RESIDENT SPECIES STUDY
SANTA CLARA RIVER ESTUARY

VENTURA WATER RECLAMATION FACILITY
NPDES PERMIT NO. CA0053651, CI-1822

Prepared for:

CITY OF SAN BUENAVENTURA
Ventura, CA

Prepared by:

ENTRIX, INC.
Ventura, CA

Project No. 325403

September 17, 2002

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Prepared for:

CITY OF SAN BUENAVENTURA
1400 Spinnaker Drive
Ventura, CA 93002

Prepared by:

ENTRIX, INC.
2140 Eastman Avenue, Suite 200
Ventura, California 93003

Project No. 325403

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Page

Matthew Carpenter, Study Project Manager

B.S., Forestry and Natural Resources, Environmental Management concentration, California Polytechnic State University, San Luis Obispo, 1995

Daniel Tormey, Ph.D., Senior Technical Contributor-Technical Co-Lead

Ph.D., Geology and Chemistry, Massachusetts Institute of Technology, 1989
B.S., Civil Engineering and Geology, Stanford University, 1983

Theodore Donn, Jr., Ph.D., Senior Technical Contributor-Statistical Analysis

Ph.D., Zoology, University of New Hampshire, 1983
B.A., Biology, Clark University, 1977

Jennifer Holder, Ph.D., Senior Technical Contributor-Technical Co-Lead

Ph.D., Zoology, University of California, Berkeley, 1991
B.A., Biology, University of California, Santa Cruz, 1983

Melissa Hetrick, Technical Contributor-Data Collection/Data Analysis

B.A., Integrative Biology, Conservation Biology Emphasis with a minor in Forestry, University of California, Berkeley, 1999

Susan Fregien, Technical Contributor-Study Implementation/Data Collection/Data Analysis

M.S., Aquatic Science, University of Washington, 1998
B.S., Geology, California State University, Sacramento, 1987

Steven Howard, Study Implementation/Data Collection/Data Analysis

B.S., Fisheries, California State University, Humboldt, 1999

Keven Ann Colgate, Data Collection/Data Analysis

BS, Forestry and Natural Resource Management, Concentration in watershed, chaparral and fire management, California Polytechnic State University, San Luis Obispo, 2001

Lidia Champion-Peterson, Data Analysis

B.S., Environmental and Occupational Health, California State University, Northridge, 1995

Terri Wallace, Data Analysis/Document Coordinator

B.A., Chemistry, University of California, Santa Barbara, 1986

Susan Williams, Senior Taxonomist

M.S., Biology, California State University, Long Beach, 1979
B.S., Marine Biology, California State University, Long Beach, 1972

Christopher Julian, Technical Contributor-Data Analysis/Taxonomy Support

B.S., Aquatic Biology, University of California, Santa Barbara, 2001

Jo-Ann Reed-Cardiff, Taxonomy Support

P.h.D., Entomology, Division of Toxicology and Physiology, University of California, Riverside, 1975
M.S., Entomology, Division of Toxicology and Physiology, University of California, Riverside, 1974

Robert Eckard, Taxonomy Support

B.A., Biological Sciences with emphasis in Field Ecology, minor in English Writing, College of Creative Studies, University of California, Santa Barbara, 2001

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The City of San Buenaventura (City) operates the Ventura Water Reclamation Facility (VWRF), a publicly-owned tertiary wastewater treatment facility with a design capacity of 14 million gallons per day (MGD), and current discharges between 7 and 10 MGD. The VWRF operates under waste discharge requirements contained in Order No. 00-143 (the Order), which also serves as the National Pollutant Discharge Elimination System (NPDES) permit (CA0053651). The Order provides effluent limits based upon levels protective of saltwater aquatic life.

The objective of the Resident Species Study is to determine whether the EPA's freshwater or saltwater criteria are appropriate for VWRF effluent. The study uses the taxonomic composition of benthic macroinvertebrates (invertebrates) living in the Santa Clara River Estuary (SCRE) as the best way to characterize the salinity tolerance ranges of resident species in the estuary. Species composition is the EPAs preferred method, as described in the California Toxic Rule (CTR). In order to use the species composition data to determine the appropriate standard, two determinations are made: 1) comparison of the taxa found in the Santa Clara River Estuary (SCRE) with those used by EPA in establishing the ambient water quality criteria for copper; and 2) the salinity tolerances of the taxa found in the SCRE.

Habitat conditions in the SCRE vary dramatically, depending on the magnitude of flow from the Santa Clara River and the state of the sand spit at the estuary's mouth (open or closed). The mouth frequently closes off at the sand spit and creates a shallow lagoon. When the sand spit is closed, the Santa Clara River is impounded and the estuary often becomes fully inundated with several feet of water. When the spit is breached, water flows freely into the ocean and a large mudflat is exposed.

Due to these variations in conditions, benthic samples for the Resident Species Study were collected from nine stations throughout the SCRE during four sampling events: 1) November 6-9, 2001, mouth closed; 2) December 10-12, 2001, mouth open; 3) April 16-19, 2002, mouth open; and 4) July 1-3, 2002, mouth closed. Three replicate benthic cores were taken at three locations within each station,, providing a total of 81 cores per sampling event and 324 cores from all four events. The analysis also considers a similar study conducted between 1997 and 1999 in the SCRE by the United States Fish and Wildlife Service.

Four measures of community benthic structure were calculated from the macroinvertebrate dataset: 1) species richness (number of species per station), 2) abundance (number of individuals per station); 3) evenness (equitability of species abundance, per station); and 4) diversity (number of species and relative abundance, per station). In addition, cluster analysis and ordination were performed to detect variations in the community structure.

The principal findings of the Resident Species Study are as follows:

- The SCRE is neither a freshwater nor a saltwater system. The majority of organisms collected in the Estuary were freshwater species tolerant of brackish conditions. The salinity tolerance of one taxa, the Cyprididae, was unknown but a brackish water or euryhaline distribution is likely. Assuming this is true, freshwater organisms that are tolerant of brackish conditions and brackish/euryhaline organisms were the predominant salinity tolerance categories present in the SCRE.

- The SCRE is unique among other estuaries found in the Southern California Bight (Point Conception south to the California/Mexico border). Published information on invertebrate communities and hydrologic conditions was found on seven estuaries of similar size to the SCRE within the Southern California Bight.. Among these estuaries, the SCRE is unique in that it receives constant year-round freshwater flows and does not have its mouth manually dredged for water quality purposes. The seven estuaries examined generally share many benthic invertebrate taxa in common. With the exception of San Dieguito Lagoon, the SCRE shares very few invertebrate taxa with these other estuaries. The species compositions of the other estuaries are in general more estuarine and marine than the SCRE.

- In comparison to the invertebrates used by the EPA to establish the freshwater copper criteria, the SCRE has an approximate 25% taxonomic overlap with the freshwater families. Of the six most common taxa found in the SCRE, four were used by the EPA in establishing the freshwater copper criteria. Most overlap between the EPA test species and SCRE species is at the genus level. In contrast, there is no taxonomic overlap at the species, genus, or family level between the taxa found in the SCRE with the families used by the EPA to establish the saltwater copper criterion. The freshwater criteria have been established based upon many of the families found in the SCRE, and are, therefore, appropriate for the SCRE.

- A majority of SCRE species are freshwater species tolerant of brackish conditions or brackish species. Similarly, the EPA test species used in establishing the freshwater copper criteria are primarily freshwater species tolerant of brackish conditions or euryhaline species. In contrast, the EPA test species used for the saltwater criteria are primarily marine organisms intolerant of brackish conditions or brackish organisms. Given this comparison, the freshwater criteria would be more protective of the salinity ranges found in the SCRE than the saltwater criteria.

- The VWRF provides supplementary water for upstream diversions that would otherwise dewater the SCRE. The SCRE supports a wide diversity of rare, threatened, and endangered species, provides a wintering ground and flyway for migrating birds, and preserves an ecosystem type threatened by human activities.

Based upon these data, the City requests that the freshwater criteria apply to the discharge from the VWRF. In an ecosystem with a species composition indicating freshwater species tolerant of brackish conditions, such as the SCRE, the hardness of the receiving water can be used to derive a site-specific objective for the metals. Accordingly, it would be appropriate for the Regional Board to use the hardness-dependent equations for freshwater metals criteria presented in the CTR to establish site-specific objectives.

The City of San Buenaventura (City) operates the Ventura Water Reclamation Facility (VWRF), a publicly-owned tertiary wastewater treatment facility with a design capacity of 14 million gallons per day (MGD). The VWRF is located on the north bank of the Santa Clara River in the city of San Buenaventura (Figure 1.1). It currently discharges approximately 7 to 10 MGD of treated municipal wastewater into the Santa Clara River Estuary (SCRE) (Figure 1.2) and reclaims approximately 0.7 MGD for landscape irrigation use. The SCRE and its surrounding marshes and riparian areas constitute the 160 acre Santa Clara River Estuary Natural Preserve.

The VWRF operates under waste discharge requirements contained in Order No. 00-143 (the Order), which also serves as the National Pollutant Discharge Elimination System (NPDES) permit (CA0053651). The Order provides effluent limits protective of saltwater aquatic life.

The California Toxics Rule (CTR), from which the saltwater effluent limits were derived, specifies that freshwater criteria apply at locations where salinities of one part per thousand (ppt) and below exist 95% or more of the time, and that saltwater water criteria apply at locations where salinities of ten ppt and above exist 95% or more of the time. The SCRE has salinities between one and ten ppt, and, as such, neither the freshwater nor the saltwater criteria readily apply. In this case, the more stringent of the criteria apply unless the CTR-implementing agency approves the application of the freshwater or saltwater criteria based on an appropriate biological assessment. In describing the application of a biological assessment, the CTR states that "in evaluating appropriate data supporting the alternative set of criteria, EPA will focus on the species composition as its preferred method".

The objective of the Resident Species Study is, therefore, to determine whether the EPA's freshwater or saltwater criteria are appropriate for VWRF effluent. The study uses the taxonomic composition of benthic macroinvertebrates (invertebrates) living in the SCRE as the best indicator of the range of salinity tolerances of species inhabiting the SCRE.

The principal findings of the Resident Species Study are as follows:

- The SCRE is neither a freshwater nor a saltwater system. The majority of organisms collected in the Estuary were freshwater species tolerant of brackish conditions. The salinity tolerance of one taxa, the Cyprididae, was unknown but a brackish water or euryhaline distribution is likely. Assuming this is true, freshwater organisms that are tolerant of brackish conditions and brackish/euryhaline organisms were the predominant salinity tolerance categories present in the SCRE.

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- The VWRF provides supplementary water for upstream diversions that would otherwise dewater the SCRE. The SCRE supports a wide diversity of rare, threatened, and endangered species, provides a wintering ground and flyway for migrating birds, and preserves an ecosystem type threatened by human activities.

As supported by the data presented in this report, the City requests that the freshwater criteria apply to the discharge from the VWRF. Of relevance to the metals that are the focus of this study, the CTR notes that:

"-chemical toxicity is often related to certain receiving water characteristics (pH, hardness, etc.) of a water body. Adoption of some criteria without consideration of these parameters could result in the criteria being overprotective" (40 CFR 131, E).

In an ecosystem with a species composition consisting of freshwater species tolerant of brackish conditions, such as the SCRE, the hardness of the receiving water can be used to derive a site-specific objective for the metals. Hardness is used as a surrogate for a number of water quality characteristics that affect the toxicity of metals in a variety of ways. Increasing hardness has the effect of decreasing the toxicity of metals (40 CFR 131 E.2.g). Accordingly, it is appropriate for the Regional Board to use the hardness-dependent equations for fresh water metals criteria presented in the CTR to establish site-specific objectives for the VWRF.

1.1 REGULATORY HISTORY

This section describes the series of studies required by the Regional Board in their consideration of effluent limitations for the VWRF. The findings of the studies provide an important context within which to judge the significance of the results of the Resident Species Study.

1.1.1 1995 NPDES PERMIT

In June 1995, the Los Angeles Regional Water Quality Control Board (Regional Board) issued the City a revised NPDES permit for the VWRF. Among the changes included in the permit were new and more restrictive limitations for many constituents. These new limits were based on water quality objectives outlined in the *California Enclosed Bays and Estuaries Plan* (April, 1991), and are generally consistent with the California Toxics Rule (USEPA, 1997). These limits were set at conservative levels to protect aquatic life and human health in the receiving waters of the SCRE. According to the permit (section II.A.3), the primary effluent limitations apply:

> *"... after the City has conducted studies to identify the sources of pollutants, implemented all reasonable measures to reduce these pollutants in the effluent, and the limits have been determined to be achievable; otherwise site specific objectives, if warranted, may be prescribed."*

Interim limits were set at the 95 percent confidence interval of the Facility's then-existing (January, 1990 – October, 1994) effluent concentrations (Table 1-1) while the studies specified in the permit were conducted.

Table 1-1. Interim Discharge Limits for Six Constituents of Concern (COCs)

Constituent	NPDES Discharge Limit (µg/L)	NPDES Interim Limit (µg/L)	Drinking Water Standard (µg/L)
Copper	2.9	98	1,300
Nickel	8.3	271	100
Lead	8.5	77	15
Zinc	86	1,181	2,000
Bis(2-ethylhexyl)phthalate	5.9	-	6
Dichlorobromomethane	22	70	60

1.1.2 PHASE 1 REPORT

In May 1996, the City completed the first of the studies outlined in the NPDES permit. In the Phase 1 report, *NPDES Limit Achievability Study, Phase 1 Achievability of Permit Limits Through Source Control Measures*, the City showed that existing treatment processes at the VWRF provided compliance for the majority of constituents in the effluent. Compliance for six constituents (zinc, copper, lead, nickel, bis(2-ethylhexyl)-phthalate and dichlorobromomethane), however, was not currently being met with existing facility controls.

1.1.3 PHASE 2 REPORT

In February 1998, the City concluded the second phase of the studies outlined in the NPDES permit. The results are reported in *NPDES Limit Achievability Study, Phase 2 Achievability of Permit Limits Through Treatment Process Modifications*. The City evaluated whether the current treatment methods could be modified to improve the removal efficiency for the six COCs. The City also investigated all reasonable alternatives to: (1) corrosion control, (2) disinfection processes, and (3) removal methods. The report found that:

- There are no wastewater treatment technologies that have a demonstrated ability to consistently achieve the necessary removal efficiency for copper, lead, nickel or bis(2-ethylhexyl)-phthalate. The processes now operating in the Facility have removal performances for these COCs consistent with similar treatment processes documented in the literature.

- Substitution of an alternative disinfection technology for chlorination, to reduce the formation of dichlorobromomethane, involves significant uncertainties in the ability to meet the permit limit.

1.1.4 PHASE 3 REPORT

On November 12, 1999, the City submitted Phase 3 of the NPDES Limit Achievability Study (ENTRIX 1999), which used biological assessment to address the applicability of freshwater aquatic standards for the VWRF discharge. The Phase 3 report evaluated site-specific objectives according to the criteria set forth in the *California Enclosed Bays and Estuaries Plan* (April 1991). The results of the Phase 3 study are as follows:

- Most of the designated beneficial uses are supported and enhanced by the VWRF's discharge. In addition, the discharge provides supplemental flow from upstream water diversion and pumping, providing additional habitat for a number of threatened and endangered species of bird and fish.

- The species composition of the SCRE indicates a primarily freshwater ecosystem, which allows consideration of water hardness in recalculating NPDES discharge limits for metals.

- The Estuary is a Natural Preserve and it is within the ESU for Southern Steelhead. As such, state regulations prohibit fishing and shellfish collection in the Estuary. Therefore, human consumption of the seafood in the Estuary is much lower than assumed in standard risk models. The report proposed that it is appropriate to consider site-specific data in calculating water quality objectives for the two organic constituents.

- A supplemental bioaccumulation study did not find significant levels of the constituents of concern in freshwater clams.

- Adjusting the permit limits by incorporating site-specific information will not impair or harm the beneficial uses of the Estuary.

- The criteria for determining the site-specific objectives set forth in the *Enclosed Bays and Estuaries Plan* are met.

1.1.5 STUDIES SUPPLEMENTAL TO THE PHASE 3 REPORT

In the Order, the Regional Board found that the Phase 3 Study was incomplete. The Regional Board proposed more thorough studies, conducted under the guidance of the Regional Board's staff, to investigate the applicability of site-specific standards, as follows:

- Bioassessment, including an analysis of the community structure of the instream macroinvertebrate assemblages at a minimum of two sites;

- Salinity Profile Study, including multiple sampling points representative of the entire estuary, and diurnal fluctuations;

- Metals Translator Study, to develop translators for copper, nickel, lead, and zinc; and

- Water Effects Ratio Study, to develop factors addressing site-specific receiving water characteristics.

1.1.5.1 Metals Translator Study

The Metals Translator Study (ENTRIX 2002) was submitted to the Regional Board on June 27, 2002. The metals translator was calculated using direct measurement, the method preferred by the EPA. The following translators were calculated:

Copper (0.86)

Nickel (0.81)

Zinc (0.84)

No translator was calculated for lead since it was not detected in any of the samples.

The Metals Translator Study also found that application of these translators is dependent on whether freshwater or saltwater water quality criteria are applied. The study recommended using the results of the Resident Species Study to define the appropriate water quality criteria. In particular, the Resident Species Study would provide data to indicate whether the hardness of the receiving water should also be applied to the effluent limitations.

The Metals Translator Study, which was conducted in parallel with the Resident Species Study, provides results that help frame the biological data from the Resident Species Study.

1.1.5.2 Resident Species Study

In June 2002, the City submitted a Resident Species Study Workplan (ENTRIX 2001) to the Regional Board, describing methods developed in consultation with the California Department of Fish and Game (CDFG) to conduct a bioassessment of the benthic macroinvertebrate communities in the SCRE. The stated objective of the study was to characterize the species composition of the SCRE for the purposes of determining the appropriate ambient water quality criteria to apply to the VWRF discharge. This report constitutes the Resident Species Study.

1.2 Objectives and Approach of the Resident Species Study

The objective of the Resident Species Study (RSS) is to use macroinvertebrate (invertebrate) community composition and abundance data to determine whether the SCRE has a species composition that indicates a predominantly freshwater or saltwater ecosystem. The findings are supplemented with invertebrate, fish, and vegetation information from prior studies in the Estuary. The City is conducting this study in response to the Regional Board's request that further information be developed for use in their determination of the applicability of freshwater criteria for establishing NPDES permit requirements.

The taxonomic composition of benthic invertebrates living in the SCRE are based on data collected from field sampling, as well as prior studies in the Estuary. Seasonal and geographic variability of the invertebrate fauna will also be evaluated. In general, a distinct separation between freshwater and saltwater fauna does not exist in estuaries. It is unusual to find species intolerant of either freshwater or saltwater. Due to the complexity of defining estuarine community boundaries, the preferred salinity regime of the SCRE's invertebrate fauna are evaluated using a combination of strategies:

- Based on a literature review of known salinity tolerance and preference information (where available), each invertebrate taxon is assigned to a salinity category (i.e., freshwater, freshwater that are tolerant of brackish, marine, etc.). The proportion of organisms in each category is evaluated to determine the predominant salinity categories of the SCRE.

- The invertebrate distribution throughout the study area is analyzed in relation to the principal areas of the estuary: the outfall channel, the estuary mixing zone, and the mouth area. The distribution will also be analyzed in relation to additional abiotic factors, such as substrate composition, water depth, dissolved oxygen, and others.

- Based on a review of previous studies, the proportion of freshwater, brackish and marine invertebrate fauna in the SCRE are compared with that known to occur in other Southern California estuaries. The environmental conditions of the comparison estuaries are summarized. This comparison will show whether the proportion of brackish and marine organisms in these estuaries is similar or greater to that in the SCRE. For comparison purposes, these other estuaries are geomorphically similar, with an upstream freshwater source.

The taxa identified in the SCRE are compared to those used by the EPA in establishing the freshwater and saltwater aquatic criteria for copper promulgated in the CTR. Taxonomic similarities are evaluated. In addition, the salinity tolerance ranges of SCRE taxa and the saltwater and freshwater EPA taxa are compared. These two assessments will indicate the most appropriate standards to apply in this transitional setting.

1.3 REPORT ORGANIZATION

This report is organized as follows:

Section 1: Introduction

Section 2: Environmental Setting of the Santa Clara River Estuary

Section 3: Methods

Section 4: Results

Section 5: Comparison of the Santa Clara Estuary to Other Estuaries in the Southern California Bight

Section 6: Comparison of Santa Clara River Invertebrates to Those Used by EPA in Establishing Ambient Water Quality Criteria

Section 7: Discussion

Section 8: Invertebrate Taxonomy References

Section 9: General References

This section contains a description of the environmental setting of the SCRE. It begins with a general consideration of species composition in estuaries. Next, the physical and biological characteristics of the SCRE are described based upon existing studies.

2.1 SPECIES COMPOSITION IN ESTUARIES

By definition, estuaries are transitional zones between freshwater and saltwater as rivers flow into coastal marine waters. By their nature, estuaries contain some of the most stressful conditions for living organisms because they are physically dynamic environments where freshwater and saltwater intermix. Estuaries typically contain a shifting salinity gradient, dependent upon factors such as volume of freshwater outflow, tides and storm events. Salinity values in estuaries can grade or vary between freshwater (0.1 to 1ppt) and marine (30 ppt and above).

Estuary studies have identified a "paradox of brackish water" (Chapman and Wang 2001). In general, the greatest numbers of species occur in fresh or marine waters, with much fewer numbers of species in the salinity range of about 5 to 8 ppt (Figure 2-1). Very few species are capable of withstanding the rapid salinity fluctuations that typically occur in estuaries (Kennish 1986). Low estuarine species richness may be due to one or a combination of factors including a highly unstable physical, chemical and biological environment; high environmental stress; highly fluctuating food availability; and lack of competition (Kennish 1986, Chapman and Wang 2001).

Estuarine organisms do not necessarily fall neatly into freshwater or saltwater categories and very few purely brackish water, estuarine species exist. A few freshwater species and marine species have adapted to brackish water conditions, whereas others are only tolerant. Still others may be capable of successfully inhabiting a range of salinity conditions.

As determined in this study, salinity is the most important controlling factor in species richness in the SCRE (Figure 2.2). In addition to salinity, other environmental factors can have a significant effect on the distribution and composition of the invertebrate community in an estuary. Results from studies of estuarine systems show that the factors of interest depend on the scale of observation (Kennish 1986, Quinn 1990). Large-scale factors include climate, topography, geology and water chemistry. Medium- or estuary-scale factors include salinity gradient, bed stability, natural and man-made disturbances, vegetation, and food supply. Small-scale factors include water depth, sediment size and composition, water movement, sediment movement, organic material, and changes in salinity, dissolved oxygen and other water quality parameters. In the current study, we are most interested in small- and medium-scale factors that affect benthic invertebrates within the Estuary. Large-scale factors are important to consider when making comparisons to other estuaries in the region.

2.2 Physical Setting of the Santa Clara River Estuary

The SCRE is situated along the Southern California coastline within Ventura County (Figure 1.1). The VWRF is located on the north edge of the estuary in the City of San Buenaventura (Figure 1.2). The Estuary and surrounding marshes and riparian areas constitute the 160 acre Santa Clara River Estuary Natural Preserve. McGrath State Beach and campground are located on the south side of the Estuary.

The Pacific Ocean is approximately 2,000 feet from the point of the VWRF discharge. The mouth of the Santa Clara River is frequently closed off by a sand bar, creating a shallow lagoon. The lagoon discharges directly into the Pacific Ocean when the sand bar is breached. When the sand bar is intact, water in the Estuary floods the lagoon and mud flats, inundating the adjacent marsh and low-lying vegetation. During these periods, water depth in the Estuary can be several feet. The sand bar is breached naturally during winter storms or when water pressure from rising water levels in the lagoon forces a breach. When the sand bar is breached, the Estuary is subject to tidal influence.

The natural hydrology of the Santa Clara River and estuary is typical of coastal Southern California watersheds, which normally have very low, dry-season flows and large storm-driven peak flows that dissipate rapidly. The natural hydrology of the Santa Clara River, though, has been greatly altered by upstream diversions and irrigation. In contrast, the VWRF outfall constantly discharges tertiary treated wastewater into the Estuary. Flow from the Santa Clara River typically does not reach the Estuary during much of the year due to agricultural and municipal water diversions. In part, the VWRF discharge compensates for upstream water diversions and provides a water source during periods when the Estuary would otherwise be dry. In turn, this continuous water source provides habitat for a wide array of aquatic organisms, waterbirds, and other vertebrates in the Estuary.

The Estuary is, by its nature, a very dynamic environment where hydrologic parameters can vary greatly over the course of any given year. The Estuary is influenced by three primary hydrologic factors: 1) the Santa Clara River inflow; 2) Pacific Ocean tides; and 3) the VWRF discharge. The Santa Clara River inflow varies in quantity, duration, frequency, and intensity from year to year, depending on rainfall and upstream diversions. The Santa Clara River also delivers varying quantities of sediment to the Estuary, which builds the sandspit at the mouth. Tidal influence from the Pacific Ocean is more consistent, however regional weather patterns, such as El Nino and La Nina, can dramatically influence tidal intensity and local near-shore currents. The Pacific Ocean and its tides also play a major role in forming the sand bar that seasonally impounds the Estuary, as well as causing wave action and degradation of the sandspit. The VWRF discharge is relatively constant, delivering between 7 and 10 million gallons of treated effluent per day. During the dry season, the VWRF discharge may contribute as much as

100 percent of the non-tidal inflow to the Estuary. There is also runoff contribution from non-point sources, such as nearby agricultural fields.

The composition of waters contributing to the Santa Clara River Estuary is quite variable. During the wet season Santa Clara River flows can easily exceed 5,000 cfs during intense storm events. Winter near-shore ocean conditions can also contribute storm-induced tidal flooding and overwash. The Estuary is most dynamic under winter and spring conditions because river and ocean influences are quite strong. Frequent flushing and inundation occurs because the sand spit breaches, promoting increased tidal connectivity. Summer river inflow is diverted upstream of the Estuary and typically drops and becomes intermittent. The summer and fall inflow is typically limited to the VWRF discharge, and the large sand spit impoundment formed at the mouth causes constant inundation. The shear volume of water impounded in the Estuary is the only factor in the sand spit breaching.

2.3 Habitat Conditions in the Santa Clara River Estuary

The Santa Clara River Estuary supports a variety of habitat types including open estuarine, freshwater marsh, brackish marsh, salt marsh, mudflat, and sand dune. Habitat conditions in the SCRE vary dramatically, depending on the magnitude of flow from the Santa Clara River and the state of the sand spit at the estuary's mouth (open or closed). The mouth frequently closes off at the sand spit and creates a shallow lagoon. When the sand spit is closed, the Santa Clara River is impounded and the estuary often becomes fully inundated with several feet of water. When the spit is breached, water flows freely into the ocean and a large mudflat is exposed.

The Estuary is home to a wide variety of wildlife including two species of federally listed endangered fish, the tidewater goby and the Southern California Steelhead. The Estuary also provides a valuable Southern California bird habitat for migratory and resident birds. State and federally listed threatened Snowy Plovers are common visitors and federally and state listed endangered Least Terns historically establish nesting colonies near the Estuary. The following sections provide a summary of biological resources found in the SCRE, based on previous studies.

2.3.1 Vegetation

Figure 2.3 depicts the vegetative units mapped during three surveys in 1999 (ENTRIX). The south side of the estuary is dominated by saltgrass, juamea, alkali heath, pickleweed, and bulrush, amongst areas of open water. Dense willow, poison oak, California blackberry, and giant reed dominate the riparian forest on the north side of the Estuary. The central part of the Estuary, where the river and tidal flows are most active, is a mosaic of mudflats, stand of giant reed, bulrush, willows, and open water. This area is only partially vegetated, primarily by nutsedge, bulrush, rush, slender aster, and water smartweed. The north side of the Estuary contains a few strands of willows, cattails, and giant reed. Only three aquatic plants have been found in the Estuary: green algae, duckweed, and ditch-grass (USFWS 1999).

2.3.2 WILDLIFE

The Estuary provides a wintering ground and flyway for migrating birds. It supports a wide diversity of avian wildlife, including a number of rare, endangered and threatened species. Among these include the California Brown Pelican, Western Snowy Plover and California Least Tern. Other wildlife known to inhabit the estuary include cottontails, California ground squirrels, bobcats, western fence lizards, king snakes, and pacific treefrogs (ENTRIX 1999; USFWS 1999).

As a river that supports federally endangered Southern California Steelhead, the Santa Clara River is a critical waterway for migrating steelhead. In addition, large numbers of the federally endangered tidewater goby inhabit the Estuary. Other fish found in the Estuary are arroyo chub, mosquitofish, green sunfish, California killifish, striped mullet, topsmelt, prickly scuplin, and fathead minnows (ENTRIX 1999; USFWS 1999).

2.3.3 PREVIOUS INVERTEBRATE STUDIES

In 1990 a Restoration and Management Plan of McGrath State Beach and the Santa Clara River Estuary Natural Preserve prepared for the California Department of Parks and Recreation included results from benthic invertebrate sampling, in addition to vegetation, fish, and water quality sampling (Swanson 1990). Sampling occurred in August and November 1989. Twenty sediment cores were collected around the perimeter of the Estuary once in each month. The mouth conditions during the sampling events were not noted. Data indicating shallow depths in the Estuary, though, during August suggest that during the event the Estuary was either open or had been open recently. Deep water levels during the November event suggest that the mouth was most likely closed during this time, allowing the estuary to become inundated. Macrofauna found during the study were *Hemigrapsus oregonesis*, *Leptocottus armatus*, chironomids, and *Liljeborgia* species. Low species diversity was attributed to wide salinity ranges in the Estuary.

In 1999 the United States Fish and Wildlife Service published an Ecological Monitoring Program of the Santa Clara River Estuary for the California Department of Parks and Recreation. Minnow trap, benthic core, and seine sampling during 12 surveys from 1997 to 1999 yielded 24 taxa of invertebrates. Results from the benthic core sampling are in Appendix B. During this survey, the SCRE mouth was closed during six surveys and open for the remaining surveys. The prolonged open status of the sand spit was caused by extremely heavy flows and flooding of the Santa Clara River resulted from excessive rainfall and El Nino conditions. The most abundant species found using benthic cores included chironomids, oligochaetes, *Hyalella Azteca*, and corixids. Additional minnow traps and seine samples also yielded large amounts of freshwater snails (Physidae), oriental shrimp (*Palaemon macrodactylus*), and Louisiana red crayfish (*Procamarus clarki*). With the exception of a shore crab and unidentified amphipod, which were determined as either marine or estuarine species, all of the invertebrates collected and identified to the genus level were determined to be freshwater taxa (USFWS 1999).

In 1999 ENTRIX, Inc collected benthic cores at four sites in the Estuary during winter, spring and summer for the City of San Buenaventura (ENTRIX 1999). In addition, invertebrates were counted in fish seine samples done at the same time. The sand bar was breached during the winter survey, closed during the spring survey, and had just closed following two months of tidal influence in the summer survey. Tubificids, chironomids, and ostracods were the most abundant species in the samples. The invertebrates found were generally characterized as freshwater species with the exception of a polychaete worm (*Cossura candida)* sampled at the mouth of the Estuary.

In this section the methods used to collect data in the field, to sort and identify invertebrates, and to statistically interpret the data are discussed. Additionally, the methods used to conduct the literature search on salinity tolerances and other Southern California estuaries are presented.

3.1 FIELD DATA COLLECTION

3.1.1 BENTHIC MACROINVERTEBRATE SURVEYS

Stratified, Non-Random Sampling Design. Sampling locations were selected using a stratified, non-random design to ensure that the diversity of habitats and physical influences in the Estuary were well represented. The Estuary was subdivided into five units for the purpose of choosing sampling stations. The sampling units were defined as: 1) the outfall channel, 2) the backwater areas, 3) the mudflat/lagoon, 4) the Santa Clara River channel downstream from the Harbor Boulevard bridge, and 5) the Santa Clara River channel upstream from the Harbor Boulevard bridge and beyond the influence of salt water which is beyond the Santa Clara Estuary high water mark.

Sampling Stations. Eleven sampling station locations were selected in the study area (Figure 3.1). Seven of the stations coincided with those used in the USFWS study (USFWS 1999). They were: B1 (outfall channel), B2 (backwater area), B3 (mudflat/lagoon near west side), B5 (lagoon near mouth), B6 (central mudflat/lagoon), B7 (Santa Clara River channel) and B8 (Santa Clara River channel near the Harbor Boulevard bridge). Four additional sampling stations included: B4 (central mudflat/lagoon), B9 (Santa Clara River channel east of the Harbor Boulevard bridge and near the edge of tidal influence), and B10 and B11 (upstream beyond the tidal influence). GPS coordinates for each station were established and used for subsequent sampling events. Table 3-1 provides the GPS coordinates of each station. In cases when water levels were too low to sample at the given GPS location for a station, a location was selected parallel to the channel as described below in Sampling Procedures. Three replicate locations were sampled per station. Three benthic cores were collected at all three replicate locations.

Sampling Schedule. Two seasonal rounds (fall/winter and spring/summer) of sample collection were conducted, beginning in November 2001 and ending in July 2002. Each seasonal sampling round consisted of two independent sampling events; one during closed mouth, impounded conditions and a second during open, free flowing conditions. The upstream reference sites B10 and B11 were only sampled once in the last sampling event (July 2002).

Sampling Procedures

Benthic Sampling.

A coring device for collecting benthic samples was constructed by replicating the design of the custom-built, pole-mounted corer used in the USFWS study. The coring device was made from an 81.3 cm long, 10.2 cm diameter (18 inches long and 4 inch diameter) PVC cylinder, a PVC pressure regulating valve, and threaded PVC handles for sampling down to 2 meters. Direct consultation for construction and operation of the coring device was provided by USFWS staff.

Two different strategies for random selection of sampling transects were utilized. The first strategy applied to the stream channel type sites and utilized CDFG's bioassessment transect selection protocol. During open mouth conditions at sample stations B1, B8, and B9, a 10 meter long line was centered on the sampling location and oriented parallel to the channel. Three sampling transects oriented perpendicular to the shore were randomly chosen (out of 11 possible transects) along the 10 meter line. The length of each sampling transect coincided with the width of the stream channel. Samples were collected while standing in the water and consisted of a composite of three 15 cm (6 in)-deep benthic cores.

The second transect selection strategy applied to closed mouth conditions at the open water sample stations B1, B2, B3, B4, B5, B6, B7, B8 and B9. At these sites, samples were taken from a boat after setting an anchor line. Samples were collected 5 meters apart, while relying on the natural drift of the boat for movement. Drift was recommended by CDFG as a means of achieving random site selection. Each sample consisted of a composite of 3 benthic cores taken to a depth of 15 cm (6 inches).

All benthic samples were sieved using a 0.5 mm mesh screen and placed in a glass jar, which was immediately filled with 10% formalin. A waterproof label was place on the outside of the jar with the following information: sample type, identification number, water body name, date, and sampler's initials. A second waterproof label was placed inside the jar with the same information. After 48 hours in formalin solution, the samples were transferred to a 70% ethanol solution. A chain of custody (COC) form was used whenever samples were transferred between parties (typically one time to the processing laboratory).

3.1.2 ENVIRONMENTAL PARAMETERS

Sampling Stations Descriptions

At each station the GPS coordinates and time were recorded. In addition, percent inundation of the estuary, mouth condition, depth, transect length, and estuary conditions were noted.

Water Quality

Concurrent measurements of salinity, temperature, dissolved oxygen, pH, conductivity, turbidity and water depth were obtained using a Horiba U-10 meter and a measuring rod. Transect length, and general vegetation composition within 20 meters of each sample location was recorded. All measurements are recorded on a bioassessment worksheet, modified from CDFG's Bioassessment Worksheet.

Substrate Sampling, Observations, and Analysis

Substrate composition is an important factor that influences benthic invertebrate presence and distribution. In the last sampling event, one substrate sample per station was collected adjacent to benthic samples, using the same pole-mounted coring device used for collecting benthic invertebrate samples. The substrate samples were sent to a qualified lab for grain size analysis and total organic content.

In addition to the one-time collection of substrate for lab analysis, substrate grain size and composition were visually estimated for each benthic core collected during each sampling event. Grain size was estimated in the field using a Geotechnical Gauge grain size chart. In general, the grain composition was dominated by a mixture of mineral sand of varying rock origin, with minor amounts of organic detritus and/or fine organic material. In estimating grain composition, the amount and type of organic material was recorded. Where fine grained materials such as clays and silts were present, the colors of these were recorded as well.

3.1.3 VEGETATION

The general composition of vegetation within 20 meters of each sample station was recorded.

3.1.4 SORTING AND TAXONOMY PROTOCOL

3.1.4.1 Materials

- Stereo microscope with light source
- 2 pair of microforceps (No. 3)

- 70% Ethanol
- Wash bottles for ethanol and water
- 20ml glass specimen vials with labels
- Glass petri plates
- Quart jar to store processed material
- Sieve with 0.5mm openings
- Spoon
- Rectangular sorting tray, approximately 24 x 14 x 5cm
- Catch basin/tray of sufficient size to hold two quart jars
- Eyedropper

3.1.4.2 Methods

Prior to the sorting process, a 20ml sample vial was filled with 70% ethanol solution and labeled with the station number, replicate, date, and investigator's name. One vial per sample was sufficient in most cases, as all specimens fit into the same vial.

3.1.4.3 Elutriation

Due to the large percentage of sand and gravel collected in the samples, sorting was performed by elutriation. Four to five spoonfuls of sample material were transferred into the sorting tray, which was then filled halfway with water. The tray was swirled gently in an effort to suspend as much organic material as possible, and the supernatant was decanted into a 500µm sieve. This process was repeated either 3 times or until it appeared that all lightweight material had been flushed from the sample and retained in the sieve. A small amount of water was then poured into the sorting tray, and the remaining material was examined under the microscope for organisms not removed by elutriation. Any invertebrates found were removed using forceps and preserved in the 20ml sample vial. The water in the tray was then decanted into the sieve, and the remaining sample material was spooned into the refuse jar. Another 4 or 5 spoonfuls of sample were then transferred into the sorting tray, and the entire process was repeated until no material remained in the sample jar. At the end of the elutriation process, the contents of the refuse jar were returned to the original sample jar and preserved in 70% ethanol for possible future reference.

Material accumulated in the sieve throughout the process was either sorted at intervals, or stored in a petri dish for final sorting at the end. In instances where this included a large quantity of plant debris, plant material was removed and stored in a separate jar with 70% ethanol for examination at the end of the elutriation process.

3.1.4.4 Final Sorting

After elutriation, material accumulated in the sieve was carefully washed into a petri dish using a wash bottle filled with 70% ethanol. This was done over a catch basin in order to contain any spills. The petri dish was then filled approximately halfway with 70% ethanol and examined under the microscope at 10x magnification. Invertebrates were removed using either forceps or an eyedropper, and preserved in the 20ml sample vial. Once all invertebrates had been removed, the remaining material was transferred from the petri dish and returned to the rest of the sample.

3.1.4.5 Subsampling

Because of the large volume of material collected in each sample (up to 3 quart jars), some samples contained extremely high numbers of ostracods and roundworms. When these were estimated to number 1000 or more, a representative subsample of the abundant taxon was collected. The percent of invertebrates subsampled was estimated and recorded in a lab notebook, as well as on waterproof paper and placed in the subsample jar. All abundance data reflecting subsampled taxa were labeled and recorded as estimates.

3.1.4.6 Taxonomy

Sorted invertebrates were identified to the lowest taxonomic level possible (preferably species level) and counted. In some cases, when the identity of an invertebrate was uncertain, specimens were sent to specialists to be identified. A list of references used can be found in Section 8, Invertebrate Taxonomy References. A list of specialists consulted can be found in List of Preparers.

3.1.5 Use of Existing Data

Three previous benthic invertebrate studies have been done on the estuary. Data from two of the studies (Swanson 1990 and ENTRIX 1999) were not statistically analyzed due to large differences in sampling procedure and sampling locations. Summaries of these studies can be found in Section 2.

Results from a U.S. Fish and Wildlife Service ecological monitoring study of the estuary from 1997 through 1999 (USFWS 1999) were analyzed and compared to the data from the current study, which used much of the same protocol as the USFWS study. Their study included the collection of benthic invertebrates from five stations during a two-year period (other habitat parameters were measured at 7 stations). All of the USFWS sampling stations' locations correspond to sampling stations in the current study. Table 3-1 shows the locations of overlapping stations. Collections were conducted on a bimonthly basis, including 6 open-mouth periods and 6 closed-mouth periods. The custom-built core sampling device used in their study was used to construct a coring device of the same design and dimensions for the current study. USFWS took 5 replicate samples during the beginning of their study and then switched 3 replicate samples.

Analyzing our data with the USFWS is complicated for two reasons. Due to changes in numbers of replicates taken, the USFWS data can only be compared with data from the current study in terms of density, as opposed to numbers of individuals. In addition, USFWS, in most cases, identified their specimens to the family level, and in the case of Annelids identified specimens to the class level. The present study identified organisms to the species level, whenever possible. To allow comparison, therefore, data from the present study was amalgamated to the family level and converted to densities (number of individuals per square-meter) to be analyzed with the USFWS data.

3.1.6 Data Analysis

The goal of this analysis was to identify assemblages of organisms within the study area that represent freshwater, estuarine and marine communities. The macroinvertebrate data were analyzed using a combination of cluster analysis and ordination (detrended correspondence analysis; DCA) techniques to reveal the spatial and temporal patterns of macroinvertebrate community composition in the study area. These analyses were conducted using PC-ORD multivariate analysis software (McHune and Mefford 1999). Indirect gradient analysis was used to identify relationships between the biological community and environmental factors such as salinity and grain size. Relationships among samples are graphically represented.

The analysis proceeded as follows:

Standard community metrics, including diversity (H'), evenness (J') (Pielou 1974), total number of individuals, and species richness (total number of species) were calculated for each sample (set of three replicate cores).

Cluster analysis and ordination techniques were based on the combined data from all three replicate cores in a given sample. These data were inspected to ensure that all data were appropriate for the community analysis. Certain data, including snail egg masses, fragmented specimens, and dead specimens, were removed from the data set. Similarly, counts for individual life stages (pupae, larvae, and adults) were combined within a single species. The data were log (x+1) transformed prior to analysis to balance the effects of rare and dominant species. Cluster analysis was based on the Bray-Curtis dissimilarity metric and an agglomerative clustering strategy (UPGMA) (Legrande and Legrande 1980; McHune and Mefford 1999). Ordination was performed by detrended correspondence analysis (DCA) on the same data set as the cluster analysis.

Transformations were used to provide a balance between the influence of the common and rare species. Untransformed data generally allot undo influence to a few dominant species, whereas the most extreme transformation (i.e., presence-absence) allocates equal weight to both rare and abundant species. The log (x+1) transformation reduces the influence of the dominant species on the analysis, while giving greater importance to the subdominant species. These transformed data were used in both the cluster analysis and ordination.

Cluster analysis is a general name for a variety of procedures that are used to create a classification of entities (e.g., samples) based on their attributes (e.g., species and their abundance) (Aldenderfer and Blashfield, 1984; Boesch, 1977; Gauch, 1982; Jongman *et al.*, 1995; Legendre and Legendre, 1983). Cluster analysis provides an objective means of identifying groups of similar samples based on a quantitative measure of their similarity, and is used to discover structure in data that is not readily apparent by visual inspection or other means (Aldenderfer and Blashfield, 1984). In cluster analysis, samples with the greatest similarity are grouped first. Additional samples with decreasing similarity are then progressively added to the groups. Cluster analysis results in the recognition of a discontinuous structure (i.e., community groups) in an environment that may be discrete, but is generally continuous (Legendre and Legendre, 1983).

The objective of the cluster analysis performed on the benthos survey data was to define groups of samples, based on species presence and abundance, that belong to the same community without imposing an *a priori* community assignment. Identified clusters were then evaluated to define the habitat to which they belong.

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). The computer program PC-ORD (McHune and Mefford 1999) was used to perform the cluster analysis.

Ordination is a term for a collection of multivariate techniques that arrange entities (e.g., samples) along derived axes on the basis of their attributes (e.g., species and abundance). The aim of ordination is to arrange the individual samples such that samples that are close together have similar species composition, and samples that are widely separated are dissimilar in species composition (Gauch, 1982; Jongman et al., 1995; Legendre and Legendre, 1983). Ordination places the points in a continuous space rather than a discrete space. In contrast to cluster analysis, ordination techniques do not explicitly form groupings of the entities. Typically, the results of an ordination analysis are presented on a two-dimensional plot, with the individual entities (e.g., samples) represented by points. Groups are then identified by inspection of the plot.

As with cluster analysis, several ordination techniques are available. In this report, detrended correspondence analysis (DCA) (Jongman et al., 1995; ter Braak, 1987) was selected as the most appropriate technique and applied to the fourth-root transformed releve data. Correspondence analysis (CA) assumes that the species abundances are unimodally distributed along the underlying environmental axis. DCA improves on CA by correcting the mathematical artifact called the arch-effect. Ordinations were performed using PC-ORD (McHune and Mefford 1999).

3.1.7 LITERATURE REVIEWS

Two literature reviews were conducted simultaneously in order to put the invertebrate sampling results into perspective. The ecological features of estuaries with the same geomorphic type as the Santa Clara River Estuary were examined in order to assess habitat similarities and differences. Point Conception is widely recognized as the transition zone between the northern and southern distributions of marine and estuarine organisms in California (Zedler 1982). The area south of Point Conception to the Mexico/California border is referred to as the Southern California Bight. Only river mouth estuaries of similar size to the SCRE within the Southern California Bight were researched. Focus was given to finding published benthic invertebrate studies of these estuaries.

A second literature search was conducted for published salinity requirements and ranges of each taxa of benthic invertebrate found in the benthic core samples. In addition, salinity tolerances were examined for the species tested by the US Environmental Protection Agency to develop fresh and saltwater of ambient water quality criteria for copper (USEPA 1985; 1995). In all cases, focus was put on finding the salinity tolerance range of the taxa identified. If no information was available at this level, salinity tolerances of taxa within the same family was noted.

For both literature searches, the following sources were used:

- Search engines including Google, Biosis, Web of Science, Alta Vista, and The Mining Company.
- California Wetlands Information System (California Resources Agency, http://www.ceres.ca.gov/wetlands)
- University of California libraries including those at Irvine, Santa Barbara, and Davis. Melvyl search engine was used at all libraries.
- Invertebrate scientists.
- Southern California estuary researchers and managers.

4.1 PHYSICAL AND CHEMICAL CHARACTERISTICS DURING THE STUDY PERIOD

The Santa Clara River Estuary undergoes periodic and alternating filling and draining. Figure 4.1 illustrates the hydrodynamics of the SCRE during the sampling period. During the first six months of the study (May to Nov. 2001) the Estuary was impounded (closed phase) for between 25 and 100 days before breaching. This condition is likely due to lower inflow from the Santa Clara River during the drying summer and fall seasons. The dry season (summer/fall) is when sand spit formation typically occurs due to beach sand deposition. In November 2001, the first rains fell in the Ventura area and runoff from the Santa Clara River increased. From November 2001 to May 2002, the Estuary was generally more open and inundation levels varied frequently. This variability is likely due to increased river inflow, wave action, and tidal interaction. The increased wave action and sand spit scour typically occurs during the November to May (winter to spring) season.

4.1.1 NATURAL HYDROLOGIC INFLUENCES

Natural hydrologic data, such as Santa Clara River streamflow and local precipitation, were collected for the study period. Daily Santa Clara River streamflow data were also obtained from the Montalvo (USGS) gaging station for the study period. In addition, monthly precipitation totals were obtained from Santa Paula (NWS) rainfall station. The Metals Translator Study (ENTRIX 2002) provides a streamflow hydrograph and monthly precipitation for the May 2001 through April 2002 study period. The 7.69 inches of total rainfall recorded at the Santa Paul station represents roughly half of the 14.33 inches of normal Ventura area rainfall. The streamflow conditions observed during the study period correspond with a dry rainfall and runoff year. Generally, lower precipitation and subsequent runoff results in a diminished influence of streamflow on sand spit breaching and lagoon flushing, as well as limited influence of freshwater inflow by volume.

4.1.1 WATER QUALITY

A variety of abiotic factors have been identified that influence the composition and distribution of invertebrates under estuarine conditions. Salinity has been shown to be one of the most controlling factors (Kennish 1986, Chapman and Wang 2001) During a recent water quality profile of the Estuary, the Metals Translator Study (ENTRIX 2002), salinity amongst other water quality parameters were examined in the Estuary over a years time. In that study, low salinities (1 to 4ppt) were observed near the discharge channel and upper Estuary, where the Santa Clara River flows in. Brackish conditions (5 to 10 ppt) were observed in the middle of the Estuary. More marine-like (>10 ppt) conditions were isolated to the area near the mouth and far southwestern portion of the Estuary, the highest salinity measurement being 30 ppt. During inundated conditions, a halocline, or salinity stratification with increasing depth, often forms near the western and southern periphery of the Estuary. 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).

The results of this study are similar to that reported in the Metals Translator Study (ENTRIX 2002). Salinity in the outfall region is relatively low (Figure 4.2c), although not meeting the EPA criterion for a freshwater system (<1 ppt for >95% of the time). Salinity in the region of the mouth is relatively high (Figure 4.2d), although not meeting the EPA criterion for a marine system (>10 ppt for >95% of the time). Salinity in the lower estuary is intermediate between that for the outfall region and for the mouth (Figure 4.2b). The lower estuary is the location of the mixing zone, as defined by the Metals Translator Study (ENTRIX 2002). In all three zones of the estuary, salinity is highest when the sand spit is breached and there is a tidal influence in the SCRE.

In addition to salinity, a variety of other water quality parameters of the estuary were profiled in the Metals Translator Study. Ranges of 7 to 10.65 (estuary mouth) were found for pH. In addition, conductivity ranged from 1.93 ms/mc to 45.20 ms/mc, turbidity from 0 to 130 NTU, dissolved oxygen measured from 1.22 mg/L to 14.30 mg/L, and temperature varied from 10.60° to 26.80° C. Total suspended solids measurements ranged from 0.05 to 87 mg/l, with an average of 16. 21 mg/l, and total dissolved solids ranged from 1,240 to 35,138 mg/l with an average of 9,798 mg/l. Summaries of water quality parameters sampled during the Resident Species Study at Stations B1 to B11 can be found in Table 4-1a-d.

The relationships between the physical parameters are summarized in Table 4-2. Salinity and conductivity are highly correlated, as expected, since they are measures of the same property. Therefore, when the term salinity is used it will refer to both salinity and conductivity. pH is also strongly correlated with salinity and conductivity. Temperature exhibits correlations with several of the sediment parameters and with salinity/conductivity. No clear physical explanation is available to explain these relationships. Sediment parameters were only collected during the dry season, closed mouth sampling event. The correlation with temperature may suggest the presence of a gradient through the estuary that influences both grain size and temperature. Based on the available data, sediment characteristics behave independently of salinity, conductivity, and pH, as would be expected.

4.1.2 Sediment Data

After salinity, substrate composition and amount of total organic carbon (TOC) have been shown to be among the most important controlling factors of composition and distribution of invertebrates in an estuary (Kennish 1986). No quantitative analysis of sediment composition and TOC of the SCRE have been published previous to this study. The Santa Clara River is known, though, to have experienced periodic winter floods, particularly during periods of El Nino influence, as occurred most recently in 1998.

These floods tend to deposit and scour sediments in the Estuary and deposit large amount of silt, lowering estuary water depths (USFWS 1999).

Grain size data were collected during a closed phase of the Estuary (Table 4-3). Sediments are on average 84% sand, silt, and clay, and 16% gravel. The only locations with greater than 12% gravel are located in the upper estuary, upstream of the outfall channel.

4.2 Benthic Macroinvertebrate Survey and Data Analysis Results

As described in Section 2, the SCRE can be divided as follows:

- Upper Estuary: Characteristic of Santa Clara River upstream of discharge, B-7, B-8, B-9, and B-10. B-9 and B-10 are greater than one-third mile upstream of the Estuary.

- Lower Estuary: Characteristic of the mixing zone used in the Metals Translator Study, B-3, B-4, B-6.

- Outfall Area: Characteristic of the vicinity of the VWRF outfall, B-1 and B-2.

- Mouth Area: Characteristic of marine conditions influenced by the Pacific Ocean, B-5.

A map depicting the Estuary and the location of the sampling stations is provided in Figure 3.1.

The analysis of benthic macroinvertebrate survey data focused on samples collected from within the Estuary (Stations B1 through B9). Stations B10 and B11 were excluded because they are representative of stream habitat and are well outside of the Estuary's influence.

Benthic samples were collected from each station during four sampling events:

November 6-9, 2001, mouth closed;

December 10-12, 2001, mouth open;

April 16-19, 2002, mouth open; and

July 1-3, 2002, mouth closed.

Nine replicate samples per station were collected, providing a total of 81 cores per sampling event and 324 cores from all four events.

The taxonomic groups identified in this study are summarized in Table 4-4. During sorting and identification of samples from the four sampling events, 38 different taxonomic groups were found, including representatives from the phyla Platyhelminthes, Mollusca, Annelida and Arthropoda. Species were identified to genus and species level when possible. Most taxa were identified to at least the family level, and in many cases, genus and species could also be determined. This level of taxonomic identification is unusually complete in comparison to other studies reviewed for this report.

4.2.1 Dominant Taxa

The dominant taxa identified are depicted within species composition charts for each station in Figures 4.3, 4.4, 4.5, 4.6, and 4.7. Figure 4.3 depicts species composition by station for the entire study. Figures 4.4 and 4.5 depict the seasonal (fall/spring) species composition for each station. Figures 4.6 and 4.7 depict the species composition by station under each hydrologic phase (mouth/open/closed). The most common taxa found during this study were Ostracoda (Cyprididae and Species 2), Chironomidae (*Chironomus sp*. and *Cladotanytarsus sp*.), Tubificidae (*Limnodrilus sp*.), Gammaridae (*Eogammarus sp*.), Physidae (*Physa sp*.), and Daphniidae (*Daphnia sp*.) (Table 4-4). These eight taxa account for 98% of all organisms collected during this study. The two most abundant taxa, Cyprididae and Chrironomidae, were distributed throughout the Estuary during all sampling periods. The distributions of other taxa were limited to specific locations and/or specific sampling periods. In general, the greatest numbers of individuals were collected during the spring sampling periods (Table 4-4).

Of these six most common taxa, four were used by the EPA in establishing the freshwater ambient water quality criteria for copper. Most overlap between the EPA test species and SCRE species is at the genus level. This comparison is made in greater detail in Section 6.

The Ostracods (seed shrimp) were the most abundant organisms collected during this study (Table 4-4, Figure 4.3). Their abundance was greater at all stations, except B8, during open-mouth conditions than during closed-mouth conditions. The numbers of Cyprididae collected increased from the fall to spring sampling periods (Figures 4.4 and 4.5). All stations except B5 (46 individuals) contained high numbers of Cyprididae (Figure 4.3). Ostracoda Species 2 was most abundant during open mouth conditions at Station B9 (Figures 4.6 and 4.7).

The geographic distribution of Chironomids identified during this study is depicted in Figure 4.8. Chironomids (midgeflies, *Cladotanytarsus* and *Chironomus* and two unidentified genera) were the second most abundant organisms collected during this study. *Cladotanytarsus* and *Chironomus* were most abundant during the closed-mouth sampling periods and were collected from all stations (Table 4-4, Figure 4.7). They were present in higher numbers during closed-mouth conditions. *Cladotanytarsus* was least abundant at Station B1 and most abundant at Stations B5, B6, and B9. *Chironomus* abundance did not vary as dramatically as that of *Cladotanytarsus*. Two other unidentified chironomid genera were also present during this study. They were collected at all sampling stations and were most abundant during closed sampling periods. As described in Section 6, Chironomids (*Chironomus*) was used as a test species by the EPA in establishing the freshwater ambient water quality criterion for copper.

Tubificid worms (*Limnodrilus sp*.) was the third most abundant taxa collected during this study. They were most abundant at sites B1, B2, B8 and B9 and least abundant at Stations B4 and B5 (Figure 4.3). These more protected, backwater stations may provide habitat conditions more conducive to increased members of *Limnodrilus* based on nutrient-rich algal growth observed in the field. The abundance of *Limnodrilus sp*. was higher during open-mouth conditions than during closed-mouth conditions at Stations B3, B6, B7, B8, and B9 (Figure 4.6 and 4.7). Relatively low abundance occurred during the spring, closed-mouth sampling period (Table 4-4). Otherwise, a seasonal distribution pattern was not observed. *Limnodrilus* is very common in B1 near the outfall channel, and distinguishes this station from all others.

The amphipod *Eogammarus sp*. (a scuds) was most abundant during the spring sampling periods and at Stations B5, B8 and B9 (Table 4-4, Figure 4.5). It was least abundant at Stations B3 and B4. With the exception of Stations B5 and B6, *Eogammarus sp.* was less abundant during closed-mouth conditions (Figure 4.7). *Gammarus*, which is in the same family (Gammaridae) as *Eogammarus*, was used as a test species by the EPA in establishing the freshwater ambient water quality criterion for copper.

The *Physa sp*. (snails) were also among the dominant taxa found during this study. The highest numbers (91% by abundance of the total number collected during the fall closed-mouth sampling period at Stations B8 and B9 (Table 4-4, Figure 4.3). Another snail species, *Pomatiopsis californica*, was also collected during the fall sampling periods (Figure 4.4). In contrast to *Physa sp*., *P. californica* was most abundant at Stations B1 and B2 and rare at the other stations. Physa was used as a test species by the EPA in establishing the freshwater ambient water quality criterion for copper.

Daphnia sp. (water fleas) were only collected during the fall, closed-mouth sampling period (Table 4-4). Daphnia was collected at all nine stations, but was most abundant at Stations B2 and B4 and least abundant at Stations B1, B8 and B9 (Figure 4.3). Daphnia was used as a test species by the EPA in establishing the freshwater ambient water quality criterion for copper.

4.2.2 UNCOMMON TAXA

Some of the least common taxa collected during this study were Neorhabdocoela, *Saccocirrus sp.*, *Emerita analoga*, and *Microphthalmus sp*. (Table 4-4). These taxa were collected only at the mouth of the Estuary (Station B5) during open mouth conditions, and were the only marine taxa collected during the study.

Other taxa that were collected from the study area in relatively low numbers include: Lymnaeidae, Lumbriculidae, Enchytraeidae, *Hyallela azteca*, Copepoda, Dyticidae, Hydrophilidae, Collembola, Ceratopogonidae, *Ephydra sp*., Ephemeroptera, and Corixidae (Table 4-4).

Lymnaeidae (snails) were found only at Station B9 during the fall closed-mouth sampling period. The Enchytraeidae are a type of tubificid worm that were found primarily at Stations B6 and B7. *Hyallela azteca* is a very common freshwater amphipod (scud) that was collected during the fall sampling periods, primarily from Station B1. Copepods were collected exclusively during the spring closed-mouth sampling period.

Insects, including various Dipterans (flies and midges) and Corixids, (waterboatmen) make up the remainder of the less common taxa collected during this study.

4.2.3 COMMUNITY STRUCTURE

Four measures of community structure were calculated from the macroinvertebrate dataset including species richness (number of species per station), abundance (number of individuals per station), evenness (per station), and diversity (H', per station). Diversity is a measure of the number of species and their relative abundances. Evenness is a measure of the equitability of the species abundances in the sample and ranges from 0 to 1. If all species in a sample were present in the same abundance, the evenness would be 1.

Figure 4.9 depicts the number of species, or species richness, by station and condition. Species richness was consistently highest during the fall closed-mouth sampling period.

Figure 4.10 depicts the total number of individuals, or abundance, by station and condition. Abundance was greatest at Stations B6 and B8 during the Spring closed-mouth sampling period and at Station B9 during the Spring open-mouth sampling period. Many of the lowest abundances occurred during the Fall open-mouth and closed-mouth sampling periods.

Figure 4.11 depicts the species diversity by station and condition. Species diversity was generally highest during the fall closed-mouth period and lowest during the spring closed-mouth or fall open-mouth periods. Highly variable species diversity was observed at most stations (e.g. at Station B4 species diversity ranged from 0.03 to 1.75), with the exception of Station B1 which ranged from 0.60 to 0.90. These patterns in diversity are probably related to the higher species richness, and lower number of individuals in the Fall closed-mouth samples.

Figure 4.12 depicts the species evenness by station and condition. Species evenness was generally highest during the fall closed-mouth period and the spring open-mouth period (0.65 to 0.75). These relatively high values indicate that, at the stations where they occurred, the community was not dominated by a particular taxon. Conversely, the lowest evenness values were observed during the spring-closed mouth and spring-open mouth periods (0.01 to 0.05), indicating a dominance by one or two taxa at those stations.

4.2.4 RELATIONSHIP TO PHYSICAL PARAMETERS

The relationship between the physical parameters and the community metrics for each sampling event are summarized in Table 4-5. Only significant correlations between the physical and biological factors are presented for clarity. Salinity (conductivity) and pH are negatively correlated with most community parameters in the spring sampling events. This suggests that the community is affected when saline conditions occur. There appears to be little relationship between the physical and community metrics during the fall season. However, during the fall metrics, open-mouth sampling event, there was a negative correlation between pH and numbers of individuals and species richness. A positive correlation was also observed between turbidity and pH and numbers of individuals.

4.2.5 Cluster Analysis

Cluster analysis was performed on the log (x+1) transformed data using the Bray-Curtis similarity metric and group-average linkage method (McHune and Mefford 1999). The resulting cluster dendogram, showing the major groupings, is presented in Figure 4.13. There is a clear separation in community composition between the fall and spring sampling periods. This separation is generally created by differences in community composition during the spring periods. Gastropoda (snails), *Daphnia sp*. and *Chironomus sp*. were more prevalent during the fall periods, whereas *Eogammarus sp*. and Cyprididae were more prevalent during the spring periods. Within each of these major groupings the samples tend to cluster based on the condition of the mouth. However, this pattern is less clear.

Species indicative of freshwater conditions, as determined by the EPA test species for freshwater ambient water quality criteria (Section 6), occur throughout the year. The community structure differences are most likely due to life history. For example, eggs present in Spring would likely be smaller than the sample mesh size and so not be represented, but the more mature life stage found in fall would be represented. In addition, some life stages include residence in the water column, and so would not be in the benthic cores.

Stations B10 and B11 (samples B10DC01 and B11DC01) are located upstream of the Estuary proper. These samples clustered at a high degree of dissimilarity as compared to the other samples. These two samples contained 24 species that were found nowhere else in the Estuary at any time. Due to the highly dissimilar nature of these samples, they were removed from further analysis in the ordination.

4.2.6 Ordination

Ordination of samples was performed using detrended correspondence analysis (DCA) on the log(x+1) transformed abundance data (McHune and Mefford 1999). An ordination plot for all stations is provided in Figure 4.14. The first ordination axis (axis 1) explained approximately 41 percent of the variance in the data, based on the *a posteriori* test described by (McHune and Mefford 1999). Axis 2 explained 13 percent, and Axis 3 explained 11 percent of the total variance. Overall, the first three ordination axes explained approximately 65 percent of the variance in the community data.

Axis 1 is most closely correlated with salinity and conductance (Figure 4.14). The open mouth periods, with higher salinity, tend to the right side of Axis 1, while the fresher, closed mouth periods tend to the left side of Axis 1. The physical interpretation of Axis 2 is less clear, but samples from the outfall channel (B-1) fall to the bottom of Axis 2, while samples from the mouth near the Pacific Ocean (B-5) fall to the top of Axis 2. It is possible that Axis 2 is most strongly associated with nutrient content, since the outfall samples had sediment indicators of higher nutrient content that the sandy samples from the mouth.

The seasonal pattern identified in the cluster analysis is apparent in the ordination, with the spring samples tending to plot towards the left along Axis 1, and the fall samples tending to plot in the center and right. However, this pattern is not as strong as in the cluster analysis. A more pronounced pattern is evident between the open and closed mouth samples.

The spring closed-mouth samples (closed squares) tend to cluster towards the left side of Axis 1. Under these conditions, you would expect the Estuary to be relatively uniform freshwater. In contrast, the spring open-mouth samples (open squares) plot along nearly 3/4 of Axis 1, suggesting that there may be a gradient of conditions in the Estuary under these conditions. The fall season samples lie towards the middle of Axis 1, with no clear differences between open and closed conditions.

The available physical (sediment and water quality) parameters were subsequently correlated with the ordination axes. Salinity (conductivity) correlated strongly with Axis 1, indicating increasing salinity values as you move to the right along the axis. pH was correlated with Axes 1 and 2.

As found for the cluster data, species indicative of freshwater conditions, as determined by the EPA test species for freshwater ambient water quality criteria (Section 6), occur throughout the year. The community structure differences are most likely due to life history.

In conclusion the spring closed mouth samples are likely indicative of a freshwater dominated system, whereas the spring open-mouth samples suggest a gradient from a freshwater community (ex. Sample B9W001) to a more saline influenced community (ex. Sample B5W001). The saline community is found at the mouth of the Estuary, in contact with the Pacific Ocean.

4.2.7 Relationships with USFWS Data

The U.S. Fish and Wildlife Service, Ventura Field Office conducted an ecological monitoring study of the Estuary from 1997 through 1999 (USFWS 1999). Their study included the collection of benthic invertebrates from five stations during a two-year period. Five of the sample stations in the current study coincided with the USFWS stations, including B1, B3, B4, B5 and B8 (Table 3-1). The USFWS collections were conducted on a bimonthly basis, including 6 open-mouth periods and 6 closed-mouth periods. Both studies used a similar sampling device of identical dimensions. The purpose of this section is to: 1) compare the results of the two studies and, 2) integrate the two data sets for an extended view of biotic variability in the Estuary.

Table 4-6 summarizes the species abundance (density) data for the USFWS study (1999) and this study. Integration of the data sets from the current study and the USFWS study is problematical for several reasons. The two primary reasons are differences in level of taxonomic detail and differences in sampling design. Taxonomic differences represent the major complication. The present study identified individual organisms to the generic or species level, whenever possible. The USFWS identified individuals to the family level, and in certain cases (e.g., annelids) to above the class level. To allow direct comparison, data from the present study were merged to the same taxonomic level as that in the USFWS study (generally the family level, Table 4-6). The lists of taxa (family or higher) from the two studies were then compared (Table 4-6).

Another factor complicating numerical comparisons between the two studies was a difference in the number of sampling stations. The USFWS study collected cores from 5 stations, whereas the current study collected samples from 9 stations. However, 5 stations from the current study were intentionally placed in the same 5 locations as the USFWS study (B1, B3, B4, B5 and B8). Therefore, to make the data sets comparable, only the data from these five stations were utilized (Table 4-6).

To collect benthic samples, both studies used a 4-inch (10 cm) diameter core. However, the USFWS collected 3 (occasionally 5) cores per station and the present study collected 3 replicates per station, with each replicate consisting of 3 cores, and therefore totaling 9 cores per station. To resolve this discrepancy and make a numerical comparison possible, the abundance data from each study were converted to densities (number of organisms per decimeter^2). Another difference between the two studies was the mesh size of the screen used to sieve the samples. The USFWS used a 1.0 mm mesh size screen, whereas the current study used an 0.5 mm mesh size screen. This discrepancy is noted, but cannot be resolved. The smaller mesh size would function both to retain smaller species, and greater numbers of individuals of all species present.

The density of organisms collected during the current study was consistently greater than in the USFWS study at all five stations. This may be due, in part, to the larger mesh size screen used in the USFWS study. The most abundant taxa collected during both studies were the Chironomidae, Oligochaeta, Daphnia and Physidae. The highest overall numbers of organisms were found at Stations B1 and B7 during the current study, and at Stations B1 and B4 during the USFWS study.

The current study found 71% of taxa found in the USFWS study. Several taxa collected during the current study were not present during the USFWS study. Ostracoda and *Eogammarus sp*. were not collected during the USFWS study, but were abundant during the current study. The reason for the lack of Ostracoda in the USFWS study is not known. They may have been absent due to natural population variability, or the difference in screen sizes used in the studies. The Ostracoda are very small animals and may have been washed through the 1.0 mm mesh screen. The gastropod, *Pomatiopsis californica*, was also collected from Station B1 only during the current study.

Hirudinea, Tipulidae, Dixidae and *Gammarus sp*. were collected in low numbers during the USFWS study, but not the current study. The *Gammarus sp*. identified in the USFWS study is in the same family (Gammaridae) as the *Eogammarus sp*. identified in the current study.

As can be seen in Table 4-6 71% of taxa found in the USFWS study were found in the current study. In addition to the discrepancies noted above, the remaining differences between the study are likely a reflection of changes in hydrology and sediment composition in the Estuary in the last few years. El Nino-influenced flows of the Santa Clara River from December 1997 to April 1998 caused the mouth of the Estuary to remain open through the period (USFWS 1999). In addition, the flood deposited large amounts of silt to the Estuary bed, lowering water depths. The addition of large amounts of silt may have adversely affected the benthic infauna (Onuf 1987). In addition, the added sediments probably lowered the volume of the tidal prism, reducing tidal exchange (USFWS 1999).

The 1997/1998 El Nino condition had lasting effects on the Estuary. Redistribution of sediment and avulsion of channels in the Estuary physically altered habitat types and microhabitat conditions for a number of aquatic organisms inhabiting the Estuary. In addition, elevated groundwater conditions resulting from El Nino caused increased freshwater inflow to the Estuary through the Summer of 1999.

The following is quoted from USFWS (1999):

Except for the yellow shore and amphipod "A", which are marine or estuarine species, all of the collected invertebrates that were identified to at least genus level appeared to be freshwater taxa (Smith and Carlton, 1975, Morris et al. 1980, Pennak 1989, Merritt and Cummins 1996).

Note that the shore crab and the unidentified amphipod are both from stations near the mouth of the SCRE and the Pacific Ocean.

4.3 Salinity Tolerance Review of Estuary Taxa

A literature review was conducted to identify salinity tolerance values for the taxa found in the Estuary during this study. Results of the literature review are in Appendix D. A summary of these results is in Figure 4.15. Salinity tolerance values were based on a variety of references, including invertebrate ecology and biology texts, peer-reviewed publications from field and laboratory studies, and reports of work performed by government agencies and consulting companies.

The amount and precision of salinity tolerance information for each taxa varied, depending on how much published research was available and the level of taxonomic identification we were able to attain. In some cases, we found laboratory or field studies performed to determine the salinity tolerance limits or distribution of a species across a salinity gradient. This type of study provided the most precision. For example, *Daphnia magna* is an extensively researched organism and we found salinity tolerance test results in the published literature. It has been determined that the ideal salinity range for *D. magna* is 0-5 ppt and they can also survive up to about 8 ppt. *Hyallela azteca* is another example of a well-researched organism. *H. Azteca* is a freshwater organism that has been shown to tolerate brackish water up to 15 ppt, and in some cases may tolerate higher salinity values. The amphipod *Eogammarus confervicolus* is reported from many Pacific coast estuary studies (Furota and Emmett 1993, Houghton 2001, Weitkamp 2001, Simenstad 2001, Bousfield 1979). Based on its ubiquitous distribution in habitats ranging from freshwater to saltwater, *E. confervicolus* has been identified as a euryhaline species (capable of inhabiting the full range of salinity values).

If the level of taxonomic identification was relatively high (i.e., family level and above), then precise salinity tolerance levels could not be determined. For example, the Cyprididae and Ostracoda species 2 are shown with dashed lines throughout their salinity range because these groups can be found in freshwater, brackish water, and saltwater habitats (Figure 4.15). It would be necessary to identify at least the genus, and possibly species, to determine which habitat these ostracods prefer. The order Cyclopoida (Class Copepoda) is another example of a taxonomic level that is too high to make a determination of salinity tolerance values. As with the Ostracods, there are Cyclopoida found in all salinity types.

Many of the taxa found in the Estuary are freshwater organisms with a tolerance to brackish conditions. However, in some cases the extent of their tolerance could not be determined because a) the number of published references with appropriate information were limited, or b) the level of taxonomic identification is too high to make a determination. For example, *Pomatiopsis californica* is a freshwater snail, but the extent of salt tolerance is unknown. The same is true for the various Chironomids found in the Estuary. Chironomids are a diverse group of freshwater insects that can be found in nearly any aquatic habitat in the world. As such, it would be necessary to know which species were found and their distribution in southern California habitats.

Based on the results of the literature review, salinity tolerance categories were developed and assigned to each taxa. The categories are as follows:

- FI = Freshwater organisms that are intolerant of brackish conditions
- FT = Freshwater organisms that are tolerant of brackish conditions
- BR = Brackish water organisms
- MT = Marine organisms that are tolerant of brackish water conditions
- MI = Marine organisms that are intolerant of brackish water conditions
- EU = Euryhaline organisms, which are tolerant of the full range of salinity conditions from freshwater to salt water
- UN = Organisms for which the salinity preference is unknown

These categories were based on salinity tolerance groups identified by researchers that specialize in estuarine systems (Bulger et al. 1993, Kennish 1986, Ketchum 1983, Chapman et al. 1982, Day 1981, and Remane and Schlieper 1971). These general groupings have been found to apply to communities of estuarine benthic infauna. These categories of organisms tend to occur in the upper, middle and lower portions of estuaries, according to their degree of saltwater tolerance. Figure 4.16 shows the proportion of each tolerance category at each station throughout this study period.

The majority of taxa found in the Estuary were freshwater organisms that are tolerant of brackish conditions (FT). The FT category contained 39% of the total organisms collected during this study. Many of these taxa tolerate salinity levels up to 5–10 ppt. Others may tolerate higher salinities, but are more likely to have reduced growth and reproductive success at those levels. All of the freshwater taxa found during this study could tolerate at least 5 ppt salinity and thus we did not assign the category FI to any taxon.

One brackish water organism, the amphipod *Eogammarus sp.,* was found during this study (8.2% of all organisms collected, Figure 4.15). The genus *Eogammarus* is found in estuarine systems from Alaska to southern California (Bousfield 1979). *Eogammarus confervicolus* is the most common species in Pacific Coast estuaries and is widely distributed. This is likely to be the species found during this study. The ideal salinity tolerance range for *E. confervicolus* is approximately 0.5–20 ppt (Figure 4.15, Bousfield 1979). In addition to the taxa found during the current study, *Palaeomon macrodactylus* (shrimp) was collected by the USFWS in benthic cores during their 1997-1999 study (USFWS 1999). *P. macrodactylus* is an introduced species that is particularly abundant in brackish water and is tolerant of salinity levels above 1 ppt (Smith and Carlton 1975).

Four marine taxa that are intolerant of brackish conditions were collected during this study (0.07 % of all organisms collected). They are Neorhabdocoela, *Saccocirrus sp., Microphthalmus sp., and Emerita analoga*. These taxa were collected only near the mouth of the estuary during open mouth conditions. The numbers collected were very low (1-36 individuals). We did not identify any marine organisms that are tolerant of brackish conditions during this study.

Two categories of organisms of unknown salinity tolerance were identified during this study (Figure 4.15). The first group is comprised of several taxa that were present in relatively low numbers and for which specific salinity tolerance information was not available (9 % of all organisms collected, Figure 4.15). Station B9 had an unusually large proportion of species of unknown salinity tolerance. This was almost entirely due to the large number of Ostracoda Species 2 that occurred at this station, largely during open mouth conditions. The proportion of this species appears to increase in abundance from the outer and middle portions of the estuary to the upper portion of the estuary (Stations B8 and B9).

The second unknown salinity tolerance category consists of the Cyprididae (44% of all organisms collected). The salinity tolerance level for this group could not be determined because the family Cyprididae (class Ostracoda) contains both marine and freshwater forms (Thorp and Covich 1991) and this organism has not been identified to species level. The taxonomy of the Cyprididae in southern California is not generally well known. This family very likely consists of more than one species and could possibly include undescribed species (D. Cadien, personal communication, Aug. 26, 2002). The abundance of Cyprididae in the samples was not correlated with salinity (regression analysis $R^2 = 0.09$). This species is present in a wide range of salinities and does not appear to select a particular range of salinities. The ubiquitous distribution of Cyprididae in the Estuary over a wide range of salinity levels suggests that this taxon is either euryhaline or toleratant of brackish water (Figure 4.17 and Figure 4.18).

The majority of organisms collected in the Estuary were in the FT and Cyprididae salinity tolerance categories (Figure 4.15 and Figure 4.16). Although the salinity tolerance of the Cyprididae is unknown, a brackish water or euryhaline distribution is likely. The predominant salinity tolerance categories present during this study include freshwater organisms that are tolerant of brackish conditions and brackish/euryhaline organisms. The brackish water organisms (particularly Cyprididae) were predominant at Stations B2, B3, B4, B7, and B8 and the freshwater organisms tolerant of brackish conditions were predominant at Stations B1, B5, B6 and B9.

5.0
COMPARISON OF THE SANTA CLARA RIVER ESTUARY TO OTHER ESTUARIES IN THE SOUTHERN CALIFORNIA BIGHT

The section of the California coast south of Point Conception and north of the California/Mexico border is commonly referred to as the Southern California Bight. Point Conception is widely recognized as the transition zone between the northern and southern distributions of marine and estuarine organisms in California (Zedler 1982). Marine invertebrate distributions and diversity change markedly at this location, as it is the point of convergence of the California Current and the California Countercurrent. Although this change in current is much less important to marsh organisms found in protected embayments than marine organisms, Southern California marshes within the Bight show more similarities in community profile than those marshes found further north and south (Zedler 1982).

While there are 26 coastal wetlands in the Southern California Bight (depicted in Figure 5.1), a relatively small amount of research has been published on the invertebrate communities in these areas. The following section discusses the benthic invertebrate studies that have been published on lagoons and estuaries of similar size to the Santa Clara River Estuary within the Southern California Bight. Included are studies in which the researchers have comprehensively sampled for benthic invertebrates, preferably using benthic cores, and where the focus of the study was the benthic community as a whole, as opposed to one type of invertebrate. Species diversity, hydrologic conditions, and water quality are discussed in order to compare the conditions of these estuaries and lagoons with the Santa Clara River Estuary. A complete list of species found in each estuary and lagoon can be found in Table 5-1. Unless otherwise noted, background information on each estuary was found in the California Coastal Conservancy's Southern California Wetlands Inventory and Information Station Database (2001).

5.1 MUGU LAGOON

Mugu Lagoon is located within the Naval Air Weapons Station, Point Mugu, southeast of the City of Oxnard. The Lagoon is approximately 1,474 acres, of which 65 % is tidal marsh, 18% open water, 9 % tidal flat, 5% salt pan, and 3% tidal creeks. The lagoon is surrounded by a weapon testing facility containing buildings, airstrips and aircraft. Additional surrounding land uses include agriculture and open space. Calleguas Creek, flows seasonally into the lagoon, with highest flows from January to March. In addition, a series of seven agricultural ditches drain into the lagoon. The lagoon was listed in 1996 as an impaired water body. High concentrations of banned pesticides have been found in the sediment of the lagoon.

According to a study performed for the U.S. Fish and Wildlife Service in 1987, the lagoon is marine dominated (Onuf, 1987). The mouth of the lagoon has been known to migrate eastward significantly, causing the lagoon to close occasionally. In general salinity tends to stay around 32 to 34 ppt. During storm events salinity levels may drop, but quickly return to marine levels.

5.1.1 Benthic Invertebrate Studies

H. Peterson studied larger macro-invertebrates from July 1969 to July 1972 (Peterson 1977). This study found relatively constant community composition throughout the study period. *Cryptomoya californica*, *Callianassa californiensis*, *Protothaca staminea*, *Sanguinolaria nuttalli*, *Dendraster excetnricus*, and *Tagelus californianus* dominated the study areas.

In addition, the U.S. Fish and Wildlife performed a comprehensive study of benthic invertebrates from 1977-1980 (Onuf 1987). Worms, small gastropods, bivalves, and large crustaceans numerically dominated the community.

More recently, benthic infauna and epifauna were collected using cores in January of 1994 as part of an ecological assessment of Point Mugu for the Naval Station (TetraTech 1998). Species lists from this report can be found in Table 5-1.

5.2 Malibu Lagoon

Malibu Lagoon is located in the City of Malibu adjacent to residential development, a golf course, Pacific Coast Highway, and public beaches. Approximately 50% of the lagoon is estuarine open water, tidal channels and mudflats, 20% is salt marsh, and 50% is creek corridor or riparian habitat. In 1983 the lagoon was restored to its current state after years of sediment and debris dumping in the area.

The once seasonal Malibu Creek now flows year-round into the estuary. The creek includes storm water runoff and roughly 8 to 10 MGD of permitted tertiary treated wastewater from October to June. Additional flows may result from leaks from neighboring septic systems. The lagoon is listed as an impaired water body and has exceeded standards for arsenic, nickel, selenium, lead, coliform, and viruses.

Naturally, the mouth of the lagoon closes during summer and opens in winter due to storm water flows. Until recently, though, the mouth of the lagoon has been dredged when water levels exceed 3.5 feet. This dredging occurs roughly twice a month. Salinity levels, therefore, vary dramatically between 3 to 32 ppt depending on mouth conditions and freshwater flows.

5.2.1 Benthic Invertebrate Studies

In 1989 Dillingham and Manion published a baseline ecological survey of the lagoon for the Topanga Las Virgenes Resource Conservation District that included benthic invertebrate samples using cores and trawl nets. During the study period (1987 to 1988), salinity stayed between 20 and 35 ppt from May to August 1987, fell to ranges between 1 to 20 ppt from mid August 1987 to January 1988, rose to ranges of 15 to 22 ppt until March 1988, and finally dropped within ranges of 0 to 10 ppt in April 1988. Although a variety of invertebrates were observed or caught in trawl nets in the estuary, benthic cores within the estuary from 1987 and 1988 yielded only two species of benthic invertebrates, *Polydora nuchalis* and *Tagelus californianus*. These species are adapted to wide ranges of salinity and water quality conditions. Low diversity may be the result of a large sewage spill in August 1987 (Dillingham and Manion 1989).

5.3 SANTA MARGARITA ESTUARY

Santa Margarita Estuary is located one mile north of the City of Oceanside on the southwestern corner of Camp Pendleton Marine Corps Base. The estuary is over 200 acres in size. Dominating habitats include 38% salt marsh, 46% salt pan, 10% upland, 4% willow woodland, and 2% brackish and fresh water marsh. Surrounding areas to the estuary are used for military training and are leased for agriculture. Interstate 5 and the railroad dissect the estuary, which restrict tidal influence inland from the mouth.

The Santa Margarita River flows seasonally into the estuary. This river frequently does not flow several months of the year. Storm water runoff and groundwater seepage also contribute to freshwater inflows. From the 1940's to 1972 secondarily treated effluent was discharged into the estuary. In 1996 the estuary was listed as impaired for eutrophication. Historically the mouth of the estuary was predominantly open until the 1970's, when it closed periodically for extended periods of time. After 1979 tidal flushing was restored. The mouth of the estuary is occasionally dredged for water quality reasons. Salinity measurements between 1986 and 1987 indicate levels between 1.5 to 30 ppt.

5.3.1 BENTHIC INVERTEBRATE STUDIES

A 1981 U.S. Fish and Wildlife study of invertebrates in the estuary found 26 species of invertebrates using benthic cores and bag seines (Salata, 1981). The study (January to April 1981) occurred during a long period of tidal flushing when the mouth of the estuary remained predominantly open. During the same time, though, fresh water flows were high to the lagoon. Salinity levels from 1980 to 1981 ranged from 6 to 35 ppt, with most measurements in the range of 15 to 35 ppt. Phyla represented were ribbon worms, segmented worms, molluscs, and arthropods.

5.4 BATIQUITOS LAGOON

Batiquitos Lagoon is located between the cities of Leucadia and Carlsbad, 28 miles north of San Diego. The lagoon is approximately 558 acres, 62% of its habitat estuarine open water, 18% southern coastal salt marsh, 15% tidal and nontidal estuarine flats, 3% coastal scrub and chaparral, and small areas of brackish and riparian areas. Adjacent to the lagoon is commercial land, a golf course, residential development, and a state beach. Highway 101, the railroad, and I-5 dissect the lagoon and limit tidal action.

San Marcos and Encinitas Creeks constitute the major freshwater flows to the lagoon. These creeks are seasonal. Additional sources of fresh water come from smaller tributary streams, storm water runoff, and groundwater seeps. From 1967 to 1974 secondary treated wastewater was discharged into the lagoon. Although once listed as an impaired water body for high coliform levels, in 1996 it was proposed that the lagoon be removed from the impaired water body list.

Until 1985 the lagoon mouth remained predominately closed. Since 1985 the Coastal Conservancy has been implementing an enhancement project that involves dredging the lagoon and keeping the mouth open to restore tidal flow. Water quality studies prior to 1985 indicate hypersaline conditions in the lagoon during summer and autumn and dry years, and brackish conditions during winter and wet years (MEC Resources Study 1993). Salinity values ranged from 0 to 100 ppt.

5.4.1 Benthic Invertebrate Studies

In 1976 Mudie, Browning and Speth published a report summarizing the invertebrates found in the lagoon in the years before 1976 as part of a California Department of Fish and Game study of the lagoon (CADFG 1976). According to the report benthic marine invertebrates are largely absent from the lagoon. Other invertebrates dominating the lagoon included water boatmen, midge larvae, and freshwater crayfish.

5.5 San Dieguito Lagoon

San Dieguito Lagoon is located north of San Diego Bay on the northern border of the City of Del Mar. Totaling roughly 520 acres, habitat types include estuarine open water (15%), southern coastal salt marsh (12%), seasonal salt marsh (11%), nonvegetated disturbed areas (9%), tidal and nontidal estuarine flats (6%), riverine flats (4%), agricultural (3%), brackish (2%), and transition zones (38%) (MEC Resources Study 1993). Adjacent land uses include the Del Mar Racetrack and Fairgrounds, a golf driving range, residential development, commercial uses, and agriculture. San Dieguito River is the primary tributary flowing into the estuary. This river is intermittent and prone to occasional flooding. Prior to 1974, treated sewage was discharged directly into the lagoon. In 1974 this discharge was redirected to flow directly into the ocean.

Within the estuary, Interstate 5 and a railroad berm restrict tidal influence and broad sandbars can cause the mouth to close for extended periods of time. This leads to cycles of hypersaline (35+ ppt) conditions in summer when flows in the San Dieguito River are low and brackish conditions (10 ppt) in winter when flows are heavier (MEC Baseline Study 1993). In the past, the mouth of the lagoon has been occasionally dredged due to water quality problems.

5.5.1 Benthic Invertebrate Studies

According to an 1976 California Department of Fish and Game study summarizing past habitat conditions of the lagoon, including benthic invertebrate communities, the mouth of the lagoon had remained closed from July 1953 until the time of the report, with the exception of a winter flood in 1966, which breached the mouth of the lagoon (CA DFG 1976). Aquatic insects, particularly water boatmen and biting midges, were among the greatest number of invertebrates sampled. Low species richness in the lagoon was attributed to wide fluctuations in salinity during the sampling period.

As part of a restoration project on the lagoon and the San Onofre Marine Mitigation Program, a Biological Baseline Study from the period March 1992 to May 1993 examined all biological aspects of the lagoon, including benthic invertebrates (MEC Baseline Study 1993). During 1992 the lagoon was closed 78% of the year. In 1993 the lagoon opened in January and remained open into November. During the closed period, salinity in most parts of the lagoon ranged between 38 to 45 ppt, with the exception of brackish areas (10 ppt) near the river outlet. During the open period in 1993, salinity from January to March remained in the range of 0 to 10 ppt due to excessive rainfall and flooding and rose to 20 to 35 ppt in most parts of the lagoon after rainfall waned in the summer and fall. In this publication, the relationship between mouth condition and species diversity is examined. Prior to 1993, annelids, along with molluscs, were dominant. After the flood in 1993, the inner lagoon was mainly colonized by annelids. Insects and crayfish occurred in brackish water habitat, amphipods and crabs were mostly found in marine habitats, and bivalve and gastropod molluscs were collected in high abundance during spring and summer in all habitats.

5.6 LOS PENASQUITOS LAGOON

Los Penasquitos Lagoon is located on the northwestern border of the City of San Diego, just south of the City of Del Mar. The lagoon is 537 acres in size. Habitat types include southern coastal salt marsh (51%), riparian (20%), estuarine open water (6%), tidal and nontidal estuarine flats (5%), brackish marsh (3%), and transition zones (16%). The areas surrounding the lagoon are residential, commercial, parks, agricultural, and a small area of light industry. In addition, Interstate 5, Pacific Coast Highway, and a railroad bisect the lagoon and impede tidal reach.

Currently Carmel Creek and Los Penasquitos creek flow year-round into the estuary due to increased residential and agricultural run-off. From 1962 to 1972 approximately 0.5-1 MGD treated sewage was discharged into the lagoon as well. Sewage is now redirected outside the estuary, but spills have been known to occur. In 1994 the lagoon was listed as an impaired water body and has exceeded limits for sediment and coliform.

The ocean inlet to the lagoon is restricted by Highway 1 (Pacific Coast Highway), causing the lagoon to be closed for extended periods of time. Starting in 1982, the San Diego Association of Governments called for periodic opening of the inlet in cases of degraded water quality. The inlet is manually opened roughly four times a year, depending on water quality. The lagoon is often nontidal in summer, leading to increased salinity in summer and autumn due to evaporation. In the wet season, storm run-off decreases salinity. Studies from 1990 to 1993 indicate levels of salinity ranging from 0.1 to 38, fluctuating dramatically within this range throughout the year (MEC Resources Study 1993).

5.6.1 BENTHIC INVERTEBRATE STUDIES

From June 1987 and December 1988 Nordby and Zedler collected benthic invertebrates with a 20 cm deep benthic cores. During this period of time, salinity values fluctuated between 20 and 38 ppt, with the exception of four brief episodes in October and November 1987 and April and December 1988 when the salinity dropped to levels ranging from 3 to 10 ppt. 37 taxa of benthic invertebrates were collected. Capitellids, spionids, and opheliid (*Euxonus mucronata*), all polychaetes, dominated the assemblage. Relatively few bivalves were collected. Nordby and Zeller attributed reduced species richness and abundance to periods of reduced salinity and flooding in the lagoon. They describe the assemblage as dominated by species that "can survive salinity shock and very low levels of dissolved oxygen, are easily reintroduced during brief periods of mouth opening, or are introduced from freshwater flows" (Nordby and Zedler 1991)

Studies by Williams and Gibson (1995) between September 1994 and September 1995 of benthic invertebrates coincided with a high rainfall event that caused flooding between January and March 1995. During the study, the mouth was open 97% of the year. Salinity levels fluctuated between 25 to 32 ppt, with the exception of the period from January to March when salinity levels dropped to 12 ppt. Numerically dominant taxa found included amphipods, capitellid worms, *Streblospio benedicti*, *Polydora nuchalis*, *Cerithidia californica*, and phoronids. Species richness was highest before freshwater flooding.

A more recent publication by Ward, West and Cordrey (2001) report findings from benthic core sampling from September 2000 to September 2001. During this time the lagoon mouth was open the entire time, with the exception of closure during the month of December. Salinity ranged from 15 to 27 ppt when the mouth was open and fell to 8 ppt when the mouth was closed. The community was dominated by polychaetes, gastropods, and amphipods.

5.7 TIJUANA ESTUARY

Tijuana Estuary is located between the City of Imperial Beach and Tijuana, Mexico. Although the estuary lies entirely in California, 75% of its watershed is in Mexico. The estuary is approximately 2,119 acres in size. Habitat types include coastal scrub and chaparral (18%), seasonal and permanent southern coastal salt marsh (27%), transition (15%), riverine flats (12%), riparian (11%), estuarine and palustrine open water (10%), tidal and nontidal salt marsh (6%), and small areas of brackish, dune, and disturbed areas (MEC Resources Study 1993).

The Tijuana River is the primary source of freshwater to the estuary. While this river naturally flows seasonally, supplemental sewage discharges make flows to the estuary year-round. Until 1988, 10 to 22 MGD of raw sewage entered the estuary. These flows have been routed to a treatment plant, but intermittent sewage spills can frequently exceed 2 MGD. In cases of low flow from the Tijuana River, groundwater from a neighboring unconfined aquifer may flow into the river. In 1994 the estuary was listed as an impaired waterbody. The estuary exceeds water quality standards for coliform, pesticides, metals, eutrophication, trash and debris.

The mouth of the estuary has remained open with the exception of long periods of closure in the 1960s and 1984. From 1985 on the estuary's mouth has been dredged when closed due to water quality concerns. In years when the estuary is open, salinity levels range from 25-32 ppt in the estuary with lower salinity levels at the river inlet. Flooding from the years 1977-1980 led to brackish conditions and salinity levels dropped to 0 ppt throughout the estuary (Nordby and Zedler 1986). Closure of the lagoon in 1984 resulted in brackish conditions in the winter (15 ppt) and hypersaline conditions in summer. The estuary mouth was dredged in 1985 and has remained primarily open since then.

5.7.1 Benthic Invertebrate Studies

An estuarine profile prepared for the U.S. Fish and Wildlife Service in 1986 summarized benthic invertebrate studies of the estuary from the 1970's to 1985. The studies demonstrate the effects of the 1977-1980 heavy rainfall events and the 1984 mouth closure on invertebrate diversity in the estuary. Before 1980, bivalve molluscs, polychaete worms, gastropod molluscs, and decapod crustaceans dominated the benthic community. After flooding, polychaetes and amphipods dominated samples.

Nordby and Zedler (1991) also sampled for benthic species from 1986 to 1989 using benthic cores. Bivalve species, including *Tagelus californianus*, *Protothaca staminea*, and *Macoma nasu*ta, polychaetes, and the decapod crustacean *Callianassa californiensis* dominated samples. The study concluded that raw sewage inflows have decreased species richness dramatically in the estuary.

Various other studies have been done in the Tijuana Estuary, but were not included in this discussion as they focus on specific species and orders of invertebrates or focused on only one type of habitat within the estuary.

5.8 Comparisons with the Santa Clara River Estuary

Southern California estuaries exhibit a wide range of hydrologic conditions due to seasonal freshwater inflows and varying mouth conditions. Like most rivers in the Southern California Bight, stream flow in the Santa Clara River varies significantly on a seasonal basis. In general, rainfall occurs during late winter and early spring, often resulting in rapid and large runoff peaks, followed by equally rapid decreases in runoff. During the summer and fall seasons, stream flow typically ceases altogether, due primarily to low runoff and upstream irrigation diversions.

However, the Santa Clara River Estuary is unique in comparison to other estuaries in the Bight due to the consistent freshwater inflow it receives from the Ventura Water Reclamation Facility (VWRF) on a year-round basis. While there are also wastewater flows into the Tijuana and Malibu Estuaries, these flows vary seasonally. In addition, the flows into Tijuana Estuary are unregulated and untreated. The San Dieguito River and Los Penasquitos Creek have more significant flows than the SCRE, but have much wider seasonal variations than the combined inflows of the Santa Clara River and the VWRF.

Another major factor affecting hydrologic conditions within Southern California estuaries is the status of their opening to the sea. These estuaries typically have a sand spit at their opening that is open or closed for varying periods of time, depending on annual and seasonal stream runoff patterns. Mouth conditions can vary dramatically geographically and temporally between and within these estuaries. All of the estuaries examined in this report, with the exception of the Santa Clara River Estuary, have been dredged on several occasions due to water quality concerns. Tijuana Estuary and Malibu Lagoon, in particular, have been dredged frequently for many years, helping to resume regular tidal flushing.

Although the mouth conditions of the Santa Clara River Estuary are similar to that of San Dieguito Lagoon, the SCRE does not exhibit the hypersaline conditions that San Dieguito experiences during the periods when the mouth is closed and freshwater inflows are low (MEC Baseline Study 1993). Los Penasquitos, like the SCRE, also has remained closed for longer periods of time, but shows much larger fluctuations in salinity than have been found in the Santa Clara River Estuary (Boland 1991, 1992, 1993). Mugu Lagoon is the least similar to the Santa Clara River Estuary in hydrology and salinity as it has very sporadic seasonal freshwater inflows, remains open most of the year, and is classified as primarily marine (Onuf 1987).

Although there is wide variation in the physical and chemical conditions of the estuaries reviewed herein, their benthic macroinvertebrate assemblages have many similarities (see Table 5.1). In contrast, comparisons of species found in the SCRE with those found in other estuaries in the Bight yield few similarities. One exception is the 1993 study of the San Dieguito Lagoon. The SCRE shared one species in common each with Los Penasquitos, Mugu, Tijuana, and Batiquitos Lagoons. These species are *Trichorixa reticulata*, *Hyalella azteca*, and *Physa sp*., all of which are known to tolerate wide ranges in salinity (Figure 4.15). In addition to *Physa sp*. and *Hyalella azteca*, eight other families were found in both the 1993 San Dieguito study and in the SCRE sampling events. In the San Dieguito study, details as to the distribution of four of these families were evaluated. Chironomidae and Corixidae species were primarily found in brackish habitat, Hydrophilidae were found in brackish and inner channel habitats during closed conditions, and Ephydridae was found in the inner channel in closed conditions.

In general, the other estuaries, including San Dieguito, had fewer oligochaetes, more polychaetes, and more decapod and isopod crustaceans than the Santa Clara River Estuary. The SCRE had more insect larvae, tubificid worms and daphnia than the other estuaries. Anthozoans and echinoderms were not found in the SCRE during either the USFWS or current studies. In addition, bivalves were present in every study except both the USFWS and the current study of the SCRE. Ostracods were absent from all of the estuaries except the San Dieguito Lagoon, Batiquitos Lagoon and the SCRE. The following list summarizes the key similarities and differences between the major components of the benthic invertebrate communities of the Santa Clara River Estuary, San Dieguito Lagoon, and the other estuaries reviewed herein.

Taxa List	**General Group**	**SCRE**	**San Dieguito**	**Others**
Diadumene leucolena	Anthozoa		X	
Nemertea	Nemertea		X	X
Cryptomoya californica	Bivalve		X	X
Tagelus californianus	Bivalve		X	X
Macoma nasuta	Bivalve		X	X
Protothaca staminea	Bivalve			X
Physa sp.	Gastropod	X	X	X
Pomatiopsis californica	Gastropod	X		
Bulla gouldiana	Gastropod			X
Assiminea californica	Gastropod			X
Cerithidea californica	Gastropod		X	X
Tubificidae	Oligochaete	X		
Microphthalmus sp.	Polychaete	X		
Saccorus sp.	Polychaete	X		
Nereis sp.	Polychaete			X
Polydora ligni	Polychaete		X	X
Polydora nuchalis	Polychaete		X	X
Streblospio benedicti	Polychaete		X	X
Capitella capitata	Polychaete		X	X
Notomastus tenuis	Polychaete			X
Axiothella rubrocinta	Polychaete		X	X
Chironomidae	Insecta	X	X	
Corixidae	Insecta	X	X	X
Corophium sp.	Crustacea		X	X
Eogammarus sp.	Crustacea	X		
Hyallela azteca	Crustacea	X	X	
Grandidierella japonica	Crustacea		X	X
Callianassa californiensis	Crustacea			X
Hemigrapsus oregonensis	Crustacea			X

Pachygrapsus crassipes	Crustacea			X
Daphnia	Crustacea	X		
Ostracoda	Crustacea	X	X	X
Dendraster excentricus	Echinodermata			X

Typically, estuarine communities are well represented by Crustacea, Mollusca (bivalves and gastropods), and Polychaeta (Kennish 1986). Antozoans, hydrozoans, and Echinodermata are also often present. The overall presence of gastropods, bivalves, Polychaeta, Crustacea, and Echinodermata in the other estuaries examined are indicative of the typical estuarine communities described by Kennish (1986). In contrast, the lack of bivalves, low numbers of Polychaeta and Echinodermata, as well as the large presence of ostracods, set the benthic community of the SCRE apart from the benthic communities of the other estuaries examined.

6.0
COMPARISON OF SANTA CLARA RIVER INVERTEBRATES TO THOSE USED BY EPA IN ESTABLISHING AMBIENT WATER QUALITY CRITERIA

As discussed in Section 2.0, the current NPDES permit limits for the VWRF are the more stringent effluent limits for priority pollutants established using water quality objectives that are protective of saltwater aquatic life. Based on the conclusions of the recently completed Metals Translator Study (ENTRIX 2002), copper is likely to be the most difficult compound to address from a compliance perspective. The Metals Translator Study found that copper concentrations in the Estuary exceeded both the daily and monthly permit limits at all stations. The other metals studied (nickel, lead and zinc) infrequently exceeded the permit limits. Thus, copper was identified as the main regulatory driver in this system.

The species composition of the resident benthic community in the SCRE has been determined in Section 4.0, and the salinity tolerance of many of these species has been derived from the literature. In order to provide a recommendation on the appropriate criteria (either freshwater or saltwater) to apply as a permit limit for copper and other metals, the species composition and salinity tolerance of the SCRE benthos is compared to that used by the EPA in establishing the ambient water quality criteria. This comparison is the most direct way to make use of the species composition data.

This section describes the methodology used by the EPA in developing the copper limit. The section concludes with a comparison of the species identified in the estuary to those used by the EPA in developing the water quality criteria for copper.

6.1 OVERVIEW OF THE AMBIENT WATER QUALITY CRITERIA METHOD

The objective of ambient water quality criteria (AWQC) is to develop standards that are protective of an aquatic community, either fresh or saltwater. Protectiveness is defined as protecting at least 95% of the species found in that community. To develop such protective values, two things must be done: (1) identify surrogate laboratory species that represent the community of interest, and (2) conduct laboratory toxicity tests with the compound of interest to develop protective standards.

US EPA (1994) provides guidance on how numerical water quality criteria for aquatic life are to be developed. If sufficient toxicological data are available, criteria are developed for both acute and chronic exposures. For freshwater organisms, the following tests are required with at least one species in 8 different families from each category as follows (from US EPA 1994):

Acute	Acute-Chronic Ratios
• The family Salmonidae in the class Osteichthyes	• At least one fish
• A second family in the class Osteichthyes, preferably a commercial or recreationally important species	• At least one invertebrate
• A third family in the Phylum Chordata (may be a fish or amphibian)	• At least one acutely sensitive freshwater species
• A planktonic crustacean such as a cladoceran or copepod	
• A benthic crustacean (ostracod, isopod, amphipod, crayfish etc.)	
• An insect (mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, midge etc)	
• A family in a phylum other than Arthropoda or Chordata, such as Rotifera, Annelida or Mullusca	
• A family in any order of insect or any other phylum not already represented.	

Additionally, the results of a test from at least one freshwater alga or vascular plant and an acceptable bioconcentration factor with an appropriate freshwater species is required.

For saltwater organisms, at least one species from 8 different families as outlined below are required (from US EPA 1994):

Acute	Acute-Chronic Ratios
• Two families in the Phylum Chordata	• At least one fish
• A family in a phylum other than Arthropoda or Chordata	• At least one invertebrate
• Either the Mysidae or the Penaeidae family	• At least one acutely sensitive saltwater species
• Three other families not in the family Chordata (may included Mysidae or Penaeidae, whichever was not used previously)	
• Any other family	

Additionally, the results of a test from at least one saltwater alga or vascular plant and an acceptable bioconcentration factor with an appropriate saltwater species is required.

The final acute value (or short-term toxicity) is estimated by statistically evaluating the dataset (freshwater and saltwater separately) and choosing a concentration corresponding to a cumulative probability of 0.05. This results in a value that is protective of 95% of the species tested. A chronic value, depending on the dataset, can be developed as described for the acute value or can be developed by dividing the acute value by an acute-chronic ratio. In either case, it is meant to also be protective of 95% of the species tested.

To develop these criteria, the criterion maximum concentration (CMC) is defined as one-half the final acute value and the criterion continuous concentration (CCC) is set equal to the lowest of the final chronic value, the final plant value or the final residue value (based on the bioconcentration tests).

6.2 EPA Basis for Development of the Copper Ambient Water Quality Criteria

Copper ambient water quality criteria (AWQC) are currently under revision (Federal Register 1999). Table 6-1 lists the species tested by the US EPA to develop fresh and saltwater AWQC. The following subsections summarize the fresh and saltwater standards.

6.2.1 Copper Freshwater Criteria

This review of the freshwater criteria for copper is based on the existing criteria document (US EPA 1995). Genus mean acute values for copper toxicity ranges from 9.92 µg/L for the cladoceran *Ceriodaphnia reticulata* to 10,240 µg/L for the stonefly *Acroneuria lycorias* (US EPA 1995; Table 6-1). Some of the same taxa identified in the Estuary were used as test species including: physid snails, *Daphnia*, gammarid amphipods and chironomids.

Based on these data, a freshwater final acute value was obtained for copper of 14.57 µg/L at a hardness of 50mg/L. This value was based on the 4 lowest acute values for three species of *Daphnia* and for *Ceriodaphnia reticulata*. The CMC of 7.285 µg/L at 50 mg/L hardness was based on dividing the final acute value by 2. The California Toxics Rule (CTR) (Federal Register 2000) bases the California freshwater CMC for copper (13 µg/L) on the US EPA (1995) dataset but assumes a hardness of 100 mg/L and expresses the value as a dissolved concentration.

Insufficient data were available to develop a freshwater chronic copper value using the 8 species procedure (US EPA 1995). Therefore, the US EPA calculated a final chronic value by dividing the final acute value discussed above by an acute-chronic ratio. Thus, the final chronic value of 5.16 µg/L at 50 mg/L hardness was chosen also as the CCC and was based on the same toxicity database discussed above for the acute value. As with the CMC, the CTR CCC is based on the EPA value using a hardness of 100 mg/L and expressing the value as a dissolved concentration.

6.2.2 Overview of the Copper Saltwater Criteria

The current criteria document for copper saltwater criteria is US EPA (1985). Genus mean acute values for saltwater toxicity ranged from 5.8 µg/l in blue mussel embryos to 7,694 µg/L in the clam *Rangia cuneata* (Table 6-1). None of the species tested in the saltwater dataset are taxa that have been observed at the Santa Clara River Estuary. The saltwater final acute value was set at 5.83 µg/L, and the CMC was set at one half this value or 2.91 µg/L. The saltwater CCC as defined by the CTR for copper (4.8 µg/L) is based on the same EPA dataset and is expressed as a dissolved concentration. In saltwater, no hardness factor is applied.

Very little chronic saltwater data are available. Therefore, the EPA set the final chronic value at 2.91 µg/L which corresponds to the EPA CMC discussed in the preceding paragraph. The saltwater CCC defined by the CTR is based on this EPA dataset and is defined as 3.1 µg/L expressed as a dissolved concentration.

6.3 Selection of Ambient Water Quality Criteria for the Santa Clara River Estuary

To select appropriate AWQC for the SCRE, the following criteria should be used (as discussed in the CTR). First the salinity of the water body should dictate whether the fresh or saltwater value should apply. If the receiving water body is less than 1 ppt, 95% of the time, the freshwater standard applies. Conversely, if the receiving water body is greater than 10 ppt, 95% of the time, the saltwater standards applies. The zone between 1 and 10 ppt is a gray area, where either the more stringent of the two values is applied or other parameters are used to evaluate applicability of the criteria.

In the case of salinity values between 1 and 10 ppt dominate, the CTR recommends that the species composition be used to determine the appropriate criteria. In applying this information, one of the most important of these parameters is the similarity in community composition between the toxicity test species used to develop the AWQC and the receiving water body. Because the AWQC are meant to protect 95% of the species in a particular community, one must be assured that similar communities are being compared. In order to evaluate community similarity, two factors were evaluated: salinity tolerances of the test species and taxonomic overlap. Each is described in the following:

6.3.1 Similarity in Salinity Tolerances

The salinity tolerances of the toxicity test species were compared with the taxa identified in the SCRE. While salinity tolerances on all species were not available, those that could be found were plotted on the salinity tolerance Figure 6.1. The complete results of the literature review can be found in Appendix D. As shown on Figure 6.1 and Figure 6.2, salinity tolerances of species from the freshwater toxicity dataset more closely match the salinity tolerances of the taxa from the SCRE than the tolerances from the saltwater toxicity dataset. Among the species on the saltwater list whose salinity tolerances were known, half are marine organisms intolerant of brackish conditions and the other half are brackish, euryhaline, or marine organisms tolerant of brackish conditions. Both the SCRE species, as well as the species on the freshwater list are primarily freshwater species tolerant of brackish conditions or euryhaline species. The salinity tolerances of the species in the freshwater toxicity dataset, therefore, more closely reflect the tolerances of the SCRE species.

6.3.2 Taxonomic Overlap

Based on the review of the copper CMC and CCC, the freshwater criteria were developed using more taxonomically similar species to those found in the SCRE than the saltwater toxicity dataset. Table 6-1 shows the overlaps at the species, genus, and family level of the species found in the SCRE and the species on the freshwater and saltwater toxicity datasets. As shown in this table, six species from the freshwater toxicity dataset overlap with those found in the estuary at the genus level (Physa, Daphnia, Gammarus, and Chironomus), and 1 species overlaps at the family level (Lumbriculidae). There is a 25% overlap between the EPA test species used to establish the freshwater copper criteria with those actually found in the SCRE. In addition, the most sensitive species found in the Estuary, *Daphnia Magna* is protected by the freshwater ambient water quality criterion. Conversely, there are no overlaps between the EPA's saltwater toxicity species and the species found in the SCRE at the species, genus, or family level. Thus, from a taxonomic perspective, the freshwater AWQC dataset for copper is more applicable to the ecological community found in the SCRE than the saltwater values.

Taken together, the comparison of the SCRE taxa with those used to establish the copper standards indicate that the freshwater criteria are the appropriate set. The freshwater species used to establish the copper criteria overlap those found in the SCRE, while there is no taxonomic overlap with the saltwater species. Salinity tolerances are similar for the freshwater test species and those in the SCRE, but dissimilar to those in the saltwater test species.

Estuaries are a highly unstable physical, chemical, and biological environments, and do not fit neatly into freshwater or saltwater categories. The SCRE is no exception, but it is unique among southern California estuaries owing to the constant freshwater influx from the VWRF. This anthropogenic benefit in part counteracts the anthropogenic detriments of upstream diversions and pumping, which would otherwise dewater the estuary for much of the year.

7.1 BENEFITS OF CONTINUING DISCHARGE

In the 1995 NPDES permit, the Regional Board states:

> *"…concurred with the findings in the [1978] facilities plan that [the facility's] discharge is not degrading the beneficial uses of the Estuary, and in fact, some of the beneficial uses, such as fish and wildlife habitat and non-contact water recreation, are enhanced by the presence of the discharge."*

The Phase 3 Study (ENTRIX 1999) summarized numerous consultations with local biological specialists. The consensus was that the SCRE supports a wide diversity of avian wildlife, including a number of rare, endangered and threatened species. It provides a wintering ground and flyway for migrating birds. The SCRE was recognized as an ecosystem that is becoming rarer in Southern California where urban development is impacting the river and wetland systems that remain. Discharge from the City's outfall increases the water in this system, thereby increasing the habitat for this avian community.

The SCRE is also a critical waterway for migrating steelhead. Under direction of the National Marine Fisheries Service (NMFS), United Water Conservation District rescues (traps and transports) downstream migrating rainbow trout/steelhead smolts captured in the Vern Freeman Diversion. These fish are released in the Santa Clara River Estuary (ENTRIX, 1996, pers. comm. 1999). Treated effluent from the City's facility augments water in the lagoon for these rescue efforts, especially during years of low flow.

7.2 INTEGRATION OF RESIDENT SPECIES STUDY RESULTS

This discussion summarizes and integrates the results of the Resident Species Study, and recommends that either the freshwater aquatic standards be applied to the VWRF discharge, or that the criterion be modified to reflect the hardness of the receiving waters.

Comparison of the species used by the EPA to establish the freshwater ambient water quality criteria show an approximate 25% overlap between SCRE species and the test species for copper. Of the six most common taxa found in the SCRE, four were used by the EPA in establishing the freshwater ambient water quality criteria for copper. Most taxonomic overlap between the EPA test species and SCRE species is at the genus level. Furthermore, the most sensitive species found in the estuary (*Daphnia magna*) is protected by the freshwater criteria. There is no taxonomic overlap at the species, genus, or family level between SCRE species and the species used by the EPA to establish the saltwater criteria.

The majority of taxa found in the Estuary were freshwater organisms that are tolerant of brackish conditions. Comparison of the salinity tolerance of species used to establish the ambient water quality criteria show significant overlap between the salinity tolerance ranges of SCRE species and the salinity tolerance ranges of test species for the freshwater criteria (Figure 6.1 and Figure 6.2). In addition, the SCRE is unique among southern California estuaries, which are predominantly estuarine and marine in invertebrate species composition.

7.3 FINAL RECOMMENDATIONS

As supported by the data presented in this report, the City requests that the freshwater criteria apply to the discharge from the VWRF. In an ecosystem with a species composition indicating a tendency to freshwater conditions, such as the SCRE, the hardness of the receiving water can be used to derive a site-specific objective for the metals. Hardness is used as a surrogate for a number of water quality characteristics that affect the toxicity of metals in a variety of ways. Increasing hardness has the effect of decreasing the toxicity of metals (40 CFR 131 E.2.g). Accordingly, it is appropriate for the Regional Board to use the hardness-dependent equations for fresh water metals criteria presented in the CTR to establish site-specific objectives for the SCRE.

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FIGURES

TABLES

FIGURES

Figure 1.1: Map of Southern California Bight Showing Location of the Santa Clara River Estuary.

Figure 1.2: Aerial Photograph of Santa Clara River Estuary Showing Benthic Sampling Stations B1 - B11.

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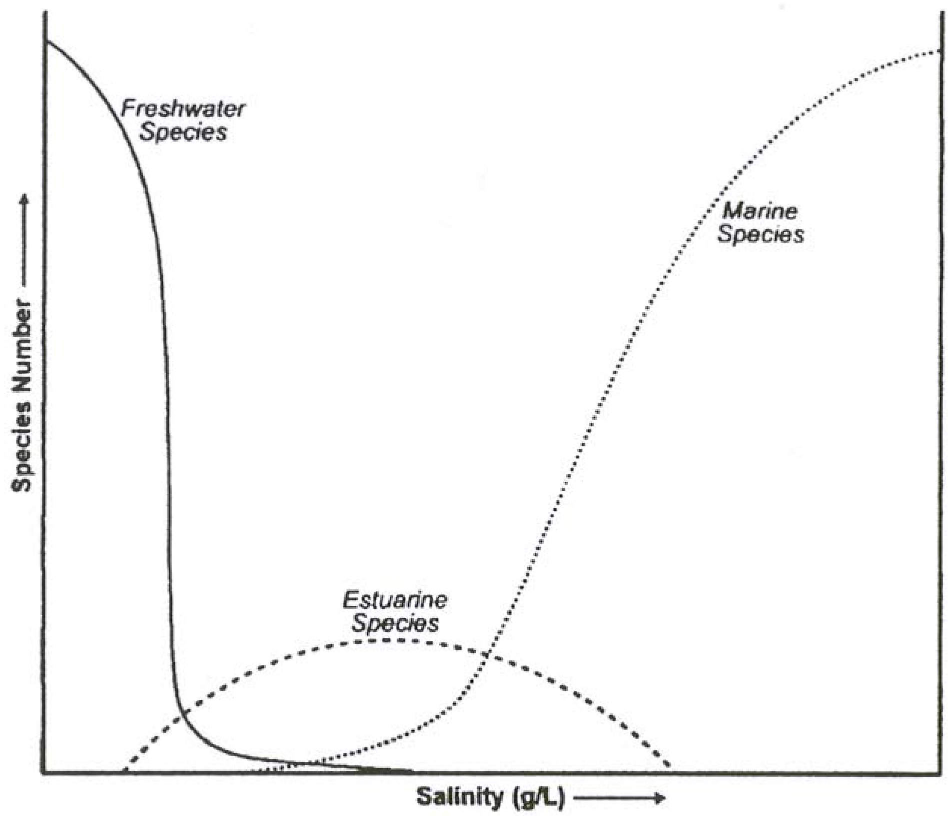


Figure 2.1 Illustration of Remane's [108] "paradox of brackish water." Species numbers and diversity are lower in estuarine than in fresh or marine waters. (Chapman and Wang 2001)

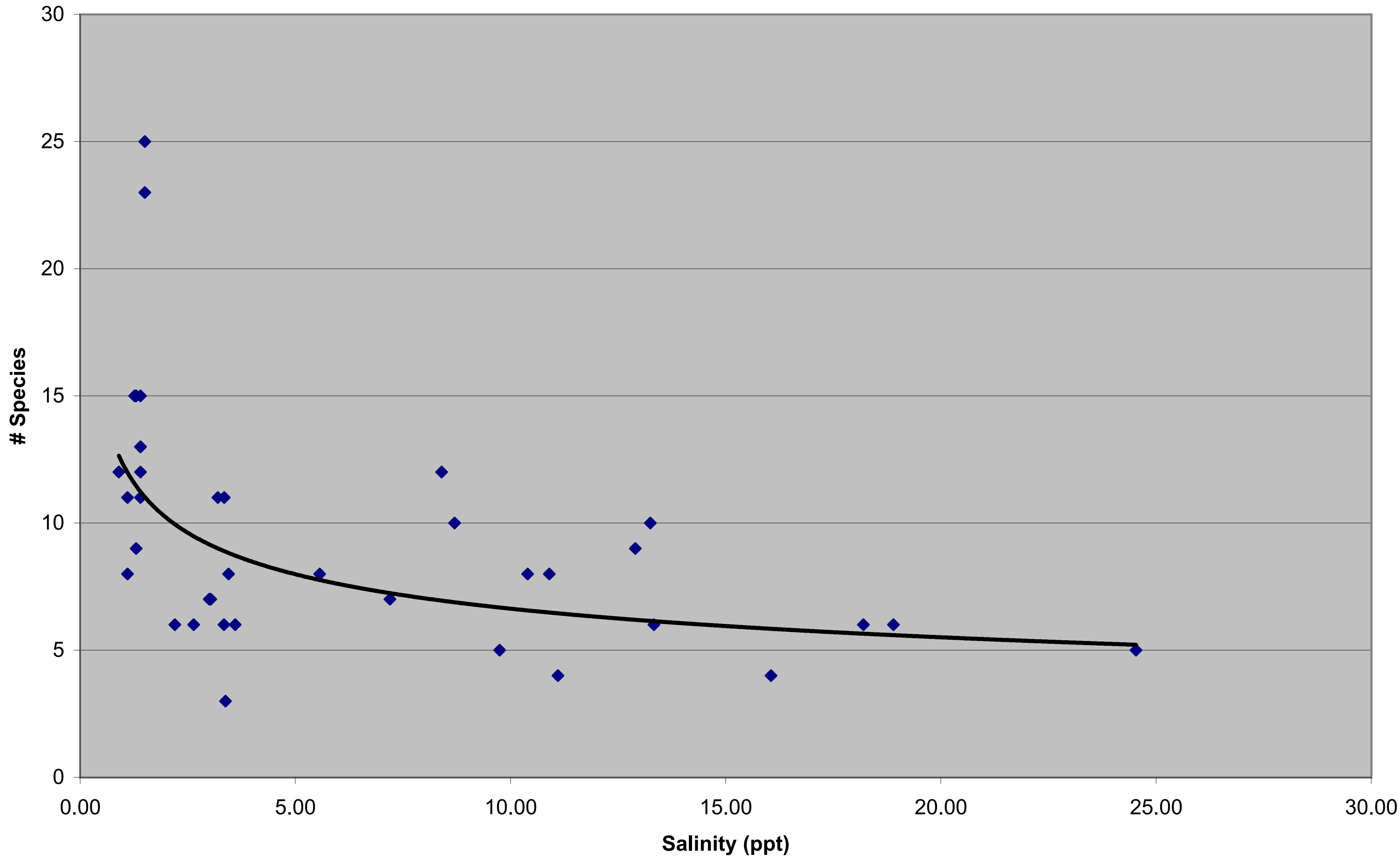


Figure 2.2 Species Richness vs. Salinity in the SCRE

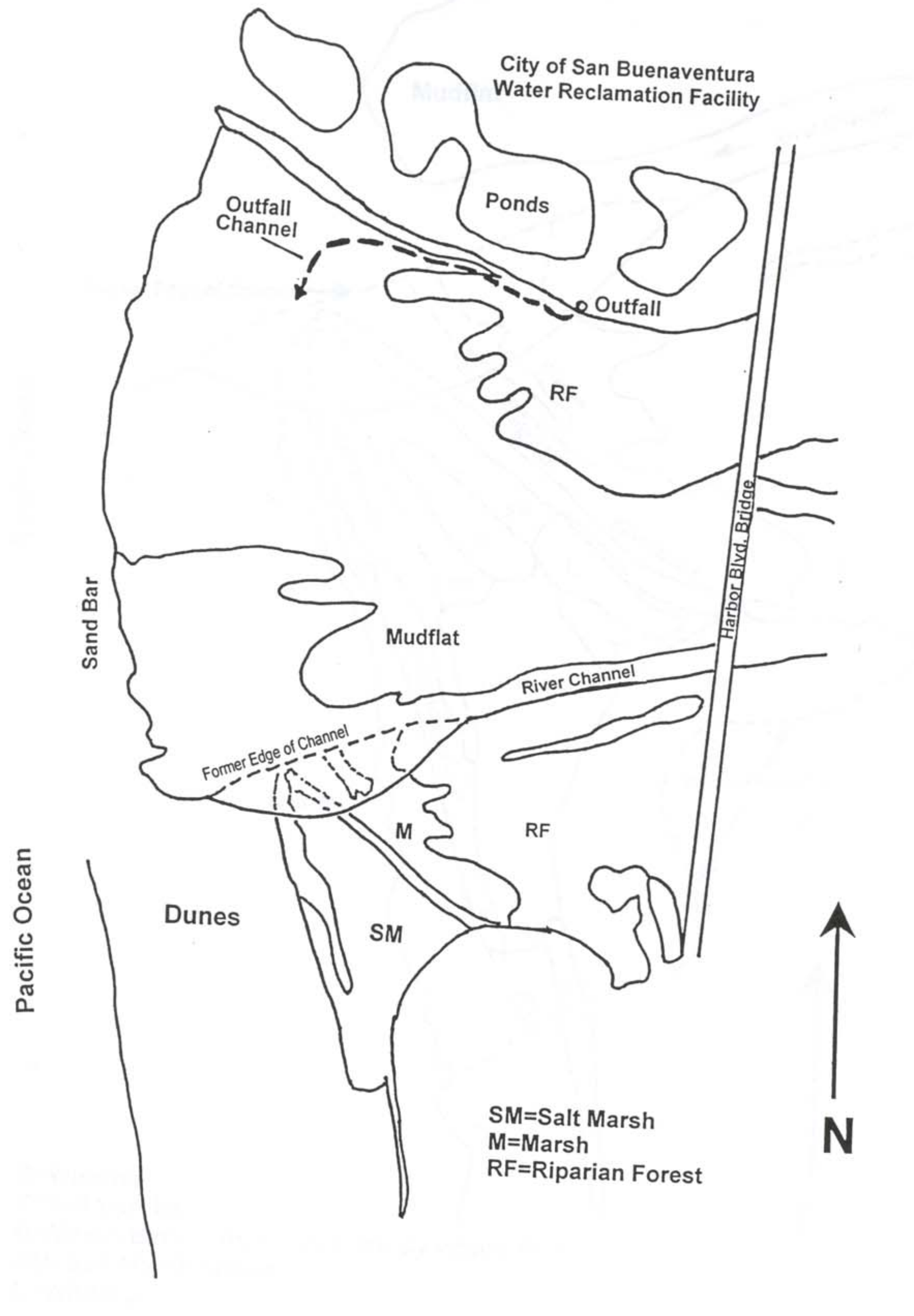


Figure 2.3. Vegetation Map of Santa Clara River Estuary (ENTRIX 1999)

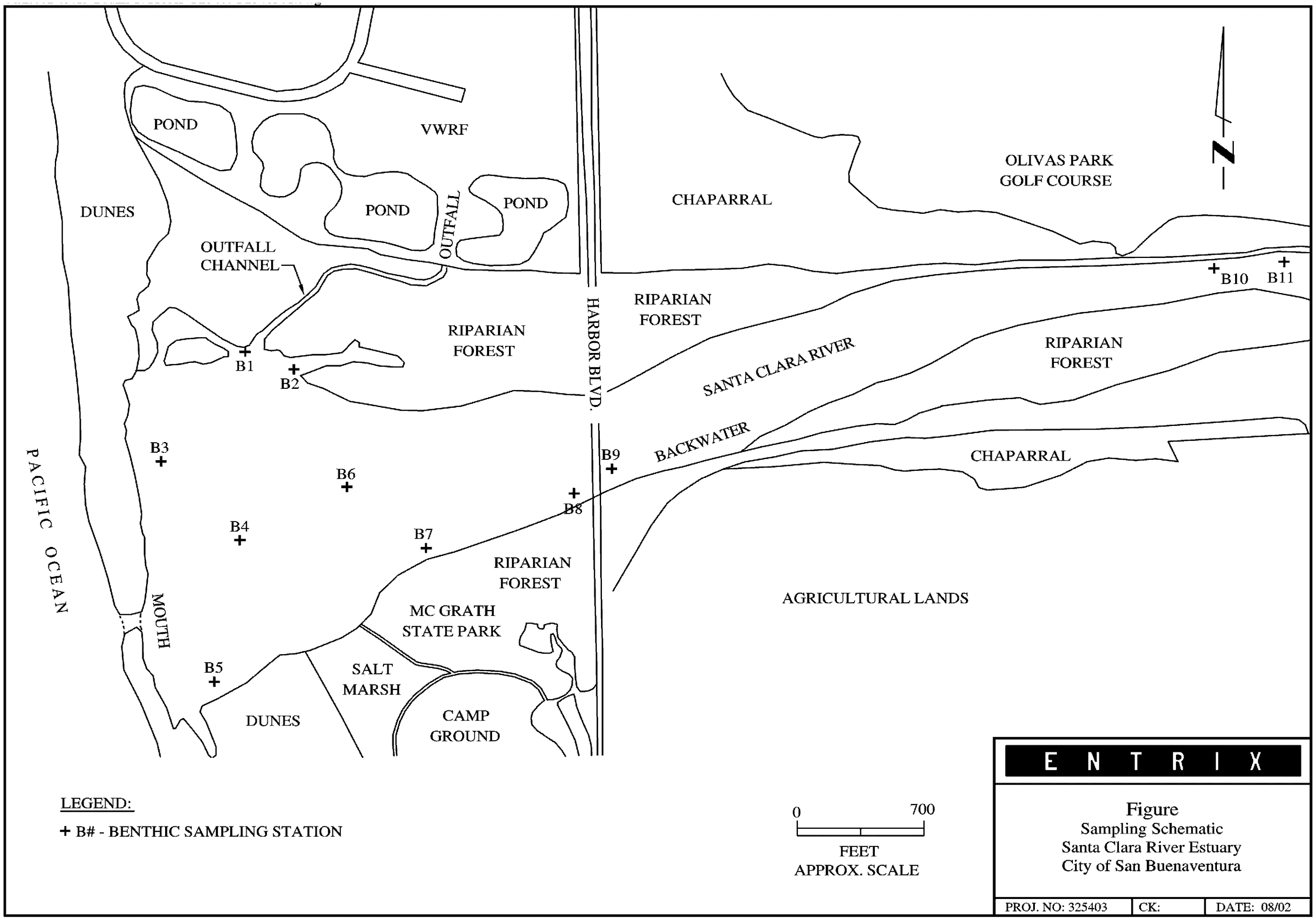


Figure 3.1: Map of Santa Clara River Estuary Showing Benthic Sampling Stations B1-B11.

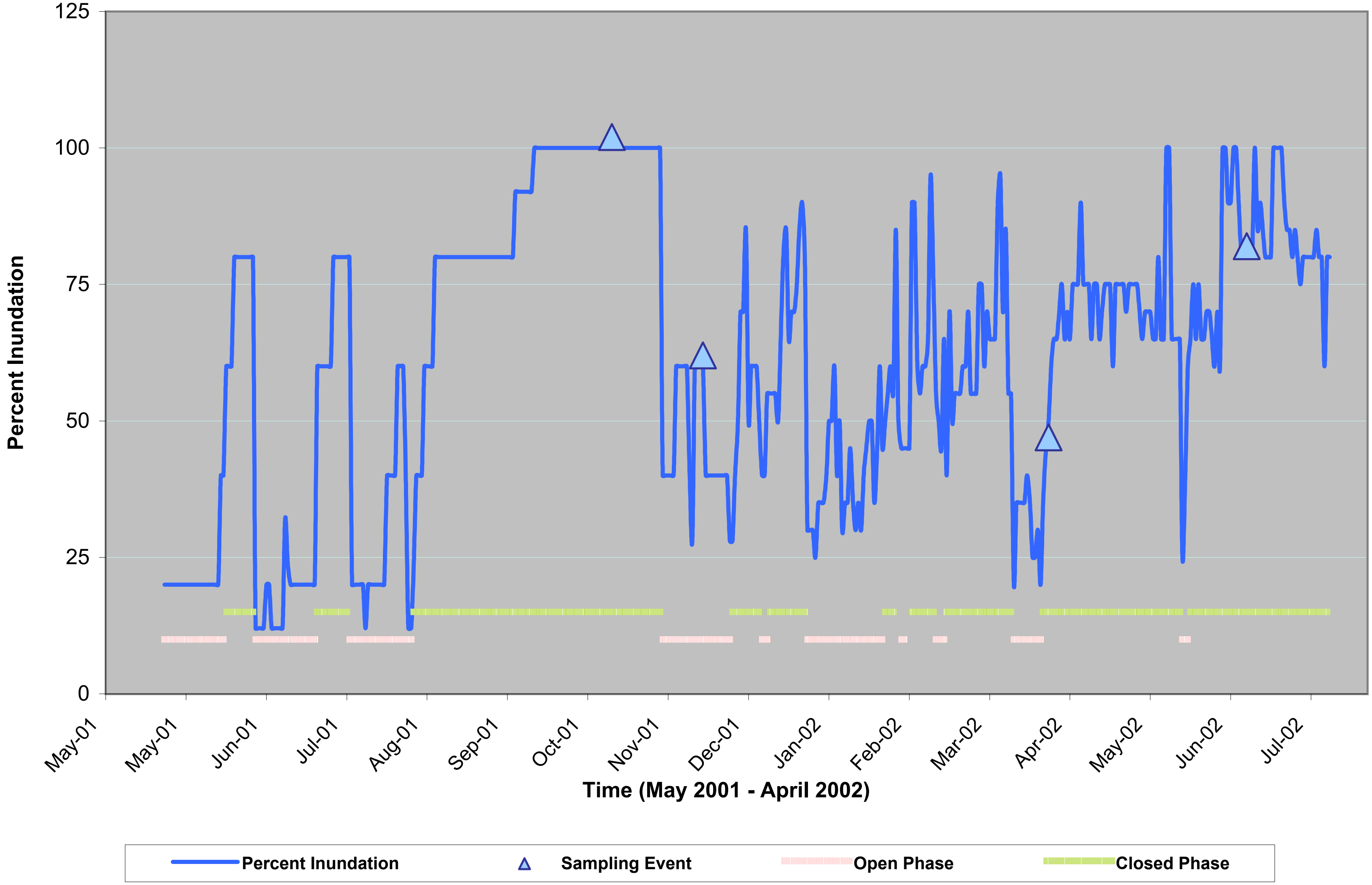


Figure 4.1: Santa Clara River Estuary Hydrodynamics From 5/01 to 7/02

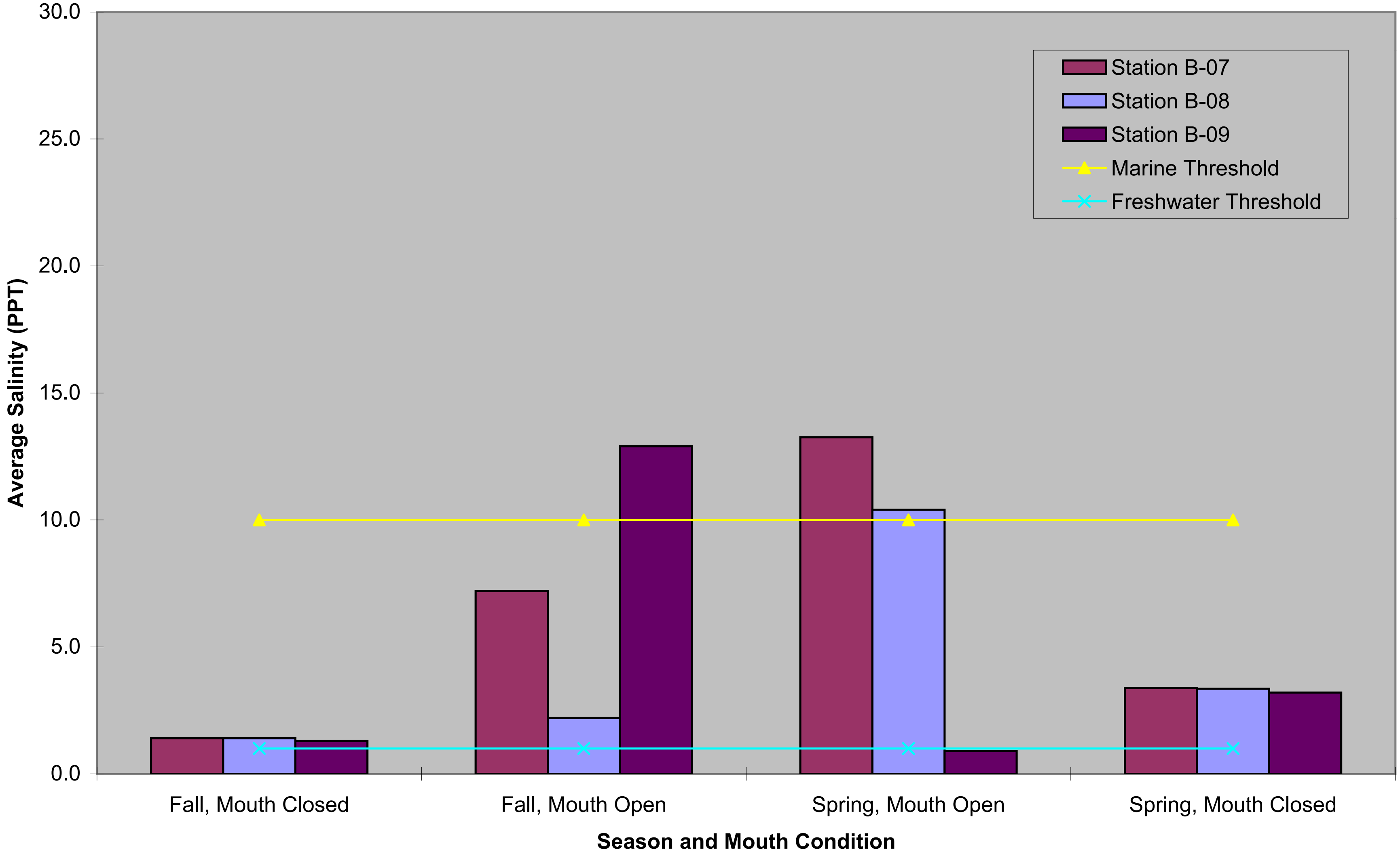


Figure 4.2a: Average Salinity by Season and Mouth Condition for Upper Estuary

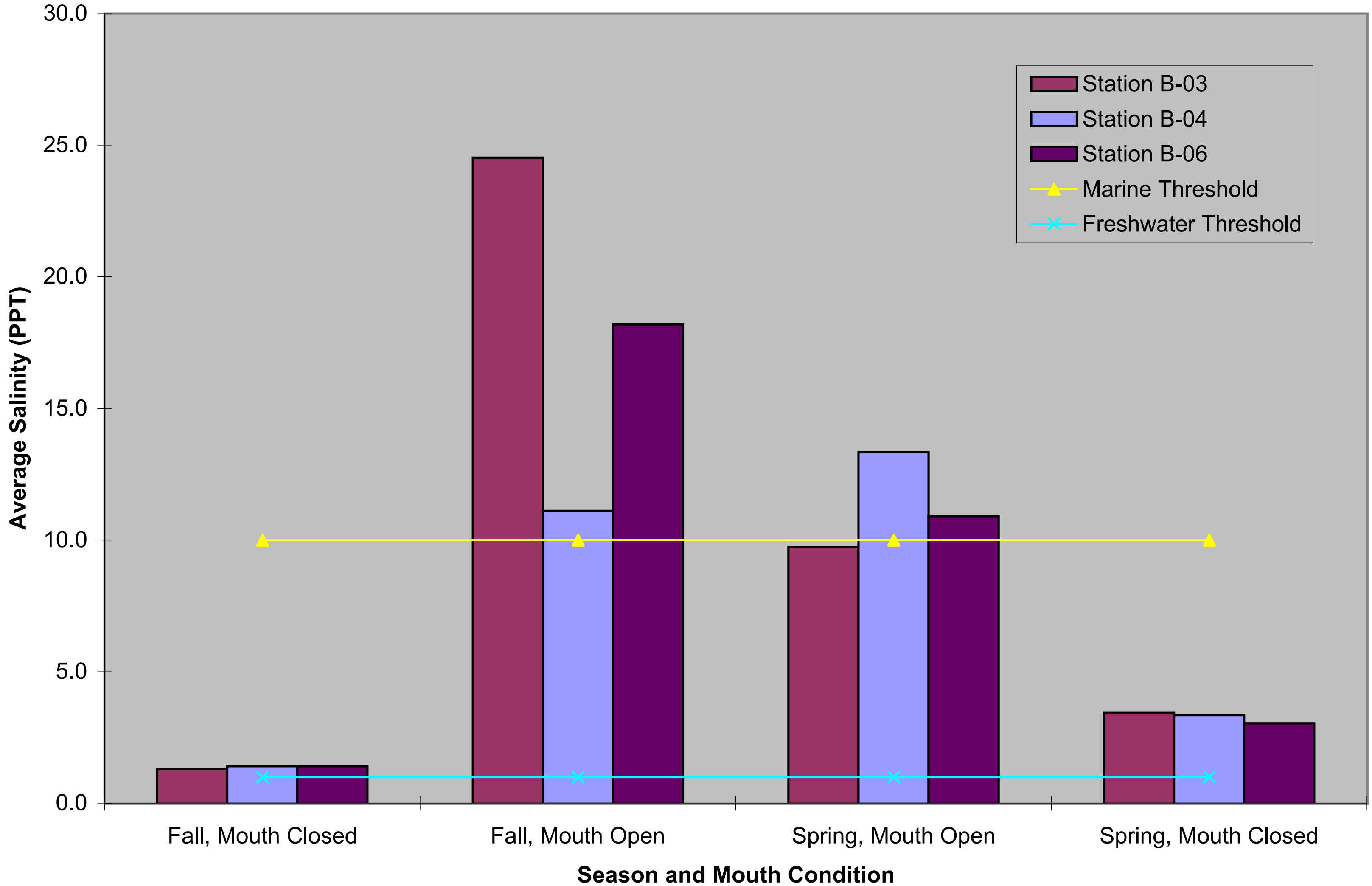


Figure 4.2b: Average Salinity by Season and Mouth Condition for Lower Estuary Region.

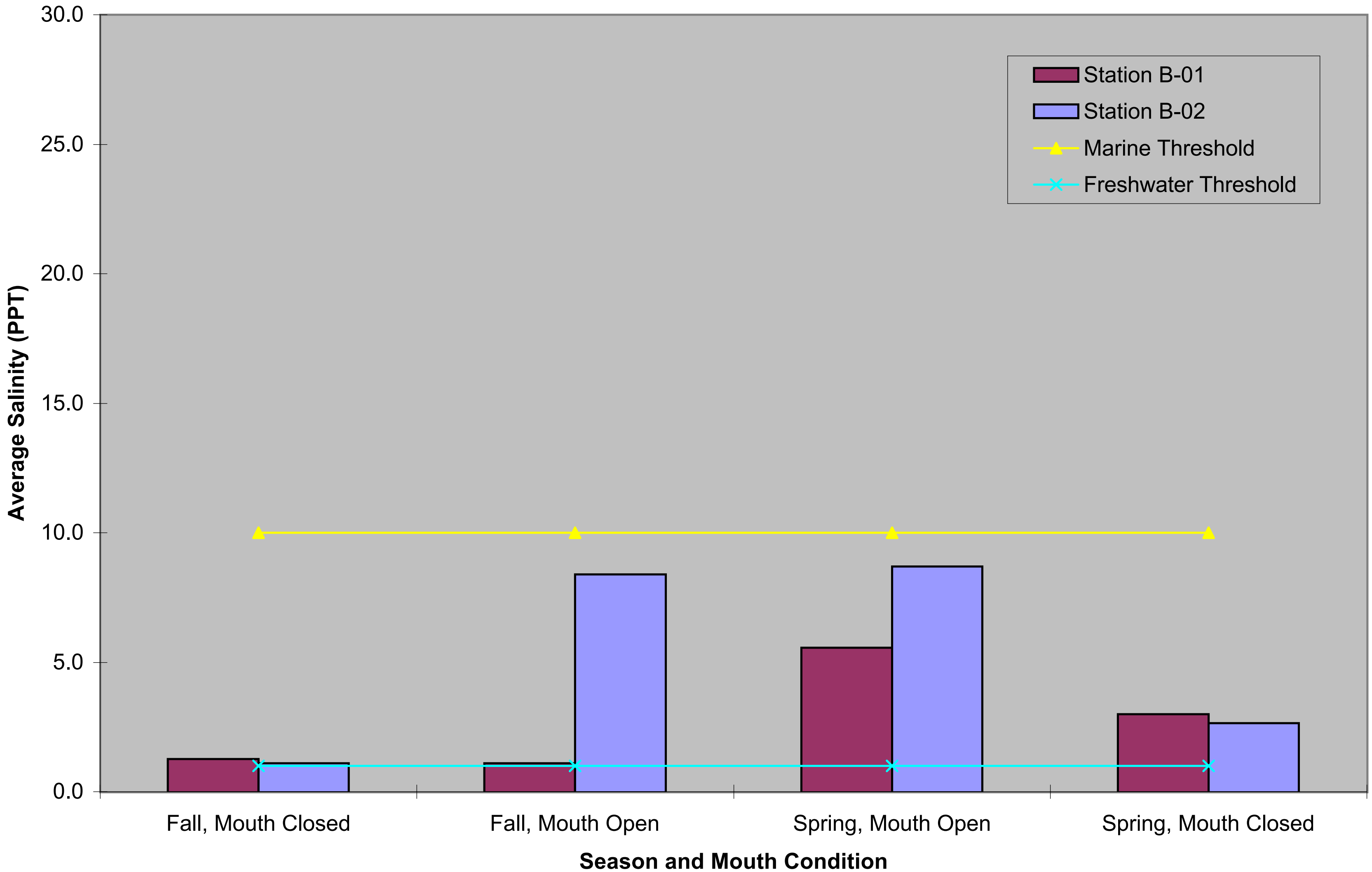


Figure 4.2c: Average Salinity by Season and Mouth Condition for Outfall Region.

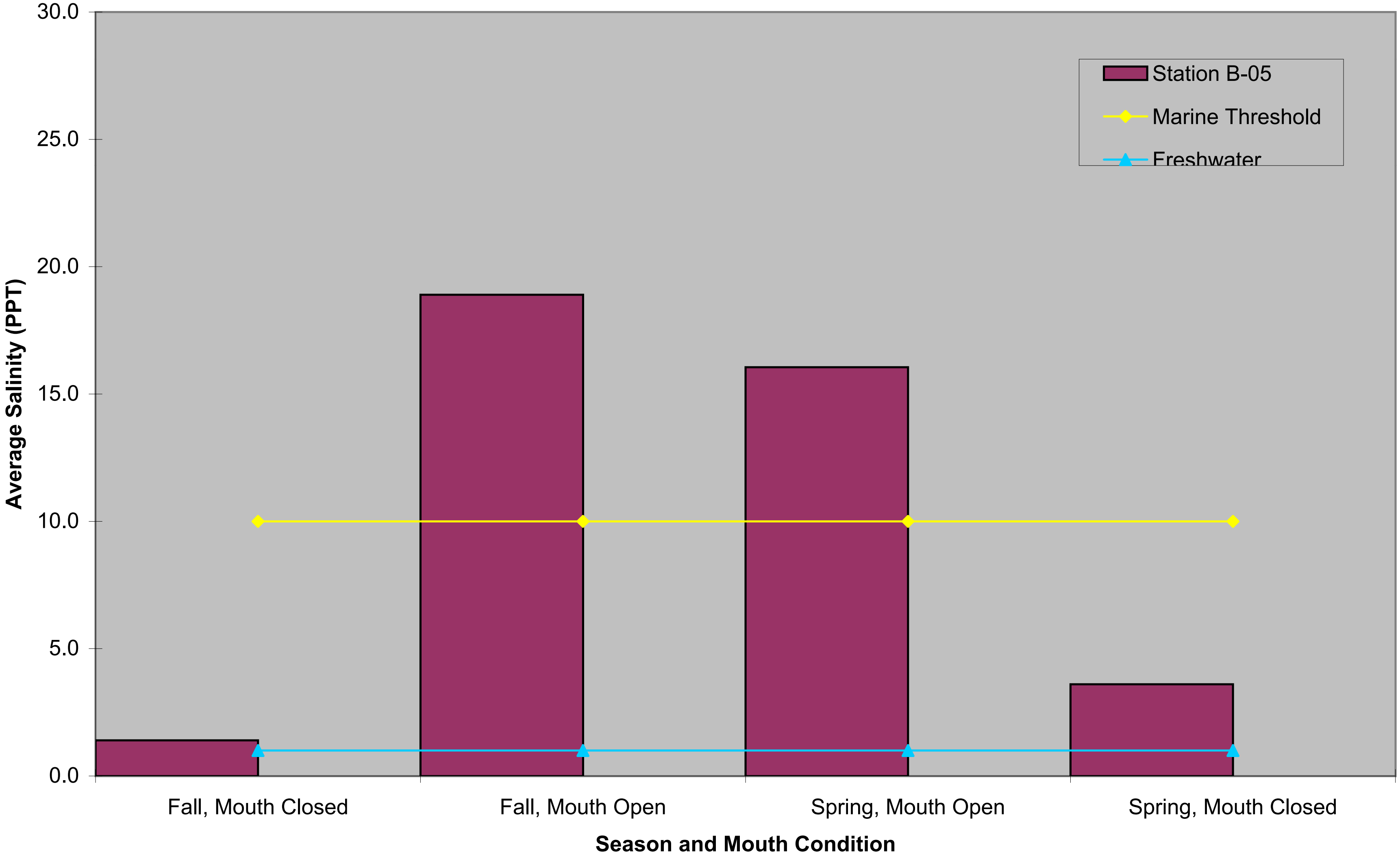


Figure 4.2d: Average Salinity by Season and Mouth Condition for Mouth Region.

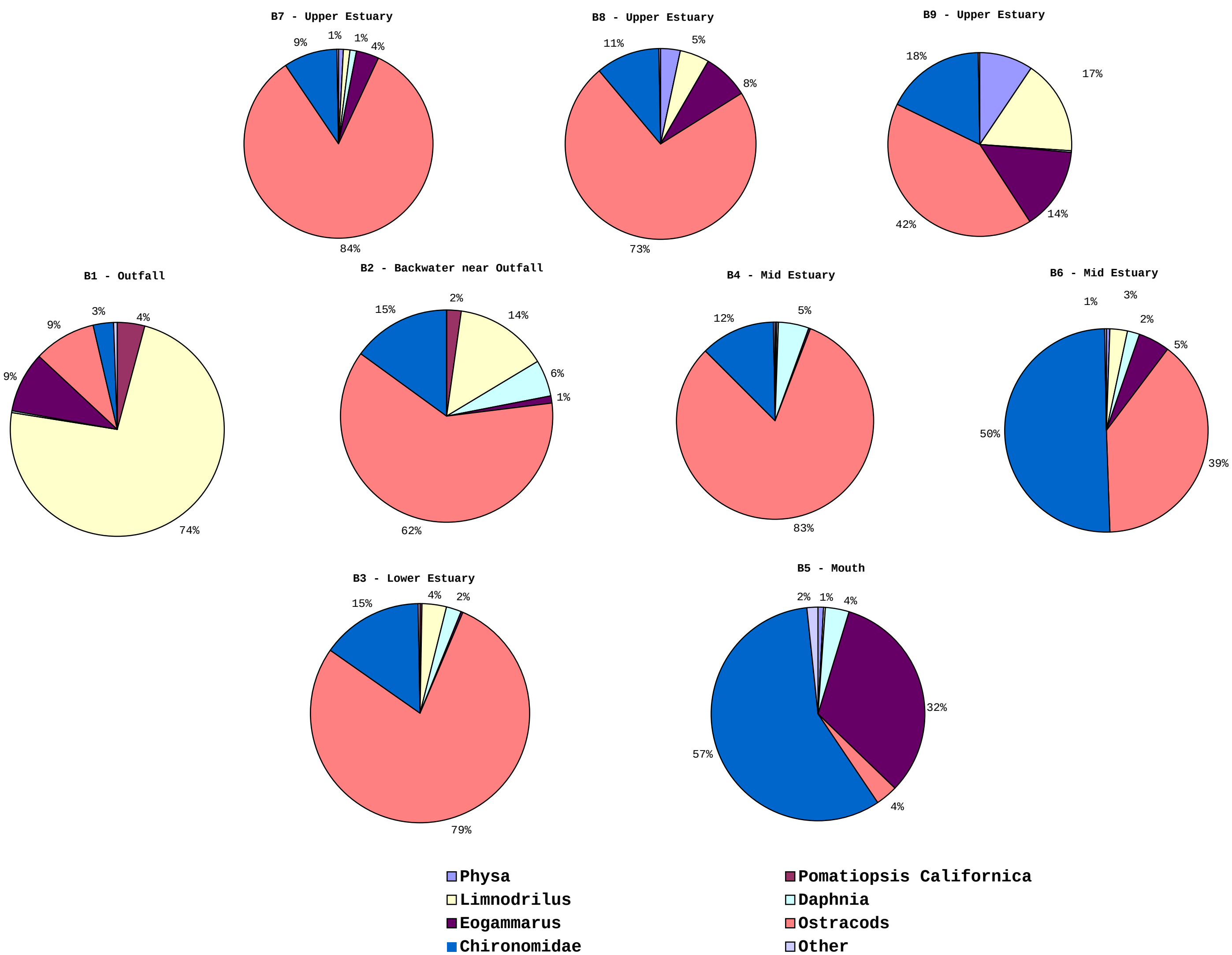


Figure 4.3: Total Species Composition of the Santa Clara River Estuary by Station.

FALL SEASON

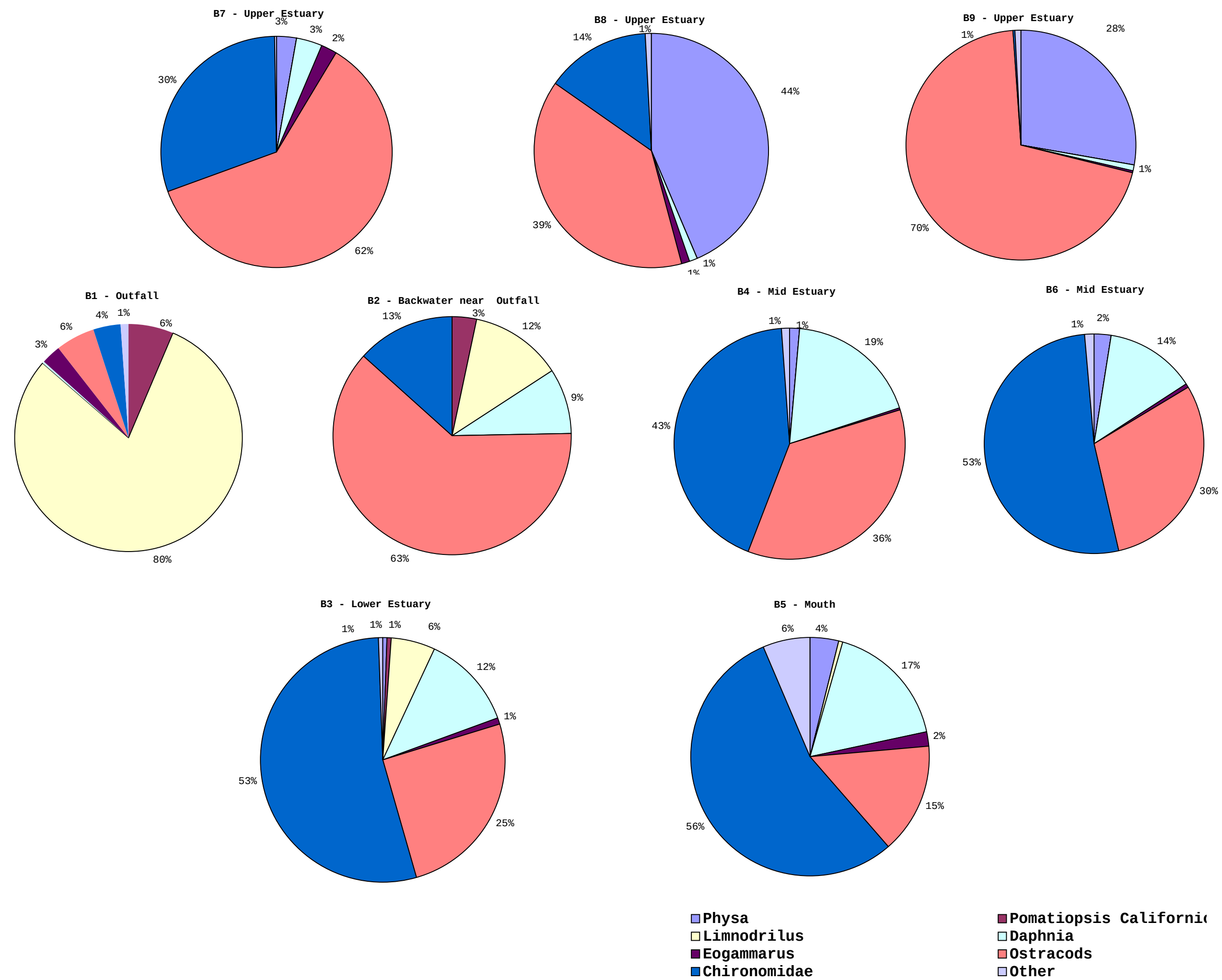


Figure 4.4: Species Composition By Station During Fall Sampling Periods.

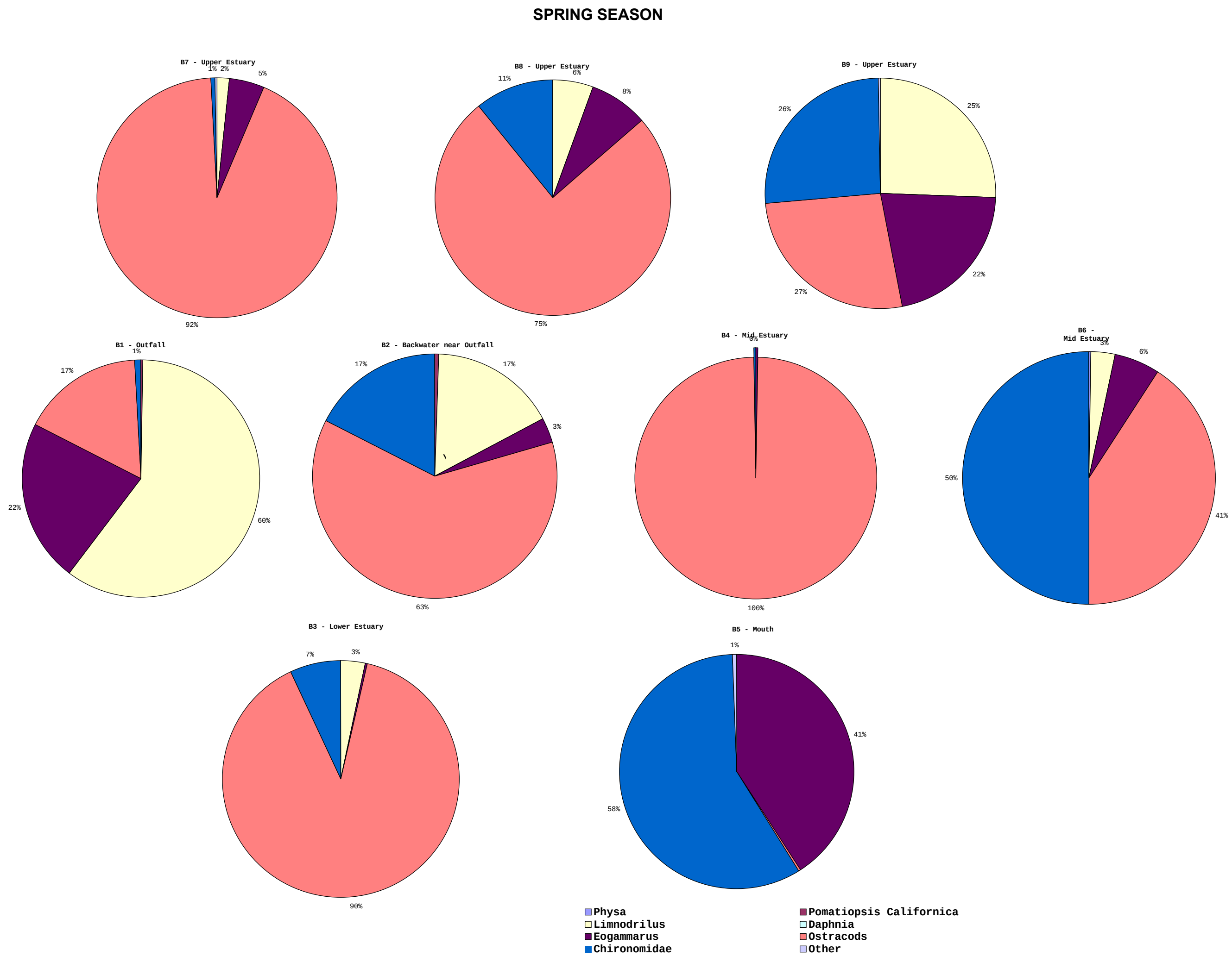


Figure 4.5: Species Composition By Station During Spring Sampling Periods.

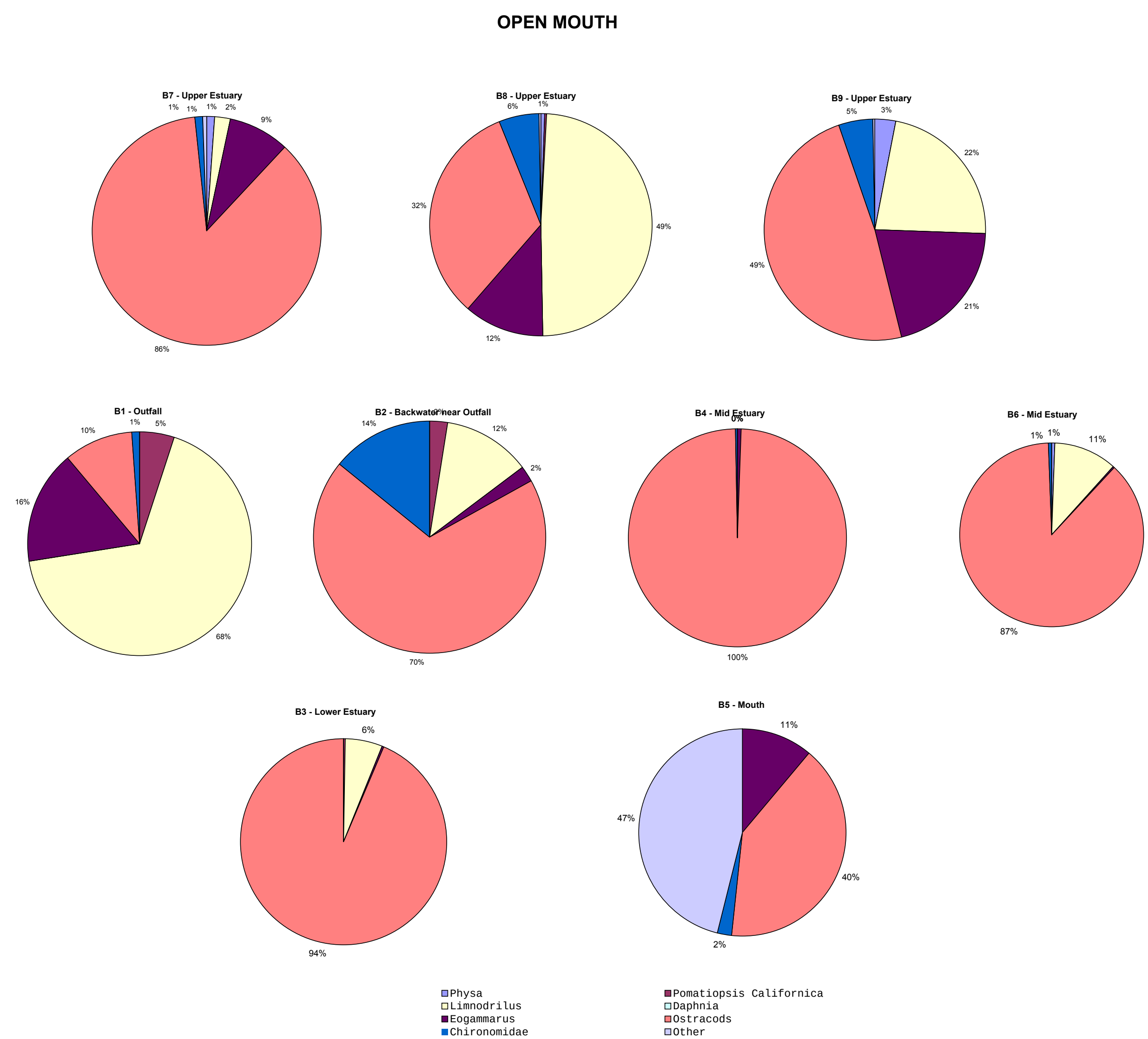


Figure 4.6: Species Composition by Station During Open Mouth Conditions.

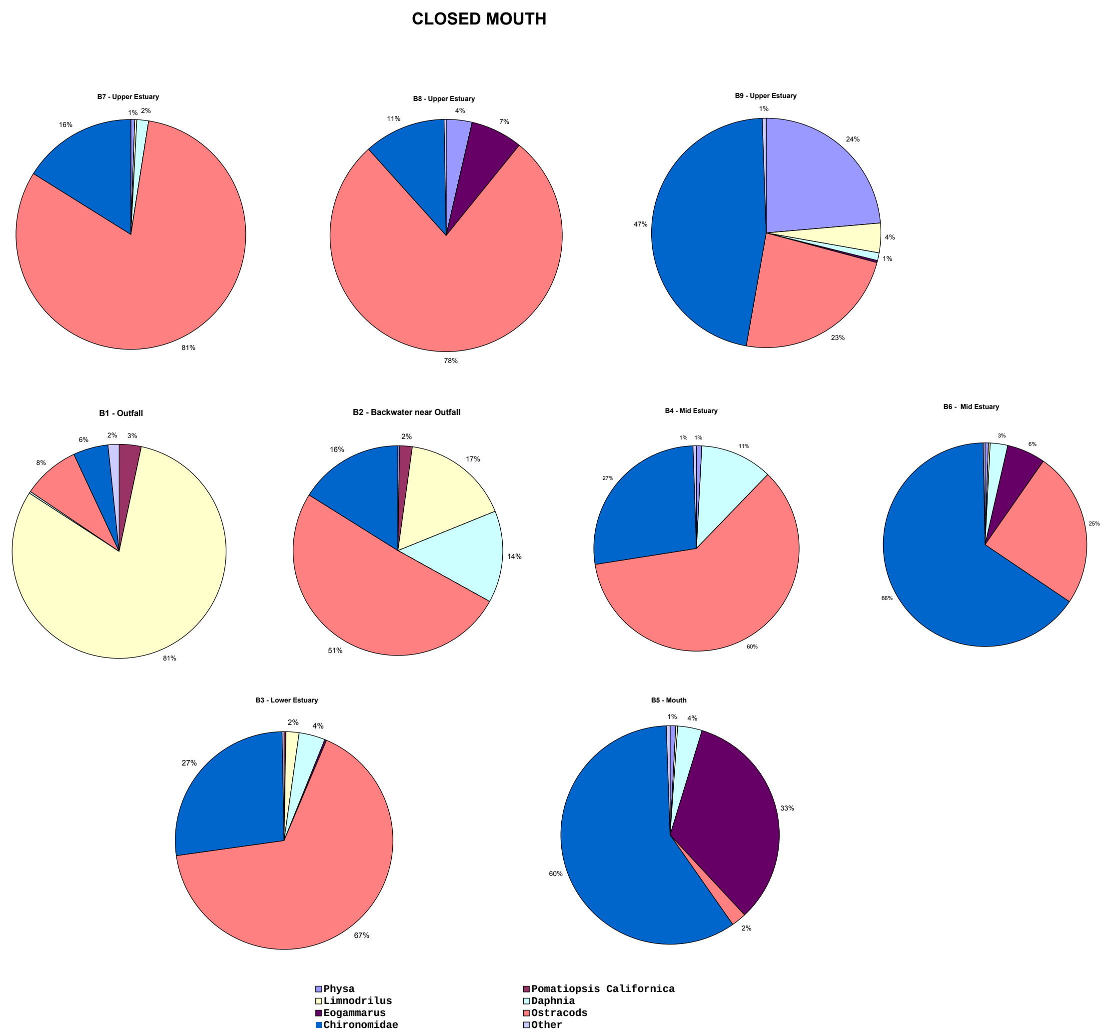


Figure 4.7: Species Composition By Station During Closed Mouth Conditions.

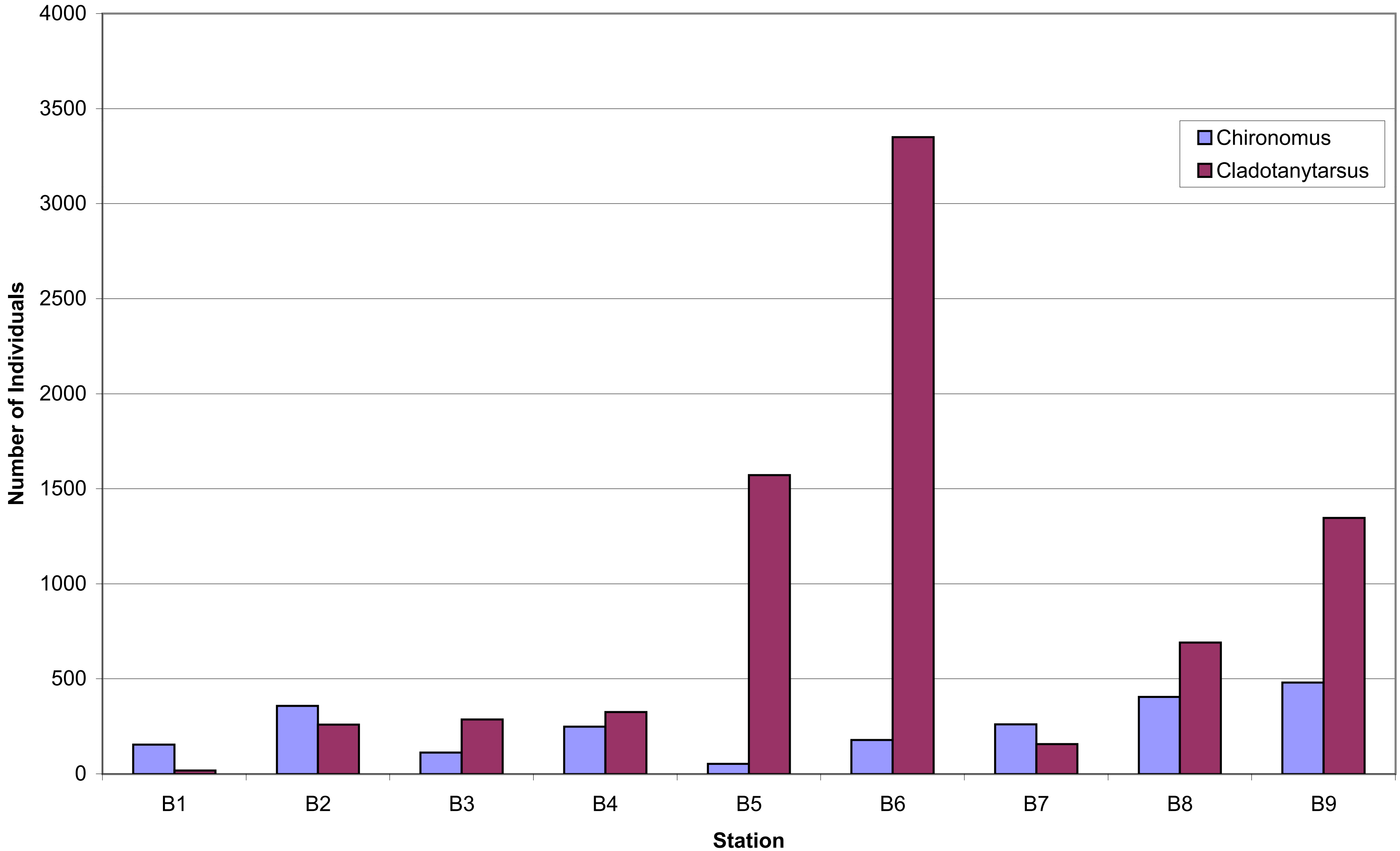


Figure 4.8: Abundance of Chironomus & Cladotanytarsus by Sampling Station

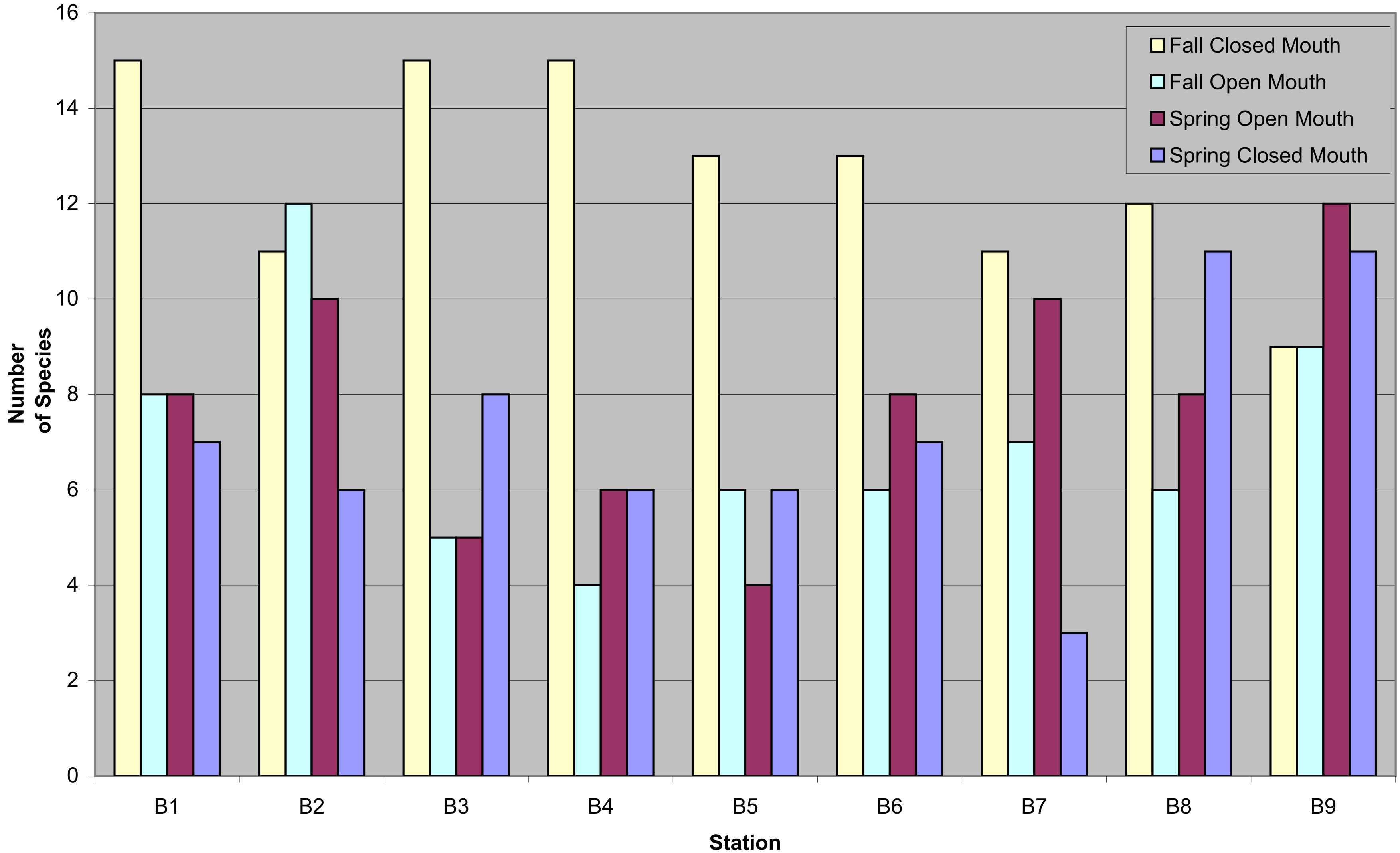


Figure 4.9: Species Richness by Station and Sampling Event.

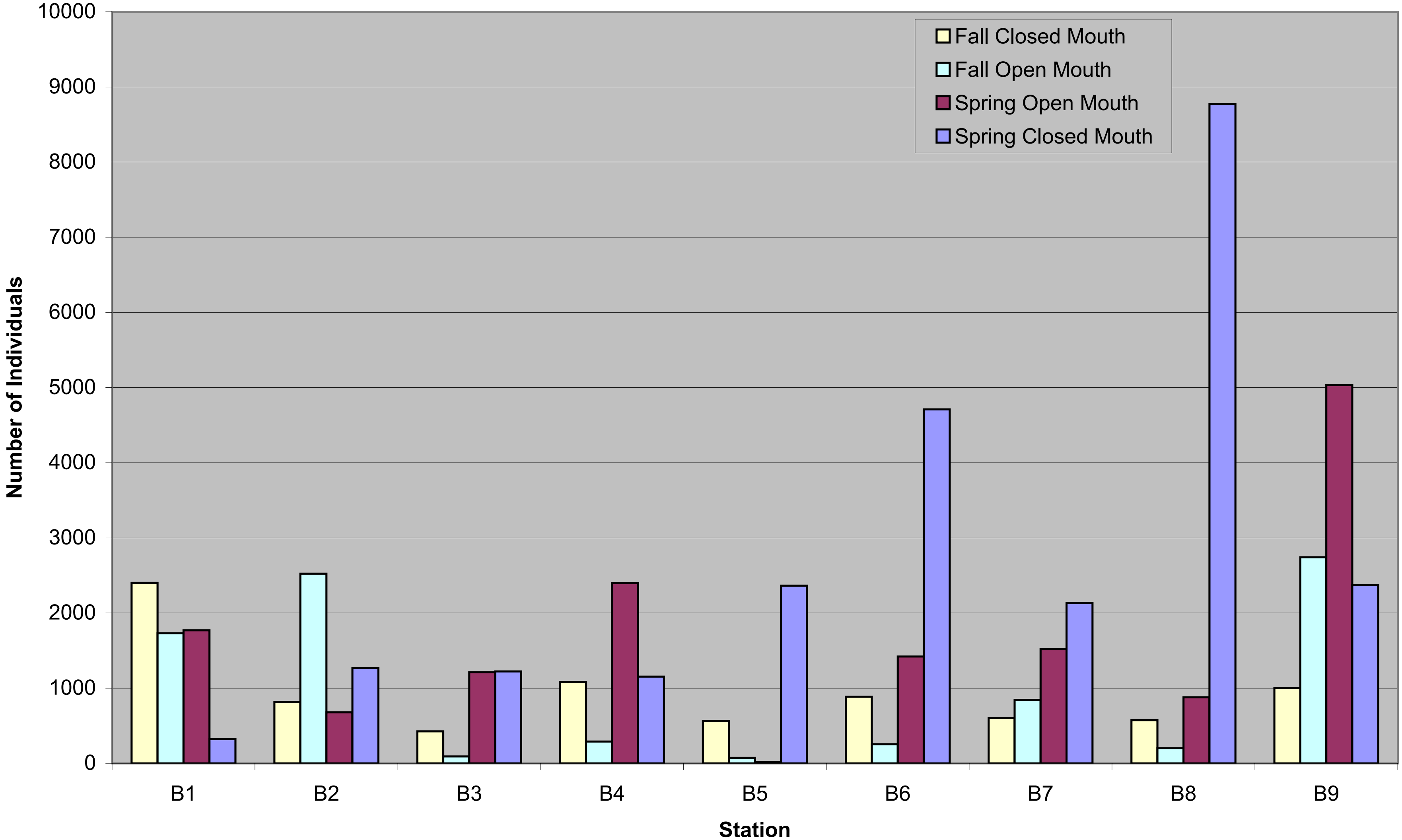


Figure 4.10: Total Invertebrate Abundance by Station and Sampling Event.

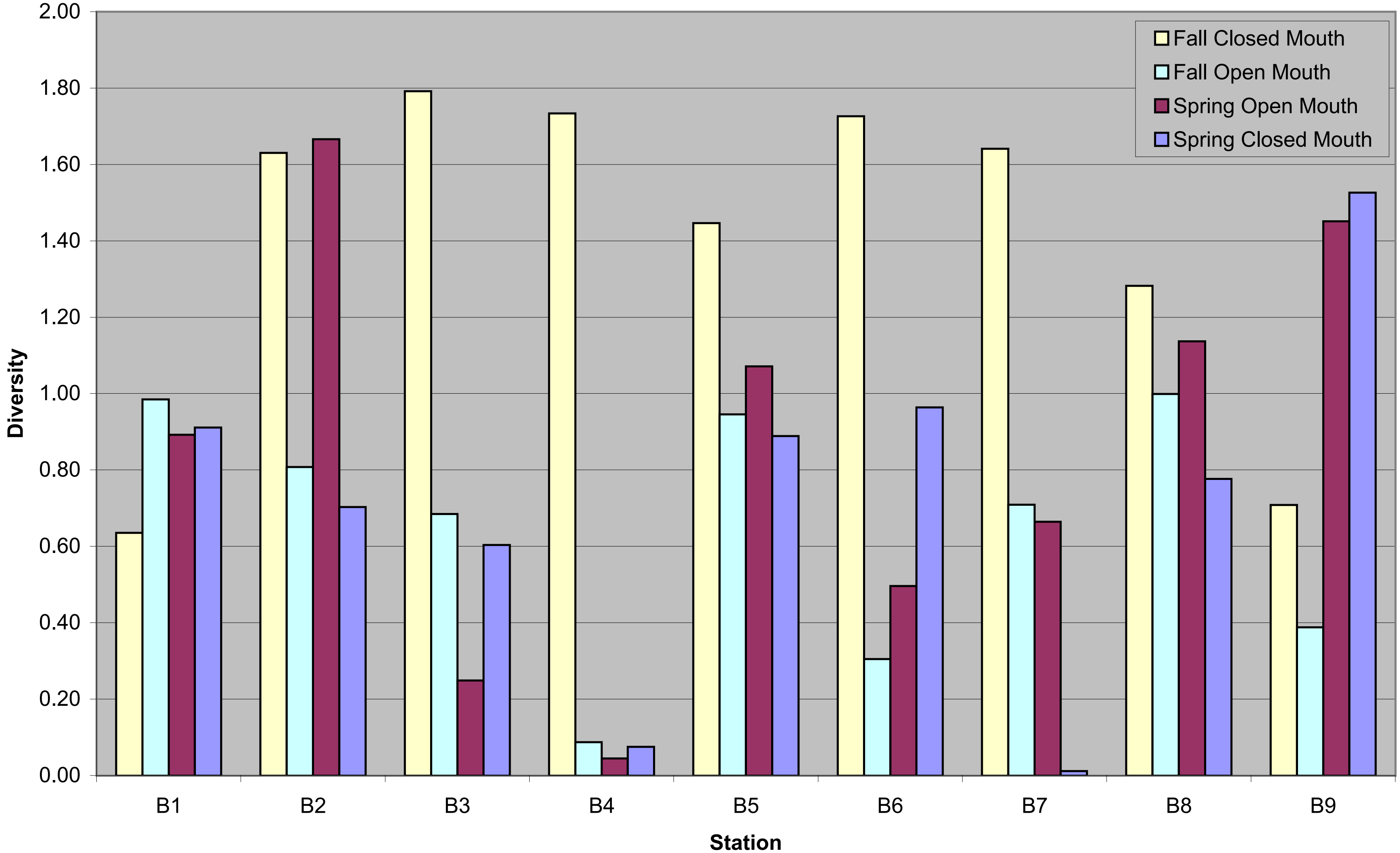


Figure 4.11: Species Diversity by Station and Sampling Event.

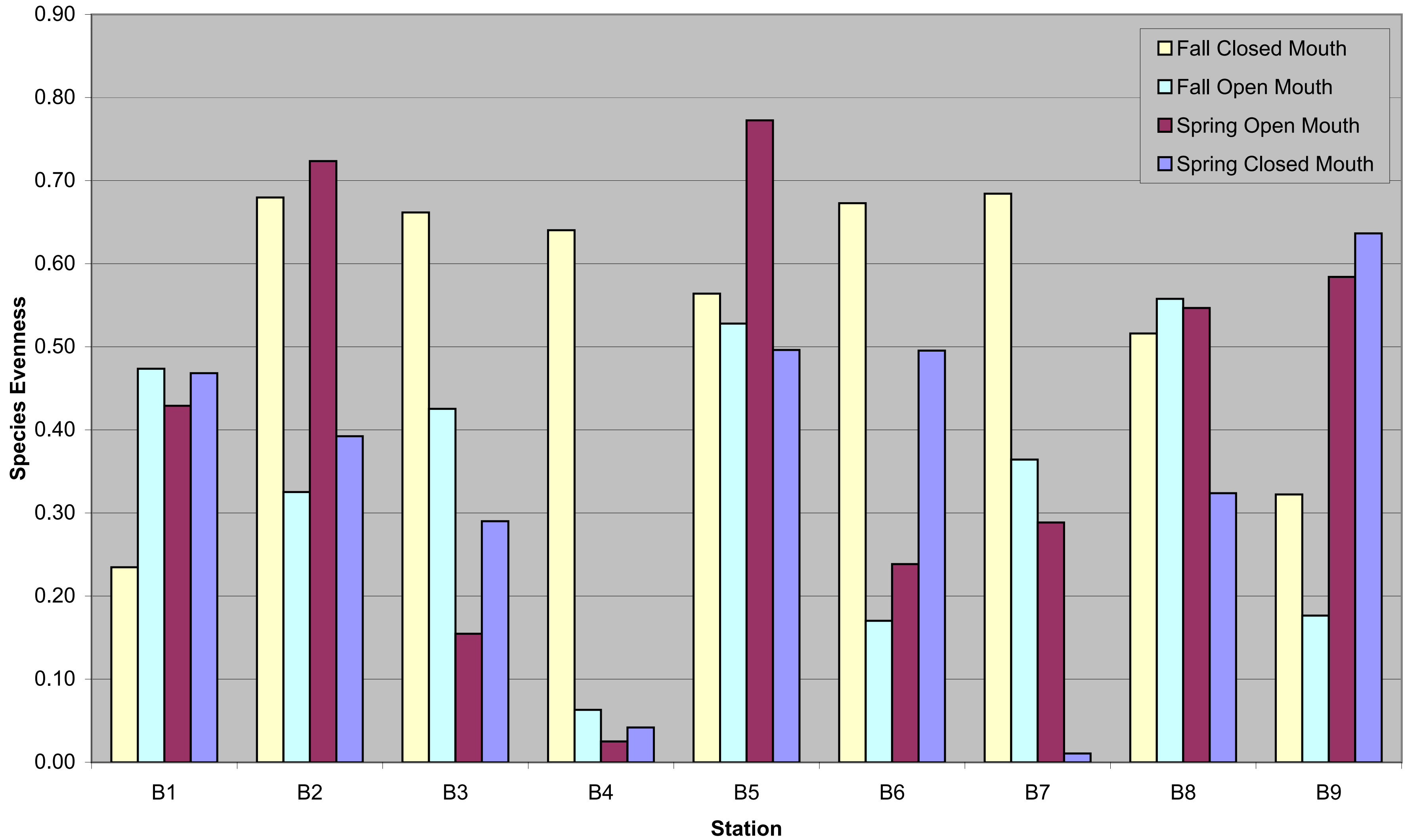


Figure 4.12: Species Evenness by Station and Sampling Event.

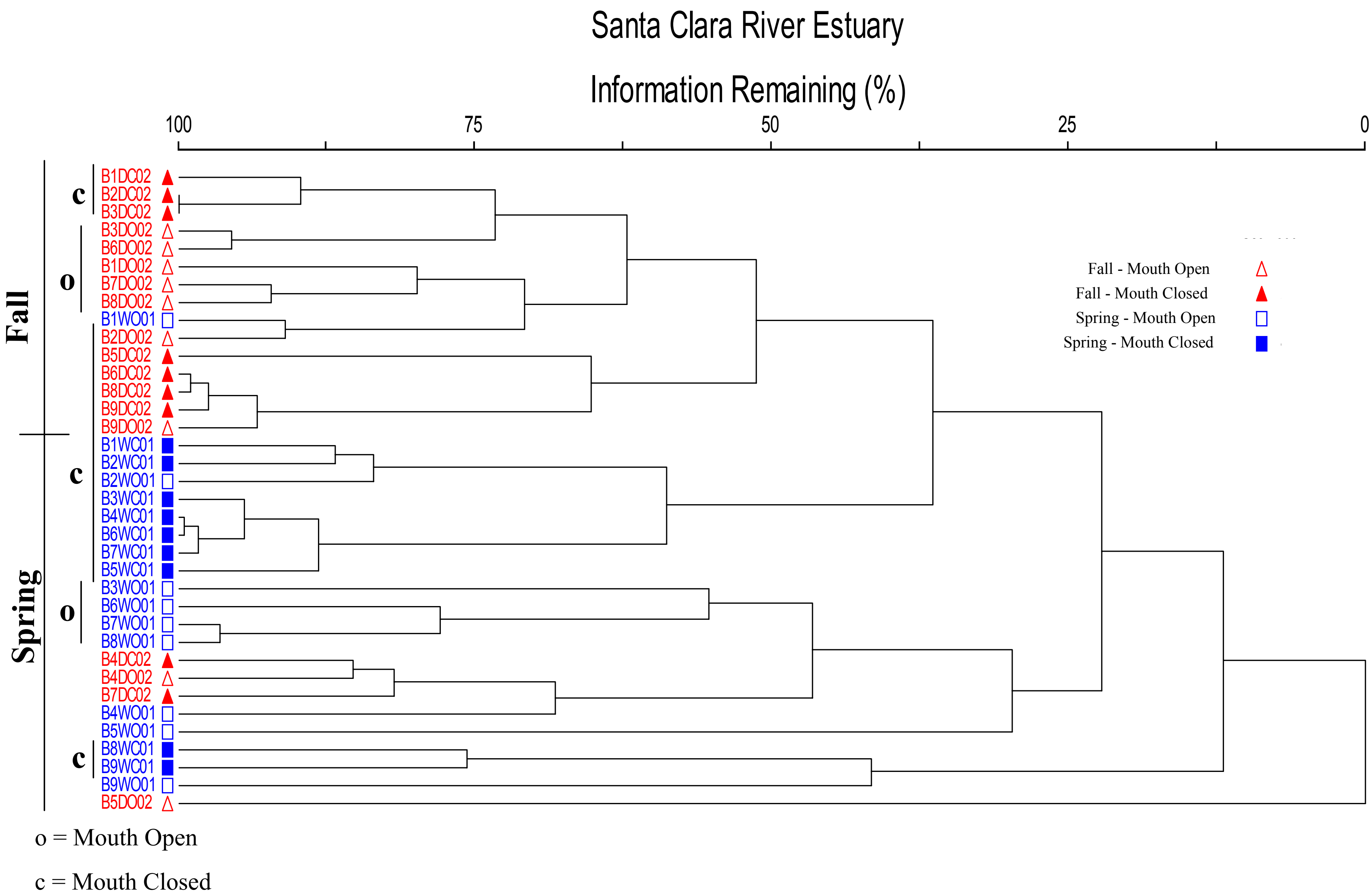


Figure 4.13: SCRE Cluster Dendrogram

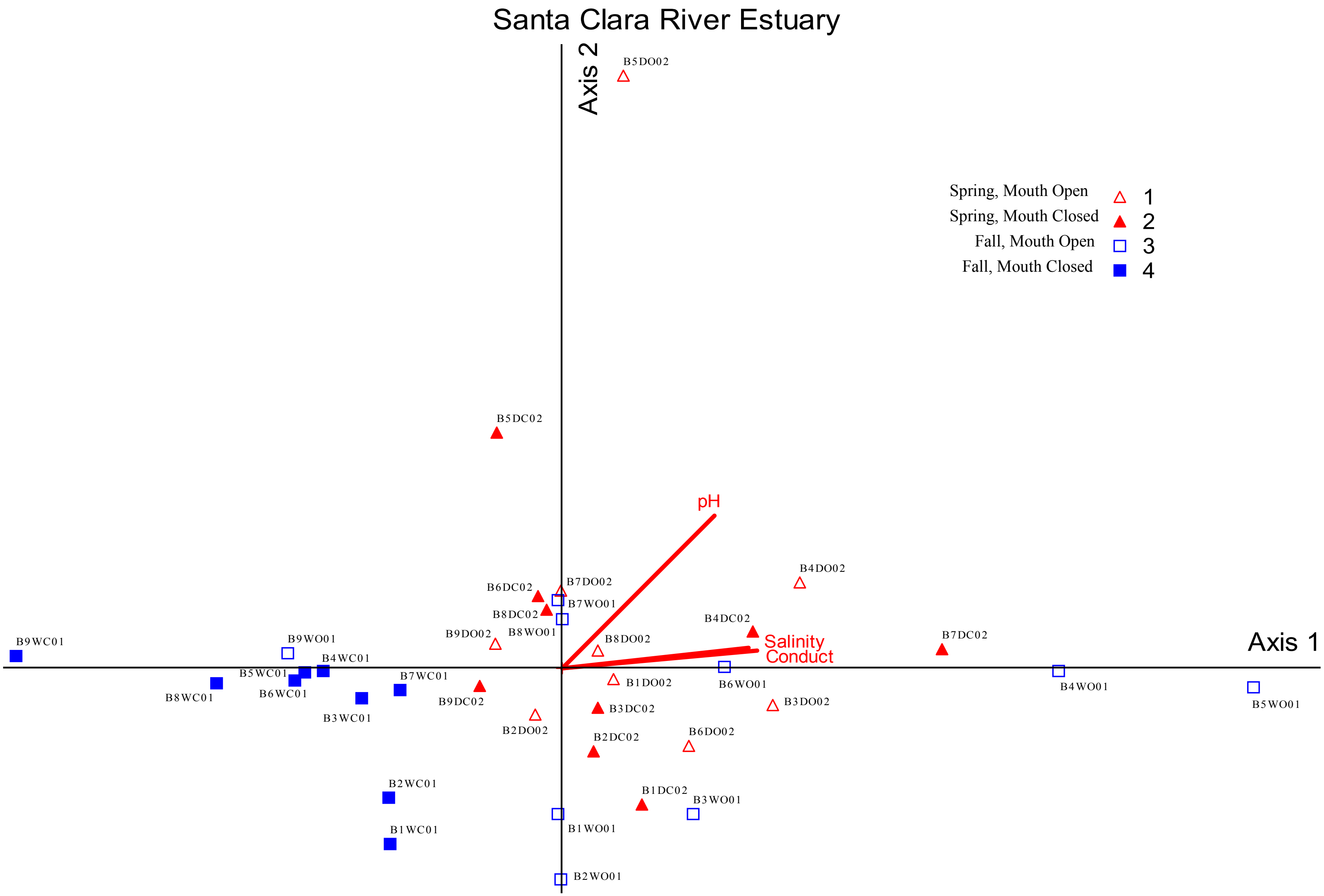
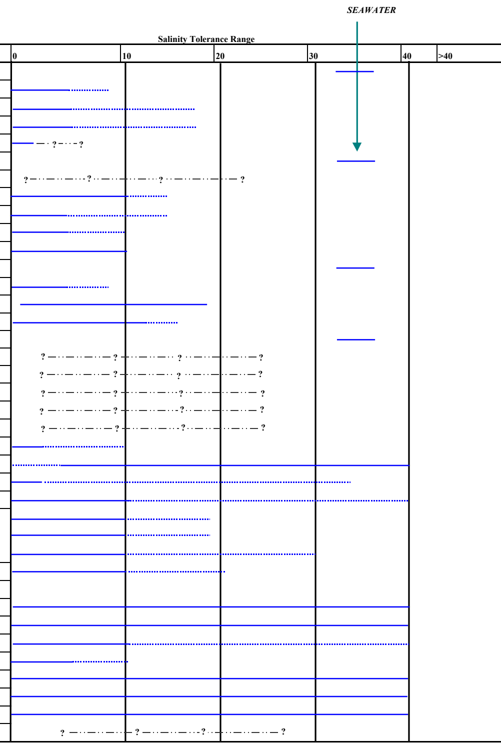


Figure 4.14: Stations B1-B9: Ordination



Tolerance Class	Phylum	Class	Order	Family	Genus	Species	Common Name	Salinity Tolerance Range: 0 10 20 30 40 >40		
MI	Platyhelminthes	Turbellaria	Neorhabdocoela							Marine species
FT	Mollusca	Gastropoda	Basommatophora	Lymnaeidae		*sp. 1*	lymnaea		up to 12 ppt	Certain species of the family Lymnaeidae can endure up to 25% seawater, which equates to approximately 8.25 ppt
FT				Physidae	*Physa*				up to 17 ppt	Some species in this family can tolerate ~17 ppt
FT					*Physa*	*sp. 1*	physa		Up to 17 ppt	Some species in this family can tolerate ~17 ppt
FT			Mesogastropoda	Pomatiopsidae	*Pomatiopsis*	*californica*	gastropod			Marine species
MI	Annelida	Archaeannelida	Canalipalpata	Saccocirridae	*Saccocirrus*					
UN		Oligochaeta	Lumbriculida	Lumbriculidae						
FT			Tubificida	Enchytraeidae			aquatic earthworms		up to 10 ppt - brackish	10 ppt to salt / brackish waters. Specific value dependent on species
FT						*sp. 2*	aquatic earthworms		up to 5 ppt-brackish	5 ppt to salt / brackish waters. Specific value dependent on species
FT				Tubificidae			aquatic earthworms			Known to inhabit salt or brackish, esp in polluted areas.
FT					*Limnodrilus*		aquatic earthworms		Up to 10 ppt	Based on L. Hoffmeisteri
MI		Polychaeta	Aciculata	Hesionidae	*Microphthalmus*					Marine species
FT	Arthropoda/Crustacea	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*		water fleas		5 ppt to max of 7.5 ppt	This species is most likely D. magna
BR		Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	*sp. 1*	scuds			
FT				Hyalellidae	*Hyallela*	*azteca*	scuds		up to 16 ppt	Commonly at salinities of 1-12 ppt, though found in saline lakes up to 16 ppt
MI			Decapoda	Hippidae	*Emerita*	*analoga*	sand crab			Marine species
UN		Maxillipoda	Cyclopoida				copepod		unknown	Taxonomic level too high
UN			Harpacticoida						unknown	Taxonomic level too high
CY		Ostracoda	Podocopina	Cyprididae		*sp. 1*	ostracod		unknown	Taxonomic level too high
UN						*sp. 2*	ostracod		unknown	Taxonomic level too high
UN						*sp. 3*	ostracod		unknown	Taxonomic level too high
FT	Arthropoda	Insecta	Coleoptera	Dytiscidae			predaceous diving beetles		no specific values	This group of Coleoptera (water beetles) is lentic (lake dwelling)
EU				Hydrophilidae	*Berosus*		water scavenger beetles		>100 ppt	
FT			Collembola	Isotomidae			springtails		no specific values	
FT			Diptera	Ceratopogonidae			biting midges		no specific values	Found in freshwater and coastal marine habitats
FT				Chironomidae			midges		0 to >100 ppt	Generally, Insecta is a freshwater group, although fly larve are often abundant in marine and brackish water environments
FT						*sp. 2*	midges		0 to >100 ppt	Generally, Insecta is a freshwater group, although fly larve are often abundant in marine and brackish water environments
FT					*Chironomus*		midges		specific value dependent o	Chronomidae are primarily freshwater insects. Literature indicates up to ~30 ppt
FT					*Cladotanytarsus*		midges		no specific values	A freshwater group, but tolerant of salt or brackish water. Literature indicates up to 20 ppt.
EU				Ephydridae						
EU					*Ephydra*		brine flies and shore flies		specific value dependent on species	
EU					*Ephydra*	*riparia*	shore fly		can be > 40 ppt	Found in freshwater to saltwater and brine pool habitats; occurrence is seasonal
UN							flies and midges		no specific values	No tolerance values found at this taxonomic level
FT			Ephemeroptera				mayflies		5-10 ppt	
EU			Hemiptera	Corixidae			water boatmen		most likely Corisella inscripta	
EU					*Corisella*	*inscripta*	water boatmen		no specific values	Known to occur in fresh, brackish, and high salinity conditions
EU					*Trichocorixa*	*reticulata*	water boatmen		0 to >37 ppt	
UN			Hymneroptera							No literature found.

Key to Tolerance Classes	% Abundance
FI = Freshwater - Intolerant of Brackish	0
FT = Freshwater - Tolerant of Brackish	39.13
BR = Primarily Brackish Water Species	8.19
MT = Marine - Tolerant of Brackish	0
MI = Marine - Intolerant of Brackish	0.07
EU = Euryhaline	0.06
UN = Salinity Tolerance Unknown	8.6
CY - Cyprididae	43.95

(solid line)	= Exact range determined from published scientific literature.
(dotted line)	= Range estimated from qualitative data or based on related species.

Figure 4.15: Salinity Tolerance Ranges for Species Present in Benthic Core Samples

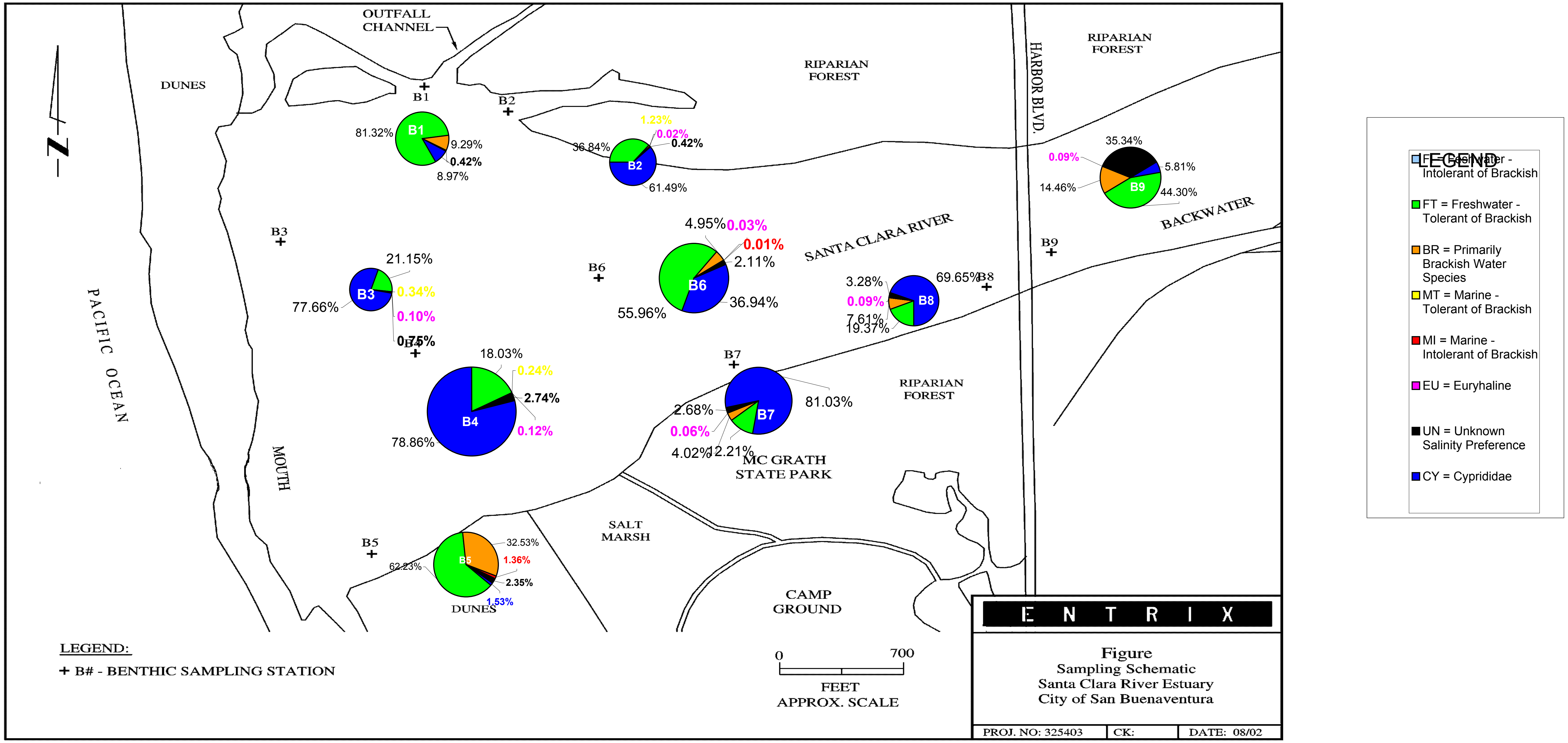


Figure 4.16: Percent Abundance of Salinity Tolerance Classes by Sampling Station.

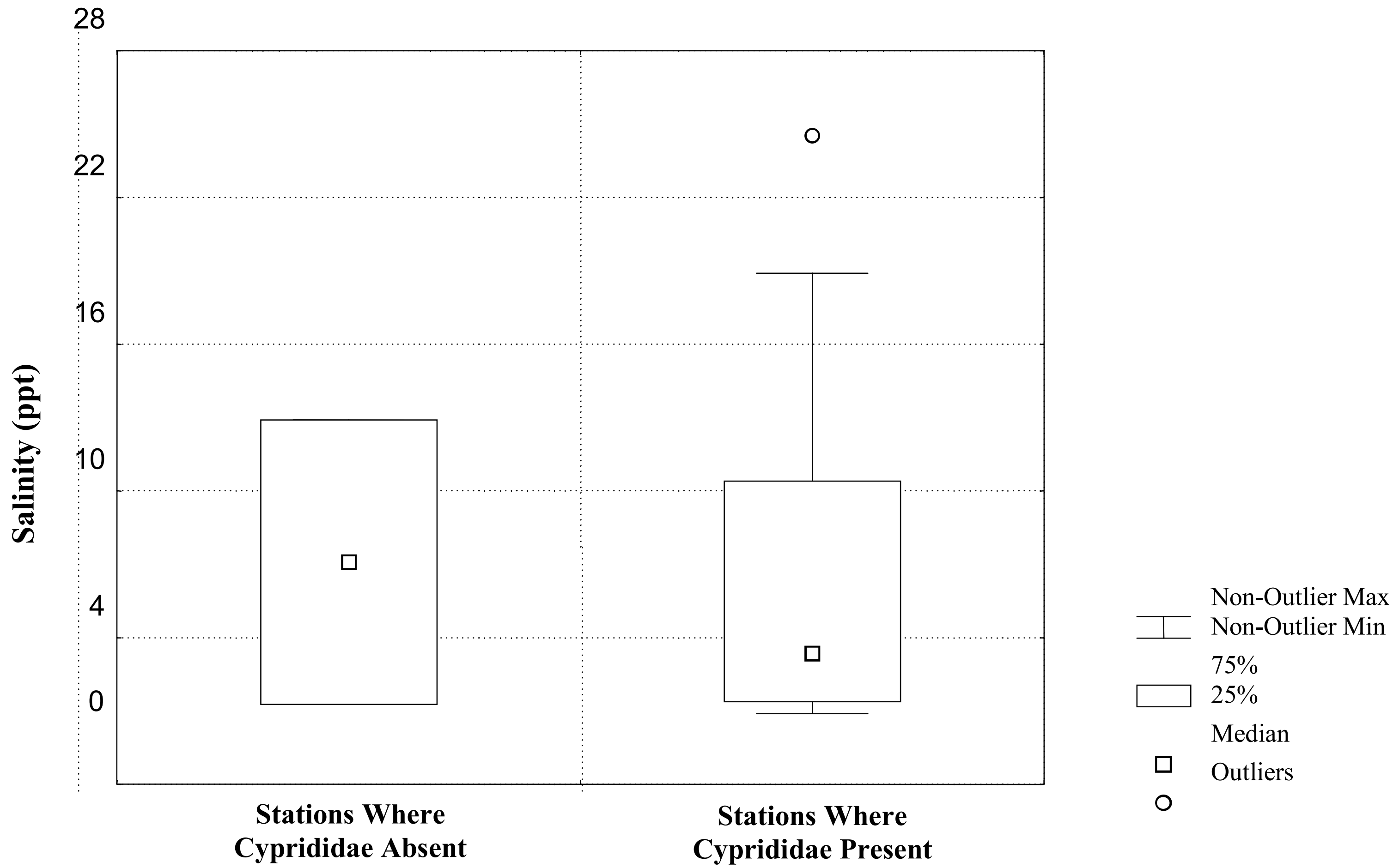


Figure 4.17: Box Plot of Salinity Correlated with Presence and Absence of Cyprididae

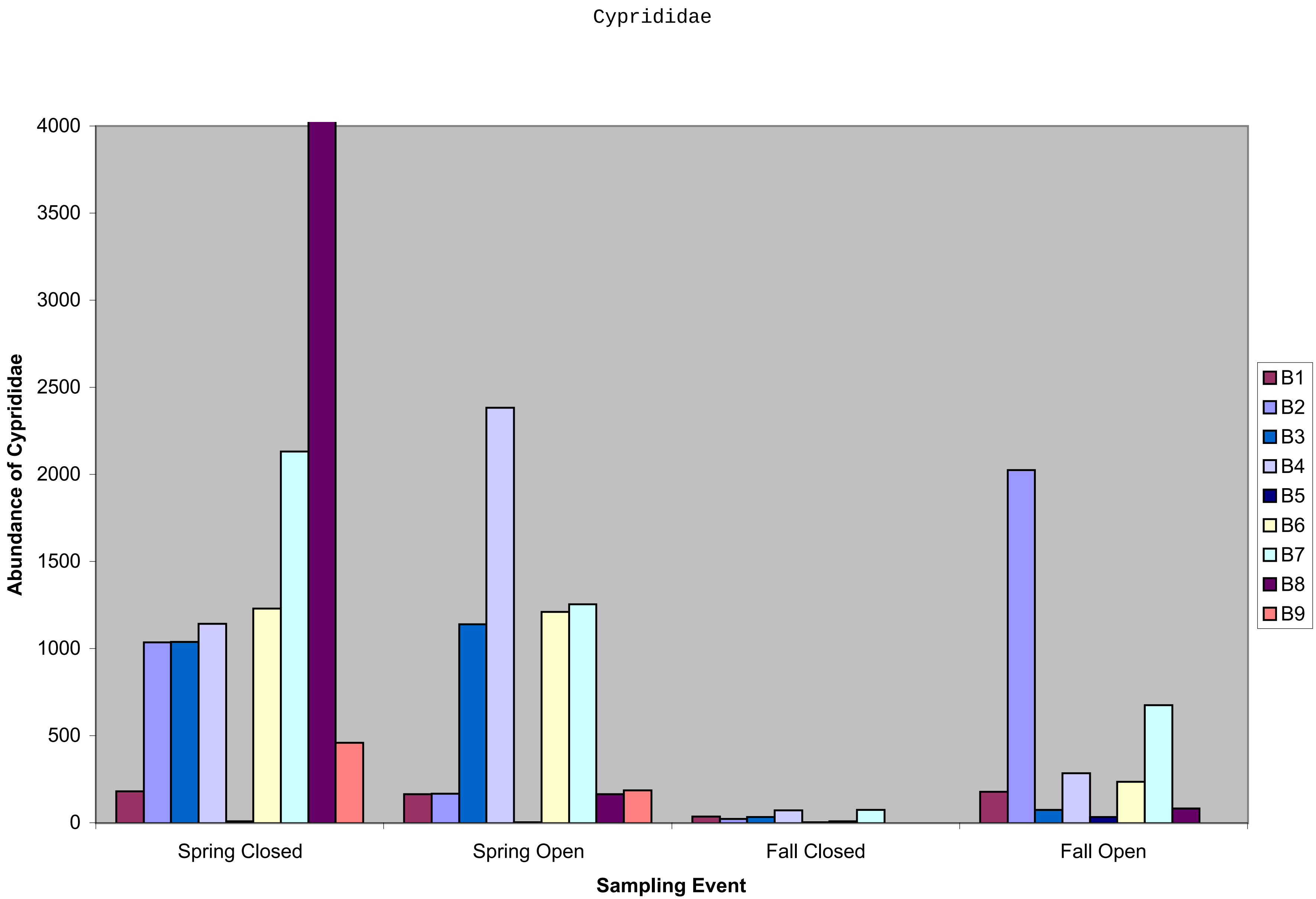


Figure 4.18 Distribution of Cyprididae in the SCRE

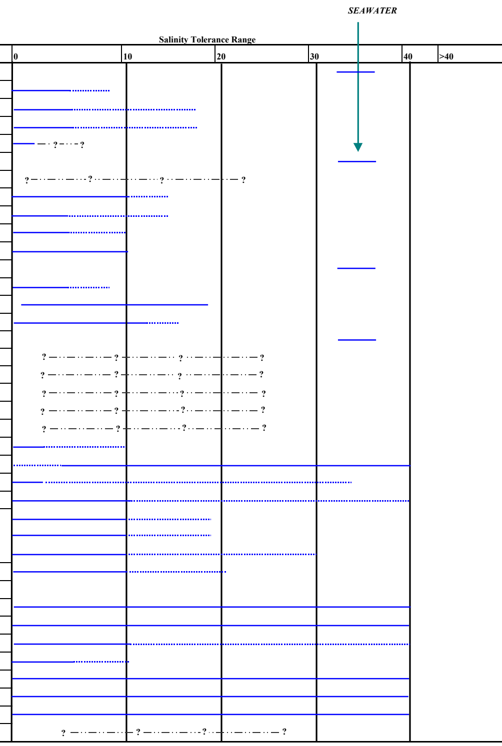
Figure 5.1: Map of Southern California Bight, Showing Lagoons and Estuaries with Size Similar to that of the Santa Clara River Estuary.

SEAWATER

Tolerance Class	Phylum	Class	Order	Family	Genus	Species	Common Name	Salinity Tolerance Range (0, 10, 20, 30, 40, >40)	Value	Notes
Freshwater Species										
FT		Bivalvia	Veneroidea	Corbiculidae	Corbicula	manilensis	Asian Clam		up to 24ppt	Data based on C. fluminea (same genus), can tolerate 13ppt briefly, or up to 24ppt if allowed to acclimate.
UN			Architaenioglossa	Viviparidae	Campelona	decisum	Snail			
FT					Physa	heterostropha	Snail		up to 17ppt	Some species of physa can endure this, not necessarily this species. Data based on genus.
FT				Physidae	Physa	integra	Snail		up to 17ppt	Some species of physa can endure this, not necessarily this species. Data based on genus.
UN			Basommatophora	Planorbidae	Gyraulus	circumstriatus	Snail			
UN				Hydrobiidae	Amnicola		Snail			
UN	Mollusca	Gastropoda	Neotaenioglossa	Pleuroceridae	Goniobasis	livescens	Snail			
UN					Nais		Worm			
FT			Haplotaxida	Naididae	Limnodrilus	hoffmeisteri	Worm		up to 5ppt	Generally found betow 5ppt, but capable of tolerating much more.
EU	Annelida	Clitellata	Lumbricula	Lumbriculidae	Lumbriculus	variegatus	Worm		11-35ppt	Data based on Grania dolichura, an estuarine worm of the same family.
UN				Lophopodidae	Lophopodella	carteri	Bryozoan			
UN					Plumatella	emarginata	Bryozoan			
UN	Ectoprocta	Phylactolaemata	Plumatellida	Plumatellidae	Pectinatella	magnifica	Bryozoan			
UN					Ceriodaphnia	reticulata				We have conductivity data for this one, need to convert to salinity.
FT					Daphnia	magna			0-8ppt	Usually found below 5ppt, but can occasionally survive salinities as high as 8ppt.
FT		Branchiopoda	Diplostraca	Daphniidae	Daphnia	pulex			At least to 3	D. Pulex (pond/lake dweller) was collected in a lake of salinity 3ppt.
UN				Crangonyctidae	Crangonyx	pseudogracilis	Water Flea			
EU			Amphipoda	Gammaridae	Gammarus	pseudolimnaeus	Water Flea		Up to >40	Data based on the Gammarus genus; mainly freshwater but with representatives that inhabit the Salton Sea.
UN					Orconectes	rusticus	Crayfish			
EU	Arthropoda/ Crustacea	Malacostraca	Decapoda	Cambaridae	Procambarus	clarkii	Crayfish		Briefly to 35	Salinity tolerance varies with size. Young may die at 8ppt, adults can withstand 35ppt for a short time.
EU					Chironomus	decorus	Midge		0-330ppt	The Chironomus genus has a very wide salinity range, no info on this species.
EU			Diptera	Chironomidae	Chironomus	tentans	Midge		0-330ppt	The Chironomus genus has a very wide salinity range, no info on this species.
UN	Arthropoda	Insecta	Plecoptera	Perlidae	Acroneuria	lycorias	Stonefly			
Saltwater Species										
UN					Campanularia	flexuosa	Hydroid			
UN	Cnidaria	Hydrozoa	Hydroida	Campanulariidae	Phialidium		Hydroid			
UN			Cydippida	Pleurobrachiidae	Pleurobrachia	pileus	Sea Gooseberry			Was collected in nearshore areas of the Black Sea.
BR	Ctenophora	Tentaculata	Lobata	Mnemidae	Mnemiopsis	mccradyi	Sea Walnut		3-17ppt	Found in Azov Sea, which is brackish. 17ppt is the max salinity of that sea, 3ppt is the lower tolerance of the species.
UN	Rotifera	Monogononta	Ploima	Brachionidae	Brachionus	plicatilis	Rotifer			
MT			Mytiloida	Mytilidae	Mytilus	edulis	Blue Mussel		Down to 5ppt	This marine species can live at low salinities, but as dwarf individuals with reduced growth rate. Upper limit not tested.
MT			Myoida	Myidae	Mya	arenaria	Softshell Clam		Down to 5ppt	These are marine/estuarine, and lower salinity tolerance varies with size. Upper limit not tested.
MI				Ostreidae	Crassostrea	virginica	Eastern Oyster		23 to 33ppt	This was given as the optimum range, and <22.7ppt had serious effects. No hard data on sruvivorship/tolerance.
MI			Ostreoida	Pectinidae	Argopecten	irradians	Bay Scallop		Down to 14ppt	Maximum not tested, 14ppt is minimum value for determining distribution.
BR				Mactridae	Rangia	cuneata	Atlantic Rangia		1-18ppt	
BR				Tellinidae	Macoma	inquinata	Stained Macoma		5-30ppt	
MI					Mercenaria	mercenaria	Northern Quahog		12-35ppt	
MI		Bivalvia	Veneroida	Veneridae	Prothaca	staminea	Pacific Littleneck		<20-30	Absolute lower limit not given.
MI					Haliotis	cracherodii	Black Abalone		Down to 25-20	Data based on Haliotis roei. Lower limit not exact. Upper tolerance not tested.
MI			Archeogastropoda	Haliotidae	Haliotis	rufescens	Red Abalone		Down to 25-20	Data based on Haliotis roei. Lower limit not exact. Upper tolerance not tested.
UN				Melongenidae	Busycon	canaliculatum	Whelk			
UN	Mollusca	Gastropoda	Neogastropoda	Nassariidae	Nassarius	obsoletus	Eastern Mudsnail			A metabolism and toxicity experiment on this species was conducted at 25ppt.
UN				Nereididae	Neanthes	arenaceodenata	Marine Worm			This species is used as an EPA test organism at <20ppt
UN			Aciculata	Phyllodocidae	Phyllodoce	maculata	Paddleworm			
MI	Annelida	Polychaeta	Canalipalpata	Cirratulidae	Cirriformia	spirrabranchia				
MI			Amphipoda	Ampeliscidae	Ampelisca	abdita			10-35ppt	This species was toxicity tested between 10 and 35ppt.
MI				Nephropidae	Homarus	americanus			>20ppt	No exact data given, found in "high salinity" (>20ppt) systems
EU				Palaemonidae	Palaemontes	pugio			.5-44ppt	
MI			Decapoda	Pandalidae	Pandalus	danae			23-36ppt	
UN		Malacostraca	Euphausiacea	Euphausiidae	Euphausia	pacifica	Krill			
EU					Acartia	clausi	Copepod		0-70ppt	
UN				Acartiidae	Acartia	tonsa	Copepod			
UN				Calanidae	Undinula	vulgaris	Copepod			
UN				Euchaetidae	Euchaeta	marina				
UN				Metridinidae	Metridia	pacifica				
EU			Calanoida	Pontellidae	Labidocera	scotti			0-70ppt	
UN	Arthropoda/Crustacea	Maxilipoda	Harpaticoida	Tisbidae	Tisbe	holothuriae				
UN	Chaetognatha	Sagittoidea	Aphragmorpha	Sagittidae	Sagitta	hispida	Arrow Worm			
UN	Echinodermata	Echinoidea	Arbacoida	Arbaciidae	Arbacia	punctulata				

(solid line)	= Exact range determined from published scientific literature.
(dashed line)	= Range estimated from qualitative data or based on related species.

Figure 6.1: Salinity Tolerance Values for Species on the EPA Copper Toxicity List



Tolerance Class	Phylum	Class	Order	Family	Genus	Species	Common Name		
MI	Platyhelminthes	Turbellaria	Neorhabdocoela						Marine species
FT	Mollusca	Gastropoda	Basommatophora	Lymnaeidae		*sp. 1*	lymnaea	up to 12 ppt	Certain species of the family Lymnaeidae can endure up to 25% seawater, which equates to approximately 8.25 ppt
FT				Physidae	*Physa*			up to 17 ppt	Some species in this family can tolerate ~17 ppt
FT					*Physa*	*sp. 1*	physa	Up to 17 ppt	Some species in this family can tolerate ~17 ppt
FT			Mesogastropoda	Pomatiopsidae	*Pomatiopsis*	*californica*	gastropod		Marine species
MI	Annelida	Archaeannelida	Canalipalpata	Saccocirridae	*Saccocirrus*				
UN		Oligochaeta	Lumbriculida	Lumbriculidae					
FT			Tubificida	Enchytraeidae			aquatic earthworms	up to 10 ppt - brackish	10 ppt to salt / brackish waters. Specific value dependent on species
FT						*sp. 2*	aquatic earthworms	up to 5 ppt-brackish	5 ppt to salt / brackish waters. Specific value dependent on species
FT				Tubificidae			aquatic earthworms		Known to inhabit salt or brackish, esp in polluted areas.
FT					*Limnodrilus*		aquatic earthworms	Up to 10 ppt	Based on L. Hoffmeisteri
MI		Polychaeta	Aciculata	Hesionidae	*Microphthalmus*				Marine species
FT	Arthropoda/Crustacea	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*		water fleas	5 ppt to max of 7.5 ppt	This species is most likely D. magna
BR		Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	*sp. 1*	scuds		
FT				Hyalellidae	*Hyallela*	*azteca*	scuds	up to 16 ppt	Commonly at salinities of 1-12 ppt, though found in saline lakes up to 16 ppt
MI			Decapoda	Hippidae	*Emerita*	*analoga*	sand crab		Marine species
UN		Maxillipoda	Cyclopoida				copepod	unknown	Taxonomic level too high
UN			Harpacticoida					unknown	Taxonomic level too high
CY		Ostracoda	Podocopina	Cyprididae		*sp. 1*	ostracod	unknown	Taxonomic level too high
UN						*sp. 2*	ostracod	unknown	Taxonomic level too high
UN						*sp. 3*	ostracod	unknown	Taxonomic level too high
FT	Arthropoda	Insecta	Coleoptera	Dytiscidae			predaceous diving beetles	no specific values	This group of Coleoptera (water beetles) is lentic (lake dwelling)
EU				Hydrophilidae	*Berosus*		water scavenger beetles	>100 ppt	
FT			Collembola	Isotomidae			springtails	no specific values	
FT			Diptera	Ceratopogonidae			biting midges	no specific values	Found in freshwater and coastal marine habitats
FT				Chironomidae			midges	0 to >100 ppt	Generally, Insecta is a freshwater group, although fly larve are often abundant in marine and brackish water environments
FT						*sp. 2*	midges	0 to >100 ppt	Generally, Insecta is a freshwater group, although fly larve are often abundant in marine and brackish water environments
FT					*Chironomus*		midges	specific value dependent o	Chronomidae are primarily freshwater insects. Literature indicates up to ~30 ppt
FT					*Cladotanytarsus*		midges	no specific values	A freshwater group, but tolerant of salt or brackish water. Literature indicates up to 20 ppt.
EU				Ephydridae					
EU					*Ephydra*		brine flies and shore flies	specific value dependent on species	
EU					*Ephydra*	*riparia*	shore fly	can be > 40 ppt	Found in freshwater to saltwater and brine pool habitats; occurrence is seasonal
UN							flies and midges	no specific values	No tolerance values found at this taxonomic level
FT			Ephemeroptera				mayflies	5-10 ppt	
EU			Hemiptera	Corixidae			water boatmen	most likely Corisella inscripta	
EU					*Corisella*	*inscripta*	water boatmen	no specific values	Known to occur in fresh, brackish, and high salinity conditions
EU					*Trichocorixa*	*reticulata*	water boatmen	0 to >37 ppt	
UN			Hymneroptera						No literature found.

Key to Tolerance Classes	% Abundance
FI = Freshwater - Intolerant of Brackish	0
FT = Freshwater - Tolerant of Brackish	39.13
BR = Primarily Brackish Water Species	8.19
MT = Marine - Tolerant of Brackish	0
MI = Marine - Intolerant of Brackish	0.07
EU = Euryhaline	0.06
UN = Salinity Tolerance Unknown	8.6
CY - Cyprididae	43.95

——— (solid line)	= Exact range determined from published scientific literature.
- - - - (dashed line)	= Range estimated from qualitative data or based on related species.

Figure 6.2: Salinity Tolerance Ranges for Species Present in Benthic Core Samples

TABLES

Constituent	NPDES Discharge Limit (µg/L)	NPDES Interim Limit (µg/L)	Drinking Water Standard (µg/L)
Copper	2.9	98	1,300
Nickel	8.3	271	100
Lead	8.5	77	15
Zinc	86	1,181	2,000
Bis(2-ethylhexyl)phthalate	5.9	-	6
Dichlorobromomethane	22	70	60

Table 1-1. Interim Discharge Limits for Six Constituents of Concern (COCs)

Station ID	Description	GPS Coordinates (WGS 84)	ENTRIX 1999	USFWS 1999
B1	Outfall Channel Mouth; Backwater Area	N 34 14.103 W 119 15.792	Station 2	Station 3
B2	Backwater near Outfall Channel Mouth	N 34 14.085 W 119 15.735	Station 4	Station 5
B3	Western Portion along Spit; Lagoon/Mudflat	N 34 13.987 W 119 15.888		Station 2
B4	Mid-Estuary; Lagoon/Mudflat	N 34 13.906 W 119 15.795		
B5	South-Western Portion near Mouth; Lagoon	N 34 13.758 W 119 15.822	Station 1	Station 1
B6	Mid-Estuary; Lagoon/Mudflat	N 34 13.963 W 119 15.670		Station 4
B7	South-Eastern Portion along McGrath State Park	N 34 13.900 W 119 15.576		Station 6
B8	Upper Estuary along McGrath State Park	N 34 13.958 W 119 15.402	Station 3	Station 7
B9	Upper Estuary in Backwater	N 34 13.985 W 119 15.360		
B10	Santa Clara River Upstream of Estuary	N 34 14.201 W 119 14.655		
B11	Santa Clara River Upstream of Estuary	N 34 14.209 W 119 14.573		

Table 3-1. Summary of Study Sampling Station Locations

Station	Avgerage Salinity (PPT)	Avgerage Dissolved Oxygen	Avgerage Temperature (C)	Avgerage Conductivity (mS/cm)	Average pH	Avgerage Turbidity (NTU)
B1	1.27	3.81	18.4	2.69	7.8	3.7
B2	1.10	0.28	17.9	2.29	7.5	25.0
B3	1.30	5.98	18.6	2.75	8.1	47.7
B4	1.40	6.81	18.0	2.88	8.3	3.0
B5	1.40	6.25	18.6	2.90	8.2	3.0
B6	1.40	7.22	18.6	2.87	8.3	2.0
B7	1.40	5.95	18.1	2.91	8.1	4.0
B8	1.40	7.20	19.1	2.95	8.2	2.0
B9	1.30	4.91	17.9	2.81	8.2	2.5
MIN	**1.10**	**0.28**	**17.9**	**2.29**	**7.5**	**2.0**
MAX	**1.40**	**7.22**	**19.1**	**2.95**	**8.3**	**47.7**
MEAN	**1.33**	**5.38**	**18.3**	**2.78**	**8.1**	**10.3**

Table 4-1a: Average Water Quality Parameter Values by Station During Fall Closed Conditions.

Station	Avgerage Salinity (PPT)	Avgerage Dissolved Oxygen	Avgerage Temperature (C)	Avgerage Conductivity (mS/cm)	Average pH	Avgerage Turbidity (NTU)
B1	1.10	5.33	14.4	2.36	8.3	21.0
B2	8.40	5.50	12.7	13.20	8.4	81.0
B3	24.53	6.85	10.7	41.70	8.6	12.0
B4	11.10	8.16	14.7	18.90	9.0	17.0
B5	18.90	7.46	14.4	32.90	8.8	11.0
B6	18.20	8.80	14.8	29.50	8.9	19.0
B7	7.20	8.39	14.9	12.40	8.8	42.0
B8	2.20	6.21	14.2	4.41	8.6	3.0
B9	12.90	4.80	10.0	21.30	8.5	28.0
MIN	**1.10**	**4.80**	**10.0**	**2.36**	**8.3**	**3.0**
MAX	**24.53**	**8.80**	**14.9**	**41.70**	**9.0**	**81.0**
MEAN	**11.61**	**6.83**	**13.4**	**19.63**	**8.6**	**26.0**

Table 4-1b: Average Water Quality Parameter Values by Station During Fall Open Conditions.

Station	Avgerage Salinity (PPT)	Avgerage Dissolved Oxygen	Avgerage Temperature (C)	Avgerage Conductivity (mS/cm)	Average pH	Avgerage Turbidity (NTU)
B1	5.57	3.72	19.2	10.96	9.5	26.0
B2	8.70	5.56	20.1	14.40	9.8	56.5
B3	9.75	2.80	14.6	15.70	9.8	7.0
B4	13.33	5.84	19.2	21.83	9.8	22.7
B5	16.05	6.50	19.7	25.80	9.9	23.5
B6	10.90	4.93	17.8	18.30	9.8	25.0
B7	13.25	3.24	17.0	21.80	9.7	30.0
B8	10.40	3.81	24.1	16.80	9.3	54.0
B9	0.90	1.31	21.8	1.91	8.1	35.0
MIN	**0.90**	**1.31**	**14.6**	**1.91**	**8.1**	**7.0**
MAX	**16.05**	**6.50**	**24.1**	**25.80**	**9.9**	**56.5**
MEAN	**9.87**	**4.19**	**19.3**	**16.39**	**9.5**	**31.1**

Table 4-1c: Average Water Quality Parameter Values by Station During Spring Open Conditions.

Station	Avgerage Salinity (PPT)	Avgerage Dissolved Oxygen	Avgerage Temperature (C)	Avgerage Conductivity (mS/cm)	Average pH	Avgerage Turbidity (NTU)
B1	3.00	3.82	23.2	5.52	8.4	N/A
B2	2.64	3.46	22.1	5.16	8.3	N/A
B3	3.45	9.00	22.0	6.07	9.2	N/A
B4	3.34	N/A	24.3	6.51	9.6	N/A
B5	3.60	N/A	24.2	6.77	9.6	N/A
B6	3.03	N/A	25.1	5.75	9.3	N/A
B7	3.38	N/A	21.3	6.36	9.4	N/A
B8	3.35	N/A	25.8	6.39	9.4	N/A
B9	3.20	10.12	25.7	6.08	9.0	N/A
MIN	**2.64**	**3.46**	**21.34**	**5.16**	**8.3**	N/A
MAX	**3.60**	**10.12**	**25.75**	**6.77**	**9.6**	N/A
MEAN	**3.22**	**6.60**	**23.74**	**6.07**	**9.1**	N/A

Table 4-1d: Average Water Quality Parameter Values by Station During Spring Closed Conditions.

	% Gravel	% Sand	% Silt & Clay	TOC	Salinity	DO	Temperature	Conductivity	pH	Turbidity
Median Grain Size	0.919						0.802			
% Gravel							0.786			
% Sand			-0.673	-0.839						
% Silt & Clay				0.910			-0.664			
TOC										
Salinity							-0.502	0.999	0.459	
DO										
Temperature								-0.499		
Conductivity									0.454	
pH										
Turbidity										

[1]For clarity, only significant correlations are shown.

Table 4-2: Correlations Between Physical Parameters

Station	Median Grain Size (mm)	Gravel (% By Mass)	Sand (% By Mass)	Silt & Clay (% By Mass)	Total Organic Carbon (g/cm^3)
B1	0.537999988	12.30	56.29	31.41	0.29
B2	0.254000008	0.36	73.22	26.43	0.30
B3	0.059999999	0.00	47.42	52.58	0.37
B4	0.416999996	0.45	95.60	3.94	0.12
B5	0.531000018	1.41	97.98	0.61	0.07
B6	1.04400003	35.17	62.74	2.08	0.11
B7	0.039000001	6.69	32.33	60.98	0.83
B8	2.407999992	50.37	49.00	0.63	
B9	1.539000034	36.30	63.13	0.57	
MIN	**0.04**	**0.00**	**32.33**	**0.57**	**0.07**
MAX	**2.41**	**50.37**	**97.98**	**60.98**	**0.83**
MEAN	**0.76**	**15.89**	**64.19**	**19.91**	**0.30**

Table 4-3: Sediment Properties By Station During Spring Closed Conditions.

Phylum	Class	Order	Family	Genus	Species	All Stations	B1	B2	B3	B4	B5	B6	B7	B8	B9
Platyhelminthes	Turbellaria	Neorhabdocoela				0									
Mollusca	Gastropoda	Basommatophora	Lymnaeidae		*sp. 1*	15									15
			Physidae	*Physa*		1214	3	2	2	19	24	26	19	327	792
				Physa	*sp. 1*	1		1							
		Mesogastropoda	Pomatiopsidae	*Pomatiopsis*	*californica*	130	86	42	1		1				
Annelida	Archiannelida	Canalipalpata	Saccocirridae	*Saccocirrus*		0									
	Oligochaeta	Lumbriculida	Lumbriculidae			0									
		Tubificida	Enchytraeidae			0									
					sp. 2	16			1	3		12			
			Tubificidae			0									
				Limnodrilus		2357	2078	254	21		3		1		
	Polychaeta	Aciculata	Hesionidae	*Microphthalmus*	*sp.*	0									
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*		976	10	294	63	255	109	154	50	9	32
	Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	*sp. 1*	26	1		5	2	13	3	2		
			Hyalellidae	*Hyalella*	*azteca*	40	35			2		3			
		Decapoda	Hippidae	*Emerita*	*analoga*	0									
	Maxillipoda	Cyclopoida				0									
		Harpacticoida				0									
	Ostracoda	Podocopina	Cyprididae		*sp. 1*	248	35	21	34	72	3	7	75	1	
					sp. 2	593	11	2	15	131	59	87	23	115	150
					sp. 3	0									
	Insecta	Coleoptera	Dytiscidae			0									
			Hydrophilidae	*Berosus*		3			1						2
		Collembola	Isotomidae			3				1	1		1		
		Diptera	Ceratopogonidae			1	1								
			Chironomidae			48	1	18	7	8	1	4	7	2	
					sp. 2	183	7	29	13	18		85	30	1	
				Chironomus		1098	118	120	72	248	52	157	257	74	
				Cladotanytarsus		1353	8	33	182	316	295	343	140	33	3
			Ephydridae			3			1					1	1
				Ephydra		1									1
				Ephydra	*riparia*	0									
						7	6				1				
		Ephemeroptera				1					1				
		Hemiptera	Corixidae			8				4				4	
				Corisella	*inscripta*	2				1				1	
				Trichocorixa	*reticulata*	1						1			
		Hymenoptera				0									

Table 4-4a: Invertebrate Abundance Data for Fall, Mouth Closed Conditions

Phylum	Class	Order	Family	Genus	Species	All Stations	B1	B2	B3	B4	B5	B6	B7	B8	B9
Platyhelminthes	Turbellaria	Neorhabdocoela				35					35				
Mollusca	Gastropoda	Basommatophora	Lymnaeidae		*sp. 1*	0									
			Physidae	*Physa*		274			1			1	22	7	243
				Physa	*sp. 1*	0									
		Mesogastropoda	Pomatiopsidae	*Pomatiopsis*	*californica*	244	173	68	2					1	
Annelida	Archiannelida	Canalipalpata	Saccocirridae	*Saccocirrus*		1					1				
	Oligochaeta	Lumbriculida	Lumbriculidae			1		1							
		Tubificida	Enchytraeidae			1				1					
					sp. 2	0									
			Tubificidae			2				2					
				Limnodrilus		1402	1230	163	9						
	Polychaeta	Aciculata	Hesionidae	*Microphthalmus*	*sp.*	1					1				
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*		0									
	Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	*sp. 1*	166	112	1				1	31	7	14
			Hyalellidae	*Hyalella*	*azteca*	7		1							6
		Decapoda	Hippidae	*Emerita*	*analoga*	0									
	Maxillipoda	Cyclopoida				0									
		Harpacticoida				0									
	Ostracoda	Podocopina	Cyprididae		*sp. 1*	3591	178	2025	75	285	33	236	676	83	
					sp. 2	2705		16	5	1	1	13	106	100	2463
					sp. 3	4	4								
	Insecta	Coleoptera	Dytiscidae			1									1
			Hydrophilidae	*Berosus*		4							3	1	
		Collembola	Isotomidae			0									
		Diptera	Ceratopogonidae			0									
			Chironomidae			0									
					sp. 2	71	2	60			1	1	2		5
				Chironomus		197	27	162				1	3		4
				Cladotanytarsus		28	4	24							
			Ephydridae			0									
				Ephydra		0									
				Ephydra	*riparia*	0									
						3		1							2
		Ephemeroptera				0									
		Hemiptera	Corixidae			0									
				Corisella	*inscripta*	3									3
				Trichocorixa	*reticulata*	0									
		Hymenoptera				0									

Table 4-4b: Invertebrate Abundance Data for Fall, Mouth Open Conditions

Phylum	Class	Order	Family	Genus	Species	All Stations	B1	B2	B3	B4	B5	B6	B7	B8	B9
Platyhelminthes	Turbellaria	Neorhabdocoela				1						1			
Mollusca	Gastropoda	Basommatophora	Lymnaeidae		*sp. 1*	0									
			Physidae	*Physa*		15						10	4		1
				Physa	*sp. 1*	0									
		Mesogastropoda	Pomatiopsidae	*Pomatiopsis*	*californica*	12	3	9							
Annelida	Archiannelida	Canalipalpata	Saccocirridae	*Saccocirrus*		0									
	Oligochaeta	Lumbriculida	Lumbriculidae			0									
		Tubificida	Enchytraeidae			0									
					sp. 2	11							11		
			Tubificidae			0									
				Limnodrilus		3939	1131	233	67	2		186	55	527	1738
	Polychaeta	Aciculata	Hesionidae	*Microphthalmus*	*sp.*	0									
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*		0									
	Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	*sp. 1*	2430	465	64	4	10	10	3	172	120	1582
			Hyalellidae	*Hyalella*	*azteca*	0									
		Decapoda	Hippidae	*Emerita*	*analoga*	4					4				
	Maxillipoda	Cyclopoida				0									
		Harpacticoida				2									2
	Ostracoda	Podocopina	Cyprididae		*sp. 1*	6670	164	168	1139	2382	2	1211	1254	163	187
					sp. 2	1156	3		1	1		2	5	4	1140
					sp. 3	1		1							
	Insecta	Coleoptera	Dytiscidae			4								1	3
			Hydrophilidae	*Berosus*		0									
		Collembola	Isotomidae			1			1						
		Diptera	Ceratopogonidae			3									3
			Chironomidae			64		20		1	1		2	4	36
					sp. 2	33		32							1
				Chironomus		70	1	15							54
				Cladotanytarsus		504		136		1		7	17	59	284
			Ephydridae			1		1							
				Ephydra		0									
				Ephydra	*riparia*	2						1		1	
						1	1								
		Ephemeroptera				1							1		
		Hemiptera	Corixidae			0									
				Corisella	*inscripta*	0									
				Trichocorixa	*reticulata*	0									
		Hymenoptera				1							1		

Table 4-4c: Invertebrate Abundance Data for Spring, Mouth Open Conditions

Phylum	Class	Order	Family	Genus	Species	All Stations	B1	B2	B3	B4	B5	B6	B7	B8	B9
Platyhelminthes	Turbellaria	Neorhabdocoela				0									
Mollusca	Gastropoda	Basommatophora	Lymnaeidae		*sp. 1*	0									
			Physidae	*Physa*		3									3
				Physa	*sp. 1*	0									
		Mesogastropoda	Pomatiopsidae	*Pomatiopsis*	*californica*	0									
Annelida	Archiannelida	Canalipalpata	Saccocirridae	*Saccocirrus*		0									
	Oligochaeta	Lumbriculida	Lumbriculidae			0									
		Tubificida	Enchytraeidae			0									
					sp. 2	0									
			Tubificidae			0									
				Limnodrilus		402	124	94	14		2	15		9	144
	Polychaeta	Aciculata	Hesionidae	*Microphthalmus*	*sp.*	0									
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*		0									
	Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	*sp. 1*	1992			1		958	353		666	14
			Hyalellidae	*Hyalella*	*azteca*	0									
		Decapoda	Hippidae	*Emerita*	*analoga*	0									
	Maxillipoda	Cyclopoida				16				1	10		2	3	
		Harpacticoida				3								3	
	Ostracoda	Podocopina	Cyprididae		*sp. 1*	14235	181	1036	1039	1141	8	1230	2130	7010	460
					sp. 2	351	1	1	1	1		51		117	179
					sp. 3	0									
	Insecta	Coleoptera	Dytiscidae			0									
			Hydrophilidae	*Berosus*		1								1	
		Collembola	Isotomidae			0									
		Diptera	Ceratopogonidae			0									
			Chironomidae			295	1	11	23	2	109	41		28	80
					sp. 2	12	1							6	5
				Chironomus		882	8	60	40			20	1	331	422
				Cladotanytarsus		6119	6	66	104	8	1277	3000		599	1059
			Ephydridae			2									2
				Ephydra		0									
				Ephydra	*riparia*	1			1						
						0									
		Ephemeroptera				0									
		Hemiptera	Corixidae			2				1					1
				Corisella	*inscripta*	0									
				Trichocorixa	*reticulata*	0									
		Hymenoptera				0									

Table 4-4d: Invertebrate Abundance Data for Spring, Mouth Closed Conditions

Fall, Closed mouth

	Median Grain Size	% Gravel	% Sand	% Silt & Clay	TOC	Salinity	DO	Temperature	Conductivity	pH	Turbidity
# Individuals	--	--	--	--	--						
# Species	--	--	--	--	--						
Diversity (H')	--	--	--	--	--						
Evenness	--	--	--	--	--						

Fall, Open mouth

	Median Grain Size	% Gravel	% Sand	% Silt & Clay	TOC	Salinity	DO	Temperature	Conductivity	pH	Turbidity
# Individuals	--	--	--	--	--		-0.75			-0.68	0.68
# Species	--	--	--	--	--					-0.73	0.83
Diversity (H')	--	--	--	--	--						
Evenness	--	--	--	--	--						

Spring, Open mouth

	Median Grain Size	% Gravel	% Sand	% Silt & Clay	TOC	Salinity	DO	Temperature	Conductivity	pH	Turbidity
# Individuals	--	--	--	--	--	-0.74	-0.67		-0.75	-0.84	
# Species	--	--	--	--	--	-0.68			-0.67	-0.67	
Diversity (H')	--	--	--	--	--						0.76
Evenness	--	--	--	--	--						

Spring, Closed mouth

	Median Grain Size	% Gravel	% Sand	% Silt & Clay	TOC	Salinity	DO	Temperature	Conductivity	pH	Turbidity
# Individuals	0.83	0.83									--[2]
# Species						-0.88			-0.88	-0.79	--
Diversity (H')						-0.81			-0.81	-0.78	--
Evenness						-0.63			-0.64	-0.66	--

[1]Only significant correlations are shown

[2]No data collected

Table 4-5: Summary of significant correlations between community parameters and physical factors by sampling event.[1]

Taxon	Density (Individuals/dm^2)									
	B1 (USFWS Site 3)		B3 (USFWS Site 2)		B4 (USFWS Site 4)		B5 (USFWS Site 1)		B8 (USFWS Site 7)	
	USFWS	ENTRIX	USFWS	ENTRIX	USFWS	ENTRIX	USFWS	ENTRIX	USFWS	ENTRIX
Turbellaria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0
Physidae	0.4	1.2	0.0	1.2	0.0	7.8	0.0	9.8	9.4	136.3
Pomatiopsidae	0.0	106.9	0.0	1.2	0.0	0.0	0.0	0.4	0.0	0.4
Saccocirridae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Oligochaeta	9.8	1861.7	2.9	45.7	2.9	3.3	0.8	2.0	21.2	218.7
Hirudinea	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Polychaeta	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Daphnia	0.0	4.1	0.0	25.7	0.0	104.0	5.3	44.5	0.8	3.7
Gammarus	0.4	0.0	0.0	0.0	1.2	0.0	0.8	0.0	0.0	0.0
Eogammarus	0.0	235.8	0.0	4.1	0.0	4.9	0.0	400.2	0.0	323.5
Hyalella azteca	10.6	14.3	0.0	0.0	0.0	0.8	0.0	0.0	1.6	0.0
Hippidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0
Cyclopoida	0.0	0.0	0.0	0.0	0.0	0.4	0.0	4.1	0.4	1.2
Harpacticoida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Ostracoda	0.0	235.4	0.0	942.1	0.0	1637.7	0.0	43.2	0.0	3097.9
Dytiscidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Hydrophilidae	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.4	0.8
Collembola	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.4	0.0	0.0
Ceratopogonidae	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tipulidae	0.0	0.0	0.4	0.0	1.5	0.0	0.4	0.0	0.0	0.0
Dixidae	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironomidae	172.2	75.1	22.4	179.9	128.4	245.6	87.6	708.3	47.7	463.9
Ephydridae	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.8
Ephemeroptera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.6	0.0
Corixidae	1.6	0.0	6.1	0.0	2.9	0.4	1.2	0.0	0.4	2.0
SUM	*195.430437*	*2534.883721*	*34.27172583*	*1201.550388*	*137.250102*	*2005.303958*	*96.20563035*	*1230.110159*	*83.63933089*	*4250.91799*

Table 4-6: Species Abundance Data from USFWS and ENTRIX Sampling

Phylum	Class	Order	Family	Genus and Species	Mugu Lagoon			Malibu Lagoon	Santa Margarita Estuary	Batiquitos Lagoon	San Dieguito Lagoon		Los Penasquitos			Tijuana Estuary						Santa Clara River Estuary	
					Peterson 1977[2]	Onuf 1987	TetraTech 1998[3]	Dillingham 1989[7]	Salata 1981	CA DFG 1976	CA DFG 1976	MEC 1993[4]	Nordby 1991[1]	Ward 2001	Williams 1995	Pre 1980[5]	Hosmer 1977[6]	Rehse 1981[6]	Griswold 1985[6]	Dexter 1985[6]	Nordby 1991[1]	**USFWS 1999**	**Entrix 2002[8]**
Protozoa	Granuloreticulosea	Foraminiderida	Miliolidae	*Quinqueloculina seminulum*					X	X	X												
	Granuloreticulosea	Foraminiferida	Rotaliidae	*Ammonia beccarii*						X	X												
Cnidaria	Anthozoa	Actiniaria	Diadumenidae	*Diadumene leucolena*								X											
	Anthozoa	Actiniaria	Halcampidae	*Halcampa crypta*								X											
	Hydrozoa	Hydroida	Corymorphidae	*Corymorpha palma*												X							
				Pienilla katlliberi												X							
Platyhelminthes	Turbellaria	Polycladida	Stylochidae	*Stylochus sp.*												X				X			
	Turbellaria			*Turbellaria spp.*																X			
	Turbellaria	Neorhabdocoela		*sp.*																			**X**
Nemertea				*sp.*		X							X							X	X		
	Anopla	Heteronemertea	Lineidae	*sp.*								X											
	Anopla	Heteronemertia	Liniedae	*Cerebratulus sp.*					X														
	Anopla	Heteronemertea	Lineidae	*Lineus ruber*			X																
	Anopla	Heteronemertea	Lineidae	*Micrura alaskensis*			X																
	Anopla	Paleonemertea	Carinomidae	*Carinoma mutabilis*			X																
	Anopla	Paleonemertea	Tubulanidae	*Carinomella lactea*			X																
	Enopla		Tetrastemmatidae	*Tetrastemma nigrifrons*			X																
Mollusca	Bivalvia			*Florimetis obesa*		X										X	X						
	Bivalvia	Myoida	Myidae	*Cryptomoya californica*	X	X						X				X	X	X					
	Bivalvia	Mytiloida	Mytilidae	*Musculista senhousei*										X	X	X				X			
	Bivalvia	Mytiloida	Mytilidae	*Mytilus edulis*												X	X		X	X			
	Bivalvia	Mytiloida	Mytilidae	*Mytilus sp.*										X									
	Bivalvia	Ostreoida	Osteaidae	*Ostrea lurida*												X			X				
	Bivalvia	Ostreoida	Pectinidae	*Leptopecten latiauratus*										X		X		X					
	Bivalvia	Veneroida	Cardiidae	*Apolymetis biangulata*	X																		
	Bivalvia	Veneroida	Cardiidae	*Laevicardium substriatum*		X					X	X	X			X	X		X	X	X		
	Bivalvia	Veneroida	Donacidae	*Donax californicus*												X							
	Bivalvia	Veneroida	Lucinidae	*Lucina nuttalli*												X	X						
	Bivalvia	Veneroida	Lucinidae	*Parvilucina tenuisculpta*								X											
	Bivalvia	Veneroida	Mactridae	*Mactra californica*					X							X	X			X			
	Bivalvia	Veneroida	Mactridae	*Spisula planulata*															X				
	Bivalvia	Veneroida	Mactridae	*Tresus nuttallii*	X											X	X						
	Bivalvia	Veneroida	Petricolidae	*Cooperella subdiaphana*							X					X							
	Bivalvia	Veneroida	Petricolidae	*Petricola cf. Tellimaulis*							X												
	Bivalvia	Veneroida	Pheridae	*Siliqua patula*												X							
	Bivalvia	Veneroida	Psammobiidae	*Nuttallia nuttallii*																			
	Bivalvia	Veneroida	Psammobidae	*Sanguinolaria nuttallii*	X											X	X	X					
	Bivalvia	Veneroida	Solecurtidae	*Tagelus californianus*	X	X	X	X	X		X		X	X	X	X	X	X		X	X		
	Bivalvia	Veneroida	Solecurtidae	*Tagelus subteres*							X	X				X							
	Bivalvia	Veneroida	Solenidae	*Solen rosaceus*																X			
	Bivalvia	Veneroida	Tellinidae	*Tellina carperenteri*							X					X	X						
	Bivalvia	Veneroida	Tellinidae	*Macoma nasuta*	X	X	X		X		X		X			X	X		X	X	X		
	Bivalvia	Veneroida	Tellinidae	*Macoma secta*												X	X						
	Bivalvia	Veneroida	Unquilidae	*Diplodonta orbellus*		X										X				X			
	Bivalvia	Veneroida	Veneridae	*Chione californiensis*					X							X		X		X			
	Bivalvia	Veneroida	Veneridae	*Chione fluctigraga*												X		X					
	Bivalvia	Veneroida	Veneridae	*Chione sp.*										X									
	Bivalvia	Veneroida	Veneridae	*Chione undatella*		X			X							X	X	X	X	X			
	Bivalvia	Veneroida	Veneridae	*Protothaca lacineata*												X							
	Bivalvia	Veneroida	Veneridae	*Protothaca staminea*	X	X	X						X	X	X	X	X	X		X	X		
	Bivalvia	Veneroida	Veneridae	*Saxidomus nuttalli*	X											X	X						
	Gastropoda			*sp.*																			**X**
	Gastropoda			*Serpulorbia scuamigeris*															X				
	Gastropoda			*Famincea vesicula*															X	X			
	Gastropoda	Anaspidea	Aplysiidae	*Aplysia californica*										X		X			X	X			
	Gastropoda	Archaeogastropoda	Turbinidae	*Eulithidium pulloide*										X									
	Gastropoda	Archaeopulmonata	Ellobiidae	*Melampus olivaceus*			X							X		X							
	Gastropoda	Basommatophora	Physidae	*sp.*																		**X**	
	Gastropoda	Basommatophora	Physidae	*Physa spp.*			X			X	X												**X**
	Gastropoda	Basommatophora	Lymnaeidae	*sp.*																			**X**
	Gastropoda	Cephalaspidea	Aglajidae	*Navanax ienermis*					X					X	X	X				X			
	Gastropoda	Cephalaspidea	Bullidae	*Bulla gouldiana*		X	X		X					X	X	X				X			
	Gastropoda	Cephalaspidea	Cylichnidae	*Acteocina culcitella*																X			
	Gastropoda	Cephalaspidea	Cylichnidae	*Acteocina faculta*												X							
	Gastropoda	Cephalaspidea	Cylichnidae	*Acteocina inculta*			X					X											
	Gastropoda	Cephalaspidea	Cylichnidae	*Acteocina sp.*		X	X							X									
	Gastropoda	Caphalaspidea	Haminoeicae	*Haminoea vesicula*						X				X									
	Gastropoda	Megagastropoda	Pomatiopsidae	*Pomatiopsis californica*																			**X**
	Gastropoda	Neogastropoda	Muristicae	*Pteropurpura festivus*					X														
	Gastropoda	Neogastrapoda	Nassariidae	*Nassarius fossatus*												X							
	Gastropoda	Neogastrapoda	Nassariidae	*Nassarius sp.*										X									
	Gastropoda	Neogastrapoda	Nassariidae	*Nassarius tegula*								X				X							
	Gastropoda	Neogastropoda	Olividae	*Olivella batica*												X							
	Gastropoda	Neogastropoda	Olividae	*Olivella biplicata*		X			X							X				X			
	Gastropoda	Neotaenioglossa	Assimineidae	*Assiminea californica*		X				X				X		X			X	X			
	Gastropoda	Neotaenioglossa	Calyptraeidae	*Crepidula fornicata*												X							
	Gastropoda	Neotaenioglossa	Calyptraeidae	*Crepidula onyx*		X										X							
	Gastropoda	Neotaenioglossa	Hydrobiidae	*sp.*								X											
	Gastropoda	Neotaenioglossa	Hydrobiidae	*Bythinella sp*						X	X												
	Gastropoda	Neotaenioglossa	Naticidae	*Polinices lewisii*												X							
	Gastropoda	Neotaenioglossa	Potamididae	*Cerithidea californica*		X	X		X		X	X		X	X	X			X	X			
	Gastropoda	Neotaenioglossa	Rissoidae	*sp.*								X											
	Gastropoda	Patelogastropoda	Lottiidae	*Collisella limatula*															X				
	Gastropoda	Sacoglossa	Stiligeridae	*Alderia modesta*								X		X									
	Gastropoda	Stylommatophora	Zonitidae	*Hawaiia minuscula*			X																

Table 5-1 Taxa Encountered in Previous Studies of Estuaries in the Southern California Bight

Phylum	Class	Order	Family	Genus and Species	Mugu Lagoon			Malibu Lagoon	Santa Margarita Estuary	Batiquitos Lagoon	San Dieguito Lagoon		Los Penasquitos			Tijuana Estuary						Santa Clara River Estuary	
					Peterson 1977[2]	Onuf 1987	TetraTech 1998[3]	Dillingham 1989[7]	Salata 1981	CA DFG 1976	CA DFG 1976	MEC 1993[4]	Nordby 1991[1]	Ward 2001	Williams 1995	Pre 1980[5]	Hosmer 1977[6]	Rehse 1981[6]	Griswold 1985[6]	Dexter 1985[6]	Nordby 1991[1]	**USFWS 1999**	**Entrix 2002[8]**
Annelida	Clitellata	Haplotaxida	Naididae	*sp.*			X																
	Clitellata	Haplotaxida	Tubificidae	*sp.*			X																
	Hirudinea			*sp.*																		**X**	
	Oligochaeta			*sp.*		X					X	X										**X**	
	Oligochaeta	Lumbriculida	Lumbriculidae	*sp.*																			**X**
	Oligochaeta	Tubificida	Enchytraeidae	*sp.*																			**X**
	Oligochaeta	Tubificida	Tubficidae	*sp.*																			**X**
	Oligochaeta	Tubificida	Tubficidae	*Limnodrilus sp.*																			**X**
	Polychaeta			*sp.*																		**X**	
	Polychaeta	Aciculata	Amphinomidae	*Pareurythoe californica*		X																	
	Polychaeta	Aciculata	Aphroditidae	*Pontogenia rostrata*										X									
	Polychaeta	Aciculata	Glyceridae	*Glycera caitata*																X			
	Polychaeta	Aciculata	Glyceridae	*Glycera dibranchiata*												X			X				
	Polychaeta	Aciculata	Glyceridae	*Glycera sp.*					X														
	Polychaeta	Aciculata	Glyceridae	*Hemipodus borealis*		X									X								
	Polychaeta	Aciculata	Goniadidae	*Glycinde polygnatha*			X																
	Polychaeta	Aciculata	Goniadidae	*Goniada sp.*		X																	
	Polychaeta	Aciculata	Goniadidae	*sp.*																X			
	Polychaeta	Aciculata	Lumbrineridae	*sp.*																X			
	Polychaeta	Aciculata	Lumbrineridae	*Lumbrineris sp.*					X														
	Polychaeta	Aciculata	Lumbrineridae	*Lumbrinereis tetraura*			X																
	Polychaeta	Aciculata	Nephtydae	*Nephtys caecoides*												X				X			
	Polychaeta	Aciculata	Nephtydae	*Nephtys californiensis*												X							
	Polychaeta	Aciculata	Nephtydae	*Nephtys punctata*												X			X				
	Polychaeta	Aciculata	Nephtydae	*Nephtys spp.*												X							
	Polychaeta	Aciculata	Nereidae	*Nereis sp.*		X			X														
	Polychaeta	Aciculata	Onuphidae	*Diopatra ornata*												X							
	Polychaeta	Aciculata	Phyllodocidae	*sp.*																X			
	Polychaeta	Aciculata	Phyllodocidae	*Eteone californica*			X																
	Polychaeta	Aciculata	Phyllodocidae	*Eteone sp.*										X									
	Polychaeta	Aciculata	Phyllodocidae	*Eumida longicornuta*			X																
	Polychaeta	Aciculata	Syllidae	*sp.*																X			
	Polychaeta	Canalipalpata	Chaetopteridae	*Chaetopterus variopedatus*												X							
	Polychaeta	Canalipalpata	Chaetopteridae	*Chaetopterus sp.*					X														
	Polychaeta	Canalipalpata	Magilonidae	*Magelona pitelkai*												X							
	Polychaeta	Canalipalpata	Magilonidae	*sp.*																X			
	Polychaeta	Canalipalpata	Oweniidae	*Owenia collaris*			X																
	Polychaeta	Canalipalpata	Oweniidae	*Owenia fusiformis*												X							
	Polychaeta	Canalipalpata	Sabellidae	*Fabricia limnicola*			X																
	Polychaeta	Canalipalpata	Sabellidae	*Sabellid sp.*		X																	
	Polychaeta	Canalipalpata	Spionidae	*Boccardia proboscidae*			X					X											
	Polychaeta	Canalipalpata	Spionidae	*Boccardia spp.*									X								X		
	Polychaeta	Canalipalpata	Spionidae	*Boccardiella hamata*								X											
	Polychaeta	Canalipalpata	Spionidae	*Minuspio cirrifera*		X																	
	Polychaeta	Canalipalpata	Spionidae	*Polydora complex*										X									
	Polychaeta	Canalipalpata	Spionidae	*Polydora cornuta*			X						X								X		
	Polychaeta	Canalipalpata	Spionidae	*Polydora ligni*								X	X								X		
	Polychaeta	Canalipalpata	Spionidae	*Polydora nuchalis*			X	X				X			X								
	Polychaeta	Canalipalpata	Spionidae	*Polydora socialis*						X	X												
	Polychaeta	Canalipalpata	Spionidae	*Polydora spp.*		X							X		X				X	X	X		
	Polychaeta	Canalipalpata	Spionidae	*Prionospio heterobranchia*			X																
	Polychaeta	Canalipalpata	Spionidae	*Prionospio lighti*			X																
	Polychaeta	Canalipalpata	Spionidae	*Prionospio pygmaea*			X																
	Polychaeta	Canalipalpata	Spionidae	*Prionospio sp.*								X				X				X			
	Polychaeta	Canalipalpata	Spionidae	*Pseudopolydora paucibranchiata*			X					X											
	Polychaeta	Canalipalpata	Spionidae	*Pseudopolydora sp.*		X																	
	Polychaeta	Canalipalpata	Spionidae	*Rhynchospio arenicola*											X								
	Polychaeta	Canalipalpata	Spionidae	*Scolelepis tridentata*			X																
	Polychaeta	Canalipalpata	Serpulidae	*Serpula vermicularis*															X				
	Polychaeta	Canalipalpata	Spionidae	*Spiophanes missionensis*		X	X														X		
	Polychaeta	Canalipalpata	Spionidae	*Streblospio benedicti*		X	X					X		X	X								
	Polychaeta	Canalipalpata	Spionidae	*Streblospio ssp.*			X																
	Polychaeta	Ctenodrilidae	Ctenodrilus	*Serratus*			X																
	Polychaeta		Arenicolidae	*Arenicola sp.*					X														
	Polychaeta		Capitellidae	*sp.*									X							X	X		
	Polychaeta		Capitellidae	*Capitella capitata*		X	X		X	X		X											
	Polychaeta		Capitellidae	*Capitella sp.*										X									
	Polychaeta		Capitellidae	*Heteromastus filiformis*								X											
	Polychaeta		Capitellidae	*Mediomastus ambiseta*			X																
	Polychaeta		Capitellidae	*Mediomastus californiensis*			X																
	Polychaeta		Capitellidae	*Mediomastus spp.*			X																
	Polychaeta		Capitellidae	*Notomastus tenuis*		X	X		X							X							
	Polychaeta		Hesionidae	*Microphthalmus sp.*																			**X**
	Polychaeta		Maldanidae	*Axiothella rubrocinta*		X	X				X					X							
	Polychaeta		Maldanidae	*sp.*																X			
	Polychaeta		Obiniidae	*Scoloplos armeceps*			X																
	Polychaeta		Opheliidae	*Armandia brevis*		X	X								X					X			
	Polychaeta		Opheliidae	*Euzonus mucronata*									X										
	Polychaeta		Opheliidae	*Ophelia*		X																	
	Polychaeta		Opheliidae	*Ophelia limocina*												X				X			
	Polychaeta		Opheliidae	*Polyopthalmus pictus*			X							X									
	Polychaeta		Orbiniidae	*sp.*																X			
	Polychaeta		Orbiniidae	*Haploscoloplos elongatus*		X										X							
	Polychaeta		Saccocirridae	*Saccocirrus sp.*																			**X**
	Polychaeta			*Dipopatra spiendicissima*												X							

Table 5-1 Taxa Encountered in Previous Studies of Estuaries in the Southern California Bight

Phylum	Class	Order	Family	Genus and Species	Mugu Lagoon			Malibu Lagoon	Santa Margarita Estuary	Batiquitos Lagoon	San Dieguito Lagoon		Los Penasquitos			Tijuana Estuary						Santa Clara River Estuary	
					Peterson 1977[2]	Onuf 1987	TetraTech 1998[3]	Dillingham 1989[7]	Salata 1981	CA DFG 1976	CA DFG 1976	MEC 1993[4]	Nordby 1991[1]	Ward 2001	Williams 1995	Pre 1980[5]	Hosmer 1977[6]	Rehse 1981[6]	Griswold 1985[6]	Dexter 1985[6]	Nordby 1991[1]	**USFWS 1999**	**Entrix 2002[8]**
Arthropoda	Arachnida	Araneae	Araneidae	*sp.*								X											
	Insecta	Coleoptera	Curculionidae	*sp.*								X											
	Insecta	Coleoptera	Dytiscidae	*sp.*																			X
	Insecta	Coleoptera	Hydrophilidae	*sp.*								X										X	
	Insecta	Coleoptera	Hydrophilidae	*Berosus sp.*																			X
	Insecta	Coleoptera	Staphylinidae	*sp.*								X											
	Insecta	Coleoptera	Tenebrionidae	*sp.*								X											
	Insecta	Coleoptera		*sp.*						X	X	X											
	Insecta	Collembola	Isotomidae	*sp.*																			X
	Insecta	Diptera	Ceratopogonidae	*sp.*								X											X
	Insecta	Diptera	Chironimidae	*sp.*								X										X	X
	Insecta	Diptera	Chironimidae	*Chironomus sp.*																			X
	Insecta	Diptera	Chironimidae	*Cladotanytarsus sp.*																			X
	Insecta	Diptera	Dixidae	*sp.*																		X	
	Insecta	Diptera	Dolichopodidae	*sp.*			X					X											
	Insecta	Diptera	Ephydridae	*sp.*								X											X
	Insecta	Diptera	Ephydridae	*Ephydra sp.*																			X
	Insecta	Diptera	Ephydridae	*Ephydra riparia*																			X
	Insecta	Diptera	Muscidae	*sp.*								X											
	Insecta	Diptera	Stratiomyidae	*sp.*								X											
	Insecta	Diptera	Syrphidae	*sp.*								X											
	Insecta	Diptera	Tabanidae	*sp.*								X											
	Insecta	Diptera	Tipulidae	*sp.*																		X	
	Insecta	Diptera		*sp.*								X											X
	Insecta	Ephemeroptera																					X
	Insecta	Ephemeroptera	Baetidae	*sp.*																		X	
	Insecta	Hemiptera		*sp.*																		X	
	Insecta	Hemiptera	Aphididae	*sp.*								X											X
	Insecta	Hemiptera	Cicadellidae	*sp.*								X											
	Insecta	Hemiptera	Corixidae	*sp.*						X	X	X										X	X
	Insecta	Hemiptera	Corixidae	*Trichocorixa sp.*					X														
	Insecta	Hemiptera	Corixidae	*Corisella Insripta*																			X
	Insecta	Hemiptera	Membracidae	*sp.*								X											
	Insecta	Hemiptera	Psyllidae	*sp.*								X											
	Insecta	Heteroptera	Corixidae	*Trichocorixa reticulata*								X		X									X
	Insecta	Heteroptera	Macroveliidae	*sp.*								X											
	Insecta	Heteroptera	Miridae	*sp.*								X											
	Insecta	Heteroptera	Pentatomidae	*sp.*								X											
	Insecta	Heteroptera	Saldidae	*sp.*								X											
	Insecta	Hymenoptera	Formicidae	*sp.*								X											
	Insecta	Hymenoptera		*sp.*								X											X
	Insecta	Lepidoptera		*sp.*								X											
	Insecta	Plecoptera		*sp.*								X											
Subphylum Crustacea	Malacostraca	Amphipoda		*sp.*																		X	
	Malacostraca	Amphipoda	Ampithoidae	*Ampithoe plumosa*															X				
	Malacostraca	Amphipoda	Caprellidae	*Caprella sp.*								X											
	Malacostraca	Amphipoda	Caprellidae	*Caprellid amphipod*		X																	
	Malacostraca	Amphipoda	Corophiidae	*Corophuim sp.*			X					X		X									
	Malacostraca	Amphipoda	Corophiidae	*Grandidierella japonica*								X		X									
	Malacostraca	Amphipoda	Eusiridae	*Tethygenia opata*								X		X									
	Malacostraca	Amphipoda	Gammaridea	*sp.*																		X	
	Malacostraca	Amphipoda	Gammaridea	*Gammaridea amphipod*		X																	
	Malacostraca	Amphipoda	Gammaridea	*Eogammarus sp.*																			X
	Malacostraca	Amphipoda	Hautoriidae	*Eohaustorius washingtonianus*												X							
	Malacostraca	Amphipoda	Hyalellidae	*Hyallela azeteca*								X										X	X
	Malacostraca	Amphipoda	Ischyroceridae	*Jassa falcata*															X				
	Malacostraca	Amphipoda	Phoxocephalidae	*Heterophoxus oculatus*								X											
	Malacostraca	Amphipoda	Talitridae	*sp.*			X																
	Malacostraca	Amphipoda	Talitridae	*Talitrus sp.*								X											
	Malacostraca	Cumacea		*sp.*																			
	Malacostraca	Decapoda	Callianassidae	*Callianassa affinis*															X				
	Malacostraca	Decapoda	Callianassidae	*Callianassa californiensis*	X	X			X	X			X			X			X	X	X		
	Malacostraca	Decapoda	Callianassidae	*Callianassa gigas*												X			X				
	Malacostraca	Decapoda	Callianassidae	*Neotrypaea californiensis*											X								
	Malacostraca	Decapoda	Cambaridae	*Procambarus sp.*						X													
	Malacostraca	Decapoda	Cancridae	*Cancer antennarius*					X										X				
	Malacostraca	Decapoda	Cancridae	*Cancer productus*															X				
	Malacostraca	Decapoda	Cancridae	*Cancer sp.*												X							
	Malacostraca	Decapoda	Crangonidae	*Crangon franciscorum*											X								
	Malacostraca	Decapoda	Gonaplacidae	*Speocarcinus californiensis*												X							
	Malacostraca	Decapoda	Grapsidae	*Hemigrapsus oregonensis*		X	X		X					X	X	X			X				
	Malacostraca	Decapoda	Grapsidae	*Pachygrapsus crassipes*			X		X	X				X	X	X			X				
	Malacostraca	Decapoda	Hippidae	*Emerita analoga*												X							X
	Malacostraca	Decapoda	Hippolytidae	*Spirontocaris palpator*															X				
	Malacostraca	Decapoda	Hippolytidae	*Hippolyte californiensis*										X									
	Malacostraca	Decapoda	Majidae	*Loxorhynchus crispatus*												X							
	Malacostraca	Decapoda	Majidae	*Pugettia producta*																			
	Malacostraca	Decapoda	Ocypodidae	*Uca crenulata*					X							X			X				
	Malacostraca	Decapoda	Paguridae	*Pagurus niritusculus*															X				
	Malacostraca	Decapoda	Paguridae	*Pagurus samuelis*															X				
	Malacostraca	Decapoda	Palaemonidae	*Palaemon maacrodactylus*										X	X								
	Malacostraca	Decapoda	Pinnotheridae	*Pinnixa franciscana*												X			X				
	Malacostraca	Decapoda	Pinnotheridae	*Scleroplax granulata*												X							
	Malacostraca	Decapoda	Portunidae	*Portunus xantusi*												X							
	Malacostraca	Decapoda	Upogebiidae	*Upogebia sp.*												X							
	Malacostraca	Isopoda	Cirolanidae	*Excirolana chiltoni*								X				X							
	Malacostraca	Isopoda	Ligiidae	*sp.*							X												
	Malacostraca	Isopoda	Oniscidae	*sp.*								X											
	Malacostraca	Isopoda	Scyphacidae	*sp.*								X											
	Maxillipoda	Cyclopoida		*sp.*								X											X
	Maxillipoda	Harpacticoid		*sp.*																			X
	Ostracoda	Podocopida		*sp.*								X											
	Ostracoda	Podocopida	Cyprididae	*sp.*																			X
	Ostracoda			*sp.*						X	X												X
		Thoracica	Balanidae	*Balanus amphitrite*															X				
		Thoracica	Balanidae	*Balanus gladula*															X				
	Branchiopoda	Anostraca	Artemiidea	*Artemia salina*					X														
	Branchiopoda	Cladocera	Daphniidae	*Daphnia sp.*																			X
	Branchiopoda	Cladocera	Daphniidae	*Daphnia magna*																		X	
	Arachnida	Araneae	Araneidae	*sp.*								X											
Ectoprocta	Gymnolaemata	Cheilostomata	Bugulidae	*Bugula sp.*								X											
Phoronida				*Phoronid sp.*		X							X								X		
			Phoronidae	*Phoronis architecta*												X							
			Phoronidae	*Phoronopsis viridis*			X																
Brachiopoda	Inarticulata	Lingulida	Lingulidae	*Glottidia albida*															X				
Echinodermata	Echinoidea	Clypeasteroida	Dendrasteridae	*Dendraster excentricus*	X	X							X			X			X	X	X		
	Holothuroidea	Apodida	Synaptidae	*Leptosynapta albicans*		X																	
	Holothuroidea	Molpadida	Molpadiidae	*Molpadia avenicola*															X				
Echiura		Xenopnuesta	Urechidae	*Urechis caupo*												X							
Sipuncula			Golfingidae	*Themiste sp.*																			
			Phascolosomatidae	*Phascolosoma agassizii*			X																
			Sipunculidae	*sp.*		X																	
			Sipunculidae	*Sipunculus nudus*												X							
Hemichordata	Enteropnuesta		Harrimanidae	*Saccoglossus sp.*												X							
			Total species found		10	40	51	2	26	14	19	66	14	31	17	78	15	8	35	38	14	**15**	**36**

[1] Study only lists species with greater than 5% abundance
[2] Study lists most abundant species. Large macro-invertebrates sampled.
[3] Sampling method unknown.
[4] subtidal and tidal cores taken
[5] Excluding Hosmer 1977. Found in Nordby 1986. Sampling methods not given.
[6] Found in Nordby 1986. Sampling methods not given
7 Only benthic infauna reported.
8 Species list includes B1-9. Upstream sites B10 and B11 not included as not in estuary.

Table 5-1 Taxa Encountered in Previous Studies of Estuaries in the Southern California Bight

Phylum	Class	Order	Family	Genus	Species	Common Name	Copper Tolerance
			Freshwater Species				(PPM)
	Bivalvia	Veneroidea	Corbiculidae	Corbicula	manilensis	Asian Clam	>2600
		Architaenioglossa	Viviparidae	Campelona	decisum	Snail	1877
				Physa	heterostropha	Snail	35.91
			Physidae	**Physa**	integra	Snail	43.07
		Basommatophora	Planorbidae	Gyraulus	circumstriatus	Snail	56.21
			Hydrobiidae	Amnicola		Snail	900
Mollusca	Gastropoda	Neotaenioglossa	Pleuroceridae	Goniobasis	livescens	Snail	166.2
				Nais		Worm	90
		Haplotaxida	Naididae	Limnodrilus	hoffmeisteri	Worm	53.08
Annelida	Clitellata	Lumbricula	**Lumbriculidae**	Lumbriculus	variegatus	Worm	242.7
			Lophopodidae	Lophopodella	carteri	Bryozoan	37.05
				Plumatella	emarginata	Bryozoan	37.05
Ectoprocta	Phylactolaemata	Plumatellida	Plumatellidae	Pectinatella	magnifica	Bryozoan	135
				Ceriodaphnia	reticulata		23
				Daphnia	**magna**		41
	Branchiopoda	Diplostraca	Daphniidae	Daphnia	pulex		16.5
			Crangonyctidae	Crangonyx	pseudogracilis	Water Flea	1290
		Amphipoda	**Gammaridae**	**Gammarus**	pseudolimnaeus	Water Flea	22.09
				Orconectes	rusticus	Crayfish	1397
Arthropoda/ Crustacea	Malacostraca	Decapoda	Cambaridae	Procambarus	clarkii	Crayfish	1990
				Chironomus	decorus	Midge	739
		Diptera	Chironomidae	**Chironomus**	tentans	Midge	197
Arthropoda	Insecta	Plecoptera	Perlidae	Acroneuria	lycorias	Stonefly	10240
			Saltwater Species				
				Campanularia	flexuosa	Hydroid	10 to 15
Cnidaria	Hydrozoa	Hydroida	Campanulariidae	Phialidium		Hydroid	36
		Cydippida	Pleurobrachiidae	Pleurobrachia	pileus	Sea Gooseberry	35
Ctenophora	Tentaculata	Lobata	Mnemidae	Mnemiopsis	mccradyi	Sea Walnut	17-29
Rotifera	Monogononta	Ploima	Brachionidae	Brachionus	plicatilis	Rotifer	100
		Mytiloida	Mytilidae	Mytilus	edulis	Blue Mussel	200
		Myoida	Myidae	Mya	arenaria	Softshell Clam	35
			Ostreidae	Crassostrea	virginica	Eastern Oyster	46
		Ostreoida	Pectinidae	Argopecten	irradians	Bay Scallop	5
			Mactridae	Rangia	cuneata	Atlantic Rangia	210
			Tellinidae	Macoma	inquinata	Stained Macoma	75
				Mercenaria	mercenaria	Northern Quahog	30
	Bivalvia	Veneroida	Veneridae	Prothaca	staminea	Pacific Littleneck	59
				Haliotis	cracherodii	Black Abalone	>32
		Archeogastropoda	Haliotidae	Haliotis	rufescens	Red Abalone	>52
			Melongenidae	Busycon	canaliculatum	Whelk	470
Mollusca	Gastropoda	Neogastropoda	Nassariidae	Nassarius	obsoletus	Eastern Mudsnail	100
			Nereididae	Neanthes	arenaceodenata	Marine Worm	100
		Aciculata	Phyllodocidae	Phyllodoce	maculata	Paddleworm	80
Annelida	Polychaeta	Canalipalpata	Cirratulidae	Cirriformia	spirrabranchia		40
		Amphipoda	Ampeliscidae	Ampelisca	abdita		90
			Nephropidae	Homarus	americanus		55
			Palaemonidae	Palaemontes	pugio		12600
		Decapoda	Pandalidae	Pandalus	danae		27
	Malacostraca	Euphausiacea	Euphausiidae	Euphausia	pacifica	Krill	14-50
				Acartia	clausi	Copepod	34-82
			Acartiidae	Acartia	tonsa	Copepod	9 to 73
			Calanidae	Undinula	vulgaris	Copepod	192
			Euchaetidae	Euchaeta	marina		188
			Metridinidae	Metridia	pacifica		176
		Calanoida	Pontellidae	Labidocera	scotti		132
Arthropoda/Crustacea	Maxilipoda	Harpaticoida	Tisbidae	Tisbe	holothuriae		80
Chaetognatha	Sagittoidea	Aphragmorpha	Sagittidae	Sagitta	hispida	Arrow Worm	43-465
Echinodermata	Echinoidea	Arbacoida	Arbaciidae	Arbacia	punctulata		300

(highlighted) = Species Found In SCRE

Table 6-1: EPA Acute Copper Toxicity Limits for Freshwater and Marine Species Showing Overlap with SCRE Taxa.

APPENDIX A

PHYSICAL AND CHEMICAL SURVEY RESULTS

Sampling Event	Station #	SampleDepth	pH	CONDUCTIVITY (mS/cm)	TURBIDITY (NTU)	DO (mg/l)	TEMPERATURE (C)	SALINITY (PPT)
		1.0	7.78	2.51	3	2.73	18.4	1.2
		3.0	7.82	2.76	4	3.81	18.4	1.3
	B01	5.0	7.89	2.81	4	4.89	18.3	1.3
		1.0	7.60	2.29	27	0.65	18.2	1.1
		3.0	7.48	2.28	24	0.20	17.7	1.1
	B02	5.0	7.39	2.29	24	0.00	17.7	1.1
		1.0	8.18	2.74	65	6.08	18.7	1.3
		3.0	8.04	2.75	40	5.88	18.6	1.3
	B03	5.0	8.00	2.76	38	5.97	18.6	1.3
		1.0	8.41	2.88	3	6.71	18.0	1.4
		3.0	8.28	2.88	3	6.87	18.0	1.4
Fall, Mouth Closed	B04	5.0	8.21	2.88	3	6.85	18.0	1.4
(11/6/01 - 11/9/01)		1.0	8.27	2.90	3	6.16	18.6	1.4
	B05	3.0	8.12	2.90	3	6.35	18.6	1.4
		1.0	8.34	2.87	2	7.43	18.6	1.4
		3.0	8.25	2.87	2	7.08	18.6	1.4
	B06	5.0	8.31	2.87	2	7.16	18.6	1.4
		1.0	8.14	2.88	4	5.41	18.1	1.4
		3.0	8.03	2.90	4	6.08	18.1	1.4
	B07	5.0	8.02	2.94	4	6.36	18.1	1.4
		1.0	8.32	2.95	2	7.70	19.2	1.4
	B08	3.0	8.17	2.94	2	6.70	18.9	1.4
		1.0	8.17	2.81	3	4.96	17.9	1.3
	B09	3.0	8.20	2.81	2	4.86	17.9	1.3
	B01	1.0	8.30	2.36	21	5.33	14.4	1.1
	B02	1.0	8.36	13.20	81	5.50	12.7	8.4
		0.5	8.61	41.70	12	6.85	10.7	25.2
		0.0						22.1
	B03	1.0						26.3
Fall, Mouth Open	B04	0.5	9.04	18.90	17	8.16	14.7	11.1
(12/10/01 - 12/12/01)		1.0	8.83	25.20	12	7.61	14.4	15.2
	B05	2.0	8.73	40.60	10	7.30	14.4	22.6
	B06	0.7	8.90	29.50	19	8.80	14.8	18.2
	B07	0.7	8.79	12.40	42	8.39	14.9	7.2
	B08	0.3	8.56	4.41	3	6.21	14.2	2.2
	B09	0.3	8.51	21.30	28	4.80	10.0	12.9
		1.0	9.75	8.52	12	2.24	19.2	2.7
		2.0	10.03	21.70	50	6.70	19.2	12.8
	B01	0.0	8.82	2.65	16	2.23	19.3	1.2
		1.0	9.45	4.60	13	2.35	18.7	2.4
	B02	2.0	10.11	24.20	100	8.78	21.5	15
		1.0	9.77	15.70	7	2.80	14.6	9.4
		1.5						10.1
	B03	0.0						4.7
Spring, Mouth Open		1.0	9.74	18.90	20	4.82	19.1	11.1
(4/16/20 - 4/19/02)		2.0	9.78	20.60	16	5.37	18.6	12.9
	B04	2.5	9.95	26.00	32	7.34	20.0	16
		1.0	9.84	22.90	25	4.85	19.4	13.9
	B05	3.0	9.98	28.70	22	8.16	20.0	18.2
	B06	1.0	9.79	18.30	25	4.93	17.8	10.9
		1.0	9.68	21.80	30	3.23	16.7	13.1
	B07	2.0	9.64	21.80	30	3.24	17.3	13.4
	B08	0.5	9.26	16.80	54	3.81	24.1	10.4
	B09	0.5	8.12	1.91	35	1.31	21.8	0.9
			7.39	2.65		4.66	23.0	1.3
		1.0	7.47	2.93		4.54	22.5	1.7
		2.0	8.35	4.29		6.97	22.9	2.4
		3.0	8.91	5.8		5.15	23.4	3.1
		4.0	9.05	7.73		1.31	23.7	4.2
	B01	4.5	9.04	9.71		0.27	23.9	5.3
			7.5	2.74		3.01	20.8	1.3
		1.0	7.51	3.23		2.91	20.8	1.4
		2.0	8.52	4.69		3.75	21.9	2.3
		3.0	9.18	6.37		7.4	23.1	3.4
	B02	4.0	8.82	8.78		0.23	23.7	4.8
			9.19	6		9.2	21.9	3.1
		1.0	9.21	6		9.51	22	3.1
		2.0	9.22	6.02		9.48	22	3.2
		3.0	9.23	6.05		9.22	22	3.2
	B03	4.0	9.24	6.3		7.6	22.3	3.4
			9.62	6.5			24.3	3.5
		1.0	9.62	6.48			24.3	3.1
		2.0	9.63	6.49			24.3	3.1
		3.0	9.67	6.52			24.3	3.5
Spring, Mouth Closed	B04	4.0	9.54	6.58			24.1	3.5
(7/01/02 - 7/03/02)			9.65	6.77			24.1	3.6
	B05	1.0	9.65	6.76			24.2	3.6
			9.22	5.64			25.2	3
		1.0	9.24	5.7			25.1	3
	B06	2.0	9.3	5.9			25.1	3.1
			9.45	6.4			23.6	3.4
		1.0	9.44	6.39			23.6	3.4
		2.0	9.45	6.39			12.6	3.4
		3.0	9.38	6.3			23.5	3.3
	B07	4.0	9.36	6.3			23.4	3.4
			9.45	6.42			26.1	3.4
		1.0	9.47	6.44			26.1	3.4
		2.0	9.47	6.43			26.1	3.4
	B08	3.0	9.24	6.27			24.7	3.2
			9.2	6.1			26.5	3.2
		1.0	9.12	6.04			26.3	3.2
		2.0	9.13	6.06			26.1	3.2
	B09	3.0	8.66	6.11		10.12	23.8	3.2
	B10		7.65	3.14		11.5	22.4	1.5
	B11		7.64	3.08		11.85	25	1.5

Table A-1 Water Quality Parameters for all Stations and Sampling Events

Station	Diameter (microns)	Phi Interval	Percent Weight
B1	4000.0000	-2.00	0.00
	2830.0000	-1.50	10.24
	2000.0000	-1.00	2.07
	1410.0000	-0.50	1.97
	1000.0000	0.00	4.57
	840.0000	0.25	8.34
	710.0000	0.50	7.91
	590.0000	0.75	9.30
	500.0000	1.00	6.71
	420.0000	1.25	5.61
	350.0000	1.50	3.81
	300.0000	1.75	2.26
	250.0000	2.00	1.43
	210.0000	2.25	0.54
	177.0000	2.50	0.89
	149.0000	2.75	0.60
	125.0000	3.00	0.29
	105.0000	3.25	0.31
	88.0000	3.50	0.50
	74.0000	3.75	0.56
	62.5000	4.00	0.69
	53.0000	4.25	0.89
	44.0000	4.50	0.45
	37.0000	4.75	0.94
	31.0000	5.00	1.22
	25.0000	5.25	2.56
	20.0000	5.50	1.92
	15.6000	6.00	3.92
	7.8000	7.00	7.54
	3.9000	8.00	4.48
	2.0200	9.00	3.11
	0.9800	10.00	2.20
	0.4900	11.00	1.26
	0.2400	12.00	0.65
	0.1200	13.00	0.25
	0.6000	14.00	0.03

Station	Diameter (microns)	Phi Interval	Percent Weight
B2	4000.0000	-2.00	0.00
	2830.0000	-1.50	0.00
	2000.0000	-1.00	0.36
	1410.0000	-0.50	0.31
	1000.0000	0.00	0.51
	840.0000	0.25	1.49
	710.0000	0.50	1.88
	590.0000	0.75	3.82
	500.0000	1.00	5.46
	420.0000	1.25	7.69
	350.0000	1.50	9.51
	300.0000	1.75	10.04
	250.0000	2.00	9.38
	210.0000	2.25	4.13
	177.0000	2.50	6.75
	149.0000	2.75	4.50
	125.0000	3.00	2.53
	105.0000	3.25	1.55
	88.0000	3.50	1.41
	74.0000	3.75	1.26
	62.5000	4.00	1.01
	53.0000	4.25	0.78
	44.0000	4.50	0.28
	37.0000	4.75	0.44
	31.0000	5.00	0.53
	25.0000	5.25	1.23
	20.0000	5.50	0.91
	15.6000	6.00	2.01
	7.8000	7.00	6.43
	3.9000	8.00	5.11
	2.0200	9.00	3.83
	0.9800	10.00	2.64
	0.4900	11.00	1.35
	0.2400	12.00	0.63
	0.1200	13.00	0.22
	0.0600	14.00	0.03

Station	Diameter (microns)	Phi Interval	Percent Weight
B3	4000.0000	-2.00	0.00
	2830.0000	-1.50	0.00
	2000.0000	-1.00	0.00
	1410.0000	-0.50	0.03
	1000.0000	0.00	0.08
	840.0000	0.25	0.19
	710.0000	0.50	0.54
	590.0000	0.75	0.82
	500.0000	1.00	0.90
	420.0000	1.25	1.02
	350.0000	1.50	1.16
	300.0000	1.75	1.12
	250.0000	2.00	0.61
	210.0000	2.25	0.15
	177.0000	2.50	0.91
	149.0000	2.75	3.48
	125.0000	3.00	6.48
	105.0000	3.25	7.66
	88.0000	3.50	7.47
	74.0000	3.75	7.32
	62.5000	4.00	7.51
	53.0000	4.25	7.79
	44.0000	4.50	3.85
	37.0000	4.75	6.92
	31.0000	5.00	5.38
	25.0000	5.25	5.66
	20.0000	5.50	2.75
	15.6000	6.00	4.12
	7.8000	7.00	5.73
	3.9000	8.00	3.32
	2.0200	9.00	2.50
	0.9800	10.00	2.03
	0.4900	11.00	1.38
	0.2400	12.00	0.79
	0.1200	13.00	0.32
	0.0600	14.00	0.04

Station	Diameter (microns)	Phi Interval	Percent Weight
B4	4000.0000	-2.00	0.00
	2830.0000	-1.50	0.29
	2000.0000	-1.00	0.17
	1410.0000	-0.50	0.47
	1000.0000	0.00	1.05
	840.0000	0.25	3.00
	710.0000	0.50	8.09
	590.0000	0.75	8.95
	500.0000	1.00	11.12
	420.0000	1.25	13.65
	350.0000	1.50	13.47
	300.0000	1.75	10.57
	250.0000	2.00	7.43
	210.0000	2.25	2.78
	177.0000	2.50	4.28
	149.0000	2.75	2.97
	125.0000	3.00	2.21
	105.0000	3.25	2.01
	88.0000	3.50	1.80
	74.0000	3.75	1.04
	62.5000	4.00	0.72
	53.0000	4.25	0.46
	44.0000	4.50	0.12
	37.0000	4.75	0.18
	31.0000	5.00	0.26
	25.0000	5.25	0.41
	20.0000	5.50	0.26
	15.6000	6.00	0.41
	7.8000	7.00	0.80
	3.9000	8.00	0.44
	2.0200	9.00	0.33
	0.9800	10.00	0.24
	0.4900	11.00	0.05
	0.2400	12.00	0.00
	0.1200	13.00	0.00
	0.0600	14.00	0.00

Station	Diameter (microns)	Phi Interval	Percent Weight
B5	4000.0000	-2.00	0.00
	2830.0000	-1.50	0.78
	2000.0000	-1.00	0.63
	1410.0000	-0.50	0.96
	1000.0000	0.00	2.12
	840.0000	0.25	4.72
	710.0000	0.50	12.83
	590.0000	0.75	14.04
	500.0000	1.00	15.54
	420.0000	1.25	15.63
	350.0000	1.50	13.33
	300.0000	1.75	9.33
	250.0000	2.00	5.22
	210.0000	2.25	1.40
	177.0000	2.50	1.41
	149.0000	2.75	0.57
	125.0000	3.00	0.39
	105.0000	3.25	0.29
	88.0000	3.50	0.14
	74.0000	3.75	0.05
	62.5000	4.00	0.02
	53.0000	4.25	0.04
	44.0000	4.50	0.04
	37.0000	4.75	0.05
	31.0000	5.00	0.05
	25.0000	5.25	0.05
	20.0000	5.50	0.03
	15.6000	6.00	0.06
	7.8000	7.00	0.13
	3.9000	8.00	0.07
	2.0200	9.00	0.06
	0.9800	10.00	0.04
	0.4900	11.00	0.00
	0.2400	12.00	0.00
	0.1200	13.00	0.00
	0.0600	14.00	0.00

Station	Diameter (microns)	Phi Interval	Percent Weight
B6	4000.0000	-2.00	0.00
	2830.0000	-1.50	30.46
	2000.0000	-1.00	4.72
	1410.0000	-0.50	4.38
	1000.0000	0.00	6.61
	840.0000	0.25	9.16
	710.0000	0.50	11.60
	590.0000	0.75	9.15
	500.0000	1.00	6.87
	420.0000	1.25	5.20
	350.0000	1.50	3.34
	300.0000	1.75	1.64
	250.0000	2.00	0.84
	210.0000	2.25	0.38
	177.0000	2.50	0.71
	149.0000	2.75	0.50
	125.0000	3.00	0.32
	105.0000	3.25	0.47
	88.0000	3.50	0.64
	74.0000	3.75	0.50
	62.5000	4.00	0.43
	53.0000	4.25	0.33
	44.0000	4.50	0.11
	37.0000	4.75	0.18
	31.0000	5.00	0.18
	25.0000	5.25	0.24
	20.0000	5.50	0.13
	15.6000	6.00	0.21
	7.8000	7.00	0.33
	3.9000	8.00	0.19
	2.0200	9.00	0.12
	0.9800	10.00	0.05
	0.4900	11.00	0.01
	0.2400	12.00	0.00
	0.1200	13.00	0.00
	0.0600	14.00	0.00

Station	Diameter (microns)	Phi Interval	Percent Weight
B7	4000.0000	-2.00	0.00
	2830.0000	-1.50	6.19
	2000.0000	-1.00	0.50
	1410.0000	-0.50	0.50
	1000.0000	0.00	0.92
	840.0000	0.25	1.12
	710.0000	0.50	1.03
	590.0000	0.75	1.56
	500.0000	1.00	1.90
	420.0000	1.25	2.33
	350.0000	1.50	2.69
	300.0000	1.75	2.80
	250.0000	2.00	2.37
	210.0000	2.25	0.85
	177.0000	2.50	1.15
	149.0000	2.75	1.23
	125.0000	3.00	1.96
	105.0000	3.25	2.28
	88.0000	3.50	2.15
	74.0000	3.75	2.44
	62.5000	4.00	3.04
	53.0000	4.25	3.58
	44.0000	4.50	1.99
	37.0000	4.75	4.31
	31.0000	5.00	4.55
	25.0000	5.25	6.70
	20.0000	5.50	4.08
	16.6000	6.00	7.43
	7.8000	7.00	12.10
	3.9000	8.00	6.26
	2.0200	9.00	3.89
	0.9800	10.00	2.65
	0.4900	11.00	1.77
	0.2400	12.00	1.13
	0.1200	13.00	0.48
	0.0600	14.00	0.06

Station	Diameter (microns)	Phi Interval	Percent Weight
B8	4000.0000	-2.00	0.00
	2830.0000	-1.50	38.16
	2000.0000	-1.00	12.21
	1410.0000	-0.50	9.18
	1000.0000	0.00	9.70
	840.0000	0.25	6.90
	710.0000	0.50	4.45
	590.0000	0.75	4.07
	500.0000	1.00	3.64
	420.0000	1.25	3.20
	350.0000	1.50	2.63
	300.0000	1.75	1.92
	250.0000	2.00	1.22
	210.0000	2.25	0.40
	177.0000	2.50	0.53
	149.0000	2.75	0.35
	125.0000	3.00	0.27
	105.0000	3.25	0.19
	88.0000	3.50	0.13
	74.0000	3.75	0.11
	62.5000	4.00	0.11
	53.0000	4.25	0.11
	44.0000	4.50	0.05
	9.0000	4.75	0.08
	37.0000	5.00	0.06
	25.0000	5.25	0.06
	20.0000	5.50	0.03
	15.6000	6.00	0.05
	7.8000	7.00	0.07
	3.9000	8.00	0.04
	2.0200	9.00	0.04
	0.9800	10.00	0.03
	0.4900	11.00	0.01
	0.2400	12.00	0.00
	0.1200	13.00	0.00
	0.0600	14.00	0.00

Station	Diameter (microns)	Phi Interval	Percent Weight
B9	4000.0000	-2.00	0.00
	2830.0000	-1.50	25.54
	2000.0000	-1.00	10.75
	1410.0000	-0.50	10.20
	1000.0000	0.00	12.05
	840.0000	0.25	10.07
	710.0000	0.50	7.39
	590.0000	0.75	6.34
	500.0000	1.00	4.96
	420.0000	1.25	3.72
	350.0000	1.50	2.71
	300.0000	1.75	1.87
	250.0000	2.00	1.22
	210.0000	2.25	0.43
	177.0000	2.50	0.67
	149.0000	2.75	0.49
	125.0000	3.00	0.36
	105.0000	3.25	0.24
	88.0000	3.50	0.17
	74.0000	3.75	0.13
	62.5000	4.00	0.11
	53.0000	4.25	0.09
	44.0000	4.50	0.04
	37.0000	4.75	0.06
	31.0000	5.00	0.04
	25.0000	5.25	0.06
	20.0000	5.50	0.03
	15.6000	6.00	0.05
	7.8000	7.00	0.07
	3.9000	8.00	0.05
	2.0200	9.00	0.05
	0.9800	10.00	0.03
	0.4900	11.00	0.00
	0.2400	12.00	0.00
	0.1200	13.00	0.00
	0.0600	14.00	0.00

Station	Diameter (microns)	Phi Interval	Percent Weight
B10	4000.0000	-2.00	0.00
	2830.0000	-1.50	0.00
	2000.0000	-1.00	0.00
	1410.0000	-0.50	0.04
	1000.0000	0.00	0.18
	840.0000	0.25	1.07
	710.0000	0.50	16.13
	590.0000	0.75	18.02
	500.0000	1.00	19.93
	420.0000	1.25	18.96
	350.0000	1.50	14.15
	300.0000	1.75	7.67
	250.0000	2.00	2.89
	210.0000	2.25	0.60
	177.0000	2.50	0.36
	149.0000	2.75	0.00
	125.0000	3.00	0.00
	105.0000	3.25	0.00
	88.0000	3.50	0.00
	74.0000	3.75	0.00
	62.5000	4.00	0.00
	53.0000	4.25	0.00
	44.0000	4.50	0.00
	37.0000	4.75	0.00
	31.0000	5.00	0.00
	25.0000	5.25	0.00
	20.0000	5.50	0.00
	15.6000	6.00	0.00
	7.8000	7.00	0.00
	3.9000	8.00	0.00
	2.0200	9.00	0.00
	0.9800	10.00	0.00
	0.4900	11.00	0.00
	0.2400	12.00	0.00
	0.1200	13.00	0.00
	0.0600	14.00	0.00

Table A-2: Grain Size Analysis from Spring, Closed Sampling Event

Station	% by Weight					Phi-Median (mm)	Phi-Mean (mm)	Sorting	Skewness	TOC (g/cc)
	Gravel	Sand	Silt	Clay	Silt&Clay					
B01	12.3	56.29	23.92	7.49	31.41	0.538	0.207	NC	NC	0.29
B02	0.36	73.22	17.72	8.7	26.43	0.254	0.105	2.719	0.653	0.3
B03	0.00	47.42	45.52	7.06	52.58	0.060	0.050	1.903	0.282	0.37
B04	0.45	95.6	3.33	0.62	3.94	0.417	0.391	0.953	0.276	0.12
B05	1.41	97.98	0.51	0.10	0.61	0.531	0.528	0.643	0.002	0.07
B06	35.17	62.74	1.90	0.18	2.08	1.044	NC	NC	NC	0.11
B07	6.69	32.33	51.00	9.99	60.98	0.039	0.049	NC	NC	0.83
B08	50.37	49.00	0.55	0.08	0.63	2.408	NC	NC	NC	ND
B09	36.30	63.13	0.50	0.08	0.57	1.539	NC	NC	NC	ND

ND = Not detected at or above 0.050% report limit.
NC = Could not be calculatd due to large percentage of gravel-sized particles

Table A-3 Geotechnical Analysis Results

APPENDIX B

MACROINVERTEBRATE SURVEY RESULTS

							Fall, Mouth Closed									Fall, Mouth Open									Spring, Mouth Open									Spring, Mouth Closed										
Phylum	Class	Order	Family	Genus	Species	Sum B1-B9	B01	B02	B03	B04	B05	B06	B07	B08	B09	B01	B02	B03	B04	B05	B06	B07	B08	B09	B01	B02	B03	B04	B05	B06	B07	B08	B09	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11
Platyhelminthes	Turbellaria	Neorhabdocoela				36														35										1													5	
		Tricladida	Planariidae	Dugesia		0																																					18	10
Nemertea						0																																					4	5
Nematoda						0																																					1	
Mollusca	Gastropoda	Basommatophora	Lymnaeidae		*sp. 1*	15									15																													
			Physidae	*Physa*		1506	3	2	2	19	24	26	19	327	792			1			1	22	7	243						10	4		1									3	83	6
				Physa	*sp. 1*	1		1																																				
		Mesogastropoda	Pomatiopsidae	*Pomatiopsis*	*californica*	386	86	42	1		1					173	68	2					1		3	9																		
						24	1		7	2		4		6	4																												2	1
Annelida	Archiannelida	Aciculata	Saccocirridae	*Saccocirrus*		1														1																								
	Clitellata	Haplotaxida	Naididae			0																																						1
	Hirudinea					0																																						1
	Oligochaeta	Lumbriculida	Lumbriculidae			1											1																											
		Tubificida	Enchytraeidae			1													1																									
					sp. 2	27			1	3		12																			11													
			Tubificidae			2													2																									
					sp. 3	0																																					2	1
				Limnodrilus		8100	2078	254	21		3		1			1230	163	9							1131	233	67	2		186	55	527	1738	124	94	14		2	15		9	144		
	Polychaeta	Canalipalpata	Hesionidae	*Microphthalmus*	*sp.*	1														1																								
Arthropoda	Branchiopoda	Diplostraca	Daphniidae	*Daphnia*		976	10	294	63	255	109	154	50	9	32																													
	Malacostraca	Amphipoda	Gammaridae	*Eogammarus*	*sp. 1*	4614	1		5	2	13	3	2			112	1				1	31	7	14	465	64	4	10	10	3	172	120	1582			1		958	353		666	14		
			Hyalellidae	*Hyalella*	*azteca*	47	35			2		3					1							6																			2	
		Decapoda	Hippidae	*Emerita*	*analoga*	4																							4															
	Maxillipoda	Cyclopoida				16																															1	10		2	3			
		Harpacticoida				5																											2								3			
	Ostracoda	Podocopina	Cyprididae		*sp. 1*	24744	35	21	34	72	3	7	75	1		178	2025	75	285	33	236	676	83		164	168	1139	2382	2	1211	1254	163	187	181	1036	1039	1141	8	1230	2130	7010	460		
					sp. 2	4805	11	2	15	131	59	87	23	115	150		16	5	1	1	13	106	100	2463	3		1	1		2	5	4	1140	1	1	1	1		51		117	179	18	2
					sp. 3	5										4										1																		
	Arachnida	Acarina				0																																					1	1
	Insecta	Coleoptera	Dytiscidae			5																		1								1	3											
			Elmidae			0																																					17	6
				Optioservus		0																																					2	
			Haliplidae	*Peltodytes*	*sp.*	0																																						
				Peltodytes	*simplex*	0																																					2	
			Hydrophilidae	*Berosus*		8			1						2							3	1																		1			
				Tropisternus	*ellipticus*	0																																					1	
		Collembola	Isotomidae			4				1	1		1														1																	
		Diptera	Ceratopogonidae			4	1																										3											
			Chironomidae			407	1	18	7	8	1	4	7	2												20		1	1		2	4	36	1	11	23	2	109	41		28	80		2
					sp. 2	299	7	29	13	18		85	30	1		2	60			1	1	2		5		32							1	1							6	5		
					sp. 3	0																																					24	17
				Chironomus		2247	118	120	72	248	52	157	257	74		27	162				1	3		4	1	15							54	8	60	40			20	1	331	422	4	
				Cladotanytarsus		8004	8	33	182	316	295	343	140	33	3	4	24									136		1		7	17	59	284	6	66	104	8	1277	3000		599	1059		
				Pentaneura		0																																					2	2
			Ephydridae			6			1					1	1											1																2		
				Ephydra		1									1																													
				Ephydra	*riparia*	3																								1		1				1								
			Simulidae			0																																						1
				Simulium		0																																						1
			Tipulidae	*Hexatoma*		0																																					4	2
						11	6				1						1							2	1																			
		Ephemeroptera				2					1																				1													
			Baetidae			0																																					3	
		Hemiptera	Aphididae			1																			1																			
			Corixidae			10				4				4																							1					1	3	3
				Corisella	*inscripta*	5				1				1										3																			43	96
				Trichocorixa	*reticulata*	1						1																																
			Naucoridae	*Ambrysus*	*occidentalis*	0																																					11	
			Notonectidae			0																																						3
			Veliidae	*Microvelia*		0																																						1
		Hymenoptera				1																									1													
		Thysanoptera				1											1																											
		Trichoptera				0																																					19	38
			Hydropsychidae	*Hydropsyche*		0																																					17	5

Table B-1 Macroinvertebrate Survey Results by Station and Sampling Event

APPENDIX C

U. S. FISH AND WILDLIFE MACROINVERTEBRATE RESULTS

Summary of abundance data for invertebrate individuals collected with a benthic coring device in the Santa Clara River Estuary, Ventura County, California. Samples were collected from October 1997 to July 1999.

							Number of Individuals Collected																
Date (Yr/Mo/Dy)	Lagoon Level, MSL (ft)	Lagoon Mouth Status	Station #	Depth, Maximum (ft)	# Cores	Total Area Cored (m2)	Chironomidae	Tipulidae	Dixidae	Baetidae	Corixidae	Unidentified Hemiptera	Hydrophilidae	Gammarus sp.	Hyalella azteca	Amphipod "A"	Daphnia magna	Cyclopoida	Physidae	Polychaeta	Oligochaeta	Hirudinea	Total Invertebrates
971017	9.3	Closed	1	5.5	5	0.041	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
			2	7.0	5	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			3	7.2	5	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			4	7.3	5	0.041	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
			7	5.4	5	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
971217	3.5	Open	1	2.0	5	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2	1.5	5	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			3	1.6	5	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			4	1.8	5	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			7	0.9	5	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
980323	4.3	Open	1	1.5	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2	1.0	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			3	1.2	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			4	1.2	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			7	1.0	3	0.025	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
980423	5.3	Open	1	1.0	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2	0.8	3	0.025	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
			3	0.8	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			4	1.0	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			7	0.9	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
980724	5.9	Closed	1	1.7	3	0.025	125	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	126
			2	2.8	3	0.025	42	1	2	0	15	0	0	0	0	0	0	0	0	0	2	0	62
			3	2.1	3	0.025	64	0	0	0	4	0	0	0	20	0	0	0	0	0	1	0	89
			4	0.9	3	0.025	57	0	0	0	6	1	0	0	0	0	0	0	0	0	0	0	64
			7	0.5	3	0.025	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
980821	6.2	Closed	1	1.7	3	0.025	51	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	55
			2	2.8	3	0.025	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			3	2.1	3	0.025	80	0	0	0	0	0	0	0	6	0	0	0	1	0	0	0	87
			4	0.9	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			7	0.5	3	0.025	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
981021	6.0	Open	1	1.9	3	0.025	11	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12
			2	3.0	3	0.025	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	5
			3	1.0	3	0.025	122	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	125
			4	0.4	3	0.025	216	3	0	0	1	0	1	0	0	0	0	0	0	0	2	0	223
			7	0.5	3	0.025	19	0	0	0	1	0	1	0	4	0	0	0	1	0	5	0	31
990115	6.0	Open	1	0.5	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
			2	1.1	3	0.025	1	0	0	0	0	0	0	0	0	8	0	0	0	4	2	0	15
			3	0.8	3	0.025	1	0	0	0	0	0	0	1	0	0	0	0	0	0	6	0	8
			4	0.3	3	0.025	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3
			7	0.6	3	0.025	12	0	0	0	0	0	0	0	0	0	0	1	0	0	28	0	41
990219	7.3	Closed	1	5.5	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2	6.0	3	0.025	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			3	5.0	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	6
			4	4.1	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			7	2.5	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
990427	6.1	Open	1	0.9	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			2	1.1	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			3	2.0	3	0.025	144	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	153
			4	1.3	3	0.025	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	7
			7	0.7	3	0.025	7	0	0	3	0	0	0	0	0	0	0	0	0	0	18	0	28
990623	7.8	Closed	1	5.5	3	0.025	4	0	0	0	0	0	0	1	0	0	10	0	0	0	0	0	15
			2	6.2	3	0.025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			3	5.9	3	0.025	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			4	4.4	3	0.025	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			7	3.0	3	0.025	48	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	49
990724	7.3	Closed	1	5.1	3	0.025	13	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	17
			2	5.0	3	0.025	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
			3	5.0	3	0.025	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
			4	3.8	3	0.025	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37
			7	2.7	3	0.025	28	0	0	0	0	0	0	0	0	0	1	0	22	0	1	0	52
Total:							1132	6	2	4	30	2	2	6	30	8	15	1	24	4	92	1	1359
Percent Composition:							83.3	0.4	0.1	0.3	2.2	0.1	0.1	0.4	2.2	0.6	1.1	0.1	1.8	0.3	6.8	0.1	

Table C-1: U.S. Fish and Wildlife 1999 SCRE Invertebrate Survey Results (USFWS 1999)

APPENDIX D

SALINITY TOLERANCE LITERATURE REVIEW

Macroinvertebrate Salinity Tolerance Data

I. Summary of Salinity Tolerance and Other Information on Macroinvertebrates Collected in the Santa Clara River Estuary

In order to classify the organisms collected from the estuary in terms of their salinity tolerances, a literature search was conducted seeking published salinity ranges for all taxa found in the benthic core samples. This comprehensive search was performed using public internet search engines, internet subscription search services (Web of Science, Biosis), three university libraries, and personal communications with invertebrate scientists. Despite the extensive breadth of the literature search, no salinity tolerance data were found for some species. In these instances, an effort was made to find information at a coarser level of taxonomic classification (genus or family). If the level of taxonomic identification was relatively high (i.e., family level and above), then precise salinity tolerance levels could not be determined.

The data below are presented by taxon, with taxa in phylogenetic order. Salinity tolerances are also presented graphically in Table 4.3.1. The solid lines represent tolerance values which were determined from published scientific literature. Dotted lines indicate that the salinity tolerance of that taxon could be as high as the value shown, based on findings in the literature, but more specific information is needed to determine the maximum or minimum salinity tolerance level for that taxon. Dashed lines indicate that the salinity tolerance for that taxon is unknown.

Plathhelminthes

Class Turbellaria
Order Neorhabdocoela (Flatworms)

No Information Available

Mollusca

Class Gastropoda
Order Basommatophora
Family Lymnaeidae

Lymnaeids are cosmopolitan in distribution and are the most diverse pulmonate group in the northern United States and Canada (Thorp and Covich 1991). Certain species of the family Lymnaeidae can endure seawater concentrations up to 25%, which equates to approximately 6.75ppt salinity (Smith 2001).

Family Physidae
Physa spp.

Snails of the family Physidae have a cosmopolitan distribution and are ubiquitous in North America (Thorp and Covich 1991).

The genus *Physa* occurs in greatest abundance where there is a moderate amount of aquatic vegetation and organic debris, and it is rare among dense mats of vegetation. A few species of *Physa* and *Elimia* can endure seawater concentrations up to 50%, which translates to a salinity tolerance of approximately 17ppt (Smith 2001). The tolerance range for the genus *Physa* as a whole could not be found.

Order Mesogastropoda

Family Pomatiopsidae

Pomatiopsis californica

No Information Available

<u>Annelida</u>

Class Archaeannelida

Order Canalipalpata

Family Saccocirridae

Saccocirrus spp.

No Information Available

Class Oligochaeta

Order Lumbriculida

Family Lumbriculidae

Salinity tolerance information on the family lumbriculidae could not be found, but information was available pertaining to one species. *Grania dolichura*, an Australian estuarine worm of this family, tolerates a salinity range of 11-35ppt (Rota and Erseus, 2000).

Order Tubificida

Family Enchytreaidae (aquatic earthworms)

The family Enchytraeidae is a freshwater group containing some species adapted to brackish and estuarine conditions (Smith and Carlton 1975, Healy and Walters 1994, Timm 1999, Rota and Erseus 2000, Wilner 1995, Smith 2001). Freshwater oligochaetes can be quite tolerant of low salt conditions characteristic of upper estuaries. (Smith 2001). "Unfortunately, the aquatic Enchytraeidae remains an obscure and difficult group taxonomically and although the family can be well-represented in aquatic oligochaete samples, there remains no practical way to distinguish genera and species" (Smith 2001). In a study of freshwater oligochaetes, Chapman et al. (1982) found that nine species tolerated up to 5ppt salinity.

Family Tubificidae

Many genera of Tubificidae have been collected in association with estuarine organisms and in salt or brackish waters (Smith 2001, Smith and Carlton 1975). These species are known to proliferate under polluted conditions, particularly at sewage outfalls. According to Smith and

Carlton (1975), many species of marine oligochaetes on the pacific coast have yet to be described.

Family Tubificidae

Limnodrilus spp.

Salinity tolerance data on the family tubificidae were not available, but two species of tubificid worms (*Tubifex tubifex* and *Limnodrilus hoffmeisteri*) are known to tolerate salinity exposure up to 10ppt (Thorp and Covich 1991).

Limnodrilus hoffmeisteri
Tolerance values for the genus *Limnodrilus* as a whole could not be found, but data pertaining to one species was available. *Limnodrilus hoffmeisteri* is an oligohaline species, usually found at salinities below 5ppt. However, Atrill (2002) notes that *L. hoffmeisteri* has a particularly high salinity tolerance.

Class Polychaeta

Order Aciculata

Family Hesionidae

Microphthalmus spp.

No Information Available

<u>Arthropoda</u>

Class Branchiuopoda

Order Diplostraca

Family Daphniidae

Daphnia spp. *(water fleas)*

Daphnia are seldom found in heavily vegetated areas – they tend to avoid rooted vegetation areas and are abundant in littoral areas (Smith 2001). They are most abundant in lakes, ponds and sluggish streams. They are not adapted to silt-laden water, but can withstand oxygen-poor habitats (Smith 2001). Although salinity tolerance data were unavailable for the genus *Daphnia*, values were obtained for *D. magna*, a common ecological assessment organism.

Schuytema et al. (1997) tested *Daphnia magna* to determine the acute and chronic tolerance of *D. magna* to salinity. "While *D. magna* may live and produce some young in salinities as high as 7.5g/L (ppt), survival and reproduction are enhanced at lower salinities, and are essentially normal at concentrations of 4 or 5 g/L or less (Schuytema et. al. 1997)." In addition, the ability of *D. magna* to tolerate relatively high levels of salinity (1 to 5ppt and occasionally to 8ppt) (Lagerspetz 1955 cited in Ranta 1979) increases its value as an assessment organism (Schuyema et. al. 1997). Tests conducted by Ingersoll et al. (1992) found that instant ocean salts were acutely toxic to *D. magna* at concentrations of 8 to 10ppt. Schuytema et al. (1997) concluded that *D. magna* can survive and reproduce in tests where freshwater sediment is overlain by salt water and where estuarine sediment is overlain by freshwater.

Class Malacostraca

Order Amphipoda

Family Gammaridae

Eogammarus sp

Eogammarus is commonly found in estuaries of the North American Pacific Coast (Bousfield 1979, Stanhope and Levings 1985, Simenstad et al. 2001, Furota and Emmett 1993, Houghton 2001). Although no specific salinity tolerance values could be found for either the *Eogammarus* genus or its constituent species, Furota and Emmett (1993) found *E. conferviculus* and *E. oclairi* in the intertidal and subtidal area of Baker Bay, Columbia River Estuary. During this study, salinity values ranged from 1.5-16.7ppt. *E. conferviculus* is also a dominant prey item for chum salmon in the Chehalis River Estuary where salinity values range from 0-12ppt (Simenstad et al, 2001).

Family Hyalellidae

Hyallela azteca

Hyallela azteca is now considered by taxonomists to be a group of related species, rather than a single widely distributed species. Numerous studies have reported *H. azteca* as occurring in brackish waters (Galat et al. 1998, Bayly 1972, Rawson and Moore 1944, Hammer et al. 1975, Kock et al. 1979, Ingersoll et al. 1992, Timms et al. 1987). Timms et al. (1987) concluded that *Hyallela azteca* was an important part of the benthic community in Canadian lakes with salinity ranges of 1-12ppt. Galat et al. (1988) conducted microcosm studies and found that *H. azteca* did well at salinities of 5.60ppt, but did not reproduce as successfully at 11ppt.

Order Decapoda

Family Hippidae

Emerita analoga

No Information Available

Class Maxillipoda

Order Cyclopoida (copepod)

No Information Available

Order Harpacticoida

No Information Available

Class Ostracoda

Order Podocopina

Family Cyprididae

Ostracods are found in many aquatic habitats, including freshwater, brackish and marine. (Smith and Carlton 1975). *Cyprideis* species are common in southern coastal areas of North America (Thorp and Covich 1991), including lagoons and estuaries (Smith and Carlton 1975).

Salinity and solute composition are important factors in the distribution of Ostracods. Different ostracod species can have very different salinity tolerances, ranging from low-salinity to hypersaline (Thorp and Covich 1991).

Most ostracods occur in < 1m water depth. They can inhabit waters with pH between 4.0 and 8.0, but most are restricted to alkaline areas because a pH <7 interferes with calcium deposition (Smith 2001). Ostracods are generally tolerant of a wide range of ecological factors.

A thorough review of salt lake ostracods by Deckker (1981) lists several species of *Heterocypris* occurring in lakes with greater than 3ppt salinity in Europe, Asia, Africa and the United States. He reports one species. *Heterocypris barbara*, surviving up to about 88ppt salinity (Galat et. al. 1988).

Class Insecta

Order Coleoptera

Family Dytiscidae (predaceous diving beetles)

In a study of water beetles in the saline lakes of Saskatchewan, Timms and Hammer (1988) found that the family Dytiscidae can tolerate a wide range of salinities. Of the 18 species sampled, one species, *Hygrotus salinarius,* was found in water with salinity as high as 71ppt and four other species were present above 25ppt. Most of the remaining species had narrow tolerance ranges between 3 and 20ppt (Timms and Hammer, 1988).

Family Hydrophilidae

Certain species of water beetles are known to be relatively tolerant (up to 30ppt salt), especially the Dytiscidae and Hydrophilidae. (USEPA, 1995). Although more concrete salinity data were not available, conductivity preference data were found. A study of Canadian saline lakes found hydrophilidae to be occasionally present in lakes with conductivity between 4544 and 13115 μScm^{-1} at 25°C, and absent altogether in lakes with conductivity less than 4544 μScm^{-1} at 25°C (Lancaster and Scudder, 1987).

***Berosus sp** (water scavenger beetles)*

The *Berosus* genus is known to occur in brackish estuarine waters (Merritt and Cummins 1996). *Berosus* are present in hypersaline salt ponds (100ppt and greater) near northern San Francisco Bay.

Order Collembola

Family Isotomidae (springtails)

Springtails are found in both freshwater and coastal marine habitats (Thorp and Covich 1991). Most are semiaquatic and are associated with lentic freshwater habitats (Merritt and Cummins 1996). The marine springtail *Anurida maritima* is an important intertidal scavenger on both coasts of North America. (Smith and Carlton 1975). Specific salinity tolerance values for this family could not be found.

Order Diptera (flies and midges)

Insects in general are not considered a major component of marine and brackish-water environments, but fly larvae (diptera) can be abundant in these habitats (Merritt and Cummins 1996). This is particularly true of the families Ceratopogonidae, Chironomidae, Tipulidae, and Ephydridae.

Family Ceratopogonidae (biting midges)

A survey of dipteran remains preserved in sediment of lakes in British Columbia found this family present in lakes with salinity between .13 and 75ppt, with most occurrences between 1.9 and 8.6ppt (Walker et al. 1995).

Family Chironomidae (midges)

Chironomidae are known to inhabit a wide range of environments. Most inhabit freshwater, but some species can tolerate elevated salinity. Almost the complete range of gradients of temperature, pH, salinity, Oxygen concentration...have been exploited (Merritt and Cummins 1996). Walker et al. (1995) found representatives from this family in lakes with salinities ranging from .04 to 369ppt.

Chironomus sp

Various *Chironomus* species are known to occur in salinities ranging from 0-30ppt (Timms 1987, Maggiore et al. 2000, Kawai et al. 2000, Colbo 1996, Williams and Williams 1998). Williams and Williams (1998) found *Chironomus aprilinus* occurring year round in salt marsh pools where the maximum salinity reached was 33% (330ppt). Various species are reported in the literature to tolerate salinities ranging from 3.1-20% (31-200ppt). (Galat et. al 1988).

Cladotanytarsus sp

Cladotanytarsus is a freshwater midge that is tolerant of brackish water conditions (Merritt and Cummins 1996). It has been found in oligohaline and mesohaline estuarine habitat (Posey and Alphin 2001). No specific salinity tolerance data were found for the genus *Cladotanytarsus*.

Family Ephydridae

Ephydridae are a diverse family containing many genera that can tolerate salinities ranging from fresh water to salt water and brine pools (Lehmkuhl 1979). In prairie lakes, the usual numerical dominance of chironomid midges shifts to dominance by dolichopodids and ephydrid brine flies above a salinity of 50 g/L (ppt) (USEPA, 1995).

Ephydra sp (brine flies and shore flies)

Species of *Ephydra* are highly specialized and exclusively aquatic. Habitats range from fresh-water ponds and lakes to the highly saline and alkaline ponds and sinks of desert and semidesert regions (Aldrich 1912, cited in Usinger 1956). The most common and widespread species, *E. riparia* breeds in water ranging from fresh to brackish. Salinity tolerance values for the genus *Ephydra* as a whole were unavailable.

Ephydra riparia (shore fly)

The brine fly, *Ephydra riparia* is known to inhabit the Salton Sea, which boasts salinities of well over 40ppt (Salton Sea Homepage).

Order Ephemeroptera

Family Baetidae

Generally considered a freshwater family, but some species tolerate saltwater inundation. Larvae raised in freshwater can withstand 5ppt salinity and those raised in brackish water can withstand 10ppt salinity Williams and Williams (1998).

Order Hemiptera

Family Corixidae (water boatmen)

Corisella inscript

Members of the genus *Corisella* are tolerant of a wide range of salinity values, including freshwater to brackish water and saline lakes (Merritt and Cummins 1996).

Trichocorixa reticulata

Trichocorixa species are characteristic of brackish pools throughout the world and can tolerate salinities above that of the sea (Smith and Carlton 1975). *T. reticulata* is a euryhaline species that is very tolerant of hyperhalinity and has been found in pools with salinity as high as 70ppt (Wilcox et al. 1998) *T. reticulata* are commonly found in brine pools of southern San Francisco Bay and northern San Pablo Bay.

Order Hymenoptera

No Information Available

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II. Salinity Tolerance Data for Species Used for EPA Acute Copper Toxicity Limits

FRESHWATER SPECIES

Mollusca

Class Bivalvia
Order Veneroidea
Family Corbiculidae
Corbicula manilensis (Asian Clam, Prosperity Clam)

No salinity tolerance data could be found for the species *Corbicula manilensis*. However, *C. fluminea*, an Asian clam of the same genus, is found both in lotic and lentic habitats over its native range in southeastern Asia. *C. fluminea* can tolerate salinities of up to 13ppt for short periods of time, and may tolerate salinities as high as 24ppt if allowed to acclimate (King et al., 1986). This freshwater species has been reported in brackish and estuarine habitats but is typically not as abundant in such habitats as in fresh waters (Carlton, 1992) as cited in (Poss 1998).

Class Gastropoda
Order Architaenioglossa
Family Viviparidae
Campeloma decisum

No salinity tolerance data were available for this taxon.

Order Basommatophora
Family Physidae

Physids have a worldwide distribution and are ubiquitous in North America (Thorp and Covich 1991). Physa occurs in greatest abundance where there is a moderate amount of aquatic vegetation and organic debris, and it is rare among dense mats of vegetation (Smith 2001).

For common species of *Physa*, 2ppm is about the limiting level of dissolved oxygen (Smith 2001). Also tolerant of high temperatures (in excess of 30 C).

Disturbance may be the next important factor, after successful colonization and adequate substrate, in determining the presence of snails in a given location. Disturbance may limit some species from disturbance prone areas (Thorp and Covich 1991).

A few species of Physa and Elimia can endure up to 50% seawater, which translates to a tolerance to salinities of approximately 17 ppt (Smith 2001).

Physa heterostropha

No salinity tolerance data were available for this taxon.

Physa integra

No salinity tolerance data were available for this taxon.

Family Planorbidae

Gyraulus circumstriatus

No salinity tolerance data were available for this taxon.

Order Neotaenioglossa

Family Hydrobiidae

Amnicola spp.

No salinity tolerance data were available for this taxon.

Family Pleuroceridae

Goniobasis livescens

No salinity tolerance data were available for this taxon.

Annelida

Class Clitellata

Order Haplotaxida

Family Naididae

Nais spp.

No salinity tolerance data were available for this taxon.

Limnodrilus hoffmeisteri

This is an oligohaline species, usually found at salinities below 5ppt. However, Atrill (2002) notes that *Limnodrilus hoffmeisteri* has a particularly high salinity tolerance.

Order Lumbricula

Family Lumbriculidae

Lumbriculus variegatus

No salinity tolerance data could be obtained for *Lumbriculus variegatus*. However, *Grania dolichura*, an Australian estuarine worm of the same family, tolerates a salinity range of 11-35ppt (Rota and Erseus, 2000).

Ectoprocta

Class Phylactolaemata

Order **Plumatellida - Bryozoans**

Family Lophopodidae

Lophopodella carteri

No salinity tolerance data were available for this taxon.

Family Plumatellidae

Plumatella emarginata

No salinity tolerance data were available for this taxon.

Pectinatella magnifica

No salinity tolerance data were available for this taxon.

<u>Arthropoda</u>

Class Branchiopoda

Order Diplostraca

Family Daphniidae

***Ceriodaphnia reticulata* –** Water Flea

C. reticulata has been collected in shallow, inshore waters of lakes and ponds. In one sampling event, *C. reticulata* occurred where water temperature was 16° C and conductivity was 1000 μS/cm (Anderson, 1974; Sprules, 1975). Common in lakes and ponds throughout North America and Europe, it is predominantly a nearshore species, most often occurring among vegetation (Green 1997).

***Daphnia magna* –** Water Flea

Schuytema et al. (1997) tested *Daphnia magna* to determine the acute and chronic tolerance of *D. magna* to salinity. "While *D. magna* may live and produce some young in salinities as high as 7.5g/L (ppt), survival and reproduction are enhanced at lower salinities, and are essentially normal at concentrations of 4 or 5 g/L or less (Schuytema et. al. 1997)." In addition, the ability of *D. magna* to tolerate relatively high levels of salinity (1 to 5ppt and occasionally to 8ppt) (Lagerspetz 1955 cited in Ranta 1979) increases its value as an assessment organism (Schuyema et. al. 1997). Tests conducted by Ingersoll et al. (1992) found that instant ocean salts were acutely toxic to *D. magna* at concentrations of 8 to 10ppt. Schuytema et al. (1997) concluded that *D. magna* can survive and reproduce in tests where freshwater sediment is overlain by salt water and where estuarine sediment is overlain by freshwater.

Daphnia pulex

D. pulex is primarily a pond-dweller although it is occasionally found in shallow water around the margins of lakes. Green (1997) reported collecting *D. pulex* from seven localities in the study area at Bachelor Lake, including ponds and on the margins of lakes. Depth of collection ranged from one meter to the surface. Water temperature at the time of collection varied from 11° C to 21° C, and conductivity ranged from 180 μS/cm to 6000 μS/cm. The salinity in Bachelor Lake was 3ppt.

Class Malacostraca

Order Amphipoda – Water fleas

Family Crangonyctidae

Crangonyx pseudogracilis

No salinity tolerance data were available for this taxon.

Family Gammaridae

Gammarus pseudolimnaeus

The *Gammarus* genus is a widespread and abundant amphipod taxon. They are primarily a freshwater group, but studies have reported *Gammarus sp.* in various brackish and estuarine habitats (Attrill et al. 1999, Peterson 1997, Platvoet and Pinkster et al. 1995). Although no salinity tolerance data were found for the species *G. pseudolimnaeus, Gammarus mucronatus* is known to inhabit the Salton Sea, which boasts salinities well above 40,000ppm (40ppt) (Salton Sea Homepage). Another congeneric, *Gammarus salinus* can tolerate salinities of 30psu (approx. 30ppt) (MarLIN).

Order Decapoda

Family Cambaridae

Orconectes rusticus – crayfish

No salinity tolerance data were available for this taxon.

Procambarus clarkii – crawfish

Crawfish tolerance to salinity is directly proportional to size. Newly hatched young may die at 8ppt, while adult crawfish can tolerate salinities up to 35ppt (sea water) for a short time (Averyl, Ramaire and McClain 1998).

Class Insecta

Order Diptera

Family Chironomidae – Midges

Chironomus decorus

Chironomus tentans

No salinity data were available for either of the above species, but some information was found at the family and genus levels. Chironomidae are known to inhabit a wide range of environments. Most inhabit freshwater, but some species can tolerate elevated salinity. Walker et al. (1995) found representatives from this family in lakes with salinities ranging from .04 to 369ppt.

Various *Chironomus* species are known to occur in salinities ranging from 0-30ppt (Timms 1987, Maggiore et al. 2000, Kawai et al. 2000, Colbo 1996, Williams and Williams 1998). Williams and Williams (1998) found *Chironomus aprilinus* occurring year round in salt marsh pools where the maximum salinity reached was 33% (330ppt). Various species are reported in the literature to tolerate salinities ranging from 3.1-20% (31-200ppt). (Galat et. al 1988).

Order Plecoptera

Family Perlidae – Stoneflies

Acroneuria lycorias

No salinity tolerance data were available for this taxon.

SALTWATER SPECIES

Cnidaria

Class Hydrozoa - Hydroids
Order Hydroida
Family Campanulariidae
Campanularia flexuosa

No salinity tolerance data were available for this taxon.

Phialidium spp.- Hydroids

No salinity tolerance data were available for this taxon.

Ctenophora – Comb Jellies

Class Tentaculata
Order Cydippida
Family Pleurobrachiidae
Pleurobrachia pileus - sea gooseberry

Order Lobata
Family Mnemidae
Mnemiopsis mccradyi –sea walnut

Mnemiopsis spp. are present in the Azov Sea, which is a brackish water body. Its salinity ranges from 0.5ppt in the Don river delta and the eastern part of the Taganrog bay to 15-17ppt in the area adjacent to Kerch Strait. Average yearly salinity varies from 9.5 to 14ppt. The lower salinity tolerance for Mnemiopsis is approximately 3% (Volvik 2001). No specific data were available pertaining to *M. mccradyi.*

Rotifera - Rotifers

Class Monogononta
Order Ploima
Family Brachionidae
Brachionus plicatilis

No salinity tolerance data were available for this taxon.

<u>Chaetognatha</u> – Arrow Worms

Class Sagittoidea
Order Aphragmorpha
Family sagittidae
Sagitta hispida (Ferosagitta hispida)

No salinity tolerance data were available for this taxon.

<u>Mollusca</u>

Class Bivalvia
Order Mytiloida
Family Mytilidae
Mytilus edulis - blue mussel

M. edulis is tolerant of a wide range of salinity compared to other biogenic reef species and is capable of penetrating into estuaries. However, feeding patterns are altered during short-term exposure to low salinities (Almada-Villela, 1984; Bohle, 1972) and this usually limits the species to the nearshore and mid to lower reaches of estuaries. Almada-Villela (1984) reported greatly reduced shell growth for a period of up to a month upon exposure to 16ppt salinity compared to 26 or 32ppt, while exposure to 22ppt caused only a small drop in growth rate. Over the span of several weeks, *M. edulis* adapts well to low salinities (Almada-Villela, 1984; Bohle, 1972), and hence can even grow as dwarf individuals in the inner Baltic Sea where salinities can be as low as 4-5ppt (Kautsky, 1982).

Order Myoida
Family Myidae
Mya arenaria – Softshell clam

This species is often abundant on estuarine flats where it can survive at salinities as low as 4-5ppt (Tyler et al 2001). Softshell clams are euryhaline, and are primarily marine in the northern part of their range and estuarine in the southern. The estuarine habitat in which they live is constantly exposed to changes in salinity from about 10 to 25ppt, mainly as a result of freshwater runoff. Under normal conditions, salinity fluctuations do not have a deleterious effect on softshell clams, which are isoconformers. However, small clams are less tolerant of low salinity than larger ones. When placed in freshwater, clams between 2 and 4mm succumb within 30-40 hours, but clams over 20mm can survive more than 50 hours. Low salinity coupled with high temperature can cause mass mortality of softshell clams (MACSIS).

Order Ostreoida
Family Ostreidae
<u>Crassostrea virginica - *Eastern oyster*</u>

Although no specific salinity tolerance values were found for this species, a toxicity study by Calabrese et al. (1973) tested *C. virginica* at 25ppt. Also, salinities below 22.7ppt were chown to have highly deleterious effects on developing larvae of *Crassostrea gigas*, an oyster of the same genus (Coglianese, 1982). This species was tested for silver toxicity at salinities ranging from 14.5-33ppt, and optimum development was observed between 23 and 33ppt (Coglianese, 1982).

Family Pectinidae

***Argopecten irradians* – Bay scallop**

The data for this species show different salinity tolerances for different developmental stages. The minimum salinity required for eggs of this species to develop is 22.5ppt. In general, the minimum salinity requirement determining overall distribution patterns of settling juveniles and adults of this species is about 14ppt. It has been reported that exposure to 12-15ppt salinity causes gill cilia to cease beating (MACSIS).

Order Veneroida

Family Mactridae

Rangia cuneata –Atlantic rangia

This species can tolerate salinities between 1 and 18ppt (Baldwin et al. 1994)

Family Tellinidae

Macoma inquinata –Stained macoma

Although no salinity data were available for this species, information was discovered pertaining to two congenerics. *Macoma baltica* has salinity tolerance of 5-30ppt (Salazar, 2000), and *Macoma nasuta* survived 0ppt (Peterson, 1972).

Family Veneridae

Mercenaria mercenaria – Northern quahog

The salinity range of M. mercenaria is from 12 to 35ppt (Salazar, 2000).

Protothaca staminea - Pacific littleneck

This species can inhabit a moderate salinity range, from less than 20 to 30ppt (MACSIS). In addition, Peterson (1972) found that *P. staminea* could withstand exposure to fresh (0ppt) water.

Class Gastropoda

Order Archaeogastropoda

Family Haliotidae

Haliotis cracherodii – Black abalone

Haliotis rufescens – Red abalone

An experiment by Higashi et al. (1989) monitoring metabolic responses of red and black abalone under salinity stress used salt concentrations of 34ppt to simulate control conditions, 17ppt for hypoosmotic stress, and 51ppt for hyperosmotic stress.

Boarder and Shpigel (2001) conducted trials that indicated the salinity tolerance of the congeneric *H. roei* to be between 25 and 20ppt. This correlates closely with the limited literature on *Haliotid* salinity tolerances, which indicate short-term survival is possible at salinities around 20ppt (Singharaiwan et al., 1992; Jarayabhand and Phapavisit, 1996; Boarder and Maguire, 1998 as cited in Boarder and Shpigel 2001).

Order Neogastropoda

Family Melongenidae

Busycon canaliculatum (Busycotypus canaliculatus) **–** Whelk

No salinity tolerance data were available for this taxon.

Family Nassariidae

Nassarius obsoletus - Eastern mudsnail

No specific tolerance values were found for this species. However, in a 72-hour experiment examining the effects of silver on the oxygen consumption of this snail, Warrington et al. (1996) utilized synthetic seawater with a salinity of 25ppt.

<u>Annelida</u>

Class Polychaeta

Order Aciculata

Family Nereididae

Neanthes arenaceodentata

Although no specific tolerance values were found, this polychaete is commonly used as an EPA test organism at salinities below 20ppt (EPA 1990).

Family Phyllodocidae

Phyllodoce maculata (Anaitides maculata)

No salinity tolerance data were available for this taxon.

Order Canalipalpata

Family Cirratulidae

Cirriformia spirabrancha

No salinity tolerance data were available for this taxon.

<u>Arthropoda</u>

Class Malacostraca

Order Amphipoda

Family Ampeliscidae

Ampelisca abdita

The Washington State Department of Ecology effluent toxicity test protocol states that this species should be tested at salinities between 10 and 35ppt (WSDOE, 1997).

Order Decapoda

Family Nephropidae

Homarus americanus

This species occurs primarily in systems where salinity exceeds 20ppt (MACSIS).

Family Palaemonidae

Palaemonetes pugio

Salinity tolerance range for this species was determined by the LD50 method to be from .5 to 44ppt (MACSIS).

Family Pandalidae

Pandalus danae

P. danae has been reported in waters with salinities from 23 to 36ppt (MACSIS).

Order Euphausiacea

Family Euphausiidae

Euphausia pacifica - Krill

No salinity tolerance data were available for this taxon.

Class Maxilipoda

Order Calanoida

Family Acartiidae

Acartia clausi

This species has a very broad salinity tolerance, surviving from 0 to 70ppt (Luczkovich, 2002).

Acartia tonsa

No salinity tolerance data were available for this taxon.

Family Calanidae

Undinula vulgaris

No salinity tolerance data were available for this taxon.

Family Euchaetidae

Euchaeta marina

No salinity tolerance data were available for this taxon.

Family Metridinidae

Metridia pacifica

No salinity tolerance data were available for this taxon.

Family Pontellidae

Labidocera scotti

This species has a very broad salinity tolerance, ranging from 0 to 70ppt (Luczkovich, 2002).

Order Harpaticoida

Family Tisbidae

Tisbe holothuriae

No salinity tolerance data were available for this taxon.

Echinodermata

Class Echinoidea

Order Arbacioida

Family Arbaciidae

Arbacia punctulata

No salinity tolerance data were available for this taxon.

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