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SURFACE WATER AMBIENT MONITORING PROGRAM (SWAMP) SYNTHESIS REPORT ON STREAM ASSESSMENTS IN THE SAN DIEGO REGION

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1. ABSTRACT

Watershed managers require regional data to develop biomonitoring tools and contextualize local assessments. However, they often rely on data generated by programs with a more local emphasis, such as studies mandated by pollution discharge permits. These programs typically study only specific sites or stream reaches, The goal of this study was to compile individual data sets from site-specific programs to see if they could be merged into a regional-scale program. We evaluated if the merged data could be used to a) perform a regional assessment of streams in southern California, and b) identify potential stressors to aquatic life in these streams. Water quality, toxicity, physical habitat, and benthic macroinvertebrate samples were collected from over 100 sites in coastal watersheds in San Diego, Riverside, and Orange counties by six different programs. The data indicated widespread impacts to many water chemistry constituents, with some, like ammonia-N and specific conductivity, exceeded aquatic life thresholds in more than 60% of samples. More than 50% of water and sediment samples were toxic to at least one indicator species (*Ceriodaphnia dubia, Hyallela azteca* or *Selenastrum capricornutum*). Of the 708 bioassessment samples included in the study, 80% were in poor condition (i.e., index of biotic integrity < 40). Impacts for all indicators were most severe in urban areas along the coast. Nonmetric multidimensional scaling of benthic macroinvertebrate communities identified two stressor gradients: a strong gradient associated with toxic contaminants in the water (e.g., metals, high specific conductivity, and organics) and a weaker gradient related to eutrophication (e.g., dissolved oxygen and nitrate). The toxic contaminant gradient was strongly associated with development in the watershed, and watersheds with more than 10% developed area were invariably in poor biological health. In conclusion, combined data sets produced potentially biased regional assessments because of their sampling designs, which emphasized evaluations of known impacts. In contrast, such data are more useful for stressor identification, as they effectively capture important gradients in the region. Integration of local programs may prove useful if they are designed in coordination to meet regional as well as local goals.

2. INTRODUCTION

With few exceptions (e.g., EPA 2006), stream monitoring has been applied in largely piecemeal fashion around the country in response to regulatory-based requirements. Southern California serves as a good example. Collectively, more than 12 agencies collect over 300 samples in the 18 major coastal watersheds in just the 6 from San Diego to Ventura. For the most part, these programs employ independent, site-specific monitoring designs that target specific discharge locations (SMC 2007).

Despite the lack of programs that focus beyond specific sites or watersheds, there is a tremendous need for regional scale evaluations of stream health. The first need for regional stream monitoring is to address questions posed by the public that tend to focus on streams as a whole as opposed to just the reaches where there are potential sources of impacts. The second need for regional stream monitoring is to develop assessment tools that watershed managers need for evaluating potential impacts. One such tool is stressor-response relationships (Van Sickle et al. 2006). Regional scale programs are one way to collect the information necessary for developing stressor-response relationships because they not only capture the full breadth of natural variation, but a wide range of anthropogenically induced impacts. It is this range of stressor impact that is important for anchoring the spectrum of stream responses. The third need for regional stream monitoring is to help set management priorities, which is especially important in these times of limited resources. Regional monitoring programs provide the context of the worst and best streams that allow managers to effectively target the locations of greatest need.

One mechanism to achieve regional scale assessments is to link multiple local- or watershed-scale programs. However, there are many challenges associated with this approach. Individual programs may not measure similar indicators or, if they do, they may not measure the indicators using similar methods. Different programs may also have differing levels of quality assurance. The result is to force all of the data to the lowest level of QA common among them, which may be insufficient for management-level assessments. Finally, even if indicators, methods, and quality assurance were similar, data management can present an enormous hurdle. Undoubtedly, each monitoring program stores its data in different ways, from simple to sophisticated, making the collation of data an unusually burdensome (if not impossible) task.

The goal of this study was to determine if multiple, local scale data sets could be combined to make regional scale assessments. In this case study, we selected data sets collected by the State of California and by numerous dischargers regulated by the National Pollutant Discharge Elimination System (NPDES) permits in the San Diego region to answer two questions of regional importance:

1) What is the health of streams in the San Diego region?
2) What are the primary stressors responsible for biological responses in the San Diego Region?

The challenge was to combine data collected over 11 different hydrologic units and a time period of 9 years. None of the data was collected in concert, none of the designs was integrated, and none of the data systems were connected in any way. Thus, this study was an evaluation of the ability of such programs to address regional needs

3. METHODS

Setting

The San Diego region includes all coastal watersheds north of the Mexican border and south of the Santa Ana River. Covering portions of Orange, Riverside, and San Diego Counties, the region encompasses nearly 4,000 mi^2 and ranges from the mountains of the Peninsular Range mountains to the Pacific Coast.

Southern California is characterized by an arid mediterranean climate, with hot dry summers and cool wet winters. Average monthly rainfalls measured at the Lindberg Airport (SDG) in San Diego, California between 1905 and 2006 show that nearly all rain fell between the months of October and April, with hardly any falling between the months of May and September (California Department of Water Resources 2007). The wettest month was January, with an average rainfall of 2.05"). Average annual rainfall at this station was 10.37".

The San Diego Region consists of several coastal rivers and streams that are grouped into 11 hydrologic units (Figure 1, Table 1). The Tijuana River is the largest in the region. Other large rivers include the Santa Margarita, San Luis Rey, San Dieguito, San Diego, Sweetwater, and Otay Rivers (Figure 1). The watersheds extend from the Lagunas, the Cuyamacas, and other mountains of the Peninsular Range. Most of the larger rivers are regulated by large dams. The streams of the San Diego Region have profound effects on coastal ecology and the Southern California Bight (Ackerman and Schiff 2003). Discharging over 300 million m^3 annually in typical years, the rivers are an important source of freshwater for San Diego and Mission Bay, as well as several estuaries and coastal wetlands.

Urban development extends along almost the entire coastal strip of the region (23% of the region), although large undeveloped areas remain in coastal northern San Diego County in Camp Pendleton Marine Corps Base. Many smaller coastal watersheds are entirely urbanized. Agricultural land use occurs in 9% of the region, and is most extensive in the San Luis Rey and San Dieguito watersheds. Open space predominates in the interior, as well as in the aforementioned Camp Pendleton, covering 68% of the region (SANDAG 1998). The extent of undeveloped open space varies among each watershed, from a low of 12% in Pueblo San Diego to a high of 92% in San Juan (Table 1).

Table 1. Watersheds in the San Diego region. Land uses are calculated from data provided by SANDAG (1998)

Watersheds	Abbreviation	HUC	Area (mi^2)	% Open	% Developed	% Agricultural
San Juan	SJ	901	496	92	7	1
Santa Margarita	SM	902	750	81	13	6
San Luis Rey	SLR	903	560	61	15	24
Carlsbad	CB	904	211	38	50	12
San Dieguito	STO	905	346	18	61	21
Los Peñasquitos	LP	906	162	43	53	4
San Diego	SD	907	440	72	26	2
Pueblo San Diego	PSD	908	56	12	88	0
Sweetwater	SW	909	230	67	29	4
Otay	OT	910	154	70	20	10
Tijuana	TJ	911	463	90	6	4
TOTAL			3868	68	23	9

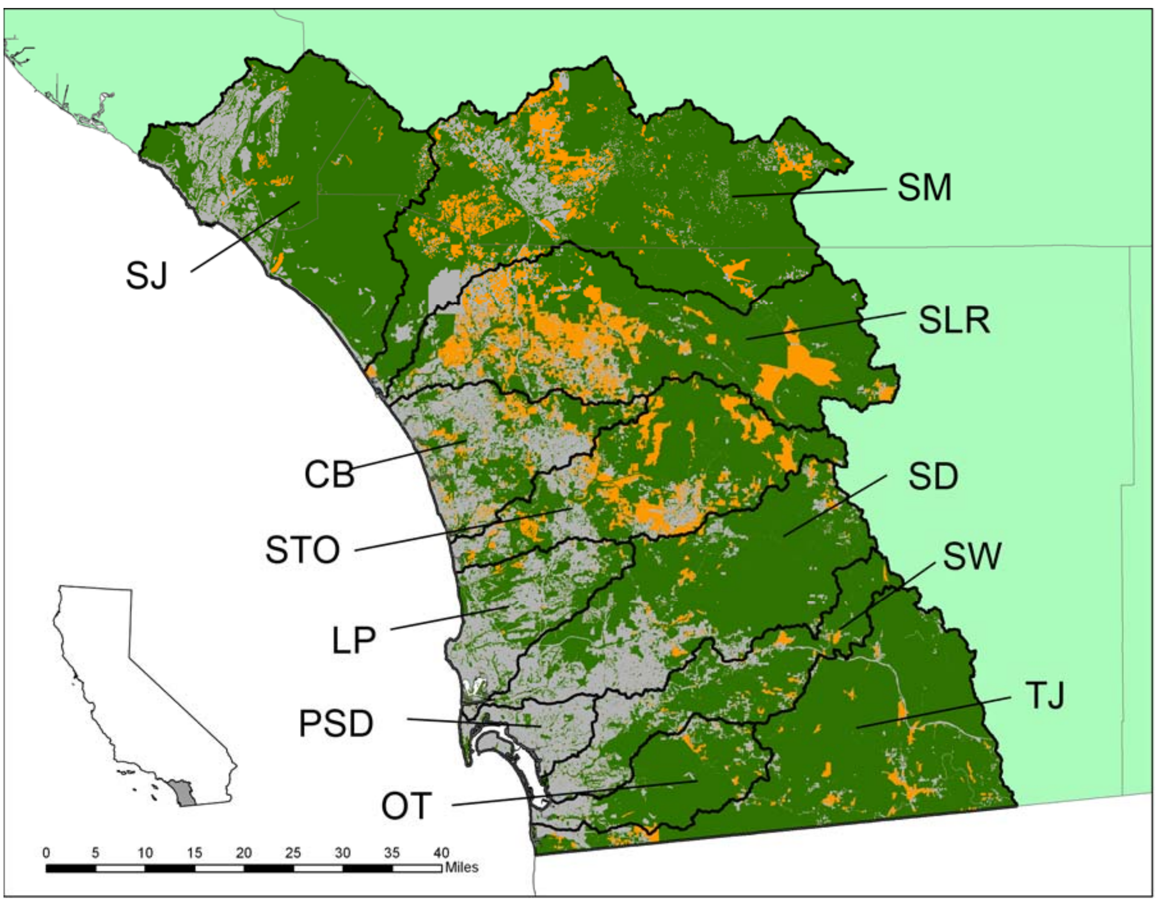

Figure 1. Hydrologic units and land use within the San Diego region. Abbreviations are given in Table 1. Dark green is undeveloped open space. Orange is agricultural land. Gray is developed land. Inset shows location of the San Diego region within California.

Sources of data

This report combines data collected by the State of California's Surface Water Ambient Monitoring Program (SWAMP) with data from California Department of Fish and Game (CDFG), and NPDES monitoring by San Diego and Orange Counties, Camp Pendleton Marine Corps Base, and the Padre Dam Municipal Water District (Table 2). All these assessment programs used a targeted design to select sites of interest for sampling. Most sites were selected in order to assess known disturbances in the watershed, although a few undisturbed sites were targeted to set reference expectations for specific studies. A total of 62 sites were sampled under SWAMP for water chemistry and toxicity. Physical habitat was assessed at all but nine of these sites. Bioassessment samples were collected at 144 sites, of which 35 were located at or within 500 m of sites with water chemistry and toxicity data (Figure 2). All four indicators were measured at 29 sites.

Table 2. Summary of data sources used in this analysis. Additional data from each of these programs was analyzed in watershed-specific reports.

Program	Years	Watersheds	Indicator	Sites	Samples
SWAMP	2000-2006	11	Bioassessment	71	17
			Water chemistry	62	233
			Toxicity	62	235
			Physical habitat	53	53
California Dept. of Fish and Game	1998-2005	11	Bioassessment	98	408
San Diego County NPDES	2002-2005	9	Bioassessment	45	169
Orange County NPDES	2002-2005	1	Bioassessment	18	87
Camp Pendleton	2004-2006	1	Bioassessment	7	14
Padre Dam MWD	2004-2006	1	Bioassessment	2	10
All programs	1998-2006	11	Bioassessment	144	708
			Water chemistry	62	233
			Toxicity	62	235
			Physical habitat	53	53

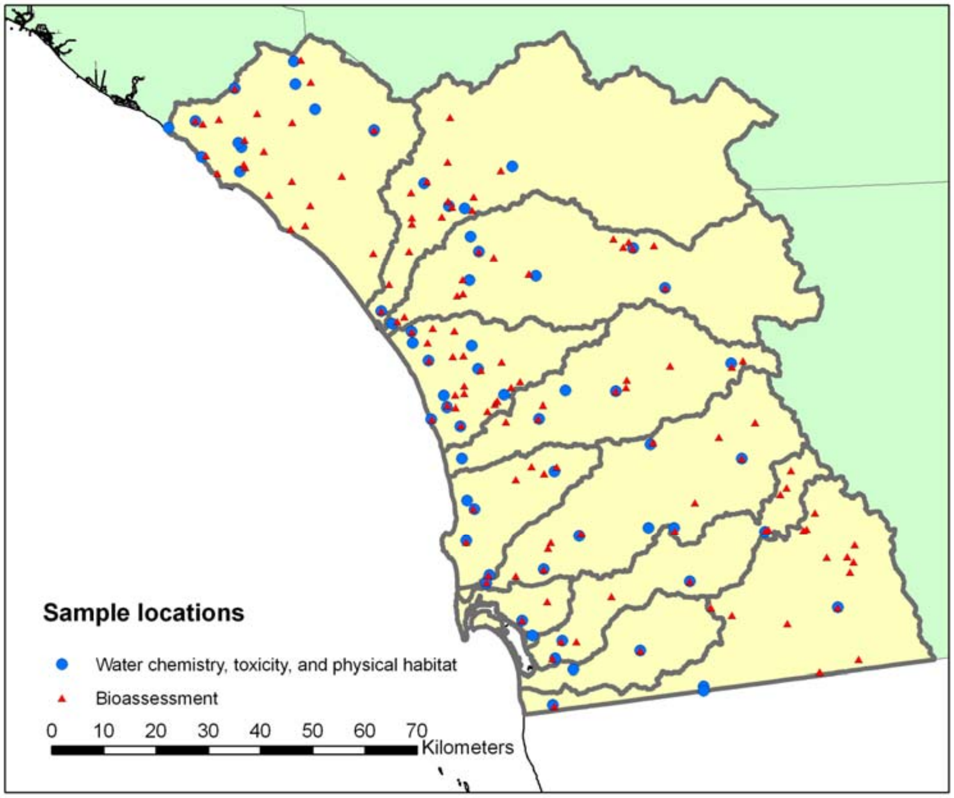

Figure 2. Locations of sampling sites. Blue circles are sites sampled under SWAMP for water chemistry, toxicity, and physical habitat. Red triangles are sites sampled for bioassessment.

To aggregate data collected under multiple programs, sites within 500 m of each other were treated as a single site. This distance was based on published measures of spatial correlation of benthic communities in streams (Gebler 2004). Although data used in this assessment cover many years (1998-2006), there was little indication that conditions had changed over the course of this study apart from a few sites in the upper Sweetwater watershed, which were affected by the 2003 Cedar Fires (see reports on specific watersheds for details about specific sites).

Indicators

Multiple indicators were used to assess the sites in the San Diego region. Water chemistry, water and sediment toxicity, benthic macroinvertebrate communities, and physical habitat.

Water chemistry was measured as per the SWAMP Quality Assurance Management Plan (QAMP) (Puckett 2002). Measured indicators included physical measures of water quality (e.g., pH, temperature dissolved oxygen, etc.), inorganics, pesticides, polycyclic aromatic hydrocarbons (PAHs), dissolved metals, pesticides, and polychlorinated biphenyls (PCBs). The Appendix contains a complete list of water chemistry constituents.

To evaluate water and sediment toxicity to aquatic life, toxicity assays were conducted on samples from each site as per the SWAMP QAMP (EPA 1993, Puckett 2002). Water toxicity was evaluated with 7-day exposures on the water flea, *Ceriodaphnia dubia*, and 96-hour exposures to the alga *Selenastrum capricornutum.* Both acute and chronic toxicity to *C. dubia* was measured as decreased survival and fecundity (i.e., eggs per female) relative to controls, respectively. Chronic toxicity to *S. capricornutum* was measured as changes in total cell count relative to controls. Sediment toxicity was evaluated with 10-day exposures on the amphipod *Hyallela azteca.* Both acute and chronic toxicity to *H. azteca* was measured as decreased survival and growth (mg per individual) relative to controls, respectively. Chronic toxicity endpoints (i.e., *C. dubia* fecundity, *H. azteca* growth, and *S. capricornutum* total cell count) were used to develop a summary index of toxicity at each site.

Physical habitat was assessed using semi-quantitative observations of 10 components relating to habitat quality, such as embeddedness, bank stability, and width of riparian zone. The assessment protocols are described in The California Stream Bioassessment Procedure (California Department of Fish and Game 2003). Each component was scored on a scale of 0 (highly degraded) to 20 (not degraded). 53 sites were assessed, although data were incomplete at 26 sites. Sites were assessed by the average component score.

To assess the ecological health of the streams in the San Diego region, 708 benthic macroinvertebrate samples were collected at 144 sites. Samples were collected using SWAMP-comparable protocols, as per the SWAMP QAMP (Puckett 2002). Three replicate samples were collected from riffles at each site; at least 300 individuals were sorted and identified from each replicate, creating a total count of over 900 individuals per site. Using a Monte Carlo simulation, all samples were reduced to 500 count for calculation of the Southern California Index of Biotic Integrity (IBI; Ode et al. 2005), a composite of seven metrics summed and scaled from 0 (poor condition) to 100 (good condition).

A GIS analysis was used to calculate simple landscape metrics for each site. Land use data came from the San Diego Association of Governments, and the Tijuana River Watershed GIS Database (SANDAG 1998, CESAR 2000). Both data sources use compatible procedures for identifying and naming land uses. Land use categories were aggregated into three classes: open space, developed land, and agricultural land. Metrics were calculated for the entire contributing watershed, as well as at a local scale (i.e., within 500 m of the sampling site).

Data Analysis

Water quality was assessed by comparing water chemistry constituents to known thresholds, when possible (SDRWQCB 1994, EPA 1997, CCR 2007).

Watersheds were compared by plotting distributions of concentrations of selected constituents. Toxicity was assessed by plotting frequency of samples with endpoints significantly different from controls for each indicator species. Bioassessment samples were assessed by calculating the Southern and Central California Index of Biotic Integrity (IBI, Ode et al. 2005), and comparing samples to a threshold of 40 (i.e., poor or very poor condition versus fair or better condition).

To assess the influence of water chemistry, toxicity, physical habitat, and land use on benthic communities, nonmetric multidimensional scaling (NMS) was used to ordinate bioassessment samples. Because of the lack of synoptic data for many sites, 500-count subsamples were averaged to produce mean abundances for each site. Number of samples per site ranged from 1 to 13. NMS was run with the following parameters: 1000 runs with real data, 100 runs with randomized data, 4 maximum number of axes, 250 maximum number of iterations, 0.2 step length, 0.000001 stability criterion. NMS was run in PC-ORD v 5.12 (McCune and Mefford 2006).

To assess the influence of environmental variables on biotic structure, water chemistry, toxicity, physical habitat, and landscape variables were correlated with NMS axis scores using Spearman's rank correlation (ρ). In addition, these variables were correlated to IBI scores to determine their relationship with biological condition. Correlation strength (based on ρ^2) rather than statistical significance was used to identify strong relationships, as the high number of tests may yield spurious significance and low power.

The SWAMP QAMP guided QA/QC for all data collected under SWAMP (See SWAMP QAMP for detailed descriptions of QA/QC protocols, Puckett 2002). QA/QC officers flagged non-compliant physical habitat, water chemistry, toxicity, and tissue results. No data were excluded as a result of QA/QC violations.

4. RESULTS

Assessment of the watersheds

Many sites showed signs of degraded water chemistry. For example, most sites had elevated nutrients, metals, and other constituents. Several of these constituents occurred in concentrations known to harm aquatic life. For example, more than 60% of samples exceeded applicable aquatic life thresholds of 0.025 mg/L of ammonia-N. Exceedances for specific conductivity, sulfate, selenium, and total phosphorus were nearly as frequent. Some anthropogenic organic constituents, such as diazinon, lack thresholds but were detected at many sites (Figure 3). Table 3 shows selected water chemistry constituents in each watershed. The full list of constituents is included in the appendix.

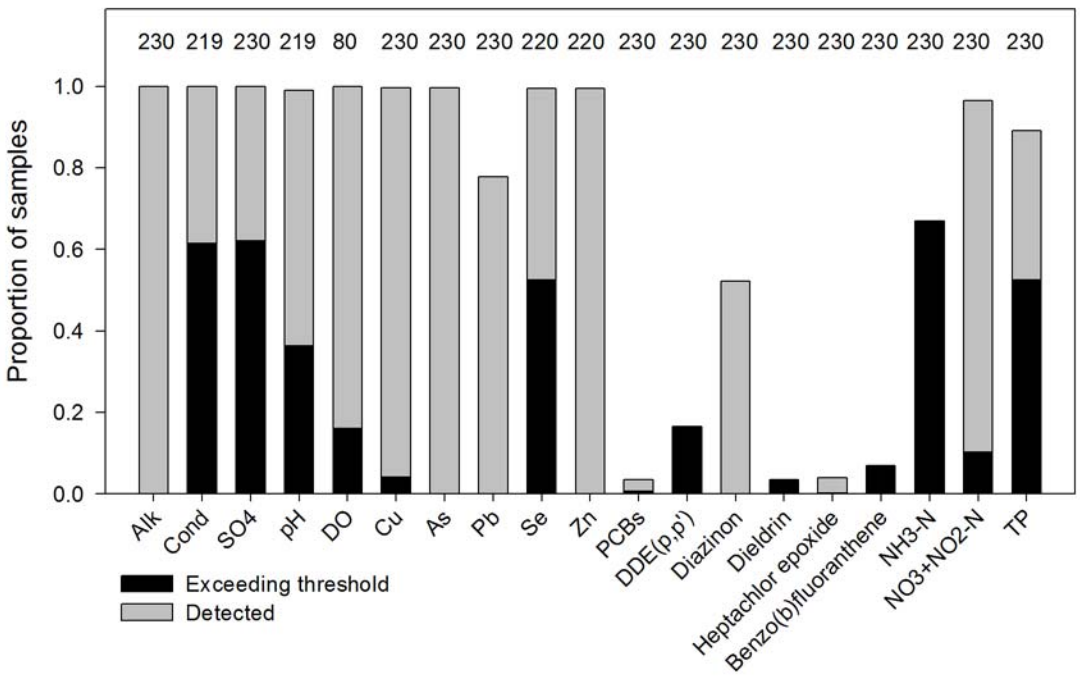

Figure 3. Proportion of samples detected (gray bars) and exceeding thresholds (black bars) for selected water chemistry constituents. Numbers above bars are numbers of samples. Abbreviations for constituents are in Table 3. Thresholds used for each constituent are shown in Table 3.

Concentrations of many constituents were high in most watersheds, although come values were extreme in sites from the Tijuana watershed that receive surface flows from Mexico (e.g., ammonia-N and phosphorus, Figure 4). Although elevated values were found throughout the region, some samples from the Tijuana River were 1 – 2 orders of magnitude more concentrated than other samples. Samples with elevated concentrations of many constituents were also found in the San Juan, Carlsbad, and Los Peñasquitos watersheds (Table 3, Appendix).

Table 3. Selected water chemistry constituents. SD = Standard deviation. n = number of samples. * = Thresholds may not apply to all samples.

					SJ			SM			SLR			CB			STO			LP		
Constituent	Symbol	Threshold	Units	Source	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Physical water quality																						
Alkalinity as CaCO3	Alk	20000	mg/l	EPA 2002	208	109	39	187	49	21	198	84	25	252	43	41	243	129	18	221	88	20
Oxygen, Dissolved	DO	6	mg/L	SDRWQCB 1994			0			0	9.4	3.6	24			0			0			0
pH		6 or 8	pH	SDRWQCB 1994	7.6	1.5	38	7.4	0.8	20	7.7	0.4	24	7.9	1.5	40	8.0	0.4	17	7.9	0.4	19
Salinity	Sal	None	ppt		1.05	1.77	32	2.62	6.16	20	0.83	0.52	24			0	2.53	5.47	17			0
Specific conductivity	Cond	1600	µS/cm	CCR 2007	2032	2839	38	4399	9779	20	1516	968	24	3800	4232	40	4316	8781	17	2981	1256	19
Sulfate	SO_4	250*	mg/l	SDRWQCB 1994	497	491	39	352	398	21	382	264	25	469	277	41	358	367	18	674	407	20
Nutrients																						
Ammonia as N	NH_3-N	0.025	mg/l	SDRWQCB 1994	0.19	0.52	39	0.02	0.05	21	0.05	0.06	25	0.12	0.11	41	0.10	0.12	18	0.09	0.06	20
Nitrate as NO3	NO_3	None	mg/l		1.79	2.20	39	22.48	19.92	20			0	16.00		1	1.96	2.58	17	0		1
Total Phosphorus as P	TP	0.1	mg/l	SDRWQCB 1994	0.22	0.27	39	0.21	0.22	21	0.21	0.24	25	0.14	0.09	41	0.24	0.35	18	0.10	0.16	20
Metals																						
Arsenic	As	50	µg/L	SDRWQCB 1994	3.4	2.5	39	2.5	3.9	21	1.3	0.9	25	4.7	2.6	41	2.1	1.7	18	3.4	0.8	20
Cadmium	Cd	5	µg/L	SDRWQCB 1994	0.26	0.34	39	0.04	0.03	21	0.03	0.02	25	0.05	0.04	41	0.03	0.03	18	0.02	0.01	20
Chromium	Cr	50	µg/L	SDRWQCB 1994	0.25	0.22	39	0.23	0.35	21	0.33	0.28	25	1.06	1.05	41	0.18	0.17	18	0.89	0.97	20
Copper	Cu	9	µg/L	EPA 1997	4.05	2.85	39	3.10	2.37	21	4.03	2.60	25	3.55	1.50	41	2.41	1.76	18	4.03	1.58	20
Lead	Pb	2.5	µg/L	EPA 1997	0.02	0.02	39	0.01	0.01	21	0.06	0.05	25	0.05	0.12	41	0.03	0.03	18	0.05	0.08	20
Manganese	Mn	5*	µg/L	EPA 2002	148	329	39	92	139	21	133	270	25	127	147	41	135	135	18	141	156	20
Nickel	Ni	52	µg/L	EPA 1997	5.55	6.76	39	0.71	1.22	21	0.97	2.14	25	2.16	1.37	41	0.70	0.79	18	3.38	3.55	20
Selenium	Se	5	µg/L	EPA 2002	7.5	10.4	38	5.9	16.8	20	4.9	4.8	24	10.6	10.1	40	3.7	5.4	17	7.8	3.7	19
Silver	Ag	3.4	µg/L	EPA 1997	0.20	1.22	39	0.09	0.29	21	0.07	0.34	25	0.05	0.28	41	0.00	0.00	18	0.06	0.25	20
Zinc	Zi	120	µg/L	EPA 2002	4.1	3.1	38	2.3	1.5	20	2.7	1.9	24	6.5	6.4	40	2.2	1.7	17	8.4	8.7	19
Organics																						
Benzo(b)fluoranthene		0.0044	ng/L	EPA 2002	3.5	9.6	39	1.0	3.2	21	0	0	25	0	0	41	3.0	5.9	18	0	0	20
PCBs		0.014	ng/L	EPA 2002	2.45	6.68	39	0	0	21	0	0	25	0	0	41	0	0	18	0	0	20
Diazinon		None	ng/L		43.97	103.77	38	7.78	18.10	20	0.67	2.43	24	68.39	101.40	40	12.64	14.90	17	50.81	51.65	19
DDE(p,p')		0.00059	ng/L	EPA 2002	0.29	0.66	39	0.90	2.64	21	0.04	0.20	25	1.37	2.24	41	0.17	0.51	18	5.30	12.71	20
DDTs		None	ng/L		0.58	1.28	39	1.48	3.89	21	0.04	0.20	25	1.93	2.79	41	0.28	0.96	18	5.65	12.75	20
Dieldrin		0.00014	ng/L	EPA 2002	0.15	0.42	39	0	0	21	0	0	25	0.02	0.16	41	0.11	0.32	18	0	0	20
Disulfoton		None	ng/L		3.95	10.28	38	0	0	20	0	0	24	33.33	38.29	40	0	0	17	52.92	64.68	19
Heptachlor epoxide		0.0038	ng/L	EPA 1997	0.21	0.70	39	0.10	0.30	21	0	0	25	0	0	41	0.11	0.32	18	0	0	20
Secbumeton		None	ng/L		3.11	13.48	38	1.75	7.83	20	4.50	12.50	24	85.00	153.57	40	0	0	17	131.16	147.98	19

Table 3, continued.

					SD			PSD			SW			OT			TJ		
Constituent	Symbol	Threshold	Units	Source	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Physical water quality																			
Alkalinity as CaCO3	Alk	20000	mg/l	EPA 2002	242	85	27	191	15	5	191	92	15	233	21	7	400	164	12
Oxygen, Dissolved	DO	6	mg/L	SDRWQCB 1994	9.5	3.0	26	113.3	198.9	4	9.2	2.0	14			0	8.3	4.3	12
pH		6 or 8	pH	SDRWQCB 1994	8.0	0.3	26	8.8	0.8	4	8.0	0.4	14	7.8	0.3	5	7.9	0.7	12
Salinity	Sal	None	ppt		1.00	0.45	26	4.19	5.66	4	1.85	1.57	14	1.30	0.85	5	0.76	0.46	12
Specific conductivity	Cond	1600	µS/cm	CCR 2007	1872	830	26	6925	9619	4	3930	3649	14	2478	1539	5	1482	887	12
Sulfate	SO_4	250*	mg/l	SDRWQCB 1994	283	159	27	437	394	5	276	190	15	217	40	7	201	133	12
Nutrients																			
Ammonia as N	NH_3-N	0.025	mg/l	SDRWQCB 1994	0.05	0.05	27	0.05	0.05	5	0.06	0.05	15	0.08	0.10	7	11.33	16.63	12
Nitrate as NO3	NO_3	None	mg/l				0	0		1			0	9.21	9.14	7			0
Total Phosphorus as P	TP	0.1	mg/l	SDRWQCB 1994	0.12	0.09	27	0.25	0.07	5	0.06	0.04	15	0.01	0.02	7	3.31	3.70	12
Metals																			
Arsenic	As	50	µg/L	SDRWQCB 1994	3.2	2.4	27	2.5	1.5	5	11.5	16.8	15	7.7	6.0	7	3.7	2.6	12
Cadmium	Cd	5	µg/L	SDRWQCB 1994	0.03	0.02	27	0.08	0.05	5	0.02	0.02	15	0.02	0.01	7	0.06	0.03	12
Chromium	Cr	50	µg/L	SDRWQCB 1994	0.64	0.74	27	1.22	0.79	5	0.96	1.06	15	0.37	0.30	7	2.67	2.94	12
Copper	Cu	9	µg/L	EPA 1997	4.16	2.06	27	8.23	3.94	5	4.25	3.05	15	2.91	1.16	7	5.14	6.25	12
Lead	Pb	2.5	µg/L	EPA 1997	0.09	0.08	27	0.51	0.28	5	0.07	0.13	15	0.02	0.02	7	0.25	0.27	12
Manganese	Mn	5*	µg/L	EPA 2002	60	116	27	61	67	5	54	71	15	41	67	7	238	228	12
Nickel	Ni	52	µg/L	EPA 1997	1.15	1.92	27	3.99	2.81	5	0.78	0.93	15	1.80	3.22	7	9.16	11.13	12
Selenium	Se	5	µg/L	EPA 2002	8.1	6.8	26	77.5	115.8	4	26.6	27.8	14	9.2	7.3	6	7.2	4.6	12
Silver	Ag	3.4	µg/L	EPA 1997	0.00	0.00	27	0.13	0.27	5	0.00	0.00	15	0.39	1.02	7	0.02	0.04	12
Zinc	Zi	120	µg/L	EPA 2002	3.9	2.3	26	13.6	4.1	4	2.9	2.0	14	2.0	0.8	6	4.5	6.6	12
Organics																			
Benzo(b)fluoranthene		0.0044	ng/L	EPA 2002	0.8	4.0	27	5.8	13.0	5	0	0	15	0	0	7	8.8	30.3	12
PCBs		0.014	ng/L	EPA 2002	0	0	27	0	0	5	0	0	15	0	0	7	0	0	12
Diazinon		None	ng/L		1.73	5.50	26	26.25	29.17	4	11.36	11.19	14	20.83	26.47	6	16.92	20.93	12
DDE(p,p')		0.00059	ng/L	EPA 2002	0	0	27	0	0	5	0	0	15	1.43	2.51	7	0	0	12
DDTs		None	ng/L		0	0	27	0	0	5	0	0	15	2.00	2.83	7	0	0	12
Dieldrin		0.00014	ng/L	EPA 2002	0	0	27	0	0	5	0	0	15	0	0	7	0	0	12
Disulfoton		None	ng/L		0	0	26	13.25	26.50	4	4.14	15.50	14	0	0	6	16.17	40.76	12
Heptachlor epoxide		0.0038	ng/L	EPA 1997	0	0	27	0	0	5	0	0	15	0	0	7	0	0	12
Secbumeton		None	ng/L		12.92	48.18	26			0			0	0	0	6			0

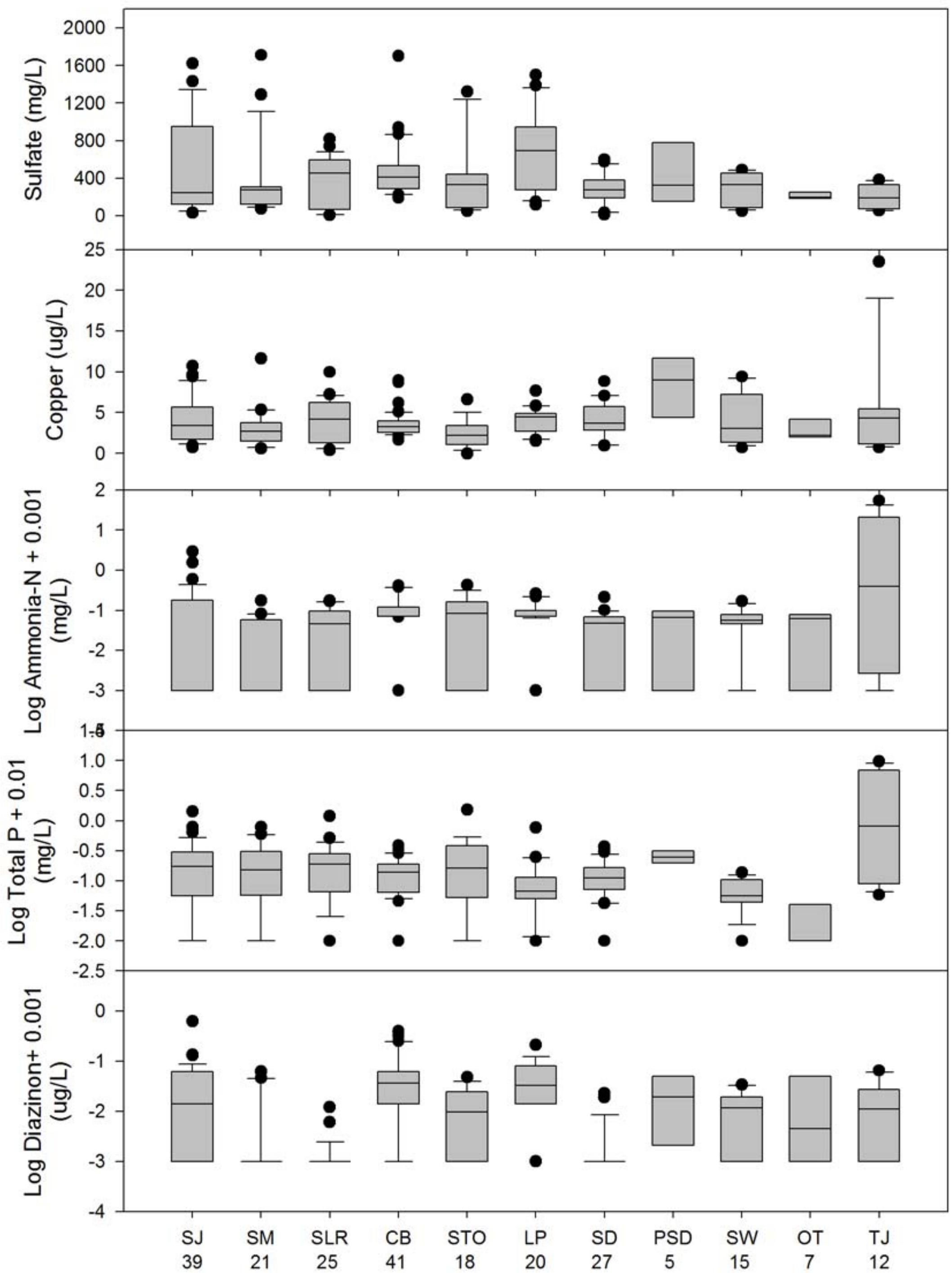

Figure 4. Concentrations of selected constituents in each sample by watershed. Box and whiskers represent 5th, 25th, 50th, 75th, and 95th percentiles. Dots represent values above the 95th or below the 5th percentile. Numbers below the X-axis represent the number of samples from that watershed for all constituents, except for diazinon (which had one less sample in each watershed).

Water and sediment toxicity was frequently observed throughout the region, although certain indicator species were more sensitive than others. For example, 59% of all water samples were toxic to the algae *S. capricornutum*. The two arthropod indicators were less sensitive, with the amphipod *H. azteca* suffering increased mortality when exposed to 27% of sediment samples, and the water flea *C. dubia* showing reduced fecundity when exposed to 34% of water samples (Figure 5).

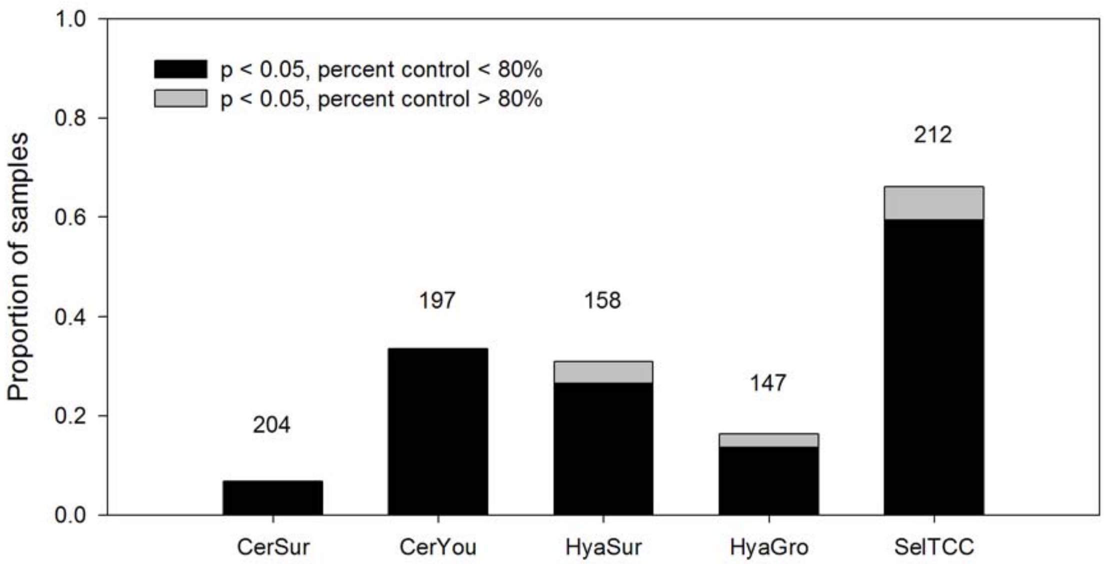

Figure 5. Frequency of toxicity for each endpoint and indicator species are shown in the black bars. Toxicity was determined if sample endpoints were less than 80% of controls, and the difference was significant at the 0.05 level. Weaker (but still significant) results are shown in the gray bars. Empty space above the bars indicate the proportion of samples not indicating toxicity. Numbers above bars indicate number of samples.

Toxicity was observed in every watershed. The frequency of toxicity to chronic endpoints (i.e., *C. dubia* young per female, *H. azteca* growth, and *S. capricornutum* total cell count) ranged from 24% of samples in the Carlsbad watershed to 90% of samples in the Tijuana watershed (Table 4).

Table 4. Mean percent control of each toxic indicator in each watershed. SD = standard deviation. n = number of samples. Freq = frequency of toxicity. -- = No toxicity detected.

	C. dubia								*H. azteca*								*S. capricornutum*				All	
	Survival				Young/female				Survival				Growth				Total cell count				Indicators	
Watershed	Mean	SD	Freq	n	Mean	SD	Freq	n	Mean	SD	Freq	n	Mean	SD	Freq	n	Mean	SD	Freq	n	Freq	n
SJ	89	27	0.11	35	92	26	0.35	34	153	193	0.29	25	80	34	0.12	28	64	35	0.64	39	0.32	161
SM	93	22	0.05	21	95	23	0.20	20	106	34	0.00	13	101	6	0.15	13	96	61	0.52	21	0.20	88
SLR	98	6	0.00	34	80	26	0.32	34	99	19	0.00	16	106	5	0.06	16	82	41	0.50	32	0.21	132
CB	96	34	0.10	39	87	43	0.44	36	121	62	0.45	40	68	34	0.13	40	70	30	0.55	40	0.33	195
STO	91	25	0.06	16	92	25	0.20	15	130	31	0.00	7	101	6	0.00	8	61	38	0.88	17	0.30	63
LP	95	34	0.16	19	104	56	0.33	18	129	79	0.38	16	82	22	0.25	16	56	27	0.84	19	0.40	88
SD	101	4	--	30	82	26	0.37	30	94	39	0.21	11	92	28	0.36	14	82	44	0.45	29	0.28	114
PSD	42	60	0.50	2	45	64	0.50	2	110	39	0.00	2	109	2	0.00	2	57	35	0.50	2	0.30	10
SW	108	4	--	2	123	17	--	2	86	15	0.14	5	102	14	0.20	7	121	100	0.50	4	0.21	20
OT	96	9	--	5	84	28	0.40	5	106	36	0.50	3	81	24	0.33	4	66	26	0.71	7	0.41	24
TJ	105		--	1	103		--	1	125	26	0.40	9	70	48	0.00	10	64	79	0.50	2	0.20	23

Physical habitat ranged from very poor to very good, although the majority of sites showed some signs of degradation. Every watershed contained some sites in good condition, except for watersheds where few sites were assessed. For example, all sites in the Santa Margarita watershed were in very good condition, with mean physical habitat scores greater than 15 (Figure 6, Table 5).

Some components of physical habitat were more often degraded than other components. For example, a large majority of sites had poor scores (< 5) for embeddedness. Degradation of velocity-depth regimes were nearly as bad, with the majority of sites scoring below 10. In contrast, sediment deposition, channel flow, and bank stability were in good condition (score > 15) at the majority of sites (Figure 7, Table 5).

Table 5. Physical habitat at sampled sites. Symbols above the columns indicate the watershed. Numbers indicate number of sites assessed within each watershed. SD = standard deviation.

		SJ		SM		SLR		CB		STO		LP		SD		SW	OT		TJ
		11		4		6		10		5		6		7		1	2		1
Component	Symbol	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	Mean	SD	Mean
Mean score	AvePHAB	10.5	4.7	15.3	0.4	13.3	2.0	11.4	2.6	14.7	3.1	10.9	4.7	11.1	3.2		8.7	5	
Epifaunal cover	EpiCov	11.0	5.1	16.3	2.2	13.3	3.2	12.1	5.6	13.8	6.0	10.7	7.3	10.3	4.6	13	8.5	6	10
Embeddedness	Embed	9.8	6.6	3.5	1.9	5.5	6.4	3.5	4.1	5.0	5.7	6.7	7.8	5.4	7.0	13	3	1	3
Velocity-Depth Regime	VelDep	8.2	4.4	14.8	2.5	10.0	1.1	12.1	4.6	11.2	4.0	10.3	4.5	7.6	4.0	8	5.5	4	9
Sediment Deposition	SedDep	11.0	6.2	13.5	1.7	15.2	1.3	13.8	4.9	17.2	0.8	12.7	8.2	15.6	4.8	13	8.5	8	5
Channel Flow	ChanFlo	11.3	6.0	17.3	2.1	15.3	3.9	13.9	5.4	16.0	6.2	12.8	5.5	14.7	4.3	13	8	6	18
Channel Alteration	ChanAlt	11.9	7.7	19.3	1.0	14.0	2.4	7.8	6.4	17.6	1.9	10.5	7.1	11.3	5.9	18	6.5	9	19
Riffle Frequency	RifFreq	11.2	7.3	17.8	1.7	12.2	4.7	10.2	6.0	13.2	7.9	11.0	7.0	7.9	6.1	13	8.5	9	16
Bank Stability	BankStab	11.0	7.5	16.5	2.4	14.5	2.1	16.3	5.4	18.0	3.4	12.8	5.4	15.3	2.8	18	16.5	4	16
Vegetative Protection	VegPro	11.4	6.8	17.8	1.3	15.3	2.9	15.4	5.3	19.2	1.8	12.8	5.3	11.3	3.3	18	14	6	15
Riparian Vegetation	RipVeg	10.5	8.2	16.5	2.4	15.3	3.8	8.9	4.7	15.4	6.3	8.2	6.8	11.7	3.4	18	8	8	19

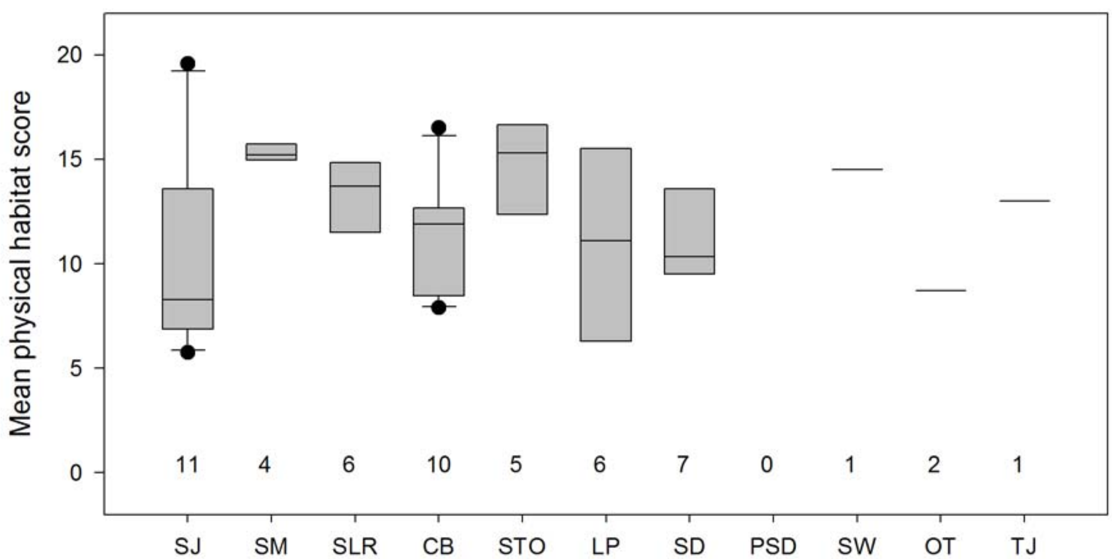

Figure 6. Mean physical habitat scores for all sites within each watershed. Box and whiskers represent 5th, 25th, 50th, 75th, and 95th percentiles. Points represent values above the 95th and below the 5th percentiles. No sites in the Pueblo San Diego watershed were assessed. Numbers indicate number of sites assessed in each watershed.

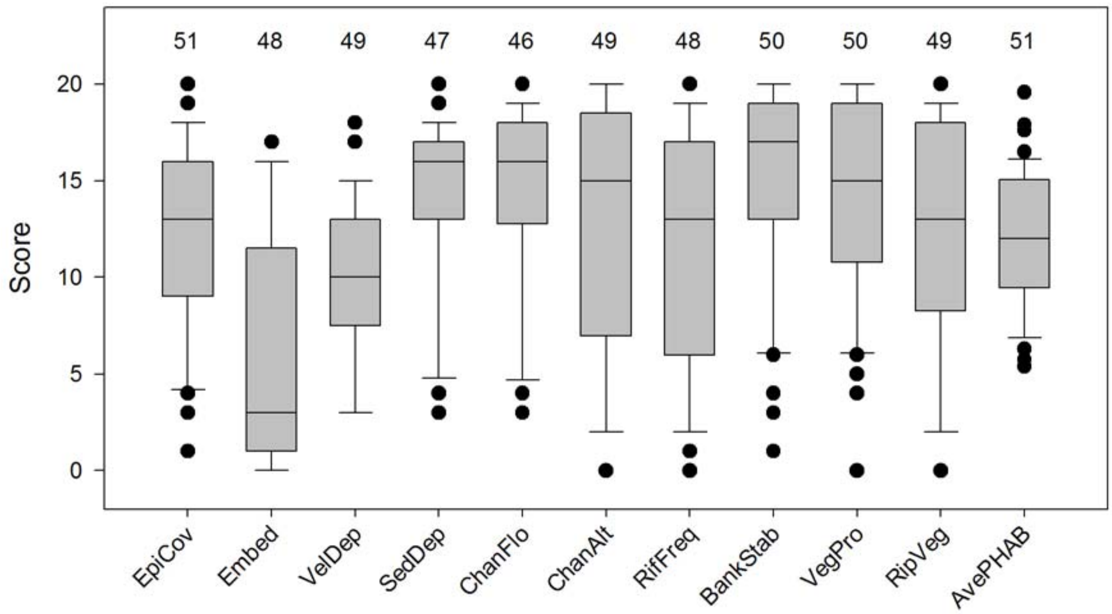

Figure 7. Scores for each component of physical habitat. Abbreviations are given in Table 5. Box and whiskers represent 5th, 25th, 50th, 75th, and 95th percentiles. Points represent values above the 95th and below the 5th percentiles. Numbers indicate number of sites assessed for each component.

IBI scores covered nearly the entire range of the index, with a low score of 0 and a high score of 93 (Table 6). However, the overwhelming majority (80%) of the 708 samples were below the impairment threshold of 39. Poor conditions were observed in every sample from 61% of sites. Good conditions (IBI > 39) were observed in samples from 39% of sites. Although samples in poor condition were found in every watershed, samples in good condition were absent from smaller coastal watersheds, like Carlsbad, Los Peñasquitos, and Pueblo San Diego. A majority of samples (65%) from the Tijuana watershed were in good condition, as were a near-majority (44%) in the Santa Margarita watershed (Figure 8). Sites with samples in good condition were largely restricted to the interior mountains of the larger watersheds. However, a few samples in good condition were occasionally detected in smaller coastal watersheds in undeveloped portions of southern Orange County and in the Camp Pendleton Marine Corps Base (Figure 9).

Table 6. Bioassessment scores by watershed. SD = Standard deviation. Frequency = frequency of samples in poor condition (i.e., IBI < 40).

				IBI		
Watershed	Sites	Samples	Years	Mean	SD	Frequency
SJ	26	132	1998-2005	25	18	0.83
SM	16	113	1998-2006	37	16	0.56
SLR	16	75	1998-2006	28	20	0.73
CB	22	125	1998-2005	13	8	1.00
STO	9	27	2000-2005	24	13	0.89
LP	10	62	1998-2006	16	8	1.00
SD	20	75	1996-2006	17	13	0.96
PSD	2	7	2003-2005	18	6	1.00
SW	10	46	1998-2005	28	20	0.74
OT	2	3	2000-2001	25	18	0.67
TJ	16	43	1999-2006	43	18	0.35

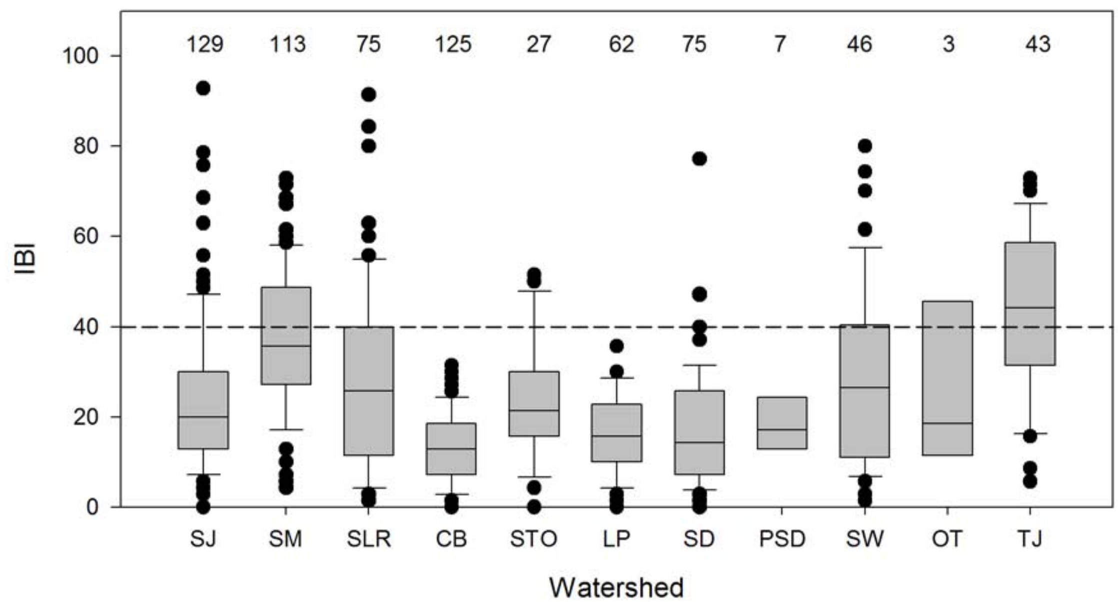

Figure 8. Boxplot of IBI scores of bioassessment samples in each watershed. Boxes and whiskers represent 5th, 25th, 50th, 75th, and 95th percentiles; points represent scores above the 95th percentile or below the 5th percentile. The dashed line represents the threshold for impaired conditions (i.e., 40).

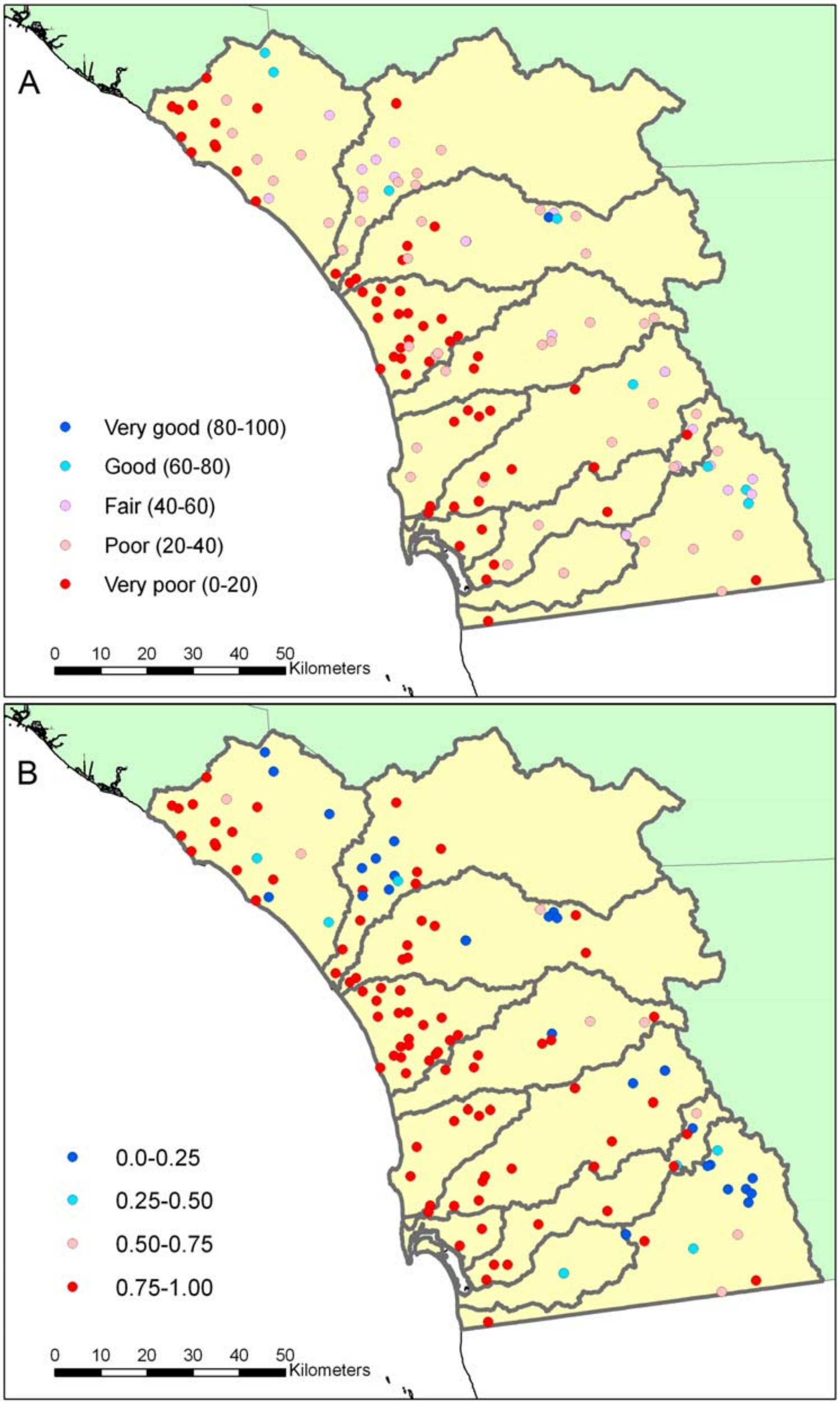

Figure 9. Distribution of IBI scores in the San Diego region. A) Mean IBI scores at each site. B) Frequency of samples in poor or very poor condition (i.e., IBI < 40).

Stressor relationships

Ordination of mean taxa abundances yielded a 3-axis solution with moderately low final stress of 17.6. The three axes combined represented 82.6% of the variance in the site-by-taxa matrix, with the third axis representing the largest portion (40%) of this variance, followed by axis 2 (23.9%) and axis 1 (18.7%). No clustering of sites in ordination plots by watershed was evident (Figure 10).

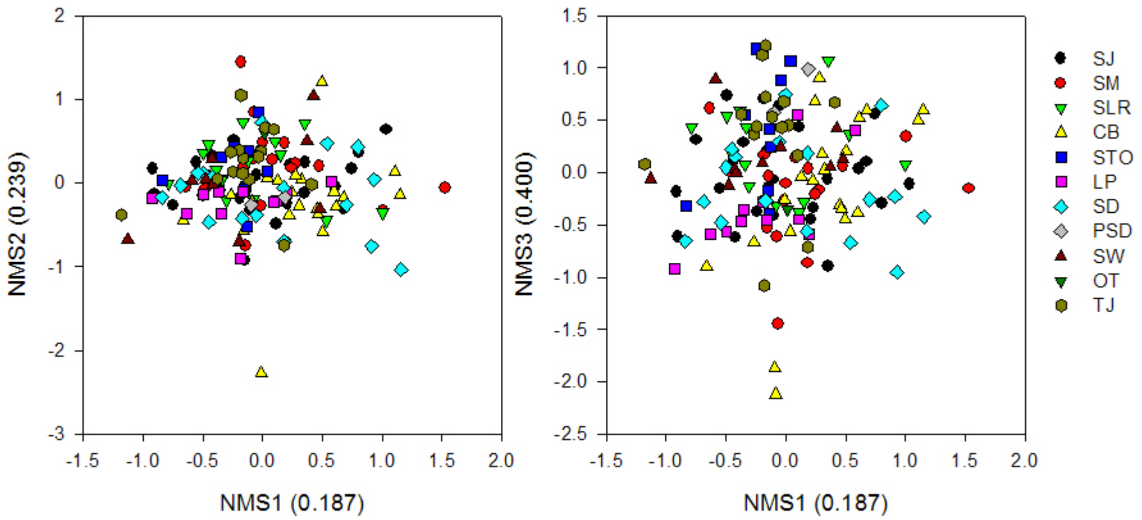

Figure 10. NMS Ordinations of sites in the San Diego region. Each point represents the ordination of the mean abundance of all samples collected at that site. Symbols represent different watersheds. Final stress was 17.6. Numbers in the axis titles is the proportion of variability represented by the axis.

Examination of weighted scores for taxa showed that that several mayflies, stoneflies, and caddisflies were located high on axis 2, while several non-insects were low on axis 2. However, there was considerable diversity within all taxonomic groups; for example, the caddisfly *Hydroptila* had relatively low score of -0.16 on axis 2, and the dipteran *Dasyhelea* had a high score of 0.57. Dipterans, like *Simulium* and Muscidae dominated the low end of axis 1, and non-insects, such as Oligochaeta, Cladocera, Corbicula, and Nematoda were at the high end. No obvious pattern characterized axis 3; the stonefly *Malenka* and the dipteran *Dasyhelea* were at the high end, while several caddisflies *Ochrotrichia*, the mayfly *Baetis,* and the clam *Corbiculum* were at the low end. (Figure 11).

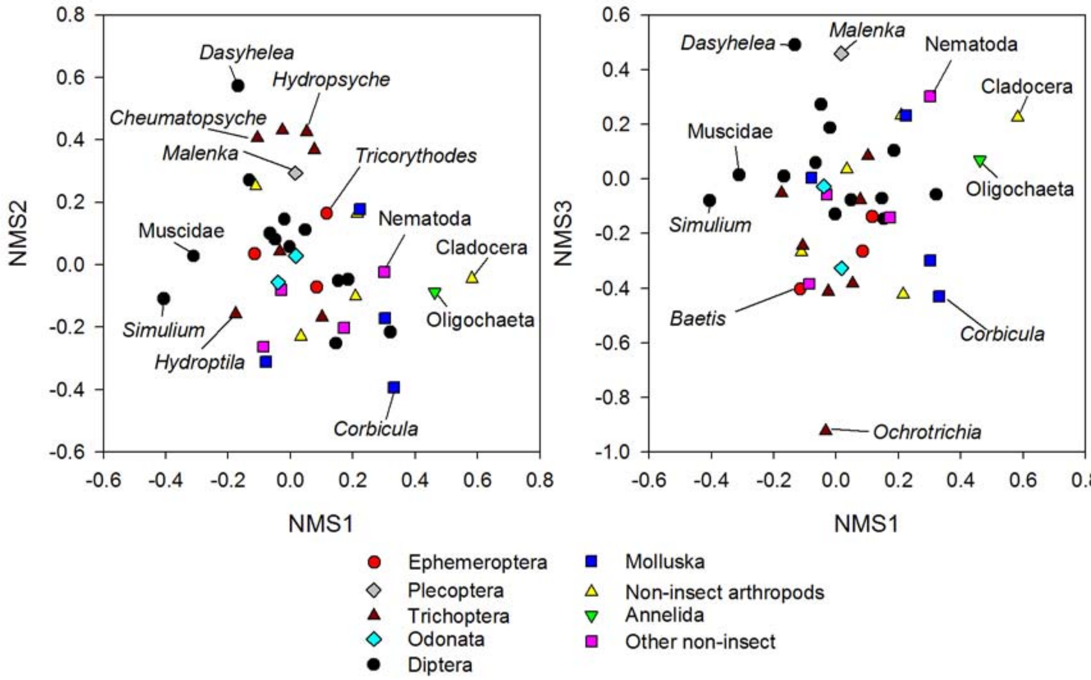

Figure 11. Weighted averages of selected taxa in ordination space. Symbols represent taxonomic groups. Only taxa appearing in 40 or more sites are shown.

Correlation of ordination axes with IBI and metric scores showed that most metrics responded strongly to axis 2 (Figure 12). In general, higher values on axis 2 corresponded to better ecological condition. For example, the IBI as well as the metrics EPT richness and % intolerant individuals had strong positive correlations with axis 2 (ρ^2 of 0.50, 0.50, and 0.54 respectively), and % non-insect taxa had a moderately strong negative relationship (ρ^2 = 0.35). Two metrics (i.e., % collectors and % tolerant taxa) showed no strong relationships with any axis, perhaps because of the ubiquity of collector and tolerant taxa at both disturbed and undisturbed sites. No metric showed strong relationships with axis 1 or 3 (Figure 12). However, the IBI showed a unimodal relationship with axis 1 (Table 7, Figure 13).

Table 7. Correlations of biological metrics with NMS axes. n = Number of sites used to calculate correlations.

		Spearman rank correlations (ρ)			
Biological metric	Symbol	NMS1	NMS2	NMS3	n
Index of biotic integrity	IBI	-0.04	0.70	0.02	44
Frequeny of impaired samples		-0.10	-0.60	-0.07	44
EPT Taxa	EPT tx	0.16	0.58	0.13	44
Coleoptera Taxa	Coleo tx	-0.11	0.71	-0.08	44
Predator Taxa	Pred tx	-0.03	0.53	-0.08	44
% Collectors	% Coll	-0.12	-0.15	0.11	44
% Intolerant	% Intol	0.02	0.74	0.20	44
% Non-Insecta Taxa	% NI tx	0.33	-0.59	-0.04	44
% Tolerant Taxa (8-10)	% Tol tx	0.22	-0.39	0.09	44

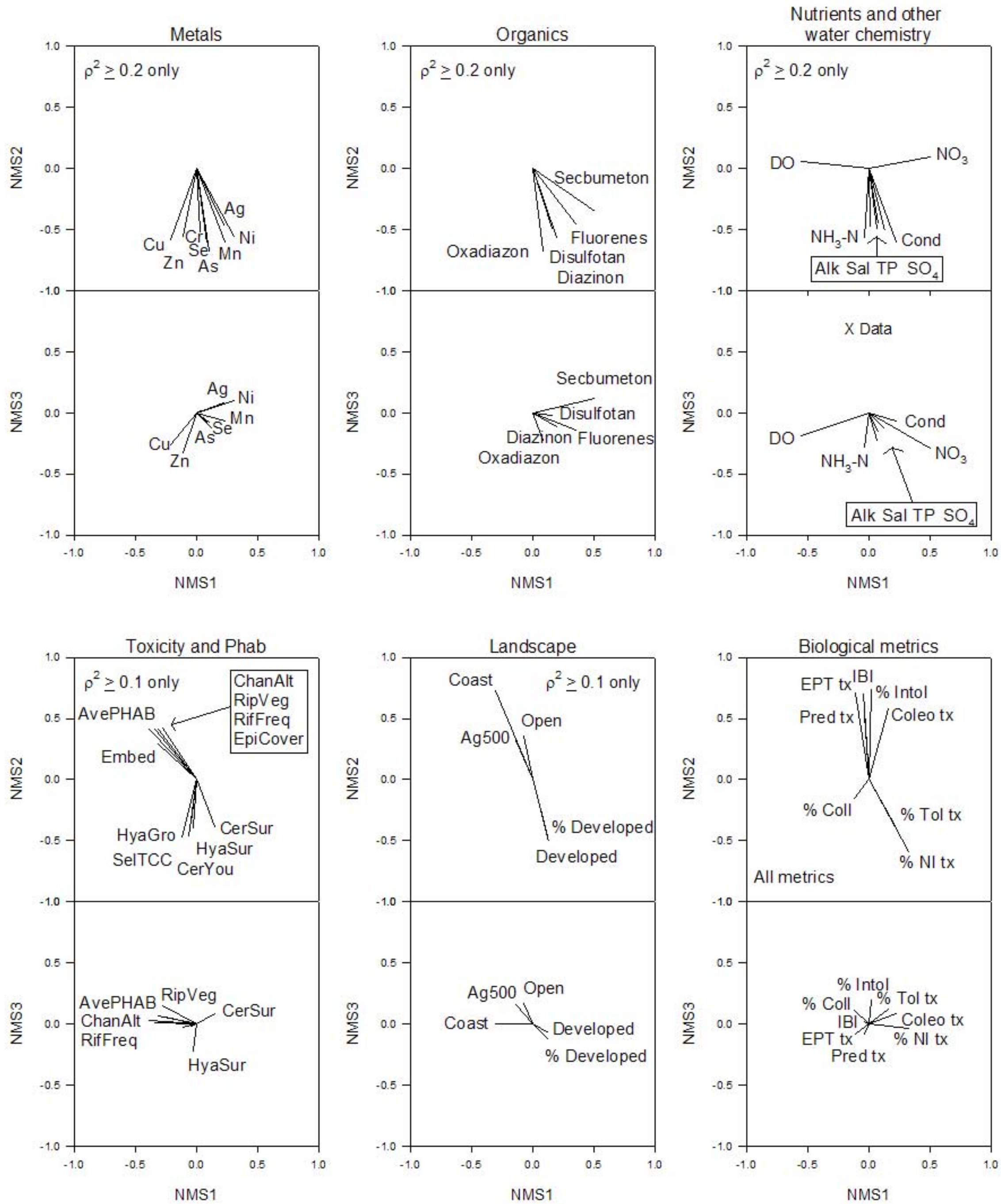

Figure 12. Correlations of variables with NMS axes. Length of vectors represent strength and direction of correlation, as measured by Spearman's rank correlation coefficient (ρ).

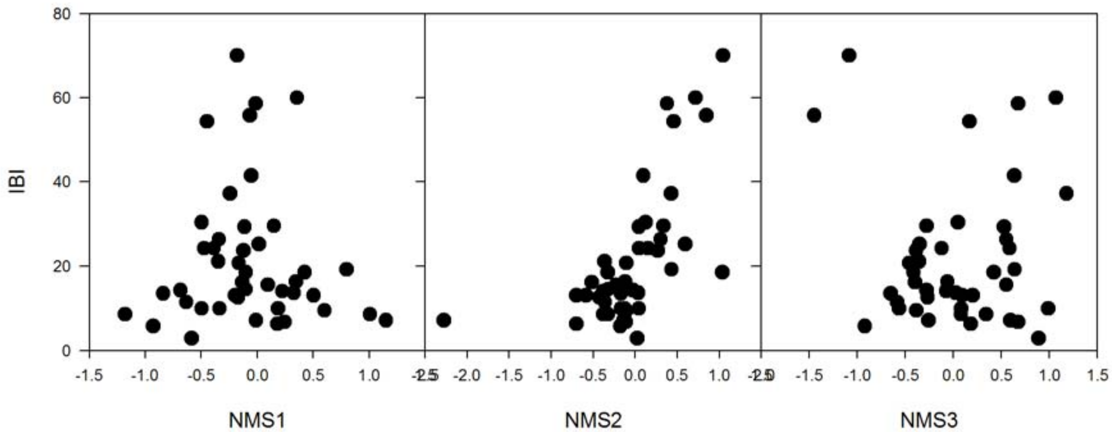

Figure 13. Relationship between IBI scores and ordination axes.

Correlation analyses revealed that many environmental variables related to water chemistry were correlated with axis 2. For example, many metals, ammonia-n, specific conductivity, sulfate, and several organic constituents (such as diazinon and secbumeton) had strong negative correlations (Spearman's $\rho^2 >$ 0.2) with this axis (Table 8). In addition, frequency of toxicity for all endpoints were negatively correlated with this axis, further suggesting that axis 2 represents a toxic contamination gradient (Table 9). In contrast, only two variables (NO_3-N and dissolved oxygen) were strongly correlated with axis 1, suggesting that this axis may represent a eutrophication or nutrient enrichment gradient. No water chemistry or toxicity variables were strongly correlated with axis 3 (Figure 12). Many of the variables that had significant correlations with axis 2 also had significant correlations with the IBI (e.g., arsenic, ammonia-N, etc., Table 8-9).

Table 8. Correlations of selected water chemistry constituents with NMS axes and IBI. N = number of sites used to calculate correlations. A) Physical water quality, metals, and nutrients. B) PAHs, PCBs, and pesticides.

		Spearman rank correlations (ρ)				
A. Water quality--Non-organic constituents	Symbol	NMS1	NMS2	NMS3	IBI	n
Physical water quality and inorganics						
Alkalinity as CaCO3	Alk	0.02	-0.48	0.00	-0.47	35
Sulfate	SO_4	0.14	-0.51	-0.14	-0.58	35
Oxygen, Dissolved	DO	-0.56	0.05	-0.19	0.10	14
pH		-0.32	-0.15	-0.06	-0.19	34
Salinity	Sal	0.06	-0.49	-0.23	-0.76	24
Specific conductivity	Cond	0.23	-0.61	-0.07	-0.72	34
Temperature		0.10	-0.32	-0.05	-0.55	34
Total Suspended Solids		0.10	-0.11	0.05	-0.13	27
Turbidity		-0.02	-0.19	-0.06	0.02	34
Velocity		0.06	0.02	-0.05	-0.08	35
Metals						
Aluminum		0.16	0.20	0.27	0.10	35
Arsenic	As	0.11	-0.68	-0.08	-0.79	35
Cadmium	Cd	0.15	-0.34	-0.33	-0.31	35
Chromium	Cr	0.03	-0.52	0.02	-0.68	35
Copper	Cu	-0.21	-0.58	-0.26	-0.58	35
Lead	Pb	-0.24	0.06	0.20	-0.04	35
Manganese	Mn	0.23	-0.60	-0.07	-0.46	35
Nickel	Ni	0.31	-0.55	0.10	-0.59	35
Selenium	Se	0.08	-0.61	-0.08	-0.78	34
Silver	Ag	0.22	-0.47	0.08	-0.51	35
Zinc	Zi	-0.11	-0.56	-0.33	-0.62	34
Nutrients						
Ammonia as N	NH_3-N	-0.03	-0.57	-0.28	-0.53	35
Nitrate + Nitrite as N		0.01	-0.14	-0.28	-0.31	35
Nitrate as N		0.01	0.03	-0.18	-0.28	27
Nitrate as NO3	NO_3	0.50	0.09	-0.29	-0.20	13
Nitrite as N		-0.07	-0.08	-0.29	-0.24	27
Nitrogen, Total Kjeldahl		-0.15	-0.38	-0.12	-0.38	35
OrthoPhosphate as P		0.20	-0.36	0.03	-0.50	23
Phosphorus as P, Total	TP	0.08	-0.46	-0.16	-0.40	35

Table 8, continued.

	Spearman rank correlations (ρ)				
B. Water quality--Organic constituents	NMS1	NMS2	NMS3	IBI	n
PAHs					
Acenaphthene	-0.15	-0.33	0.05	-0.33	35
Benz(a)anthracene	-0.15	-0.33	0.05	-0.33	35
Benzo(b)fluoranthene	-0.07	-0.39	-0.08	-0.22	35
Chrysene	-0.16	-0.34	0.01	-0.30	35
Fluorenes, C2 -	0.36	-0.45	-0.14	-0.41	33
Naphthalenes, C3 -	-0.15	-0.41	-0.10	-0.15	33
Naphthalenes, C4 -	-0.15	-0.34	-0.22	-0.12	33
Phenanthrene	-0.06	-0.39	0.00	-0.32	35
PCBs					
PCBs	0.05	-0.18	-0.20	0.02	35
Pesticides					
DDE(p,p')	0.33	-0.23	-0.25	-0.23	35
DDTs	0.35	-0.23	-0.25	-0.19	35
Demeton-s	0.38	-0.20	-0.09	-0.26	34
Diazinon	0.19	-0.57	-0.12	-0.57	34
Dimethoate	0.15	-0.34	-0.05	-0.21	34
Dioxathion	-0.31	-0.26	0.17	-0.33	34
Disulfoton	0.16	-0.49	-0.02	-0.52	34
Endosulfan sulfate	-0.01	-0.07	-0.35	0.05	35
Endrin Aldehyde	0.35	-0.14	0.05	-0.33	35
HCH, alpha	0.06	-0.42	-0.32	-0.14	34
HCH, delta	0.24	-0.44	-0.17	-0.20	34
Oxadiazon	0.08	-0.67	-0.23	-0.61	34
Oxychlordane	0.32	-0.13	0.05	-0.13	34
Parathion, Methyl	0.09	0.00	-0.32	-0.06	34
Prometon	0.43	-0.15	0.33	-0.46	28
Propazine	0.01	-0.34	-0.23	-0.37	28
Secbumeton	0.51	-0.35	0.12	-0.43	28
Terbuthylazine	0.32	-0.29	0.03	-0.39	28
Thiobencarb	-0.31	-0.15	-0.40	0.08	34

Table 9. Correlations of toxicity endpoints with NMS axes and IBI. N = number of sites used to calculate correlations.

		Spearman rank correlations (ρ)				
Toxicity indicator	Symbol	NMS1	NMS2	NMS3	IBI	n
C. dubia survival (% control)		0.00	0.25	-0.11	0.16	32
C. dubia young/female (% control)		0.01	0.27	-0.20	0.29	32
H. azteca survival (% control)		-0.03	0.45	0.23	0.47	33
H. azteca growth (% control)		0.28	0.02	-0.07	0.13	32
S. capricornutum total cell count (% control)		0.00	0.61	0.08	0.35	34
C. dubia survival frequency	CerSur	0.15	-0.39	0.09	-0.36	32
C. dubia young/female frequency	CerYou	-0.06	-0.46	0.00	-0.40	32
H. azteca survival frequency	HyaSur	-0.03	-0.40	-0.22	-0.42	33
H. azteca growth frequency	HyaGro	-0.04	-0.35	-0.02	-0.36	32
S. capricornutum total cell count frequency	SelTcc	-0.12	-0.47	-0.03	-0.27	34

Physical habitat variables were correlated with both axis 1 and 2, although none with ρ^2> 0.2. The strongest physical habitat variables were riparian vegetation, riffle frequency, channel alteration, and epifaunal cover with ρ^2 with axis 2 of 0.17-0.18; these variables all had significant relationships with the IBI as well. Correlations with axis 1 were weaker, with ρ^2 ranging from 0.10-0.15. Therefore, physical habitat degradation appears to be associated with both water chemistry contamination and eutrophication (Table 10, Figure 12).

Table 10. Correlations of physical habitat assessments with NMS axes and IBI. N = number of sites used to calculate correlations.

		Spearman rank correlations (ρ)				
Physical habitat component	Symbol	NMS1	NMS2	NMS3	IBI	n
Epifaunal cover	EpiCover	-0.26	0.39	0.06	0.45	30
Embeddedness	Embed	-0.31	0.29	0.07	0.53	28
Velocity-depth regime	VelDep	0.00	0.09	-0.12	0.04	28
Sediment deposition	SedDep	0.07	0.08	0.12	-0.13	26
Channel flow	ChanFlo	0.02	0.04	-0.20	-0.08	27
Channel alteration	ChanAlt	-0.39	0.41	0.03	0.64	29
Riffle frequency	RifFreq	-0.34	0.41	0.01	0.64	28
Bank stability	BankStab	0.01	0.22	0.16	-0.02	30
Vegetative protection	VegPro	-0.04	0.28	0.09	0.12	30
Riparian zone	RipZone	-0.28	0.42	0.15	0.59	29
Mean score	AvePHAB	-0.32	0.41	0.02	0.50	28

Analysis of landscape-scale variables suggest that the extent of development in the watershed strongly influences benthic community structure. For example, total developed area in the watershed, as well as percent of developed land in the watershed, both had strong negative relationships with axis 2 (ρ^2 of 0.26 and 0.21, respectively). Landscape metrics reflecting local land use were more weakly correlated with axis 2, with local developed land having a ρ^2 of 0.13. Axis 2 was most strongly correlated with distance from coast (ρ^2 = 0.53), perhaps reflecting the higher intensity of development along the coast. No landscape-scale variable correlated strongly with axis 1 or 3 (Table 11, Figure 12).

Table 11. Correlations of landscape metrics with NMS axes and IBI. N = number of sites used to calculate correlations.

Variable	Symbol	Unit	NMS1	NMS2	NMS3	IBI	n
Land use, watershed-wide							
Open space in watershed	Open	log km^2	0.00	0.02	0.05	0.03	44
Agricultural land in watershed		log km^2	0.00	0.03	-0.02	0.02	44
Developed land in watershed	Developed	log km^2	0.13	-0.51	-0.07	-0.70	44
Percent open space in watershed		%	-0.07	0.35	0.17	0.42	44
Percent agricultural land in watershed		%	0.03	0.16	-0.01	0.13	44
Percent developed land in watershed	% Developed	%	0.13	-0.46	-0.12	-0.58	44
Land use, local							
Percent open space within 500 m		%	0.06	0.23	-0.02	0.41	44
Percent agricultural land within 500 m	Ag500	%	-0.14	0.32	0.16	0.23	44
Percent developed land within 500 m		%	0.02	-0.37	-0.10	-0.55	44
Other landscape-scale variables							
Distance from coast	Coast	km	-0.30	0.72	0.00	0.72	44
Watershed area	WSA	log km^2	0.00	-0.12	-0.01	-0.10	44

Inspection of scatterplots revealed that some variables had a strong influence on the IBI. For example, IBI scores were never above 30 where more than 10% of the watershed was developed. Similar relationships were observed with other variables, such as arsenic concentration, frequency of acute toxicity to *C. dubia*, sulfate, and arsenic. In contrast, more linear relationships were observed for other variables, such as distance from coast. Wedge-shaped relationships, were observed for several nutrients, such as ammonia-N and total phosphorus (Figure 14). Several variables showed no discernible relationship, such as dissolved oxygen and frequency of toxicity to *S. capricornutum.*

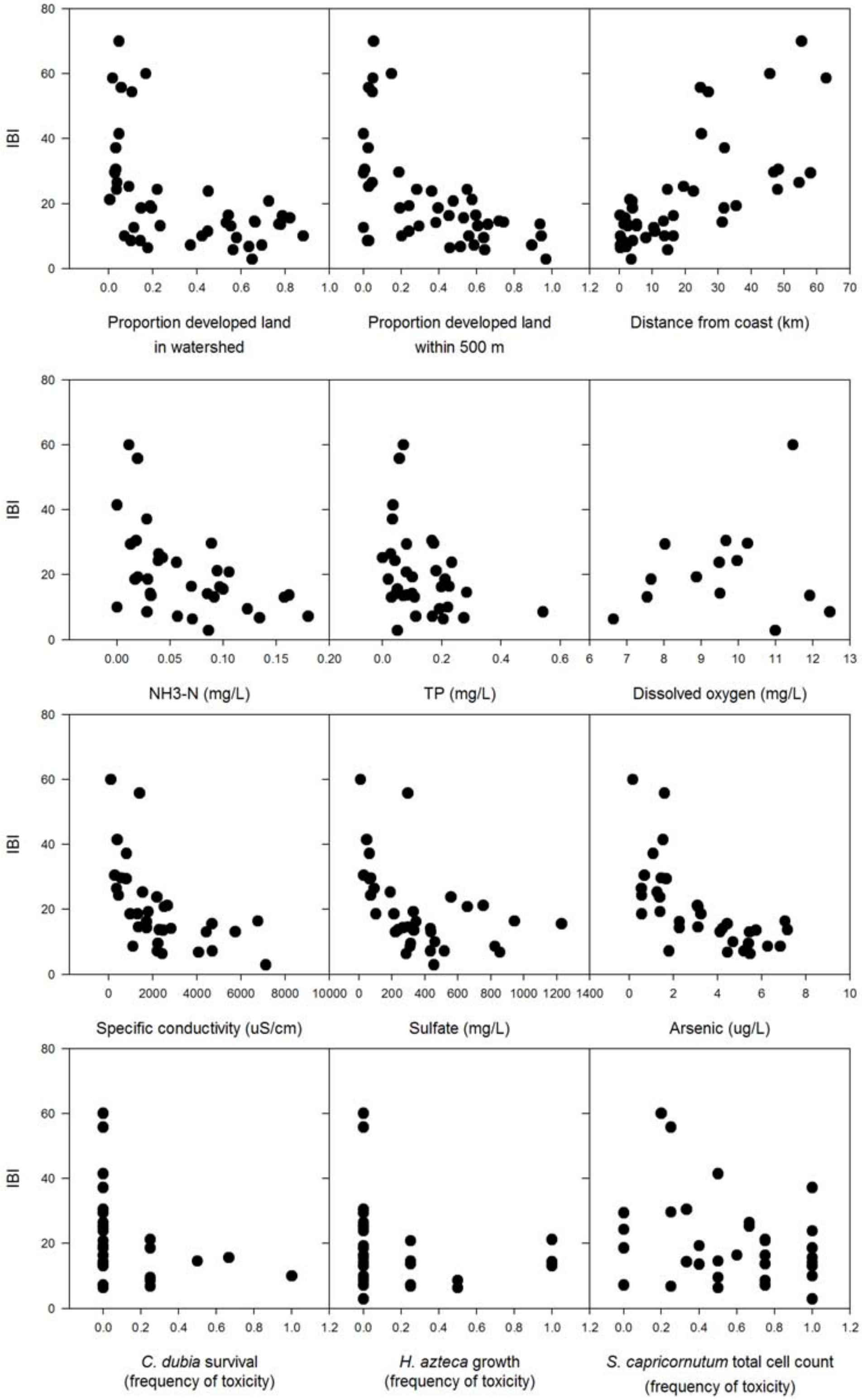

Figure 14. Relationships between IBI scores and landscape, nutrient, water quality, and toxicity variables.

Ternary plots of sites according to land use in the watershed further suggested a strong role for development in the watershed as limiting biological health (Figure 15). Sites in fair or good condition (mean IBI > 40) were tightly clustered on the right side of plots, where developed land was minimal. Similar patterns were observed for watershed-wide and local scales.

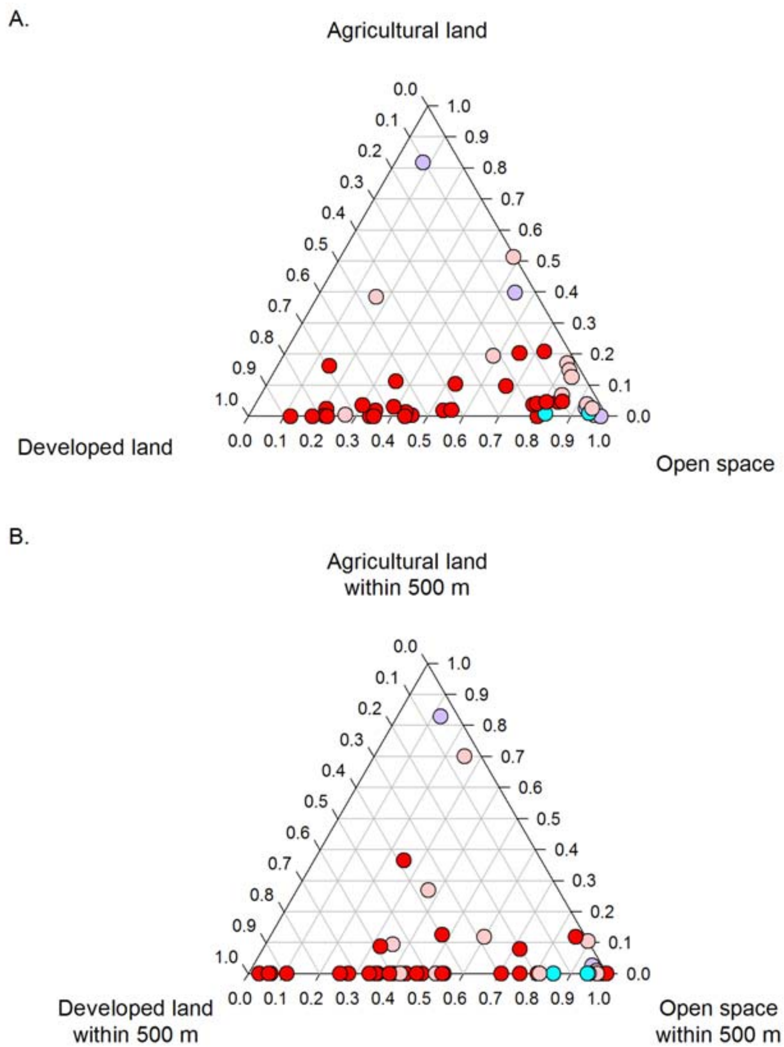

Figure 15. Ternary plots of sites showing land use in A) the contributing watershed, and B) within 500 m. Red dots indicate sites in very poor condition (mean IBI 0 - 20). Pink dots indicate sites in poor condition (mean IBI 20 – 40). Purple dots indicate sites in fair condition (mean IBI 40 – 60). Blue circles indicate sites in good condition (mean IBI 60 – 80).

5. DISCUSSION

Assessment of the region

Impacts to streams in southern California in this study were pervasive, and were associated with a large suite of potential stressors, including multiple water chemistry constituents, toxic waters and sediments, and degraded physical habitat. Impacts to all indicators were observed, and in most cases impacts were widespread. In general, smaller coastal watersheds (e.g., Carlsbad, Los Peñasquitos, Pueblo San Diego, and Otay) were more impacted, suffering from elevated water contaminants, high toxicity, degraded physical habitat, and poor biological condition. However, all watersheds contained sites suffering impacts to multiple indicators.

Despite the prevalence of observed impacts, some watersheds contained sites in good health. Larger watersheds with extensive undeveloped areas (e.g., Santa Margarita, San Diego, and Tijuana) contained sites in moderate to good health, generally clustered in the interior. Bioassessment samples from these sites were frequently in fair or good condition, and contamination of the water column was less severe. The San Juan hydrologic unit was unique in that it contained sites in moderate to good health near the coast. Unlike all other watersheds, the San Juan hydrologic unit contains extensive undeveloped coastal areas, where these sites were located.

Using data from local programs for regional assessments was a qualified success. These programs generated considerable quantities of data within the San Diego region, measuring multiple indicators in all watersheds. However, extrapolating results from the sites in this study to the entire San Diego region should be done cautiously. All sites were targeted for sampling, often because impairment was suspected at many of these sites. Therefore, the assumption that the sites in the study represent the region as a whole is most likely violated, resulting in a regional assessment that may be worse than the true condition.

Sampling was typically driven by municipal stormwater permits or other mandates, resulting in a high concentration of sites in densely populated and highly developed areas along the coast. Because of this focus on urban streams vast areas of the interior, such as the upper San Luis Rey River and the Santa Margarita, contained no sites (Figure 2).

Relationship between stressors, ecological health, and land use

Despite the limits of the data in making regional assessments, they helped determine the relationships between ecological health and potential stressors to aquatic life. The targeted selection of sites by local programs was adequate to establish gradients of most stressors, such as nutrients or metals in the water column. Poor biological condition was associated with elevated metals, organic constituents, nutrients, specific conductivity, pH, and many other water chemistry constituents. Water and sediment toxicity was more frequent at biologically impacted sites than at sites in good biological condition. Degraded physical habitat was also associated with poor biological condition.

Nonmetric multidimensional scaling of benthic communities suggests ecosystem health was degraded in two different ways: toxic contamination of the water column and eutrophication. These two gradients of degradation correspond to two of the three ordination axes (axes 2 and 1, respectively). Sites located on the low end of axis 2 had elevated concentrations of many contaminants, such as metals and organic constituents, as well as elevated specific conductivity, sulfates, and other water quality constituents. Furthermore, toxicity was frequently evident at sites on the low end of axis 2. In contrast, the eutrophication gradient was strongly related to dissolved oxygen and to concentrations of nitrate; sites on the high end of axis 1 may be in a nutrient-enriched state. Physical habitat scores were related to both axes, suggesting that degradation of physical habitat is associated with both eutrophication and with contamination of the water column. The lack of strong relationships between the third axis and potential stressors suggest that this axis represents either responses to unmeasured stressors, or natural variability in stream communities. Such variability may arise from environmental heterogeneity, as well as biotic processes like dispersal, predation, and competition among stream biota (Power et al. 1998).

The fact that the IBI and its composite metrics were all strongly correlated to axis 2 suggests that the IBI is a good tool to detect impacts from altered water chemistry, as well as degraded physical habitat. However, the weak relationship with axis 1 suggests that it may not be sensitive to impacts caused by eutrophication. A complementary index, either based on macroinvertebrate taxa that respond to this gradient (e.g., *Simulium,* Oligochaeta, Cladocera, etc.) or based on assemblages with higher sensitivity to eutrophication (e.g., periphyton) may improve assessment of impacts related to nutrient enrichment.

The nature of the data collected for this assessment does not allow identification of stressors that were directly responsible for the observed impacts to ecological health. However, the extent of developed land had one of the strongest associations with poor health observed in this study. It is evident that increased development in watersheds—perhaps as little as 10 percent—could seriously impact stream ecosystems. Similar thresholds have been identified in many other regions of the world (e.g., Hatt et al. 2004, Walsh et al. 2007). Although agricultural land within the watershed was not shown to be associated with impacts to aquatic life, watersheds with extensive agricultural activity were minimally represented in the data set, Furthermore, agricultural land may include areas that are minimally affected, such as lightly grazed pasture.

Land use may affect stream health at both local as well as watershed scales. Our data showed that both watershed-scale and local-scale land use measured were associated with poor biological integrity. Furthermore, local conditions, as reflected by physical habitat condition, was also associated with biological health. The role near-stream conditions and riparian buffers in biological integrity has long been recognized (Hickey and Doran 2004, Moore and Palmer 2005). However, recent research suggests that watershed condition is more important than local riparian condition (e.g., Walsh et al. 2007). This study supports the finding of other studies that protection of aquatic life may require addressing local habitat, as well as watershed-wide alterations of land use and stream hydrology (Taylor et al. 2004, Walsh et al. 2005).

Conclusions

Most sites within the San Diego region were in poor condition.

Multiple lines of evidence suggested that many sites in the San Diego region were in poor condition. For example, over half of all water samples exceeded applicable aquatic life thresholds for multiple water chemistry constituents, such as ammonia-n, selenium, specific conductivity, or sulfate. Water or sediment toxicity was evident in the majority of samples; toxicity to the alga *Selenastrum capricornutum* was the most widespread affecting 59% of all samples. Impacts to benthic macroinvertebrate communities were particularly prevalent, with 80% of over 700 bioassessment samples in poor or very poor condition. Good bioassessment condition was never observed at 87 of the 144 (60%) sites assessed.

Multiple stressors were associated with poor biological condition

Poor biological condition was associated with many potential stressors, including altered water chemistry, high toxicity and degraded physical habitat. Nonmetric multidimensional scaling showed that benthic communities responded to two different gradients of stressors: toxic contaminants in the water column (e.g., trace metals, organic constituents) and eutrophication (e.g., nutrients, low dissolved oxygen). The toxic contaminant gradient accounted for more of the variability observed in biological communities compared to the eutrophication gradient and was closely related to frequency of toxicity, as well as the index of biotic integrity. Degradation of physical habitat was associated with both toxic contaminant and eutrophication gradients.

Development in the watershed was a strong predictor of biological health.

Sites with extensive development in the contributing watershed were invariably in poor condition. The data suggest that development in as little as 10% of the watershed was enough to degrade biological integrity, although other stressors may affect aquatic life in undeveloped watersheds. Development in the watershed correlated strongly with the toxic contaminant gradient.

Recommendations

SWAMP should integrate its monitoring with other monitoring programs in the region to increase cost-efficiency

SWAMP is an important foundation for monitoring in the San Diego Region. SWAMP provides a high-quality data set that is not constrained to specific waterbodies or pollutant categories. It cannot, however, monitor all waterbodies for all of the important attributes RWQCB staff need for decision-making. This study found that hundreds of samples were collected for NPDES monitoring in the San Diego Region, sometimes in the same locations at the same time as SWAMP. SWAMP should look to integrate its monitoring with NPDES monitoring to extend its resources. This was a similar recommendation to what the SPARC had provided to the SWRCB during its most recent external review of the SWAMP program.

SWAMP should redesign its monitoring program to improve effectiveness at addressing important monitoring questions.

One of the primary questions to be addressed by the SWAMP program was “what is the health of streams in the San Diego Region?”. Answering this question was hindered due to a potentially biased monitoring design that targeted sites for sampling. Often, these were sites with known sources of pollutants. A probabilistic monitoring design would provide a more accurate assessment of stream health overall while requiring fewer sample sites. The probabilistic design has been used by others including the US EPA’s Perennial Stream Assessment (PSA) and the Southern California Stormwater Monitoring Coalition’s Regional Watershed Monitoring Program (SMC).

Identify a set of core indicators that can help determine impacts to beneficial uses

Two challenges affected the ability to assess regional stream health and examine stressor-response relationships. First, few bioassessment samples were collected synoptically with water chemistry, toxicity, or physical habitat assessments. The lack of synoptic data obscures potentially strong stressor relationships, as stresses may wax or wane between sampling events. Second, potentially important indicators were not measured. Impacts such as eutrophication may be detected most effectively using other indicators like periphyton (attached algae). Once again, there is opportunity to integrate and collaborate with local scale monitoring programs such as NPDES and larger scale programs such as PSA and SMC to define a list of core indicators. This also presents another opportunity for cost efficiency, where the hundreds of chemicals monitored during this study need not be measured.

SWAMP should ensure that there is an infrastructure to support its collaborative programs

One problem encountered during this study was the inability to combine data sets from different programs. Differing data structures, QA requirements, plus field and laboratory methods hindered effective progress towards meaningful interpretations of the data. SWAMP should engage in shared information management systems, integrated quality assurance system checks, and common field and laboratory method manuals to ensure that integration among monitoring programs becomes seamless. These activities have already made a start including California's Environmental Data Exchange Network (CEDEN) and the intercalibration exercises being conducted by the SMC.

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7. APPENDICES

APPENDIX

Water quality constituents at each watershed. SD = standard deviation. n = number of samples.

			San Juan			Santa Margarita		
Physical water quality and inorganics	Symbol	Units	Mean	SD	n	Mean	SD	n
Alkalinity as CaCO3	Alk	mg/l	208	109	39	187	49	21
Chloride		mg/l			0			0
Fine-ASTM		%			0			0
Fine-ASTM,Passing No. 200 Sieve		%	24.9	24.6	25	6.5	7.0	12
Oxygen, Dissolved	DO	mg/L			0			0
Oxygen, Saturation		%	105	33	38	99	25	20
pH		pH	7.6	1.5	38	7.4	0.8	20
Salinity	Sal	ppt	1.05	1.77	32	2.62	6.16	20
Specific conductivity	Cond	µS/cm	2032	2839	38	4399	9779	20
Sulfate	SO_4	mg/l	497	491	39	352	398	21
Suspended Sediment Concentration		%	70.5	117.2	8			0
Temperature		ºC	16.8	3.2	38	16.1	4.1	20
Total Organic Carbon		mg/L			0			0
Total Suspended Solids		mg/L	101	241	31	25	48	21
Turbidity		NTU	35.5	76.8	38	33.1	101.0	20
Velocity		ft/s	0.4	0.9	39	0.5	0.9	21
Nutrients								
Ammonia as N	NH_3-N	mg/l	0.19	0.52	39	0.02	0.05	21
Nitrate + Nitrite as N		mg/l	0.42	0.52	39	4.86	4.52	21
Nitrate as N		mg/l	0.41	0.51	39	4.84	4.52	21
Nitrate as NO3	NO_3	mg/l	1.79	2.20	39	22.48	19.92	20
Nitrite as N		mg/l	0.02	0.02	39	0.02	0.01	21
Nitrogen, Total Kjeldahl		mg/l	0.80	0.90	39	0.67	0.72	21
OrthoPhosphate as P		mg/l	3.45	20.80	39	2.30	9.79	21
Phosphorus as P,Total	TP	mg/l	0.22	0.27	39	0.21	0.22	21
Metals								
Aluminum		µg/L	3.3	8.6	39	4.5	13.5	21
Arsenic	As	µg/L	3.4	2.5	39	2.5	3.9	21
Cadmium	Cd	µg/L	0.26	0.34	39	0.04	0.03	21
Chromium	Cr	µg/L	0.25	0.22	39	0.23	0.35	21
Copper	Cu	µg/L	4.05	2.85	39	3.10	2.37	21
Lead	Pb	µg/L	0.02	0.02	39	0.01	0.01	21
Manganese	Mn	µg/L	148	329	39	92	139	21
Nickel	Ni	µg/L	5.55	6.76	39	0.71	1.22	21
Selenium	Se	µg/L	7.5	10.4	38	5.9	16.8	20
Silver	Ag	µg/L	0.20	1.22	39	0.09	0.29	21
Zinc	Zi	µg/L	4.1	3.1	38	2.3	1.5	20
Bacteria								
Enterococcus		MPN/100 ml	70		1	10		1
Fecal Coliform		MPN/100 ml	170		1	50		1
Total Coliform		MPN/100 ml	190		1	900		1

Appendix, continued.

			San Juan			Santa Margarita		
PAHs	Symbol	Units	Mean	SD	n	Mean	SD	n
Acenaphthene		ng/L	0	0	39	0	0	21
Acenaphthylene		ng/L	0	0	39	0	0	21
Anthracene		ng/L	0	0	39	0	0	21
Benz(a)anthracene		ng/L	0	0	39	0	0	21
Benzo(a)pyrene		ng/L	1.7	10.8	39	0	0	21
Benzo(b)fluoranthene		ng/L	3.5	9.6	39	1.0	3.2	21
Benzo(e)pyrene		ng/L	1.3	6.3	39	0	0	21
Benzo(g,h,i)perylene		ng/L	4.3	14.4	39	0	0	21
Benzo(k)fluoranthene		ng/L	1.4	8.9	38	0	0	20
Biphenyl		ng/L	0	0	38	0	0	20
Chrysene		ng/L	0.8	3.4	39	0	0	21
Chrysenes, C1 -		ng/L	1.9	7.4	38	0	0	20
Chrysenes, C2 -		ng/L	2.7	9.3	38	0	0	20
Chrysenes, C3 -		ng/L	19.6	111.4	38	0	0	20
Dibenz(a,h)anthracene		ng/L	2.4	15.1	39	0	0	21
Dibenzothiophene		ng/L	1.7	6.4	38	0	0	20
Dibenzothiophenes, C1 -		ng/L	10.4	21.1	38	5.4	8.4	20
Dibenzothiophenes, C2 -		ng/L	18.1	38.9	38	10.5	12.9	20
Dibenzothiophenes, C3 -		ng/L	9.4	25.1	38	2.3	7.1	20
Dimethylnaphthalene, 2,6-		ng/L	0	0	38	0	0	20
Dimethylphenanthrene, 3,6-		ng/L			0			0
Fluoranthene		ng/L	0.82	3.74	39	0	0	21
Fluoranthene/Pyrenes, C1 -		ng/L	0.39	2.43	38	0	0	20
Fluorene		ng/L	0	0	39	0	0	21
Fluorenes, C1 -		ng/L	2.06	6.06	38	0.57	2.55	20
Fluorenes, C2 -		ng/L	0.93	3.26	38	0	0	20
Fluorenes, C3 -		ng/L	5.89	13.27	38	4.27	12.54	20
Indeno(1,2,3-c,d)pyrene		ng/L	3.79	17.96	39	0	0	21
Methyldibenzothiophene, 4-		ng/L			0			0
Methylfluoranthene, 2-		ng/L			0			0
Methylfluorene, 1-		ng/L			0			0
Methylnaphthalene, 1-		ng/L	0	0	38	0	0	20
Methylnaphthalene, 2-		ng/L	0	0	38	0	0	20
Methylphenanthrene, 1-		ng/L	0	0	38	0	0	20
Naphthalene		ng/L	1.34	6.42	39	0	0	21
Naphthalenes, C1 -		ng/L	1.30	6.53	38	0	0	20
Naphthalenes, C2 -		ng/L	1.17	4.07	38	0	0	20
Naphthalenes, C3 -		ng/L	3.65	8.57	38	1.70	5.27	20
Naphthalenes, C4 -		ng/L	7.44	21.33	38	0	0	20
Perylene		ng/L	1.83	8.04	38	0	0	20
Phenanthrene		ng/L	0	0	39	0	0	21
Phenanthrene/Anthracene, C1 -		ng/L	4.99	9.68	38	5.01	8.55	20
Phenanthrene/Anthracene, C2 -		ng/L	2.57	7.07	38	0.50	2.24	20
Phenanthrene/Anthracene, C3 -		ng/L	2.81	8.01	38	0	0	20
Phenanthrene/Anthracene, C4 -		ng/L	0.44	2.74	38	0	0	20
Pyrene		ng/L	2.65	8.10	39	0	0	21
Trimethylnaphthalene, 2,3,5-		ng/L	0	0	38	0	0	20

Appendix, continued.

			San Juan			Santa Margarita		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n
PCB 005		ng/L	0.35	1.71	38	0	0	20
PCB 008		ng/L	0.41	2.50	38	0	0	20
PCB 015		ng/L	0	0	38	0	0	20
PCB 018		ng/L	0	0	38	0	0	20
PCB 027		ng/L	0	0	38	0	0	20
PCB 028		ng/L	0	0	38	0	0	20
PCB 029		ng/L	0	0	38	0	0	20
PCB 031		ng/L	0.11	0.65	38	0	0	20
PCB 033		ng/L	0	0	38	0	0	20
PCB 044		ng/L	0	0	38	0	0	20
PCB 049		ng/L	0	0	38	0	0	20
PCB 052		ng/L	0.32	1.95	38	0	0	20
PCB 056		ng/L	0	0	38	0	0	20
PCB 060		ng/L	0	0	38	0	0	20
PCB 066		ng/L	0	0	38	0	0	20
PCB 070		ng/L	0	0	38	0	0	20
PCB 074		ng/L	0	0	38	0	0	20
PCB 087		ng/L	0.82	2.01	38	0	0	20
PCB 095		ng/L	0	0	38	0	0	20
PCB 097		ng/L	0	0	38	0	0	20
PCB 099		ng/L	0	0	38	0	0	20
PCB 101		ng/L	0	0	38	0	0	20
PCB 105		ng/L	0	0	38	0	0	20
PCB 110		ng/L	0	0	38	0	0	20
PCB 114		ng/L	0	0	38	0	0	20
PCB 118		ng/L	0	0	38	0	0	20
PCB 128		ng/L	0	0	38	0	0	20
PCB 137		ng/L	0	0	38	0	0	20
PCB 138		ng/L	0	0	38	0	0	20
PCB 141		ng/L	0	0	38	0	0	20
PCB 149		ng/L	0	0	38	0	0	20
PCB 151		ng/L	0	0	38	0	0	20
PCB 153		ng/L	0	0	38	0	0	20
PCB 156		ng/L	0	0	38	0	0	20
PCB 157		ng/L	0	0	38	0	0	20
PCB 158		ng/L	0	0	38	0	0	20
PCB 170		ng/L	0	0	38	0	0	20
PCB 174		ng/L	0	0	38	0	0	20
PCB 177		ng/L	0	0	38	0	0	20
PCB 180		ng/L	0	0	38	0	0	20
PCB 183		ng/L	0	0	38	0	0	20
PCB 187		ng/L	0.16	0.72	38	0	0	20
PCB 189		ng/L	0	0	38	0	0	20
PCB 194		ng/L	0.18	1.14	38	0	0	20
PCB 195		ng/L	0.18	1.14	38	0	0	20
PCB 200		ng/L	0	0	38	0	0	20
PCB 201		ng/L	0	0	38	0	0	20
PCB 203		ng/L	0	0	38	0	0	20
PCB 206		ng/L	0	0	38	0	0	20

Appendix, continued.

			San Juan			Santa Margarita		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n
PCB 209		ng/L	0	0	38	0	0	20
PCB-1016		ng/L	0		1	0		1
PCB-1221		ng/L	0		1	0		1
PCB-1232		ng/L	0		1	0		1
PCB-1242		ng/L	0		1	0		1
PCB-1248		ng/L	0		1	0		1
PCB-1254		ng/L	0		1	0		1
PCB-1260		ng/L	0		1	0		1
PCBs		ng/L	2.45	6.68	39	0	0	21
Pesticides								
Aldrin		ng/L	0	0	39	0	0	21
alpha-BHC		ng/L	0		1	0		1
Ametryn		ng/L	0	0	38	0	0	20
Aspon		ng/L	0	0	38	0	0	20
Atraton		ng/L	0	0	38	0	0	20
Atrazine		ng/L	0	0	38	0	0	20
Azinphos ethyl		ng/L	0	0	38	0	0	20
Azinphos methyl		ng/L	0	0	38	0	0	20
beta-BHC		ng/L	0		1	0		1
Bolstar		ng/L	0	0	38	0	0	20
Carbophenothion		ng/L	0	0	38	0	0	20
Chlordane (tech)		ng/L	0		1	0		1
Chlordane, cis-		ng/L	0.29	1.49	38	0	0	20
Chlordane, trans-		ng/L	0.03	0.16	38	0	0	20
Chlordene, alpha-		ng/L	0	0	38	0	0	20
Chlordene, gamma-		ng/L	0.34	1.16	38	0	0	20
Chlorfenvinphos		ng/L	0	0	38	0	0	20
Chlorpyrifos		ng/L	0	0	38	0	0	20
Chlorpyrifos methyl		ng/L	0	0	38	0	0	20
Ciodrin		ng/L	0	0	38	0	0	20
Coumaphos		ng/L	0	0	38	0	0	20
Dacthal		ng/L	0.24	0.71	38	0	0	20
DDD(o,p')		ng/L	0	0	38	0	0	20
DDD(p,p')		ng/L	0.03	0.16	39	0.05	0.22	21
DDE(o,p')		ng/L	0.03	0.16	38	0	0	20
DDE(p,p')		ng/L	0.29	0.66	39	0.90	2.64	21
DDMU(p,p')		ng/L	0	0	38	0	0	20
DDT(o,p')		ng/L	0	0	38	0.10	0.45	20
DDT(p,p')		ng/L	0.23	0.83	39	0.43	1.57	21
DDTs		ng/L	0.58	1.28	39	1.48	3.89	21
delta-BHC		ng/L	0		1	0		1
Demeton-s		ng/L	0	0	38	0	0	20
Diazinon		ng/L	43.97	103.77	38	7.78	18.10	20
Dichlofenthion		ng/L	0	0	38	0	0	20
Dichlorvos		ng/L	0	0	38	0	0	20
Dicrotophos		ng/L	0	0	38	0	0	20
Dieldrin		ng/L	0.15	0.42	39	0	0	21
Dimethoate		ng/L	1.05	6.49	38	0	0	20
Dioxathion		ng/L	0	0	38	0	0	20

Appendix, continued.

			San Juan			Santa Margarita		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n
Disulfoton		ng/L	3.95	10.28	38	0	0	20
Endosulfan I		ng/L	0.14	0.38	39	0.05	0.22	21
Endosulfan II		ng/L	0.04	0.24	39	0	0	21
Endosulfan sulfate		ng/L	0.10	0.31	39	0.05	0.22	21
Endrin		ng/L	0.05	0.22	39	0	0	21
Endrin Aldehyde		ng/L	0	0	39	0	0	21
Endrin Ketone		ng/L	0	0	38	0	0	20
Ethion		ng/L	0	0	38	0	0	20
Ethoprop		ng/L	0	0	38	0	0	20
Famphur		ng/L	0	0	38	0	0	20
Fenchlorphos		ng/L	0	0	38	0	0	20
Fenitrothion		ng/L	0	0	38	0	0	20
Fensulfothion		ng/L	0	0	38	0	0	20
Fenthion		ng/L	0	0	38	0	0	20
Fonofos		ng/L	0	0	38	0	0	20
gamma-BHC (Lindane)		ng/L	0		1	0		1
HCH, alpha		ng/L	0.04	0.24	38	0	0	20
HCH, beta		ng/L	0	0	38	0.10	0.45	20
HCH, delta		ng/L	0.13	0.34	38	0	0	20
HCH, gamma		ng/L	0	0	38	0	0	20
Heptachlor		ng/L	0	0	39	0	0	21
Heptachlor epoxide		ng/L	0.21	0.70	39	0.10	0.30	21
Hexachlorobenzene		ng/L	0.18	0.68	38	0	0	20
Leptophos		ng/L	0	0	38	0	0	20
Malathion		ng/L	0	0	38	0	0	20
Merphos		ng/L	0	0	38	0	0	20
Methidathion		ng/L	0	0	38	0	0	20
Methoxychlor		ng/L	0	0	39	0	0	21
Mevinphos		ng/L	0	0	38	0	0	20
Mirex		ng/L	0	0	38	0	0	20
Molinate		ng/L	0	0	38	0	0	20
Naled		ng/L	0	0	38	0	0	20
Nonachlor, cis-		ng/L	0.03	0.16	38	0.05	0.22	20
Nonachlor, trans-		ng/L	0.05	0.23	38	0.05	0.22	20
Oxadiazon		ng/L	46.21	164.92	38	22.15	68.41	20
Oxychlordane		ng/L	0.11	0.31	38	0.05	0.22	20
Parathion, Ethyl		ng/L	0	0	38	0	0	20
Parathion, Methyl		ng/L	0	0	38	0	0	20
Phorate		ng/L	0	0	38	0	0	20
Phosmet		ng/L	0	0	38	0	0	20
Phosphamidon		ng/L	0	0	38	0	0	20
Prometon		ng/L	0	0	38	0	0	20
Prometryn		ng/L	0	0	38	0	0	20
Propazine		ng/L	0	0	38	0	0	20
Secbumeton		ng/L	3.11	13.48	38	1.75	7.83	20
Simazine		ng/L	0.89	5.52	38	35.90	100.34	20
Simetryn		ng/L	0	0	38	0	0	20
Sulfotep		ng/L	0	0	38	0	0	20
Tedion		ng/L	0.05	0.23	38	0	0	20

Appendix, continued.

			San Juan			Santa Margarita		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n
Terbufos		ng/L	0	0	38	0	0	20
Terbuthylazine		ng/L	0	0	38	0	0	20
Terbutryn		ng/L	0	0	38	0	0	20
Tetrachlorvinphos		ng/L	0	0	38	0	0	20
Thiobencarb		ng/L	3.95	24.33	38	0	0	20
Thionazin		ng/L	0	0	38	0	0	20
Tokuthion		ng/L	0	0	38	0	0	20
Toxaphene		ng/L	0		1	0		1
Trichlorfon		ng/L	0	0	38	0	0	20
Trichloronate		ng/L	0	0	38	0	0	20

Appendix, continued.

			San Luis Rey			Carlsbad		
Physical water quality and inorganics	Symbol	Units	Mean	SD	n	Mean	SD	n
Alkalinity as CaCO3	Alk	mg/l	198	84	25	252	43	41
Chloride		mg/l	95	129	3			0
Fine-ASTM		%			0	24.4	27.1	30
Fine-ASTM,Passing No. 200 Sieve		%			0	24.9	20.0	10
Oxygen, Dissolved	DO	mg/L	9.4	3.6	24			0
Oxygen, Saturation		%	98	39	24	102	32	40
pH		pH	7.7	0.4	24	7.9	1.5	40
Salinity	Sal	ppt	0.83	0.52	24			0
Specific conductivity	Cond	µS/cm	1516	968	24	3800	4232	40
Sulfate	SO_4	mg/l	382	264	25	469	277	41
Suspended Sediment Concentration		%			0			0
Temperature		ºC	17.1	4.5	24	18.5	3.0	40
Total Organic Carbon		mg/L			0	2.24		1
Total Suspended Solids		mg/L	45	79	25	15		1
Turbidity		NTU	12.0	19.0	24	3.5	3.9	40
Velocity		ft/s	0.5	0.9	25	0.7	1.4	41
Nutrients								
Ammonia as N	NH_3-N	mg/l	0.05	0.06	25	0.12	0.11	41
Nitrate + Nitrite as N		mg/l	5.13	5.50	25	6.35	11.47	41
Nitrate as N		mg/l	5.10	5.49	25	3.70		1
Nitrate as NO3	NO_3	mg/l			0	16.00		1
Nitrite as N		mg/l	0.03	0.04	25	0		1
Nitrogen, Total Kjeldahl		mg/l	0.89	1.18	25	0.49	0.20	41
OrthoPhosphate as P		mg/l	31.00		1	0.12	0.07	41
Phosphorus as P,Total	TP	mg/l	0.21	0.24	25	0.14	0.09	41
Metals								
Aluminum		µg/L	6.0	6.4	25	14.7	71.5	41
Arsenic	As	µg/L	1.3	0.9	25	4.7	2.6	41
Cadmium	Cd	µg/L	0.03	0.02	25	0.05	0.04	41
Chromium	Cr	µg/L	0.33	0.28	25	1.06	1.05	41
Copper	Cu	µg/L	4.03	2.60	25	3.55	1.50	41
Lead	Pb	µg/L	0.06	0.05	25	0.05	0.12	41
Manganese	Mn	µg/L	133	270	25	127	147	41
Nickel	Ni	µg/L	0.97	2.14	25	2.16	1.37	41
Selenium	Se	µg/L	4.9	4.8	24	10.6	10.1	40
Silver	Ag	µg/L	0.07	0.34	25	0.05	0.28	41
Zinc	Zi	µg/L	2.7	1.9	24	6.5	6.4	40
Bacteria								
Enterococcus		MPN/100 ml	93		1	490		1
Fecal Coliform		MPN/100 ml	170		1	900		1
Total Coliform		MPN/100 ml	1600		1	1600		1

Appendix, continued.

			San Luis Rey			Carlsbad		
PAHs	Symbol	Units	Mean	SD	n	Mean	SD	n
Acenaphthene		ng/L	0	0	25	1	5	41
Acenaphthylene		ng/L	0	0	25	0	0	41
Anthracene		ng/L	0	0	25	4	14	41
Benz(a)anthracene		ng/L	0	0	25	0	0	41
Benzo(a)pyrene		ng/L	0	0	25	0	0	41
Benzo(b)fluoranthene		ng/L	0	0	25	0	0	41
Benzo(e)pyrene		ng/L	0	0	25	0	0	41
Benzo(g,h,i)perylene		ng/L	0.3	1.3	25	0	0	41
Benzo(k)fluoranthene		ng/L	0	0	24	0	0	40
Biphenyl		ng/L	0	0	24	0	0	40
Chrysene		ng/L	0	0	25	0	0	41
Chrysenes, C1 -		ng/L	0	0	24	0	0	10
Chrysenes, C2 -		ng/L	0	0	24	0	0	10
Chrysenes, C3 -		ng/L	0	0	24	0	0	10
Dibenz(a,h)anthracene		ng/L	0	0	25	0	0	41
Dibenzothiophene		ng/L	0.3	1.7	24	0	0	10
Dibenzothiophenes, C1 -		ng/L	0	0	24	0	0	10
Dibenzothiophenes, C2 -		ng/L	0	0	24	0	0	10
Dibenzothiophenes, C3 -		ng/L	0	0	24	0	0	10
Dimethylnaphthalene, 2,6-		ng/L	0	1	24	0	0	40
Dimethylphenanthrene, 3,6-		ng/L	0	0	18			0
Fluoranthene		ng/L	0	0	25	0	0	41
Fluoranthene/Pyrenes, C1 -		ng/L	0	0	24	0	0	10
Fluorene		ng/L	0	0	25	1	4	41
Fluorenes, C1 -		ng/L	0	0	24	0	0	10
Fluorenes, C2 -		ng/L	0	0	24	28.82	5.41	10
Fluorenes, C3 -		ng/L	0	0	24	0	0	10
Indeno(1,2,3-c,d)pyrene		ng/L	0	0	25	0	0	41
Methyldibenzothiophene, 4-		ng/L	0	0	18			0
Methylfluoranthene, 2-		ng/L	0	0	18			0
Methylfluorene, 1-		ng/L	0	0	18			0
Methylnaphthalene, 1-		ng/L	0	0	24	0	0	40
Methylnaphthalene, 2-		ng/L	0	0	24	0	0	40
Methylphenanthrene, 1-		ng/L	0	0	24	0	0	40
Naphthalene		ng/L	0.20	1.01	25	4.27	11.60	41
Naphthalenes, C1 -		ng/L	0.46	2.25	24	0	0	10
Naphthalenes, C2 -		ng/L	1.34	3.81	24	0	0	10
Naphthalenes, C3 -		ng/L	0	0	24	0	0	10
Naphthalenes, C4 -		ng/L	0	0	24	0	0	10
Perylene		ng/L	0	0	24	0	0	40
Phenanthrene		ng/L	0	0	25	4	14	41
Phenanthrene/Anthracene, C1 -		ng/L	0	0	24	0	0	10
Phenanthrene/Anthracene, C2 -		ng/L	0	0	24	0	0	10
Phenanthrene/Anthracene, C3 -		ng/L	0	0	24	0	0	10
Phenanthrene/Anthracene, C4 -		ng/L	0	0	24	0	0	10
Pyrene		ng/L	0	0	25	0	0	41
Trimethylnaphthalene, 2,3,5-		ng/L	0	0	24	0	0	40

Appendix, continued.

			San Luis Rey			Carlsbad		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n
PCB 005		ng/L	0	0	24	0	0	40
PCB 008		ng/L	0	0	24	0	0	40
PCB 015		ng/L	0	0	24	0	0	40
PCB 018		ng/L	0	0	24	0	0	40
PCB 027		ng/L	0	0	24	0	0	40
PCB 028		ng/L	0	0	24	0	0	40
PCB 029		ng/L	0	0	24	0	0	40
PCB 031		ng/L	0	0	24	0	0	40
PCB 033		ng/L	0	0	24	0	0	40
PCB 044		ng/L	0	0	24	0	0	40
PCB 049		ng/L	0	0	24	0	0	40
PCB 052		ng/L	0	0	24	0	0	40
PCB 056		ng/L	0	0	24	0	0	40
PCB 060		ng/L	0	0	24	0	0	40
PCB 066		ng/L	0	0	24	0	0	40
PCB 070		ng/L	0	0	24	0	0	40
PCB 074		ng/L	0	0	24	0	0	40
PCB 087		ng/L	0	0	24	0	0	40
PCB 095		ng/L	0	0	24	0	0	40
PCB 097		ng/L	0	0	24	0	0	40
PCB 099		ng/L	0	0	24	0	0	40
PCB 101		ng/L	0	0	24	0	0	40
PCB 105		ng/L	0	0	24	0	0	40
PCB 110		ng/L	0	0	24	0	0	40
PCB 114		ng/L	0	0	24	0	0	40
PCB 118		ng/L	0	0	24	0	0	40
PCB 128		ng/L	0	0	24	0	0	40
PCB 137		ng/L	0	0	24	0	0	40
PCB 138		ng/L	0	0	24	0	0	40
PCB 141		ng/L	0	0	24	0	0	40
PCB 149		ng/L	0	0	24	0	0	40
PCB 151		ng/L	0	0	24	0	0	40
PCB 153		ng/L	0	0	24	0	0	40
PCB 156		ng/L	0	0	24	0	0	40
PCB 157		ng/L	0	0	24	0	0	40
PCB 158		ng/L	0	0	24	0	0	40
PCB 170		ng/L	0	0	24	0	0	40
PCB 174		ng/L	0	0	24	0	0	40
PCB 177		ng/L	0	0	24	0	0	40
PCB 180		ng/L	0	0	24	0	0	40
PCB 183		ng/L	0	0	24	0	0	40
PCB 187		ng/L	0	0	24	0	0	40
PCB 189		ng/L	0	0	24	0	0	40
PCB 194		ng/L	0	0	24	0	0	40
PCB 195		ng/L	0	0	24	0	0	40
PCB 200		ng/L	0	0	24	0	0	40
PCB 201		ng/L	0	0	24	0	0	40
PCB 203		ng/L	0	0	24	0	0	40
PCB 206		ng/L	0	0	24	0	0	40

Appendix, continued.

			San Luis Rey			Carlsbad		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n
PCB 209		ng/L	0	0	24	0	0	40
PCB-1016		ng/L	0		1	0		1
PCB-1221		ng/L	0		1	0		1
PCB-1232		ng/L	0		1	0		1
PCB-1242		ng/L	0		1	0		1
PCB-1248		ng/L	0		1	0		1
PCB-1254		ng/L	0		1	0		1
PCB-1260		ng/L	0		1	0		1
PCBs		ng/L	0	0	25	0	0	41
Pesticides								
Aldrin		ng/L	0	0	25	0.05	0.22	41
alpha-BHC		ng/L	0		1	0		1
Ametryn		ng/L	0	0	24	0	0	40
Aspon		ng/L	0	0	24	0	0	40
Atraton		ng/L	0	0	24	0	0	40
Atrazine		ng/L	8.13	39.80	24	11.88	27.66	40
Azinphos ethyl		ng/L	0	0	24	0	0	40
Azinphos methyl		ng/L	0	0	24	1.00	6.32	40
beta-BHC		ng/L	0		1	0		1
Bolstar		ng/L	0	0	24	0	0	40
Carbophenothion		ng/L	0	0	24	4.00	12.15	40
Chlordane (tech)		ng/L	0		1	0		1
Chlordane, cis-		ng/L	0.04	0.20	24	0.03	0.16	40
Chlordane, trans-		ng/L	0	0	24	0	0	40
Chlordene, alpha-		ng/L	0	0	24	0	0	40
Chlordene, gamma-		ng/L	0	0	24	0.35	1.44	40
Chlorfenvinphos		ng/L	0	0	24	0	0	40
Chlorpyrifos		ng/L	0	0	24	0	0	40
Chlorpyrifos methyl		ng/L	0	0	24	0	0	40
Ciodrin		ng/L	0	0	24	0	0	40
Coumaphos		ng/L	0	0	24	0	0	40
Dacthal		ng/L	0	0	24	0.23	0.49	40
DDD(o,p')		ng/L	0	0	24	0.08	0.35	40
DDD(p,p')		ng/L	0	0	25	0.05	0.22	41
DDE(o,p')		ng/L	0	0	24	0	0	40
DDE(p,p')		ng/L	0.04	0.20	25	1.37	2.24	41
DDMU(p,p')		ng/L	0	0	24	0	0	40
DDT(o,p')		ng/L	0	0	24	0	0	40
DDT(p,p')		ng/L	0	0	25	0.44	1.07	41
DDTs		ng/L	0.04	0.20	25	1.93	2.79	41
delta-BHC		ng/L	0		1	0		1
Demeton-s		ng/L	0	0	24	5.00	13.40	40
Diazinon		ng/L	0.67	2.43	24	68.39	101.40	40
Dichlofenthion		ng/L	0	0	24	0	0	40
Dichlorvos		ng/L	0	0	24	0	0	40
Dicrotophos		ng/L	0	0	24	1.00	6.32	40
Dieldrin		ng/L	0	0	25	0.02	0.16	41
Dimethoate		ng/L	0	0	24	6.00	14.46	40
Dioxathion		ng/L	0	0	24	4.00	12.15	40

Appendix, continued.

			San Luis Rey			Carlsbad		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n
Disulfoton		ng/L	0	0	24	33.33	38.29	40
Endosulfan I		ng/L	0	0	25	0.05	0.22	41
Endosulfan II		ng/L	0	0	25	0.43	1.31	41
Endosulfan sulfate		ng/L	0	0	25	0.02	0.16	41
Endrin		ng/L	0	0	25	0.08	0.37	41
Endrin Aldehyde		ng/L	0	0	25	0.51	1.73	41
Endrin Ketone		ng/L	0	0	24	0	0	40
Ethion		ng/L	0	0	24	0	0	40
Ethoprop		ng/L	0	0	24	0	0	40
Famphur		ng/L	0	0	24	0	0	40
Fenchlorphos		ng/L	0	0	24	0	0	40
Fenitrothion		ng/L	0	0	24	0	0	40
Fensulfothion		ng/L	0	0	24	0	0	40
Fenthion		ng/L	0	0	24	0	0	40
Fonofos		ng/L	0	0	24	0	0	40
gamma-BHC (Lindane)		ng/L	0		1	0		1
HCH, alpha		ng/L	0	0	24	0.33	0.88	40
HCH, beta		ng/L	0	0	24	0.46	2.54	40
HCH, delta		ng/L	0	0	24	0.15	0.43	40
HCH, gamma		ng/L	0	0	24	0.08	0.35	40
Heptachlor		ng/L	0	0	25	0	0	41
Heptachlor epoxide		ng/L	0	0	25	0	0	41
Hexachlorobenzene		ng/L	0	0	24	0.12	0.27	40
Leptophos		ng/L	0	0	24	0	0	40
Malathion		ng/L	0	0	24	0.93	5.85	40
Merphos		ng/L	0	0	24	0	0	40
Methidathion		ng/L	0	0	24	1.00	6.32	40
Methoxychlor		ng/L	0	0	25	0.02	0.16	41
Mevinphos		ng/L	0	0	24	5.00	13.40	40
Mirex		ng/L	0	0	24	0	0	40
Molinate		ng/L	0	0	24	0	0	40
Naled		ng/L	0	0	24	5.00	13.40	40
Nonachlor, cis-		ng/L	0	0	24	0	0	40
Nonachlor, trans-		ng/L	0	0	24	0.05	0.22	40
Oxadiazon		ng/L	5.08	8.87	24	64.74	292.81	40
Oxychlordane		ng/L	0	0	24	0	0	40
Parathion, Ethyl		ng/L	0	0	24	0	0	40
Parathion, Methyl		ng/L	0	0	24	0.75	4.74	40
Phorate		ng/L	0	0	24	0	0	40
Phosmet		ng/L	0	0	24	0	0	40
Phosphamidon		ng/L	0	0	24	0	0	40
Prometon		ng/L	0	0	24	7.18	20.81	40
Prometryn		ng/L	0	0	24	0	0	40
Propazine		ng/L	0	0	24	7.00	14.18	40
Secbumeton		ng/L	4.50	12.50	24	85.00	153.57	40
Simazine		ng/L	19.17	60.61	24	0	0	40
Simetryn		ng/L	0	0	24	0	0	40
Sulfotep		ng/L	0	0	24	0	0	40
Tedion		ng/L	0	0	24	0	0	40

Appendix, continued.

			San Luis Rey			Carlsbad		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n
Terbufos		ng/L	0	0	24	0	0	40
Terbuthylazine		ng/L	7.29	15.43	24	242.40	488.92	40
Terbutryn		ng/L	0	0	24	0	0	40
Tetrachlorvinphos		ng/L	0	0	24	1.00	6.32	40
Thiobencarb		ng/L	0	0	24	0	0	40
Thionazin		ng/L	0	0	24	0	0	40
Tokuthion		ng/L	0	0	24	0	0	40
Toxaphene		ng/L	0		1	0		1
Trichlorfon		ng/L	0	0	24	0	0	40
Trichloronate		ng/L	0	0	24	0	0	40

Appendix, continued.

			San Dieguito			Los Peñasquitos		
Physical water quality and inorganics	Symbol	Units	Mean	SD	n	Mean	SD	n
Alkalinity as CaCO3	Alk	mg/l	243	129	18	221	88	20
Chloride		mg/l			0			0
Fine-ASTM		%			0	33.3	31.8	13
Fine-ASTM,Passing No. 200 Sieve		%	18.1	7.1	7	32.2	53.0	3
Oxygen, Dissolved	DO	mg/L			0			0
Oxygen, Saturation		%	86	19	17	107	34	19
pH		pH	8.0	0.4	17	7.9	0.4	19
Salinity	Sal	ppt	2.53	5.47	17			0
Specific conductivity	Cond	µS/cm	4316	8781	17	2981	1256	19
Sulfate	SO_4	mg/l	358	367	18	674	407	20
Suspended Sediment Concentration		%			0			0
Temperature		ºC	15.1	6.0	17	19.4	4.4	19
Total Organic Carbon		mg/L			0			0
Total Suspended Solids		mg/L	18	23	18	0		1
Turbidity		NTU	5.9	5.3	17	14.5	26.2	19
Velocity		ft/s	0.3	0.5	18	1.1	1.5	20
Nutrients								
Ammonia as N	NH_3-N	mg/l	0.10	0.12	18	0.09	0.06	20
Nitrate + Nitrite as N		mg/l	0.44	0.60	18	0.52	0.70	20
Nitrate as N		mg/l	0.42	0.58	18	0		1
Nitrate as NO3	NO_3	mg/l	1.96	2.58	17	0		1
Nitrite as N		mg/l	0.02	0.03	18	0		1
Nitrogen, Total Kjeldahl		mg/l	1.08	0.81	18	0.58	0.55	20
OrthoPhosphate as P		mg/l	0.16	0.15	18	0.04	0.04	20
Phosphorus as P,Total	TP	mg/l	0.24	0.35	18	0.10	0.16	20
Metals								
Aluminum		µg/L	3.9	5.4	18	5.7	7.5	20
Arsenic	As	µg/L	2.1	1.7	18	3.4	0.8	20
Cadmium	Cd	µg/L	0.03	0.03	18	0.02	0.01	20
Chromium	Cr	µg/L	0.18	0.17	18	0.89	0.97	20
Copper	Cu	µg/L	2.41	1.76	18	4.03	1.58	20
Lead	Pb	µg/L	0.03	0.03	18	0.05	0.08	20
Manganese	Mn	µg/L	135	135	18	141	156	20
Nickel	Ni	µg/L	0.70	0.79	18	3.38	3.55	20
Selenium	Se	µg/L	3.7	5.4	17	7.8	3.7	19
Silver	Ag	µg/L	0.00	0.00	18	0.06	0.25	20
Zinc	Zi	µg/L	2.2	1.7	17	8.4	8.7	19
Bacteria								
Enterococcus		MPN/100 ml	2400		1	11		1
Fecal Coliform		MPN/100 ml	240		1	500		1
Total Coliform		MPN/100 ml	1600		1	1600		1

Appendix, continued.

			San Dieguito			Los Peñasquitos		
PAHs	Symbol	Units	Mean	SD	n	Mean	SD	n
Acenaphthene		ng/L	0	0	18	0	0	20
Acenaphthylene		ng/L	0	0	18	0	0	20
Anthracene		ng/L	0	0	18	0	0	20
Benz(a)anthracene		ng/L	0	0	18	0	0	20
Benzo(a)pyrene		ng/L	1.0	4.4	18	0	0	20
Benzo(b)fluoranthene		ng/L	3.0	5.9	18	0	0	20
Benzo(e)pyrene		ng/L	0.9	4.0	18	0	0	20
Benzo(g,h,i)perylene		ng/L	10.1	42.9	18	0	0	20
Benzo(k)fluoranthene		ng/L	0	0	17	0	0	19
Biphenyl		ng/L	0	0	17	0	0	19
Chrysene		ng/L	0	0	18	0	0	20
Chrysenes, C1 -		ng/L	0	0	17	0	0	4
Chrysenes, C2 -		ng/L	3.9	16.2	17	0	0	4
Chrysenes, C3 -		ng/L	0.7	3.0	17	0	0	4
Dibenz(a,h)anthracene		ng/L	0	0	18	0	0	20
Dibenzothiophene		ng/L	0	0	17	0	0	4
Dibenzothiophenes, C1 -		ng/L	6.6	8.4	17	0	0	4
Dibenzothiophenes, C2 -		ng/L	13.6	13.0	17	0	0	4
Dibenzothiophenes, C3 -		ng/L	4.5	9.9	17	0	0	4
Dimethylnaphthalene, 2,6-		ng/L	2	8	17	0	0	19
Dimethylphenanthrene, 3,6-		ng/L			0			0
Fluoranthene		ng/L	6.99	24.36	18	0	0	20
Fluoranthene/Pyrenes, C1 -		ng/L	0.63	2.60	17	0	0	4
Fluorene		ng/L	0	0	18	0	0	20
Fluorenes, C1 -		ng/L	1.29	3.65	17	0	0	4
Fluorenes, C2 -		ng/L	0	0	17	27.93	2.53	4
Fluorenes, C3 -		ng/L	2.93	5.49	17	8.28	16.55	4
Indeno(1,2,3-c,d)pyrene		ng/L	2.93	12.42	18	0	0	20
Methyldibenzothiophene, 4-		ng/L			0			0
Methylfluoranthene, 2-		ng/L			0			0
Methylfluorene, 1-		ng/L			0			0
Methylnaphthalene, 1-		ng/L	0	0	17	0	0	19
Methylnaphthalene, 2-		ng/L	0	0	17	0	0	19
Methylphenanthrene, 1-		ng/L	1	6	17	0	0	19
Naphthalene		ng/L	0	0	18	1.75	7.83	20
Naphthalenes, C1 -		ng/L	0	0	17	0	0	4
Naphthalenes, C2 -		ng/L	2.81	11.57	17	0	0	4
Naphthalenes, C3 -		ng/L	2.06	5.82	17	5.45	10.90	4
Naphthalenes, C4 -		ng/L	1.25	3.52	17	0	0	4
Perylene		ng/L	0	0	17	0	0	19
Phenanthrene		ng/L	2	11	18	0	0	20
Phenanthrene/Anthracene, C1 -		ng/L	7.96	15.35	17	0	0	4
Phenanthrene/Anthracene, C2 -		ng/L	3.74	7.48	17	0	0	4
Phenanthrene/Anthracene, C3 -		ng/L	3.28	10.12	17	0	0	4
Phenanthrene/Anthracene, C4 -		ng/L	0.64	2.64	17	0	0	4
Pyrene		ng/L	24.61	82.69	18	0	0	20
Trimethylnaphthalene, 2,3,5-		ng/L	0	0	17	0	0	19

			San Dieguito			Los Peñasquitos		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n
PCB 005		ng/L	0	0	17	0	0	19
PCB 008		ng/L	0	0	17	0	0	19
PCB 015		ng/L	0	0	17	0	0	19
PCB 018		ng/L	0	0	17	0	0	19
PCB 027		ng/L	0	0	17	0	0	19
PCB 028		ng/L	0	0	17	0	0	19
PCB 029		ng/L	0	0	17	0	0	19
PCB 031		ng/L	0	0	17	0	0	19
PCB 033		ng/L	0	0	17	0	0	19
PCB 044		ng/L	0	0	17	0	0	19
PCB 049		ng/L	0	0	17	0	0	19
PCB 052		ng/L	0	0	17	0	0	19
PCB 056		ng/L	0	0	17	0	0	19
PCB 060		ng/L	0	0	17	0	0	19
PCB 066		ng/L	0	0	17	0	0	19
PCB 070		ng/L	0	0	17	0	0	19
PCB 074		ng/L	0	0	17	0	0	19
PCB 087		ng/L	0	0	17	0	0	19
PCB 095		ng/L	0	0	17	0	0	19
PCB 097		ng/L	0	0	17	0	0	19
PCB 099		ng/L	0	0	17	0	0	19
PCB 101		ng/L	0	0	17	0	0	19
PCB 105		ng/L	0	0	17	0	0	19
PCB 110		ng/L	0	0	17	0	0	19
PCB 114		ng/L	0	0	17	0	0	19
PCB 118		ng/L	0	0	17	0	0	19
PCB 128		ng/L	0	0	17	0	0	19
PCB 137		ng/L	0	0	17	0	0	19
PCB 138		ng/L	0	0	17	0	0	19
PCB 141		ng/L	0	0	17	0	0	19
PCB 149		ng/L	0	0	17	0	0	19
PCB 151		ng/L	0	0	17	0	0	19
PCB 153		ng/L	0	0	17	0	0	19
PCB 156		ng/L	0	0	17	0	0	19
PCB 157		ng/L	0	0	17	0	0	19
PCB 158		ng/L	0	0	17	0	0	19
PCB 170		ng/L	0	0	17	0	0	19
PCB 174		ng/L	0	0	17	0	0	19
PCB 177		ng/L	0	0	17	0	0	19
PCB 180		ng/L	0	0	17	0	0	19
PCB 183		ng/L	0	0	17	0	0	19
PCB 187		ng/L	0	0	17	0	0	19
PCB 189		ng/L	0	0	17	0	0	19
PCB 194		ng/L	0	0	17	0	0	19
PCB 195		ng/L	0	0	17	0	0	19
PCB 200		ng/L	0	0	17	0	0	19
PCB 201		ng/L	0	0	17	0	0	19
PCB 203		ng/L	0	0	17	0	0	19
PCB 206		ng/L	0	0	17	0	0	19

Appendix, continued.

			San Dieguito			Los Peñasquitos		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n
PCB 209		ng/L	0	0	17	0	0	19
PCB-1016		ng/L	0		1	0		1
PCB-1221		ng/L	0		1	0		1
PCB-1232		ng/L	0		1	0		1
PCB-1242		ng/L	0		1	0		1
PCB-1248		ng/L	0		1	0		1
PCB-1254		ng/L	0		1	0		1
PCB-1260		ng/L	0		1	0		1
PCBs		ng/L	0	0	18	0	0	20
Pesticides								
Aldrin		ng/L	0	0	18	0.15	0.67	20
alpha-BHC		ng/L	0		1	0		1
Ametryn		ng/L	0	0	17	0	0	19
Aspon		ng/L	0	0	17	0	0	19
Atraton		ng/L	0	0	17	6.84	29.82	19
Atrazine		ng/L	0	0	17	28.68	35.70	19
Azinphos ethyl		ng/L	0	0	17	0	0	19
Azinphos methyl		ng/L	0	0	17	4.21	12.61	19
beta-BHC		ng/L	0		1	0		1
Bolstar		ng/L	0	0	17	0	0	19
Carbophenothion		ng/L	0	0	17	9.37	19.00	19
Chlordane (tech)		ng/L	0		1	0		1
Chlordane, cis-		ng/L	0.06	0.24	17	0	0	19
Chlordane, trans-		ng/L	0	0	17	0	0	19
Chlordene, alpha-		ng/L	0	0	17	0.63	2.75	19
Chlordene, gamma-		ng/L	0	0	17	0.37	1.16	19
Chlorfenvinphos		ng/L	0	0	17	0	0	19
Chlorpyrifos		ng/L	0	0	17	0	0	19
Chlorpyrifos methyl		ng/L	0	0	17	0	0	19
Ciodrin		ng/L	0	0	17	0	0	19
Coumaphos		ng/L	0	0	17	2.63	11.47	19
Dacthal		ng/L	0	0	17	0.16	0.37	19
DDD(o,p')		ng/L	0	0	17	0	0	19
DDD(p,p')		ng/L	0	0	18	0.05	0.22	20
DDE(o,p')		ng/L	0	0	17	0	0	19
DDE(p,p')		ng/L	0.17	0.51	18	5.30	12.71	20
DDMU(p,p')		ng/L	0	0	17	0	0	19
DDT(o,p')		ng/L	0	0	17	0	0	19
DDT(p,p')		ng/L	0.11	0.47	18	0.30	0.92	20
DDTs		ng/L	0.28	0.96	18	5.65	12.75	20
delta-BHC		ng/L	0		1	0		1
Demeton-s		ng/L	0	0	17	0	0	19
Diazinon		ng/L	12.64	14.90	17	50.81	51.65	19
Dichlofenthion		ng/L	0	0	17	0	0	19
Dichlorvos		ng/L	0	0	17	0	0	19
Dicrotophos		ng/L	0	0	17	7.37	17.90	19
Dieldrin		ng/L	0.11	0.32	18	0	0	20
Dimethoate		ng/L	0	0	17	24.68	35.77	19
Dioxathion		ng/L	0	0	17	10.53	18.10	19

Appendix, continued.

Pesticides	Symbol	Units	San Dieguito Mean	SD	n	Los Peñasquitos Mean	SD	n
Disulfoton		ng/L	0	0	17	52.92	64.68	19
Endosulfan I		ng/L	0.06	0.24	18	0.05	0.22	20
Endosulfan II		ng/L	0	0	18	0.54	1.54	20
Endosulfan sulfate		ng/L	0.06	0.24	18	0.05	0.22	20
Endrin		ng/L	0	0	18	0.05	0.22	20
Endrin Aldehyde		ng/L	0	0	18	0.15	0.67	20
Endrin Ketone		ng/L	0	0	17	0	0	19
Ethion		ng/L	0	0	17	0	0	19
Ethoprop		ng/L	0	0	17	2.11	9.18	19
Famphur		ng/L	0	0	17	0	0	19
Fenchlorphos		ng/L	0	0	17	0	0	19
Fenitrothion		ng/L	0	0	17	0	0	19
Fensulfothion		ng/L	0	0	17	0	0	19
Fenthion		ng/L	0	0	17	4.21	12.61	19
Fonofos		ng/L	1.57	6.48	17	0	0	19
gamma-BHC (Lindane)		ng/L	0		1	0		1
HCH, alpha		ng/L	0	0	17	2.05	8.71	19
HCH, beta		ng/L	0	0	17	0.42	1.39	19
HCH, delta		ng/L	0.06	0.24	17	0.05	0.23	19
HCH, gamma		ng/L	0.06	0.24	17	0.05	0.23	19
Heptachlor		ng/L	0	0	18	0	0	20
Heptachlor epoxide		ng/L	0.11	0.32	18	0	0	20
Hexachlorobenzene		ng/L	0	0	17	0.15	0.29	19
Leptophos		ng/L	0	0	17	0	0	19
Malathion		ng/L	0	0	17	18.95	82.59	19
Merphos		ng/L	0	0	17	0	0	19
Methidathion		ng/L	0	0	17	0	0	19
Methoxychlor		ng/L	0	0	18	0.05	0.22	20
Mevinphos		ng/L	0	0	17	8.97	17.97	19
Mirex		ng/L	0.06	0.24	17	0	0	19
Molinate		ng/L	0	0	17	15.79	37.46	19
Naled		ng/L	0	0	17	10.53	18.10	19
Nonachlor, cis-		ng/L	0	0	17	0	0	19
Nonachlor, trans-		ng/L	0	0	17	0	0	19
Oxadiazon		ng/L	8.65	15.04	17	47.01	44.26	19
Oxychlordane		ng/L	0	0	17	0	0	19
Parathion, Ethyl		ng/L	0	0	17	2.11	9.18	19
Parathion, Methyl		ng/L	0	0	17	8.26	23.47	19
Phorate		ng/L	0	0	17	0	0	19
Phosmet		ng/L	0	0	17	0	0	19
Phosphamidon		ng/L	0	0	17	0	0	19
Prometon		ng/L	0	0	17	0	0	19
Prometryn		ng/L	0	0	17	0	0	19
Propazine		ng/L	0	0	17	17.11	35.25	19
Secbumeton		ng/L	0	0	17	131.16	147.98	19
Simazine		ng/L	0	0	17	0	0	19
Simetryn		ng/L	0	0	17	0	0	19
Sulfotep		ng/L	0	0	17	0	0	19
Tedion		ng/L	0.12	0.33	17	0	0	19

Appendix, Continued.

			San Dieguito			Los Peñasquitos		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n
Terbufos		ng/L	0	0	17	0	0	19
Terbuthylazine		ng/L	0	0	17	380.37	373.84	19
Terbutryn		ng/L	0	0	17	0	0	19
Tetrachlorvinphos		ng/L	0	0	17	0	0	19
Thiobencarb		ng/L	0	0	17	69.74	218.99	19
Thionazin		ng/L	0	0	17	0	0	19
Tokuthion		ng/L	0	0	17	2.11	9.18	19
Toxaphene		ng/L	0		1	0		1
Trichlorfon		ng/L	0	0	17	0	0	19
Trichloronate		ng/L	0	0	17	2.11	9.18	19

Appendix, continued.

			San Diego			Pueblo San Diego		
Physical water quality and inorganics	Symbol	Units	Mean	SD	n	Mean	SD	n
Alkalinity as CaCO3	Alk	mg/l	242	85	27	191	15	5
Chloride		mg/l	330		1			0
Fine-ASTM		%			0			0
Fine-ASTM,Passing No. 200 Sieve		%			0			0
Oxygen, Dissolved	DO	mg/L	9.5	3.0	26	113.3	198.9	4
Oxygen, Saturation		%	102	32	26	175	98	4
pH		pH	8.0	0.3	26	8.8	0.8	4
Salinity	Sal	ppt	1.00	0.45	26	4.19	5.66	4
Specific conductivity	Cond	µS/cm	1872	830	26	6925	9619	4
Sulfate	SO_4	mg/l	283	159	27	437	394	5
Suspended Sediment Concentration		%			0			0
Temperature		ºC	19.3	4.1	26	25.7	5.4	4
Total Organic Carbon		mg/L			0			0
Total Suspended Solids		mg/L	34	104	27	38	42	5
Turbidity		NTU	7.2	8.9	26	6.2	7.4	4
Velocity		ft/s	0.8	1.1	27	4.0	8.9	5
Nutrients								
Ammonia as N	NH_3-N	mg/l	0.05	0.05	27	0.05	0.05	5
Nitrate + Nitrite as N		mg/l	15.64	57.07	27	0.41	0.47	5
Nitrate as N		mg/l	15.62	57.08	27	0.39	0.45	5
Nitrate as NO3	NO_3	mg/l			0	0		1
Nitrite as N		mg/l	0.03	0.04	27	0.02	0.02	5
Nitrogen, Total Kjeldahl		mg/l	0.79	0.36	26	1.81	0.45	5
OrthoPhosphate as P		mg/l	0.10		1	32.00		1
Phosphorus as P,Total	TP	mg/l	0.12	0.09	27	0.25	0.07	5
Metals								
Aluminum		µg/L	7.9	9.0	27	7.4	9.4	5
Arsenic	As	µg/L	3.2	2.4	27	2.5	1.5	5
Cadmium	Cd	µg/L	0.03	0.02	27	0.08	0.05	5
Chromium	Cr	µg/L	0.64	0.74	27	1.22	0.79	5
Copper	Cu	µg/L	4.16	2.06	27	8.23	3.94	5
Lead	Pb	µg/L	0.09	0.08	27	0.51	0.28	5
Manganese	Mn	µg/L	60	116	27	61	67	5
Nickel	Ni	µg/L	1.15	1.92	27	3.99	2.81	5
Selenium	Se	µg/L	8.1	6.8	26	77.5	115.8	4
Silver	Ag	µg/L	0.00	0.00	27	0.13	0.27	5
Zinc	Zi	µg/L	3.9	2.3	26	13.6	4.1	4
Bacteria								
Enterococcus		MPN/100 ml	520		1	11		1
Fecal Coliform		MPN/100 ml	900		1	900		1
Total Coliform		MPN/100 ml	1600		1	1600		1

Appendix, continued.

			San Diego			Pueblo San Diego		
PAHs	Symbol	Units	Mean	SD	n	Mean	SD	n
Acenaphthene		ng/L	1	3	27	0	0	5
Acenaphthylene		ng/L	0	0	27	0	0	5
Anthracene		ng/L	0	0	27	0	0	5
Benz(a)anthracene		ng/L	0	2	27	3	7	5
Benzo(a)pyrene		ng/L	0.6	3.0	27	4.6	10.3	5
Benzo(b)fluoranthene		ng/L	0.8	4.0	27	5.8	13.0	5
Benzo(e)pyrene		ng/L	0.4	2.3	27	0	0	5
Benzo(g,h,i)perylene		ng/L	0.8	4.3	27	5.9	13.2	5
Benzo(k)fluoranthene		ng/L	0	0	26	7.3	14.5	4
Biphenyl		ng/L	0	0	26	0	0	4
Chrysene		ng/L	0.3	1.5	27	4.3	9.6	5
Chrysenes, C1 -		ng/L	0	0	26	0	0	4
Chrysenes, C2 -		ng/L	0	0	26	0	0	4
Chrysenes, C3 -		ng/L	0	0	26	0	0	4
Dibenz(a,h)anthracene		ng/L	0	0	27	6.4	14.4	5
Dibenzothiophene		ng/L	0	0	26	3.7	7.5	4
Dibenzothiophenes, C1 -		ng/L	0	0	26	18.4	32.9	4
Dibenzothiophenes, C2 -		ng/L	0	0	26	35.6	65.5	4
Dibenzothiophenes, C3 -		ng/L	0	0	26	1.4	2.8	4
Dimethylnaphthalene, 2,6-		ng/L	0	0	26	4	7	4
Dimethylphenanthrene, 3,6-		ng/L	0	0	19	0	0	4
Fluoranthene		ng/L	0.68	3.54	27	4.68	6.69	5
Fluoranthene/Pyrenes, C1 -		ng/L	0.60	3.04	26	0	0	4
Fluorene		ng/L	0	0	27	0	0	5
Fluorenes, C1 -		ng/L	0	0	26	0	0	4
Fluorenes, C2 -		ng/L	0	0	26	0	0	4
Fluorenes, C3 -		ng/L	0	0	26	17.38	34.75	4
Indeno(1,2,3-c,d)pyrene		ng/L	0.83	4.33	27	7.14	15.97	5
Methyldibenzothiophene, 4-		ng/L	0	0	19	2.38	4.76	4
Methylfluoranthene, 2-		ng/L	0	0	19	0	0	4
Methylfluorene, 1-		ng/L	0	0	19	0	0	4
Methylnaphthalene, 1-		ng/L	0	0	26	0	0	4
Methylnaphthalene, 2-		ng/L	0	0	26	0	0	4
Methylphenanthrene, 1-		ng/L	0	0	26	0	0	4
Naphthalene		ng/L	0.19	0.97	27	1.23	2.76	5
Naphthalenes, C1 -		ng/L	0	0	26	0	0	4
Naphthalenes, C2 -		ng/L	0.51	1.80	26	4.93	9.85	4
Naphthalenes, C3 -		ng/L	1.15	3.31	26	7.43	8.64	4
Naphthalenes, C4 -		ng/L	0	0	26	2.90	5.80	4
Perylene		ng/L	0	0	26	0	0	4
Phenanthrene		ng/L	0	1	27	5	7	5
Phenanthrene/Anthracene, C1 -		ng/L	0.77	2.72	26	6.90	8.29	4
Phenanthrene/Anthracene, C2 -		ng/L	0.63	2.23	26	11.00	14.07	4
Phenanthrene/Anthracene, C3 -		ng/L	0	0	26	2.55	5.10	4
Phenanthrene/Anthracene, C4 -		ng/L	0	0	26	0	0	4
Pyrene		ng/L	0.77	3.98	27	1.45	3.23	5
Trimethylnaphthalene, 2,3,5-		ng/L	0	0	26	0	0	4

Appendix, continued.

			San Diego			Pueblo San Diego		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n
PCB 005		ng/L	0	0	26	0	0	4
PCB 008		ng/L	0	0	26	0	0	4
PCB 015		ng/L	0	0	26	0	0	4
PCB 018		ng/L	0	0	26	0	0	4
PCB 027		ng/L	0	0	26	0	0	4
PCB 028		ng/L	0	0	26	0	0	4
PCB 029		ng/L	0	0	26	0	0	4
PCB 031		ng/L	0	0	26	0	0	4
PCB 033		ng/L	0	0	26	0	0	4
PCB 044		ng/L	0	0	26	0	0	4
PCB 049		ng/L	0	0	26	0	0	4
PCB 052		ng/L	0	0	26	0	0	4
PCB 056		ng/L	0	0	26	0	0	4
PCB 060		ng/L	0	0	26	0	0	4
PCB 066		ng/L	0	0	26	0	0	4
PCB 070		ng/L	0	0	26	0	0	4
PCB 074		ng/L	0	0	26	0	0	4
PCB 087		ng/L	0	0	26	0	0	4
PCB 095		ng/L	0	0	26	0	0	4
PCB 097		ng/L	0	0	26	0	0	4
PCB 099		ng/L	0	0	26	0	0	4
PCB 101		ng/L	0	0	26	0	0	4
PCB 105		ng/L	0	0	26	0	0	4
PCB 110		ng/L	0	0	26	0	0	4
PCB 114		ng/L	0	0	26	0	0	4
PCB 118		ng/L	0	0	26	0	0	4
PCB 128		ng/L	0	0	26	0	0	4
PCB 137		ng/L	0	0	26	0	0	4
PCB 138		ng/L	0	0	26	0	0	4
PCB 141		ng/L	0	0	26	0	0	4
PCB 149		ng/L	0	0	26	0	0	4
PCB 151		ng/L	0	0	26	0	0	4
PCB 153		ng/L	0	0	26	0	0	4
PCB 156		ng/L	0	0	26	0	0	4
PCB 157		ng/L	0	0	26	0	0	4
PCB 158		ng/L	0	0	26	0	0	4
PCB 170		ng/L	0	0	26	0	0	4
PCB 174		ng/L	0	0	26	0	0	4
PCB 177		ng/L	0	0	26	0	0	4
PCB 180		ng/L	0	0	26	0	0	4
PCB 183		ng/L	0	0	26	0	0	4
PCB 187		ng/L	0	0	26	0	0	4
PCB 189		ng/L	0	0	26	0	0	4
PCB 194		ng/L	0	0	26	0	0	4
PCB 195		ng/L	0	0	26	0	0	4
PCB 200		ng/L	0	0	26	0	0	4
PCB 201		ng/L	0	0	26	0	0	4
PCB 203		ng/L	0	0	26	0	0	4
PCB 206		ng/L	0	0	26	0	0	4

Appendix, continued.

			San Diego			Pueblo San Diego		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n
PCB 209		ng/L	0	0	26	0	0	4
PCB-1016		ng/L	0		1	0		1
PCB-1221		ng/L	0		1	0		1
PCB-1232		ng/L	0		1	0		1
PCB-1242		ng/L	0		1	0		1
PCB-1248		ng/L	0		1	0		1
PCB-1254		ng/L	0		1	0		1
PCB-1260		ng/L	0		1	0		1
PCBs		ng/L	0	0	27	0	0	5
Pesticides								
Aldrin		ng/L	0	0	27	0	0	5
alpha-BHC		ng/L	0		1	0		1
Ametryn		ng/L	0	0	26			0
Aspon		ng/L	0	0	26	0	0	4
Atraton		ng/L	0	0	26			0
Atrazine		ng/L	3.27	16.67	26			0
Azinphos ethyl		ng/L	0	0	26	0	0	4
Azinphos methyl		ng/L	0	0	26	0	0	4
beta-BHC		ng/L	0		1	0		1
Bolstar		ng/L	0	0	26	0	0	4
Carbophenothion		ng/L	0	0	26	0	0	4
Chlordane (tech)		ng/L	0		1	0		1
Chlordane, cis-		ng/L	0	0	26	0	0	4
Chlordane, trans-		ng/L	0	0	26	0	0	4
Chlordene, alpha-		ng/L	0	0	26	0	0	4
Chlordene, gamma-		ng/L	0	0	26	0	0	4
Chlorfenvinphos		ng/L	0	0	26	0	0	4
Chlorpyrifos		ng/L	0	0	26	0	0	4
Chlorpyrifos methyl		ng/L	0	0	26	0	0	4
Ciodrin		ng/L	0	0	26	0	0	4
Coumaphos		ng/L	0	0	26	0	0	4
Dacthal		ng/L	0	0	26	0	0	4
DDD(o,p')		ng/L	0	0	26	0	0	4
DDD(p,p')		ng/L	0	0	27	0	0	5
DDE(o,p')		ng/L	0	0	26	0	0	4
DDE(p,p')		ng/L	0	0	27	0	0	5
DDMU(p,p')		ng/L	0	0	26	0	0	4
DDT(o,p')		ng/L	0	0	26	0	0	4
DDT(p,p')		ng/L	0	0	27	0	0	5
DDTs		ng/L	0	0	27	0	0	5
delta-BHC		ng/L	0		1	0		1
Demeton-s		ng/L	0	0	26	0	0	4
Diazinon		ng/L	1.73	5.50	26	26.25	29.17	4
Dichlofenthion		ng/L	0	0	26	0	0	4
Dichlorvos		ng/L	0	0	26	0	0	4
Dicrotophos		ng/L	0	0	26	0	0	4
Dieldrin		ng/L	0	0	27	0	0	5
Dimethoate		ng/L	0	0	26	0	0	4
Dioxathion		ng/L	0	0	26	73.50	94.18	4

Appendix, continued.

			San Diego			Pueblo San Diego		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n
Disulfoton		ng/L	0	0	26	13.25	26.50	4
Endosulfan I		ng/L	0	0	27	0	0	5
Endosulfan II		ng/L	0	0	27	0	0	5
Endosulfan sulfate		ng/L	0	0	27	0	0	5
Endrin		ng/L	0	0	27	0	0	5
Endrin Aldehyde		ng/L	0	0	27	0	0	5
Endrin Ketone		ng/L	0	0	26	0	0	4
Ethion		ng/L	0	0	26	0	0	4
Ethoprop		ng/L	0	0	26	0	0	4
Famphur		ng/L	0	0	26	0	0	4
Fenchlorphos		ng/L	0	0	26	0	0	4
Fenitrothion		ng/L	0	0	26	0	0	4
Fensulfothion		ng/L	0	0	26	0	0	4
Fenthion		ng/L	0	0	26	0	0	4
Fonofos		ng/L	0	0	26	0	0	4
gamma-BHC (Lindane)		ng/L	0		1	0		1
HCH, alpha		ng/L	0	0	26	0	0	4
HCH, beta		ng/L	0	0	26	0	0	4
HCH, delta		ng/L	0	0	26	0	0	4
HCH, gamma		ng/L	0	0	26	0	0	4
Heptachlor		ng/L	0	0	27	0	0	5
Heptachlor epoxide		ng/L	0	0	27	0	0	5
Hexachlorobenzene		ng/L	0	0	26	0	0	4
Leptophos		ng/L	0	0	26	0	0	4
Malathion		ng/L	1.27	6.47	26	0	0	4
Merphos		ng/L	0	0	26	0	0	4
Methidathion		ng/L	0	0	26	0	0	4
Methoxychlor		ng/L	0	0	27	0	0	5
Mevinphos		ng/L	0	0	26	0	0	4
Mirex		ng/L	0	0	26	0	0	4
Molinate		ng/L	0	0	26	0	0	4
Naled		ng/L	0	0	26	0	0	4
Nonachlor, cis-		ng/L	0	0	26	0	0	4
Nonachlor, trans-		ng/L	0	0	26	0	0	4
Oxadiazon		ng/L	7.23	9.52	26	19.00	15.53	4
Oxychlordane		ng/L	0	0	26	0	0	4
Parathion, Ethyl		ng/L	0	0	26	0	0	4
Parathion, Methyl		ng/L	0	0	26	0	0	4
Phorate		ng/L	0	0	26	0	0	4
Phosmet		ng/L	0	0	26	0	0	4
Phosphamidon		ng/L	0	0	26	0	0	4
Prometon		ng/L	0	0	26			0
Prometryn		ng/L	0	0	26			0
Propazine		ng/L	8.23	26.98	26			0
Secbumeton		ng/L	12.92	48.18	26			0
Simazine		ng/L	10.46	25.68	26			0
Simetryn		ng/L	0	0	26			0
Sulfotep		ng/L	0	0	26	0	0	4
Tedion		ng/L	0	0	26	0	0	4

Appendix, continued.

			San Diego			Pueblo San Diego		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n
Terbufos		ng/L	0	0	26	0	0	4
Terbuthylazine		ng/L	16.42	64.61	26			0
Terbutryn		ng/L	0	0	26			0
Tetrachlorvinphos		ng/L	0	0	26	0	0	4
Thiobencarb		ng/L	4.46	22.75	26	0	0	4
Thionazin		ng/L	0	0	26	0	0	4
Tokuthion		ng/L	0	0	26	0	0	4
Toxaphene		ng/L	0		1	0		1
Trichlorfon		ng/L	0	0	26	0	0	4
Trichloronate		ng/L	0	0	26	0	0	4

Appendix, continued.

			Sweetwater			Otay			Tijuana		
Physical water quality and inorganics	Symbol	Units	Mean	SD	n	Mean	SD	n	Mean	SD	n
Alkalinity as CaCO3	Alk	mg/l	191	92	15	233	21	7	400	164	12
Chloride		mg/l	1740	622	2			0			0
Fine-ASTM		%			0			0			0
Fine-ASTM,Passing No. 200 Sieve		%			0	2.3		1			0
Oxygen, Dissolved	DO	mg/L	9.2	2.0	14			0	8.3	4.3	12
Oxygen, Saturation		%	99	25	14	123	31	5	90	51	12
pH		pH	8.0	0.4	14	7.8	0.3	5	7.9	0.7	12
Salinity	Sal	ppt	1.85	1.57	14	1.30	0.85	5	0.76	0.46	12
Specific conductivity	Cond	µS/cm	3930	3649	14	2478	1539	5	1482	887	12
Sulfate	SO_4	mg/l	276	190	15	217	40	7	201	133	12
Suspended Sediment Concentration		%			0			0			0
Temperature		ºC	17.9	6.7	14	15.5	2.1	5	19.4	7.0	12
Total Organic Carbon		mg/L			0			0			0
Total Suspended Solids		mg/L	7	6	14	22	37	7	36	51	12
Turbidity		NTU	4.1	5.0	14	2.5	1.4	5	12.3	13.3	12
Velocity		ft/s	1.1	1.2	15	1.2	1.8	6	0.8	1.2	12
Nutrients											
Ammonia as N	NH_3-N	mg/l	0.06	0.05	15	0.08	0.10	7	11.33	16.63	12
Nitrate + Nitrite as N		mg/l	5.21	8.04	15	2.11	2.11	7	0.23	0.32	12
Nitrate as N		mg/l	5.19	8.01	15	2.08	2.07	7	0.18	0.33	12
Nitrate as NO3	NO_3	mg/l			0	9.21	9.14	7			0
Nitrite as N		mg/l	0.02	0.03	15	0.03	0.04	7	0.05	0.11	12
Nitrogen, Total Kjeldahl		mg/l	0.72	0.35	15	0.73	0.37	7	13.00	15.53	12
OrthoPhosphate as P		mg/l	0.02		1	2.01	5.29	7			0
Phosphorus as P,Total	TP	mg/l	0.06	0.04	15	0.01	0.02	7	3.31	3.70	12
Metals											
Aluminum		µg/L	5.5	8.2	15	1.3	2.0	7	5.7	5.1	12
Arsenic	As	µg/L	11.5	16.8	15	7.7	6.0	7	3.7	2.6	12
Cadmium	Cd	µg/L	0.02	0.02	15	0.02	0.01	7	0.06	0.03	12
Chromium	Cr	µg/L	0.96	1.06	15	0.37	0.30	7	2.67	2.94	12
Copper	Cu	µg/L	4.25	3.05	15	2.91	1.16	7	5.14	6.25	12
Lead	Pb	µg/L	0.07	0.13	15	0.02	0.02	7	0.25	0.27	12
Manganese	Mn	µg/L	54	71	15	41	67	7	238	228	12
Nickel	Ni	µg/L	0.78	0.93	15	1.80	3.22	7	9.16	11.13	12
Selenium	Se	µg/L	26.6	27.8	14	9.2	7.3	6	7.2	4.6	12
Silver	Ag	µg/L	0.00	0.00	15	0.39	1.02	7	0.02	0.04	12
Zinc	Zi	µg/L	2.9	2.0	14	2.0	0.8	6	4.5	6.6	12
Bacteria											
Enterococcus		MPN/100 ml	2400		1	210		1			0
Fecal Coliform		MPN/100 ml	900		1	500		1			0
Total Coliform		MPN/100 ml	1600		1	1600		1			0

Appendix, continued.

			Sweetwater			Otay			Tijuana		
PAHs	Symbol	Units	Mean	SD	n	Mean	SD	n	Mean	SD	n
Acenaphthene		ng/L	0	0	15	0	0	7	1	4	12
Acenaphthylene		ng/L	0	0	15	0	0	7	1	4	12
Anthracene		ng/L	0	0	15	0	0	7	1	3	12
Benz(a)anthracene		ng/L	0	0	15	0	0	7	3	12	12
Benzo(a)pyrene		ng/L	0	0	15	0	0	7	6.6	23.0	12
Benzo(b)fluoranthene		ng/L	0	0	15	0	0	7	8.8	30.3	12
Benzo(e)pyrene		ng/L	0	0	15	0	0	7	12.2	42.1	12
Benzo(g,h,i)perylene		ng/L	0	0	15	0	0	7	13.8	47.6	12
Benzo(k)fluoranthene		ng/L	0	0	14	0	0	6	2.8	9.6	12
Biphenyl		ng/L	0	0	14	0	0	6	7	16	12
Chrysene		ng/L	0	0	15	0	0	7	9.7	33.5	12
Chrysenes, C1 -		ng/L	0	0	14	0	0	6	18.9	65.5	12
Chrysenes, C2 -		ng/L	0	0	14	0	0	6	24.3	78.5	12
Chrysenes, C3 -		ng/L	0	0	14	0	0	6	23.3	80.8	12
Dibenz(a,h)anthracene		ng/L	0	0	15	0	0	7	1.7	5.9	12
Dibenzothiophene		ng/L	0	0	14	0	0	6	3.5	9.8	12
Dibenzothiophenes, C1 -		ng/L	0	0	14	3.6	5.6	6	35.1	82.8	12
Dibenzothiophenes, C2 -		ng/L	0	0	14	7.4	8.6	6	95.5	271.1	12
Dibenzothiophenes, C3 -		ng/L	0	0	14	0	0	6	89.0	264.3	12
Dimethylnaphthalene, 2,6-		ng/L	0	0	14	0	0	6	31	80	12
Dimethylphenanthrene, 3,6-		ng/L	0	0	14			0	14.02	43.42	12
Fluoranthene		ng/L	0.53	2.06	15	0	0	7	26.98	71.43	12
Fluoranthene/Pyrenes, C1 -		ng/L	0	0	14	0	0	6	58.74	177.90	12
Fluorene		ng/L	0	0	15	0	0	7	7	22	12
Fluorenes, C1 -		ng/L	0	0	14	0	0	6	43.72	121.07	12
Fluorenes, C2 -		ng/L	0	0	14	0	0	6	0	0	12
Fluorenes, C3 -		ng/L	0	0	14	0	0	6	0	0	12
Indeno(1,2,3-c,d)pyrene		ng/L	0	0	15	0	0	7	4.53	15.70	12
Methyldibenzothiophene, 4-		ng/L	0	0	14			0	12.58	31.73	12
Methylfluoranthene, 2-		ng/L	0	0	14			0	5.89	20.41	12
Methylfluorene, 1-		ng/L	0	0	14			0	16.57	44.06	12
Methylnaphthalene, 1-		ng/L	0	0	14	0	0	6	10	32	12
Methylnaphthalene, 2-		ng/L	0	0	14	0	0	6	15	51	12
Methylphenanthrene, 1-		ng/L	0	0	14	0	0	6	11	29	12
Naphthalene		ng/L	0.47	1.82	15	0	0	7	9.83	34.06	12
Naphthalenes, C1 -		ng/L	0	0	14	0	0	6	26.53	84.37	12
Naphthalenes, C2 -		ng/L	0	0	14	0	0	6	83.41	240.10	12
Naphthalenes, C3 -		ng/L	0	0	14	0	0	6	155.11	427.76	12
Naphthalenes, C4 -		ng/L	0	0	14	0	0	6	48.74	120.60	12
Perylene		ng/L	0	0	14	0	0	6	2.58	8.95	12
Phenanthrene		ng/L	0	0	15	0	0	7	26	57	12
Phenanthrene/Anthracene, C1 -		ng/L	0.36	1.34	14	0	0	6	69.21	157.09	12
Phenanthrene/Anthracene, C2 -		ng/L	0.41	1.53	14	0	0	6	157.18	438.58	12
Phenanthrene/Anthracene, C3 -		ng/L	0	0	14	0	0	6	109.16	347.01	12
Phenanthrene/Anthracene, C4 -		ng/L	0	0	14	0	0	6	27.80	90.90	12
Pyrene		ng/L	0.44	1.70	15	0	0	7	26.23	70.99	12
Trimethylnaphthalene, 2,3,5-		ng/L	0	0	14	0	0	6	19	40	12

Appendix, continued.

PCBs	Symbol	Units	Sweetwater Mean	Sweetwater SD	Sweetwater n	Otay Mean	Otay SD	Otay n	Tijuana Mean	Tijuana SD	Tijuana n
PCB 005		ng/L	0	0	14	0	0	6	0	0	12
PCB 008		ng/L	0	0	14	0	0	6	0	0	12
PCB 015		ng/L	0	0	14	0	0	6	0	0	12
PCB 018		ng/L	0	0	14	0	0	6	0	0	12
PCB 027		ng/L	0	0	14	0	0	6	0	0	12
PCB 028		ng/L	0	0	14	0	0	6	0	0	12
PCB 029		ng/L	0	0	14	0	0	6	0	0	12
PCB 031		ng/L	0	0	14	0	0	6	0	0	12
PCB 033		ng/L	0	0	14	0	0	6	0	0	12
PCB 044		ng/L	0	0	14	0	0	6	0	0	12
PCB 049		ng/L	0	0	14	0	0	6	0	0	12
PCB 052		ng/L	0	0	14	0	0	6	0	0	12
PCB 056		ng/L	0	0	14	0	0	6	0	0	12
PCB 060		ng/L	0	0	14	0	0	6	0	0	12
PCB 066		ng/L	0	0	14	0	0	6	0	0	12
PCB 070		ng/L	0	0	14	0	0	6	0	0	12
PCB 074		ng/L	0	0	14	0	0	6	0	0	12
PCB 087		ng/L	0	0	14	0	0	6	0	0	12
PCB 095		ng/L	0	0	14	0	0	6	0	0	12
PCB 097		ng/L	0	0	14	0	0	6	0	0	12
PCB 099		ng/L	0	0	14	0	0	6	0	0	12
PCB 101		ng/L	0	0	14	0	0	6	0	0	12
PCB 105		ng/L	0	0	14	0	0	6	0	0	12
PCB 110		ng/L	0	0	14	0	0	6	0	0	12
PCB 114		ng/L	0	0	14	0	0	6	0	0	12
PCB 118		ng/L	0	0	14	0	0	6	0	0	12
PCB 128		ng/L	0	0	14	0	0	6	0	0	12
PCB 137		ng/L	0	0	14	0	0	6	0	0	12
PCB 138		ng/L	0	0	14	0	0	6	0	0	12
PCB 141		ng/L	0	0	14	0	0	6	0	0	12
PCB 149		ng/L	0	0	14	0	0	6	0	0	12
PCB 151		ng/L	0	0	14	0	0	6	0	0	12
PCB 153		ng/L	0	0	14	0	0	6	0	0	12
PCB 156		ng/L	0	0	14	0	0	6	0	0	12
PCB 157		ng/L	0	0	14	0	0	6	0	0	12
PCB 158		ng/L	0	0	14	0	0	6	0	0	12
PCB 170		ng/L	0	0	14	0	0	6	0	0	12
PCB 174		ng/L	0	0	14	0	0	6	0	0	12
PCB 177		ng/L	0	0	14	0	0	6	0	0	12
PCB 180		ng/L	0	0	14	0	0	6	0	0	12
PCB 183		ng/L	0	0	14	0	0	6	0	0	12
PCB 187		ng/L	0	0	14	0	0	6	0	0	12
PCB 189		ng/L	0	0	14	0	0	6	0	0	12
PCB 194		ng/L	0	0	14	0	0	6	0	0	12
PCB 195		ng/L	0	0	14	0	0	6	0	0	12
PCB 200		ng/L	0	0	14	0	0	6	0	0	12
PCB 201		ng/L	0	0	14	0	0	6	0	0	12
PCB 203		ng/L	0	0	14	0	0	6	0	0	12
PCB 206		ng/L	0	0	14	0	0	6	0	0	12

Appendix, continued.

			Sweetwater			Otay			Tijuana		
PCBs	Symbol	Units	Mean	SD	n	Mean	SD	n	Mean	SD	n
PCB 209		ng/L	0	0	14	0	0	6	0	0	12
PCB-1016		ng/L	0		1	0		1			0
PCB-1221		ng/L	0		1	0		1			0
PCB-1232		ng/L	0		1	0		1			0
PCB-1242		ng/L	0		1	0		1			0
PCB-1248		ng/L	0		1	0		1			0
PCB-1254		ng/L	0		1	0		1			0
PCB-1260		ng/L	0		1	0		1			0
PCBs		ng/L	0	0	15	0	0	7	0	0	12
Pesticides											
Aldrin		ng/L	0	0	15	0	0	7	0	0	12
alpha-BHC		ng/L	0		1	0		1			0
Ametryn		ng/L			0	0	0	6			0
Aspon		ng/L	0	0	14	0	0	6	0	0	12
Atraton		ng/L			0	0	0	6			0
Atrazine		ng/L			0	6.80	16.66	6			0
Azinphos ethyl		ng/L	0	0	14	0	0	6	0	0	12
Azinphos methyl		ng/L	0	0	14	0	0	6	0	0	12
beta-BHC		ng/L	0		1	0		1			0
Bolstar		ng/L	0	0	14	0	0	6	0	0	12
Carbophenothion		ng/L	0	0	14	0	0	6	0	0	12
Chlordane (tech)		ng/L	0		1	0		1			0
Chlordane, cis-		ng/L	0	0	14	0	0	6	0	0	12
Chlordane, trans-		ng/L	0	0	14	0	0	6	0	0	12
Chlordene, alpha-		ng/L	0	0	14	0	0	6	0	0	12
Chlordene, gamma-		ng/L	0	0	14	0	0	6	0	0	12
Chlorfenvinphos		ng/L	0	0	14	0	0	6	0	0	12
Chlorpyrifos		ng/L	0	0	14	0	0	6	2.00	6.93	12
Chlorpyrifos methyl		ng/L	0	0	14	0	0	6	0	0	12
Ciodrin		ng/L	0	0	14	0	0	6	0	0	12
Coumaphos		ng/L	0	0	14	0	0	6	0	0	12
Dacthal		ng/L	0	0	14	0	0	6	0	0	12
DDD(o,p')		ng/L	0	0	14	0	0	6	0	0	12
DDD(p,p')		ng/L	0	0	15	0	0	7	0	0	12
DDE(o,p')		ng/L	0	0	14	0	0	6	0	0	12
DDE(p,p')		ng/L	0	0	15	1.43	2.51	7	0	0	12
DDMU(p,p')		ng/L	0	0	14	0	0	6	0	0	12
DDT(o,p')		ng/L	0	0	14	0	0	6	0	0	12
DDT(p,p')		ng/L	0	0	15	0.57	0.98	7	0	0	12
DDTs		ng/L	0	0	15	2.00	2.83	7	0	0	12
delta-BHC		ng/L	0		1	0		1			0
Demeton-s		ng/L	0	0	14	0	0	6	0	0	12
Diazinon		ng/L	11.36	11.19	14	20.83	26.47	6	16.92	20.93	12
Dichlofenthion		ng/L	0	0	14	0	0	6	0	0	12
Dichlorvos		ng/L	0	0	14	0	0	6	0	0	12
Dicrotophos		ng/L	0	0	14	0	0	6	0	0	12
Dieldrin		ng/L	0	0	15	0	0	7	0	0	12
Dimethoate		ng/L	0	0	14	0	0	6	0	0	12
Dioxathion		ng/L	34.43	52.78	14	0	0	6	96.67	231.08	12

Appendix, continued.

			Sweetwater			Otay			Tijuana		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n	Mean	SD	n
Disulfoton		ng/L	4.14	15.50	14	0	0	6	16.17	40.76	12
Endosulfan I		ng/L	0	0	15	0	0	7	0	0	12
Endosulfan II		ng/L	0	0	15	0	0	7	0	0	12
Endosulfan sulfate		ng/L	0	0	15	0	0	7	0	0	12
Endrin		ng/L	0	0	15	0	0	7	0	0	12
Endrin Aldehyde		ng/L	0	0	15	0	0	7	0	0	12
Endrin Ketone		ng/L	0	0	14	0	0	6	0	0	12
Ethion		ng/L	0	0	14	0	0	6	0	0	12
Ethoprop		ng/L	0	0	14	0	0	6	0	0	12
Famphur		ng/L	0	0	14	0	0	6	0	0	12
Fenchlorphos		ng/L	0	0	14	0	0	6	0	0	12
Fenitrothion		ng/L	0	0	14	0	0	6	0	0	12
Fensulfothion		ng/L	0	0	14	0	0	6	0	0	12
Fenthion		ng/L	0	0	14	0	0	6	0	0	12
Fonofos		ng/L	0	0	14	0	0	6	4.50	15.59	12
gamma-BHC (Lindane)		ng/L	0		1	0		1			0
HCH, alpha		ng/L	0	0	14	0	0	6	0	0	12
HCH, beta		ng/L	0	0	14	0	0	6	0	0	12
HCH, delta		ng/L	0	0	14	0	0	6	0	0	12
HCH, gamma		ng/L	0	0	14	0	0	6	0	0	12
Heptachlor		ng/L	0	0	15	0	0	7	0	0	12
Heptachlor epoxide		ng/L	0	0	15	0	0	7	0	0	12
Hexachlorobenzene		ng/L	0	0	14	0	0	6	0	0	12
Leptophos		ng/L	0	0	14	0	0	6	0	0	12
Malathion		ng/L	0	0	14	0	0	6	0	0	12
Merphos		ng/L	0	0	14	0	0	6	0	0	12
Methidathion		ng/L	0	0	14	0	0	6	0	0	12
Methoxychlor		ng/L	0	0	15	0	0	7	0	0	12
Mevinphos		ng/L	0	0	14	0	0	6	0	0	12
Mirex		ng/L	0	0	14	0	0	6	0	0	12
Molinate		ng/L	0	0	14	0	0	6	0	0	12
Naled		ng/L	0	0	14	0	0	6	0	0	12
Nonachlor, cis-		ng/L	0	0	14	0	0	6	0	0	12
Nonachlor, trans-		ng/L	0	0	14	0	0	6	0	0	12
Oxadiazon		ng/L	11.14	14.58	14	28.33	38.13	6	0	0	12
Oxychlordane		ng/L	0	0	14	0	0	6	0	0	12
Parathion, Ethyl		ng/L	0	0	14	0	0	6	0	0	12
Parathion, Methyl		ng/L	0	0	14	0	0	6	0	0	12
Phorate		ng/L	0	0	14	0	0	6	0	0	12
Phosmet		ng/L	0	0	14	0	0	6	0	0	12
Phosphamidon		ng/L	0	0	14	0	0	6	0	0	12
Prometon		ng/L			0	0	0	6			0
Prometryn		ng/L			0	0	0	6			0
Propazine		ng/L			0	0	0	6			0
Secbumeton		ng/L			0	0	0	6			0
Simazine		ng/L			0	0	0	6			0
Simetryn		ng/L			0	0	0	6			0
Sulfotep		ng/L	0	0	14	0	0	6	0	0	12
Tedion		ng/L	0	0	14	0	0	6	0	0	12

Appendix, continued.

			Sweetwater			Otay			Tijuana		
Pesticides	Symbol	Units	Mean	SD	n	Mean	SD	n	Mean	SD	n
Terbufos		ng/L	0	0	14	0	0	6	0	0	12
Terbuthylazine		ng/L			0	0	0	6			0
Terbutryn		ng/L			0	0	0	6			0
Tetrachlorvinphos		ng/L	0	0	14	0	0	6	0	0	12
Thiobencarb		ng/L	0	0	14	0	0	6	0	0	12
Thionazin		ng/L	0	0	14	0	0	6	0	0	12
Tokuthion		ng/L	0	0	14	0	0	6	0	0	12
Toxaphene		ng/L	0		1	0		1			0
Trichlorfon		ng/L	0	0	14	0	0	6	0	0	12
Trichloronate		ng/L	0	0	14	0	0	6	0	0	12