Annual Benthic Macroinvertebrate Monitoring (2005, 2007, 2008) 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). 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 (2001–2008).

		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	AUG	1	6						1	6				1		River-wide CSBP/ CMAP monitoring (TID/MID 2003, 2005, 2009; McBain & Trush 2008)
2002	JUL	1	6	6		6				3	3		1	1	1	
2003	JUL	1	3	1		1				3	1	1		1	1	
2004	JUL	1	3	2		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	3				
	AUG	1	6	1						6	1	1		1	1	

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

1.2 Purpose and Goals

The report provides a summary and analysis of BMI monitoring for the lower Tuolumne River conducted in 2005, 2007, and 2008 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 2005, 2007, and 2008 using metrics outlined by the current CMAP.
2. Provide a summary update of long-term trends derived from data collected from 1988–2008 at specific locations along the Tuolumne, with regard to effects of water year type and changes in instream flows.

A separate BMI assessment in the vicinity of RM 45.3 was conducted in May 2008 (McBain and Trush 2008) to examine the effects of high suspended sediment and turbidity conditions during runoff events of January-February 2008 from the Peaslee Creek watershed near La Grange. We provide a brief discussion of these results in the context of longer term river wide surveys.

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 (2005, 2007, and 2008).

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 in 2005, 2007, and 2008 are shown in Figure 1. Sampling sites, months, location (RM), method, and quantities of samples collected are shown in Table 1. Although the majority of sampling took place in late July (July 24–26, 2007 and July 29–31, 2008) to provide comparable data from year to year and avoid short-term community shifts due to variable insect emergence timing, high flows in summer 2005 delayed sampling until August 30 through September 1st .

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. In 2008 however, samples were taken as three separate replicates. After identification, the 2008 samples were composited statistically and treated as one sample.

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 Riffle 23C, samples were collected at evenly spaced transects along the riffle. At Riffle 4A, samples were taken within the 200 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 turned over, scrubbed to dislodge organisms, and removed from the cylinder. After all larger rocks were removed; the gravel was agitated by hand to a depth of 5–10 cm for 30 seconds. 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 1988–2008 at riffle 4A (RM 51.6) 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 m²	Variable

3 RESULTS

3.1 Environmental Conditions and Physical Habitat Data

The annual hydrographs of the lower Tuolumne River below La Grange Dam (USGS 11289650) are included in Appendix A. The 30-day average flow prior to sampling was approximately 803 cfs in 2005, 118 cfs in 2007, and 102 cfs in 2008. Daily average flow at the time of sampling in these three years was 332 cfs, 112 cfs, and 89 cfs, respectively. 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, which is not that surprising because 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 2001–2004 are presented in Table 5, with results for recent kick-net samples collected in 2005, 2007, and 2008 shown in Table 6. Figures 2–5 show the variation by riffle of selected metrics in the lower Tuolumne River for the most recent years. Taxonomic richness was generally highest in the upper reaches of the study area, although in 2008 there was also relatively high taxonomic richness at the most downstream site (Figure 2). The EPT index was highest at Riffles 4A and 23C in 2007 and 2008, while in 2005 the highest EPT index values were found in Riffle 23C and the three sites downstream of riffle 23C (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 (1988-2008)

Table 7 presents metrics from Hess sampling at Riffles 4A from 1988–2008 as well as more recent data (2001–2008) 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 (t-test, $p=0.28$). The EPT/Chironomid ratio increased since 1996, but not significantly (t-test, $p=0.09$).

Interestingly, 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 (t-test, $p=0.37$). Regression of the Shannon Diversity Index with Water Year Type Index, however, suggests some decrease in overall diversity with increasing basin-wide flows ($r^2=0.71$). The percentage of insects in the Hess samples was significantly higher since 1996 (t-test, $p=0.001$). The dominant taxon percentage increased since 1996 (t-test, $p=0.06$), with variations partly explained by Water Year Type Index ($r^2=0.62$).

Table 5. CMAP metrics for historical Kick Net samples by river mile (2001–2004)

Year	2001		2002					2003						2004					
Riffle	A4	57	A4	4A	23C	57	72	A4	4A	23C	31	57	72	A4	4A	23C	31	57	72
River Mile	51.6	31.5	51.6	48.8	42.3	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	25	25	20	22	20	25	23	25	33	21	21	30	22	28	23	20	25	27	26
EPT Taxa	8	7	5	7	5	8	5	7	8	9	7	10	7	8	9	7	10	11	8
Ephemeroptera Taxa	2	3	1	3	2	5	4	3	3	5	5	6	3	4	4	5	7	7	4
Plecoptera Taxa	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Trichoptera Taxa	5	4	3	4	3	3	1	3	5	4	2	4	4	3	5	2	3	4	4
Composition Measures																			
EPT Index	55	47	31	62	24	34	38	41	39	85	77	52	17	33	77	82	77	68	24
Percent Insects	91	70	88	86	53	70	55	73	83	90	85	70	48	85	90	85	85	76	41
Percent Chironomid	22	14	9	24	12	25	15	22	43	1	5	7	24	21	13	2	1	4	16
Percent Baetidae	29	3	25	4	6	13	1	31	2	35	22	23	4	26	1	11	8	21	1
Percent Hydropsychidae	12	42	5	2	16	13	2	4	0	36	48	26	6	2	1	56	51	29	8
EPT/Chironomid Ratio	2	3	3	3	2	1	2	2	1	91	15	7	1	2	6	51	108	16	1
Shannon Diversity	2.48	2.09	1.70	2.00	2.30	2.70	2.20	2.42	2.52	1.90	1.86	2.34	2.44	2.20	1.60	1.68	1.92	2.45	2.21
Tolerance Measures																			
Tolerance Value	5	5	6	5	5	5	5	6	5	5	4	4	5	6	5	4	4	4	5
Percent Intolerant Organisms	9	1	1	4	2	3	2	3	0	1	5	2	1	3	1	1	4	12	7
Percent Tolerant Organisms	14	1	10	8	14	2	21	24	4	1	1	1	1	15	1	0	1	1	2
Percent Dominant Taxon	29	42	46	47	29	16	33	31	26	36	48	26	30	31	53	56	51	29	40
Sensitive EPT Index	4	1	1	5	2	2	2	2	4	1	5	2	2	3	1	1	4	12	7
Feeding Measures																			
Percent Collector-Gatherers	43	18	41	79	34	46	63	62	59	48	29	33	30	42	62	23	26	43	57
Percent Collector-Filterers	25	44	51	2	15	13	2	19	13	37	51	29	14	41	9	57	51	29	12
Percent Scrapers	8	11	1	6	20	13	3	2	2	5	9	12	9	4	1	7	12	13	10
Percent Predators	3	15	6	8	31	26	32	2	2	5	3	10	9	1	1	9	6	6	2
Percent Shredders	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Percent Others	21	13	0	4	0	1	0	14	24	4	9	16	39	12	27	4	6	9	19
Quantitative Measures																			
Abundance (total in sample)	1,307	1,642	6,680	833	310	1,642	944	3,554	7,548	1,611	943	1,110	335	3,519	3,468	2,749	2,232	813	659
Density (No./m^2)	6,873	8,634	35,953	44,82	1,668	8,634	5,079	6,231	13,234	2,825	1,654	1,946	587	6,169	6,081	4,820	3,913	4,276	3,466

Table 6. CMAP metrics for Kick Net samples collected in 2005, 2007, and 2008 by river mile

Year	2005						2007						2008					
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	31	33	37	23	20	16	25	28	28	17	23	22	24	30	16	16	23	27
EPT Taxa	7	10	7	5	4	5	9	8	9	6	11	8	7	10	9	9	7	7
Ephemeroptera Taxa	3	5	5	3	3	3	5	5	5	4	6	4	3	6	7	6	4	2
Plecoptera Taxa	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Trichoptera Taxa	3	4	2	1	1	2	4	3	4	2	5	4	4	3	2	3	3	5
Composition Measures																		
EPT Index	58	66	94	90	92	83	61	65	86	53	59	35	37	68	79	35	39	25
Percent Insects	85	95	95	97	98	98	97	87	91	62	84	48	97	85	83	63	59	40
Percent Chironomid	10	11	6	3	3	14	33	20	3	0	4	7	52	16	1	1	10	8
Percent Baetidae	49	45	57	54	46	78	31	35	9	2	3	1	27	30	15	4	7	0
Percent Hydropsychidae	2	19	33	31	29	3	1	22	59	35	39	23	1	24	49	24	23	11
EPT/Chironomid Ratio	5	6	29	28	34	6	2	3	33	130	14	5	1	4	109	65	4	3
Shannon Diversity	1.84	1.89	1.22	1.64	1.61	1.56	2.09	2.34	1.73	1.83	2.13	2.38	2.42	2.39	1.82	2.05	2.45	2.25
Tolerance Measures																		
Tolerance Value	6	6	5	5	5	5	6	5	4	4	4	5	6	5	4	5	4	5
Percent Intolerant Organisms	6	1	2	1	0	0	3	3	5	0	12	5	2	7	1	6	6	5
Percent Tolerant Organisms	6	2	0	0	0	0	10	5	0	2	0	13	9	0	0	0	0	1
Percent Dominant Taxon	49	44	57	41	38	45	29	33	59	35	39	23	27	27	49	24	23	31
Sensitive EPT Index	4	5	3	2	0	1	3	2	2	0	4	2	2	4	1	1	1	1
Feeding Measures																		
Percent Collector-Gatherers	66	53	59	57	48	83	38	54	15	14	17	26	38	56	22	14	42	40
Percent Collector-Filterers	18	38	33	32	32	4	22	26	60	35	39	34	33	24	49	24	25	12
Percent Scrapers	6	2	4	8	17	3	2	2	19	17	32	10	1	6	13	28	10	13
Percent Predators	2	2	1	2	0	6	1	4	3	32	4	17	7	2	11	9	10	7
Percent Shredders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percent Others	8	6	3	2	2	5	38	13	3	2	7	13	21	12	4	26	14	28
Quantitative Measures																		
Abundance (total in sample)	1,057	1,031	463	1,201	513	273	306	522	388	247	428	240	296	360	275	185	118	345
Density (No./m^2)	1,853	1,808	812	2,106	899	479	537	915	680	433	750	421	520	632	483	324	207	606

Table 7. BMI community metrics for long-term Hess sampling sites at riffles R4A (RM 48.8) and R23C (RM 42.3) (1988–2008).

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

[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 2005, 2007 and 2008 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 2005, 2007, and 2008, the invertebrate sampling on the lower Tuolumne River focused on these differences along the longitudinal gradients in riffle habitats.

The percentages of EPT organisms were generally higher upstream of Riffles 23C (RM 42.8) and generally decreased with distance downstream (Figure 3). In 2005, however, the proportion of EPT organisms remained relatively high as the distance downstream increased. This may have been caused by late-season sampling and relatively high flows (803 cfs in 2005, compared to 118 cfs and 102 cfs, in 2007 and 2008, respectively) during the summer which kept the water cooler and more oxygenated, thus favoring less tolerant organisms.

For the riffles sampled in 2005, 2007, and 2008, the EPT/chironomid ratio was greatest along the middle reaches of the study area (Figure 4). This result is similar to that found by sampling conducted in 2003 and 2004 (Table 5). Although these findings typically indicate a decrease in biological impairment, it is also important to note that the high EPT/Chironomid ratio is correlated with a lower Shannon Diversity index (Table 4), which should increase with less environmental stress. The lower levels of diversity seem to be the result of dominance by Hydropsyche caddisflies (Table 4). Again, these findings agree with previous studies (TID/MID 2005, Table 5).

In examining the effects of excessive fine sediment loading from the Peaslee Creek watershed during runoff events of January-February 2008, McBain and Trush (2008) concluded that although evidence of fine sediment deposition was apparent on recent gravel augmentation patches in the RM 43 project area, reported BMI abundances and community metrics (e.g., Total taxa, EPT taxa, Hilsenhoff) were variable and did not indicate impairment. For the riffles that have been monitored over a longer period downstream of Peaslee Creek (R23C [RM 42.3] and R31 [RM 38.1]), only overall taxonomic richness in summer sampling appears to decline in summer 2008 relative to the preceding 5 years (Table 5 and Table 6). Based upon comparison of historical riverwide BMI data collected to date, there appears to be no evidence of impairment due to the 2008 sediment loading events from Peaslee Creek.

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 these 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 1988–2008 at riffle 4A (RM 51.6) 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). Chironomids generally declined in the post-FSA period and EPT species increased (TID/MID 2003). The present study, summarizing data from 2005, 2007–2008, continues to illustrate these trends.

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Figures

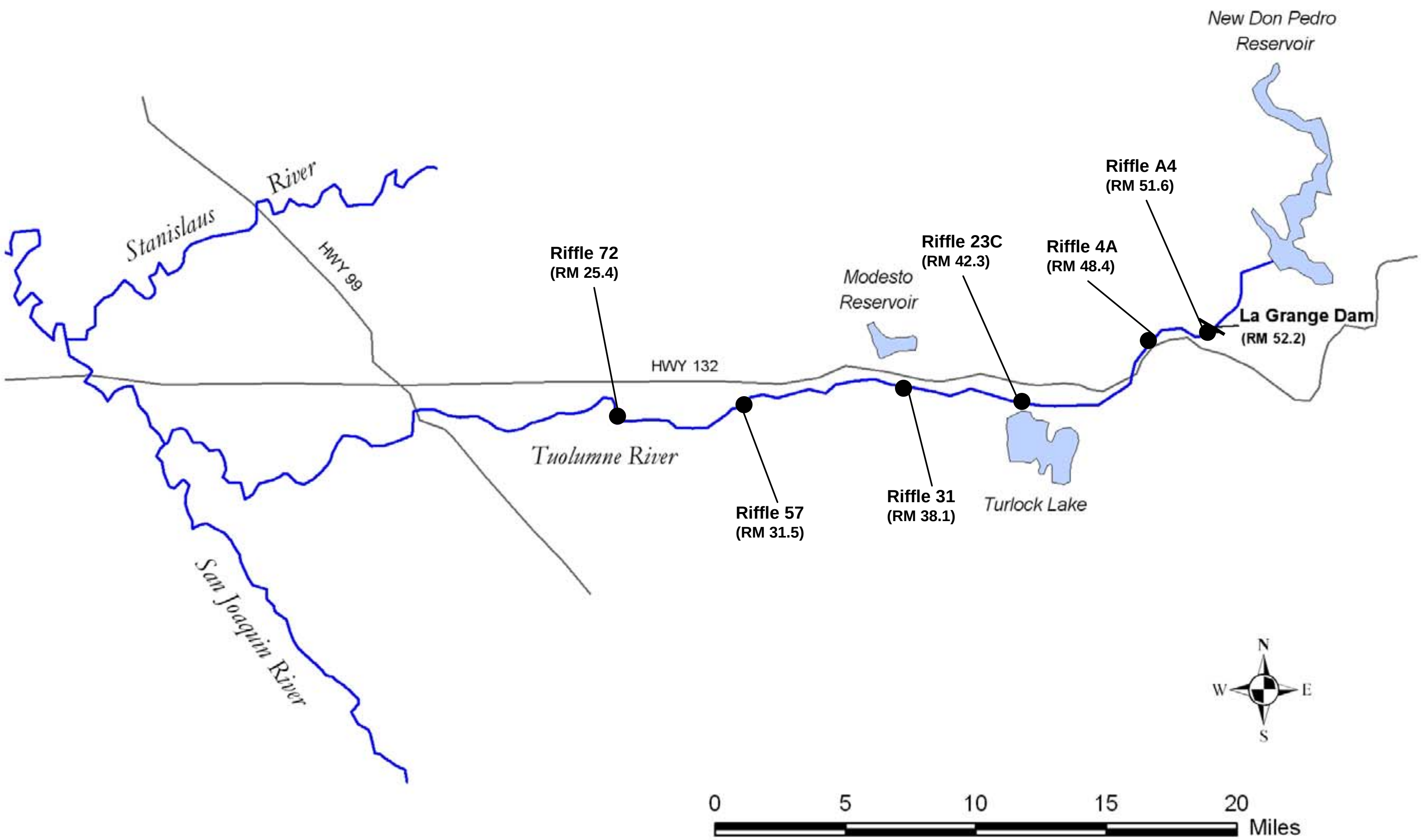

Figure 1. Locations of invertebrate sampling sites on the lower Tuolumne River, 2003-2004.

Stillwater Sciences

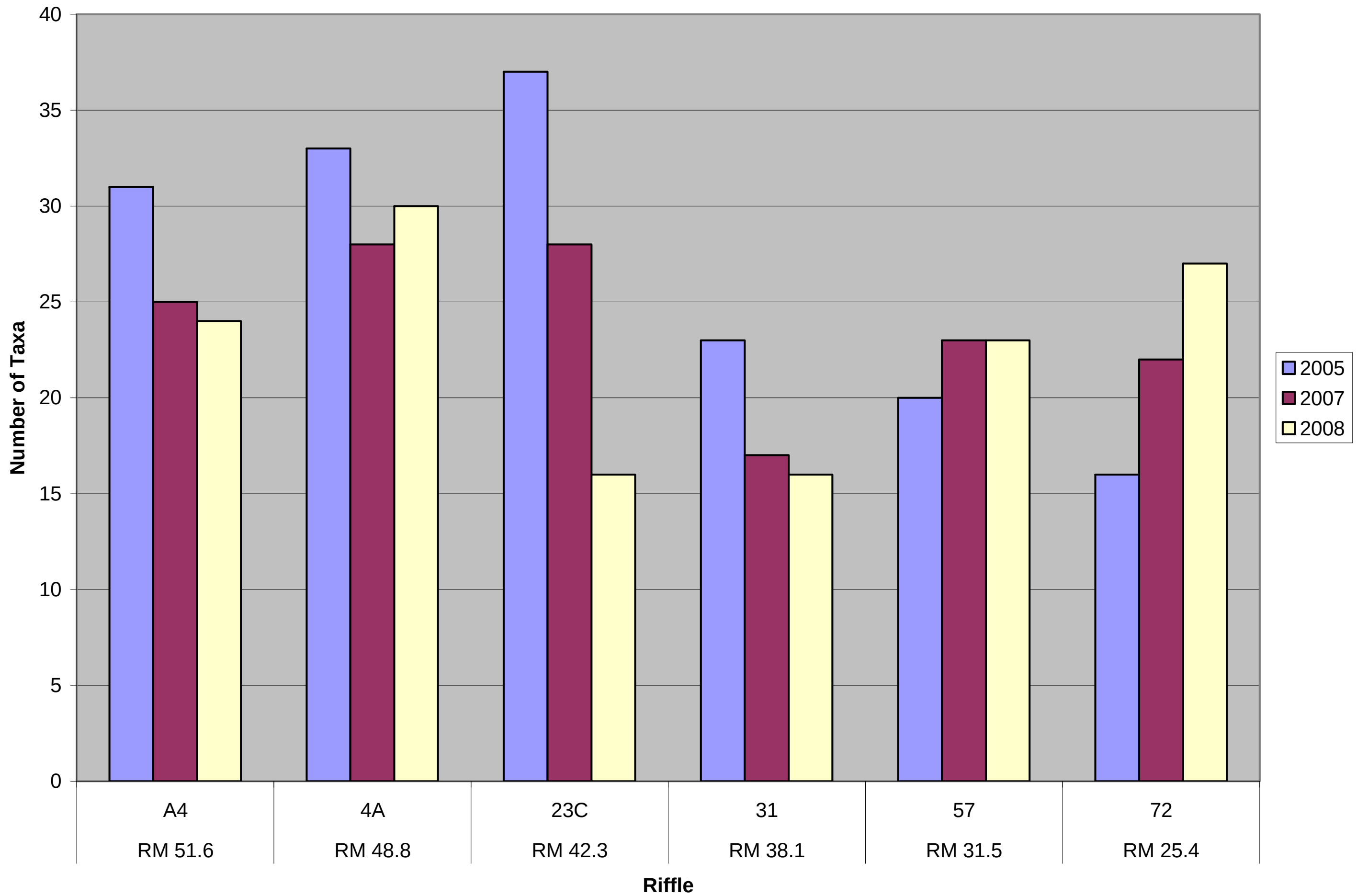

Figure 2. Taxonomic richness by site for 2005, 2007, and 2008

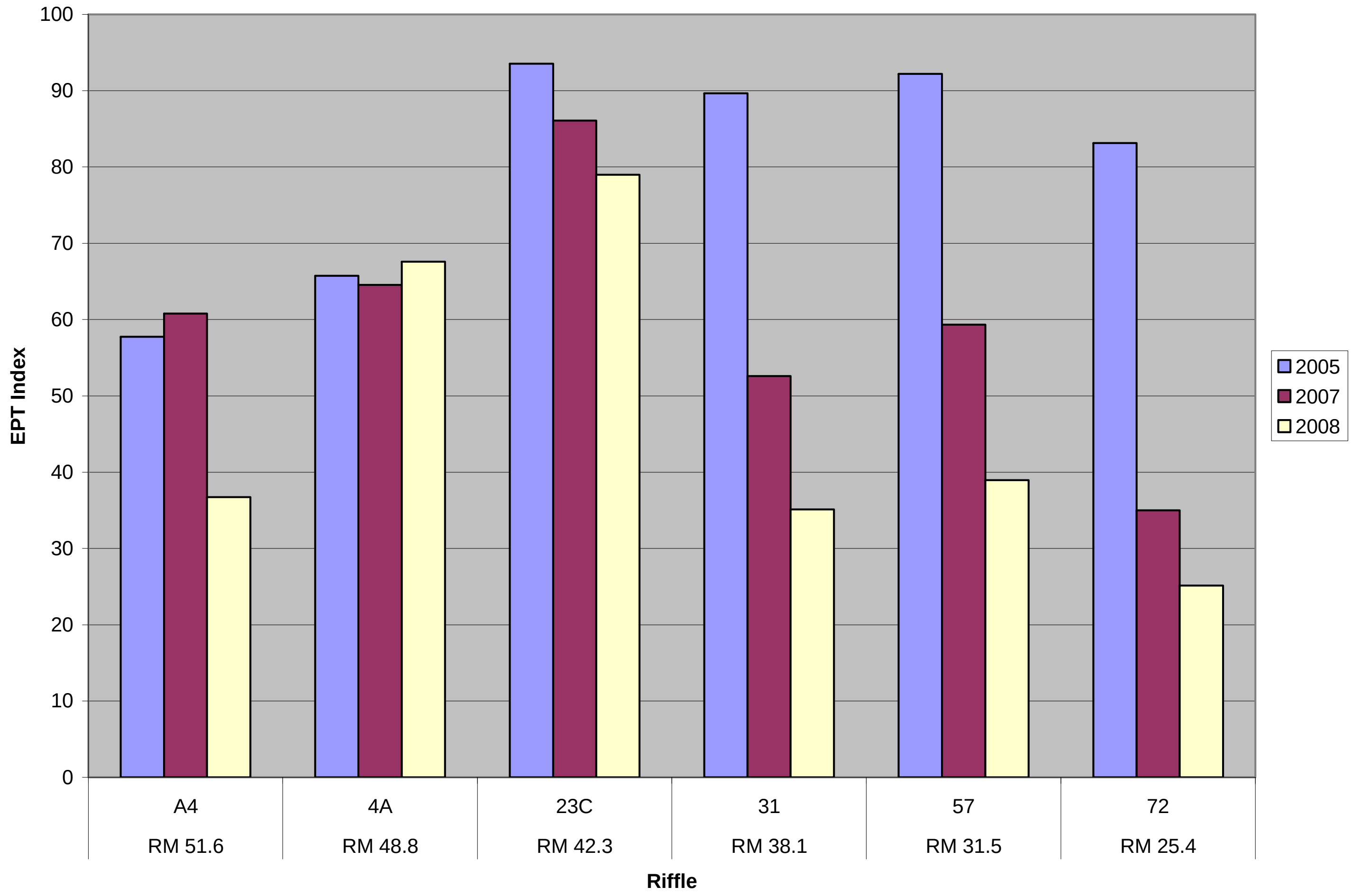

Figure 3. EPT index by site for 2005, 2007, and 2008

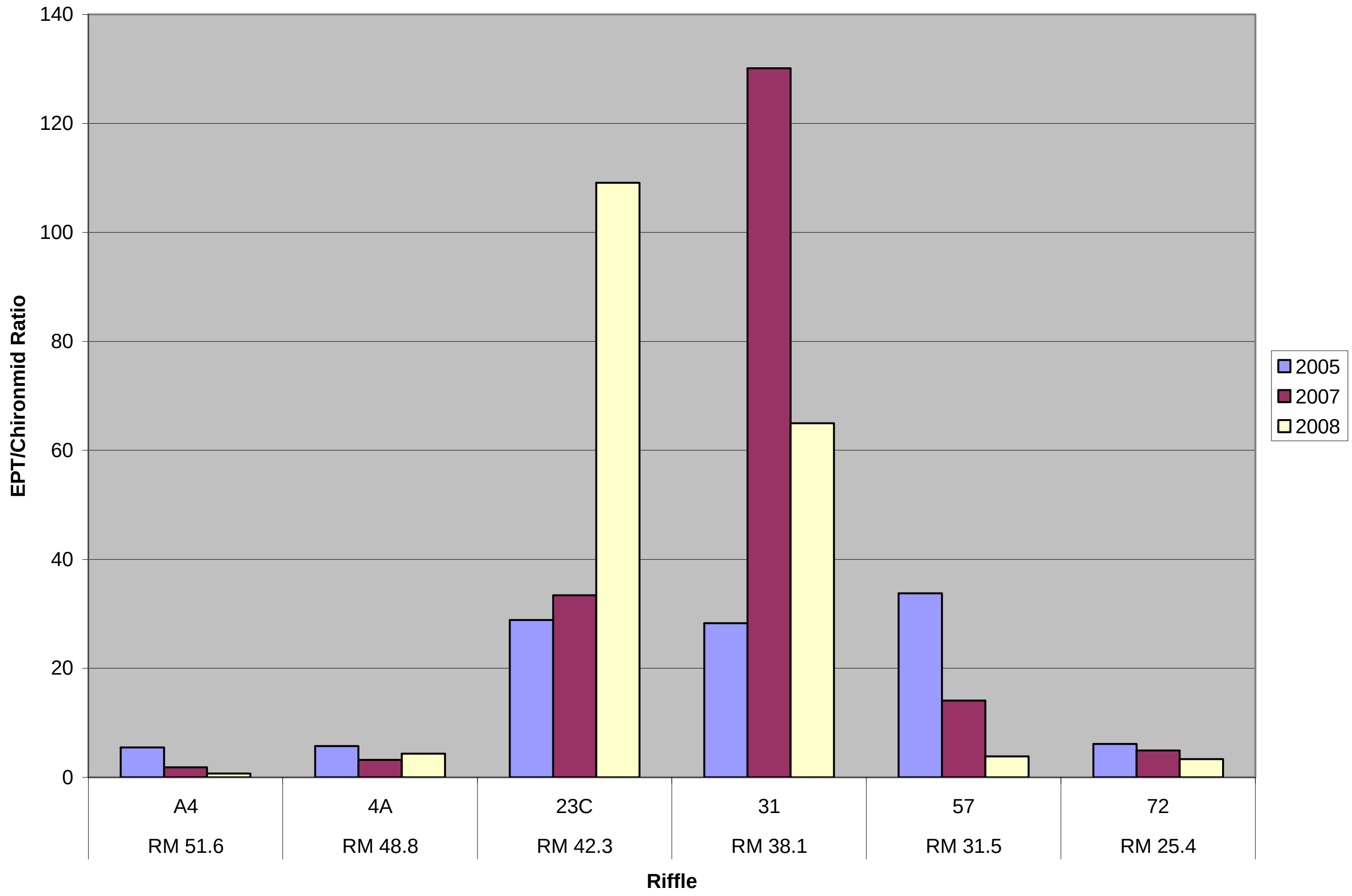

Figure 4. EPT/Chironomid ratio by site for 2005, 2007, and 2008

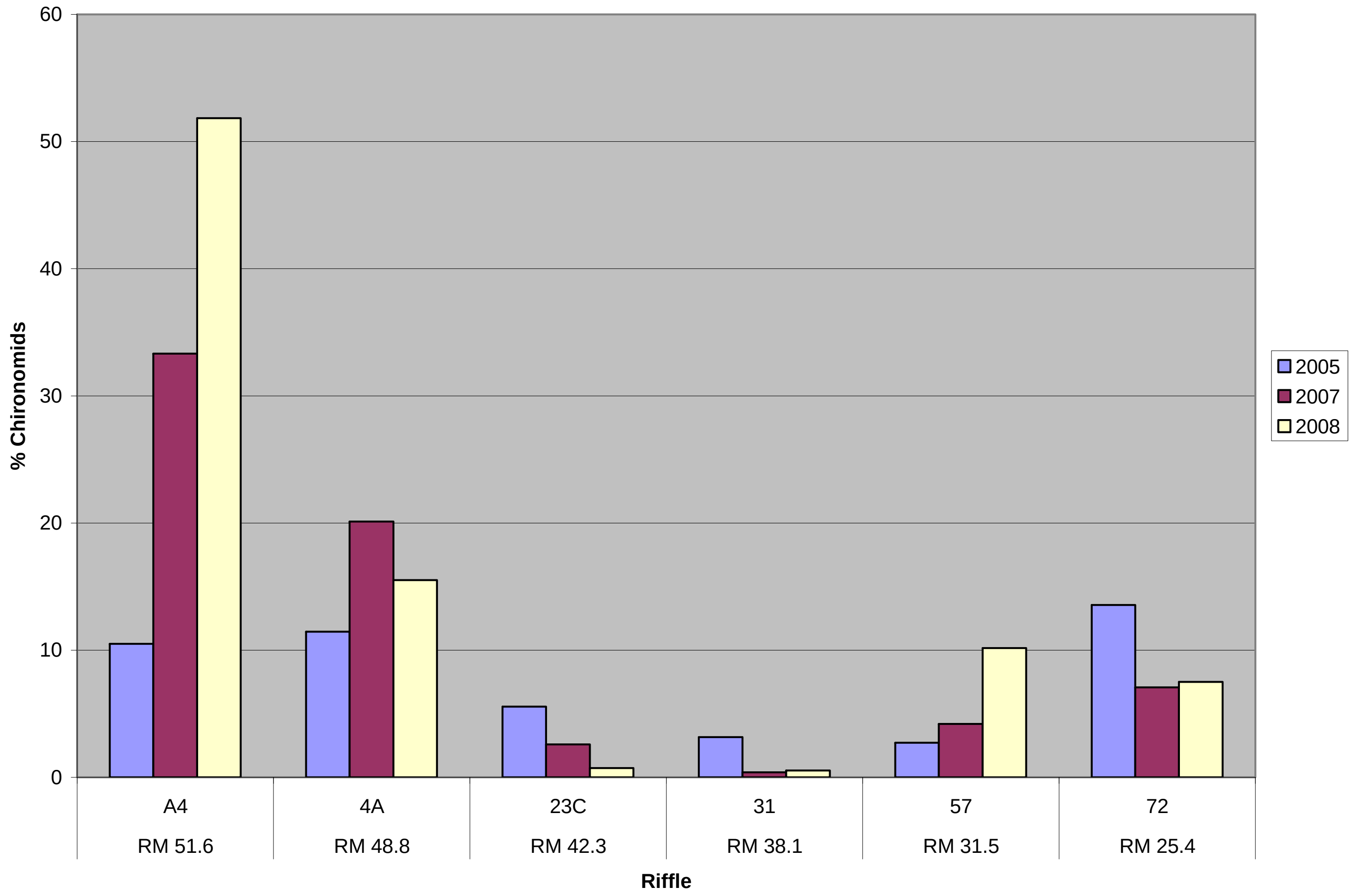

Figure 5. Percent chironomids by site for 2005, 2007, and 2008.

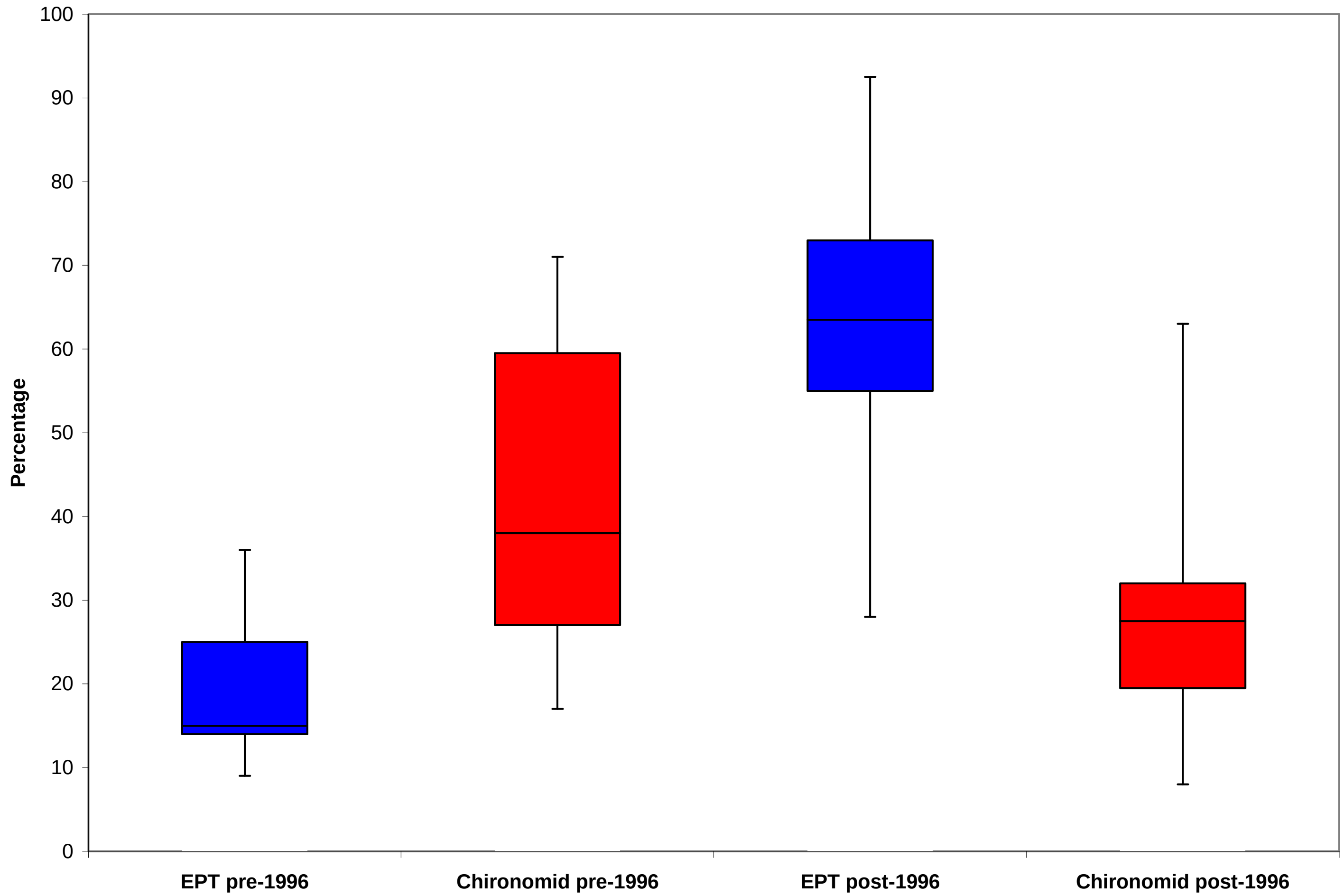

Figure 6. Comparison of EPT and Chironomid percentages at Riffle 4A before and after 1995 FSA flows (Note: boxes show lower, median and upper quartile values. Whiskers represent minimum and maximum values).

Appendices

Appendix A

Lower Tuolumne Discharge at La Grange (USGS) 2005, 2007, and 2008

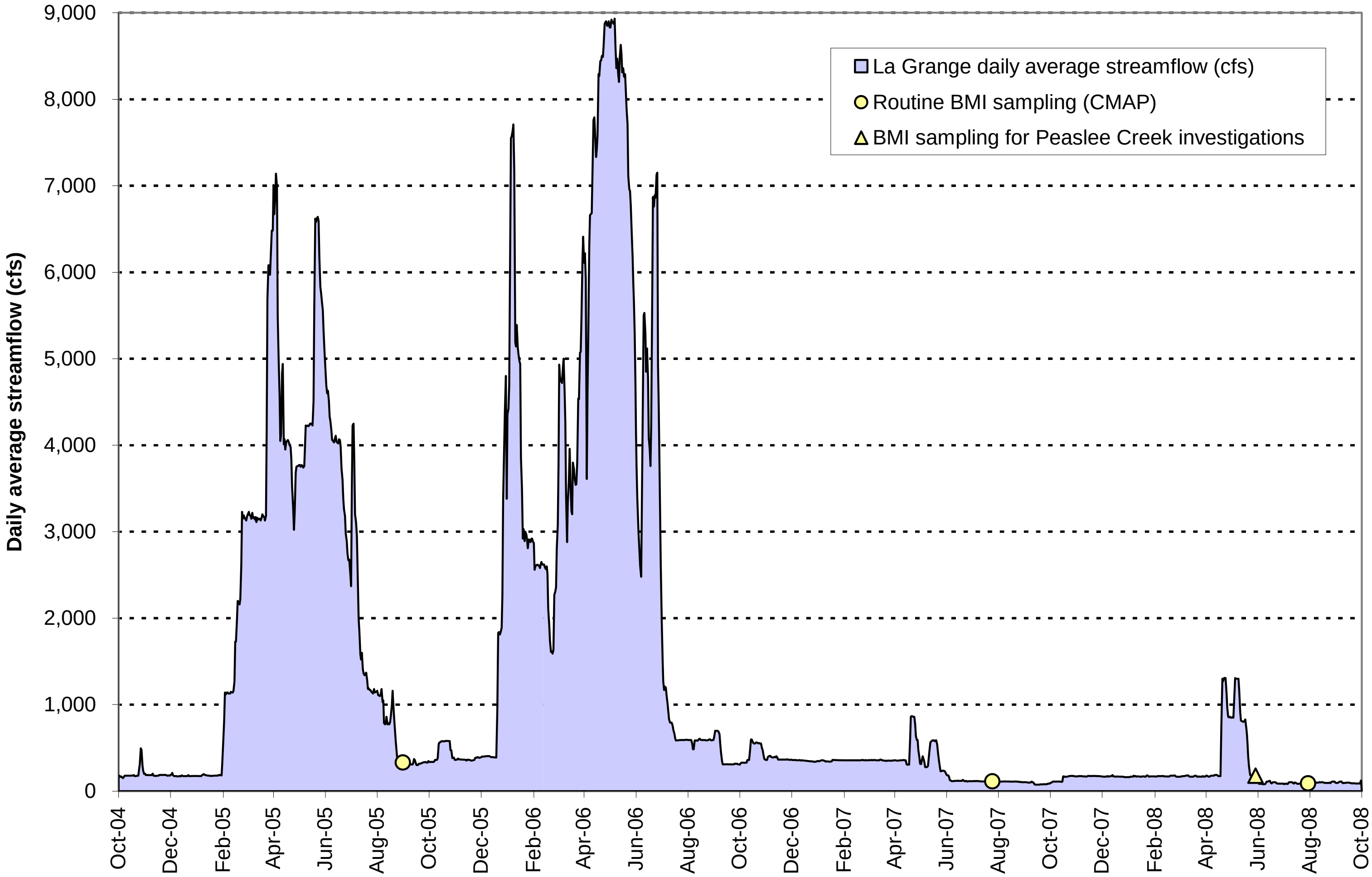

Figure A-1. Daily Average Flow (cfs) at La Grange (USGS 11289650) for Water Years 2005-2008 (Note: No BMI samples collected in 2006 due to high flows).

Appendix B

Site characterization and physical habitat data

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

River Mile	Location	2005	2007	2008
Temperature (C)				
51.6	Riffle A4	11.9	11.6	11.7
48.8	Riffle 4A	12.9	13.7	14.8
42.3	Riffle 23C	15.3	19.7	20.9
38.1	Riffle 31	16.8	22.6	24.2
31.5	Riffle 57	18.7	24.1	27.0
25.4	Riffle 72	21.5	27.2	27.6
pH				
51.6	Riffle A4	7.6	7.2	7.5
48.8	Riffle 4A	7.4	7.2	
42.3	Riffle 23C	7.6	7.4	7.5
38.1	Riffle 31	7.4	8.6	7.4
31.5	Riffle 57	7.4	7.5	8.1
25.4	Riffle 72	7.3	7.6	8.1
Dissolved Oxygen (mg/L)				
51.6	Riffle A4	12.4	10.2	10.6
48.8	Riffle 4A	11.2	10.8	11.4
42.3	Riffle 23C	11.0	12.2	9.3
38.1	Riffle 31	10.5	9.6	9.3
31.5	Riffle 57	9.8	8.7	9.0
25.4	Riffle 72	9.3	8.6	10.8
Specific Conductance (µS/cm)				
51.6	Riffle A4	26	32	36
48.8	Riffle 4A	30	34	37
42.3	Riffle 23C	32	42	48
38.1	Riffle 31	43	60	67
31.5	Riffle 57	51	69	78
25.4	Riffle 72	89	126	136
Average Depth (ft)				
51.6	Riffle A4	2.0	1.3	1.1
48.8	Riffle 4A	1.3	1.5	1.5
42.3	Riffle 23C	1.3	1.0	1.0
38.1	Riffle 31	1.8	1.2	1.2
31.5	Riffle 57	1.7	1.2	0.8
25.4	Riffle 72	1.9	1.7	1.3
Average Velocity (fps)				
51.6	Riffle A4	3.3	1.8	2.0
48.8	Riffle 4A	3.7	2.5	1.7
42.3	Riffle 23C	3.7	2.5	1.8
38.1	Riffle 31	3.2	2.0	1.3
31.5	Riffle 57	3.0	2.1	1.6
25.4	Riffle 72	3.8	2.8	2.3

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

Year	River Mile	Location	Habitat Parameters			Percent composition of substrate					Substrate consolidation	Gradient (%)
			Percent Canopy	Substrate Complexity Score	Embeddedness Score	Fines	Gravel	Cobble	Boulder	Bedrock		
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

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 2005, 2007, 2008.

PHYLUM / **Class** / **Order** / Family / *Taxon*	Density of Kick Samples (no/m^2) for 2005, 2007, 2008																	
	Riffle A4			Riffle 4A			Riffle 23C			Riffle 31			Riffle 57			Riffle72		
	9/1/2005	7/26/2007	7/31/2008	8/30/2005	7/24/2007	7/29/2008	8/31/2005	7/25/2007	7/30/2008	9/1/2005	7/26/2007	7/31/2008	9/1/2005	7/26/2007	7/31/2008	9/1/2005	7/26/2007	7/31/2008
ANNELIDA																		
Oligochaeta	217	9	7	32	75	58	2	18	14	11	9	21	4	49	47	5	61	187
ARTHROPODA																		
Arachnida																		
Acari	33	4	9	16	11	30	7	7	16	11	4	72	4	33	12	2	39	124
Insecta																		
Coleoptera																		
Elmidae																		
Ordobrevia nubifera							4		9	63	12	14	4	11	2			
Diptera																		
Blephariceridae								4										
Agathon				7			2											
Ceratopogoninae										4								
Chironomidae																		
Apedilum																	2	
Hydrobaenus																		
Parakiefferiella																		
Pentaneura	4																	
Procladius																		
Pseudochironomus																		
Chironomidae-pupae	12	11	18	14	9	2	7	4		11	2		4	7	4	16	4	21
Chironominae																		
Cardiocladius	2			5			4			14			2			30		
Cladotanytarsus													7			4		2
Corynoneura			2			2		2		7			2					
Cricotopus			4			7							2	4		11		2
Cricotopus Bicinctus Gr.		2	16			4						2			2	4	4	7
Cricotopus Trifascia Gr.														5				
Dicrotendipes		2																
Eukiefferiella	7	4		18	4													
Eukiefferiella Devonica Gr.	82	42	46	16	42		4											
Micropsectra																		
Nanocladius						2		2										
Orthocladius				2														
Orthocladius complex	23	2	12	46	26	7				14							9	2
Paratanytarsus	2	5																
Phaenopsectra							2											
Polypedilum			5	9	7	35	4	7		7			4		4			4
Rheocricotopus					7	4		2										
Rheotanytarsus	7		40	32	2	2							2		2			2
Synorthocladius						5				7						2	2	
Tanytarsus		102	89	11	25	4		2	2	4			2		2			4

Table C1 (cont.)

PHYLUM / **Class** / **Order** / Family / *Taxon*	Density of Kick Samples (no/m^2) for 2005, 2007, 2008																	
	Riffle A4			Riffle 4A			Riffle 23C			Riffle 31			Riffle 57			Riffle72		
	9/1/2005	7/26/2007	7/31/2008	8/30/2005	7/24/2007	7/29/2008	8/31/2005	7/25/2007	7/30/2008	9/1/2005	7/26/2007	7/31/2008	9/1/2005	7/26/2007	7/31/2008	9/1/2005	7/26/2007	7/31/2008
Thienemanniella									2					16	4		11	2
Tvetenia Bavarica Gr.	28						2											
Tvetenia Vitracies Gr.		4	2	9	40	26									2			
Diamesinae																		
Potthastia Gaedii Gr.															4			
Potthastia Longimana Gr.	5		2															
Empididae																		
Chelifera - Metachela	9			2	4	5	2											
Clinocera	2																	
Hemerodromia								2										
Muscidae			2															
Simuliidae																		
Simulium	282	11	37	305	16		7	4		11			21			2		
Tanypodinae																		
Ablabesmyia																		
Thienemannimyia complex	18	7	35	16	23					4			2					2
Tipulidae																		
Antocha	5	4	5	5	4	7		2							2			
Ephemeroptera																		
Baetidae																		
Acentrella						14			44			2						
Acentrella insignificans		9		7	19		5	16		256			68	9		156		
Baetis bicaudatus																		
Baetis tricaudatus	882	156	140	803	300	173	459	39	25	870		5	345			216		
Camelobaetidius									2		2	7		11	9		2	
Centroptilum														2				
Centroptilum - Procloeon																		
Fallceon quilleri								4	2		7				5		4	2
Ephemerellidae																		
Ephemerella excrusians						2												
Ephemerella inermis/infrequens		2																
Serratella micheneri	5	12	7	2	7	5			5			5		18	9		2	
Heptageniidae																		
Ecdyonurus criddlei	4	4	5	7	2	11	14	84	49	105	32	2	151	12		9		
Leptohyphidae																		
Tricorythodes minutus			4	4	16	39		11	16		33	4		16	4		14	39
Lepidoptera																		
Pyralidae																		
Petrophila								7	7	4	26	74		144	18	4	19	39
Odonata																		
Aeshnidae																		
Aeshna																		
Coenagrionidae																		
Argia																	4	7
Plecoptera																		

Table C1 (cont.)

PHYLUM / **Class** / **Order** / Family / *Taxon*	Density of Kick Samples (no/m^2) for 2005, 2007, 2008																	
	Riffle A4			Riffle 4A			Riffle 23C			Riffle 31			Riffle 57			Riffle72		
	9/1/2005	7/26/2007	7/31/2008	8/30/2005	7/24/2007	7/29/2008	8/31/2005	7/25/2007	7/30/2008	9/1/2005	7/26/2007	7/31/2008	9/1/2005	7/26/2007	7/31/2008	9/1/2005	7/26/2007	7/31/2008
Nemouridae																		
Malenka	4			4			2											
Perlodidae																		
Isoperla						5				4								
Trichoptera																		
Glossosomatidae																		
Glossosoma	100	4	2	9	18	25	14	19						21				
Protoptila								11						53			16	30
Hydropsychidae																		
Hydropsyche	40	4		347	198	147	265	402	236	653	151	77	265	295	47	16	98	65
Hydroptilidae																		
Hydroptila	5	133	32	4	32	7								2	4	2	4	4
Leucotrichia																		2
Oxythira		4	2															
Lepidostomatidae																		
Lepidostoma																		
Lepidostoma - larvae				4														
Leptoceridae																		
Mystacides																		
Nectopsyche								2	4		4	11		9	4		9	12
Polycentropodidae																		
Polycentropus												2						
CNIDARIA																		
Hydrozoa																		
Anthoathecatae																		
Hydridae																		
Hydra																		
MOLLUSCA																		
Bivalvia																		
Pelecypoda																		
Corbiculidae																		
Corbicula											2		2	2			46	
Corbicula fluminea								2										2
Sphaeriidae																		
Pisidium																		
Gastropoda																		
Basommatophora																		
Ancylidae																		
Ferrissia								2							2			7
Lymnaeidae																		
Lymnaea						2												
Physidae																		
Physa - Physella	2	2									2						2	2
Planorbidae	2			7										2				
Gyraulus																	7	

Table C1 (cont.)

	Density of Kick Samples (no/m^2) for 2005, 2007, 2008																	
PHYLUM	Riffle A4			Riffle 4A			Riffle 23C			Riffle 31			Riffle 57			Riffle72		
Class / **Order** / Family / *Taxon*	9/1/2005	7/26/2007	7/31/2008	8/30/2005	7/24/2007	7/29/2008	8/31/2005	7/25/2007	7/30/2008	9/1/2005	7/26/2007	7/31/2008	9/1/2005	7/26/2007	7/31/2008	9/1/2005	7/26/2007	7/31/2008
Menetus				32			5											2
Neotaenioglossa																		
Hydrobiidae																		
NEMATODA	5			23	12			2		7	2	2	5	2	2	4		4
PLATYHELMINTHES																		
Tubellaria																		
Tricladida	2			5	12	2		18	53	14	137	26		32	21		67	35
SUBPHYLUM CRUSTACEA																		
Malacostraca																		
Amphipoda																		
Crangonyctidae																		
Crangonyx	5			2	2	2	2	4		4	4							
Stygobromus	2				4		2	9		25			7					
Hyalellidae																		
Hyalella																		
Isopoda																		
Asellidae																		
Caecidotea	11	4		9	2	2												
Ostracoda								2			7							

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.

	Density of Hess Samples (no./m^2)					
PHYLUM	Riffle 4A		Riffle 4A		Riffle 4A	
Class	8/30/2005		7/24/2007		7/29/2008	
Order / Family / *Taxon*	MEAN	SD	MEAN	SD	MEAN	SD
ANNELIDA						
Oligochaeta	307	205	590	357	493	168
ARTHROPODA						
Arachnida						
Acari	293	180	230	253	197	100
Insecta						
Coleoptera						
Elmidae						
Ordobrevia nubifera						
Diptera						
Blephariceridae			17	20		
Agathon	200	131			7	10
Ceratopogoninae						
Chironomidae						
Apedilum						
Hydrobaenus						
Parakiefferiella						
Pentaneura	27	41			3	5
Procladius						
Pseudochironomus						
Chironomidae-pupae	173	138	100	40	35	34
Chironominae						
Cardiocladius	27	41				
Cladotanytarsus						
Corynoneura	93	155	80	40	15	15
Cricotopus			67	62	25	42
Cricotopus Bicinctus Gr.			43	61	7	8
Cricotopus Trifascia Gr.						
Dicrotendipes					2	4
Eukiefferiella	427	261	47	48	7	16
Eukiefferiella Devonica Gr.	627	743	457	477	38	50
Micropsectra	120	84			2	4
Nanocladius			57	50	3	5
Orthocladius			3	8		
Orthocladius complex	387	255	243	144	43	31
Paratanytarsus					2	4
Phaenopsectra						
Polypedilum	67	94	253	158	218	142
Rheocricotopus			217	108	103	97
Rheotanytarsus	187	187	33	33	5	5
Synorthocladius	13	33	80	75	23	31
Tanytarsus	107	157	347	140	23	29
Thienemanniella			73	47	28	41

Table C2 (cont.)

PHYLUM / **Class** / **Order** / Family / *Taxon*	Density of Hess Samples (no./m^2)					
	Riffle 4A		Riffle 4A		Riffle 4A	
	8/30/2005		7/24/2007		7/29/2008	
	MEAN	SD	MEAN	SD	MEAN	SD
Tvetenia Bavarica Gr.						
Tvetenia Vitracies Gr.	387	397	437	306	205	166
Diamesinae						
Potthastia Gaedii Gr.			40	63	5	8
Potthastia Longimana Gr.	13	33	3	8		
Empididae						
Chelifera - Metachela	93	79			18	24
Clinocera						
Hemerodromia						
Muscidae						
Simuliidae						
Simulium	2133	890	77	61		
Tanypodinae						
Ablabesmyia					3	8
Thienemannimyia complex	120	121	470	195	35	21
Tipulidae						
Antocha	13	33	70	21	50	39
Ephemeroptera						
Baetidae						
Acentrella					72	71
Acentrella insignificans	27	41	340	231		
Baetis bicaudatus			527	1290		
Baetis tricaudatus	17547	2362	2630	25	890	1169
Camelobaetidius						
Centroptilum						
Centroptilum - Procloeon						
Fallceon quilleri	13	33	20	8	7	8
Ephemerellidae						
Ephemerella excrusians	13	33	3	1581		
Ephemerella inermis/infrequens						
Serratella micheneri	27	41	47	47	12	16
Heptageniidae						
Ecdyonurus criddlei	40	67	20	18	75	54
Leptohyphidae						
Tricorythodes minutus	27	41	117	67	295	235
Lepidoptera						
Pyralidae						
Petrophila	40	44				
Odonata						
Aeshnidae						
Aeshna						
Coenagrionidae						
Argia						
Plecoptera						
Nemouridae						

Table C2 (cont.)

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m^2)					
	Riffle 4A		Riffle 4A		Riffle 4A	
	8/30/2005		7/24/2007		7/29/2008	
	MEAN	SD	MEAN	SD	MEAN	SD
Malenka						
Perlodidae						
Isoperla			7	10	20	23
Trichoptera						
Glossosomatidae						
Glossosoma	93	79	127	180	125	83
Protoptila						
Hydropsychidae						
Hydropsyche	3013	1642	1750	1152	1323	1539
Hydroptilidae						
Hydroptila	40	67	233	158	40	32
Leucotrichia						
Oxythira			3	8	8	12
Lepidostomatidae						
Lepidostoma						
Lepidostoma - larvae	13	33			2	4
Leptoceridae						
Mystacides					3	8
Nectopsyche						
Polycentropodidae						
Polycentropus						
CNIDARIA						
Hydrozoa						
Anthoathecatae						
Hydridae						
Hydra			3	8		
MOLLUSCA						
Bivalvia						
Pelecypoda						
Corbiculidae						
Corbicula	13	33				
Corbicula fluminea						
Sphaeriidae						
Pisidium						
Gastropoda						
Basommatophora						
Ancylidae						
Ferrissia						
Lymnaeidae						
Lymnaea					3	8
Physidae						
Physa - Physella			3	8		
Planorbidae	40	67	3	8		
Gyraulus			13	24	8	13
Menetus					48	36

Table C2 (cont.)

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m^2)					
	Riffle 4A		Riffle 4A		Riffle 4A	
	8/30/2005		7/24/2007		7/29/2008	
	MEAN	SD	MEAN	SD	MEAN	SD
Neotaenioglossa						
Hydrobiidae						
NEMATODA	187	173	57	57	73	104
PLATYHELMINTHES						
Tubellaria						
Tricladida	387	234	30	45	62	38
SUBPHYLUM CRUSTACEA						
Malacostraca						
Amphipoda						
Crangonyctidae						
Crangonyx	13	33	13	16	45	55
Stygobromus	67	163	60	147	2	4
Hyalellidae						
Hyalella						
Isopoda						
Asellidae						
Caecidotea	27	41			22	21
Ostracoda					3	8

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		Riffle 23C		Riffle 23C	
	8/31/2005		7/25/2007		7/30/2008	
	MEAN	SD	MEAN	SD	MEAN	SD
ANNELIDA						
Oligochaeta	122	71	113	53	248	241
ARTHROPODA						
Arachnida						
Acari	33	21	122	62	135	109
Insecta						
Coleoptera						
Elmidae						
Ordobrevia nubifera	160	259	53	69	80	96
Diptera						
Blephariceridae			70	110		
Agathon	95	105			15	28
Ceratopogoninae						
Chironomidae						
Apedilum						
Hydrobaenus					2	4
Parakiefferiella						
Pentaneura					2	4
Procladius					2	4
Pseudochironomus						
Chironomidae-pupae	43	60	3	8	3	5
Chironominae						
Cardiocladius	7	16				
Cladotanytarsus						
Corynoneura	13	21	10	9	2	4
Cricotopus	10	17	2	4		
Cricotopus Bicinctus Gr.	2	4	3	8	7	10
Cricotopus Trifascia Gr.						
Dicrotendipes						
Eukiefferiella	123	104	7	10		
Eukiefferiella Devonica Gr.	2	4				
Micropsectra						
Nanocladius			25	21	3	5
Orthocladius	57	59				
Orthocladius complex	30	46	2	4	2	4
Paratanytarsus						
Phaenopsectra	2	4				
Polypedilum	45	39	77	84	3	5
Rheocricotopus			12	10		
Rheotanytarsus	2	4	3	5		
Synorthocladius	5	12	2	4	7	12
Tanytarsus	13	21	5	8	18	8
Thienemanniella	17	20	53	25	22	21

Table C3 (cont.)

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m^2)					
	Riffle 23C		Riffle 23C		Riffle 23C	
	8/31/2005		7/25/2007		7/30/2008	
	MEAN	SD	MEAN	SD	MEAN	SD
Tvetenia Bavarica Gr.						
Tvetenia Vitracies Gr.	2	4	3	8	3	5
Diamesinae						
Potthastia Gaedii Gr.						
Potthastia Longimana Gr.						
Empididae			3	5		
Chelifera - Metachela	5	8			7	5
Clinocera						
Hemerodromia	2	4			3	5
Muscidae						
Simuliidae						
Simulium	23	48	15	20	2	4
Tanypodinae						
Ablabesmyia					3	5
Thienemannimyia complex	2	4	2	4	2	4
Tipulidae						
Antocha	2	4	3	8		
Ephemeroptera						
Baetidae						
Acentrella					92	39
Acentrella insignificans	32	46	80	47		
Baetis bicaudatus						
Baetis tricaudatus	4398	3859	227	290	168	224
Camelobaetidius						
Centroptilum						
Centroptilum - Procloeon						
Fallceon quilleri			15	23	12	13
Ephemerellidae						
Ephemerella excrusians	2	4			58	97
Ephemerella inermis/infrequens						
Serratella micheneri			10	13	3	5
Heptageniidae						
Ecdyonurus criddlei	62	52	342	254	60	57
Leptohyphidae						
Tricorythodes minutus	3	8	90	123	132	112
Lepidoptera						
Pyralidae						
Petrophila			23	31	57	20
Odonata						
Aeshnidae						
Aeshna					2	4
Coenagrionidae						
Argia					2	4
Plecoptera						
Nemouridae						

Table C3 (cont.)

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m^2)					
	Riffle 23C		Riffle 23C		Riffle 23C	
	8/31/2005		7/25/2007		7/30/2008	
	MEAN	SD	MEAN	SD	MEAN	SD
Malenka						
Perlodidae						
Isoperla			3	8	2	4
Trichoptera						
Glossosomatidae						
Glossosoma	215	73	65	51	3	8
Protoptila			48	41	5	12
Hydropsychidae						
Hydropsyche	1017	965	2433	2229	1327	914
Hydroptilidae						
Hydroptila						
Leucotrichia						
Oxythira			5	8	2	4
Lepidostomatidae						
Lepidostoma						
Lepidostoma - larvae						
Leptoceridae						
Mystacides						
Nectopsyche			5	8		
Polycentropodidae						
Polycentropus					2	4
CNIDARIA						
Hydrozoa						
Anthoathecatae						
Hydridae						
Hydra						
MOLLUSCA						
Bivalvia						
Pelecypoda						
Corbiculidae						
Corbicula	70	104				
Corbicula fluminea					7	10
Sphaeriidae						
Pisidium					2	4
Gastropoda						
Basommatophora						
Ancylidae						
Ferrissia			2	4		
Lymnaeidae						
Lymnaea						
Physidae						
Physa - Physella						
Planorbidae	15	20				
Gyraulus			3	8		
Menetus					2	4

Table C3 (cont.)

PHYLUM / Class / Order / Family / *Taxon*	Density of Hess Samples (no./m^2)					
	Riffle 23C		Riffle 23C		Riffle 23C	
	8/31/2005		7/25/2007		7/30/2008	
	MEAN	SD	MEAN	SD	MEAN	SD
Neotaenioglossa						
Hydrobiidae			2	4	2	4
NEMATODA	10	15	13	20	13	10
PLATYHELMINTHES						
Tubellaria						
Tricladida	10	15	162	116	163	168
SUBPHYLUM CRUSTACEA						
Malacostraca						
Amphipoda						
Crangonyctidae						
Crangonyx			12	29	5	8
Stygobromus	62	83	15	20	65	70
Hyalellidae						
Hyalella						
Isopoda						
Asellidae						
Caecidotea						
Ostracoda					8	12

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