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Variability in Lotic Communities in Three Contrasting Stream Environments in the Santa Ana River Basin, California, 1999–2001

Scientific Investigations Report 2008-5217

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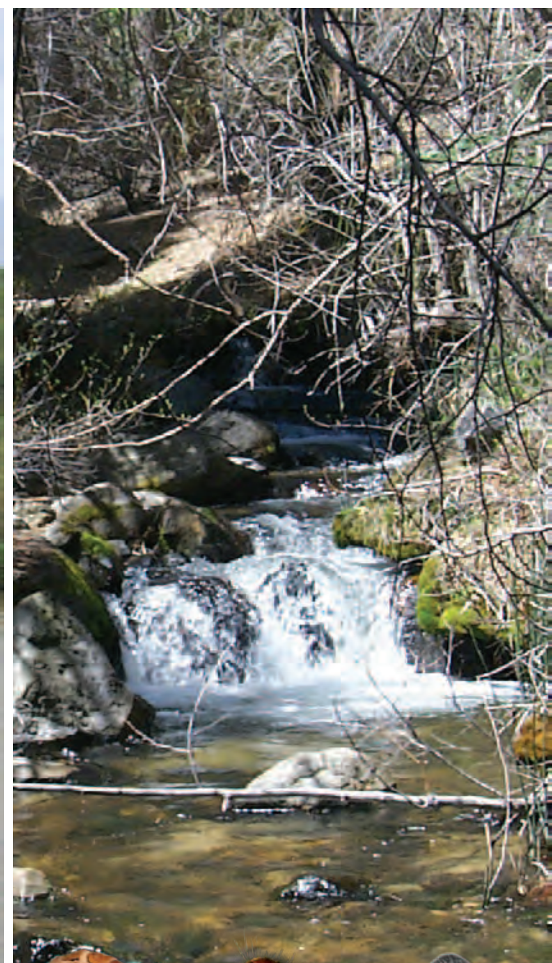

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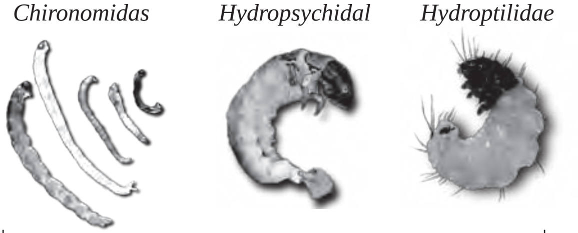
Photograph:	**Photograph:**	**Photograph:**
Santa Ana River below Prado Dam (photo credit: Carmen A. Burton, U.S. Geological Survey, taken January 8, 1998)	Santa Ana River at Metropolitan Water District's pipeline crossing near Arlington (photo credit: Carmen A. Burton, U.S. Geological Survey, taken January 7, 1998)	South Fork of Santa Ana River (photo credit: Carmen A. Burton, U.S. Geological Survey, taken January 6, 1998)

National Water-Quality Assessment Program

Description of invertebrates and algae

Aquatic invertebrates

Chironomidas *Hydropsychidal* *Hydroptilidae*



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Freshwater algae

Cocconeis placentula

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By Carmen A. Burton

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U.S. Department of the Interior
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FOREWORD

The U.S. Geological Survey (USGS) is committed to providing the Nation with credible scientific information that helps to enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (http://www.usgs.gov/). Information on the Nation's water resources is critical to ensuring long-term availability of water that is safe for drinking and recreation and is suitable for industry, irrigation, and fish and wildlife. Population growth and increasing demands for water make the availability of that water, now measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, State, and local information needs and decisions related to water-quality management and policy (http://water.usgs.gov/nawqa). The NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. From 1991-2001, the NAWQA Program completed interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units (http://water.usgs.gov/nawqa/studyu.html).

Multiple national and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are reassessed. These assessments extend the findings in the Study Units by determining status and trends at sites that have been consistently monitored for more than a decade, and filling critical gaps in characterizing the quality of surface water and ground water. For example, increased emphasis has been placed on assessing the quality of source water and finished water associated with many of the Nation's largest community water systems. During the second decade, NAWQA is addressing five national priority topics that build an understanding of how natural features and human activities affect water quality, and establish links between sources of contaminants, the transport of those contaminants through the hydrologic system, and the potential effects of contaminants on humans and aquatic ecosystems. Included are topics on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on aquatic ecosystems, and transport of contaminants to public-supply wells. These topical studies are conducted in those Study Units most affected by these issues; they comprise a set of multi-Study-Unit designs for systematic national assessment. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, selected trace elements, and aquatic ecology are continuing.

The USGS aims to disseminate credible, timely, and relevant science information to address practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, regional, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Matthew C. Larsen

Associate Director for Water

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Abbreviations and Acronyms

(Clarification or additional information given in parentheses)

ANOVA	analysis of variance
CV	coefficient of variation
DTH	depositional-targeted habitat
EPT	sum of Ephemeroptera, Plecoptera, and Trichoptera
FFG	functional feeding groups
IDAS	Invertebrate Data Analysis System (USGS)
P	significance level
PRD	Santa Ana River below Prado Dam
QMH	qualitative multihabitat
RTH	richest-targeted habitat
SF	South Fork of the Santa Ana River near Angeles Oaks
UPH	Santa Ana River at upper powerhouse near Running Springs

Organizations

EPA	U.S. Environmental Protection Agency
MWD	Santa Ana River at Metropolitan Water District's pipeline crossing near Arlington
NAWQA	National Water-Quality Assessment (USGS)
NWQL	National Water Quality Laboratory (USGS)
SAWPA	Santa Ana Watershed Project Authority
USGS	U.S. Geological Survey

Units of Measurement

cm	centimeter (1 cm = 0.3937 in)
ft	foot (feet)
in.	inch
km	kilometer (1 km = 0.6214 mi)
km^2	square kilometer
m	meter (1 m = 3.281 ft)
m^2	square meter
mi	mile
mi^2	square mile
mm	millimeter (10^{-3} meter)
µm	micrometer (10^{-6} meter)

Notes

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

$$°F = (1.8 \times °C) + 32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Variability in Lotic Communities in Three Contrasting Stream Environments in the Santa Ana River Basin, California, 1999–2001

By Carmen A. Burton

Abstract

Biotic communities and environmental conditions can be highly variable between natural ecosystems. The variability of natural assemblages should be considered in the interpretation of any ecological study when samples are either spatially or temporally distributed. Little is known about biotic variability in the Santa Ana River Basin. In this report, the lotic community and habitat assessment data from ecological studies done as part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) program are used for a preliminary assessment of variability in the Santa Ana Basin.

Habitat was assessed, and benthic algae, benthic macroinvertebrate, and fish samples were collected at four sites during 1999–2001. Three of these sites were sampled all three years. One of these sites is located in the San Bernardino Mountains, and the other two sites are located in the alluvial basin. Analysis of variance determined that the three sites with multiyear data were significantly different for 41 benthic algae metrics and 65 macroinvertebrate metrics and fish communities. Coefficients of variation (CVs) were calculated for the habitat measurements, metrics of benthic algae, and macroinvertebrate data as measures of variability. Annual variability of habitat data was generally greater at the mountain site than at the basin sites. The mountain site had higher CVs for water temperature, depth, velocity, canopy angle, streambed substrate, and most water-quality variables. In general, CVs of most benthic algae metrics calculated from the richest-targeted habitat (RTH) samples were greater at the mountain site. In contrast, CVs of most benthic algae metrics calculated from depositional-targeted habitat (DTH) samples were lower at the mountain site. In general, CVs of macroinvertebrate metrics calculated from qualitative multihabitat (QMH) samples were lower at the mountain site. In contrast, CVs of many metrics calculated from RTH samples were greater at the mountain site than at one of the basin sites. Fish communities were more variable at the basin sites because more species were present at these sites.

Annual variability of benthic algae metrics was related to annual variability in habitat variables. The CVs of benthic algae metrics related to the most CVs of habitat variables included QMH taxon richness, the RTH percentage richness, RTH abundance of tolerant taxa, RTH percentage richness of halophilic diatoms, RTH percentage abundance of sestonic diatoms, DTH percentage richness of nitrogen heterotrophic diatoms, and DTH pollution tolerance index. The CVs of macroinvertebrate metrics related to the most CVs of habitat variables included the RTH trichoptera, RTH EPT, RTH scraper richness, RTH nonchironomid dipteran abundance (in percent), and RTH EPA (U.S. Environmental Protection Agency) tolerance, which is based on abundance. Many of the CVs of habitat variables related to CVs of macroinvertebrate metrics were the same habitat variables that were related to the CVs of benthic algae metrics. On the basis of these results, annual variability may have a role in the relationship of benthic algae and macroinvertebrates assemblages with habitat and water quality in the Santa Ana Basin. This report provides valuable baseline data on the variability of biological communities in the Santa Ana Basin.

Introduction

Biotic communities and habitat conditions are known to be highly heterogeneous in natural ecosystems. This heterogeneity is observed at multiple spatial scales ranging from river systems to microhabitats within stream reaches. Variability of natural assemblages should be considered in the interpretation of any ecological study when samples are either spatially or temporally distributed.

Variance of community composition or habitat can be a factor with ecological relevance (Palmer and others, 1997). Many papers (some cited by Palmer and others, 1997) suggest three reasons why studying variance in biotic communities or habitat may aid in understanding stream ecosystems. First, factors that affect ecological processes may be identified by a close examination of individual data points that contribute to variance. Second, changes in variance with spatial scale may lead to a better understanding of stream ecosystems. And third, identification of domains, areas of scale where the variance of a factor does not change (Wiens, 1989), also may lead to better understanding of stream ecosystems.

Effects of variability in benthic algae or habitat have not been studied extensively. However, Cardinale and others (2002) found that increased habitat heterogeneity resulted in increased primary productivity of stream algae. Large spatial variability was observed in some marine algae within similar habitats at the local scale (Wahl, 2001). On the other hand, variability in benthic macroinvertebrate assemblages has been studied for many years. Needham and Usinger (1956) studied the macroinvertebrate genera in a riffle in Prosser Creek, near Truckee, California, and found that most genera preferred moderate depths and velocities. In more recent studies, variation in macroinvertebrates was found at scales as small as groups (patches) of stones (Barmuta, 1990; Downes and others, 1993; Palmer and others, 2000). For example, in a northern Virginia stream, the spatial arrangement of patches or microhabitats was correlated to macroinvertebrate abundance (Palmer and others, 2000). In central Texas, a greater abundance of most macroinvertebrates was found toward the heads of riffles (Brown and Brown, 1984), which contrasts with the findings in Prosser Creek by Needham and Usinger (1956). In northern New Hampshire, benthic macroinvertebrate richness increased and macroinvertebrate variability decreased with increasing habitat heterogeneity (Brown, 2003). In two rivers with different channel forms in New Zealand, seasonal variation in species composition was lower in the river that had the less stable streambed substrate (Fowler and Death, 2000). Spatial variation in macroinvertebrates also occurs at larger scales, such as between streams or ecoregions, for macroinvertebrate richness metrics (Li and others, 2001). All these studies indicate a relationship between macroinvertebrate variability and habitat.

Several studies indicate that variation in fish assemblages is correlated to environmental variables or variation in these variables. Herbert and Gelwick (2003) explained variation in fish assemblages in a Texas stream by instream structure, hydrologic and physicochemical factors, and drainage features. In Minnesota and North Dakota, some species of fish were correlated with low variability in physical and chemical variables (Koel and Peterka, 2003). In central Europe, Slavik and Bartos (2001) observed decreased variation in fish assemblages in response to anthropogenic increases in variation in the physical environment, specifically for dissolved oxygen. Fayram and others (2005) observed higher variability of index of biotic integrity scores for cold-water fish in smaller Wisconsin streams compared with larger streams.

Because factors affecting variability of biota depend on scale (Andrew and others, 2003; Heino and others, 2003; Li and others 2001; Wiens, 1989), scale needs to be considered when changes in biological communities are assessed over space. This could partially explain why findings of different studies do not always agree (Wiens, 1989).

Few studies of biological communities have been conducted in the Santa Ana River Basin. The U.S. Forest Service has collected biological data pertaining to forest lands, especially data on fish populations. The Santa Ana Watershed Project Authority (SAWPA) funded a study to determine the attainable uses of the Santa Ana River, especially in the inland basin. The U.S. Fish and Wildlife Service, the California Department of Fish and Game, and SAWPA are involved in a study to devise strategies to aid the endangered Santa Ana sucker. Very few studies of macroinvertebrates or benthic algae have been conducted in the basin and none have addressed the issues of spatial or annual variability.

The U.S. Geological Survey (USGS) incorporated ecological studies as part of the National Water-Quality Assessment (NAWQA) program (Gilliom and others, 1995). The Santa Ana Basin is one of more than 50 major river basins in the United States (U.S.) included in the NAWQA program. One purpose of these studies is to use the condition of aquatic biological communities as an indicator of the physical and chemical condition of water and hydrologic systems in the U.S. (Gilliom and others, 1995). The data from the Santa Ana NAWQA study was used for a preliminary assessment of variability in the Santa Ana Basin.

The purposes of this report are to assess (1) annual variability at each site for various biological measures, (2) the relationship of variability in biological measures to habitat and water quality variability, and (3) implications of any such relationship for biomonitoring or water management issues in the Santa Ana Basin. In addition, biological community information and habitat assessment data are listed in the appendixes.

Study Design

Description of Study Area

The Santa Ana River Basin is the largest stream system in southern California, encompassing almost 6,900 km^2 (2,670 mi^2) of densely populated coastal area (fig. 1). The river begins in the San Bernardino Mountains (which reach altitudes exceeding 3,000 m (10,000 ft)) and flows more than 160 km (100 mi) to the Pacific Ocean. The watershed is home to almost 4.8 million people, and the population is expected to reach 7 million by the year 2025 (Santa Ana Watershed Project Authority, accessed June 9, 2003).

The basin is divided between two ecoregions, the Southern California Mountains ecoregion and the Southern and Central California Chaparral and Oak Woodlands ecoregion (U.S. Environmental Protection Agency, accessed September 3, 2004). Most of the urban and agricultural land uses occur in the alluvium-filled valleys and coastal plains of the Southern and Central California Chaparral and Oak Woodlands ecoregion (fig. 1).

The basin has a Mediterranean climate, characterized by hot, dry summers and cool, wet winters. Average annual precipitation ranges from about 25 to 60 cm (10 to 24 in.) in the coastal plains and inland valleys, and from 60 to 120 cm (24 to 48 in.) in the San Gabriel and San Bernardino Mountains (U.S. Army Corps of Engineers, 1994). This study started at the beginning of a drought period with annual precipitation well below the norm (Belitz and others, 2004).

The hydrologic system of the basin has been greatly altered. At higher elevations in the mountains, the streams are relatively unaltered except for intense recreational use and some diversions for hydroelectric power production on the Santa Ana River. At the transition from the mountains to the valley, most streams are diverted directly to public drinking-water supplies or to ground-water-recharge facilities. As a result of these alterations to the system and the natural Mediterranean climate, streams generally do not flow onto the valley floor, except during large stormflows that exceed the capacity of the diversions.

Flow is re-established in many low-elevation valley streams by various combinations of urban runoff, ground water, or discharges from wastewater treatment plants. These streams are composed of 70–100 percent treated wastewater (Mendez and Belitz, 2002). All of the base-flow of the river is diverted to a ground-water-recharge facility several miles downstream of Prado Dam. During the period of this study (summer 1999 to summer 2001), precipation was less than the 30-year average. Streamflows in many tributaries to the Santa Ana River were generally near historical lows during base-flow conditions.

Data Collection and Analysis

Site Selection

The Santa Ana Basin study design for NAWQA included seven surface-water fixed sites as part of a surface-water network. These sites were chosen to either represent stream water-quality conditions resulting from a specific land use or to represent stream water-quality conditions resulting from a combination of land uses and other influences. Ecology studies were not carried out at three of the fixed sites because the channels were completely or partially concrete-lined. The four remaining sites ranged from high in the San Bernardino Mountains near the headwaters of the Santa Ana River to just below Prado Dam (fig. 1). These four sites are listed in table 1.

The first site is located on the South Fork of the Santa Ana River near Angeles Oaks in the San Bernardino Mountains (hereinafter, SF). It is an alpine site located in the Southern California Mountains ecoregion (U.S. Environmental Protection Agency, accessed Sept. 3, 2004). The stream channel consists mostly of bedrock, boulders, and cobbles. Land use is undeveloped forest, mainly pines.

The second site is located on the Santa Ana River at the upper powerhouse near Running Springs (hereinafter, UPH). This site is located near the base of the San Bernardino Mountains in the Southern California Mountains ecoregion (fig. 1). The stream channel consists mostly of large boulders and cobbles. Land use is mostly undeveloped chaparral forest with willows, cottonwoods, and alders in the riparian corridor. This site is located upstream of the Seven Oaks Dam, which was under construction during the period of this study. The water quality from this site is similar to that measured at a USGS gage located near the Seven Oaks Dam, which was part of the NAWQA surface-water network.

The third site is located upstream of the Metropolitan Water District's pipeline crossing of the Santa Ana River in the inland basin (hereinafter, MWD). This site is located within the Southern and Central California Chaparral and Oak Woodlands ecoregion (fig. 1). The river at this site is a broad, shallow, sand channel constricted by bedrock outcrops on both banks. Baseflow is primarily treated wastewater supplemented with ground water forced upward by the bedrock outcrops. The riparian vegetation was primarily *Arundo donax* (an invasive, non-native cane), with small amounts of cattails, rushes, willows, and cottonwoods. The *A. donax* was removed during the second and third years of the study. Outside of the riparian corridor, land use is primarily urban.

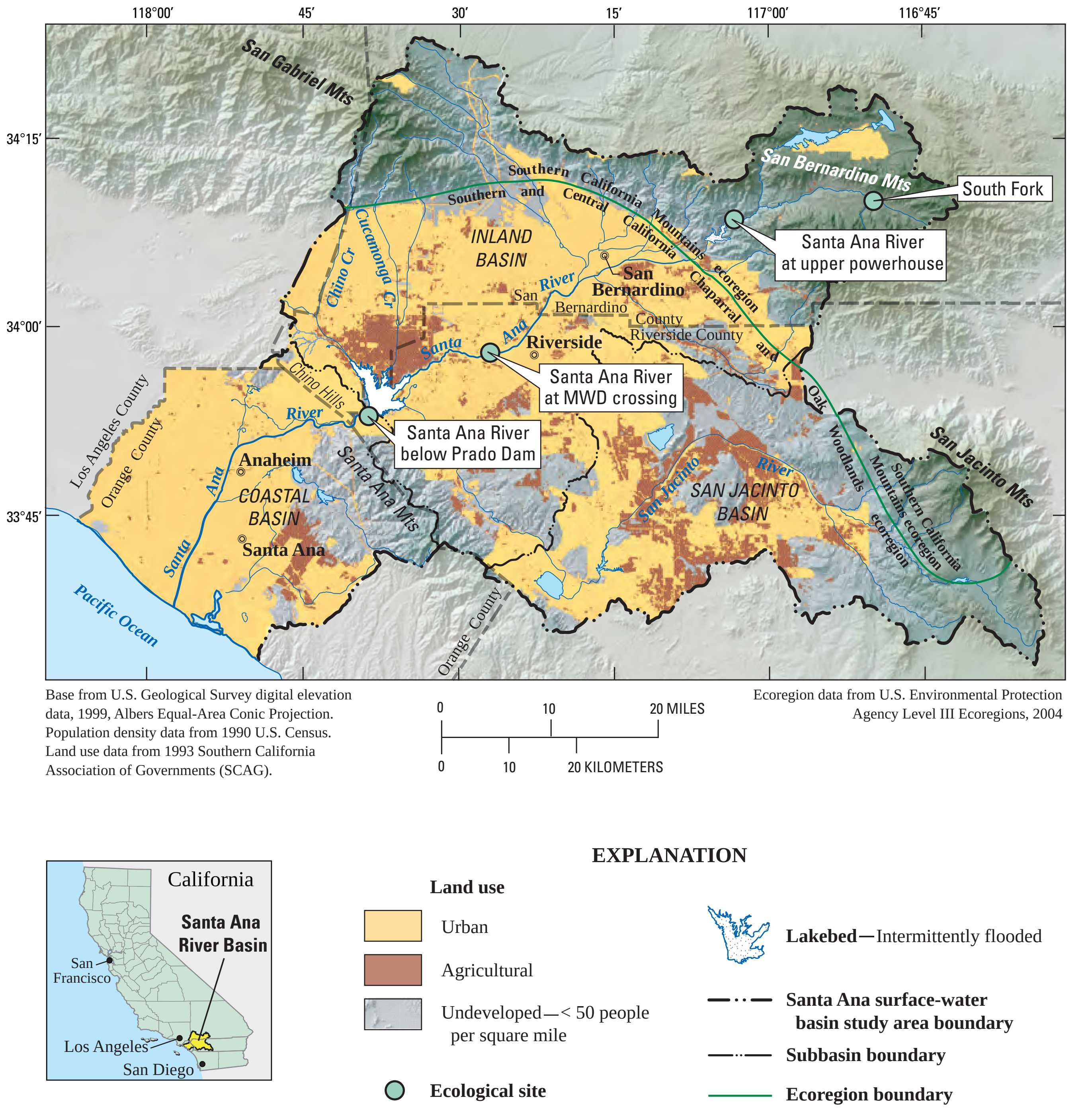

Figure 1. Location of study area, ecology sites, landuse, and ecoregions within the study area.

The fourth site is located on the Santa Ana River below Prado Dam (hereinafter, PRD). This site is also located in the Southern and Central California Chaparral and Oak Woodlands ecoregion (fig. 1). The stream channel consists of mainly cobbles and gravel. Prado Dam is operated for flood control and a permanent pool is not maintained behind the dam. Baseflow is primarily treated wastewater. Upstream of Prado Dam, a series of wetlands were constructed to act as a treatment facility for the removal of nitrate from the Santa Ana River.

Table 1. Sites sampled for benthic algae, macroinvertebrates, fish, and habitat assessment during the summers of 1999, 2000, and 2001 in the Santa Ana River Basin, California.

[mi^2, square mile; MWD, Metropolitan Water District; no., number; USGS, U.S. Geological Survey]

Sample identification	USGS station no.	Station name	Total basin area (mi^2)	Ecology sampling dates
SF99	341014116494801	South Fork of the Santa Ana River	7	July 21−22, 1999
SF00				July 10−11, 2000
SF01				July 23−25, 2001
UPH99	340843117032501	Santa Ana River at upper powerhouse	154	July 19−20, 1999
UPH00				Sept. 15 and 21, 2000[1]
MWD99	11066460	Santa Ana River at MWD crossing	825	July 26−27, 1999
MWD00				July 11−12, 2000
MWD01				July 26−27, 2001
PRD99	11074000	Santa Ana River below Prado Dam	1,439	July 28−29, 1999
PRD00				July 13−14, 2000
PRD01				July 29−Aug. 2, 2001

[1] Sampled fish and habitat only.

Sample Collection

Benthic algae, benthic macroinvertebrate, and fish community data were collected and stream habitat assessed at all sites during low-flow conditions (July to August) from 1999 to 2001 (table 1) to minimize variability resulting from seasonality. Three sites, PRD, MWD, and SF were sampled each year; one site, UPH, was sampled for macroinvertebrates and benthic algae in 1999, and fish and habitat conditions were assessed in 1999 and 2000. 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 conditions were assessed along 11 transects in the reach as described by Fitzpatrick and others (1998). Habitat variables, such as channel width, velocity and substrate variables, and their method of collection, are listed in table 2.

Water-quality samples were collected monthly at PRD (1999–2001) and MWD (1999–2000) as part of the surface-water fixed-site network for NAWQA (Gilliom and others, 1995; Kent and Belitz, 2004). Water-quality samples were collected monthly at SF for the first year (1999) and then quarterly for the next two years. Water-quality samples were collected at the UPH site once in August 2000, but were collected monthly at the USGS gage located about 2 mi downstream for all three years. Only samples collected during the summer months (June–September) were used for analysis to minimize seasonal effects in variability. Water samples were analyzed for major ions, nutrients, and organic carbon at the USGS's National Water Quality Laboratory (NWQL).

Benthic algae samples were collected according to NAWQA protocols (Porter and others, 1993; Moulton and others, 2002) and are briefly summarized below. Three types of samples were collected, one qualitative and two quantitative. Qualitative benthic algae samples were collected from each microhabitat available in the reach using a variety of methods. The subsamples from each microhabitat were composited in a single container.

The quantitative benthic algae samples were collected from five representative areas in each of two different types of microhabitats: depositional-targeted habitat or DTH (which refers to the habitat in the stream where sediments are deposited) and the richest-targeted habitat or RTH (which refers to the habitat where the highest number of taxa is expected to be found). DTH benthic algae samples were collected from the surficial (5–7 mm) layer of epipelic (silt or mud) or epipsammic (sand) microhabitat at five locations within the reach. One-half of a 47-mm Petri dish was gently pushed upside down into the sediment. A stainless-steel spatula was slipped underneath the Petri dish to seal the algae subsample inside the Petri dish. The five subsamples were composited in a single container.

The RTH benthic algae samples were collected from rocks at all stream reaches, except for MWD where the sample was collected from woody snags. Rocks or snags were selected from five areas within a reach at each site. The top-rock scrape method was used except for the sample at UPH. This sample was collected from the top of rocks using the SG-92 benthic algae sampler as described by Porter and others (1993). These methods remove the benthic algae from the rock surface by scrubbing with a small brush. AT MWD, submerged woody snags (5 to 10 snags) were collected and scraped, and the area measured as described by Moulton and others (2002). The subsamples from each area were composited in a single container.

Table 2. Physical habitat variables measured and method of measurement, during the summers of 1999, 2000, and 2001, at four sites in the Santa Ana River Basin, California.

[ft/s, feet per second; m, meter; mm, millimeter; na, not applicable; >, greater than]

Variable (units)	Method of measurement	Equipment used
Reach length (m)	Mid-channel distance from top to bottom of sampling reach	Measuring tape
Reach water-surface gradient	Vertical drop from top to bottom of sampling reach	Surveying level and rod
Wetted channel width (m)	Width of wetted channel at 11 equidistant transects	Measuring tape
Bankful width (m)	Channel width from top of left bank to top of right bank, measured at each of 11 equidistant transects	Measuring tape
Depth (m)	Depth at thalweg (deepest point) and two additional evenly spaced points, measured at each of 11 equidistant transects	Calibrated wading rod
Water velocity (ft/s)	Velocity at thalweg and two additional evenly spaced points, measured at each of 11 equidistant transects	Marsh-McBirney electronic flow meter
Shape index	Calculated[1]	na
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 and right banks, measured at each of 11 equidistant transects	Densiometer
Geomorphic channel units (percent)	Percentage of reach distance consisting of pool, riffle, and run	Measuring tape
Streambed substrate[2]	Dominant substrate at thalweg and two additional evenly spaced points, measured at each of 11 equidistant transects	Visual estimate
Heterogeneity index	Calculated[3]	na

[1] $w/(d^{d/dmax})$ at 11 equidistant transects, where w = wetted channel width, d = mean depth of water along transect, and dmax = maximum depth of water along transect.

[2]The dominant streambed 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 (Fitzpatrick and others, 1998).

[3] Geometric mean of the coefficients of variation for shape index, water velocity, riparian canopy closure, and streambed substrate.

All three types of composited benthic algae samples were preserved in 4-percent formalin. Benthic algae was identified and(or) enumerated at the National Academy of Sciences in Philadelphia, Pennsylvania, according to Charles and others (2002).

Benthic macroinvertebrate samples also were collected according to NAWQA protocols (Cuffney and others, 1993; Moulton and others, 2002). Two types of samples were collected, qualitative and semiquantitative. The qualitative multihabitat (QMH) macroinvertebrate samples were collected using a D-frame kick net equipped with a 210-µm mesh net. All habitat types present at each site were sampled.

The semiquantitative macroinvertebrate samples were RTH samples collected from five representative areas of riffles at PRD, UPH, and SF. Woody snags were used for RTH samples at MWD because riffles were not present at this site. Samples were collected using a modified slack sampler (mesh size 425 µm) with an area of 0.25 m^2. These five subsamples were composited in a single container. The RTH and QMH samples were preserved with 10-percent formalin and sent to the Biological Unit of the NWQL for identification and(or) enumeration according to Moulton and others (2000).

Fish community data were collected following NAWQA protocols (Meador and others, 1993; Moulton and others, 2002). Fish were collected using a Smith-Root Model 12B backpack electrofisher. Additional fish were collected at PRD by seining. Fish were identified to species, weighed, measured, and checked for external anomalies, then returned to the stream.

Data Analysis

Habitat variables were summarized as mean and standard deviation for each year at each site. Water-quality data from samples collected from June to September in each year were summarized as mean and standard deviation. Discharge and water temperature were summarized using data from continuous monitors when possible; otherwise, discrete samples were used. Data for habitat and water-quality variables can be found in appendix 1. To assess the annual habitat variability, coefficients of variation (CV) were calculated from the annual means of habitat variables at sites with multiyear data.

Benthic algae and macroinvertebrate species lists were constructed using all taxa collected in all sample types. Benthic algae were identified to species in most cases. Benthic algae taxa and their densities, where applicable, can be found in appendixes 2, 3, and 4. To assess similarity in taxa among sites and years, the taxa lists for QMH, RTH, and DTH data for all sites were analyzed using an unweighted group average linkage clustering analysis of percentage of similarities. Metrics were calculated using autecological and tolerance information (Van Dam and others, 1994; Bahls, 1993; Lange-Bertalot, 1979). Metrics calculated from the benthic algae data can be found in appendix 5.

Benthic macroinvertebrates were generally identified to genus. Ambiguous individuals identified at a higher taxonomic level (usually family) were distributed among the lower taxa (usually genera) in accordance with the relative abundance of each genus when more than half of the individuals were identified at the lower level. Otherwise, data were aggregated at the higher level of taxonomy. Benthic macroinvertebrates and their densities, where applicable, can be found in appendixes 6 and 7. To assess similarity in taxa among sites and years, the taxa lists for QHM, RTH, and DTH data for all sites were analyzed using an unweighted group average linkage clustering analysis of percentage of similarities. The taxa data also were summarized as biological metrics using the Invertebrate Data Analysis System (IDAS) program developed by the USGS (Cuffney, 2003). The metrics calculated from macroinvertebrate data can be found in appendix 8.

Analysis of variance (ANOVA) was used to determine which benthic algae and macroinvertebrate metrics were significantly different ($P < 0.05$) between the three sites with multiyear data. CVs were calculated for each metric that was significantly different between sites. The CV was used as a measure of temporal variance to compare sites with multiyear data. Biplots were used to examine the relationships between the CVs of benthic algae or macroinvertebrate metrics and the CVs of habitat variables. Metrics of benthic algae or macroinvertebrates that were not present at all three sites were not used in comparisons involving variance.

Fish data were summarized as relative abundance of fish species and the mean and range of the weight and length of individuals measured for each species. Appendix 9 gives the summary of fish data. Fish abundance data for all sites were analyzed using an unweighted group average linkage clustering analysis of percentage of similarities among fish samples.

Variability of Benthic Algae, Macroinvertebrates, and Fish

Benthic Algae

The cluster dendrogram of benthic algae data indicates that, for each site, the 2000 and 2001 samples were more similar to each other compared with the 1999 sample (fig. 2). This pattern was observed with QMH, RTH, and DTH samples. This may be a result of a storm that occurred in the mountains two weeks before sampling in 1999. The higher flows from the storm may have disturbed the benthic algae, especially those in depositional zones. Some benthic algae species, such as stalked diatoms (*Gomphonema*) (Burkholder, 1996; Kutka and Richards, 1996; Peterson, 1996) or prostrate diatoms with mucilaginous forms (*Achnanthes*, *Cocconeis*) (Goldsborough and Robinson, 1996; Hill, 1996; Kutka and Richards, 1996), recover more quickly from high flows. Higher abundances of these types of diatoms in the 1999 samples support the hypothesis that the storm was responsible for the differences.

Of the 116 metrics calculated, CVs were calculated for the 41 metrics (table 3) that were significantly different among sites. In general, CVs of most benthic algae metrics calculated from the RTH samples were higher at SF than at MWD or PRD (table 3). In contrast, CVs of most metrics calculated from DTH samples were lower at SF. MWD generally had the highest CVs for metrics from DTH samples. CVs of most metrics that were calculated for both RTH and DTH samples were in the same ranges (<30, 30–100, >100). This suggests that, in general, annual variability was not strongly related to different microhabitats (pools vs. riffles or woody snags).

Differences in annual variability may be a result of comparing the smaller SF site with the larger MWD and PRD sites (Vannote and others, 1980). Only four RTH metrics and two DTH metrics had CVs greater than 100 percent, indicating relatively low annual variation at all three sites for most benthic algae metrics. This may be a result of the study occurring during drought years (Belitz and others, 2004).

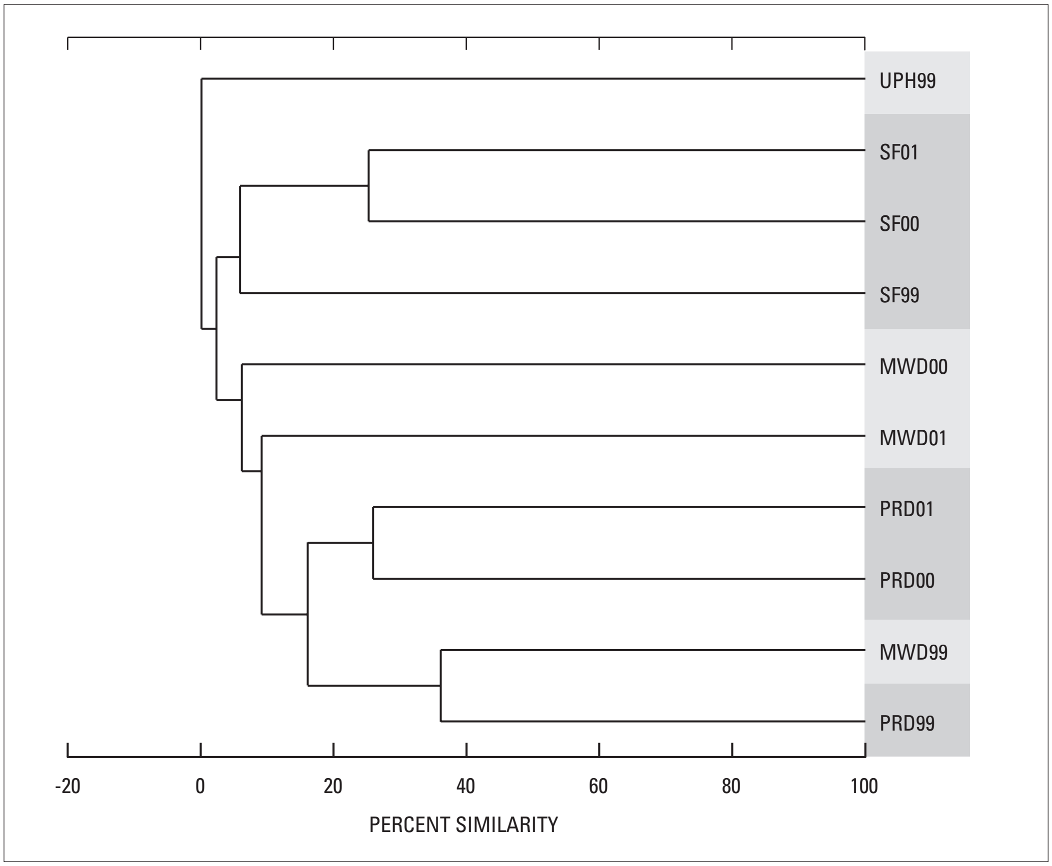

Figure 2. Cluster dendrogram showing the results of an unweighted group average linkage cluster analysis of benthic algae data collected from four sites (SF, UPH, MWD, and PRD) in the Santa Ana River Basin, California, 1999–2001. See table 1 for sample codes.

Macroinvertebrates

The cluster dendrogram of benthic macroinvertebrate data indicates that the similarities between samples for each site is much higher than was observed in the benthic algae samples, suggesting little effect from the 1999 storm (fig. 3). Of the 167 metrics calculated for macroinvertebrates, CVs were calculated for the 65 metrics (table 4) that were significantly different among sites.

Differences in annual variation among sites were observed for both richness and abundance metrics in the Santa Ana River Basin. In general, CVs of macroinvertebrate metrics calculated from QMH samples were lower at SF than at MWD or PRD. In contrast, CVs of many metrics calculated from RTH samples were higher at SF than at MWD. PRD and SF had about the same number of high values for metrics from RTH samples; this is similar to the trend that was observed for benthic algae. MWD generally had lower CVs for RTH richness metrics than PRD, but had higher CVs for RTH abundance metrics. The higher CVs for abundance at MWD may be due to the unstable sand streambed. However, in a New Zealand study, Fowler and Death (2000) found less monthly variability at the site with the most unstable streambed substrate. They attributed this to the fewer number of species present at that site. In contrast, MWD had higher taxa richness than PRD during this study. The differences in temporal variability between this study (annual) and the New Zealand study (monthly) may have been due to the different temporal scales. Similar to algae, the CVs for almost all of the macroinvertebrate metrics were relatively low. Only six metrics, mainly abundance metrics, had CVs greater than 100 percent. This suggests that during the period of this study, annual variability in macroinvertebrate assemblages was low for all three sites. This low variability may be the result of fewer scouring events from stormflows because of the drought.

Table 3. Coefficients of variation for benthic algae metrics that showed significant differences between sites, Santa Ana River Basin, California, 1999-2001.

[Coefficients of variation are given in percent; significance is at P<0.05. CV, coefficient of variation ; MWD, Metropolitan Water District; QMH, qualitative habitat; RTH, richest targeted habitat; DTH, depositional habitat; nd, not detected]

Metric	CV for South Fork of Santa Ana River	CV for Santa Ana River and MWD Crossing	CV for Santa Ana River below Prado Dam
Metrics from QMH data			
Taxon richness	3.4	10.6	9.5
Phylum richness	26.6	21.7	34.6
Metrics from RTH data			
Simpson's diversity index	15.2	1.1	4.3
Taxon richness	13.3	12.5	7.1
Taxon abundance	60.9	138.2	60.5
Diatom richness	16.1	10.6	3.8
Blue-green algae abundance	173.2	122.2	173.2
Obligative nitrogen autotrophic diatom richness (in percent)	70.3	98.2	37.9
Halophobic (fresh) diatom richness (in percent)	9.7	nd	5.1
Sestonic diatom richness (in percent)	nd	9.7	59.3
Motile diatom richness (in percent)	12.5	7.9	11.7
Tolerant taxon richness (in percent)	38.0	15.6	12.7
Intolerant taxon richness (in percent)	14.5	55.5	20.9
Nitrogen heterotrophic diatom abundance (percent)	69.9	35.5	37.6
Facultative nitrogen autotroph abundance (in percent)	7.9	22.1	0.9
Halophilic diatom abundance (percent)	127.5	12.1	22.0
Halophobic (fresh-brackish) diatom abundance (in percent)	3.8	3.7	10.2
Sestonic diatom abundance (in percent)	nd	37.9	39.7
Motile diatom abundance (percent)	67.5	4.1	11.0
Bahl's tolerance index based on abundance	5.8	10.5	5.3
Tolerant taxon abundance (in percent)	51.0	5.7	6.0
Intolerant taxon abundance (in percent)	19.3	108.2	15.7
Siltation index	60.6	12.8	5.2
Pollution tolerance index	8.1	20.6	6.0

Table 3. Coefficients of variation for benthic algae metrics that showed significant differences between sites, Santa Ana River Basin, California, 1999-2001.—Continued

[Coefficients of variation are given in percent; significance is at P<0.05. CV, coefficient of variation ; MWD, Metropolitan Water District; QMH, qualitative habitat; RTH, richest targeted habitat; DTH, depositional habitat; nd, not detected]

Metric	CV for South Fork of Santa Ana River	CV for Santa Ana River and MWD Crossing	CV for Santa Ana River below Prado Dam
Metrics from DTH data			
Simpson's diversity index	5.5	9.1	3.8
Nitrogen heterotrophic diatom richness (in percent)	29.5	9.3	8.8
Obligative nitrogen autotrophic diatom richness (in percent)	25.5	72.2	51.7
Eutrophic diatom richness (in percent)	9.9	8.8	4.4
Halophilic diatom richness (in percent)	13.5	21.8	28.6
Alkaline diation richness (in percent)	1.8	3.5	3.1
Sestonic diatom richness (in percent)	173.2	173.2	23.4
Motile diatom richness (in percent)	5.4	8.7	8.5
Intolerant taxon richness (in percent)	12.7	17.4	30.8
Facultative nitrogen autotroph abundance (in percent)	1.1	48.7	31.7
Obligative nitrogen autotroph abundance (in percent)	22.1	38.3	81.9
Eutrophic diatom abundance (in percent)	25.6	6.0	11.4
Halophobic (fresh-brackish) diatom abundance (in percent)	80.0	173.2	102.8
Motile diatom abundance (in percent)	22.7	16.1	11.0
Bahl's tolerance index based on abundance	5.7	15.6	5.4
Siltation index	11.4	34.6	14.4
Pollution tolerance index	17.2	22.9	6.6

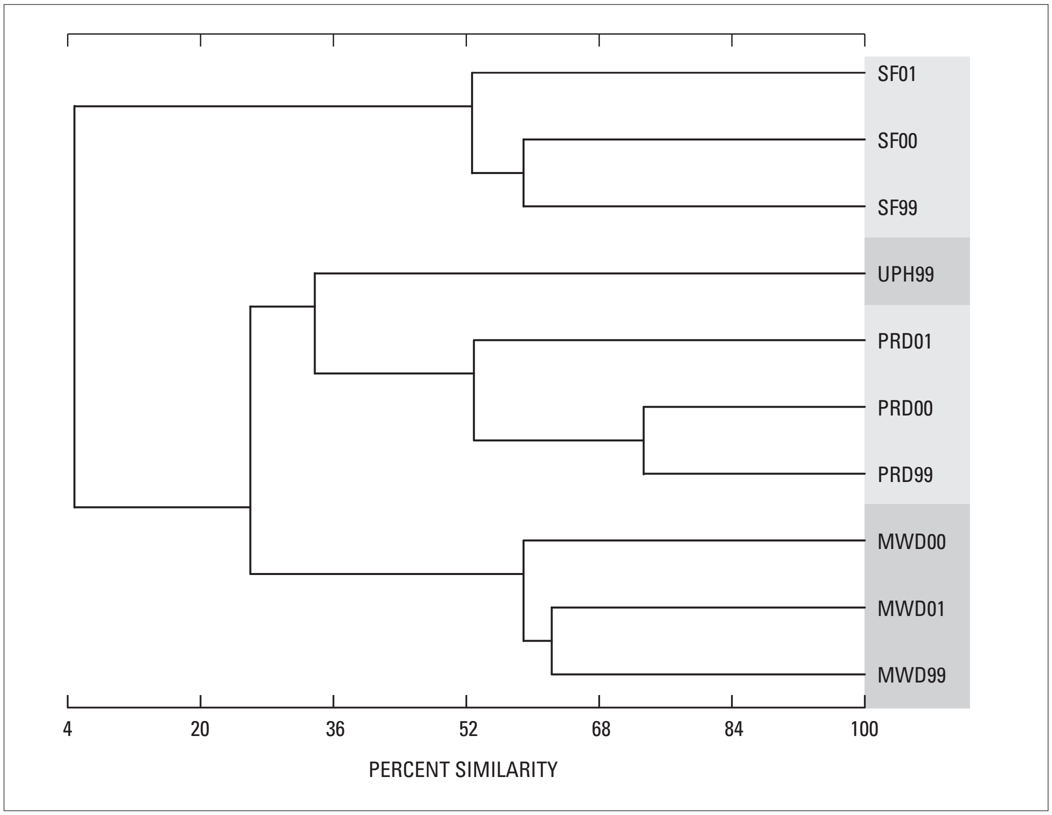

Figure 3. Cluster dendrogram showing the results of an unweighted group average linkage cluster analysis of macroinvertebrate data collected from four sites (SF, UPH, MWD, and PRD) in the Santa Ana River Basin, California, 1999–2001. See table 1 for sample codes.

The difference in CV between SF and MWD or PRD for a particular metric is generally greater than the difference in CV between MWD and PRD. This trend may be partially a result of ecoregion differences because SF is located in a different ecoregion than MWD and PRD. It is also possible that differences in stream size may also be a partial explanation for differences in variability between SF and the basin sites, as was suggested for benthic algae.

Fish

The cluster dendrogram for fish data shows that the samples from each site were generally similar, indicating low annual variability (fig. 4). However, fish samples from SF and UPH were less variable from year to year than the samples from PRD and MWD. The main reason for the low variability at SF and UPH is the low number of species (1 or 2) present compared with several species found at either MWD or PRD. For this reason, variability between sites or between years was not further investigated. More detailed information on the distribution of fish in the basin can be found in Brown and others (2005).

Table 4. Coefficients of variation for benthic macroinvertebrate metrics that showed significant differences among three sites, Santa Ana River Basin, California, 1999–2001.

[Coefficients of variation are given in percent. Significance is at P < 0.05; CV, coefficient of variation; EPA, Environmental Protection Agency; EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; MWD, Metropolitan Water District; nd, not detected; QMH, qualitative multihabitat; RTH, richest-targeted habitat]

Metric	CV for South Fork of Santa Ana River	CV for Santa Ana River at MWD Crossing	CV for Santa Ana River below Prado Dam
Metrics from QMH data			
Taxon richness	7.7	8.9	15.6
Ephemeroptera richness	15.8	25.0	21.7
Trichoptera richness	20.8	21.7	0.0
EPT richness	11.3	8.7	12.4
EPT/Chironmid richness	12.1	23.3	11.1
Diptera richness	9.2	7.5	9.4
Chironomid richness	13.3	15.8	5.6
Nonchironomid dipteran richness	19.9	10.2	50.0
Noninsect richness	0.0	17.3	20.0
Nonmidge dipterans and noninsect richness	12.1	4.7	24.7
Odonate richness	nd	0.0	114.6
Ephemeroptera richness (percent)	14.4	33.3	8.2
Trichoptera richness (percent)	20.9	16.1	16.8
EPT richness (percent)	3.6	16.6	4.5
Diptera richness (percent)	1.8	11.7	7.2
Chironomid richness (percent)	10.7	15.1	13.7
Noninsect richness (percent)	7.6	9.6	6.2
Nonmidge dipterans and noninsect richness (percent)	10.3	5.3	11.5
Oligochaete richness (percent)	7.6	44.8	16.7
Average EPA tolerance value based on richness	2.2	2.2	1.6
Filterer richness	20.0	0.0	25.0
Gatherer richness	14.0	14.5	17.6
Scraper richness	21.7	43.3	0.0
Filterer richness (percent)	13.1	7.1	15.3
Scraper richness (percent)	18.0	46.0	17.0
Metrics from RTH data			
Taxon richness	5.1	13.9	30.7
Ephemeroptera richness	19.9	17.3	34.6
Trichoptera richness	39.0	0.0	0.0
EPT richness	12.5	10.8	15.7
EPT/Chironmid richness	11.6	50.2	23.4
Orthoclad richness	20.0	0.0	49.5
Odonate richness	nd	0.0	nd
Coleoptera richness	173.2	100.0	nd
EPT richness (percent)	16.2	10.2	44.1
Odonate richness (percent)	nd	14.7	nd

Table 4. Coefficients of variation for benthic macroinvertebrate metrics that showed significant differences among three sites, Santa Ana River Basin, California, 1999–2001.—Continued

[Coefficients of variation are given in percent. Significance is at P < 0.05; CV, coefficient of variation; EPA, Environmental Protection Agency; EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; MWD, Metropolitan Water District; nd, not detected; QMH, qualitative multihabitat; RTH, richest-targeted habitat]

Metric	CV for South Fork of Santa Ana River	CV for Santa Ana River at MWD Crossing	CV for Santa Ana River below Prado Dam
Noninsect richness (percent	34.6	34.2	15.4
Oligochaete richness (percent)	37.7	24.3	32.5
Taxon abundance	35.0	19.5	48.1
Ephemeroptera abundance	33.9	21.3	111.7
Nonchironomid diptera abundance	74.5	21.8	39.7
Nonmidge dipterans and noninsect abundance	3.9	110.9	46.3
Mollusc and crustacean abundance	173.2	nd	155.4
Oligochaete abundance	76.1	17.8	35.1
Ephemeroptera abundance (percent)	25.1	41.4	79.3
Trichoptera abundance (percent)	36.5	44.5	12.7
Tanytarsinii abundance (percent)	51.0	173.2	91.9
Nonchironomid dipteran abundance (percent)	46.2	31.3	80.4
Nonmidge dipterans and noninsect abundance (percent)	19.9	118.7	41.3
Coleoptera abundance (percent)	173.2	93.7	nd
Mollusc and crustacean abundance (percent)	173.2	nd	166.0
Average EPA tolerance value based on richness	8.5	5.7	1.6
EPA tolerance value (average, abundance-weighted)	12.7	5.5	5.1
Percentage of most abundant taxon	2.1	60.0	14.0
Percentage of two most abundant taxon	10.2	32.6	4.3
Simpson’s diversity index	2.7	7.9	43.1
Predator richness	37.8	17.3	50.0
Scraper richness	21.7	43.3	43.3
Shredder richness	21.7	50.0	0.0
Filterer richness (percent)	34.6	14.7	15.1
Scraper richness (percent)	20.1	62.2	23.4
Predator abundance	33.4	41.4	45.8
Gatherer abundance	41.7	13.6	42.8
Predator abundance (percent)	22.7	48.7	85.9
Gatherer abundance (percent)	19.8	27.5	45.3
Filterer abundance (percent)	34.2	22.8	14.7

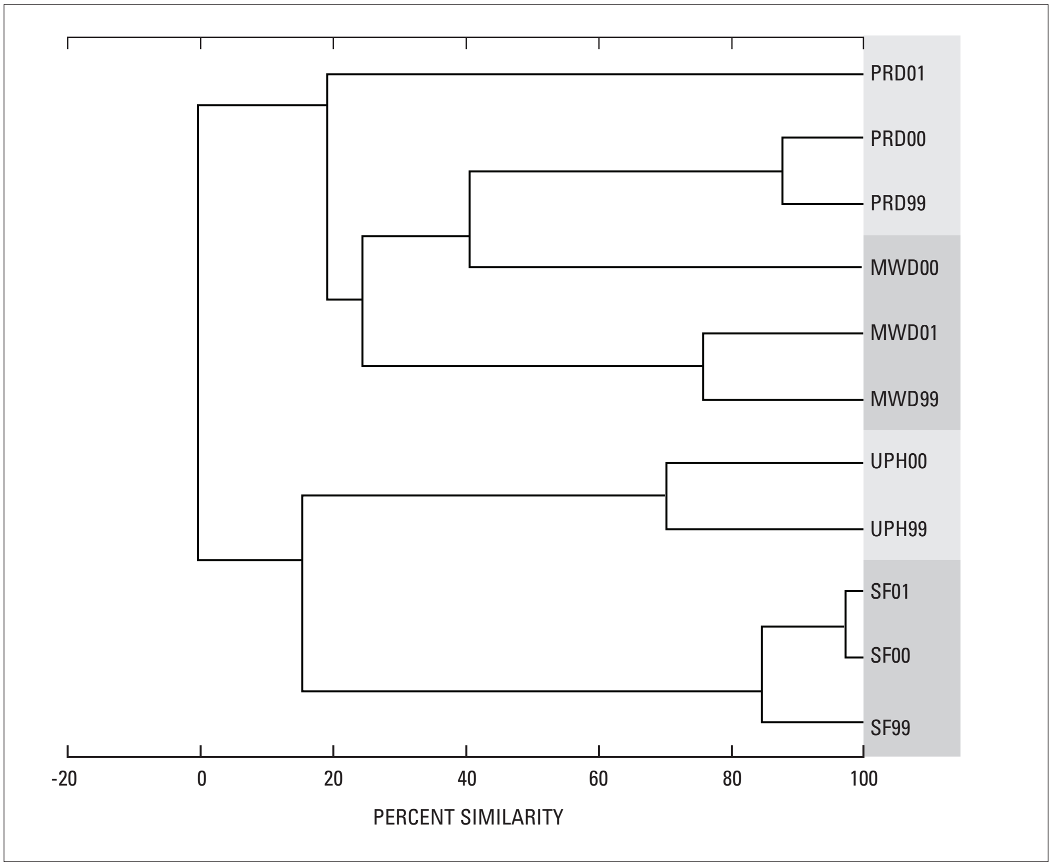

Figure 4. Cluster dendrogram showing the results of an unweighted group average linkage cluster analysis of fish data collected from four sites (SF, UPH, MWD, and PRD) in the Santa Ana River Basin, California, 1999–2001.
See table 1 for sample codes.

Variability in Habitat and Water Quality

Differences in CV between sites were observed for many habitat and water-quality variables. Annual variability was greater at SF than at the basin sites for most of the habitat and water-quality variables (table 5). SF had higher CVs for water temperature, depth, velocity, canopy angle, streambed substrate, and most water-quality variables. The CVs for these variables ranged from 10 to 105 percent. In general, the CVs at SF were higher than those for wilderness streams in Idaho (Robinson and others, 2000). This suggests the physical environment was more dynamic at SF than at the Idaho streams. The CV for the heterogeneity index was low (three percent) suggesting little change in channel complexity during the three years.

The multiyear CVs (table 5) for the habitat and water-quality variables, such as channel width, water temperature, and specific conductance, for PRD and MWD were generally low (frequently less than 30 percent). The CVs for riparian canopy closure and the heterogeneity index were higher at MWD. This increase was due to the removal of *Arundo donax*, an invasive cane species, which began during summer 2000. As a result, shading at the channel margins was greatly reduced during the last two years of the study.

Table 5. Coefficients of variation of habitat variables for the three summers of 1999–2001 for three sites in the Santa Ana River Basin, California.

[CV, coefficient of variation; mm, millimeter; MWD, Metropolitan Water District; >, greater than]

Variable	CV for South Fork of Santa Ana River	CV for Santa Ana River at MWD Crossing	CV for Santa Ana River below Prado Dam
Discharge	46.8	19.6	11.6
Water temperature	15.4	5.9	5.2
Reach gradient	0.9	0.0	40.3
Wetted channel width	24.6	26.5	25.5
Bankfull width	21.6	25.9	24.5
Depth	44.3	37.9	39.3
Velocity	100.8	35.2	63.9
Shape index	17.7	22.2	7.2
Canopy angle	105.4	7.5	57.0
Riparian canopy closure	12.9	63.6	16.1
Streambed substrate[1]	40.5	3.4	38.9
Run	66.4	0.0	9.1
Riffle	5.4	0.0	18.1
Pool	55.4	0.0	93.0
Heterogeneity index[2]	3.3	139.5	40.9
Specific conductance	9.8	2.6	2.0
Oxygen, dissolved	8.0	9.5	4.8
Chloride, dissolved	41.8	5.1	3.8
Nitrite + nitrate, dissolved	15.4	12.1	7.4
Orthophosphate, dissolved	66.1	7.2	15.5
Total organic carbon	53.3	16.0	38.0

[1]The streambed substrate size 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 (Fitzpatrick and others, 1998).

[2]The heterogeneity index is the geometric mean of the coefficient of variation of shape index, riparian canopy closure, stream velocity, and streambed substrate.

Relationship of Biological Variability to Habitat Variability

Benthic Algae

Many studies have shown that benthic algae assemblages are correlated to a variety of environmental variables (Leland, 1995; DeNicola, 1996; Hill and others, 2000; Sherwood and others, 2000; Kennen and Ayers, 2002). In the Santa Ana River Basin, many benthic algae metrics were associated with habitat and water-quality variables (Burton and others, 2005). However, it may be just as important to investigate the role variability may have in the interaction of benthic algae and habitat as suggested by Palmer and others (1997).

Associations of CVs of benthic algae metrics with the CVs of habitat variables suggest a relationship between the variability in benthic algae metrics and habitat variables (see fig. 5 for examples). Of the 41 benthic algae metrics that were significantly different among sites, the CVs of 22 showed a relationship with the CV of at least one habitat variable. One QMH metric, four RTH metrics, and two DTH metrics were related to the CVs of three habitat variables (table 6). The QMH metric is taxon richness. The RTH metrics included percentage richness and abundance of tolerant taxa (tolerant taxa as defined by Lange-Bertelot [1979]), percentage richness of halophobic diatoms, and percentage abundance of sestonic diatoms. The DTH metrics included percentage richness of nitrogen heterotrophic diatoms and the pollution tolerance index. The habitat variables that were related most often to benthic algae metrics included water temperature, water depth, streambed substrate, the percentage of the reach consisting of run, specific conductance, and concentrations of chloride and orthophosphate.

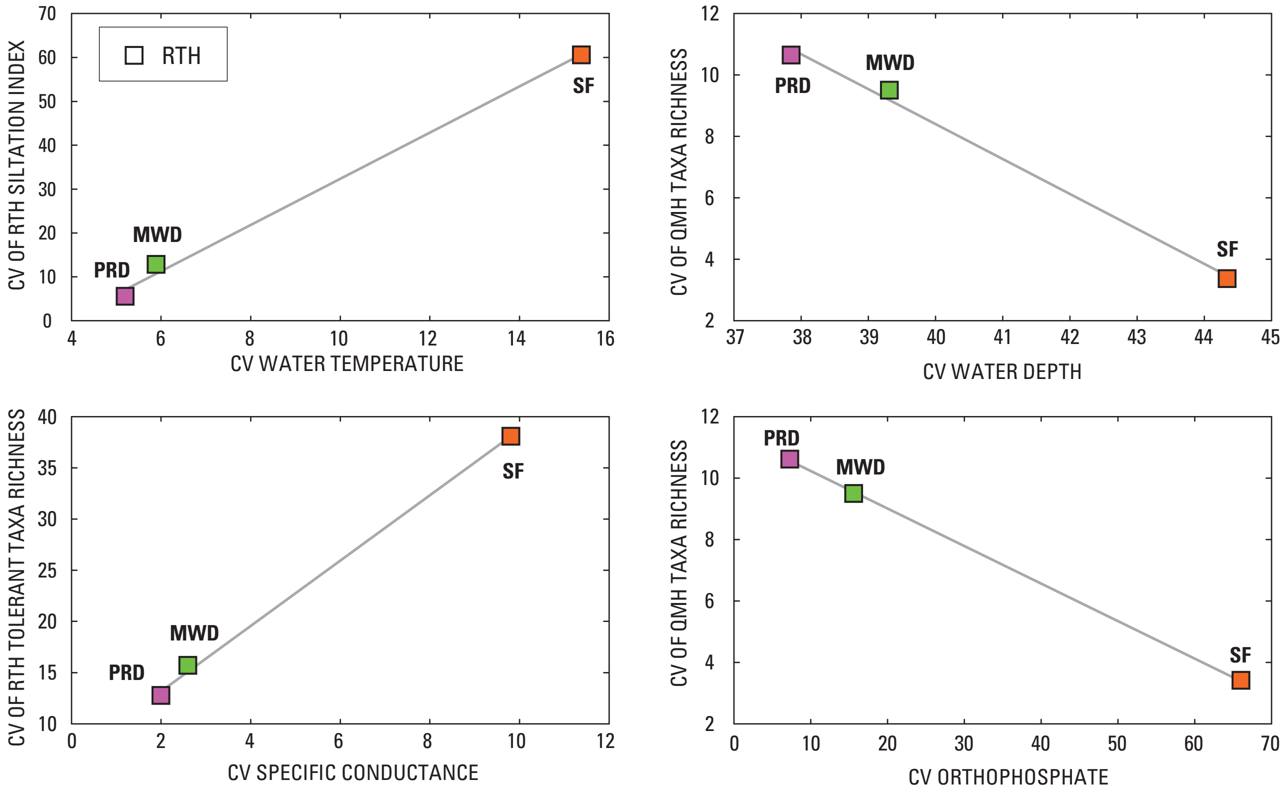

Figure 5. The relationships of the coefficient of variation of selected habitat variables to the coefficient of variation of selected benthic algae metrics collected at three sites (SF, MWD, and PRD) in the Santa Ana River Basin, California, 1999–2001. See table 1 for sample codes and list of Abbreviations and Acronyms for definitions.

This study suggests that variability of benthic algae metrics is related to variability of habitat variables in the Santa Ana River Basin. However, ecoregion differences and the stream size also may have effects. This study included three sites with only three years of data. Additional studies that would include more sites over a longer time period would be needed to better understand the relationship between benthic algae variability and the variability of habitat. Also, this study addresses temporal variability on only an annual scale. Variability on shorter (seasonal) or longer (decadal) temporal scales may also occur.

Macroinvertebrates

Many studies have shown that macroinvertebrate assemblages are correlated to a variety of environmental variables (Brown and Brown, 1984; Barmuta, 1990; Fore and others, 1996; Leland and Fend, 1998; Brown and May, 2000). Brown and Brown (1984) showed correlations of macroinvertebrate assemblages with streambed substrate size, velocity, depth, dissolved oxygen, and water temperature. Correlations of specific conductance with macroinvertebrates assemblages have also been found (Leland and Fend, 1998; Brown and May, 2000). Higher abundance and richness of different types of functional feeding groups (FFG) have been observed in riffles (high velocity) even though more detritus (food) was available in pools (low velocity) with different substrate sizes (Barmuta, 1990). Similar relationships have also been observed in the Santa Ana River Basin (Brown and others, 2005; Burton and others, 2005). However, as with benthic algae, it may be just as important to investigate the interaction of habitat variability and variability in macroinvertebrate assemblages.

Of the 65 macroinvertebrate metrics that showed significant differences between sites, the CVs of 44 macroinvertebrate metrics showed a relationship with the CV of at least one habitat variable (see fig. 6 for examples). The CVs of six RTH metrics showed a relationship with the CVs of more than two habitat variables (table 7). The RTH metrics included the sum of Ephemeroptera, Plecoptera, and trichoptera (EPT) and scraper richness, percentage abundance of trichoptera and nonchironomid dipteran, and U.S. Environmental Protection Agency (EPA) tolerance (as described in Barbour and others, 1999), which is based on abundance. The habitat variables with CVs related to the most CVs of macroinvertebrate metrics included water temperature, water depth, riparian canopy closure, streambed substrate, percentage of the reach consisting of run, specific conductance, and orthophosphate concentrations.

Table 6. Benthic algae metric coefficients of variation that show a positive or negative association with the coefficient of variation of at least one habitat variable.

[(+), suggests a positive association with the algae metric; (–), suggests a negative association with the algae metric. CV, coefficient of variation; DTH, depositional-targeted habitat; QMH, qualitative multihabitat; RTH, richest-targeted habitat; mm, millimeter; nd, not detected]

QMH and RTH algae metric CVs and associated habitat variable CVs		
QMH taxon richness Depth (–) Run (–) Orthophosphate, dissolved (–)	**Halophobic (fresh) diatom richness (percent)** Wetted channel width (–) Canopy angle (+) Total organic carbon (+)	**Sestonic diatom abundance (percent)** Water temperature (–) Specific conductance (–) Chloride, dissolved (–)
QMH phylum richness Oxygen, dissolved (–)	**Tolerant taxon richness (percent)** Water temperature (+) Specific conductance (+) Chloride, dissolved (+)	**Motile diatom abundance (percent)** Run (+) Orthophosphate, dissolved (+)
Simpson's diversity index Depth (+)	**Nitrogen heterotrophic diatom abundance (percent)** Run (+) Orthophosphate, dissolved (+)	**Tolerant taxon abundance (percent)** Water temperature (+) Specific conductance (+) Chloride, dissolved (+)
Taxon abundance Riparian canopy closure (+) Streambed substrate[1] (–)	**Halophilic diatom abundance (percent)** Run (+) Orthophosphate, dissolved (+)	**Siltation index** Water temperature (+) Specific conductance (+)
Blue-green algae abundance Riparian canopy closure (–) Streambed substrate (+)	**Halophobic (fresh-brackish) diatom abundance (percent)** Wetted channel width (+)	
DTH algae metric CVs and associated habitat variable CVs		
Nitrogen heterophic diatom richness (percent) Water temperature (+) Specific conductance (+) Chloride, dissolved (+)	**Sestonic diatom richness (percent)** Reach gradient (–)	**Siltation index** Riparian canopy closure (+)
Obligative nitrogen autotrophic diatom richness (percent) Velocity (–) Canopy angle (–)	**Facultative nitrogen autotroph abundance (percent)** Bankfull width (+)	**Pollution tolerance index** Shape index (+) Riffle (–) Oxygen, dissolved (+)
Alkaline diation richness (percent) Depth (–)	**Halophobic (fresh-brackish) diatom abundance (percent)** Heterogeneity index[2] (+)	

[1]The streambed substrate size 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 (Fitzpatrick and others, 1998).

[2] The heterogenieity index is the geometric mean of the coefficient of variation of the shape index, the riparian closure, stream velocity, and streambed substrate.

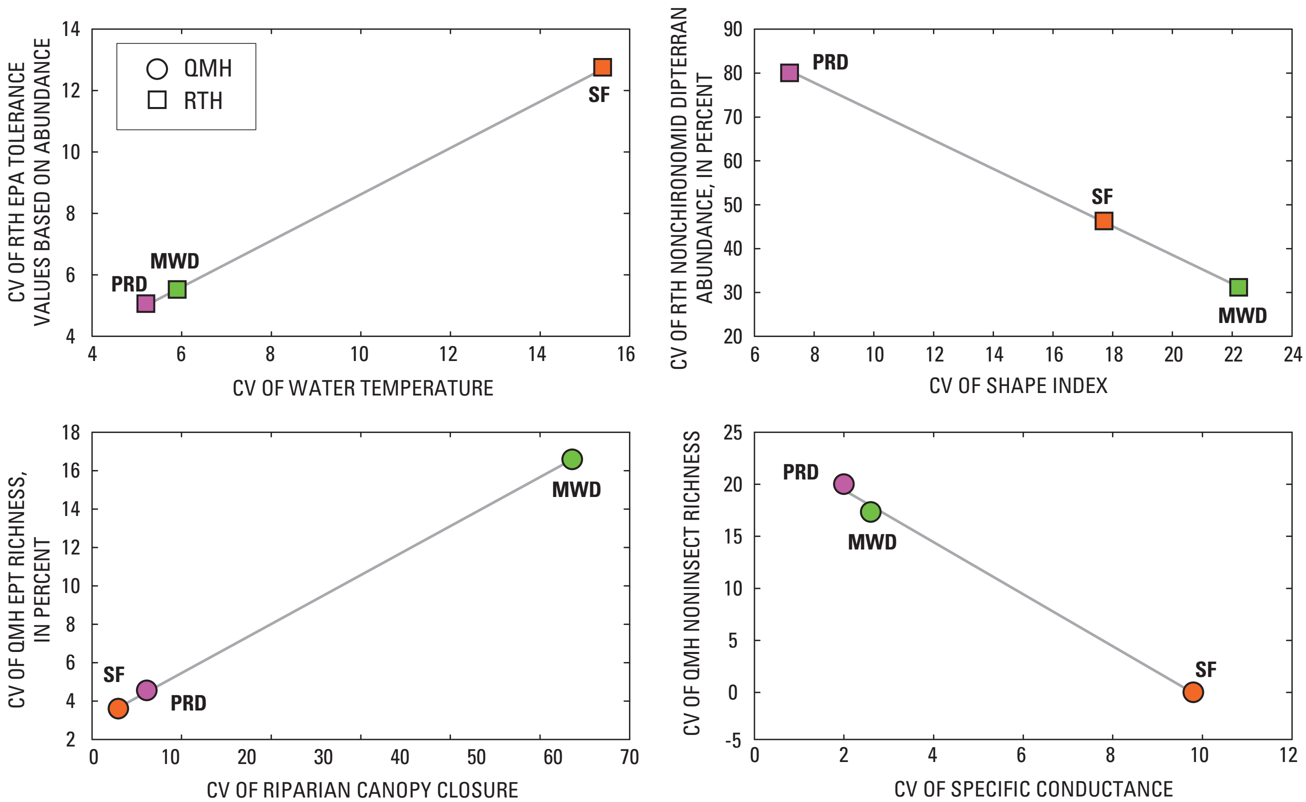

Figure 6. The relationships of the coefficient of variation of selected habitat variables to the coefficient of variation of selected macroinvertebrate metrics collected at three sites. (SF, MWD, and PRD) in the Santa Ana River Basin, California, 1999–2001. CV, coefficient of variation; EPA, U.S. Environmental Protection Agency; EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; RTH, richest-targeted habitat; DTH, depositional-targeted habitat; QMH, qualitative multihabitat.

This study suggests that annual variability of habitat variables may be related to variability of macroinvertebrate metrics in the Santa Ana River Basin. However, it is also possible that ecoregion differences and stream size may have effects on macroinvertebrate variability. As noted previously, this study included three sites with only three years of data. Additional studies would be needed to better define this relationship. More sites over a longer time period are necessary to better understand the role of variability in the relationship between habitat and macroinvertebrates and at what scales these relationships exist. Studies using individual taxa, in addition to metrics, may need to be investigated to determine some of these relationships.

Implications of Variability to Biomonitoring or Water Management Issues

Aquatic ecosystems are naturally dynamic and vary over space and time. This report shows the annual variability for habitat, water quality, and biological communities. The differences in biological communities at small and large temporal scales need to be documented in the Santa Ana River to determine if observed changes in communities are within the range of natural variability or if human activities may be the cause. This information would be important for any biomonitoring program that evaluates whether the ecosystem is improving or degrading in quality.

The effects of physical variability on aquatic life are important considerations for water management and stream improvement projects. Biological communities are composed of species adapted for some measure of variability in the hydrologic system during their life cycle. However, large differences in flow, such as floods, at the wrong time can have a detrimental effect on aquatic organisms. Streams with homogeneous habitat will not provide preferred habitat or necessary food resources for some species. Concrete channels with shallow flow may be highly productive for algae and can reduce nitrate concentrations (Kent and others, 2005), but such channels usually provide habitat for few species of algae, macroinvertebrates, or fish (Brown and others, 2005; Burton and others, 2005).

Table 7. Macroinvertebrate metric coefficient of variations that show a positive or negative association with the coefficient of variation of at least one habitat variable.

[(+), suggests a positive association with the macroinvertebrate metric; (–), suggests a negative association with the macroinvertebrate metric. CV, coefficient of variation; EPA, Environmental Protection Agency; EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; QMH, qualitative multihabitat; RTH, richest-targeted habitat; mm, milimeter]

QMH macroinvertebrate metric CVs and associated habitat variable CVs		
Ephemeroptera richness	**Nonmidge dipterans and noninsect richness**	**Chironomid richness (percent)**
Bankfull width (+)	Shape index (–) Riffle (+)	Bankfull width (+)
Trichoptera richness	**Odonate richness**	**Noninsect richness (percent)**
Reach gradient (–)	Reach gradient (+)	Pool (–)
Chironomid richness	**Trichoptera richness (percent)**	**Oligochaete richness (percent)**
Shape index (+) Riffle (–)	Run (+) Orthophosphate, dissolved (+)	Heterogeneity index[2] (+)
Nonchironomid dipteran richness	**EPT richness (percent)**	**EPA tolerance value (average, richness-weighted)**
Shape index (–) Riffle (+)	Riparian canopy closure (+) Streambed substrate[1] (–)	Reach gradient (–)
Noninsect richness	**Diptera richness (percent)**	**Scraper richness (percent)**
Water temperature (–) Specific conductance (–)	Velocity (–) Canopy angle (–)	Streambed substrate (–)
RTH macroinvertebrate metric CVs and associated habitat variable CVs		
Taxon richness	**Coleoptera richness**	**Taxon abundance**
Nitrite + nitrate, dissolved (–)	Nitrite + nitrate, dissolved (+)	Pool (+)
Trichoptera richness	**Noninsect richness (percent)**	**Nonchironomid diptera abundance**
Water temperature (+) Specific conductance (+) Chloride, dissolved (+)	Reach gradient (–)	Bankfull width (–)
EPT richness	**Odonate richness (percent)**	**Nonmidge dipterans and noninsect abundance**
Shape index (–) Riffle (+) Oxygen, dissolved (–)	Riparian canopy closure (+) Streambed substrate (–)	Wetted channel width (+) Total organic carbon (–)
EPT/Chironmid richness	**Oligochaete richness (percent)**	**Mollusc and crustacean abundance**
Heterogeneity index (+)	Wetted channel width (–) Total organic carbon (+)	Riparian canopy closure (–) Streambed substrate (+)

Table 7. Macroinvertebrate metric coefficient of variations that show a positive or negative association with the coefficient of variation of at least one habitat variable.—Continued

[(+), suggests a positive association with the macroinvertebrate metric; (–), suggests a negative association with the macroinvertebrate metric. CV, coefficient of variation; EPA, Environmental Protection Agency; EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; QMH, qualitative multihabitat; RTH, richest-targeted habitat; mm, milimeter]

RTH macroinvertebrate metric CVs and associated habitat variable CVs —Continued		
Oligochaete abundance Bankfull width (–) Depth (+)	**Mollusc and crustacean abundance (percent)** Riparian canopy closure (–) Streambed substrate (+)	**Scraper richness** Water temperature (–) Specific conductance (–) Chloride, dissolved (–)
Trichoptera abundance (percent) Shape index (+) Riffle (–) Oxygen, dissolved (+)	**EPA tolerance value (average, richness-weighted)** Nitrite + nitrate, dissolved (+)	**Shredder richness** Pool (–)
Tanytarsinii abundance (percent) Heterogeneity index (+)	**EPA tolerance value (average, abundance-weighted)** Water temperature (+) Specific conductance (+) Chloride, dissolved (+)	**Filterer richness (percent)** Water temperature (+) Chloride, dissolved (+)
Nonchironomid dipteran abundance (percent) Shape index (–) Riffle (+) Oxygen, dissolved (–)	**Percentage of most abundant taxon** Heterogeneity index (+)	**Scraper richness (percent)** Riparian canopy closure (+) Streambed substrate (–)
Nonmidge dipterans and noninsect abundance (percent) Heterogeneity index (+)	**Predator richness** Pool (+)	**Gatherer abundance** Streambed substrate (+)
Coleoptera abundance (percent) Nitrite + nitrate, dissolved (+)		**Predator abundance (percent)** Nitrite + nitrate, dissolved (–)

[1]The streambed substrate size 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 (Fitzpatrick and others, 1998).

[2]The heterogenieity index is the geometric mean of the coefficient of variation of the shape index, the riparian closure, stream velocity, and streambed substrate.

Summary and Conclusions

Understanding variability of natural assemblages is important in the interpretation of any ecological study. Data from an ecological study conducted during the summers 1999–2001 by the Santa Ana River Basin study unit of the USGS's NAWQA program were used to do a preliminary assessment of variability in the Santa Ana River Basin. Twenty-two habitat and water-quality variables were measured at three sites in the basin. The appendixes list the 233 taxa of benthic algae, 144 taxa of macroinvertebrates, and 16 taxa of fish that were collected. Significant differences in benthic algae metrics, macroinvertebrate metrics, and fish assemblages and variability were observed among the three sites. Annual variability in most habitat and water-quality variables was higher at the alpine site located in the mountains (SF) than at the basin sites (MWD and PRD). In general, annual variability in RTH benthic algae metrics was higher at SF, but annual variability in DTH metrics was lower. Annual variability in RTH macroinvertebrate metrics was higher at SF and PRD than at MWD. In contrast, annual variability in QMH macroinvertebrate metrics was lower at SF than at MWD or PRD. Annual variability in fish assemblages was higher at MWD and PRD primarily because of the higher number of species present at these sites. The CVs of seven benthic algae metrics and six macroinvertebrate metrics were correlated to the CVs of many of the habitat variables measured.

The variability of physiochemical variables is likely to have a role in structuring the annual variability of aquatic communities in the Santa Ana River Basin. However, some of the differences observed in habitat and aquatic communities between sites may be attributed to differences in ecoregions or stream size rather than variability. Although the data collected have a limited temporal scope, this report provides valuable baseline data on the variability of biological communities in the Santa Ana River Basin. Additional sampling at more sites over several years to address variability would be needed to better understand the variability in the composition of biological communities in the Santa Ana River Basin.

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Appendixes

Appendix 1. Values for environmental variables measured during summers of 1999, 2000, and 2001 at four sites in the Santa Ana River Basin, California.

[See table 1 for explanation of sample identification. Values are mean ± standard deviation unless n = 1; °C, degrees Celsius; E, estimated; ft/s, feet per second; ft^3/s, cubic feet per second; m, meter; mg/L, milligrams per liter; mi, mile; mm, millimeter; n, sample size; µS/cm, microsiemens per centimeter; >, greater than; <, less than; —, no data]

Variable	Sample identification										
	SF99	**SF00**	**SF01**	**UPH99**	**UPH00**	**MWD99**	**MWD00**	**MWD01**	**PRD99**	**PRD00**	**PRD01**
Discharge (ft^3/s)	3.8	3.0	1.31	10.2	2.5 ± 1.2	99 ± 16	76 ± 8	74 ± 8	210 ± 31	189 ± 18	191 ± 11
Water temperature (°C)	12.2 ± 1.2	10.1 ± 1.7	10.9 ± 1.5	22	19.6 ± 3.0	21.8 ± 1.4	22.4 ± 1.0	25.0 ± 4.2	23.7 ± 1.4	24.2 ± 1.2	24.4 ± 1.0
Reach length (m)	150	150	150	200	200	900	900	900	540	540	540
Reach gradient	0.082	0.083	0.084	0.040[1]	0.039	0.003	0.003	0.003	0.003	0.001	0.003
Wetted channel width (mean) (m, n = 11)	3.4 ± 0.7	3.2 ± 0.8	2.9 ± 0.8	8.0 ± 3.6	7.5 ± 2.5	59.7 ± 11.4	42.4 ± 7.4	46.0 ± 13.5	17.8 ± 4.2	17.0 ± 4.4	18.7 ± 5.3
Bankfull width (m, n = 11)	4.2 ± 0.6	3.9 ± 0.9	3.9 ± 1.0	19.4 ± 5.2	7.8 ± 2.5	64.1 ± 10.7	60.0 ± 14.3	63.4 ± 22.5	21.8 ± 4.2	22.0 ± 4.7	20.5 ± 6.9
Depth (m, n = 33)	0.17 ± 0.07	0.16 ± 0.07	0.15 ± 0.08	0.26 ± 0.14	0.19 ± 0.11	0.13 ± 0.05	0.12 ± 0.04	0.12 ± 0.05	0.75 ± 0.27	0.64 ± 0.25	0.66 ± 0.29
Velocity (ft/s, n = 33)	1.10 ± 1.00	1.20 ± 1.18	0.64 ± 0.63	0.67 ± 0.73	0.37 ± 0.38	1.32 ± 0.43	1.44 ± 0.39	1.23 ± 0.55	1.95 ± 1.26	2.33 ± 1.45	2.02 ± 1.32
Shape index (n = 11)	12.4 ± 11.9	12.0 ± 11.7	8.8 ± 3.8	12.2 ± 9.0	20.3 ± 13.1	143 ± 131	96 ± 55	103 ± 65	14.4 ± 5.4	13.4 ± 5.1	15.5 ± 5.2
Canopy angle (degrees, n = 11)	9 ± 16	20 ± 15	16 ± 17	112 ± 33	88 ± 29	152 ± 6	142 ± 8	147 ± 16	64 ± 42	61 ± 29	56 ± 35
Riparian canopy closure (percent, n = 22)	92 ± 12	94 ± 7	91 ± 16	24 ± 21	78 ± 28	82 ± 20	70 ± 19	14 ± 17[2]	88 ± 16	87 ± 19	100 ± 1
Streambed substrate[3] (n = 33)	7.0 ± 2.2	5.8 ± 3.1	6.2 ± 2.6	7.9 ± 2.0	8.3 ± 0.5	3.0 ± 0.2	3.0 ± 0	3.0 ± 0	5.5 ± 2.5	5.8 ± 2.2	6.8 ± 2.2
Run (percent)	4	8	16	30	33	100	100	100	82	74	69
Riffle (percent)	76	83	76	60	55	0	0	0	18	22	26
Pool (percent)	20	8	8	9	13	0	0	0	0	4	6
Heterogeneity index[4]	43.4	44.9	42.0	64.4	35.1	25.7	1.4	2.4	37.5	37.2	15.9

Appendix 1. Values for environmental variables measured during summers of 1999, 2000, and 2001 at four sites in the Santa Ana River Basin, California.—Continued

[See table 1 for explanation of sample identification. Values are mean ± standard deviation unless n = 1; °C, degrees Celsius; E, estimated; ft/s, feet per second; ft^3/s, cubic feet per second; m, meter; mg/L, milligrams per liter; mi, mile; mm, millimeter; n, sample size; µS/cm, microsiemens per centimeter; >, greater than; <, less than; —, no data]

Variable	Sample identification										
	SF99	SF00	SF01	UPH99	UPH00	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Specific conductance (µS/cm, n = 6)	66 ± 4	71 ± 2	78 ± 11	253	282	899 ± 11[5]	932 ± 21[5]	856 ± 15	961 ± 11[5]	966 ± 6.5[5]	974 ± 33[5]
Oxygen, dissolved (mg/L, n = 6)	8.5 ± 0.8	9.3 ± 0.6	8.9 ± 0.6	8.1	8.4 ± 0.4	8.1 ± 0.6	7.4 ± 0.5	6.6 ± 0.6	8.2 ± 0.3	8.2 ± 0.4	8.1 ± 0.4
Chloride, dissolved (mg/L, n = 4)	0.75 ± .44	0.62 ± 0.07	0.69 ± 0.20	5.6 ± 0.5[6]	8.4 ± 1.3[6]	77.2 ± 2.7	83.6 ± 2.2	—	105 ± 2.2	108 ± 3.4	112 ± 3.0
Nitrite + nitrate, dissolved (mg/L, n = 4)	<0.05 ± 0	<0.05 ± 0	E 0.04 ± 0.01	0.092 ± 0.025[6]	E0.054 ± 0.039[6]	6.6 ± 0.92	6.0 ± 0.50	—	5.5 ± 0.35	5.3 ± 0.32	5.1 ± 0.45
Orthophosphate, dissolved (mg/L, n = 4)	E 0.008 ± 0.008	E 0.009 ± 0.007	<0.02 ± 0	E 0.018 ± 0.011[6]	<0.01 ± 0[6]	0.79 ± 0.05	0.83 ± 0.06	—	0.93 ± 0.20	0.85 ± 0.10	0.78 ± 0.03
Total organic carbon (mg/L, n = 4)	2.1 ± 1.6	1.5 ± 0.8	—	—	—	3.0 ± 0.5	2.4 ± 0.1	—	3.0 ± 0.5	6.7 ± 0.9	8.2 ± 1.2

[1]Reach gradient for UPH99 determined from bottom of thalweg instead of water surface.

[2]Lower percentage of riparian canopy closure is a result of Arundo donax removal.

[3]The streambed substrate size 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 (Fitzpatrick and others, 1998).

[4]The heterogeneity index is the geometric mean of the coefficient of variation of shape index, riparian canopy closure, stream velocity, and streambed substrate.

[5]Values are from continuous monitoring, June to September.

[6]Values are from gaging station 11051500 located about 2.5 mi downstream.

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.

[Under sample identification, a “0” represents taxa was not present in the sample and a “1” represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Total taxa per sample		57	59	61	71	67	72	84	93	82	89
Chlorophyta (green algae)											
Closterium lunula (Möller) Nitzsch	2	0	0	0	0	1	0	1	0	0	0
Scenedesmus acuminatus (Lagerheim) Chodat	1	0	0	0	0	0	0	0	1	0	0
Scenedesmus acutus Meyen	2	0	0	0	1	0	0	0	1	0	0
Scenedesmus ecornis (Ralfs) Chodat	1	0	0	0	0	0	0	0	1	0	0
Scenedesmus quadricauda (Turpin) Brébisson	4	0	0	0	0	1	1	1	1	0	0
Scenedesmus spinosus Chodat	1	0	0	0	0	0	0	0	1	0	0
Spirogyra sp.	2	0	0	0	0	1	0	0	1	0	0
Stigeoclonium lubricum (Dillwyn) Kützing	1	0	0	0	0	1	0	0	0	0	0
Chrysophyta (diatoms)											
Achnanthes cf. grischuna CLASON Wüthrich	4	1	0	0	1	1	0	0	1	0	0
Achnanthes conspicua Mayer	1	0	0	0	1	0	0	0	0	0	0
Achnanthes sp. 1 ANS WRC	1	1	0	0	0	0	0	0	0	0	0
Achnanthidium exiguum (Grunow) Czarnecki	9	1	0	1	1	1	1	1	1	1	1
Achnanthidium exiguum var. heterovalvum (Krasske) Czarnecki	1	0	0	0	0	0	1	0	0	0	0
Achnanthidium minutissimum (Kützing) Czarnecki	6	0	1	1	0	0	1	1	0	1	1
Achnanthidium pyrenaicum (Hustedt) Kobayasi	1	0	0	1	0	0	0	0	0	0	0
Adlafia bryophila (Petersen) Lange-Bertalot	2	0	0	0	1	1	0	0	0	0	0
Adlafia minuscula (Grunow) Lange-Bertalot	2	1	0	0	1	0	0	0	0	0	0
Amphora copulata (Kützing) Schoeman and Archibald	4	0	1	1	0	0	1	0	0	1	0
Amphora holsatica Hustedt	1	0	0	0	0	0	1	0	0	0	0
Amphora montana Krasske	1	0	0	0	0	0	0	0	1	0	0
Amphora ovalis (Kützing) Kützing	3	0	1	1	0	0	1	0	0	0	0
Amphora pediculus (Kützing) Grunow	10	1	1	1	1	1	1	1	1	1	1
Amphora sp. 1 ANS WRC	2	0	0	0	0	0	1	1	0	0	0
Amphora veneta Kützing	6	0	0	0	0	1	1	1	1	1	1
Anabaena oscillarioides Bory	1	0	0	0	0	0	0	0	1	0	0
Asterionella formosa Hassal	2	0	0	0	0	0	0	0	1	0	1
Aulacoseira ambigua (Grunow) Simonsen	3	0	0	0	0	0	0	0	1	1	1
Aulacoseira granulata (Ehrenberg) Simonsen	3	0	0	0	0	0	0	0	1	1	1
Bacillaria paradoxa Gmelin	5	0	0	0	0	0	1	1	1	1	1

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Under sample identification, a “0” represents taxa was not present in the sample and a “1” represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Caloneis bacillum (Grunow) Cleve	5	1	0	1	1	1	0	0	0	0	1
Chamaepinnularia bremensis (Hustedt) Lange-Bertalot	1	0	0	0	1	0	0	0	0	0	0
Characium pringsheimii Braun	1	0	0	0	0	0	0	0	1	0	0
Chroococcus limneticus Lemmermann	1	0	0	0	0	0	1	0	0	0	0
Cladophora glomerata (Linnaeus) Kützing	3	0	0	0	1	1	0	0	1	0	0
Cocconeis fluviatilis Wallace	1	0	0	1	0	0	0	0	0	0	0
Cocconeis neodiminuta Krammer	5	1	1	1	0	0	1	0	0	0	1
Cocconeis pediculus Ehrenberg	4	1	0	0	1	0	1	1	0	0	0
Cocconeis placentula Ehrenberg	1	0	0	0	1	0	0	0	0	0	0
Cocconeis placentula var. *euglypta* (Ehrenberg) Cleve	6	1	1	1	1	1	0	0	1	0	0
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck	10	1	1	1	1	1	1	1	1	1	1
Cocconeis placentula var. *pseudolineata* Geitler	2	1	0	1	0	0	0	0	0	0	0
Craticula accomoda (Hustedt) Mann	2	0	0	0	0	0	0	0	1	0	1
Craticula cuspidata (Kützing) Mann	1	0	0	0	0	0	0	0	0	0	1
Craticula halophila (Grunow) Mann	2	0	0	0	0	1	0	0	0	0	1
Craticula molestiformis (Hustedt) Lange-Bertalot	2	0	0	0	0	0	1	0	1	0	0
Cryptomonas erosa Ehrenberg	1	0	0	0	0	0	0	0	1	0	0
Cyclotella atomus Hustedt	3	0	0	0	0	0	0	0	1	1	1
Cyclotella meneghiniana Kützing	6	0	0	0	0	1	1	1	1	1	1
Cyclotella pseudostelligera Hustedt	2	0	0	0	0	1	0	0	1	0	0
Cyclotella stelligera (Cleve and Grunow) Van Heurck	1	0	0	0	0	0	0	0	1	0	0
Cymbella affinis Kützing	2	0	1	0	1	0	0	0	0	0	0
Cymbella delicatula Kützing	1	0	0	0	0	0	0	0	0	1	0
Cymbella gracilis (Ehrenberg) Kützing	1	0	0	0	0	0	0	0	0	0	1
Cymbella sp. 6 ANS WRC	2	0	0	0	0	1	0	0	1	0	0
Cymbella tumida (Brébisson ex Kützing) Van Heurck	1	0	0	0	0	0	0	0	0	1	0
Denticula kuetzingii Grunow	2	0	0	0	0	0	0	1	0	0	1
Diadesmis confervacea Kützing	5	0	0	1	0	0	1	1	0	1	1
Diadesmis contenta (Grunow ex Van Heurck) Mann	1	1	0	0	0	0	0	0	0	0	0
Diadesmis perpusilla (Grunow) Mann	1	1	0	0	0	0	0	0	0	0	0
Diatoma mesodon (Ehrenberg) Kützing	3	1	1	1	0	0	0	0	0	0	0
Diatoma vulgaris Bory	2	0	0	0	1	0	0	1	0	0	0
Diploneis pseudovalis Hustedt	2	0	0	0	0	0	0	1	0	0	1

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Under sample identification, a “0” represents taxa was not present in the sample and a “1” represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Diploneis puella (Schumann) Cleve	1	0	0	0	0	0	0	0	1	0	0
Encyonema minutum (Hilse) Mann	7	0	1	1	1	0	1	1	0	1	1
Encyonema muelleri (Hustedt) Mann	1	0	0	0	1	0	0	0	0	0	0
Encyonema prostratum (Berkeley) Kützing	1	0	1	0	0	0	0	0	0	0	0
Encyonema silesiacum (Bleisch) Mann	5	1	1	1	1	1	0	0	0	0	0
Encyonopsis microcephala (Grunow) Krammer	1	0	0	0	0	1	0	0	0	0	0
Epithemia sorex Kützing	2	0	0	1	1	0	0	0	0	0	0
Epithemia turgida (Ehrenberg) Kützing	1	0	0	0	1	0	0	0	0	0	0
Fallacia pygmaea (Kützing) Stickle and Mann	3	0	0	0	0	0	1	0	0	1	1
Fallacia tenera (Hustedt) Mann	1	0	0	0	0	0	0	0	1	0	0
Fistulifera saprophila (Lange-Bertalot and Bonik) Lange-Bertalot	1	0	0	0	0	0	0	1	0	0	0
Fragilaria bidens Heiberg	1	0	1	0	0	0	0	0	0	0	0
Fragilaria capucina Desmazières	4	0	1	1	1	0	0	0	1	0	0
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	1	0	0	1	0	0	0	0	0	0	0
Fragilaria cf. *bicapitata* Mayer	2	1	0	0	1	0	0	0	0	0	0
Fragilaria crotonensis Kitton	3	0	0	0	0	0	0	1	0	1	1
Fragilaria pinnata var. *lancettula* (Schumann) Hustedt	2	1	0	0	0	0	0	0	1	0	0
Fragilaria vaucheriae (Kützing) Petersen	7	1	1	1	1	0	0	1	1	0	1
Frustulia amphipleuroides (Grunow) Cleve-Euler	3	1	1	1	0	0	0	0	0	0	0
Frustulia vulgaris (Thwaites) DeToni.	1	0	1	0	0	0	0	0	0	0	0
Geissleria acceptata (Hustedt) Lange-Bertalot and Metzeltin	5	1	1	1	1	1	0	0	0	0	0
Geissleria decussis (Hustedt) Lange-Bertalot and Metzeltin	6	0	1	1	1	1	1	1	0	0	0
Geissleria paludosa (Hustedt) Lange-Bertalot and Metzeltin	2	0	1	1	0	0	0	0	0	0	0
Gomphoneis herculeana (Ehrenberg) Cleve	1	0	0	1	0	0	0	0	0	0	0
Gomphonema aff. *subclavatum* ANS NAWQA EAM	2	0	1	0	0	0	1	0	0	0	0
Gomphonema affine Kützing	1	0	1	0	0	0	0	0	0	0	0
Gomphonema clevei Fricke	1	0	1	0	0	0	0	0	0	0	0
Gomphonema kobayasii Kociolek and Kingston	3	0	1	1	1	0	0	0	0	0	0
Gomphonema micropus Kützing	1	0	0	0	0	0	0	0	0	0	1
Gomphonema minutum (C.A. Agardh) C.A. Agardh	7	1	1	1	1	0	0	1	0	1	1

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Under sample identification, a "0" represents taxa was not present in the sample and a "1" represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Gomphonema olivaceum (Lyngbya) Kützing	1	0	0	0	1	0	0	0	0	0	0
Gomphonema parvulum (Kützing) Kützing	9	0	1	1	1	1	1	1	1	1	1
Gomphonema pumilum (Grunow) Reichett and Lange-Bert.	2	1	0	0	0	0	0	0	1	0	0
Gomphonema rhombicum Fricke	3	1	0	1	1	0	0	0	0	0	0
Gomphonema subclavatum (Grunow) Grunow	1	0	0	0	1	0	0	0	0	0	0
Gomphonema truncatum Ehrenberg	1	0	1	0	0	0	0	0	0	0	0
Gyrosigma attenuatum (Kützing) Rabenhorst	1	0	0	0	0	0	0	0	0	1	0
Gyrosigma nodiferum (Grunow) Reimer	2	0	0	0	0	0	0	0	0	1	1
Gyrosigma parkerii (Harrison) Elmore	1	0	0	0	0	0	0	0	0	1	0
Gyrosigma scalproides (Rabenhorst) Cleve	3	0	0	0	0	0	0	1	1	0	1
Gyrosigma spencerii (Quekett) Griff. and Henfr.	1	0	0	0	0	0	0	0	1	0	0
Hannaea arcus (Ehrenberg) Patrick	1	0	0	0	0	0	0	1	0	0	0
Hantzschia amphioxys (Ehrenberg) Grunow	1	0	0	1	0	0	0	0	0	0	0
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin and Witkowski	5	0	0	0	0	0	1	1	1	1	1
Karayevia clevei (Grunow) Kingston	1	0	0	0	1	0	0	0	0	0	0
Karayevia clevei var. *rostrata* (Hustedt) Kingston	1	0	0	0	1	0	0	0	0	0	0
Lemnicola hungarica (Grunow) Round and Basson	5	0	1	0	0	0	0	1	1	1	1
Luticola goeppertiana (Bleisch) Mann	6	0	0	0	0	1	1	1	1	1	1
Mayamaea atomus (Kützing) Lange-Bertalot	9	1	1	0	1	1	1	1	1	1	1
Melosira varians Agardh.	7	0	0	1	1	0	1	1	1	1	1
Meridion circulare var. *constrictum* (Ralfs) Van Heurck	1	0	0	1	0	0	0	0	0	0	0
Navicula antonii Lange Bertalot	4	0	0	1	1	1	0	0	0	1	0
Navicula biconica Patrick	7	0	1	1	1	1	1	1	0	0	1
Navicula canalis Patrick	1	0	0	0	0	0	0	0	0	1	0
Navicula capitatoradiata Germain	3	0	0	0	1	0	0	1	0	1	0
Navicula caterva Hohn and Hellerm.	2	0	0	0	0	1	1	0	0	0	0
Navicula cryptocephala Kützing	5	0	1	1	0	1	0	1	0	1	0
Navicula cryptotenella Lange-Bertalot in Kramm. and Lange-Bertalot	8	1	1	1	1	1	0	0	1	1	1
Navicula erifuga Lange-Bertalot	6	0	0	0	0	1	1	1	1	1	1
Navicula germainii Wallace	5	0	0	0	0	1	1	1	1	0	1
Navicula gregaria Donkin	10	1	1	1	1	1	1	1	1	1	1
Navicula incertata Hustedt	2	0	0	0	0	1	1	0	0	0	0
Navicula ingenua Hustedt	1	0	0	0	0	0	0	0	1	0	0

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Under sample identification, a “0” represents taxa was not present in the sample and a “1” represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Navicula lanceolata (Agardh) Ehrenberg	4	0	0	1	1	0	0	1	0	1	0
Navicula longicephala Hustedt	1	0	0	0	0	0	0	0	0	0	1
Navicula menisculus Schumann	1	1	0	0	0	0	0	0	0	0	0
Navicula minima Grunow	10	1	1	1	1	1	1	1	1	1	1
Navicula perminuta Grunow	3	0	0	1	0	0	0	1	0	0	1
Navicula recens Lange-Bertalot	4	0	0	0	0	0	1	1	0	1	1
Navicula reichardtiana Lange-Bertalot	2	0	0	0	0	0	0	0	0	1	1
Navicula rhynchocephala Kützing	2	0	0	0	0	1	0	0	0	0	1
Navicula rostellata Kützing	5	0	0	0	0	1	1	1	0	1	1
Navicula sanctaecrucis Østrup	2	0	0	0	0	0	1	1	0	0	0
Navicula schroeteri var. *escambia* Patrick	3	0	0	0	0	0	0	1	0	1	1
Navicula sp. 1 ANS NAWQA EAM	2	0	1	0	0	0	0	0	0	1	0
Navicula subminuscula Manguin	6	0	0	0	0	1	1	1	1	1	1
Navicula submuralis Hustedt	1	0	0	0	0	0	1	0	0	0	0
Navicula symmetrica Patrick	5	0	0	0	0	1	0	1	1	1	1
Navicula tantula Hustedt	1	0	0	0	1	0	0	0	0	0	0
Navicula tenelloides Hustedt	5	0	1	0	0	0	0	1	1	1	1
Navicula tripunctata (O. F. Müll.) Bory	6	1	1	1	1	0	0	1	0	1	0
Navicula trivialis Lange-Bertalot	1	0	0	0	0	0	0	0	0	0	1
Navicula veneta Kützing	9	1	0	1	1	1	1	1	1	1	1
Navicula wildii Lange-Bertalot	1	0	0	0	0	0	0	1	0	0	0
Neidium binodis (Ehrenberg) Hust.	1	0	0	0	1	0	0	0	0	0	0
Neidium dubium (Ehrenberg) Cleve	1	0	1	0	0	0	0	0	0	0	0
Nitzschia acicularioides Hustedt	1	0	0	0	0	0	0	0	1	0	0
Nitzschia acicularis (Kützing) Smith	1	0	0	0	0	0	0	0	0	1	0
Nitzschia aequorea Hustedt	1	0	0	0	0	0	1	0	0	0	0
Nitzschia agnita Hustedt	1	0	0	0	0	0	0	0	1	0	0
Nitzschia amphibia Grunow	8	0	0	1	1	1	1	1	1	1	1
Nitzschia amphibioides Hustedt	1	0	0	0	0	0	0	1	0	0	0
Nitzschia angustiforaminata Lange-Bertalot	1	0	0	0	0	0	1	0	0	0	0
Nitzschia archibaldii Lange-Bertalot	4	0	0	0	0	0	1	1	0	1	1
Nitzschia bacillum Hustedt	1	0	0	0	0	0	0	0	1	0	0
Nitzschia capitellata Hustedt	5	0	0	0	0	1	1	0	1	1	1
Nitzschia cf. *bacillum* LAIRD Hustedt	3	1	0	0	1	1	0	0	0	0	0
Nitzschia clausii Hantzsch	1	0	0	0	0	0	0	0	0	0	1
Nitzschia communis Rabenhorst	2	0	0	0	0	0	0	0	1	0	1

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Under sample identification, a “0” represents taxa was not present in the sample and a “1” represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Nitzschia compressa var. *vexans* (Grunow) Lange-Bertalot	1	0	0	0	0	1	0	0	0	0	0
Nitzschia desertorum Hustedt	6	0	0	0	0	1	1	1	1	1	1
Nitzschia diserta Hustedt	1	0	0	0	0	0	0	0	1	0	0
Nitzschia dissipata (Kützing) Grunow	9	1	1	1	1	0	1	1	1	1	1
Nitzschia dissipata var. *media* (Hantzsch) Grunow	1	0	0	0	1	0	0	0	0	0	0
Nitzschia elegantula Grunow	2	0	0	0	0	1	0	0	1	0	0
Nitzschia filiformis (W. Smith) Van Heurck	2	0	0	0	0	0	0	1	0	1	0
Nitzschia flexoides Geitler	1	0	0	0	0	0	0	0	0	0	1
Nitzschia fonticola Grunow	8	0	0	1	1	1	1	1	1	1	1
Nitzschia fonticola var. *pelagica* Hustedt	1	0	0	0	0	0	0	0	1	0	0
Nitzschia frustulum (Kützing) Grunow	4	0	0	1	0	0	0	1	1	0	1
Nitzschia fruticosa Hustedt	2	0	0	0	0	1	0	0	1	0	0
Nitzschia gracilis Hantzsch ex Rabenhorst	1	0	0	0	0	0	0	0	1	0	0
Nitzschia hantzschiana Rabenhorst	1	0	0	0	0	0	0	0	0	0	1
Nitzschia inconspicua Grunow	10	1	1	1	1	1	1	1	1	1	1
Nitzschia intermedia Hantzsch ex Cl.eve et Grunow	2	0	0	0	0	0	0	0	1	0	1
Nitzschia lacuum Lange-Bertalot	1	0	0	0	0	1	0	0	0	0	0
Nitzschia levidensis var. salinarum Grunow	1	0	0	0	0	0	0	0	0	1	0
Nitzschia liebethruthii Rabenhorst	1	0	0	0	0	0	0	0	1	0	0
Nitzschia linearis (Agardh ex W. Smith) W. Smith	2	1	0	1	0	0	0	0	0	0	0
Nitzschia microcephala Grunow	3	0	0	0	1	1	0	0	1	0	0
Nitzschia palea (Kützing) Smith	7	0	1	0	0	1	1	1	1	1	1
Nitzschia paleacea Grunow in Van Heurck	1	0	0	0	0	0	0	0	1	0	0
Nitzschia perminuta (Grunow) Peragallo	3	0	0	0	0	0	1	1	0	1	0
Nitzschia pusilla Grunow	4	0	1	0	0	0	0	1	0	1	1
Nitzschia recta Hantzsch ex Rabenhorst	3	1	1	0	0	0	0	0	0	0	1
Nitzschia sigma (Kützing) W. Smith	4	0	0	0	0	0	1	1	0	1	1
Nitzschia sigmoidea (Nitzschia) W. Smith	3	0	1	1	0	0	0	1	0	0	0
Nitzschia sinuata var. delognei (Grunow) Lange-Bertalot	1	0	0	0	1	0	0	0	0	0	0
Nitzschia sociabilis Hustedt	5	0	0	0	0	0	1	1	1	1	1
Nitzschia solita Hustedt	3	0	0	0	0	1	0	1	1	0	0
Nitzschia supralitorea Lange-Bertalot	4	0	0	0	1	1	1	0	1	0	0
Nitzschia thermalis Kützing	1	0	0	0	0	0	0	0	1	0	0
Nitzschia tubicola Grunow in Cleve et Grunow	3	1	0	0	0	1	0	0	1	0	0

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Under sample identification, a “0” represents taxa was not present in the sample and a “1” represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Nitzschia umbonata Lange-Bertalot	1	0	0	0	0	0	0	1	0	0	0
Nupela lapidosa (Krasske) Lange-Bertalot	1	0	0	0	0	0	0	1	0	0	0
Oedogonium sp.	1	0	0	0	1	0	0	0	0	0	0
Opephora olsenii M Moller	2	0	1	1	0	0	0	0	0	0	0
Oscillatoria limnetica Lemmermann	1	0	0	0	0	0	1	0	0	0	0
Parlibellus protracta (Grunow) Witkowski, Lange-Bertalot et Metzeltin	3	1	1	0	0	0	0	0	0	0	1
Pediastrum simplex (Meyen) Lemmermann	1	0	0	0	0	0	0	0	1	0	0
Phormidium formosum	1	0	0	0	0	0	0	0	1	0	0
Phormidium granulatum	1	0	0	0	1	0	0	0	0	0	0
Pinnularia divergentissima (Grunow) Cl.	1	0	0	0	0	0	0	0	0	1	0
Pinnularia subcapitata Greg.	1	0	0	0	1	0	0	0	0	0	0
Placoneis elginensis (Greg.) Cox	2	0	0	0	0	0	1	0	0	0	1
Placoneis pseudoanglica (Lange-Bertalot) Cox	1	0	0	0	0	0	0	0	0	1	0
Planothidium daui (Foged) Lange-Bertalot	2	1	0	1	0	0	0	0	0	0	0
Planothidium delicatulum (Kützing) Round et Bukhtiyarova	2	0	0	0	0	1	0	1	0	0	0
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	6	0	1	1	0	0	1	1	0	1	1
Planothidium granum (Hohn and Hellermann) Lange-Bertalot	1	0	1	0	0	0	0	0	0	0	0
Planothidium hauckianum (Grunow) Round and Bukhtiyarova	1	0	0	0	0	0	1	0	0	0	0
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	6	1	1	1	1	1	0	0	1	0	0
Planothidium rostratum (Østrup) Lange-Bertalot	2	1	1	0	0	0	0	0	0	0	0
Pleurosigma salinarum Grunow	1	0	0	0	0	0	0	0	0	1	0
Pleurosira laevis (Ehrenberg) Compere	4	0	0	0	0	0	1	1	0	1	1
Protoderma viride Kützing	1	0	0	0	0	1	0	0	0	0	0
Psammothidium bioretii (Germ.) Bukht. and Round	3	1	1	1	0	0	0	0	0	0	0
Psammothidium chlidanos (Hohn and Hellerman) Lange-Bertalot	1	0	0	1	0	0	0	0	0	0	0
Psammothidium helveticum (Hustedt) Bukhtiyarova and Round	1	1	0	0	0	0	0	0	0	0	0
Psammothidium rossii (Hustedt) Bukhtiyarova and Round	1	1	0	0	0	0	0	0	0	0	0

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Under sample identification, a “0” represents taxa was not present in the sample and a “1” represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Psammothidium subatomoides (Hustedt) Bukhtiyarova and Round	1	1	0	0	0	0	0	0	0	0	0
Pseudostaurosira brevistriata (Grunow in V.H.) Williams and Round	2	0	1	0	0	0	0	0	1	0	0
Reimeria sinuata (Greg.) Kociolek and Stoermer	8	1	1	1	1	1	0	1	0	1	1
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	9	1	1	1	1	0	1	1	1	1	1
Rhopalodia gibba (Ehr.) O. Müll.	1	0	0	0	1	0	0	0	0	0	0
Rossithidium pusillum (Grunow) Round and Bukhtiyarova	2	1	0	0	0	0	0	0	0	1	0
Sellaphora bacillum (Ehr.) Mann	1	0	0	0	1	0	0	0	0	0	0
Sellaphora pupula (Kütz.) Meresckowsky	7	0	0	1	0	1	1	1	1	1	1
Sellaphora seminulum (Grunow) Mann	10	1	1	1	1	1	1	1	1	1	1
Simonsenia delognei (Grunow) Lange-Bert.	1	0	0	0	0	1	0	0	0	0	0
Skeletonema potamos (Weber) Hasle	1	0	0	0	0	0	0	0	1	0	0
Staurosira construens (Ehrenberg) Williams and Round	2	0	0	0	0	0	1	1	0	0	0
Staurosira construens var. *pumila* (Grunow) Kingston	3	1	0	0	0	1	0	0	1	0	0
Staurosira construens var. *subsalina* (Hust.) Andresen and others	1	0	0	0	0	0	1	0	0	0	0
Staurosira construens var. *venter* (Ehr.) Hamilton	6	1	1	0	1	0	1	1	0	0	1
Staurosira elliptica (Schumann) Williams and Round	2	0	1	0	0	0	1	0	0	0	0
Staurosirella leptostauron (Ehrenberg) Williams and Round	1	0	0	1	0	0	0	0	0	0	0
Staurosirella pinnata (Ehrenberg) Williams and Round	4	1	1	0	1	0	0	0	1	0	0
Stephanodiscus hantzschii Grunow	2	0	0	0	0	0	0	0	1	1	0
Stephanodiscus medius Håkansson	1	0	0	0	0	1	0	0	0	0	0
Surirella angusta Kützing	4	0	0	0	0	0	1	1	0	1	1
Surirella brebissonii Kramm. and Lange-Bert.	3	0	0	0	0	0	0	1	0	1	1
Surirella minuta Bréb.	1	0	0	0	0	1	0	0	0	0	0
Surirella robusta Ehrenberg	4	0	0	0	0	0	0	1	1	1	1
Surirella tenera Greg.	1	0	0	0	0	0	0	0	1	0	0
Synedra parasitica (W. Sm.) Hust.	6	0	1	1	0	0	0	1	1	1	1
Synedra ulna (Nitz.) Ehr.	4	0	0	0	0	0	1	1	0	1	1
Synedra ulna var. *contracta* Østr.	2	0	0	0	1	0	0	0	1	0	0
Tabularia fasciculata (Ag.) Williams and Round	1	0	0	0	0	0	0	0	0	1	0
Tabularia tabulata (C. A. Ag.) Snoeijs	5	1	0	0	0	1	0	1	1	0	1
Terpsinoe musica Ehrenberg	1	0	0	0	0	0	0	1	0	0	0

Appendix 2. Benthic algae taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Under sample identification, a "0" represents taxa was not present in the sample and a "1" represents taxa was present in the sample]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Thalassiosira sp. 1 NAWQA DW SANA	1	0	0	0	0	0	0	0	0	0	1
Thalassiosira weissflogii (Grunow) Fryxell and Hasle	2	0	0	0	0	0	1	0	0	0	1
Tryblionella apiculata Greg.	6	0	0	0	0	1	1	1	1	1	1
Tryblionella calida (Grunow) Mann	3	0	0	0	0	0	1	1	0	1	0
Tryblionella compressa (Bailey) Poulin	1	0	0	0	0	0	0	0	0	1	0
Tryblionella levidensis W. Smith	2	0	0	0	0	0	1	0	0	0	1
Cyanophyta (blue-green algae)											
Blennothrix brebissonii (Kützing ex Gomont) Anagnostidis & Komárek	1	1	0	0	0	0	0	0	0	0	0
Homoeothrix janthina (Bornet et Flahault) Starmach	2	1	0	0	1	0	0	0	0	0	0
Lyngbya sp.	2	0	0	0	0	1	0	1	0	0	0
Nostoc commune Vaucher	1	0	0	0	1	0	0	0	0	0	0
Oscillatoria sp.	1	0	0	0	0	0	0	1	0	0	0
Unknown Cyanophyte Oscillatoriales (no sheath)	4	1	0	0	1	1	0	0	1	0	0
Unknown Cyanophyte Oscillatoriales (sheath)	5	1	0	0	0	1	1	0	1	1	0
Euglenophyta											
Euglena sp.	2	0	0	0	1	0	0	0	1	0	0
Trachelomonas hispida (Perty) Stein	1	0	0	0	0	1	0	0	0	0	0
Rhodophyta (red algae)											
Unknown Rhodophyte Florideophycidae (chantransia)	3	1	0	0	0	1	0	0	1	0	0

Appendix 3. Benthic algae taxa and their densities from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Total taxa per sample		31	26	34	38	33	26	32	45	42	39
Chlorophyta (green algae)											
Scenedesmus acutus Meyen	1	0	0	0	0	0	0	0	15,831	0	0
Scenedesmus quadricauda (Turpin) Brébisson	3	0	0	0	0	45,791	572,669	2,125	0	0	0
Stigeoclonium lubricum (Dillwyn) Kützing	1	0	0	0	0	177,439	0	0	0	0	0
Chrysophyta (diatoms)											
Achnanthes cf. *grischuna* CLASON Wüthrich	3	410	0	0	27,593	0	0	0	3,449	0	0
Achnanthidium exiguum (Grunow) Czarnecki	3	0	0	0	0	4,295	195,344	0	0	0	1,402
Achnanthidium minutissimum (Kützing) Czarnecki	4	0	1,162	10,745	0	0	195,344	1,284	0	0	0
Achnanthidium pyrenaicum (Hustedt) Kobayasi	1	0	0	546	0	0	0	0	0	0	0
Amphora pediculus (Kützing) Grunow	5	20	0	0	172,455	4,295	146,508	0	8,623	0	0
Amphora veneta Kützing	4	0	0	0	0	4,295	97,672	2,353	5,174	0	0
Aulacoseira ambigua (Grunow) Simonsen	1	0	0	0	0	0	0	0	0	25,470	0
Aulacoseira granulata (Ehrenberg) Simonsen	1	0	0	0	0	0	0	0	0	6,367	0
Bacillaria paradoxa Gmelin	1	0	0	0	0	0	0	0	1,725	0	0
Caloneis bacillum (Grunow) Cleve	2	39	0	0	13,796	0	0	0	0	0	0
Cocconeis neodiminuta Krammer	2	10	0	0	0	0	0	0	0	0	1,402
Cocconeis pediculus Ehrenberg	2	20	0	0	193,149	0	0	0	0	0	0
Cocconeis placentula Ehrenberg	1	0	0	0	55,185	0	0	0	0	0	0
Cocconeis placentula var. *euglypta* (Ehrenberg) Cleve	5	322	1,245	5,464	186,251	8,590	0	0	0	0	0
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck	10	2,740	13,534	9,470	482,873	12,884	97,672	856	1,725	38,205	2,804
Cocconeis placentula var. *pseudolineata* Geitler	2	10	0	17,666	0	0	0	0	0	0	0
Cyclotella meneghiniana Kützing	3	0	0	0	0	0	0	0	77,606	25,470	2,804
Cyclotella pseudostelligera Hustedt	1	0	0	0	0	0	0	0	12,072	0	0
Cyclotella stelligera (Cleve and Grunow) Van Heurck	1	0	0	0	0	0	0	0	3,449	0	0
Cymbella affinis Kützing	1	0	0	0	462,178	0	0	0	0	0	0
Cymbella delicatula Kützing	1	0	0	0	0	0	0	0	0	216,492	0
Cymbella gracilis (Ehrenberg) Kützing	1	0	0	0	0	0	0	0	0	0	21,030
Cymbella sp. 6 ANS WRC	1	0	0	0	0	0	0	0	94,852	0	0

Appendix 3. Benthic algae taxa and their densities from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Cymbella tumida (Brébisson ex Kützing) Van Heurck	1	0	0	0	0	0	0	0	0	6,367	0
Denticula kuetzingii Grunow	1	0	0	0	0	0	0	1,070	0	0	0
Diadesmis confervacea Kützing	2	0	0	364	0	0	0	7,915	0	0	0
Diatoma mesodon (Ehrenberg) Kützing	2	0	249	2,914	0	0	0	0	0	0	0
Diploneis pseudovalis Hustedt	1	0	0	0	0	0	0	0	0	0	1,402
Encyonema minutum (Hilse) Mann	3	0	0	1,457	13,796	0	0	0	0	6,367	0
Encyonema muelleri (Hustedt) Mann	1	0	0	0	6,898	0	0	0	0	0	0
Encyonema silesiacum (Bleisch) Mann	2	10	0	0	89,676	0	0	0	0	0	0
Epithemia sorex Kützing	1	0	0	0	255,233	0	0	0	0	0	0
Epithemia turgida (Ehrenberg) Kützing	1	0	0	0	96,575	0	0	0	0	0	0
Fallacia pygmaea (Kützing) Stickle and Mann	1	0	0	0	0	0	0	0	0	0	1,402
Fistulifera saprophila (Lange-Bertalot and Bonik) Lange-Bertalot	1	0	0	0	0	0	0	12,407	0	0	0
Fragilaria capucina Desmazières	1	0	83	0	0	0	0	0	0	0	0
Fragilaria cf. *bicapitata* Mayer	1	0	0	0	13,796	0	0	0	0	0	0
Fragilaria crotonensis Kitton	1	0	0	0	0	0	0	0	0	0	4,907
Fragilaria pinnata var. *lancettula* (Schumann) Hustedt	1	10	0	0	0	0	0	0	0	0	0
Fragilaria vaucheriae (Kützing) Petersen	3	0	83	1,275	0	0	0	0	3,449	0	0
Frustulia amphipleuroides (Grunow) Cleve-Euler	1	0	0	728	0	0	0	0	0	0	0
Geissleria acceptata (Hustedt) Lange-Bertalot and Metzeltin	3	29	415	4,371	0	0	0	0	0	0	0
Geissleria paludosa (Hustedt) Lange-Bertalot and Metzeltin	2	0	83	182	0	0	0	0	0	0	0
Gomphonema clevei Fricke	1	0	3,072	0	0	0	0	0	0	0	0
Gomphonema kobayasii Kociolek and Kingston	3	0	415	911	200,047	0	0	0	0	0	0
Gomphonema minutum (C.A. Agardh) C.A. Agardh	5	49	249	1,821	55,185	0	0	0	0	12,735	0
Gomphonema parvulum (Kützing) Kützing	8	0	0	728	13,796	12,884	634,867	1,925	24,144	89,144	9,814
Gomphonema pumilum (Grunow) Reichett and Lange-Bertalot	2	176	0	0	0	0	0	0	8,623	0	0
Gomphonema rhombicum Fricke	3	351	0	2,914	393,196	0	0	0	0	0	0
Gomphonema subclavatum (Grunow) Grunow	1	0	0	0	6,898	0	0	0	0	0	0
Gomphonema truncatum Ehrenberg	1	0	83	0	0	0	0	0	0	0	0

Appendix 3. Benthic algae taxa and their densities from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Gyrosigma attenuatum (Kützing) Rabenhorst	1	0	0	0	0	0	0	0	0	19,102	0
Gyrosigma nodiferum (Grunow) Reimer	2	0	0	0	0	0	0	0	0	70,042	2,804
Gyrosigma scalproides (Rabenhorst) Cleve	1	0	0	0	0	0	0	0	0	0	21,030
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin and Witkowski	1	0	0	0	0	0	0	0	12,072	0	0
Karayevia clevei var. *rostrata* (Hustedt) Kingston	1	0	0	0	6,898	0	0	0	0	0	0
Lemnicola hungarica (Grunow) Round and Basson	1	0	0	0	0	0	0	428	0	0	0
Luticola goeppertiana (Bleisch) Mann	4	0	0	0	0	2,147	0	10,696	0	12,735	7,010
Mayamaea atomus (Kützing) Lange-Bertalot	5	0	0	0	0	143,876	976,719	1,711	1,725	6,367	0
Melosira varians Agardh	5	0	0	728	6,898	0	0	1,711	0	6,367	6,309
Navicula biconica Patrick	3	0	0	0	0	122,402	48,836	1,284	0	0	0
Navicula canalis Patrick	1	0	0	0	0	0	0	0	0	25,470	0
Navicula capitatoradiata Germain	1	0	0	0	0	0	0	0	0	6,367	0
Navicula caterva Hohn and Hellerm.	1	0	0	0	0	4,295	0	0	0	0	0
Navicula cryptotenella Lange-Bertalot. in Kramm. and Lange-Bertalot.	7	1,102	996	10,199	13,796	0	0	0	24,144	63,674	65,192
Navicula erifuga Lange-Bertalot	4	0	0	0	0	68,717	0	0	346,641	82,777	10,515
Navicula germainii Wallace	1	0	0	0	0	0	0	0	5,174	0	0
Navicula gregaria Donkin	6	0	83	728	0	8,590	0	0	24,144	38,205	701
Navicula lanceolata (Agardh) Ehrenberg	2	0	0	0	13,796	0	0	1,284	0	0	0
Navicula minima Grunow	5	185	0	1,639	0	17,179	439,524	0	0	0	1,402
Navicula perminuta Grunow	2	0	0	728	0	0	0	0	0	0	1,402
Navicula recens Lange-Bertalot	3	0	0	0	0	0	97,672	0	0	464,822	107,952
Navicula reichardtiana Lange-Bertalot	1	0	0	0	0	0	0	0	0	0	1,402
Navicula rostellata Kützing	2	0	0	0	0	0	0	0	0	25,470	1,402
Navicula schroeteri var. *escambia* Patrick	2	0	0	0	0	0	0	428	0	0	4,206
Navicula sp.1 ANS NAWQA DW	1	0	249	0	0	0	0	0	0	0	0
Navicula subminuscula Manguin	6	0	0	0	0	287,751	3,418,517	12,621	46,564	63,674	4,907
Navicula symmetrica Patrick	4	0	0	0	0	38,653	0	0	27,593	25,470	6,309
Navicula tenelloides Hustedt	2	0	83	0	0	0	0	0	10,347	0	0
Navicula tripunctata (O. F. Müll.) Bory	5	488	166	728	1,069,219	0	0	0	0	12,735	0
Navicula veneta Kützing	6	0	0	0	0	152,465	390,688	3,423	20,695	6,367	1,402

Appendix 3. Benthic algae taxa and their densities from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Nitzschia acicularioides Hustedt	1	0	0	0	0	0	0	0	5,174	0	0
Nitzschia acicularis (Kützing) Smith	1	0	0	0	0	0	0	0	0	6,367	0
Nitzschia agnita Hustedt	1	0	0	0	0	0	0	0	3,449	0	0
Nitzschia amphibia Grunow	6	0	0	0	0	12,884	2,148,782	35,297	17,246	101,879	10,515
Nitzschia amphibioides Hustedt	1	0	0	0	0	0	0	856	0	0	0
Nitzschia archibaldii Lange-Bertalot	4	0	0	0	0	0	244,180	2,567	0	6,367	1,402
Nitzschia bacillum Hustedt	1	0	0	0	0	0	0	0	3,449	0	0
Nitzschia capitellata Hustedt	1	0	0	0	0	0	0	0	5,174	0	0
Nitzschia cf. *bacillum* LAIRD Hustedt	1	0	0	0	0	38,653	0	0	0	0	0
Nitzschia communis Rabenhorst	1	0	0	0	0	0	0	0	3,449	0	0
Nitzschia desertorum Hustedt	3	0	0	0	0	0	0	428	0	38,205	4,206
Nitzschia dissipata (Kützing) Grunow	6	0	83	11,838	0	0	146,508	0	13,797	89,144	12,618
Nitzschia elegantula Grunow	1	0	0	0	0	2,147	0	0	0	0	0
Nitzschia fonticola Grunow	5	0	0	0	41,389	8,590	293,016	0	6,898	0	7,010
Nitzschia frustulum (Kützing) Grunow	4	0	0	728	0	0	0	428	20,695	0	1,402
Nitzschia inconspicua Grunow	9	10	0	1,275	6,898	85,896	2,539,469	5,562	46,564	19,102	56,780
Nitzschia linearis (Agardh ex W. Smith) W. Smith	2	20	0	5,646	0	0	0	0	0	0	0
Nitzschia palea (Kützing) Smith	6	0	0	0	0	304,930	1,611,586	10,910	141,416	216,492	14,020
Nitzschia perminuta (Grunow) Peragallo	2	0	0	0	0	0	195,344	2,567	0	0	0
Nitzschia pusilla Grunow	1	0	0	0	0	0	0	0	0	0	1,402
Nitzschia recta Hantzsch ex Rabenhorst	1	0	0	0	0	0	0	0	0	0	2,804
Nitzschia sigmoidea (Nitzschia) W. Smith	1	0	0	364	0	0	0	0	0	0	0
Nitzschia sinuata var. *delognei* (Grunow) Lange-Bertalot	1	0	0	0	48,287	0	0	0	0	0	0
Nitzschia sociabilis Hustedt	3	0	0	0	0	0	146,508	0	25,869	6,367	0
Nitzschia supralitorea Lange-Bertalot	1	0	0	0	0	141,728	0	0	0	0	0
Nitzschia tubicola Grunow in Cleve and Grunow	1	0	0	0	0	0	0	0	3,449	0	0
Opephora olsenii M Moller	2	0	415	4,735	0	0	0	0	0	0	0
Pinnularia subcapitata Greg.	1	0	0	0	6,898	0	0	0	0	0	0
Placoneis pseudoanglica (Lange-Bertalot) Cox	1	0	0	0	0	0	0	0	0	6,367	0
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	3	0	166	3,096	0	0	48,836	0	0	0	0

Appendix 3. Benthic algae taxa and their densities from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	6	273	415	546	13,796	8,590	0	0	8,623	0	0
Pleurosira laevis (Ehrenberg) Compere	2	0	0	0	0	0	0	642	0	0	1,402
Psammothidium chlidanos (Hohn and Hellermann) Lange-Bertalot	1	0	0	546	0	0	0	0	0	0	0
Reimeria sinuata (Greg.) Kociolek and Stoermer	5	39	498	911	165,556	0	0	0	0	6,367	0
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	6	107	498	1,093	131,065	0	0	0	0	12,735	12,618
Rhopalodia gibba (Ehrenberg) O. Müll.	1	0	0	0	13,796	0	0	0	0	0	0
Rossithidium pusillum (Grunow) Round and Bukhtiyarova	2	20	0	0	0	0	0	0	0	6,367	0
Sellaphora bacillum (Ehrenberg) Mann	1	0	0	0	6,898	0	0	0	0	0	0
Sellaphora pupula (Kützing) Meresckowsky	2	0	0	0	0	0	244,180	0	1,725	0	0
Sellaphora seminulum (Grunow) Mann	7	20	249	0	0	64,422	195,344	1,711	3,449	6,367	0
Simonsenia delognei (Grunow) Lange-Bertalot	1	0	0	0	0	2,147	0	0	0	0	0
Staurosira construens var. *pumila* (Grunow) Kingston	1	0	0	0	0	21,474	0	0	0	0	0
Staurosira construens var. *venter* (Ehrenberg) Hamilton	3	20	83	0	6,898	0	0	0	0	0	0
Staurosirella leptostauron (Ehrenberg) Williams and Round	2	0	249	2,185	0	0	0	0	0	0	0
Staurosirella pinnata (Ehrenberg) Williams and Round	1	0	0	0	0	0	0	0	3,449	0	0
Stephanodiscus hantzschii Grunow	1	0	0	0	0	0	0	0	0	6,367	0
Surirella minuta Brébisson.	1	0	0	0	0	4,295	0	0	0	0	0
Surirella robusta Ehrenberg	1	0	0	0	0	0	0	0	0	6,367	0
Synedra parasitica (W. Smith) Hust.	1	0	0	0	0	0	0	0	3,449	0	0
Synedra ulna (Nitzschia) Ehrenberg	3	0	0	0	0	0	97,672	4,706	0	0	1,402
Synedra ulna var. *contracta* Østrup	1	0	0	0	6,898	0	0	0	0	0	0
Tabularia fasciculata (Agardh) Williams and Round	1	0	0	0	0	0	0	0	0	6,367	0
Tabularia tabulata (C. A. Agardh) Snoeijs	5	10	0	0	0	19,327	0	856	18,970	0	2,103
Tryblionella apiculata Greg.	1	0	0	0	0	0	0	428	0	0	0
Tryblionella compressa (Bailey) Poulin	1	0	0	0	0	0	0	0	0	12,735	0

Appendix 3. Benthic algae taxa and their densities from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Cyanophyta (blue-green algae)											
Blennothrix brebissonii (Kützing ex Gomont) Anagnostidis and Komárek	1	27,735	0	0	0	0	0	0	0	0	0
Homoeothrix janthina (Bornet and Flahault) Starmach	2	12,275	0	0	85,951,377	0	0	0	0	0	0
Lyngbya sp.	1	0	0	0	0	0	0	4,250	0	0	0
Nostoc commune Vaucher	1	0	0	0	1,484,615	0	0	0	0	0	0
Oscillatoria sp.	1	0	0	0	0	0	0	850	0	0	0
Phormidium granulatum	1	0	0	0	3,281,780	0	0	0	0	0	0
Unknown Cyanophyte Oscillatoriales (no sheath)	3	9,496	0	0	0	463,631	0	0	649,088	0	0
Unknown Cyanophyte Oscillatoriales (sheath)	3	36,131	0	0	0	818,510	4,772,243	0	0	0	0
Euglenophyta											
Euglena sp.	1	0	0	0	0	0	0	0	3,958	0	0
Rhodophyta (red algae)											
Unknown Rhodophyte Florideophycidae (chantransia)	2	23,856	0	0	0	0	0	0	87,073	0	0

Appendix 4. Benthic algae taxa and their densities from depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Total taxa per sample		38	28	42	40	39	42	59	62	45	58
Chlorophyta (green algae)											
Closterium lunula (Möller) Nitzsch	1	0	0	0	0	713,360	0	0	0	0	0
Scenedesmus acutus Meyen	1	0	0	0	0	0	0	0	11,440,899	0	0
Scenedesmus ecornis (Ralfs) Chodat	1	0	0	0	0	0	0	0	3,813,633	0	0
Scenedesmus quadricauda (Turpin) Brébisson	1	0	0	0	0	0	58,965	0	0	0	0
Chrysophyta (diatoms)											
Achnanthes cf. *grischuna* CLASON Wüthrich	4	6,746,216	0	0	4,741,228	2,358,052	0	0	201,653	0	0
Achnanthes conspicua Mayer	1	0	0	0	382,357	0	0	0	0	0	0
Achnanthes sp. 1 ANS WRC	1	210,819	0	0	0	0	0	0	0	0	0
Achnanthidium exiguum (Grunow) Czarnecki	4	0	0	0	38,236	0	220,383	234,717	100,827	0	0
Achnanthidium minutissimum (Kützing) Czarnecki	6	0	160,017	437,923	0	0	14,692	403,714	0	208,092	46,686
Achnanthidium pyrenaicum (Hustedt) Kobayasi	1	0	0	19,906	0	0	0	0	0	0	0
Adlafia minuscula (Grunow) Lange-Bertalot	1	210,819	0	0	0	0	0	0	0	0	0
Amphora copulata (Kützing) Schoeman and Archibald	2	0	0	0	0	0	29,384	0	0	52,023	0
Amphora ovalis (Kützing) Kützing	1	0	0	0	0	0	29,384	0	0	0	0
Amphora pediculus (Kützing) Grunow	9	843,277	0	29,858	3,058,857	138,709	58,769	18,777	403,308	104,046	16,674
Amphora sp. 1 ANS WRC	2	0	0	0	0	0	44,077	28,166	0	0	0
Amphora veneta Kützing	6	0	0	0	0	208,063	352,613	178,385	2,016,539	156,069	40,016
Asterionella formosa Hassal	2	0	0	0	0	0	0	0	201,653	0	16,674
Aulacoseira ambigua (Grunow) Simonsen	3	0	0	0	0	0	0	0	302,480	468,206	10,004
Aulacoseira granulata (Ehrenberg) Simonsen	3	0	0	0	0	0	0	0	1,008,269	208,092	13,339
Bacillaria paradoxa Gmelin	4	0	0	0	0	0	14,692	150,219	0	156,069	10,004
Caloneis bacillum (Grunow) Cleve	2	0	0	9,953	0	138,709	0	0	0	0	0
Chamaepinnularia bremensis (Hustedt) Lange-Bertalot	1	0	0	0	305,885	0	0	0	0	0	0
Cocconeis neodiminuta Krammer	3	632,457	8,206	9,953	0	0	0	0	0	0	0
Cocconeis pediculus Ehrenberg	2	0	0	0	0	0	29,384	103,276	0	0	0
Cocconeis placentula var. *euglypta* (Ehrenberg) Cleve	4	210,819	0	59,717	802,950	0	0	0	201,653	0	0

Appendix 4. Benthic algae taxa and their densities from depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Cocconeis placentula var. *lineata* (Ehrenberg) Van Heurck	9	14,546,530	315,931	49,764	38,236	0	44,077	150,219	504,135	52,023	10,004
Cocconeis placentula var. *pseudolineata* Geitler	1	0	0	348,347	0	0	0	0	0	0	0
Craticula accomoda (Hustedt) Mann	2	0	0	0	0	0	0	0	100,827	0	6,669
Craticula halophila (Grunow) Mann	1	0	0	0	0	0	0	0	0	0	6,669
Craticula molestiformis (Hustedt) Lange-Bertalot	1	0	0	0	0	0	0	0	201,653	0	0
Cyclotella atomus Hustedt	2	0	0	0	0	0	0	0	0	156,069	6,669
Cyclotella meneghiniana Kützing	5	0	0	0	0	0	58,769	75,110	8,166,986	884,389	103,376
Cyclotella pseudostelligera Hustedt	1	0	0	0	0	0	0	0	2,016,539	0	0
Cymbella affinis Kützing	1	0	0	0	38,236	0	0	0	0	0	0
Cymbella delicatula Kützing	1	0	0	0	0	0	0	0	0	104,046	0
Cymbella sp. 6 ANS WRC	1	0	0	0	0	138,709	0	0	0	0	0
Denticula kuetzingii Grunow	2	0	0	0	0	0	0	56,332	0	0	3,335
Diadesmis confervacea Kützing	4	0	0	0	0	0	367,305	84,498	0	104,046	133,388
Diadesmis contenta (Grunow ex Van Heurck) Mann	1	210,819	0	0	0	0	0	0	0	0	0
Diatoma mesodon (Ehrenberg) Kützing	3	1,264,915	53,339	49,764	0	0	0	0	0	0	0
Diploneis pseudovalis Hustedt	1	0	0	0	0	0	0	9,389	0	0	0
Diploneis puella (Schumann) Cleve	1	0	0	0	0	0	0	0	201,653	0	0
Encyonema minutum (Hilse) Mann	3	0	0	9,953	38,236	0	14,692	0	0	0	0
Encyonema silesiacum (Bleisch) Mann	3	316,229	0	0	152,943	208,063	0	0	0	0	0
Encyonopsis microcephala (Grunow) Krammer	1	0	0	0	0	277,417	0	0	0	0	0
Fallacia pygmaea (Kützing) Stickle and Mann	2	0	0	0	0	0	0	0	0	52,023	13,339
Fragilaria bidens Heiberg	1	0	4,103	0	0	0	0	0	0	0	0
Fragilaria capucina Desmazières	3	0	8,206	0	114,707	0	0	0	201,653	0	0
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot	1	0	0	9,953	0	0	0	0	0	0	0
Fragilaria cf. *bicapitata* Mayer	1	1,475,735	0	0	0	0	0	0	0	0	0
Fragilaria crotonensis Kitton	2	0	0	0	0	0	0	0	0	52,023	140,058
Fragilaria pinnata var. *lancettula* (Schumann) Hustedt	2	737,867	0	0	0	0	0	0	201,653	0	0
Fragilaria vaucheriae (Kützing) Petersen	5	421,638	0	29,858	0	0	0	9,389	201,653	0	13,339
Frustulia amphipleuroides (Grunow) Cleve-Euler	1	0	0	4,976	0	0	0	0	0	0	0

Appendix 4. Benthic algae taxa and their densities from depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Geissleria acceptata (Hustedt) Lange-Bertalot and Metzeltin	5	4,532,614	32,824	278,678	76,471	138,709	0	0	0	0	0
Geissleria decussis (Hustedt) Lange-Bertalot et Metzeltin	6	0	4,103	14,929	191,178	346,772	29,384	75,110	0	0	0
Geissleria paludosa (Hustedt) Lange-Bertalot et Metzeltin	1	0	0	29,858	0	0	0	0	0	0	0
Gomphonema aff. *subclavatum* ANS NAWQA EAM	1	0	36,927	0	0	0	0	0	0	0	0
Gomphonema kobayasii Kociolek and Kingston	3	0	38,979	44,788	1,491,193	0	0	0	0	0	0
Gomphonema minutum (C.A. Agardh) C.A. Agardh	4	0	0	69,669	152,943	0	0	197,163	0	0	3,335
Gomphonema olivaceum (Lyngb.) Kütz.	1	0	0	0	38,236	0	0	0	0	0	0
Gomphonema parvulum (Kütz.) Kütz.	9	0	4,103	9,953	114,707	693,545	44,077	244,106	1,310,750	468,206	120,049
Gomphonema pumilum (Grunow) Reichett and Lange-Bertalot	1	948,687	0	0	0	0	0	0	0	0	0
Gomphonema rhombicum Fricke	2	421,638	0	24,882	0	0	0	0	0	0	0
Gyrosigma scalproides (Rabenhorst) Cleve	2	0	0	0	0	0	0	0	100,827	0	6,669
Hannaea arcus (Ehrenberg) Patrick	1	0	0	0	0	0	0	18,777	0	0	0
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin and Witkowski	2	0	0	0	0	0	0	37,555	0	52,023	0
Karayevia clevei (Grunow) Kingston	1	0	0	0	38,236	0	0	0	0	0	0
Lemnicola hungarica (Grunow) Round and Basson	4	0	0	0	0	0	0	18,777	100,827	52,023	3,335
Luticola goeppertiana (Bleisch) Mann	4	0	0	0	0	277,417	0	56,332	100,827	0	3,335
Mayamaea atomus (Kützing) Lange-Bertalot	6	0	4,103	0	76,471	0	14,692	56,332	604,961	0	3,335
Melosira varians Agardh	5	0	0	0	38,236	0	73,461	37,555	403,308	0	6,669
Meridion circulare var. *constrictum* (Ralfs) Van Heurek	1	0	0	4,976	0	0	0	0	0	0	0
Navicula antonii Lange Bertalot	2	0	0	9,953	802,950	0	0	0	0	0	0
Navicula cryptocephala Kützing	3	0	0	9,953	0	0	0	18,777	0	52,023	0
Navicula cryptotenella Lange-Bertalot in Kramm. and Lange-Bertalot	5	6,324,578	184,635	303,560	0	69,354	0	0	0	0	3,335
Navicula erifuga Lange-Bertalot	6	0	0	0	0	1,456,444	132,230	168,997	1,411,576	312,137	20,008
Navicula germainii Wallace	4	0	0	0	0	277,417	14,692	28,166	201,653	0	0

Appendix 4. Benthic algae taxa and their densities from depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Navicula gregaria Donkin	10	843,277	14,361	29,858	114,707	346,772	14,692	150,219	806,616	364,160	16,674
Navicula lanceolata (Agardh) Ehrenberg	2	0	0	4,976	0	0	0	0	0	52,023	0
Navicula longicephala Hustedt	1	0	0	0	0	0	0	0	0	0	6,669
Navicula minima Grunow	7	2,002,783	8,206	0	2,867,678	0	14,692	75,110	100,827	52,023	0
Navicula perminuta Grunow	2	0	0	19,906	0	0	0	18,777	0	0	0
Navicula recens Lange-Bertalot	4	0	0	0	0	0	44,077	18,777	0	208,092	23,343
Navicula rhynchocephala Kützing	2	0	0	0	0	138,709	0	0	0	0	3,335
Navicula rostellata Kützing	4	0	0	0	0	69,354	514,228	112,664	0	52,023	0
Navicula sanctaecrucis Østrup	1	0	0	0	0	0	0	18,777	0	0	0
Navicula subminuscula Manguin	6	0	0	0	0	693,545	44,077	103,276	3,730,599	988,435	100,041
Navicula symmetrica Patrick	1	0	0	0	0	0	0	0	0	0	6,669
Navicula tenelloides Hustedt	1	0	0	0	0	0	0	0	0	52,023	0
Navicula tripunctata (O. F. Müll.) Bory	2	0	6,155	19,906	0	0	0	0	0	0	0
Navicula trivialis Lange-Bertalot	1	0	0	0	0	0	0	0	0	0	6,669
Navicula veneta Kützing	8	210,819	0	0	688,242	416,127	29,384	56,332	604,961	52,023	53,355
Navicula wildii Lange-Bertalot	1	0	0	0	0	0	0	18,777	0	0	0
Neidium binodis (Ehrenberg) Hust.	1	0	0	0	76,471	0	0	0	0	0	0
Nitzschia acicularis (Kützing) Smith	1	0	0	0	0	0	0	0	0	52,023	0
Nitzschia agnita Hustedt	1	0	0	0	0	0	0	0	201,653	0	0
Nitzschia amphibia Grunow	8	0	0	19,906	76,471	554,835	176,307	600,876	5,847,966	728,321	260,107
Nitzschia archibaldii Lange-Bertalot	4	0	0	0	0	0	14,692	18,777	0	208,092	30,012
Nitzschia capitellata Hustedt	4	0	0	0	0	277,417	0	0	1,008,269	52,023	20,008
Nitzschia cf. *bacillum* LAIRD Hustedt	2	0	0	0	229,414	20,251,510	0	0	0	0	0
Nitzschia clausii Hantzsch	1	0	0	0	0	0	0	0	0	0	6,669
Nitzschia communis Rabenhorst	2	0	0	0	0	0	0	0	5,646,311	0	20,008
Nitzschia desertorum Hustedt	6	0	0	0	0	277,417	14,692	28,166	201,653	832,366	30,012
Nitzschia diserta Hustedt	1	0	0	0	0	0	0	0	806,616	0	0
Nitzschia dissipata (Kützing) Grunow	7	421,638	43,082	144,315	458,828	0	14,692	0	0	260,115	6,669
Nitzschia filiformis (W. Sm.) Van Heurek	1	0	0	0	0	0	0	9,389	0	0	0
Nitzschia fonticola Grunow	7	0	0	4,976	382,357	0	73,461	37,555	1,008,269	884,389	33,347
Nitzschia frustulum (Kützing) Grunow	3	0	0	0	0	0	0	93,887	1,209,924	0	13,339
Nitzschia fruticosa Hustedt	1	0	0	0	0	0	0	0	201,653	0	0
Nitzschia inconspicua Grunow	10	1,159,505	8,206	44,788	2,752,971	277,417	205,691	93,887	1,915,712	52,023	80,033
Nitzschia intermedia Hantzsch ex Cl. and Grunow	1	0	0	0	0	0	0	0	1,714,058	0	0

Appendix 4. Benthic algae taxa and their densities from depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Nitzschia lacuum Lange-Bertalot	1	0	0	0	0	138,709	0	0	0	0	0
Nitzschia liebethruthii Rabenhorst	1	0	0	0	0	0	0	0	201,653	0	0
Nitzschia linearis (Agardh ex W. Sm.) W. Sm.	1	0	0	34,835	0	0	0	0	0	0	0
Nitzschia microcephala Grunow	3	0	0	0	0	138,709	0	37,555	201,653	0	0
Nitzschia palea (Kützing) Smith	6	0	0	0	0	12,067,681	1,145,993	572,710	11,292,623	4,838,130	166,735
Nitzschia paleacea Grunow in Van Heurek	1	0	0	0	0	0	0	0	201,653	0	0
Nitzschia perminuta (Grunow) Peragallo	2	0	0	0	0	0	14,692	0	0	52,023	0
Nitzschia pusilla Grunow	3	0	0	0	0	0	0	18,777	0	1,196,527	200,082
Nitzschia recta Hantzsch ex Rabenhorst	1	316,229	0	0	0	0	0	0	0	0	0
Nitzschia sigma (Kütz.) W. Sm.	3	0	0	0	0	0	0	9,389	0	208,092	3,335
Nitzschia sigmoidea (Nitzschia) W. Sm.	1	0	12,309	0	0	0	0	0	0	0	0
Nitzschia sinuata var. *delognei* (Grunow) Lange-Bertalot	1	0	0	0	3,250,035	0	0	0	0	0	0
Nitzschia sociabilis Hustedt	2	0	0	0	0	0	0	18,777	201,653	0	0
Nitzschia solita Hustedt	2	0	0	0	0	0	0	18,777	201,653	0	0
Nitzschia supralitorea Lange-Bertalot	2	0	0	0	420,592	0	0	0	1,814,885	0	0
Nitzschia thermalis Kützing	1	0	0	0	0	0	0	0	604,961	0	0
Nitzschia tubicola Grunow in Cleve and Grunow	3	210,819	0	0	0	138,709	0	0	201,653	0	0
Nitzschia umbonata Lange-Bertalot	1	0	0	0	0	0	0	9,389	0	0	0
Nupela lapidosa (Krasske) Lange-Bertalot	1	0	0	0	0	0	0	46,943	0	0	0
Opephora olsenii M Moller	1	0	0	129,386	0	0	0	0	0	0	0
Parlibellus protracta (Grunow) Witkowski, Lange-Bertalot and Metzeltin	2	210,819	0	0	0	0	0	0	0	0	3,335
Planothidium daui (Foged) Lange-Bertalot	2	737,867	0	29,858	0	0	0	0	0	0	0
Planothidium delicatulum (Kützing) Round and Bukhtiyarova	2	0	0	0	0	138,709	0	18,777	0	0	0
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	6	0	100,524	238,867	0	0	58,769	431,880	0	52,023	13,339
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	5	12,859,975	0	144,315	2,829,443	416,127	0	0	1,008,269	0	0
Planothidium rostratum (Østrup) Lange-Bertalot	1	0	102,575	0	0	0	0	0	0	0	0
Pleurosira laevis (Ehrenberg) Compere	1	0	0	0	0	0	0	9,389	0	0	0

Appendix 4. Benthic algae taxa and their densities from depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Psammothidium bioretii (Germ.) Bukhtiyarova and Round	3	421,638	18,464	29,858	0	0	0	0	0	0	0
Psammothidium helveticum (Hustedt) Bukhtiyarova and Round	1	210,819	0	0	0	0	0	0	0	0	0
Psammothidium subatomoides (Hustedt) Bukhtiyarova et Round	1	210,819	0	0	0	0	0	0	0	0	0
Pseudostaurosira brevistriata (Grunow in Van Heurek) Williams and Round	2	0	4,103	0	0	0	0	0	201,653	0	0
Reimeria sinuata (Greg.) Kociolek and Stoermer	5	1,370,325	20,515	39,811	879,421	208,063	0	0	0	0	0
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	6	737,867	6,155	79,622	76,471	0	0	9,389	0	0	3,335
Rossithidium pusillum (Grunow) Round and Bukhtiyarova	1	210,819	0	0	0	0	0	0	0	0	0
Sellaphora bacillum (Ehrenberg) Mann	1	0	0	0	38,236	0	0	0	0	0	0
Sellaphora pupula (Kütz.) Meresckowsky	6	0	0	0	0	485,481	88,153	234,717	705,788	104,046	10,004
Sellaphora seminulum (Grunow) Mann	9	210,819	12,309	0	76,471	277,417	58,769	150,219	1,209,924	260,115	56,690
Staurosira construens (Ehrenberg) Williams and Round	1	0	0	0	0	0	88,153	0	0	0	0
Staurosira construens var. *pumila* (Grunow) Kingston	2	1,054,096	0	0	0	762,899	0	0	0	0	0
Staurosira construens var. *venter* (Ehrenberg) Hamilton	2	210,819	0	0	0	0	102,846	0	0	0	0
Staurosirella leptostauron (Ehrenberg) Williams and Round	2	0	10,258	79,622	0	0	0	0	0	0	0
Staurosirella pinnata (Ehrenberg) Williams and Round	2	0	8,206	0	76,471	0	0	0	0	0	0
Stephanodiscus hantzschii Grunow	2	0	0	0	0	0	0	0	302,480	104,046	0
Surirella angusta Kützing	2	0	0	0	0	0	0	18,777	0	52,023	0
Surirella brebissonii Kramm. and Lange-Bertalot	2	0	0	0	0	0	0	9,389	0	0	3,335
Surirella tenera Greg.	1	0	0	0	0	0	0	0	403,308	0	0
Synedra parasitica (W. Sm.) Hust.	2	0	0	19,906	0	0	0	0	0	0	13,339
Synedra ulna (Nitzschia) Ehrenberg	3	0	0	0	0	0	14,692	75,110	0	0	3,335
Synedra ulna var. *contracta* Østr.	1	0	0	0	0	0	0	0	201,653	0	0
Tabularia tabulata (C. A. Agardh) Snoeijs	1	0	0	0	0	0	0	0	201,653	0	0

Appendix 4. Benthic algae taxa and their densities from depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square centimeter]

Scientific name	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Thalassiosira sp. 1 NAWQA DW SANA	1	0	0	0	0	0	0	0	0	0	36,682
Thalassiosira weissflogii (Grunow) Fryxell and Hasle	1	0	0	0	0	0	0	0	0	0	3,335
Tryblionella apiculata Greg.	6	0	0	0	0	138,709	29,384	28,166	201,653	156,069	6,669
Tryblionella calida (Grunow) Mann	1	0	0	0	0	0	44,077	0	0	0	0
Cyanophyta (blue-green algae)											
Nostoc commune Vaucher	1	0	0	0	78,713,503	0	0	0	0	0	0
Unknown Cyanophyte Oscillatoriales (no sheath)	3	42,011,835	0	0	0	12,127,128	0	0	11,440,899	0	0
Unknown Cyanophyte Oscillatoriales (sheath)	2	18,623,803	0	0	0	29,961,139	0	0	0	0	0
Euglenophyta											
Euglena sp.	2	0	0	0	596,314	0	0	0	3,813,633	0	0
Trachelomonas hispida (Perty) Stein	1	0	0	0	0	713,360	0	0	0	0	0

Appendix 5. Benthic algae metrics calculated from qualitative multihabitat, richest-targeted habitat, and depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.

[EPA, Environmental Protection Agency; no., number; no./cm^2, number of individuals per square centimeter]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Metrics from qualitative multihabitat (presence/absence) data										
Taxon richness (no. of taxa)	57	59	61	72	71	73	86	99	82	89
Genus richness (no. of taxa)	50	36	45	36	33	33	48	34	35	45
Family richness (no. of taxa)	19	9	11	12	9	8	12	10	7	11
Phylum richness (no. of taxa)	5	3	5	6	3	2	3	2	1	2
Metrics from richest-targeted habitats (RTH)										
Simpson's diversity index	0.785	0.681	0.923	0.180	0.877	0.873	0.892	0.827	0.900	0.880
Taxon richness (no. of taxa)	31	26	34	38	33	26	32	45	42	39
Taxon abundance (no./cm^2)	115,983	24,906	109,269	95,015,334	3,113,772	19,995,700	135,579	1,856,234	1,910,223	420,596
Diatom richness (no. of taxa)	26	26	34	35	29	24	29	41	42	39
Green algae richness (no. of taxa)	0	0	0	0	2	1	1	1	0	0
Blue-green algae richness (no. of taxa)	4	0	0	3	2	1	2	1	0	0
Euglenoid algae richness (no. of taxa)	0	0	0	0	0	0	0	1	0	0
Red algae richness (no. of taxa)	1	0	0	0	0	0	0	1	0	0
Diatom richness (percent)	83.9	100.0	100.0	92.1	93.5	96.0	93.5	93.2	100.0	100.0
Green algae richness (percent)	0.0	0.0	0.0	0.0	6.5	4.0	3.2	2.3	0.0	0.0
Blue-green algae richness (percent)	12.9	0.0	0.0	7.9	6.1	3.8	6.3	2.2	0.0	0.0
Euglenoid algae richness (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0
Red algae richness (percent)	3.2	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0
Diatom abundance (no./cm^2)	6,490	24,906	109,269	4,297,562	1,608,401	14,650,788	128,354	1,100,284	1,910,223	420,596
Green algae abundance (no./cm^2)	0	0	0	0	223,230	572,669	2,125	15,831	0	0
Blue-green algae abundance (no./cm^2)	85,637	0	0	90,717,772	1,282,141	4,772,243	5,100	649,088	0	0
Euglenoid algae abundance (no./cm^2)	0	0	0	0	0	0	0	3,958	0	0
Red algae abundance (no./cm^2)	23,856	0	0	0	0	0	0	87,073	0	0
Diatom abundance (percent)	5.6	100.0	100.0	4.5	51.7	73.3	94.7	59.3	100.0	100.0
Green algae abundance (percent)	0.0	0.0	0.0	0.0	7.2	2.9	1.6	0.9	0.0	0.0
Blue-green algae abundance (percent)	73.8	0.0	0.0	95.5	41.2	23.9	3.8	35.0	0.0	0.0
Euglenoid algae abundance (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Red algae abundance (percent)	20.6	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0
Nitrogen heterotrophic diatom richness (percent)	20.0	6.2	25.0	12.0	41.2	27.8	36.8	20.8	32.0	36.4
Facultative nitrogen autotrophic diatom richness (percent)	73.3	68.8	60.0	56.0	47.1	55.6	36.8	58.3	48.0	45.5

Appendix 5. Benthic algae metrics calculated from qualitative multihabitat, richest-targeted habitat, and depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[EPA, Environmental Protection Agency; no., number; no./cm^2, number of individuals per square centimeter]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Obligative nitrogen autotrophic diatom richness (percent)	6.7	25.0	10.0	32.0	0.0	5.6	10.5	4.2	8.0	4.5
Nitrogen fixing diatom richness (percent)	0.0	0.0	0.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0
Eutrophic diatom richness (percent)	77.8	73.7	86.4	78.6	100.0	89.5	85.7	89.3	86.7	81.5
Oligotrophic diatom richness (percent)	0.0	0.0	0.0	7.1	0.0	5.3	4.8	0.0	3.3	3.7
Halophilic diatom richness (percent)	10.0	5.3	17.4	10.0	30.0	21.1	38.1	31.3	19.4	34.5
Halophobic (fresh) diatom richness (percent)	5.0	5.3	4.3	3.3	0.0	0.0	0.0	3.1	3.2	3.4
Halophobic (fresh-brackish) diatom richness (percent)	90.0	89.5	78.3	86.7	70.0	78.9	61.9	65.6	77.4	58.6
Alkaline diatom richness (percent)	76.5	68.4	69.6	72.4	78.9	63.2	71.4	77.8	71.0	82.1
Acidiphilic diatom richness (percent)	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0	0.0	3.6
Seston richness (percent)	0	0	0	0	4.3	5.0	4.17	8.8	12.9	3.1
Motile diatom richness (percent)	40.0	31.6	39.1	24.1	58.3	66.7	58.3	57.1	62.5	71.9
EPA tolerant species richness (percent)	22.2	37.5	50.0	27.3	80.0	58.3	70.0	53.3	54.5	66.7
EPA intolerant species richness (percent)	66.7	62.5	50.0	72.7	10.0	33.3	20.0	26.7	36.4	25.0
Nitrogen heterotrophic diatom abundance (percent)	5.0	1.3	8.0	0.8	29.6	45.2	62.0	31.9	25.6	51.9
Facultative nitrogen autotroph abundance (percent)	94.1	95.1	82.2	73.3	18.3	15.2	11.7	26.1	25.6	25.8
Obligative nitrogen autotroph abundance (percent)	0.9	3.5	8.6	25.9	0.0	1.5	3.5	2.0	21.3	11.4
Nitrogen fixing diatom abundance (percent)	0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0
Eutrotphic diatom abundance (percent)	76.5	85.1	65.3	91.9	100.0	97.1	95.3	96.0	85.8	74.5
Oligotrophic diatom abundance (percent)	0.0	0.0	0.0	0.4	0.0	1.5	2.4	0.0	13.4	5.6
Halophilic diatom abundance (percent)	0.5	0.4	4.2	5.8	26.5	23.5	20.9	59.5	37.9	50.0
Halophobic (fresh) diatom abundance (percent)	6.8	1.2	4.0	0.7	0.0	0.0	0.0	0.4	12.9	5.6
Halophobic (fresh-brackish) diatom abundance (percent)	92.7	98.3	91.8	93.6	73.5	76.5	79.1	40.1	49.2	44.4
Alkalinic diatom abundance (percent)	97.8	87.6	74.0	90.0	56.7	75.4	75.1	76.9	78.8	87.3
Acidophilic diatom abundance (percent)	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	5.6
Seston abundance (percent)	0	0	0	0	3.2	4.3	1.9	2.9	2.9	1.3
Motile diatom abundance (percent)	31.7	7.3	44.1	30.7	80.2	86.8	85.0	73.2	84.9	91.3

Appendix 5. Benthic algae metrics calculated from qualitative multihabitat, richest-targeted habitat, and depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[EPA, Environmental Protection Agency; no., number; no./cm², number of individuals per square centimeter]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Bahl's tolerance index based on abundance	2.7	2.9	2.6	3.0	1.4	1.5	1.7	1.8	1.9	2.0
EPA tolerant diatom abundance (percent)	41.9	22.6	15.6	1.6	94.1	86.0	95.9	72.4	79.1	70.7
EPA intolerant diatom abundance (percent)	57.2	77.4	84.4	98.4	0.8	10.1	2.7	20.4	19.8	26.1
Siltation index	27.8	6.7	31.0	27.8	70.9	77.0	59.5	71.9	68.3	75.8
Pollution tolerance index	2.4	2.8	2.8	3.0	1.1	1.6	1.7	1.6	1.7	1.8
Metrics from depositional-targeted habitats (DTH)										
Simpson's diversity index	0.831	0.874	0.928	0.456	0.794	0.897	0.952	0.934	0.878	0.942
Taxon richness (no. of taxa)	38	28	42	40	39	42	59	62	45	58
Taxon abundance (no./cm²)	124,303,047	1,230,904	2,985,835	107,336,588	88,456,683	4,451,935	5,633,214	95,340,782	15,606,876	2,000,822
Diatom richness (no. of taxa)	36	28	42	38	35	41	59	58	45	58
Green algae richness (no. of taxa)	0	0	0	0	1	1	0	2	0	0
Blue-green algae richness (no. of taxa)	2	0	0	1	2	0	0	1	0	0
Euglenoid algae richness (no. of taxa)	0	0	0	1	1	0	0	1	0	0
Red algae richness (no. of taxa)	0	0	0	0	0	0	0	0	0	0
Diatom richness (percent)	94.7	100.0	100.0	95.0	89.7	100.0	100.0	96.7	100.0	100.0
Green algae richness (percent)	0.0	0.0	0.0	0.0	2.6	2.4	0.0	3.3	0.0	0.0
Blue-green algae richness (percent)	5.3	0.0	0.0	2.5	5.1	0.0	0.0	1.6	0.0	0.0
Euglenoid algae richness (percent)	0.0	0.0	0.0	2.5	2.6	0.0	0.0	1.6	0.0	0.0
Red algae richness (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diatom abundance (no./cm²)	63,667,409	1,230,904	2,985,835	28,026,771	44,941,696	4,392,970	5,633,214	64,831,718	15,606,876	2,000,822
Green algae abundance (no./cm²)	0	0	0	0	713,360	58,965	0	15,254,532	0	0
Blue-green algae abundance (no./cm²)	60,635,638	0	0	78,713,503	42,088,267	0	0	11,440,899	0	0
Euglenoid algae abundance (no./cm²)	0	0	0	596,314	713,360	0	0	3,813,633	0	0
Red algae abundance (no./cm²)	0	0	0	0	0	0	0	0	0	0
Diatom abundance (percent)	51.2	100.0	100.0	26.1	50.8	100.0	100.0	81.0	100.0	100.0
Green algae abundance (percent)	0.0	0.0	0.0	0.0	0.8	1.3	0.0	19.0	0.0	0.0
Blue-green algae abundance (percent)	48.8	0.0	0.0	73.3	47.6	0.0	0.0	12.0	0.0	0.0
Euglenoid algae abundance (percent)	0.0	0.0	0.0	0.6	0.8	0.0	0.0	4.0	0.0	0.0
Red algae abundance (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nitrogen heterotrophic diatom richness (percent)	15.8	23.5	13.6	29.2	25.0	29.6	29.4	28.6	24.3	25.0
Facultative nitrogen autotrophic diatom richness (percent)	63.2	47.1	68.2	54.2	45.0	55.6	52.9	45.7	59.5	60.0

Appendix 5. Benthic algae metrics calculated from qualitative multihabitat, richest-targeted habitat, and depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[EPA, Environmental Protection Agency; no., number; no./cm^2, number of individuals per square centimeter]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Obligative nitrogen autotrophic diatom richness (percent)	21.1	29.4	18.2	16.7	15.0	7.4	2.9	5.7	8.1	2.5
Nitrogen fixing diatom richness (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eutrophic diatom richness (percent)	57.1	57.9	68.0	80.8	78.3	93.3	87.5	92.9	85.0	88.9
Oligotrophic diatom richness (percent)	4.8	0.0	4.0	0.0	0.0	3.3	2.5	0.0	5.0	0.0
Halophilic diatom richness (percent)	13.0	10.0	11.1	10.3	24.0	35.5	36.6	22.7	35.0	41.3
Halophobic (fresh) diatom richness (percent)	13.0	5.0	3.7	6.9	4.0	0.0	0.0	2.3	2.5	0.0
Halophobic (fresh-brackish) diatom richness (percent)	69.6	80.0	81.5	82.8	72.0	64.5	61.0	75.0	62.5	58.7
Alkaline diatom richness (percent)	65.0	63.2	65.4	64.3	75.0	73.3	70.0	75.6	77.5	80.4
Acidiphilic diatom richness (percent)	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seston richness (percent)	0.0	0.0	3.3	0.0	0.0	2.9	0.0	14.9	15.0	9.6
Motile diatom richness (percent)	40.9	36.8	40.0	42.3	73.1	61.8	70.5	59.6	70.0	62.0
EPA tolerant species richness (percent)	55.6	42.9	38.5	53.8	53.8	56.3	57.1	63.2	50.0	52.9
EPA intolerant species richness (percent)	44.4	57.1	53.8	46.2	23.1	31.3	23.8	15.8	21.4	29.4
Nitrogen heterotrophic diatom abundance (percent)	8.6	4.7	5.8	32.3	11.5	31.2	36.5	38.3	19.5	43.5
Facultative nitrogen autotroph abundance (percent)	82.8	82.5	81.1	48.6	14.2	28.0	41.2	20.4	36.7	39.2
Obligative nitrogen autotroph abundance (percent)	8.6	12.8	13.1	19.1	3.1	3.2	1.4	0.7	1.5	0.2
Nitrogen fixing diatom abundance (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eutrotphic diatom abundance (percent)	72.9	49.0	47.0	91.9	96.2	99.1	88.1	99.0	88.5	78.7
Oligotrophic diatom abundance (percent)	0.5	0.0	0.6	0.0	0.0	0.4	0.4	0.0	1.1	0.0
Halophilic diatom abundance (percent)	4.1	2.5	4.7	14.3	7.0	37.6	28.0	28.9	19.4	30.2
Halophobic (fresh) diatom abundance (percent)	15.2	5.9	2.9	20.6	5.5	0.0	0.0	0.3	0.7	0.0
Halophobic (fresh-brackish) diatom abundance (percent)	79.9	89.6	90.6	65.2	87.4	62.4	71.8	70.8	79.9	69.8
Alkalinic diatom abundance (percent)	88.5	69.1	60.4	88.1	65.3	48.5	54.5	65.7	48.6	58.9
Acidophilic diatom abundance (percent)	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seston abundance (percent)	0.0	0.0	0.3	0.0	0.0	1.7	0.0	34.0	6.8	9.5
Motile diatom abundance (percent)	25.6	29.9	39.6	53.6	89.9	73.4	65.9	66.2	81.0	68.7

Appendix 5. Benthic algae metrics calculated from qualitative multihabitat, richest-targeted habitat, and depositional-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[EPA, Environmental Protection Agency; no., number; no./cm^2, number of individuals per square centimeter]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Bahl's tolerance index based on abundance	2.4	2.7	2.6	2.1	1.3	1.6	1.8	1.7	1.6	1.8
EPA tolerant diatom abundance (percent)	84.7	10.4	24.1	59.9	92.2	87.6	68.0	88.6	85.9	86.4
EPA intolerant diatom abundance (percent)	15.3	89.6	73.8	40.1	3.0	6.9	21.5	6.6	7.4	11.0
Siltation index	18.0	22.5	21.7	43.2	83.6	56.2	42.3	64.7	74.3	55.7
Pollution tolerance index	2.04	2.85	2.73	2.07	1.18	1.32	1.81	1.48	1.50	1.67

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.

[UPH was not sampled in 2000 or 2001. Under Sample identification, a “0” represents taxa was not present in the sample, and a “1” represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Total taxa per sample		57	49	52	55	42	39	36	28	22	30
Platyhelminthes											
Turbellaria	6	1	1	1	0	1	0	1	1	0	0
Nemertea											
Enopla											
Hoplonemertea											
Tetrastmmatidae											
Prostoma sp.	1	0	0	0	0	1	0	0	0	0	0
Nematoda	4	1	1	1	1	0	0	0	0	0	0
Bryozoa	1	0	0	0	0	0	0	0	1	0	0
Mollusca											
Gastropoda											
Basomamatophor											
Physidae											
Physella sp.	7	0	0	0	1	1	1	1	1	1	1
Bivalvia											
Veneroida											
Corbiculidae											
Corbicula sp.	3	0	0	0	0	0	1	0	1	0	1
Sphaeriidae											
Pisidiinae											
Pisidium sp.	3	1	1	1	0	0	0	0	0	0	0
Annelida											
Oligochaeta											
Lumbriculida											
Lumbriculidae	2	0	0	0	1	0	0	0	0	0	1
Tubificida											
Naididae	7	0	0	0	1	1	1	1	1	1	1
Tubificidae	8	1	1	1	0	1	0	1	1	1	1

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[UPH was not sampled in 2000 or 2001. Under Sample identification, a “0” represents taxa was not present in the sample, and a “1” represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Enchytraeida											
Enchytraeidae	4	1	1	1	0	1	0	0	0	0	0
Arthropoda											
Arachnida	6	1	1	1	0	1	1	1	0	0	0
Malacostraca											
Decapoda											
Pleocyemata											
Astacidae											
Pacifastacus sp.	2	0	0	0	0	0	1	1	0	0	0
Amphipoda											
Gammaridea											
Hyalellidae											
Hyalella sp.	3	0	0	0	0	0	1	0	0	1	1
Collembola	1	0	0	0	0	0	1	0	0	0	0
Insecta											
Ephemeroptera											
Furcatergalia											
Leptophlebiidae											
Paraleptophlebia sp.	3	1	1	1	0	0	0	0	0	0	0
Ephemerellidae											
Caudatella sp.	3	1	1	1	0	0	0	0	0	0	0
Drunella sp.	4	1	1	1	1	0	0	0	0	0	0
Ephemerella sp.	2	1	1	0	0	0	0	0	0	0	0
Serratella sp.	2	1	0	0	1	0	0	0	0	0	0
Leptohyphidae											
Tricorythodes sp.	5	0	0	0	1	1	1	1	0	0	1
Pisciforma											
Ameletidae											
Ameletus sp.	2	1	0	1	0	0	0	0	0	0	0
Baetidae	8	1	1	1	1	0	0	1	1	1	1
Baetis sp.	8	1	1	1	1	1	1	1	0	0	1
Callibaetis sp.	3	0	0	0	1	0	1	1	0	0	0

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[UPH was not sampled in 2000 or 2001. Under Sample identification, a “0” represents taxa was not present in the sample, and a “1” represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Camelobaetidius sp.	4	0	0	0	0	1	1	1	1	0	0
Diphetor sp.	2	0	1	0	1	0	0	0	0	0	0
Fallceon sp.	7	0	0	0	1	1	1	1	1	1	1
Setisura											
Heptageniidae											
Cinygmula sp.	2	1	1	0	0	0	0	0	0	0	0
Epeorus sp.	4	1	1	1	1	0	0	0	0	0	0
Ironodes sp.	3	1	1	1	0	0	0	0	0	0	0
Rhithrogena sp.	3	1	1	1	0	0	0	0	0	0	0
Odonata											
Zygoptera											
Coenagrionidae											
Hetaerina sp.	5	0	0	0	0	1	1	1	0	1	1
Argia sp.	4	0	0	0	0	1	1	1	0	0	1
Anisoptera											
Gomphidae	1	0	0	0	0	0	0	0	0	0	1
Progomphus sp.	3	0	0	0	0	1	1	1	0	0	0
Libellulidae											
Paltothemis sp.	1	0	0	0	1	0	0	0	0	0	0
Plecoptera											
Euholognatha											
Nemouridae											
Amphinemurinae											
Malenka sp.	1	1	0	0	0	0	0	0	0	0	0
Nemourinae											
Zapada sp.	2	1	0	1	0	0	0	0	0	0	0
Systellognatha											
Chloroperlidae											
Chloroperlinae											
Suwallia sp.	3	1	1	1	0	0	0	0	0	0	0
Peltoperlidae											
Peltoperlinae											

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[UPH was not sampled in 2000 or 2001. Under Sample identification, a “0” represents taxa was not present in the sample, and a “1” represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Yoraperla sp.	3	1	1	1	0	0	0	0	0	0	0
Perlidae											
Acroneuriinae											
Acroneuriini											
Calineuria sp.	4	1	1	1	1	0	0	0	0	0	0
Hesperoperla sp.	4	1	1	1	1	0	0	0	0	0	0
Perlodidae	1	1	0	0	0	0	0	0	0	0	0
Hemiptera											
Heteroptera											
Belostomatidae	2	0	0	0	1	0	1	0	0	0	0
Corixidae											
Corixinae											
Corixini											
Corisella sp.	2	0	0	0	0	0	0	0	1	0	1
Sigara sp.	1	0	0	0	0	0	0	0	1	0	0
Trichocorixa sp.	3	0	0	0	0	0	0	0	1	1	1
Gerridae											
Gerrinae	1	0	0	0	1	0	0	0	0	0	0
Hebridae											
Hebrinae											
Merragata sp.	3	0	0	0	0	1	1	1	0	0	0
Veliidae											
Microveliinae											
Microvelia sp.	2	0	0	0	1	0	1	0	0	0	0
Rhagoveliinae											
Rhagovelia sp.	5	0	0	0	0	1	1	1	0	1	1
Trichoptera											
Spicipalpia											
Glossosomatidae	1	0	0	1	0	0	0	0	0	0	0
Agapetinae											
Agapetus sp.	1	0	0	0	1	0	0	0	0	0	0
Hydroptilidae											

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[UPH was not sampled in 2000 or 2001. Under Sample identification, a "0" represents taxa was not present in the sample, and a "1" represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Hydroptilinae											
Hydroptila sp.	7	0	0	0	1	1	1	1	1	1	1
Oxyethira sp.	1	0	0	0	0	1	0	0	0	0	0
Rhyacophilidae											
Rhyacophila sp.	4	1	1	1	1	0	0	0	0	0	0
Annulipalpia											
Philopotamidae											
Philopotaminae											
Dolophilodes sp.	3	1	0	1	1	0	0	0	0	0	0
Hydropsychidae											
Arctopsychinae											
Parapsyche sp.	3	1	1	1	0	0	0	0	0	0	0
Hydropsychinae											
Ceratopsyche sp.	3	0	1	1	1	0	0	0	0	0	0
Hydropsyche sp.	8	1	0	0	1	1	1	1	1	1	1
Polycentropodidae											
Polycentropodinae											
Polycentropus sp.	1	0	0	0	1	0	0	0	0	0	0
Psychomyiidae											
Psychomyiinae											
Tinodes sp.	1	0	0	0	1	0	0	0	0	0	0
Integripalpia											
Apataniidae											
Apatania sp.	2	1	0	1	0	0	0	0	0	0	0
Brachycentridae											
Micrasema sp.	4	1	1	1	1	0	0	0	0	0	0
Lepidostomatidae											
Lepidostomatinae											
Lepidostoma sp.	2	0	1	0	1	0	0	0	0	0	0
Limnephilidae											
Dicosmoecinae											
Cryptochia sp.	1	0	0	1	0	0	0	0	0	0	0

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[UPH was not sampled in 2000 or 2001. Under Sample identification, a “0” represents taxa was not present in the sample, and a “1” represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Limnephilinae											
Psychoglypha sp.	1	0	1	0	0	0	0	0	0	0	0
Uenoidae											
Thremmatinae											
Neophylax sp.	2	1	0	1	0	0	0	0	0	0	0
Helicopsychidae											
Helicopsyche sp.	2	0	0	0	1	0	1	0	0	0	0
Lepidoptera											
Pyralidae											
Nymphulinae											
Argyactini											
Petrophila sp.	2	0	0	0	1	0	1	0	0	0	0
Coleoptera											
Myxophaga											
Hydroscaphidae											
Hydroscapha sp.	1	0	0	0	0	1	0	0	0	0	0
Adephaga											
Amphizoidae											
Amphizoa sp.	1	0	1	0	0	0	0	0	0	0	0
Dytiscidae											
Hydroporinae											
Bidessini											
Liodessus sp.	1	0	0	0	0	0	1	0	0	0	0
Hydroporini	2	0	1	0	1	0	0	0	0	0	0
Haliplidae											
Peltodytes sp.	1	0	0	0	0	1	0	0	0	0	0
Polyphaga											
Staphylinidae	1	0	0	0	0	1	0	0	0	0	0
Hydrophilidae											
Ametor sp.	2	1	0	1	0	0	0	0	0	0	0
Enochrus sp.	3	0	0	0	1	1	0	1	0	0	0
Laccobius sp.	1	0	0	0	0	1	0	0	0	0	0

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[UPH was not sampled in 2000 or 2001. Under Sample identification, a “0” represents taxa was not present in the sample, and a “1” represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Tropisternus sp.	3	0	0	0	0	1	1	1	0	0	0
Dryopidae											
Helichus sp.	1	0	0	0	1	0	0	0	0	0	0
Postelichus sp.	4	0	0	0	1	1	1	0	1	0	0
Elmidae	1	0	0	1	0	0	0	0	0	0	0
Microcylloepus sp.	1	0	0	0	0	1	0	0	0	0	0
Optioservus sp.	1	0	0	0	1	0	0	0	0	0	0
Zaitzevia sp.	1	0	0	0	1	0	0	0	0	0	0
Psephenidae											
Psephenus sp.	1	0	0	0	1	0	0	0	0	0	0
Diptera											
Nematocera											
Ceratopogonidae	1	0	0	1	0	0	0	0	0	0	0
Ceratopogoninae	1	0	1	0	0	0	0	0	0	0	0
Probezzia sp.	1	1	0	0	0	0	0	0	0	0	0
Dasyheleinae											
Dasyhelea sp.	2	0	0	0	1	0	0	1	0	0	0
Chironomidae											
Chironominae											
Chironomini											
Chironomus sp.	2	0	0	0	0	0	0	1	0	1	0
Cryptochironomus sp.	3	0	0	0	0	0	0	0	1	1	1
Dicrotendipes sp.	6	0	0	0	1	1	1	1	1	0	1
Endotribelos sp.	2	0	0	0	0	0	1	0	0	0	1
Microtendipes sp.	1	0	0	0	1	0	0	0	0	0	0
Nilothauma sp.	1	0	0	0	0	0	0	1	0	0	0
Paratendipes sp.	2	0	1	1	0	0	0	0	0	0	0
Phaenopsectra sp.	1	0	0	0	1	0	0	0	0	0	0
Polypedilum sp.	6	0	1	1	1	1	1	0	0	0	1
Saetheria sp.	3	0	0	0	0	1	1	1	0	0	0
Pseudochironomini											
Pseudochironomus sp.	6	0	0	0	1	1	1	1	1	1	0
Tanytarsini											
Micropsectra sp.	3	1	1	1	0	0	0	0	0	0	0
Rheotanytarsus sp.	7	1	0	0	1	1	0	1	1	1	1

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[UPH was not sampled in 2000 or 2001. Under Sample identification, a “0” represents taxa was not present in the sample, and a “1” represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Tanytarsus sp.	3	0	0	0	1	0	0	0	1	1	0
Diamesinae											
Diamesini											
Pagastia sp.	4	1	1	1	1	0	0	0	0	0	0
Pseudodiamesa sp.	2	1	1	0	0	0	0	0	0	0	0
Orthocladiinae											
Brillia sp.	3	1	1	1	0	0	0	0	0	0	0
Cardiocladius sp.	1	0	0	0	1	0	0	0	0	0	0
Chaetocladius sp.	1	0	0	1	0	0	0	0	0	0	0
Corynoneura sp.	1	1	0	0	0	0	0	0	0	0	0
Cricotopus sp.	7	0	0	0	1	1	1	1	1	1	1
Eukiefferiella sp.	5	1	1	1	1	1	0	0	0	0	0
Euryhapsis sp.	1	1	0	0	0	0	0	0	0	0	0
Heleniella sp.	3	1	1	1	0	0	0	0	0	0	0
Limnophyes sp.	2	1	0	0	0	1	0	0	0	0	0
Nanocladius sp.	3	0	0	0	0	0	0	0	1	1	1
Orthocladius sp.	1	1	0	0	0	0	0	0	0	0	0
Parametriocnemus sp.	2	1	0	1	0	0	0	0	0	0	0
Paraphaenocladius sp.	1	1	0	0	0	0	0	0	0	0	0
Rheocricotopus sp.	8	0	1	1	0	1	1	1	1	1	1
Synorthocladius sp.	1	1	0	0	0	0	0	0	0	0	0
Thienemanniella sp.	1	1	0	0	0	0	0	0	0	0	0
Tvetenia sp.	3	1	1	1	0	0	0	0	0	0	0
Prodiamesinae											
Odontomesa sp.	1	0	1	0	0	0	0	0	0	0	0
Prodiamesa sp.	1	0	1	0	0	0	0	0	0	0	0
Tanypodinae											
Macropelopiini											
Brundiniella sp.	3	1	1	1	0	0	0	0	0	0	0
Macropelopia sp.	1	0	1	0	0	0	0	0	0	0	0
Pentaneurini	2	0	1	1	0	0	0	0	0	0	0
Ablabesmyia sp.	2	0	0	0	0	0	0	0	1	0	1
Labrundinia sp.	1	0	0	0	0	1	0	0	0	0	0
Paramerina sp.	1	0	0	0	0	0	0	1	0	0	0
Pentaneura sp.	7	0	0	0	1	1	1	1	1	1	1
Tanypodini											

Appendix 6. Macroinvertebrate taxa collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[UPH was not sampled in 2000 or 2001. Under Sample identification, a “0” represents taxa was not present in the sample, and a “1” represents taxa was present in the sample]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Tanypus sp.	2	0	0	0	0	0	0	0	0	1	1
Dixidae											
Dixa sp.	2	1	0	1	0	0	0	0	0	0	0
Psychodidae	3	1	1	1	0	0	0	0	0	0	0
Maruina sp.	1	0	0	0	1	0	0	0	0	0	0
Simuliidae	1	0	0	0	0	0	1	0	0	0	0
Prosimulium sp.	3	1	1	1	0	0	0	0	0	0	0
Simulium sp.	7	1	0	1	1	1	0	1	1	0	1
Thaumaleidae	1	0	0	1	0	0	0	0	0	0	0
Tipulidae											
Limoniinae											
Dicranota sp.	2	0	1	1	0	0	0	0	0	0	0
Limonia sp.	2	0	0	0	0	1	0	1	0	0	0
Brachycera											
Empididae											
Clinocerinae	1	1	0	0	0	0	0	0	0	0	0
Hemerodromiinae	2	0	1	1	0	0	0	0	0	0	0
Hemerodromia sp.	7	0	0	0	1	1	1	1	1	1	1
Neoplasta sp.	1	1	0	0	0	0	0	0	0	0	0
Ephydridae	2	0	0	0	0	0	1	0	1	0	0
Pelecorhynchidae											
Glutops sp.	3	1	1	1	0	0	0	0	0	0	0
Stratiomyidae											
Stratiomyinae											
Caloparyphus sp.	4	0	0	0	1	1	1	1	0	0	0
Euparyphus sp.	4	0	0	0	1	1	1	1	0	0	0
Tabanidae											
Tabanus sp.	1	0	0	0	0	0	1	0	0	0	0

Appendix 7. Macroinvertebrate taxa from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.

[Values are number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Total taxa per sample		33	33	36	40	27	22	29	19	10	15
Platyhelminthes											
Turbellaria	4	0	34	0	0	35	0	42	14	0	0
Nemertea											
Enopla											
Hoplonemertea											
Tetrastmmatidae											
Prostoma sp.	1	0	0	0	0	35	0	0	0	0	0
Nematoda	3	11	22	55	0	0	0	0	0	0	0
Bryozoa	1	0	0	0	0	0	0	0	14	0	0
Mollusca											
Gastropoda	1	0	0	0	0	0	0	0	14	0	0
Basomamatophor											
Physidae											
Physella sp.	1	0	0	0	601	0	0	0	0	0	0
Bivalvia											
Veneroida											
Corbiculidae											
Corbicula sp.	2	0	0	0	0	0	0	0	18	0	2
Sphaeriidae	1	0	11	0	0	0	0	0	0	0	0
Annelida											
Oligochaeta											
Lumbriculida											
Lumbriculidae	1	0	0	0	0	0	0	0	0	0	32
Tubificida											
Naididae	7	0	0	0	47	330	408	242	136	103	162
Tubificidae	5	0	0	1	0	0	0	42	15	41	65
Enchytraeida											
Enchytraeidae	4	13	123	148	0	35	0	0	0	0	0
Arthropoda											
Arachnida	6	224	381	387	0	233	510	123	0	0	0

Appendix 7. Macroinvertebrate taxa from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Insecta											
Ephemeroptera											
Furcatergalia											
Leptophlebiidae											
Paraleptophlebia sp.	1	0	11	0	0	0	0	0	0	0	0
Ephemerellidae											
Caudatella sp.	3	1,061	122	129	0	0	0	0	0	0	0
Drunella sp.	4	882	1,041	1,382	33	0	0	0	0	0	0
Ephemerella sp.	1	0	14	0	0	0	0	0	0	0	0
Serratella sp.	2	18	0	0	227	0	0	0	0	0	0
Leptohyphidae											
Tricorythodes sp.	4	0	0	0	117	1,491	1,224	1,297	0	0	0
Pisciforma											
Baetidae	1	0	0	0	0	0	0	0	14	0	0
Baetis sp.	7	739	493	1,898	691	0	0	84	0	40	170
Camelobaetidius sp.	3	0	0	0	0	1,588	736	162	0	0	0
Diphetor sp.	1	0	0	0	30	0	0	0	0	0	0
Fallceon sp.	5	0	0	0	0	893	799	1,293	0	20	56
Setisura											
Heptageniidae											
Cinygmula sp.	2	13	11	0	0	0	0	0	0	0	0
Epeorus sp.	4	186	34	92	166	0	0	0	0	0	0
Ironodes sp.	3	26	11	46	0	0	0	0	0	0	0
Rhithrogena sp.	3	2	11	46	0	0	0	0	0	0	0
Odonata											
Zygoptera											
Coenagrionidae											
Hetaerina sp.	3	0	0	0	0	35	9	4	0	0	0
Argia sp.	3	0	0	0	0	6	213	42	0	0	0
Anisoptera	1	0	0	0	23	0	0	0	0	0	0
Plecoptera											
Euholognatha											
Nemouridae											
Nemourinae											

Appendix 7. Macroinvertebrate taxa from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Zapada sp.	2	45	0	258	0	0	0	0	0	0	0
Systellognatha											
Chloroperlidae											
Chloroperlinae											
Suwallia sp.	1	0	56	0	0	0	0	0	0	0	0
Peltoperlidae											
Peltoperlinae											
Yoraperla sp.	3	45	190	55	0	0	0	0	0	0	0
Perlidae											
Acroneuriinae											
Acroneuriini											
Calineuria sp.	3	1	11	0	4	0	0	0	0	0	0
Hesperoperla sp.	3	11	11	0	2	0	0	0	0	0	0
Perlodidae	1	11	0	0	0	0	0	0	0	0	0
Hemiptera											
Heteroptera											
Hebridae											
Hebrinae											
Merragata sp.	1	0	0	0	0	0	53	0	0	0	0
Veliidae											
Rhagoveliinae											
Rhagovelia sp.	1	0	0	0	0	0	53	0	0	0	0
Trichoptera											
Spicipalpia											
Glossosomatidae	1	0	0	18	0	0	0	0	0	0	0
Agapetinae											
Agapetus sp.	1	0	0	0	29	0	0	0	0	0	0
Hydroptilidae											
Hydroptilinae											
Hydroptila sp.	7	0	0	0	346	1,522	6,695	1,820	67	202	32
Rhyacophilidae											
Rhyacophila sp.	3	24	34	37	0	0	0	0	0	0	0

Appendix 7. Macroinvertebrate taxa from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Annulipalpia											
Philopotamidae											
Philopotaminae											
Dolophilodes sp.	2	1	0	0	1	0	0	0	0	0	0
Hydropsychidae											
Arctopsychinae											
Parapsyche sp.	2	0	90	398	0	0	0	0	0	0	0
Hydropsychinae											
Ceratopsyche sp.	2	0	0	9	53	0	0	0	0	0	0
Hydropsyche sp.	8	67	0	0	1,873	1,654	1,535	1,138	2,878	4,798	9,838
Polycentropodidae											
Polycentropodinae											
Polycentropus sp.	1	0	0	0	26	0	0	0	0	0	0
Psychomyiidae											
Psychomyiinae											
Tinodes sp.	1	0	0	0	164	0	0	0	0	0	0
Integripalpia											
Apataniidae											
Apatania sp.	2	13	0	166	0	0	0	0	0	0	0
Brachycentridae											
Micrasema sp.	4	132	325	258	46	0	0	0	0	0	0
Lepidostomatidae											
Lepidostomatinae											
Lepidostoma sp.	1	0	0	0	23	0	0	0	0	0	0
Uenoidae											
Thremmatinae											
Neophylax sp.	2	1	0	2	0	0	0	0	0	0	0
Helicopsychidae											
Helicopsyche sp.	1	0	0	0	138	0	0	0	0	0	0
Lepidoptera											
Pyralidae											
Nymphulinae											

Appendix 7. Macroinvertebrate taxa from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Argyactini											
Petrophila sp.	2	0	0	0	23	0	53	0	0	0	0
Coleoptera											
Myxophaga											
Hydroscaphidae											
Hydroscapha sp.	1	0	0	0	0	66	0	0	0	0	0
Polyphaga											
Hydrophilidae											
Enochrus sp.	1	0	0	0	0	0	0	42	0	0	0
Laccobius sp.	1	0	0	0	0	35	0	0	0	0	0
Tropisternus sp.	2	0	0	0	0	3	0	42	0	0	0
Dryopidae											
Helichus sp.	1	0	0	0	2	0	0	0	0	0	0
Postelichus sp.	2	0	0	0	1	6	0	0	0	0	0
Elmidae	1	0	0	18	0	0	0	0	0	0	0
Optioservus sp.	1	0	0	0	70	0	0	0	0	0	0
Zaitzevia sp.	1	0	0	0	24	0	0	0	0	0	0
Psephenidae											
Psephenus sp.	1	0	0	0	2	0	0	0	0	0	0
Diptera											
Nematocera											
Ceratopogonidae	1	0	0	37	0	0	0	0	0	0	0
Ceratopogoninae	1	0	11	0	0	0	0	0	0	0	0
Dasyheleinae											
Dasyhelea sp.	2	0	0	0	46	0	0	42	0	0	0
Chironomidae											
Chironominae											
Chironomini											
Chironomus sp.	1	0	0	0	0	0	0	81	0	0	0
Dicrotendipes sp.	4	0	0	0	0	35	110	123	15	0	0
Endotribelos sp.	1	0	0	0	0	0	57	0	0	0	0
Microtendipes sp.	1	0	0	0	47	0	0	0	0	0	0
Nilothauma sp.	1	0	0	0	0	0	0	42	0	0	0
Saetheria sp.	3	0	0	0	0	136	331	365	0	0	0

Appendix 7. Macroinvertebrate taxa from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Pseudochironomini											
Pseudochironomus sp.	6	0	0	0	47	101	220	1,216	15	21	0
Tanytarsini											
Micropsectra sp.	3	11	57	55	0	0	0	0	0	0	0
Rheotanytarsus sp.	6	11	0	0	658	0	0	246	15	42	240
Diamesinae											
Diamesini											
Pagastia sp.	4	22	114	498	24	0	0	0	0	0	0
Orthocladiinae											
Brillia sp.	3	13	11	44	0	0	0	0	0	0	0
Cardiocladius sp.	1	0	0	0	55	0	0	0	0	0	0
Chaetocladius sp.	1	0	0	66	0	0	0	0	0	0	0
Cricotopus sp.	7	0	0	0	82	583	893	2,280	706	1,005	206
Eukiefferiella sp.	5	142	103	22	217	51	0	0	0	0	0
Heleniella sp.	1	0	0	44	0	0	0	0	0	0	0
Nanocladius sp.	2	0	0	0	0	0	0	0	94	0	34
Parametriocnemus sp.	2	13	0	66	0	0	0	0	0	0	0
Paraphaenocladius sp.	1	13	0	0	0	0	0	0	0	0	0
Rheocricotopus sp.	5	0	11	0	0	0	128	356	24	0	34
Tvetenia sp.	3	77	217	88	0	0	0	0	0	0	0
Tanypodinae											
Macropelopiini											
Brundiniella sp.	1	0	0	55	0	0	0	0	0	0	0
Pentaneurini	5	0	23	18	117	101	0	0	0	0	34
Ablabesmyia sp.	1	0	0	0	0	0	0	0	15	0	0
Paramerina sp.	1	0	0	0	0	0	0	84	0	0	0
Pentaneura sp.	2	0	0	0	0	0	257	0	30	0	0
Dixidae											
Dixa sp.	1	0	0	18	0	0	0	0	0	0	0
Psychodidae	2	0	11	18	0	0	0	0	0	0	0
Maruina sp.	1	0	0	0	23	0	0	0	0	0	0
Simuliidae	3	0	0	221	0	0	306	0	0	0	32
Prosimulium sp.	2	1	78	0	0	0	0	0	0	0	0
Simulium sp.	5	33	0	0	783	236	0	450	28	0	0
Thaumaleidae	1	0	0	18	0	0	0	0	0	0	0

Appendix 7. Macroinvertebrate taxa from richest-targeted habitat samples collected from four sites in the Santa Ana River Basin, California, 1999–2001.—Continued

[Values are number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Taxon	Number of samples with an occurrence	Sample identification									
		SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Tipulidae											
Limoniinae											
Dicranota sp.	1	0	11	0	0	0	0	0	0	0	0
Limonia sp.	2	0	0	0	0	101	0	323	0	0	0
Brachycera											
Empididae											
Hemerodromiinae	1	0	34	0	0	0	0	0	0	0	0
Hemerodromia sp.	7	0	0	0	47	563	257	135	107	81	32
Neoplasta sp.	1	34	0	0	0	0	0	0	0	0	0
Pelecorhynchidae											
Glutops sp.	1	0	0	18	0	0	0	0	0	0	0
Stratiomyidae											
Stratiomyinae											
Caloparyphus sp.	4	0	0	0	184	465	563	619	0	0	0
Euparyphus sp.	2	0	0	0	0	35	0	177	0	0	0

Appendix 8. Macroinvertebrate metrics calculated from qualitative and richest-targeted samples from four sites in the Santa Ana River Basin, California, 1999–2001.

[EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; no., number; no./m^2, number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Metrics from qualitative (presence/absence) data										
Taxon richness (no. of taxa)	57	49	52	55	43	39	36	28	22	30
Ephemeroptera richness (no. of taxa)	11	10	8	8	3	4	5	3	2	3
Plecoptera richness (no. of taxa)	7	4	5	2	0	0	0	0	0	0
Trichoptera richness (no. of taxa)	7	6	9	11	3	3	2	2	2	2
EPT richness (no. of taxa)	25	20	22	21	6	7	7	5	4	5
EPT/Chironmid richness (no. of taxa)	1.5	1.3	1.7	1.8	0.5	0.9	0.7	0.5	0.4	0.5
Diptera richness (no. of taxa)	25	21	22	18	16	14	16	13	11	13
Chironomid richness (no. of taxa)	17	15	13	12	11	8	10	10	10	11
Orthoclad richness (no. of taxa)	12	5	7	3	4	2	2	3	3	3
Tanytarsinii richness (no. of taxa)	2	1	1	2	1	0	1	2	2	1
Nonchironomid dipteran richness (no. of taxa)	8	6	9	6	5	6	6	3	1	2
Noninsect richness (no. of taxa)	5	5	5	3	8	6	6	5	4	6
Nonmidge dipterans and noninsect richness (no. of taxa)	13	11	14	9	13	12	12	8	5	8
Odonate richness (no. of taxa)	0	0	0	1	3	3	3	0	1	3
Coleoptera richness (no. of taxa)	1	2	2	7	8	3	2	1	0	0
Mollusc and crustacean richness (no. of taxa)	1	1	1	1	1	4	2	2	2	3
Gastropod richness (no. of taxa)	0	0	0	1	1	1	1	1	1	1
Bivalve richness (no. of taxa)	1	1	1	0	0	1	0	1	0	1
Corbicula richness (no. of taxa)	0	0	0	0	0	1	0	1	0	1
Amphipod richness (no. of taxa)	0	0	0	0	0	1	0	0	1	1
Oligochaete richness (no. of taxa)	2	2	2	2	3	1	2	2	2	3
Average EPA tolerance (richness-weighted)	3.7	3.9	3.7	4.4	6.1	5.8	5.9	6.0	6.1	6.0
Ephemeroptera richness (percent)	19.3	20.4	15.4	14.5	7.0	10.3	13.9	10.7	9.1	10.0
Plecoptera richness (percent)	12.3	8.2	9.6	3.6	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera richness (percent)	12.3	12.2	17.3	20.0	7.0	7.7	5.6	7.1	9.1	6.7
EPT richness (percent)	43.9	40.8	42.3	38.2	14.0	17.9	19.4	17.9	18.2	16.7
Diptera richness (percent)	43.9	42.9	42.3	32.7	37.2	35.9	44.4	46.4	50.0	43.3
Chironomid richness (percent)	29.8	30.6	25.0	21.8	25.6	20.5	27.8	35.7	45.5	36.7
Orthoclad richness (percent)	21.1	10.2	13.5	5.5	9.3	5.1	5.6	10.7	13.6	10.0
Tanytarsini richness (percent)	3.5	2.0	1.9	3.6	2.3	0.0	2.8	7.1	9.1	3.3
Nonmidge dipteran richness (percent)	14.0	12.2	17.3	10.9	11.6	15.4	16.7	10.7	4.5	6.7

Appendix 8. Macroinvertebrate metrics calculated from qualitative and richest-targeted samples from four sites in the Santa Ana River Basin, California, 1999–2001—Continued.

[EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; no., number; no./m^2, number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Noninsect richness (percent)	8.8	10.2	9.6	5.5	18.6	15.4	16.7	17.9	18.2	20.0
Nonmidge dipterans and noninsect richness (percent)	22.8	22.4	26.9	16.4	30.2	30.8	33.3	28.6	22.7	26.7
Odonate richness (percent)	0.0	0.0	0.0	1.8	7.0	7.7	8.3	0.0	4.5	10.0
Coleoptera richness (percent)	1.8	4.1	3.8	12.7	18.6	7.7	5.6	3.6	0.0	0.0
Mollusc and crustacean richness (percent)	1.8	2.0	1.9	1.8	2.3	10.3	5.6	7.1	9.1	10.0
Gastropod richness (percent)	0.0	0.0	0.0	1.8	2.3	2.6	2.8	3.6	4.5	3.3
Bivalve richness (percent)	1.8	2.0	1.9	0.0	0.0	2.6	0.0	3.6	0.0	3.3
Corbicula richness (percent)	0.0	0.0	0.0	0.0	0.0	2.6	0.0	3.6	0.0	3.3
Amphipod richness (percent)	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.0	4.5	3.3
Oligochaete richness (percent)	3.5	4.1	3.8	3.6	7.0	2.6	5.6	7.1	9.1	10.0
Filterer richness (no. of taxa)	6	4	5	7	3	3	3	5	3	4
Gatherer richness (no. of taxa)	24	19	19	17	15	12	16	10	7	9
Omnivore richness (no. of taxa)	0	0	1	0	0	1	1	0	0	0
Parasite richness (no. of taxa)	1	1	1	1	0	0	0	0	0	0
Predator richness (no. of taxa)	12	14	12	11	14	12	10	7	7	10
Scraper richness (no. of taxa)	6	4	6	11	2	4	2	2	2	2
Shredder richness (no. of taxa)	4	4	4	5	5	3	2	2	1	2
Filterer richness (percent)	11.3	8.7	10.4	13.5	7.7	8.6	8.8	19.2	15.0	14.8
Gatherer richness (percent)	45.3	41.3	39.6	32.7	38.5	34.3	47.1	38.5	35.0	33.3
Omnivore richness (percent)	0.0	0.0	2.1	0.0	0.0	2.9	2.9	0.0	0.0	0.0
Parasite richness (percent)	1.9	2.2	2.1	1.9	0.0	0.0	0.0	0.0	0.0	0.0
Predator richness (percent)	22.6	30.4	25.0	21.2	35.9	34.3	29.4	26.9	35.0	37.0
Scraper richness (percent)	11.3	8.7	12.5	21.2	5.1	11.4	5.9	7.7	10.0	7.4
Shredder richness (percent)	7.5	8.7	8.3	9.6	12.8	8.6	5.9	7.7	5.0	7.4
Metrics from richest-targeted habitats (RTH)										
Taxon richness (no. of taxa)	33	33	36	40	27	22	29	19	10	15
Ephemeroptera richness (no. of taxa)	8	9	6	6	3	3	4	1	2	2
Plecoptera richness (no. of taxa)	5	4	2	2	0	0	0	0	0	0
Trichoptera richness (no. of taxa)	6	3	7	10	2	2	2	2	2	2
EPT richness (no. of taxa)	19	16	15	18	5	5	6	3	4	4
EPT/Chironmid richness (no. of taxa)	0.8	0.7	0.7	0.4	1.3	0.8	2.3	2.4	2.3	1.5
Diptera richness (no. of taxa)	11	12	16	13	11	10	15	10	4	7

Appendix 8. Macroinvertebrate metrics calculated from qualitative and richest-targeted samples from four sites in the Santa Ana River Basin, California, 1999–2001—Continued.

[EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; no., number; no./m^2, number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Chironomid richness (no. of taxa)	8	7	10	8	6	7	9	8	3	5
Orthoclad richness (no. of taxa)	5	4	6	3	2	2	2	3	1	3
Tanytarsinii richness (no. of taxa)	2	1	1	1	0	0	1	1	1	1
Nonchironomid dipteran richness (no. of taxa)	3	5	6	5	5	3	6	2	1	2
Noninsect richness (no. of taxa)	2	4	3	2	5	2	4	5	2	4
Nonmidge dipterans and noninsect richness (no. of taxa)	5	9	9	7	10	5	10	7	3	6
Odonate richness (no. of taxa)	0	0	0	1	2	2	2	0	0	0
Coleoptera richness (no. of taxa)	0	0	1	5	4	0	2	0	0	0
Mollusc and crustacean richness (no. of taxa)	0	1	0	1	0	0	0	2	0	1
Gastropod richness (no. of taxa)	0	0	0	1	0	0	0	1	0	0
Bivalve richness (no. of taxa)	0	1	0	0	0	0	0	1	0	1
Corbicula richness (no. of taxa)	0	0	0	0	0	0	0	1	0	1
Amphipod richness (no. of taxa)	0	0	0	0	0	0	0	0	0	0
Oligochaete richness (no. of taxa)	1	1	2	1	2	1	2	2	2	3
Ephemeroptera richness (percent)	24.2	27.3	16.7	15.0	11.1	13.6	13.8	5.3	20.0	13.3
Plecoptera richness (percent)	15.2	12.1	5.6	5.0	0.0	0.0	0.0	0.0	0.0	0.0
Trichoptera richness (percent)	18.2	9.1	19.4	25.0	7.4	9.1	6.9	10.5	20.0	13.3
EPT richness (percent)	57.6	48.5	41.7	45.0	18.5	22.7	20.7	15.8	40.0	26.7
Diptera richness (percent)	33.3	36.4	44.4	32.5	40.7	45.5	51.7	52.6	40.0	46.7
Chironomid richness (percent)	24.2	21.2	27.8	20.0	22.2	31.8	31.0	42.1	30.0	33.3
Orthoclad richness (percent)	15.2	12.1	16.7	7.5	7.4	9.1	6.9	15.8	10.0	20.0
Tanytarsini richness (percent)	6.1	3.0	2.8	2.5	0.0	0.0	3.4	5.3	10.0	6.7
Nonmidge dipteran richness (percent)	9.1	15.2	16.7	12.5	18.5	13.6	20.7	10.5	10.0	13.3
Noninsect richness (percent)	6.1	12.1	8.3	5.0	18.5	9.1	13.8	26.3	20.0	26.7
Nonmidge dipterans and noninsect richness (percent)	15.2	27.3	25.0	17.5	37.0	22.7	34.5	36.8	30.0	40.0
Odonate richness (percent)	0.0	0.0	0.0	2.5	7.4	9.1	6.9	0.0	0.0	0.0
Coleoptera richness (percent)	0.0	0.0	2.8	12.5	14.8	0.0	6.9	0.0	0.0	0.0
Mollusc and crustacean richness (percent)	0.0	3.0	0.0	2.5	0.0	0.0	0.0	10.5	0.0	6.7
Gastropod richness (percent)	0.0	0.0	0.0	2.5	0.0	0.0	0.0	5.3	0.0	0.0
Bivalve richness (percent)	0.0	3.0	0.0	0.0	0.0	0.0	0.0	5.3	0.0	6.7
Corbicula richness (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.0	6.7
Amphipod richness (percent)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Appendix 8. Macroinvertebrate metrics calculated from qualitative and richest-targeted samples from four sites in the Santa Ana River Basin, California, 1999–2001—Continued.

[EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; no., number; no./m^2, number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Oligochaete richness (percent)	3.0	3.0	5.6	2.5	7.4	4.5	6.9	10.5	20.0	20.0
Taxon abundance (no./m^2)	3,897	3,718	6,694	7,091	10,371	15,413	12,913	4,218	6,351	10,967
Ephemeroptera abundance (no./m^2)	2,927	1,747	3,594	1,262	3,972	2,760	2,836	14	60	226
Plecoptera abundance (no./m^2)	113	269	314	6	0	0	0	0	0	0
Trichoptera abundance (no./m^2)	238	448	888	2,699	3,176	8,230	2,959	2,945	5,000	9,870
EPT abundance (no./m^2)	3,278	2,464	4,795	3,967	7,148	10,989	5,794	2,958	5,060	10,095
Dipteran abundance (no./m^2)	370	683	1,289	2,331	2,406	3,123	6,539	1,050	1,148	611
Chironomid abundance (no./m^2)	302	538	958	1,247	1,006	1,996	4,793	915	1,067	547
Orthoclad abundance (no./m^2)	258	343	331	353	634	1,020	2,635	824	1,005	274
Tanytarsini abundance (no./m^2)	22	57	55	658	0	0	246	15	42	240
Nonmidge dipteran abundance (no./m^2)	68	146	331	1,084	1,399	1,127	1,746	135	81	64
Noninsect abundance (no./m^2)	237	549	536	648	667	918	450	196	143	261
Nonmidge dipterans and noninsect abundance (no./m^2)	2,066	2,045	2,196	331	224	325	1,732	305	694	867
Odonate abundance (no./m^2)	0	0	0	23	41	222	46	0	0	0
Coleoptera abundance (no./m^2)	0	0	18	98	110	0	84	0	0	0
Mollusc and crustacean abundance (no./m^2)	0	11	0	601	0	0	0	32	0	2
Gastropod abundance (no./m^2)	0	0	0	601	0	0	0	14	0	0
Bivalve abundance (no./m^2)	0	11	0	0	0	0	0	18	0	2
Corbicula abundance (no./m^2)	0	0	0	0	0	0	0	18	0	2
Amphipod abundance (no./m^2)	0	0	0	0	0	0	0	0	0	0
Oligochaete abundance (no./m^2)	13	123	149	47	365	408	285	150	143	258
Ephemeroptera abundance (percent)	75	47	54	18	38	18	22	0	1	2
Plecoptera abundance (percent)	3	7	5	0	0	0	0	0	0	0
Trichoptera abundance (percent)	6	12	13	38	31	53	23	70	79	90
EPT abundance (percent)	84	66	72	56	69	71	45	70	80	92
Dipteran abundance (percent)	10	18	19	33	23	20	51	25	18	6
Chironomid abundance (percent)	8	14	14	18	10	13	37	22	17	5
Orthoclad abundance (percent)	7	9	5	5	6	7	20	20	16	2
Tanytarsini abundance (percent)	1	2	1	9	0	0	2	0	1	2
Nonmidge dipteran abundance (percent)	2	4	5	15	13	7	14	3	1	1
Noninsect abundance (percent)	6	15	8	9	6	6	3	5	2	2
Nonmidge dipterans and noninsect abundance (percent)	20	13	17	8	4	3	24	8	19	13

Appendix 8. Macroinvertebrate metrics calculated from qualitative and richest-targeted samples from four sites in the Santa Ana River Basin, California, 1999–2001—Continued.

[EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; no., number; no./m^2, number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Odonate abundance (percent)	0	0	0	0	0	1	0	0	0	0
Coleoptera abundance (percent)	0	0	0	1	1	0	1	0	0	0
Mollusc and crustacean abundance (percent)	0	0	0	8	0	0	0	1	0	0
Gastropod abundance (percent)	0	0	0	8	0	0	0	0	0	0
Bivalve abundance (percent)	0	0	0	0	0	0	0	0	0	0
Corbicula abundance (percent)	0	0	0	0	0	0	0	0	0	0
Amphipod abundance (percent)	0	0	0	0	0	0	0	0	0	0
Oligochaete abundance (percent)	0	3	2	1	4	3	2	4	2	2
Average EPA tolerance (richness-weighted)	3.3	3.7	3.8	3.9	6.1	5.5	5.9	5.7	5.7	5.8
Average EPA tolerance (abundance-weighted)	2.2	2.5	2.8	4.8	5.0	5.3	5.5	4.6	4.5	4.2
Percentage of most abundant taxon	27.2	28.0	28.4	26.4	16.0	43.4	17.7	68.2	75.6	89.7
Percentage of two most abundant taxon	49.9	41.2	49.0	37.5	31.3	53.4	31.7	85.0	91.4	91.9
Simpson's diversity	0.83	0.87	0.86	0.89	0.89	0.78	0.91	0.50	0.40	0.19
Filterer richness (no. of taxa)	5	3	3	6	2	2	3	4	2	4
Gatherer richness (no. of taxa)	11	11	14	12	10	8	15	8	4	6
Omnivore richness (no. of taxa)	0	0	1	0	0	0	0	0	0	0
Parasite richness (no. of taxa)	1	1	1	0	0	0	0	0	0	0
Predator richness (no. of taxa)	5	10	6	7	8	6	6	3	1	2
Scraper richness (no. of taxa)	6	4	6	10	1	2	1	2	1	1
Shredder richness (no. of taxa)	3	2	3	4	3	1	2	1	1	1
Filterer richness (percent)	16.1	9.7	8.8	15.4	8.3	10.5	11.1	22.2	22.2	28.6
Gatherer richness (percent)	35.5	35.5	41.2	30.8	41.7	42.1	55.6	44.4	44.4	42.9
Omnivore richness (percent)	0.0	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parasite richness (percent)	3.2	3.2	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Predator richness (percent)	16.1	32.3	17.6	17.9	33.3	31.6	22.2	16.7	11.1	14.3
Scraper richness (percent)	19.4	12.9	17.6	25.6	4.2	10.5	3.7	11.1	11.1	7.1
Shredder richness (percent)	9.7	6.5	8.8	10.3	12.5	5.3	7.4	5.6	11.1	7.1
Filterer abundance (no./m^2)	245	414	488	3,462	1,890	1,841	1,834	2,939	4,840	10,112
Gatherer abundance (no./m^2)	2,110	1,277	3,071	1,654	4,266	3,721	4,891	327	204	496
Omnivore abundance (no./m^2)	0	0	18	0	0	0	0	0	0	0

Appendix 8. Macroinvertebrate metrics calculated from qualitative and richest-targeted samples from four sites in the Santa Ana River Basin, California, 1999–2001—Continued.

[EPT, sum of Ephemeroptera, Plecoptera, and Trichoptera; no., number; no./m^2, number of individuals per square meter. UPH was not sampled in 2000 or 2001]

Metric	Sample identification									
	SF99	SF00	SF01	UPH99	MWD99	MWD00	MWD01	PRD99	PRD00	PRD01
Parasite abundance (no./m^2)	11	22	55	0	0	0	0	0	0	0
Predator abundance (no./m^2)	962	1,344	1,891	302	812	843	349	151	81	66
Scraper abundance (no./m^2)	241	67	370	1,562	1,522	6,748	1,820	81	202	32
Shredder abundance (no./m^2)	102	202	358	108	690	893	2,603	706	1,005	206
Filterer abundance (percent)	6.7	12.5	7.8	48.8	20.6	13.1	16.0	69.9	76.4	92.7
Gatherer abundance (percent)	57.5	38.4	49.1	23.3	46.5	26.5	42.5	7.8	3.2	4.5
Omnivore abundance (percent)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parasite abundance (percent)	0.3	0.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Predator abundance (percent)	26.2	40.4	30.2	4.3	8.8	6.0	3.0	3.6	1.3	0.6
Scraper abundance (percent)	6.6	2.0	5.9	22.0	16.6	48.0	15.8	1.9	3.2	0.3
Shredder abundance (percent)	2.8	6.1	5.7	1.5	7.5	6.4	22.6	16.8	15.9	1.9

Appendix 9. Data from fish collected from four sites during the summers 1999–2001 in the Santa Ana River Basin, California.

[See table 1 for explanation of sample identification. UPH was not sampled in 2001. g, gram; mm, millimeter; na, not applicable; YOY, young of the year; —, no data]

Sample identification	Scientific name	Common name	Number collected	Relative abundance (percent)	Mean weight (g)	Range weight (g)	Mean standard length (mm)	Range standard length (mm)	Mean total length (mm)	Range total length (mm)
SF99[1]	*Salmo trutta*	Brown trout	86	100.0	49.4	3.1–127	134	49–195	158	69–230
SF00	*Salmo trutta*	Brown trout	114	100.0	46.1	5.9–176	129	65–218	155	80–261
SF01	*Salmo trutta*	Brown trout	120	100.0	24.8	1.1–81	104	38–175	125	46–210
UPH99[1]	*Salmo trutta*	Brown trout	27	10.1	72.7	8.0–251	140	75–244	165	90–292
	Oncorhynchus mykiss[2]	Rainbow trout	240	89.9	43.3	1.5–151	111	48–210	134	56–252
UPH00[1]	*Salmo trutta*	Brown trout	21	14.5	64.9	8.2–241	139	79–255	168	97–302
	Oncorhynchus mykiss[2]	Rainbow trout	124	85.5	42.8	4.2–99	131	62–194	160	75–233
MWD99	*Gila orcutti*[2]	Arroyo chub	46	24.7	23.1	0.5–805	68	29–166	79	35–178
	Catostomus santaanae[2]	Santa Ana sucker	11	5.9	13.9	0.5–23	85	30–110	100	36–126
	Lepomis cyanellus	Green sunfish	3	1.6	14.3	1.3–40	62	36–113	72	45–125
	Gambusia affinis	Western mosquitofish	53	28.5	0.8	0.2–2.0	13	13–44	37	17–54
	Ameiurus natalis	Yellow bullhead	63	33.9	10.2	0.6–68	59	30–153	71	36–178
	Tilapia mossambica	Mozambique tilapia	2	1.1	16.7	1.4–32	63	34–92	79	41–117
	Pimephales promelas	Fathead minnow	7	3.8	1.6	0.4–5.6	41	30–64	49	36–75
	Cyprinus carpio	Common carp	1	0.5	257.0	na	215	na	258	na
MWD00	*Gila orcutti*[2]	Arroyo chub	41	10.8	3.9	0.9–26	52	35–105	60	41–120
	Catostomus santaanae[2]	Santa Ana sucker	72	19.0	2.3	1.0–5.9	50	39–66	59	46–80
	Gambusia affinis	Western mosquitofish	249	65.7	1.0	0.1–1.9	35	20–43	43	23–58
	Ameiurus natalis	Yellow bullhead	14	3.7	12.6	0.7–73	71	29–155	84	34–181
	Pimephales promelas	Fathead minnow	2	0.5	1.2	0.9–1.4	42	38–46	50	45–55
	Cyprinus carpio	Common carp	1	0.3	—	na	280	na	340	na
MWD01	*Gila orcutti*[2]	Arroyo chub	93	47.2	2.8	0.5–14	46	30–94	55	36–100
	Catostomus santaanae[2]	Santa Ana sucker	14	7.1	8.9	0.8–31	65	34–115	79	40–140
	Micropterus salmoides	Largemouth bass	1	0.5	21.9	na	97	na	118	na
	Gambusia affinis	Western mosquitofish	38	19.3	0.9	0.1–2.3	33	18–44	40	23–53
	Ameiurus natalis	Yellow bullhead	46	23.4	21.9	1.1–112	85	35–175	101	37–112
	Pimephales promelas	Fathead minnow	5	2.5	1.7	1.2–2.4	44	40–50	53	47–60
PRD99	*Lepomis macrochirus*	Bluegill	28	4.4	23.0	0.2–46	79	19–105	98	23–130
	Ictalurus punctatus	Channel catfish	6	0.9	85.2	32–167	173	130–225	214	163–282
	Cyprinus carpio	Common carp	86	13.4	280.3	7.9–1,933	193	66–450	237	81–550
	Pimephales promelas	Fathead minnow	246	38.3	1.0	0.5–3.0	37	19–55	45	22–65
	Carassius auratus	Goldfish	37	5.8	60.8	30–178	126	101–185	157	125–226
	Lepomis cyanellus	Green sunfish	3	0.5	14.0	—	77	—	92	—
	Micropterus salmoides	Largemouth bass	8	1.2	66.3	52–90	147	138–160	173	162–190
	Cottus asper	Prickly sculpin	1	0.2	26.0	na	105	na	121	na

Appendix 9. Data from fish collected from four sites during the summers 1999–2001 in the Santa Ana River Basin, California.—Continued

[See table 1 for explanation of sample identification. UPH was not sampled in 2001. g, gram; mm, millimeter; na, not applicable; YOY, young of the year; —, no data]

Sample identification	Scientific name	Common name	Number collected	Relative abundance (percent)	Mean weight (g)	Range weight (g)	Mean standard length (mm)	Range standard length (mm)	Mean total length (mm)	Range total length (mm)
	Gambusia affinis	Western mosquitofish	211	32.8	0.9	0.3–1.3	33	22–38	40	28–46
	Ameiurus natalis	Yellow bullhead	17	2.6	32.8	1.5–100	101	32–173	116	42–200
PRD00	*Lepomis macrochirus*	Bluegill	11	1.7	16.6	0.6–38	66	25–99	83	31–124
	Cyprinus carpio	Common carp	71	11.3	80.4	3.2–928	107	49–320	135	60–420
	Pimephales promelas	Fathead minnow	268	42.5	1.2	0.6–2.6	40	34–51	50	41–62
	Carassius auratus	Goldfish	58	9.2	78.9	0.6–254	122	31–205	158	38–265
	Lepomis cyanellus	Green sunfish	27	4.3	17.1	0.3–36	71	25–100	88	29–123
	Micropterus salmoides	Largemouth bass	7	1.1	38.9	4.3–143	96	56–170	119	69–213
	Poecilia latipinna	Sailfin molly	3	0.5	1.8	1.3–2.6	39	37–42	48	45–52
	Catostomus santaanae[2]	Santa Ana sucker	1	0.2	YOY	na	YOY	na	YOY	na
	Gambusia affinis	Western mosquitofish	172	27.3	0.5	0.1–1.5	27	19–39	33	21–48
	Ameiurus natalis	Yellow bullhead	12	1.9	2.1	0.6–4.5	41	20–60	50	32–72
PRD01	*Lepomis macrochirus*	Bluegill	3	1.6	53.2	1.5–81	88	32–120	110	41–145
	Ictalurus punctatus	Channel catfish	1	0.6	228.0	na	255	na	310	na
	Cyprinus carpio	Common carp	39	21.4	376.4	2.8–1,182	215	48–355	276	60–460
	Pimephales promelas	Fathead minnow	36	19.8	1.9	0.6–3.8	46	30–59	55	35–71
	Carassius auratus	Goldfish	23	12.6	127.6	17–266	146	80–200	188	105–260
	Lepomis cyanellus	Green sunfish	52	28.6	14.8	0.6–48	67	28–108	81	33–48
	Micropterus salmoides	Largemouth bass	13	7.1	62.4	2.6–500	102	48–270	124	55–330
	Poecilia latipinna	Sailfin molly	2	1.1	2.8	0.9–4.6	39	32–46	49	40–57
	Gambusia affinis	Western mosquitofish	6	3.3	1.1	0.4–1.6	33	30–36	41	36–45
	Ameiurus natalis	Yellow bullhead	7	3.8	54.3	1.9–103	119	40–175	140	46–205

[1]Fish data from one pass instead of two passes using a backpack electrofisher.

[2]Native species.

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