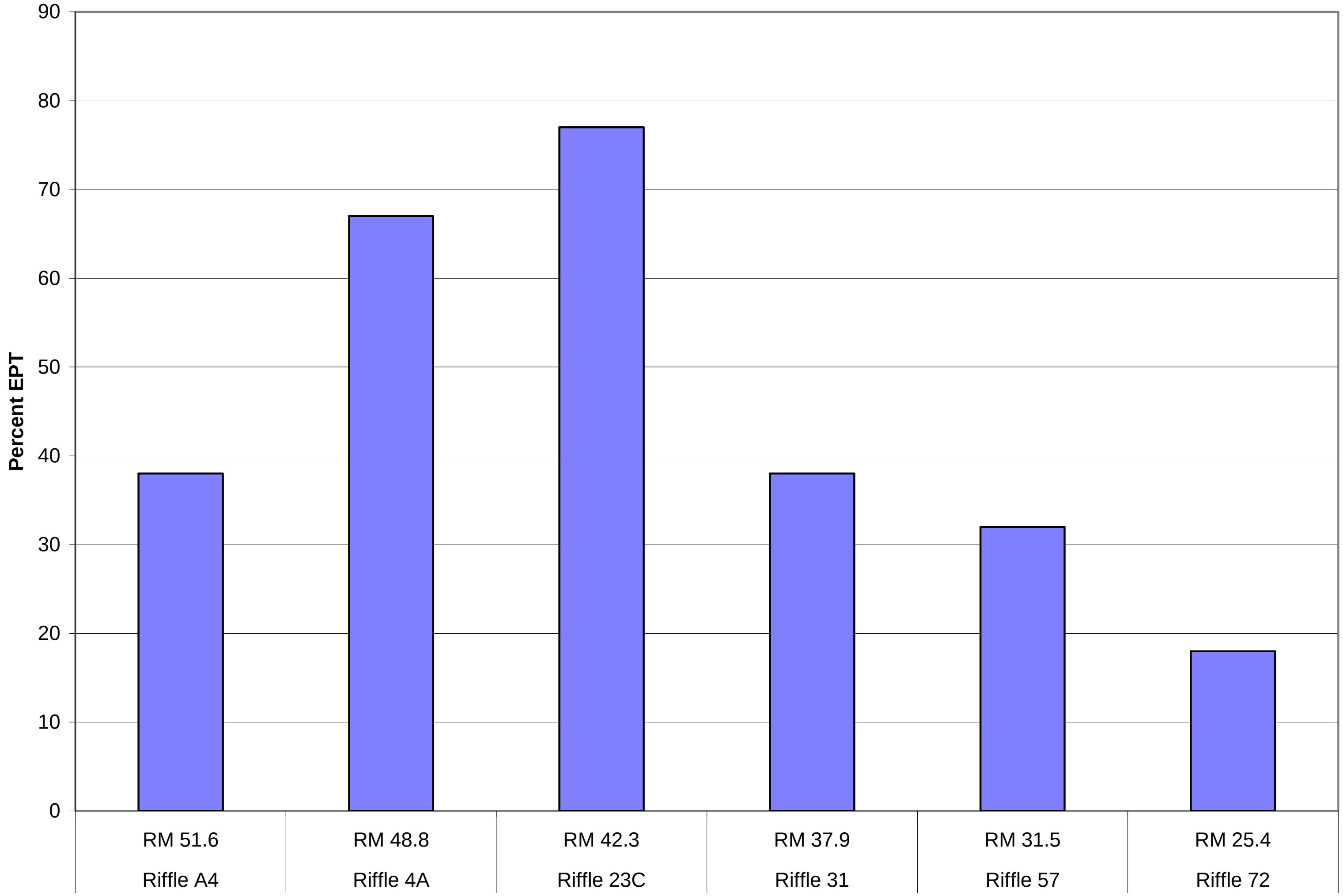

Figure 3. EPT index by site for 2009.

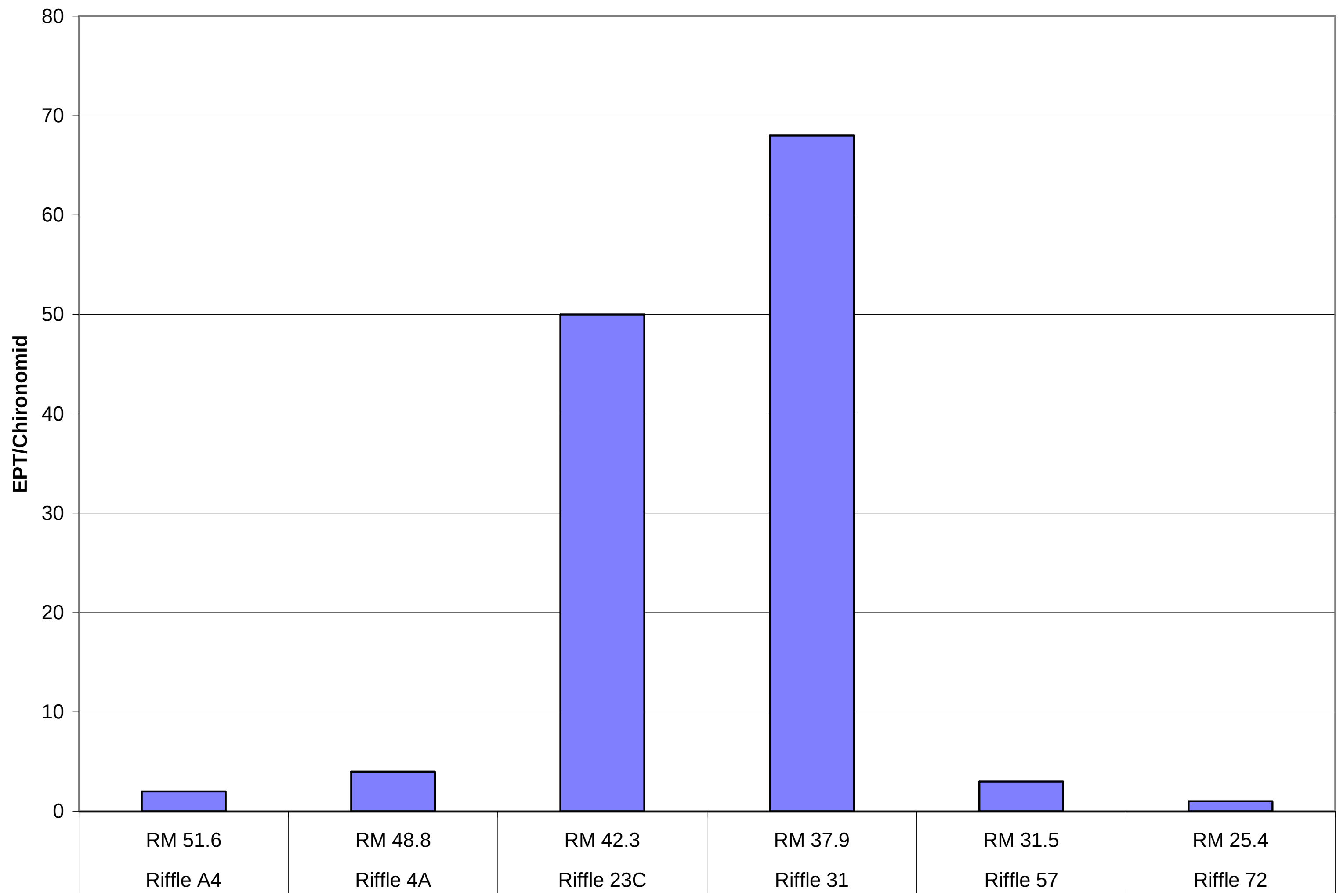

Figure 4. EPT/Chironomid ratio by site for 2009.

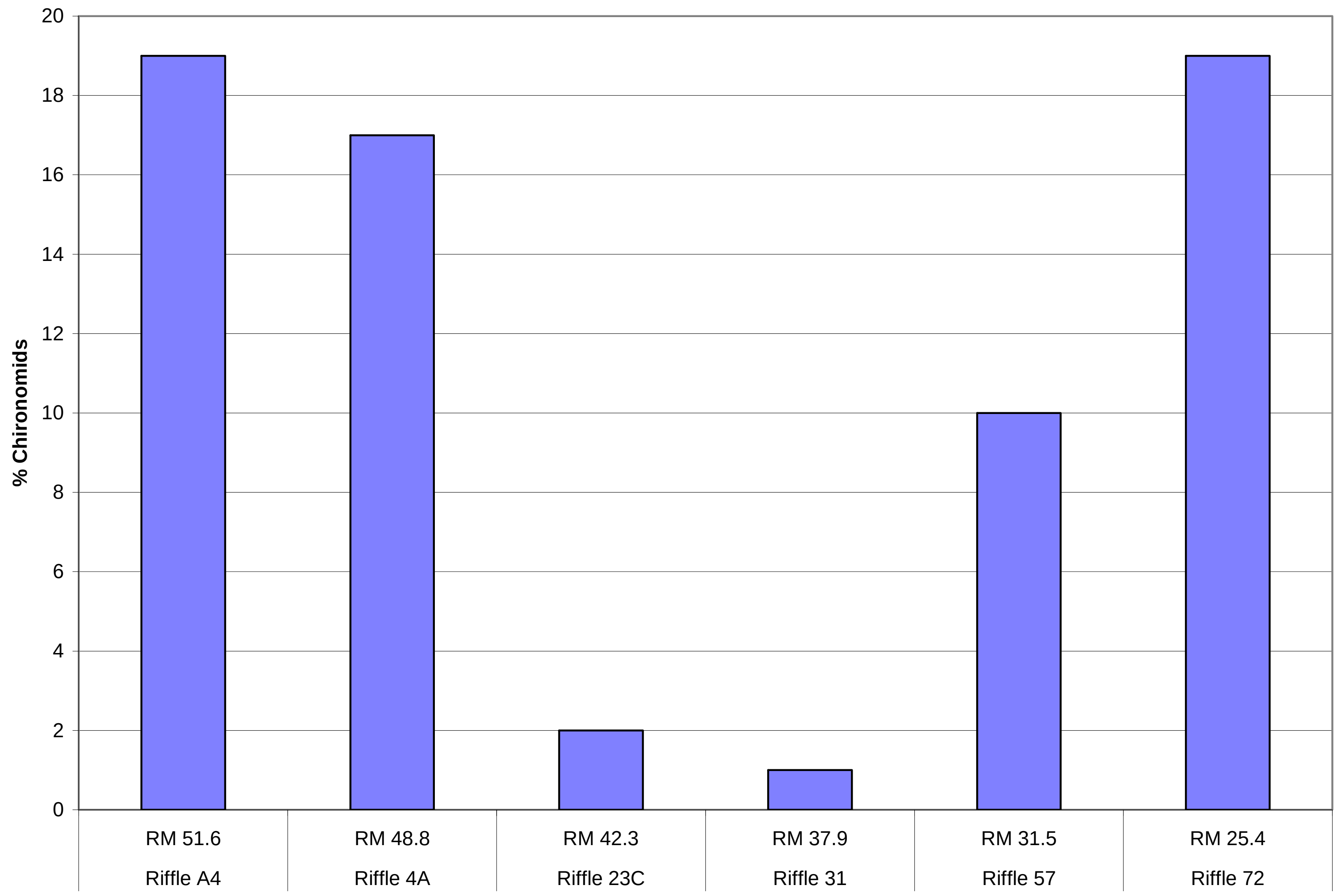

Figure 5. Percent chironomids by site for 2009.

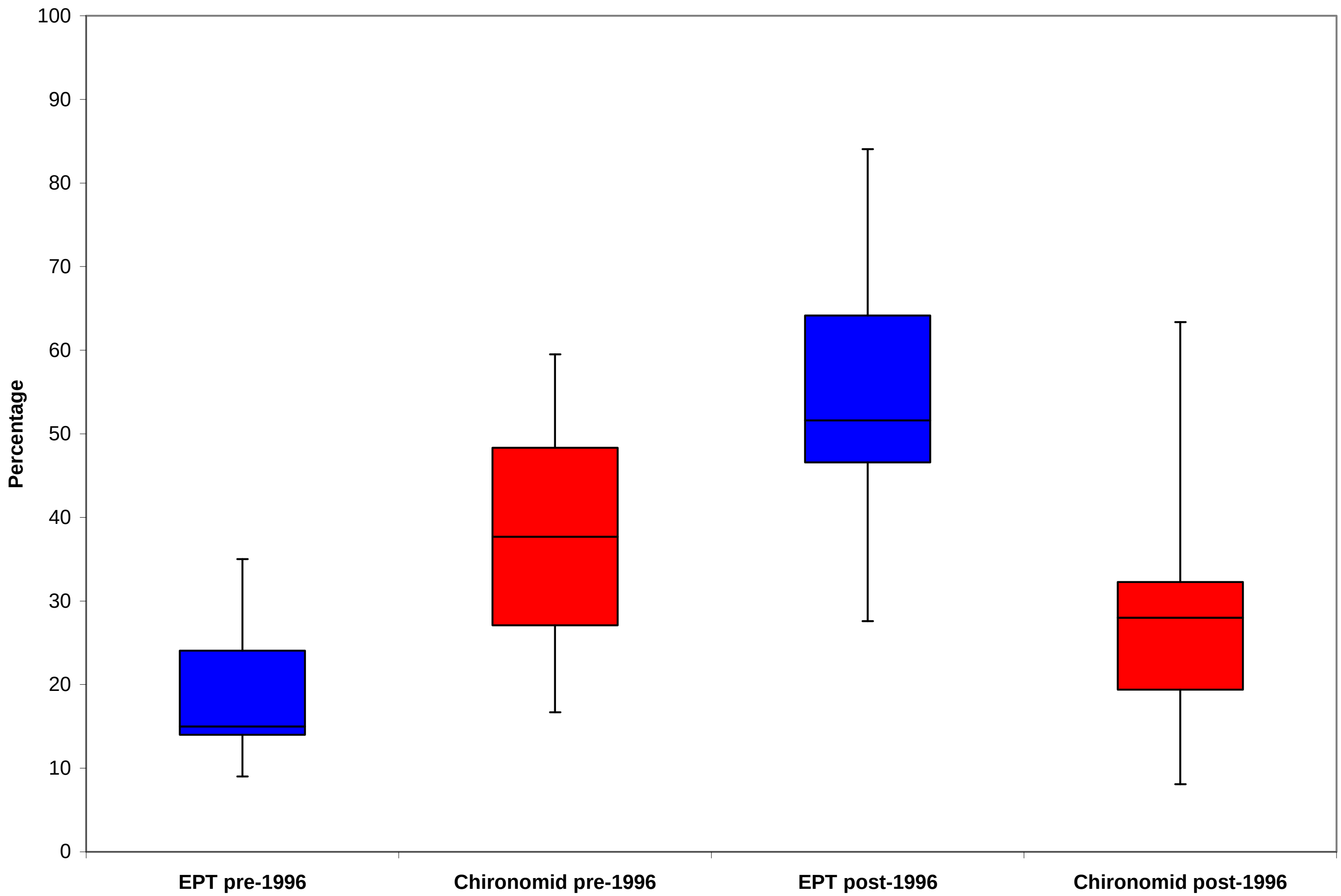

Figure 6. Comparison of EPT and Chironomid percentages at Riffle 4A before and after 1995 FSA flows (Note: boxes show lower, median and upper quartile values. Whiskers represent minimum and maximum values).

Appendices

Appendix A

Lower Tuolumne Discharge at La Grange (USGS) 2009

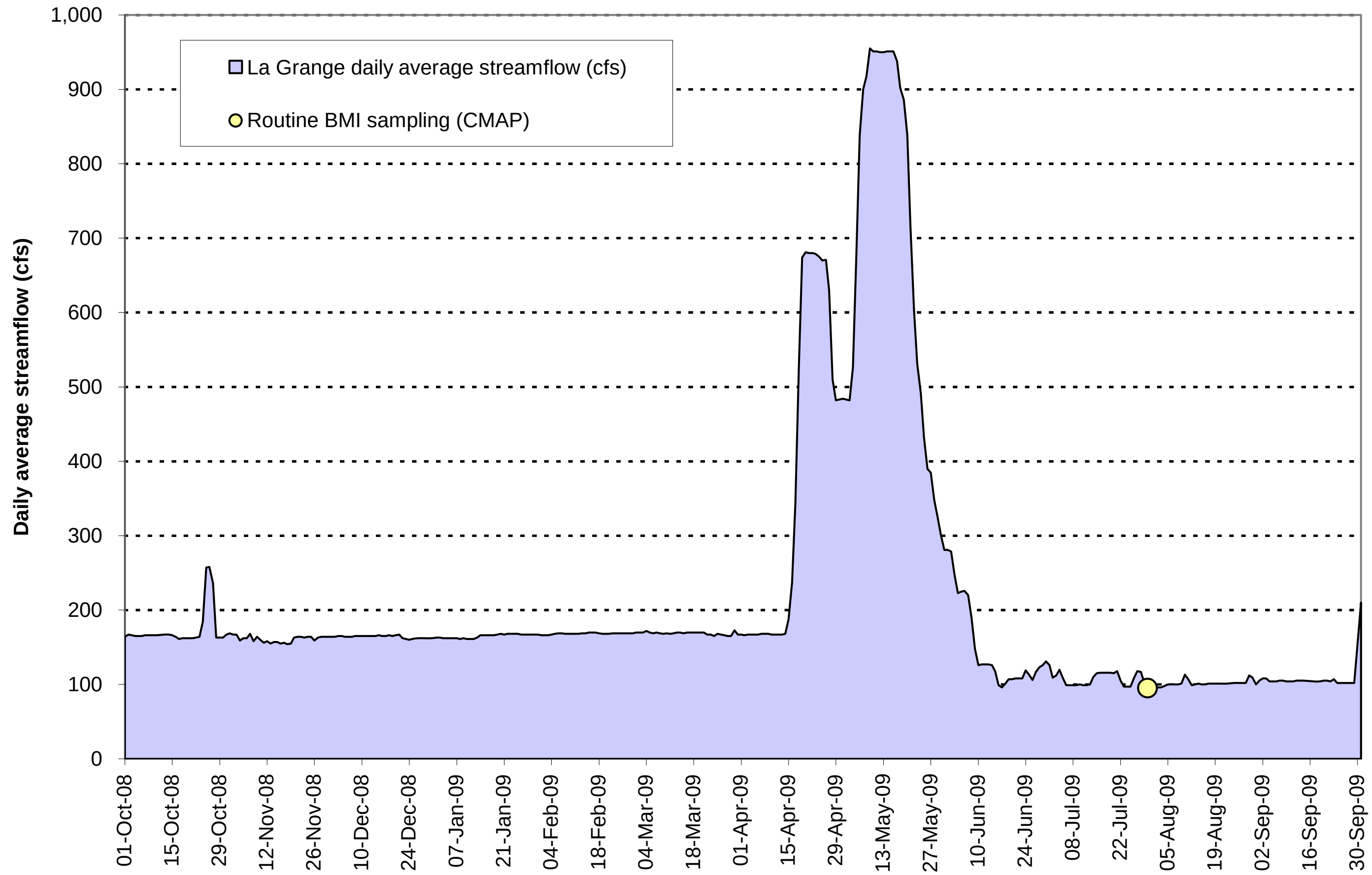

Figure A-1. Daily Average Flow (cfs) at La Grange (USGS 11289650) for Water Year 2009.

Appendix B

Site characterization and physical habitat data

Table B1. Water quality parameters by year for each location.

River Mile	Location	2001[1]	2002[2]	2003	2004	2005	2007	2008	2009
Temperature (C)									
51.6	Riffle A4	11.7	12.5	11.8	12.1	11.9	11.6	11.7	11.6
48.8	Riffle 4A	-	15.2	13.2	16.1	12.9	13.7	14.8	14.4
42.3	Riffle 23C	21.9	24.4	16.9	22.2	15.3	19.7	20.9	20.6
38.1	Riffle 31	-	22.9	19.0	25.9	16.8	22.6	24.2	23.2
31.5	Riffle 57	27.3	25.3	23.8	27.7	18.7	24.1	27.0	21.6
25.4	Riffle 72	-	27.2	25.4	29.1	21.5	27.2	27.6	27.9
pH									
51.6	Riffle A4	7.2	7.9	7.5	7.4	7.6	7.2	7.5	6.5
48.8	Riffle 4A	-	7.9	7.8	7.6	7.4	7.2	NA	6.6
42.3	Riffle 23C	7.7	8.4	7.8	7.6	7.6	7.4	7.5	6.6
38.1	Riffle 31	-	7.7	7.9	7.4	7.4	8.6	7.4	6.7
31.5	Riffle 57	8.5	8.1	8.5	7.8	7.4	7.5	8.1	7.5
25.4	Riffle 72	-	8.9	8.4	8.2	7.3	7.6	8.1	8.1
Dissolved Oxygen (mg/L)									
51.6	Riffle A4	12.8	13.1	10.9	9.4	12.4	10.2	10.6	11.6
48.8	Riffle 4A	-	10.6	8.9	10.3	11.2	10.8	11.4	11.7
42.3	Riffle 23C	11.7	13.8	8.7	9.0	11.0	12.2	9.3	9.4
38.1	Riffle 31	-	8.4	11.8	11.3	10.5	9.6	9.3	8.9
31.5	Riffle 57	NA	8.2	8.0	7.9	9.8	8.7	9.0	9.2
25.4	Riffle 72	-	10.3	12.6	10.4	9.3	8.6	10.8	10.3
Specific Conductance (µS/cm)									
51.6	Riffle A4	32	41	36	32	26	32	36	34
48.8	Riffle 4A	-	46	37	35	30	34	37	36
42.3	Riffle 23C	49	56	41	50	32	42	48	44
38.1	Riffle 31	-	87	50	80	43	60	67	58
31.5	Riffle 57	97	106	58	83	51	69	78	65
25.4	Riffle 72	-	180	88	139	89	126	136	118
Average Depth (ft)									
51.6	Riffle A4	1.8	1.3	1.8	1.3	2.0	1.3	1.1	1.2
48.8	Riffle 4A	-	1.1	1.4	1.0	1.3	1.5	1.5	1.1
42.3	Riffle 23C	1.7	1.1	1.3	0.7	1.3	1.0	1.0	0.8
38.1	Riffle 31	-	0.6	1.3	1.3	1.8	1.2	1.2	1.2
31.5	Riffle 57	1.4	1.3	1.8	1.2	1.7	1.2	0.8	1.0
25.4	Riffle 72	-	1.5	2.0	1.8	1.9	1.7	1.3	1.4
Average Velocity (fps)									
51.6	Riffle A4	2.8	2.7	2.8	2.3	3.3	1.8	2.0	2.0
48.8	Riffle 4A	-	0.8	1.1	0.6	3.7	2.5	1.7	1.6
42.3	Riffle 23C	2.5	1.8	2.6	3.1	3.7	2.5	1.8	2.4
38.1	Riffle 31	-	1.3	3.2	3.1	3.2	2.0	1.3	1.4
31.5	Riffle 57	2.6	2.2	3.5	3.0	3.0	2.1	1.6	1.3
25.4	Riffle 72	-	2.3	3.1	2.4	3.8	2.8	2.3	2.4

[1] Samples collected at Riffle 21 (RM 42.9) site rather than Riffle 23C (RM 42.3) site.
[2] Samples collected at Riffle 33 (RM 37.7) site rather than Riffle 31 (RM 38.1) site.

Table B2. Physical habitat parameters by year for each location.

Year	River Mile	Location	Habitat Parameters: Percent Canopy	Habitat Parameters: Substrate Complexity Score	Habitat Parameters: Embeddedness Score	Percent composition of substrate: Fines	Percent composition of substrate: Gravel	Percent composition of substrate: Cobble	Percent composition of substrate: Boulder	Percent composition of substrate: Bedrock	Substrate consolidation	Gradient (%)
2002	51.6	Riffle A4	3	16	18	2	15	80	3	0	loose	0.3
	48.8	Riffle 4A	4	15	15	10	10	80	0	0	loose	0.2
	42.3	Riffle 23C	3	15	16	10	15	75	0	0	loose	0.2
	37.7	Riffle 33	1	15	15	15	10	75	0	0	compact	0.4
	31.5	Riffle 57	3	16	14	5	15	75	5	0	loose	0.1
	25.4	Riffle 72	1	15	15	20	35	45	0	0	loose	0.2
2003	51.6	Riffle A4	6	16	18	2	15	80	3	0	loose	0.3
	48.8	Riffle 4A	5	15	15	10	10	80	0	0	loose	0.2
	42.3	Riffle 23C	6	15	16	15	15	70	0	0	loose	0.3
	38.1	Riffle 31	0	15	15	15	15	70	0	0	compact	0.3
	31.5	Riffle 57	3	16	14	5	15	75	5	0	loose	0.1
	25.4	Riffle 72	1	15	15	20	35	45	0	0	loose	0.2
2004	51.6	Riffle A4	6	16	18	2	15	80	3	0	loose	0.3
	48.8	Riffle 4A	4	15	15	10	15	70	5	0	loose	0.2
	42.3	Riffle 23C	20	15	16	10	25	60	5	0	very loose	0.4
	38.1	Riffle 31	0	15	15	15	10	70	5	0	loose	0.3
	31.5	Riffle 57	3	14	14	5	15	75	5	0	loose	0.1
	25.4	Riffle 72	1	13	13	30	50	20	0	0	loose	0.2
2005	51.6	Riffle A4	6	16	18	5	15	70	10	0	loose	0.2
	48.8	Riffle 4A	4	15	17	5	15	70	10	0	loose	0.2
	42.3	Riffle 23C	20	15	16	40	10	50	0	0	very loose	0.2
	38.1	Riffle 31	0	15	17	5	20	70	5	0	loose	0.1
	31.5	Riffle 57	4	14	16	5	20	70	5	0	loose	0.2
	25.4	Riffle 72	1	13	16	25	50	25	0	0	very loose	0.2
2007	51.6	Riffle A4	6	16	18	10	15	60	15	0	loose	0.2
	48.8	Riffle 4A	4	15	17	5	15	70	10	0	loose	0.2
	42.3	Riffle 23C	20	15	16	15	35	45	5	0	loose	0.2
	38.1	Riffle 31	0	15	17	5	20	70	5	0	loose	0.1
	31.5	Riffle 57	4	14	16	15	20	60	5	0	loose	0.2
	25.4	Riffle 72	2	13	16	25	60	15	0	0	very loose	0.2
2008	51.6	Riffle A4	5	16	18	10	15	60	15	0	loose	0.2
	48.8	Riffle 4A	5	15	17	5	15	70	10	0	loose	0.2
	42.3	Riffle 23C	20	15	16	15	35	45	5	0	loose	0.2
	38.1	Riffle 31	1	15	17	5	20	70	5	0	loose	0.1
	31.5	Riffle 57	5	14	16	15	20	60	5	0	loose	0.2
	25.4	Riffle 72	2	13	16	25	60	15	0	0	loose	0.2
2009	51.6	Riffle A4	5	16	18	5	15	65	15	0	loose	0.2
	48.8	Riffle 4A	3	15	17	5	15	70	10	0	semi-compacted	0.2
	42.3	Riffle 23C	20	15	16	15	35	45	5	0	loose	0.2
	38.1	Riffle 31	1	15	17	5	20	70	5	0	loose	0.1
	31.5	Riffle 57	2	14	16	15	20	60	5	0	loose	0.2
	25.4	Riffle 72	2	13	16	25	60	15	0	0	loose	0.2

Table B3. Scoring of habitat parameters from CSBP (1999).

Habitat Parameter	Condition Category (Score)			
	Optimal (20-16)	**Suboptimal (11-15)**	**Marginal (6-10)**	**Poor (0-5)**
Substrate Complexity	Greater than 70% (50% for low gradient streams) of substrate available for epifaunal colonization and fish cover; most favorable is a mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% (30-50% for low gradient streams) mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% (10-30% for low gradient streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for low gradient streams) stable habitat; lack of habitat is obvious; substrate unstable or lacking.
Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobbles provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.

Appendix C

Invertebrate Identification Tables

Table C1. Kick sample identifications and estimated density, lower Tuolumne River 2009.

PHYLUM / **Class** / **Order** / Family / *Taxon*	Density of Kick Samples (no/m^2) for 2009					
	Riffle A4	Riffle 4A	Riffle 23C	Riffle 31	Riffle 57	Riffle72
	7/31/2009	7/29/2009	7/30/2009	7/31/2009	7/31/2009	7/31/2009
ANNELIDA						
Hirudinea						
Rhyncobdellida						
Glossiphoniidae						
Helobdella				6		
Oligochaeta	72	115	11	83	23	187
ARTHROPODA						
Arachnida						
Acari	100	105	115	238	143	124
Insecta						
Coleoptera						
Elmidae						
Ordobrevia nubifera			126	37	9	
Zaitzevia			6			
Diptera						
Blephariceridae						
Agathon		10				
Chironomidae						
Limnophyes	14					
Pagastia					2	
Pentaneura			6			
Chironomidae-pupae	72	19	6		9	21
Chironominae						
Cladotanytarsus						2
Corynoneura	43		6			
Cricotopus	14					2
Cricotopus Bicinctus Gr.		5				7
Eukiefferiella	230	5		3		
Eukiefferiella Devonica Gr.	187	10				
Nanocladius						
Orthocladius complex	201	19	6		48	2
Paratanytarsus	29	5				
Phaenopsectra						
Polypedilum	14	139			2	4
Rheocricotopus	29	10				
Rheotanytarsus	230	24	6		5	2
Synorthocladius						
Tanytarsus	244		6	3	4	4
Thienemanniella			23	3	2	2
Tvetenia Vitracies Gr.	215	206				
Diamesinae						
Potthastia Gaedii Gr.						
Potthastia Longimana Gr.						
Empididae						
Chelifera - Metachela		14				
Clinocera						
Hemerodromia						

Table C1 (cont.)

PHYLUM / Class / Order / Family / *Taxon*	Density of Kick Samples (no/m^2) for 2009					
	Riffle A4	Riffle 4A	Riffle 23C	Riffle 31	Riffle 57	Riffle72
	7/31/2009	7/29/2009	7/30/2009	7/31/2009	7/31/2009	7/31/2009
Simuliidae						
Simulium	3157	33	6	11		
Tanypodinae						
Ablabesmyia					4	
Thienemannimyia complex	29	5				2
Tipulidae						
Antocha						
Ephemeroptera						
Baetidae						
Acentrella	29	29	103	3		
Baetis tricaudatus	2827	492	551			
Camelobaetidius				20	14	
Centroptilum - Procloeon				3	2	
Fallceon quilleri			6		4	2
Ephemerellidae						
Serratella micheneri		124	17	32	7	
Heptageniidae						
Ecdyonurus criddlei		124	92	9	4	
Leptohyphidae						
Tricorythodes minutus		62	75	29	2	39
Lepidoptera						
Pyralidae						
Petrophila			161	327	61	39
Odonata						
Coenagrionidae						
Argia				6	4	7
Plecoptera						
Perlodidae						
Isoperla		19				
Trichoptera						
Glossosomatidae						
Glossosoma	158	225	6			
Protoptila						30
Hydropsychidae						
Hydropsyche	115	684	2043	436	52	65
Hydroptilidae						
Hydroptila	43	19	6	3	4	4
Leucotrichia				3		2
Oxythira						
Lepidostomatidae						
Lepidostoma						
Leptoceridae						
Mystacides					2	
Nectopsyche				49	154	12
Oecetis						
Polycentropodidae						
Polycentropus				3		

Table C1 (cont.)

PHYLUM / **Class** / **Order** / Family / *Taxon*	Density of Kick Samples (no/m^2) for 2009					
	Riffle A4	Riffle 4A	Riffle 23C	Riffle 31	Riffle 57	Riffle72
	7/31/2009	7/29/2009	7/30/2009	7/31/2009	7/31/2009	7/31/2009
CNIDARIA						
Hydrozoa						
Anthoathecatae						
Hydridae						
Hydra						
MOLLUSCA						
Bivalvia						
Pelecypoda						
Corbiculidae						
Corbicula fluminea			92	9	9	2
Sphaeriidae						
Pisidium		5				
Gastropoda						
Basommatophora						
Ancylidae						
Ferrissia			11	20	23	7
Lymnaeidae						
Lymnaea	14	5				
Physidae						
Physa - Physella	14				7	2
Planorbidae						
Gyraulus						
Menetus	86	38	46	40	34	2
Neotaenioglossa						
Hydrobiidae						
Hydrobiidae					4	
NEMATODA		5			5	4
PLATYHELMINTHES						
Turbellaria						
Tricladida	43	57	218	158	109	35
Subphylum Crustacea						
Malacostraca						
Amphipoda						
Crangonyctidae						
Crangonyx		14				
Stygobromus			17	3		
Hyalellidae						
Hyalella				11		
Isopoda						
Asellidae						
Caecidotea	72	14				

Analyst: Robert W. Wisseman (Aquatic Biology Associates, Inc)
ID Level: Pacific Northwest Level 3, consistent with CSBP Level 2
Sample Replicates= 1
Area sampled= 0.57 m^2

Table C2. Riffle 4A Hess sample identifications and mean denisty.

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m^2) Riffle 4A 7/29/2009 MEAN	SD
ANNELIDA		
Hirudinea		
Rhyncobdellida		
Glossiphoniidae		
Helobdella		
Oligochaeta	2815	1402
ARTHROPODA		
Arachnida		
Acari	1558	1114
Insecta		
Coleoptera		
Elmidae		
Ordobrevia nubifera		
Zaitzevia		
Diptera		
Blephariceridae		
Agathon		
Chironomidae		
Limnophyes		
Pagastia		
Pentaneura		
Chironomidae-pupae	106	76
Chironominae		
Cladotanytarsus		
Corynoneura	105	79
Cricotopus	28	34
Cricotopus Bicinctus Gr.	279	610
Eukiefferiella	5	13
Eukiefferiella Devonica Gr.	285	512
Nanocladius		
Orthocladius complex	363	355
Paratanytarsus	324	466
Phaenopsectra	9	22
Polypedilum	2528	2360
Rheocricotopus	160	162
Rheotanytarsus	41	62
Synorthocladius	113	157
Tanytarsus	303	281
Thienemanniella	52	78
Tvetenia Vitracies Gr.	1926	2304
Diamesinae		
Potthastia Gaedii Gr.	980	2400
Potthastia Longimana Gr.	93	229
Empididae		
Chelifera - Metachela	128	73
Clinocera	4	11
Hemerodromia		

Table C2 (cont.)

PHYLUM / **Class** / **Order** / Family / *Taxon*	Density of Hess Samples (no./m^2) Riffle 4A 7/29/2009 MEAN	SD
Hemerodromia		
Simuliidae		
Simulium	40	67
Tanypodinae		
Ablabesmyia		
Thienemannimyia complex	143	72
Tipulidae		
Antocha	49	54
Ephemeroptera		
Baetidae		
Acentrella	386	327
Baetis tricaudatus	5193	5971
Camelobaetidius		
Centroptilum - Procloeon		
Fallceon quilleri	23	37
Ephemerellidae		
Serratella micheneri	303	95
Heptageniidae		
Ecdyonurus criddlei	522	306
Leptohyphidae		
Tricorythodes minutus	678	416
Lepidoptera		
Pyralidae		
Petrophila	45	64
Odonata		
Coenagrionidae		
Argia		
Plecoptera		
Perlodidae		
Isoperla	93	118
Trichoptera		
Glossosomatidae		
Glossosoma	853	805
Protoptila		
Hydropsychidae		
Hydropsyche	5476	5049
Hydroptilidae		
Hydroptila	716	691
Leucotrichia		
Oxythira	27	65
Lepidostomatidae		
Lepidostoma	7	16
Leptoceridae		
Mystacides		
Nectopsyche		
Oecetis		
Polycentropodidae		
Polycentropus		

Table C2 (cont.)

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m²) Riffle 4A 7/29/2009 MEAN	SD
CNIDARIA		
Hydrozoa		
Anthoathecatae		
Hydridae		
Hydra	107	132
MOLLUSCA		
Bivalvia		
Pelecypoda		
Corbiculidae		
Corbicula fluminea		
Sphaeriidae		
Pisidium	151	194
Gastropoda		
Basommatophora		
Ancylidae		
Ferrissia		
Lymnaeidae		
Lymnaea	12	22
Physidae		
Physa - Physella		
Planorbidae		
Gyraulus	59	94
Menetus	255	216
Neotaenioglossa		
Hydrobiidae		
Hydrobiidae		
NEMATODA	185	148
PLATYHELMINTHES		
Turbellaria		
Tricladida	434	463
Subphylum Crustacea		
Malacostraca		
Amphipoda		
Crangonyctidae		
Crangonyx	321	211
Stygobromus	12	19
Hyalellidae		
Hyalella	7	16
Isopoda		
Asellidae		
Caecidotea	211	116

Analyst: Robert W. Wisseman (Aquatic Biology Associates, Inc)
ID Level: Pacific Northwest Level 3, consistent with CSBP Level 2
Sample Replicates= 6
Area sampled= 0.6 m^2

Table C3. Riffle 23C Hess sample identifications and mean density.

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m^2) Riffle 23C 7/30/2009 MEAN	SD
ANNELIDA		
Hirudinea		
Rhyncobdellida		
Glossiphoniidae		
Helobdella		
Oligochaeta	730	397
ARTHROPODA		
Arachnida		
Acari	1669	2162
Insecta		
Coleoptera		
Elmidae		
Ordobrevia nubifera	2713	5653
Zaitzevia	70	126
Diptera		
Blephariceridae		
Agathon	66	88
Chironomidae		
Limnophyes		
Pagastia		
Pentaneura		
Chironomidae-pupae	23	15
Chironominae		
Cladotanytarsus		
Corynoneura	79	120
Cricotopus	5	13
Cricotopus Bicinctus Gr.	3	8
Eukiefferiella	3	8
Eukiefferiella Devonica Gr.		
Nanocladius	3	8
Orthocladius complex	10	11
Paratanytarsus	3	8
Phaenopsectra		
Polypedilum	148	111
Rheocricotopus	37	61
Rheotanytarsus	3	7
Synorthocladius	13	16
Tanytarsus	73	123
Thienemanniella	462	521
Tvetenia Vitracies Gr.	39	61
Diamesinae		
Potthastia Gaedii Gr.		
Potthastia Longimana Gr.		
Empididae		
Chelifera - Metachela	9	10
Clinocera		
Hemerodromia	27	65

Table C3 (cont.)

PHYLUM / **Class** / **Order** / Family / *Taxon*	Density of Hess Samples (no./m^2)	
	Riffle 23C	
	7/30/2009	
	MEAN	SD
Simuliidae		
Simulium	58	61
Tanypodinae		
Ablabesmyia		
Thienemannimyia complex	3	8
Tipulidae		
Antocha		
Ephemeroptera		
Baetidae		
Acentrella	637	793
Baetis tricaudatus	1504	1949
Camelobaetidius		
Centroptilum - Procloeon		
Fallceon quilleri	59	128
Ephemerellidae		
Serratella micheneri	33	30
Heptageniidae		
Ecdyonurus criddlei	529	924
Leptohyphidae		
Tricorythodes minutus	407	671
Lepidoptera		
Pyralidae		
Petrophila	1402	2765
Odonata		
Coenagrionidae		
Argia		
Plecoptera		
Perlodidae		
Isoperla		
Trichoptera		
Glossosomatidae		
Glossosoma	13	24
Protoptila	3	8
Hydropsychidae		
Hydropsyche	8508	10694
Hydroptilidae		
Hydroptila		
Leucotrichia		
Oxythira		
Lepidostomatidae		
Lepidostoma		
Leptoceridae		
Mystacides		
Nectopsyche	57	129
Oecetis	27	65
Polycentropodidae		
Polycentropus	7	10

Table C3 (cont.)

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m^2) Riffle 23C 7/30/2009 MEAN	SD
CNIDARIA		
Hydrozoa		
Anthoathecatae		
Hydridae		
Hydra	3	8
MOLLUSCA		
Bivalvia		
Pelecypoda		
Corbiculidae		
Corbicula fluminea	851	1252
Sphaeriidae		
Pisidium	29	64
Gastropoda		
Basommatophora		
Ancylidae		
Ferrissia	57	129
Lymnaeidae		
Lymnaea	3	8
Physidae		
Physa - Physella		
Planorbidae		
Gyraulus		
Menetus	85	123
Neotaenioglossa		
Hydrobiidae		
Hydrobiidae	7	10
NEMATODA	23	39
PLATYHELMINTHES		
Turbellaria		
Tricladida	2781	2527
Subphylum Crustacea		
Malacostraca		
Amphipoda		
Crangonyctidae		
Crangonyx	106	191
Stygobromus	533	920
Hyalellidae		
Hyalella	3	7
Isopoda		
Asellidae		
Caecidotea		

Analyst: Robert W. Wisseman (Aquatic Biology Associates, Inc)
ID Level: Pacific Northwest Level 3, consistent with CSBP Level 2
Sample Replicates= 6
Area sampled= 0.6 m^2