Periphyton and Macroinvertebrate Communities at Five Sites in the San Joaquin River Basin, California, during June and September, 2001

By Larry R. Brown and Jason T. May

In cooperation with the Central Valley Regional Water Quality Control Board

Scientific Investigations Report 2004-5098

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Geological Survey, Reston, Virginia: 2004

For sale by U.S. Geological Survey, Information Services
Box 25286, Denver Federal Center
Denver, CO 80225

For more information about the USGS and its products:
Telephone: 1-888-ASK-USGS
World Wide Web: http://www.usgs.gov/

Suggested citation:
Brown, L.R., and May, J.T., 2004, Periphyton and macroinvertebrate communities at five sites in the San Joaquin River Basin, California, during June and September, 2001: U.S. Geological Survey Scientific Investigations Report 2004-5098, 43 p.

Contents

Figures

Tables

Conversion Factors, Abbreviations, and Acronyms

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
inch (in.)	2.54	centimeter (cm)
kilometer (km)	0.6214	mile (mi)
liter (L)	1.057	quart (qt)
meter (m)	3.281	foot (ft)
mile (mi)	1.609	kilometer (km)
millimeter (mm)	0.03937	inch (in.)
square centimeter (cm^2)	0.1550	square inch (in^2)
square meter (m^2)	0.0002471	acre
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Abbreviations and Acronyms

CVRWQCB	Central Valley Regional Water Quality Control Board
dca	Detrended Correspondence Analysis
dth	Depositional Targeted Habitat
NAWQA	National Water Quality Assessment Program
PNAS	Philadelphia National Academy of Science
qmh	Qualitative Multihabitat
rth	Richest Targeted Habitat
tmdl	Total Maximum Daily Load
USGS	U.S. Geological Survey
µm	micrometer

Periphyton and Macroinvertebrate Communities at Five Sites in the San Joaquin River Basin, California, during June and September, 2001

By: Larry R. Brown and Jason T. May

Abstract

The effects of agriculture, particularly from the use of pesticides, on aquatic ecosystems in the San Joaquin River Basin concern many aquatic resource managers, water quality managers, and water users. A total of five sites were sampled once in June 2001 and once in September 2001 to document the periphyton (attached algae) community, the benthic macroinvertebrate (insects and non-insects) community, and stream habitat conditions. The purposes of the study were to document existing conditions and, to the extent possible, relate the periphyton and macroinvertebrate community condition to environmental conditions.

A total of 161 taxa of algae were collected during the study. Samples from the richest targeted habitat, woody debris, included 109 taxa. In both the June and September samples, greater than 95 percent of the taxa collected were diatoms. Cluster analysis and detrended correspondence analysis of sample data showed that Orestimba Creek had a very different periphyton community than the Merced and Tuolumne Rivers. Salt Slough and the San Joaquin River had community compositions that were intermediate between the two extremes. A total of 126 taxa of macroinvertebrates were collected during the study. Samples from woody debris included 59 taxa. The samples included a variety of both insect and non-insect taxa. Cluster analysis and detrended correspondence analysis of sample data showed that Orestimba Creek was very different from the Merced River and Tuolumne River, similar to the results for periphyton. Orestimba Creek was dominated by non-insects, while the Merced and Tuolumne Rivers were dominated by insects. Salt Slough was more similar to Orestimba Creek because of the abundance of non-insects. The San Joaquin River was more similar to the Merced and Tuolumne Rivers.

There was no evidence of major differences between June and September samples for either the periphyton or macroinvertebrate communities. Specific conductance (a surrogate for salinity) and several habitat measures were associated with differences in the periphyton and macroinvertebrate communities at the five sites. Additional sampling at more sites over a longer period of time will likely be necessary before the effects of water quality and habitat conditions on aquatic communities are fully understood in the San Joaquin River Basin.

Introduction

Agriculture in California's San Joaquin Valley is both productive and valuable. The availability of water for irrigation, the Mediterranean climate, and the long growing season have combined to make the valley one of the most intensively farmed and economically important agricultural regions in the United States. In 2000, California's agricultural industry produced a gross cash income of 27 billion dollars and supplied more than half of the nation's fruits, nuts, and vegetables (California Department of Food and Agriculture 2001). The San Joaquin Valley accounted for most of this production.

This agricultural activity includes widespread and intensive use of various pesticides. The occurrence and concentrations of these compounds and their effects on water quality have been a long-standing concern in the region (Domagalski and others, 1997; Panshin and others, 1998; Kratzer, 1999; Kratzer and others, 2002; Domagalski and Munday, 2003; Zamora and others, 2003). The potential toxicity of dissolved pesticides to aquatic organisms has been a particular concern (Foe and Connor, 1991; Foe, 1995; Kuivila and Foe, 1995). Studies addressing the potential toxicity have focused on the results of laboratory toxicity tests (Foe and Connor, 1991; Foe, 1995; Kuivila and Foe, 1995). Toxicity to the invertebrate *Ceriodaphnia dubia* has often been observed in these studies, and the toxicity was linked to several dissolved pesticides. However, the effects of dissolved pesticides on the resident aquatic communities of affected water bodies have not been evaluated in detail.

The Central Valley Regional Water Quality Control Board (CVRWQCB) is in the process of formulating and applying pesticide total maximum daily loads (TMDLs) in various water bodies of the San Joaquin River Basin. As part of this process, biological assessments (hereinafter, bioassessments) have been identified as an important tool for assessing the success of the TMDLs in protecting or improving beneficial uses of these water bodies. Most existing bioassessment procedures have been developed for small wadeable streams with riffles. These procedures are difficult to apply in most Central Valley streams, which tend to have fine grained bottoms and few, if any, riffles. Protocols developed by the National Water Quality Assessment Program (NAWQA) for bioassessment of macroinvertebrate and algae communities (Moulton and others, 2002) have been successfully used by U.S. Geological Survey (USGS) personnel in the San Joaquin River and its tributaries (Brown and May, 2000a,b; Leland and others, 2001). A detailed NAWQA protocol for characterization of stream habitat also has been developed (Fitzpatrick and others, 1998).

Purpose and Scope

The purpose of this report is to present the results of bioassessments of macroinvertebrate and periphyton communities, using NAWQA protocols, in selected water bodies of the San Joaquin River Basin. The results of stream habitat assessments conducted in support of the bioassessments are also reported. These results will be used to document existing conditions in the selected water bodies. The importance of habitat quality and water quality in determining the community structure of the resident macroinvertebrate and algae communities also was assessed.

Study Area

The perennial San Joaquin River Basin drains a total area of 7,345 mi^2. Of this area, 59 percent lies in the Sierra Nevada, 11 percent in the Coast Ranges, and 30 percent in the San Joaquin Valley. The Sierra Nevada and Coast Ranges portions of the drainage are predominantly forested land. Virtually all irrigated agriculture and most pesticide applications occur in the San Joaquin Valley portion of the drainage; thus, this study focuses on the San Joaquin Valley portion of the perennial San Joaquin River Basin (*fig. 1*).

The climate in the San Joaquin Valley is arid-to-semiarid, characterized by hot, dry summers and cool, wet winters. Most precipitation falls during November through April. The average annual precipitation ranges from 13 to 40 cm in the valley and increases to amounts ranging from 102 to more than 228 cm at the higher altitudes in the Sierra Nevada (Gronberg and others, 1998; Panshin and others, 1998). Precipitation is highly variable from year to year. The year that was sampled in this study, 2001, was classified as dry on the basis of a water availability index with the categories—wet, above normal, below normal, dry, and critical (California Department of Water Resources, 2003). Most of the precipitation in the San Joaquin River Basin occurs as snow in the Sierra Nevada.

The surface-water hydrology of the San Joaquin River drainage has been substantially altered to store and distribute water derived from snowmelt in the Sierra Nevada. Every major river in the study area has one or more reservoirs. This water is subsequently used for irrigated agriculture and a variety of other urban and environmental uses. USGS streamflow records for 1951 to 1995 show 66 percent of the flow of the perennial San Joaquin River was contributed by the three large eastern tributaries: the Merced River (15 percent), the Tuolumne River (30 percent), and the Stanislaus River (21 percent). Bear Creek, Mud and Salt Sloughs, ephemeral streams draining the Coast Ranges, drainage canals that flow directly to the San Joaquin River and occasionally the upper San Joaquin River upstream of Bear Creek, contributed the remaining 34 percent of streamflow.

Methods

Sampling Design

The CVRWQCB helped identify five sites to be sampled in the study (*table 1*, *fig. 1*). Each site was sampled twice, once in June 2001 and once in September 2001. The sites were sampled twice to determine if there were any major differences in periphyton or benthic macroinvertebrate communities related to spring (June) or summer (September) sampling. All sampling activity was conducted within a reach of stream defined as 20 times the mean channel width, and within the range of 150 m to 1,000 m long. Habitat variables were assessed according to Fitzpatrick and others (1998) during both visits. The habitat variables and methods of measurement are given in *table 2*. Individual habitat variables at a reach were measured at one of three scales—the entire reach, at 11 equidistant transects across the stream, or at three points each on each of the 11 equidistant transects (*table 2*). We also used daily flow records to evaluate flow variability at the sites. Data were obtained from either USGS or California Department of Water Resources gaging stations.

Periphyton

Three different types of periphyton samples were collected—richest targeted habitat (RTH), depositional targeted habitat (DTH), and qualitative multihabitat (QMH) (Moulton and others, 2002). The RTH sample represents a habitat that is found at all sites, and that is expected to have a high diversity of species. From previous studies (Leland and others, 2001), large woody debris (snags) was selected as the RTH habitat. The DTH sample was taken from low velocity areas with fine substrate. The QMH sample was collected from all available habitat types with the purpose of assembling a complete species list for the site. All sampling procedures are described in detail in Moulton and others (2002).

The RTH sample was collected by removing a snag from the water and scraping a small area from the top of the snag with a knife. All the material removed was placed in a sample bottle and the area scraped was measured with a ruler. One snag was sampled at each of five different locations within the sampling reach. All samples were composited into a single

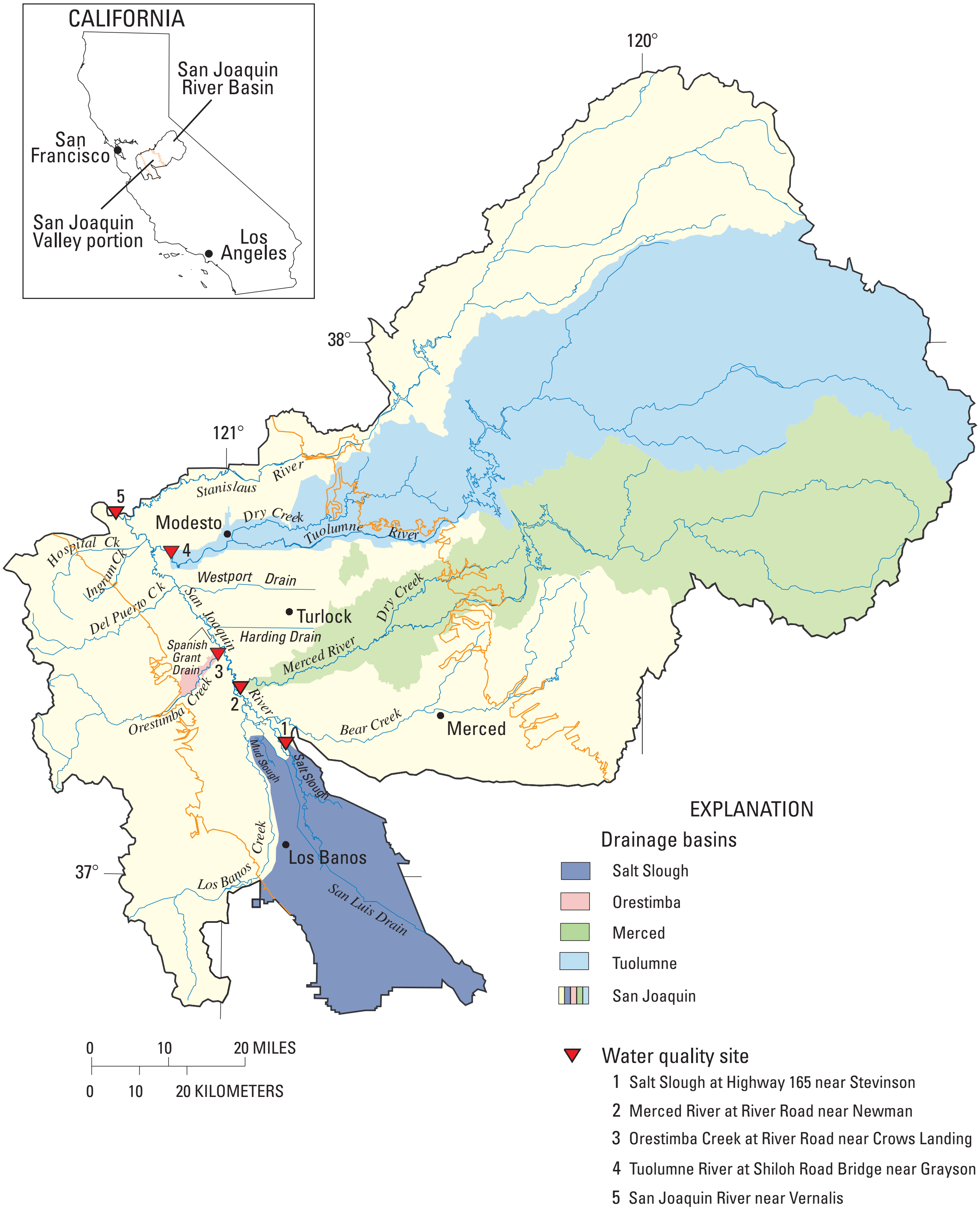

Figure 1. Locations of sampling sites and drainage basins in the San Joaquin River Basin, California.

Table 1. Sites sampled in 2001 in the San Joaquin River Basin, California.

[mi^2, square mile]

USGS Station Number	Site number	Station name	Total basin area[1] (mi^2)	Valley- portion of basin area[2] (mi^2)	Dates sampled
11261100	1	Salt Slough at Highway 165 near Stevinson	492	492	June 27 and September 19, 2001
11273500	2	Merced River at River Road near Newman	1,276	321	June 26 and September 18, 2001
11274538	3	Orestimba Creek at River Road near Crows Landing	196	11	June 25 and September 17, 2001
11290200	4	Tuolumne River at Shiloh Road Bridge near Grayson	1,897	319	June 28 and September 20, 2001
11303500	5	San Joaquin River near Vernalis	13,536	7,395	June 29 and September 21, 2001

[1] Topographical drainage basin.

[2] Portion of the topographical drainage basin on the valley floor with perennial flow.

Table 2. Physical habitat variables measured in June and September 2001 at five sites in the San Joaquin River Basin, California.

[m, meter; m/km, meter per kilometer; m/s, meter per second; mm, milimeter]

Variable (units)	How measured	Equipment used
Reach length (m)	Mid-channel distance from top to bottom of sampling reach	Laser rangefinder
Reach water-surface gradient (m/km)	Vertical drop from top to bottom of sampling reach	Surveying level and surveying rod
Geomorphic channel units (m)	Percentage of reach distance consisting of pool, riffle, and run	Laser rangefinder or measuring tape
Wetted channel width (m)	Width of wetted channel at 11 equidistant transects	Laser rangefinder or measuring tape
Bankfull channel width[1] (m)	Channel width from top of left bank to top of right bank, at each of 11 equidistant transects	Laser rangefinder or measuring tape
Canopy angles (degrees)	Degrees of open sky, measured from the midpoint of each of 11 equidistant transects	Clinometer
Riparian canopy closure (percent)	Percentage of canopy at the left bank and the right bank, measured at each of 11 equidistant transects	Densiometer
Bank angle (degrees)	Horizontal angle (degrees) of the bank at the left bank and the right bank, measured at each of 11 equidistant transects	Clinometer
Bank height (m)	Vertical distance from the deepest part of the channel to the top of the bank, measured for the left and right bank at each of 11 equidistant transects	Hand level and surveying rod
Bank substrate[2]	Dominant bank substrate at left and right bank at each of 11 equidistant transects	Visual estimate
Depth (m)	Depth at thalweg (deepest point) and two additional evenly spaced points, at each of 11 equidistant transects	Calibrated wading rod, or depth sounder
Water velocity (m/s)	Water velocity at thalweg (deepest point) and two additional evenly spaced points, at each of 11 equidistant transects	Marsh-McBirney electronic flow meter
Bed substrate[2]	Dominant substrate at thalweg (deepest point) and two additional evenly spaced points, at each of 11 equidistant transects	Visual estimate

[1] In regulated rivers, the traditional concept of bank (channel formed by the 1.5 to 2 year flood) is difficult to apply. For these measurements we used visible water marks, erosion, trash lines, and vegetation as indicators of "bank" position.

[2] The dominant substrate was characterized as: 1, concrete; 2, silt, mud, or detritus; 3, sand (>0.063–2 mm); 4, fine/medium gravel (>2–16 mm); 5, coarse gravel (>16–32 mm); 6, very coarse gravel (>32–64 mm); 7, small cobble (>64–128 mm); 8, large cobble (>128–256 mm); 9, small boulder (>256–512 mm); 10, large boulder, irregular bedrock, irregular hardpan, or irregular artificial surface.

bottle and preserved in a solution of 4 percent buffered formalin.

The DTH sample was collected using the inverted petri-dish method. The lid of a 47-mm petri dish is placed underwater and all air bubbles removed from the underside. The petri dish is then carefully pressed into the substrate, edge-side down. A spatula is then slid under the lid and sealed against the edge of the petri dish. This shallow core is then removed and the material scraped and washed into the sample bottle. As with the RTH samples, one petri-dish sample was taken at each of five different locations within the sampling reach. All samples were composited into a single bottle and preserved with 4 percent buffered formalin.

The QMH sample was collected with a variety of methods including the scraping of woody debris and the petri-dish method. In addition, a turkey baster was used to sample periphyton from sand, aquatic macrophytes, and filamentous algae. All the samples were composited into a single bottle and preserved in a solution of 4 percent buffered formalin.

Periphyton were identified and enumerated at the Philadelphia National Academy of Science (PNAS) according to Charles and others (2002).

Benthic Macroinvertebrates

Two types of macroinvertebrate samples were collected, an RTH and a QMH. Similar to periphyton, the RTH sample was collected from woody debris. A section of woody debris was removed from a larger piece using pruning shears or a saw. The pieces were then gently removed from the water and placed in a bucket. A 500-µm mesh net was held downstream of the snag to capture organisms that were dislodged during snag removal. One sample was taken from a single snag at each of five different locations within the sampling reach. The associated macroinvertebrates were then removed by gently brushing and hand picking with forceps. All organisms from the snags and net were then rinsed in a 500-µm sieve. All organisms were combined in a single bottle and preserved in a solution of 10 percent buffered formalin. The length and average diameter of each snag was measured for calculation of sample areas.

The QMH sample was collected from all available habitat types within the reach. All sampling was conducted with a 500-µm mesh D-frame net. Woody debris and other hard substrates (concrete and rock) were sampled by brushing material into the net. The net was swept through aquatic macrophytes, filamentous algae, overhanging terrestrial vegetation and areas with fine substrates. All organisms from the net were then rinsed in a 500-µm sieve. All organisms were combined in a single bottle and preserved in a solution of 10 percent buffered formalin.

Macroinvertebrates were identified and enumerated at the USGS's National Water Quality Laboratory using the procedures of Moulton and others (2000).

Data Analysis

Habitat variables were summarized as mean and standard deviation for each sampling event at each site. Daily flow records were summarized graphically, and as mean, standard deviation, and coefficient of variation. Periphyton and macroinvertebrate species lists were constructed using all taxa collected in all sample types. Quantitative analyses (see below) were conducted on RTH algae data (cells/cm^2) and RTH macroinvertebrate data (organisms/m^2). DTH algae data were not analyzed quantitatively (see below) because accurate counts of diatoms were not possible in the samples from Orestimba Creek. A combination of low diatom density and excessive fine sediment in Orestimba Creek made it unfeasible to concentrate the sample to the extent needed to obtain accurate diatom counts. The taxa present in the DTH samples from sites other than Orestimba Creek were included in the taxa lists for those sites.

RTH macroinvertebrate and RTH algae data were analyzed using cluster analysis and ordination (detrended correspondence analysis). Data were analyzed as presence–absence and as densities. Only species found at two or more sites were included in these analyses. This was a compromise between the value of rare species in characterizing sites (Cao and others, 2001), and the uncertainty regarding the capability of sampling procedures to detect rare species. Presence–absence data were analyzed using Jaccards similarities followed by a group average linkage method cluster analysis. Jaccards similarity is calculated as, 2C/(A + B + C), where A is the number of taxa found only at site 1, B is the number of taxa found only at site 2, and C is the number of taxa found at both sites. Jaccards similarity varies from 1 (all taxa shared) to 0 (no taxa shared). Clustering, in general, is a group of methods that produce a hierarchical arrangement of samples that are based on similarities between samples (see Gauch, 1982). The method starts with each sample assigned to a cluster with a single member and then uses a distance measure to group similar clusters into larger clusters until a final single cluster contains all the samples. Thus, more similar sites are closer in distance and cluster together. The results are portrayed graphically as a dendrogram (see *fig. 3* as an example). The similarity of different groups can be assessed by observing the "percentage of information remaining" at branching points. All information is present when individual sites are considered and no information remains when all sites have been combined into a single group.

Detrended correspondence analysis (DCA), a special case of correspondence analysis, is an indirect ordination technique. This means that community structure at specific sites (the group of taxa found there) is determined independently of environmental variables. The basic idea behind correspondence analysis is that species are assigned weighted scores depending on their interrelationships and then the samples are scored on the basis of the abundance of each species in that sample. The result of the analysis is a set of species scores and

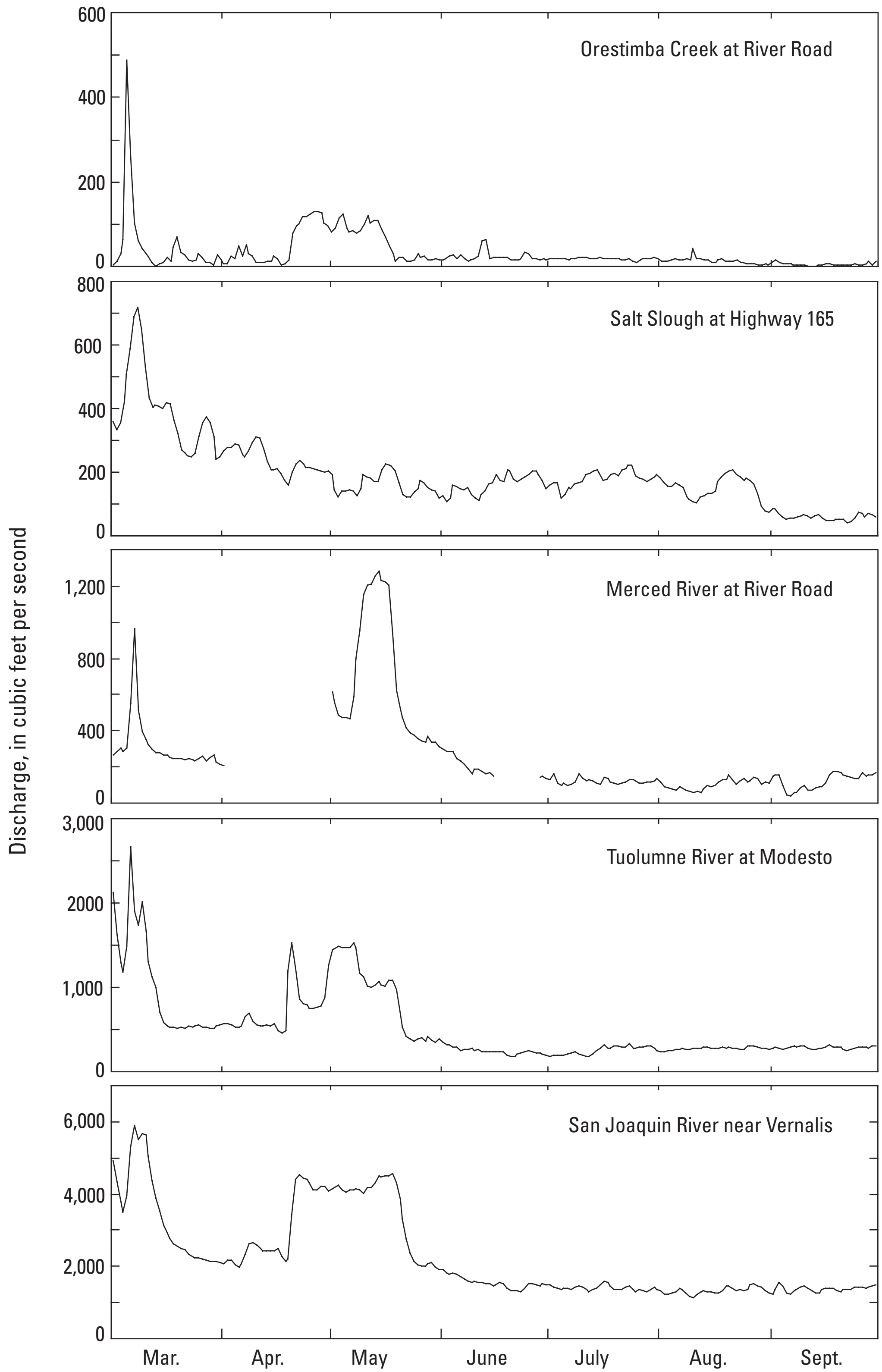

Figure 2. Discharge records from March through April for sampling sites in the San Joaquin River Basin, California. Some site names are abbreviated from those in table 1. The Tuolumne River at Shiloh Road site is replaced by the Tuolumne River at Modesto site USGS gaging station 11290000), which is located several miles upstream from the Tuolumne River at Shiloh Road site. Periods when the gage at the Merced River site was not operating properly are indicated by the broken line.

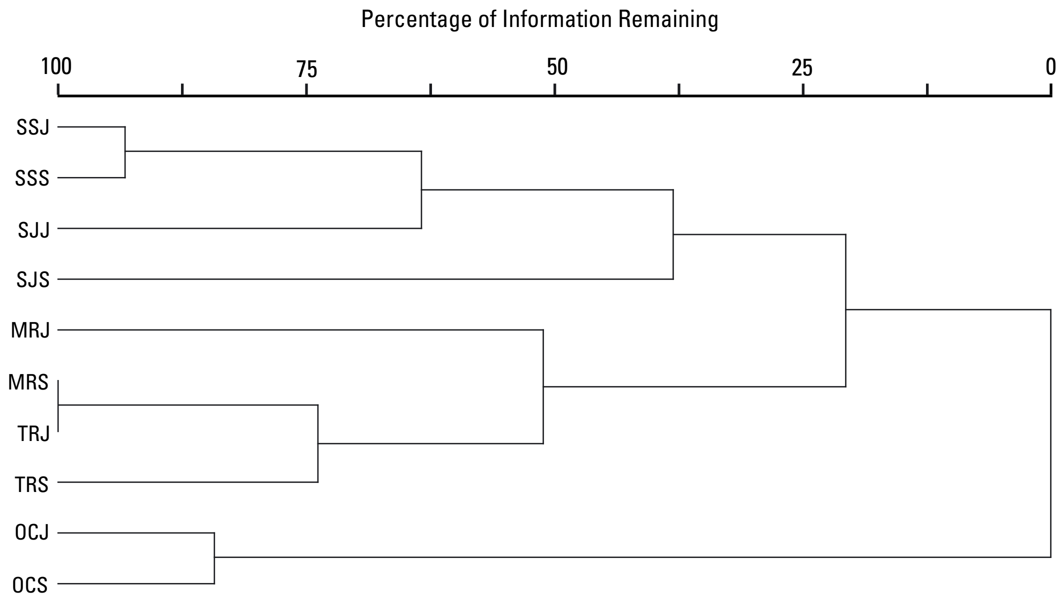

Figure 3. Cluster dendrogram showing the results of a group average linkage cluster analysis of periphyton presense–absense data. The first two letters of the site codes refer to the river (OC, Orestimba Creek; SS, Salt Slough; SJ, San Joaquin River; MR, Merced River; TR, Tuolumne River). The third letter indicates the month of sampling (J, June; S, September).

a set of sample scores that can be used to understand ecological relationships between species and samples (see *fig. 4* as an example). Relationships of communities to environmental variables must be determined after the ordination, for example, by correlating sample scores with values for environmental variables, such as specific conductance.

Relationships of RTH algae and RTH invertebrate communities to environmental variables were explored using correlation analysis. Pearson product-moment correlations were calculated between the environmental variables and the sample scores on DCA axis 1. Data were then plotted for all correlations with $r > 0.5$. Significance values are not reported because the data likely violate several assumptions of correlation. Most importantly, the June and September samples collected from each site would not be expected to be independent. Taxa present in June have a high probability of also being present in September. However, the plots might be useful in identifying variables of interest for future studies.

Results and Discussion

Environmental Variables

The sites sampled ranged from a small agricultural drain, Orestimba Creek, to a large river, the San Joaquin River, and these differences are reflected in the values for habitat variables (*table 3*, at back of report). Orestimba Creek is notable for having a much steeper gradient, steeper banks, and a more closed canopy than the other sites (*table 3*).

There are differences between June and September for several sites, related to discharge (*table 3*). Discharge was similar in June and September at the Merced River, Tuolumne River, and San Joaquin River sites. September discharge was a quarter or less of June discharge at Salt Slough and Orestimba Creek. These changes in discharge were associated with declines in mean water depth and water velocity (*table 3*). There were some differences in specific conductance between June and September, especially for Salt Slough and Orestimba Creek, both of which had increases of about 50 percent from June to September (*table 3*).

There are also differences in discharge patterns among the sites (*fig. 2* and *table 4*). All the streams exhibited an early March high flow, likely related to rainfall. All sites except Salt Slough, had elevated flows from mid-April to mid-May related to water releases made for salmon management activities in the San Joaquin River. Flows in the Merced, Tuolumne, and San Joaquin Rivers were relatively constant during June through September. Flows in Salt Slough and Orestimba Creek were more variable during this time (*table 4*). Orestimba Creek was the most variable stream during the summer, with a coefficient of variation of 51 percent. Flow at Orestimba Creek varied between 1 and 41 ft^3/s.

Periphyton

A total of 161 taxa of algae were collected during the study (*table 5*, at back of report). All but three taxa were identified to species. Two of the three taxa are the cyanophytes (bluegreen algae) *Oscillatoria* and *Lyngbya*, and the third is

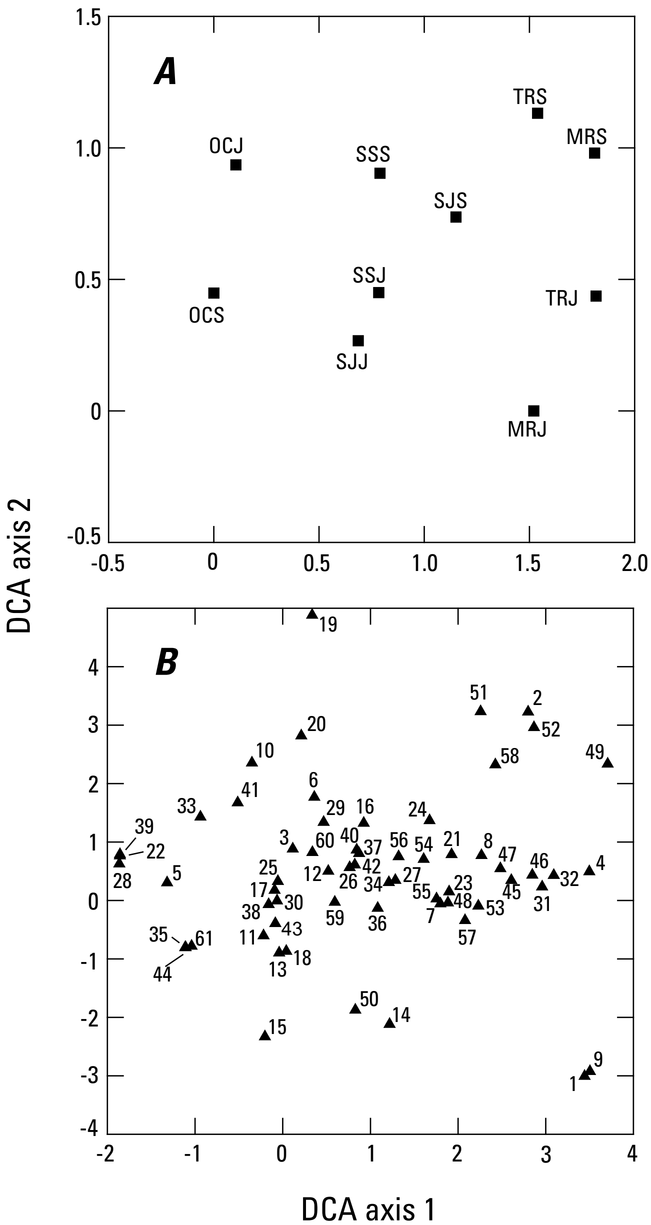

Figure 4. Plots of site scores and taxa scores on the first two axes of a detrended correspondence analysis (DCA) of periphyton abundance data. The first two letters of the site codes refer to the river (OC, Orestimba Creek; SS, Salt Slough; SJ, San Joaquin River; MR, Merced River; TR, Tuolumne River). The third letter indicates the month of sampling (J, June; S, September). Taxa codes are listed in table 6. (A) Site scores. (B) Taxa scores.

an unidentified diatom in the genus *Caloneis*. The periphyton were dominated by diatoms. Of the 161 taxa collected, 155 (96 percent) were diatoms. Many of the taxa were rare, with 67 (42 percent) found in only one sample. The number of taxa found in each sample varied from 39 to 67. Orestimba Creek had the lowest number of taxa, with 39 in June and 40 in September. Salt Slough had more taxa than Orestimba Creek (52 in June and 50 in September) but fewer than the other sites, which ranged from 58 to 67 taxa. The differences between seasons were minor, with a maximum difference of four taxa at the San Joaquin River site. The low number of taxa found at Orestimba Creek was at least partially due to the low density of algae cells in the DTH sample. The high concentration of fine sediment in these samples made it unfeasible to concentrate the samples so that accurate counts could be conducted; however, the PNAS did state that there were very few algae of any kind in these samples.

The RTH samples collected from snag habitat included 109 taxa, including 106 species of diatoms (97 percent) (*table 6*, at back of report). In addition, the samples included one species of Chlorophyta (green algae) and two taxa of Cyanophyta (blue-green algae). Forty-eight taxa (43 percent) were found in only one sample and were not included in the quantitative analyses.

Jaccards similarities vary from 0.255 to 0.636 among the samples. This means that after removing the taxa found in only one sample, any two samples shared from 25 percent to 63 percent of the total taxa found in those two samples. The cluster analysis (*fig. 3*) indicates that samples collected from the same site in June and September tend to be more similar to each other than to samples collected from other sites; however, there are some exceptions. The highest similarity (0.636) is found between the June sample from the Tuolumne River and the September sample from the Merced River. The June sample from the San Joaquin River is more similar to the two Salt Slough samples (0.535 and 0.512) than to the September sample from the San Joaquin River (0.413).

The first four axes of the DCA explain 28, 7, 4, and 1 percent of the variance, respectively. A plot of sample scores on the first two DCA axes (*fig. 4*) generally supports the results of the cluster analysis. Scores on DCA axis 1 of samples from the same site tend to be similar between the two months sampled. DCA axis 1 scores show that Orestimba Creek was most different from the Merced and Tuolumne Rivers with Salt Slough (SSJ and SSS on *fig. 4A*) and the San Joaquin River (SJJ and SJS) having intermediate scores (*fig. 4A*). DCA axis 2 mainly separates samples from different months (*fig. 4A*). September samples tend to have higher scores on DCA axis 2 compared with June samples, except for Orestimba Creek, which has the opposite pattern.

Interpretation of the taxa score plot (*fig. 4B*) is difficult because there are few environmental preference and tolerance data available for species of algae. Basically, taxa located to the left in the taxa plot (*fig. 4B*) tend to be more abundant in samples with low scores on DCA axis 1 (*fig. 4A*), and taxa located to the right in the taxa plot (*fig. 4B*) tend to be more abundant in samples with higher scores on DCA axis 1 (*fig. 4A*).

Specific conductance, water temperature, and several habitat variables appear to be related to periphyton DCA axis 1 site scores (*fig. 5*). The habitat relationships of gradient, open canopy, and shade are dependent on Orestimba Creek being very different from the other sites (*fig. 5*). High variability in flow (*tables 3* and *4*) at Orestimba Creek is probably also an important factor affecting ecological communities,

Table 4. Discharge statistics for the periods from March 1, 2001 to the date of the June 2001 sample (spring) and from the June sample to the September 2001 sample (summer).

[ft^3/s, cubic feet per second]

Station name	Time period	Minimum discharge (ft^3/s)	Maximum discharge (ft^3/s)	Mean discharge (ft^3/s)	Standard deviation	Coefficient of variation
Salt Slough at Highway 165 near Stevinson	Spring	106	717	241	120	50
	Summer	48	223	53	53	38
Merced River at River Road near Newman[1]	Spring	150	1,284	440	317	72
	Summer	38	176	110	29	27
Orestimba Creek at River Road near Crows Landing	Spring	1	488	47	59	126
	Summer	1	41	13	7	51
Tuolumne River at Shiloh Road Bridge near Grayson[1]	Spring	182	2,670	732	495	68
	Summer	178	329	268	37	14
San Joaquin River near Vernalis	Spring	1,310	5,900	2,900	1,232	42
	Summer	1,150	1,600	1,365	86	6

[1] Discharge calculated from data provided by the California Department of Water Resources.

especially because the low flows probably resulted in much of the habitat for periphyton and invertebrates being exposed to air for some amount of time. Bank angle could be related to the degree of shading as indicated by a low value for open canopy angle and a high percent canopy cover (*table 3*). It is unclear how bank substrate would directly affect periphyton communities on woody debris. It seems likely that bank angle, water temperature, and the other habitat variables simply indicate that Orestimba Creek is a unique habitat among the five sites—a relatively steep, incised stream receiving mainly agricultural drainage water—which favors a different periphyton community compared with the other sites. It is unclear whether inclusion of a wider variety of water bodies in the analysis, with a wider range of habitat characteristics, would strengthen or weaken these habitat relationships.

Leland and others (2001) found that specific conductance (a surrogate for salinity) was a major determinant of periphyton community structure in the lower San Joaquin River drainage. In addition, dissolved inorganic nitrogen concentration was found to be a good predictor of periphyton communities as long as sufficient numbers of tributary sites with low concentrations of inorganic nitrogen were included in the model (Leland and others, 2001). The importance of specific conductance in structuring the periphyton community is supported by the plot of DCA axis 1 site scores against specific conductance (*fig. 5*). We did not collect nutrient data as part of this study; therefore, we cannot comment on the potential effects of inorganic nitrogen on the periphyton community.

Macroinvertebrates

A total of 126 taxa of macroinvertebrates were identified from a least one sample during the study (*table 7*, at back of report). Specimens were reported at a variety of taxonomic levels for various reasons. Most often, small or damaged individuals of insect larvae could not be identified to species. Some non-insect taxa are also difficult to identify because of size, or poorly known or difficult taxonomy.

A total of 59 taxa were found in the RTH samples collected from snag habitat (*table 8*, at back of report). Twenty taxa were found in only one sample. Taxa per sample ranged from 10 in the September sample from Salt Slough to 27 in the September sample from Merced River. Orestimba Creek and Salt Slough had fewer species in September compared with June. The Merced, Tuolumne, and San Joaquin Rivers had the same or more species in the September samples compared to the June samples (*table 8*).

Jaccards similarities vary from 0.115 to 0.652 among the samples. This means that after removing the taxa found in only one sample, any two samples shared from 11 to 65 percent of the total taxa found at those two sites. The cluster analysis (*fig. 6*) indicates that the June and September samples from Orestimba Creek are very similar to each other and the June and September samples from Salt Slough are very similar to each other. The macroinvertebrate communites of Orestimba Creek and Salt Slough were very different from each other and from the other sites. In contrast, June samples from the Merced and Tuolumne Rivers have the highest similarity (0.636), and September samples from these sites have the second highest similarity (0.630). The San Joaquin River samples are more similar to the Merced and Tuolumne River samples than to the Orestimba Creek and Salt Slough samples (*fig. 6*). The June sample from the San Joaquin River is more similar to the Merced and Tuolumne River samples than the September sample from the San Joaquin River.

The first four axes of the DCA explain 32, 9, 3, and 1 percent of the variance, respectively. A plot of sample scores on the first two DCA axes (*fig. 7A*) generally supports the

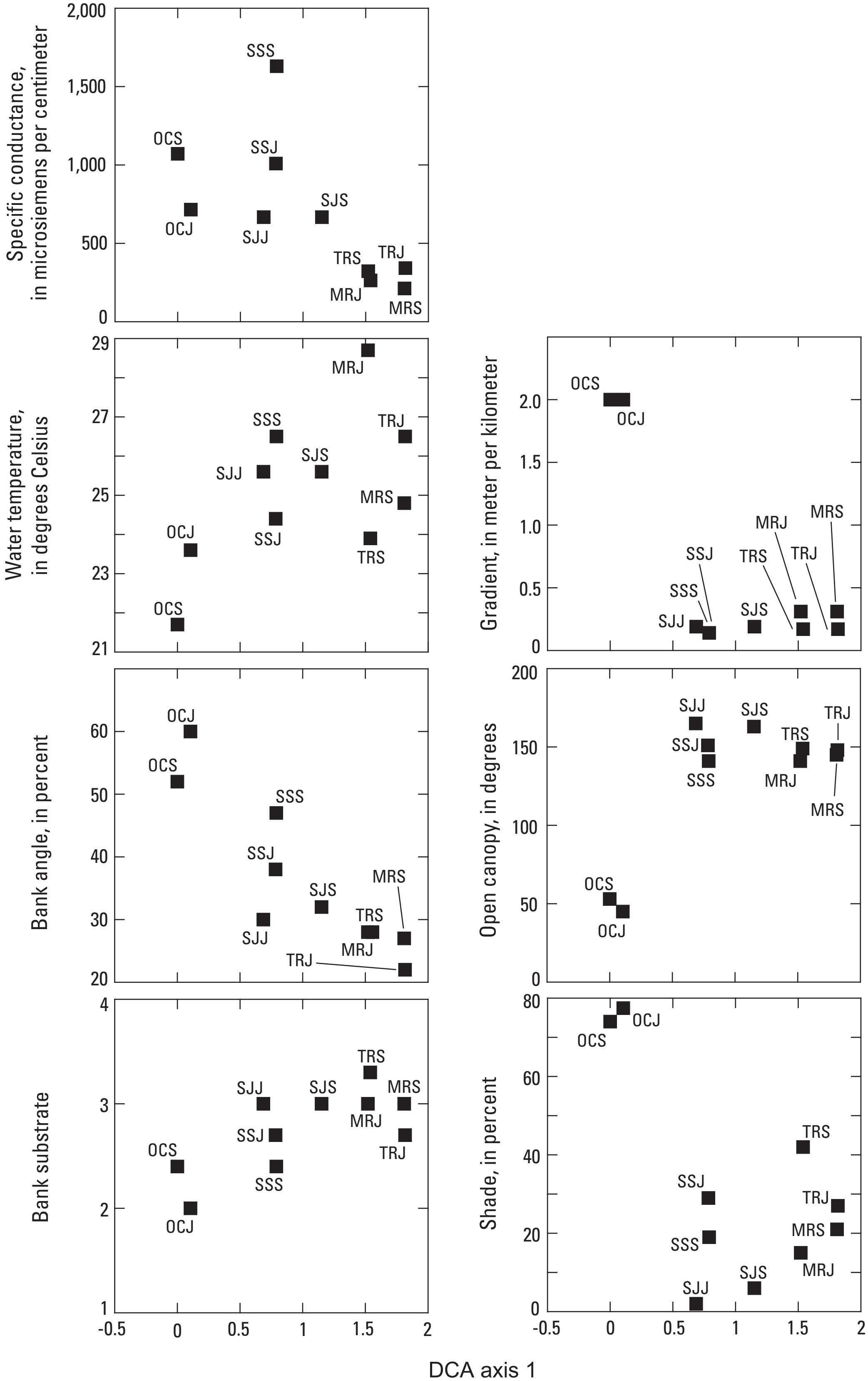

Figure 5. Plots of periphyton detrended correspondence analysis (DCA) axis 1 site scores with selected environmental variables. The first two letters of the site codes refer to the river (OC, Orestimba Creek; SS, Salt Slough; SJ, San Joaquin River; MR, Merced River; TR, Tuolumne River). The third letter indicates the month of sampling (J, June; S, September). For bank substrate, 2 = silt and 3 = sand.

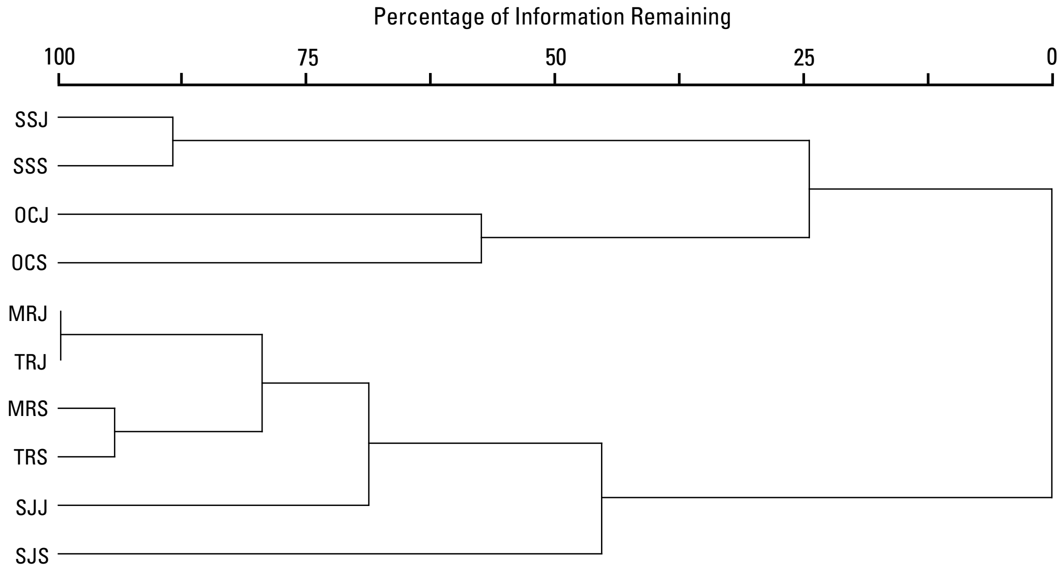

Figure 6. Cluster dendrogram showing the results of a group average linkage cluster analysis of macroinvertebrate presence–absence data. The first two letters of the site codes refer to the river (OC, Orestimba Creek; SS, Salt Slough; SJ, San Joaquin River; MR, Merced River; TR, Tuolumne River). The third letter indicates the month of sampling (J, June; S, September).

results of the cluster analysis. DCA axis 1 scores show that samples from Orestimba Creek and Salt Slough are distinct from samples from the other streams. The more intermediate position of the September San Joaquin River sample is consistent with the position of this sample in the cluster dendrogram (*fig. 6*). There is no obvious pattern to the distribution of samples along DCA axis 2 (*fig. 7A*).

Examination of the taxa plot (*fig. 7B*) shows two groups of taxa, similar to the two groups of sample scores. One group, with scores of less than one, is dominated by non-insect taxa, except for several groups of dipterans including ceratopogonids (21), dolichopodids (39), and several genera of chironomids (29 and 30). The group with scores greater than one is dominated by insects with the only non-insects being the amphipod, *Hyallela azteca* (13), and the water mites (11). The two plots together show that samples from Orestimba Creek and Salt Slough were characterized by high abundances of non-insects. Samples from the Merced, Tuolumne, and San Joaquin Rivers were characterized by high abundances of insects.

These results are consistent with earlier work in the Central Valley. Brown and May (2000a,b) found that environmentally stressful agricultural drains and urban streams were dominated by the same tolerant non-insect taxa observed in this study. Brown and May (2000a) found that tributaries draining the Sierra Nevada (including the Stanislaus, Tuolumne, and Merced Rivers) had similar benthic macroinvertebrat communities characterized by high abundances of insects. Brown and May (2000a) defined two groups of “drain sites” that included samples from agricultural drains, including Orestimba Creek and an urban stream. Further analysis by Brown and May (2000a) found that specific conductance and the percentage of agricultural and urban land use in the basins are important variables that explain the differences in macroinvertebrates among sites, with the drain sites representing the most stressful environments and the tributary sites representing the least stressful environments. Similarly, Leland and Fend (1998) found that tributary rivers—Stanislaus, Tuolumne, and Merced Rivers—had different macroinvertebrate communities than sloughs or sections of the San Joaquin River influenced by large inputs of agricultural drainage water. Leland and Fend (1998) also identified salinity as an important explanatory variable for understanding benthic macroinvertebrate communities in the Central Valley.

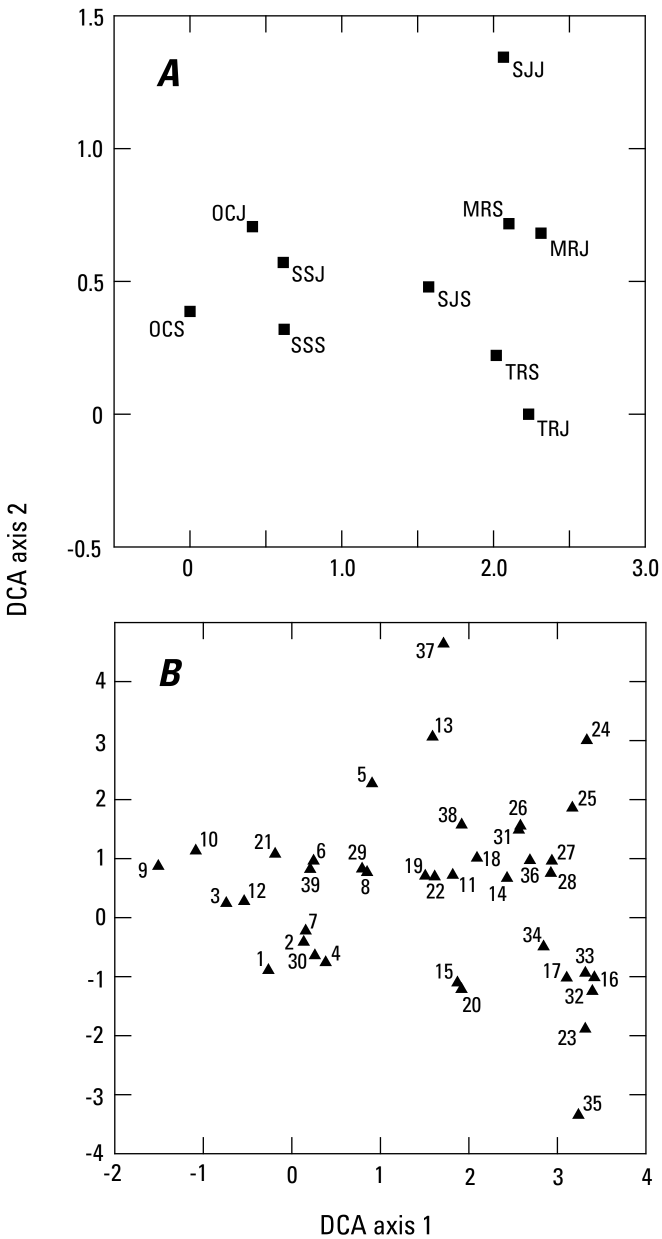

Figure 7. Plots of site scores and taxa scores on the first two axes of a detrended correspondence analysis (DCA) of macroinvertbrate abundance data. The first two letters of the site codes refer to the river (OC, Orestimba Creek; SS, Salt Slough; SJ, San Joaquin River; MR, Merced River; TR, Tuolumne River). The third letter indicates the month of sampling (J, June; S, September). Taxa codes are listed in table 8. (A) Site scores. (B) Taxa scores.

Examination of plots of DCA axis 1 scores against environmental variables (*fig. 8*) supports the importance of specific conductance, a surrogate for salinity. Similar to the results for periphyton, values for Orestimba Creek samples appear to be responsible for the relationships between DCA axis 1 and water temperature, gradient, shade, and open canopy. The differences in bank substrate are small, basically indicating a slightly higher occurrence of silt (a score of 2) along with sand (a score of 3) at Orestimba Creek and Salt Slough compared with the other sites. As noted earlier for periphyton, the relationship of DCA axis 1 to bank angle may be related to canopy cover. Channel width and bankfull width (not plotted, but similar to channel width) also appear to have relationships to DCA axis 1 sample scores; however, it seems unlikely this relationship is real because the widest channel at the San Joaquin River site actually had intermediate DCA axis 1 scores. As mentioned earlier for periphyton, flow fluctuation and low flows at Orestimba Creek (*table 3*) are also probably important in determining composition of the periphyton and macroinvertebrate communities.

We did not sample pesticides in this study, despite concerns regarding potential toxicity of dissolved pesticides to aquatic life (Foe and Connor, 1991; Foe, 1995; Kuivila and Foe, 1995). However, dissolved pesticide concentrations were measured at these sites as part of another study, covering the period from April to August 2001 (Domagalski and Munday, 2003). In general, dissolved pesticides were most frequently detected and at the highest concentrations at Orestimba Creek. Unfortunately, Orestimba Creek also had the most unique habitat, so the relative effects of dissolved pesticides and other habitat and water-quality variables, particularly specific conductance, cannot be separated. This is a common problem when evaluating bioassessment data (Brown and others, 1999). Further, the ecological risks associated with dissolved pesticides are typically assessed for single pesticides (Giddings and others, 2000) rather than for complex mixtures found in San Joaquin Basin streams.

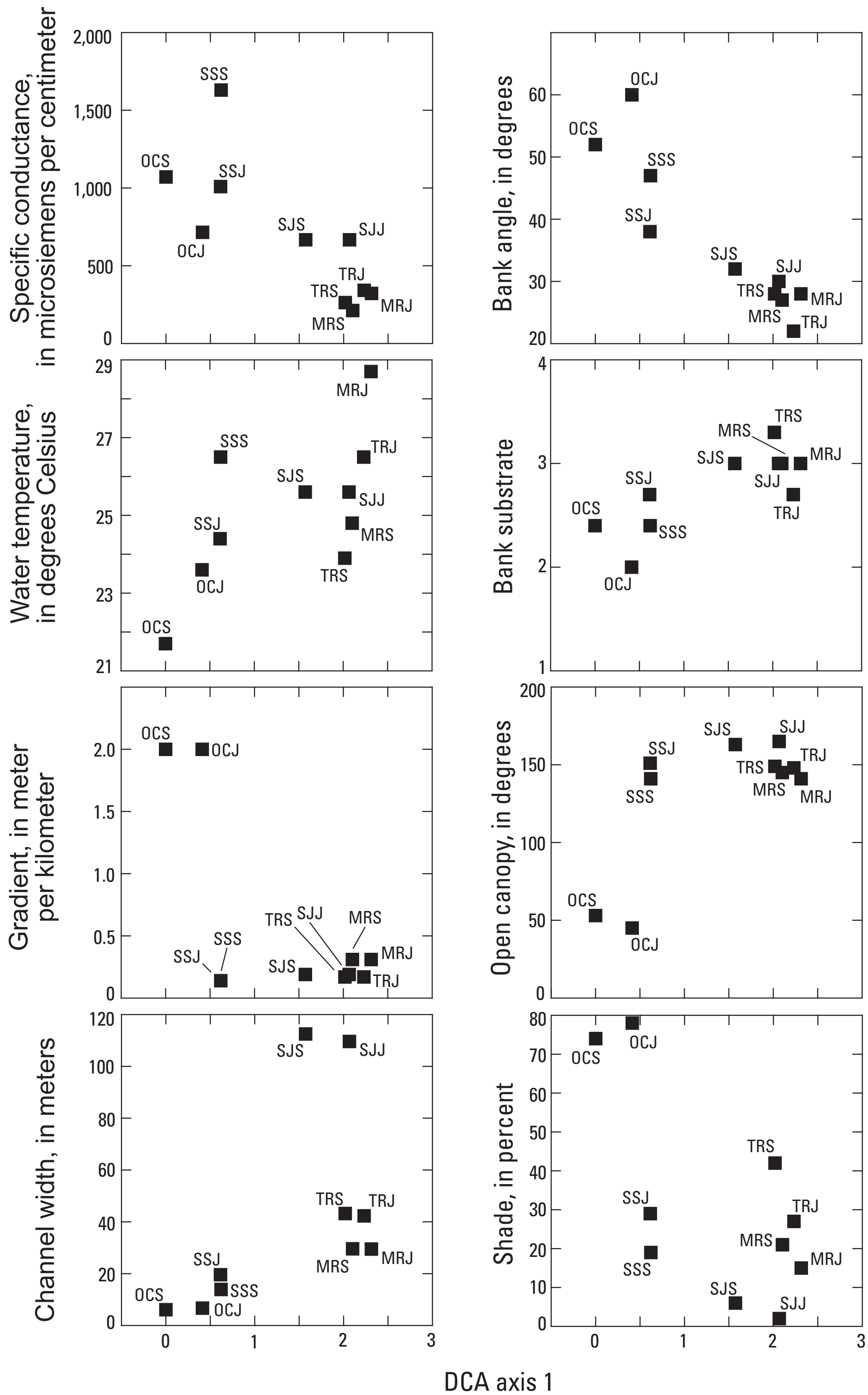

Figure 8. Plots of macroinvertebrate detrended correspondence analysis (DCA) axis 1 site scores with selected environmental variables. The first two letters of the site codes refer to the river (OC, Orestimba Creek; SS, Salt Slough; SJ, San Joaquin River; MR, Merced River; TR, Tuolumne River). The third letter indicates the month of sampling (J, June; S, September). For bank substrate, 2 = silt and 3 = sand.

Summary and Conclusion

The widespread and intensive use of agricultural pesticides in the San Joaquin River Basin is a long standing concern in relation to potential toxicity to aquatic organisms. Data on the periphyton and macroinvertebrate communities and physical habitat were collected at five sites in the San Joaquin River Basin in June and September 2001 to provide background on existing conditions and to provide initial information on environmental factors that might be affecting the communities. A total of 161 taxa of algae and 126 taxa of macroinvertebrates were collected. Cluster analyses and detrended correspondence analysis of the data showed that the periphyton community of Orestimba Creek was different from the periphyton communities of the Merced and Tuolumne Rivers. Periphyton communites of Salt Slough and the San Joaquin River had compositions that were intermediate between Orestimba Creek and the Merced and Tuolumne Rivers. With regard to macroinvertebrates, community composition of Salt Slough was similar to Orestimba Creek, and community composition of the San Joaquin River was similar to the Merced and Tuolumne Rivers.

Examination of data plots suggested that specific conductance, a surrogate for salinity, might be an important variable affecting the composition of periphyton and macroinvertebrate communities, as had been found in earlier studies. Several physical measures of the environment also appeared to be related to the composition of periphyton and macroinvertebrate communities; however, several of these apparent relationships were mainly related to the unique communities and habitat conditions in Orestimba Creek. Orestimba Creek also had very different flow characteristics from the other sites. This study did not include extensive measures of water quality, including pesticides, that might also be influencing biological communities. Data from another study indicated that Orestimba Creek was the stream most affected by dissolved pesticides; however, there is no way to separate the effects of pesticides from those of other water quality and habitat variables.

This study provides valuable baseline data for the San Joaquin River Basin. However, the data collected have a limited temporal and spatial scope. Continued sampling at more sites over several years will likely be needed to more fully understand the composition of periphyton and macroinvertebrate communities in the San Joaquin River Basin. Habitat and water quality assessments should be conducted in concert with biological sampling to provide the necessary data to better understand the effect of land and water use on those communities.

References

Brown, L.R., and May, J.T., 2000a, Macroinvertebrate assemblages on woody debris and their relations with environmental variables in the lower Sacramento and San Joaquin River drainages, California: Environmental Monitoring and Assessment, v. 64, p. 311–329.

Brown, L.R,. and May, J.T., 2000b, Benthic macroinvertebrate assemblages and their relations with environmental variables in the Sacramento and San Joaquin River drainages, California, 1993–1997: U.S. Geological Survey Water-Resources Investigations Report 00-4125.

Brown, L.R., Kratzer, C.R., and Dubrovsky N.M., 1999, Integrating chemical, water quality, habitat, and fish assemblage data from the San Joaquin River drainage, California, *in* Scow, K.M., and others, eds., Integrated assessment of ecosystem health: Boca Raton, Fla., Lewis Publishers, p.25–62.

Cao, Y., Larsen, D.P., and Thorne, R. St.-J., 2001, Rare species in multivariate analysis for bioassessment—some considerations: Journal of the North American Benthological Society v. 20, p. 144–153.

California Department of Food and Agriculture, 2001, Agricultural Resource Directory 2001: Sacramento, Calif., California Department of Food and Agriculture, 174 p.

California Department of Water Resources, 2003, Division of Flood Management: accessed February 20, 2003, at http: cdec.water.ca.gov/cgi-progs/iodir/WSIHIST

Charles, D.F., Knowles, Candia, and Davis, R.S., eds., 2002, Protocols for the analysis of algal samples collected as part of the U.S. Geological Survey National Water-Quality Assessment Program: Philadelphia, Pa., Patrick Center for Environmental Research Report No. 02-06, Academy of Natural Sciences, 124 p.

Domagalski, J.L., Dubrovsky, N.M., and Kratzer, C.R., 1997, Pesticides in the San Joaquin River, California—Inputs from dormant sprayed orchards: Journal of Environmental Quality, v. 26, no. 2, p. 454–465.

Domagalski, J.L., and Munday, C.M., 2003, Evaluation of diazinon and chlorpyrifos concentrations and loads, and other pesticide concentrations, at selected sites in the San Joaquin Valley, California, April to August, 2001: U.S. Geological Survey, Water-Resources Investigations Report 03-4088, 60 p.

Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R., Maupin, M.A., and Gurtz, M.E., 1998, Revised methods for characterizing stream habitat in the National Water-Quality Assessment Program: U.S. Geological Survey, Water-Resources Investigations Report 98-4052. 67 p.

Foe, C.G., and Connor, Valerie, 1991, San Joaquin watershed bioassay results, 1988–1990: Sacramento, Calif., Central Valley Regional Water Quality Control Board Staff Memorandum, 79 p.

Foe, C.G., 1995, Insecticide concentrations and invertebrate bioassay mortality in agricultural return water from the San Joaquin Basin: Sacramento, Calif., Central Valley Regional Water Control Board, 190 p.

Gauch, H.G., 1982, Multivariate analysis in community ecology: Cambridge, UK, Cambridge University Press, 314 p.

Giddings, J.M., Hall, L.W., Jr., and Solomon, K.R., 2000, Ecological risks of diazinon from agricultural use in the Sacramento–San Joaquin River Basins, California: Risk Analysis, v. 20, no. 5, p. 545–572.

Gronberg, J.M., Dubrovsky, N.M., Kratzer, C.R., Domagalski, J.L., Brown, L.R., and Burow, K.R., 1998, Environmental setting of the San Joaquin–Tulare Basins, California, 1992–1995: U.S. Geological Survey Water-Resources Investigations Report 97-4205, 45 p.

Kratzer, C.R., 1999, Transport of diazinon in the San Joaquin River Basin, California: Journal of the American Water Resources Association, v. 35, no. 2, p. 379–395.

Kratzer, C.R., Zamora, Celia, and Knifong, D.L., 2002, Diazinon and chlorpyrifos loads in the San Joaquin River Basin, California, January and February 2000: U.S. Geological Survey Water-Resources Investigations Report 02-4013, 38 p.

Kuivila, K.M., and Foe, C.G., 1995, Concentrations, transport and biological effects of dormant spray pesticides in the San Francisco Estuary: Environmental Toxicology and Chemistry, v.14, p. 1141–1150.

Leland, H.V, and Fend, S.V., 1998, Benthic invertebrate distributions in the San Joaquin River, California, in relation to physical and chemical factors: Canadian Journal of Fisheries and Aquatic Sciences, v. 55, p. 1051–1067.

Leland, H.V., Brown, L.R., and Mueller, D.K., 2001, Distribution of algae in the San Joaquin River, California, in relation to nutrient supply, salinity, and other environmental factors: Freshwater Biology, v. 46, p. 1139–1167.

Moulton, S.R., II, Carter, J.L., Grotheer, S.A., Cuffney, T.F., and Short, T.M., 2000, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Processing, taxonomy, and quality control of benthic macroinvertebrate samples: U.S. Geological Survey Open-File Report 00-212, 49 p.

Moulton, S.R., II, Kennen, J.G., Goldstein, R.M., and Hambrook, J.A., 2002, Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 02-150, 75 p.

Panshin, S.Y., Dubrovsky, N.M., Gronberg, J.M., and Domagalski, J.L., 1998, Occurrence and distribution of dissolved pesticides in the San Joaquin River Basin, California: U.S. Geological Survey Water-Resources Investigations Report 98-4032, 88 p.

Zamora, Celia, Kratzer, C.R., Majewski, M.S., and Knifong, D.L., 2003, Diazinon and chlorpyrifos loads in precipitation and urban and agricultural storm runoff during January and February 2001 in the San Joaquin Basin, California: U.S. Geological Survey Water-Resources Investigations Report 03-4091, 56 p.

Table 3. Values for environmental variables measured during June and September 2001 at five sites in the San Joaquin River Basin, California.

[Values are mean ± standard deviation unless n = 1; m, meter; n, sample size; ft^3/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter; m/km, meter per kilometer; mg/L, milligram per liter; m/s, meter per second; —, not measured]

Station name	Reach length (m, n=1)	Discharge (ft^3/s, n=1)	Water temperature (°C, n=1)	pH (n=1)	Specifc conductance (µS/cm, n=1)	Dissolved oxygen (mg/L, n=1)	Reach water-surface gradient (m/km, n=1)	Water depth (m, n=33)	Water velocity (m/s, n=33)
June 2001									
Salt Slough at Highway 165 near Stevinson	600	204	24.4	7.3	1,009	7.5	0.14	0.99 ± 0.49	0.36 ± 0.14
Merced River at River Road near Newman	600	225[1]	28.7	7.4	322	8.8	0.31	0.57 ± 0.29	0.30 ± 0.13
Orestimba Creek at River Road near Crows Landing	150	29	23.6	7.7	715	8.2	2	0.42 ± 0.17	0.47 ± 0.19
Tuolumne River at Shiloh Road Bridge near Grayson	500	224[1]	26.5	7.5	342	8.2	0.17	0.60 ± 0.22	0.35 ± 0.09
San Joaquin River near Vernalis	1,000	1,510	25.6	8.3	667	12	0.19	0.91 ± 0.45	0.47 ± 0.12
September 2001									
Salt Slough at Highway 165 near Stevinson	600	52	26.5	8.1	1,630	9.4	—	0.59 ± 0.33	0.21 ± 0.08
Merced River at River Road near Newman	600	176[1]	24.8	7.5	212	9.5	—	0.62 ± 0.23	0.38 ± 0.15
Orestimba Creek at River Road near Crows Landing	150	6	21.7	8	1,071	9.7	—	0.26 ± 0.13	0.24 ± 0.20
Tuolumne River at Shiloh Road Bridge near Grayson	500	287[1]	23.9	7.7	263	9.2	—	0.75 ± 0.25	0.36 ± 0.10
San Joaquin River near Vernalis	1,000	1,370	25.6	8.3	667	12	—	0.94 ± 0.53	0.39 ± 0.14

[1] Discharge calculated from data provided by the California Department of Water Resources.

Table 3. Values for environmental variables measured during June and September 2001 at five sites in the San Joaquin River Basin, California—Continued.

[Values are mean ± standard deviation unless n = 1; m, meter; n, sample size; ft³/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter; m/km, meter per kilometer; mg/L, milligram per liter; m/s, meter per second; —, not measured]

Station name	Bed substrate (n=33)	Pool (percent)	Run (percent)	Riffle (percent)	Wetted channel width (m, n=11)	Bankfull channel width (m, n=11)	Canopy angle (degrees, n=11)	Riparian canopy closure (percent)	Bank angle (degrees, n=22)	Bank height (m, n=22)	Bank substrate (n=22)
June 2001											
Salt Slough at Highway 165 near Stevinson	2.0 ± 0	0	100	0	19.6 ± 1.8	21.7 ± 1.8	151 ± 9	29 ± 31	38 ± 27	0.33 ± 0.09	2.7 ± 2.3
Merced River at River Road near Newman	3.0 ± 0	0	100	0	29.5 ± 5.6	30.3 ± 5.6	141 ± 21	15 ± 22	28 ± 22	0.42 ± 0.08	3.0 ± 0
Orestimba Creek at River Road near Crows Landing	3.5 ± 1.0	13	84	3	6.7 ± 1.4	7.3 ± 1.4	45 ± 42	78 ± 23	60 ± 28	0.29 ± 0.05	2.0 ± 0
Tuolumne River at Shiloh Road Bridge near Grayson	3.0 ± 0	0	100	0	42.3 ± 4.7	43.5 ± 4.9	148 ± 16	27 ± 22	22 ± 17	0.52 ± 0.06	2.7 ± 2.3
San Joaquin River near Vernalis	3.1 ± 0.3	0	100	0	109.6 ± 18.6	112.0 ± 18.5	165 ± 3	2 ± 4	30 ± 25	0.59 ± 0.11	3.0 ± 0
September 2001											
Salt Slough at Highway 165 near Stevinson	2.6 ± 1.4	0	100	0	13.9 ± 3.0	20.4 ± 2.9	141 ± 13	19 ± 16	47 ± 32	0.58 ± 0.06	2.4 ± 1.7
Merced River at River Road near Newman	3.0 ± 0	0	100	0	29.6 ± 5.9	46.4 ± 12.2	145 ± 18	21 ± 26	27 ± 27	0.61 ± 0.1	3.0 ± 0
Orestimba Creek at River Road near Crows Landing	3.4 ± 1.0	13	84	3	6.1 ± 2.4	8.6 ± 2.3	53 ± 38	74 ± 24	52 ± 16	0.69 ± 0.06	2.4 ± 1.7
Tuolumne River at Shiloh Road Bridge near Grayson	3.0 ± 0	0	100	0	43.2 ± 5.1	47.6 ± 3.9	149 ± 16	42 ± 32	28 ± 17	0.70 ± 0.09	3.3 ± 1.5
San Joaquin River near Vernalis	3.0 ± 0	0	100	0	112.5 ± 23.3	115.7 ± 22.9	163 ± 5	6 ± 11	32 ± 24	0.69 ± 0.24	3.0 ± 0

[1] Discharge calculated from data provided by the California Department of Water Resources.

Table 5. Periphyton taxa collected from each of five sites in June and September 2001 in the San Joaquin River Basin, California.

[Frequency of occurrence refers to the number of samples in which a taxon was found. "?" denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Total taxa per sample:		52	50	67	64	39	40	61	58	63	59
Chlorophyta (Green algae)											
Cosmarium margaritatum (Lund) Roy & Bissett	1	0	0	1	0	0	0	0	0	0	0
Netrium digitus Ehrenberg	1	0	0	1	0	0	0	0	0	0	0
Scenedesmus quadricauda var. *longispina* fo. *assymmetricus* (Hortobágyi) Uherkovich	5	0	0	1	1	0	0	1	0	1	1
Chrysophyta (Golden algae, only diatoms listed)											
Achnanthes lanceolata var. *haynaldii* (Schaarschmidt) Cleve	1	1	0	0	0	0	0	0	0	0	0
Achnanthes oblongella Østrup	1	0	0	0	1	0	0	0	0	0	0
Achnanthes subhudsonis var. *kraeuselii* (Cholnoky) Cholnoky	5	0	1	1	0	0	0	1	0	1	1
Achnanthidium exiguum var. *heterovalvum* (Krasske) Czarnecki	6	0	1	1	1	0	0	1	1	0	1
Achnanthidium minutissimum (Kützing) Czarnecki	10	1	1	1	1	1	1	1	1	1	1
Achnanthidium pyrenaicum (Hustedt) Kobayasi	5	0	0	1	1	0	0	1	1	1	0
Actinocyclus normanii (Gregory) Hustedt	3	0	0	0	1	0	0	1	1	0	0
Adlafia bryophila (Petersen) Lange-Bertalot	3	0	0	0	0	0	0	1	1	1	0
Amphora acutiuscula Kützing	1	0	0	0	0	0	0	0	0	0	1
Amphora inariensis Krammer	4	0	0	0	0	1	1	0	1	1	0
Amphora ovalis (Kützing) Kützing	1	0	0	0	0	0	0	1	0	0	0
Amphora veneta Kützing	7	0	1	0	1	0	1	1	1	1	1

Table 5. Pe

[Frequency of occurrence refers to the number of samples in which a taxon was found. "?" denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Aulacoseira granulata (Ehrenberg) Simonsen	3	0	1	0	0	0	0	1	0	0	1
Bacillaria paradoxa Gmelin	10	1	1	1	1	1	1	1	1	1	1
Brachysira serians (Brebisson) Round et Mann	1	0	0	0	0	0	1	0	0	0	0
Caloneis bacillum (Grunow) Cleve	1	0	0	0	1	0	0	0	0	0	0
Caloneis sp. 1 ?	1	0	0	0	0	0	1	0	0	0	0
Cavinula jaernefelti (Hustedt) Mann and Stickle	4	0	0	1	1	0	0	1	1	0	0
Cocconeis cf. *neothumensis* Krammer	1	0	0	1	0	0	0	0	0	0	0
Cocconeis disculus (Schumann) Cleve	1	1	0	0	0	0	0	0	0	0	0
Cocconeis pediculus Ehrenberg	1	1	0	0	0	0	0	0	0	0	0
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck	7	0	1	1	1	0	0	1	1	1	1
Craticula accomoda (Hustedt) Mann	1	0	0	0	0	0	0	0	0	0	1
Craticula citrus (Krasske) Reichardt	1	1	0	0	0	0	0	0	0	0	0
Craticula cuspidata (Kützing) Mann	2	0	0	1	0	0	0	1	0	0	0
Craticula molestiformis (Hustedt) Lange-Bertalot	8	0	1	0	1	1	1	1	1	1	1
Craticula submolesta (Hustedt) Lange-Bertalot	1	0	0	0	0	1	0	0	0	0	0
Cyclostephanos invisitatus (Hohn et Hellerman) Theriot, Stoermer et Håkansson	1	0	0	0	0	0	0	0	0	1	0
Cyclotella atomus Hustedt	7	1	1	1	0	0	1	1	0	1	1
Cyclotella meneghiniana Kützing	10	1	1	1	1	1	1	1	1	1	1
Cyclotella ocellata Pantosek	1	0	0	0	0	0	0	0	0	0	1

Table 5. Pe

[Frequency of occurrence refers to the number of samples in which a taxon was found. ”?” denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Cyclotella pseudostelligera Hustedt	1	0	0	0	0	0	0	1	0	0	0
Cymbella affinis Kützing	1	0	0	0	0	0	0	0	0	0	1
Cymbella laevis Naegeli ex Kützing	1	0	0	0	0	0	1	0	0	0	0
Cymbella turgidula Grunow	2	0	0	0	0	0	0	1	1	0	0
Diadesmis confervacea Kützing	5	1	0	0	1	0	0	1	1	1	0
Diatoma vulgaris Bory	3	0	0	1	0	0	0	0	0	1	1
Diploneis elliptica (Kützing) Cleve	1	1	0	0	0	0	0	0	0	0	0
Diploneis oblongella (Naegeli ex Kützing) Ross	3	1	1	0	1	0	0	0	0	0	0
Diploneis parma Cleve	1	1	0	0	0	0	0	0	0	0	0
Diploneis smithii (Brébisson ex Smith) Cleve	1	0	0	0	1	0	0	0	0	0	0
Encyonema lunatum (Smith) Van Heurck	2	0	0	1	0	0	1	0	0	0	0
Encyonema minutum (Hilse) Mann	7	0	0	1	1	1	1	0	1	1	1
Encyonema prostratum (Berkeley) Kützing	1	0	0	0	0	1	0	0	0	0	0
Encyonema silesiacum (Bleisch) Mann	2	0	0	1	0	0	0	0	0	1	0
Epithemia sorex Kützing	2	1	1	0	0	0	0	0	0	0	0
Eunotia incisa Smith ex Gregory	2	0	0	0	1	0	0	1	0	0	0
Eunotia pectinalis var. *minor* (Kützing) Rabenhorst	3	1	0	1	1	0	0	0	0	0	0
Eunotia tenella (Grunow) Cleve	1	0	0	0	0	0	0	0	1	0	0
Fallacia pygmaea (Kützing) Stickle et Mann	5	1	1	0	0	0	1	0	0	1	1
Fallacia tenera (Hustedt) Mann	1	0	0	1	0	0	0	0	0	0	0
Fragilaria capucina Desmazières	1	0	0	0	0	0	0	0	0	0	1

Table 5. Pe

[Frequency of occurrence refers to the number of samples in which a taxon was found. ”?” denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	6	1	0	1	1	1	0	0	1	1	0
Fragilaria crotonensis Kitton	1	0	0	1	0	0	0	0	0	0	0
Fragilariforma constricta (Ehrenberg) Williams et Round	1	0	0	0	0	0	0	1	0	0	0
Fragilariforma virescens (Ralfs) Williams et Round	1	0	0	0	0	0	0	1	0	0	0
Frustulia rhomboides (Ehrenberg) De Toni	1	0	0	0	0	0	0	0	1	0	0
Gomphonema kobayasii Kociolek & Kingston	6	1	1	1	1	1	0	0	0	0	1
Gomphonema mexicanum Grun. in V. H.	1	0	0	0	0	0	0	1	0	0	0
Gomphonema parvulius (Lange-Bertalot et Reichardt) Lange-Bertalot et Reichardt	2	0	0	0	0	1	0	0	1	0	0
Gomphonema parvulum (Kütz.) Kütz.	9	1	1	1	1	1	1	1	1	1	0
Gomphonema rhombicum Fricke	2	0	0	1	0	0	0	0	1	0	0
Gyrosigma spencerii (Quek.) Griff. & Henfr.	6	1	1	1	1	0	1	0	1	0	0
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	8	1	1	1	1	0	0	1	1	1	1
Karayevia clevei (Grunow) Kingston	1	0	0	0	0	0	0	0	1	0	0
Luticola goeppertiana (Bleisch) Mann	4	1	0	0	1	0	1	1	0	0	0
Luticola mutica (Kutz.) Mann	2	1	0	0	0	1	0	0	0	0	0
Luticola nivalis (Ehrenberg) Mann	2	0	0	0	0	1	1	0	0	0	0
Mayamaea agrestis (Hustedt) Lange-Bertalot	2	0	0	0	0	0	0	1	0	1	0

Table 5. Pe

[Frequency of occurrence refers to the number of samples in which a taxon was found. "?" denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Mayamaea atomus (Kützing) Lange-Bertalot	7	0	1	1	0	1	0	1	1	1	1
Melosira varians Ag.	8	1	1	1	1	0	0	1	1	1	1
Meridion circulare (Grev.) Ag.	4	0	1	1	1	0	0	0	0	0	1
Navicula absoluta Hustedt	1	0	0	0	0	0	0	0	0	0	1
Navicula arvensis fo. *major* Mang.	1	0	0	0	0	0	0	1	0	0	0
Navicula arvensis Hustedt	5	0	1	1	1	0	1	0	1	0	0
Navicula capitatoradiata Germain	3	0	0	1	0	0	0	0	0	1	1
Navicula cincta (Ehr.) Ralfs	1	0	0	0	0	1	0	0	0	0	0
Navicula cryptocephala Kützing	1	0	0	0	0	0	0	0	1	0	0
Navicula cryptotenella L.B. in Kramm. & L.-B.	9	1	1	0	1	1	1	1	1	1	1
Navicula erifuga Lange-Bert.	1	0	0	0	0	1	0	0	0	0	0
Navicula exigua var. *capitata* Patr.	1	0	0	0	1	0	0	0	0	0	0
Navicula festiva Krass.	1	0	0	0	0	0	0	1	0	0	0
Navicula gregaria Donk.	10	1	1	1	1	1	1	1	1	1	1
Navicula hustedtii Krass.	3	0	0	0	1	0	0	1	1	0	0
Navicula integra (W. Sm.) Ralfs	1	0	1	0	0	0	0	0	0	0	0
Navicula menisculus Schum.	1	0	0	0	0	0	0	0	0	1	0
Navicula minima Grunow	7	0	0	1	1	1	1	1	1	1	0
Navicula notha Wallace	3	0	0	0	0	1	1	0	0	0	1
Navicula praeterita Hustedt	1	0	1	0	0	0	0	0	0	0	0
Navicula radiosa Kützing	10	1	1	1	1	1	1	1	1	1	1
Navicula recens Lange-Bert.	10	1	1	1	1	1	1	1	1	1	1
Navicula rostellata Kützing	2	0	0	1	0	0	0	0	1	0	0
Navicula sanctaecrucis Østrup	6	1	0	1	1	0	0	1	1	0	1
Navicula schroeteri var. *escambia* Patr.	10	1	1	1	1	1	1	1	1	1	1

Table 5. Pe

[Frequency of occurrence refers to the number of samples in which a taxon was found. ”?” denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Navicula subminuscula Mang.	10	1	1	1	1	1	1	1	1	1	1
Navicula tenelloides Hustedt	1	1	0	0	0	0	0	0	0	0	0
Navicula tripunctata (O. F. Müll.) Bory	4	1	0	1	0	0	1	0	0	1	0
Navicula trivialis Lange-Bertalot	1	0	0	0	0	0	0	0	0	1	0
Navicula veneta Kützing	2	0	0	0	0	1	0	1	0	0	0
Navicula viridulacalcis (Hustedt) Lange-Bertalot	7	0	1	1	1	0	1	1	1	1	0
Neidium ampliatum (Ehr.) Kramm.	1	0	0	1	0	0	0	0	0	0	0
Nitzschia aequorea Hustedt	2	0	1	0	1	0	0	0	0	0	0
Nitzschia amphibia Grunow	10	1	1	1	1	1	1	1	1	1	1
Nitzschia cf. *acidoclinata*	1	0	0	0	1	0	0	0	0	0	0
Nitzschia cf. *rosenstockii* Lange-Bert.	1	0	0	0	1	0	0	0	0	0	0
Nitzschia clausii Hantz.	3	0	0	0	0	1	1	0	0	0	1
Nitzschia dissipata (Kützing) Grunow	8	1	1	1	0	1	1	0	1	1	1
Nitzschia filiformis (W. Sm.) V. H.	1	0	0	0	0	0	0	0	0	0	1
Nitzschia flexa Schum.	2	0	0	0	0	1	1	0	0	0	0
Nitzschia fonticola Grunow	10	1	1	1	1	1	1	1	1	1	1
Nitzschia heufleriana Grunow	1	0	0	0	1	0	0	0	0	0	0
Nitzschia inconspicua Grunow	10	1	1	1	1	1	1	1	1	1	1
Nitzschia intermedia Hantz. ex Cl. et Grun.	1	0	0	0	0	0	0	0	0	1	0
Nitzschia lanceolata W. Sm.	1	0	0	0	0	0	0	0	0	1	0
Nitzschia linearis (Ag. ex W. Sm.) W. Sm.	4	1	1	1	0	0	0	0	0	1	0
Nitzschia nana Grun. in V. H.	1	0	0	0	0	1	0	0	0	0	0
Nitzschia palea (Kützing) Smith	10	1	1	1	1	1	1	1	1	1	1
Nitzschia reversa W. Sm.	8	1	1	1	0	1	1	1	0	1	1

Table 5. Pe

[Frequency of occurrence refers to the number of samples in which a taxon was found. "?" denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Nitzschia sigma (Kütz.) W. Sm.	2	0	0	0	0	0	1	0	0	1	0
Nitzschia siliqua Arch.	1	0	1	0	0	0	0	0	0	0	0
Nitzschia sinuata var. *tabellaria* (Grun.) Grun. in V.H.	2	0	0	0	0	0	0	1	0	0	1
Pinnularia intermedia (Lagerst.) Cl.	1	1	0	0	0	0	0	0	0	0	0
Placoneis clementis (Grun) Cox	7	1	0	1	1	0	0	1	1	1	1
Placoneis elginensis (Greg.) Cox	1	0	0	0	0	0	0	1	0	0	0
Plagiotropis lepidoptera var. *proboscidea* (Cl.) Reim.	1	0	0	0	0	0	0	0	0	0	1
Planothidium apiculatum (Patrick) Lange-Bertalot	4	0	0	1	1	0	0	0	1	0	1
Planothidium biporomum (Hohn et Hellerman) Lange-Bertalot	2	0	0	1	1	0	0	0	0	0	0
Planothidium delicatulum (Kützing) Round et Bukhtiyarova	1	0	0	0	0	0	0	0	0	1	0
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	8	1	1	1	1	0	0	1	1	1	1
Planothidium rostratum (Østrup) Lange-Bertalot	4	0	0	1	1	0	0	1	1	0	0
Pleurosigma salinarum Grunow	1	0	0	0	0	0	0	0	0	0	1
Pleurosira laevis (Ehrenberg) Compere	2	0	0	0	0	0	0	0	1	1	0
Psammothidium bioretii (Germ.) Bukht. et Round	1	0	0	0	1	0	0	0	0	0	0
Pseudostaurosira brevistriata (Grun. in V.H.) Williams & Round	3	1	0	1	0	0	0	0	0	1	0
Reimeria sinuata (Greg.) Kociolek & Stoermer	3	0	0	1	0	0	0	0	0	1	1
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	7	1	1	1	0	0	0	1	1	1	1

Table 5. Pe

[Frequency of occurrence refers to the number of samples in which a taxon was found. "?" denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Rhopalodia operculata (C. Ag.) Häkens.	1	0	0	0	0	0	0	0	1	0	0
Sellaphora bacillum (Ehr.) Mann	3	0	0	1	1	0	0	0	0	1	0
Sellaphora pupula (Kütz.) Meresckowsky	9	1	1	1	1	1	0	1	1	1	1
Sellaphora rectangularis (Greg.) Lange-Bertalot & Metzeltin	1	0	0	0	0	0	0	1	0	0	0
Sellaphora seminulum (Grun.) Mann	8	0	0	1	1	1	1	1	1	1	1
Skeletonema potamos (Weber) Hasle	2	1	0	0	0	0	0	0	0	0	1
Staurosira construens var. *venter* (Ehr.) Hamilton	10	1	1	1	1	1	1	1	1	1	1
Staurosirella pinnata (Ehrenberg) Williams et Round	8	1	1	1	1	0	0	1	1	1	1
Surirella brebissonii Kramm. & Lange-Bert.	3	1	1	0	0	0	0	0	0	1	0
Surirella minuta Bréb.	1	0	0	1	0	0	0	0	0	0	0
Surirella tenera Greg.	1	0	0	0	1	0	0	0	0	0	0
Synedra ulna (Nitz.) Ehr.	6	1	1	1	1	0	0	1	1	0	0
Tabellaria flocculosa (Roth) Kütz.	1	0	1	0	0	0	0	0	0	0	0
Tabularia tabulata (C. A. Ag.) Snoeijs	1	0	0	0	0	0	0	0	1	0	0
Thalassiosira pseudonana Hasle & Heimdal	1	0	1	0	0	0	0	0	0	0	0
Thalassiosira weissflogii (Grun.) Fryxell & Hasle	3	0	0	0	1	0	0	0	0	1	1
Tryblionella apiculata Greg.	4	1	1	0	0	0	0	0	0	1	1
Tryblionella calida (Grun.) Mann	3	0	0	0	0	1	1	0	0	1	0
Tryblionella levidensis Wm. Sm.	2	0	0	0	1	0	0	0	1	0	0
Cyanophyta (Blue-green algae)											

Table 5. Pe

[Frequency of occurrence refers to the number of samples in which a taxon was found. ”?” denotes unidentified species]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Lyngbya sp.	2	0	0	1	1	0	0	0	0	0	0
Microcystis aeruginosa Kützing	2	0	1	0	0	0	0	0	0	0	1
Oscillatoria sp.	6	1	0	1	1	0	0	1	0	1	1

Table 6. Periphyton ta

[Periphyton taxa units are density in cells/cm^2. Taxa codes were only assigned to species occurring in more than one sample. —, no code assigned; "?" denotes unidentified species]

Scientific Name	Taxa code	Salt Slough		Merced River		Orestimba CreeK		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Chlorophyta (Green algae)											
Scenedesmus quadricauda var. *longispina* fo. *assymmetricus* (Hortobágyi) Uherkovich	52	0	0	0	141,608	0	0	0	0	0	31,859
Chrysophyta (Golden algae, all taxa listed are diatoms)											
Achnanthes oblongella Østrup	—	0	0	0	14,373	0	0	0	0	0	0
Achnanthes subhudsonis var. *kraeuselii* (Cholnoky) Cholnoky	1	0	0	13,561	0	0	0	14,387	0	0	0
Achnanthidium exiguum var. *hetero-valvum* (Krasske) Czarnecki	2	0	21,287	0	57,491	0	0	14,387	59,814	0	0
Achnanthidium minutissimum (Kütz-ing) Czarnecki	3	0	0	23,248	0	50,107	5,569	0	99,690	0	0
Achnanthidium pyrenaicum (Hus-tedt) Kobayasi	4	0	0	11,624	28,746	0	0	43,160	19,938	0	0
Adlafia bryophila (Petersen) Lange-Bertalot	—	0	0	0	0	0	0	0	19,938	0	0
Amphora acutiuscula Kützing	—	0	0	0	0	0	0	0	0	0	31,753
Amphora inariensis Krammer	5	0	0	0	0	15,418	11,137	0	0	7,086	0
Amphora ovalis (Kützing) Kützing	—	0	0	0	0	0	0	28,773	0	0	0
Amphora veneta Kützing	6	0	10,644	0	0	0	5,569	0	39,876	35,432	841,452
Bacillaria paradoxa Gmelin	7	5,202	138,369	7,749	43,118	0	0	14,387	0	7,086	0
Brachysira serians (Brebisson) Round et Mann	—	0	0	0	0	0	5,569	0	0	0	0
Caloneis sp. 1 ?	—	0	0	0	0	0	5,569	0	0	0	0
Cavinula jaernefelti (Hustedt) Mann and Stickle	—	0	0	0	14,373	0	0	0	0	0	0
Cocconeis cf. *neothumensis* Kram-mer	—	0	0	1,937	0	0	0	0	0	0	0
Cocconeis disculus (Schumann) Cleve	—	226	0	0	0	0	0	0	0	0	0
Cocconeis pediculus Ehrenberg	—	226	0	0	0	0	0	0	0	0	0

Table 6. Periphyton taxa from r

[Periphyton taxa units are density in cells/cm^2. Taxa codes were only assigned to species occurring in more than one sample. —, no code assigned; "?" denotes unidentified species]

Scientific Name	Taxa code	Salt Slough		Merced River		Orestimba CreeK		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck	8	0	10,644	81,367	57,491	0	0	374,055	199,379	42,519	79,382
Craticula accomoda (Hustedt) Mann	—	0	0	0	0	0	0	0	0	0	15,876
Craticula cuspidata (Kützing) Mann	9	0	0	1,937	0	0	0	14,387	0	0	0
Craticula molestiformis (Hustedt) Lange-Bertalot	10	0	21,287	0	0	15,418	16,706	0	19,938	14,173	0
Craticula submolesta (Hustedt) Lange-Bertalot	—	0	0	0	0	3,854	0	0	0	0	0
Cyclostephanos invisitatus (Hohn et Hellerman) Theriot, Stoermer et Håkansson	—	0	0	0	0	0	0	0	0	21,259	0
Cyclotella atomus Hustedt	11	2,488	0	0	0	0	44,549	0	0	106,297	190,517
Cyclotella meneghiniana Kützing	12	6,558	478,968	1,937	0	0	5,569	0	39,876	552,742	571,552
Cyclotella pseudostelligera Hustedt	—	0	0	0	0	0	0	28,773	0	0	0
Cymbella affinis Kützing	—	0	0	0	0	0	0	0	0	0	31,753
Cymbella laevis Naegeli ex Kützing	—	0	0	0	0	0	5,569	0	0	0	0
Diadesmis confervacea Kützing	13	452	0	0	0	0	0	0	0	35,432	0
Diatoma vulgaris Bory	14	0	0	7,749	0	0	0	0	0	7,086	0
Diploneis oblongella (Naegeli ex Kützing) Ross	—	0	10,644	0	0	0	0	0	0	0	0
Diploneis parma Cleve	—	452	0	0	0	0	0	0	0	0	0
Encyonema lunatum (Smith) Van Heurck	15	0	0	1,937	0	0	5,569	0	0	0	0
Encyonema minutum (Hilse) Mann	16	0	0	13,561	14,373	3,854	11,137	0	19,938	0	15,876
Encyonema prostratum (Berkeley) Kützing	—	0	0	0	0	3,854	0	0	0	0	0
Eunotia incisa Smith ex Gregory	—	0	0	0	14,373	0	0	0	0	0	0
Fallacia pygmaea (Kützing) Stickle et Mann	17	905	10,644	0	0	0	5,569	0	0	7,086	79,382
Fragilaria capucina Desmazières	—	0	0	0	0	0	0	0	0	0	15,876
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	18	226	0	5,812	0	3,854	0	0	0	7,086	0

Table 6. Periphyton taxa from r

[Periphyton taxa units are density in cells/cm^2. Taxa codes were only assigned to species occurring in more than one sample. —, no code assigned; "?" denotes unidentified species]

Scientific Name	Taxa code	Salt Slough		Merced River		Orestimba CreeK		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Gomphonema kobayasii Kociolek & Kingston	—	0	0	0	0	3,854	0	0	0	0	0
Gomphonema mexicanum Grun. in V. H.	—	0	0	0	0	0	0	14,387	0	0	0
Gomphonema parvulius (Lange-Bertalot et Reichardt) Lange-Bertalot et Reichardt	19	0	0	0	0	7,709	0	0	79,752	0	0
Gomphonema parvulum (Kütz.) Kütz.	20	452	21,287	0	14,373	7,709	16,706	0	19,938	0	0
Gyrosigma spencerii (Quek.) Griff. & Henfr.	—	0	0	0	0	0	55,686	0	0	0	0
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	21	452	21,287	5,812	28,746	0	0	14,387	39,876	85,037	365,158
Luticola mutica (Kutz.) Mann	—	0	0	0	0	3,854	0	0	0	0	0
Luticola nivalis (Ehrenberg) Mann	22	0	0	0	0	19,272	33,412	0	0	0	0
Mayamaea atomus (Kützing) Lange-Bertalot	23	0	0	9,687	0	3,854	0	14,387	39,876	0	0
Melosira varians Ag.	24	226	10,644	9,687	14,373	0	0	0	39,876	63,778	15,876
Navicula arvensis Hustedt	—	0	0	0	0	0	11,137	0	0	0	0
Navicula cryptotenella L.B. in Kramm. & L.-B.	25	905	53,219	0	0	543,471	100,235	57,547	0	0	79,382
Navicula exigua var. *capitata* Patr.	—	0	0	0	28,746	0	0	0	0	0	0
Navicula festiva Krass.	—	0	0	0	0	0	0	14,387	0	0	0
Navicula gregaria Donk.	26	3,392	10,644	3,875	57,491	73,234	334,117	172,641	19,938	21,259	63,506
Navicula minima Grunow	27	0	0	25,185	100,610	11,563	5,569	374,055	39,876	35,432	0
Navicula notha Wallace	28	0	0	0	0	69,379	361,960	0	0	0	0
Navicula praeterita Hustedt	—	0	10,644	0	0	0	0	0	0	0	0
Navicula radiosa Kützing	29	2,262	42,575	0	14,373	80,943	211,607	14,387	39,876	99,210	142,888
Navicula recens Lange-Bert.	30	8,820	10,644	0	0	389,295	501,175	86,320	0	240,939	523,923
Navicula rostellata Kützing	31	0	0	79,430	0	0	0	0	99,690	0	0
Navicula sanctaecrucis Østrup	32	0	0	0	28,746	0	0	158,254	0	0	476,293

Table 6. Periphyton taxa from r

[Periphyton taxa units are density in cells/cm^2. Taxa codes were only assigned to species occurring in more than one sample. —, no code assigned; "?" denotes unidentified species]

Scientific Name	Taxa code	Salt Slough		Merced River		Orestimba CreeK		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Navicula schroeteri var. *escambia* Patr.	33	0	21,287	0	0	154,176	16,706	0	0	70,864	0
Navicula subminuscula Mang.	34	452	0	29,060	71,864	15,418	5,569	86,320	139,566	14,173	15,876
Navicula tripunctata (O. F. Müll.) Bory	35	0	0	0	0	0	38,980	0	0	21,259	0
Navicula trivialis Lange-Bertalot	—	0	0	0	0	0	0	0	0	63,778	0
Navicula viridulacalcis (Hustedt) Lange-Bertalot	36	0	63,862	42,621	114,983	0	100,235	14,387	0	49,605	0
Neidium ampliatum (Ehr.) Kramm.	—	0	0	1,937	0	0	0	0	0	0	0
Nitzschia amphibia Grunow	37	3,845	95,794	11,624	100,610	80,943	83,529	100,707	179,441	42,519	174,641
Nitzschia clausii Hantz.	—	0	0	0	0	0	0	0	0	0	111,135
Nitzschia dissipata (Kützing) Grunow	38	905	21,287	9,687	0	15,418	194,902	0	0	0	63,506
Nitzschia flexa Schum.	39	0	0	0	0	7,709	11,137	0	0	0	0
Nitzschia fonticola Grunow	40	12,891	627,981	1,937	28,746	15,418	50,118	115,094	179,441	85,037	31,753
Nitzschia inconspicua Grunow	41	1,357	53,219	0	0	558,889	0	0	0	21,259	0
Nitzschia lanceolata W. Sm.	—	0	0	0	0	0	0	0	0	7,086	0
Nitzschia linearis (Ag. ex W. Sm.) W. Sm.	—	0	0	0	0	0	0	0	0	28,346	0
Nitzschia nana Grun. in V. H.	—	0	0	0	0	57,816	0	0	0	0	0
Nitzschia palea (Kützing) Smith	42	63,549	3,608,229	46,495	301,830	84,797	1,007,919	676,176	199,379	956,669	3,175,289
Nitzschia reversa W. Sm.	43	9,272	659,912	1,937	0	0	27,843	0	0	28,346	0
Nitzschia sigma (Kütz.) W. Sm.	44	0	0	0	0	0	22,274	0	0	14,173	0
Nitzschia sinuata var. *tabellaria* (Grun.) Grun. in V.H.	—	0	0	0	0	0	0	14,387	0	0	0
Pinnularia intermedia (Lagerst.) Cl.	—	2,488	0	0	0	0	0	0	0	0	0
Placoneis clementis (Grun) Cox	46	226	0	15,498	143,728	0	0	86,320	119,628	0	79,382
Placoneis elginensis (Greg.) Cox	—	0	0	0	0	0	0	14,387	0	0	0
Plagiotropis lepidoptera var. *proboscidea* (Cl.) Reim.	—	0	0	0	0	0	0	0	0	0	15,876
Planothidium apiculatum (Patrick) Lange-Bertalot	47	0	0	5,812	0	0	0	0	19,938	0	15,876

Table 6. Periphyton taxa from r

[Periphyton taxa units are density in cells/cm². Taxa codes were only assigned to species occurring in more than one sample. —, no code assigned; "?" denotes unidentified species]

Scientific Name	Taxa code	Salt Slough		Merced River		Orestimba CreeK		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Planothidium biporomum (Hohn et Hellerman) Lange-Bertalot	—	0	0	3,875	0	0	0	0	0	0	0
Planothidium delicatulum (Kützing) Round et Bukhtiyarova	—	0	0	0	0	0	0	0	0	7,086	0
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	48	452	10,644	30,997	0	0	0	86,320	199,379	7,086	0
Planothidium rostratum (Østrup) Lange-Bertalot	49	0	0	0	158,101	0	0	187,027	19,938	0	0
Psammothidium bioretii (Germ.) Bukht. et Round	—	0	0	0	28,746	0	0	0	0	0	0
Pseudostaurosira brevistriata (Grun. in V.H.) Williams & Round	50	226	0	3,875	0	0	0	0	0	21,259	0
Reimeria sinuata (Greg.) Kociolek & Stoermer	—	0	0	1,937	0	0	0	0	0	0	0
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	51	0	0	0	0	0	0	0	19,938	0	47,629
Rhopalodia operculata (C. Ag.) Häkens.	—	0	0	0	0	0	0	0	19,938	0	0
Sellaphora bacillum (Ehr.) Mann	53	0	0	5,812	28,746	0	0	0	0	7,086	0
Sellaphora pupula (Kütz.) Meresckowsky	54	1,131	10,644	27,122	43,118	3,854	0	1,424,285	179,441	262,198	428,664
Sellaphora rectangularis (Greg.) Lange-Bertalot & Metzeltin	—	0	0	0	0	0	0	14,387	0	0	0
Sellaphora seminulum (Grun.) Mann	55	0	0	11,624	14,373	0	5,569	28,773	39,876	28,346	0
Staurosira construens var. *venter* (Ehr.) Hamilton	56	3,845	244,806	583,131	7,042,690	7,709	11,137	3,740,547	8,593,254	942,497	1,698,780
Staurosirella pinnata (Ehrenberg) Williams et Round	57	226	0	25,185	0	0	0	589,855	1,076,649	134,642	79,382
Surirella brebissonii Kramm. & Lange-Bert.	—	0	10,644	0	0	0	0	0	0	0	0
Synedra ulna (Nitz.) Ehr.	58	905	21,287	0	28,746	0	0	28,773	59,814	0	0
Tabellaria flocculosa (Roth) Kütz.	—	0	10,644	0	0	0	0	0	0	0	0
Thalassiosira weissflogii (Grun.) Fryxell & Hasle	59	0	0	0	0	0	0	0	0	14,173	63,506

Table 6. Periphyton taxa from r

[Periphyton taxa units are density in cells/cm². Taxa codes were only assigned to species occurring in more than one sample. —, no code assigned; "?" denotes unidentified species]

Scientific Name	Taxa code	Salt Slough		Merced River		Orestimba CreeK		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Tryblionella apiculata Greg.	60	678	53,219	0	0	0	0	0	0	28,346	15,876
Tryblionella calida (Grun.) Mann	61	0	0	0	0	0	5,569	0	0	14,173	0
Cyanophyta (Blue-green algae)	—										
Microcystis aeruginosa Kützing	—	0	0	0	0	0	0	0	0	0	31,859
Oscillatoria sp.	45	0	0	0	56,643	0	0	27,759	0	13,351	0

Table 7. Macroinvertebrate taxa collected from each of five sites in June and September 2001 in the San Joaquin River Basin, California.

[Frequency of occurrence refers to the number of samples in which a taxon was found.]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Total taxa per sampling site		19	24	49	49	33	24	54	51	40	54
Platyhelminthes											
Turbellaria	3	0	0	0	0	1	1	0	1	0	0
Nemertea											
Enopla											
Hoplonemertea											
Tetrastemmatidae											
Prostoma sp.	5	0	0	0	1	1	1	1	1	0	0
Nematoda	3	0	0	0	0	1	1	0	0	0	1
Bryozoa											
Phylactolaemata											
Urnatella gracilis Leidy	3	0	0	0	0	1	0	1	0	0	1
Mollusca											
Gastropoda											
Basommatophora											
Ancylidae											
Ferrissia sp.	3	0	0	1	0	1	0	0	1	0	0
Lymnaeidae	2	0	0	0	0	0	1	0	0	0	1
Pseudosuccinea columella (Say)	2	0	0	1	0	0	0	0	1	0	0
Fossaria sp.	1	0	0	0	1	0	0	0	0	0	0
Physidae											
Physella sp.	9	1	1	1	1	1	1	0	1	1	1
Planorbidae											
Menetus sp.	3	0	0	1	0	0	0	0	1	0	1
Bivalvia											
Veneroida											
Corbiculidae											
Corbicula sp.	9	0	1	1	1	1	1	1	1	1	1
Annelida											
Oligochaeta											
Megadrile	3	0	0	0	1	1	1	0	0	0	0
Lumbriculida											
Lumbriculidae	1	0	0	0	0	1	0	0	0	0	0
Tubificida											
Naididae	10	1	1	1	1	1	1	1	1	1	1

Table 7. Macroinvertebrate taxa collected from each of five sites in June and September 2001 in the San Joaquin River Basin, California.—Continued

[Frequency of occurrence refers to the number of samples in which a taxon was found.]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Tubificidae	4	1	0	0	0	1	1	0	0	0	1
Enchytraeida											
Enchytraeidae	2	0	0	0	0	1	1	0	0	0	0
Polychaeta	1	0	0	0	0	0	1	0	0	0	0
Sabellida											
Sabellidae	2	0	0	0	0	1	1	0	0	0	0
Arthropoda											
Arachnida											
Acari	8	0	0	1	1	1	1	1	1	1	1
Malacostraca											
Isopoda	1	0	0	0	0	0	0	0	0	1	0
Decapoda											
Cambaridae	1	0	0	0	1	0	0	0	0	0	0
Amphipoda	1	0	0	0	0	0	0	0	0	0	1
Corophiidae											
Corophium sp.	4	1	1	0	0	0	0	0	0	1	1
Gammaridae											
Gammarus sp.	2	1	0	0	0	0	1	0	0	0	0
Hyalellidae											
Hyalella azteca (Saussure)	5	1	0	1	1	1	0	0	0	1	0
Insecta											
Collembola	1	0	0	0	0	0	0	0	1	0	0
Ephemeroptera											
Baetidae	7	0	0	1	1	1	0	1	1	1	1
Baetis sp.	1	0	0	0	0	0	0	0	0	0	1
Baetis tricaudatus Dodds	1	0	0	0	0	0	0	0	0	0	1
Callibaetis sp.	5	1	1	1	1	0	0	1	0	0	0
Camelobaetidius sp.	3	0	0	1	0	0	0	1	1	0	0
Centroptilum/Procloeon sp.	4	0	0	0	0	0	0	1	1	1	1
Fallceon quilleri (Dodds)	7	0	1	1	1	0	0	1	1	1	1
Heterocloeon sp.	2	0	0	0	1	0	0	1	0	0	0
Caenidae											
Caenis sp.	2	0	0	0	1	0	0	0	1	0	0
Ephemerellidae											
Ephemerella sp.	1	0	0	1	0	0	0	0	0	0	0
Heptageniidae	3	0	0	1	0	0	0	0	1	0	1

Table 7. Macroinvertebrate taxa collected from each of five sites in June and September 2001 in the San Joaquin River Basin, California.—Continued

[Frequency of occurrence refers to the number of samples in which a taxon was found.]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Heptagenia sp.	2	0	0	0	0	0	0	0	0	1	1
Leptohyphidae											
Tricorythodes sp.	3	0	0	1	0	0	0	1	1	0	0
Odonata											
Zygoptera											
Calopterygidae											
Hetaerina sp.	3	0	0	1	1	0	0	1	0	0	0
Hetaerina americana (Fabricius)	1	0	0	1	0	0	0	0	0	0	0
Coenagrionidae	6	1	1	1	1	0	0	1	1	0	0
Argia sp.	2	0	0	0	0	0	0	1	0	0	1
Argia emma Kennedy	1	0	0	0	0	0	0	0	1	0	0
Coenagrion/ Enallagma sp.	3	0	1	0	1	0	0	1	0	0	0
Anisoptera											
Aeshnidae											
Anax sp.	1	0	0	0	0	0	0	1	0	0	0
Gomphidae	1	0	0	0	1	0	0	0	0	0	0
Hemiptera											
Corixidae	1	0	0	0	0	0	1	0	0	0	0
Palmacorixa sp.	1	1	0	0	0	0	0	0	0	0	0
Trichocorixa sp.	7	1	1	1	1	0	0	1	0	1	1
Corisella sp.	2	0	0	1	0	0	0	1	0	0	0
Gelastocoridae											
Gelastocoris oculatus (Fabricius)	2	0	0	0	0	0	0	0	1	1	0
Gerridae	2	0	0	0	1	0	0	0	1	0	0
Naucoridae											
Ambrysus sp.	1	0	0	0	0	0	0	0	0	1	0
Saldidae											
Saldula sp.	1	0	0	0	0	0	0	1	0	0	0
Veliidae											
Rhagovelia sp.	3	1	1	1	0	0	0	0	0	0	0
Rhagovelia distincta Champion	2	0	1	1	0	0	0	0	0	0	0
Trichoptera											
Hydroptilidae	3	0	0	0	1	0	0	1	0	1	0

Table 7. Macroinvertebrate taxa collected from each of five sites in June and September 2001 in the San Joaquin River Basin, California.—Continued

[Frequency of occurrence refers to the number of samples in which a taxon was found.]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Hydroptila sp.	7	0	0	1	1	1	0	1	1	1	1
Hydropsychidae	6	0	0	1	1	0	0	1	1	1	1
Hydropsyche sp.	8	1	1	1	1	0	0	1	1	1	1
Hydropsyche californica Banks	8	1	1	1	1	0	0	1	1	1	1
Leptoceridae											
Nectopsyche sp.	2	0	0	1	0	0	0	0	1	0	0
Nectopsyche gracilis (Banks)	2	0	0	0	1	0	0	1	0	0	0
Lepidoptera	2	0	0	0	1	1	0	0	0	0	0
Pyralidae											
Petrophila sp.	3	0	0	0	0	0	0	0	1	1	1
Coleoptera											
Dytiscidae											
Oreodytes sp.	1	0	0	0	0	0	0	0	0	0	1
Laccophilus sp.	2	0	0	0	0	0	0	0	1	0	1
Elmidae											
Microcylloepus sp.	1	0	0	0	1	0	0	0	0	0	0
Hydraenidae											
Ochthebius sp.	1	0	0	0	0	1	0	0	0	0	0
Hydrophilidae	3	0	0	1	1	0	0	0	0	0	1
Enochrus sp.	1	0	0	0	0	0	0	0	0	0	1
Tropisternus sp.	1	0	1	0	0	0	0	0	0	0	0
Diptera											
Nematocera	1	0	0	0	0	1	0	0	0	0	0
Ceratopogonidae	1	0	0	0	0	1	0	0	0	0	0
Dasyheleinae											
Dasyhelea sp.	2	0	0	0	0	1	0	0	0	0	1
Chironomidae	7	0	0	1	1	1	0	1	1	1	1
Chironominae	5	0	0	1	1	0	0	1	1	0	1
Chironomini (tribe)	5	0	1	1	0	0	1	1	0	0	1
Apedilum sp.	1	0	0	0	0	0	0	0	0	0	1
Chironomus sp.	3	1	0	0	0	0	0	1	1	0	0
Cryptochironomus sp.	4	0	0	0	1	0	0	1	1	1	0

Table 7. Macroinvertebrate taxa collected from each of five sites in June and September 2001 in the San Joaquin River Basin, California.—Continued

[Frequency of occurrence refers to the number of samples in which a taxon was found.]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Dicrotendipes sp.	9	1	1	1	1	0	1	1	1	1	1
Endotribelos hesperium (Sublette)	1	0	1	0	0	0	0	0	0	0	0
Glyptotendipes sp.	2	0	0	1	0	0	0	0	0	0	1
Goeldichironomus sp.	1	0	1	0	0	0	0	0	0	0	0
Nilothauma sp.	2	0	0	0	1	0	0	1	0	0	0
Parachironomus sp.	1	0	0	0	0	0	0	0	0	0	1
Paracladopelma sp.	1	0	0	0	0	0	0	1	0	0	0
Paralauterborniella nigrohalterale (Malloch)	2	0	0	1	0	0	0	0	1	0	0
Polypedilum sp.	5	0	0	1	1	0	0	1	1	1	0
Robackia sp.	1	0	0	0	0	0	0	0	1	0	0
Stenochironomus sp.	4	0	0	1	1	0	0	0	1	1	0
Tanytarsini	4	0	0	1	0	0	0	1	0	1	1
Cladotanytarsus sp.	5	0	0	0	1	0	0	1	1	1	1
Micropsectra/Tanytarsus sp.	6	0	0	1	1	0	0	1	1	1	1
Paratanytarsus sp.	1	1	0	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	6	0	0	1	1	0	0	1	1	1	1
Tanytarsus sp.	6	0	0	1	1	0	0	1	1	1	1
Orthocladiinae	6	0	0	1	1	1	0	0	1	1	1
Psectrocladius sp.	1	0	0	0	0	0	0	1	0	0	0
Pseudosmittia sp.	1	0	0	0	0	1	0	0	0	0	0

Table 7. Macroinvertebrate taxa collected from each of five sites in June and September 2001 in the San Joaquin River Basin, California.—Continued

[Frequency of occurrence refers to the number of samples in which a taxon was found.]

Taxon	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
		June	September	June	September	June	September	June	September	June	September
Cricotopus/ Orthocladius sp.	8	0	1	1	1	1	1	1	0	1	1
Cricotopus sp.	10	1	1	1	1	1	1	1	1	1	1
Cricotopus bicinctus group	10	1	1	1	1	1	1	1	1	1	1
Nanocladius sp.	4	0	1	0	0	1	0	1	0	0	1
Parakiefferiella sp.	4	0	0	0	1	0	0	0	1	1	1
Rheocricotopus sp.	2	0	0	0	0	1	0	0	0	1	0
Synorthocladius sp.	1	0	0	1	0	0	0	0	0	0	0
Thienemanniella sp.	3	0	0	1	0	0	0	1	1	0	0
Tanypodinae											
Pentaneurini	1	0	0	1	0	0	0	0	0	0	0
Ablabesmyia sp.	4	0	0	1	1	0	0	1	1	0	0
Thienemannimyia group sp. (Coffman and Ferrington)	4	0	1	0	0	0	1	1	0	0	1
Tanypodini											
Tanypus sp.	3	1	1	0	0	0	0	0	0	0	1
Psychodidae											
Psychoda sp.	1	0	0	0	0	0	1	0	0	0	0
Simuliidae	5	0	0	0	1	0	0	1	1	1	1
Simulium sp.	4	0	0	0	0	0	0	1	1	1	1
Tipulidae	1	0	0	0	1	0	0	0	0	0	0
Antocha sp.	1	0	0	0	0	0	0	0	0	1	0
Limonia sp.	1	0	0	0	0	0	0	0	1	0	0
Brachycera	3	0	0	0	0	1	1	1	0	0	0
Tabanidae											
Tabanus sp.	1	0	0	0	0	0	1	0	0	0	0
Empididae	1	0	0	0	0	0	0	1	0	0	0
Hemerodromia sp.	5	0	0	1	0	1	0	1	0	1	1
Neoplasta sp.	2	0	0	0	0	0	0	1	1	0	0
Dolichopodidae	3	0	0	0	1	1	0	0	0	0	1

Table 8. Macroinvertebrate

[Taxa codes were only assigned to taxa found in two or more samples. Frequency of occurrence refers to the number of samples in which a taxon was found. Macroinvertebrate taxa units are in organisms/m2; —, no code assigned.]

Taxon	Taxa code	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
			June	September	June	September	June	September	June	September	June	September
Total taxa per sampling site			15	10	19	27	21	12	22	22	18	24
Platyhelminthes												
Turbellaria	1	3	0	0	0	0	18	25	0	62	0	0
Nemertea												
Enopla												
Hoplonemertea												
Tetrastemmatidae												
Prostoma sp.	2	4	0	0	0	139	54	148	0	132	0	0
Nematoda	3	4	0	135	0	0	1,089	1,582	0	0	0	285
Bryozoa												
Phylactolaemata												
Urnatella gracilis Leidy	4	5	126	135	0	0	18	0	509	0	0	143
Mollusca												
Gastropoda												
Basommatophora												
Ancylidae												
Ferrissia sp.	5	2	0	0	48	0	18	0	0	0	0	0
Physidae												
Physella sp.	6	2	0	0	0	69	127	0	0	0	0	0
Bivalvia												
Veneroida												
Corbiculidae												
Corbicula sp.	7	7	126	135	0	69	36	41	0	132	0	577
Annelida												
Oligochaeta												
Megadrile	—	1	0	0	0	10	0	0	0	0	0	0
Lumbriculida												

Table 8. Macroinvertebrate taxa from

[Taxa codes were only assigned to taxa found in two or more samples. Frequency of occurrence refers to the number of samples in which a taxon was found. Macroinvertebrate taxa units are in organisms/m2; —, no code assigned.]

Taxon	Taxa code	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
			June	September	June	September	June	September	June	September	June	September
Lumbriculidae	—	1	0	0	0	0	42	0	0	0	0	0
Tubificida												
Naididae	8	10	4,319	2,399	371	3,330	563	1,533	24,997	1,171	18,206	7,327
Tubificidae	9	2	0	0	0	0	109	227	0	0	0	0
Enchytraeida	10	3	126	0	0	0	944	25	0	0	0	0
Polychaeta												
Sabellida												
Sabellidae	—	1	0	0	0	0	0	239	0	0	0	0
Arthropoda												
Arachnida												
Acari	11	8	0	0	3,155	4,301	381	25	13,771	7,952	2,342	2,730
Malacostraca												
Amphipoda												
Corophiidae												
Corophium sp.	12	2	5,977	270	0	0	0	0	0	0	0	0
Gammaridae												
Gammarus sp.	—	1	378	0	0	0	0	0	0	0	0	0
Hyalellidae												
Hyalella azteca (Saussure)	13	3	0	0	0	69	18	0	0	0	258	0
Insecta												
Ephemeroptera												
Baetidae	14	7	0	0	141	347	18	0	3,060	784	781	713
Caenidae												
Caenis sp.	—	1	0	0	0	69	0	0	0	0	0	0
Heptageniidae	15	2	0	0	0	0	0	0	0	62	0	285
Heptagenia sp.												
Leptohyphidae												
Tricorythodes sp.	—	1	0	0	0	0	0	0	1,018	0	0	0
Odonata												

Table 8. Macroinvertebrate taxa from

[Taxa codes were only assigned to taxa found in two or more samples. Frequency of occurrence refers to the number of samples in which a taxon was found. Macroinvertebrate taxa units are in organisms/m2; —, no code assigned.]

Taxon	Taxa code	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
			June	September	June	September	June	September	June	September	June	September
Zygoptera												
Calopterygidae												
Hetaerina sp.	16	3	0	0	12	69	0	0	1,018	0	0	0
Coenagrionidae	17	5	0	0	48	139	0	0	1,533	62	0	7
Trichoptera												
Hydroptilidae												
Hydroptila sp.	18	7	126	0	326	833	18	0	2,042	652	1,303	0
Hydropsychidae												
Hydropsyche sp.	19	8	11,961	26,839	1,398	3,553	0	0	7,675	5,881	15,626	13,806
Lepidoptera												
Pyralidae												
Petrophila sp.	20	2	0	0	0	0	0	0	0	62	0	143
Coleoptera												
Elmidae												
Microcylloepus sp.	—	1	0	0	0	69	0	0	0	0	0	0
Hydrophilidae	—	1	0	0	0	69	0	0	0	0	0	0
Diptera												
Nematocera												
Ceratopogonidae	21	3	126	0	0	0	73	0	0	0	0	143
Chironomidae												
Chironominae												
Chironomini (tribe)												
Cryptochironomus sp.	—	1	0	0	0	69	0	0	0	0	0	0
Dicrotendipes sp.	22	8	889	667	141	2,775	0	0	1,533	388	1,303	2,010
Endotribelos hesperium (Sublette)	—	1	126	0	0	0	0	0	0	0	0	0
Glyptotendipes sp.	—	1	0	0	0	0	0	0	0	0	0	862
Goeldichironomus sp.	—	1	0	270	0	0	0	0	0	0	0	0
Nilothauma sp.	23	2	0	0	0	69	0	0	509	0	0	0

Table 8. Macroinvertebrate taxa from

[Taxa codes were only assigned to taxa found in two or more samples. Frequency of occurrence refers to the number of samples in which a taxon was found. Macroinvertebrate taxa units are in organisms/m2; —, no code assigned.]

Taxon	Taxa code	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
			June	September	June	September	June	September	June	September	June	September
Parachironomus sp.	—	1	0	0	0	0	0	0	0	0	0	428
Paracladopelma sp.	—	1	0	0	0	0	0	0	509	0	0	0
Polypedilum sp.	24	3	0	0	512	1,734	0	0	0	0	258	0
Stenochironomus sp.	25	4	0	0	93	208	0	0	0	264	258	0
Tanytarsini												
Cladotanytarsus sp.	26	4	0	0	0	486	0	0	0	62	258	143
Paratanytarsus sp.	—	1	511	0	0	0	0	0	0	0	0	0
Rheotanytarsus sp.	27	6	0	0	927	1,804	0	0	6,634	264	1,819	1,290
Tanytarsus sp.	28	6	0	0	3,807	2,359	0	0	96,923	3,972	8,839	8,332
Orthocladiinae												
Pseudosmittia sp.	—	1	0	0	0	0	18	0	0	0	0	0
Cricotopus sp.	29	10	4,199	6,807	560	1,873	2,015	346	7,658	590	9,626	3,015
Nanocladius sp.	30	5	889	397	0	0	18	0	509	0	0	143
Parakiefferiella sp.	31	4	0	0	0	416	0	0	0	194	523	285
Rheocricotopus sp.	—	1	0	0	0	0	0	0	0	0	258	0
Synorthocladius sp.	—	1	0	0	48	0	0	0	0	0	0	0
Thienemanniella sp.	32	3	0	0	649	0	0	0	4,083	264	0	0
Tanypodinae												
Pentaneurini												
Ablabesmyia sp.	33	4	0	0	93	69	0	0	509	62	0	0
Thienemannimyia group sp. (Coffman and Ferrington)	34	5	0	0	234	69	0	0	509	62	0	428
Psychodidae												
Psychoda sp.	—	1	0	0	0	0	0	12	0	0	0	0
Simuliidae	36	3	0	0	0	0	0	0	1,533	0	258	285
Tipulidae												
Limoniinae	37	2	6	0	0	0	0	0	0	0	258	0
Brachycera	—	1	0	0	0	0	0	214	0	0	0	0
Empididae												

Table 8. Macroinvertebrate taxa from

[Taxa codes were only assigned to taxa found in two or more samples. Frequency of occurrence refers to the number of samples in which a taxon was found. Macroinvertebrate taxa units are in organisms/m2; —, no code assigned.]

Taxon	Taxa code	Frequency of occurrence	Salt Slough		Merced River		Orestimba Creek		Tuolumne River		San Joaquin River	
			June	September	June	September	June	September	June	September	June	September
Hemerodromia sp.	38	5	0	0	234	0	54	0	509	0	258	720
Neoplasta sp.	35	2	0	0	0	0	0	0	2,551	62	0	0
Dolichopodidae	39	2	0	0	0	0	18	0	0	0	0	143