San Francisco Estuary Regional Monitoring Program for Trace Substances

Results of the

Benthic Pilot Study

1994-1997

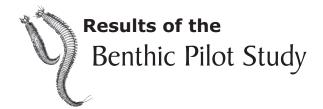
Part 1—Macrobenthic Assemblages of the San Francisco Bay-Delta, and their Responses to Abiotic Factors

Bruce Thompson and Sarah Lowe, San Francisco Estuary Institute

Michael Kellogg, City and County of San Francisco

Technical Report 39 • August, 2000





Contents

Executive Summary	8
Introduction	10
Objectives	10
Environmental Setting	11
Methods	
Sample Collection & Analysis	12
Data Analysis	
Results and Discussion	14
Identification of Benthic Assemblages	14
Species Composition & Distribution of Assemblages	16
Number of Taxa, Total Abundance & Biomass	22
Asssemblage Response to Changes in Abiotic Factors	23
Summary & Conclusions	26
Acknowledgments	
Literature Cited	29
Appendix 1	33



Figure 1

Chart of San Francisco Bay and Delta showing benthic sampling locations, pg. 11

Figure 2

Principal coordinates axes for benthic samples 1994-1996, pg. 14

Figure 3

Dendrogram from classification analysis of benthic samples, pg. 17

Figure 4

Mean number of taxa, total abundances, and biomass at each site, pg. 21

Figure 5

Benthic and abiotic variables over time at Rio Vista (D24), pg. 25

Figure 6

Benthic and abiotic variables over time at Grizzly Bay (D7), pg. 26

Figure 7

Benthic and abiotic variables over time at Davis Point (BD41) & South Bay (BA21), pg. 27

Figure 8

Benthic and abiotic variables over time Alameda (BB70) & Redwood Creek (BA41), pg. 27



Table 1

Monitoring data used, pg. 10

Table 2

Benthic monitoring sites classified in each sub-assemblage, pg. 15

Table 3

Two-way table of mean abundances and number of occurrences, pg. 16

Table 4

Rank correlation coefficients between several abiotic variables and ordination axis scores, pg. 19

Table 5

Rank correlation coefficients between number of taxa and total abundances, and several abiotic variables in each sub-assemblage, pg. 23

Table 6

Mean (range) of selected abiotic variables for the benthic assemblages in San Francisco Bay-Delta, pg. 24



Appendix 1

Listing of selected biotic and abiotic variables, pg. 33

Executive Summary

The Benthic Pilot Study began in 1994 because the original RMP Base Program did not include any *in situ* biological indicators of contaminant effects, and such information was considered to be an important component of Bay assessments. Benthic sampling is a common component of most coastal and aquatic monitoring programs in the US. Benthos are monitored because they are a key component of the ecosystem that links sediments to the aquatic food web and provides food for bottom feeding fish and birds. Benthic organisms facilitate other important sediment functions, such as nutrient and carbon flux, by their burrowing and feeding activities. Most infaunal organisms are not very motile and must respond to a variety of natural environmental factors including changes in salinity, turbidity, dissolved oxygen. Thus, benthos are considered to be reliable indicators of local sediment conditions. Understanding benthic responses to natural environmental fluctuations is essential before assessments of effects from anthropogenic factors (e.g. diversions of freshwater inflows, dredging, contamination, introduced species) can be made.

The objective of the Benthic Pilot Study was to evaluate the use of benthic information for determining environmental conditions in the Estuary. The results of the RMP Benthic Pilot Study are reported in two Parts. Part 1 describes the distribution of the benthic assemblages identified in the Bay and Delta, the species composition and abundances of these assemblages, and shows the influences of variable Delta outflow, salinity, and sediment-type on them. The Benthic Pilot Study was a collaborative study including data from the RMP, Department of Water Resources, Bay Area Discharger's Association, and the Bay Protection and Toxic Clean-up Program.

Three major macrobenthic assemblages in San Francisco Bay and Delta were identified: a Fresh-brackish assemblage in the Delta, an Estuarine assemblage in the North Bay and extreme South Bay, and a Marine assemblage in the Central and Lower Bays. The major assemblages were distributed along the estuarine salinity gradient. Each assemblage was composed of two or three subassemblages. The Fresh-brackish assemblage had three sub-assemblages: the muddy sediment sub-assemblage dominated by the introduced freshwater clam Corbicula fluminea, oligochaetes, and amphipods, a sandy sediment sub-assemblages that included many of the same species in muddy sediments, but with very low numbers of taxa and abundances, and an Estuarine transition subassemblage in the estuarine turbidity maximum zone (entrapment zone) that was dominated by the introduced Asian clam Potamocorbula amurensis and amphipods. The Estuarine assemblage was composed of two sub-assemblages, a Main estuarine sub-assemblage dominated by P. amurensis and the amphipod Ampelisca abdita, and an Estuarine margin sub-assemblage dominated by opportunistic and pollution tolerant taxa such as tubificid oligochaetes. The Marine assemblage was composed of a muddy sediment sub-assemblage dominated by several amphipod species, and a sandy sediment sub-assemblage dominated by only a few polychaete taxa with low abundances. The sub-assemblages appeared to reflect differences in salinity or sediment-type (grain-size, total organic carbon), but the factors that distinguished the Estuarine margin sub-assemblage were not identified. The benthos of San Francisco Bay-Delta included many species typical of other west coast estuaries, and the distribution of the assemblages was similar to other US estuaries.

The number of taxa, total abundances, and biomass were highest in the Marine muddy sub-assemblage and lowest in the Fresh-brackish sandy sub-assemblage. However, the Marine sandy, and Estuarine transition sub-assemblages also had low numbers of taxa and abundances. All of the sub-assemblages with reduced abundances were characterized by dynamic hydrologic conditions that apparently affected the ability of many organisms to survive.

Species composition and abundances within each sub-assemblage was generally consistent over time. However, the species composition and abundances, thus sub-assemblage designation at some sites changed in response to changes in salinity or sediment-type related to seasonal Delta outflow. Therefore, the spatial distribution of some sub-assemblages changed as well. The response times of the benthos to changes in abiotic factors were slightly different depending on the event and assemblage. Response times varied from immediate in the Fresh-brackish assemblage to several months in the other assemblages. Responses in the Estuarine and Marine assemblages were not well characterized; more frequent sampling is needed.

Benthic variables (e.g. species composition, number of taxa, etc.) characteristic of each sub-assemblage may be considered as indicators of those sub-assemblages and their associated salinity and sediment-type regimes. Properly tested and evaluated, these indicators may be useful in assessing the condition of the benthos in subsequent samples. Significant deviations from "normal" or "reference" conditions by an indicator, or suite of indicators, could denote the existence of abnormal or unusual abiotic conditions. Learning to interpret such indicators would be valuable for a variety of restoration, management, and regulatory purposes, and is the focus of Part 2 of this Technical Report.

One of the most important outcomes from the Benthic Pilot Study was the demonstration that collaboration among several different benthic sampling programs could produce a more comprehensive assessment of the Bay than any single program. Such collaboration should be continued and attempted for other ecosystem components such as plankton, and fish monitoring.

Several questions and information needs were identified for further study:

- There are many locations that have not been sampled. Do the assemblages identified represent all of the benthic assemblages in the Bay-Delta, or are there more to discover?
- What is the distribution of the Estuarine margin sub-assemblage, and
 which abiotic factors influence it most? Is it a natural feature of all
 estuary margin areas caused by continuous fresh water inputs, high
 suspended sediment loads, and bird and fish predation on the benthos,
 etc.? What is the role of sediment contamination?
- What are the response times of the benthos to changes in salinity or sediment-type in the Marine and Estuarine assemblages?
- What processes are responsible for the observed reduction in number of taxa and abundances in the Estuarine transition sub-assemblage?

Macrobenthic Assemblages of the San Francisco Bay-Delta, and Their Responses to Abiotic Factors

Bruce Thompson and Sarah Lowe, San Francisco Estuary Institute Michael Kellogg, City and County of San Francisco

Introduction

Benthic macrofauna (larger than 0.5 mm) have been studied extensively in San Francisco Bay (reviewed by Nichols, 1973; Nichols and Pamatmat, 1988). The first quantitative benthic samples were collected by the *USS Albatross* in the Central Bay in 1912 (Sumner *et al.*, 1914). Urbanization of the Bay Area created the need for studies of the effects of decreased water quality on the benthos (Filice, 1959; Storrs *et al.*, 1966; Daniel and Chadwick, 1972). In the 1980s, several monitoring programs sampled the benthos (Schemel, 1990, 1995; Hymanson *et al.*, 1994), and new programs were started in the 1990s (Table 1). Other studies of San Francisco Bay benthos have focused on long-term changes in the benthos at specific sites (Nichols and Thompson, 1985a,b; Hymanson *et al.*, 1994), changes in the benthos (Nichols *et al.*, 1990) and zooplankton (Kimmerer *et al.*, 1994) in the Suisun Bay following the introduction of the Asian clam *Potamocorbula amurensis*, and on the ecology of individual benthic species (KLI, 1983; Thompson and Nichols, 1988; Werner and Holibaugh, 1993). Detailed descriptions of the benthic assemblages of the Bay-Delta have not been previously reported.

Many of the benthic organisms that inhabit the Bay and Delta are non-native, or introduced (Nichols and Pamatmat, 1988; Cohen and Carlton, 1995). Introduced taxa contributed an average of 11 to 79 percent to their assemblages in the Bay (Lee *et al.*, 1999), which complicates efforts to understand the benthic assemblages of the Bay-Delta since the species that form the assemblages have not coevolved. Therefore, it is all the more important to periodically document the condition of the Bay's benthos, so that the almost certain changes in the future can be tracked.

Objectives

The purpose of this paper is to describe the species composition, abundances, and distribution of benthic assemblages in the Bay-Delta, to identify the abiotic factors that have the most influence on the assemblages, and examine how the assemblages change in response to those variables.

Table 1. Monitoring data used. 1997 data were not used in the ordination and classification analysis.

Program	Dates	Sampling Frequency	No. of Sites	Replicates	Tot. Samples
SFEI RMP	1994-1997	semi-annually	9	none	74
BADA LEMP	1994-1997	semi-annually	9	none	54
DWR	1994-1997	monthly	15	3 - 4	436
BPTCP	1992, 1994	occasional	7	5 in 1992	7

^{*} not including replicates

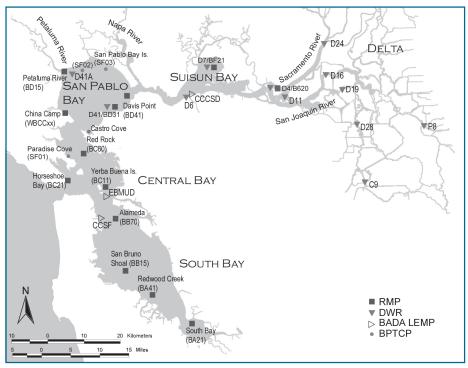


Figure 1. Chart of San Francisco Bay and Delta showing benthic sampling locations for the Regional Monitoring Program (RMP), Department of Water Resources (DWR), the Bay Area Discharger's Association Local Effects Monitoring Program (BADA LEMP), and the Bay Protection and Toxic Cleanup Program (BPTCP).

A benthic assemblage refers to the coexisting organisms that inhabit a location (or locations) at a specific time (or period of time). The species composition and abundances of an assemblage may vary slightly from location-to-location, or time-to-time because assemblages are the manifestation of the responses of many individual organisms to slight differences in physical factors such as salinity or sediment-type, in biological factors such as competition or predation, and in organism life-cycles. These factors usually change gradually over space and time and eventually result in recognizable changes in benthic species composition and abundances that may be identified as a distinct sub-assemblage, or a completely different benthic assemblage. Differences between assemblages or sub-assemblages may reflect changes in only a few, or many taxa.

Environmental Setting

San Francisco Bay is a highly industrialized and urbanized Estuary composed of several connected embayments (Figure 1). The Central Bay is under strong marine influence, South Bay is a semi-enclosed embayment with numerous, relatively small, local freshwater inflows, and San Pablo Bay and Suisun Bay are strongly influenced by freshwater flows from the Sacramento and San Joaquin Rivers, through the Delta, which drains about 40 percent (153,000 km²) of California. Seasonal weather patterns in California and the Bay Area affect salinity and sedimentation in the Bay. Most rainfall occurs between November and April, probably transporting the majority of the contamination loads to the Bay annually (Gunther *et al.*, 1987). Freshwater flow through the Delta is also seasonal with the highest inflows usually occurring between November and May, and contributes about 90 percent of the freshwater inflow to the Bay. Summers are generally dry with little rain or runoff (Conomos *et al.*, 1985). In

January, 1997 extremely heavy rains in central California caused flooding in the Sierra Nevada and the Central Valley which resulted in peak Delta outflow of $7350~\text{m}^3\text{s}^{-1}$ (e.g. Figure 5). Sampling throughout the Bay and Delta in subsequent months demonstrated the influence of such high flows on the benthos.

Methods

Sample Collection and Analysis

The data used in this paper were from several different monitoring programs conducted in the San Francisco Bay and Delta (Table 1). The Regional Monitoring Program for Trace Substances (RMP) sampled in the wet period (Jan. or Feb.) and in the dry period (Aug. or Sep.) between 1994 and 1997. Their samples included four Wetland Pilot Study sites at China Camp from March 1996. The Bay Area Discharger's Association's Local Effects Monitoring Program (BADA LEMP) sampled near the East Bay Municipal Utility District (EBMUD), City and County of San Francisco (CCSF), and Central Contra Costa Sanitary District (CCCSD) wastewater discharges. Three sites, ranging between 50-350 m from the discharges were sampled on the same schedule as the RMP (Thompson et al., 1999a). The California Bay Protection and Toxic Clean-up Program (BPTCP) conducted benthic sampling at four sites along a suspected contamination gradient in Castro Cove in May 1992 (Carney et al., 1994), and at three prospective "reference" sites in Central, and San Pablo Bays in September 1994 (Hunt et al., 1998a). The California Department of Water Resources (DWR) has conducted monthly benthic sampling in the Delta, Suisun, and San Pablo Bays as part of their Compliance Monitoring Program (CMP) since 1975. This study included their data from 1994 to 1997. They modified their program in 1996, and added or deleted some sites. Thus, samples from some of their sites were not collected continuously between 1994-1997. The sites sampled by the above programs were selected based on the objectives of each program. None of the samples were randomly collected. Thus, the samples may not be representative of their habitats or locations.

Single samples were collected at the RMP and LEMP sites, except in August 1994 when three replicates were collected at three RMP sites (Horseshoe Bay, Alameda, Davis Point), and all LEMP sites. Five replicates were collected at the BPTCP Castro Cove sites in 1992, but single samples were collected at their reference sites in 1994. DWR collected three replicates at each site in 1994 and 1995, but collected four replicates subsequently. Replicates from each site were averaged for the analyses in this report, except as noted below for the 1992 BPTCP samples.

A $0.05~\rm m^2$ Ponar grab was used to collect most of the samples. The 12 CCCSD samples were collected with a $0.1~\rm m^2$ Smith-McIntyre. The sample was split in half to equal the area of the other samples, and only one-half was analyzed. The four BPTCP Castro Cove samples were collected using a $0.018~\rm m^2$ grab sampler. Owing to species-area considerations (e.g. Connor and McCoy, 1979) in samples of different sizes, abundances in the BPTCP samples were equated to abundances in the other samples by summing the abundances of unique taxa in three of the replicates producing an estimate based on $0.054~\rm m^2$.

All samples were sieved through nested 1.0 and 0.5 mm screens. The data from both screen fractions were combined for analysis. The animals were preserved in 10 percent seawater buffered formalin and identified to the lowest practical taxon, usually species. Since each program used different taxonomists, it was necessary to standardize the species names in order to analyze all of the data together. This required an assessment of taxonomic differences, then resolution through discussions by the taxonomists (see Acknowledgments) to produce a standardized species list.

A suite of abiotic variables was measured by all four programs, but all variables were not measured at all sites. Each program has formal quality assurance protocols. A review of the quality assurance data from each program revealed no exceptions and it was assumed that the results were accurate. Methods of sample collection and analysis for the RMP are detailed in SFEI (1999), for LEMP in BADA (1994), for DWR in DWR (1997), and for BPTCP in Hunt *et al.* (1998a,b).

Results were standardized where methods differed. DWR's total organic material values were divided by two to estimate total organic carbon (TOC) values. DWR's specific conductance values were converted to salinity values using the formula:

Salinity (practical salinity units, psu) = -100 ($\ln(1-EC/178.5)$), where EC = specific conductance (millSiemen cm⁻¹).

DWR's Delta Outflow Index (DOI) was used as a measure of freshwater flow from the Delta into the Bay. Monthly average DOI values reflected freshwater outflow from the Delta past Chipps Island.

Sediment contamination was measured at all but the DWR sites. Three of the DWR sites were within 0.6 nautical miles of RMP sites where sediment contamination was monitored. Since sediments at those locations appeared to be homogeneous at that scale, RMP sediment contamination data was used synoptically with DWR's sediment and benthic data sampled in the same month at San Pablo Bay (D41), Grizzly Bay (D7), and Collinsville (D4C). Where sediment chemistry analyses produced results below the minimum detection limit (MDL), a value of one-half the MDL was used in calculations and analyses.

The Effects Range-Median (ERM) sediment quality guidelines that were "frequently" associated with biological effects (Long et al., 1995, 1998) were used to create a composite measure of sediment contamination, the mean Effects Range-Median quotient (mERMq). The use of the mERMq assumes additive, or cumulative effects of many sediment contaminants of varying concentrations. It provided a single sediment contamination variable for use with other summary abiotic variables (e.g. salinity, percent sand, TOC, etc.) in evaluations of benthic responses to a variety of abiotic factors. Concentrations of nine trace elements (arsenic, cadmium, chromium, copper, mercury, nickel, lead, silver, zinc), low molecular weight PAHs, high molecular weight PAHs, total DDTs, and total PCBs were used. Each concentration was divided by the respective ERM value to produce a quotient, then the quotients were summed to produce a cumulative ERM quotient. Occasionally, some sediment contaminants were not measured, therefore the quotients were averaged by dividing by the number of contaminants used to calculate each sum (never less than 11). Although ERM values exist for many individual PAH and DDT compounds, the 13 contaminants used were selected to avoid biasing the mERMq towards any class of organic compounds. ERM quotients have been used previously by Long et al. (1998), Carr et al. (1996), Canfield et al. (1996), Thompson et al. (1999b), and Hyland et al. (1999).

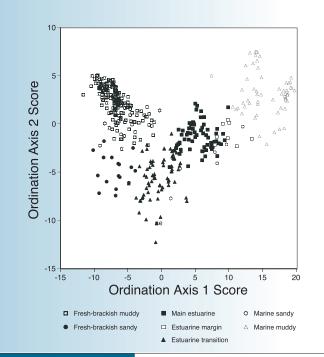
The use of data from different programs, some different samplers, conversions and substitutions as described above, all have the potential to increase variability, introduce systematic bias, and confound data interpretation. Therefore, the results of this study should be viewed with a meta-analytic perspective. The results obtained using the data as described appeared to be sensible and intuitive and did not appear to produce unusual results. Moreover, the value of synthesizing data from several studies outweighs the risks of misinterpretation, if prudent steps are taken.

DATA ANALYSIS

Benthic assemblages were identified using ordination and classification analysis (Smith *et al.*, 1988) that identify sets of samples (locations and times) with similar

species composition and abundances. Similar methods have been used extensively to identify and describe benthic assemblages (e.g. Boesch, 1973; Poore and Kudenov, 1978; Haedrich *et al.*, 1980; Thompson and Jones, 1987). Ordination and classification analysis was conducted on all 1992-1996 data which included 424 samples from 44 sites, and 354 taxa. Principal coordinates analysis (Gower, 1966, 1967) was used for ordination of the samples. Ordination and classification of the samples were based on a matrix of Bray-Curtis dissimilarity

Figure 2. Principal coordinates axes for benthic samples. Each point reflects the species composition and abundances of each benthic sample in relation to the other samples.



indices (Bray and Curtis, 1957) contrasting the benthic community composition with all pairs of samples. Prior to computing the dissimilarity values, the data were transformed by a square root and standardized by the taxon mean (values > 0). Dissimilarities greater than 0.80 were re-estimated with the step-across procedure (Williamson, 1978; Bradfield and Kenkel, 1987). Inter-taxon dissimilarities for classification of taxa into groups from similar habitats were computed as the distances between the abundance-weighted-average positions of each taxon in the sample ordination space. The flexible clustering procedure (Lance and Williams, 1966) was used to produce the dendrograms classifying the samples and taxa. A two-way table of the groupings x abundances (Table 2) was produced from the results of the classifications.

Samples collected in 1997 were not included in the ordination and classification analyses to define the assemblages because the data was not available until after those analyses were completed. The 1997 data were used to extend the time series plots to evaluate abiotic influences. These samples were assigned to one of the sub-assemblages identified by ordination and classification analysis using a similarity index (Sorenson, 1948) that compared the species composition of each 1997 sample to the

average species composition in each sub-assemblage (e.g. Table 2). The resulting sub-assemblage assignments are included in Appendix 1. Correlation analyses were accomplished using Statistical Analysis System procedures (SAS, 1995).

Results and Discussion

IDENTIFICATION OF BENTHIC ASSEMBLAGES

The benthic samples formed three primary principal coordinates (=ordination) axes that accounted for 83.7 percent of the variation in species composition and abundances among the sites. The first axis accounted for 62.8 percent, the second accounted for 12.5 percent (Figure 2), and the third accounted for 8.5 percent (not shown). Adjacent samples in the ordination space had similar species composition and abundances. The samples in each of seven sub-assemblages reflect the groupings identified by the classification analysis (Figure 3). The samples within each sub-assemblage had similar species composition and abundances (Table 2).

Plots of ordination scores revealed that the samples appeared to be distributed along ordination axis 1 related to the estuarine salinity gradient (Figure 2),

Table 2. Two-way table of mean abundances, and number of occurrences (in parentheses) for the most common and abundant taxa in each benthic sub-assemblage. The order of the assemblages (columns) is from normal classification analysis (Figure 3) and the order of the taxa (rows) is from inverse classification analysis. Taxon codes: O = oligochaete; C = crustacean; P = polychaete; N = nematode; Pe = pelecypod; A= amphipod; T = tanaid; Cu = cumacean; Os = ostracod, Ci = cirriped, Ch = chironomid.

	·	Fresh- brackish Muddy	Fresh- brackish Sandy	Estuarine transition	Marine Sandy	Main Estuarine	Estuarine Margin	Marine Muddy
Total Number of Taxa	mean (range)	13 (13-23)	4 (2-7)	4 (1-9)	7 (4-11)	10 (3-22)	16 (10-22)	36 (13-66)
Total Abundance	(3 -)	443 (21-3079)	33 (3-109)	89 (1-691)	38 (6-114)	362	1130 (156-1976)	2110
Biomass (g)		-	-	3.1 (0.01-15)	0.2 (0.02-0.8)	42.2 (0.6-241)	-	9.9 (0.3-68)
Species	Taxon	n = 192	18	72	6	68	8	60
Chaetogaster limnaei	0	1 (1)	1 (2)					
Paratendipes sp. A	Ch	1 (5)	6 (8)					
Cyprideis sp. A	Os	15 (27)	- (-)					
Manayunkia speciosa	P	117 (103)						
Aulodrilus limnobius	0	14 (97)						
Dorylaimus sp. A	N	13 (106)	1 (1)	1 (1)				
Corbicula fluminea	Pe	50 (191)	` '	1 (17)				
Limnodrilus hoffmeisteri	0	36 (180)	1 (5)	2 (10)				
Varichaetadrilus angustipeni		30 (188)	1 (12)	1 (19)				
Corophium spinicorne	s O	20 (120)	1 (12)	1 (4)		1 (1)		
Corophium stimpsoni	Ā	57 (162)	2 (12)					
Gammarus daiberi		, ,	. ,	4 (19)		1 (1)		
	A	36 (172)	4 (15)	4 (32)		1 (4)		
Marenzelleria viridis	P	6 (70)	2 (11)	20 (57)		2 (21)		
Tubificoides heterochaetus	0	4 (2)		2 (27)		1 (12)	40 (4)	4 (4)
Corophium alienense	A	1 (3)		26 (33)		5 (9)	16 (4)	1 (1)
Grandifoxus grandis	A	F (FA)	4 (5)	1 (2)	4 (0)	3 (2)	0 (4)	4 (00)
Potamocorbula amurensis	Pe	5 (54)	1 (5)	28 (67)	1 (2)	162 (67)	3 (4)	4 (28)
Tubificoides fraseri	0	4 (4)	1 (1)	1 (8)		1 (7)		4 (0)
Balanus improvisus	Ci	1 (4)		1 (12)		3 (28)		1 (3)
Neanthes succinea	Р	4 (0.0)		1 (4)		3 (54)	1 (1)	1 (8)
Nippoleucon hinumensis	Cu	1 (38)		3 (26)		22 (49)	145 (8)	8 (31)
Grandidierella japonica	Α	1 (6)		1 (9)		4 (29)	46 (6)	3 (19)
Eusarsiella zostericola	Os	1 (1)		1 (1)		2 (20)	36 (4)	1 (21)
Gemma gemma	Pe					1 (4)	70 (4)	1 (2)
Pseudopolydora kempi	Р			1 (2)		1 (2)	36 (4)	1 (3)
Streblospio benedicti	Р			1 (1)		3 (37)	116 (8)	1 (2)
Glycera tenuis	Р				2 (4)			
Tellina bodegensis	Pe				1 (2)			
Hesionura coineaui difficilis	Р				3 (3)			
Heteropodarke heteromorph	a P				18 (4)			
Corophium spp.	Α			1 (1)	. ,		92 (5)	53 (23)
Corophium acherusicum	Α			` ,	1 (1)	1 (17)		745 (34)
Corophium insidiosum	Α	1 (1)			` '	` '	` '	50 (14)
Ampelisca abdita	Α	` '		1 (14)		135 (52)	55 (4)	697 (56)
Corophium heteroceratum	Α			1 (7)		9 (42)		133 (55)
Glycera americana	P			(- /	1 (2)	1 (1)	1 (8)	()
Tubificidae	0			1 (5)	1 (3)	3 (13)	404 (4)	9 (54)
Nematoda	N			. (=/	8 (3)	1 (2)	37 (4)	25 (53)
Exogone lourei	P			1 (2)	J (J)	1 (1)	3. (.)	26 (41)
Leptochelia dubia	T			. (~)		. (')		50 (37)
Mediomastus spp.	P			1 (1)	1 (1)	1 (3)		37 (52)
Photis spp.	A			' (')	' (')	· (3)		43 (28)
י ווטנוט טעע.	$\overline{}$							TO (20)

but no salinity data were included in the ordination analysis. Only species composition and abundances from each sample were used. Correlation analysis confirmed that principal coordinate axis 1 scores were most highly correlated with salinity (Table 3). However, several other variables were also significantly correlated with axis 1 scores suggesting that several abiotic factors actually influenced benthic assemblage distributions. Total suspended sediments (TSS) was significantly correlated with axis 1 scores, but TSS was only measured at the RMP sites. TSS and TOC were most highly correlated with axis 2 scores, but less so than with axis 1 scores. Axis 3 scores were significantly correlated with percent sand, fines, and depth. Delta outflow, near-bottom water temperature, and dissolved oxygen (DO) were not significantly correlated with any of the axis scores. While the correlation analysis showed the general and relative influences of abiotic factors on the distribution of the assemblages in the Bay-Delta, data from representative sites in each sub-assemblage revealed time delays in benthic responses to Delta outflow, salinity, and sediment-type that were not adequately reflected in the correlation analysis (see Assemblage Responses to Changes in Abiotic Factors).

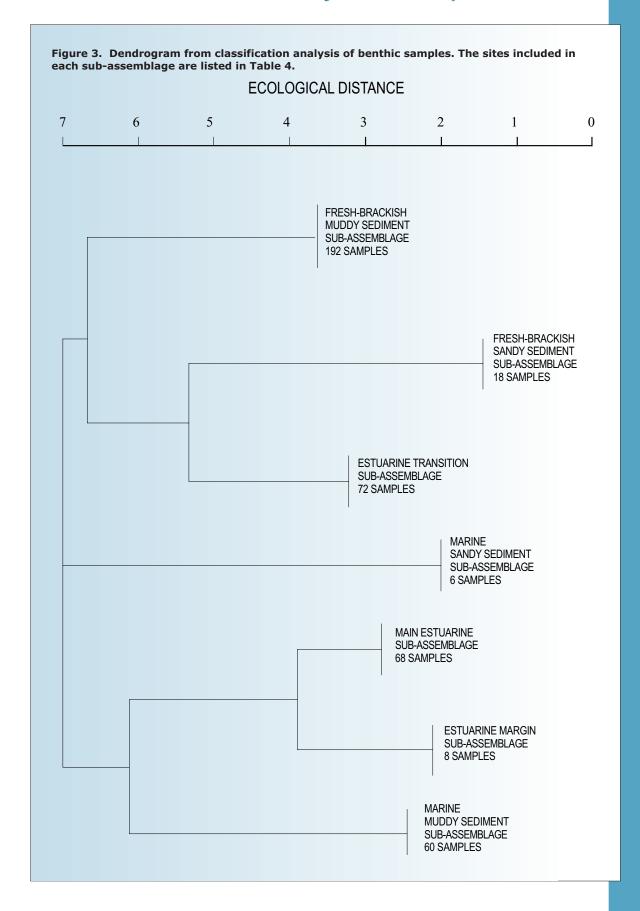
The information from classification and ordination analyses, and examination of two-way tables of abundances identified three major benthic assemblages in the Bay-Delta: a Fresh-brackish assemblage, an Estuarine assemblage, and a Marine assemblage. Each assemblage was composed of two or three sub-assemblages that differed slightly in species composition or dominance. An important finding of those analyses was that the spatial distribution of the sub-assemblages changed temporally. Samples from some sites were occasionally classified in different sub-assemblages. As shown in a subsequent section, these changes were related to changes in salinity and sediment-type as affected by changes in Delta outflow. However, the average species composition and abundances within each sub-assemblage was temporally consistent regardless of the distribution of the assemblage.

Species Composition and Distribution of Assemblages The Fresh-Brackish Assemblage

This assemblage was defined by the DWR samples from the Delta. Three sub-assemblages were identified, a muddy sediment, sandy sediment, and an

Table 3. Rank correlation coefficients between several abiotic variables and ordination axis scores. * significant a=0.05; ** significant at a=0.01. TOC = total organic carbon, TSS = total suspended solids, Dflow = Delta outflow, mERMq = mean ERM quotient.

Abiotic Varia	able n	Axis 1	Axis 2	Axis 3
Salinity	336	0.808**	-0.123*	-0.072
Temperature	306	-0.113*	0.061	0.074
Depth	284	0.176**	0.164	-0.544**
% Sand	422	-0.062	-0.121*	-0.558**
% Fines	422	0.047	0.122*	0.555**
% Gravel	422	0.306**	0.002	-0.151**
TOC	419	-0.496**	0.346**	0.390**
TSS	52	-0.572**	-0.538**	0.550**
mERMq	115	0.350**	0.262**	0.278**
Dflow	394	-0.009	-0.031	-0.081
Dissolved O ₂	58	0.112	-0.126	-0.145



Estuarine transition sub-assemblage. Although many of the same species inhabited all three sub-assemblages (Table 2), differences in species composition, number of taxa, total abundances, and shifts in numerical dominance differentiated the sub-assemblages.

Muddy sediment sub-assemblage

This sub-assemblage included 192 samples from 10 sites in the Delta (Table 4). The sediments at these sites were usually composed of silty-clay. Samples from every month over the three years sampled were included demonstrating temporally stable species composition and abundances within the assemblage.

The most abundant species in this assemblage was the polychaete *Manayunkia speciosa* (Table 2). Native to eastern North America, it was first collected in the Delta in 1963 and was probably introduced with water used to transport game fish, though it may have been introduced via freshwater ballast (Cohen and Carlton, 1995). It is one of the few species of this genus that inhabits fresh water, and appears to be a good indicator for freshwater muddy sediments as they were not collected in the other sub-assemblages. These filter-feeding, colonial worms (3-5 mm long) live in tubes constructed of fine sediment particles bound together with a mucous secretion. They reproduce by budding and releasing young adult worms from the parental tube. The most frequently collected species was the introduced clam, *Corbicula fluminea*. Native to Asia, they were first collected in the Delta in 1945 (Cohen and Carlton, 1995).

Sandy sediment sub-assemblage

This sub-assemblage included 18 samples from four sites in the Delta (Table 4). Sediment at these sites averaged 84.7 percent sand, which was significantly higher than at the muddy sediment sub-assemblage which averaged 28.7 percent sand (Kruskal Wallis test, p=0.0001). Samples from all of the sandy sediment sites were classified as components of the muddy sediment, or Estuarine transition sub-assemblages at different times. These shifts appeared to be the result of changes in sediment-type associated with changes in flow conditions (see Assemblage Responses to Changes in Abiotic Factors).

Most of the same species collected at the sandy sites were also collected at the muddy sites. However, the sandy sites had greatly reduced numbers of taxa (Table 2, Figure 4). *C. fluminea* was the most common and abundant species at the sandy sites. The oligochaete *Chaetogaster limnaei* and the crustacean *Paratendipes* sp. A appeared to prefer freshwater, sandy locations and may be used as indicators of those conditions.

Estuarine transition sub-assemblage

This sub-assemblage included 72 samples from six sites at the confluence of the Sacramento River, Suisun, and San Pablo Bays (Table 4). All of the sites included in this sub-assemblage were classified with one of the adjacent sub-assemblages at some other time, demonstrating the dynamic distribution of the Estuarine transition assemblage. All of the LEMP samples from near the CCCSD wastewater discharge except one (Feb. 1995) were also classified as part of this sub-assemblage, indicating similar species composition and abundances as the other Estuarine transition samples. Sites classified as Estuarine transition were generally located within the estuary turbidity maximum zone where salinities and suspended sediment concentrations fluctuate greatly depending on Delta outflow (Burau *et al.*, 1998).

The most common and abundant species of this sub-assemblage included both Fresh-brackish, and Estuarine assemblage species (Table 2). The reduced

frequencies of occurrence of the component taxa compared to other sub-assemblages illustrates the variable nature of this sub-assemblage. The introduced Asian clam, *Potamocorbula amurensis* was the most common and abundant inhabitant of the Estuarine transition sub-assemblage (Table 2) accounting for an average of 43 percent of total abundances. Since its introduction in 1986 (Carlton *et al.*, 1990) they have become dominant members of the benthos in the Bay. They were collected in almost 99 percent of the estuarine samples between 1994 and 1996, and were members of all major benthic assemblages in the Bay-Delta. The highest abundances were collected at the Petaluma River (BD15) in August, 1997 where 42,800 m⁻² were collected. They contributed the largest portion of benthic biomass. The presence of this clam since 1986 has changed the ecology of Suisun Bay by its intensive filtering ability which has reduced plankton abundances (Werner and Hollibaugh, 1993; Kimmerer *et al.*, 1994).

ESTUARINE ASSEMBLAGE

Samples from Suisun Bay, San Pablo Bay, and South Bay grouped together to represent the Estuarine assemblage (Table 4). In contrast to the other major assemblages, sites with muddy and sandy sediments were not distinguished as separate sub-assemblages despite the fact that seven samples from four sites

Table 4. Benthic monitoring sites in each sub-assemblage, 1992-1996. Sites listed in more than one sub-assemblage reflect occasional shifts in species composition at those sites.

Assemblage Sub-assemblage	Sites Na	ame (Code)
Fresh-brackish		. (2222)
Muddy sediments	 Franks Tract (D19) Old River (D28A L,R) Sherman Is. (D11) Twitchell Is. (D16) 	 Buckley Cove (P8) Clifton Court (C9) Rio Vista (D24) Collinsville (D4 L,R)
Sandy sediments	•Rio Vista (D24) •Collinsville (D4 L,C)	•Twitchell Is. (D16)
Estuarine transition	•Grizzly Bay (D7) •CCCSD •Davis Point (BD41)	•Pacheco Creek (D6) •Collinsville (D4C)
Estuarine		
Main	 Pacheco Creek (D6) Petaluma R. (BD15) Petaluma R. (D41A) South Bay (BA21) SFO2 	Davis Point (BD41)Pinole Point (D41)Grizzly Bay (D7)SFO3CCCSD
Margin	Castro Cove	•China Camp (WBCC)
Marine Muddy sediments	•SFO1 •Alameda (BB70) •EBMUD •Redwood Ck. (BA41)	•Horseshoe Bay (BC21) •Yerba Buena Is. (BC11) •San Bruno Sh. (BB15) •CCSF
Sandy sediments	•Red Rock (BC60)	

(BD41, D41, D6, CCCSD) had sediments with more than 70 percent sand. This result indicates that estuarine sites with a wide range of sediment-types are inhabited by similar benthos. Two sub-assemblages were identified: a Main estuarine, and an Estuarine margin sub-assemblage. The factors that distinguish the two sub-assemblages were not evident in the data collected.

Main estuarine sub-assemblage

This sub-assemblage included 68 samples from 11 sites (Table 4). Samples from San Pablo Bay and South Bay with similar salinity regimes were included in this sub-assemblage. Samples from all months were included suggesting stable species composition and abundances within the assemblage. However, samples from five sites were classified with adjacent sub-assemblages at different times (Table 4). The most common and abundant species was the introduced Asian clam Potamocorbula amurensis (Table 2). The introduced amphipod Ampelisca abdita was also among the most abundant species collected. It is a tube dwelling amphipod, about 1-4 mm in length. Native to northwest Atlantic coastal estuaries, it was first collected in San Francisco Bay in 1954; it may have arrived with shipments of Atlantic oysters around the turn of the century, or it could have been introduced to the Bay via ballast water (Cohen and Carlton, 1995). They were collected in about 76 percent of the Main estuarine sub-assemblage samples. Their abundances were variable in estuarine samples, due to their life history. They are usually most abundant in the summer and fall and least abundant in the winter months (KLI, 1983; Weston, 1997).

Estuarine margin sub-assemblage

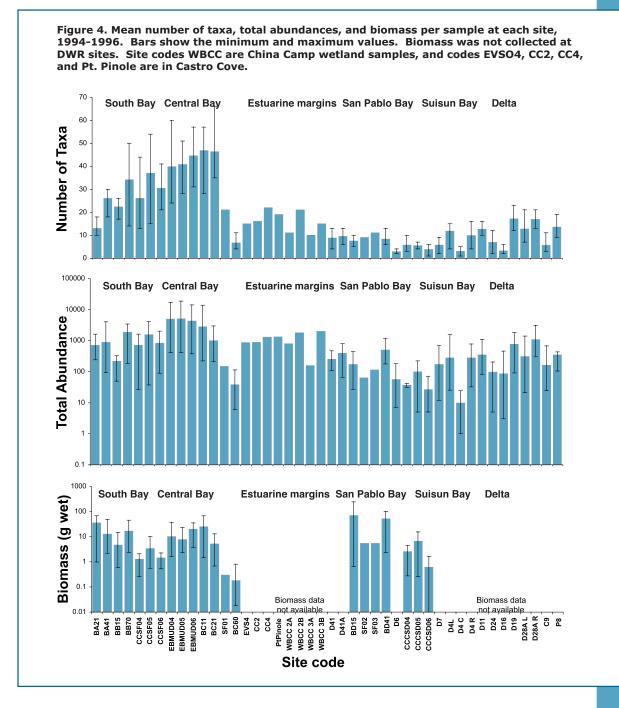
Four sites along a gradient into an abandoned oil refinery discharge in Castro Cove, and four sites from the China Camp wetland tidal channels were classified together as a sub-assemblage of the Estuarine assemblage. The dominant species in this sub-assemblage included several opportunistic and pollution tolerant species such as tubificid oligochaetes and the spionid polychaete *Streblospio benedicti* (Table 2) which was introduced to the Bay in the 1930's (Carlton and Cohen, 1995). They feed on suspended organic material and are tolerant of sediment contamination and organic loading (Pearson and Rosenberg, 1978; Dauer, 1993). *A. abdita* abundances decreased along the gradient into Castro Cove, but none were collected in the China Camp samples.

MARINE ASSEMBLAGE

Samples collected at nine sites in the Central, and South Bays between Redwood Creek (BA41) and Paradise Cove (SF01) composed the Marine assemblage. Two sub-assemblages, the muddy, and sandy sediment sub-assemblages were distinguished.

Muddy sediment sub-assemblage

This sub-assemblage was represented by 60 samples from eight sites (Table 4). Samples from both the wet and dry sampling periods were included suggesting little seasonal variation in species composition within that sub-assemblage. However, one sample from San Bruno Shoal (BB15) was classified with the Main estuarine sub-assemblage during the wet period (Feb. 1995). Samples from near the EBMUD and CCSF wastewater discharges were classified along with adjacent RMP Central Bay samples, indicating that the discharge sites had similar species composition and abundances as Central Bay sites farther from the discharge.



The benthos that inhabited the Marine muddy sediments included marine and estuarine organisms. The most abundant taxa were amphipods (six species) and the polychaete *Euchone limnicola* (Table 2). Although average abundances of the amphipod *Corophium acherusicum* were highest, their apparent dominance reflected a large influx (densities up to 246,880 m⁻²) at several sites sampled in August 1995. Their abundances had decreased by the following sampling period and remained low until another influx occurred in August 1997, albeit to a lesser degree. Their abundance peaks occurred following the two winters with the highest levels of freshwater runoff. *A. abdita* was the most commonly collected species (93 % of the samples) in the Marine muddy assemblage. The cumacean

Leptochelia dubia and the amphipod *Corophium insidiosum* appeared to be good indicators of Marine muddy habitats as they were not collected from other sub-assemblages.

Sandy sediment sub-assemblage

The samples collected near Red Rock (BC60) identified a sandy sediment sub-assemblage of the Marine assemblage. This site was located mid-channel, in an area of strong currents and was composed of over 85 percent sand. These samples were characterized by low numbers of species and abundances, typical of sandy locations (Table 2). The most abundant taxa were the polychaete *Heteropodarke heteromorpha* and nematodes. *H. heteromorpha* and the polychaetes *Hesionura coineaui difficulis* and *Glycera tenuis* were only collected at Red Rock. Since Red Rock was the only Marine sandy site sampled, it is not known whether other sandy Central Bay locations had similar benthos.

Number of Taxa, Total Abundance, and Biomass

Over 537 macrobenthic benthic taxa were identified in the Bay and Delta samples collected between 1992 and 1997. A spatial gradient of increasing numbers of taxa and total abundances extended from the South Bay into Central Bay (Figure 4). The highest total abundances in the Central Bay were collected in August 1995 due to the influx of the amphipod *C. acherusicum* described above. The number of taxa and total abundance decreased from Central Bay into San Pablo Bay, to a minimum in Suisun Bay. Suisun Bay is within the estuary turbidity maximum zone that is characterized by dynamic tidal and seasonal changes in salinity and turbidity. Number of taxa and abundances increased slightly in the Delta, but were at their lowest values where sediments were sandy (e.g. Twitchell Is., D16).

By sub-assemblage, the number of taxa and total abundance were highest in the Marine muddy sub-assemblage (Table 2). The lowest number of taxa was collected in the Fresh-brackish sandy sub-assemblage, but the Estuarine transition sub-assemblage also had low numbers of taxa. Reduced numbers of taxa and abundances were also characteristic of the Marine sandy sub-assemblage. Total biomass was only measured at the RMP and LEMP sites. The highest biomass occurred at the Estuarine assemblage sites due to the large numbers of *P. amurensis* collected there (Figure 4).

Temporal variation in the number of taxa, total abundance, and biomass was observed at all sites as evidenced by the range of values shown on Figure 1.4. Variations in total abundance were mainly due to seasonal fluctuations in amphipod abundances. For example, the large influx of *C. acherusicum* in Central Bay in 1995, and annual fluctuations of *A. abdita* reflected their life histories. Fluctuations in biomass were largely due to chance collection of large bivalves or other large organisms in a sample.

Variations in the number of taxa and total abundance within sub-assemblages were mainly affected by seasonal differences in salinity and sediment-type. In the Marine muddy sub-assemblage, numbers of taxa and total abundances were most highly correlated with salinity (Table 5), but sediment-type (percent fines) and contamination (mERMq) were also significantly correlated with numbers of taxa. Sensitivity to salinity change is typical of stenohaline organisms (Carriker, 1967). In the Main estuarine sub-assemblage, only salinity was significantly correlated with number of taxa. In the Estuarine transition, and Fresh-brackish muddy sub-assemblages, sediment type was most highly correlated with both the number of taxa and total abundances. There were no significant correlations for the Fresh-brackish sandy assemblage due to the reduced number sample.

Table 5. Rank correlation coefficients between number of taxa and total abundances and several abiotic variables in each sub-assemblage, 1994 - 1996. TOC=total organic carbon, mERMq=mean ERM quotient. Marine sandy and Estuarine margin sub-assemblages were not analyzed due to very low sample size (n=6-8).

	Salinity	Fines	TOC	mERMq
Marine muddy (n)	(60)	(60)	(60)	(59)
No. Taxa	0.361**	-0.428**	-0.251	-0.320*
Tot. Abundance	0.342**	-0.024	-0.071	-0.037
Main Estuarine	(46)	(68)	(68)	(20)
No. Taxa	0.343*	-0.094	0.057	-0.013
Tot. Abundance	0.248	0.185	0.183	0.005
Estuarine transition	(70)	(71)	(71)	(20)
No. Taxa	-0.015	0.503**	0.381**	0.048
Tot. Abundance	0.241*	0.562**	0.513**	0.057
Fresh-brackish muddy	(167)	(192)	(192)	(0)
No. Taxa	-0.263**	0.446**	0.485**	-
Tot. Abundance	-0.130	0.424**	0.356**	-
Fresh-brackish sandy	(6)	(17)	(17)	(0)
No. Taxa	0.415	0.050	0.420	-
Tot. Abundance	0.065	0.022	0.190	-

^{*} p < 0.05

Since salinity and sediment-type were most closely related to the distribution of sub-assemblages (axis scores), number of taxa, and total abundances, the sub-assemblages could be further defined by the ranges of these abiotic variables measured in the samples that composed each group (Table 6). Each sub-assemblage had characteristic ranges of salinity and sediment-type to which the organisms were apparently adapted. The ranges of salinity for the three major assemblages are very similar to those reported for other temperate estuaries. The upper range of salinity in the Fresh-brackish assemblage was 5.1 psu and the average salinity for the Estuarine transition sub-assemblage was 4.9 psu, both very near the generalized 5 psu limit for oligohaline zone. Similarly, the upper salinity range for the Estuarine transition, the mean salinity for the Main estuarine sub-assemblages, and the lower limit for the Marine assemblages were all about 16 psu, near the generalized 18 psu upper limit of the mesohaline zone (Carriker, 1967; Boesch, 1977).

Assemblage Response to Changes in Abiotic Factors

Each of the major assemblages described above has different hydrologic and tidal regimes. Freshwater inflow was expected to have more influence than tides in the Delta and at the confluence of the Sacramento and San Joaquin Rivers, while tides were expected to have the most influence in the Central Bay. Further, benthic responses to changes in water or sediment conditions were expected to exhibit time lags to such events. Benthic responses to selected abiotic variables were evaluated by examining changes over time at representative sites from several sub-assemblages.

Benthic samples from three DWR sites in the Delta (D4L, D24, D16) were sometimes classified as Fresh-brackish muddy, and sometimes classified as Fresh-brackish sandy sub-assemblage sites. At D24 near Rio Vista on the Sacramento River, peak Delta outflow in February 1996 and January 1997 resulted in

^{**} p < 0.01

sediments with 98-99 percent sand and an immediate decrease in the number of taxa (Figure 5). High Delta outflows could have altered the sediments through resuspension and transport of the fine sediment, or bedload transport of sand from upstream. The assemblage was classified as Fresh-brackish sandy during high outflows in the winter of 1996, then switched to the muddy sub-assemblage in July 1996 when outflows decreased and sediments became more muddy. The assemblage switched back to the sandy sub-assemblage coincident with the January 1997 flood flows, then again reverted to the muddy sub-assemblage, with increased numbers of taxa, about a month after outflows decreased to below about 1000 m³s⁻¹. The extreme temporal variability in percent sand may reflect substrate heterogeneity in space and time, to be expected in the Delta channels. In general, there was good correspondence between outflow, sediment-type, and assemblage response at D24.

Benthic responses at the other two Delta sites were not as clearly associated with high Delta outflows. Samples from D16 near Twitchell Island (not plotted, see Appendix 1) on the San Joaquin River were also classified as the sandy sub-assemblage coincident with peak outflows, but the samples alternated between the muddy, and sandy sub-assemblage from one to three month intervals, apparently unrelated to outflow or percent sand. The number of taxa was consistently low (< 9) at this site and did not decrease sharply with peak outflow or changes in sediment-type. At D4L on the Sacramento River, high outflow in February 1996 resulted in a shift from the muddy- to the sandy sub-assemblage, but even higher outflow events in January and March 1995, and January 1997 did not, and sediments remained fine through those events (see Appendix 1). The apparent shifts in assemblage designations at D16 and D4L may reflect substrate heterogeneity, especially at D16. Another explanation could be that the actual magnitude of the flows at each location in the Delta were not adequately reflected in the use of the Delta outflow index. However, when responses were

Table 6. Mean (range) of selected abiotic variables for the benthic assemblages in San Francisco Bay-Delta, 1994-1996.

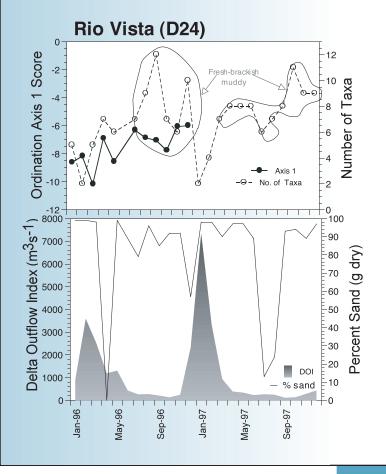
Assemblage	Salinity	Fines (%)	TOC (%)
Fresh-brackish			
Muddy sediments	<u>0.68</u>	<u>71.8</u>	<u>3.86</u>
	(0 - 5.1)	(1 - 100)	(0.3 - 21.7)
Sandy sediments	<u>0.08</u>	<u>15.3</u>	<u>0.74</u>
	(0 - 0.1)	(0 - 100)	(0.20 - 2.5)
Estuarine	<u>4.9</u>	<u>50.9</u>	<u>2.05</u>
transition	(0 - 15.9)	(0 - 100)	(0.10 - 3.9)
Estuarine			
Main	<u>16.1</u>	<u>88.2</u>	<u>2.63</u>
	(0.1 - 30.7)	(13 - 100)	(0.10 - 5.1)
Margin	<u>22.8</u>	<u>91.8</u>	<u>2</u>
	(22 - 24)	(67.2 - 99)	(1.1 - 3.3)
Marine			
Muddy sediments	<u>27.5</u>	<u>73.9</u>	<u>1</u>
	(16.3 - 33.3)	(30 - 97)	(0.33 - 2.22)
Sandy sediments	<u>26.6</u>	<u>4.7</u>	<u>0.4</u>
	(15.6 - 31.9)	(2 - 7)	(<0.01 - 0.96)

observed, they occurred on time scales ranging from immediate to several months.

Samples from site D7 in Grizzly Bay were classified as Estuarine transition most of the time (Figure 6). However, on three occasions samples were classified as Main estuarine (Feb. 1994, Dec. 1994, Jan. 1995) when several estuarine species (e.g. Nippoleucon hinumensis) increased in abundance. The change in species composition occurred following periods of low Delta outflow, three to five months after salinities had increased above about 10.5 psu due to seawater intrusion that apparently transported organisms or larvae from the the lower Estuary. The assemblage reverted back to Estuarine transition the month following elevated Delta outflows that resulted in decreased salinities. Delta outflows in 1995 and 1996 were apparently of such magnitude that salinities at D7 remained low and the benthos remained Estuarine transition. Benthic response to elevated salinities at the end of 1997 was not evaluated.

Analysis from the 1970s and 1980s showed that the establishment of several estuarine species (e.g. *Mya arenaria*) in Grizzly Bay (D7) occurred following about 16 months of reduced flows (Nichols *et al.*, 1990). The results presented in this paper showed that assemblage at D7 shifted at much shorter time scales. The differences between the two studies are probably

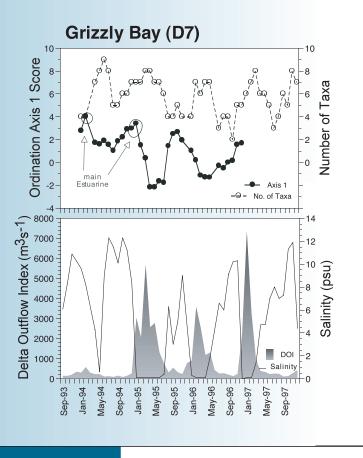
Figure 5. Plot of ordination axis 1 scores, number of taxa, percent sand and Delta outflow over time at a DWR site in the Sacramento River: Rio Vista (D24). Circled samples were classified as Fresh-brackish muddy, all other samples as Fresh-brackish sandy. Delta outflow data courtesy of the DWR.



due to changes in the sub-assemblages following the introductions of *P. amurensis*, and *N. hinumensis*. The benthos at D7 described in this paper represents conditions eight, or more years after the introductions of these species in 1986, which is very different from that described by Nichols *et al.* (1990). Following an initial assemblage adjustment (about 2 years) where decreases in numbers of taxa, abundances, and decreased abundances of the resident bivalves *Macoma baltica* and *Mya arenaria* corresponded with large increases *in P. amurensis* abundances (Nichols *et al.*, 1990), benthic species composition appears to have remained stable (Hymanson *et al.*, 1994). Species composition and abundances reported in this paper are similar to the post-*P. amurensis* benthos in Grizzly Bay (Nichols *et al.*, 1990), and at Collinsville (D4, Hymanson *et al.*, 1994).

Samples from site D6 (Bull's Head Point) also switched between Main estuarine and Estuarine transition sub-assemblages, but inconsistently (not plotted, see Appendix 1). They switched to Estuarine transition coincident with high Delta outflow in February 1996, but did not revert to Main estuarine during low Delta outflow in the summer of that year. The benthos remained Estuarine

Figure 6. Plot of ordination axis 1 scores, number of taxa, percent sand and Delta outflow over time at a DWR site in Grizzly Bay (D7). Circled samples were classified as Main estuarine, all other samples as Estuarine transition. Delta outflow data courtesy of the DWR.



transition through the flood flow in January 1997 then switched back to Main estuarine in June 1997 when outflow decreased. The proximity of this site to Pacheco Creek may have influenced the salinity, confounding the effect of Delta outflow.

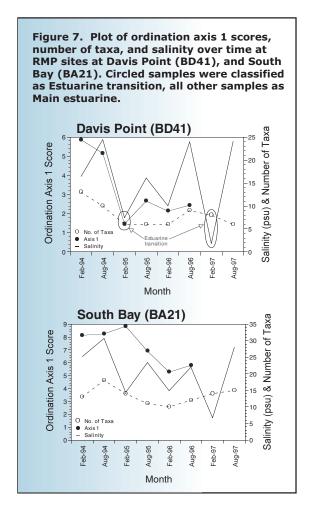
At two Main estuarine subassemblage sites, seasonal freshwater flows, from a variety of Bay tributaries, resulted in salinity fluctuations (Figure 7). At BD41 (Davis Point, in San Pablo Bay) the assemblage changed from Main estuarine to Estuarine transition when salinities decreased below about 10 psu in February 1995 and January 1997. That site is adjacent to the mouth of the Napa River which probably contributed to reduced salinities during the wet sampling period. A similar switch from Main estuarine to Estuarine transition occurred at D41 (Pinole Point) in February 1997 following the flood flows in January, then reverted back to Main estuarine in March. The Main estuarine site in the South Bay (BA21) also exhibited seasonal salinity fluctuations, but did not switch sub-assemblages when salinities decreased in January 1997.

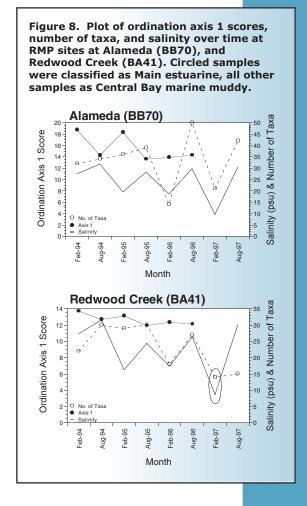
In the Central Bay, salinities also fluctuated seasonally, and appeared to influence the species composition and number of taxa (Figure 8). Three samples from sites usually classified with the Marine muddy sub-assemblage were classified with the Main estuarine sub-assemblage when salini-

ties decreased during the winter (BB15, Feb. 1995; BA41 and CCSF, Feb. 1997). By the following August, the benthos had returned to the Marine muddy subassmblage. Flood flows in January 1997 resulted in near-bottom salinities as low as 8.7 psu in February, and the benthic samples from most Central Bay sites included many species characteristic of the Estuarine sub-assemblages (e.g. *Potamocorbula amurensis*, *Nippoleucon hinumensis*), and reduced numbers of taxa. Because the Central Bay sites were sampled semi-annually, benthic response times that may have occurred at more frequent time scales, could not be determined.

Summary and Conclusions

The species composition, abundances, and distribution of Fresh-brackish, Estuarine, and Marine assemblages in the San Francisco Bay and Delta were primarily influenced by the estuarine salinity gradient and sediment-type. Although not measured at all sites, total suspended sediments (TSS) also appeared related to the differences among the assemblages. Each major assemblage included sub-assemblages that reflected fluctuations in salinity and





sediment-type, or in the case of the Estuarine margin sub-assemblage, other unidentified factors (discussed below). Since all areas of the Bay and Delta were not sampled, other assemblages may exist (e.g. mudflats, South and Central Bay shoals, rocky areas in Central Bay, Delta sloughs, etc.).

Consistent with conclusions from previous studies (Nichols and Pamatmat, 1988), species composition within each sub-assemblage was relatively stable between 1994 and 1997. San Francisco Bay's marine and estuarine benthic assemblages included many species that also inhabit other northern California coastal estuaries, such as Bodega, and Humboldt Bays (Jacobi *et al.*, 1998), and the zonation of the benthos is similar to most other estuaries in the US. However, the high proportions of introduced benthic species and the large volumes of freshwater inflows to San Francisco Bay and Delta make the benthic assemblages more unique and dynamic than those in other Estuaries.

Although species composition within sub-assemblages was temporally consistent, the spatial distribution of the sub-assemblages changed in response to changes in salinity or sediment-type associated with variations in Delta outflow or inflows from other Bay tributaries. The distribution of the Fresh-brackish assemblages in the Delta appeared to be related to changes in sediment-type that resulted from fluctuations in Delta outflow. Assemblage responses occurred at time scales from immediate to several months. The distribution of the Estuarine transition assemblage in San Pablo and Suisun Bays appeared to be related to variations in salinity that resulted from fluctuations in Delta outflow. Assem

blage responses occurred at time scales of several months. The relatively short time-scales (months) of assemblage shifts observed in the Fresh-brackish and Estuarine transition sub-assemblages reflected the highly variable environment in the Delta and Suisun Bays at those time scales. The distributions of the Main estuarine and Marine muddy sub-assemblages were more temporally stable, with only a few sites fluctuating in the wettest winters. The responses appeared to be related to salinity variations due to increased freshwater inflows from Bay tributaries. Assemblage response times in these sub-assemblages also appeared to be about one month, but only a few such responses were observed from DWR's monthly sampling in San Pablo Bay. Semi-annual sampling in the Marine assemblages precluded any conclusions about response times. More monthly sampling at more sites over several years is needed to document the response times of the benthos to changes in salinity.

The methods used (ordination and classification) to identify and track the sub-assemblage shifts described in this paper are well established and commonly used. Temporal changes in species composition and abundances at some sites were apparently sufficient to produce shifts between sub-assemblages, and were so interpreted. Because some sub-assemblages (Fresh-brackish sandy, Estuarine transition) had low numbers of taxa, changes of a few species resulted in an assemblage shift. The interpretations presented were influenced by the fact that the shifts occurred between consistently identified sub-assemblages and were generally related to changes in abiotic factors.

The processes and mechanisms that result in the reduced number of taxa and total abundances in the Estuarine transition sub-assemblage are poorly understood. Similar responses by the benthos to the estuary turbidity maximum zone (entrapment zone) are characteristic of most estuaries (e.g. Carriker, 1967). But, whether it is frequent changes in salinity and the resulting osmoregulatory problems of organisms, increased turbidity and the resulting impairment of respiratory or feeding capabilities, or the presence of *P. amurensis*, has not been studied in San Francisco Bay. Elevated sediment contamination associated with asynchronous reproduction by *P. amurensis* (Parchaso *et al.*, 1997) and sediment toxicity (Thompson *et al.*, 1999b), and pulses of dissolved pesticides from agricultural runoff in California's Central Valley (Kuivila and Foe, 1995) have been observed in that segment of San Francisco Bay, suggesting that contamination could also be a factor. Further study is needed to understand the relationships between the benthos and abiotic factors in the Estuarine transition sub-assemblage.

Factors that distinguished the Estuarine margin sub-assemblage fauna from that of the Main estuarine sub-assemblage were not evident in the data analyzed. Due to the proximity to apparently contaminated sediments in Castro Cove (Carney et al., 1994) and the presence of many opportunistic and pollution tolerant taxa, it was initially assumed that the Estuarine margin sub-assemblage represented a benthic response to contaminated sediments. However, there was no significant difference between sediment contaminant concentrations (as mERMq) in the Castro Cove and China Camp samples (mean = 0.341) and the adjacent Main estuarine sub-assemblage samples from San Pablo Bay (mean = 0.245, Wilcoxon 2-sample test, p = 0.173). Therefore, other factors were probably involved. The species composition of the Estuarine margin sub-assemblage resembled that from Nichols and Thompson's (1985b) South Bay mudflat sites that they considered to be routinely disturbed from a variety of causes (e.g. wind and tide induced erosion and deposition of surface sediments, freshwater inundation, seasonal algal growth). However, the species composition also resembled that from some of the samples collected by the BPTCP along the Central Bay margins a few months after the flood flows in 1997, that were considered to be impacted by sediment contamination (Hunt et al., 1998b). It could not be determined whether the Estuarine margin sub-assemblage is a

normal, persistent sub-assemblage of the estuary margins, and whether it represents a response to contaminated sediments or other forms of disturbance such as increased sedimentation, frequent pulses of freshwater runoff, etc.

The LEMP samples from near the Central Bay wastewater discharges were classified along with the Marine muddy sub-assemblage. However, sediment contamination (as mERMq) was significantly higher at the LEMP sites (mean = 0.322) than at the other Central Bay sites (mean = 0.249; Wilcoxon 2-sample test, p = 0.0001), suggesting that the elevated sediment contamination was not to levels that caused large differences in species composition and abundances. Most of the CCCSD samples were classified along with the Estuarine transition sub-assemblage, and had significantly lower mERMq values (mean=0.167) than those from the other Estuarine transition sites (mean=0.267; p=0.0014). The responses of the benthic assemblages to sediment contamination will be considered in more detail in Part 2 of the Benthic Pilot Study.

Acknowledgments

This study could not have been conducted without the inclusion of benthic data from the Department of Water Resources, BADA LEMP, and BPTCP programs. We thank Heather Peterson (DWR), Jim Salerno (BADA), and Rusty Fairey (Calif. Dept. of Fish and Game, Moss Landing, BPTCP) for access to their data and helpful discussions. BADA contributed financial support for portions of this study. Harlan Proctor and Leo Winternitz (Environmental Services, DWR), and Ms. Arleen Navarret (Biology Laboratory, City and County of San Francisco) coordinated their respective agency's participation in this study. Heather Peterson, formerly with DWR, and Cindy Messer of DWR provided assistance with acquisition and interpretation of their data. The taxonomists who identified the specimens were Mr. Wayne Fields (Hydrozoology, Sacramento) for the DWR material, and Michael Kellogg, Kathy Langan-Cranford, Patricia McGregor, and Brian Sak (City and County of San Francisco) for the remaining samples. Jim Oakden and Peter Slattery, Moss Landing Marine Laboratory, conducted the BPTCP benthic analyses. Dr. Bob Smith and Ms. Laura Riege conducted the classification and ordination analysis and provided discussions on interpretation. Sediment contaminant analyses were conducted by RMP Principal Investigators: Bill Ellgas at EBMUD, Russ Flegal at UCSC, Eric Prestbo at Brooks-Rand, Seattle, Wally Jarman at Univ. Utah, Bob Risebrough at Bodega Bay Institute, and Jose Sericano at Texas A&M Univ. Lauren Gravitz, Jung Yoon, and Ted Daum, SFEI assisted with data base. Reviews and comments from the following people improved this Technical Report: Jeff Hyland, NOAA, Charleston; Steve Ferraro, EPA, Newport; Bob Smith, Ojai, CA; Don Stevens, Dynamac International, Newport; Fred Nichols, USGS, Menlo Park.

Literature Cited

- Bay Area Dischargers Association, 1994. Local Effects Monitoring Program, Quality Assurance Project Plan.
- Boesch, D., 1973. Classification and community structure of macrobenthos in the Hampton Roads area, Virginia. Mar. Biol., 21:226-244.
- Boesch, D., 1977. A new look at the zonation of benthos along the estuarine gradient. *In* Ecology of the Marine Benthos, B. Coull, ed. University of South Carolina Press, Columbia, SC., pp. 245-266.
- Bradfield, G.E. and N.C. Kenkel, 1987. Nonlinear ordination using shortest path adjustment of ecological distances. Ecology, 68:750-753.
- Bray, J.R. and J.T. Curtis, 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr., 27:325-349.

- Burau, J.R., J.W. Gartner, and M. Stacey, 1998. Results from the Hydrodynamic Element of the 1994 Entrapment Zone Study in Suisun Bay. <u>In</u> Report of the 1994 Entrapment Zone Study Ch. 2. Kimmerer, W. [ed.]. Interagency Ecological Program for the San Francisco Bay/Delta Estuary Tech. Rept. 56, January 1998. Tiburon, CA
- Canfield, T.J., F.J. Dwyer, J.F. Fairchild, P.S. Haverland, C.G. Ingersoll, N.E. Kemble, D.R. Mount, T.W. LaPoint, G.A. Burton and M.C. Swift, 1996. Assessing contamination in great lakes sediments using benthic invertebrate communities and the sediment quality triad approach. Journal of Great Lakes Res., 22:565_583.
- Carlton, J.T., J.K. Thompson, *et al.*, 1990. Remarkable invasion of the San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. I. Introduction and dispersal. Mar. Ecol. Prog. Ser., 66:81-94.
- Carney, D., J. Oliver and P. Iampietro, 1994. Amphipod toxicity and benthic community analysis. In, San Francisco Estuary Pilot Regional Monitoring Program: Sediment Studies, Final Report for the San Francisco Regional Water Quality Control Board and the State Water Resources Control Board, Sacramento, CA.
- Carr, R.S., E.R. Long, H.L. Windom, D.C. Chapman, G. Thursby, G.M. Sloane, and D.A. Wolfe, 1996. Sediment quality assessment studies of Tampa Bay, Florida. Environ. Toxicol. Chem., 15:1218–1231.
- Carriker, M.R.,1967. Ecology of estuarine benthic invertebrates: A perspective. In G. Lauff (Ed.), Estuaries. Am. Assoc. Adv. Sci. Publication No. 83, Washington, D.C., pp. 442-487.
- Cohen, A.N. and J.T. Carlton, 1995. Nonindigenous aquatic species in a United States estuary: A case study of the biological invasions of the San Francisco Bay and Delta. Report for the National Sea Grant College Program, CT and the U.S. Fish and Wildlife Service, Washington, DC. Report No. PB 96-166525.
- Connor, E.F., E.D. McCoy, 1979. The statistics and biology of the species-area relationship. Amer. Nat., 113:791-833.
- Conomos, T.J., R. Smith and J. Gartner, 1985. Environmental setting of San Francisco Bay. Hydrobiologia, 129:1-12.
- Daniel, D.A. and H.K. Chadwick, 1972. A study of toxicity and biostimulation in San Francisco Bay-Delta waters: California State Water Resources Control Board, v. VII, Publication 44, 78 pp.
- Dauer, D.M., 1993. Biological criteria, environmental health and estuarine macrobenthic community structure. Mar. Poll. Bull., 26:249_257.
- DWR, 1997. Water Quality Conditions in the Sacramento-San Joaquin Delta During 1994. California Dept. Water Resources, Env. Services Office, Sacramento, CA, 52 pp.
- Filice, F.P., 1959. The effects of wastes on the distribution of bottom invertebrates in San Francisco Bay estuary. Wassman J. Biol., 17:1-17.
- Gower, J.C., 1966. Some distance properties of latent root and vector methods used in multivariate analysis. Biometrica, 53:325-338.
- Gower, J.C., 1967. Multivariate analysis and multidimensional geometry. The Statistician, 17:13-28.
- Gunther, A., J. Davis, D. Phillips, 1987. An assessment of the loading of toxic contaminants to the San Francisco-Bay-Delta. Technical Report from San Francisco Estuary Institute, Richmond, Ca., 330 pp.
- Haedrich, R., G. Rowe, and P. Polloni, 1980. The megabenthic fauna in the deep sea south of New England, USA. Mar. Biol., 57:165-179.
- Hunt, J.W., B.S. Anderson, B.M. Philips, J. Newman, R. Tjeerdema, M. Stephenson, M. Puckett, R. Fairly, R.W. Smith and K. Taberski, 1998a. Evaluation and use of sediment reference sites and toxicity tests in San

- Francisco Bay. Final Report for the California State Water Resources Control Board, Sacramento, CA.
- Hunt, J.W., B.S. Anderson, B. Phillips, J. Newman, R. Tjeerdema, K. Taberski, C. Wilson, M. Stephenson, H. Puckett, R. Fairey and J. Oakden, 1998b. Sediment quality and biological effects in San Francisco Bay. State Water Resources Control Board, Sacramento, Ca.
- Hyland, J., R. VanDolah, and T. Snoots, 1999. Predicting stress in benthic communities of southeastern U.S. estuaries in relation to chemical contamination of sediments. Environ. Toxicol. and Chem., 18:2557-2564.
- Hymanson, Z., D. Mayer, and J. Steinbeck, 1994. Long-term trends in benthos abundance and persistence in the upper Sacramento-San Joaquin Estuary, Summary Report: 1980-1990. Interagency Ecological Program Technical Report 38. Calif. Dept. Water Resources, Sacramento, CA., 66 pp.
- Jacobi, M., R. Fairey, C. Roberts, E. Landrau, et. al. (9 authors), 1998. Chemical and biological measures of sediment quality and tissue bioaccumulation in the north coast region. California State Water Resources Control Board, Sacramento, CA. 79 pp.
- Kimmerer, W.J., E. Gartside, and J.J. Orsi, 1994. Predation by an introduced clam as the probable cause of substantial declines in zooplankton in San Francisco Bay. Mar. Ecol.-Prog. Series, 113:81-93.
- KLI (Kinnetics Laboratory Inc.), 1983. Life history analysis of *Ampelisca milleri* Final Report to East Bay Dischargers Association. Kinnetic Laboratories Inc., Santa Cruz, CA.
- Kuivila, K.M. and C.G. Foe, 1995. Concentrations, transport and biological effects of dormant spray pesticides in the San Francisco Estuary, California. Environ. Tox. and Chem., 14:1141-1150.
- Lance, G.N. and W.T. Willliams, 1966. A generalized sorting strategy for computer classifications. Nature, 212:218-225.
- Lee, H. III, B. Thompson, and S. Lowe, 1999. Impacts of nonindigenous species on subtidal benthic assemblages in the San Francisco Estuary. Draft Rept. to US. EPA Region IX.
- Long, E.R., D.D. MacDonald, S.L. Smith and F.D. Calder, 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Env. Mgmt., 19:81–97.
- Long, E.R., L.J. Field and D.D. MacDonald, 1998. Predicting toxicity in marine sediments with numerical sediment quality guidelines. Environ. Toxicol. Chem., 17: 714-727.
- Nichols, F.H., 1973. A review of benthic faunal surveys in San Francisco Bay. U.S. Geological Survey Circ., 677, 20pp.
- Nichols, F.H., and J.K. Thompson, 1985a. Time scales of change in the San Francisco Bay benthos. Hydrobiologia, 129:121-138.
- Nichols, F.H., and J.K. Thompson, 1985b. Persistence of an introduced mudflat community in South San Francisco Bay, California. Mar. Ecol. Prog. Ser., 24: 83-97.
- Nichols, F.H., and M.M. Pamatmat, 1988. The Ecology of the soft-bottom benthos of San Francisco Bay: A community profile. U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 85(7.19).
- Nichols, F.H., J.K. Thompson and L.E. Schemel, 1990. Remarkable invasion of San Francisco Bay (San Francisco, CA) by the Asian Clam *Potamocorbula amurensis*. II. Displacement of a former community. Mar. Ecol. Prog. Ser., 66:95-101.
- Parchaso, F., C. Brown, J. Thompson, and S. Luoma, 1997. *In situ* effects of trace contaminants on the ecosystem in the San Francisco Bay Estuary, 1995: the necessary link to establishing water quality standards II. USGS, Menlo Park, CA, Open-File Report 97-420, 19 pp.

- Pearson, T.H. and R. Rosenberg, 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev. 16: 229–311.
- Poore, G. and J. Kudenov, 1978. Benthos of the Port of Melborne: The Yarra River and Hobsons Bay, Victoria. Aust. J. Mar. Freshwater Res., 29:141-155.
- SAS, 1995. SAS Procedures Guide, Version 6. SAS Institute, Inc., Cary, NC.
- Schemel, L.E., A.Y. Ota, J.G. Harmon, J.M. Shay, and R.N. Adorador, 1990. Benthic Macrofauna and ancillary data for San Francisco Bay, CA, January to November 1988. USGS Open-file Report 89-596, Sacramento, CA.
- Schemel, L.E., A.Y. Ota, J.G. Harmon, J.M. Shay, and R.N. Adorador, 1995. Benthic Macrofauna and ancillary data for San Francisco Bay, CA, September 1986. USGS Open-file Report 95-291, Sacramento, CA.
- SFEI, 1999. 1997 Annual Report of the Regional Monitoring Program for Trace Substances. San Francisco Estuary Inst., Richmond, CA.
- Smith, R.W., B.B. Bernstein, and R.L. Cimberg, 1988. Community-environmental relationships in the benthos: Applications of multivariate analytical techniques. In, Marine Organisms as Indicators. D. F. Soule and G. S. Kleppel eds., Springer-Verlag New York, pp. 247-326.
- Sorensen, T. 1948, A method of establishing groups of equal amplitude in plant society based on similarity of species content. K. Danske Vidensk. Selsk., 5:1-34.
- Storrs, P.N., E.A. Pearson and R.E. Selleck, 1966. A comprehensive study of San Francisco Bay, final report. V. Summary of physical, chemical, and biological water and sediment data. Univ. Calif. (Berkeley), Sanit. Eng. Res. Lab. Rep., 67:1-140
- Sumner, F.B., G.D. Louderback, W.L. Schmitt, and G.E. Johnston, 1914. A report on the physical conditions in San Francisco Bay, based upon the operations of the United States Fisheries Steamer Albatross, 1912-1913. Univ. Calif. Publ. Zool. 14:1-198.
- Thompson, B. and G. Jones. 1987, Benthic macrofaunal assemblages of slope habitats in the southern California Borderland. Occasional Papers of Allan Hancock Foundation, New Ser. No. 6. Univ. So. Calif., Los Angeles, CA., 21 pp.
- Thompson, B., S. Lowe, L. Gravitz, 1999a. Sediment conditions near wastewater discharges in San Francisco Bay. Technical Report to the Bay Area Discharger's Association, San Francisco Estuary Institute, Richmond, CA.
- Thompson, B., B. Anderson, J. Hunt, K. Taberski, B. Phillips, 1999b. Relationships between sediment contamination and toxicity in San Francisco Bay. Mar. Environ. Res., 48:285-309.
- Thompson, J.K., and F.H. Nichols, 1988. Food availability controls the seasonal cycle of growth in the bivalve *Macoma balthica* in San Francisco Bay, California. J. Exp. Mar. Biol. Ecol., 116:43:61.
- Werner, I., and J. Hollibaugh, 1993. *Potamocorbula amurensis*: Comparisons of clearance rates and assimilation efficiencies for phytoplankton and bacterioplankton. Limnol. Oceanog. 38:949-964.
- Weston, D.P., 1997. Population dynamics of *Ampelisca abdita* in San Francisco Bay. 1996 Annual Report: Regional Monitoring Program for Trace Substances. San Francisco Estuary Institute, Richmond, CA.
- Williamson, M.H., 1978. The ordination of incidence data. J. Ecol., 66:911-920.

Appendix 1. Sample information for samples analyzed in this report.

Assemblage Designations: Mm=Marine muddy, Ms=Marine sandy, Et=Estuarine transition, Fbm=Fresh-brackish muddy, Me=Main estuarine, Fbs=Fresh-brackish sandy,

Agency	Site Code	Sample Date	Assem- blage	Delta Outflow Index	Salinity (ppt)	% Fines (<63um)	тос	mERMq	Number of Taxa (per sample)	Total Abundance
RMP	BA21	02/16/94	Me	582	25.2	81	0.835	0.3296	13	1603
RMP	BA21	08/29/94	Me	97	30.7	92	1.260	0.3077	18	372
RMP	BA21	02/21/95	Me	2,063	14.4	97	0.960	0.2782	14	237
RMP	BA21	08/29/95	Me	310	23.4	98	1.330	0.2886	11	748
RMP	BA21	02/21/96	Me	3,589	14.9	99	1.520	0.3784	10	696
RMP	BA21	08/01/96	Me	275	22.0	97	1.440	0.3136	12	497
RMP	BA21	02/04/97	Me	3,315	6.7	97	1.400	0.3405	14	383
RMP	BA21	08/12/97	Me	244	28.0	91	1.400	0.3574	15	764
RMP	BA41	02/15/94	Mm	582	27.3	88	0.800	0.3053	22	131
RMP	BA41	08/30/94	Mm	97	31.6	78	0.580	0.2289	30	97
RMP	BA41	02/21/95	Mm	2,063	16.3	67	1.640	0.2471	29	92
RMP	BA41	08/29/95	Mm	310	24.4	80	1.130	0.2807	30	814
RMP	BA41	02/21/96	Mm	3,589	17.4	88	1.210	0.3230	18	127
RMP	BA41	08/01/96	Mm	275	26.4	93	1.240	0.2960	27	4022
RMP	BA41	02/04/97	Me	3,315	8.7	97	1.200	0.2918	14	521
RMP	BA41	08/12/97	Mm	244	30.1	76	1.200	0.3323	15	250
RMP	BB15	02/15/94	Mm	582	27.7	69	0.330	0.1787	24	81
RMP	BB15	08/30/94	Mm	97	31.6	57	0.620	0.2362	23	327
RMP	BB15	02/21/95	Me	2,063	17.0	82	1.110	0.2416	22	49
RMP	BB15	08/29/95	Mm	310	25.8	66	0.880	0.2276	26	323
RMP	BB15	02/21/96	Mm	3,589	17.8	89	1.230	0.2406	17	196
RMP	BB15	08/01/96	Mm	275	27.5	54	0.780	0.2210	22	327
RMP	BB15	02/04/97	Mm	3,315	15.3	58	0.800	0.2363	16	292
RMP	BB15	08/12/97	Mm	244	30.4	48	1.100	0.2369	18	386
RMP	BB70	02/15/94	Mm	582	27.6	82	1.065	0.2869	32	654
RMP	BB70	08/30/94	Mm	97	31.8	70	0.947	0.2910	34	1856
RMP	BB70	02/21/95	Mm	2,063	19.6	76	1.010	0.2914	36	1924
RMP	BB70	08/28/95	Mm	310	28.3	97	2.220	0.2677	39	3114
RMP	BB70	02/21/96	Mm	3,589	18.7	80	1.030	0.2887	14	183
RMP	BB70	08/01/96	Mm	275	29.8	85	1.190	0.2660	50	3405
RMP	BB70	02/03/97	Mm	3,315	9.7	90	1.200	0.3040	21	77
	BB70		Mm	244	30.6	64	1.100		42	786
RMP		08/12/97				43		0.3280	42 47	
RMP	BC11	02/14/94	Mm	582	27.9		0.760	0.1828		522
RMP	BC11	08/29/94	Mm	97	31.6	65	0.890	0.2459	56 57	684
RMP	BC11	02/20/95	Mm	2,063	22.1	67	1.240	0.1794	57	878
RMP	BC11	08/28/95	Mm	310	28.9	92	1.680	0.2584	48	13705
RMP	BC11	02/20/96	Mm	3,589	23.4	78	1.120	0.2707	28	221
RMP	BC11	08/01/96	Mm	275	31.1	61	1.010	0.2192	45	620
RMP	BC11	02/03/97	Mm	3,315		70	1.000	0.2257	39	811
RMP	BC11	08/11/97	Mm	244	29.8	38	0.900	0.2867	54	2229
RMP	BC21	02/14/94	Mm	582	29.8	65	1.047	0.3150	41	640
RMP	BC21	08/29/94	Mm	97	32.3	55	0.837	0.2827	38	511
RMP	BC21	02/20/95	Mm	2,063	20.1	66	1.010	0.2203	41	557
RMP	BC21	08/28/95	Mm	310	30.8	31	0.550	0.1602	57	1050
RMP	BC21	02/20/96	Mm	3,589	25.4	30	0.830	0.1885	35	212
RMP	BC21	08/02/96	Mm	275	31.3	41	0.720	0.2124	66	2924
RMP	BC21	02/03/97	Mm	3,315	10.5	48	0.700	0.2643	36	594
RMP	BC21	08/11/97	Mm	244	31.2	34	0.700	0.1988	51	2042
RMP	BC60	02/11/94	Ms	582	29.2	5	0.000	0.1528	6	6
RMP	BC60	08/26/94	Ms	97	31.9	2	0.960	0.1331	4	28
RMP	BC60	02/17/95	Ms	2,063	26.2	7	0.540	0.1324	5	12
RMP	BC60	08/25/95	Ms	310	30.0	5		0.1403	6	25
RMP	BC60	02/20/96	Ms	3,589	15.6	5	0.080	0.1471	8	41
RMP	BC60	08/02/96	Ms	275	26.5	4		0.1431	11	114
RMP	BC60	02/03/97	Ms	3,315	30.7	13	0.100	0.1528	5	33
RMP	BC60	08/11/97	Ms	244	31.1	41	0.600	0.2427	8	24
RMP	BD15	02/17/95	Me	2,063	3.6	97	1.440	0.3342	6	44
RMP	BD15	08/25/95	Me	310	18.1	89	1.200	0.3035	9	27
RMP	BD15	02/16/96	Me	3,589	3.9	97	1.170	0.3783	10	177
RMP	BD15	08/05/96	Me	275	21.2	99	1.530	0.2956	5	435
RMP	BD15	01/31/97	Me	7,350	0.7	100	1.500	0.3696	8	57
RMP	BD15	08/08/97	Me	244	25.9	96	1.500	0.3690	7	2311
RMP	BD13 BD41	02/11/94	Me	582	16.4	25	0.218	0.3090	13	1188
RMP	BD41	08/26/94	Me	97	24.5	16	0.145	0.1706	10	452
RMP	BD41	02/17/95	Et	2,063	7.5	30	0.980	0.1772	6	609
RMP	BD41	08/25/95	⊑ι Me	310	7.5 16.1	20	0.370	0.1772	6	280
RMP	BD41	08/23/93	Me	3,589	10.1	18	0.370	0.1835	6	175
		08/05/96								
RMP	BD41		Me	275	24.0	13	0.250	0.1797	9	291
RMP	BD41	01/31/97	Et Mo	7,350	1.8	10	0.300	0.1704	8	59 30
RMP	BD41	08/08/97	Me	244	24.1	8	0.100	0.1860	6	20
RMP	SF01	09/07/94	Mm	158	32.0	95	1.210		21	147
RMP	SF02	09/07/94	Me	158	30.0	99	0.987		9	63
RMP	SF03	09/08/94	Me	158	38.0	99	1.413		11	114
RMP	WBCC 2A		Em	2,063		99	2.300	0.3682	11	782
RMP	WBCC 2B	03/01/95	Em	5,682		98	3.300	0.3496	21	1793
RMP	WBCC 3A		Em	2,063		99	2.000	0.3253	10	156
RMP	WBCC 3B	03/01/95	Em	5,682		98	2.600	0.3322	15	1976
IXIVII						4	0.252	0.1096	5	

Appendix 1(Cont'd.). Sample information for samples analyzed in this report.
Assemblage Designations: Mm=Marine muddy, Ms=Marine sandy, Et=Estuarine transition, Fbm=Fresh-brackish muddy, Me=Main estuarine, Fbs=Fresh-brackish sandy, Em=Estuarine margin.
Ancillary Data: Delta Outflow Index=m³/second, Total Organic Carbon=TOC, mERMq=Mean ERM Quotient

Agency	Site Code	Sample Date	Assem- blage	Delta Outflow Index	Salinity (ppt)	% Fines (<63um)	тос	mERMq	Number of Taxa (per sample)	Total Abundance
BADA	CCCSD04	02/06/95	Me	2,063	0.0	23	0.439	0.1673	10	31
BADA	CCCSD04	08/24/95	Et	310	5.5	0	0.193	0.1621	3	33
BADA	CCCSD04	03/29/96	Et	2,520	2.0	0	0.261	0.1627	5	38
BADA	CCCSD05	09/09/94	Et Et	158	14.1	37	1.328	0.1531	5	44
BADA	CCCSD05		Et Et	2,063	0.0	0	0.104	0.1974	4	5
BADA BADA	CCCSD05	08/24/95 03/29/96	Et Et	310 2,520	5.5 2.0	0	0.467 0.670	0.1962 0.1889	6 7	123 220
BADA	CCCSD05		Et	158	2.0		0.670	0.1009	5	12
BADA	CCCSD06		Et	2,063	0.0	0	0.192	0.1994	1	5
BADA	CCCSD06		Et	310	5.5	Ö	0.077	0.1279	3	18
BADA	CCCSD06		Et	2,520	2.0	Ō	0.137	0.1699	6	71
BADA	CCSF04	09/08/94	Mm	158	30.6	55	0.644	0.4334	44	844
BADA	CCSF04	02/13/95	Mm	2,063	24.0	84	0.960	0.3531	13	27
BADA	CCSF04	08/15/95	Mm	310	30.6	91	1.183	0.2681	24	1594
BADA	CCSF04	03/26/96	Mm	2,520	27.2	90	0.964	0.3907	25	68
BADA	CCSF04	08/13/96	Mm	275	33.2	73	1.050	0.3435	24	957
BADA	CCSF04	02/26/97	Me	3,315	22.9	99	1.239	0.3870	6	12
BADA	CCSF04	08/15/97	Mm	244	35.0	91	1.175	0.5055	48	2282
BADA	CCSF05	09/08/94	Mm	158	30.8	46	0.573	0.4015	54	2443
BADA	CCSF05	02/13/95	Mm	2,063	24.0	86	0.948	0.3134	39	357
BADA	CCSF05	08/15/95	Mm	310	30.6	82 79	1.166	0.3229	36 15	4073
BADA BADA	CCSF05 CCSF05	03/26/96 08/13/96	Mm Mm	2,520 275	24.2 33.2	79 59	1.128 0.961	0.3780 0.3643	41	37 858
BADA	CCSF05	08/13/96	Mm	3,315	23.1	97	1.222	0.3643	11	31
BADA	CCSF05	08/15/97	Mm	244	34.0	65	0.991	0.4220	29	1031
BADA	CCSF05	09/08/94	Mm	158	31.0	57	0.562	0.4220	41	1082
BADA	CCSF06	02/13/95	Mm	2,063	23.8	93	0.830	0.3382	28	115
BADA	CCSF06	08/15/95	Mm	310	30.7	95	1.074	0.3437	36	2016
BADA	CCSF06	03/26/96	Mm	2,520	25.6	91	1.184	0.3496	21	88
BADA	CCSF06	08/13/96	Mm	275	33.3	80	1.185	0.3706	26	784
BADA	CCSF06	02/26/97	Mm	3,315	23.7	98	1.172	0.3665	7	8
BADA	CCSF06	08/15/97	Mm	244	34.0	92	1.140	0.3956	33	594
BADA	EBMUD04		Mm	158	31.4	51	0.551	0.1850	60	4866
BADA	EBMUD04		Mm	2,063	21.1	75	0.938	0.3134	28	413
BADA	EBMUD04		Mm	310	28.4	93	0.901	0.3124	49	16760
BADA	EBMUD04		Mm	2,520	21.4	90	1.113	0.3364	24	462
BADA	EBMUD04		Mm	275	33.3	84	1.236	0.2978	38	2018
BADA	EBMUD04		Mm	3,315	24.3	96	1.260	0.4007	24	105
BADA BADA	EBMUD04 EBMUD05		Mm Mm	244 158	31.0 31.4	70 60	1.122 0.763	0.3501 0.1784	50 51	3237 2448
BADA	EBMUD05		Mm	2,063	21.1	82	0.703	0.1704	36	967
BADA	EBMUD05		Mm	310	28.5	90	1.172	0.4384	43	18723
BADA	EBMUD05		Mm	2,520	19.3	91	0.945	0.3299	28	416
BADA	EBMUD05		Mm	275	33.1	77	1.165	0.2942	46	2507
BADA	EBMUD05		Mm	3,315	23.3	95	1.288	0.3655	26	129
BADA	EBMUD05		Mm	244	32.0	77	1.237	0.4069	58	3948
BADA	EBMUD06	09/23/94	Mm	158	31.4	53	0.642	0.2265	57	2574
BADA	EBMUD06	02/14/95	Mm	2,063	21.1	69	0.782	0.2570	54	3205
BADA	EBMUD06	08/16/95	Mm	310	27.9	81	1.000	0.3594	40	14041
BADA	EBMUD06		Mm	2,520	22.0	84	1.189	0.3388	31	1171
BADA	EBMUD06		Mm	275	33.3	82	1.186	0.3123	41	371
BADA	EBMUD06		Mm	3,315	23.3	91	1.291	0.3415	23	202
BADA	EBMUD06		Mm	244	32.5	81	1.326	0.3853	57	3601
BPTCP-92	CC2	05/01/92	Em	96		67	0.842	0.1883	16	881
BPTCP-92	CC4	05/01/92	Em	96		85	1.332	0.2921	22	1291
BPTCP-92 BPTCP-92	EVS4	05/01/92	Em	96		99	1.952	0.7104	15	864
	PtPinole	05/01/92	Em	96		56	0.794	0.1585	19	1302
DWR	C9	01/22/96	Fbm	907	•	55	1.750	•	10	318
DWR	C9	02/21/96	Fbm	3,589		9 4	0.550	•	3	136
DWR	C9	03/20/96	Fbm	2,520			0.650		4 7	245
DWR DWR	C9 C9	04/29/96 05/16/96	Fbm Fbm	1,191 1,305	•	23 3	0.800 0.500	•	7	73 90
DWR	C9	06/18/96	Fbm	435	•	24	0.950	•	11	673
DWR	C9	07/16/96	Fbm	262	•	34	1.100	•	6	130
DWR	C9	08/28/96	Fbm	275	•	2	0.400		5	82
DWR	C9	09/11/96	Fbm	208		2	0.300	:	5	57
DWR	C9	10/08/96	Fbm	131		2	0.250		3	25
DWR	C9	11/14/96	Fbm	244		3	0.350		3	24
DWR	C9	12/11/96	Fbm	2,322		7	0.350		3	50
DWR	C9	02/20/97	Fbs	3,315		1	0.300		2	8
DWR	C9	03/24/97	Fbm	939		17	0.650		11	86
DWR	C9	04/22/97	Fbm	384		5	0.350		12	201
DWR	C9	05/21/97	Fbm	341	•	21	1.350		13	458
DWR	C9	06/18/97	Fbm	231		7	0.450	•	10	585
DWR	C9	07/22/97	Fbm	265		3	0.350	•	8	269
DWR	C9	08/19/97	Fbm	244		15	0.850	•	6	102
	C9	09/16/97	Fbs	112		2	0.250	•	4	48
		10/20/07	Eh-							
DWR DWR	C9	10/28/97	Fbs	137	•	1	0.200	•	4	38
		10/28/97 11/18/97 12/16/97	Fbs Fbm Fbs	137 288 435		1 1 1	0.200 0.250 0.200		4 6 3	38 94 24

Appendix 1(Cont'd.). Sample information for samples analyzed in this report. Assemblage Designations: Mm=Marine muddy, Ms=Marine sandy, Et=Estuarine transition, Fbm=Fresh-brackish muddy, Me=Main estuarine, Fbs=Fresh-brackish sandy, Em=Estuarine margin.

Agency	Site Code	Sample Date	Assem- blage	Delta Outflow Index	Salinity (ppt)	% Fines (<63um)	тос	mERMq	Number of Taxa (per sample)	Total Abundanc
DWR	D11	02/08/94	Fbm	582	1.4	100	3.600		11	91
OWR	D11	04/12/94	Fbm	233	0.5	100	3.650		13	312
)WR	D11	05/23/94	Fbm	227	0.7	100	3.650		12	648
WR	D11	06/09/94	Fbm	111	2.4	100	3.300		15	1099
WR	D11	07/20/94	Fbm	129	3.2	99	3.550		12	296
)WR	D11	08/09/94	Fbm	97	3.5	99	3.600		11	166
WR	D11	09/21/94	Fbm	158	1.8	99	3.900		12	340
WR	D11	10/19/94	Fbm	92	3.9	99	3.750		11	299
WR	D11	11/21/94	Fbm	152	3.8	99	3.650		12	263
)WR	D11	12/16/94	Fbm	273	1.0	99	3.250		13	452
WR	D11	01/17/95	Fbm	3,044	0.1	99	3.050		14	245
WR	D11	02/15/95	Fbm	2,063	0.1	100	3.450		11	212
WR	D11	03/15/95	Fbm	5,682	0.1	100	3.550		15	215
WR	D11	04/27/95	Fbm	2,573	0.1	99	3.300		13	398
WR	D11	05/17/95	Fbm	2,779	0.1	99	3.850		15	402
DWR	D11	06/27/95	Fbm	1,326	0.1	99	5.050	•	15	573
)WR	D11	07/13/95	Fbm	761	0.1	100	3.450		16	498
)WR	D11	08/24/95	Fbm	310	0.2	100	2.900	•	14	528
)WR	D11	09/26/95	Fbm	558	0.1	99	3.200		10	271
)WR	D11	10/25/95	Fbm	323	0.1	99	3.050		12	261
)WR	D11	11/27/95	Fbm	237	0.7	99	3.450		12	167
DWR	D11	12/27/95	Fbm	785	0.1	100	3.150		10	82
)WR	D16	01/24/96	Fbs	907		1	0.400		2	3
)WR	D16	02/23/96	Fbs	3,589		0	0.200		2	5
OWR	D16	03/22/96	Fbs	2,520		1	0.200		2	14
WR	D16	04/29/96	Fbs	1,191		0	0.300		4	21
WR	D16	05/16/96	Fbm	1,305		86	2.750		4	240
OWR	D16	07/18/96	Fbs	262		1	0.250		3	20
OWR	D16	08/30/96	Fbs	275		2	0.650		3	18
WR	D16	09/13/96	Fbs	208		60	1.650		2	12
WR	D16	10/09/96	Fbm	131	•	1	0.350	•	3	23
)WR	D16	11/14/96	Fbm	244	•	30	1.450		4	455
WR	D16	12/11/96	Fbm	2,322	•	91	3.200	•	6	125
WR	D16		Fbs		•	82		•	5	58
		01/23/97		7,350	•		2.700			
WR	D16	02/21/97	Fbs	3,315		78	2.950		4	37
)WR	D16	03/24/97	Fbm	939		92	2.700		7	199
)WR	D16	04/24/97	Fbs	384		25	0.850		1	16
WR	D16	05/23/97	Fbm	341		66	2.200		5	60
OWR	D16	06/20/97	Fbm	231		74	2.200		5	112
OWR	D16	07/24/97	Fbm	265		91	2.550		8	167
OWR	D16	08/21/97	Fbs	244		35	0.650		3	127
OWR	D16	09/18/97	Fbs	112		89	2.450		5	103
OWR	D16	10/28/97	Fbm	137		18	4.600		5	77
OWR	D16	11/18/97	Fbs	288		86	2.400		3	100
OWR	D16	12/18/97	Fbs	435		77	2.400		3	22
WR	D19	01/18/94	Fbm	306	0.2	97	4.850		17	1060
WR	D19	02/08/94	Fbm	582	0.2	99	4.100		20	660
)WR	D19	04/12/94	Fbm	233	0.2	95	4.350		19	950
)WR	D19	05/23/94	Fbm	227	0.2	96	4.450	•	19	952
)WR	D19	06/09/94	Fbm	111	0.2	97	4.400	•	23	1469
WR	D19	07/20/94	Fbm	129	0.4	87	5.050	•	17	693
WR	D19		Fbm	97	0.4	97		•	18	
		08/09/94					4.700	•		899
)WR	D19	09/21/94	Fbm	158	0.3	93	4.650		17	1541
)WR	D19	10/19/94	Fbm	92	0.5	98	4.400	•	18	1823
WR	D19	11/21/94	Fbm	152	0.4	97	4.600		17	478
WR	D19	12/16/94	Fbm	273	0.4	97	4.550		17	812
WR	D19	01/17/95	Fbm	3,044	0.1	96	4.100		15	1075
WR	D19	02/15/95	Fbm	2,063	0.1	97	4.300		16	323
WR	D19	03/15/95	Fbm	5,682	0.2	99	4.200		12	91
WR	D19	04/27/95	Fbm	2,573	0.1	98	4.050		14	238
WR	D19	05/17/95	Fbm	2,779	0.1	98	5.150		17	690
WR	D19	06/27/95	Fbm	1,326	0.1	98	5.850		14	567
WR	D19	07/13/95	Fbm	761	0.1	94	4.800		18	670
WR	D19	08/24/95	Fbm	310	0.1	92	4.800		12	664
WR	D19	09/26/95	Fbm	558	0.1	97	4.150		18	1422
WR	D19	10/25/95	Fbm	323	0.1	98	4.200	•	21	963
WR	D19	11/27/95	Fbm	237	0.1	97	4.000	•	16	405
WR	D19	12/27/95	Fbm	785	0.1	98	4.200	•	18	1383
)WR	D24	01/24/96	Fbs	907		1	0.450		5	96
WR	D24	02/23/96	Fbs	3,589		1	0.500		2	5
WR	D24	03/22/96	Fbs	2,520		2	0.750		5	69
WR	D24	04/29/96	Fbs	1,191		100	1.300		7	92
WR	D24	05/16/96	Fbs	1,305		1	0.550		6	109
WR	D24	07/18/96	Fbm	262		21	1.050		7	54
WR	D24	08/30/96	Fbm	275		4	0.800		9	104
WR	D24	09/13/96	Fbm	208	•	15	1.100	-	12	134
WR	D24	10/09/96	Fbm	131		8	0.700	•	7	95
	D2+	10/03/30	Fbm	244		8	0.700	•	6	95 95

Appendix 1(Cont'd.). Sample information for samples analyzed in this report. Assemblage Designations: Mm=Marine muddy, Ms=Marine sandy, Et=Estuarine transition, Fbm=Fresh-brackish muddy, Me=Main estuarine, Fbs=Fresh-brackish sandy,

Agency	Site Code	Sample Date	Assem- blage	Delta Outflow Index	Salinity (ppt)	% Fines (<63um)	тос	mERMq	Number of Taxa (per sample)	Total Abundance
DWR	D24	12/11/96	Fbm	2,322	•	43	1.650	•	10	204
DWR	D24	01/24/97	Fbs	7,350		2	0.600		2	26
DWR	D24	02/21/97	Fbs	3,315		2	0.500		4	30
DWR	D24	03/24/97	Fbm	939		10	0.700		7	47
DWR	D24	04/24/97	Fbm	384		27	1.150		9	30
DWR	D24	05/23/97	Fbm	341		3	0.500		8	144
OWR	D24	06/20/97	Fbm	231		11	0.800		8	101
DWR	D24	07/24/97	Fbm	265		87	2.350		6	264
DWR	D24	08/21/97	Fbs	244		76	1.900		7	202
DWR	D24	09/18/97	Fbm	112		7	0.650	•	8	163
DWR	D24	10/28/97	Fbm	137		6	0.600		11	194
DWR	D24	11/20/97	Fbm	288		11	0.800		9	88
DWR	D24	12/18/97	Fbm	435		3	0.550		9	123
OWR	D28A L	01/18/94	Fbm	306	0.2	90	7.350		15	188
DWR	D28A L	02/08/94	Fbm	582	0.2	38	3.250		16	670
DWR	D28A L	04/12/94	Fbm	233	0.2	77	6.150		15	212
DWR	D28A L	05/23/94	Fbm	227	0.2	90	7.200		10	795
DWR	D28A L	06/09/94	Fbm	111	0.2	86	3.600	•	14	1380
DWR	D28A L	07/20/94	Fbm	129	0.4	83	6.250		18	197
DWR	D28A L	08/09/94	Fbm	97	0.4	96	6.800		9	64
OWR	D28A L	09/21/94	Fbm	158	0.5	83	5.700		11	162
OWR	D28A L	10/19/94	Fbm	92	0.4	82	6.200		11	244
OWR	D28A L	11/21/94	Fbm	152	0.4	88	6.050		11	202
OWR	D28A L	12/16/94	Fbm	273	0.4	38	3.550		15	528
OWR	D28A L	01/17/95	Fbm	3,044	0.1	70	5.200		9	122
OWR	D28A L	02/15/95	Fbm	2,063	0.1	31	2.550		7	21
OWR	D28A L	03/15/95	Fbm	5,682	0.2	71	5.650		8	91
OWR	D28A L	04/27/95	Fbm	2,573	0.1	92	7.250		15	431
OWR	D28A L	05/17/95	Fbm	2,779	0.1	17	1.450		14	259
DWR	D28A L	06/27/95	Fbm	1,326	0.1	86	8.100		13	175
OWR	D28A L	07/13/95	Fbm	761		85	6.300		13	228
OWR	D28A L	08/24/95	Fbm	310	0.1	82	6.350		13	254
DWR	D28A L	09/26/95	Fbm	558	0.1	44	3.000		18	361
OWR	D28A L	10/25/95	Fbm	323	0.1	93	7.200		9	128
OWR	D28A L	11/27/95	Fbm	237	0.1	97	5.650		9	38
OWR	D28A L	12/27/95	Fbm	785	0.1	50	4.300		18	196
OWR	D28A L	01/22/96	Fbm	907	0.1	93	5.700		17	394
DWR	D28A L	02/21/96	Fbm	3,589	0.2	96	5.950		21	729
DWR	D28A L	03/20/96	Fbm	2,520	0.2	71	5.500		7	73
DWR	D28A L	04/29/96	Fbm	1,191	0.2	86	4.950		16	1080
DWR	D28A L	05/16/96	Fbm	1,305	0.2	74	5.400		12	158
DWR	D28A L	06/18/96	Fbm	435	0.1	48	3.600		11	223
DWR	D28A L	07/16/96	Fbm	262	0.1	91	6.650		12	195
DWR	D28A L	08/28/96	Fbm	275	0.1	69	5.100		11	171
DWR	D28A L	09/11/96	Fbm	208	0.1	88	7.400		13	208
OWR	D28A L	10/08/96	Fbm	131	0.2	77	5.550		8	78
OWR	D28A L	11/14/96	Fbm	244	0.3	76	5.750		12	51
OWR	D28A L	12/11/96	Fbm	2,322	0.2	84	5.850		12	319
DWR	D28A L	01/23/97	Fbm	7,350	0.1	35	3.050		15	414
OWR	D28A L	02/20/97	Fbm	3,315	0.1	86	6.600		12	715
OWR	D28A L	03/24/97	Fbm	939	0.1	93	6.700		13	343
OWR	D28A L	04/22/97	Fbm	384	0.1	87	6.100		13	122
OWR	D28A L	05/21/97	Fbm	341	0.2	75	5.600	•	10	55
DWR	D28A L	06/18/97	Fbm	231	0.1	70	4.900		12	114
OWR	D28A L	07/22/97	Fbm	265	0.1	64	4.350	•	9	37
OWR	D28A L	08/19/97	Fbm	244	0.1	20	1.300	•	9	152
OWR	D28A L	09/16/97	Fbm	112	0.1	57	4.000		10	232
DWR	D28A L	10/28/97	Fbm	137	0.1	55	3.950	•	7	73
DWR	D28A L	11/18/97	Fbm	288	0.4	26	1.850	•	13	631
DWR	D28A L	12/16/97	Fbm	435	0.5	58	4.650		10	135
DWR	D28A R	01/18/94	Fbm	306	0.2	92	5.900		21	832
DWR	D28A R	02/08/94	Fbm	582	0.2	90	5.600		18	1071
DWR	D28A R	04/12/94	Fbm	233	0.2	87	5.200		20	1166
DWR	D28A R	05/23/94	Fbm	227	0.2	88	5.400	•	17	1235
DWR	D28A R	06/09/94	Fbm	111	0.2	80	4.400	•	17	1023
DWR	D28A R	07/20/94	Fbm	129	0.2	86	5.500	•	19	514
WR	D28A R D28A R	08/09/94	Fbm	97	0.4	86	4.950		19	514 543
DWR DWR	D28A R D28A R	08/09/94	Fbm	158	0.4	94	6.100		14	308
	D28A R D28A R				0.5	94 86			14	
)WR		10/19/94	Fbm	92 152			5.350			1065
)WR	D28A R	11/21/94	Fbm	152	0.4	86	4.750		17	403
)WR	D28A R	12/16/94	Fbm	273	0.4	90	5.300		18	961
)WR	D28A R	01/17/95	Fbm	3,044	0.1	90	6.100		20	3079
WR	D28A R	02/15/95	Fbm	2,063	0.1	93	5.500		14	1757
WR	D28A R	03/15/95	Fbm	5,682	0.2	89	5.700		16	1373
OWR	D28A R	04/27/95	Fbm	2,573	0.1	97	5.750		14	1032
OWR	D28A R	05/17/95	Fbm	2,779	0.1	97	6.700		18	1095
OWR	D28A R	06/27/95	Fbm	1,326	0.1	97	8.050		20	1683
OWR	D28A R	07/13/95	Fbm	761		97	5.700		20	1716
	D28A R	08/24/95	Fbm	310	0.1	95	5.250		15	1240
OWR	DZO/TIT									

Appendix 1(Cont'd.). Sample information for samples analyzed in this report. Assemblage Designations: Mm=Marine muddy, Ms=Marine sandy, Et=Estuarine transition, Fbm=Fresh-brackish muddy, Me=Main estuarine, Fbs=Fresh-brackish sandy, Em=Estuarine margin.

Agency	Site Code	Sample Date	Assem- blage	Delta Outflow Index	Salinity (ppt)	% Fines (<63um)	тос	mERMq	Number of Taxa (per sample)	Total Abundance
DWR	D28A R	10/25/95	Fbm	323	0.1	90	5.350		17	476
DWR	D28A R	11/27/95	Fbm	237	0.1	90	6.850		13	358
DWR DWR	D28A R D4 C	12/27/95	Fbm Et	785 306	0.1 2.4	68 69	3.600	•	14 1	488 2
DWR	D4 C	01/18/94 02/08/94	Et Et	582	0.3	31	2.700 0.528	0.2418	3	7
DWR	D4 C	04/12/94	Et	233	0.8	0	0.650	0.2410	4	10
DWR	D4 C	05/23/94	Et	227	1.5	1	0.550		3	7
DWR	D4 C	06/09/94	Et	111	2.9	0	0.550	•	4	14
DWR	D4 C	07/20/94	Et	129	4.4	8	1.050		3	5
DWR	D4 C	08/09/94	Et	97	2.8	50	0.890	0.2620	3	4
DWR DWR	D4 C D4 C	09/21/94	Et Et	158 92	3.2 5.1	0	0.600	-	2 2	8 5
DWR	D4 C	10/19/94 11/21/94	Et	152	5.0	0	0.500 0.550	•	2	9
DWR	D4 C	12/16/94	Et	273	3.0	Ö	0.600		4	16
DWR	D4 C	01/17/95	Et	3,044	0.1	4	0.700		4	7
DWR	D4 C	02/15/95	Et	2,063	0.1	12	0.271	0.1841	3	4
DWR	D4 C	03/15/95	Et	5,682	0.1	0	0.600		1	1
DWR	D4 C	04/27/95	Fbs	2,573	0.1	0	0.450	-	4	24
DWR	D4 C	05/17/95	Fbs	2,779	0.0	0	0.750	•	4	20
DWR DWR	D4 C D4 C	06/27/95 07/13/95	Fbs Fbs	1,326 761	0.1 0.1	0 0	0.750 0.500	-	5 5	22 18
DWR	D4 C	08/24/95	Et	310	0.1	27	0.770	0.1915	4	10
DWR	D4 C	09/26/95	Fbs	558	0.1	90	2.500	0.1010	4	6
DWR	D4 C	10/25/95	Et	323	0.3	0	0.500		2	3
DWR	D4 C	11/27/95	Et	237	1.3	0	0.050		1	1
DWR	D4 C	12/27/95	Et	785	0.1	0	0.550	-	1	20
DWR	D4 L	01/18/94	Fbm	306	2.4	66	1.950		10	317
DWR	D4 L	02/08/94	Fbm	582	1.3	4	0.650	-	6	35
DWR	D4 L	04/12/94	Fbm	233	0.8	92	4.200	•	10	179
DWR DWR	D4 L D4 L	05/23/94 06/09/94	Fbm Fbm	227 111	1.5 2.9	11 74	1.250 4.300		8 13	145 1554
DWR	D4 L	07/20/94	Fbm	129	4.4	71	3.100	•	10	95
DWR	D4 L	08/09/94	Fbm	97	3.1	50	3.250		13	147
DWR	D4 L	09/21/94	Fbm	158	3.2	85	5.400		15	148
DWR	D4 L	10/19/94	Fbm	92	5.1	34	2.300		14	268
DWR	D4 L	11/21/94	Fbm	152	5.0	13	1.500		10	166
DWR	D4 L	12/16/94	Fbm	273	3.0	90	4.750		11	136
DWR	D4 L	01/17/95	Fbm	3,044	0.1	81	3.500	-	15	215
DWR	D4 L	02/15/95	Fbm	2,063	0.1	88	3.750	•	14	231
DWR DWR	D4 L D4 L	03/15/95 04/27/95	Fbm Fbm	5,682 2,573	0.1 0.1	84 92	3.700 3.600		15 12	478 387
DWR	D4 L	05/17/95	Fbm	2,779	0.1	97	4.600	•	15	884
DWR	D4 L	06/27/95	Fbm	1,326	0.1	98	5.350		13	707
DWR	D4 L	07/13/95	Fbm	761	0.1	96	4.900		13	665
DWR	D4 L	08/24/95	Fbm	310	1.0	97	4.650		13	367
DWR	D4 L	09/26/95	Fbm	558	0.1	73	2.700		11	98
DWR	D4 L	10/25/95	Fbm	323	0.3	92	4.700	-	13	100
DWR	D4 L	11/27/95	Fbm	237	1.3	91	3.900	•	14	130
DWR DWR	D4 L D4 L	12/27/95 01/23/96	Fbm Fbm	785 907	0.1 0.1	51 86	15.200 4.100		9 12	65 172
DWR	D4 L	02/23/96	Fbm	3,589	0.1	29	0.340	0.2185	13	181
DWR	D4 L	03/22/96	Fbs	2,520	0.1		0.040	0.2100	6	25
DWR	D4 L	04/29/96	Fbm	1,191	0.1	97	1.700		4	30
DWR	D4 L	05/17/96	Fbm	1,305	0.1	89	4.000		14	645
DWR	D4 L	07/18/96	Fbm	262	0.6	88	3.500		13	233
DWR	D4 L	08/30/96	Fbm	275	.*_	9	0.250	0.2151	13	139
DWR	D4 L	09/13/96	Fbm	208	1.8	65	3.200		13	133
DWR	D4 L	10/09/96	Fbm	131	3.2	60	21.650		10	138
DWR DWR	D4 L	11/15/96	Fbm	244 2,322	3.3	80 89	3.800		11 15	106 110
DWR	D4 L D4 L	12/12/96 01/22/97	Fbm	7,350	0.1	98	4.100 5.200		14	227
DWR	D4 L	02/21/97	Fbm	3,315	0.0	13	0.300	0.2023	14	329
DWR	D4 L	03/26/97	Fbm	939	0.1	92	4.100		17	419
DWR	D4 L	04/24/97	Fbm	384	0.4	38	1.850		14	754
DWR	D4 L	05/23/97	Fbm	341	0.3	88	3.800		11	1190
DWR	D4 L	06/20/97	Fbm	231	0.9	90	3.700		11	617
DWR	D4 L	07/24/97	Fbm	265	0.7	70	3.350		14	153
DWR	D4 L	08/21/97	Fbm	244	0.3	7 95	0.100	0.2021	10	237
DWR DWR	D4 L D4 L	09/18/97 10/29/97	Fbm Fbm	112 137	1.2 4.0	85 65	3.850		13 15	225 276
DWR	D4 L D4 L	11/29/97	Fbm	288	6.1	93	3.250 3.300		19	354
DWR	D4 L	12/18/97	Fbm	435	0.1	93 81	3.650		11	95
DWR	D4 R	01/18/94	Fbm	306	2.4	97	2.800		9	251
DWR	D4 R	02/08/94	Fbm	582	1.3	15	1.800		6	198
DWR	D4 R	04/12/94	Fbm	233	0.8	50	1.850		10	508
DWR	D4 R	05/23/94	Fbm	227	1.5	54	1.900		9	355
DWR	D4 R	06/09/94	Fbm	111	2.9	92	3.000		12	775
DWR	D4 R	07/20/94	Fbm	129	4.4	96 23	2.900	•	8 7	202
DWR	D4 R	08/09/94	Fbm	97	3.1	23	1.400	•	1	188

Appendix 1(Cont'd.). Sample information for samples analyzed in this report. Assemblage Designations: Mm=Marine muddy, Ms=Marine sandy, Et=Estuarine transition, Fbm=Fresh-brackish muddy, Me=Main estuarine, Fbs=Fresh-brackish sandy, Fm=Estuarine marrin

Agency	Site Code	Sample Date	Assem- blage	Delta Outflow Index	Salinity (ppt)	% Fines (<63um)	тос	mERMq	Number of Taxa (per sample)	Total Abundance
DWR	D4 R	09/21/94	Fbm	158	3.2	82	2.200		9	270
DWR	D4 R	10/19/94	Et	92	5.1	1	0.450		7	68
DWR	D4 R	11/21/94	Et	152	5.0	23	1.200		4	32
DWR	D4 R	12/16/94	Fbm	273	3.0	53	2.100		9	219
DWR	D4 R	01/17/95	Fbm	3,044	0.1	55	1.850		11	194
DWR	D4 R	02/15/95	Fbm	2,063	0.1	83	2.350		10	234
DWR	D4 R	03/15/95	Fbm	5,682	0.1	76	2.200	•	12	171
DWR	D4 R	04/27/95	Fbm	2,573	0.1	81	2.200		15	238
DWR	D4 R	05/17/95	Fbm	2,779	0.0	82	3.150		16	418
DWR	D4 R	06/27/95	Fbm	1,326	0.1	39	1.750		14	351
DWR	D4 R	07/13/95	Fbm	761	0.1	28	1.900		9	185
DWR	D4 R	08/24/95	Fbm	310	1.0	53	2.000		13	580
DWR	D4 R	09/26/95	Fbm	558	0.1	49	1.750		11	262
DWR	D4 R	10/25/95	Fbm	323	0.3	44	1.700		11	436
DWR	D4 R	11/27/95	Fbm	237	1.3	33	1.750		9	166
DWR	D4 R	12/27/95	Fbm	785	0.1	55	2.050	•	5	50
DWR	D41	01/23/96	Me	907	15.2	95	3.050		12	466
DWR	D41	02/22/96	Me	3,589	21.2	72	1.660	0.2967	10	169
DWR	D41	03/21/96	Me	2,520	5.6	97	3.850		9	223
DWR	D41	04/30/96	Me	1,191	11.8	97	3.400		11	263
DWR	D41	05/17/96	Me	1,305	20.4	88	2.800	•	13	225
DWR	D41	07/17/96	Me	262	20.0	97	3.800	0.0070	7	174
DWR	D41	08/29/96	Me	275	24.2	48	0.900	0.2272	7	371
DWR	D41	09/12/96	Me	208	26.5	98	3.850		9	223
DWR	D41	10/10/96	Me	131	25.0	87	3.200		4	107
DWR	D41	11/14/96	Me	244	26.4	95	2.900	•	8	263
DWR	D41	12/12/96	Me	2,322	12.7	86	2.750		7	272
DWR	D41	02/24/97	Et M-	3,315	5.5	90	0.900	0.3465	5	250
DWR	D41	03/26/97	Me	939	16.3	72	3.750		4	25
DWR	D41	04/23/97	Me	384	20.4	95	3.550	•	6	71
DWR	D41	05/22/97	Me	341	21.2	90	3.000	•	8	1931
DWR	D41	06/19/97	Me	231	21.2	93	3.550	•	10	512
DWR	D41	07/23/97	Me	265	22.6	99	4.000		7 9	298
DWR	D41	08/20/97	Me	244	25.7	55	1.000	0.2867		381
DWR	D41 D41	09/17/97	Me	112	23.9	85	3.050		11	156
DWR		10/29/97	Me	137	26.5	99	3.600		14	271
DWR DWR	D41 D41	11/19/97	Me Me	288 435	27.8 23.3	10 98	0.850		10 12	31 42
	D41 D41A	12/15/97			23.3		3.250		11	
DWR DWR	D41A D41A	01/19/94 02/09/94	Me Me	306 582		99 98	3.550 3.250		10	784 580
DWR	D41A	04/14/94	Me	233	•	95	3.300	•	13	201
DWR	D41A	05/24/94	Me	227	•	98	3.400	•	12	739
DWR	D41A	06/10/94	Me	111	•	98	5.100	•	12	695
DWR	D41A	07/21/94	Me	129	•	98	3.950	•	12	763
DWR	D41A	08/10/94	Me	97	•	98	2.900		10	480
DWR	D41A	09/22/94	Me	158	•	98	3.100	•	9	453
DWR	D41A D41A		Me	92		98		•	11	439
DWR	D41A D41A	10/20/94 11/30/94	Me	152		98	3.400 3.200	-	12	708
DWR	D41A D41A	12/14/94	Me	273	•	97	3.350	•	13	654
DWR	D41A D41A	01/18/95	Me	3,044	7.4	98	3.350	•	9	498
DWR	D41A	02/16/95	Me	2,063	3.3	96	3.100	-	7	175
DWR	D41A D41A	03/16/95	Me	5,682	3.4	98	3.350	•	6	239
DWR	D41A D41A	04/28/95	Me	2,573	10.9	99	3.050	•	7	71
DWR	D41A D41A	05/19/95	Me	2,779	7.2	99	3.050	•	10	147
DWR	D41A	06/28/95	Me	1,326	11.4	99	4.500	•	6	80
DWR	D41A D41A	07/14/95	Me	761	13.3	98	2.900	•	6	65
DWR	D41A D41A	08/25/95	Me	310	19.1	99	2.850	•	10	153
DWR	D41A	09/28/95	Me	558	15.9	95	3.450	•	12	227
DWR	D41A	10/27/95	Me	323	20.0	96	3.300	•	10	434
DWR	D41A D41A	11/28/95	Me	237	24.4	96	3.250	•	10	456
DWR	D41A	12/28/95	Me	785	20.4	97	3.150	•	9	422
DWR	D41A D41A	01/23/96	Me	907		98	3.250	•	9	248
DWR	D41A	02/22/96	Me	3,589		97	3.350	•	10	113
DWR	D41A	03/21/96	Me	2,520	•	95	3.400	•	6	132
DWR	D41A D41A	04/30/96	Me	1,191	•	98	3.100	•	8	283
DWR	D41A	05/17/96	Me	1,305	•	95	2.600	•	8	172
DWR	D41A D41A	03/17/96	Me	262	•	98	3.350		10	255
DWR	D41A	08/29/96	Me	275	•	98	3.250		11	461
DWR	D41A	09/12/96	Me	208	•	98	3.550	•	10	468
DWR	D41A D41A	10/10/96	Me	131	•	98	3.250	•	9	429
DWR	D41A D41A	11/14/96	Me	244	•	98	2.950	•	7	380
DWR	D41A D41A	12/12/96	Me	2,322	•	99	3.200	•	9	709
DWR	D41A D41A	02/24/97	Me	3,315	•	99	3.000		5	709 55
DWR	D41A	03/26/97	Me	939	•	98	3.050	•	8	160
DWR	D41A D41A	03/26/97	Me	384	•	98	3.100		10	725
DWR	D41A D41A	05/22/97	Me	341	•	98	2.950	•	14	1243
DWR	D41A D41A	06/19/97	Me	231	•	99	2.750	•	14	419
DWR	D41A D41A	06/19/97	Me	265		99 96	2.750	•	12	820
			Me	244	•	98	3.100	•	12	642
DWR	D41A	08/20/97								

Appendix 1(Cont'd.). Sample information for samples analyzed in this report.

Assemblage Designations: Mm=Marine muddy, Ms=Marine sandy, Et=Estuarine transition, Fbm=Fresh-brackish muddy, Me=Main estuarine, Fbs=Fresh-brackish sandy, Fm=Estuarine margin

Agency	Site Code	Sample Date	Assem- blage	Delta Outflow Index	Salinity (ppt)	% Fines (<63um)	тос	mERMq	Number of Taxa (per sample)	Total Abundance
DWR	D41A	10/29/97	Me	137		98	3.050		16	1176
DWR	D41A	11/19/97	Me	288		98	2.900		15	1212
DWR	D41A	12/15/97	Me	435		98	2.850		14	1323
DWR	D6	01/23/96	Me	907	2.5	15	1.150		3	94
DWR	D6	02/22/96	Et	3,589	2.0	23	1.400		2	40
DWR	D6	03/21/96	Et	2,520	0.1	61	2.350		2	88
DWR	D6	04/30/96	Et	1,191	1.7	24	3.650		3	26
DWR	D6	05/17/96	Et	1,305	7.4	23	1.300		4	180
DWR	D6	07/17/96	Et	262	10.4	43	2.100		3	89
DWR	D6	08/29/96	Et	275	10.3	90	3.300		4	44
DWR	D6	09/12/96	Et	208	12.8	95	3.700		2	7
DWR	D6	10/10/96	Et	131	15.9	85	3.300		3	16
DWR	D6	11/15/96	Et	244	15.6	1	0.700		2	14
DWR	D6	12/12/96	Et	2,322	3.6	73	2.750		3	11
DWR	D6	01/22/97	Et	7,350	0.1	92	3.500		3	40
DWR	D6	02/24/97	Et	3,315	1.1	94	3.600		3	44
DWR	D6	03/26/97	Et	939	6.0	86	3.250		7	61
DWR	D6	04/23/97	Et	384	10.2	20	1.250		5	66
DWR	D6	05/22/97	Et	341	11.0	75	2.650		7	123
DWR	D6	06/19/97	Me	231	10.8	95	3.350		7	180
DWR	D6	07/23/97	Me	265	12.2	86	3.550	•	6	171
DWR	D6	08/20/97	Et	244	12.1	98	3.550	•	5	38
DWR	D6	09/17/97	Me	112	13.2	98	3.450		6	164
DWR	D6	10/29/97	Me	137	16.6	99	3.400		8	70
DWR	D6	11/19/97	Me	288	17.5	98	3.400	•	9	121
	D6		Me	435	12.0	96 65		•	9	75
DWR DWR	D6 D7	12/15/97	ivie Et	435 306	9.6	65 100	3.300		9 4	75 130
		01/19/94					3.600	0.0500		
DWR	D7	02/09/94	Me	582	5.8	99	1.464	0.3529	4	212
DWR	D7	04/14/94	Et	233	4.3	100	3.600		7	163
DWR	D7	05/24/94	Et	227	0.6	100	3.500		8	273
DWR	D7	06/10/94	Et	111	9.0	100	3.600		9	356
DWR	D7	07/21/94	Et	129	12.3	100	3.200		8	691
DWR	D7	08/10/94	Et	97	12.7	98	1.470	0.3260	5	216
DWR	D7	09/22/94	Et	158	10.1	100	3.450		5	478
DWR	D7	10/20/94	Et	92	12.3	100	3.300		6	318
DWR	D7	11/29/94	Et	152	11.2	100	3.600		6	247
DWR	D7	12/13/94	Me	273	8.4	100	3.100		7	624
DWR	D7	01/18/95	Me	3,044	0.1	100	2.900		7	307
DWR	D7	02/16/95	Et	2,063	0.2	99	1.375	0.2788	7	89
DWR	D7	03/16/95	Et	5,682	0.1	100	3.250		8	89
DWR	D7	04/28/95	Et	2,573	0.1	100	3.200		8	166
DWR	D7	05/18/95	Et	2,779	0.1	100	3.650		7	226
DWR	D7	06/28/95	Et	1,326	0.1	100	3.850		7	102
DWR	D7	07/14/95	Et	761	0.4	100	3.500		6	79
DWR	D7	08/25/95	Et	310	5.5	97	1.400	0.2334	4	12
DWR	D7	09/28/95	Et	558	3.0	100	3.300		4	39
DWR	D7	10/27/95	Et	323	5.0	100	3.450		5	35
DWR	D7	11/28/95	Et	237	9.0	100	3.400		4	18
DWR	D7	01/23/96	Et	907	0.3	100	3.350		4	48
DWR	D7	02/22/96	Et	3,589	0.1	98	1.370	0.3210	7	57
DWR	D7	03/21/96	Et	2,520	0.1	100	3.500		6	54
DWR	D7	04/30/96	Et	1,191	0.1	31	3.400		7	103
DWR	D7	05/17/96	Et	1,305	1.9	99	3.000		7	88
DWR	D7	07/17/96	Et	262	6.6	87	2.950		3	20
DWR	D7	08/29/96	Et	275	7.1	97	1.380	0.3000	4	23
DWR	D7	09/12/96	Et	208	9.1	100	3.450		4	51
DWR	D7	10/10/96	Et	131	10.2	100	3.300		2	14
DWR	D7	11/15/96	Et	244	10.3	100	3.250		5	102
DWR	D7	12/11/96	Et	2,322		100	3.200	•	5	123
DWR	D7	01/22/97	Et .	7,350	0.1	100	3.600	•	6	156
DWR	D7	02/24/97	Et	3,315	0.1	99	1.400	0.3156	7	139
DWR	D7	03/26/97	Et	939	1.4	100	3.400	2.0.00	8	150
DWR	D7	04/23/97	Et	384	5.4	100	3.250	•	5	53
DWR	D7	05/22/97	Et	341	4.7	100	3.100	•	6	95
DWR	D7	06/19/97	Et	231	7.0	100	3.050	•	5	115
DWR	D7	07/23/97	Et	265	8.0	100	3.200		3	69
DWR	D7 D7		Et	265 244	7.9	99	1.400	0.3664	4	63
		08/20/97					3.450	0.3004		
DWR	D7	09/17/97	Et E+	112	7.3	100			6	90 106
DWR	D7	10/29/97	Et Et	137	11.3	100	3.150	•	5	196
DWR	D7	11/19/97	Et	288	11.9	100	3.200		8	170
DWR	D7	12/15/97	Et	435	4.4	100	3.000		7	247
DWR	P8	01/22/96	Fbm	907	0.2	93	3.350		14	207
DWR	P8	02/21/96	Fbm	3,589	0.2	37	1.450		14	240
DWR	P8	03/20/96	Fbm	2,520	0.1	29	1.250		18	429
DWR	P8	04/29/96	Fbm	1,191	0.2	23	1.050		17	308
DWR	P8	05/16/96	Fbm	1,305	0.2	30	1.150		19	412
DWR	P8	06/24/96	Fbm	435	0.2	52	1.850		13	344
DWR	P8	07/16/96	Fbm	262	0.4	35	1.400		12	296
DWR	P8	08/28/96	Fbm	275	0.4	24	1.150		9	267
	P8	09/11/96	Fbm	208	0.3	15	0.850		10	231

Results of the Benthic Pilot Study 1994-1997

Appendix 1(Cont'd.). Sample information for samples analyzed in this report. Assemblage Designations: Mm=Marine muddy, Ms=Marine sandy, Et=Estuarine transition, Fbm=Fresh-brackish muddy, Me=Main estuarine, Fbs=Fresh-brackish sandy,

Agency	Site Code	Sample Date	Assem- blage	Delta Outflow Index	Salinity (ppt)	% Fines (<63um)	тос	mERMq	Number of Taxa (per sample)	Total Abundance
DWR	P8	10/08/96	Fbm	131	0.2	60	2.100		12	128
DWR	P8	11/14/96	Fbm	244	0.4	21	0.900		10	146
DWR	P8	12/11/96	Fbm	2,322	0.1	39	1.500		10	104
DWR	P8	01/23/97	Fbm	7,350	0.1	41	1.650		17	284
DWR	P8	02/20/97	Fbm	3,315	0.1	48	1.650		15	225
DWR	P8	03/24/97	Fbm	939	0.2	74	2.450		19	269
DWR	P8	04/22/97	Fbm	384	0.4	57	1.700		15	292
DWR	P8	05/21/97	Fbm	341	0.2	82	2.650		14	298
DWR	P8	06/18/97	Fbm	231	0.3	71	2.450		14	482
DWR	P8	07/22/97	Fbm	265		81	2.500		15	669
DWR	P8	08/19/97	Fbm	244	0.4	26	0.750		12	381
DWR	P8	09/16/97	Fbm	112	0.3	54	2.050		14	285
DWR	P8	10/28/97	Fbm	137	0.3	70	2.200		13	336
DWR	P8	11/19/97	Fbm	288	0.3	63	1.650		14	201
DWR	P8	12/16/97	Fbm	435	0.4	91	2.900		12	172

