THE CITY OF SAN BUENAVENTURA

Santa Clara River Estuary Macroinvertebrate Bioassessment Monitoring Annual Report 2007

THE CITY OF SAN BUENAVENTURA

CITY OF VENTURA

Presented by:

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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; Aquatic Bioassay 2004, 2005 and 2006).

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, Aquatic Bioassay & Consulting Laboratories scientists conducted bioassessment monitoring of the Santa Clara River Estuary during both the spring and fall of 2007, according to the City's NPDES permit and the California Stream Bioassessment Protocol (CSBP 2003).

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 become inundated with water from the VWRF. Depth of the estuary during peak inundation can reach nearly 10 ft above Mean Sea Level (MSL) (USFWS 1999).

In 1855, the Estuary was estimated to have encompassed 870 acres (Swanson et al. 1990, State Coastal Conservancy et al. 1997), but its size has declined to its present 160 acres, due to 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) have been 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-toxic 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 surveys has 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 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 21st, 2007 and September 23rd, 2007 by Aquatic Bioassay & Consulting Laboratories biologists. All procedures were conducted as outlined in the project scope of work and in accordance with modifications to 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

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 in the Santa Clara River. 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 0.05 m^2 petite ponar grab. This sampling device replaced the PVC coring device (10.2 cm diameter) used in previous surveys. Each sample was sieved through a 0.5 mm mesh screen on shore and preserved in 95% ethanol. Single samples for particle size were collected in Whirl Pacs from each site and placed on ice. 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. Water levels ranged from 36 to 60 inches during October when the Estuary was closed off from the ocean. As a result, samples at each station were collected from an inflatable, 16 ft AVON.

For the second year, stream flow data was not available for 2007 because the gauging device was destroyed by large storms during the 2005 winter. Instead, average monthly rain data were obtained for the Oxnard Airport from the Western Regional Climate Center in Reno, NV.

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

Laboratory Methods

Sample Processing

During sorting and taxonomic 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 vials. Once all invertebrates had been removed, the remaining material was transferred from the Petri dish and combined with the rest of the sample.

QA / QC

Sorting

The sample matrix remaining after sorting was completed, was periodically evaluated to determine elutriation efficiency. Approximately 10% of the grundge from each sample was placed into a Petri dish and observed under a microscope at 10 times magnification to verify that no BMIs had been missed during the sorting process. Sorting efficiencies were over 99.5%.

Taxonomic Effort

All of the organisms removed during the sorting process were then identified to Level 1 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 and preserved with 70% ethanol and 5% glycerin. Of the samples (10%) that were sent to the Department of Fish and Game's, Aquatic Bioassessment Laboratory in Rancho Cordova, CA, all passed the QA/QC check.

Particle Size Analysis

Sediments were analyzed for particle size distribution using a Horiba 920 particle size analyzer following Standard Methods, 20 ed. (APHA 1998). Duplicate sub-samples from each sample were re-suspended in de-ionized water, and then injected into the analyzer. The analyzer is capable of measuring particle sizes ranging from clay (<2µ) up through course sand (2000µ).

Data Analysis

Multi-metric analysis

Biological metrics were calculated as specified by the California Stream Bioassessment Procedure (CSBP) (2003) and were used to describe the benthic macroinvertebrate population. Each of the EPT metrics was zero and was, therefore, not reported. This was due to the absence of Ephemeroptera, Plecoptera and Trichoptera, upon which many of the key metrics in the CSBP are based. Additionally, estuarine taxa predominated 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 6 and 7 (Appendix C) were found in Barbour et al. (1999) and Mandaville (2002). Biological metrics were calculated with chironomid identification held to the level of family. The following metrics were calculated. 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 (%), Chironominae (%);
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 2007).

Cluster analysis was used to define groups of samples, based on species presence and abundance. Identified clusters were then evaluated to define the habitat to which they belonged. 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 dendrogram was formed using the un-weighted 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.

Ordination analysis displays the sampling stations as points in a multidimensional space and was used to graphically display how stations in the Estuary differed on a environmental gradients. The distance between the stations (points) in the space is proportional to the dissimilarity of the communities found at the respective stations. The different dimensions of the ordination space, called axes, define independent gradients of biological change in the community data. The projections of the station points onto the various axes are called scores. The axes are ordered so that the first axis displays a maximal amount of the community change, the second axis defines a maximal amount of the remaining community change, and so on for subsequent axes. Often most of the relevant community changes are displayed in a few ordination axes.

RESULTS

Annual Stream Flow & Estuary Inundation

The Estuary undergoes periodic filling and draining throughout the year due to the periodic closure, then reopening, of the sand spit at its mouth. 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.

In previous years stream flow in the Santa Clara River was measured at the Montalvo gauging station in Ventura, which is just upstream of the Estuary. Since the gauging station was destroyed during the large winter storms in 2005, we have presented the average monthly rainfall collected at the Oxnard Airport. While clearly not a direct measure of stream flow in the Santa Clara River, these data help to illustrate the size of the winter storms during 2007.

During the period between January and December, 2007, drought conditions occurred throughout southern California. Measurable rain fell at Oxnard Airport on only 15 days and totaled 3.7 inches (Figure 2). The heaviest rainfall of the year occurred in January (1.17 in) and December (1.06 in). Rainfall during all other months ranged between 0.01 and 0.52 inches, except in March, May, July and August when no measurable rain was recorded. Each of the four quarterly water quality surveys occurred during dry weather. The May bioassessment survey was conducted nearly a month (29 days) following light rain at the Oxnard airport in April. As a result the May survey was conducted when river discharge was low. September sampling followed a small rain event totaling 0.20 inches. This was the first measurable rainfall for nearly four months. Due to the extremely dry conditions in the watershed, discharge in the River did not increase on days following the event.

During May and September the berm at the mouth of the Estuary was intact due to the lack of winter storms. This resulted in water depths ranging from 22 to 60 inches (Table 2). As a result, sampling during the event was conducted from the 16 ft AVON.

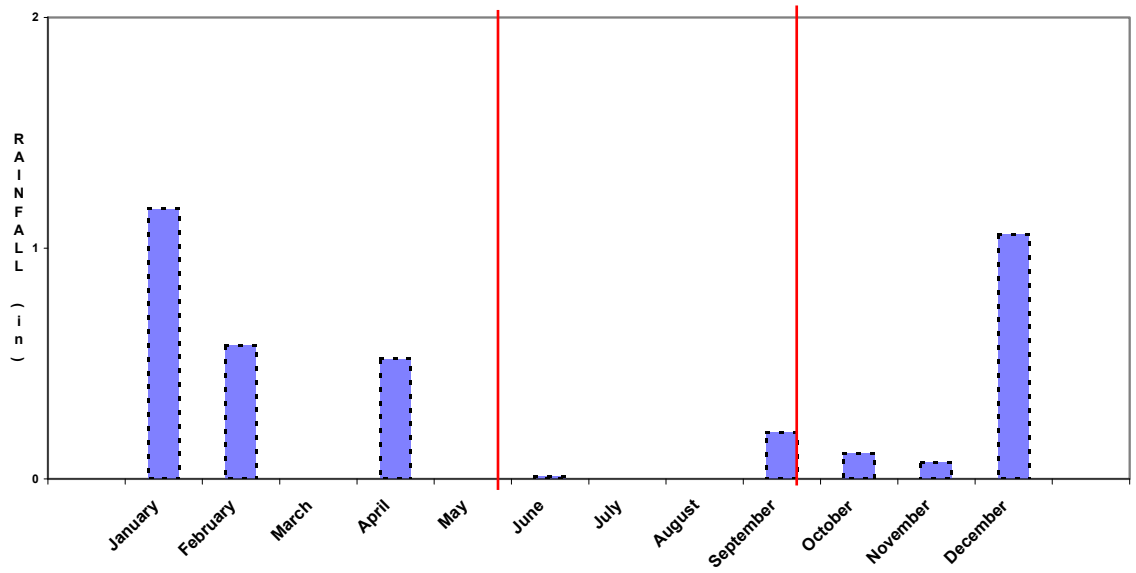


Figure 2. Monthly average rainfall recorded at Oxnard Airport, January to December, 2007. Red lines indicate days when sampling in the Estuary took place.

General Weather Observations

During May, sampling was conducted under overcast skies with 10 kilometer visibility (Table 2). Wind was from the west to southwest at 10 knots. Water color was brow at all Stations. The brown color was a result of the algal mats covering the sediments at these stations. In October sampling occurred under clear skies with 20 to 25 km visibility. Winds were east to northwest from 2 to 5 knots. Water color was green at each station, except B3 where it was brown. The berm at the entrance to the Estuary as closed during both surveys.

Physical Measurements and Water Quality

May

In May the berm was closed, and the Estuary was inundated. There were no true banks so that width measurements were not possible and flow velocity was below detection (Table 2). There was no canopy cover over any of the sites and vegetation was limited to the banks of the channels. The observed composition of bottom sediments varied widely, ranging from fines to sand and gravel.

The pH ranged from lowest in and near the effluent channel (7.2 to 7.5) to greatest in the outer Estuary (8.1 to 8.3). Dissolved oxygen concentrations varied widely from 1.03 to 2.95 at Stations B2 and B1, respectively, to 13.39 at Station B7. The low dissolved oxygen at Stations B1 and B2 may have been due to depletion due to overnight respiration. The extremely high dissolved oxygen reading at B7 was probably the result of oxygen production by algae. Water temperatures were similar among sites, ranging from 18.7 to 20.6. Salinity ranged from 1.4 at Station B2 to 2.1 at Station B7 in the outer Estuary.

October

In October, the Estuary was inundated so that width measurements were not possible and flow velocity was below detection (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 was sand at all sites, except B2 where it was gravel.

The pH ranged from 7.76 at B2 to 9.03 at B7. Dissolved oxygen concentrations were low at B2 above the effluent discharge, and greatest at B3 in the outer Estuary. Water temperatures were similar across sites, ranging from 15.9 to 16.9. Salinity was 1.2 at all sites.

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, 2007.

Sampling Stations	Spring				Fall			
	BI	B2	B3	B7	BI	B2	B3	B7
Date	21-May-2007	21-May-2007	21-May-2007	21-May-2007	23-Sep-2007	23-Sep-2007	23-Sep-2007	23-Sep-2007
Time	10:10	9:21	8:30	11:32	10:02	9:40	9:02	7:56
Survey Program	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab
Depth (in)	60	60	36	36	60	36	60	48
Latitude (°N)	34.23511	34.23486	34.23353	34.23145	34.23505	34.23485	34.23314	34.23195
Longitude (°W)	119.2632	119.26295	119.26512	119.25964	119.2632	119.26295	119.26502	119.25967
Weather	Overcast	Overcast	Overcast	Overcast	Clear	Clear	Clear	Clear
Air Vis. (km)	10	10	10	10	25	25	20	20
Esturary Status	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed
Wind Sp. (Kn)	10	10	10	10	4	4	5	2
Wind Dir. (°M)	225	225	225	270	90	90	315	90
Color	Brown	Brown	Brown	Brown	Green	Green	Brown	Green
Comments	None	None	None	None	None	None	None	None
Transect Width (m)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Velocity (ft/sec)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
% Canopy	0	0	0	0	0	0	0	0
Composition	Fines	Sand Gravel	Sand Gravel	Sand	Sand	Gravel	Sand	Sand
Embededness (%)	100	100	100	100	100	100	100	100
Sample Depth (in)	60	60	24	36	34	22	34	28
pH	7.51	7.22	8.07	8.32	8.52	7.76	8.93	9.03
Conductance (mS/cm)	2.61	2.40	2.98	3.60	1.96	19.23	1.95	1.98
Dissolved Oxygen (mg/L)	2.95	1.03	7.88	13.39	6.39	2.80	11.12	10.68
Temperature (°C)	20.6	18.7	19.6	19.6	16.9	16.7	16.0	15.9
Salinity (ppt)	1.5	1.4	1.8	2.1	1.2	1.2	1.2	1.2

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 size frequency distributions in Appendix B, Table 5. 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.

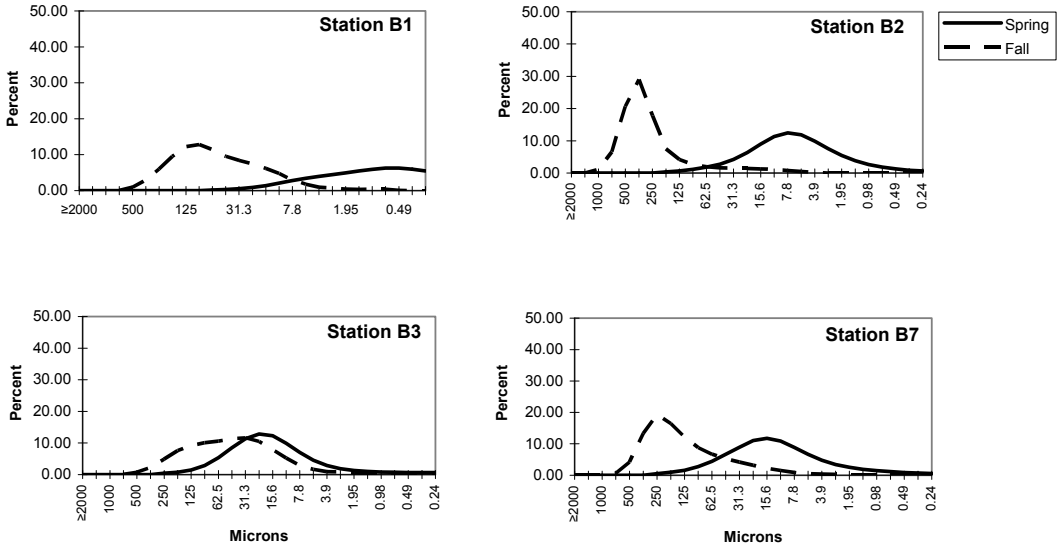
Sediments particle sizes shifted from predominately finer sediments at all sites in May to courser silts and sand in the fall (Table 3, Figure 3). This shift was most dramatic at Stations B1, B2 and B7. In the spring, sediments ranged from 60% fines at Station B1 in the effluent channel to 92% at Station B7 in the outer Estuary. In contrast, the percentage of sand ranged from 0.2 to 11%. During the fall sediments ranged from 8% fines at Station B2 to 54% at Station B3. In contrast, sand ranged from 45 to 91%.

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, 2007.

Station / Season	Particle Fraction Summary (%)					Percentile (microns)			Category [2.]	Percentile (phi)			Sorting Index [3.]	Sorting [3.]
	Gravel[1.]	Sand	Silt	Clay	Fines	16%	50% [2.]	84%		16%	50%	84%		
May														
B1	0.0	0.2	15.4	44.7	60.1	16	25	38	medium silt	6.0	5.3	4.7	0.6	moderately well sorted
B2	0.0	4.0	67.9	24.0	91.9	95	131	156	very fine sand	3.4	2.9	2.7	0.4	well sorted
B3	0.0	10.8	69.1	7.7	76.8	32	151	210	fine sand	5.0	2.7	2.2	1.4	poorly sorted
B7	0.0	10.3	69.6	12.6	82.2	81	152	194	fine sand	3.6	2.7	2.4	0.6	moderately well sorted
October														
B1	0.0	55.9	41.9	2.3	44.1	13	53	142	course silt	6.2	4.2	2.8	1.7	poorly sorted
B2	0.0	91.6	8.4	0.0	8.4	112	273	435	medium sand	3.1	1.9	1.2	1.0	poorly sorted
B3	0.0	45.5	52.0	2.5	54.5	13	39	123	course silt	6.3	4.7	3.0	1.7	poorly sorted
B7	0.0	81.6	18.1	0.3	18.4	38	136	265	fine sand	4.7	2.9	1.9	1.4	poorly sorted

1. Percentage of sample retained on a 2 mm sieve.
2. 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.
3. <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 3. Sediment particle size in microns by percent distribution (%) for spring and fall 2007 sampling surveys.



Macrobenthic Invertebrates

Summary

There were a combined total of 13,259 organisms collected from the four stations during the spring and fall 2007 bioassessment surveys (Table 4) (Appendix C, Tables 6 and 7). The combined total number of organisms collected in the grab samples at all four stations were much greater in the spring (11,505) compared to the fall (1,754).

A total of 32 unique species were collected during both surveys combined, with a total of 29 collected in the spring and 21 in the fall. Numbers of species collected at each site was similar between surveys. In the spring the greatest numbers of species were collected at Station B2 (24). In the fall, the greatest numbers of species were collected at Stations B2 and B3 (13 each).

Bioassessment Metrics

Biological metrics were calculated according to the California Lentic and Stream Bioassessment protocols and are presented in Figure 4. Statistical comparisons of each biological metric among stations and seasons are presented in Appendix C, Table 8. The EPT (Ephemeroptera, Plecoptera, and Tricoptera) metrics could not be applied because there were no members of these indicator groups present in the estuary.

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 infauna 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.

Spring abundances exceeded fall at each station and were greatest at Stations B2, upstream of the outfall and Station B3 in the outer effluent channel (Figure 4). Lowest abundances were measured in the fall across sites, ranging from 287 to 713. There were no significant differences in abundance among stations, in either season, by ANOVA.

Taxonomic richness is a simple measure of population health and is the number of separate macroinvertebrate species collected per sampling effort (i.e. one 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 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.

Average taxonomic richness was greatest in the spring at each station compared to the fall (Figure 4). Taxonomic richness was similar among sites for each season. There were no significant differences in taxonomic richness among stations, in either season by ANOVA.

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 comprise the total population at the site.

Dominance was greatest in the fall at all stations, except at Station B2 where it was nearly identical (Figure 4). There was no difference among stations by ANOVA for either season.

Shannon diversity: is similar to numbers of species; but contains an evenness 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 greatest at all sites in the spring compared to the fall (Figure 4). Diversity was greatest at Station B2, above the effluent channel. There were no significant differences by ANOVA among sites, for either season.

Tolerant Taxa: The average tolerance value and 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.

Average tolerance values were very similar between seasons and among stations (Figure 4). Average tolerance values ranged from 8.2 to 9.1 in the spring and 8.1 to 8.8 in the fall. There were no significant differences among sites for the spring survey, while average tolerance was significantly greater at Station B2 compared to all other sites in the fall (Appendix C, Table 8). Percent tolerant individuals was somewhat greater in the fall across sites and there were no significant differences among stations for either season.

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 (collector gatherers + collector filterers) is presented herein since they were by far the most dominant 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 percentage of collectors was far greater compared to any of the other feeding groups collected in the Estuary and exceeded 88% during both seasons, at each station. There was no clear seasonal difference in the percentage of collector organisms. The percentage of collectors was not significantly different among stations during either the spring or fall.

Species Composition

The most abundant species collected during the spring and fall by grab at each of the four stations are presented in Figure 5 and Appendix C, Tables 9 and 10.

Few species accounted for most of the abundance at each site during both seasons. During the spring the oligochaete worm, *Limnodrilus sp*, was the most abundant species collected at Stations B1, B2 and B3. Ostracods (Cyprididae and *Limnocythere sp*) dominated at Station B7. Each of these species, plus midge fly larvae (*Chrionomus sp*.) and a true fly (*Dicrotendipes sp*.) combined to account for at least 75% of the abundances at each station. In the fall, ostracods accounted for over 60% of the abundances at Stations B1 and B2 (*Limnocythere sp*.) and over 90% of the abundance at B3 (*Limnocythere sp* + Cyprididae). Limnodrilus sp was the second most abundant species at B1, B2 and B3.

2006 Cluster & Ordination Analysis

Results of species by station cluster analysis are presented as a two-way table in Figure 6. Ordination results for Axes 1, 2 and 3 are presented in Figure 7. Station and species dendrograms are presented in Appendix C, Figures 8 and 9.

Cluster analysis is useful because it groups stations by the relative abundances of species found at each site in the survey area. Sites with species compositions that are very different from one another will be more dissimilar and will group a greater "distance" apart from one another. If the VWRF effluent is creating a habitat in the effluent channel (Station B1) that is different from other locations in the survey area, we would expect the species composition to be different, making Station B1 group alone in the cluster analysis. It must be noted that many different physical characteristics, including sediment grain size and salinity, can have a profound affect on the composition of benthic communities.

Ordination analysis further distinguishes community patterns into three or more dimensions or axes. Each axis represents an environmental gradient that describes a portion of the variation that is driving the distribution of infauna in the survey area. Each station represents a point in the ordination space, and the previously discussed cluster groups are circled to illuminate the patterns.

Four station groups and six species groups were delineated by cluster analysis (Figure 6). Station groups 1 and 2 included all sites collected during the fall. Group 1 included outer Estuary sites B3 and B7, while group 2 was represented by Station B1 in the effluent channel and B2 located just above the effluent channel. Groups 3 and 4 included all sites collected during the spring. Group 3 was represented by sites B1 and B2, while group 4 included B3 and B7.

Ordination Axis 1 represented 56% of the variation in community structure in this survey and separated the fall from the spring sampling events (Figure 7). Axis 2 represented 31% of variation in the community structure and appeared to separate stations based on their distance to the effluent discharge. Interestingly, Stations B2 and B3 were more similar to Station B1 in the fall and more similar to Station B7 in the spring. Some possible explanations for this shift could be changes between surveys in water depth, particle size, temperature or salinity.

DISCUSSION

The 2007 bioassessment survey of the Santa Clara River Estuary included two sampling events in the spring and fall. During both surveys the berm at the mouth of the Estuary was closed. During both seasons water quality, sediment grain size and biological samples were collected. Biological samples were collected at each of four stations (Stations B1, B2, B3 and B7) specified in the City of San Buenaventura's NPDES permit. During this survey, a Petite Ponar grab was used instead of the coring device utilized during previous surveys (USFWS 1999). The goal of this survey was to determine if the discharge from the Ventura Water Reclamation Facility (VWRF) affects the biological communities in the Santa Clara River Estuary.

Flow during 2007 on the Santa Clara River was not measured because the gauging stations were lost as a result of the large winter storms that occurred throughout southern California in 2005. During the period between January and December, 2007, drought conditions occurred throughout southern California. Measurable rain fell at Oxnard Airport on only 15 days and totaled 3.7 inches. The heaviest rainfall of the year occurred in January (1.17 in) and December (1.06 in). Rainfall during all other months ranged between 0.01 and 0.52 inches, except in March, May, July and August when no measurable rain was recorded. This lack of rainfall and low discharge from the Santa Clara River during the period previous to sampling in 2007, allowed the sand spit across the entrance to the Estuary to become well established. As a result, the Estuary was inundated during both the spring and fall surveys. During both May and September sampling events, the berm at the mouth of the Estuary was intact due to the lack of winter storms. This resulted in water depths ranging from 22 to 60 inches. As a result, sampling during both events was conducted from the 16 ft AVON

Water quality in the Estuary during 2007 was typical of past surveys and depicted the dynamic and quickly changing environment of this system. Water temperature in the Estuary was relatively warm during both surveys and ranged from 15.9 to 20.6 °C. These findings were within the range of past studies (13.94 to 29.04, USFWS 1999). pH ranged within normal values from 7.2 in the effluent channel in the spring to a high of 9.03 at Station B7 in the main river channel in the fall. As in past surveys, dissolved oxygen concentrations in the Estuary were highly variable ranging from 1.03 mg/L at Station B2 to 13.39 mg/L at Station B7, both during the spring. Station B2 is located upstream of the effluent channel and is mostly quiescent. It is highly unlikely that this single dissolved oxygen data point is related to the discharge. The low dissolved oxygen at this site may have been due to depletion due to overnight bacterial respiration. Measurements taken later in the day may have shown increased dissolved oxygen concentrations as a result of algal photosynthesis. Temperature, pH and dissolved oxygen (except for the single low reading at Station B2 in the spring) 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), 2003, 2004, 2005 and 2006 (Aquatic Bioassay 2004 to 2007).

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). Salinity during the 2007 survey fell within the EPA's freshwater criterion (<2.0 ppt, 95% of the time) at each station during both seasons, except at Station B7 in the spring when it slightly exceeded this threshold

(2.1 ppt). 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 into the Estuary. 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). In 2007, sediment particle sizes shifted from predominately finer sediments at all sites in May to courser silts and sand in the fall. This shift was most dramatic at Stations B1, B2 and B7. In the spring, sediments ranged from 60% fines at Station B1 in the effluent channel to 82% at Station B7 in the outer Estuary. In contrast, the percentage of sand ranged from 0.2 to 11%. During the fall sediments ranged from 8% fines at Station B2 to 54% at Station B3. In contrast, sand ranged from 45 to 91%. This shift in particle size distributions between seasons creates a highly dynamic habitat that makes it difficult for benthic organisms to maintain stable populations. As a result, one would expect only organisms that are highly adapted to these conditions to occur here.

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 2007 survey were those found in either freshwater or estuarine environments (USFWS 1999, ENTRIX 2003, Aquatic Bioassay 2004 to 2007). The total numbers of organisms collected by grab in 2007 (13,259) was similar to 2004 (12,207), but greater than in 2005 (4,637). Also, the numbers were far greater than the numbers collected by Greenwald et al. (USFWS 1999) using a coring device (total = 1,359) across 5 stations during 12 separate surveys between 1997 and 1998. It is not known what causes these differences, but points out the highly dynamic nature of the Estuary environment.

The combined total number of organisms collected in the grab samples at all four stations were much greater in the spring (11,505) compared to the spring (1,754). Normally, lower numbers of organisms might be expected during the spring due to scouring and deposition of upstream sediments during storm events. 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).

A total of 32 unique species were collected during both surveys combined, with a total of 29 collected in the spring and 21 in the fall. The numbers of species collected in 2007 were greater than in 2005, but similar to 2003 and 2004 (Aquatic Bioassay 2004, 2005 and 2006); and were greater than the 2002 spring survey (25) and fall survey (30) (ENTRIX 2003). During surveys conducted from 1997 to 1998 by Greenwald et al. (USFWS 1999) taxonomic richness averaged 24.

The composition of species in the Estuary during the 2007 surveys was dominated by only a few species that were similar to those collected in past surveys. During the spring the oligochaete worm, *Limnodrilus sp*, was the most abundant species collected at Stations B1, B2 and B3. Ostracods (Cyprididae and *Limnocythere sp*) dominated at Station B7. Each of these species, plus midge fly larvae (*Chrionomus sp*.) and a true fly (*Dicrotendipes sp*.) combined to account for at least 75% of the abundances at each station. In the fall, ostracods accounted for over 60% of the abundances at Stations B1 and B2 (*Limnocythere sp*.) and over 90% of the abundance at B3 (*Limnocythere sp* + Cyprididae). *Limnodrilus sp*. was the second most abundant species at B1, B2 and B3.

The species collected during this and past surveys were dominated by those with high tolerance values, typical of organisms capable of living under stressful conditions that include either habitat disruption or pollution (CDFG 1999). Average tolerance values were very similar between seasons and among stations. Average tolerance values ranged from 8.2 to 9.1 in the spring, and 8.1 to 8.8 in the fall.

Cluster and ordination analyses were used to identify how the biological communities measured during 2007 differed between sites and seasons. Cluster analysis is useful because it groups stations by the relative abundances of species found at each site in the survey area. Sites with species compositions that are very different from one another will be more dissimilar and will group a greater "distance" apart from one another. If the VWRF effluent is creating a habitat in the effluent channel (Station B1) that is different from other locations in the survey area, we would expect the species composition to be different, making Station B1 group alone in the cluster analysis. Ordination analysis further distinguishes community patterns into three or more dimensions or axes. Each axis represents an environmental gradient that describes a portion of the variation that is driving the distribution of infauna in the survey area. Each station represents a point in the ordination space, and the previously discussed cluster groups are circled to illuminate the patterns.

Cluster analysis identified seasons as the strongest driver determining the composition of the biological communities in the estuary. Two main station groups representing spring and fall were delineated. Ordination axis 1 represented 56% of the variation in community structure in this survey and also separated the fall from the spring sampling event. Axis 2 represented 31% of variation in the community structure and appeared to separate stations based on their distance to the effluent discharge. Interestingly, Stations B2 and B3 were more similar to Station B1 in the fall and more similar to Station B7 in the spring. Some possible explanations for this shift could be changes between surveys in water depth, particle size, temperature or salinity.

Conditions in the Estuary are heavily influenced by its location downstream of heavy agricultural inputs and non-point sources, the shifting habitat conditions that occur as a result of fluctuating salinity, the continuous rise and fall of the water level and the scouring and deposition that occur as a result of seasonal storms. These factors combine to make this a very difficult habitat for benthic organisms to survive in. The highly tolerant biological population found at the Estuary stations reflects these conditions. The composition, abundances, numbers of taxa, diversity, tolerance and feeding types were similar among all sites during both seasons in 2007. This indicates that the VWRF effluent is not adversely effecting the benthic macroinvertebrate populations residing there.

Table 4. Summary of abundances by species and location during both spring and fall, 2007 bioassessment surveys of the Santa Clara River Estuary. Stations B1 thru B7 abundances are averages (n = 3; except Station B2 in the spring where n = 1); littoral sweep samples are total counts.

Identified Taxa	Spring				Fall			
	B1	B2	B3	B7	B1	B2	B3	B7
Apedilum sp	3		21					
Berosus sp	1	4	3	2				
Chironomidae	7		8	7				
Chironomus sp	248	687	114	91	10	4	10	9
Cladotanytarsus sp			10				3	1
Corisella sp.	1	3						
Corixidae	31	13	45	11				
Cricotopus sp	17	40	46	43			1	
Cyprididae	22	402	696	730	27	44	48	504
Dasyhelea sp		4	1	1				
Dicrotendipes sp	99	27	16	6	2	1	3	
Dolichopodidae		2	1	4				
Eogammarus sp.	14	25	61	59				
Ephydra sp		64		26	2	3		
Hyalella sp	22	3	8	10		2		
Isotomidae	10	5	5					
Limnocythere sp	55	1188	678	274	203	119	235	161
Limnodrilus sp	418	2278	1769	347	35	84	57	11
Lumbriculidae	2	7		1	8	3	2	
Micropsectra sp				7				
Nematoda	1	46	3	15		1		1
Parachironomus sp	18	7	7					1
Paratanytarsus sp	8	18					2	
Physa/Physella sp	2	4	68	2	1	2		
Procladius sp	6	24		3			2	
Tanypus sp	35	6	8	8				8
Tanytarsus sp	34	57	244	58			6	1
Tropisternus sp			3					
Tryonia sp	21	3			11	4		
Cyclopoida					9	65	13	22
Chydoridae						1	8	3
Hydra sp								1
Mean Abundance	**1073**	**4916**	**3813**	**1703**	**308**	**333**	**389**	**724**
Mean Taxa	**23**	**24**	**22**	**21**	**10**	**13**	**13**	**12**

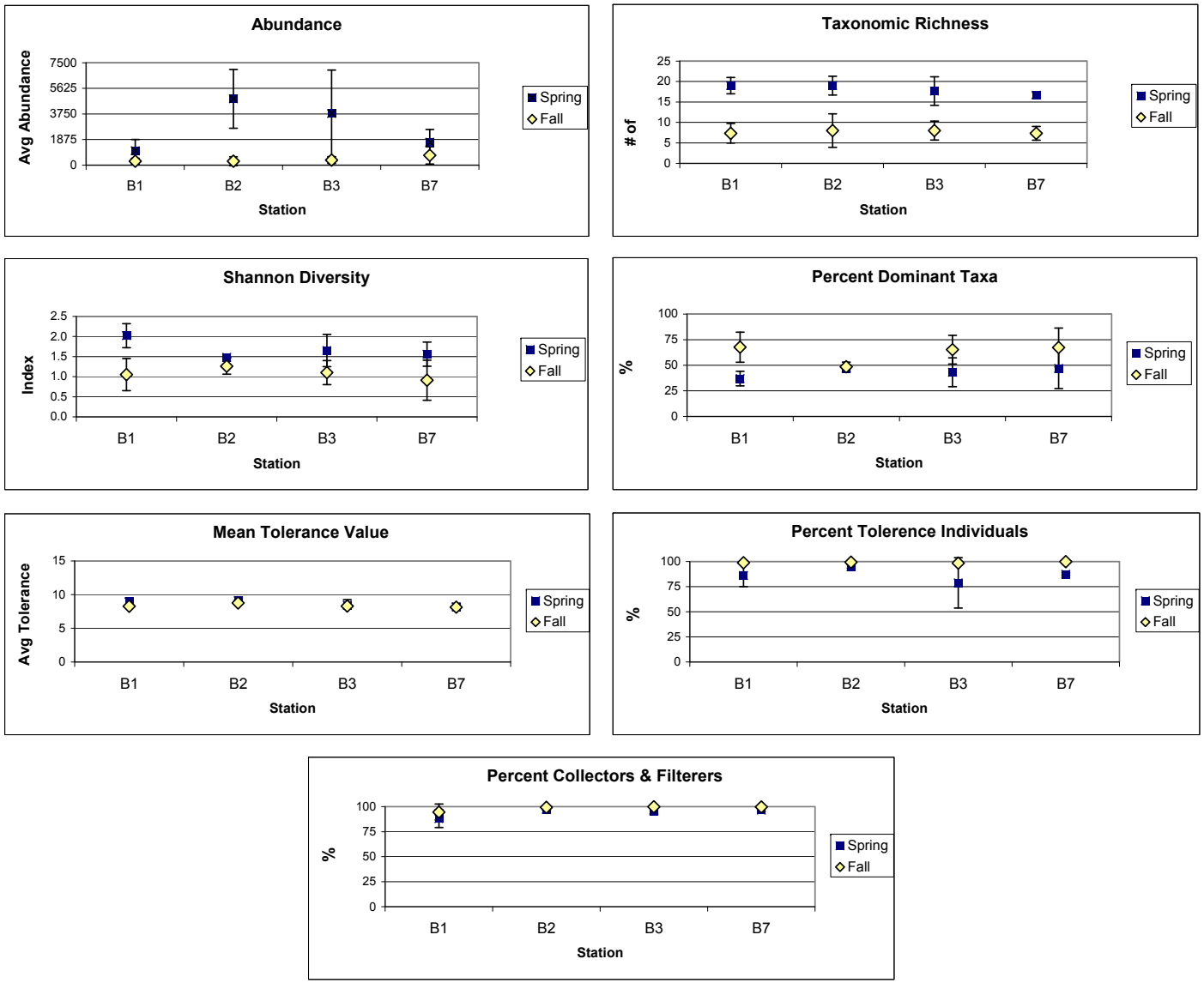


Figure 4. Average (± 95% CI) BMI metrics calculated for populations collected during the spring and fall 2007.

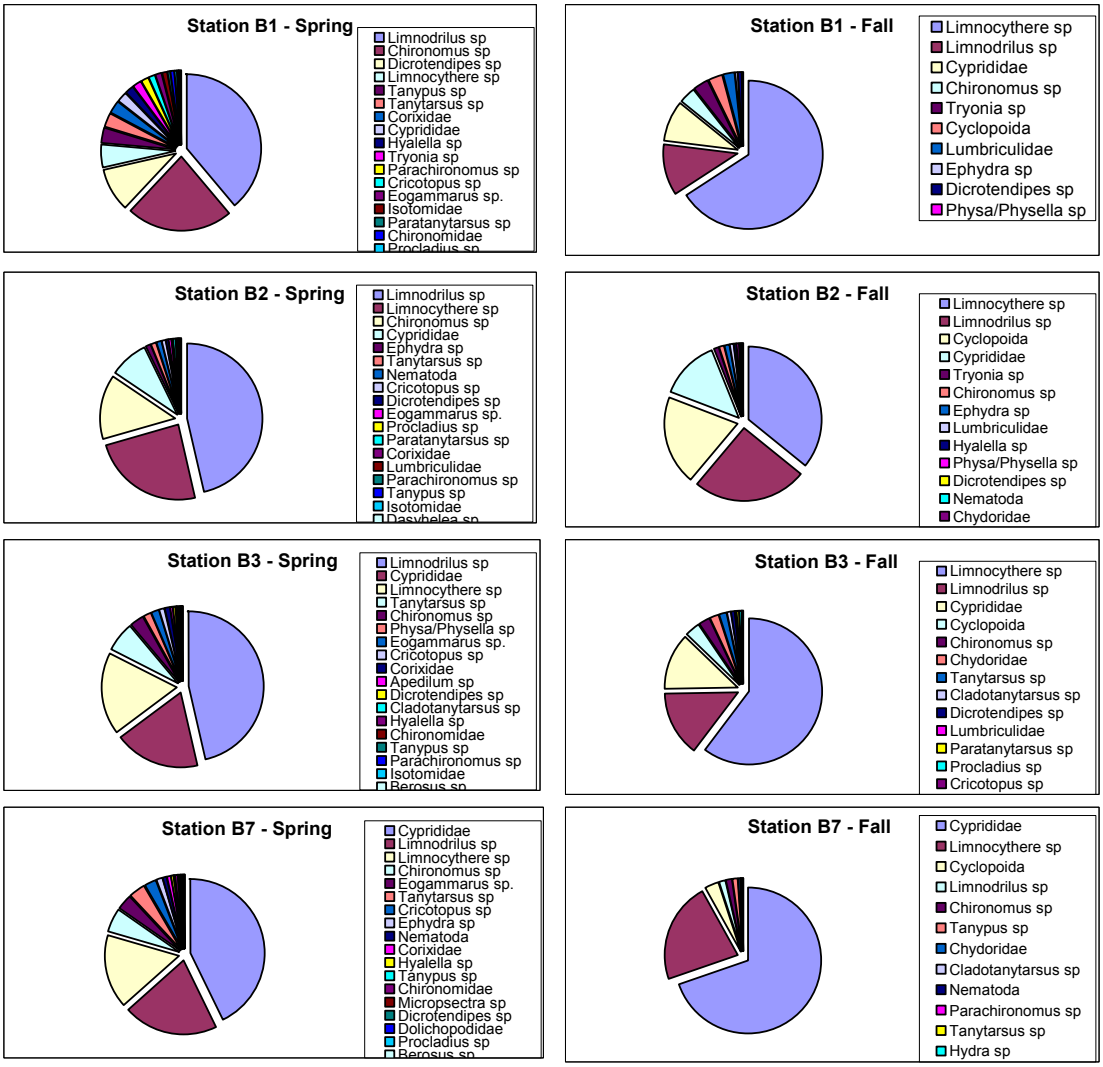


Figure 5. Cumulative percent abundance of most common species collected in the Santa Clara River Estuary from four sites during the spring and fall of 2007.

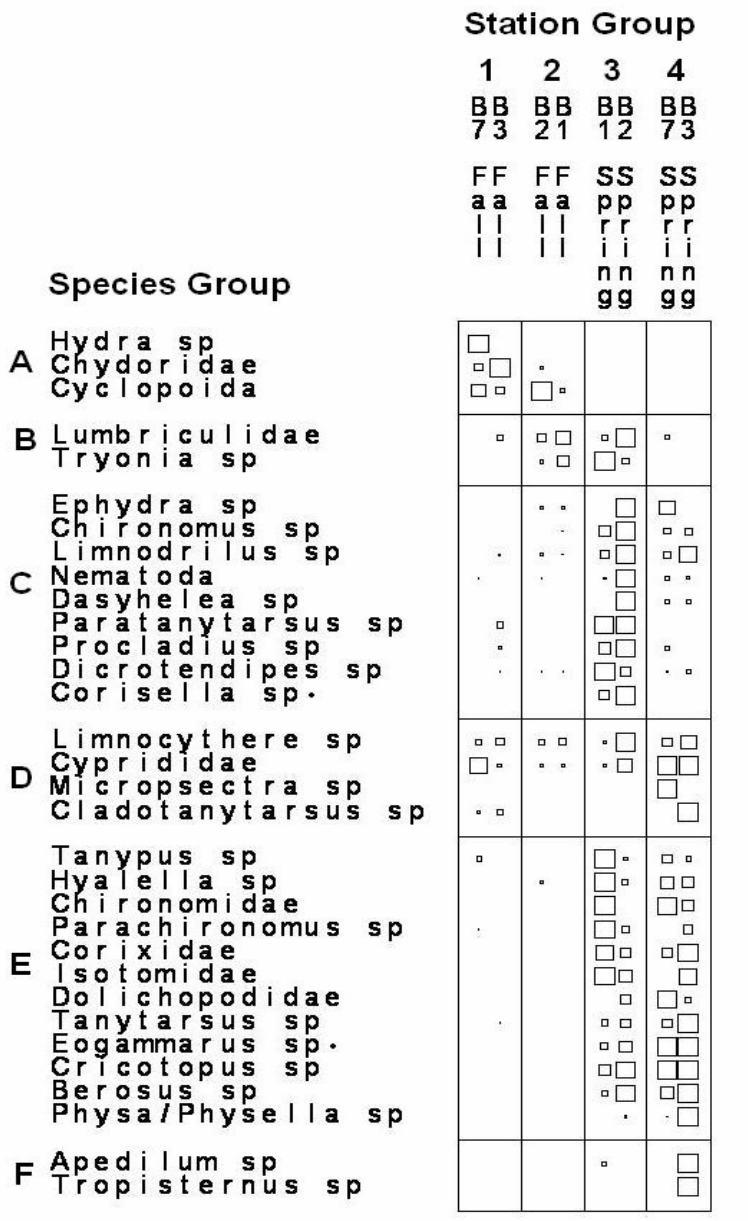


Figure 6. Two-way coincidence table of species vs. station groups created by cluster analysis (UPGMA, Sneath and Sokal 1973). The Bray-Curtis dissimilarity index was used to calculate the distances among stations and species (Gauch 1982, Jongman et. al. 1995). Abundance data were square root transformed. Symbols associated with each cell represent average relative species abundances for each station. Only the most frequently occurring organisms were used in the analysis ($n \geq 1$) which represented 99% of the total population. Dendrograms and multivariate methods can be found in the Appendix.

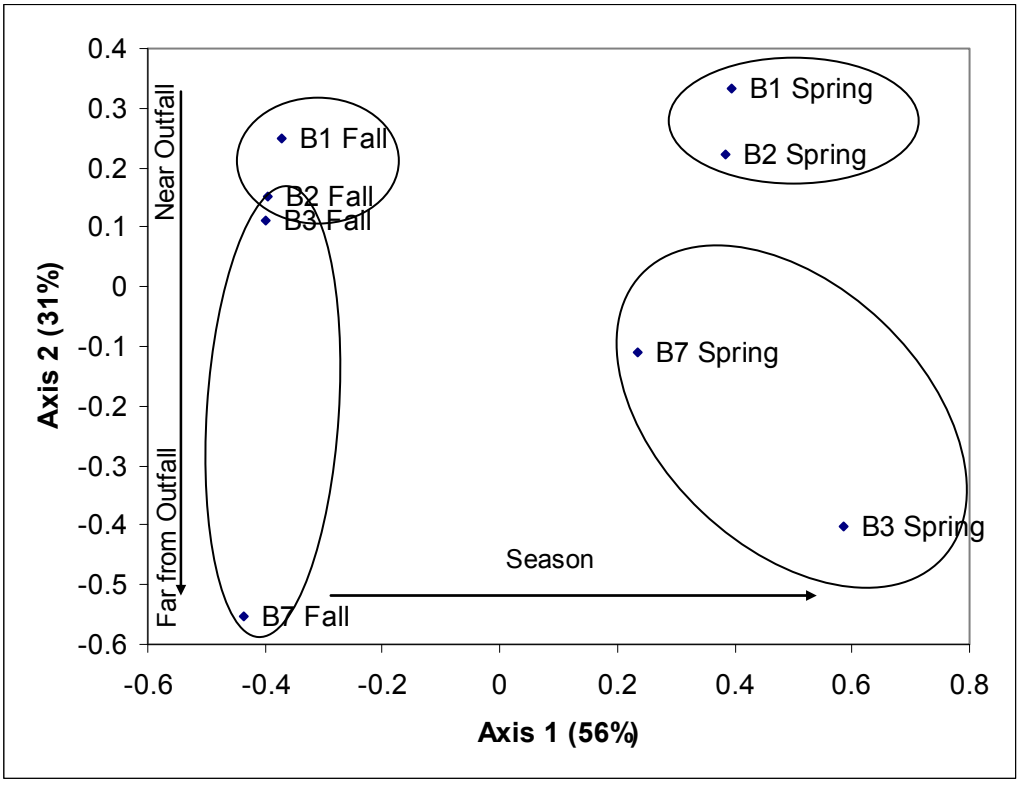


Figure 7. Ordination space plots for axis 1 vs axis 2, with cluster groups circled and stations identified.

APPENDIX A - REFERENCES

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APPENDIX B – SEDIMENT PARTICLE SIZE

Table 5. Cumulative particle sizes in microns and phi for the four sampling locations in the Santa Clara River Estuary for spring and fall, 2007.

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	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.33	0.53	0.89	1.42	2.10	2.80	3.43	3.95	4.44	4.96	5.47	5.89	6.25	6.25	5.95	5.47	
B2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.65	1.17	1.81	2.78	4.21	6.37	8.99	11.33	12.43	11.86	9.89	7.54	5.46	3.82	2.63	1.82	1.25	0.87	0.62	
B3	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.72	1.43	2.89	5.36	8.52	11.30	12.86	12.23	9.85	6.96	4.53	2.86	1.86	1.30	0.99	0.81	0.72	0.67	0.65	0.65	
B7	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.94	1.62	2.76	4.46	6.65	8.96	11.02	11.78	10.89	8.88	6.67	4.79	3.44	2.52	1.89	1.44	1.13	0.89	0.71	0.59	
October																												
B1	0.00	0.00	0.00	0.06	0.97	2.91	6.03	9.49	12.21	12.84	11.35	9.49	8.36	7.42	6.14	4.78	2.99	1.75	0.96	0.70	0.44	0.31	0.36	0.36	0.08	0.00	0.00	
B2	0.00	0.00	1.13	6.59	20.67	29.02	17.80	7.50	4.17	2.70	2.00	1.62	1.47	1.41	1.30	1.13	0.77	0.47	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
B3	0.00	0.00	0.00	0.05	0.75	2.21	4.93	7.61	9.22	10.08	10.64	11.32	11.61	10.49	7.86	5.27	2.91	1.64	0.95	0.77	0.54	0.39	0.38	0.33	0.07	0.00	0.00	
B7	0.00	0.00	0.00	0.66	4.23	13.31	19.30	16.40	12.21	8.80	6.69	5.25	4.19	3.17	2.20	1.50	0.90	0.56	0.35	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

APPENDIX C - MACROINVERTEBRATES

Table 6. Taxa list and abundances by replicate for spring 2007.

Identified Taxa	Tol Val (TV)	Func Feed Grp	B1			B2			B3			B7		
			1	2	3	1	2	3	1	2	3	1	2	3
Insecta Taxa														
Collembola														
Isotomidae	5	cg	14	6		7	3		4	8	4			
Hemiptera														
Corisella sp.	8	p	1					3						
Corixidae	8	p	12	57	23	8	24	8	38	61	36	13	3	17
Coleoptera														
Berosus sp	5	p		1		1		6	5	2	1		2	2
Tropisternus sp	5	p							2	3				
Diptera														
Apedilum sp	6	cg			3					29	13			
Chironomidae	6	cg	1	16	4						8	1	6	13
Chironomus sp	10	cg	450	273	21	275	797	990	251	36	55	19	50	205
Cladotanytarsus sp	7	cg							7	15	8			
Cricotopus sp	7	cg	8	31	11	17	62	42	42	67	29	35	11	82
Dasyhelea sp	6	cg				1	5	6		1				1
Dicrotendipes sp	8	cg	108	172	17	4	29	48	8	23			6	
Dolichopodidae	4	p					1	2		1		6	2	
Ephydra sp	6	sh				2		125				1	66	10
Micropsectra sp	7	cg										3	10	
Parachironomus sp	6	cg	20	26	7		7		9	4				
Paratanytarsus sp	6	cf	12		4			18						
Procladius sp	9	p	8	9	2		41	7				1		4
Tanypus sp	10	p	16	75	14			6		8		3	5	16
Tanytarsus sp	6	cf	32	44	25	21	31	120	226	315	191	19	78	77
Non-Insecta Taxa														
Limnodrilus sp	10	cg	662	524	67	1244	2947	2643	2580	2640	87	78	97	867
Nematoda	5	p	2	1	1	65	47	26	1	4				15
Amphipoda														
Eogammarus sp.	6	cg	14	14		30	39	6	57	89	36	47	47	83
Hyalella sp	8	cg	30	23	12	3	3	2	15	9	1	21	2	7
Basommatophora														
Physa/Physella sp	8	sc	2	1		3	4		115	82	8	1	2	
Hypsogastropoda														
Tryonia sp	8	sc	10	51	1	3	5	1						
Lumbriculida														
Lumbriculidae	5	cg		2			12	2				1		
Podocopida														
Cyprididae	8	cg	30	31	4	316	639	252	897	1053	138	264	1152	774
Limnocythere sp	8	cg	104	59	3	675	1467	1422	1740	288	6	326	180	315
TOTAL			**1536**	**1416**	**219**	**2675**	**6163**	**5735**	**5997**	**4738**	**621**	**839**	**1719**	**2488**

Table 7. Taxa list and abundances by replicate for fall 2007.

Identified Taxa	Tol Val (TV)	Func Feed Grp	B1			B2			B3			B7		
			1	2	3	1	2	3	1	2	3	1	2	3
Insecta Taxa														
Diptera														
Chironomus sp	10	cg	17	5	9	6	3	2	8	8	14	5	17	6
Cladotanytarsus sp	7	cg							3				1	
Cricotopus sp	7	cg									1			
Dicrotendipes sp	8	cg			2	1	1				3			
Ephydra sp	6	sh	4	1	1	3								
Parachironomus sp	6	cg										1		
Paratanytarsus sp	6	cf									2			
Procladius sp	9	p									2			
Tanypus sp	10	p										8		
Tanytarsus sp	6	cf							9		3		1	
Non-Insecta Taxa														
Limnodrilus sp	10	cg	81	6	17	139	94	20	115	31	24	1	14	17
Nematoda	5	p				1							1	
Amphipoda														
Hyalella sp	8	cg				2	2							
Basommatophora														
Physa/Physella sp	8	sc	1		1	2	1							
Cycopoida														
Cyclopoida	8	cf	9			104	26		3	22		4	36	27
Diplostraca														
Chydoridae		cf					1		3	13				3
Hydridae														
Hydra sp	5	p											1	
Hypsogastropoda														
Tryonia sp	8	sc	7		15	4								
Lumbriculida														
Lumbriculidae	5	cg	8				3				2			
Podocopida														
Cyprididae	8	cg	32	37	13	75		13	117	27	1	660	784	68
Limnocythere sp	8	cg	342	198	69	280	46	31	369	135	200	90	387	7
TOTAL			**501**	**247**	**127**	**617**	**177**	**66**	**627**	**236**	**252**	**769**	**1242**	**128**

Table 8. Bioassessment metrics calculated for each station during the spring and fall 2007 Santa Clara River Estuary survey. Metrics are presented as means, standard deviations, coefficients of variation (cv) and 95% CI. 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.

		Spring								Fall							
		Station				Comparison Among Sites by				Station					Comparison Among Sites by		
Metric		B1	B2	B3	B7	Avg	F-Ratio	p	Multiple Comparisons	B1	B2	B3	B7	Avg	F-Ratio	p	Multiple Comparisons
Community Richness Measures																	
Abundance	**mean**	1057	4858	3785	1682	2846	**2.98**	**0.10**		292	287	372	713	360	1.01	0.34	
	st. dev.	728	1902	2812	825	1567				191	291	221	559	436			
	cv	68.9	39.2	74.3	49.1	57.8				65.5	101.7	59.5	78.4	1.1			
	95% CI	824	2153	3182	934	1773				216	330	250	633	494			
Taxonomic richness	**mean**	19	19	18	17	18	0.93	0.47		7	8	8	7	8	0.08	0.97	
	st. dev.	2	2	3	1	2				2	4	2	2	2			
	cv	9	11	17	4	10				28	45	25	21	30			
	95% CI	2	2	4	1	2				2	4	2	2	3			
% Dominant Taxa	**mean**	36.9	46.8	43.2	46.9	43	0.53	0.68		67.6	48.5	65.2	67.3	62.2	1.63	0.26	
	st. dev.	6.3	0.9	12.5	17.5	9				13.0	4.1	12.4	16.8	11.6			
	cv	16.9	1.9	28.8	37.4	21				19.2	8.4	19.0	24.9	17.9			
	95% CI	7.1	1.0	14.1	20	11				14.7	4.6	14.0	19.0	13.1			
Shannon Diversity	**mean**	2.0	1.5	1.7	1.6	2	**2.91**	**0.10**		1.1	1.3	1.1	0.9	1	0.65	0.60	
	st. dev.	0.3	0.0	0.3	0.2	0				0.4	0.1	0.3	0.4	0			
	cv	14.5	1.0	18.8	15.2	12				36.7	10.8	22.9	44.7	29			
	95% CI	0.3	0.0	0.4	0.3	0				0.4	0.2	0.3	0.5	0			
Mean Tolerance Value	**mean**	9.0	9.1	8.4	8.2	9	2.45	0.13		8.3	8.8	8.3	8.1	8	**5.09**	**0.03**	B2>B7, B1, B3
	st. dev.	0.4	0.1	0.7	0.4	0				0.2	0.3	0.1	0.2	0			
	cv	4.6	1.1	8.6	5.3	5				1.8	3.5	1.2	2.8	2			
	95% CI	0.5	0.1	0.8	1	1				0.2	0.3	0.1	0.3	0			
Percent Tolerant Individuals (8-10)	**mean**	86.1	95.0	78.7	87.4	87	5.67[1]	0.13		98.8	99.2	98.3	99.9	99.0	1.18	0.38	
	st. dev.	9.8	1.4	22.1	1.1	9				1.1	0.9	1.6	0.2	1.0			
	cv	11.4	1.5	28.1	1.2	11				1.1	0.9	1.6	0.2	1.0			
	95% CI	11.1	1.6	25.1	1	10				1.2	1.0	1.8	0.2	1.0			
Percent Intolerant Individuals (0-2)	**mean**	0.0	0.0	0.0	0.0	0	N/A			0.0	0.0	0.0	0.0	0.0	N/A		
	st. dev.	0.0	0.0	0.0	0.0	0				0.0	0.0	0.0	0.0	0.0			
	cv	-	-	-	-	-				-	-	-	-	-			
	95% CI	0.0	0.0	0.0	0.0	0				0.0	0.0	0.0	0.0	0.0			
Percent Collectors & Filterers	**mean**	88.1	97.2	95.6	96.6	94	4.84[1]	0.18		94.6	99.3	99.7	99.6	98.3	3.76[1]	0.29	
	st. dev.	7.9	0.7	2.4	1.1	3				7.0	0.8	0.5	0.5	2.2			
	cv	8.9	0.7	2.5	1.2	3				7.4	0.8	0.5	0.5	2.3			
	95% CI	8.9	0.8	2.7	1.3	3				7.9	0.9	0.5	0.6	2.5			
Percent Collectors	**mean**	81.6	96.0	81.8	93.3	88	1.44	0.30		94.0	88.6	93.3	90.6	91.6	0.22	0.88	
	st. dev.	13.0	1.6	17.3	2.2	9				6.7	10.0	7.0	12.2	9.0			
	cv	15.9	1.6	21.1	2.3	10				7.1	11.3	7.5	13.4	9.8			
	95% CI	14.7	1.8	19.5	3	10				7.6	11.3	8.0	13.8	10.2			
Percent Filterers	**mean**	6.4	1.2	13.7	3.3	6	**7.11[1]**	**0.07**		0.6	10.7	6.4	9.0	6.7	0.79	0.53	
	st. dev.	5.9	1.0	14.8	1.1	6				1.0	9.3	7.3	12.6	7.6			
	cv	92.0	82.8	108.1	33.7	79				173.2	86.9	113.7	140.1	128.5			
	95% CI	6.7	1.2	16.8	1	7				1.2	10.6	8.2	14.2	8.6			
Percent Grazers	**mean**	1.7	0.1	1.6	0.1	1	**8.63[1]**	**0.03**	None	4.7	0.5	0.0	0.0	1.3	5.52[1]	0.14	
	st. dev.	1.8	0.1	0.3	0.1	1				6.9	0.5	0.0	0.0	1.8			
	cv	106.0	100.0	18.7	86.6	78				144.9	94.4	-	-	119.6			
	95% CI	2.0	0.1	0.3	0	1				7.8	0.6	0.0	0.0	2.1			
Percent Predators	**mean**	10.3	1.9	2.8	1.9	4.2	3.8	0.28		0.0	0.1	0.3	0.4	0.2	0.80	0.53	
	st. dev.	7.9	0.9	2.8	1.0	3.2				0.0	0.1	0.5	0.5	0.3			
	cv	76.7	48.3	98.1	55.8	69.7					173.2	173.2	132.3	159.6			
	95% CI	8.9	1.0	3.1	1	4				0.0	0.1	0.5	0.6	0.3			
Percent Shredders	**mean**	0.0	0.8	0.0	1.4	0.6	0.99	0.44		0.7	0.2	0.0	0.0	0.2	**8.74**	**0.01**	B1>B7, B3, B2
	st. dev.	0.0	1.2	0.0	2.1	0.8				0.2	0.3	0.0	0.0	0.1			
	cv	-	162.0		143.4	152.7				34.6	173.2	-	-	103.9			
	95% CI	0.0	1.4	0.0	2	1				0.3	0.3	0.0	0.0	0.2			
Percent Chironomidae	**mean**	45.8	16.4	22.9	11.8	24.2	5.17[1]	0.16		4.7	2.1	5.5	2.7	4	1.00	0.44	
	st. dev.	3.4	4.8	22.6	3.6	8.6				3.5	1.0	3.8	1.8	3			
	cv	7.3	29.5	99.0	30.8	41.6				75.2	45.0	69.3	66.3	64			
	95% CI	3.8	5.5	25.6	4	10				4.0	1.1	4.3	2.0	3			

[1.] Variences not equal, ANOVA by Kruskall-Wallis one way ANOVA on ranks and multiple comparison by Kruskall-Wallis Z-test

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

Significant (p <0.05)

Table 9. Ten most abundant species collected from each sampling site (reps = 3) in Santa Clara River Estuary during the spring 2007.

SCRE B1		SCRE B2		SCRE B3		SCRE B7	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**
Limnodrilus sp	38.9	*Limnodrilus sp*	46.3	*Limnodrilus sp*	46.4	Cyprididae	42.9
Chironomus sp	23.1	Limnocythere sp	24.2	*Cyprididae*	18.3	*Limnodrilus sp*	20.4
Dicrotendipes sp	9.2	Chironomus sp	14.0	*Limnocythere sp*	17.8	*Limnocythere sp*	16.1
Limnocythere sp	5.2	Cyprididae	8.2	*Tanytarsus sp*	6.4	*Chironomus sp*	5.4
Tanypus sp	3.3	Ephydra sp	1.3	*Chironomus sp*	3.0	*Eogammarus sp.*	3.5
Tanytarsus sp	3.1	Tanytarsus sp	1.2	*Physa/Physella sp*	1.8	*Tanytarsus sp*	3.4
Corixidae	2.9	Nematoda	0.9	*Eogammarus sp.*	1.6	*Cricotopus sp*	2.5
Cyprididae	2.0	Cricotopus sp	0.8	*Cricotopus sp*	1.2	*Ephydra sp*	1.5
Hyalella sp	2.0	Dicrotendipes sp	0.5	*Corixidae*	1.2	*Nematoda*	0.9
Tryonia sp	1.9	Eogammarus sp.	0.5	*Apedilum sp*	0.6	*Corixidae*	0.6
Parachironomus sp	1.6	Procladius sp	0.5	*Dicrotendipes sp*	0.4	*Hyalella sp*	0.6
Cricotopus sp	1.6	Paratanytarsus sp	0.4	*Cladotanytarsus sp*	0.3	*Tanypus sp*	0.5
Eogammarus sp.	1.3	Corixidae	0.3	*Hyalella sp*	0.2	*Chironomidae*	0.4
Isotomidae	0.9	Lumbriculidae	0.1	Chironomidae	0.2	Micropsectra sp	0.4
Paratanytarsus sp	0.7	Parachironomus sp	0.1	Tanypus sp	0.2	*Dicrotendipes sp*	0.4
Chironomidae	0.7	Tanypus sp	0.1	*Parachironomus sp*	0.2	*Dolichopodidae*	0.2
Procladius sp	0.6	*Isotomidae*	0.1	Isotomidae	0.1	Procladius sp	0.1
Apedilum sp	0.3	*Dasyhelea sp*	0.1	Berosus sp	0.1	Berosus sp	0.1
Lumbriculidae	0.2	*Berosus sp*	0.1	*Nematoda*	0.1	*Physa/Physella sp*	0.1
Physa/Physella sp	0.1	Physa/Physella sp	0.1	*Tropisternus sp*	0.1	*Dasyhelea sp*	0.1
Nematoda	0.12	Corisella sp.	0.1	Dasyhelea sp	0.0	Lumbriculidae	0.1
Berosus sp	0.09	*Tryonia sp*	0.1	Dolichopodidae	0.0		
Corisella sp.	0.09	*Hyalella sp*	0.1				
		Dolichopodidae	0.0				

Table 10. Ten most abundant species collected from each sampling site (reps = 3) in Santa Clara River Estuary during the fall 2007.

SCRE B1		SCRE B2		SCRE B3		SCRE B7	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**
Limnocythere sp	65.8	Limnocythere sp	35.8	Limnocythere sp	60.3	Cyprididae	69.6
Limnodrilus sp	11.2	*Limnodrilus sp*	25.4	*Limnodrilus sp*	14.6	*Limnocythere sp*	22.3
Cyprididae	8.9	Cyclopoida	19.5	Cyprididae	12.4	Cyclopoida	3.1
Chironomus sp	3.6	*Cyprididae*	13.2	Cyclopoida	3.2	Limnodrilus sp	1.5
Tryonia sp	3.4	Tryonia sp	1.2	*Chironomus sp*	2.6	Chironomus sp	1.3
Cyclopoida	2.9	*Chironomus sp*	1.1	*Chydoridae*	2.1	Tanypus sp	1.1
Lumbriculidae	2.6	Ephydra sp	0.9	Tanytarsus sp	1.5	*Chydoridae*	0.4
Ephydra sp	0.6	*Lumbriculidae*	0.9	*Cladotanytarsus sp*	0.8	*Cladotanytarsus sp*	0.1
Dicrotendipes sp	0.6	*Hyalella sp*	0.6	Dicrotendipes sp	0.8	Nematoda	0.1
Physa/Physella sp	0.3	Physa/Physella sp	0.45	*Lumbriculidae*	0.51	*Parachironomus sp*	0.1
		Dicrotendipes sp	0.30	*Paratanytarsus sp*	0.51	Tanytarsus sp	0.14
		Nematoda	0.30	*Procladius sp*	0.51	*Hydra sp*	0.14
		Chydoridae	0.30	*Cricotopus sp*	0.26		

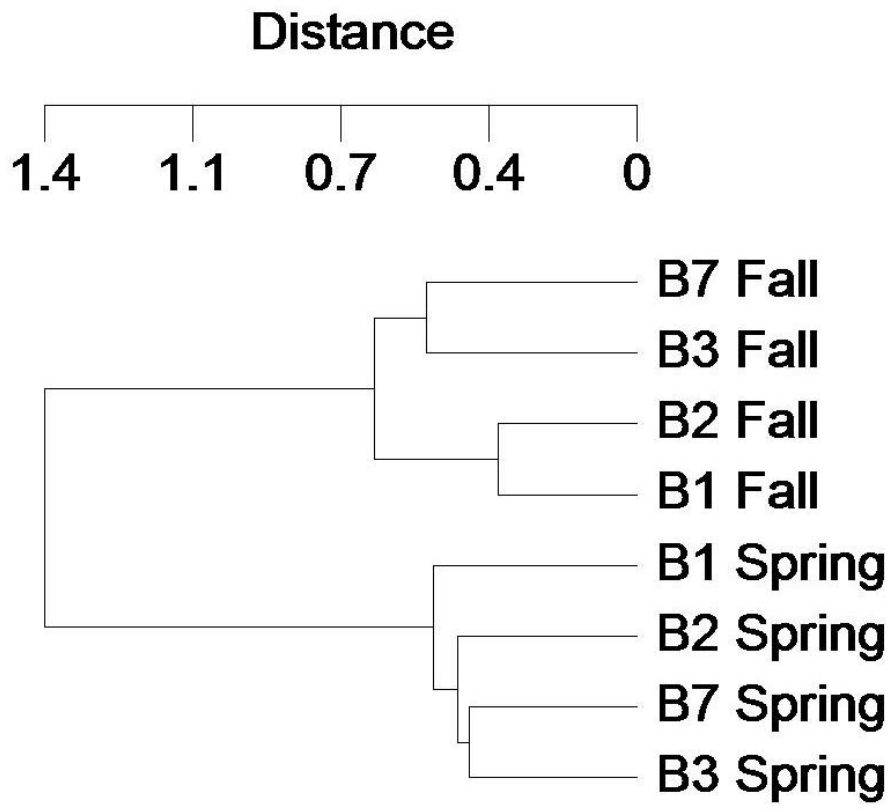

Figure 8. Station dendrogram for BMI population collected in 2007. Distances calculated using Bray-Curtis dissimilarity index.

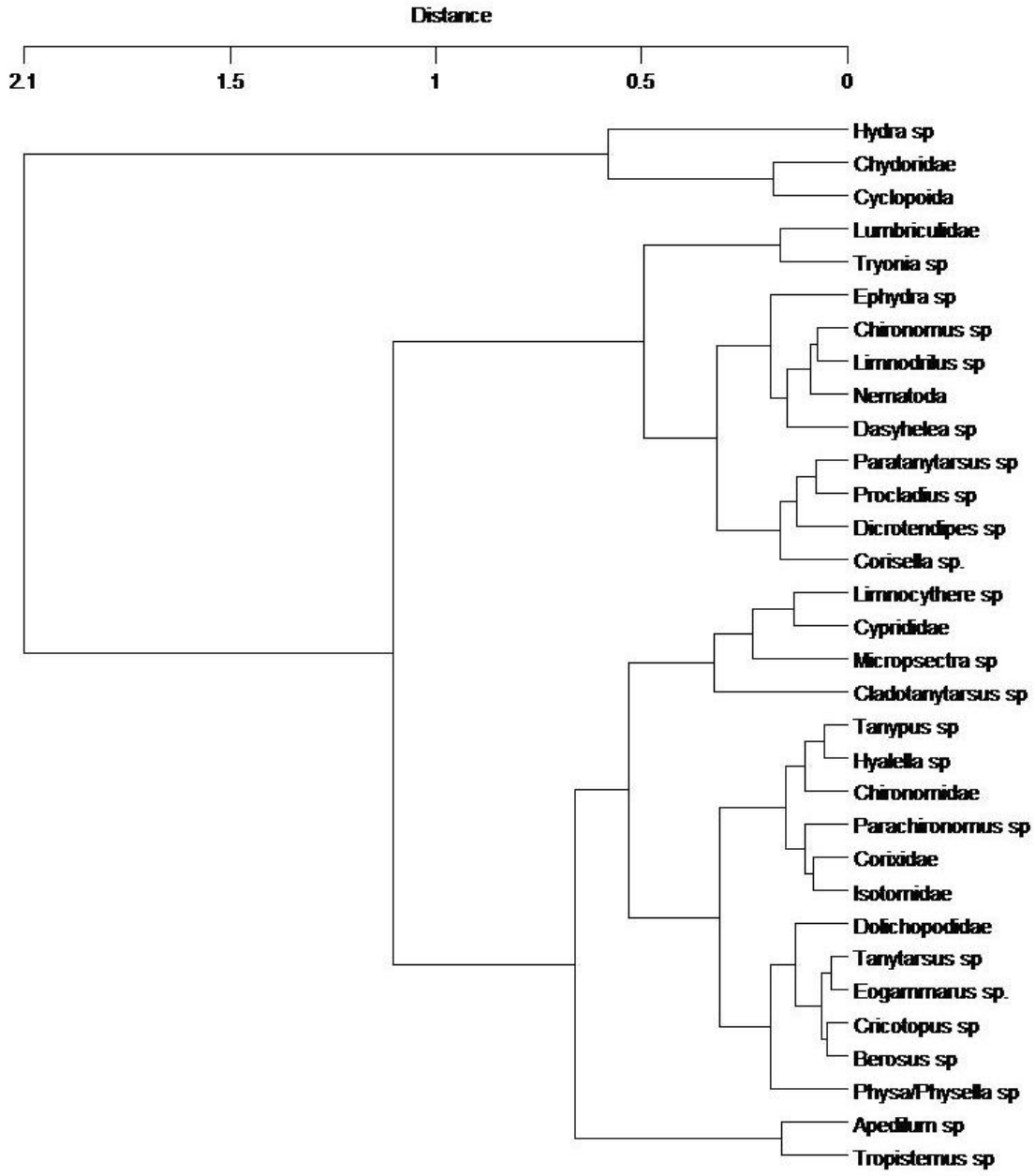

Figure 9. Species dendrogram for BMI population collected in 2007. Distances calculated using Bray-Curtis dissimilarity index.

APPENDIX D - STATISTICS

Statistical Analyses

Six biological metrics were used to compare the benthic infauna assemblages that were collected from both on and near the NEIBP CAD site (Table 2-1). Abundance, numbers of species, Shannon Diversity and the Benthic Response Index (BRI) were calculated for the benthic infauna data.

Total Abundance – is the abundance of infauna collected per sampling effort. Abundance included all of the non-colonial animals collected from one replicate Van Veen grab (0.1 square meter surface area) and retained on a 1.0.

Numbers of Species – is the number of separate infauna species collected per sampling effort (i.e. one Van Veen grab). In general, stations with higher numbers of species per grab tend to be in areas of healthier communities.

Shannon Diversity (H') – is a diversity index whose calculation includes both numbers of species and the relative abundance of each species. 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.

The Shannon Diversity Index (H') (Shannon and Weaver 1963) is defined as:

$$H' = -\sum_{s} \{(n_j/N) \, Ln(n_j/N)\}$$

where: n_j = number of individuals of the jth species

N = total indiv. of all species in the sample

s = number of species in the sample.

Schwartz' Dominance. Schwartz's Dominance Index (D) is defined as the minimum number of species required accounting for 75% of the individuals in a sample (Schwartz 1978).

Table 2-1. Community population metrics and their expected response to an impact.

Indicator	Reference	Expected Pattern with Increasing Disturbance
Total abundance	Pearson and Rosenberg (1978)	Increases, then decreases with increasing outfall effects
Number of species	Pearson and Rosenberg (1978)	Initial increase, then decrease with increasing impact
H' - Shannon information diversity	Pielou (1969)	Initial increase, then decrease with increasing impact

Analysis of Variance (ANOVA)

ANOVA's were used to compare population variables and sediment chemistry concentrations among stations. ANOVA analysis requires two steps. In the first step, differences in a variable among stations are evaluated to determine if they are sufficiently large to be statistically significant ($p \leq 0.05$). If they are, then a second test must be performed to determine which stations are significantly different from another station or stations. In this report, this second step is called the comparison of means. For example, a comparison of means stating: OS1 > OS2, OS3 > OS4, indicates that, for that particular variable, Station OS1 is significantly larger than Stations OS2, OS3, and OS4, and Stations OS2 and OS3 are also significantly larger than Station OS4. For chemical contaminants, if stations near the outfall are significantly higher than stations farther away, that compound should be evaluated further. For population variables, the opposite is true.

Ordination Analysis

Ordination analysis displays the sampling stations as points in a multidimensional space. The distance between the stations (points) in the space are proportional to the dissimilarity of the communities found at the respective stations. The different dimensions of the ordination space, called axes, define independent gradients of biological change in the community data. The projections of the station points onto the various axes are called scores. The axes are ordered so that the first axis displays a maximal amount of the community change, the second axis defines a maximal amount of the remaining community change, and so on for subsequent axes. Often most of the relevant community changes are displayed in a few ordination axes.

Cluster Analysis

Cluster analysis defines groups of stations with similar community composition. The results are displayed in a hierarchical tree-like structure called a dendrogram. On the dendrogram, two groups are first defined, and within these groups subgroups are defined. Subsequently, subgroups within the subgroups are defined. This process is continued until all stations are a separate subgroup. The hierarchical nature of the dendrogram allows the analyst to choose groups of stations that represent a scale of community differences relevant to the present project.

Cluster analysis is also used to define groups of species that tend to have similar distributional patterns among stations.

Dissimilarity Index

Both the ordination and cluster analyses require the input of a dissimilarity matrix, which quantifies the (biological community) dissimilarity between all pairs of stations. The Bray-Curtis dissimilarity index (Bray and Curtis 1957) with the stepacross procedure was used (Williamson 1978, Bradfield and Kenkel 1987). Before computation of the dissimilarity index, the species abundance data were transformed by square root and were standardized by a species mean of abundance values greater than zero. The square root transformation tends to dampen some of the noise often found in positively skewed species abundance data. The Bray-Curtis index has been shown to perform well when used with a species standardization (Faith et al. 1987, Smith 1976). Smith (1976) demonstrates how the species mean standardization in particular should best emphasize

species abundance counts that change commensurate to changes along community gradients.

All dissimilarity indices are incapable of properly measuring community change for highly dissimilar stations (Swan 1970, Beals 1973). This is because that once two stations have no species in common, the dissimilarity index values cannot continue to increase in value as stations become more dissimilar in community composition. The non-monotonic pattern of species abundance values along community gradients also contributes to this lack of index sensitivity for relatively large amounts of community change. The stepacross procedure applied to the computed dissimilarity matrix corrects for this deficiency of the dissimilarity index. Here the larger dissimilarity values (>0.8 on a scale of 0 to 1) are reestimated from the shorter dissimilarity values, resulting in larger dissimilarity values that are more commensurate with the degree of actual community change.

Two-way Coincidence Table

A two-way coincidence table is the station-species abundance data matrix displayed as a table of symbols indicating the relative abundances of the species at the stations. The rows and columns of the table are arranged to correspond to the order of stations and species along the respective station and species dendrograms. Since similar entities (stations or species) will tend to be closer together along a dendrogram, the row and column orders will efficiently show the pattern of species over the stations and station groups.

Since the rows and columns of the two-way coincidence table are ordered according to the dendrograms, the two-way coincidence table is also used to help delimit the station and species groups defined by the cluster analyses. At each potential separation of subgroups defined by the dendrogram, the two way coincidence table is examined to see the corresponding group differences in terms of species presences and abundances. This allows the analyst to choose groups with a level of community differences consistent with the goals of the project.