THE CITY OF SAN BUENAVENTURA

Santa Clara River Estuary Macroinvertebrate Bioassessment Monitoring Annual Report 2006

THE CITY OF SAN BUENAVENTURA

CITY OF VENTURA

Presented by:

Aquatic Bioassay & Consulting Laboratories, Inc.

29 N. Olive St.
Ventura, CA
805 643 5621

March 2007

AQUATIC BIOASSAY & CONSULTING LABORATORIES, INC.

TABLE OF CONTENTS

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 2006, 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 26th, 2006 and October 19th, 2006 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.

Stream flow data was not available for 2006 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

Elutriation

Due to the large amount of sand and gravel present in the benthic core samples after they had been passed through the 0.5 mm screen, each sample was elutriated in the field. The sample was placed in a 5 gallon bucket and then river water that had been filtered using the 0.5 mm screen was added to just cover the sediment. The bucket was then gently swirled gently to suspend organic material in the sample and the supernatant was decanted through a 0.5 mm screen. This process was repeated numerous times until the supernatant was nearly clear. All of the elutriated material on the 0.5 mm screen was then rinsed into a ½ gallon wide mouth jar and preserved in 70% alcohol. The sand and gravel were placed into a separate ½ gallon wide mouth jar and preserved in 70% alcohol, and then scanned by a supervising Biologist in the laboratory for any remaining animals. The field elutriation method successfully removed 99% of the organisms from all samples.

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 on. 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 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 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 2001).

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 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.

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 2006.

During the period between January and December, 2006, measurable rain fell at Oxnard Airport on 49 days and totaled 11.6 inches (Figure 2). The heaviest rainfall of the year occurred in March (2.81 in) and April (2.76 in). Rainfall during all other months ranged between 2.28 and 0.01 inches, except in July and September when no measurable rain was recorded. The May bioassessment survey was conducted four days following an inch of rain at the Oxnard airport. Continuous observation of the river following this event indicated that river flow did not increase to the point where the biological communities in the river would have been disrupted. October sampling followed a relatively dry period with only trace rain that did not affect river flow.

During the May sampling event the berm at the mouth of the Estuary was still breached from the winter storms, the River was flowing freely to the ocean, and water depth ranged from 2 to 8 inches throughout the Estuary (Table 2). By the October sampling event the berm at the mouth of the Estuary was closed and water depth in the Estuary ranged from 36 to 60 inches.

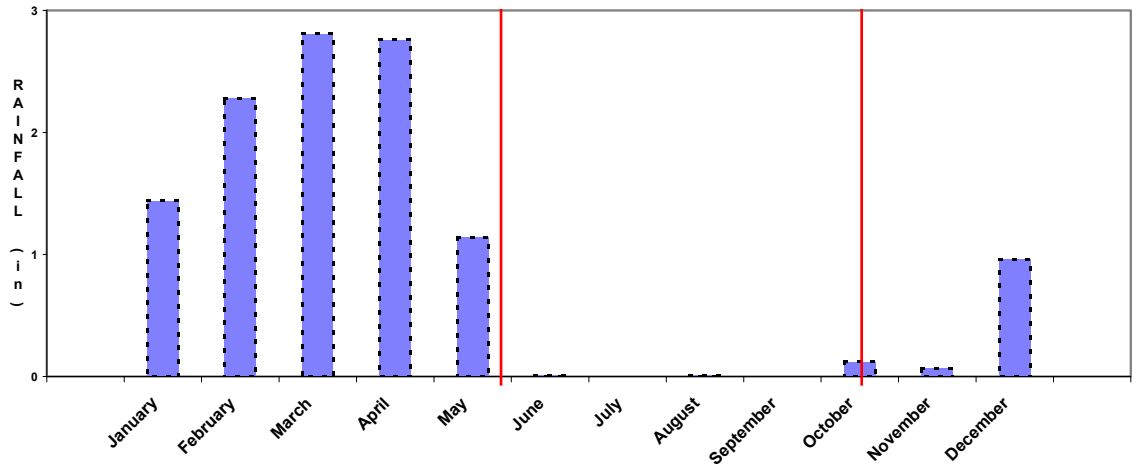


Figure 2. Monthly average rainfall recorded at Oxnard Airport, January to December, 2006. Red lines indicate days when sampling in the Estuary took place.

General Observations

During May, sampling was conducted under partly cloudy skies with 15 to 20 kilometer visibility (Table 2). Wind was from the south to west from between 3 and 10 knots. Water color was green at Stations B1 and B3, and brown at Stations B2 and B7. The brown color was a result of the algal mats covering the sediments at these stations. In October sampling occurred under partly cloudy to clear skies with 30 to 32 km visibility. Winds were northwest from 1 to 5 knots. Water color was green at Stations B1 and B2 and brown at B3 and B7.

Physical Measurements and Water Quality

May

In May the width of the sampling transects varied from 8 to 40 meters, while the water velocity ranged from 0.0 ft/sec at Station B2 to 0.36 ft/sec at Station B1 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 was sand, except at Station B3 which also contained cobble. Each site was 100% embedded.

The pH ranged from a low at of 4.47 at Station B2 upstream of the effluent channel, to a high of 8.20 at Station B7 in the main River channel. Dissolved oxygen concentrations varied widely from 7.25 at Station B1 to 13.80 at Station B7. This extremely high dissolved oxygen reading was probably the result of oxygen production by algae. Water temperature exceeded 20 °C at all sites and was 30 °C at Station B7. Salinity ranged from 1.3 at Station B1 in the main effluent channel to 14 at Station B2 upstream of the outfall.

October

In October, transect widths ranged from 2.5 (Station B7) to 5 m (Stations B1 and B3) (Table 2). There was no measurable water velocity at any site, due to the partially inundated conditions. There was no canopy cover over any of the stations. The composition of bottom sediments sand at all sites and a mixture of sand and cobble at Station B1.

The pH ranged from 8.00 to 8.15. Dissolved oxygen concentrations were low at all sites ranging from 3.10 to 5.55 mg/L. Water temperatures ranged from 17.8 to 19.3 °C at all sites. Salinity ranged from 1.5 ppt at Stations B2 to 1.9 ppt at 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, 2006.

Sampling Stations	Spring BI	Spring B2	Spring B3	Spring B7	Fall BI	Fall B2	Fall B3	Fall B7
Date	26-May-2006	26-May-2006	26-May-2006	26-May-2006	19-Oct-2006	19-Oct-2006	19-Oct-2006	19-Oct-2006
Time	9:30	9:55	8:58	12:30	11:04	10:43	10:02	12:30
Survey Program	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab	Bioassessment Grab
Depth (in)	8	3	6	2	60	36	60	36
Latitude	34° 14.092	34° 14.089	34° 14.010	34° 13.881	34° 14.092	34° 14.092	34° 13.987	34° 13.891
Longitude	119° 15.809	119° 15.791	119° 15.905	119° 15.591	119° 15.786	119° 15.788	119° 15.903	119° 15.580
Weather	Partly Cloudy	Clear	Overcast	Clear	Clear	Clear	Clear	Clear
Air Vis. (km)	15	15	10	20	30	30	30	30
Esturary Status	Open	Open	Open	Open	Closed	Closed	Closed	Closed
Wind Sp. (Kn)	5	10	3	5	5	6	2	1
Wind Dir. (°M)	225	180	270	270	315	315	315	90
Color	Green	Brown	Green	Brown	Green	Green	Brown	Green
Comments	None	None	None	None	None	None	None	None
Transect Width (m)	20	8	40	18	5	3	5	2.5
Velocity (ft/sec)	0.36	0.00	0.35	0.29	NR	NR	NR	NR
% Canopy	0	0	0	0	0	0	0	0
Composition	Sand	Sand	Sand Cobble	Sand	Sand Gravel	Sand	Sand	Sand
Embededness (%)	100	100	100	100	100	100	100	100
Sample Depth (in)	8	3	6	2	60	36	60	36
pH	7.96	4.47	7.83	8.20	8.09	8.00	8.15	8.00
Conductance (mS/cm)	2.53	22.73	4.32	4.20	2.97	2.95	3.01	3.09
Dissolved Oxygen (mg/L)	7.25	11.06	7.33	13.80	4.84	3.10	5.55	3.48
Temperature (°C)	24.2	23.8	23.7	30.3	19.1	19.3	18.8	17.8
Salinity (ppt)	1.3	14.0	2.4	2.0	1.7	1.5	1.7	1.9

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 at all stations and during both surveys were composed of very fine sand to medium sand, except at Station B3 in May when the sediments were coarse silt (Table 3 and Figure 3). Sediments at Stations B1 and B2 did not change as dramatically between sampling seasons and were moderately well sorted. Sediments at Station B3 shifted from 81% fines in May to 14% in October, while sediments at Station B7 shifted from 1% fines to 27% fines between seasons.

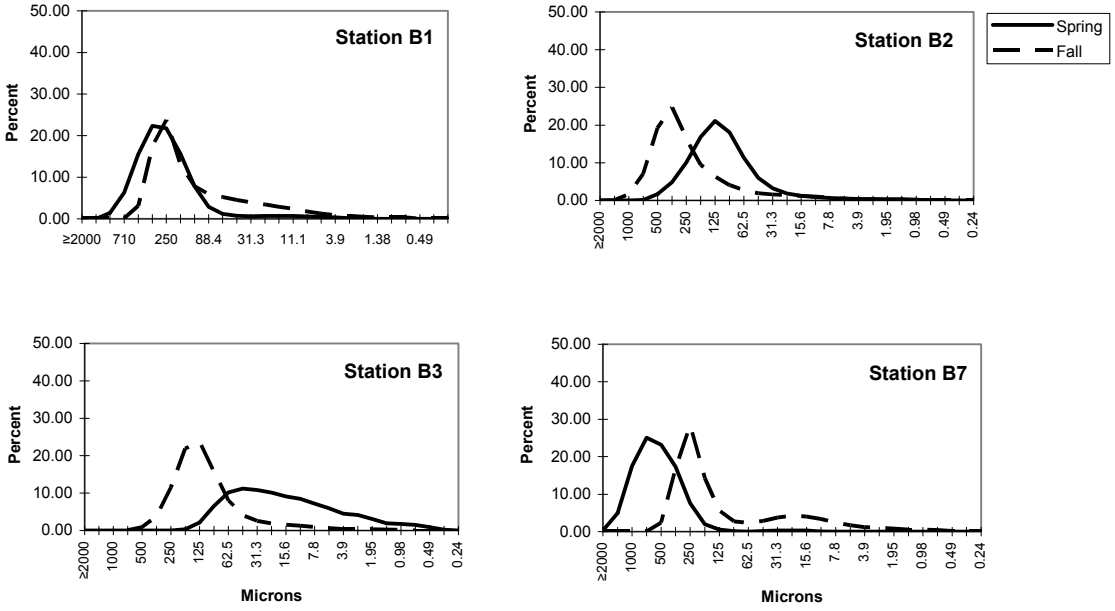
The shifts, or lack thereof, in particle size distributions between seasons at these sites are probably the result of their locations in the Estuary. Stations B1 and B2 located in or near the effluent channel are not subjected to river scouring, except after very large storms. After the deposition of sediments during the winter storms, the quiescent conditions allowed the sediments to remain relatively unchanged between sampling events. This was less pronounced at Station B3, which is more exposed to the conditions in the outer Estuary. Station B7 in the river channel is exposed to highly variable conditions, including river scour after storms, quiescent conditions during inundation and tidal inflow from the ocean.

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, 2006.

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	8.3	95.0	4.8	0.2	5.0	121	236	412	medium sand	3.0	2.1	1.3	0.9	moderately well sorted
B2	0.0	84.0	14.7	1.2	16.0	44	95	181	very fine sand	4.5	3.4	2.5	1.0	moderately well sorted
B3	0.0	19.1	67.3	13.6	80.9	3	16	49	coarse silt	8.2	5.9	4.3	1.9	poorly sorted
B7	0.0	98.7	1.3	0.0	1.3	273	484	811	medium sand	1.9	1.0	0.3	0.8	moderately well sorted
October														
B1	58.2	76.4	21.2	2.4	23.6	24	152	274	fine sand	5.6	2.7	1.8	0.9	moderately sorted
B2	0.0	91.5	8.5	0.0	8.5	92	259	438	medium sand	4.2	3.2	2.6	1.0	moderately sorted
B3	0.0	85.6	13.3	1.2	14.4	47	105	178	very fine sand	1.1	0.5	0.1	1.9	poorly sorted
B7	0.0	72.6	23.7	3.7	27.4	15	167	268	fine sand	6.2	2.9	2.0	0.8	moderately 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 2006 sampling surveys.



Macrobenthic Invertebrates

Summary

There were a combined total of 5,769 organisms collected from the four stations during the spring and fall 2006 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 was greater in the fall (4,333) compared to the spring (1,436).

A total of 23 unique species were collected during both surveys combined, with a total of 16 collected in the spring and 18 in the fall. In the spring the greatest numbers of species were collected at Stations B2 and B3 (11 each). In the fall, the greatest numbers of species were collected at Station B2 (16).

Bioassessment Metrics

Biological metrics were calculated according to the California Lentic and Stream Bioassessment protocols and are presented in Table 4 and 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.

Fall abundances exceeded spring abundances at each station and were greatest at Stations B2, upstream of the outfall and Station B7 in the river channel. Lowest abundances were measured at Stations B1, in the effluent channel, and B7 during the spring. 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 fall at each station compared to the spring. The greatest taxonomic richness was found at Station B2 and the lowest was at Station B1 during the spring. 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 spring at Station B2 and least at Station B1 in the fall. Dominance was significantly greater at Stations B2 and B3 in the spring compared to Stations B1 and B7. Dominance was marginally significantly different among stations in the fall.

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 low, not exceeding 1.5 at any site, in either season. Diversity was greatest at Station B2 in the fall and least at Stations B2 and B3 in the spring. In the spring diversity was significantly greater at Stations B1 and B7 compared to B2 and B3. In the fall diversity was significantly greater at Station B2 compared to Stations B3 and B7.

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 greatest in the spring at all sites compared to the fall. Tolerance values were similar across sites during each season (spring range = 8.2 to 9.6 and fall range = 6.4 to 7.0). There were no significant differences among sites for either season. Percent tolerance followed the same trend and was greatest across sites during the spring compared to the fall. In the spring, percent tolerance was significantly greater at Stations B1 and B3 compared to Station B7.

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 70% during both seasons and 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.

During the spring the oligochaete worm, *Limnodrilus sp*, accounted for nearly 90% of the population at Stations B2 and B3. Four species accounted for 95% of the population at Station B1 and included a gastropod snail (Hydrobiidae), *Limnodrilus sp*, an ostracod (*Limnocythere sp*) and an amphipod crustacean (*Hyalella sp*). Three species accounted for 95% of the population at Station B7 including a cypridid ostratcod (Cyprididae), *Limnodrilus sp*, a true fly (Orthocladiinae). By the fall survey the composition of species was dominated by midge larvae (Chrironominae) at each of the four sites. Other abundant species in the survey area included: gastropod snails (Hydrobiidae), *Limnocythere sp*, cypridid ostracods and flies (Orthocladiinae).

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.

Two station groups and three species groups were delineated by cluster analysis (Figure 6). Station group 1 included all sites collected during the fall and group 2 included all sites collected during the spring. Species groups A and B represented species that were relatively abundant in the fall at all four stations, while species group C was represented by species that were relatively abundant in the spring.

Ordination Axis 1 represented 49% of the variation in community structure in this survey and seemed to separate the fall from the spring sampling event (Figure 7). Axis 2 represented 26% 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. Axis 3 represented 11% of the variation and appears to be related to seasonal shifts in particle size. Particle sizes at Stations B2 and B3 shifted from finer to courser sediments between spring and fall surveys, while Stations B1 and B7 shifted from courser to finer sediments between spring and fall (Figure 3).

DISCUSSION

The 2006 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 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 coring device relies on vacuum pressure to keep samples intact as they are brought to the surface and works well in sediments composed of silt and clay, but not so well in sandy sediments. In past surveys, a single littoral sweep was conducted at Station B1 using a kick net. However, since the Estuary provides critical habitat for the endangered tidewater goby, which can be inadvertently collected with the kick net, the littoral sweep was permanently excluded from the sampling design by the Los Angeles Regional Water Quality Control Board. The goal of this survey was to determine if the discharge from the Ventura Water Reclamation Facility affects the biological communities in the Santa Clara River Estuary.

Flow during 2006 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, 2006, measurable rain fell at Oxnard Airport on 49 days and totaled 11.6 inches. The heaviest rainfall of the year occurred in March (2.81 in) and April (2.76 in). Rainfall during all other months ranged between 2.28 and 0.01 inches, except in July and September when no measurable rain was recorded.

The large rain events during 2005 caused widespread flooding along the Santa Clara River flood plain. The high flow in the River caused the banks to be scoured, severely eroded and denuded of vegetation. Huge quantities of sediments were washed downriver, into the Estuary, and out to sea. The sand spit was almost completely removed from the mouth of the Estuary and the River flowed continuously to the sea. By 2006 the sand spit across the entrance to the Estuary was completely reestablished. As a result, the inundation cycle of filling and emptying the Estuary based on whether the berm was opened or closed was reestablished. In addition, the vegetative cover on the banks of the Estuary had returned to previous densities. During the May 2006 sampling event the berm at the mouth of the Estuary was still breached from the winter storms, the River was flowing freely to the ocean, and water depth ranged from 2 to 8 inches throughout the Estuary. By the October sampling event the berm at the mouth of the Estuary was closed and water depth in the Estuary ranged from 36 to 60 inches.

Water quality in the Estuary during 2006 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 17.8 to 30.3 °C. These findings were just above the range of past studies (13.94 to 29.04, USFWS 1999). pH ranged from 4.47 to a high of 8.2. The low pH reading occurred at Station B2 during the spring when flow at this site was not detectable. Respiration occurring at the sediment surface as a result of naturally occurring bacteria might have caused this low reading. The low pH was not caused by the VWRF effluent since this site is located upstream of the plant discharge. Dissolved oxygen concentrations in the Estuary were highly variable ranging from 3.10 mg/L at Station B2 in fall to

13.80 mg/L during the spring at Station B7. Temperature, pH (except for the single low reading at Station B2 in the spring) 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), 2003, 2004 and 2005 (Aquatic Bioassay 2005).

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 2006 survey, salinity during spring ranged from 1.3 in the effluent discharge to 14.0 ppt just upstream of the discharge at Station B2. In the fall salinity was similar across sites due to inundated conditions and ranged from 1.5 to 1.9 at all sites. Salinity during the 2006 survey fell within the EPA's freshwater criterion (<2.0 ppt, 95% of the time) at each station during the fall and at Stations B1 and B7 in the spring, and was below that of brackish water (5 to 10 ppt) at Station B3 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 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). Sediments at all stations and during both surveys were composed of very fine sand to medium sand, except at Station B3 in May when the sediments were coarse silt. Sediments at Stations B1 and B7 shifted from lower to greater proportions of fine sediments from spring to fall, while at Stations B2 and B3 sediments shifted from greater to lower proportions of fine sediments. These shifts were most pronounced at Station B2, B3 and B7, while sediment sizes remained relatively unchanged at Station B1 in the effluent channel. The shifts, or lack thereof, in particle size distributions between seasons at these sites are probably the result of their locations in the Estuary. After the deposition of sediments during the winter storms, the quiescent conditions allowed the sediments to remain relatively unchanged between sampling events. This was less pronounced at Station B3, which is more exposed to the conditions in the outer Estuary. Station B7 in the river channel is exposed to highly variable conditions, including river scour after storms, quiescent conditions during inundation and tidal inflow from the ocean.

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 2006 survey were those found in either freshwater or estuarine environments (USFWS 1999, ENTRIX 2003). The total numbers of organisms collected by grab in 2006 (5,769) was similar to 2005 (4,637), but far less than in 2004 when a total of 12,207 organisms were collected (Aquatic Bioassay 2005), but 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 was greater in the fall (4,333) compared to the spring (1,436). This large increased abundance in the fall was similar to previous surveys. 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).

The numbers of species present in the Estuary during both the spring and fall 2006 surveys totaled 23 unique species, with a total of 16 taxa collected in the spring and 18 in the fall. The numbers of species collected in 2006 were less than in 2005, but similar to 2003 and 2004 (Aquatic Bioassay 2004, 2005 and 2006); and were similar to the 2002 spring survey (25) and less than the 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 2006 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*, accounted for nearly 90% of the population at Stations B2 and B3. Four species accounted for 95% of the population at Station B1 and included a gastropod snail (Hydrobiidae), *Limnodrilus sp*, an ostracod (*Limnocythere sp*) and an amphipod crustacean (*Hyalella sp*). Three species accounted for 95% of the population at Station B7 including a cypridid ostratcod (Cyprididae), *Limnodrilus sp*, and true flies (Orthocladiinae). By the fall survey the composition of species was dominated by midge larvae (Chrironominae) at each of the four sites. Other abundant species in the survey area included: gastropod snails (Hydrobiidae), *Limnocythere sp*, cypridid ostracods and flies (Orthocladiinae).

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 that include either habitat disruption or pollution (CDFG 1999). The percentage of tolerant taxa (tolerance value = 8 to 10) was greatest in the spring at all sites compared to the fall. Tolerance values were similar across sites during each season (fall range = 8.2 to 9.6 and spring range = 6.4 to 7.0).

Cluster and ordination analyses were used to identify how the biological communities measured during 2006 differed between sites and seasons. Cluster analysis is useful because is 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 station groups representing spring and fall were delineated. Ordination Axis 1 represented 49% of the variation in community structure in this survey and also separated the fall from the spring sampling event. Axis 2 represented 26% 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. Axis 3 represented 11% of the variation might be related to the seasonal shifts in particle size mentioned above.

Although the Estuary is located downstream of heavy agricultural inputs and waste treatment facilities, the major disturbances to the biological communities 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 2006 survey appear to be most influenced by these factors. Differences between sites appear to be changing water levels and shifts in sediment particle size.

Table 4. Summary of abundances by species and location during both spring and fall, 2006 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	Tol Val (TV)	Func Feed Grp	Spring				Fall			
			B1	B2	B3	B7	B1	B2	B3	B7
Berosus sp	5	p	0	0	0	0	0	1	0	1
Bezzia/Palpomyia sp	6	p	0	0	0	0	1	0	0	0
Chironominae	6	cg	0	0	0	0	229	664	677	996
Chydoridae		cf	1	5	0	0	0	0	0	0
Corisella sp.	8	p	0	0	0	0	0	0	6	0
Corixidae	8	p	0	2	1	0	2	3	1	7
Cyclopoida	8	cf	0	0	1	0	0	0	0	0
Cyprididae	8	cg	2	8	19	147	25	31	22	99
Dolichopodidae	4	p	0	8	2	2	0	1	0	1
Ephydra sp	6	sh	0	4	1	2	0	1	1	0
Hyalella sp	8	cg	19	2	40	0	5	5	1	0
Hydrobiidae	8	sc	59	0	0	0	184	164	6	1
Isotomidae	5	cg	0	1	2	2	0	0	0	0
Limnocythere sp	8	cg	21	2	2	1	49	286	336	1
Limnodrilus sp	10	cg	56	309	594	66	22	115	2	3
Lumbriculidae	5	cg	0	0	0	0	2	8	0	0
Nematoda	5	p	0	0	0	0	0	1	0	0
Orthocladiinae	5	cg	0	10	6	35	14	58	46	20
Physa/Physella sp	8	sc	0	0	0	1	0	22	11	150
Pionidae	5	p	0	0	0	0	1	3	0	0
Simulium sp	6	cf	0	0	1	0	0	0	0	0
Tanypodinae	7	p	0	0	0	0	5	9	0	34
Tropisternus sp	5	p	0	0	0	3	0	0	0	0
Total Average Abundance by Station			**159**	**350**	**670**	**258**	**540**	**1372**	**1109**	**1311**
Average Numbers of Species			**6**	**11**	**11**	**9**	**12**	**16**	**11**	**11**

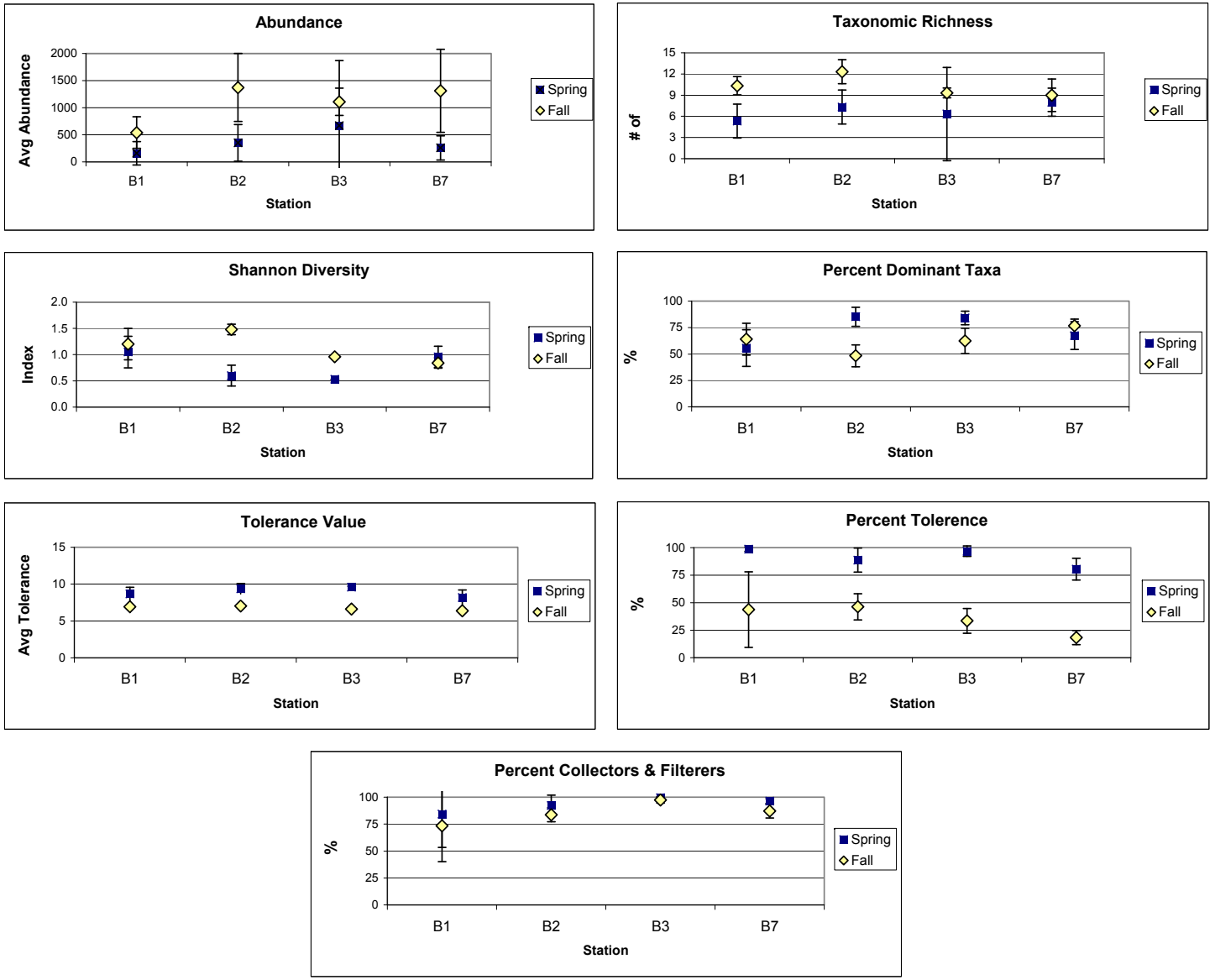


Figure 4. Average (± 95% CI) BMI metrics calculated for populations collected during the spring and fall 2006.

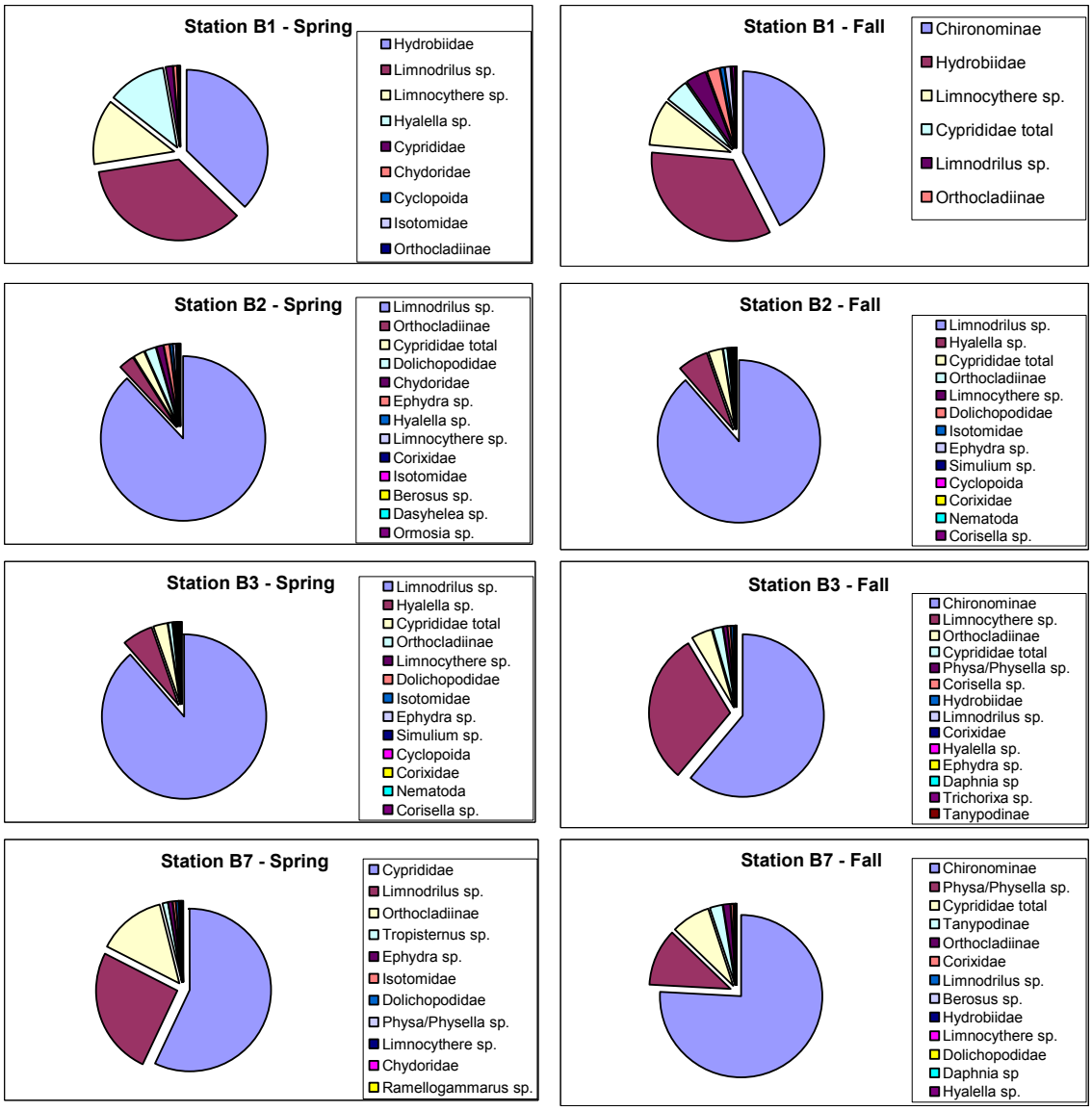


Figure 5. Cumulative percent abundance of most common species collected in the Santa Clara River Estuary from four sites during the spring and fall of 2006.

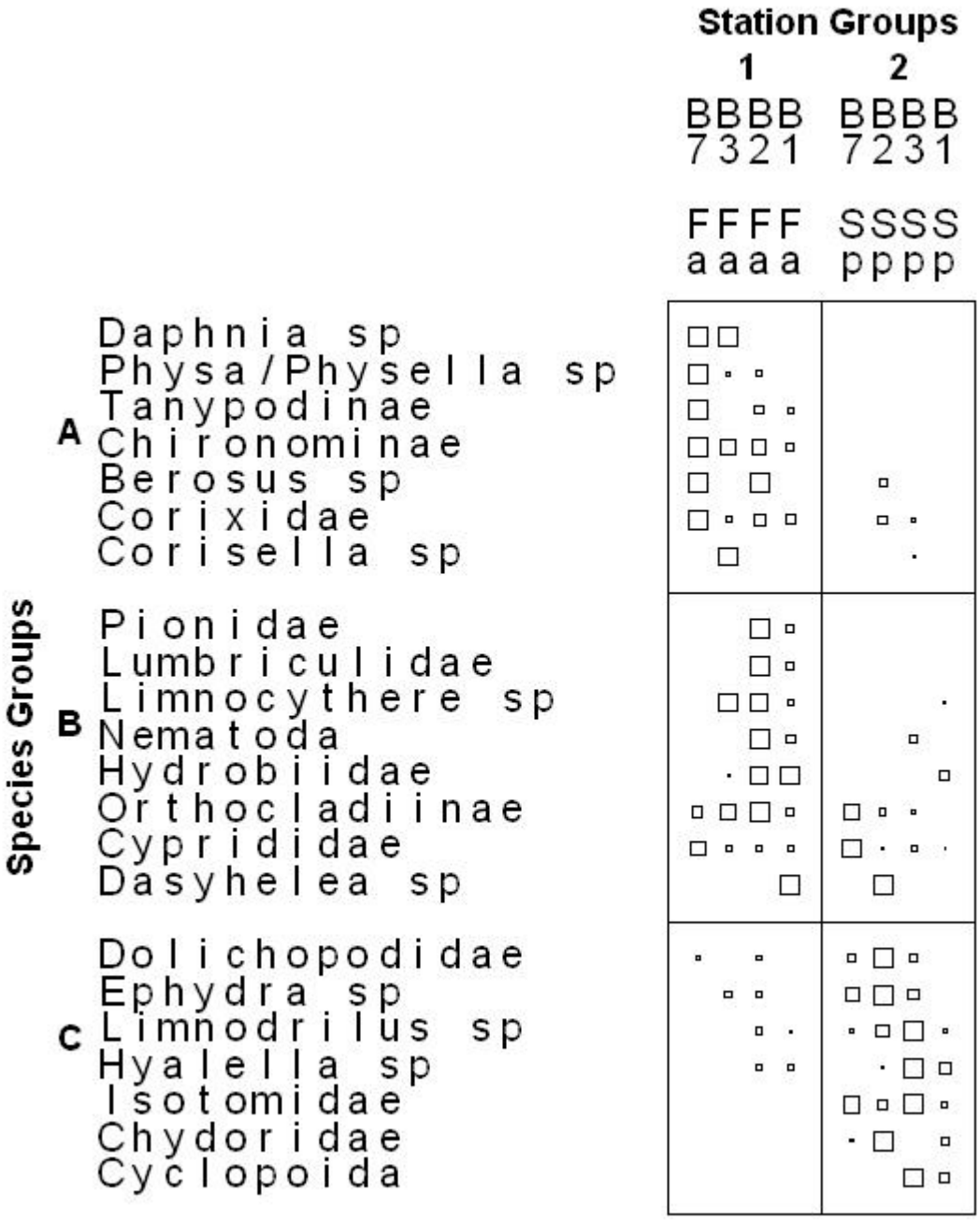
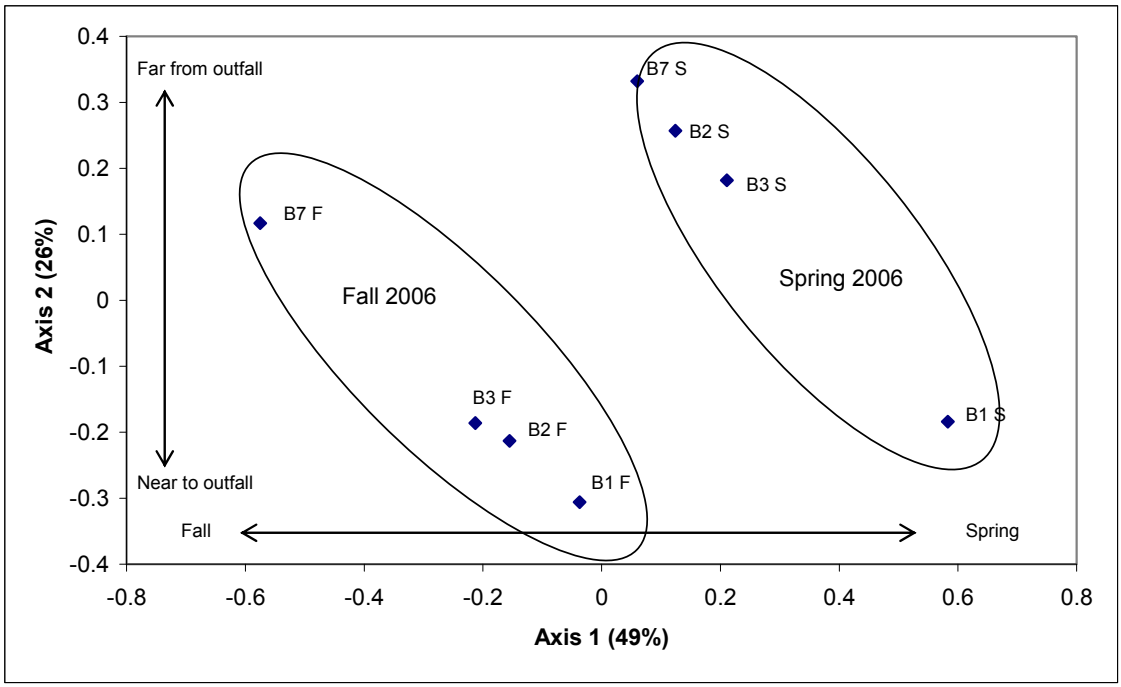


Figure 6. Two-way coincidence table of species vs. station groups created by cluster analysis (UPGMA, Sneath and Sokal 1973). The Bray-Curtis dissimilarity index was used to calculate the distances among stations and species (Gauch 1982, Jongman et. al. 1995). Abundance data were square root transformed. 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 ≥ 1) which represented 99% of the total population. "Fa" indicates fall, and "Sp" indicates spring. Dendrograms and multivariate methods can be found in the Appendix.



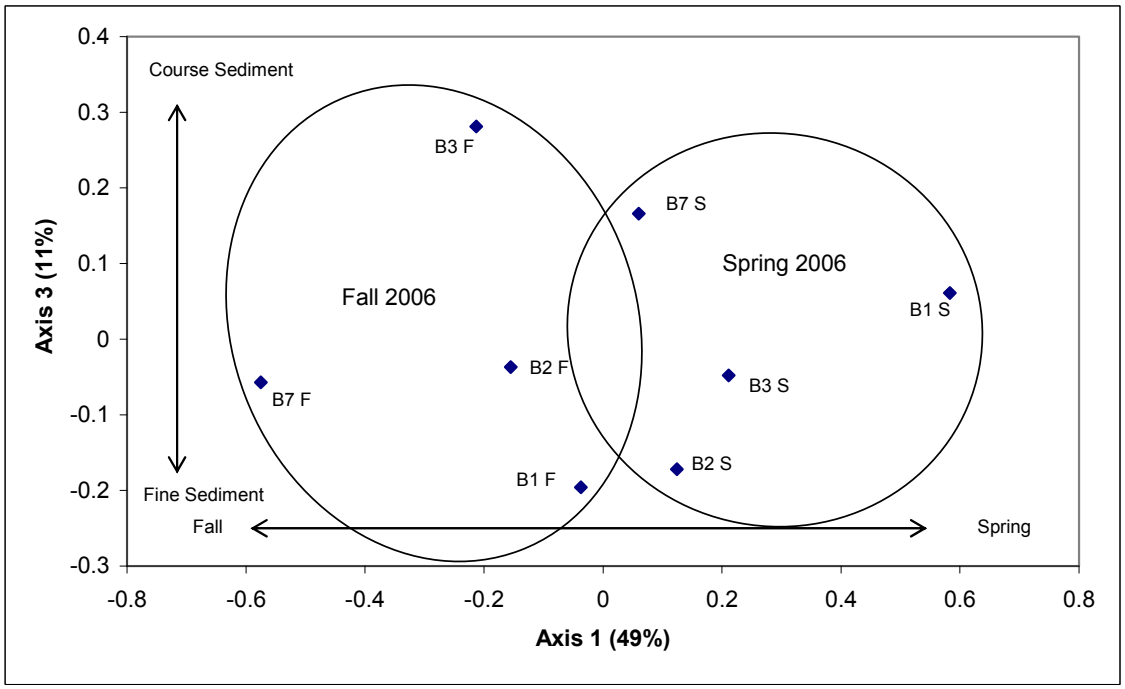


Figure 7. Ordination space plots for axis 1 vs axes 2 and 3, with cluster groups circled and stations identified.

APPENDIX A - REFERENCES

General references

APHA, 1998. Standard methods for the Examination of Water and Wastewater. Am. Publ. Health Assn., Am. Water Work Assn., Water Poll. Control Fed. 20th ed.

Aquatic Bioassay and Consulting Labororatories. 2004. Santa Clara River Estuary, Macroinvertebrate Bioassessment Survey, Annual Report 2003.

Aquatic Bioassay and Consulting Labororatories. 2005. Santa Clara River Estuary, Macroinvertebrate Bioassessment Survey, Annual Report 2004.

Aquatic Bioassay and Consulting Labororatories. 2006. Santa Clara River Estuary, Macroinvertebrate Bioassessment Survey, Annual Report 2005.

CDFG, California Department of Fish and Game. 1999. California Stream Bioassessment Procedure. California.

CSBP, Harrington, J.M. 2003. California stream bioassessment procedures. California Department of Fish and Game, Water Pollution Control Laboratory. Rancho Cordova, CA.

California Department of Fish and Game. 2003. List of California Macroinvertebrate Taxa and Standard Taxonomic Effort. California.

Chapman, Peter M. and Feiyue Wang. 2001. Assessing Sediment Contamination in Estuaries. Environmental Toxicology and Chemistry, Vol. 20, No. 1, pp. 3-22, 2001.

ENTRIX. 1999. City of San Buenaventura Ventura Water Reclamation Facility, NPDES Limit Achievability Study, Phase 3: Alternative Standards. ENTRIX, Inc. Ventura Office. 87 pp.

ENTRIX, Inc. 2002. Metals translator study. Santa Clara River Estuary. Ventura Water Reclamation Facility NPDES permit number CA 0053561, CI-1822. Prepared for the City of San Buenaventura. September 2002.

ENTRIX. 2003. 2002 Annual report, macroinvertebrate bioassessment monitoring, Santa Clara River Estuary. Prepared for the City of San Buenaventura, Water Reclamation Facility. Ventura, CA.

Ferren, W.R. 1989. Recent research on and new management issues for Southern California estuarine Wetlands. pp. 55-97 in A.A. Schoenerr (ed.), Endangered plant communities of Southern California. Proceedings of the 15th Annual Symposium, Southern California Botanists, October 28, 1989. Published by Southern California Botanists, Rancho Santa Ana Botanic Gardens, Claremont, CA.

Ferren, W.R., M.H. Capelli, A. Parikh, D.L. Magney, K. Clark, J.R. Haller. 1990. Botanical resources at Emma Wood State Beach and the Ventura River Estuary, CA; inventory and management. Prepared for State of California, Department of Parks and Recreation. Prepared by Environmental Research Team, The Herbarium, Department of Biological Sciences, University of California, Santa Barbara, Environmental Report No. 15. 310 pp.

Ferran, W.R., P.L. Fiedler, R.A. Leidy, K.D. Lafferty, and L. Mertes. 1996. Wetlands of California, part III: key to and catalogue of wetlands of the Central and Southern California coast and coastal watershed. Madrono, 43(1): 183:233.

Gauch, H.G., Jr. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge, U.K.

Gray, J.S. 1981. *The Ecology of Marine Sediments, An Introduction to the Structure and Function of Benthic Communities.* Cambridge Univ. Press, Cambridge. 185 p.

Jongman, R.H.G., C.J.F. ter Braak, and O.F.R. van Tongeren. 1995. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge, UK. 299 pp.

Kennish, M.J. 1990. Ecology of Estuaries, Volume II Biological Aspects. CRC Press,Boca Raton, FL.

NCSS. 2001. Number Cruncher Statistical Systems. Kaysville, UT.

Plumb, R.H. 1981. Procedures for Handling and Chemical Analysis of Sediment and Water Samples. USEPA Contract No. 48-05-572010.

Swanson, M.L., J. Michael, and J. McIver. 1990. McGrath State Beach Santa Clara River Estuary Natural Preserve Restoration and Management Plan. Prepared for California Department of Parks and Recreation, Central Coast Region, Monterey, CA. 75 pp.

Zedler, J.B. 1982. The ecology of southern California coastal salt marshes: a community profile. U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. FWS/OBS-81/54. 110 pp.

Taxonomic identification resources used

Brown, H. P. 1976. Aquatic Dryopoid Beetles (Coleoptera) of the United States. U. S. EPA. Cincinnati, Ohio. 82 Pages.

Burch, J. B. 1973. Biota of Freshwater Ecosystems Identification Manual No. 11, Freshwater Unionacean Clams (Mollusca: Pelecypoda) of North America. U. S. Environmental Protection Agency, Project # 18050, Contract # 14-12-894. 176 Pages.

Burch, J. B. 1973. Freshwater Unionacean Clams (Mollusca:gastropoda) of North America. U. S. Environmental Protection Agency, EPA-600\3-82-023. Contract # 68-03-1290. 193 Pages.

Edmunds, G. F., Jr., S. L. Jensen and L. Berner. 1976. The Mayflies of North and Central America. North Central Publishing Co., St. Paul, Minnesota. 330 Pages.

ENTRIX, Inc. 2002. Resident species study. Santa Clara River Estuary. Ventura Water Reclamation Facility NPDES permit number CA 0053561, CI-1822. Prepared for the City of San Buenaventura. September 2002.

John H. Epler, 2001. Identification manual for the larval chironomidae (Diptera) of North and South Carolina.

Johannsen, O. A. 1977. Aquatic Diptera: Eggs, Larvae, and Pupae of Aquatic Flies. Published by the University, Ithaca, New York. 210 Pages.

Klemm, D. J. 1972. Biota of Freshwater Ecosystems Identification Manual No. 8, Freshwater Leeches (Annelida: Hirundinea) of North America. U.S. Environmental Protection Agency. Project # 18050, Contract # 14-12-894. 53 Pages.

Klemm, D. J. 1985. A Guide to the Freshwater Annelida (Polychaeta, Naidid and Tubificid Oligochaeta and Hirudinea) of North America. Kendall/Hunt Publishing Co., Dubuque, Iowa. 198p.

McCafferty, W. P. 1981. Aquatic Entomology. Jones and Bartlett Publishers, Inc., Boston. 448 Pages.

Merritt, R. W. and K. W. Cummins (Editors). 1996. An Introduction to the Aquatic Insects of North America, Third Edition. Kendall/Hunt Publishing Co., Dubuque, Iowa. 862 Pages.

Pennak, R. W. 1989. Freshwater Invertebrates of the United States, Third Edition, John Wiley and Sons, Inc, New York, 628 Pages.

Peckarsky, B.L., P.R. Fraissinet, M.A. Penton, and D. J. Conklin, Jr. 1990. Freshwate Macroinvertebrates of Northeastern North America. Cornell University Press, Ithaca, N.Y. 442 Pages.

Stewart, K. W. and B. P. Stark. 1988. Nymphs of North American Stonefly Genera (Plecoptera). University of North Texas Press, Denton Texas. 460 Pages.

Swanson, M.L. Josselyn, M. and J. McIver. 1990. McGrath State Beach: Santa Clara River Estuary Natural Preserve Restoration and Management Plan. Unpublished report prepared for the California Department of Parks and Recreation. October 1990.

Thorp J. H. and A. P. Covich (Editors). 1991. Ecology and Classification of Freshwater Invertebrates. Academic Press, Inc., San Diego, California. 911 Pages.

Wiederholm, T. (Editor) 1983. Chironomidae of the Holarctic Region. Entomologica Scandinavica. 457 Pages.

Wiggins, G. B. 1996. Larvae of North American Caddisfly Genera (Tricoptera). Second Edition, University of Toronto Press. Toronto. 457 Pages.

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, 2006.

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	0.03	1.45	6.36	15.54	22.33	21.80	15.59	7.81	2.86	1.21	0.72	0.65	0.68	0.70	0.69	0.57	0.45	0.33	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00
B2	0.00	0.00	0.00	0.10	1.71	4.85	10.02	16.86	21.10	18.04	11.33	6.01	3.26	1.86	1.19	0.90	0.66	0.50	0.37	0.37	0.34	0.33	0.20	0.00	0.00	0.00	0.00
B3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	2.09	6.51	10.18	11.21	10.86	10.10	9.09	8.45	7.18	5.97	4.48	4.19	3.05	1.94	1.75	1.51	0.90	0.22	0.00
B7	0.31	4.98	17.49	25.03	23.24	17.34	7.62	2.00	0.60	0.12	0.00	0.19	0.33	0.35	0.31	0.08	0.00	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	0.10	3.11	17.42	23.80	12.87	7.84	6.01	5.25	4.57	3.99	3.44	2.88	2.43	1.78	1.26	0.85	0.72	0.52	0.38	0.37	0.32	0.07	0.00	0.00
B2	0.00	0.05	1.64	6.98	19.22	24.70	16.40	9.44	6.33	4.06	2.67	1.90	1.59	1.41	1.21	1.01	0.69	0.44	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	0.91	3.77	11.45	21.91	23.69	15.73	8.03	4.05	2.57	1.92	1.55	1.27	0.90	0.61	0.41	0.38	0.32	0.28	0.19	0.00	0.00	0.00	0.00
B7	0.00	0.00	0.00	0.08	2.45	16.77	28.35	14.28	5.54	2.77	2.35	2.86	3.77	4.32	4.00	3.36	2.42	1.76	1.24	1.11	0.81	0.58	0.52	0.44	0.22	0.00	0.00

APPENDIX C - MACROINVERTEBRATES

Table 6. Taxa list and abundances by replicate for spring 2006.

SCRE 2006 Spring

Species abundance values

Identified Taxa	Tol Val (TV)	Func Feed Grp	B1			B2			B3			B7		
			1	2	3	1	2	3	1		3	1	2	3
Insecta Taxa														
Collembola														
Isotomidae	5	cg	1				2		6			3	1	1
Hemiptera														
Corisella sp.	8	p							1					
Corixidae	8	p					5		2					
Coleoptera														
Berosus sp	5	p					1							
Tropisternus sp	5	p										1	3	4
Diptera														
Dasyhelea sp	6	cg					1							
Dolichopodidae	4	p				5		19	7			3	2	
Ephydra sp	6	sh				2	5	4	3		1	2	4	
Ormosia sp	3	cg				1								
Orthocladiinae	5	cg			1	21	2	7	9		8	42	56	8
Simulium sp	6	cf							4					
Non-Insecta Taxa														
Oligochaeta														
Limnodrilus sp	10	cg	66		103	623	203	102	1679	7	96	103	35	59
Nematoda	5	p							1					
Amphipoda														
Hyalella sp	8	cg	18	6	32		5		112	2	7			
Ramellogammarus sp	4	cg											1	
Basommatophora														
Physa/Physella sp	8	sc										2		
Cycopoida														
Cyclopoida	8	cf	1						3					
Diplostraca														
Chydoridae		cf	2		1	16								1
Hypsogastropoda														
Hydrobiidae	8	sc			178									
Podocopida														
Cyprididae	8	cg		3	4	24			56			308	133	1
Limnocythere sp	8	cg	2	4	57	1	2	2	7			1	1	
TOTAL			**90**	**13**	**376**	**693**	**226**	**134**	**1890**	**9**	**112**	**465**	**236**	**74**

Table 7. Taxa list and abundances by replicate for fall 2006.

SCRE 2006 Fall

Species abundance values

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														
Hemiptera														
Corisella sp.	8	p								19				
Corixidae	8	p	3	3				9	3			7	5	8
Trichorixa sp.	8	p								1				
Coleoptera														
Berosus sp	5	p					4						4	
Diptera														
Bezzia/Palpomyia sp	6	p			1									
Chironominae	6	cg	177	242	269	540	1062	390	718	656	658	505	1455	1029
Dasyhelea sp	6	cg		1										
Dolichopodidae	4	p				3							2	
Ephydra sp	6	sh					2		2					
Orthocladiinae	5	cg	15	14	12	66	87	21	46	27	64	25	18	16
Tanypodinae	7	p	5	3	8	8	5	13			1	31	43	27
Non-Insecta Taxa														
Oligochaeta														
Limnodrilus sp	10	cg	32		35	23	262	60	3	2	1		3	6
Nematoda	5	p	1			2	1							
Acariformes														
Pionidae	5	p		2		1	5	3						
Amphipoda														
Hyalella sp	8	cg	4	7	5		15				2		1	
Basommatophora														
Physa/Physella sp	8	sc		1		2	44	21	1	22	11	22	339	88
Diplostraca														
Daphnia sp	8	cf							1					1
Hypsogastropoda														
Hydrobiidae	8	sc	482	7	64	245	127	119	7	7	3	2		
Lumbriculida														
Lumbriculidae	5	cg	6				19	5						
Podocopida														
Cyprididae	8	cg	7	23	45	9	56	29	21	29	16	78	150	69
Limnocythere sp	8	cg	85	3	60	562	187	110	522	119	368		1	1
Trombidformes														
Sperchon sp	8	p				1								
TOTAL			**817**	**306**	**499**	**1462**	**1876**	**780**	**1324**	**882**	**1124**	**670**	**2021**	**1245**

Table 8. Bioassessment metrics calculated for each station during the spring and fall 2006 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 ANOVA				Station					Comparison Among Sites by ANOVA		
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	160	351	670	258	360	1.15[1]	0.76		541	1373	1110	1312	360	1.96	0.20	
	st. dev.	191	300	1058	196	436				258	553	221	678	436			
	cv	1.2	0.9	1.6	0.8	1.1				0.5	0.4	0.2	0.5	1.1			
	95% CI	216	339	1197	222	494				292	626	250	767	494			
Taxonomic richness	mean	5	7	6	8	7	0.36	0.79		10	12	9	9	11	**3.38**	**0.08**	
	st. dev.	2	2	6	2	3				1	2	1	2	1			
	cv	39	28	93	22	45				11	12	6	22	10			
	95% CI	2	2	7	2	3				1	2	1	2	1			
% Dominant Taxa	mean	55.6	85.3	84.1	67.4	73	**5.20**	**0.03**	B2, B3>B1, B7	64.0	48.3	62.4	76.7	58.2	**3.99**	**0.05**	
	st. dev.	15.3	7.9	5.7	11.7	10				13.3	9.2	10.6	5.5	11.0			
	cv	27.6	9.3	6.7	17.3	15				20.8	19.1	17.1	7.1	19.0			
	95% CI	17.4	9.0	6.4	13	12				15.1	10.4	12.0	6.2	12.5			
Shannon Diversity	mean	1.1	0.6	0.5	1.0	1	**6.18**	**0.02**	B1, B7>B2, B3	1.2	1.5	1.0	0.8	1	**8.42**	**0.01**	B2>B3, B7
	st. dev.	0.2	0.2	0.0	0.2	0				0.3	0.1	0.0	0.1	0			
	cv	21.8	29.8	2.9	22.3	19				23.8	8.8	2.6	13.4	12			
	95% CI	0.3	0.2	0.0	0.2	0				0.3	0.1	0.0	0.1	0			
Mean Tolerance Value	mean	8.7	9.4	9.6	8.2	9	**2.99**	**0.10**		6.9	7.0	6.6	6.4	7	5.04	0.17	
	st. dev.	0.8	0.6	0.1	0.9	1				0.7	0.1	0.2	0.1	0			
	cv	8.8	6.2	1.0	10.4	7				10.1	0.8	3.1	1.8	5			
	95% CI	0.9	0.7	0.1	1	1				0.8	0.1	0.2	0.1	0			
Percent Tolerance Value (8-10)	mean	98.7	88.7	96.8	80.6	91	**4.35**	**0.04**	B1, B3>B7	43.8	46.3	33.5	18.3	41.2	1.67	0.25	
	st. dev.	1.8	9.7	4.2	8.7	6				30.3	10.5	9.9	5.7	16.9			
	cv	1.8	10.9	4.4	10.8	7				69.3	22.7	29.7	31.0	40.6			
	95% CI	2.0	10.9	4.8	10	7				34.3	11.9	11.2	6.4	19.1			
Percent Intolerance Value (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	84.2	92.3	99.5	96.4	93	4.08[1]	0.25		73.4	83.6	97.4	87.1	84.8	5.82[1]	0.12	
	st. dev.	27.3	8.5	0.5	1.9	10				29.4	5.8	2.6	5.7	12.6			
	cv	32.4	9.2	0.5	1.9	11				40.0	6.9	2.6	6.5	16.5			
	95% CI	30.9	9.6	0.5	2.1	11				33.2	6.5	2.9	6.4	14.2			
Percent Collectors	mean	83.0	91.5	99.3	95.9	92	4.71[1]	0.19		73.4	83.6	97.3	87.1	84.8	5.70[1]	0.13	
	st. dev.	26.6	7.6	0.6	2.6	9				29.4	5.8	2.5	5.6	12.6			
	cv	32.0	8.3	0.6	2.7	11				40.0	6.9	2.6	6.5	16.5			
	95% CI	30.1	8.6	0.7	3	11				33.2	6.5	2.9	6.4	14.2			
Percent Filterers	mean	1.2	0.8	0.1	0.5	1	0.43	0.74		0.0	0.0	0.0	0.0	0.0	0.67	0.60	
	st. dev.	1.8	1.3	0.2	0.8	1				0.0	0.0	0.1	0.1	0.0			
	cv	152.1	173.2	173.2	173.2	168						173.2	173.2	173.2			
	95% CI	2.1	1.5	0.3	1	1				0.0	0.0	0.1	0.1	0.0			
Percent Grazers	mean	15.8	0.0	0.0	0.1	4	2.21[1]	0.53		24.8	14.6	1.7	9.2	13.7	6.17[1]	0.10	
	st. dev.	27.3	0.0	0.0	0.2	7				30.1	4.8	1.4	6.8	12.1			
	cv	173.2			173.2	173				121.2	32.9	83.4	74.6	79.2			
	95% CI	30.9	0.0	0.0	0	8				34.0	5.5	1.6	7.7	13.7			
Percent Predators	mean	0.0	5.9	0.2	2.8	79.3	**9.07[1]**	**0.03**	B3>B1	1.8	1.7	0.9	3.7	1.5	2.61	0.12	
	st. dev.	0.0	7.3	0.3	2.3	15.7				0.8	1.3	1.2	1.7	1.1			
	cv	-	124.2	173.2	83.2	20.1				40.9	79.9	143.3	45.6	88.0			
	95% CI	0.0	8.2	0.4	3	18				0.8	1.5	1.4	1.9	1.2			
Percent Shredders	mean	0.0	1.8	0.4	0.7	4.2	2.56	0.13		0.0	0.0	0.1	0.0	0.0	2.21[1]	0.53	
	st. dev.	0.0	1.4	0.5	0.9	6.7				0.0	0.1	0.1	0.0	0.1			
	cv	-	75.6	128.9	127.0	140.8					173.2	173.2		173.2			
	95% CI	0.0	1.6	0.5	1	8				0.0	0.1	0.1	0.0	0.1			
Percent Chironomidae	mean	0.1	3.0	2.5	14.5	14.2	**5.87**	**0.02**	B7>B2, B3, B1	55.5	52.6	66.5	81.6	58	1.80	0.23	
	st. dev.	0.2	2.2	4.0	8.0	11.2				30.3	9.9	10.0	5.8	17			
	cv	173.2	70.9	156.4	55.3	99.8				54.6	18.8	15.1	7.2	30			
	95% CI	0.2	2.4	4.5	9	13				34.3	11.2	11.3	6.6	19			

[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 2006.

SCRE B1		SCRE B2		SCRE B3		SCRE B7	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**
Hydrobiidae	*37.2*	*Limnodrilus sp.*	*88.1*	*Limnodrilus sp.*	*88.6*	Cyprididae	*57.0*
Limnodrilus sp.	*35.3*	Orthocladiinae	*2.8*	*Hyalella sp.*	*6.0*	*Limnodrilus sp.*	*25.4*
Limnocythere sp.	*13.2*	Cyprididae total	*2.3*	Cyprididae total	*2.8*	Orthocladiinae	*13.7*
Hyalella sp.	*11.7*	Dolichopodidae	*2.3*	Orthocladiinae	*0.8*	*Tropisternus sp.*	*1.0*
Cyprididae	*1.5*	Chydoridae	*1.5*	*Limnocythere sp.*	*0.3*	*Ephydra sp.*	*0.8*
Chydoridae	*0.6*	*Ephydra sp.*	*1.0*	Dolichopodidae	*0.3*	Isotomidae	*0.6*
Cyclopoida	*0.2*	*Hyalella sp.*	*0.5*	Isotomidae	*0.3*	Dolichopodidae	*0.6*
Isotomidae	*0.2*	*Limnocythere sp.*	*0.5*	*Ephydra sp.*	*0.2*	*Physa/Physella sp.*	*0.3*
Orthocladiinae	*0.2*	Corixidae	*0.5*	*Simulium sp.*	*0.2*	*Limnocythere sp.*	*0.3*
		Isotomidae	*0.2*	Cyclopoida	*0.1*	Chydoridae	*0.1*
		Berosus sp.	*0.1*	Corixidae	*0.1*	*Ramellogammarus sp.*	*0.1*
		Dasyhelea sp.	*0.1*	Nematoda	*0.0*		
		Ormosia sp.	*0.1*	*Corisella sp.*	*0.0*		

Table 10. Ten most abundant species collected from each sampling site (reps = 3) in Santa Clara River Estuary during the fall 2006.

SCRE B1		SCRE B2		SCRE B3		SCRE B7	
Taxa	**%**	**Taxa**	**%**	**Taxa**	**%**	**Taxa**	**%**
Chironominae	*42.4*	Chironominae	*48.4*	Chironominae	*61.0*	Chironominae	*75.9*
Hydrobiidae	*34.1*	*Limnocythere sp.*	*20.9*	*Limnocythere sp.*	*30.3*	*Physa/Physella sp.*	*11.4*
Limnocythere sp.	*9.1*	Hydrobiidae	*11.9*	Orthocladiinae	*4.1*	Cyprididae total	*7.5*
Cyprididae total	*4.6*	*Limnodrilus sp.*	*8.4*	Cyprididae total	*2.0*	Tanypodinae	*2.6*
Limnodrilus sp.	*4.1*	Orthocladiinae	*4.2*	*Physa/Physella sp.*	*1.0*	Orthocladiinae	*1.5*
Orthocladiinae	*2.5*	*Cyprididae total*	*2.3*	*Corisella sp.*	*0.6*	Corixidae	*0.5*
Hyalella sp.	*1.0*	Physa/Physella sp.	*1.6*	Hydrobiidae	*0.5*	*Limnodrilus sp.*	*0.2*
Tanypodinae	*1.0*	*Tanypodinae*	*0.6*	*Limnodrilus sp.*	*0.2*	*Berosus sp.*	*0.1*
Lumbriculidae	*0.4*	*Lumbriculidae*	*0.6*	Corixidae	*0.1*	Hydrobiidae	*0.1*
Corixidae	*0.4*	Hyalella sp.	*0.36*	*Hyalella sp.*	*0.06*	*Limnocythere sp.*	*0.1*
Prionidae	*0.1*	Prionidae	*0.22*	*Ephydra sp.*	*0.06*	Dolichopodidae	*0.05*
Nematoda	*0.06*	Corixidae	*0.22*	*Daphnia sp*	*0.03*	*Daphnia sp*	*0.03*
Physa/Physella sp.	*0.06*	*Berosus sp.*	*0.10*	*Trichorixa sp.*	*0.03*	*Hyalella sp.*	*0.03*
Bezzia/Palpomyia sp.	*0.06*	Nematoda	*0.07*	Tanypodinae	*0.03*		
Dasyhelea sp.	*0.06*	Dolichopodidae	0.1				
		Ephydra sp.	0.0				
		Sperchon sp.	*0.02*				

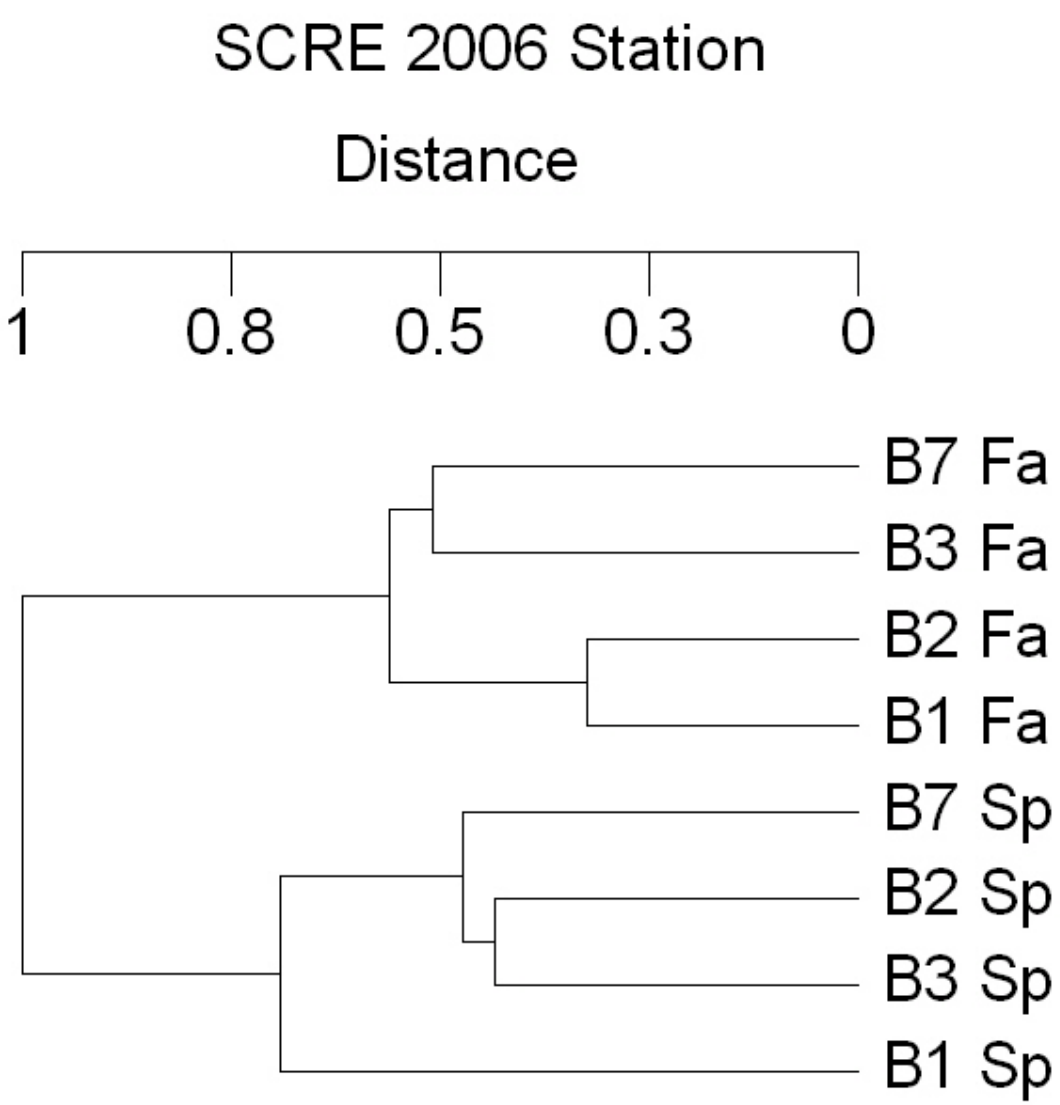


Figure 8. Station dendrogram for BMI population collected in 2006. Distances calculated using Bray-Curtis dissimilarity index.

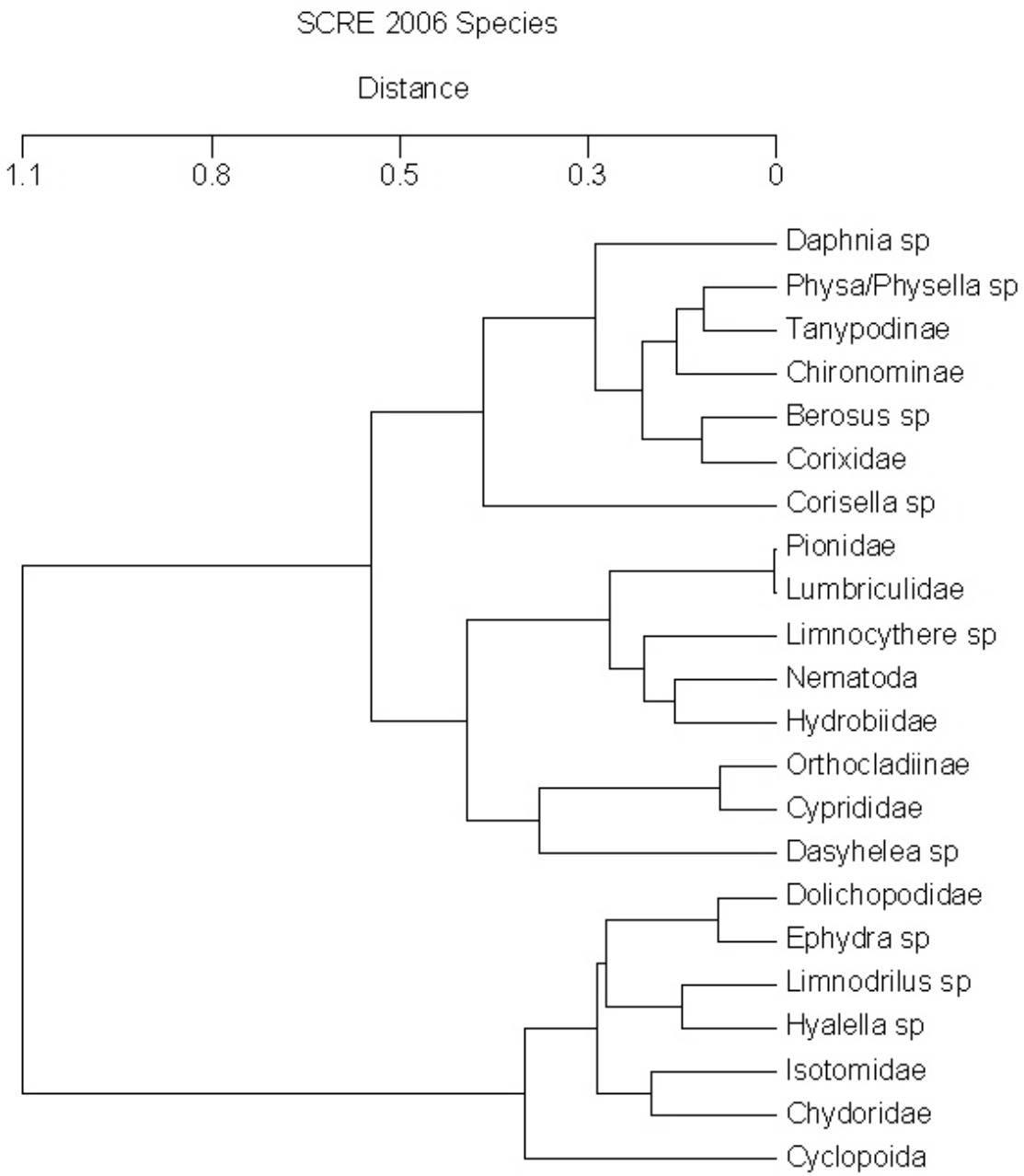


Figure 9. Species dendrogram for BMI population collected in 2006. Distances calculated using Bray-Curtis dissimilarity index.

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.