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CALIFORNIA WATER BODIES

San Diego Regional Water Quality Control Board: 1999 Biological Assessment Annual Report

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INTRODUCTION

The State of California began its efforts to develop water quality biocriteria in 1993. Because water quality regulatory authority in California is divided into nine autonomous Regional Water Quality Control Boards, the State of California has taken a regional approach to biocriteria development instead of the statewide approach common in other states. The California Department of Fish and Game (DFG) helped to coordinate this approach by developing and distributing standardized sampling, laboratory and quality assurance procedures for state bioassessment programs called the California Stream Bioassessment Procedure (CSBP). The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour et al. 1999) and is recognized by the EPA as California's standardized bioassessment procedure (Davis et al. 1996).

The CSBP is a cost-effective tool that utilizes measures of the stream's benthic macroinvertebrate (BMI) community and its physical/ habitat structure. BMI communities can be very complex, being composed of tens to hundreds of species. Individual species reside in streams for periods ranging from a month to several years. Because they are sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993), BMIs can provide considerable information regarding the biological condition of water bodies. Together, biological and physical assessments integrate the effects of water quality over time, are sensitive to multiple aspects of water and habitat quality, and provide the public with more familiar expressions of ecological health (Gibson 1996).

In 1997, the San Diego Regional Water Quality Control Board (San Diego RWQCB) contracted DFG to help them incorporate bioassessment into their ambient water quality monitoring program. The initial sampling strategy was designed to gather a baseline of information to support several project goals:

- To include biological information in the San Diego RWQCB's ongoing water quality monitoring programs
- To create a species list of BMIs known from the region
- To establish a biological classification of different stream types in the region
- To identify potential reference sites for the San Diego regional bioassessments
- To determine the best index period for sampling BMI communities
- To select appropriate metrics for southern California stream bioassessments

This document reports the results of the bioassessments conducted on May, September and, November 1998 and May 1999 at 48 locations spread throughout the San Diego region. A second document will be generated in the summer of 2000 that will include the results of another sampling event (November 1999) and will present a preliminary Index of Biological Integrity (IBI). Karr (1981) first published the IBI as a consistent means of measuring the societal goal of biological integrity. Based on a combination of tested biological attributes of water resources, the IBI provides a cumulative site assessment as a single score value (Davis and Simon 1995). The IBI is the end point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995). In March 2002, a final report will present a working IBI for the San Diego region which will be fortified with bioassessment results from selected reference and test sites sampled in May and October 2000 and May 2001.

MATERIALS AND METHODS

Monitoring Reach Delineation

Sampling reaches were delineated according to the methods described in the CSBP (Harrington 1999). Reaches consisted of at least a five-riffle stretch of stream in which all riffles had similar gradient and substrate characteristics. Occasionally, it was not possible to find 5 contiguous riffles of similar characteristics at a site and fewer riffles (3 or 4) were used. Monitoring reach descriptions are summarized in Table 1 and a map of sampling locations is presented in Figure 1. Photographs of all sites are attached to this report as GIF files in Appendix I.

Monitoring activities occurred over four sampling periods: May 14-23, 1998, September 1-7, 1998, November 10-18, 1998 and May 9-16, 1999.

BMI Sampling

Riffle length was determined for each riffle and a random number table was used to establish a point randomly along the upstream third of the riffle from which a transect was established perpendicular to the stream flow. Starting with the transect at the lowermost riffle, the benthos within a 2 ft^2 area was disturbed upstream of a 1 ft wide, 0.5 mm mesh D-frame kick-net. Sampling of the benthos was performed manually by rubbing cobble and boulder substrates in front of the net followed by "kicking" the upper layers of substrate to dislodge any invertebrates remaining in the substrates. The duration of sampling ranged from 60-120 seconds, depending on the amount of boulder and cobble-sized substrates that required rubbing by hand; more and larger substrates required more time to process. Three locations representing the habitats along the transect were sampled and combined into a composite sample (representing a six ft^2 area). This composite sample was transferred into a 500 ml wide-mouth plastic jar containing approximately 200 ml of 95% ethanol. This technique was repeated for each of three riffles in each reach.

Physical Habitat Quality Assessment

Physical habitat quality was assessed for the monitoring reaches using U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) (Barbour *et al*. 1999). Habitat quality assessments were recorded for each monitoring reach during each sampling event. Photographs were taken within each of the monitoring reaches to document overall riffle condition at the time of sampling. At a minimum, photographs were taken upstream and downstream through each riffle sampled.

Physical Habitat Characteristics

In addition to the physical habitat quality assessments, we recorded several additional measures of habitat characteristics at the riffle scale. The following measurements were taken in the vicinity of the BMI collection sites: GPS coordinates, elevation, riffle gradient, riffle width and depth, canopy cover, substrate complexity, substrate consolidation and the proportion of different substrate sizes (substrate composition). This data is available upon request from the ABL.

Ambient Water Chemistry Recording

Ambient water chemistry was recorded at each site using a Yellow Springs Instruments (YSI 3800 or YSI 85) water quality meter. Recorded measurements included water temperature, dissolved oxygen concentration, specific conductance, salinity and pH. Ambient chemistry data are more complete in the more recent sampling events.

Table 1. BMI sampling site information for reaches sampled within the San Diego region indicating site ID, GPS coordinates and sampling dates.

WATERSHED NAME	LOCATION DESCRIPTION	SITE ID	LATITUDE/ LONGITUDE	May 98	Sept 98	Nov 98	May 99
Aliso Creek	Reach consisted of 3 riffles upstream of Pacific Park Drive	AC-PPD	N33E34' 30.6", W117E 42' 53.9"	x	x	x	x
Aliso Creek	Reach consisted of 5 riffles parallel to Country Club Road upstream of Hwy 1	AC-CCR	N33E30' 51.2" W117E 44' 34.9"	x	x	x	x
San Juan Creek	Arroyo Trabuco Creek; Reach consisted of 5 riffles within Avery Gravel Yard at end of Avery Parkway	ATC-AP	N33E35' 3.0" W117E 38' 9.0"	-	x	x	x
San Juan Creek	Reach consisted of 5 riffles upstream of Highway 74	SJC-74	N33E31' 9.0" W117E 37' 25.4"	-	x	x	x
Santa Margarita River	Reach consisted of 5 riffles 2 miles upstream of Willow Glen Road	SMR-WGR	N33E25' 49.3" W117E 11' 43.1"	x	x	x	x
Santa Margarita River	Reach consisted of 5 riffles downstream of Sandia Road (near DeLuz/ Pico Road)	SMR-DP	N33E 24' 51.0" W117E 14' 26.3"	x	x	x	x
Santa Margarita River	Reach consisted of 5 riffles downstream of Santa Margarita Road, Camp Pendleton	SMR-CP	N33E 20' 22.1" W117E 19' 51.9"	x	x	x	x
Santa Margarita River	Reach consisted of 5 riffles upstream of Stuart Mesa Blvd., Camp Pendleton	SMR-SMB	N33E14' 12.1" W117E 23' 30.3"	x	-	-	x
Santa Margarita River	Murrietta Creek: Reach consisted of 5 riffles near USGS gauging station	MC-GS	N33E28' 36.8" W117E 08' 25.5"	x	x	x	x
Santa Margarita River	Temecula Creek: Reach consisted of 5 riffles immediately downstream of I-15	TC-I-15	N33E28' 27.9" W117E 08' 16.8"	x	x	x	x
Santa Margarita River	Rainbow Creek: Reach consisted of 3 riffles upstream of Willow Glen Road	RC-WGR	N33E24' 26.1" W117E 11' 58.9"	x	x	x	x
Santa Margarita River	Murietta Creek: Reach consisted of 3 riffles downstream of Calle del Oso Oro	MC-WB	N33E34' 5.7" W117E 14' 21.2"	x	-	-	-
Santa Margarita River	Sandia Creek: Reach consisted of 5 riffles along Sandia Creek Drive, 0.7 miles upstream of Rock Mountain Road	SC-SCR	N33E 25' 27.3" W117E 14' 53.2"	x	x	x	x
San Luis Rey River	Reach consisted of 5 riffles upstream and downstream of Lilac Road	KC-LR	N33E17' 38.1" W117E 05' 10.3"	x	x	x	x
San Luis Rey River	Reach consisted of 5 riffles about 50 meters upstream of pullout opposite Outdoor Education School on Highway 76	SLRR-PG	N33E15' 44.5" W116E 48' 29.5"	x	x	x	x
San Luis Rey River	Reach consisted of 3 riffles downstream of old Hwy 395 and I -15	SLRR-395	N33E19' 27.8" W117E 09' 28.2"	x	x	x	x
San Luis Rey River	Reach consisted of 3 riffles upstream of Mission Road	SLRR-MR	N33E15' 41.6" W117E 14' 06.1"	x	x	x	x
Carlsbad	Loma Alta Creek: Reach consisted of 5 riffles downstream of College Blvd.	LAC-CB	N33E12' 18.0" W117E 17' 13.4"	x	x	x	x

Carlsbad	Loma Alta Creek: Reach consisted of 5 riffles downstream of El Camino Real	LAC-ECR	N33E11' 57.6" W117E 19' 48.2"	x	x	x	x
Carlsbad	Buena Vista Creek: Reach consisted of 5 riffles downstream of Santa Fe Avenue	BVR-ED	N33E11' 57.9" W117E 14' 35.1"	x	x	x	x

Table 1 (continued).

WATERSHED NAME	LOCATION DESCRIPTION	SITE ID	LATITUDE/ LONGITUDE	May 98	Sept 98	Nov 98	May 99
Carlsbad	Buena Vista Creek: Reach consisted of 5 riffles upstream of South Vista Way	BVR-SVW	N33E10' 48.7" W117E 19' 41.1"	x	x	x	x
Carlsbad	Agua Hedionda Creek: Reach consisted of 5 riffles downstream of Sycamore Avenue	AHC-SA	N33E09' 22.5" W117E 13' 34.0"	x	x	-	-
Carlsbad	Agua Hedionda Creek: Reach consisted of 5 riffles downstream of El Camino Real	AHC-ECR	N33E08' 57.0" W117E 17' 46.9"	x	x	x	x
Carlsbad	Tecolote Creek: Reach consisted of 5 riffles upstream of Gardena Ave. and Cross Street	TC-TCNP	N32E46' 30.6" W117E 11' 15.5"	-	-	x	x
Carlsbad	San Marcos Creek: Reach consisted of 5 riffles 50 m upstream of Mc Mahr Road intersection	SMC-M	N33E07' 47.8" W117E 11' 29.0"	x	x	x	x
Carlsbad	San Marcos Creek: Reach consisted of 5 riffles downstream of Santar Place	SMC-SP	N33E08' 37.0" W117E 08' 54.2"	x	x	x	x
Carlsbad	San Marcos Creek: Reach consisted of 5 riffles 50 m upstream of Mc Mahr Road intersection	SMC-RSFR	N33E06' 12.9" W117E 13' 33.6"	x	x	x	x
Carlsbad	San Marcos Creek: Reach consisted of 5 riffles downstream of Rancho Santa Fe Road	SMC-LCCC	N33E05' 18.7" W117E 14' 43.6"	x	x	x	x
Carlsbad	Encinitas Creek: Reach consisted of 5 riffles downstream of Green Valley Rd	EC-GVR	N33E04' 17.5" W117E 15' 43.8"	x	x	x	x
Escondido Creek	Reach consisted of 5 riffles downstream of Harmony Grove bridge	EC-HRB	N33E06' 31.6" W117E 06' 41.2"	x	x	x	x
Escondido Creek	Reach consisted of 5 riffles downstream of Elfin Forest Resort	EC-EF	N33E04' 17.6" W117E 09' 52.0"	x	x	x	x
Escondido Creek	Reach consisted of 5 riffles upstream of Rancho Santa Fe Road	EC-RSFR	N33E02' 10.2" W117E 14' 6.1"	x	-	-	-
Los Penasquitos Creek	Rattlesnake Creek: Reach consisted of 5 riffles adjacent to Hillary Park	RC-HP	N32E57' 36.0" W117E 02' 31.2"	x	x	x	x
Los Penasquitos Creek	Reach consisted of 5 riffles upstream of Cobblestone Creek Road	LPC-CCR	N32E56' 55.9" W117E 04' 06.6"	x	x	x	x
Los Penasquitos Creek	Reach consisted of 5 riffles upstream of Black Mountain Road	LPC-BMR	N32E56' 24.8" W117E 07' 36.5"	x	x	x	x
Los Penasquitos Creek	Carroll Canyon Creek: Reach consisted of 5 riffles downstream of I-805 at Sorrento Valley Road	CCC-805	N32E53' 30.3" W117E 12' 53.9"	-	x	x	x
San Diego River	Reach consisted of 5 riffles upstream of Mission Dam	SDR-MD	N32E50' 25.8" W117E 02' 20.7"	x	x	x	x
San Diego River	Reach consisted of 5 riffles at the downstream boundary of Mission Trails Regional Park	SDR-MT	N32E49' 06.9" W117E 03' 55.1"	x	x	x	x

San Diego River	Reach consisted of 5 riffles adjacent to the River Valley golf course	SDR-1	N32E45' 53.9" W117E 11' 28.9"	**X**	**X**	**X**	**X**
Sweetwater River	Reach consisted of 5 riffles downstream of Riverside Drive near I-8	SR-79	N32E50' 20.8" W116E 36' 51.2"	**X**	**X**	**X**	**X**
Sweetwater River	Reach consisted of 5 riffles upstream of Hwy 94	SR-94	N32E43' 59.9" W117E 56' 19.0"	**X**	**X**	**X**	**X**
Sweetwater River	Reach consisted of 5 riffles downstream of Sweetwater Road	SR-WS	N32E39' 29.1" W117E 02' 36.4"	**X**	**X**	**X**	**X**

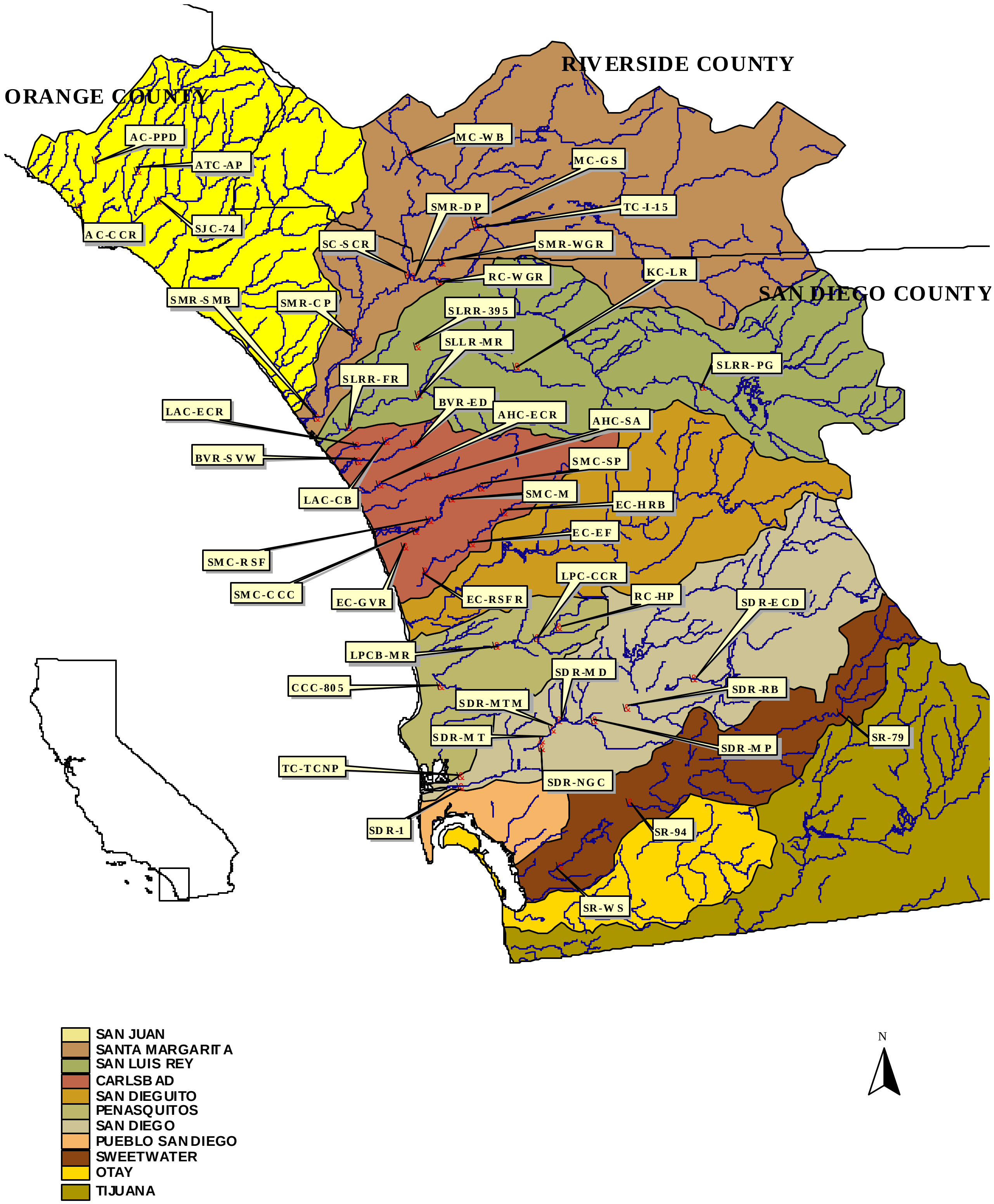

Figure 1. Bioassessement sampling locations within the San Diego region showing major watersheds.

BMI Laboratory Analysis

At the laboratory, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm brass mesh) and transferred into a tray marked with twenty, 25 cm^2 grids. All detritus was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 5% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as "remnant" material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. BMIs were then identified to a standard taxonomic level, typically genus level for insects and order or class for non-insects using standard taxonomic keys (Brown 1972, Edmunds et al. 1976, Klemm 1985, Merritt and Cummins 1995, Pennak 1989, Stewart and Stark 1993, Surdick 1985, Thorp and Covich 1991, Usinger 1963, Wiederholm 1983, 1986, Wiggins 1996, Wold 1974).

Data Analysis

A taxonomic list of BMIs identified from the samples was entered into a Microsoft Excel® spreadsheet program. Excel® was used to calculate and summarize BMI community based metric values. A description of the metric values used to describe the community is shown in Table 2.

Each of the monitoring reaches was given a relative BMI Ranking Score based on 6 of the BMI metric values selected as described above (Table 2; metrics 1,2,6, 7, 14 and 15). The scores were computed as follows:

$$Score = \sum (x_i - \bar{x}) / sem_i$$

where: x_i = site value for the *i*-th metric; x bar = overall mean for the *i*-th metric; sem_i = standard error of the mean for the *i*-th metric. An overall score of "0" is the average for all sites.

Watershed Land Use Characterization

Watershed areas and composition of different land use categories were calculated with ArcView GIS software (v. 3.2) using land use data provided by the San Diego Association of Governments (SanDAG) and the Southern California Association of Governments (SCAG). The SanDAG data was based on 1995 aerial surveys and the SCAG data was based on 1993 aerial surveys. All land use shapefiles were converted to Teale Albers Equal Area Projections using the projection conversion utility in ArcView. All other shapefiles were obtained from the Teale GIS Data Library (www.gislab.teale.ca.gov/ wwwgis/files_html/dataview.html).

Watershed area was calculated as the area upstream of each site according to the boundaries defined in Figure 1, which are based on the Teale Hydrologic Basins shapefile for watershed sub-units. In cases in which sampling locations occurred in the middle of a hydro-basin sub-unit, the downstream boundary of each watershed was adjusted to include only those areas upstream of the sampling location.

Land use designations were based on the Lu_95 and Code_93 codes (these are land use data based on 1995 and 1993 aerial surveys) contained in the land use shapefiles. All land use designations were grouped into one of six categories: 1) Undeveloped Lands, 2) Developed Lands, 3) Golf Courses, 4) Agriculture: Orchards/ Vineyards, 5) Agriculture: Row Crops, and 6) Agriculture: Intensive. The percentage contribution of each of these categories was calculated for the area upstream of each site as shown in Figure 2.

Selection of Appropriate Metrics

The metrics used to calculate the relative ranking scores were selected by visual inspection of the relationship between all the bioassessment metrics and several physical variables. The primary variables used were the independent measures of land use: Percent Developed Lands and Percent Undeveloped Land. We also evaluated the relationship between the community metrics and physical/ habitat scores, total watershed area and percentage of agricultural lands in the area upstream of each site.

Stream Order

Stream order was determined from the State Water Quality Control Board's Hydrologic Basin Planning Area maps of the San Diego region (revised 1995) following methodology described by Strahler (1957). Since stream order was not calculated from USGS 7 ½ minute maps, these ordinal assignments should not be used outside of this study.

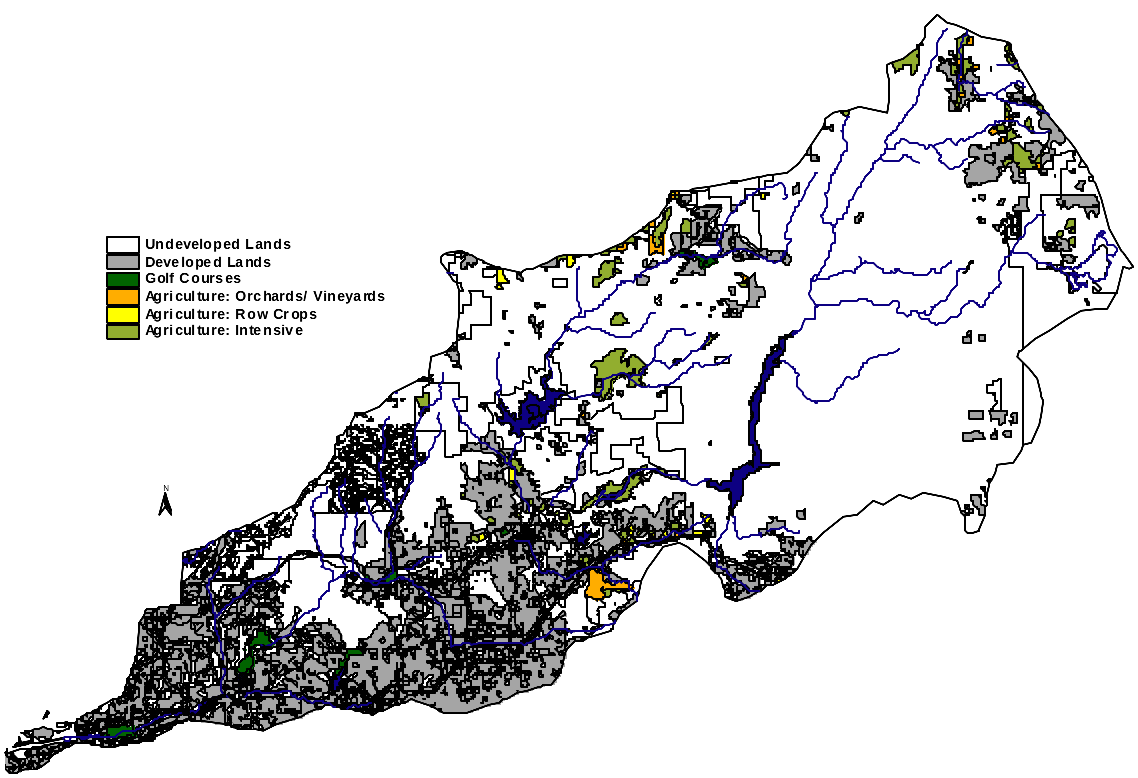

Figure 2. Watershed map of site SDR-1 showing the distribution of major land use categories in the watershed.

Table 2. Bioassessment metrics used to describe characteristics of the benthic macroinvertebrate (BMI) community at sampling reaches within the San Diego region.

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	decrease
Dipteran Taxa	Number of taxa in the insect order (Diptera," true flies")	increase
Non-Insect Taxa	Number of non-insect taxa	increase
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Percent Hydropsychidae	Percent composition of the tolerant caddisfly family Hydropsychidae	increase
Percent Baetidae	Percent composition of the tolerant mayfly family Baetidae	increase
Percent Diptera	Percent composition of the tolerant insect order Diptera	increase
Percent Non-Insects	Percent composition of the generally tolerant non-insect taxa	increase
Percent Chironomidae	Percent composition of the tolerant dipteran family Chironomidae	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable

Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Abundance		
Estimated Abundance	Estimated number of BMIs in sample calculated by extrapolating from the proportion of organisms counted in the subsample	variable

RESULTS

Dominant BMI Taxa/ General Taxonomic Notes

Complete lists of BMIs identified from each sampling event are presented in Appendix IIa-IId. The five dominant taxa observed in each of the monitoring reaches are presented in Tables 3a -3d.

May 1998—Although there were 114 taxa found in the 39 sites we sampled, the vast majority of these taxa were rarely found. The BMI communities at almost all sites were primarily dominated by a few disturbance tolerant insect taxa and worms. Four groups of taxa were especially abundant at all sites: midges (Diptera: Chironomidae), blackflies (Diptera: Simuliidae), minnow mayflies (Ephemeroptera: Baetidae) and segmented worms (Annelida: Oligochaeta). Beetles (Coleoptera) were extremely rare at all sites. Only 6 sites had more than one beetle taxon and 30 sites had no beetle taxa. While dipteran taxa alone comprised over 30% of the BMI taxa, two families (Simuliidae and Chironomidae) were responsible for the vast majority of the individuals. True bugs (Hemiptera), dobsonflies (Megalopterans) and dragonflies (Odonates) were rare at most sites, only the damselfly *Argia* (Odonata: Coenagrionidae) was common at any site. Mayfly taxa (Ephemeroptera) were overwhelmingly represented by *Baetis* (Baetidae) and a few other baetids, as well as some *Tricorythodes* (Leptohyphidae). There were only two stonefly (Plecoptera) taxa found in 3 of the 39 sites in this study. The caddisfly community was largely dominated by the filter-feeding *Hydropsyche* (Trichoptera: Hydropsychidae) and a few sites had the hydroptilid caddisfly, *Hydroptila*. Only 5 sites had more than these two caddisfly taxa, despite the occurrence of 11 caddisfly taxa overall. Although there was an above average number of non-insect taxa (28 out of 114) nearly all of the abundance was accounted for by worms; the remaining non-insect taxa were rare. Across most sites there was a marked dominance by orthoclad midges (Chironomidae: Orthocladiinae), the mayfly *Baetis* and worms.

September 1998—There were 150 taxa identified from the September samples and although there were more taxa than in the May 1998 samples, the distribution of taxa was largely similar. Beetle taxa (Coleoptera) were slightly more abundant, but were still uncommon, with 24 of the sites having 2 or fewer taxa. Nearly a third of the taxa (48) were dipterans, again dominated by chironomid midges and blackflies, with occasional dominance of soldierfly larvae (Stratiomyiidae). A few more hemipteran and odonate taxa were found in September than were in May. Mayflies were similar to the May samples, except that *Fallceon* replaced *Baetis* as the dominant baetid mayfly. Again, stoneflies were absent from all sites except for the shredder, *Malenka sp*. (Plecoptera: Nemouridae), which was present at only three sites. There were more hydroptilid caddisfly taxa in the September samples than in May; otherwise, there were few caddisflies other than *Hydropsyche*. The 30 non-insect taxa collected in September were more evenly distributed among worm, ostracod, flatworm (Planariidae) and mite (Acari) groups than the May non-insects that were primarily worms. There was a decreased dominance by the orthoclad midges, more dominance by non-insect groups and more dominance by hydropsychid caddisflies.

November 1998—There were 147 taxa identified from the November samples and the distribution of taxa was nearly identical to the September samples. Only 5 of the sites had more than 2 beetle taxa, and there were 42 dipteran taxa. There were a few more odonate taxa and more stonefly taxa than May 1998 or September 1998, although only four sites had any stoneflies. The dominance of *Fallceon* decreased from the September samples, as *Fallceon* and *Baetis* abundances were roughly equivalent. Dominance of individual taxa in the November samples was very similar to the September samples.

May 1999—There were more taxa in May 1999 samples (130) and these were distributed much like those of the May 1998 samples. The BMI communities at almost all sites were primarily dominated by a few disturbance tolerant insect taxa and worms. Four groups of taxa were especially abundant at all sites: midges (Diptera: Chironomidae), blackflies (Diptera: Simuliidae), minnow mayflies (Ephemeroptera: Baetidae) and segmented worms (Annelida: Oligochaeta). Beetles (Coleoptera) were extremely rare at all sites. The dominance of a few taxa was renewed in these samples, with high dominance of *Baetis* (replacing *Fallceon*), blackflies, worms and chironomid midges. May 1999 samples contained 36 dipteran taxa and 27 non-insect taxa.

<u>BMI Community Metrics</u>
BMI metric values are presented by transect in Appendix IVa-IVd and summarized by reach mean and coefficient of variation in Appendix Va-Vd.

Richness
May 1998—Average Taxonomic Richness ranged from a low of 6 taxa to a high of 22 taxa with most sites having between 10 and 15 taxa. Only two sites had 20 or more taxa. The relatively sensitive EPT taxa were also very low. No sample had more than 7 EPT taxa and only 4 sites had 5 or more EPT taxa.

September 1998—Average Taxonomic Richness was nearly twice as high in September samples. Richness ranged between 11 and 34 taxa and 23 sites had at least 20 taxa. Samples contained between 0 and 11 EPT taxa and only 9 sites had 5 or more EPT taxa.

November 1998—Richness measures were similar to those of September samples. Sites averaged between 7 and 36 taxa and 21 sites had at least 20 taxa. There were 13 EPT taxa at one site and 17 sites had at least 5 EPT taxa.

May 1999—Richness measures were similar to those of May 1998. Although between 6 and 31 taxa were collected on average from sites in the May 1999 samples, there were only two sites with 20 or more taxa. There was a high of 12 taxa on average and 11 sites had 5 or more taxa. May 1999 samples contained 36 dipteran taxa and 27 non-insect taxa.

Composition Measures
May 1998—Shannon Diversity values were low at all sites, ranging from 0.9 to 2.2. Only two sites had diversity scores higher than 2.0. Although there were very few EPT taxa, these taxa were occasionally the most abundant organisms in samples. EPT Index scores were fairly consistent; EPT individuals contributed at least a third and often as much as two thirds of the community in these samples. However, sensitive EPT taxa were rare. All but 3 sites had any sensitive EPT taxa and only one site had more than 3% EPT taxa. The filter-feeding caddisfly family, Hydropsychidae, was rare in these samples, only once making up more

than 5% of the community in a sample (SC-SCR). Baetid mayflies (Ephemeroptera: Baetidae) on the other hand were ubiquitous; baetids were not among the top five most abundant taxa in only five sites. All sites were dominated by one or a few taxa. The most abundant taxon comprised between 28 and 79 percent of the total BMI community. The BMI communities at 18 sites were dominated by at least 50% of one taxon.

September 1998—Community diversity was considerably higher in the September samples than in May samples. There were 17 sites with Shannon Diversity scores of 2.0 or higher. Sensitive EPT were rare; only three sites had more than 5% sensitive EPT taxa. Dominance was somewhat less pronounced in the September samples than in the May samples. In 14 sites the most dominant taxon comprised more than 50% of the BMI community.

November 1998—Community composition was similar to that of the September samples. Twenty sites had Shannon Diversity scores of at least 2.0, only 1 site was comprised of more than 3% sensitive EPT taxa and the most abundant taxon comprised greater than 50% of the community at 10 sites.

May 1999—Community composition was similar to that of the May 1998 samples, but diversity was more similar to the September and November samples. There were 19 sites with diversity scores of 20 or greater, 3 sites had more than 5% EPT taxa and 16 sites were influenced by a taxon with greater than 50%.

Tolerance Measures

May 1998—All tolerance measures indicated communities that were very tolerant to disturbance or extremely tolerant to disturbance. Average tolerance values ranged between 4.4 and 7.4, high community tolerance numbers, and only 8 sites had scores lower than 5.0. Intolerant taxa were rare at all locations. Almost all sites had no intolerant taxa and only one contained greater than 5% intolerant taxa.

September 1998—Tolerance measures were similar to those of May 1998. Average tolerance values varied between 4.2 and 8.6, only 6 sites had scores lower than 5.0, only three sites had greater than 5% intolerant taxa and 12 sites had greater than 40% tolerant taxa.

November 1998—Community tolerance measures were again very high. Average tolerance values ranged between 4.3 and 7.9, 12 sites had tolerance scores lower than 5.0, 2 sites had greater than 5% intolerant taxa and 5 sites had greater than 40% tolerant taxa.

May 1999—Average tolerance values ranged between 4 and 8, 1 site had a tolerance score lower than 5.0, 3 sites had greater than 5% intolerant taxa and 5 sites had greater than 40% tolerant taxa.

Functional Feeding Groups

May 1998—All of the FFGs were present within the entire project, but shredders were encountered rarely and in only a few sites (Tables 3a-3d). Only two sites had any shredding insects. Shredders are usually associated with streams with an intact riparian canopy since shredding insects feed mostly on accumulations of decomposing coarse particulate organic matter. Although there were many predator taxa, these also represented a small proportion of the community; only 9% of communities were comprised of more than 3% predatory taxa. Most organisms in this watershed were either collector-gatherers or filtering collectors, both of which feed on fine particulate organic matter (FPOM). In this system, FPOM feeders represented at least 85 percent of the community at all sites except two. The relative proportion of collector-gatherers to filterers varied considerably.

September 1998—Although the communities were again primarily comprised of collectors, filterers and grazers, there was a much more even distribution of feeding groups. Predator taxa comprised >5% of individuals in all but 2 of the sites and 13 sites were comprised of at least 20% predaceous organisms. Shredder taxa were again rare, but 12 sites had shredder taxa and three had more than 5% shredders.

November 1998—Distributions of functional groups in the November communities were roughly similar to those of the September samples. Predators comprised >5% of individuals in all but 5 sites and 11 sites had more than 20% predators.

May 1999—The abundance of predators and shredders was very low. Only 9 sites had more than 5% predatory organisms and only 3 sites had more than 5% shredders.

Abundance

May 1998—Abundance of organisms was extremely variable, ranging between a low of 400 organisms per sample and a high of 15,000 organisms per sample. Most samples contained between 2,000 and 5,000 organisms.

September 1998—Abundance was much lower than in the May samples, ranging between 400 and 7,000 organisms per sample with most containing between 1,000 and 3,000 organisms.

November 1998—Abundance was similar to the September samples but even lower, ranging between 68 and 7,500 with the majority having between 500 and 3,000 organisms per sample.

May 1999—Abundance was similar to the May 1998 samples with much higher abundances than in the late summer/ fall samples. Abundance varied between 300 and 13,000 organisms per sample. Most of the samples contained between 3,000 and 10,000 organisms.

Physical Habitat Quality Assessment

Physical habitat quality scores are summarized in Table 4 and raw habitat data are presented in Appendix VIa-VId.

May 1998—The majority of sites in this study had similar physical habitat characteristics. With the exception of one site that scored in the high end of the "poor" range (BVR-ED) and one site that scored in the low end of the "excellent" range (SLRR-PG), all sites scored either "fair" or "good". Most sites had fairly good riparian protection and bank vegetation, but had moderate amounts of sediment deposition and low substrate diversity. Sediment often completely covered larger substrates and filled interstitial spaces with deposits of sand and silt. These high sediment levels are associated with high embeddedness scores, poor to non-existent instream cover and low variability in velocity and depth regimes.

September 1998—All sites scored in the fair to good range and were very similar to their condition to the May 1998 sampling event.

November 1998— All sites scored in the fair to good range except for BVR-ED and SLRR-PG, which had similar scores to the May 1998 values.

May 1999—Scores were on average somewhat higher than they were in the 1998 sampling events, partially due to slight discrepancies in scoring criteria between these events and partially due to the influence of more water in the watersheds during the sampling period. Six sites had total physical/ habitat scores of more than 150, the cutoff for "excellent" physical habitat quality. The May 1999 scores reflect the most recent and most reliable determinations of physical habitat for the sites in this project.

Table 4. Physical habitat quality scores for sampling reaches within eight watersheds in the San Diego region in May 1998. Scores for each habitat parameter range from 0 (poor) to 20 (excellent).

Habitat Parameter	ALISO CREEK		SANTA MARGARITA RIVER								
	AC-PPD	AC-CCR	SMR-WGR	SMR-DP	SMR-CP	SMR-SMB	MC-GS	TC-I-15	RC-WGR	MC-WB	SC-SCR
May 1998	90	87	128	121	98	81	101	109	135	75	122
September 1998	81	60	136	118	111	-	100	115	134	-	124
November 1998	90	75	129	129	97	-	81	111	144	-	115
May 1999	111	92	158	129	90	86	109	136	135	-	128

Habitat Parameter	SAN LUIS REY RIVER					CARLSBAD						
	KC-LR	SLRR-PG	SLRR-395	SLRR-MR	SLRR-FR	LAC-CB	LAC-ECR	BVR-ED	BVR-SVW	AHC-SA	AHC-ECR	TC-TCNP
May 1998	138	151	101	91	91	63	69	49	73	80	83	-
September 1998	111	148	88	99	93	66	81	64	72	74	79	-
November 1998	107	158	96	108	108	73	62	44	59	-	57	114
May 1999	113	167	104	100	117	79	97	68	80	-	86	140

Table 4 (continued). Physical habitat quality scores for sampling reaches within eight watersheds in the San Diego region in May 1998. Scores for each habitat parameter range from 0 (poor) to 20 (excellent).

Habitat Parameter	CARLSBAD					ESCONDIDO CREEK			LOS PENASQUITOS CREEK			
	SMC-M	SMC-SP	SMC-LCCC	SMC-RSFR	EC-GVR	EC-HRB	EC-EF	EC-RSFR	RC-HP	LPC-CCR	CCC-805	LPC-BMR
May 1998	107	103	122	108	105	87	121	86	74	112		125
September 1998	109	105	104	108	104	75	112	-	70	105	122	95
November 1998	125	90	115	127	107	94	122	-	62	108	106	106
May 1999	126	120	132	128	116	98	150	-	79	130	136	125

Habitat Parameter	SAN DIEGO RIVER			SWEETWATER RIVER			SAN JUAN CREEK		
	SDR-MD	SDR-MT	SDR-1	SR-79	SR-94	SR-WS	SJC-74	OC-FR	ATC-AP
May 1998	107	142	87	93	71	89	-	-	-
September 1998	114	143	95	123	76	88	111	-	113
November 1998	101	136	106	110	72	95	106	-	97
May 1999	130	152	120	164	78	103	125	-	150

In two cases (sites MC-GS and ATC-AP), samples were not taken at the same location in each sampling event. The May 1999 and November 1998 samples of MC-GS were taken about 150 m downstream of the site sampled in May 1998 and September 1998 to take advantage of better flows in the downstream reach. The May 1999 samples at site ATC-AP were collected approximately 1 km upstream of the September and November 1998 samples. These differences are reflected in the physical habitat scores for these sites. All other samples were collected from the same locations at all sampling events.

Ambient Chemistry

Records of ambient chemical measures are summarized in Appendix VIIa-VIId. Many of the ambient chemistry measures are not available for the earliest sampling events due to problems with field water chemistry meters.

Selection of Appropriate Metrics

All biological metrics, physical habitat metrics, chemistry and land use data were incorporated into one dataset and analyzed in the statistical analysis package SYSTAT 8.0. A copy of the data file is presented in Microsoft Excel 5.0 format in Appendix VIII.

There was a strong concordance between the different variables used to select the most discriminating biological metrics. The land use variable Percent Developed Area, and to a lesser degree, Percent Undeveloped Area described the best relationships between physical variables and biological metrics (Figures 4 and 5; both describe only Sept 98 and Nov 98 data, but May 98 and May 99 data had similar patterns). Since there were 6 categories used to describe land use in these watersheds, the percentages of developed and undeveloped lands are not directly correlated. The richness variables and Shannon's Diversity Index had the tightest relationship between land use and metric values, increasing with Percent Developed Area and decreasing with Percent Undeveloped Area. Although there was a positive relationship between the Percent Chironomidae and the Percent Developed Area, developed area did not explain very much of the variability in this metric. The percentage of sensitive EPT organisms was much higher in watersheds with lower levels of development, however, the value of the Sensitive EPT metric was limited because the majority of communities did not include any sensitive EPT taxa.

Although they usually provided similar results, there were much poorer relationships between most of the biological measures and the variables: physical/ habitat score, watershed area and total agricultural land use. On the basis of the land use variables, six metrics best described the variability in biological condition: Taxonomic Richness, EPT Taxa, Sensitive EPT Index, Shannon Diversity, Percent Intolerant, and Percent Chironomidae.

BMI Ranking Score

The BMI ranking scores were calculated independently for each sampling event and are presented in Figures 3a-3d. Sites are grouped by major watershed unit and color-coded to indicate stream order at each site. In each figure, the "mean" line represents the average rank score of all sites. The rank scores are relative to each other and are only comparable within a sampling event and not comparable among sampling events.

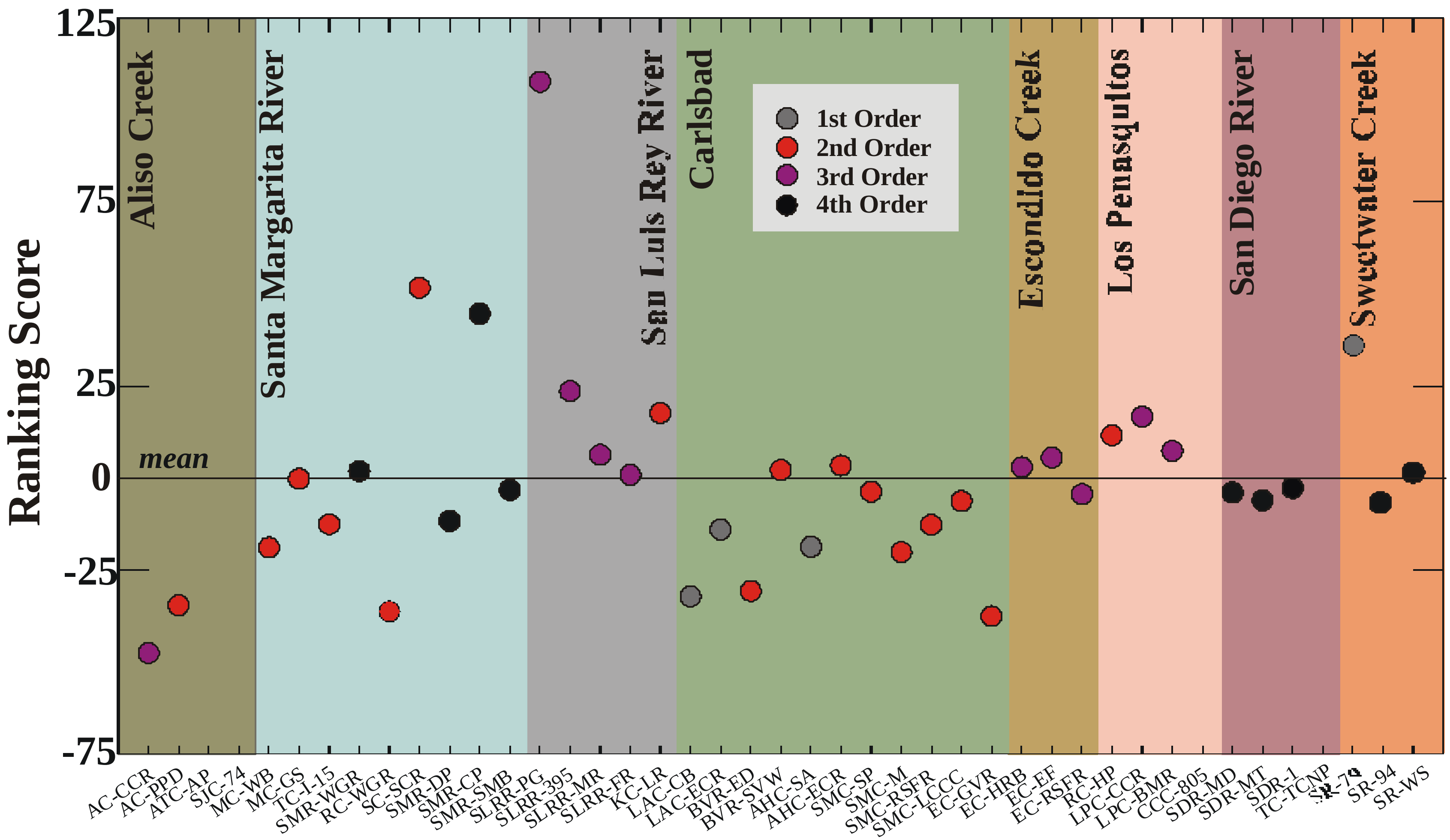

Figure 3a. BMI ranking scores for macroinvertebrate monitoring sites sampled in May 98 for the San Diego Regional Bioassessment Monitoring Project.

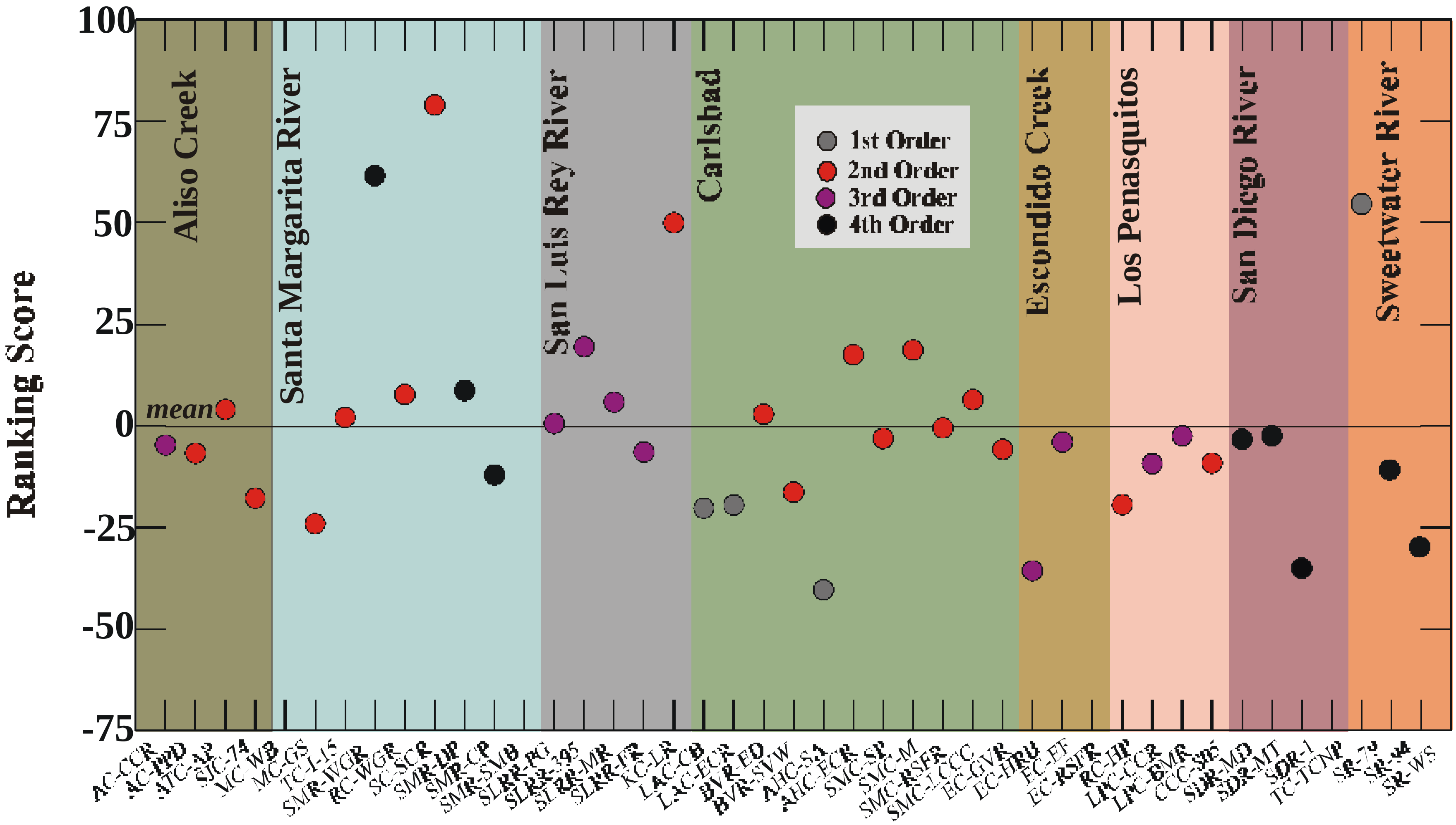

Figure 3b. BMI ranking scores for macroinvertebrate monitoring sites sampled in September 98 for the San Diego Regional Bioassessment Monitoring Project.

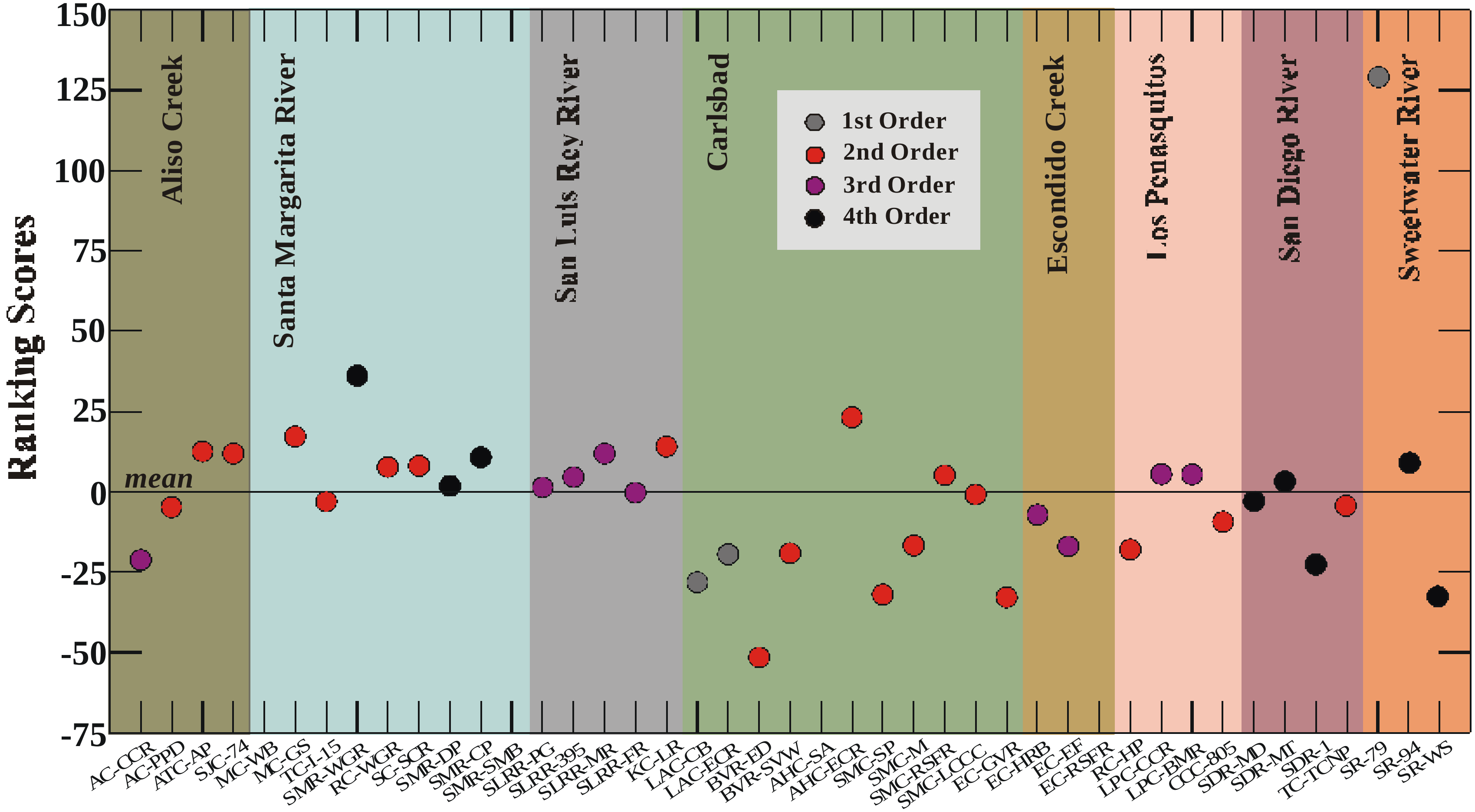

Figure 3c. BMI ranking scores for macroinvertebrate monitoring sites sampled in November 98 for the San Diego Regional Bioassessment Monitoring Project.

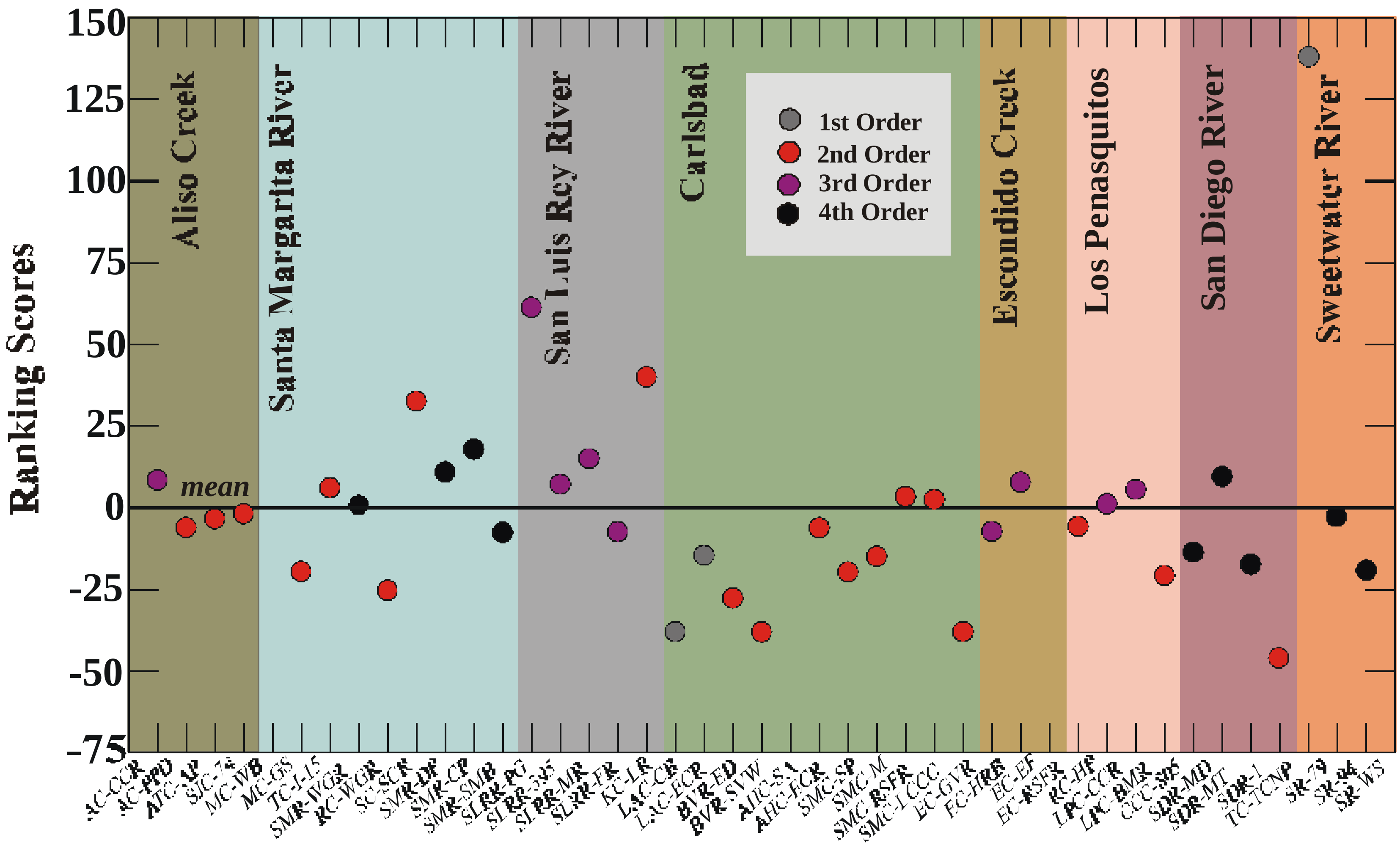

Figure 3d. BMI ranking scores for macroinvertebrate monitoring sites sampled in May 99 for the San Diego Regional Bioassessment Monitoring Project.

For the most part, relative rankings of sites were consistent across all sampling events. There were some patterns in relative ranking of the major watershed units, but there was little concentration of good and bad areas within the San Diego region. The best and worst sites were spread throughout the entire region and only two major watershed units ranked consistently higher or lower than the other watersheds. Most sites in the San Luis Rey River watershed and several in the Santa Margarita watershed ranked higher than other watersheds in the region. In contrast, almost all of the sites in the Carlsbad watershed unit, a grouping of several small watersheds, had well below average ranking scores.

A few sites stood out as particularly good or particularly bad. Sites SR-79 and SC-SCR always had much better metric scores than others and sites KC-LR and SMR-WGR usually had much better than average scores. The worst sites were not as consistent among sampling events. While site LAC-CB scored poorly in three of four sampling events (May 98, Nov 98 and May 99), SR-WS, EC-GVR, and BVR-ED only scored poorly in two sampling events. Several other sites (AC-PPD, AC-CCR, SMR-SMB, RC-WGR, MC-WB, AHC-SA, EC-HRB, SDR-1, SMC-SP, BVR-SVW and TC-TCNP) only scored poorly in one of the four sampling events.

Physical/ Habitat Score

There was no seasonal component to the relationship between ranking score and total physical habitat score, but there was a consistent positive relationship between these variables (Figure 7, Sept 98 and Nov 98 data).

Watershed Area/ Stream Order

Watershed area had very little influence on any of the biological metrics measured in this study (Figure 8, Sept 98 and Nov 98 data). In contrast, and although watershed area and stream order are correlated, some factors were affected by stream order (Figure 9, Sept 98 and Nov 98 data). Taxa richness did not vary with stream order, but EPT taxa increased in the first three stream orders and decreased in fourth order streams. Shannon Diversity was unrelated to stream order in the fall sampling event but was slightly related to stream order in the May samples, having lower values in fourth order streams than first through third order streams. The percentage of Chironomidae consistently decreased with increasing stream order. The Sensitive EPT and Percent Intolerant Organisms metrics did not have enough values greater than "0" to detect any pattern.

Seasonality of Metrics

Several bioassessment metrics were strongly affected by sampling season. In general, there were many fewer taxa and less diverse BMI communities collected in the May sampling events than the fall (Sept 98 and Nov 98) sampling events. This pattern was apparent in most of the metrics reviewed above. Of the six metrics selected for the ranking score calculation, all but one (Percent Intolerant Organisms) had a strong seasonal component to its values (Figure 6, Sept 98 and Nov 98 data). Several other metrics also had similar seasonal patterns, but were not as good at discriminating among sites (Percent Dipterans, Dipteran

Taxa, Percent Non-Insects, Non-Insect Taxa, Percent Predators, Abundance).

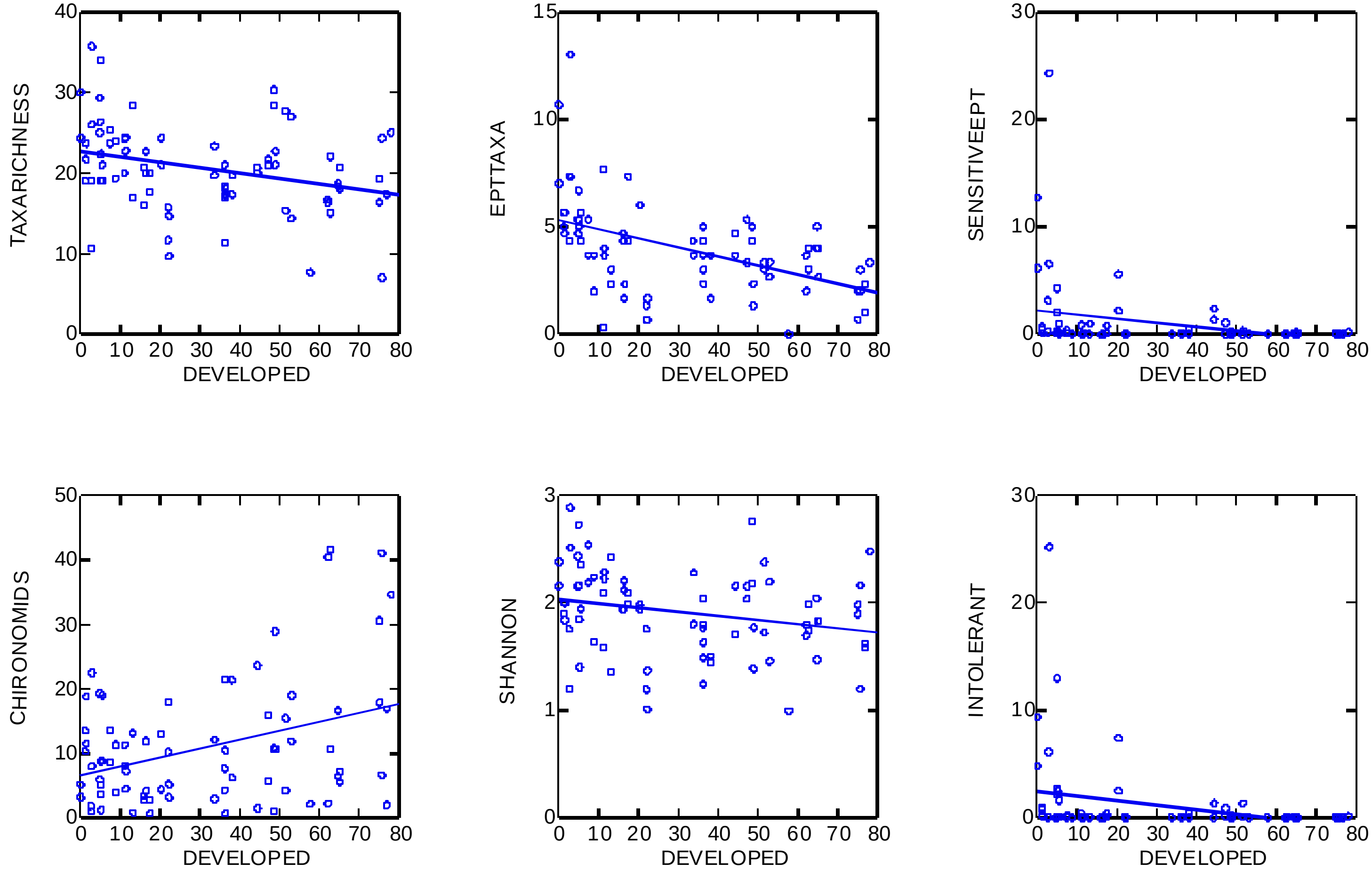

Figure 4. Relationship between major bioassessment metrics and the percentage of developed land in each watershed. Slopes of best fit lines do not imply statistical significance. See Appendix VII for explanation of axes.

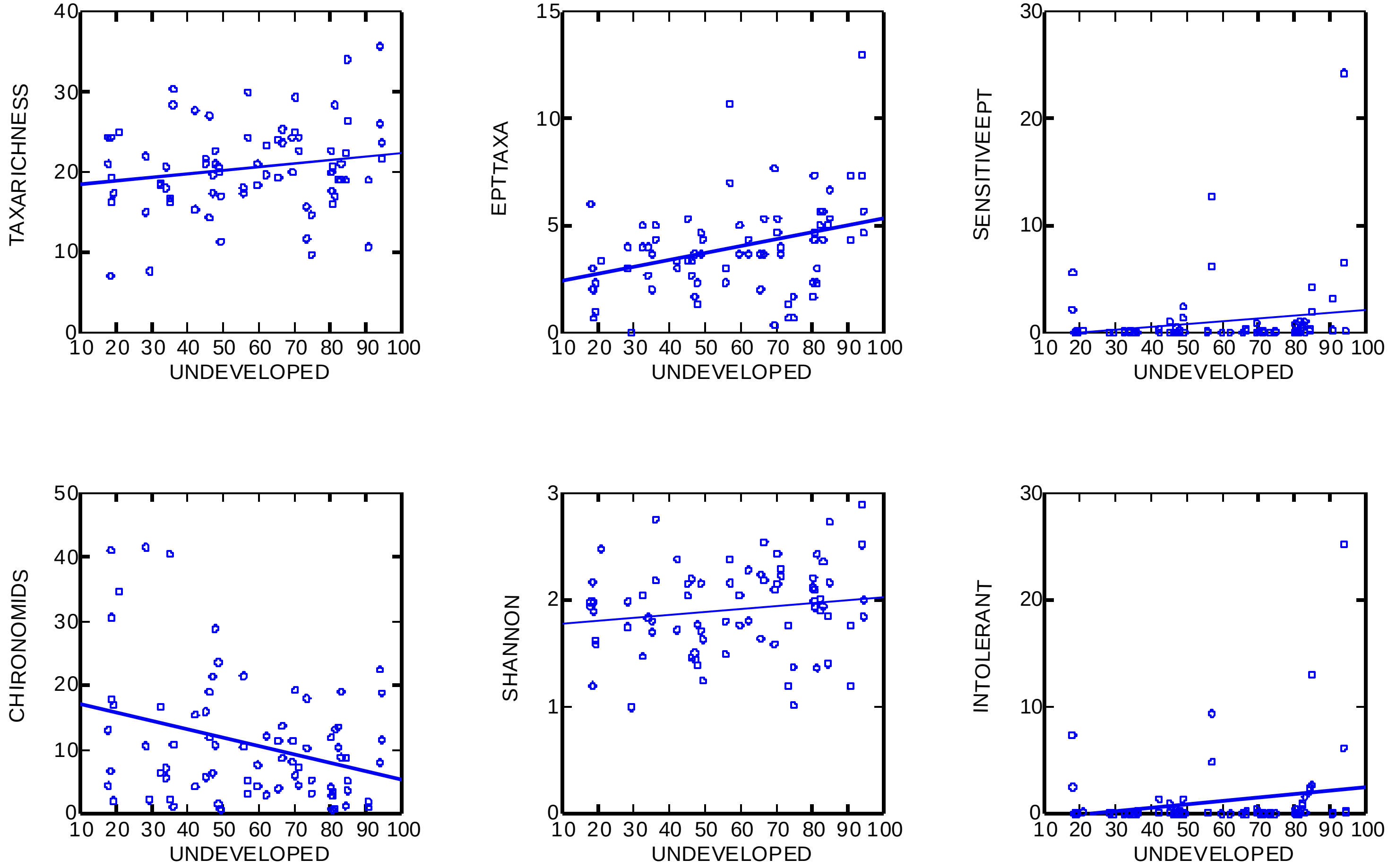

Figure 5. Relationship between major bioassessment metrics and the percentage of undeveloped land in each watershed. Slopes of best fit lines do not imply statistical significance. See Appendix VII for explanation of axes.

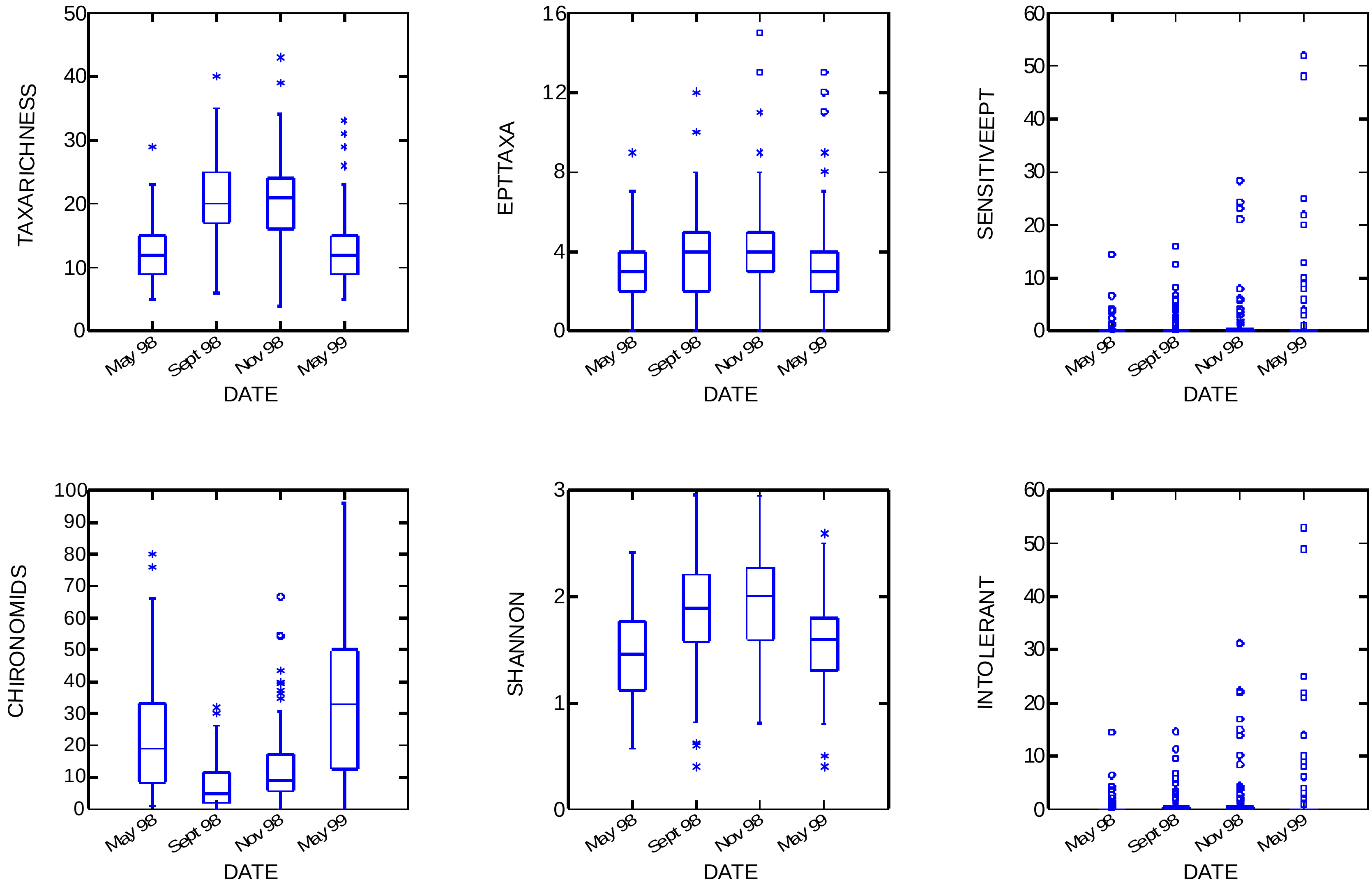

Figure 6. Boxplots describing the relationship between major bioassessment metrics and sampling date. See Appendix VII for an explanation of axes.

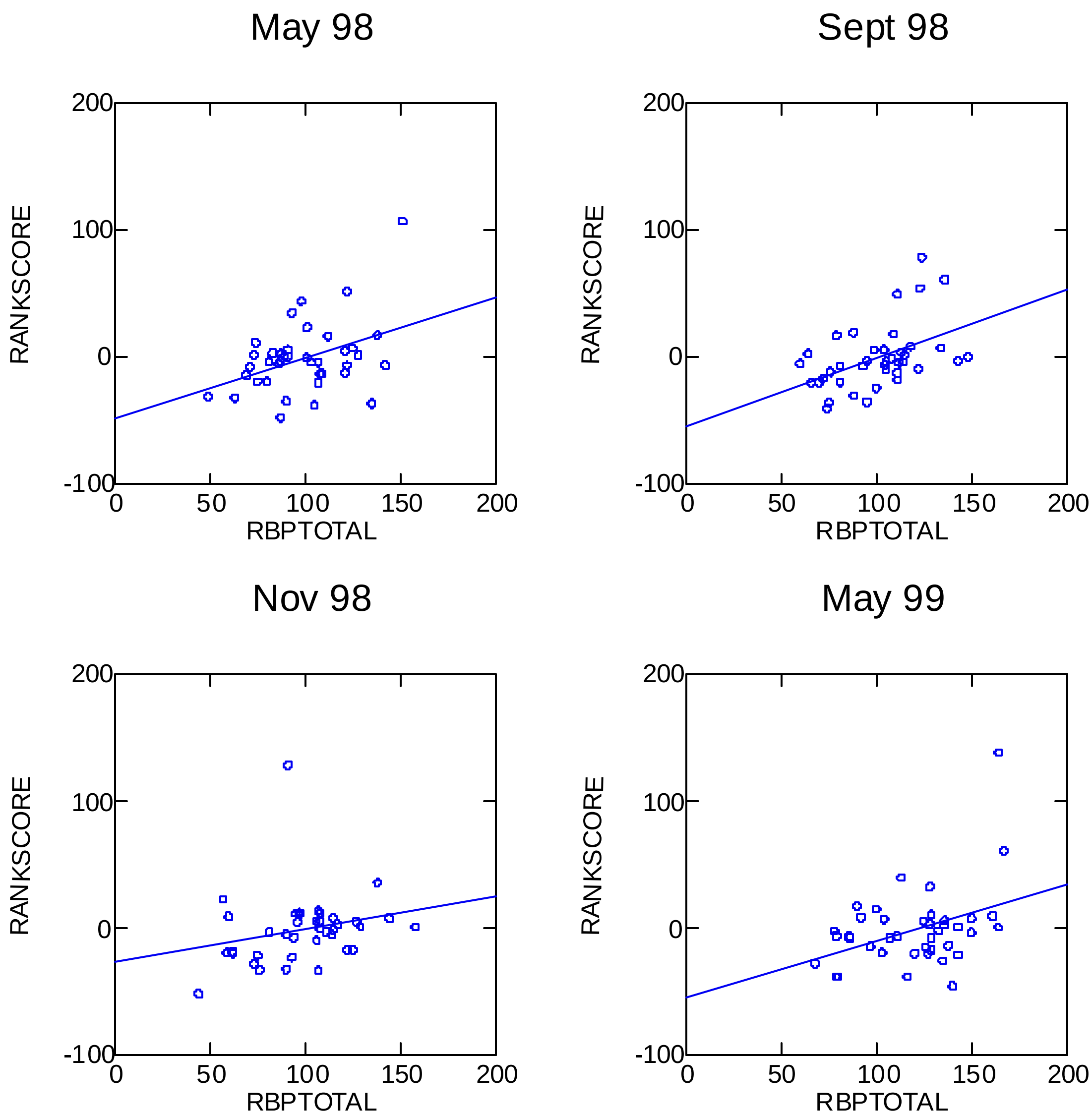

Figure 7. Relationship between physical/ habitat scores and the ranking scores of sites in the San Diego region. Slopes of best fit lines do not imply statistical significance. See Appendix VII for explanation of axes.

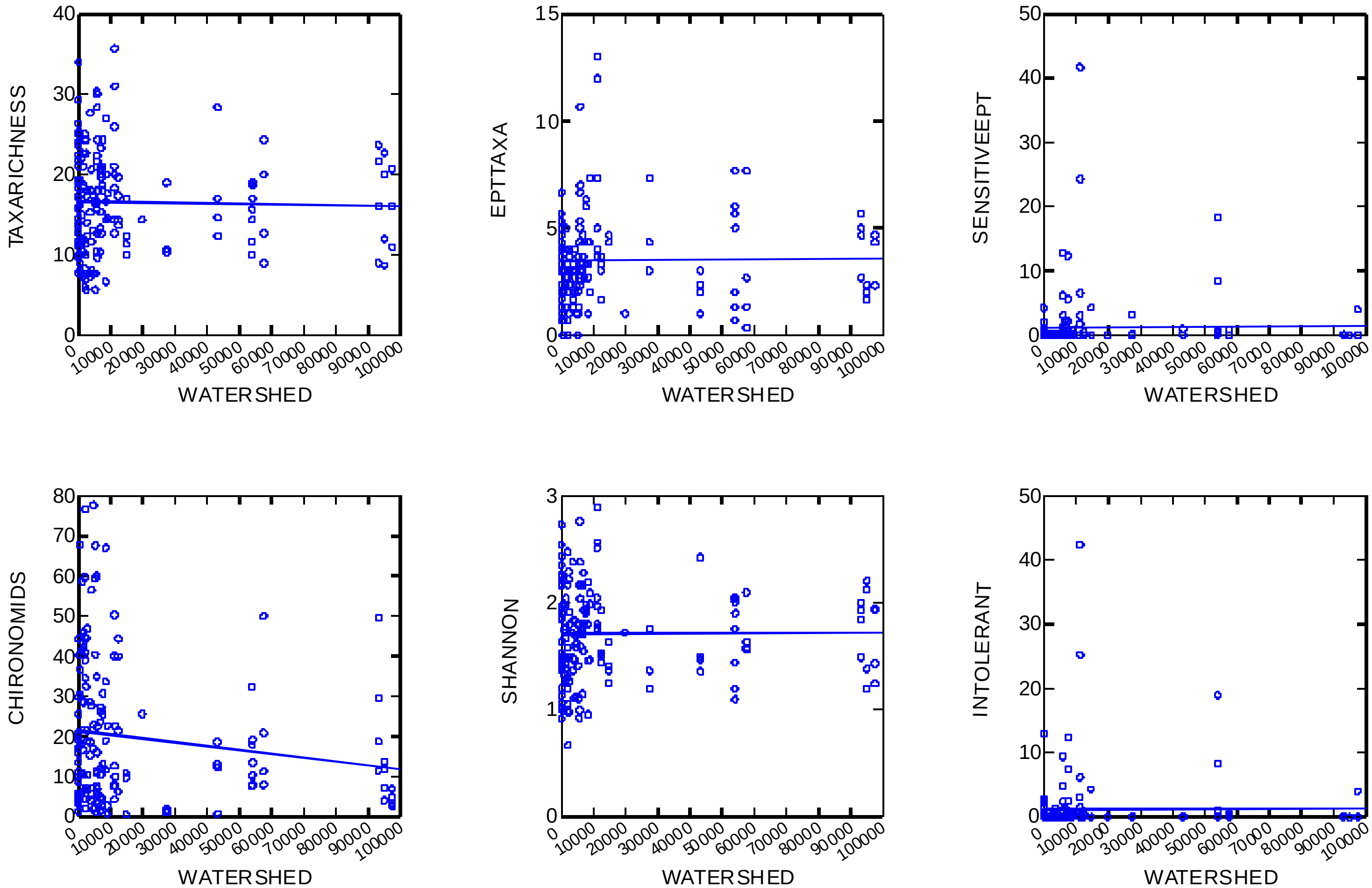

Figure 8. Relationship between major bioassessment metrics and the area encompassed by each watershed. Watershed areas are expressed in square coverage units x 10^4. See Appendix VII for explanation of axes.

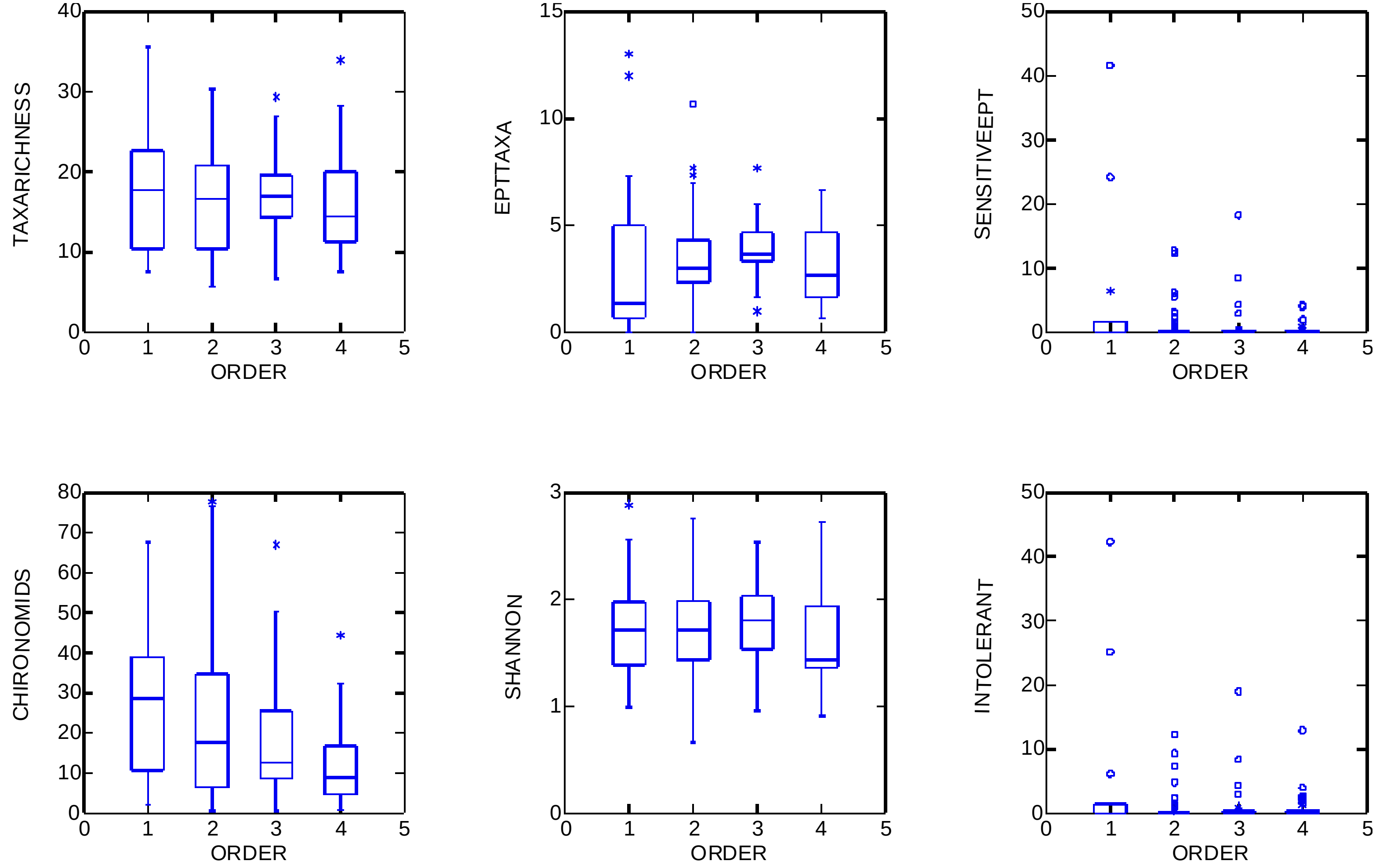

Figure 9. Relationship between major bioassessment metrics and the stream order at each site. See Appendix VII for explanation of axes.

DISCUSSION

The primary objectives of this project were to introduce biological information to the San Diego RWQCB's ambient monitoring program and to provide baseline data on the BMI community in regional streams. Other project objectives described in this report were derived from the EPA's conceptual model for biocriteria development (Gibson 1996). These objectives were to:

1) classify similar streams and stream reaches within San Diego region watersheds, including possible reference sites,

2) determine the best time of year or index period for continued sampling of BMIs in watersheds of the San Diego region, and

3) determine the most appropriate set of biological metrics to use for describing BMI communities in watersheds of the San Diego region.

Ultimately, these objectives will lead to the production of workable IBI using a modified approach outlined by the EPA (Barbour et al. 1999) and Karr and Chu (1999). A regional IBI has been developed successfully for another region of California following this approach (Harrington 1998). The IBI is the end point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon 1995).

Site Classification and Selection of Reference Sites

The biological metric values calculated for the sites monitored during this project were not notably different for first to fourth order streams. This suggests that a single biological standard or IBI could be used for the all streams in watersheds of the San Diego region. This observation should be verified with further sampling in sections of small and large streams.

On the basis of this initial survey, the San Luis Rey River watershed and parts of the Santa Margarita River and Sweetwater River watersheds are good candidates to provide reference conditions for this region. However, more work needs to be done to survey additional parts of the region for additional reference sites, particularly in the upper regions of watersheds like the Santa Margarita, San Luis Rey and Sweetwater Rivers, as well as other watersheds such as the San Dieguito River, the Otay River and the Tijuana River, which were not sampled in this study. The U.S. EPA's Western Environmental Monitoring and Assessment Project (EMAP) is currently underway and includes many additional sites within the region covered by the San Diego RWQCB. Bioassessment projects managed by the City of San Diego should also be included in future coordination efforts.

Index Period

There was a strong seasonal component to the average metric values at each site, especially for the measures of taxonomic richness. There was no corresponding seasonal component to the physical/ habitat scores. There was no discernable seasonal component to the relative ranking scores of most sites, indicating that biomonitoring projects could be performed at either time of year and be expected to produce reasonably similar results. However, there should be different expectations for biological indices of BMI community structure in the spring and fall.

Interestingly, organism abundance, which is generally considered to be a poor metric of biological condition, was strongly affected by season, as average abundance estimates in the May samples were several times higher than in the fall samples. However, abundance was unrelated to other measures of biological condition.

Selection of Biological Metrics

In this study we used the proportion of developed/ undeveloped land as an index of human activity in each watershed. This variable is roughly equivalent to the Percent Impervious Surface used successfully by Karr and Chu (1999) to select suitable biological metrics for developing an Index of Biotic Integrity (IBI). The following six biological metrics were selected on the basis of the strongest correlation with an independent measure of human disturbance (percent developed area):
general taxonomic richness, EPT taxonomic richness, Shannon Diversity Index, Percent Chironomidae, percent Sensitive EPT and Percent Intolerant Organisms. Although the six metrics used to establish the ranking scores described in this report provided the best available measures of biological integrity, many of these metrics were extremely variable (Figures 4 and 5) and should be further tested when more data are available from a more complete range of reference sites.

RECOMMENDATIONS

1. We recommend the use of two index periods (Spring and Fall) to measure the biological condition of water bodies in the San Diego region. There is a strong seasonal component to average metric values that strongly affects the expected values of several of the metrics of the most value to a regional index. Biological data obtained from one season should not be applied to the other.

2. On the basis of this initial survey, the San Luis Rey River watershed and parts of the Santa Margarita River and Sweetwater River watersheds are good candidates to provide reference conditions for this region.

3. We recommend the addition of more reference sites for the region, especially in the upper watersheds and in some of the watersheds that were not sampled or sampled minimally in this study. Selection of additional sites should be coordinated with other efforts in the region currently being conducted by the US EPA and City of San Diego.

4. On a preliminary basis, we recommend the use of six bioassessment metrics as the best discriminators of water quality in the San Diego region: Taxa Richness, EPT Taxa Richness, Shannon Diversity, Percent Chironomidae, and Percent Intolerant Organisms. We recommend further testing of additional metrics upon the addition of future datasets to improve the effectiveness of regional bioassessments.

5. The ranking scores described in this report are based on a multimetric approach to bioassessment. We

recommend the development of a multivariate IBI to be used to complement the strengths of the multimetric approach.

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