SANTA CLARA RIVER ESTUARY
Macroinvertebrate Bioassessment Monitoring
Annual Report 2003

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INTRODUCTION

This report is submitted in fulfillment of the City of San Buenaventura's bioassessment monitoring portion of National Pollutant Elimination Discharge System (NPDES) permit No. CA0052651 (Order No. 00-143). The City owns and operates the Ventura Water Reclamation Facility (VWRF) adjacent to the north edge of the Santa Clara River Estuary (SCRE). The VWRF discharges tertiary treated effluent into the Estuary at a relatively constant rate of between 7 and 10 million gallons each day. The monitoring program described herein was developed based on several past studies of the Estuary (Engineering Science 1976; Swanson 1990; USFWS 1999; ENTRIX 1999, 2002 and 2003).

The main objective of this program is to assess if the effluent emanating from the VWRF is impacting the populations of organisms living in the SCRE, taking into account the influence of both physical habitat and seasonal differences between sampling locations. Potential impacts would include differences in the abundance, diversity and/or composition of organisms residing in the effluent channel (Stations B1 and B2) versus those located in the lower estuary (Station B3) and in the main river channels (Station B7).

To address this objective, during both the spring and fall of 2003, Aquatic Bioassay & Consulting scientists conducted bioassessment monitoring of the Santa Clara River Estuary according to the City's NPDES permit and the California Stream Bioassessment Protocol (CSBP). The methods, findings and discussion of these surveys are presented in this report.

Site Description

The Santa Clara River is the longest free-flowing river in southern California. Its 70 mile length provides drainage to a 1,600 mi^2 watershed. Flow in the river typically reaches 100,000 cubic feet per second (cfs) during winter and spring storm flows (Swanson et al. 1990). The SCRE is located at the mouth of the river and is characterized as a typical river mouth estuary (Ferran 1989, Ferran et al. 1996). The Estuary is a highly dynamic environment due to hydrology patterns that can vary greatly during the year. The flow of water into the SCRE is influenced by dry and wet weather flow from the Santa Clara River, Pacific Ocean tides and the effluent emanating from the City of San Buenaventura's, Ventura Water Reclamation Facility (VWRF). During the winter and spring the river is open to the ocean due to sandbar-breaching storm flows. During the summer and fall the sandbar becomes well established due to lack of rainfall, low river flow and small summer surf. Once established the berm creates a barrier to flow and allows the Estuary to inundate with water from the VWRF. Depth of the estuary during peak inundation can reach nearly 10 ft (feet above MSL) (USFWS 1999).

In 1855, the Estuary is estimated to have encompassed 870 acres (Swanson et al. 1990, State Coastal Conservancy et al. 1997), but its size in recent years has shrunk to 160 acres as a result the diversion of upstream river flow to municipal water

projects and agriculture (ENTRIX 2002). This reduction in flow, has in part, been replaced by the relatively constant flow of tertiary treated effluent (7 to 10 MGD) from the VWRF. The tertiary treatment process creates effluent essentially free of organics and is very low in nutrients. This flow provides a water source to the Estuary during periods when it would otherwise be dry. Since most southern California estuaries experience drought during the summer and fall (Zedler 1982), this has created a unique, low salinity habitat for a wide array of aquatic organisms, water birds and other vertebrates. The lack of understanding regarding the relationship between the biological resources found in the estuary and the unique habitat created by the VWRF, has prompted the use of bioassessment monitoring to elucidate the dynamics of this ecosystem.

Bioassessment Monitoring

During the past 150 years direct measurements of biological communities including plants, invertebrates, fish, and microbial life have been used as indicators of degraded water quality. In addition, biological assessments (bioassessments) can be used as a watershed management tool for surveillance and compliance of land-use best management practices (Jones and Clark 1987; Lenat and Crawford 1994; Weaver and Garman 1994; Karr 1998 and Karr et al. 2000). Combined with measurements of watershed characteristics, land-use practices, in-stream habitat, and water chemistry, bioassessment can be a cost-effective tool for long-term trend monitoring of watershed conditions (Davis and Simons 1996).

Biological communities act to integrate the effects of water quality conditions and various anthropogenic stressors in a stream or river system by responding with changes in their population abundances and species composition over time. These populations are sensitive to multiple aspects of water and habitat quality and provide the public with more familiar expressions of ecological health than the results of chemical and toxicity tests (Gibson 1996). Furthermore, biological assessments when integrated with physical and chemical assessments, better define the effects of point-source discharges of contaminates and provide a more appropriate means for evaluating discharges of non-chemical substances (e.g. nutrients and sediment), especially when monitoring demonstrates changes over time or along concentration gradients.

Water resource monitoring using benthic macroinvertebrates (BMI) is by far the most popular method used throughout the world. BMIs are ubiquitous, relatively stationary and their large species diversity provides a spectrum of responses to environmental stresses (Rosenberg and Resh 1993). Individual species of BMIs reside in the aquatic environment for a period of months to several years and are sensitive, in varying degrees, to temperature, dissolved oxygen, sedimentation, scouring, nutrient enrichment and chemical and organic pollution (Resh and Jackson 1993). Finally, BMIs represent a significant food source for aquatic and terrestrial animals and provide a wealth of ecological and bio-geographical information (Erman 1996).

In the United States the evaluation of biotic conditions from community data uses a combination of multi-metric and multivariate techniques. In multi-metric techniques, a set of biological measurements ("metrics"), each representing a different aspect of the community data, is calculated for each site. An overall site score is calculated as the sum of individual metric scores. Sites are then ranked according to their scores and classified into groups with "good", "fair" and "poor" water quality. This system of scoring and ranking sites is referred to as an Index of Biotic Integrity (IBI) and is the end point of a multi-metric analytical approach recommended by the EPA for

development of biocriteria (Davis and Simon 1995). The original IBI was created for assessment of fish communities (Karr 1981), but was subsequently adapted for BMI communities (Kerans and Karr 1994). Borrowing from the multi-metric approach, the California Department of Fish and Game developed the California Stream Bioassessment Procedure (CSBP) (CDFG 1999) that are currently being integrated into the NPDES monitoring programs for waste discharge agencies throughout the State and is specified for use in the City of Ventura's NPDES permit.

The evaluation of biological data collected from Santa Clara River Estuary during the 2003 surveys posed an interesting analysis problem. While the organisms collected from the Estuary were typical of past surveys (Engineering Science 1976; Swanson 1990; USFWS 1999; ENTRIX 1999, 2002 and 2003) and for estuaries in general, they are not typical of the inland streams for which the metrics in the CSBP were developed. As a result, the 2003 survey data were analyzed using both multi-metric and multivariate techniques to help elucidate any population effects that may have been present as a result of the City of Ventura's effluent. This approach was taken in an attempt to glean as much information as possible from the biological data. By combining the results of these two approaches it is hoped that the best explanation of the population patterns found in the Estuary can be achieved than would be accomplished by using either technique alone.

MATERIALS AND METHODS

Sampling was conducted on May 15th, 2003 and October 15th, 2003 by Aquatic Bioassay & Consulting Laboratory biologists. All procedures were conducted as outlined in the project scope of work and in accordance with the California Department of Fish and Games, California Stream Bioassessment Protocol, their Lentic Bioassessments Procedures and the 1997-1999 USFWS study of the estuary.

Field Methods

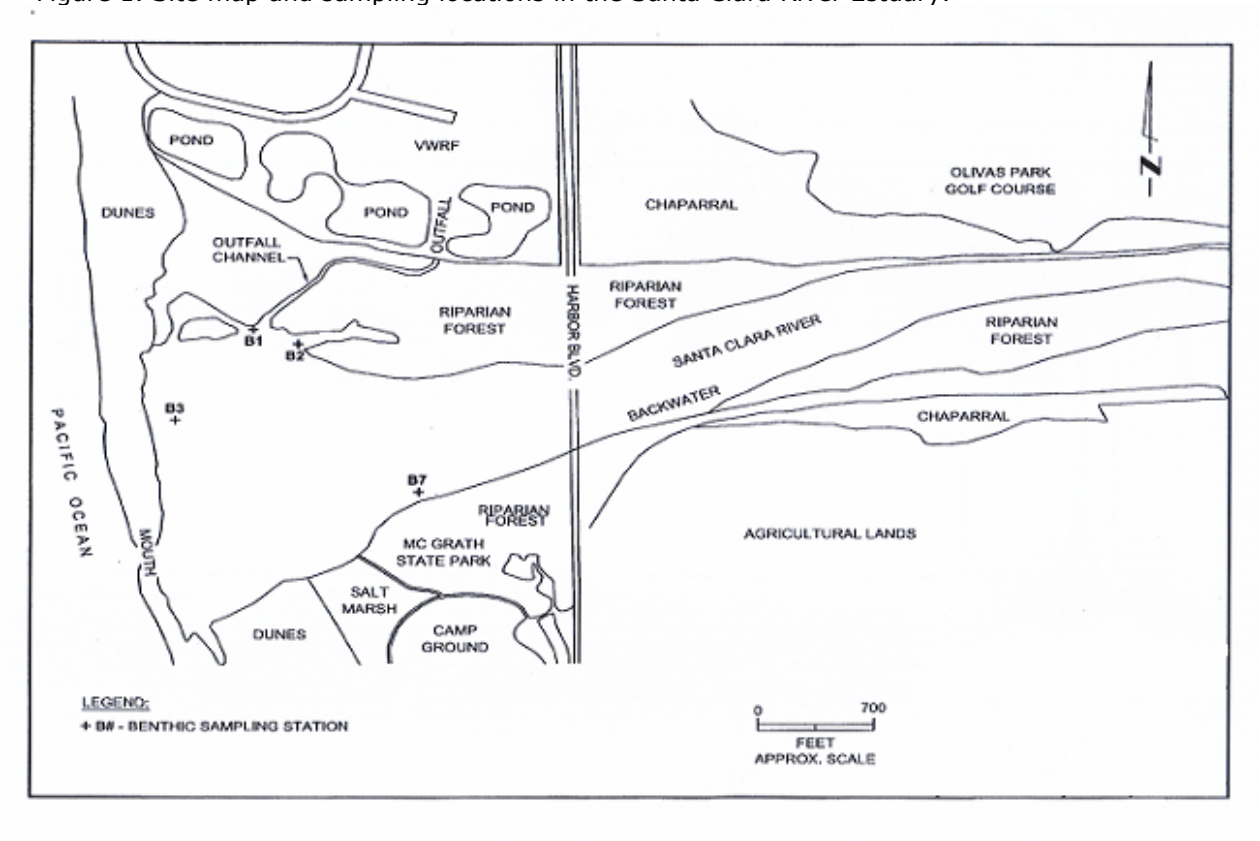
The May, 2003 event occurred during open mouth, free flowing conditions. The October event occurred when the berm was well established and the Estuary was inundated. Stations were located using a hand held DGPS. During each survey water quality, bioassessment and particle size samples were collected at four locations (Stations B1, B2, B3 and B7) (Figure 1). These sites were selected as a subset of the stations surveyed during previous studies (USFWS 1999, ENTRIX 2002). Station B1 is located in the main effluent channel, with Station B2 located just upstream of it. Station B3 is located inside the sand spit berm in the lower estuary and Station B7 is located on the southwest side of the Estuary in the main river channel.

Triplicate benthic samples were collected at each station using a PVC coring device with a 10.2 cm diameter. Samples were sieved through a 0.5 mm mesh screen and preserved in 95% ethanol. A single littoral sweep was conducted at Station B1 using a kick net and processed as above. Single samples for particle size were collected at each site.

Water quality measurements were collected using a laboratory calibrated YSI 85 handheld meter. Salinity, temperature, dissolved oxygen and pH were recorded on a modified CDFG Bioassessment Worksheet at each site. Physical habitat measurements were collected for transect length, grain size and composition, and general vegetation composition within 20 meters of each sample location.

Stream flow data for 2003 were downloaded from the United States Geologic Survey's web site at: http://waterdata.usgs.gov/ca/nwis/

Figure 1. Site map and sampling locations in the Santa Clara River Estuary.



Laboratory Methods

Sample Processing

Elutriation

Due to the large amount of sand and gravel present in the benthic core samples, sorting was performed by elutriation. Six tablespoonfuls of sample material were transferred into a 2000 mL Erlhynmeyer flask filled with 1500 mL of water. The flask was swirled gently to suspend organic material in the sample and the supernatant was decanted into a 500 um sieve. The flask was gently refilled with 1500 mL of water and the sub sample decanted again. This process was completed seven times for each six spoonful sub sample. After each sub sample was completed the remaining sample material was placed into a refuse jar. After the entire sample was completed, contents of the refuse jar were returned to the original sample container and preserved in 70% alcohol for possible future reference.

After elutriation, material accumulated on the sieve was concentrated on the sieve with water and then washed into a 250 mL sample container using 70% alcohol. This was done over a catch basin to contain any spills. During analysis, samples were transferred to Petri dishes containing 70% alcohol and examined under the microscope at 10 times magnification. Invertebrates were removed using forceps and placed in a 20 mL sample vial. Once all invertebrates had been removed, the

remaining material was transferred from the Petri dish and returned to the rest of the sample.

Ostracod Sub Sampling

Ostracods were not sub sampled. All organisms which appeared to have been alive at the time of preservation were removed and identified. Ostracod counts are absolute benthic macroinvertebrates (BMIs) collected in each sample.

Littoral Sweep Sub Sampling

The littoral sweep sample was sub-sampled using a 30.0 by 36.0 cm Caton Tray fitted with 0.5 mm mesh. The tray was divided into 30- 6.0 x 6.0 quadrats. The entire littoral sweep sample was placed into the Caton tray and distributed to a uniform depth. Five quadrats were randomly selected, removed and the BMIs removed and identified. Littoral sweep taxa abundances were converted to the whole sample count by multiplying by a factor of 6.

QA/QC

Elutriation

The remaining sample matrix from decanted sub samples was periodically evaluated to determine elutriation efficiency. Approximately 20 mL of the remaining sample matrix from the first, last, and middle elutriated sub sample from each sample was placed into a Petri dish and observed under a microscope at 10 times magnification to verify that no BMIs were being missed by the elutriation process. Elutriation efficiency was over 99.5%.

Laboratory

Approximately 10% of the sorted samples were evaluated to determine laboratory processing efficiency. The processed matrix for these samples was evaluated to determine the number of organisms missed during the initial sorting. Mean processing efficiency was 97%.

Taxonomic Effort

All the organisms removed during the sorting process were then identified to Level 3 standard taxonomic effort in accord with the List of California Macroinvertebrate Taxa and Standard Taxonomic Effort (revision date: 27 January, 2003). Standard taxonomic keys used for the identifications are listed in a separate section below. Voucher specimens were retained for all unique taxa. The identified taxa from the processed portion of each sample were placed in separate vials placed and preserved with 70% ethanol and 5% glycerin. Chironomid reference slides were prepared in mounting compound and sealed.

Particle Size Analysis

Sediments were analyzed for particle size distribution using a Horiba 920 particle size analyzer following Procedures for Handling and Chemical Analysis of Sediment and Water Samples, R.H. Plumb, US EPA Contract 4805572010, May 1981; and, Standard Methods, 20 ed. (APHA 1998). Duplicate sub-samples from each sample were re-suspended in de-ionized water, then injected into the analyzer. The analyzer

is capable of measuring particle sizes ranging from clay (<2µ) up to course sand (2000µ).

Data Analysis

Multi-metric analysis

Biological metrics were calculated as specified by the California Stream Bioassessment Procedure (CSBP) (1999) and used to describe the benthic macroinvertebrate population. Each of the EPT metrics were zero and, therefore, not reported. This was due to the absence of Ephemeroptera, Plecoptera and Trichoptera which many of the key metrics in the CSBP are based on. Additionally, estuarine taxa predominate in the survey area, and no specific metrics have been developed for them. Tolerance values and Functional Feeding Group types identified in California Department of Fish and Game (2003) were used for most taxa. Tolerance Values and Functional Feeding Groups in Bold text in Tables 1 and 2 (Appendix B) were found in Barbour et al. (1999) and Mandaville (2002). Biological metrics were calculated with chironomid identification held to the level of subfamily. The following metrics were calculated and their responses to impaired conditions are listed in Table 1:

1. Richness measures: taxa richness, cumulative taxa;
2. Composition measures: Shannon diversity;
3. Tolerance/intolerance measures: tolerance value, intolerant organisms (%), tolerant organisms (%), dominant taxa (%), Chironomidae (%);
4. Functional feeding group: collectors (%), filterers (%), grazers (%), predators (%), shredders (%);
5. Abundance estimates.

Table 1. Bioassessment metrics used to describe characteristics of the BMI community results for the Santa Clara River Estuary.

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	decrease
Ephemeroptera Taxa	Number of taxa in the insect order Ephemeroptera (mayflies)	decrease
Plecoptera Taxa	Number of taxa in the insect order Plecoptera (stoneflies)	decrease
Trichoptera Taxa	Number of taxa in the insect order Trichoptera (caddisflies)	decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae	decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	decrease
Shannon Diversity	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver 1963)	decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	increase
Percent Hydropsychidae	Percent of organisms in the caddisfly family Hydropsychidae	increase
Percent Baetidae	Percent of organisms in the mayfly family Baetidae	increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	variable
Percent Predators	Percent of macrobenthos that feed on other organisms	variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	decrease
Estimated Abundance	Estimated number of BMIs in sample calculated by extrapolating from the proportion of organisms counted in the subsample	variable

Univariate and Multivariate Analysis

Descriptive statistics were calculated for each of the multi-metric community metrics and included the mean, standard deviation and coefficient of variation. These metrics were also assessed using One-Way Analysis of Variance (ANOVA) with each metric representing the dependent variable and station location representing the independent variable. Assumptions of the ANOVA test were evaluated using the skewness of normality residuals, Kurtosis of normality residuals, Omnibus normality of residuals, and the Modified-Levene Equal-Variance Test. When a data set did not pass any one of these tests, the Kruskal-Wallis One-Way ANOVA on Ranks was used. Multiple comparisons were performed using Newman-Keuls Multiple-Comparison Test for data with equal variances and Kruskal-Wallis Multiple-Comparison Z-Value Test for data with unequal variances (NCSS 2001).

For this report statistical significance is highlighted at two levels. For most ecologists, a pattern that is strong enough so that there is only a one chance or less in 20 that it is random is said to be statistically significant. In other words, the probability (p) is that there is only a 5% chance (0.05) or less that the pattern is random ($p \leq 0.05$). A pattern that has only one chance in ten or less (but more than one chance in 20) is said to be "marginally significant". That is, the probability is less than 10% but greater than 5% of being random ($0.05 < p \leq 0.10$).

Cluster analysis was used to define groups of samples, based on species presence and abundance, which belong to the same community without imposing an *a priori* community assignment. Identified clusters were then evaluated to define the habitat to which they belong. In cluster analysis, samples with the greatest similarity are grouped first. Additional samples with decreasing similarity are then progressively added to the groups. The percentage dissimilarity (Bray-Curtis) metric (Gauch, 1982; Jongman et al., 1995) was used to calculate the distances between all pairs of samples. The cluster dendogram was formed using the unweighted pair-groups method using arithmetic averages (UPGMA) clustering algorithm (Sneath and Sokal, 1973). All steps were completed using the computer program MVSP (Multivariate Statistical Package, v3.12, 2000). Only the most commonly occurring species were used in the analysis, in this case only those that occurred at more than one station and season. Clusters that were created for station and species groups were merged into a single two-way table depicting the most frequently collected species by station.

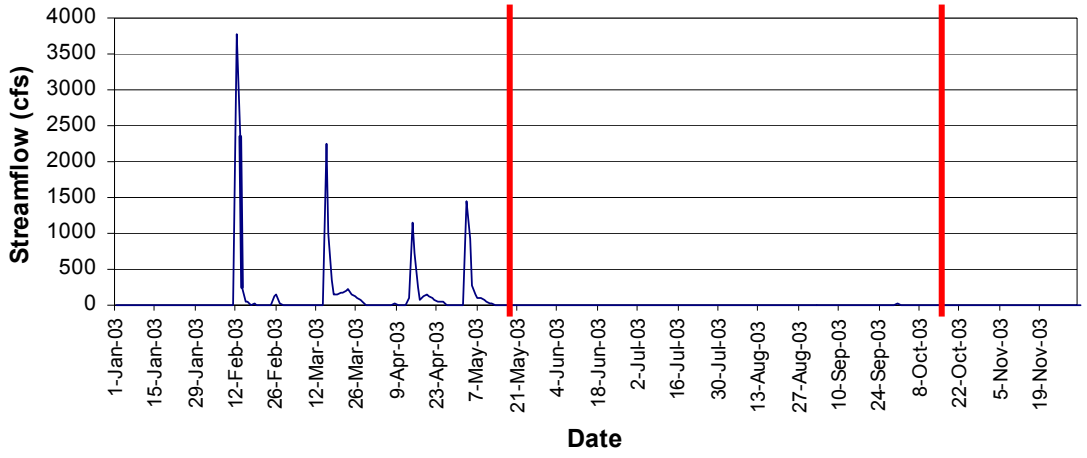
RESULTS

Annual Stream Flow & Estuary Inundation

Flow during 2003 on the Santa Clara River was measured at the Montalvo gauging station near the 101 freeway in Ventura (USGS 11114000). River flow peaked following rain events in February (3,700 cfs), March (2,300 cfs), April (1,100 cfs) and May (1,400 cfs), 2003 (Figure 2). The Estuary undergoes periodic filling and draining throughout the year due to the periodic closure, then reopening of the sand spit at its mouth. During 2003 the berm at the mouth of the Estuary was closed 61% and open 39% of the year. The Estuary is, on average, closed during low river flow, usually during the summer and fall. Open Estuary conditions prevail during the winter and spring after rain events increase river flow.

The May 15th sampling event followed the final rainfall event of the season. As a result, the berm at the mouth of the estuary was open and all river flow was discharging to the ocean. Water depth in the estuary during the May survey did not exceed 6 inches at any of the sampling locations (Table 3). The October 15th, 2003 sampling event followed five months of dry weather, typical of southern California. Prior to sampling, the berm at the mouth of the Estuary had been closed for 23 continuous days. As a result the estuary was inundated with water to depths ranging from 24 inches (Stations B2, B3 and B7) to 60 inches (Station B1). The inundation of the Estuary was the result of both upstream dry weather flow from the Santa Clara River and the VCWDF.

Figure 2. Stream flow on the Santa Clara River measured at the Montalvo gauging station (USGS 11114000) near the 101 freeway in Ventura, CA. Daily measurements are in cubic feet per second (cfs). Spring and fall sampling events are indicated by red lines that bisect the date.



General Observations

During May, sampling was conducted under clear skies with ten kilometer visibility (Table 2). Wind was from the west from between 3 and 12 knots. Water color at all stations was light green, except at Station B2 where the color was brownish. A tidewater goby was accidentally collected in the kick net at Station B1, and then returned to the water. A subsurface layer of black sediments were evidence of anaerobic conditions at Station B2. In October sampling occurred under overcast skies with 14 to 20 km visibility. Winds were from the north at 2 knots. Water color was brown at all sites.

Physical Measurements and Water Quality

May

In May the width of the sampling transects varied from 2 to 9 meters, while the water velocity ranged from 0 cfs at Station B7 to 18.9 cubic feet per second at Station B3 near the mouth of the estuary (Table 2). There was no canopy cover over any of the sites and vegetation was limited to the banks of the channels. The composition of bottom sediments ranged from mixed cobble, gravel and sand at Station B1 to sand at all other stations. Embeddedness (a measure of silting) was only estimated at 65% for Station B1 where cobble and gravel were present.

The pH ranged from a low at of 7.8 at Station B7 in the main river channel, to a high of 8.3 at Station B2 above the outfall. Dissolved oxygen concentrations were high in all cases and varied from 9.6 at Station B1 to 14.9 at Station B2. Water temperature exceeded 20 °C at all sites. Salinity was lowest at Stations B1 and B3 (1.3 to 1.5 ppt) and highest at Station B7 (12 ppt). The high salinity measurement at B7 was probably due to its location in the main river channel which is more subject to tidal flooding than the other stations.

October

In October the transect widths varied from 2 to 5 meters at Stations B1, B2 and B7 (Table 2). Station B3 was located in the middle of the estuary where inundation was complete and, as a result, was not located in a defined channel. Also as a result of inundation, there was no measurable water velocity at any of the four sites. There was no canopy cover over Stations B1, B2 or B3, but Station B7 had 25% cover as a result of high growing willows and cotton woods on the bank nearby. The composition of bottom sediments ranged from mixed cobble, gravel and sand at Station B1 to sand at Stations B2 and B3 and a mixture of fine sand and gravel at Station B7. Embeddedness was 65% at Station B1 and 75% at Station B7 where mixtures of cobble, sand and gravel were present.

The pH ranged from lows of 7.6 and 7.3 at Stations B1 and B2 respectively, in the effluent channel to highs of 8.4 and 9.2 at Stations B3 and B7. Dissolved oxygen concentrations followed a similar trend with lowest values measured in the effluent channel (4.0 and 3.8 mg/L, Stations B1 and B2 respectively) to highest at Stations in the river channel (8.9 and 7.2 mg/L, Station B3 and B7 respectively). Water temperature exceeded 20 °C at all sites. Salinity ranged from 1.4 ppt in the effluent channel (Station B1) to 2.3 ppt in the main river channel (Station B7).

Table 2. Station locations, sampling weather, transect characteristics and water quality measurements collected from four sites in the Santa Clara River Estuary during both spring and fall sampling events, 2003.

Sampling Stations	Spring B1	Spring B2	Spring B3	Spring B7	Fall B1	Fall B2	Fall B3	Fall B7
Date	5/15/2003	5/15/2003	5/15/2003	5/15/2003	10/15/2004	10/15/2004	10/15/2004	10/15/2004
Time	12:39	11:45	08:32	15:23	09:30	10:50	08:50	12:00
Survey Program	Bioassessment Coring Littoral Sweep	Bioassessment Coring	Bioassessment Coring	Bioassessment Coring	Bioassessment Coring Littoral Sweep	Bioassessment Coring	Bioassessment Coring	Bioassessment Coring
Depth (in)	6	6	6	3	60	24	24	24
Latitude	34° 14'103"	34° 14'091"	34° 13'987"	34° 13'887"	34° 14'103"	34° 14'091"	34° 13'987"	34° 13'887"
Longitude	119° 15'792"	119° 15'777"	119° 15'903"	119° 15'580"	119° 15'792"	119° 15'777"	119° 15'903"	119° 15'580"
Weather	Clear	Clear	Clear	Clear	Overcast	Overcast	Overcast	Overcast
Air Vis. (km)	10	10	10	10	14	14	20	14
Esturary Status	Open	Open	Open	Open	Closed	Closed	Closed	Closed
Wind Sp. (Kn)	5	4	3	12	2	2	2	2
Wind Dir. (°M)	270	270	270	270	35	35	35	35
Color	Light Green	Brown	Light Green	Light Green	Brown	Brown	Brown	Brown
Comments	Tidewater Goby collected in kicknet	Anaerobic subsurface layer	None	High tide influence earlier in day	None	None	None	None
Transect Width (m)	6	8	9	2	5	4	N/A[2]	2
Velocity (ft/sec)	16	0	19	1	0	0	0	0
% Canopy	0	0	0	0	0	0	0	25
Composition	Sand Cobble Gravel	Sand Silt	Sand	Sand	Sand Cobble Gravel	Fine Sand	Sand	Fine Sand
Embededness (%)	65	N/A[1]	N/A[1]	N/A[1]	65	N/A[1]	N/A[1]	75
Sample Depth (in)	6	6	6	3	60	24	24	24
pH	8.10	8.32	8.05	7.80	7.64	7.33	8.44	9.20
Conductance (mS/cm)	2.40	6.40	2.70	19.50	2.53	2.60	2.96	4.07
Dissolved Oxygen (mg/L)	9.60	14.90	10.47	13.60	4.00	3.78	8.97	7.20
Temperature (°C)	22.5	23.5	20.6	24.1	21.2	21.1	20.5	21.8
Salinity (ppt)	1.3	3.6	1.5	12.0	1.4	1.5	1.7	2.3

N/A[1] - no cobble, rock or gravel present
N/A[2] - Due to inundation of estuary, no clear banks or channel.

Sediment Particle Size

The particle composition of aquatic sediments is integral to understanding the chemical and biological characteristics of a habitat. Chemical contaminants tend to adhere more strongly to finer particles since they provide a large surface area when compared to course particles. In addition, aquatic organisms that inhabit the surface and top layers of the sediments tend to have unique preferences regarding particle size and will only occur where these criteria are met. The Santa Clara River estuary is a highly dynamic environment with seasonal river flow and inundation patterns continuously modifying the composition of the surface sediments. To begin to understand the distributions of aquatic organisms within the Estuary, it is critical to first understand the distribution of sediments and any seasonal changes that may occur between surveys (Gray 1981).

The physical characteristics and distribution of particles at the four Estuary stations are summarized in Table 3 and Figure 3. Results are presented in cumulative percentages by size range in Appendix B, Table 4. Two sediment characteristics can be inferred from the graphs (Figure 3). Position of the midpoint of the curve will tend to be associated with the median particle size. If the midpoint tends to be toward the larger micron sizes, then it can be assumed that the sediments will tend to be coarser overall. If the midpoint is near the smaller micron sizes, then it can be assumed that the sediments are mostly fine. Sediment sizes that range from 2000 to 62 microns are defined as sand, sediments ranging from 62 to 3.9 microns are defined as silt, and sediments that are 3.9 microns or less are defined as clay (Wentworth Sediment Scale, see Gray 1981). A second pattern discernible from the graph is how homogeneous the distributions of sediments are. Sediments that tend to have a narrow range of sizes are considered homogeneous or well sorted. Others, which have a wide range of sizes, are considered to be heterogeneous or poorly sorted.

Samples collected from the four Estuary stations can be divided into two groups based on the similarity of their partitioned fractions, median particle sizes and sorting index values (Table 3). Sediments at Stations B1 and B2 located in or near the effluent channel were each composed of mostly fine sand and were poorly sorted, meaning that they had a fairly wide distribution of particle sizes (Figure 2). Stations B3 and B7 varied more in particle distribution between seasons with Station B3 composed of fine silt in the spring and course silt in the fall, while Station B7 was composed of course sand in the spring and course silt in the fall.

The shifts, or lack thereof, in particle size distributions between seasons at these sites are probably the result of their locations in the Estuary. The most dramatic difference between seasons was at Station B7 which is located in the main river channel where sediments are constantly in flux. During the spring after the winter storm season had ended, the sediments here were courser as a result of storm scouring that had removed the finer particles. During the inundation period in the fall, finer particles were able to settle out as a result of the more quiescent conditions. Station B3, located in lower portion of the Estuary, had a somewhat higher concentration of fine particles that accumulated during both seasons. Both Stations B1 and B2 are located in a well protected side channel where the flow regime is fairly constant throughout the year. These sites are not subjected to heavy river scouring except during very large storms.

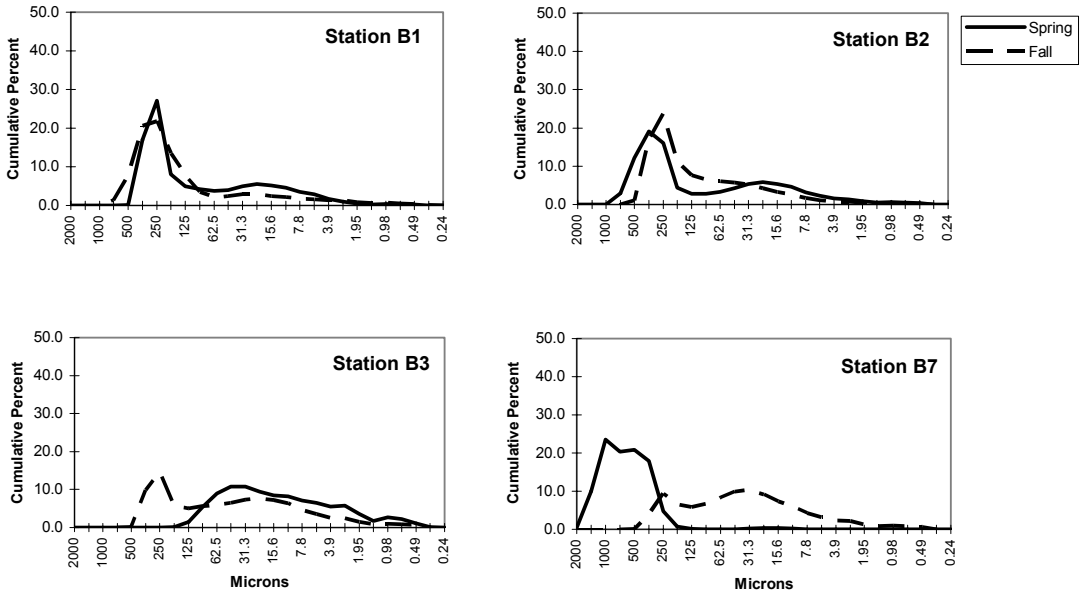
Table 3. Sediment particle size fractions (%), percentiles (16th, 50th & 84th) and sorting index values for stations located in the Santa Clara River Estuary during the spring and fall, 2003.

Station / Season	Particle Fraction Summary (%)				Percentile (microns)			Category [1.]	Percentile (phi)			Sorting Index [2.]	Sorting [2.]
	Sand	Silt	Clay	Fines	16%	50% [1.]	84%		16%	50%	84%		
May													
B1	65.2	32.2	2.6	34.8	11.7	138.0	255.5	fine sand	6.4	2.9	2.0	2.2	very poor
B2	63.5	32.4	4.1	36.5	12.2	164.4	338.0	fine sand	6.4	2.6	1.6	2.4	very poor
B3	15.9	66.8	17.3	84.1	2.6	13.8	44.0	fine silt	8.6	6.2	4.5	2.0	very poor
B7	98.9	1.2	0.0	1.2	300.0	541.2	920.2	course sand	1.7	0.9	0.1	0.8	moderate
October													
B1	78.2	17.4	4.4	21.8	43.2	177.1	312.3	fine sand	4.5	2.5	1.7	1.4	poor
B2	73.3	24.6	2.1	26.7	22.6	136.6	259.7	fine sand	5.5	2.9	1.9	1.8	poor
B3	46.7	45.9	7.4	53.3	6.6	37.9	214.6	course silt	7.2	4.7	2.2	2.5	very poor
B7	40.7	52.5	6.8	59.3	7.4	32.1	153.9	course silt	7.1	5.0	2.7	2.2	very poor

[1.] 0-4 = clay, 4-8 = very fine silt, 8-16 = fine silt, 16-31 = medium silt, 31-63 = coarse silt, 63-125 = very fine sand, 125-250 = fine sand, 250-500 = medium sand, 500-1000 = coarse sand.

[2.] <0.35 = very well sorted, 0.35-0.50 = well sorted, 0.50-0.71 = moderately well sorted, 0.71-1.00 = moderately sorted, 1.0-2.0 = poorly sorted, 2.0-4.0 = very poorly sorted, >4.0 = extremely poorly sorted.

Figure 2. Sediment particle size in microns by cumulative distribution (%) for spring and fall 2003 sampling surveys.



Macrobenthic Invertebrates

Summary

There were a combined total of 15,773 organisms collected from the four stations during the spring and fall bioassessment surveys (Table 4) (Appendix C, Tables 5 and 6). Of these, the majority were collected in the single littoral sweeps at Station B1 for both surveys (n = 10,180). A total of 28 unique species were collected during both surveys combined, with a total of 17 collected in the spring and 26 in the fall. Nearly equal numbers of taxa were collected in the littoral sweep samples (spring = 16, fall = 15), while a greater number of taxa were collected by core device during the fall (n = 24), than the spring (n = 13).

Bioassessment Metrics

Biological metrics were calculated according to the California Lentic and Stream Bioassessment protocols. The EPT (Ephemeroptera, Plecoptera, and Tricoptera) metrics could not be applied because there were no members of indicator group present in the estuary (Figures 3 and 4; Appendix C, Tables 7 and 8).

Total abundance: is a measure of the total number of individuals found at a site. The simplest measure of resident animal health is the abundance of invertebrates collected per sampling effort. However, abundance is not a particularly good indicator of benthic infaunal health. For example, some of the most populous benthic areas are those within the immediate vicinity of organic enrichment. The reason for this apparent contradiction is that environmental stress can exclude many sensitive species from an area. Those few organisms that can tolerate the stressful condition (e.g. pollutant) flourish because they have few competitors. If the area becomes too stressful, however, even the tolerant species cannot survive, and the abundance declines, as well.

The average abundances of organisms collected at each of the four sites during the spring and fall in the Santa Clara River Estuary by both littoral sweep and core are presented in Figures 3 and 4 (Appendix C, Tables 7 and 8). During both spring and fall, abundances were highest in the littoral sweep samples collected at Station B1 (5,032 and 5,148 respectively) in the effluent channel. During the spring, abundances were significantly higher at Stations B1 (1,320) and B2 (1,061), compared to Stations B3 (220) and B7 (29) (ANOVA, $p < 0.01$). The dramatic drop in abundance at B3 and B7 are probably the result of their locations in more open and less sheltered portions of the Estuary which during the spring were subject to greater storm flows as compared to the back channel stations. In the fall, when the Estuary was inundated, abundances were greatest at Station B2 (1,654) and lower, but similar, at Stations B1 (586), B3 (176) and B7 (546). Increased abundance at Station B7 during the fall may be due to the more quiescent conditions present during inundation.

Taxonomic richness: is a simple measure of population health and is the number of separate macroinvertebrate species collected per sampling effort (i.e. one core grab). Because of its simplicity, numbers of species is often underrated as an index. If the sampling effort and area sampled are the same for each station, however, this

Table 4. Summary of total abundances by species and location during both spring and fall, 2003 bioassessment surveys of the Santa Clara River Estuary. Stations B1 thru B7 abundances are total counts, while littoral sweep samples are estimates.

Species	Tolerance Value (TV)	Functional Feeding Group*	Spring 03						Fall 03					
			Littoral Sweep	Cores				Total by Core	Littoral Sweep	Cores				Total by Core
			B1	B1	B2	B3	B7		B1	B1	B2	B3	B7	
Berosus sp.	5	p	0	0	0	0	0	0	6	0	5	0	0	5
Ceratopogonidae	6	p	0	0	0	0	0	0	0	0	0	0	1	1
Chironominae	6	cg	77	111	34	2	1	149	234	23	10	57	107	197
Chydoridae	.	cf	211	0	0	0	0	0	12	0	0	0	0	0
Corisella sp.	8	p	25	0	13	0	1	15	102	3	5	0	1	9
Cyclopoida	8	cf	14	0	0	0	0	0	762	8	11	7	5	31
Cyprididae	8	cg	2242	52	18	0	0	70	558	7	47	8	9	72
Daphnia sp	8	cf	21	0	0	0	0	0	150	1	5	2	18	25
Dasyhelea sp.	6	cg	0	0	0	0	0	0	0	0	1	0	0	1
Dolichopodidae	4	p	0	0	1	0	0	1	0	0	0	1	1	2
Eogammarus sp.	6	cg	623	284	0	12	1	296	0	0	0	0	3	3
Ephydra sp.	6	sh	0	0	0	0	0	0	0	0	2	0	2	4
Fossaria sp.	8	sc	0	0	0	0	0	0	0	0	1	0	0	1
Harpacticoida	0	cf	3	0	0	0	0	0	0	0	0	0	0	0
Hyalella sp.	8	cg	127	31	1	0	0	31	12	6	1	0	0	7
Hydra sp.	5	p	0	0	0	0	0	0	6	0	0	0	0	0
Hydroporus sp.	5	p	0	0	0	0	0	0	0	0	1	0	4	5
Isotomidae	5	cg	1	0	45	18	1	64	90	12	1	3	8	24
Limnocythere sp.	8	cg	463	430	747	52	19	1248	2874	347	1284	42	338	2012
Limnodrilus sp.	10	cg	1096	331	162	108	6	607	90	146	264	3	29	443
Nematoda	5	0	0	0	0	27	0	27	0	0	0	45	0	45
Orthocladiinae	5	cg	116	75	6	1	0	81	36	0	2	7	6	15
Physa/Physella sp.	8	sc	0	0	0	0	0	0	0	0	1	0	4	5
Pomatiopsis sp.	8	sc	0	0	0	0	0	0	204	26	12	0	0	39
Sciomyzidae	6	p	0	0	0	0	0	0	0	0	1	0	0	1
Simulium sp. (L)	6	cf	5	1	0	0	0	1	0	0	0	0	0	0
Tanypodinae	7	p	7	4	35	0	0	39	0	7	0	0	9	16
Zoniagrion exclamationis	9	p	1	0	0	0	0	0	12	0	0	0	0	0
Total Abundance by Station			**5032**	**1319**	**1061**	**220**	**29**	**2630**	**5148**	**587**	**1654**	**176**	**547**	**2963**
Numbers of Species			**16**	**11**	**10**	**7**	**7**	**13**	**15**	**13**	**20**	**11**	**17**	**24**

* p = predator; cg = collector gatherer; cf = collector filterer, cg = collector grazer; sc = scaper

index can be one of the most informative. In general, stations with higher numbers of species per grab tend to be in areas of healthier communities.

Taxonomic richness was similar in the littoral sweep samples taken at Station B1 for both the spring and fall sampling events (16 and 15 respectively) (Figures 3 and 4; Appendix C, Tables 7 and 8). For the core samples in the spring, taxa richness was significantly different among stations, decreasing from a high of 10 at Station B1 to 5 at B7 (ANOVA, $p < 0.001$). During the fall taxa richness was significantly higher at Stations B2 (16) and B7 (15), and lower at B1 (11) and B3 (9) (ANOVA, $p < 0.01$). Taxonomic richness doubled in spring (24) compared to fall (13).

Percent dominance: reflects the proportion of the total abundance at a site represented by the most abundant species. For example, if 100 organisms are collected at a site and species A is the most abundant with 30 individuals, the percent dominance index score for this site is 30%. The benthic environment tends to be healthier when the dominance index is low, which indicates that more species compose the total abundance at the site.

Dominance was generally high across both seasons and stations regardless of sampling technique (Figures 3 and 4; Appendix C, Tables 7 and 8). For the littoral sweep samples, dominance was lowest in the spring (40%) and highest in the fall (60%). For the core samples, during the spring dominance was lowest at Station B1 (40%) in the effluent channel, while higher and similar at Stations B2 (63%), B3

(51%) and B7 (66%). During the fall dominance was similar across sites and was highest at Station B2 (69%) and lowest at B3 (52%).

Figure 3. Bioassessment metrics calculated for populations collected from the Santa Clara River Estuary during the spring 2003.

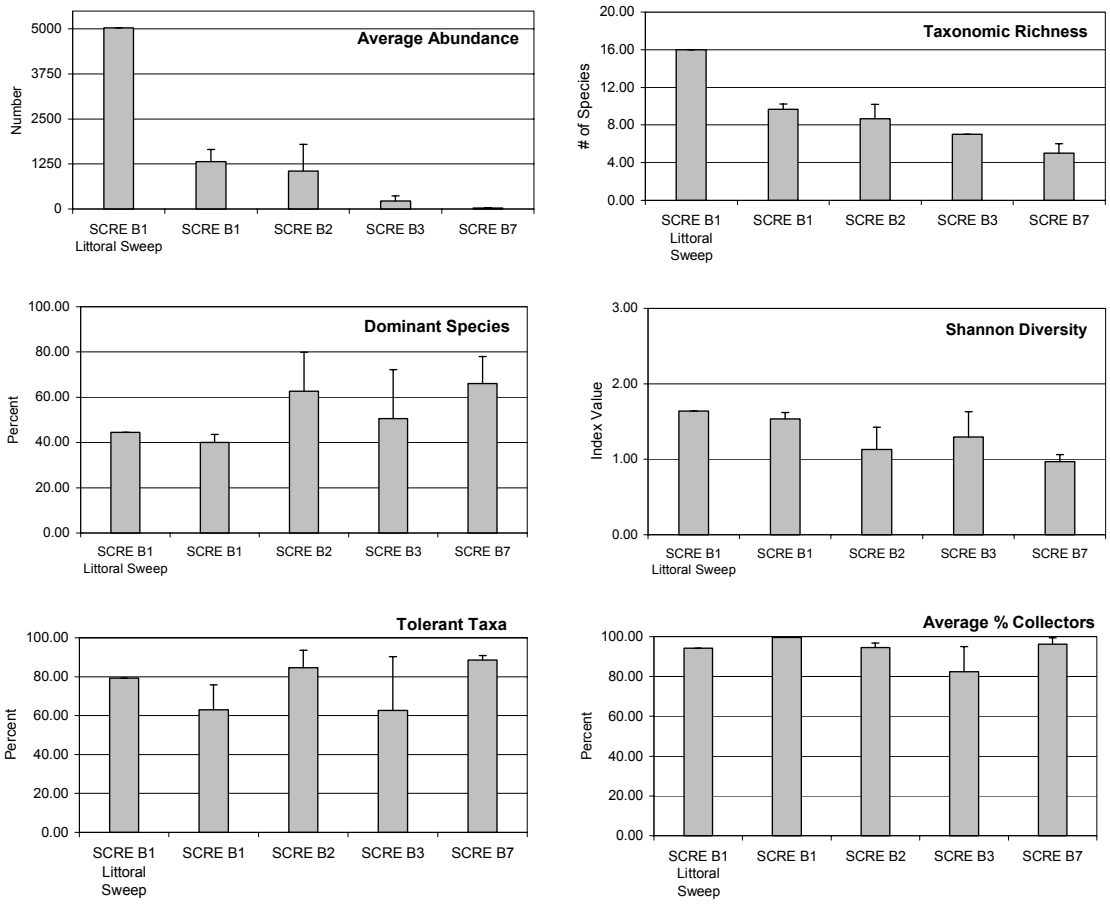
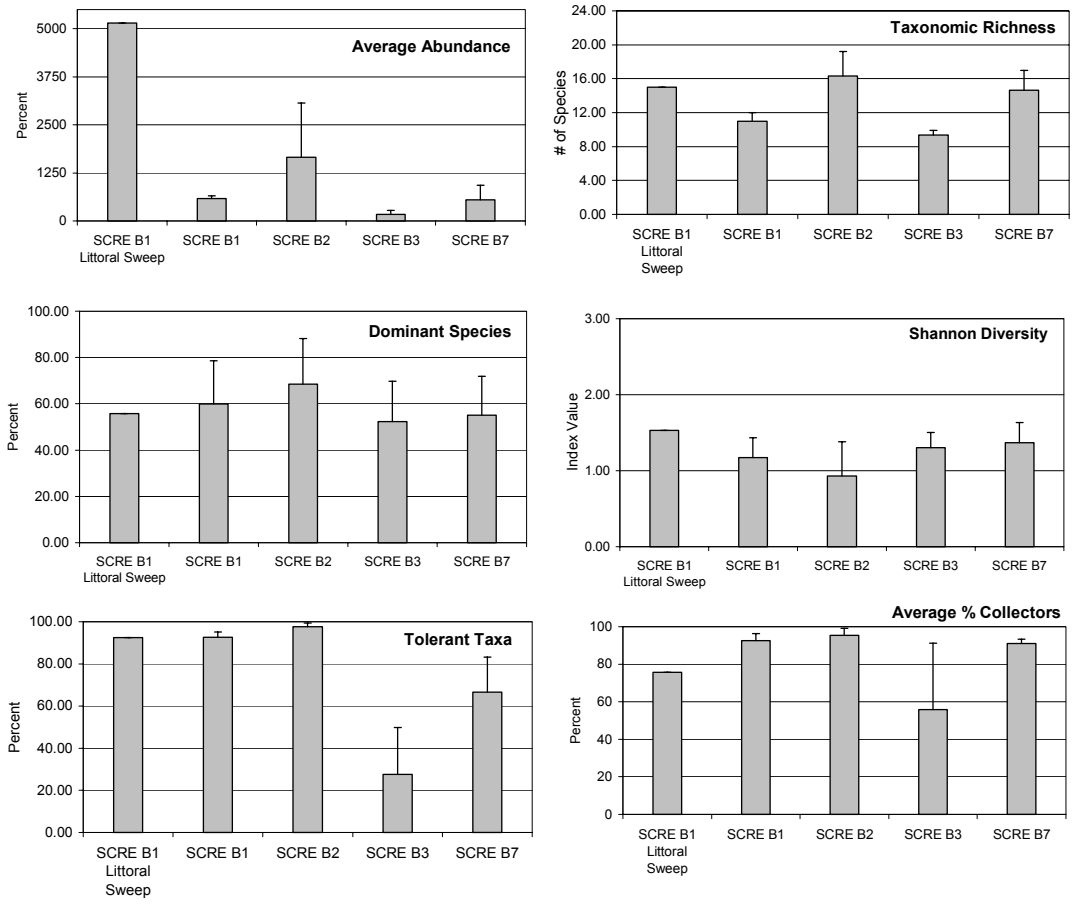


Figure 4. Bioassessment metrics calculated for populations collected from the Santa Clara River Estuary during the fall 2003.



Shannon diversity: is similar to numbers of species; but contains an eveness component as well. For example, two samples may have the same numbers of species and the same numbers of individuals. However, one station may have most of its numbers concentrated into only a few species while a second station may have its numbers evenly distributed among its species. The diversity index would be higher for the latter station. Diversity values range from 0 to 4, with values approaching four indicating greater diversity and presumably a more healthy population.

Diversity was generally low across seasons and stations, not exceeding 2 at any site (Figures 3 and 4; Appendix C, Tables 7 and 8). Diversity was similar in the littoral sweep samples during both the spring (1.64) and fall (1.53). For core samples, the spring diversity was highest at stations B1 (1.54) and lowest at Station B7 (0.97). In the fall diversity was highest at Stations B3 (1.31) and B7 (1.37). Lowest diversity was measured at B3 (0.93).

Tolerant Taxa: The percentage of tolerant taxa collected at a site helps to assess the ability of organisms to tolerate pollution and habitat impairment. Based on the CSBP and EPA protocols, each taxon is assigned a tolerance value from 0 (highly intolerant) to 10 (highly tolerant). The Tolerance Value for a site is calculated by multiplying the tolerance value of each species with a tolerance value ranging from 8 to 10, by its abundance, then dividing by the total abundance for the site. When a large proportion of the organisms at a site are tolerant, it indicates that conditions at the site are stressful. Stressful conditions can be the result of highly variable habitat conditions or the presence of impairment due to pollution. The tolerance values for each species were developed in different parts of the United States and can therefore be region specific. Also, different organisms can be tolerant to one type of disturbance, but highly sensitive to another. For example, an organism that is highly sensitive to sediment disturbance may be very insensitive to organic pollution. With these drawbacks in mind, the Tolerance Values generally depict disturbances when coupled with other metrics and can provide good information regarding the system.

The percentage of tolerant taxa was high across seasons and stations in the Santa Clara River Estuary (Figures 3 and 4; Appendix C, Tables 7 and 8). Tolerant taxa were slightly higher in the fall littoral sweep sample (92%) compared to the spring (79%). In the spring core samples, tolerant taxa were highest, but not significantly so, at Stations B2 (85%) and B7 (88%), and lowest at Stations B1 and B3 (63% each). During the fall tolerant taxa composed nearly 100% of the species at Stations B1 (93%) and B2 (98%). The percentage of tolerant taxa was significantly lower among stations during both seasons at Station B3 (28%) (ANOVA, $p < 0.01$).

Percent Collectors: The percent composition of the functional feeding groups provides information regarding the balance of feeding strategies represented in an aquatic assemblage. The combined feeding strategies of the organisms in a reach provide information regarding the form and transfer of energy in the habitat. When the feeding strategy of a stream system is out of balance it can be inferred that the habitat is stressed. For the purposes of this study, species were grouped by feeding strategy as predators, collectors, filterers, scrapers, and shredders. The percentage of collectors is presented herein since they were by far the most dominate feeding strategy represented in the Estuary. Collectors are organisms that gather up deposited fine particulate organic matter (FPOM) by browsing or burrowing in the sediments.

The relative percentage collectors was far greater compared to any of the other feeding groups collected in the Estuary and were high across both seasons and stations (Figures 3 and 4; Appendix C, Tables 7 and 8). Collectors were highest in the spring littoral sweep sample (94%) compared to the fall sample (76%). During the spring percent collectors exceeded 90% in all core samples. In the fall, collectors were greater than 90% at each station, except Station B3 where they composed only 56% of the population.

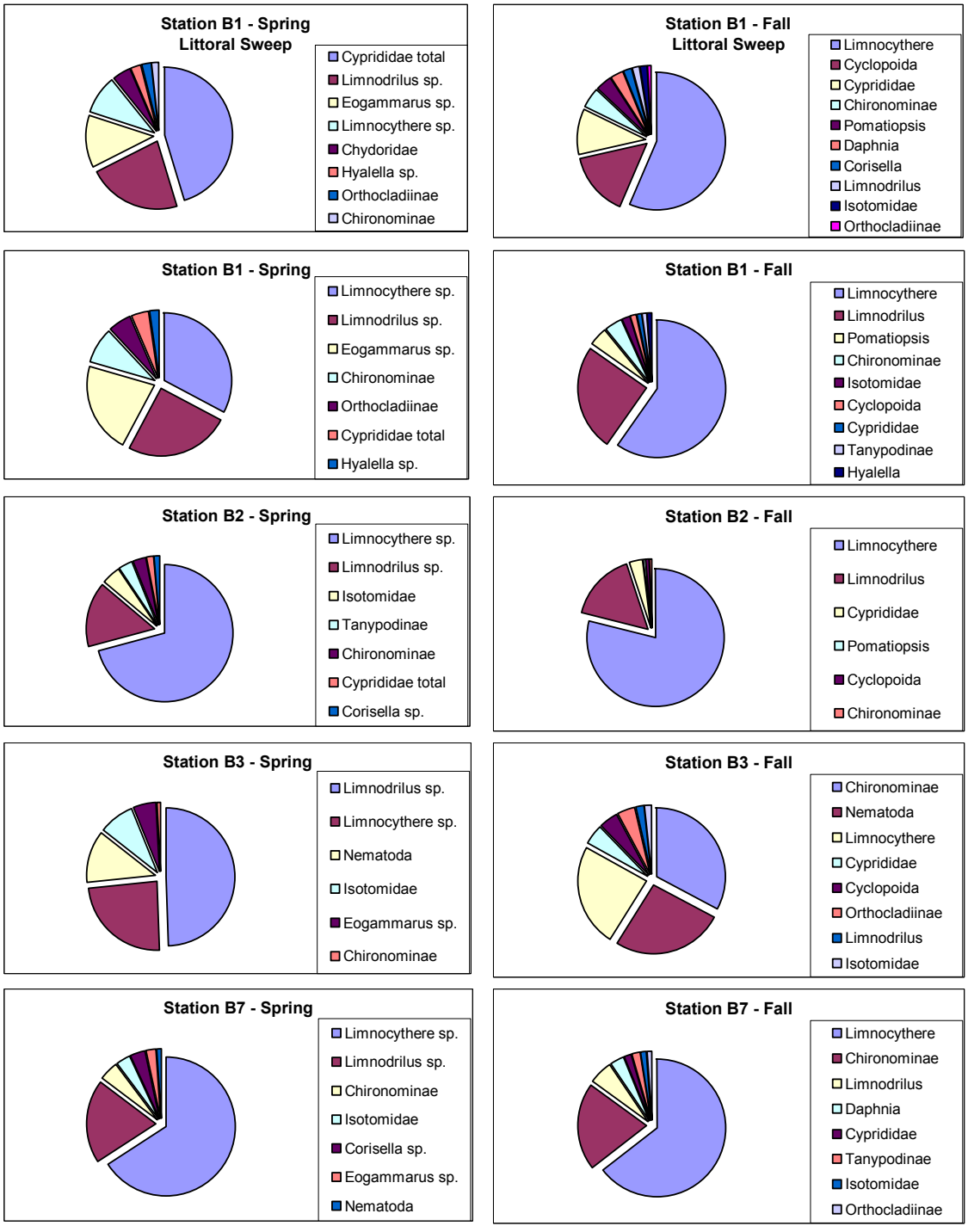
Most Abundant Species

The most abundant species collected during the spring and fall by both littoral sweep at Station B1 and by core at each of the four stations are presented in Figure 6 and Appendix C, Tables 9 and 10. The composition of species in the littoral sweep samples was similar between the spring and fall sampling events. In the spring, cypridid ostracods were the most dominant taxa accounting for 44% of the population. The next most abundant species included an oligochaete (*Limnodrilus sp.,* 22%), the amphipod, *Eogammarus sp*. (12%), and *Limnocythere sp.* (9%) another ostracod. During the fall ostracods again dominated the abundance (*Limnocythere sp*. 56% and cypridids 11%) and were joined by the copepod, *Cyclopoida sp*. (15%) and chironomids (5%).

The two most common species collected by core in the survey area were the ostracod, *Limnocythere sp*., and the tubificid oligochaete, *Limnodrilus sp*. Each of these organisms is very tolerant of perturbations with tolerance values of 8 and 10 respectively. During the spring *Limnocythere sp.* (range 32% at B1 to 70% at B2) was most abundant at every site except Station B3 where *Limnodrilus sp.* (49%) was most prevalent. In each case where *Limnocythere sp.* was most abundant, *Limnodrilus sp.* was second. Other species that were present during the spring in relatively large numbers included the amphipod, *Eogammarus sp.* (21%) and chironomids (8%) at Station B1; isotomids (4%) and the chironomid, *Tanypodinae sp.* (3%) at Station B2; nematodes (12%), isotomids (8%) and *Eogammarus sp.* (5%) at Station 3; and, chironomids (4%) and isotomids (3%) at Station B7.

In the fall, Limnocythere sp. was the most abundant species at Stations B1 (56%), B2 (78%) and B7 (62%). *Limnodrilus sp.* was next most abundant at Station B1 (25%) and B2 (16%), and third most abundant at B7 (5%). The relative abundance of species was somewhat different at Station B3 where chrionomids (32%), nematodes (26%), and *Limnocythere sp.* (24%) prevailed. It should be noted that B3 was the only site in the survey area where nematodes were collected. Other species that were present in relatively large numbers in the fall included the gastropod *Pomatiopsis sp.* (4%) and chironomids (4%) at Station B1; cypridid ostracods (2%) at B2; cypridid's (5%), copepods (4%), Orthocladiinae (chrironomid) (4%) at B3; and, *Daphnia sp.* (3%) at B7.

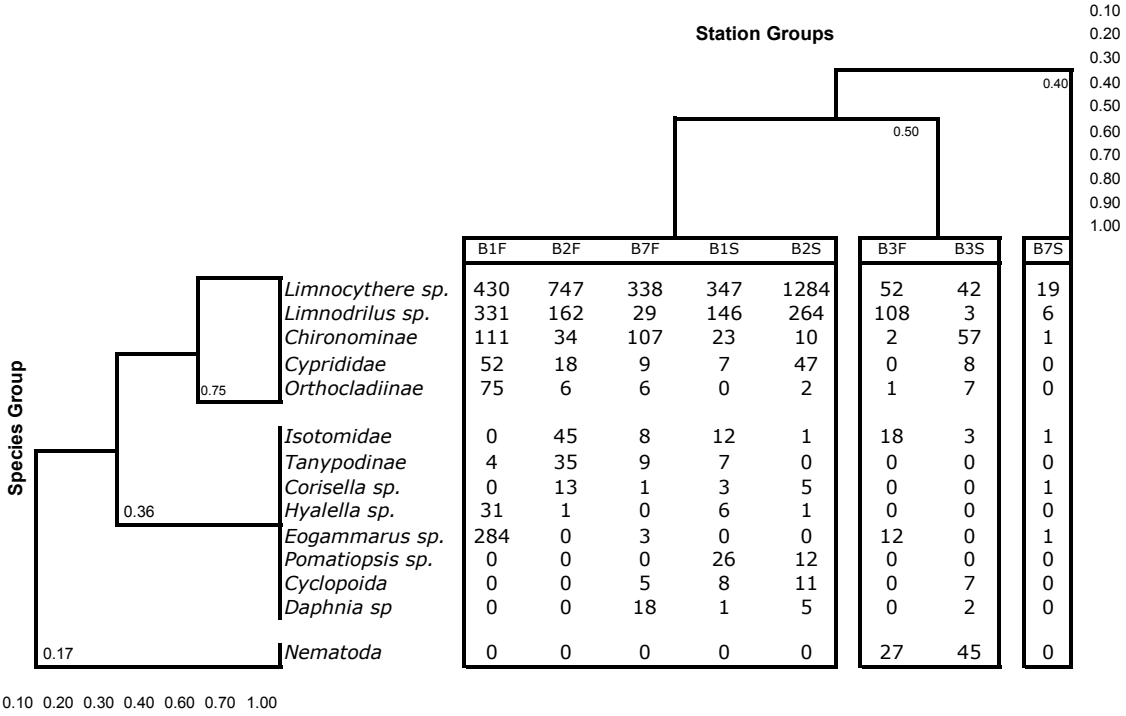
Figure 6. Cumulative percent abundance of most common species collected in the Santa Clara River Estuary from four sites during the spring and fall of 2003.



Cluster Analysis

Stations clustered into three groups based mainly on location (Figure 7). Stations B1 and B2 in the effluent channel were most similar and grouped together for both the spring and fall sampling events as did Station B7 in the fall. In the spring Station B7 grouped by itself. Station B3 for both spring and fall formed one group. The dissimilarity for this group was driven by the exclusive presence of nematodes during both seasons. During the fall Station B7 was most dissimilar to all other stations, owing mostly to the low numbers of organisms collected there.

Figure 7. Two-way coincidence table of species vs. station groups created by cluster analysis (UPGMA, Sneath and Sokal 1973). The Bray-Curtis dissimilarity index was used to calculate the distances among stations and species (Gauch 1982, Jongman et. al. 1995). Values associated with each cell are average (n = 3) species abundances for each station. Only the most frequently occurring organisms were used in the analysis (n ≥ 14) which represented 99% of the total population.



	B1F	B2F	B7F	B1S	B2S	B3F	B3S	B7S
Limnocythere sp.	430	747	338	347	1284	52	42	19
Limnodrilus sp.	331	162	29	146	264	108	3	6
Chironominae	111	34	107	23	10	2	57	1
Cyprididae	52	18	9	7	47	0	8	0
Orthocladiinae	75	6	6	0	2	1	7	0
Isotomidae	0	45	8	12	1	18	3	1
Tanypodinae	4	35	9	7	0	0	0	0
Corisella sp.	0	13	1	3	5	0	0	1
Hyalella sp.	31	1	0	6	1	0	0	0
Eogammarus sp.	284	0	3	0	0	12	0	1
Pomatiopsis sp.	0	0	0	26	12	0	0	0
Cyclopoida	0	0	5	8	11	0	7	0
Daphnia sp	0	0	18	1	5	0	2	0
Nematoda	0	0	0	0	0	27	45	0

DISCUSSION

The 2003 bioassessment survey of the Santa Clara River Estuary included two sampling events; one when the Estuary mouth was open in the spring and the other during closed conditions in the fall. During both seasons water quality, sediment grain size and biological samples were collected. Biological samples were collected using a core device developed during previous surveys (USFWS 1999) at each of four stations (Stations B1, B2, B3 and B7) specified in the City of San Buenaventura's NPDES permit. Additionally, a single littoral sweep sample was collected at Station B1 during the spring and fall. The goal of this survey was to determine the effects, if any, the discharge from the VWRF has had on the biological communities in the Estuary.

River flow into the Estuary was typical of past years with winter and spring storms occurring during February, March, April and May. These rain events lead to removal of the sand berm at the mouth of the Estuary, thus allowing the Estuary to drain to the ocean. Sampling for the spring season occurred within a week of the final storm of the season when the sand berm was absent and the Estuary was essentially drained. During the dry weather season in the summer and fall, the berm redeveloped. As a result the Estuary began a cycle of inundation due to flow from the Santa Clara River and the VWRF, combined with periodic partial draining as the sand berm was breached due to hydraulic and tidal pressure. Sampling in the fall occurred during a period when the Estuary had been closed to the ocean for 23 consecutive days.

Water quality in the Estuary during 2003 was typical of past surveys and depicted the dynamic and quickly changing environment of this estuary system. Water temperature in the Estuary was relatively warm during both surveys, especially during the spring. Temperatures ranged from 20.5° C at Station B3 in fall to 24.1° C at Station B7 in the spring. These findings were within the range of past studies (13.94 to 29.04° C, USFWS 1999). pH ranged from 7.3 in the effluent channel at Station B2 during the fall to a high of 9.2 at Station B7 during the same survey. Dissolved oxygen concentrations in the Estuary were highly variable ranging from 3.78 mg/L at Station B2 in fall to 14.9 mg/L during the spring at Station B2. Temperature, pH and dissolved oxygen all fell well within the ranges reported by Greenwald et al (USFWS 1999) during a comprehensive survey in the Estuary conducted from July 1997 to July 1998. This year's water quality results were also similar to measurements collected during 2002 (ENTRIX 2003).

Salinity has been shown in past studies to be the most controlling factor influencing the composition and distribution of invertebrates under estuarine conditions (Kennish 1986, Chapman and Wang 2001). For the 2003 survey, salinity during spring ranged from 1.3 ppt in the effluent channel to 12 ppt at Station B7 in the river channel. During the fall salinity was less variable ranging from 1.4 ppt at Station B1 to 2.3 ppt at B7. The spring sampling occurred after a high tide inundated the southwest edge of the Estuary where B7 is located. Salinity during the 2003 survey fell just above the EPA's freshwater criterion (<1.0 ppt, 95% of the time) and below that of brackish water (5 to 10 ppt) at every station except B7, where salinity reached 12 ppt in the spring. During the recent Metals Translator Study in the Estuary, salinity was examined over a year's time (ENTRIX 2002). In that study, low salinities (1 to 4 ppt) were observed near the discharge channel and upper Estuary where the Santa

Clara River flows in. Brackish conditions (5 to 10 ppt) were observed in the middle of the Estuary. More marine-like (>10 ppt) conditions were isolated to the area near the mouth and far southwestern portion of the Estuary, the highest salinity measurement being 30 ppt. Past studies of the Estuary by Merrit-Smith from August 1998 to January 1999 and USFWS from 1997 to 1999 indicate salinity ranges from 0.6 to 32.8 ppt, with high levels of variance both temporally and spatially (ENTRIX 1999; USFWS 1999).

After salinity, sediment particle size appears to have the greatest influence on the distribution of invertebrates in an estuary system (Kennish 1986). Sediment sizes ranged from course sand at Station B7 in the river channel during the spring to fine silt at Station B3 during the spring. The shifts, or lack thereof, in particle size distributions at the Estuary stations between seasons are probably the result of their locations in the Estuary. The most dramatic difference between seasons at any site occurred at Station B7 which is located in the main river channel where sediments are constantly in flux. During the spring after the winter storm season had ended, the sediments here were probably courser due to the deposition of new upstream sediments and the removal of the finer particles. During the inundation period in the fall, finer particles again accumulated at B7, most likely due to the more quiescent conditions. Station B3, located in lower portion of the Estuary, had a somewhat higher concentration of fine particles that accumulated during both seasons. Both Stations B1 and B2 are located in a well protected side channel where the flow regime is fairly constant throughout the year. These sites are not subjected to heavy scouring except during very large storms.

The macrobenthic invertebrate community found in the Santa Clara River Estuary represents a community that has adapted to the highly dynamic conditions discussed above. As with past surveys, all of the organisms represented during the 2003 survey were those found in either freshwater or estuarine environments (USFWS 1999, ENTRIX 2003). The numbers of species collected at all stations by core in the spring (13) was less than half the number collected in the fall (24). Lower numbers of species during the spring was due to the very low numbers found at Stations B3 and B7 (7 each). These stations are located in the main channel of the Santa Clara River which are more subject to scouring and deposition of upstream sediments during storm events. Since sampling occurred within a week of the final large storm of the year, it is probable that many species were either swept away or buried. The numbers of species collected in 2003 were somewhat lower overall when compared to the 2002 survey, when taxa richness was highest during the fall closed estuary sampling (30) and lowest during the spring open estuary sampling (25) (ENTRIX (2003); but similar to the number of species (24) found in the Estuary by Greenwald et al. (USFWS 1999) during multiple surveys from 1997 to 1998.

Total abundances of organisms collected during the 2003 survey were similar between the spring and fall. In past surveys the numbers of organisms present in the Estuary were generally greater during the summer and fall closed estuary conditions when compared to the spring (USFWS 1999, ENTRIX 2002 and 2003). By far the most abundant and ubiquitous species collected by core from all sites combined were the ostracod, *Limnothrere sp.* (60% of the population) and the tubificid oligochaete, *Limnodrilus sp.* (20%). During the 2002 survey Limnodrilus sp. were abundant and found at every site, but instead of *Limnothrere sp.*, the Cypridid ostracods were most abundant (ENTRIX 2003). Other abundant species collected by core during the 2003 survey included Eogammarus sp., Isotomids, Chironomids (midgeflies), Nematodes, Pomatiopsis (gastropod), and Cyclopodia (copepod). Each of these was also found in

relatively similar abundances across stations during the 2002 survey (ENTRIX 2003). Compared to this survey (2003), when 10,625 organisms were collected, Greenwald et al. (USFWS 1999) collected far fewer organisms by coring device (total = 1,359) across 5 stations during 12 separate surveys between 1997 and 1998. It is not known whether these differences can be attributed to a true increase in the numbers of organisms present in the Estuary during this time period or differences in sampling technique.

The results of sampling by littoral sweep were mixed. When compared with the core sampling device, littoral sweep samples yielded much larger abundances during each season, with over 5,000 individuals collected in each sample during both surveys. Additionally, the numbers of taxa collected by littoral sweep were similar to those collected by core. The total number of taxa collected during both surveys and sampling techniques combined was 28. Of these, 9 were unique to the coring device, while only 2 were unique to the littoral sweep. This shows that while the littoral sweep is more efficient in terms of total numbers of organisms collected, it is less efficient in terms of the numbers of species collected. Nematodes were only collected by core in the fall at Station B3. When analyzed by cluster analysis this single factor caused B3 to group by itself in terms of dissimilarity with other stations.

The species collected during this and past surveys were dominated by those with moderate to high tolerance values, typical of organisms capable of living under stressful conditions including either habitat disruption or pollution (CDFG 1999). While the Estuary is located downstream of heavy agricultural inputs, the major disturbances are mostly due to shifting habitat conditions. Fluctuating salinity as a result of tidal influence, the continuous rise and fall of the water level in the Estuary and the scouring and deposition that occur as a result of seasonal storms combine to make this a very difficult habitat to survive in.

The composition of the biological population found at SCRE stations during the 2003 survey appear to be most influenced by these factors. Differences between sites appear to be changing water levels and shifts in sediment particle size. For example, the composition of organisms found at Station B7 in the fall was most similar to outfall Stations B1 and B2. This was most likely due to the inundation of freshwater during the fall as a result of river flow at Station B7 and the VWRF effluent at Stations B1 and B2. This, combined with sediments that were similar in composition among these sites, led to similar population compositions. While Station B3 grouped separately, only large numbers of nematodes made this site different from the others. Station B7 was the most dissimilar from the other sites during the spring due to the very low abundance of organisms found there. This may have been the result of the deposition of finer upstream sediments during spring river flow, increased salinity and the concurrent loss of habitat complexity and benthic productivity.

APPENDIX A - REFERENCES

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APPENDIX B – SEDIMENT PARTICLE SIZE

Table 4. Cumulative particle sizes in microns and phi for the four sampling locations in the Santa Clara River Estuary for spring and fall, 2003.

Station / Season	phi Size																											
	-1	-0.5	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	5	11	11.5	12	
	Microns																											
	≥2000	1410	1000	710	500	354	250	177	125	88.4	62.5	44.2	31.3	22.1	15.6	11.1	7.8	5.5	3.9	2.8	1.95	1.38	0.98	0.69	0.49	0.35	0.24	
	crs sand	crs sand	med sand	med sand	fine sand	med sand	fine sand	very fine sand	very fine sand	very fine sand	very fine sand	very fine sand	crs silt	crs silt	crs silt	silt	fine silt	very fine silt	very fine silt	clay	clay	clay	clay	clay	clay	clay	clay	
May																												
B1	0.00	0.00	0.00	0.00	0.13	16.99	27.07	8.04	4.99	4.20	3.77	4.01	4.90	5.49	5.16	4.54	3.48	2.92	1.69	0.91	0.44	0.29	0.38	0.37	0.22	0.00	0.00	
B2	0.00	0.00	0.00	2.92	12.16	19.10	16.08	4.34	2.82	2.82	3.26	4.21	5.38	5.87	5.37	4.58	3.19	2.26	1.55	1.34	0.80	0.52	0.59	0.47	0.35	0.02	0.00	
B3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	1.44	5.38	8.91	10.78	10.76	9.48	8.43	8.19	7.16	6.51	5.51	5.82	3.59	1.72	2.65	2.25	1.11	0.15	0.00	
B7	0.53	9.97	23.59	20.38	20.85	17.90	4.80	0.72	0.12	0.00	0.00	0.00	0.26	0.33	0.31	0.24	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
October																												
B1	0.00	0.00	0.00	1.35	7.54	20.64	21.76	13.49	7.77	3.50	2.21	2.43	2.95	2.85	2.41	2.17	1.78	1.52	1.27	1.31	0.85	0.54	0.71	0.53	0.36	0.08	0.00	
B2	0.00	0.00	0.00	0.00	1.06	16.87	23.78	11.37	7.68	6.49	6.05	5.74	5.22	4.30	3.30	2.54	1.65	1.12	0.76	0.67	0.43	0.33	0.35	0.20	0.09	0.00	0.00	
B3	0.00	0.00	0.00	0.00	0.17	9.86	14.41	5.69	5.00	5.60	5.98	6.55	7.31	7.61	7.18	6.43	4.70	3.54	2.61	2.44	1.48	0.92	1.00	0.86	0.62	0.04	0.00	
B7	0.00	0.00	0.00	0.00	0.07	3.78	9.36	6.58	5.84	6.73	8.31	9.94	10.33	9.09	7.32	6.01	4.27	3.23	2.36	2.18	1.36	0.90	0.95	0.82	0.56	0.03	0.00	

APPENDIX C - MACROINVERTEBRATES

Table 5. Identified taxa for the Spring 2003 sampling event, by lifestage, by Station for Santa Clara River Estuary Stations.

						Tolerance Value (TV)	*Functional Feeding Group (FFG)*	SCRE B1 Littoral Sweep	SCRE B1			SCRE B2			SCRE B3			SCRE B7		
Phylum	**Class**	**Order**	**Family**	**Genus**	**Scientific Name**			1	1	2	3	1	2	3	1	2	3	1	2	3
Cnidaria		Actiniaria	Ophuroidea		**Ophuroidea (damaged)**	.	.				1									
Nematoda					**Nematoda**	5	.								35	31	14	1		
Mollusca	Gastropoda	Basommatiphora	Physidae	Physa/Physella	***Physa/Physella sp.***	8	sc													
			Lymanaeidae	*Fossaria*	***Fossaria sp.***	8	sc													
		Mesogastropoda	Hydrobiidae	*Pomatiopsis*	***Pomatiopsis sp.***	**8**	**sc**													
Annelida	Oligochaeta		Lumbriculidae		**Lumbriculidae**	5	cg			1										
			Tubificidae	*Limnodrilus*	***Limnodrilus sp.***	10	cg	1096	58	314	621	62	114	311	30	21	274	12	2	3
Arthropoda	Branchiopoda	Diplostraca	Chydoridae		**Chydoridae**	.	**cf**	211												
			Daphniidae	*Daphnia*	***Daphnia sp***	**8**	**cf**	21												
	Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	***Eogammarus sp.***	6	cg	623	361	351	140				2	10	23		1	1
			Talitridae	*Hyallela*	***Hyalella sp.***	8	cg	127	41		51		2							
		Decapoda	Astacidae	*Pacifastacus*	***Pacifasticus sp.***	6	om													
	Maxillipoda	Cycopoida			**Cyclopoida**	**8**	**cf**	14												
		Harpacticoida			**Harpacticoida**	**8**	**cf**	3												
	Ostracoda	Podocopina	Cyprididae		**Cyprididae type 1**	8	cg	340	12	15	18	2	21	2						
					Cyprididae type 2	8	cg	1659	20	15	69		24							
					Cyprididae type 3	8	cg	233		2	1	1	2	1						
					Cyprididae type 4	8	cg	10			5									
					Cyprididae total	8	cg													
			Limnocytheridae	*Limnocythere*	***Limnocythere sp.***	8	cg	463	366	603	320	102	1273	866	87	14	56	18	29	11
	Insecta	Collembola	Isotomidae		**Isotomidae**	**5**	**cg**	1				21	98	16	12	30	12		3	
		Zygoptera	Coenagrionidae	*Zoniagrion*	***Zoniagrion* imm.?**	9	p	1												
		Hemiptera	Corixidae	*Corisella*	***Corisella sp.***	8	p	25	1			3	12	25				1	2	
		Coleoptera	Dryopidae	*Helichus*	***Helichus sp.* (A)**	5	sh													
				Hydroporus	***Hydroporus sp. (L)***	5	p													
			Hydrophilidae	*Berosus*	***Berosus sp.* (L)**	5	p													
		Diptera	Ceratopogonidae		**Ceratopogonidae (P)**	6	p													
				Dasyhelea	***Dasyhelea sp.***	6	cg													
						.	.													
			Chironomidae		**Chironominae**	6	cg													
					Chironomini	6	cg													
				Chironomus sp.	***Chironomus sp.***	10	cg	9	13	24		19	23	44						
				***Chironomus sp.* (P)**	***Chironomus sp.* (P)**	10	cg		3	2										
				Dicrotendipes sp.	***Dicrotendipes sp.***	8	cg	46	50	100	69						2			1
				Dicrotendipes sp. (P)	***Dicrotendipes sp. (P)***	8	cg			6	6									
				Phaenopsectra/Tribelos sp.	***Phaenopsectra/Tribelos sp.***	7	sc	2											1	
				Polypedilum sp.	***Polypedilum sp.***	6	sc	3		1										
					Tanytarsini	6	cg													
				Paratanytarsus sp.	***Paratanytarsus sp.***	6	cg	13	9	21	11			1						
				Tanytarsus	***Tanytarsus***	6	cf	4	3	13	3	5	1	10	2	2		2		
					Orthocladiinae	5	cg													
				Cricotopus	***Cricotopus sp.***	7	cg	47	7	64	35		4	2						
					***Cricotopus sp.* (P)**	7	cg				5									
				Cricotopus Binctus Gr.	***Cricotopus Binctus Gr.***	7	cg	21		16	26		5	6		1				
				Eukiefferiella	***Eukiefferiella sp.***	8	cg	7	1	3	3									
				Orthocladius Complex	***Orthocladius Complex***	6	cg	7	3	13	8									
				Rheocricotopus	***Rheocricotopus sp.***	6	cg	23	4	24	12				1		1			
				Thienemanniella	***Thienemanniella sp.***	6	cg	9												
					***Thienemanniella sp.* (P)**	6	cg	2												
					Tanypodinae	7	p													
					Pentaneurini	6	p													
				Apedilum	***Apedilum sp.***	6	p	2	1	2										
				Pentaneura	***Pentaneura sp.***	6	p	5		7	2									
				Tanypus	***Tanypus sp.***	10	p					14	32	54						
					Tanypus sp. (P)	10	p						2	2						
					Procladius sp.	9	p													
			Dolichopodidae		***Dolichopodidae* (L)**	4	p			1			1	1						
			Ephydridae	***Ephydra***	***Ephydra sp.* (L)**	6	sh													
				Hydrellia	***Hydrellia sp. (L)***	6	sh													
			Muscidae	***Limnophora***	***Limnophora sp.* (L)**	6	p													
			Sciomyzidae		**Sciomyzidae (P)**	6	p													
			Simulidae	***Simulium***	***Simulium sp.* (L)**	6	cf	5		1	1									
					Total BMIs/sample			5032	953	1599	1407	229	1614	1341	169	109	382	34	38	16

Table 6. Identified Taxa, by lifestage, by Station for Santa Clara River Estuary Stations, October 2003.
ABC Laboratories Project Fall 2003

						Tolerance Value (TV)	Functional Feeding Group (FFG	Station Nam / Station Num / Replicate N	SCRE B1 littoral Swee	SCRE B1			SCRE B2			SCRE B3			SCRE B7		
Phylum	**Class**	**Order**	**Family**	**Genus**	**Scientific Name**				1	1	2	3	1	2	3	1	2	3	1	2	3
Cnidaria	Hydrozoa	Hydroida		*Hydra*	***Hydra sp.***	5	p		1			1									
Nematoda					**Nematoda**	5	.									5	71	60			
Mollusca	Gastropoda	Basommatiphora	Physidae	Physa/Physella	***Physa/Physella sp.***	8	sc						1		3		1		7	1	3
			Lymanaeidae	*Fossaria*	***Fossaria sp.***	8	sc						1		1						
		Mesogastropoda	Hydrobiidae	*Pomatiopsis*	***Pomatiopsis sp.***	**8**	**sc**		34	51	15	13	15	8	14						
Annelida	Oligochaeta		Lumbriculidae		**Lumbriculidae**	5	cg														
			Tubificidae	*Limnodrilus*	***Limnodrilus sp.***	10	cg		15	256	117	66	351	166	276	6		4	28	19	41
Arthropoda	Branchiopoda	Diplostraca	Chydoridae		**Chydoridae**	**.**	**cf**		2												
			Daphniidae	*Daphnia*	***Daphnia sp***	**8**	**cf**		25	2		1	5	4	5	1	2	2	1	8	44
	Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	***Eogammarus sp.***	6	cg								1				6		2
			Talitridae	*Hyallela*	***Hyalella sp.***	8	cg		2	13	2	2	2		1						
		Decapoda	Astacidae	*Pacifastacus*	***Pacifasticus sp.***	6	om							1							
	Maxillipoda	Cycopoida			**Cyclopoida**	**8**	**cf**		127	8	5	10	7	20	7	15	3	4	1	1	13
		Harpacticoida			**Harpacticoida**	**8**	**cf**														
	Ostracoda	Podocopina	Cypridiidae		**Cypridiidae type 1**	8	cg		76	9	4	4	15	89	23	5	5	13	7	10	11
					Cypridiidae type 2	8	cg		13	2			2								
					Cypridiidae type 3	8	cg		4			3	1	10		2					
					Cypridiidae type 4	8	cg														
					Cypridiidae total	8	cg														
			Limnocytheridae	*Limnocythere*	***Limnocythere sp.***	8	cg		479	245	311	486	754	2924	174	123	1	2	286	50	679
	Insecta	Collembola	Isotomidae		**Isotomidae**	**5**	**cg**		15	6	16	13	3	1		1	3	5	3	2	18
		Zygoptera	Coenagrionidae	*Zoniagrion*	***Zoniagrion exclamationis***	9	p		2												
		Hemiptera	Corixidae	*Corisella*	***Corisella sp.***	8	p		17	7		1	5	3	7						3
		Coleoptera	Dryopidae	*Helichus*	***Helichus sp.* (A)**	5	sh														
				Hydroporus	***Hydroporus sp. (L)***	5	p						3						11	1	1
			Hydrophilidae	*Berosus*	***Berosus sp.* (L)**	5	p		1				9	2	3						
		Diptera	Ceratopogonidae		**Ceratopogonidae (P)**	6	p												2		1
				Dasyhelea	***Dasyhelea sp.***	6	cg						1		1				1		
						.	.														
			Chironomidae		**Chironominae**	6	cg														
					Chironomini	6	cg														
				Chironomus sp.	***Chironomus sp.***	10	cg		7	17	22	14	2	3	2	2			92	28	42
				Chironomus sp. (P)	***Chironomus sp.* (P)**	10	cg			3	5	1							4		
				Dicrotendipes sp.	***Dicrotendipes sp.***	8	cg		3								1				
				Dicrotendipes sp. (P)	***Dicrotendipes sp. (P)***	8	cg														
				Phaenopsectra/Tribelos sp.	***Phaenopsectra/Tribelos sp.***	7	sc														
				Polypedilum sp.	***Polypedilum sp.***	6	sc														
					Tanytarsini	6	cg														
				Paratanytarsus sp.	***Paratanytarsus sp.***	6	cg		29	1	1	1	3		3	3		1			
				Tanytarsus	***Tanytarsus***	6	cf			3	1	1	5	8	3	104	9	50	70	38	48
					Orthocladiinae	5	cg														
				Cricotopus	***Cricotopus sp.***	7	cg		6		1		2	1	2	14	2	3			7
					***Cricotopus sp.* (P)**	7	cg									3			11		
				Cricotopus Binctus Gr.	***Cricotopus Binctus Gr.***	7	cg														
				Eukiefferiella	***Eukiefferiella sp.***	8	cg														
				Orthocladius Complex	***Orthocladius Complex***	6	cg														
				Rheocricotopus	***Rheocricotopus sp.***	6	cg														
				Thienemanniella	***Thienemanniella sp.***	6	cg														
					***Thienemanniella sp.* (P)**	6	cg														
					Tanypodinae	7	p														
					Pentaneurini	6	p														
				Apedilum	***Apedilum sp.***	6	p														
				Pentaneura	***Pentaneura sp.***	6	p														
				Tanypus	***Tanypus sp.***	10	p			6	6	7	1						13	2	11
					Tanypus sp. (P)	10	p													1	
					Procladius sp.	9	p				1										1
			Dolichopodidae		***Dolichopodidae* (L)**	4	p									2			1	2	1
			Ephydridae	*Ephydra*	***Ephydra sp.* (L)**	6	sh						2	2	2				1	3	3
			Muscidae	*Limnophora*	***Limnophora sp.* (L)**	6	p								1						
			Sciomyzidae		**Sciomyzidae (P)**	6	p								2						
			Simuliidae	*Simulium*	***Simulium sp.* (L)**	6	cf														
								BMIs per subsample	765												
					Total BMIs/sample				4590	629	507	624	1190	3242	531	286	98	144	545	166	929

Table 7. Bioassessment metrics calculated for each station during the spring 2003 Santa Clara River Estuary survey. Metrics are presented as means, standard deviations and coefficients of variation (cv), including the littoral sweep at Station B1. ANOVA was used to determine significance among stations for each metric (alpha ≤0.05). Significant differences between stations were delineated using Newman-Keuls Multiple-Comparison Test. When assumptions of equal variances were not met, Kruskall Wallis One Way ANOVA on Ranks and Kruskal-Wallis Multiple-Comparison Z-Value Test were applied.

Metric		SCRE B1 Littoral Sweep	SCRE B1	SCRE B2	SCRE B3	SCRE B7	Comparison Among Sites			
							Overall	ANOVA F-Ratio	ANOVA p	Multiple Comparisons
Abundance	mean	5032	1320	1061	220	29	1532	7.10	0.01**	B1, B2 > B3, B7
	st. dev.	N/A	332	734	143	12	305			
	cv	N/A	25	69	65	40	50			
Taxonomic richness	mean	16.00	9.67	8.67	7.00	5.00	9.27	13.67	0.001**	B1, B2 > B3 > B7
	st. dev.	N/A	0.58	1.53	0.00	1.00	0.78			
	cv	N/A	5.97	17.63	0.00	20.00	10.90			
Shannon Diversity	mean	1.64	1.54	1.13	1.30	0.97	1.31	3.27	0.08*	
	st. dev.	N/A	0.08	0.30	0.33	0.10	0.20			
	cv	N/A	5.49	26.39	25.73	9.87	16.87			
% dominant taxa	mean	44.55	40.08	62.66	50.55	66.00	52.77	1.83	0.22	
	st. dev.	N/A	3.53	17.25	21.66	11.93	13.59			
	cv	N/A	8.80	27.52	42.85	18.07	24.31			
Percent Chironomidae	mean	3.97	13.72	9.87	1.77	4.92	6.85	5.27	0.03**	B1 > B3
	st. dev.	N/A	4.40	6.28	0.98	1.99	3.41			
	cv	N/A	32.05	63.62	55.53	40.47	47.92			
Tolerance Value	mean	7.74	7.67	8.06	7.67	8.13	7.85	0.29	0.84	
	st. dev.	N/A	0.62	0.20	1.33	0.37	0.63			
	cv	N/A	8.08	2.53	17.33	4.53	8.12			
Percent Intolerance Value (0-2)	mean	0.06	0.00	0.00	0.00	0.00	0.01	N/A	N/A	
	st. dev.	N/A	0.00	0.00	0.00	0.00	0.00			
	cv	N/A	0.00	0.00	0.00	0.00	0.00			
Percent Tolerance Value (8-10)	mean	79.27	62.91	84.60	62.58	88.51	75.57	2.25	0.16	
	st. dev.	N/A	12.81	8.98	27.74	2.34	12.97			
	cv	N/A	20.36	10.61	44.34	2.64	19.49			
Percent Collectors	mean	94.30	99.61	94.52	82.39	96.28	93.42	5.97[1.]	0.11	
	st. dev.	N/A	0.26	2.32	12.68	3.23	4.62			
	cv	N/A	0.26	2.46	15.38	3.36	5.36			
Percent Filterers	mean	5.05	0.04	0.00	0.00	0.00	1.02	6.6[1.]	0.08*	
	st. dev.	N/A	0.04	0.00	0.00	0.00	0.01			
	cv	N/A	87.13	0.00	0.00	0.00	21.78			
Percent Grazers	mean	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A	
	st. dev.	N/A	0.00	0.00	0.00	0.00	0.00			
	cv	N/A	0.00	0.00	0.00	0.00	0.00			
Percent Predators	mean	0.66	0.33	5.48	0.00	2.73	1.84	6.21	0.02**	
	st. dev.	N/A	0.26	2.32	0.00	2.64	1.31			
	cv	N/A	80.31	42.33	0.00	96.45	54.77			
Percent Shredders	mean	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A	
	st. dev.	N/A	0.00	0.00	0.00	0.00	0.00			
	cv	N/A	0.00	0.00	0.00	0.00	0.00			

[1.] Data does not fit assumptions of equal variances; Kruskall/Wallis One Way ANOVA on ranks used.

* Marginally Significant (0.05 < p < 0.10), difference generally not large enough for multiple comparisons to detect.

** Significant (p <0.05)

N/A - Not Applicable

Table 8. Bioassessment metrics calculated for each station during the fall 2003 Santa Clara River Estuary survey. Metrics are presented as means, standard deviations and coefficients of variation (cv), including the littoral sweep at Station B1. ANOVA was used to determine significance among stations for each metric (alpha ≤0.05). Significant differences between stations were delineated using Newman-Keuls Multiple-Comparison Test. When assumptions of equal variances were not met, Kruskall Wallis One Way ANOVA on Ranks and Kruskal-Wallis Multiple-Comparison Z-Value Test were applied.

Metric		SCRE B1 Littoral Sweep	SCRE B1	SCRE B2	SCRE B3	SCRE B7	Comparison Among Sites			
							Overall	ANOVA F-Ratio	ANOVA p	Multiple Comparisons
Average Abundance	mean	5148.0	586.7	1654.3	176.0	546.7	1622.33	6.49[1.]	0.09*	
	st. dev.	.	69.0	1413.9	98.0	381.5	490.61			
	cv	.	11.8	85.5	55.7	69.8	55.68			
Taxonomic richness	mean	15.00	11.00	16.33	9.33	14.67	13.27	8.33	0.01**	B2, B7 > B1, B3
	st. dev.	.	1.00	2.89	0.58	2.31	1.69			
	cv	.	9.09	17.67	6.19	15.75	12.17			
Shannon Diversity	mean	1.53	1.18	0.93	1.31	1.37	1.26	1.19	0.37	
	st. dev.	.	0.26	0.45	0.20	0.26	0.29			
	cv	.	22.03	48.31	15.17	19.16	26.17			
% dominant taxa	mean	55.83	59.98	68.51	52.37	55.11	58.36	0.46	0.72	
	st. dev.	.	18.63	19.62	17.40	16.82	18.12			
	cv	.	31.06	28.64	33.22	30.52	30.86			
Percent Chironomidae	mean	5.24	5.30	1.12	31.27	29.39	14.46	5.59	0.02**	B3, B7 > B1, B2
	st. dev.	.	1.79	0.76	16.80	15.65	8.75			
	cv	.	33.69	67.86	53.72	53.26	52.13			
Tolerance Value	mean	7.85	8.34	8.52	6.14	7.45	7.66	14.40	0.01**	B1, B2, B7 > B3
	st. dev.	.	0.32	0.43	0.79	0.29	0.46			
	cv	.	3.88	5.07	12.89	3.86	6.42			
Percent Intolerance Value (0-2)	mean	0.00	0.00	0.00	0.00	0.00	0.00	N/A	N/A	
	st. dev.	3.46	0.00	0.00	0.00	0.00	0.69			
	cv	.	0.00	0.00	0.00	0.00	0.00			
Percent Tolerance Value (8-10)	mean	92.54	92.58	97.69	27.58	66.54	75.39	15.68	0.01**	B1, B2, B7 > B3
	st. dev.	.	2.63	1.63	22.29	16.75	10.82			
	cv	.	2.84	1.66	80.79	25.17	27.62			
Percent Collectors	mean	75.64	92.54	95.39	55.85	91.02	82.09	4.95[1.]	0.18	
	st. dev.	.	3.73	3.65	35.29	2.34	11.25			
	cv	.	4.03	3.82	63.19	2.57	18.40			
Percent Filterers	mean	17.95	1.45	1.34	4.95	3.97	5.93	4.06[1.]	0.25	
	st. dev.	.	0.41	0.81	0.73	3.14	1.27			
	cv	.	28.19	60.70	14.64	79.12	45.66			
Percent Grazers	mean	3.96	4.38	1.69	0.34	0.74	2.22	2.94	0.09*	
	st. dev.	.	3.26	1.59	0.59	0.49	1.48			
	cv	.	74.27	94.03	173.21	67.15	102.16			
Percent Predators	mean	2.45	1.63	1.37	0.23	3.50	1.84	5.56	0.02**	B7 > B3
	st. dev.	.	0.38	1.15	0.40	1.51	0.86			
	cv	.	23.29	84.09	173.21	43.16	80.94			
Percent Shredders	mean	0.00	0.00	0.20	0.00	0.77	0.19	8.51[1.]	0.03**	B7 > B1, B3
	st. dev.	.	0.00	0.16	0.00	0.90	0.27			
	cv	.	0.00	79.26	0.00	116.69	48.99			

[1.] Data does not fit assumptions of equal variances; Kruskall/Wallis One Way ANOVA on ranks used.

* Marginally Significant (0.05 < p < 0.10), difference generally not large enough for multiple comparisons to detect.

** Significant (p <0.05)

N/A - Not Applicable

Table 9. Ten most abundant species collected from each sampling site (reps = 3) in Santa Clara River Estuary during the spring 2003

SCRE Littoral Sweep B1		SCRE B1		SCRE B2		SCRE B3		SCRE B7	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**
Cyprididae total	*44.55*	*Limnocythere sp.*	*32.56*	*Limnocythere sp.*	*70.38*	*Limnodrilus sp.*	*49.24*	*Limnocythere sp.*	*65.91*
Limnodrilus sp.	*21.78*	*Limnodrilus sp.*	*25.08*	*Limnodrilus sp.*	*15.30*	*Limnocythere sp.*	*23.79*	*Limnodrilus sp.*	*19.32*
Eogammarus sp.	*12.38*	*Eogammarus sp.*	*21.52*	*Isotomidae*	*4.24*	*Nematoda*	*12.12*	*Chironominae*	*4.55*
Limnocythere sp.	*9.20*	*Chironominae*	*8.44*	*Tanypodinae*	*3.27*	*Isotomidae*	*8.18*	*Isotomidae*	*3.41*
Chydoridae	*4.19*	*Orthocladiinae*	*5.66*	*Chironominae*	*3.23*	*Eogammarus sp.*	*5.30*	*Corisella sp.*	*3.41*
Hyalella sp.	*2.52*	*Cyprididae total*	*3.97*	*Cyprididae total*	*1.66*	*Chironominae*	*0.91*	*Eogammarus sp.*	*2.27*
Orthocladiinae	*2.31*	*Hyalella sp.*	*2.32*	*Corisella sp.*	*1.26*	*Orthocladiinae*	*0.45*	*Nematoda*	*1.14*
Chironominae	*1.53*	*Tanypodinae*	*0.30*	*Orthocladiinae*	*0.53*	*Ophuroidea (damaged)*	*0.00*	*Ophuroidea (damaged)*	*0.00*
Corisella sp.	*0.50*	*Simulium sp. (L)*	*0.05*	*Hyalella sp.*	*0.06*	*Physa/Physella sp.*	*0.00*	*Physa/Physella sp.*	*0.00*
Daphnia sp	*0.42*	*Ophuroidea (damaged)*	*0.03*	*Dolichopodidae (L)*	*0.06*	*Fossaria sp.*	*0.00*	*Fossaria sp.*	*0.00*

Table 10. Ten most abundant species collected from each sampling site (reps = 3) in Santa Clara River Estuary during the fall 2003

SCRE Littoral Sweep B1		SCRE B1		SCRE B2		SCRE B3		SCRE B7	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**
Limnocythere	55.8	*Limnocythere*	59.2	*Limnocythere*	77.6	Chironominae	32.2	*Limnocythere*	61.9
Cyclopoida	14.8	*Limnodrilus*	24.9	*Limnodrilus*	16.0	Nematoda	25.8	Chironominae	19.6
Cyprididae	10.8	*Pomatiopsis*	4.5	Cyprididae	2.8	*Limnocythere*	23.9	*Limnodrilus*	5.4
Chironominae	4.5	Chironominae	4.0	*Pomatiopsis*	0.7	Cyprididae	4.7	*Daphnia*	3.2
Pomatiopsis	4.0	Isotomidae	2.0	Cyclopoida	0.7	Cyclopoida	4.2	Cyprididae	1.7
Daphnia	2.9	Cyclopoida	1.3	Chironominae	0.6	Orthocladiinae	4.2	Tanypodinae	1.7
Corisella	2.0	Cyprididae	1.3	*Corisella*	0.3	*Limnodrilus*	1.9	Isotomidae	1.4
Limnodrilus	1.7	Tanypodinae	1.1	*Daphnia*	0.3	Isotomidae	1.7	Orthocladiinae	1.1
Isotomidae	1.7	*Hyalella*	1.0	*Berosus*	0.3	*Daphnia*	0.9	Cyclopoida	0.9
Orthocladiinae	0.7	*Corisella*	0.5	*Ephydra*	0.1	Dolichopodidae	0.4	*Hydroporus*	0.8