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CHARACTERIZATION OF BENTHIC COMMUNITIES AND PHYSICAL HABITAT IN THE STANISLAUS, TUOLUMNE, AND MERCED RIVERS, CALIFORNIA

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Abstract. The primary goal of this study was to characterize physical habitat and benthic communities (macroinvertebrates) in the Stanislaus, Tuolumne and Merced Rivers in California's San Joaquin Valley in 2003. These rivers have been listed as impaired water bodies (303 (d) list) by the State of California due to the presence of organophosphate (OP) insecticides chlorpyrifos and diazinon, Group A pesticides (i.e., organochlorine pesticides), mercury, or unknown toxicity. Based on 10 instream and riparian physical habitat metrics, total physical habitat scores in the Stanislaus River ranged from 124 to 188 (maximum possible total score is 200). The highest total habitat score was reported at the upstream site. Tuolumne River physical habitat scores ranged from 86 to 167. Various Tuolumne River physical habitat metrics, including total habitat score, increased from downstream to upstream in this river. Merced River physical habitat scores ranged from 121 to 170 with a significant increase in various physical habitat metrics, including total habitat score, reported from downstream to upstream. Channel flow (an instream metric) and bank stability (a riparian metric) were the most important physical habitat metrics influencing the various benthic metrics for all three rivers. Abundance measures of benthic macroinvertebrates (5,100 to 5,400 individuals) were similar among the three rivers in the San Joaquin watershed. Benthic communities in all three rivers were generally dominated by: (1) Baetidae species (mayflies) which are a component of EPT taxa generally considered sensitive to environmental degradation; (2) Chironomidae (midges) which can be either tolerant or sensitive to environmental stressors depending on the species; (3) Ephemerellidae (mayflies) which are considered sensitive to pollution stress; and (4) Naididae (aquatic worms) which are generally considered tolerant to environmental stressors. The presence of 117 taxa in the Stanislaus River, 114 taxa in the Tuolumne River and 96 taxa in the Merced River implies that the benthic communities in these streams are fairly diverse but without a clear definition of benthic community expectations it is unknown if these water bodies are actually impaired.

Keywords: benthic communities, physical habitat, San Joaquin River watershed

1. Introduction

Due to abundant water and long growing seasons, California's San Joaquin Valley is one of the most productive agricultural areas in the United States (Dubrovsky *et al.*, 1998). Intense agricultural development in the San Joaquin Valley has modified many of the natural lotic systems in this area (May and Brown, 2000). The changing landscape coupled with various other anthropogenic factors has created stressful conditions for resident aquatic biological communities. The following factors may have contributed to the decline of aquatic resources in California's Central Valley: water diversion, changes in basin hydrology, loss of habitat, introduction of exotic species and contaminants (e.g., organophosphate insecticides) (Foe, 1995). Activities such as diking, dredging, filling of wetlands and significant diversion of freshwater flows for irrigated agriculture and urban use have also altered fish habitat and resulted in adverse impacts on fish populations (Moyle *et al.*, 1992).

Major tributaries on the east side of the San Joaquin River include the Stanislaus, Tuolumne and Merced Rivers. The subwatershed area for these rivers encompasses approximately 600,000 acres roughly bounded by Turlock, Modesto, South San Joaquin, Merced, and Oakdale irrigation districts. The lower regions of these three major east side San Joaquin Rivers (~50 to 60 miles) have been listed as impaired water bodies (303 d list) due to the following constituents: Stanislaus River (diazinon, Group A pesticides, and mercury), Tuolumne River (diazinon, Group A pesticides and unknown toxicity) and Merced River (diazinon, chlorpyrifos, and Group A pesticides). Biological monitoring data were not used to assign the 303 d listings described above.

In recent years, assessments of benthic invertebrate assemblages and physical habitat (bioassessments) have been initiated in wadeable streams in California's Central Valley (Hall and Killen, 2001–2003; Brown and May, 2000; Jim Harrington, personal communication). These efforts are valuable for determining the status of aquatic biological communities across large spatial scales and landuse types (agricultural and urban). Information on the status of resident biological communities is particularly useful for determining impaired water bodies, developing Total Maximum Daily Loads (TMDLs), and measuring success of voluntary or regulatory actions. Bioassessments serve monitoring needs through three primary functions: (1) screening or initial assessment of conditions; (2) characterization of impairment and diagnosis; and (3) trend monitoring to evaluate improvements from mitigation practices.

The primary goal of this study was to characterize physical habitat and benthic communities in the Stanislaus, Tuolumne and Merced Rivers located on the east side of the San Joaquin River. These data were collected to determine if these water bodies appear to be impaired based on the presence of resident benthic biological communities.

2. Methods

2.1. Site Selection

The east side San Joaquin Rivers sampled during this study were the Stanislaus, Tuolumne and Merced Rivers (Figure 1). The specific sites sampled, as shown in Figure 1, covered approximately 25, 37 and 38 miles in the Stanislaus River,

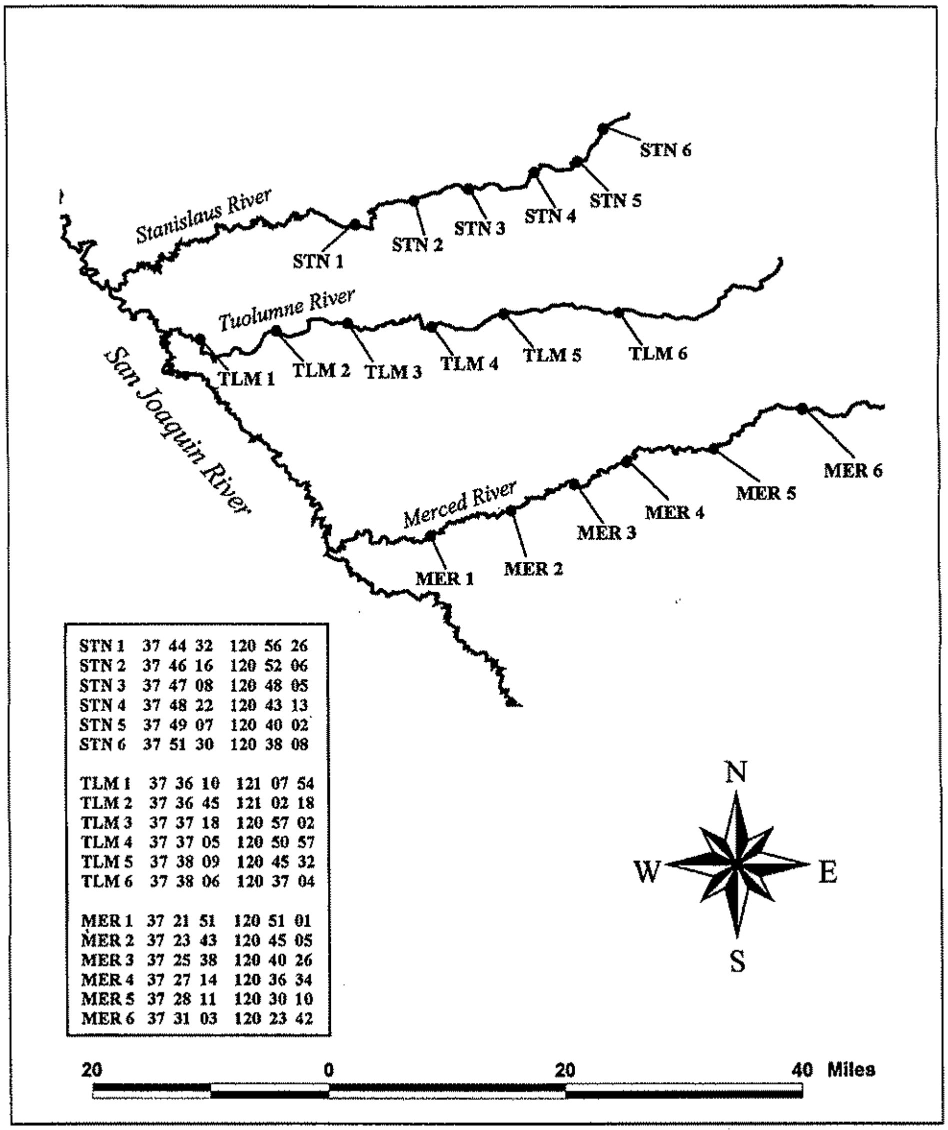

Figure 1. San Joaquin River basin showing station locations for the Stanislaus, Tuolumne and Merced Rivers.

Tuolumne River and Merced River, respectively. The predominate land use type near each of these water bodies is agriculture.

Six sample sites were selected for sampling in each river using a stratified random design with approximate equal spacing among sample sites (Table I; Figure 1). Initial site visits were conducted for all streams in April of 2003. Exact sample stations were determined in each river and landowner contacts were made to access the sample sites for the late spring/early summer sampling.

TABLE I

Sample site names, coordinates and water quality parameters measured during late spring 2003 in the Stanislaus, Tuolumne and Merced Rivers

Site	Latitude	Longitude	Water temperature (C)	Specific conductivity (μmhos/L)	pH	Dissolved oxygen (mg/L)	Turbidity NTU
STN1	37 44 32	120 56 26	15.5	60.4	6.64	8.13	1.81
STN2	37 46 16	120 52 06	14.3	54.1	7.18	9.62	1.45
STN3	37 47 08	120 48 05	14.2	50.2	7.34	9.81	1.16
STN4	37 48 22	120 43 13	14.7	48.3	7.70	10.45	1.26
STN5	37 49 07	120 40 02	13.4	45.6	7.53	10.18	0.79
STN6	37 51 30	120 38 08	12.4	44.3	7.42	8.99	1.17
TLM1	37 36 10	121 07 54	20.8	88.8	7.41	6.76	8.60
TLM2	37 36 45	121 02 18	20.1	81.2	7.12	7.13	7.62
TLM3	37 37 18	120 57 02	19.3	65.3	7.24	7.94	3.34
TLM4	37 37 05	120 50 57	18.8	58.1	6.98	8.68	2.45
TLM5	37 38 09	120 45 32	17.5	43.0	7.32	10.07	2.17
TLM6	37 38 06	120 37 04	15.5	37.9	7.34	10.65	1.14
MER 1	37 21 51	120 51 01	22.9	117.1	6.73	6.51	4.62
MER 2	37 23 43	120 45 05	22.5	87.4	6.72	6.46	3.45
MER 3	37 25 38	120 40 26	23.6	55.7	7.16	6.90	2.43
MER 4	37 27 14	120 36 34	22.9	54.0	7.65	8.86	4.36
MER 5	37 28 11	120 30 10	20.5	45.7	7.87	9.19	1.58
MER 6	37 31 03	120 23 42	16.4	40.1	7.64	9.52	1.17

2.2. Physical Habitat Assessments

Physical habitat was evaluated at each site concurrently with benthic collections and water quality evaluations. The physical habitat evaluation methods followed California Stream Bioassessment Protocols (CSBP) described in Harrington and Born (2000). The physical habitat metrics used for this study are based on nationally standardized protocols described in Barbour *et al.* (1999). A total of 10 continuous metrics scored on a 0–20 scale were evaluated. Other non-continuous metrics including percent canopy, % gradient, and substrate composition were also measured as described in Harrington and Born (2000).

2.3. Benthic Macroinvertebrate Sampling

Benthic macroinvertebrates were collected in the late spring of 2003 from three replicate samples at sample sites in the three rivers. The sample site selections and sampling procedures were conducted in accordance with CSBP methods described in Harrington and Born (2000). Sampling reaches were approximately equally spaced along the stream starting at the confluence. Within each of these sample reaches, a riffle was located (if possible) for the collection of benthic macroinvertebrates. A tape measure was placed along the riffle and potential sampling transects were located at each meter interval of the tape. Using a random numbers table, three transects were randomly selected for sampling from among those available within the riffle. Benthic samples were taken using a standard D-net with 0.5 mm (0.019 inches) mesh starting with the most downstream portion of the riffle. A 1×2 foot section of the riffle immediately upstream of the net was disturbed to a depth of 4–6 inches to dislodge and collect the benthic macroinvertebrates. Large rocks and woody debris were scrubbed and leaves were examined to dislodge organisms clinging to these substrates. Within each of the randomly chosen transects, three replicate samples were collected to reflect the structure and complexity of the habitat within the transect. If habitat complexity was lacking, samples were taken near the side margins and thalweg of the transect and the procedures described above were followed. All samples were preserved with 95% ethanol.

Due to the physical nature of these rivers, it was often difficult to locate a substantial number of riffles to sample. In various cases, there was only a single section of riffle available within a selected reach to sample and in some instances there were no riffles present. In cases where riffles were lacking, alternative sampling methods for non-riffle areas were used as outlined in Harrington and Born (2000). This involved sampling the best available 1×2 foot sections of habitat throughout the reach using the same procedures described above. Nine 1×2 foot sections were randomly selected for sampling. Groups of three 1×2 foot sections were composited for each replicate for a total of three replicates per site.

2.4. Taxonomy of Benthic Macroinvertebrates

The goal of this study was to identify all benthic samples to the species level if possible. Species level identifications will be particularly useful if and when Indices of Biotic Integrity (IBIs) are developed for wadeable streams/rivers in California's Central Valley. For taxa such as oligochaetes and chironomids, family and genus level, respectively, were often the lowest level of identification possible.

The benthic macroinvertebrate sorting, subsampling (resulting in a maximum of 300 individuals) and identifications were conducted by California's Department of Fish and Game (CDFG) in Rancho Cordova, California. Level 3 identifications (species level identifications) followed protocols outlined in Harrington and Born (2000). Slide preparations and mounting for species such as chironomids and oligochaetes followed protocols from the United States Geological Survey National Quality Control laboratory described in Moulton *et al.* (2000).

2.5. Water Quality Measurements

The following water quality parameters were measured at each stream site using procedures described in Kazyak (1997): temperature, specific conductivity, pH, dissolved oxygen, and turbidity.

2.6. Statistical Analysis

Principal components analysis (PCA) was used to determine the relationship among the various physical habitat and benthic metrics to identify groups of metrics that covary. Spatial trends (upstream to downstream) of both physical habitat and benthic metrics within each river were examined using Spearmans Rank Correlation Coefficients and significance levels. The relationship among physical habitat and benthic metrics was also determined by using Spearmans Rank Correlation Analysis. The physical habitat and benthic metrics were compared among the three streams using the Wilcoxon Rank-Sum Test and Kruskal-Wallis test.

3. Results

3.1. Physical Habitat

3.1.1. *Stanislaus River*

The total physical habitat scores in the Stanislaus River ranged from 124 to 188 for the ten metrics that were scored on a 0 to 20 scale (Table II). With the exception of embeddedness, most of the metrics were fairly consistent among the six sites. Higher scores for the various habitat metrics (including the total score) were reported at the upstream site.

Other descriptive physical habitat metrics that were not scored on a 0–20 scale are presented in Table III. These metrics are not scored on a 0–20 scale because some are bimodal (i.e., too much or too little canopy can be advantageous) and others are just descriptive. Flow could not be measured at four sites due to high water conditions. The percent canopy cover ranged from 0 to 15% for the six sites. The gradient ranged from 0.5 to 3%; higher gradient was reported upstream. The % fines ranged from 10 to 84% with lower % fines generally reported upstream.

3.1.2. *Tuolumne River*

Tuolumne River total physical habitat scores for the 10 metrics that were scored on a 0 to 20 scale ranged from 86 to 167 (Table II). Total scores gradually increased from downstream to upstream. Embeddedness, sediment deposition, and frequency of bends/riffles were variable among the six sites. Other descriptive metrics for the six Tuolumne River sites in Table III showed that % canopy ranged from 0 to 60%,

TABLE II

Scoring of individual physical habitat metrics (0–20 scale) and final habitat score (maximum of 200) for sites in Stanislaus, Tuolumne and Merced Rivers

Site	Epi Subs	Embedd	Veloc Depth Divers	Sedim Depos	Chan Flow Status	Chan Alt	Freq Bends Riffles	Left Bank Stab	Right Bank Stab	L Bank Veget. Protect	R Bank Veget. Protect	L Bank Ripar Zone	R Bank Ripar Zone	Total
STN1	11	7	11	16	20	16	6	8	7	10	6	8	4	130
STN2	20	19	15	16	20	16	16	9	9	9	8	8	5	170
STN3	18	17	15	16	20	16	11	7	8	8	8	8	6	158
STN4	15	1	11	9	20	17	8	9	8	9	6	8	3	124
STN5	19	19	15	17	20	18	16	8	7	8	7	8	6	168
STN6	20	20	16	19	20	20	20	10	9	8	10	7	9	188
TLM1	8	2	11	5	20	13	5	5	3	4	3	4	3	86
TLM2	8	3	11	5	20	15	5	6	6	5	7	5	6	102
TLM3	12	3	20	16	20	16	6	7	6	6	7	3	5	127
TLM4	16	13	15	16	20	17	15	8	6	6	6	8	8	154
TLM5	16	14	19	15	20	16	16	9	8	6	9	6	8	162
TLM6	19	19	15	18	20	16	12	9	9	8	8	7	7	167
MER1	12	1	19	13	17	19	5	3	7	6	9	4	6	121
MER2	16	16	20	13	16	16	14	6	5	8	7	6	6	149
MER3	18	18	20	16	19	15	13	8	7	7	7	7	7	162
MER4	16	16	19	14	17	16	16	6	8	8	8	8	8	160
MER5	19	18	20	16	15	16	13	8	8	8	8	9	8	166
MER6	19	19	19	17	20	15	16	9	8	9	7	9	3	170

% gradient ranged from 1 to 2%, and % fines ranged from 10 to 100%. Flow could not be measured at five sites due to high water conditions.

3.1.3. *Merced River*

The total physical habitat scores in the Merced River ranged from 121 to 170 for the 10 metrics that were scored on a 0 to 20 scale (Table II). The lowest total physical habitat score (121) was reported at the most downstream site (MER1) while the highest score (170) was reported at the most upstream site (MER6). Scores for embeddedness and frequency of bends and riffles were lower at the most downstream sites when compared with other sites. Other descriptive physical habitat metrics for the six Merced River sites in Table III showed that mean site flow ranged from 0.27 to 0.80 m/s (for the five sites that could be measured), % canopy ranged from 0 to 5%, % gradient was consistently 1.5 to 2% and % fines ranged from 5 to 95%.

3.2. Summary Statistical Analysis for All Rivers

Principal Components Analysis (PCA) was used for all rivers to determine the relationship among habitat metrics and identify metrics that covary (i.e., increase or decrease together). The 10 habitat metrics that were scored on a 0 to 20 scale had

TABLE III

Physical habitat characteristics for the Stanislaus, Tuolumne and Merced Rivers that were not scored on a 0–20 scale

Site	Mean flow (m/s)	Canopy cover (%)	Gradient (%)	Fines (%)	Gravel (%)	Cobble (%)	Boulder (%)	Bedrock (%)
STN1	0*	9	0.5	80	20	0	0	0
STN2	0*	10	1	20	15	50	10	5
STN3	0.82	15	1	15	40	40	5	0
STN4	0*	0	2	84	10	3	3	0
STN5	0.80	9	2	20	40	25	15	0
STN6	0*	9	3	10	20	40	20	10
TLM1	0*	34	1	100	0	0	0	0
TLM2	0*	0	1	100	0	0	0	0
TLM3	0*	0	1	100	0	0	0	0
TLM4	0.89	0	1	20	20	50	10	0
TLM5	0*	0	1.5	15	45	35	5	0
TLM6	0*	60	2	10	50	40	0	0
MER1	0.27	3	2	95	5	0	0	0
MER2	0.46	0	2	20	50	30	0	0
MER3	0.80	5	1.5	10	20	60	10	0
MER4	0.65	0	2	20	10	60	10	0
MER5	0*	0	2	10	20	40	30	0
MER6	0.62	0	2	5	10	45	40	0

*No flow readings taken due to high flows or depth.

three eigenvalues that were greater than 1 (Table IV). The significance of this finding is that 10 habitat metrics contain three important factors which explained 83% of the variance in the data set. The metrics important to each factor are presented in Table V. Bend/riffle frequency, epifaunal substrate, riparian buffer, and sediment deposition were heavily loaded on the first factor. This group of metrics included both instream as well as riparian metrics. Metric loading on factor two included: bank stability, velocity/depth/ diversity, and channel flow. These three metrics are both instream and riparian metrics. Factor three had loading for bank vegetation, channel alteration, and embeddedness. As reported above for the other two factors, these three metrics included both instream and riparian metrics.

Correlations among raw physical habitat metrics grouped by factors identified by PCA showed correlations are high among the four metrics supporting factor 1 (Table VI). In factor 2, a significant correlation was reported between channel flow and velocity/depth/diversity; however, significant correlations among the other metrics in factor 2 were not reported. In factor 3, bank vegetation was significantly correlated with both channel alteration and embeddedness. Channel alteration was not significantly correlated with embeddedness.

TABLE IV
Eigenvalues and proportion of variance explained for the correlation matrix of the ten habitat metrics

	Eigenvalue	Proportion	Cumulative
Factor 1	5.66*	0.5658	0.5658
Factor 2	1.61*	0.1608	0.7266
Factor 3	1.05*	0.1051	0.8317
Factor 4	0.62	0.0622	0.8939
Factor 5	0.45	0.0450	0.9390
Factor 6	0.24	0.0241	0.9630
Factor 7	0.19	0.0186	0.9817
Factor 8	0.11	0.0114	0.9930
Factor 9	0.05	0.0049	0.9980
Factor 10	0.02	0.0020	1.0000

*Eigenvalue > 1.0.

TABLE V
Eigenvectors for the three dominant factors of the correlation matrix of habitat metrics

Metric	Factor 1	Factor 2	Factor 3
Factor 1			
BENRIFF	0.3686*	0.0188	−.2466
EPI SUB	0.3964*	0.0352	−.1320
RIPBUFF	0.3495*	−.0358	−.0845
SED DEP	0.3617*	0.0266	0.0946
Factor 2			
BANKSTAB	0.3286+	0.3920*	0.0076
VEL DPTH	0.2058	−.5722*	−.0495
CH FLOW	−.0631	0.7154*	−.1125
Factor 3			
BANKVEG	0.3463+	0.0388	0.3550*
CHAN ALT	0.2039	0.0420	0.7843*
EMBEDDED	0.3717+	−.0160	−.3864*

*Highest loading > 0.3 for each metric.
+Loadings > 0.3 but not highest.

The correlation matrix in Table VII showed significant correlations among river characteristics that were not scored on a 0 to 20 scale (i.e., width, depth) and some metrics that were scored on a 0 to 20 scale. Due to the high water conditions in these rivers, depth and velocity were not measured at all sites. The largest number of significant correlations occurred for the stream width (correlation coefficients ranging from −0.51 to −0.69) and velocity (correlation coefficients ranging from 0.71 to 0.82). Width was negatively correlated with epifaunal substrate, riparian

TABLE VI
Correlation matrix for raw physical habitat metrics grouped by factors indentified by the PCA

Habitat metric	BEN RIFF	EPI SUB	RIP BUFF	SED DEP	BANK STAB	VEL DPTH	CHAN FLOW	BANK VEG	CHAN ALT	EMBEDD	TOTAL
BENRIFF	1.00	0.85	0.76	0.64	0.63	0.41	−0.06	0.55	0.33	0.88	0.90
	–	<.0001	0.0002	0.0040	0.0048	0.0879	0.8221	0.0173	0.1860	<.0001	<.0001
EPI SUB	0.85	1.00	0.73	0.78	0.76	0.43	−0.09	0.72	0.36	0.89	0.95
	<.0001	–	0.0006	0.0001	0.0003	0.0722	0.7085	0.0008	0.1397	<.0001	<.0001
RIPBUFF	0.76	0.73	1.00	0.60	0.61	0.28	−0.26	0.60	0.37	0.77	0.81
	0.0002	0.0006	–	0.0085	0.0069	0.2592	0.3044	0.0089	0.1341	0.0002	<.0001
SED DEP	0.64	0.78	0.60	1.00	0.65	0.51	−0.00	0.71	0.46	0.72	0.86
	0.0040	0.0001	0.0085	–	0.0033	0.0321	0.9845	0.0009	0.0528	0.0007	<.0001
BANKSTAB	0.63	0.76	0.61	0.65	1.00	0.06	0.29	0.74	0.32	0.61	0.77
	0.0048	0.0003	0.0069	0.0033	–	0.8220	0.2506	0.0004	0.1884	0.0067	0.0002
VEL DPTH	0.41	0.43	0.28	0.51	0.06	1.00	−0.57	0.33	0.14	0.42	0.49
	0.0879	0.0722	0.2592	0.0321	0.8220	–	0.0131	0.1823	0.5721	0.0856	0.0375
CH FLOW	−0.06	−0.09	−0.26	−0.00	0.29	−0.57	1.00	−0.18	−0.08	−0.11	−0.08
	0.8221	0.7085	0.3044	0.9845	0.2506	0.0131	–	0.4779	0.7479	0.6577	0.7411
BANKVEG	0.55	0.72	0.60	0.71	0.74	0.33	−0.18	1.00	0.57	0.59	0.77
	0.0173	0.0008	0.0089	0.0009	0.0004	0.1823	0.4779	–	0.0130	0.0107	0.0002
CHAN ALT	0.33	0.36	0.37	0.46	0.32	0.14	−0.08	0.57	1.00	0.14	0.41
	0.1860	0.1397	0.1341	0.0528	0.1884	0.5721	0.7479	0.0130	–	0.5918	0.0875
EMBEDD	0.88	0.89	0.77	0.72	0.61	0.42	−0.11	0.59	0.14	1.00	0.92
	<.0001	<.0001	0.0002	0.0007	0.0067	0.0856	0.6577	0.0107	0.5918	–	<.0001
TOTAL	0.90	0.95	0.81	0.86	0.77	0.49	−0.08	0.77	0.41	0.92	1.00
	<.0001	<.0001	<.0001	<.0001	0.0002	0.0375	0.7411	0.0002	0.0875	<.0001	–

Note. The p-values in the body of the table are for the hull hypothesis that the correlation is 0.0. In the body of the table the correlation coefficients (top) are paired with the p-value (bottom) for the null hypothesis that the correlation is 0.0

TABLE VII

Correlation matrix for stream width, depth, velocity, and canopy measurements against the raw physical habitat metrics and the total habitat metric score

Habitat metric	Width	Depth	Velocity	Canopy
BANKSTAB	−0.40	0.15	0.73	0.06
	0.1005	0.7209	0.0386*	0.8224
BANKVEG	−0.42	0.11	−0.36	−0.15
	0.0845	0.7920	0.3843	0.5631
CHAN ALT	−0.00	0.54	−0.37	−0.21
	0.9876	0.1704	0.3653	0.3992
EPI SUB	−0.66	0.18	0.71	0.04
	0.0030*	0.6733	0.0470*	0.8617
RIPBUFF	−0.52	−0.04	0.82	−0.11
	0.0256*	0.9216	0.0134*	0.6596
VEL DPTH	−0.51	−0.81	−0.63	−0.34
	0.0305*	0.0138*	0.0962	0.1724
BENRIFF	−0.69	−0.01	0.60	−0.12
	0.0015*	0.9784	0.1182	0.6402
SED DEP	−0.43	0.39	0.78	0.04
	0.0726	0.3400	0.0236*	0.8865
EMBEDD	−0.67	−0.01	0.68	0.12
	0.0024*	0.9726	0.0653	0.6297
CH FLOW	0.20	0.50	0.76	0.29
	0.4314	0.2052	0.0272*	0.2504
TOTAL	−0.66	0.07	0.74	−0.03
	0.0031*	0.8714	0.0362*	0.8975
Sample Size	18	8	8	18

Note. In the body of the table are the correlation coefficient (top), p-value (middle) and sample size (bottom). The p-value is for the null hypothesis that the correlation is 0.0.
*p-value < 0.05.

buffer, velocity/depth/diversity, bend/riffle frequency and embeddedness. Velocity was positively correlated with bank stability, epifaunal substate, riparian buffer, sediment deposition, and channel flow. Depth was negatively correlated with velocity/depth/diversity. Canopy was not significantly correlated with any of the habitat metrics.

The Spearman Rank Correlation test for trends was conducted for each physical habitat metric in each river to examine trends that might be associated with changing morphology of the stream between upstream and downstream (Table VIII). The Tuolumne River appears to have the strongest gradient from upstream to downstream in physical habitat metrics. Bank stability, bank vegetation, bend/riffle

TABLE VIII

Spearman rank correlation coefficients (top) and p-values (bottom) for upstream-downstream trend in the Physical Habitat metrics and the total physical habitat index

Habitat metric	Stanislaus	Tuolumne	Merced
BANKSTAB	0.3947	1.0000	0.9429
	0.4387	<.0001*	0.0048*
BANKVEG	0.0000	0.8986	0.7407
	1.0000	0.0149*	0.0922
BENRIFF	0.6957	0.8117	0.6179
	0.1248	0.0499*	0.1911
CHAN ALT	0.9411	0.6983	−.6172
	0.0051*	0.1228	0.1917
CH FLOW	–	–	0.2319
	–	–	0.6584
EMBEDD	0.5218	0.9856	0.8533
	0.2883	0.0003*	0.0307*
EPI SUB	0.4928	0.9710	0.8827
	0.3206	0.0012*	0.0198*
RIPBUFF	0.6088	0.7537	0.5508
	0.1997	0.0835	0.2574
SED DEP	0.5768	0.7945	0.8827
	0.2307	0.0590	0.0198*
VEL DPTH	0.6172	0.5296	−.0976
	0.1917	0.2798	0.8541
TOTAL	0.4286	1.0000	0.9429
	0.3965	<.0001*	0.0048*
Sample Size	6	6	6

*p-value < 0.05.

frequency, embeddedness, and epifaunal substrate showed a positive correlation with site indicating an increase in values moving upriver. Total habitat scores also showed a significant increase from downstream to upstream in the Tuolumne River. The Merced River also showed a strong gradient from upstream to downstream in physical habitat metrics. Bank stability, embeddedness, epifaunal substrate, sediment deposition and total habitat score showed a positive correlation with site indicating an increase in values moving upriver.

Velocity/depth/diversity, bank vegetation, and channel flow showed significant differences among the three rivers (Table IX). Velocity/depth/diversity was higher in the Merced River than the Stanislaus River. The bank vegetation metric was higher in the Stanislaus River than the Tuolumne River. Channel flow was higher in both the Stanislaus and Tuolumne Rivers when compared with the Merced River.

TABLE IX

Mean scores for each physical habitat metric and the total for each river with the p-values for comparing the means among rivers based on the Kruskal-Wallace test

	Mean for each River			Kruskal Wallace	Pairwise comparison		
Habitat metric	Stanislaus	Tuolumne	Merced	p-value	ST	SM	TM
VEL DPTH	13.83	15.17	19.50	0.0063*		*	
EPI SUB	17.17	13.17	16.67	0.2170			
BENRIFF	12.83	9.83	12.83	0.4480			
CHAN ALT	17.17	15.50	16.17	0.1653			
BANKVEG	16.17	12.50	15.33	0.0239*	*		
RIPBUFF	13.33	11.67	13.50	0.6802			
SED DEP	15.50	12.50	14.83	0.4939			
EMBEDD	13.83	9.00	14.67	0.3880			
BANKSTAB	16.50	13.67	13.83	0.1732			
CH FLOW	20.00	20.00	17.33	0.0021*		*	*
TOTAL	156.33	133.00	154.67	0.3347			

Note. Pairwise comparisons between creeks are based on the Wilcoxon rank sum test.
ST: Stanislaus vs Tuolumne; SM: Stanislaus vs Merced; TM: Tuolumne vs Merced.
*p-value < 0.05.

3.3. Benthic Macroinvertebrates

3.3.1. *Stanislaus River*

Approximately 5,400 individual macroinvertebrates were picked and identified from 117 taxa collected from six Stanislaus River sites (Table X). The eight most abundant taxa – *Baetis tricaudatus*, *Serratella micheneri*, *Tanytarsus* sp., *Nais communis/variabilis*, *Cricotopus* sp., *Serratella* sp., *Tricorythodes* sp., and *Rheotanytarsus* sp. – comprised 51% of the total individuals collected (Table X). Baetidae, Ephemerellidae, and Chironomidae were generally the most dominant taxa. Baetidae (mayflies) – the most dominant taxa – are considered in the mid-range for tolerance to most environmental stressor. However, this taxa is generally considered tolerant of sedimentation and nutrient enrichment (Harrington and Born, 2000). Baetids are excellent swimmers and can survive in high flow environments. Ephemerellidae (mayflies) are generally considered sensitive to pollution stress (Harrington and Born, 2000). Chironomids (midges) can be either sensitive or tolerant to environmental stressors depending on the species (Stribling *et al.*, 1998).

Total taxa richness ranged from 45 at upstream site (STN6) to 75 at the most downstream site (STN1) (Figure 2). Taxa richness was reasonably consistent among the three transects at each site but the number of individuals per site was more variable (Figure 3). The number of individuals collected at each site showed lower values at the two downstream sites and the highest abundance value at the upstream site (Figure 3).

TABLE X
Total and taxon abundance for benthic macroinvertebrates in Stanislaus River

Lowest taxa	Higher taxa	Total *N*	Total %	Cumulative %
Baetis tricaudatus	Baetidae/Ephemeroptera	909	16.68	16.68
Serratella micheneri	Ephemerellidae/Ephemeroptera	496	9.10	25.78
Tanytarsus sp.	Chironomidae/Diptera	273	5.01	30.79
Nais communis/variabilis	Naididae/Oligochaeta	249	4.57	35.36
Cricotopus sp.	Chironomidae/Diptera	239	4.39	39.75
Serratella sp.	Ephemerellidae/Ephemeroptera	236	4.33	44.08
Tricorythodes sp.	Leptohyphidae/Ephemeroptera	195	3.58	47.66
Rheotanytarsus sp.	Chironomidae/Diptera	184	3.38	51.04
Simulium sp.	Simuliidae/Diptera	178	3.27	54.30
Acentrella insignificans	Baetidae/Ephemeroptera	172	3.16	57.46
Cricotopus bicinctus group	Chironimidae/Diptera	171	3.14	60.60
Hydroptila sp.	Hydroptilidae/Trichoptera	142	2.61	63.20
Lumbricina	Oligochaeta	138	2.53	65.74
Tubificidae	Tubificidae	135	2.48	68.21
Lebertia sp.	Lebertiidae/Arachnida	112	2.06	70.27
Hydropsyche californica	Hydropsychidae/Trichoptera	96	1.76	72.03
Isoperla sp.	Perlodidae/Plecoptera	94	1.73	73.76
Turbellaria	Platyhelminthes	87	1.60	75.35
Phaenopsectra sp.	Chironomidae/Diptera	83	1.52	76.88
Orthocladius complex	Chironomidae/Diptera	80	1.47	78.34
Pisidium sp.	Sphaeriidae/Bivalvia	69	1.27	79.61
Physa sp.	Physidae/Gastropoda	64	1.17	80.79
Corbicula sp.	Corbiculidae/Bivalvia	62	1.14	81.92
Micropsectra sp.	Chironomidae/Diptera	55	1.01	82.93
Acentrella sp.	Baetidae/Ephemeroptera	50	0.92	83.85
Crangonyx sp.	Crangonyctidae/Malacostraca	50	0.92	84.77
Sperchon sp.	Sperchontidae/Arachnida	49	0.90	85.67
Ophidonais serpentina	Naididae/Oligochaeta	47	0.86	86.53
Corixidae	Hemiptera	44	0.81	87.34
Cladotanytarsus sp.	Chironomidae/Diptera	40	0.73	88.07
Eukiefferiella sp.	Chironomidae/Diptera	40	0.73	88.81
Lepidostoma sp.	Lepidostomatidae/Trichoptera	40	0.73	89.54
Oxyethira sp.	Hydroptilidae/Trichoptera	36	0.66	90.20
Paratanytarsus sp.	Chironomidae/Diptera	33	0.61	90.81
Cardiocladius sp.	Chironomidae/Diptera	31	0.57	91.37
Nais barbata	Naididae/Oligochaeta	29	0.53	91.91
Glossosoma sp.	Glossosomatidae/Trichoptera	28	0.51	92.42
Lumbriculidae	Lumbriculida/Oligochaeta	28	0.51	92.93

(*Continued on next page*)

TABLE X
(*Continued*)

Lowest taxa	Higher taxa	Total N	Total %	Cumulative %
Polypedilum sp.	Chironomidae/Diptera	24	0.44	93.37
Tvetenia vitracies group	Chironomidae/Diptera	21	0.39	93.76
Centroptilum sp.	Baetidae/Ephemeroptera	18	0.33	94.09
Parakiefferiella sp.	Chironomidae/Diptera	18	0.33	94.42
Sigara vallis	Corixidae/Hemiptera	17	0.31	94.73
Acentrella turbida	Baetidae/Ephemeroptera	16	0.29	95.03
Potthastia gaedii group	Chironomidae/Diptera	16	0.29	95.32
Hyalella sp.	Hyalellidae/Malacostraca	16	0.29	95.61
Thienemanniella sp.	Chironomidae/Diptera	11	0.20	95.82
Corynoneura sp.	Chironomidae/Diptera	10	0.18	96.00
Menetus sp.	Planorbidae/Gastropoda	10	0.18	96.18
Petrophila sp.	Pyralidae/Hemiptera	10	0.18	96.37
Chironomus sp.	Chironomidae/Diptera	9	0.17	96.53
Prostoma sp.	Tertastemmatidae/Enopla	9	0.17	96.70
Tvetenia sp.	Chironomidae/Diptera	8	0.15	96.84
Enchytraeidae	Tubificida/Oligochaeta	8	0.15	96.99
Helobdella stagnalis	Glossiphoniidae/Hirudinea	8	0.15	97.14
Orthocladius sp.	Chironomidae/Diptera	7	0.13	97.27
Tvetenia bavarica group	Chironomidae/Diptera	7	0.13	97.39
Hygrobates sp.	Hygrobatidae/Arachnida	7	0.13	97.52
Ferrissia sp.	Ancylidae/Gastropoda	5	0.09	97.61
Ostracoda	Ostracoda	5	0.09	97.71
Stempellina sp.	Chironimidae/Diptera	5	0.09	97.80
Heptageniidae	Ephemeroptera	5	0.09	97.89
Naididae	Naididae/Oligochaeta	5	0.09	97.98
Antocha sp.	Tipulidae/Diptera	5	0.09	98.07
Limnodrilus hoffmeisteri	Tubificidae/Oligochaeta	5	0.09	98.16
Ischnura sp.	Coenagrionidae/Odonata	4	0.07	98.24
Aulodrilus pigueti	Tubificidae/Oligochaeta	4	0.07	98.31
Acari	Arachnida	3	0.06	98.37
Pacifastacus leniusculus	Astacidae/Decopoda	3	0.06	98.42
Pacifastacus sp.	Astacidae/Decopoda	3	0.06	98.48
Brillia sp.	Chironomidae/Diptera	3	0.06	98.53
Microtendipes pedellus group	Chironomidae/Diptera	3	0.06	98.59
Orthocladiinae	Chironomidae/Diptera	3	0.06	98.64
Paracladopelma sp.	Chironomidae/Diptera	3	0.06	98.70
Synorthocladius sp.	Chironomidae/Diptera	3	0.06	98.75
Coenagrionidae	Odonata	3	0.06	98.81

(*Continued on next page*)

TABLE X
(*Continued*)

Lowest taxa	Higher taxa	Total *N*	Total %	Cumulative %
Corisella decolor	Corixidae/Hemiptera	3	0.06	98.86
Neoplasta sp.	Chironomidae/Diptera	3	0.06	98.92
Nixe sp.	Heptageniidae/Ephemeroptera	3	0.06	98.97
Nectopsyche sp.	Leptoceridae/Trichoptera	3	0.06	99.03
Fossaria sp.	Lymnaeidae/Gastropoda	3	0.06	99.08
Chaetogaster diaphanus	Naididae/Oligochaeta	3	0.06	99.14
Nais sp.	Naididae/Oligochaeta	3	0.06	99.19
Ablabesmyia sp.	Chironomidae/Diptera	2	0.04	99.23
Stenochironomus sp.	Chironomidae/Diptera	2	0.04	99.27
Dubiraphia sp.	Elmidae/Coleoptera	2	0.04	99.30
Empididae	Chironomidae/Diptera	2	0.04	99.34
Wiedemannia sp.	Chironomidae/Diptera	2	0.04	99.38
Protoptila sp.	Glossosomatidae/Trichoptera	2	0.04	99.41
Atractides sp.	Hygrobatidae/Arachnida	2	0.04	99.45
Muscidae	Diptera	2	0.04	99.49
Gyraulus sp.	Planorbidae/Gastropoda	2	0.04	99.52
Sphaerium sp.	Sphaeriidae/Bivalvia	2	0.04	99.56
Bezzia/Palpomyia	Ceratopogonidae/Diptera	1	0.02	99.58
Ceratopogonidae	Diptera	1	0.02	99.60
Apedilum sp.	Chironomidae/Diptera	1	0.02	99.61
Cricotopus trifascia group	Chironomidae/Diptera	1	0.02	99.63
Cryptochironomus sp.	Chironomidae/Diptera	1	0.02	99.65
Cryptotendipes sp.	Chironomidae/Diptera	1	0.02	99.67
Limnophyes sp.	Chironomidae/Diptera	1	0.02	99.69
Pentaneura sp.	Chironomidae/Diptera	1	0.02	99.71
Psectrocladius sp.	Chironomidae/Diptera	1	0.02	99.72
Robackia demeijerei	Chironomidae/Diptera	1	0.02	99.74
Stempellinella sp.	Chironomidae/Diptera	1	0.02	99.76
Synorthocladius semivirens	Chironomidae/Diptera	1	0.02	99.78
Zavrelimyia/Paramerina	Chironomidae/Diptera	1	0.02	99.80
Clinocera sp.	Empididae/Diptera	1	0.02	99.82
Hemerodromia sp.	Empididae/Diptera	1	0.02	99.83
Tropisternus sp.	Hydrophilidae/Coleoptera	1	0.02	99.85
Hydropsyche sp.	Hydropsychidae/Trichoptera	1	0.02	99.87
Dero digitata	Naididae/Oligochaeta	1	0.02	99.89
Dero nivea	Naididae/Oligochaeta	1	0.02	99.91
Pristina aequiseta	Naididae/Oligochaeta	1	0.02	99.93
Pristina leidyi	Naididae/Oligochaeta	1	0.02	99.94
Slavina appendiculata	Naididae/Oligochaeta	1	0.02	99.96
Stylaria lacustris	Naididae/Oligochaeta	1	0.02	99.98
Pionidae	Pionidae/Arachnida	1	0.02	100.00
Total		5449		

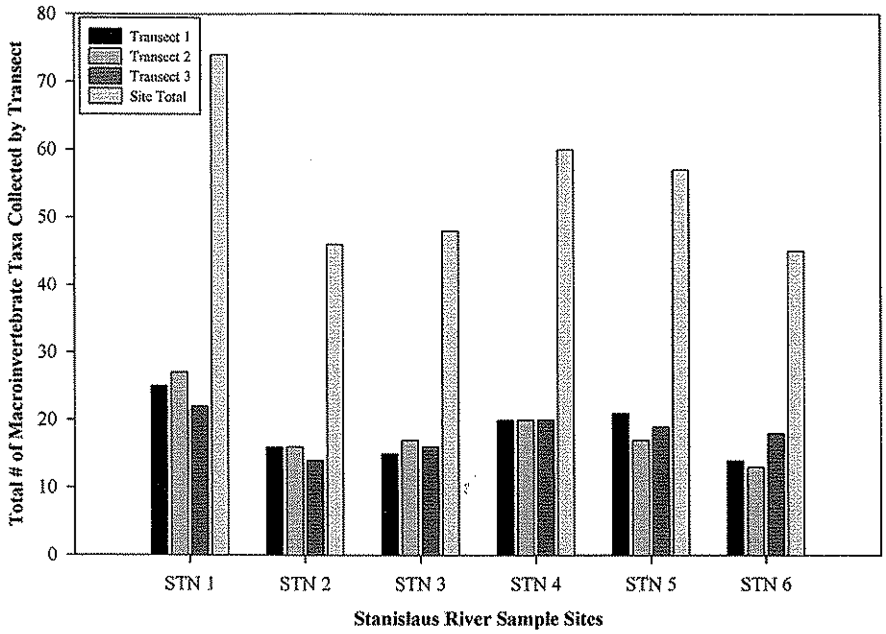

Figure 2. Macroinvertebrate richness for each transect and site total for the six Stanislaus River sites.

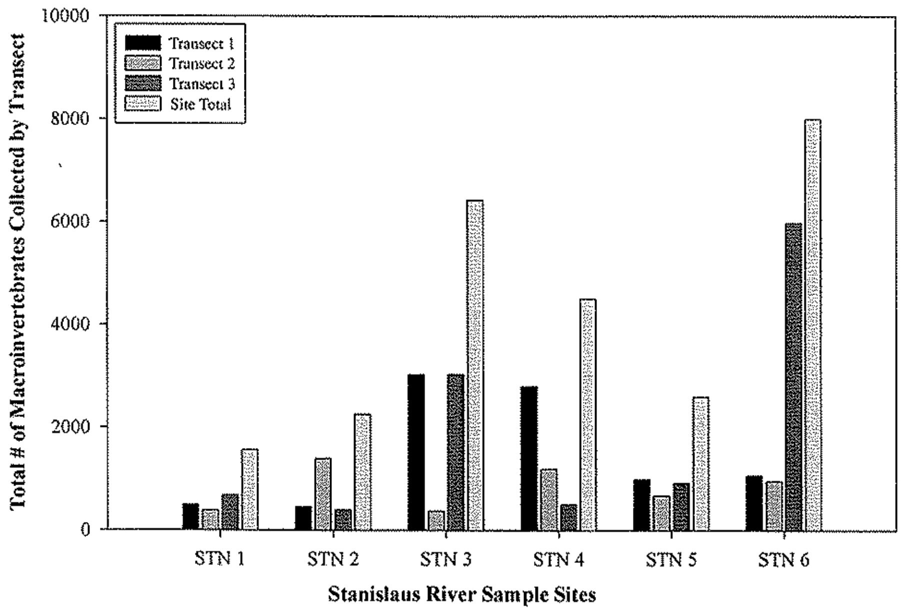

Figure 3. Macroinvertebrate abundance for each transect and site total for the six Stanislaus River sites.

Benthic metrics summarized in Table XI were generally variable among sites with some spatial patterns evident. The most downstream site (STN1) showed high mean values for taxonomic richness, cumulative taxa, and tolerance values. The most upstream site (STN6) showed the highest mean abundance value but the lowest mean values for taxonomic richness, cumulative taxa, EPT taxa, and % intolerant taxa. The mean % Baetidae were generally higher at STN2 and STN6. Shredders – a feeding guild generally associated with non-stressed environments – were only found at the three upstream sites.

3.3.2. *Tuolumne River*

Approximately 5,100 individual macroinvertebrates were picked and identified from 114 taxa collected from six sites in the Tuolumne River (Table XII). The following taxa comprised approximately 52% of the total number of individuals collected: *Rheotanytarsus* sp., *Nais communis/variabilis*, *Baetis tricaudatus*, *Oxyethira* sp., *Centroptilum* sp., *Tricorythodes* sp., *and Cricotopus* sp. The most dominant higher taxa were Chironomidae, Baetidae, Naididae, Hydroptilidae, and Leptohyphidae. Chironomids can be either tolerant or sensitive to environmental stressors depending on the species (Stribling *et al.*, 1998). Baetidae (mayflies) are in the mid-range for tolerance to most environmental stressors but are a component of EPT taxa which are generally considered sensitive to environmental stressors (Harrington and Born, 2000). Naididae (aquatic worms) are generally considered tolerant of environmental stressors (Harrington and Born, 2000). Both Hydroptilidae (caddisflies) and Leptohyphidae (mayflies) are considered in the mid-range for tolerance to most environmental stressors but are both components of EPT tax which are considered sensitive to environmental stressors (Harrington and Born, 2000).

Total taxa richness ranged from 39 at downstream site TLM2 to 69 at upstream site TLM4 (Figure 4). Richness was fairly consistent among the transects at most of the sites. The number of individuals per transect at each site was consistent for most of the sites except TLM6 (Figure 5). Lowest total site abundance occurred at TLM1 (Figure 5).

Various mean benthic metrics for the Tuolumne River sites summarized in Table XIII showed the following: (1) taxa richness, cumulative taxa, and tolerance values were higher at TLM4; (2) EPT taxa and % collectors/gatherers were similar among all sites; (3) % intolerant taxa were higher at the two upstream sites (TLM5 and TLM6); (4) % Baetidae were higher at the most upstream site (TLM6); (5) % shredders – taxa associated with non-stressed environments – were higher at the most downstream site (TLM1) and (6) abundance was lower at the most downstream site (TML1).

3.3.3. *Merced River*

Approximately 5,400 individual macroinvertebrates were picked and identified from 96 taxa in six Merced River sites (Table XIV). *Baetis tricaudatus*, *Corbicula*

TABLE XI
Benthic metrics by transect (including the means) for the six Stanislaus River sites

	STN1					STN2					STN3					STN4					STN5					STN6				
	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV
Taxonomic Richness	25	27	22	25	10	16	16	14	15	8	15	17	16	16	6	20	20	20	20	0	21	17	19	19	11	14	13	18	15	18
Cumulative Taxa				74					46					48					60					57					45	
Percent Dominant Taxon	14	11	11	12	13	28	24	38	30	25	20	19	21	20	6	23	14	21	19	24	16	18	22	19	19	42	47	35	41	15
Number Ephemeroptera Taxa	5	4	4	4	13	3	3	3	3	0	5	5	5	5	0	3	4	4	4	16	4	3	4	4	16	1	2	3	2	50
Number Plecoptera Taxa	0	0	0	0	–	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1	0	0	0	173	0	0	0	0	–
Number Trichoptera Taxa	3	2	2	2	25	2	3	2	2	25	3	3	3	3	0	4	4	3	4	16	4	3	2	3	33	4	3	3	3	17
EPT Taxa	8	6	6	7	17	6	7	6	6	9	9	9	9	9	0	8	9	8	8	7	9	6	6	7	25	5	5	6	5	11
Cumulative EPT Taxa				20					19					27					25					21					16	
EPT Index (%)	33	29	15	26	37	68	70	77	72	6	84	65	79	76	13	44	34	23	34	32	33	20	21	25	28	46	54	46	49	9
Sensitive EPT Index (%)	13	16	6	12	43	22	28	25	25	13	45	40	40	42	7	28	19	12	20	39	9	3	3	5	75	2	4	6	4	48
Shannon Diversity	3.4	3.4	3.3	3.3	0.8	2.2	2.4	2.1	2.2	8.1	2.3	2.6	2.4	2.5	6.4	3.0	3.2	3.1	3.1	3.6	2.8	2.7	2.7	2.7	1.8	2.0	2.2	2.6	2.2	14.9
Tolerance Value	5.5	5.6	5.9	5.7	4.2	4.4	4.2	4.2	4.3	2.9	3.4	3.9	3.8	3.7	6.6	4.7	5.1	5.1	5.0	5.6	5.4	5.6	5.5	5.5	2.2	5.3	5.2	5.2	5.2	1.3
Percent Intolerant Taxa (0–2)	13	8	9	10	24	13	27	23	21	33	29	25	20	25	18	15	16	16	16	3	20	13	6	13	57	14	8	6	9	48
Percent Tolerant Taxa (8–10)	38	44	36	39	10	20	20	8	16	45	7	13	20	13	49	25	21	21	22	10	25	31	39	32	22	14	15	18	16	11
Percent Baetidae	4	1	2	3	56	45	39	48	44	10	25	23	33	27	20	4	2	5	4	38	16	2	7	8	87	42	47	36	42	14
Percent Chironomidae	32	28	31	31	7	9	14	8	10	30	6	20	10	12	61	30	37	28	32	15	47	44	43	44	4	21	24	28	24	14
Percent Hydropsychidae	0	0	0	0	0	1	3	4	3	48	12	2	5	6	87	0	0	0	0	173	0	1	0	0	98	1	2	1	1	45
Percent Collectors Gatherers	71	62	63	65	7	80	85	86	83	4	69	84	83	78	10	81	78	87	82	6	84	82	89	85	4	70	77	74	74	5
Percent Collector-Filterers	1	8	13	7	86	14	9	13	12	21	14	2	5	7	93	3	4	1	3	46	1	1	1	1	37	23	12	10	15	47
Percent Scrapers	7	7	6	7	11	0	2	1	1	76	3	3	3	3	3	1	0	1	1	89	4	2	1	2	80	1	2	0	1	88
Percent Predators	13	15	13	13	10	6	4	1	3	76	13	11	9	11	19	8	10	6	8	24	5	9	4	6	46	5	5	7	5	20
Percent Shredder Taxa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5	5	0	5	6	0	4	88	7	8	6	7	16
Abundance (#/sample)	497	389	678	521	28	463	1395	398	752	74	3029	373	3028	2143	72	2804	1192	507	1501	79	997	673	921	864	20	1069	954	5977	2666	108

TABLE XII
Total and taxon abundance for benthic macroinvertebrates in Tuolumne River

Lowest taxa	Higher taxa	Total *N*	Total %	Cumulative %
Rheotanytarsus sp.	Chironomidae/Diptera	491	9.54	9.54
Nais communis/variabilis	Naididae/Oligochaeta	488	9.48	19.01
Baetis tricaudatus	Baetidae/Ephemeroptera	428	8.31	27.33
Oxyethira sp.	Hydroptilidae/Trichoptera	352	6.84	34.16
Centroptilum sp.	Baetidae/Ephemeroptera	346	6.72	40.88
Tricorythodes sp.	Leptohyphidae/Ephemeroptera	280	5.44	46.32
Cricotopus sp.	Chironomidae/Diptera	279	5.42	51.74
Cricotopus bicinctus group	Chironomidae/Diptera	244	4.74	56.48
Hydropsyche californica	Hydropsychidae/Trichoptera	197	3.83	60.30
Nectopsyche sp.	Leptoceridae/Trichoptera	171	3.32	63.62
Corbicula sp.	Corbiculidae/Bivalvia	154	2.99	66.61
Ophidonais serpentina	Naididae/Oligochaeta	133	2.58	69.20
Serratella micheneri	Ephemerellidae/Ephemeroptera	123	2.39	71.59
Hyalella sp.	Hyalellidae/Malacostraca	96	1.86	73.45
Turbellaria	Platyhelminthes	94	1.83	75.28
Dicrotendipes sp.	Chironomidae/Diptera	83	1.61	76.89
Acentrella insignificans	Baetidae/Ephemeroptera	77	1.50	78.38
Hydroptila sp.	Hydroptilidae/Trichoptera	70	1.36	79.74
Chironomus sp.	Chironomidae/Diptera	64	1.24	80.99
Serratella sp.	Ephemerellidae/Ephemeroptera	61	1.18	82.17
Polypedilum sp.	Chironomidae/Diptera	55	1.07	83.24
Simulium sp.	Simuliidae/Diptera	52	1.01	84.25
Cardiocladius sp.	Chironomidae/Diptera	51	0.99	85.24
Sperchon sp.	Sperchontidae/Arachnida	50	0.97	86.21
Caecidotea occidentalis	Isopoda/Malacostraca	46	0.89	87.10
Tanytarsus sp.	Chironomidae/Diptera	38	0.74	87.84
Phaenopsectra sp.	Chironomidae/Diptera	32	0.62	88.46
Tubificidae	Tubificidae	31	0.60	89.07
Menetus sp.	Planorbidae/Gastropoda	30	0.58	89.65
Micropsectra sp.	Chironomidae/Diptera	29	0.56	90.21
Orthocladius complex	Chironomidae/Diptera	25	0.49	90.70
Nixe sp.	Heptageniidae/Ephemeroptera	25	0.49	91.18
Dubiraphia sp.	Elmidae/Colroptera	24	0.47	91.65
Fallceon quilleri	Baetidae/Ephemeroptera	23	0.45	92.10
Prostoma sp.	Tertastemmatidae/Enopla	21	0.41	92.50
Lumbricina	Oligochaeta	20	0.39	92.89
Hygrobates sp.	Hygrobatidae/Arachnida	20	0.39	93.28

(*Continued on next page*)

TABLE XII
(*Continued*)

Lowest taxa	Higher taxa	Total *N*	Total %	Cumulative %
Hydropsyche sp.	Hydropsychidae/Trichoptera	19	0.37	93.65
Stylaria lacustris	Naididae/Oligochaeta	18	0.35	94.00
Acentrella sp.	Baetidae/Ephemeroptera	16	0.31	94.31
Eukiefferiella sp.	Chironomidae/Diptera	16	0.31	94.62
Lebertia sp.	Lebertiidae/Arachnida	16	0.31	94.93
Slavina appendiculata	Naididae/Oligochaeta	16	0.31	95.24
Physa sp.	Physidae/Gastropoda	14	0.27	95.51
Ferrissia sp.	Ancylidae/Gastropoda	12	0.23	95.75
Synorthocladius sp.	Chironomidae/Diptera	12	0.23	95.98
Thienemanniella sp.	Chironomidae/Diptera	12	0.23	96.21
Serratella teresa	Ephemerellidae/Ephemeroptera	11	0.21	96.43
Orthocladiinae	Chironomidae/Diptera	9	0.17	96.60
Parakiefferiella sp.	Chironomidae/Diptera	8	0.16	96.76
Lumbriculidae	Lumbriculida/Oligochaeta	8	0.16	96.91
Microtendipes sp.	Chironomidae/Diptera	7	0.14	97.05
Robackia demeijerei	Chironomidae/Diptera	7	0.14	97.18
Cladotanytarsus sp.	Chironomidae/Diptera	6	0.12	97.30
Cryptotendipes sp.	Chironomidae/Diptera	6	0.12	97.42
Hydrellia sp.	Chironomidae/Diptera	6	0.12	97.53
Heptageniidae	Ephemeroptera	6	0.12	97.65
Petrophila sp.	Pyralidae/Hemiptera	6	0.12	97.77
Cricotopus trifascia group	Chironomidae/Diptera	5	0.10	97.86
Paratanytarsus sp.	Chironomidae/Diptera	5	0.10	97.96
Crangonyx sp.	Crangonyctidae/Malacostraca	5	0.10	98.06
Hydrobiidae	Neotaenioglossa/Gastropoda	5	0.10	98.15
Isoperla sp.	Perlodidae/Plecoptera	5	0.10	98.25
Acari	Arachnida	4	0.08	98.33
Dasyhelea sp.	Ceratopogonidae/Diptera	4	0.08	98.41
Corynoneura sp.	Chironomidae/Diptera	4	0.08	98.49
Stempellinella sp.	Chironomidae/Diptera	4	0.08	98.56
Fossaria sp.	Lymnaeidae/Gastropoda	4	0.08	98.64
Dero sp.	Naididae/Oligochaeta	4	0.08	98.72
Ostracoda	Ostracoda	3	0.06	98.78
Psectrocladius sp.	Chironomidae/Diptera	3	0.06	98.83
Thienemannimyia group	Chironimidae/Diptera	3	0.06	98.89
Enchytraeidae	Tubificida/Oligochaeta	3	0.06	98.95
Brechmorhoga mendax	Libellulidae/Odonata	3	0.06	99.01
Ablabesmyia sp.	Chironomidae/Diptera	2	0.04	99.05

(*Continued on next page*)

TABLE XII
(*Continued*)

Lowest taxa	Higher taxa	Total *N*	Total %	Cumulative %
Apedilum sp.	Chironomidae/Diptera	2	0.04	99.09
Chironomini	Chironomidae/Diptera	2	0.04	99.13
Limnophyes sp.	Chironomidae/Diptera	2	0.04	99.16
Microtendipespedellus grp.	Chironomidae/Diptera	2	0.04	99.20
Coenagrionidae	Odonata	2	0.04	99.24
Stylurus sp.	Gomphidae/Odonata	2	0.04	99.28
Lepidostoma sp.	Lepidostomatidae/Trichoptera	2	0.04	99.32
Gyraulus sp.	Planorbidae/Gastropoda	2	0.04	99.36
Polycentropus sp.	Polycentropodidae/Trichoptera	2	0.04	99.40
Ormosia sp.	Tipulidae/Diptera	2	0.04	99.44
Pacifastacus sp.	Astacidae/Decopoda	1	0.02	99.46
Camelobaetidius sp.	Baetidae/Ephemeroptera	1	0.02	99.48
Caenis latipennis	Caenidae/Ephemeroptera	1	0.02	99.50
Ceratopogon sp.	Ceratopogonidae/Diptera	1	0.02	99.51
Ceratopogonidae	Diptera	1	0.02	99.53
Nanocladius sp.	Chironomidae/Diptera	1	0.02	99.55
Parametriocnemus sp.	Chironomidae/Diptera	1	0.02	99.57
Potthastia longimana group	Chironomidae/Diptera	1	0.02	99.59
Synorthocladius semivirens	Chironomidae/Diptera	1	0.02	99.61
Tvetenia vitracies group	Chironomidae/Diptera	1	0.02	99.63
Zavrelimyia/Paramerina	Chironomidae/Diptera	1	0.02	99.65
Argia sp.	Coenagrionidae/Odonata	1	0.02	99.67
Ischnura sp.	Coenagrionidae/Odonata	1	0.02	99.69
Corixidae	Hemiptera	1	0.02	99.71
Hemerodromia sp.	Empididae/Diptera	1	0.02	99.73
Neoplasta sp.	Empididae/Diptera	1	0.02	99.75
Glossiphoniidae	Hirudinea	1	0.02	99.77
Helobdella stagnalis	Glossiphoniidae/Hirudinea	1	0.02	99.79
Protoptila sp.	Glossosomatidae/Trichoptera	1	0.02	99.81
Helicopsyche sp.	Helicopsychidae/Trichoptera	1	0.02	99.83
Laccobius sp.	Hydrophilidae/Coleoptera	1	0.02	99.84
Tropisternus sp.	Hydrophilidae/Coleoptera	1	0.02	99.86
Chaetogaster diaphanus	Naididae/Oligochaeta	1	0.02	99.88
Naididae	Naididae/Oligochaeta	1	0.02	99.90
Nais barbata	Naididae/Oligochaeta	1	0.02	99.92
Sphaerium sp.	Sphaeriidae/Bivalvia	1	0.02	99.94
Ephemeroptera	Ephemeroptera	1	0.02	99.96
Limonia sp.	Tipulidae/Diptera	1	0.02	99.98
Aulodrilus pigueti	Tubificidae/Oligochaeta	1	0.02	100.00
Total		5149		

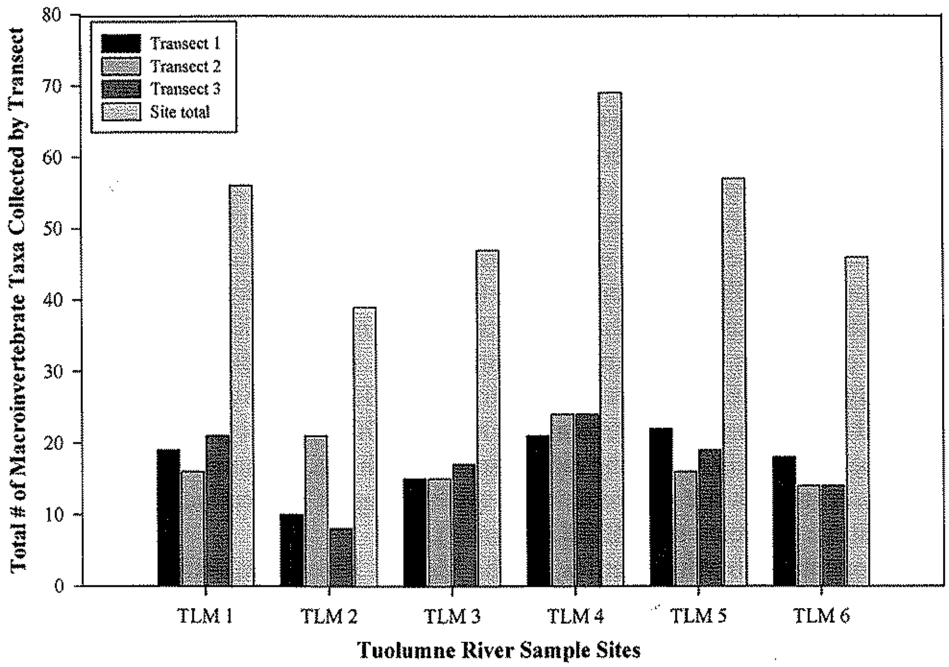

Figure 4. Macroinvertebrate richness for each transect and site total for the six Tuolumne River sites.

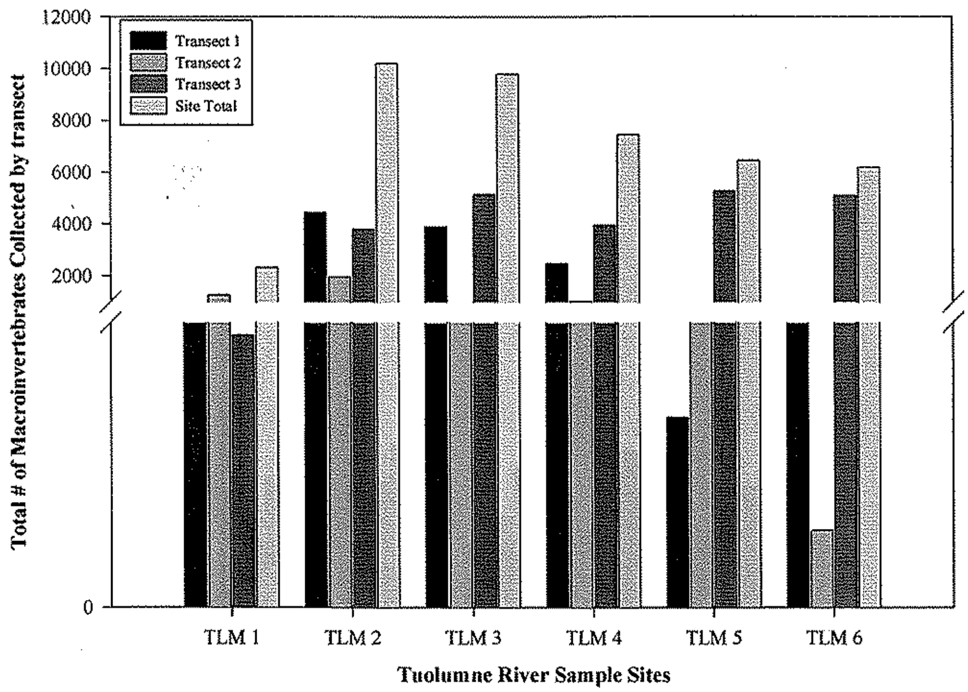

Figure 5. Macroinvertebrate abundance for each transect and site total for the six Tuolumne River sites.

sp., *Rheotanytarsus* sp., *Hydropsyche californica and Serratella micheneri* comprised 53% of the individuals collected. Baetidae, Corbiculidae, Chironomidae, Hydropsychidae, and Ephemerellidae were the most dominant higher taxa collected. Baetidae are considered in the mid-range for tolerance for most environmental stressors but are generally considered tolerant of sedimentation and nutrient enrichment (Harrington and Born, 2000). Corbiculidae (clams) are generally considered tolerant of environmental stressors (Harrington and Born, 2000). Chironomidae can be either tolerant or sensitive to environmental degradation depending on the species (Stribling *et al.*, 1998). Hydropsychidae (mayflies) are considered in the mid-range for tolerance to most environmental stressors but are one of the more tolerant families of caddisflies (Harrington and Born, 2000). Ephemerellidae (mayflies) are generally considered sensitive to pollution stress (Harrington and Born, 2000).

Total taxa richness ranged from 47 at MER5 to 70 at MER4 (Figure 6). Richness was generally consistent among the transects at each site. The number of individuals per transect at each site was somewhat variable (Figure 7). Benthic abundance was higher at the upstream site MER6 (Figure 7).

Various mean benthic metrics for the Merced River sites summarized in Table XV showed the following: (1) % intolerant taxa, % Baetidae, and % collectors/gatherers were higher at upriver site MER5; (2) taxonomic richness and EPT taxa were similar among all sites; (3) abundance was much higher at the most upriver

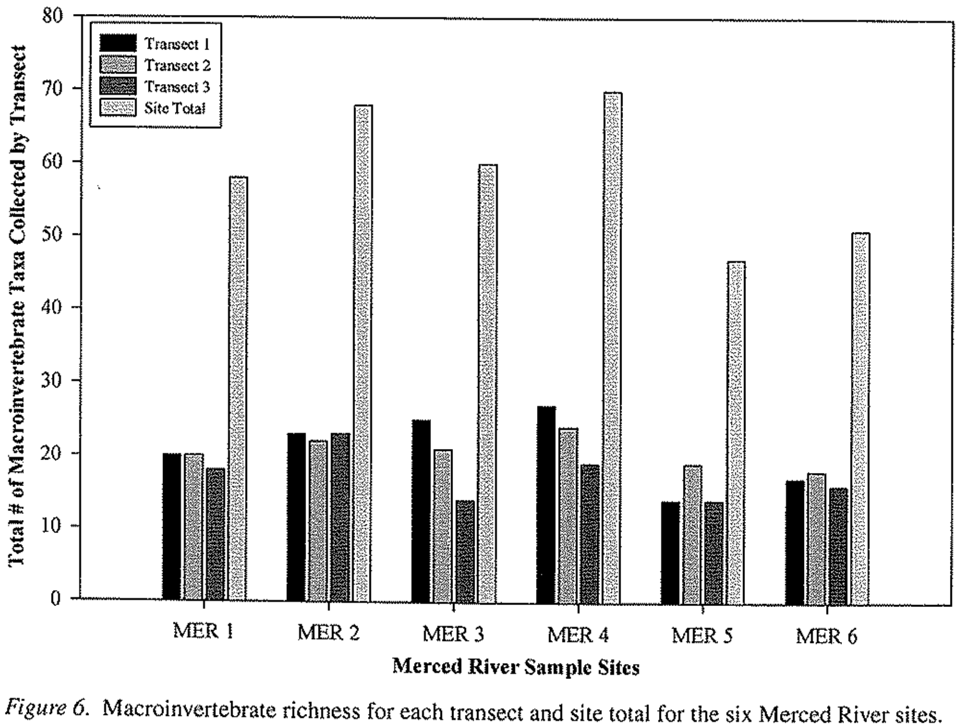

Figure 6. Macroinvertebrate richness for each transect and site total for the six Merced River sites.

TABLE XIII
Benthic metrics by transect (including the means) for the six Tuolumne River sites

	TLM1					TLM2					TLM3					TLM4					TLM5					TLM6				
	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV
Taxonomic Richness	19	16	21	19	13	10	21	8	13	54	15	15	17	16	7	21	24	24	23	8	22	16	19	19	16	18	14	14	15	15
Cumulative Taxa				56					39					47					69					57					46	
Percent Dominant Taxon	35	33	14	27	42	34	19	32	28	29	30	25	33	29	15	44	36	44	41	11	20	16	22	20	15	30	31	39	33	14
Number Ephemeroptera Taxa	3	3	4	3	17	2	5	0	2	108	3	2	4	3	33	3	6	7	5	39	5	3	5	4	27	6	4	4	5	25
Number Plecoptera Taxa	0	0	0	0	–	0	0	0	0	–	0	0	0	0	–	0	0	0	0	–	0	0	0	0	–	1	0	1	1	87
Number Trichoptera Taxa	4	4	5	4	13	3	4	4	4	16	3	3	4	3	17	3	3	3	3	0	4	0	3	2	89	1	1	3	2	69
EPT Taxa	7	7	9	8	15	5	9	4	6	44	6	5	8	6	24	6	9	10	8	25	9	3	8	7	48	8	5	8	7	25
Cumulative EPT Taxa				23					18					19					25					20					21	
EPT Index (%)	17	22	23	20	16	67	47	13	42	64	29	62	61	51	37	27	31	23	27	14	66	31	67	54	38	60	53	72	62	16
Sensitive EPT Index (%)	15	14	19	16	16	66	41	11	39	70	26	48	47	40	31	2	4	3	3	39	15	18	9	14	33	10	11	15	12	19
Shannon Diversity	2.5	2.7	3.0	2.7	7.8	2.1	2.7	2.3	2.3	12.1	2.5	2.6	2.4	2.5	4.1	2.2	2.6	2.3	2.4	7.4	2.6	2.7	2.6	2.6	2.4	2.5	2.1	2.1	2.2	10.5
Tolerance Value	5.0	5.1	5.2	5.1	1.2	3.7	4.4	5.4	4.5	19.8	4.9	4.4	3.9	4.4	10.9	5.5	5.4	5.6	5.5	1.5	4.8	4.9	4.6	4.7	3.2	4.9	5.7	4.7	5.1	10.0
Percent Intolerant Taxa (0–2)	6	6	10	7	33	10	10	0	7	87	7	7	6	6	7	5	9	8	7	30	19	20	11	17	29	17	15	21	18	18
Percent Tolerant Taxa (8–10)	28	19	15	21	32	20	30	0	17	92	33	27	24	28	18	24	22	25	24	7	19	33	22	25	30	22	38	7	23	69
Percent Baetidae	10	2	14	8	72	29	21	0	17	90	5	5	35	15	116	5	8	4	6	38	22	0	27	16	88	40	33	50	41	21
Percent Chironomidae	31	25	50	35	37	21	24	62	36	64	24	14	16	18	30	53	48	58	53	9	13	28	17	19	38	24	3	8	12	94
Percent Hydropsychidae	0	1	1	1	93	0	0	0	0	88	0	0	0	0	173	7	6	7	6	11	16	0	17	11	87	8	8	6	7	19
Percent Collectors Gatherers	88	71	78	79	11	60	67	85	71	18	73	42	79	65	30	80	77	85	81	5	75	74	69	73	4	78	70	74	74	5
Percent Collector-Filterers	2	7	11	7	71	0	2	1	1	88	2	2	0	1	67	12	9	7	10	26	18	3	17	12	69	19	19	20	19	2
Percent Scrapers	1	0	2	1	100	3	2	1	2	61	1	2	1	1	40	2	6	2	3	68	3	2	1	2	32	1	9	2	4	109
Percent Predators	2	4	1	2	63	0	6	0	2	173	1	6	2	3	78	5	8	5	6	31	4	21	10	12	76	2	1	4	2	47
Percent Shredder Taxa	5	0	10	5	97	0	0	0	0	0	0	0	0	0	0	5	0	0	2	173	0	0	0	0	0	0	0	0	0	0
Abundance (#/sample)	581	1254	478	771	55	4449	1948	3800	3399	38	3907	741	5139	3262	70	2472	1021	3953	2482	59	334	841	5278	2151	126	955	135	5096	2062	129

TABLE XIV
Total and taxon abundance for benthic macroinvertebrates in Merced River

Lowest taxa	Higher taxa	Total *N*	Total %	Cumulative %
Baetis tricaudatus	Baetidae/Ephemroptera	1019	19.00	19.00
Corbicula sp.	Corbiculidae/Bivalvia	605	11.28	30.29
Rheotanytarsus sp.	Chironomidae/Diptera	478	8.91	39.20
Hydropsyche californica	Hydropsychidae/Trichoptera	435	8.11	47.31
Serratella micheneri	Ephemerellidae/Ephemroptera	322	6.01	53.32
Tricorythodes sp.	Leptohyphidae/Ephemeroptera	288	5.37	58.69
Cricotopus sp.	Chironomidae/Diptera	258	4.81	63.50
Simulium sp.	Simuliidae/Diptera	256	4.77	68.28
Acentrella insignificans	Baetidae/Ephemroptera	223	4.16	72.44
Polypedilum sp.	Chironomidae/Diptera	141	2.63	75.07
Hydroptila sp.	Hydroptilidae/Trichoptera	101	1.88	76.95
Lumbricina	Oligochaeta	74	1.38	78.33
Hydropsyche sp.	Hydropsychidae/Trichoptera	73	1.36	79.69
Eukiefferiella sp.	Chironomidae/Diptera	57	1.06	80.75
Cardiocladius sp.	Chironomidae/Diptera	53	0.99	81.74
Serratella sp.	Ephemerellidae/Ephemeroptera	50	0.93	82.67
Lebertia sp.	Lebertiidae/Arachnida	43	0.80	83.48
Orthocladius complex	Chironomidae/Diptera	40	0.75	84.22
Nectopsyche sp.	Leptoceridae/Trichoptera	39	0.73	84.95
Turbellaria	Platyhelminthes	39	0.73	85.68
Hyalella sp.	Hyalellidae/Malacostraca	36	0.67	86.35
Centroptilum sp.	Baetidae/Ephemeroptera	33	0.62	86.96
Leucrocuta sp.	Heptageniidae/Ephemeroptera	33	0.62	87.58
Cricotopus bicinctus group	Chironimidae/Diptera	32	0.60	88.18
Fallceon quilleri	Baetidae/Ephemeroptera	31	0.58	88.75
Micropsectra sp.	Chironomidae/Diptera	31	0.58	89.33
Dugesia tigrina	Planariidae/Platyhelminthes	31	0.58	89.91
Menetus sp.	Planorbidae/Gastropoda	31	0.58	90.49
Hygrobates sp.	Hygrobatidae/Arachnida	30	0.56	91.05
Sperchon sp.	Sperchontidae/Arachnida	30	0.56	91.61
Tvetenia vitracies group	Chironimidae/Diptera	28	0.52	92.13
Tanytarsus sp.	Chironomidae/Diptera	26	0.48	92.61
Protoptila sp.	Glossosomatidae/Trichoptera	25	0.47	93.08
Nais communis/ variabilis	Naididae/Oligochaeta	25	0.47	93.55
Petrophila sp.	Planorbidae/Gastropoda	23	0.43	93.98
Thienemanniella sp.	Chironomidae/Diptera	21	0.39	94.37
Ophidonais serpentina	Naididae/Oligochaeta	19	0.35	94.72
Acentrella turbida	Baetidae/Ephemeroptera	18	0.34	95.06

(*Continued on next page*)

TABLE XIV
(*Continued*)

Lowest taxa	Higher taxa	Total *N*	Total %	Cumulative %
Phaenopsectra sp.	Chironomidae/Diptera	16	0.30	95.36
Oxyethira sp.	Hydroptilidae/Trichoptera	15	0.28	95.64
Physa sp.	Physidae/Gastropoda	15	0.28	95.92
Heptageniidae	Ephemeroptera	14	0.26	96.18
Gyraulus sp.	Planorbidae/Gastopoda	13	0.24	96.42
Ferrissia sp.	Ancylidae/Gastopoda	12	0.22	96.64
Parakiefferiella sp.	Chironomidae/Diptera	10	0.19	96.83
Robackia demeijerei	Chironomidae/Diptera	10	0.19	97.02
Synorthocladius semivirens	Chironomidae/Diptera	10	0.19	97.20
Ferrissia rivularis	Ancylidae/Gastropoda	9	0.17	97.37
Brechmorhoga mendax	Libellulidae/Odonata	9	0.17	97.54
Isoperla sp.	Perlodidae/Plecoptera	9	0.17	97.71
Chimarra sp.	Philopotamidae/Trichoptera	9	0.17	97.87
Acentrella sp.	Baetidae/Ephemeroptera	8	0.15	98.02
Atractides sp.	Hygrobatidae/Arachnida	8	0.15	98.17
Dubiraphia sp.	Elmidae/Coleoptera	7	0.13	98.30
Brillia sp.	Chironomidae/Diptera	6	0.11	98.41
Heptagenia sp.	Heptageniidae/Ephemeroptera	6	0.11	98.53
Nixe sp.	Heptageniidae/Ephemeroptera	5	0.09	98.62
Wormaldia sp.	Philopotamidae/Trichoptera	5	0.09	98.71
Dicrotendipes sp.	Chironomidae/Diptera	4	0.07	98.79
Tubificidae	Oligochaeta	4	0.07	98.86
Ostracoda	Ostracoda	3	0.06	98.92
Hetaerina americana	Calopterygidae/Odonata	3	0.06	98.97
Crangonyx sp.	Crangonyctidae/Malacostraca	3	0.06	99.03
Microcylloepus sp.	Elmidae/Coleoptera	3	0.06	99.09
Fossaria sp.	Lymnaeidae/Gastropoda	3	0.06	99.14
Sabellidae	Canalipalpata/Polychaeta	3	0.06	99.20
Prostoma sp.	Tertastemmatidae/Enopla	3	0.06	99.25
Acari	Arachnida	2	0.04	99.29
Camelobaetidius similis	Baetidae/Ephemeroptera	2	0.04	99.33
Camelobaetius warreni	Baetidae/Ephemeroptera	2	0.04	99.37
Paracladopelma sp.	Chironomidae/Diptera	2	0.04	99.40
Potthastia longimana group	ChironomidaeDiptera	2	0.04	99.44
Synorthocladius sp.	ChironomidaeDiptera	2	0.04	99.48
Tanytarsini	ChironomidaeDiptera	2	0.04	99.52
Argia sp.	Coenagrionidae/Odonata	2	0.04	99.55
Ceraclea sp.	Leptoceridae/Trichoptera	2	0.04	99.59

(*Continued on next page*)

TABLE XIV
(*Continued*)

Lowest taxa	Higher taxa	Total N	Total %	Cumulative %
Lumbriculidae	Lumbriculida/Oligochaeta	2	0.04	99.63
Siphlonurus sp.	Siphlonuridae/Ephemeroptera	2	0.04	99.66
Baetis flavistriga	Baetidae/Ephemeroptera	1	0.02	99.68
Ablabesmyia sp.	Chironomidae/Diptera	1	0.02	99.70
Cladotanytarsus sp.	Chironomidae/Diptera	1	0.02	99.72
Cricotopus trifascia group	Chironomidae/Diptera	1	0.02	99.74
Cryptochironomus sp.	Chironomidae/Diptera	1	0.02	99.76
Orthocladiinae	Chironomidae/Diptera	1	0.02	99.78
Parametriocnemus sp.	Chironomidae/Diptera	1	0.02	99.79
Paratanytarsus sp.	Chironomidae/Diptera	1	0.02	99.81
Psectrocladius sp.	Chironomidae/Diptera	1	0.02	99.83
Rheocricotopus sp.	Chironomidae/Diptera	1	0.02	99.85
Stempellina sp.	Chironomidae/Diptera	1	0.02	99.87
Ischnura sp.	Coenagrionidae/Odonata	1	0.02	99.89
Sigara sp.	Corixidae/Hemiptera	1	0.02	99.91
Anisogammarus sp.	Gammaridae/Malacostraca	1	0.02	99.93
Oligochaeta	Oligochaeta	1	0.02	99.94
Malenka sp.	Nemouridae/Plecoptera	1	0.02	99.96
Menetus opercularis	Planorbidae/Gastropoda	1	0.02	99.98
Musculium sp.	Sphaeriidae/Bivalvia	1	0.02	100.00
Total		5362		

site (MER6); and (4) % shredders – taxa associated with non-stressed environments – were only found at the most upriver site (MER6).

3.4. Summary Statistical Analysis for All Rivers

PCA was used to determine the relationship among the benthic metrics and identify metrics that covary (Table XVI). Six eigenvalues exceeded 1 indicating that there were six important factors in these data. Cumulative taxa, % scrapers, and taxonomic richness were heavily loaded on factor 1 (Table XVII). Factor 2 was composed of cumulative EPT taxa, EPT index, EPT taxa, number of Ephemeroptera taxa, and % Hydropsychidae. Percent collectors/filterers, % dominant taxa, % intolerant taxa, % predators, and Shannon Diverstiy were significant for Factor 3. Factor 4 was composed of number of Plecoptera taxa, % Chironomidae, and % collectors/gatherers. Number of Trichoptera taxa, % Baetidae, sensitive EPT index and tolerance value were significant metrics in Factor 5 (Table XVII). Factor 6 was composed of abundance and % shredder taxa.

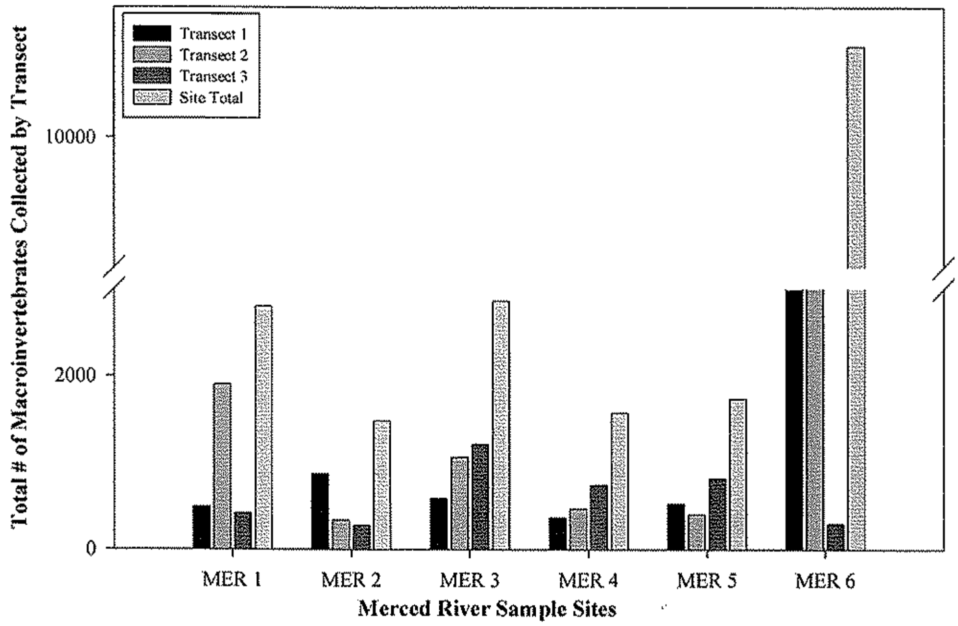

Figure 7. Macroinvertebrate abundance for each transect and site total for the six Merced River sites.

Spearmans Rank Correlation Analysis showed a significant ($p < 0.05$) spatial trend in the Tuolumne River for EPT index, number of Trichoptera taxa, % collectors/filterers, and % scrapers (Table XVIII). Number of Trichoptera taxa showed a decrease from downstream to upstream. EPT index, % collectors/filterers, and % scrappers showed an increase from downstream to upstream. In the Merced River, % Baetidae and % collectors/gatherers showed an increase from downstream to upstream. The % collectors/filterers decreased from downstream to upstream in the Merced River. In the Stanislaus River, percent shredder taxa increased from downstream to upstream.

A comparison among benthic metrics in the Stanislaus, Tuolumne, and Merced Rivers in Table XIX showed that cumulative EPT taxa, EPT taxa, number of Ephemeroptera taxa, and % collectors/filterers were higher in the Merced River when compared with either the Stanislaus or Tuolumne Rivers. Percent Hydropsychidae were higher in the Merced River than the Stanislaus River. Percent predators were higher in the Stanislaus River than the Merced River.

3.5. Relationship of Physical Habitat and Benthos

Spearman's Rank Correlation Analysis showed that channel flow and bank stability were the most important physical habitat metrics influencing the various benthic metrics (Table XX). Channel flow was positively correlated with abundance and %

TABLE XV

Benthic metrics by transect (including the means) for the six Merced River sites

	MER-1					MER-2					MER-3					MER-4					MER-5					MER-6				
	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV	T1	T2	T3	Mean	CV
Taxonomic Richness	20	20	18	19	6	23	22	23	23	3	25	21	14	20	28	27	24	19	23	17	14	19	14	16	18	17	18	16	17	6
Cumulative Taxa				58					68					60					70					47					51	
Percent Dominant Taxon	35	34	40	36	9	21	33	30	28	22	27	17	25	23	23	16	23	32	23	35	30	16	45	31	47	25	30	29	28	9
Number Ephemeroptera Taxa	6	5	6	6	10	5	6	4	5	20	6	7	5	6	17	6	7	6	6	9	6	6	4	5	22	5	5	5	5	0
Number Plecoptera Taxa	0	0	0	0	–	0	0	0	0	–	0	0	0	0	–	0	0	0	0	–	0	0	0	0	–	1	2	1	1	43
Number Trichoptera Taxa	3	3	3	3	0	4	4	4	4	0	5	3	3	4	31	5	5	4	5	12	3	4	3	3	17	3	2	2	2	25
EPT Taxa	9	8	9	9	7	9	10	8	9	11	11	10	8	10	16	11	12	10	11	9	9	10	7	9	18	9	9	8	9	7
Cumulative EPT Taxa				26					27					29					33					26					26	
EPT Index (%)	22	35	33	30	24	42	36	41	39	8	37	58	71	55	31	55	58	76	63	17	70	54	79	68	19	55	53	50	53	5
Sensitive EPT Index (%)	7	6	6	6	10	6	6	4	5	22	9	10	8	9	10	21	15	13	17	25	10	17	9	12	36	9	12	13	11	21
Shannon diversity	2.4	2.5	2.3	2.4	4.0	2.7	2.4	2.4	2.5	6.1	2.4	2.5	2.5	2.4	7.1	2.7	2.5	2.2	2.5	9.5	2.2	2.7	1.8	2.3	19.7	2.8	2.5	2.7	2.7	5.2
Tolerance Value	5.9	5.3	5.5	5.6	5.1	5.3	5.5	5.4	5.4	1.1	5.2	4.8	4.6	4.9	5.8	4.7	4.9	4.5	4.7	4.3	4.6	4.7	4.6	4.6	1.1	4.9	4.9	4.9	4.9	0.2
Percent Intolerant Taxa (0–2)	11	5	11	9	38	5	14	9	9	52	13	20	14	16	25	12	17	17	15	21	25	22	15	21	24	13	17	13	14	17
Percent Tolerant Taxa (8–10)	21	25	22	23	9	18	24	18	20	16	21	15	7	14	48	35	30	11	25	49	8	22	8	13	64	13	17	19	16	20
Percent Baetidae	7	9	13	10	32	19	14	20	18	20	7	20	34	20	67	17	26	33	25	31	52	27	50	43	32	35	32	29	32	9
Percent Chironomidae	11	43	20	24	68	19	8	13	13	41	40	30	20	30	33	15	9	11	12	27	25	34	12	24	47	35	35	37	36	4
Percent Hydropsychidae	0	3	8	4	109	11	6	8	9	29	6	16	24	15	62	6	9	22	12	69	7	4	19	10	77	7	6	4	6	27
Percent Collectors Gatherers	32	74	41	49	44	48	32	45	42	20	67	69	63	66	4	61	54	61	59	7	91	85	74	83	10	84	81	82	82	1
Percent Collector-Filterers	50	15	48	38	52	39	52	43	45	15	19	20	32	24	29	22	30	30	27	16	7	5	22	11	80	11	11	9	11	12
Percent Scrapers	1	2	1	1	80	2	7	2	4	67	5	7	3	5	42	9	12	3	8	55	1	1	0	1	68	2	2	1	2	22
Percent Predators	5	3	5	4	32	6	4	6	5	14	3	2	2	2	29	4	2	4	3	33	0	6	3	3	87	3	5	8	5	53
Percent Shredder Taxa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	3	173
Abundance (#/sample)	484	1896	414	931	90	868	334	281	494	66	586	1061	1211	953	34	364	467	738	523	37	523	397	813	578	37	4434	5969	295	3566	82

TABLE XVI
Eigenvalues and proportion of variance explained for the correlation matrix of the 23 benthic metrics

	Eigenvalue	Proportion	Cumulative
Factor 1	6.5739	0.2858	0.2858
Factor 2	5.5448	0.2411	0.5269
Factor 3	3.1477	0.1369	0.6638
Factor 4	1.9341	0.0841	0.7478
Factor 5	1.8362	0.0798	0.8277
Factor 6	1.1048	0.0480	0.8757
Factor 7	0.8302	0.0361	0.9118
Factor 8	0.6673	0.0290	0.9408
Factor 9	0.5215	0.0227	0.9635
Factor 10	0.3081	0.0134	0.9769
Factor 11	0.1791	0.0078	0.9847
Factor 12	0.1456	0.0063	0.9910
Factor 13	0.1117	0.0049	0.9959
Factor 14	0.0660	0.0029	0.9987
Factor 15	0.0162	0.0007	0.9994
Factor 16	0.0095	0.0004	0.9999
Factor 17	0.0032	0.0001	1.0000
Factor 18	0.0000	0.0000	1.0000
Factor 19	0.0000	0.0000	1.0000
Factor 20	0.0000	0.0000	1.0000
Factor 21	0.0000	0.0000	1.0000
Factor 22	0.0000	0.0000	1.0000
Factor 23	0.0000	0.0000	1.0000

collectors/gatherers. Channel flow was negatively correlated with cumulative EPT taxa, EPT taxa, number of Ephemeroptera taxa, percent collectors/filterers, and percent Hydropsychidae. Bank stability was positively correlated with EPT index, number of Plecoptera taxa, % Baetidae, % collectors/gatherers and % intolerant taxa. Bank stability was negatively correlated with number of Trichoptera taxa.

The correlation matrix in Table XXI for habitat metrics not scored on a 0–20 scale shows that width and depth have the highest number of significant relationships with the various benthic metrics. Width was negatively correlated with EPT index, % collectors/filterers, % Hydropsychidae, and % intolerant taxa. Width was positively correlated with % Chironomidae. Depth was negatively correlated with cumulative EPT taxa, EPT taxa, number of Ephemeroptera taxa and % Hydropsychidae. Velocity was negatively correlated with % collectors/filterers and positively correlated with % collectors/gatherers.

TABLE XVII
Eigenvectors for the six dominant factors of the correlation matrix of benthic metrics

Metric	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Factor 1						
Cumulative Taxa	0.3715*	−.0236	0.0780	0.0460	−.0176	0.0078
Percent Scrapers	0.2568*	0.1288	0.1329	−.1827	−.0107	0.1141
Taxonomic Richness	0.3715*	−.0236	0.0780	0.0460	−.0176	0.0078
Factor 2						
Cumulative EPT Taxa	0.2180	0.2764*	0.0211	0.2470	0.2500	0.0114
EPT Index	−.1970	0.3347*	0.1319	−.0764	−.0520	0.0139
EPT Taxa	0.2180	0.2764*	0.0211	0.2470	0.2500	0.0114
Number Ephemeroptera Taxa	0.2435	0.2779*	0.0422	0.1614	−.0211	0.2637+
Percent Hydropsychidae	0.1179	0.3446*	−.0297	0.0909	−.0533	0.2168
Factor 3						
Percent Collector-Filterers	0.1940	0.2340	−.2511*	−.1378	−.1820	−.1431
Percent Dominant Taxon	−.1137	0.0304	−.4633*	0.0787	−.1345	0.1943
Percent Intolerant Taxa (0–2)	−.1134	0.2753+	0.3163*	0.1889	−.1581	−.1543
Percent Predators	0.0966	−.1092	0.3934*	−.0412	−.1729	0.0817
Shannon Diversity	0.1829	−.2411	0.3263*	0.0308	0.0615	−.1602
Factor 4						
Number Plecoptera Taxa	−.1647	0.0639	0.2867+	0.3074*	−.0832	−.0644
Percent Chironomidae	0.0758	−.2717+	−.0878	0.3802*	0.1200	0.3683+
Percent Collectors Gatherers	−.2138	−.0976	0.1930	0.4470*	−.0400	0.0599
Factor 5						
Number Trichoptera Taxa	0.1189	0.0357	−.2016	0.0212	0.5581*	−.3659+
Percent Baetidae	−.2361	0.2480	−.0813	0.0365	−.2695*	−.1310
Sensitive EPT Index	−.2150	0.0288	0.2160	−.3012+	0.4216*	0.0472
Tolerance Value	0.2503+	−.2035	−.2050	0.0958	−.3136*	−.0049
Factor 6						
Abundance (#/sample)	−.1973	−.1248	−.0293	−.0000	0.2399	0.5381*
Percent Shredder Taxa	−.0522	−.2398	−.1250	0.3751+	0.0234	−.4089*

3.6. Water Quality

3.6.1. *Stanislaus River*

Water quality conditions showed a spatial pattern for the various sites in the Stanislaus River (Table I). Temperature and conductivity generally decreased from downstream to upstream. Dissolved oxygen and pH were somewhat lower at the downstream site. Turbidity was lower one of the upstream sites (STN5).

TABLE XVIII

Spearman Rank Correlation coefficients (top) and p-values (bottom) for upstream-downstream trend in the Benthic metrics

Benthic metric	Stanislaus	Tuolumne	Merced
Abundance (#/sample)	0.7714	−.4286	0.3714
	0.0724	0.3965	0.4685
Cumulative EPT Taxa	−.1429	0.1429	−.1518
	0.7872	0.7872	0.7741
Cumulative Taxa	−.4857	0.1429	−.4286
	0.3287	0.7872	0.3965
EPT Index (%)	−.1429	0.8286	0.6571
	0.7872	0.0416*	0.1562
EPT Taxa	−.1429	0.1429	−.1518
	0.7872	0.7872	0.7741
Number Ephemeroptera Taxa	−.5218	0.6571	−.2029
	0.2883	0.1562	0.6998
Number Plecoptera Taxa	−.1852	0.6547	0.6547
	0.7254	0.1583	0.1583
Number Trichoptera Taxa	0.7650	−1.000	−.2571
	0.0763	<.0001*	0.6228
Percent Baetidae	0.2571	0.4286	0.9429
	0.6228	0.3965	0.0048*
Percent Chironomidae	0.3714	−.4857	0.2571
	0.4685	0.3287	0.6228
Percent Collector-Filterers	−.0857	0.8286	−.8857
	0.8717	0.0416*	0.0188*
Percent Collectors Gatherers	0.2571	0.0857	0.8286
	0.6228	0.8717	0.0416*
Percent Dominant Taxon	0.4286	0.3143	−.2029
	0.3965	0.5441	0.6998
Percent Hydropsychidae	0.0580	0.7537	0.2000
	0.9131	0.0835	0.7040
Percent Intolerant Taxa (0–2)	−.3714	0.7356	0.6000
	0.4685	0.0956	0.2080
Percent Predators	−.4286	0.4638	−.0290
	0.3965	0.3542	0.9565
Percent Scrapers	−.4928	0.8117	−.0857
	0.3206	0.0499*	0.8717
Percent Shredder Taxa	0.8804	−.5071	0.6547
	0.0206*	0.3046	0.1583

(*Continued on next page*)

TABLE XVIII
(*Continued*)

Benthic metric	Stanislaus	Tuolumne	Merced
Percent Tolerant Taxa (8–10)	−.3143	0.4286	−.4286
	0.5441	0.3965	0.3965
Sensitive EPT Index (%)	−.6000	−.6000	0.7143
	0.2080	0.2080	0.1108
Shannon Diversity	−.2571	−.5508	0.2029
	0.6228	0.2574	0.6998
Taxonomic Richness	−.4857	0.1429	−.4286
	0.3287	0.7872	0.3965
Tolerance Value	0.0286	0.2319	−.6571
	0.9572	0.6584	0.1562

*p-value < 0.05.

3.6.2. *Tuolumne River*

A spatial pattern in water quality conditions was generally reported in the Tuolumne River (Table I). Temperature, conductivity, and turbidity decreased from downstream to upstream at all sites. Dissolved oxygen generally increased from downstream to upstream. pH was generally consistent at all sites.

3.6.3. *Merced River*

Both conductivity and dissolved oxygen showed spatial patterns from downstream to upstream (Table I). Conductivity decreased from downstream to upstream while dissolved oxygen increased from downstream to upstream. Temperature was lower at the most upstream Merced River site when compared with the five downstream sites. pH was somewhat lower at the two downstream sites. Turbidity was somewhat lower at the two upstream sites.

4. Discussion

4.1. Physical Habitat

Water augmentation, sediment loading and impaired physical habitat have been identified as the three major stressors to aquatic life in California streams (Jim Harrington, California Department of Fish and Game, personal communication). Altered physical habitat structure is also considered one of the major stressors of aquatic systems throughout the United States resulting in extinctions, local expirations and population reductions of aquatic fauna (Karr *et al.*, 1986; Rankin, 1995). Identifying degraded physical habitat in streams is particularly critical for

TABLE XIX

Mean scores for each benthic metric for each river with the p-values for comparing the means among rivers based on the Kruskal-Wallace test

	Mean for each River			Kruskal Wallace	Pairwise comparison		
Benthic metric	Stanislaus	Tuolumne	Merced	p-value	ST	SM	TM
Abundance (#/sample)	1408.0	2101.7	1174.2	0.4075			
Cumulative EPT Taxa	21.33	21.00	27.83	0.0038*		*	*
Cumulative Taxa	55.00	52.33	59.00	0.3942			
EPT Index (%)	46.72	42.83	51.39	0.6343			
EPT Taxa	7.11	7.00	9.28	0.0038*		*	*
Number Ephemeroptera Taxa	3.61	3.83	5.56	0.0037*		*	*
Number Plecoptera Taxa	0.56	0.11	0.22	0.2015			
Number Trichoptera Taxa	2.94	3.06	3.50	0.4520			
Percent Baetidae	21.17	17.22	24.67	0.4657			
Percent Chironomidae	25.56	28.83	23.17	0.8484			
Percent Collector-Filterers	7.50	8.39	25.83	0.0250*		*	*
Percent Collectors Gatherers	78.06	73.61	63.56	0.2475			
Percent Dominant Taxon	23.56	29.83	28.22	0.3758			
Percent Hydropsychidae	1.78	4.28	9.22	0.0270*		*	
Percent Intolerant Taxa (0–2)	15.61	10.39	14.06	0.2151			
Percent Predators	8.00	4.56	3.94	0.0493*		*	
Percent Scrapers	2.44	2.28	3.39	0.7506			
Percent Shredder Taxa	2.61	1.11	0.33	0.3043			
Percent Tolerant Taxa (8–10)	23.06	22.67	18.56	0.4337			
Sensitive EPT Index (%)	17.83	20.78	10.06	0.4944			
Shannon Diversity	2.69	2.47	2.44	0.7692			
Taxonomic Richness	18.33	17.44	19.67	0.3942			
Tolerance Value	4.89	4.89	5.01	0.9242			

Pairwise comparisons between rivers are based on the Wilcoxon rank sum test.
ST: Stanislaus vs Tuolumne; SM: Stanislaus vs Merced; TM: Tuolumne vs Merced.
*p-value < 0.05.

bioassessments as failure to do so can sometimes hinder investigations on the effects of toxic chemicals or other water quality related stressors. There is a small but still significant risk of reporting a water quality related impact when one does not exist (false positive) when habitat assessments are insufficient or absent (Rankin, 1995). Physical habitat evaluations are not intended to replace biological assessments but rather to add an additional line of evidence about the status of lotic systems when conducted in concert with biological assessments. Evaluation of physical habitat in River systems of the San Joaquin watershed is particularly important due to the intensive development and landscape modifications in this area.

TABLE XX

Spearman rank correlation coefficients (top) and p-values (bottom) for benthic metrics versus habitat metrics

Benthic metric	BANK STAB	BANK VEG	CHAN ALT	EPI SUB	RIP BUFF	VEL DPTH	BEN RIFF	SED DEP	EMBE DDED	CHAN FLOW	TOTAL
Abundance (#/sample)	0.13	−0.10	0.04	−0.11	−0.14	0.00	0.01	−0.03	−0.14	0.48	−0.03
	0.6119	0.7005	0.8796	0.6543	0.5692	0.9889	0.9707	0.9201	0.5891	0.0445*	0.8952
Cumulative EPT Taxa	−0.25	−0.00	−0.21	0.14	0.21	0.41	0.08	−0.03	0.13	−0.57	0.06
	0.3095	0.9887	0.3981	0.5778	0.3944	0.0946	0.7590	0.9073	0.6037	0.0144*	0.7988
Cumulative Taxa	−0.26	−0.07	0.01	−0.14	0.08	0.03	0.02	0.02	−0.10	−0.23	−0.08
	0.2973	0.7777	0.9792	0.5773	0.7482	0.9015	0.9417	0.9373	0.6975	0.3645	0.7605
EPT Index (%)	0.52	0.53	−0.11	0.57	0.45	0.43	0.39	0.41	0.57	−0.16	0.56
	0.0273*	0.0231*	0.6525	0.0135*	0.0627	0.0742	0.1050	0.0925	0.0137*	0.5140	0.0157*
EPT Taxa	−0.25	−0.00	−0.21	0.14	0.21	0.41	0.08	−0.03	0.13	−0.57	0.06
	0.3095	0.9887	0.3981	0.5778	0.3944	0.0946	0.7590	0.9073	0.6037	0.0144*	0.7988
Number Ephemeroptera Taxa	−0.13	0.13	−0.11	0.22	0.35	0.52	0.12	0.25	0.24	−0.55	0.22
	0.6184	0.6006	0.6650	0.3732	0.1525	0.0280*	0.6268	0.3215	0.3337	0.0178*	0.3848
Number Plecoptera Taxa	0.48	0.34	−0.09	0.44	−0.02	−0.18	0.17	0.16	0.25	0.36	0.26
	0.0426*	0.1634	0.7169	0.0669	0.9365	0.4836	0.4991	0.5228	0.3175	0.1403	0.2914
Number Trichoptera Taxa	−0.57	−0.43	−0.17	−0.36	−0.15	0.04	−0.15	−0.55	−0.29	−0.40	−0.39
	0.0138*	0.0762	0.5020	0.1410	0.5489	0.8748	0.5406	0.0170*	0.2375	0.1004	0.1105
Percent Baetidae	0.56	0.54	0.06	0.66	0.48	0.34	0.54	0.46	0.69	−0.19	0.64
	0.0149*	0.0204*	0.8219	0.0031*	0.0447*	0.1618	0.0214*	0.0558	0.0017*	0.4537	0.0040*
Percent Chironomidae	−0.19	−0.47	0.03	−0.24	−0.06	−0.36	−0.10	−0.22	−0.23	0.30	−0.24
	0.4551	0.0502	0.9158	0.3328	0.8196	0.1418	0.6935	0.3888	0.3533	0.2242	0.3279
Percent Collector-Filterers	0.02	0.12	0.18	0.19	0.19	0.13	−0.41	−0.67	0.56	0.19	0.18
	0.9374	0.6494	0.4815	0.4529	0.4557	0.6129	0.0950	0.0024*	0.0159*	0.4525	0.4870

(*Continued on next page*)

TABLE XX
(*Continued*)

Benthic metric	BANK STAB	BANK VEG	CHAN ALT	EPI SUB	RIP BUFF	VEL DPTH	BEN RIFF	SED DEP	EMBE DDED	CHAN FLOW	TOTAL
Percent Collectors Gatherers	0.50	−0.04	−0.12	0.32	0.22	−0.40	0.23	0.09	0.24	0.51	0.21
	0.0350*	0.8756	0.6229	0.1931	0.3854	0.1000	0.3590	0.7149	0.3474	0.0305*	0.3993
Percent Dominant Taxon	−0.03	−0.04	0.36	0.15	0.14	0.23	0.21	0.14	0.10	−0.14	0.16
	0.9098	0.8605	0.1448	0.5542	0.5667	0.3684	0.4048	0.5906	0.6948	0.5716	0.5391
Percent Hydropsychidae	0.14	0.20	−0.19	0.43	0.56	0.66	0.45	0.31	0.53	−0.48	0.47
	0.5860	0.4275	0.4472	0.0738	0.0157*	0.0027*	0.0616	0.2103	0.0227*	0.0442*	0.0490*
Percent Intolerant Taxa (0–2)	0.57	0.53	−0.08	0.66	0.48	0.17	0.37	0.37	0.56	−0.10	0.54
	0.0134*	0.0222*	0.7432	0.0031*	0.0421*	0.5129	0.1337	0.1310	0.0159*	0.6848	0.0208*
Percent Predators	0.26	0.31	0.19	0.03	0.13	−0.23	0.04	0.22	−0.01	0.27	0.11
	0.2943	0.2147	0.4526	0.9097	0.6184	0.3625	0.8665	0.3797	0.9699	0.2765	0.6637
Percent Scrapers	−0.04	0.15	−0.15	−0.02	0.31	0.07	0.09	0.20	0.21	−0.13	0.13
	0.8885	0.5434	0.5460	0.9451	0.2160	0.7936	0.7290	0.4365	0.4101	0.6015	0.6020
Percent Shredder Taxa	0.12	−0.15	0.30	0.05	−0.08	−0.40	0.18	−0.14	−0.07	0.34	−0.02
	0.6406	0.5616	0.2195	0.8310	0.7566	0.0983	0.4815	0.5825	0.7812	0.1621	0.9311
Percent Tolerant Taxa (8–10)	−0.14	−0.07	0.13	−0.35	−0.22	−0.24	−0.25	0.07	−0.33	0.21	−0.23
	0.5900	0.7881	0.6120	0.1538	0.3842	0.3291	0.3107	0.7794	0.1876	0.3943	0.3614
Sensitive EPT Index (%)	−0.09	−0.15	−0.36	−0.33	−0.37	−0.21	−0.45	−0.32	−0.33	0.29	−0.36
	0.7231	0.5448	0.1372	0.1854	0.1336	0.3929	0.0639	0.1972	0.1860	0.2426	0.1469
Shannon Diversity	−0.09	−0.12	−0.14	−0.39	−0.37	−0.47	−0.37	−0.23	−0.44	0.28	−0.39
	0.7276	0.6232	0.5874	0.1111	0.1279	0.0497*	0.1347	0.3563	0.0696	0.2561	0.1139
Taxonomic Richness	−0.26	−0.07	0.01	−0.14	0.08	0.03	0.02	0.02	−0.10	−0.23	−0.08
	0.2973	0.7777	0.9792	0.5773	0.7482	0.9015	0.9417	0.9373	0.6975	0.3645	0.7605
Tolerance Value	−0.20	−0.09	0.35	−0.14	−0.03	−0.10	−0.00	0.05	−0.13	−0.11	−0.08
	0.4371	0.7246	0.1496	0.5777	0.9172	0.6955	0.9897	0.8464	0.6027	0.6759	0.7506

*p-value $<=0.05$.

TABLE XXI

Spearman rank correlation coefficients (top) and p-values (bottom) for benthic metrics versus physical habitat measurements (not scored on a 0–20 scale)

Benthic metric	Width	Depth	Velocity	Canopy
Abundance (#/sample)	0.3319	0.3100	0.3129	−.3368
	0.1784	0.4550	0.4504	0.1717
Cumulative EPT Taxa	−.4115	−.7497	−.1275	−.1975
	0.0898	0.0322*	0.7634	0.4320
Cumulative Taxa	−.1915	−.4620	−.0680	−.2410
	0.4466	0.2491	0.8729	0.3354
EPT Index (%)	−.5587	−.2826	0.2114	0.0620
	0.0160*	0.4977	0.6153	0.8069
EPT Taxa	−.4115	−.7497	−.1275	−.1975
	0.0898	0.0322*	0.7634	0.4320
Number Ephemeroptera Taxa	−.4673	−.7924	−.2093	−.0971
	0.0506	0.0190*	0.6188	0.7015
Number Plecoptera Taxa	−.1578	0.4326	0.1816	0.1817
	0.5318	0.2844	0.6669	0.4706
Number Trichoptera Taxa	0.0712	−.6000	−.0983	−.3271
	0.7789	0.1158	0.8168	0.1851
Percent Baetidae	−.4172	−.2758	0.0177	0.2591
	0.0850	0.5085	0.9668	0.2991
Percent Chironomidae	0.4942	0.3371	0.4280	−.2114
	0.0371*	0.4143	0.2901	0.3997
Percent Collector-Filterers	−.4770	−.6311	−.7850	−.0273
	0.0453*	0.0933	0.0210*	0.9145
Percent Collectors Gatherers	0.0700	0.5574	0.7773	0.1827
	0.7827	0.1512	0.0232*	0.4680
Percent Dominant Taxon	0.0752	−.0812	−.2915	0.1027
	0.7669	0.8484	0.4836	0.6852
Percent Hydropsychidae	−.7730	−.9149	0.1537	−.0761
	0.0002*	0.0014*	0.7164	0.7641
Percent Intolerant Taxa (0–2)	−.6113	0.1176	0.3885	0.1599
	0.0070*	0.7815	0.3416	0.5262
Percent Predators	−.1080	0.7037	0.2983	−.1900
	0.6696	0.0514	0.4730	0.4502
Percent Scrapers	−.2781	−.5929	0.2422	0.0574
	0.2638	0.1214	0.5633	0.8209
Percent Shredder Taxa	0.1840	0.6556	0.3849	0.0979
	0.4648	0.0776	0.3464	0.6992

(*Continued on next page*)

TABLE XXI
(*Continued*)

Benthic metric	Width	Depth	Velocity	Canopy
Percent Tolerant Taxa (8–10)	0.2919	0.4154	–.0391	0.0126
	0.2399	0.3060	0.9268	0.9605
Sensitive EPT Index (%)	0.2836	0.2090	0.2575	–.0333
	0.2541	0.6193	0.5382	0.8955
Shannon Diversity	0.2969	0.4859	0.0512	–.1274
	0.2315	0.2222	0.9041	0.6145
Taxonomic Richness	–.1915	–.4620	–.0680	–.2410
	0.4466	0.2491	0.8729	0.3354
Tolerance Value	0.2000	0.0011	–.3609	0.0497
	0.4262	0.9979	0.3798	0.8446
Sample Size	18	8	8	18

*p-value $< = 0.05$.

Due to the limited number of sites sampled in the three rivers in the present study and lack of historical data for similar river systems in the region, an extensive discussion or comparison of these physical habitat data across large spatial scales is problematic. Based on our limited sampling during 2003, the mean total physical habitat scores (133–156) in all three rivers were not significantly different (Table IX). These mean scores for each river are generally higher than the total physical scores reported for three agricultural streams (73–108) sampled in 2003 on the west side of the San Joaquin watershed (Hall and Killen, 2004). However, it is unknown if the physical habitat conditions of these three rivers are below realistic expectations without additional physical habitat data from similar river systems within this geographic area.

4.2. Regulatory and Ecological Implications

The state of California has classified the lower regions (~50 to 60 miles) of these three east side rivers as impaired water bodies (303 d list) due to the following constituents: Stanislaus River (diazinon, Group A pesticides, and mercury), Tuolumne River (diazinon, Group A pesticides, and unknown toxicity) and Merced River (diazinon, chlorpyrifos, and Group A pesticides) (www.swrcb.ca.gov). These water bodies were listed as impaired based on either pesticide or mercury concentrations exceeding a threshold (water quality criteria) or toxicity reported from single species toxicity tests (i.e., *Ceriodaphnia dubia* toxicity tests: U. S. EPA. 2002a). Unfortunately, the status of resident biological communities was not considered when these water bodies were classified as impaired because these data were not available. The benthic community data generated from these three rivers in 2003 is therefore useful for providing another line of evidence for determining the biological condition of these water bodies. A recent report by the NRC (National Research Council, 2001), addressing various issues associated with TMDLs and impaired water bodies, stated that biological criteria should be used in conjunction with physical and chemical criteria to determine whether a water body is meeting its designated use. This NRC report further supports the use of biological data for determining the status (or potential impairment) of water bodies by stating that biological criteria are more closely related to designated uses of a waterbody than are chemical or physical measurements. A recent EPA report entitled "*Consolidated Assessment and Listing Methodology*" (CALM document) clearly supports the use of bioassessments for determining attainment of aquatic life based water quality standards by stating that bioassessment data are core indicators (critical or essential indicators) (U.S. EPA, 2002b). This CALM document also endorses the use of multiple lines of evidence (chemical, toxicity and bioassessment data) for making valid designations of impaired water bodies (U.S. EPA, 2002b).

Benthic communities in all three rivers in the San Joaquin watershed were generally dominated by: (1) Baetidae species (mayflies) which are a component of EPT taxa generally considered sensitive to environmental degradation; (2) Chironomidae which can be either tolerant or sensitive to environmental stressors; (3) Ephemerellidae (mayflies) which are considered sensitive to pollution stress; and (4) Naididae (aquatic worms) which are generally considered tolerant to environmental stressors. The most abundant species in these three rivers are therefore comprised of both sensitive as well as tolerant species.

Critical issues to address with the benthic community data from these rivers are: (1) What are the biological (benthic) expectations for these rivers? and (2) Do these rivers meet these biological expectations and are they impaired based on the status of resident benthic communities? Unfortunately, a reference river is not available for this watershed to compare benthic communities for each river. Therefore, the traditional approach often used to interpret the status of benthic communities is not feasible. The presence of 117 taxa in the Stanislaus River, 114 taxa in the Tuolumne River and 96 taxa in the Merced River implies that the benthic communities in these streams are fairly diverse but without a clear definition of benthic community expectations it is unknown if these water bodies are actually impaired (degraded). Extensive spatial and temporal assessments of benthic communities in concert with physical habitat assessments are needed in rivers of California's Central Valley in order to identify the range of benthic community expectations and identify potential reference areas. Annual bioassessments are also recommended for the Stanislaus, Tuolumne, and Merced Rivers to establish a long-term historical data base for both benthic communities and physical habitat. Historical biological baseline data are particularly critical for determining the success of management practices which seek an improvement in biological integrity as a desired outcome.

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