Macrobenthic Communities

Shelter Island Yacht Basin

Chapter 3
Macrobenthic Communities

INTRODUCTION

Benthic macroinvertebrates are important members of marine ecosystems, serving vital functions in wide ranging capacities. For example, many species that live within or on the surface of the sediments (i.e., infauna and epifauna, respectively) provide the prey base for fish and other marine predators, while other species decompose organic material as a crucial step in nutrient cycling. In addition, correlations between environmental factors and benthic community structure often provide useful measures of anthropogenic impact (Pearson and Rosenberg 1978). For this reason, the characterization of macrobenthic communities has long been recognized as an integral component of marine ecological assessments.

Macrobenthic communities in San Diego Bay are influenced by many physical, chemical, and biological factors. These include the various attributes of the bottom waters (e.g., temperature, salinity, dissolved oxygen, current velocity) and sediments (e.g., particle size distribution, sediment chemistry), as well as biological factors such as food availability, competition, and predation. These factors are controlled by both natural processes and human activities, which ultimately determine the structure of the Bay's benthic communities. For example, differences in tidal flushing, evaporation, and freshwater input create unique hydrodynamic regions throughout the Bay (see Largier 1995), while human activities such as dredging and shipbuilding affect the physical environment through habitat alteration or the deposition of toxic compounds (USDoN, SWDIV and SDUPD 2000). Most previous studies of the San Diego Bay benthos have focused on anthropogenic impacts from known point sources. A comprehensive survey of the bay's macrofauna, with adequate coverage to address both natural and anthropogenic influences on community structure, has not been done prior to this study.

This chapter presents an assessment of macrobenthic communities sampled throughout San Diego Bay in the summer of 1998. Included is a discussion of the factors that may influence the composition and distribution of the various assemblages. In addition, this chapter presents a comparison of the San Diego Bay macrofauna to that occurring in the other bays and harbors sampled during the Bight'98 regional survey of the Southern California Bight (SCB). These data will provide a baseline against which to measure future trends, monitor populations of indigenous and nonindigenous species, and assess the overall ecological condition of the Bay.

MATERIALS & METHODS

Collection and Processing of Samples

Benthic samples were collected at 46 stations in San Diego Bay during July and August of 1998 (Figure 3.1). These stations were randomly located throughout the Bay and ranged in depth from 3.0 to 15.6 m. One sample was collected at each site using a 0.1 m^2 modified van Veen grab. Criteria established by the United States Environmental Protection Agency to ensure the consistency of grab samples were followed with regard to sample disturbance and depth of penetration (see USEPA 1987). All samples were sieved through a 1.0 mm mesh screen and processed aboard ship. Organisms retained on the screen were relaxed for approximately 30

Figure 3.1

Macrobenthic stations sampled in San Diego Bay during 1998.

minutes in a magnesium sulfate solution. The samples were then fixed with buffered formalin for a minimum of 72 hours, rinsed with fresh water, and transferred to 70% ethanol. All of the organisms were sorted from the debris into major taxonomic groups, after which they were identified to species or the lowest taxon possible and enumerated. Complete details regarding the project's experimental design, randomized station location procedures, field sampling methods and sample processing protocols are available in the Bight'98 field manual (FSLC 1998).

Data Analyses

The following community structure parameters were calculated for each station: species richness (number of species per grab); abundance (number of individuals per grab); Shannon diversity index (H' per grab); Pielou's evenness index (J' per grab); Swartz dominance index (minimum number of species accounting for 75% of the abundance in each grab).

Ordination (principal coordinates) and classification (hierarchical agglomerative clustering) analyses were performed to examine spatial patterns in the overall similarity of the macrobenthic assemblages. These analyses were performed using Ecological Analysis Package (EAP) software (see Smith 1982, Smith et al. 1988). Prior to analysis the abundance data were square root transformed and the data set was reduced by excluding any taxon represented by only one animal.

Environmental correlates to the biological distribution patterns were investigated by overlaying rank-ordered values for the various environmental parameters onto plots of stations distributed in ordination space (see Field et al. 1982). The parameters used for these comparisons included station depth, percent fines (silt and clay sediment fraction), total organic carbon (TOC), total nitrogen (TN), several trace metals (i.e., copper, mercury, zinc and lead), total DDT (tDDT), total polycyclic aromatic hydrocarbons (tPAH) and total polychlorinated biphenyls (tPCB). The above chemical parameters were identified as contaminants of concern by either Fairey et al. (1996) or USDoN, SWDIV and SDUPD (2000), and were detected during this study in concentrations exceeding the Effects Range-Low (ERL) guidelines developed by NOAA (Long et al. 1995).

Comparison of San Diego Bay to Other Embayments

In addition to San Diego Bay, the macrobenthos from eight other southern California bays was sampled during Bight'98. From north to south these embayments are Ventura Harbor, Channel Islands Harbor, Marina Del Rey, Los Angeles/Long Beach Harbor, Anaheim Bay, Newport Bay, Dana Point Harbor, and Mission Bay. Including San Diego Bay stations, a total of 114 sites were surveyed by 11 participating agencies. Methodologies and protocols for the collection and processing of these samples were the same as for those outlined previously. Data analysis, however, was limited by the differences in sampling effort among the embayments. For example, Ventura Harbor was represented by a single station with only 11 species, and therefore was not included in comparisons of the dominant taxa in southern California bays. Ordination and classification analyses were performed on a dataset including all 114 stations, following methods described above.

Table 3.1

Summary of abundance (Abun) and species richness (SR) for major taxa (Polychaeta, Crustacea, Mollusca, Other Phyla combined) collected in San Diego Bay during 1998. Data are expressed as means per sample (no./0.1 m^2). Ranges of values for individual samples are shown in parentheses.

	Polychaeta	Mollusca	Crustacea	Other Phyla	Total
Abun	545 (74-2145)	164 (11-1187)	103 (2-839)	17 (1-91)	830 (102-3149)
SR	23 (14-48)	9 (3-26)	9 (2-21)	6 (1-14)	47 (25-96)

RESULTS

Community Structure

In total, 38,187 macrobenthic organisms representing 340 taxa were identified from the 46 San Diego Bay samples. The dominant higher taxonomic groups were polychaetes, molluscs and crustaceans (Table 3.1). Polychaetes averaged 545 individuals and 23 taxa per 0.1 m^2 grab sample. Molluscs and crustaceans averaged 164 and 103 individuals per sample respectively, and each about nine taxa per sample. All of the remaining taxa combined (e.g., echinoderms, nemerteans, cnidarians, etc.) averaged 17 individuals and less than six taxa per grab. A conservative estimate identified 18 species that are considered not native to San Diego. These nonindigenous species represented 24% of the total macrofauna in the Bay.

A small number of species (< 5%) accounted for over 80% of the individual animals collected from San Diego Bay. These numerically dominant taxa also tended to be widely distributed throughout the Bay. The majority of taxa, however, occurred in low numbers, with over 25% being represented by single individuals. Although some of the many taxa with low to moderate abundances were widely distributed, most were not. In total, only 22 species were found at more than half the stations. Hence, the benthos was dominated by relatively few species in terms of both abundance and distribution.

The dominant macrofauna in San Diego Bay are listed in Table 3.2. A capitellid polychaete, *Mediomastus* sp (a species complex), was the most abundant organism. This worm was present in every sample, with populations varying from 2 to 521 per 0.1 m^2. Another polychaete, the spionid *Prionospio heterobranchia*, was also found at all stations. The second most abundant animal was the nonindigenous bivalve *Musculista senhousia*, which occurred in densities exceeding 1100 per m^2. This ecologically important mussel was also found at more than 95% of the stations. Two other nonindigenous species that were also widespread and abundant were the spionid polychaete *Pseudopolydora paucibranchiata* and the bivalve *Theora lubrica*. Finally, a crustacean, the tanaid *Synaptotanais notabilis* (=*Zeuxo normani* in Fairey et al. 1996), was highly abundant at a small group of stations, most of which were located within the Shelter Island Yacht Basin.

There was considerable variation in the overall structure of the macrobenthic assemblages distributed throughout the Bay (see Appendix C.1). Species richness varied among stations, ranging from 25 to 96 species per 0.1 m^2 grab (mean = 47/grab). In general, there were higher numbers of species at stations located

Table 3.2

Dominant macroinvertebrates at San Diego Bay benthic stations sampled during 1998. Included are the 10 most abundant taxa overall and per occurrence, and the 10 most widely occurring taxa. Data are expressed as: MS = mean number per 0.1 m^2 over all samples; MO = mean number per 0.1 m^2 per occurrence; and PO = percent occurrence.

Species (Taxa)	Higher Taxa	MS	MO	PO
Ten Most Abundant				
1. *Mediomastus* sp	Polychaeta: Capitellidae	108.2	108.2	100%
2. *Musculista senhousia* [1]	Mollusca: Bivalvia	85.5	89.3	96%
3. *Euchone limnicola*	Polychaeta: Sabellidae	84.7	99.9	85%
4. *Pseudopolydora paucibranchiata* [1]	Polychaeta: Spionidae	72.0	89.5	80%
5. Lumbrineridae [2]	Polychaeta: Lumbrineridae	44.0	54.8	80%
6. *Amphideutopus oculatus*	Crustacea: Amphipoda	31.8	39.6	80%
7. *Synaptotanais notabilis*	Crustacea: Tanaidacea	31.6	145.2	22%
8. *Prionospio heterobranchia*	Polychaeta: Spionidae	31.5	31.5	100%
9. *Lumbrineris* sp C	Polychaeta: Lumbrineridae	28.8	29.4	98%
10. *Leitoscoloplos pugettensis*	Polychaeta: Orbiniidae	28.6	30.6	94%
Ten Most Abundant per Occurrence				
1. *Synaptotanais notabilis*	Crustacea: Tanaidacea	31.6	145.2	22%
2. *Mediomastus* sp	Polychaeta: Capitellidae	108.2	108.2	100%
3. *Euchone limnicola*	Polychaeta: Sabellidae	84.7	99.9	85%
4. *Pseudopolydora paucibranchiata* [1]	Polychaeta: Spionidae	72.0	89.5	80%
5. *Musculista senhousia* [1]	Mollusca: Bivalvia	85.5	89.3	96%
6. Lumbrineridae [2]	Polychaeta: Lumbrineridae	44.0	54.8	80%
7. *Fabricinuda limnicola*	Polychaeta: Sabellidae	21.0	46.1	46%
8. *Amphideutopus oculatus*	Crustacea: Amphipoda	31.8	39.6	80%
9. *Exogone lourei*	Polychaeta: Syllidae	28.5	33.6	85%
10. *Prionospio heterobranchia*	Polychaeta: Spionidae	31.5	31.5	100%
Ten Most Widespread				
1. *Mediomastus* sp	Polychaeta: Capitellidae	108.2	108.2	100%
2. *Prionospio heterobranchia*	Polychaeta: Spionidae	31.5	31.5	100%
3. *Lumbrineris* sp C	Polychaeta: Lumbrineridae	28.8	29.4	98%
4. *Musculista senhousia* [1]	Mollusca: Bivalvia	85.5	89.3	96%
5. *Pista agassizi*	Polychaeta: Terebellidae	27.4	28.7	96%
6. *Leitoscoloplos pugettensis*	Polychaeta: Orbiniidae	28.6	30.6	94%
7. *Theora lubrica* [1]	Mollusca: Bivalvia	25.6	29.4	87%
8. *Glycera americana*	Polychaeta: Glyceridae	3.8	4.4	87%
9. *Euchone limnicola*	Polychaeta: Sabellidae	84.7	99.9	85%
10. *Exogone lourei*	Polychaeta: Syllidae	28.5	33.6	85%

1 = nonindigenous species
2 = unidentified juveniles and/or damaged specimens

near the mouth of the Bay, and fewer taxa at sites towards the backwaters. Macrofaunal abundance was also highly variable, ranging from 102 to 3,149 animals per grab and with an average density of 830 animals per sample. Species dominance was expressed as the minimum number of species composing 75% of a community by abundance, with lower values indicating higher dominance (Swartz 1978). These values varied from 3 to 16 species per station, with the lowest dominance typically occurring at sites nearer the mouth of the Bay. Similarly, species diversity was highest near the Bay's mouth, with H' values ranging between 1.7 and 3.4 (mean = 2.5) at the various stations.

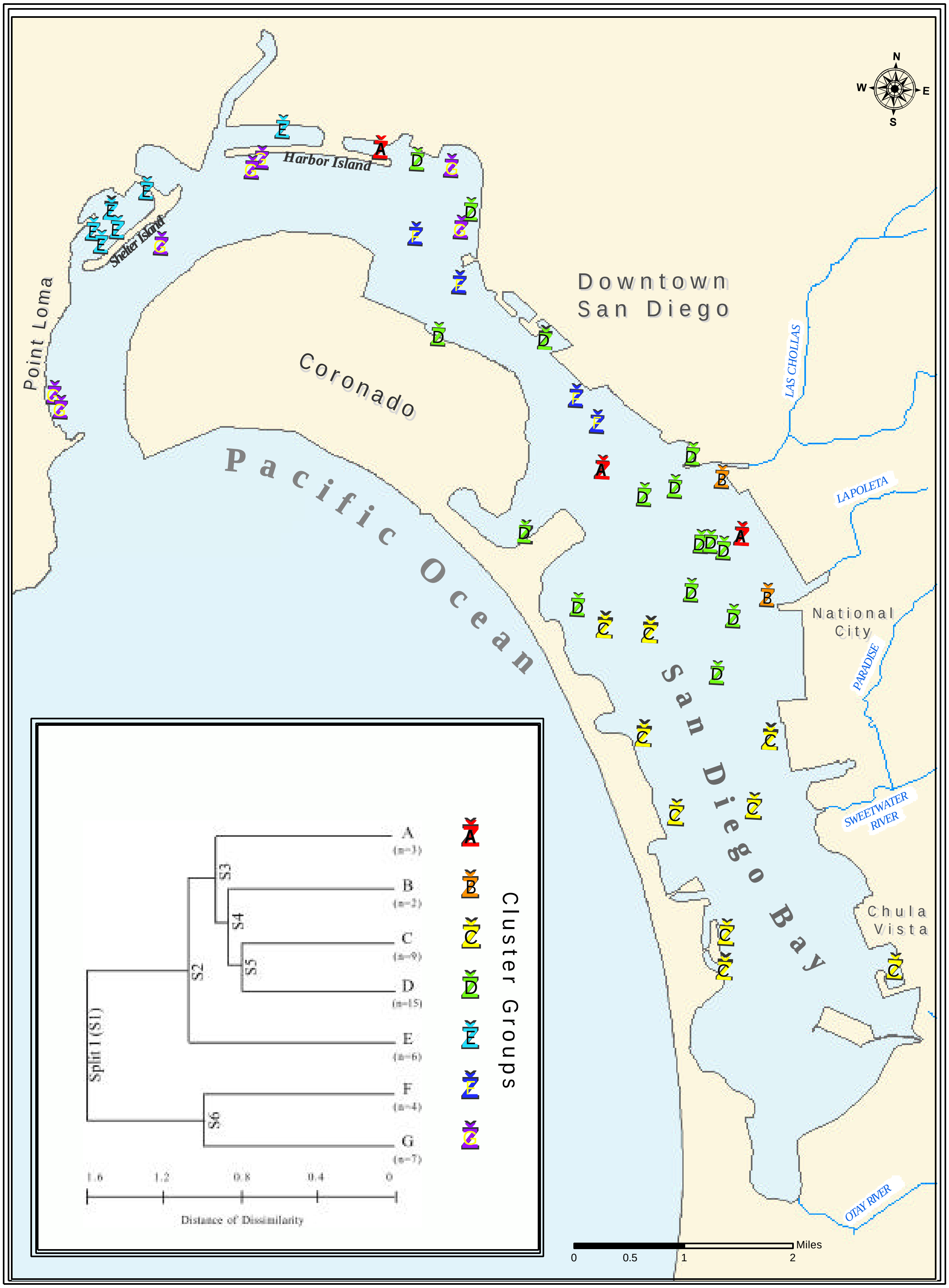


Figure 3.2

Summary of results of classification analysis of macrofaunal abundance data from the 1998 survey of San Diego Bay. Major station cluster groups are color-coded on the map to reveal spatial patterns in the distribution of benthic assemblages.

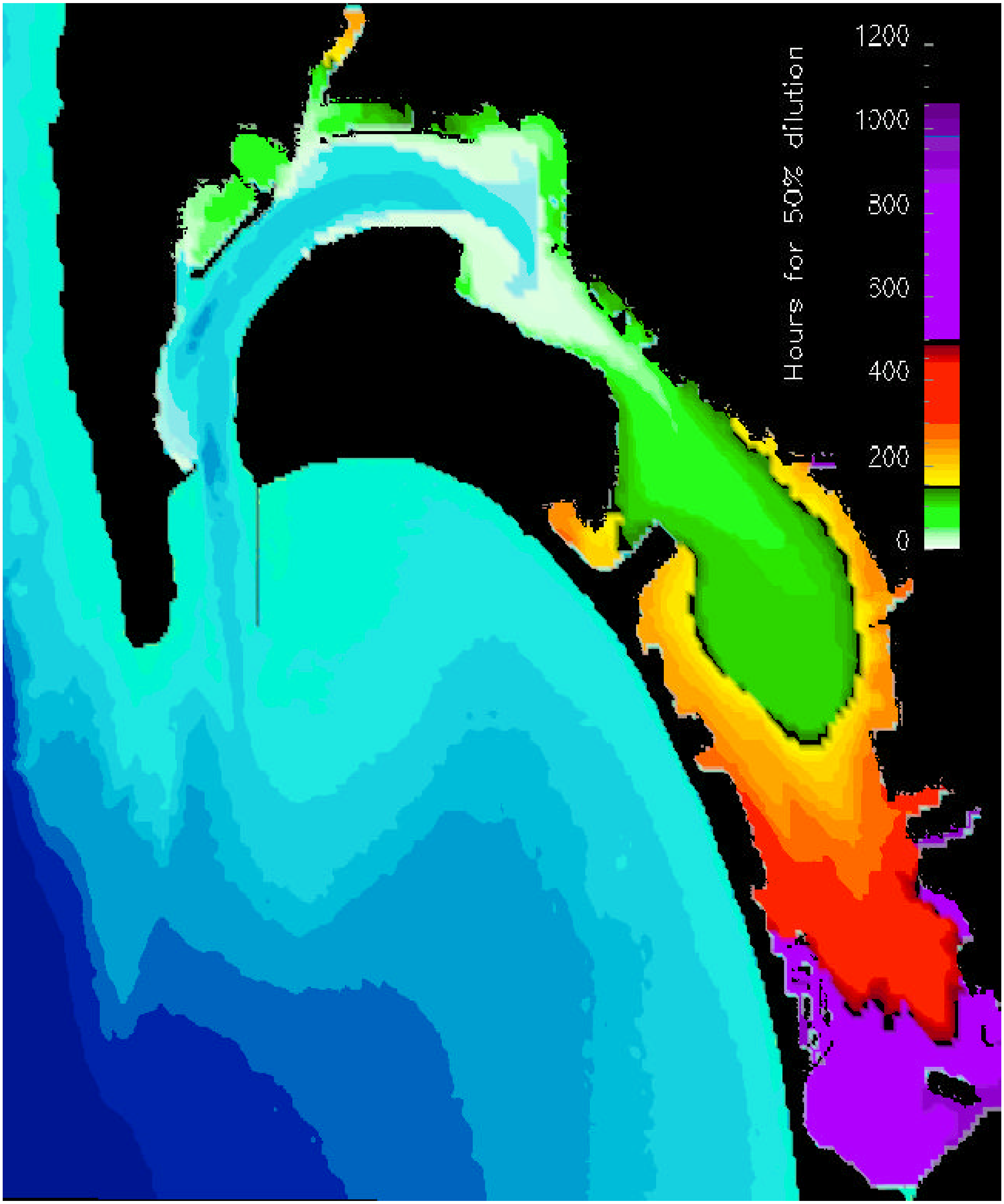


Figure 3.3

Tidal flushing simulation for San Diego Bay representing the number of hours for water in the Bay to be diluted or exchanged by 50% at a 100 cm tidal amplitude. Average tidal amplitude was 85 cm with a maximum spring tide of 270 cm (Sutton and Helly 2002). Graphics provided courtesy of John Helly of the San Diego Supercomputer Center.

Table 3.3

Summary of environmental parameters and contaminants of concern for San Diego Bay sediments corresponding to macrofaunal cluster groups A-G. Data are expressed as group averages for those stations with detected values. Depth=m; Fines =% silt+clay; trace metals = parts per million; tDDT and tPAH= parts per billion; tPCB = parts per trillion; nd = not detected. ERL=Effects Range-Low; ERM=Effects Range-Median (Long et al. 1995). Ranges of values for individual samples are shown in parentheses. Highest group averages for contaminants of concern are in bold type.

Cluster Group	Depth	Fines	Cu	Hg	Zn	Pb	tDDT	tPAH	tPCB
A	7.5	50	110	0.49	172	42	2060	834	**33150**
	(3.0-10.6)	(38-60)	(52-146)	(0.32-0.70)	(106-206)	(27-53)	(nd-2060)	(17-1934)	(nd-49800)
B	10.5	71	**196**	0.51	**300**	**119**	**7300**	**2675**	17050
	(10.1-10.9)	(69-73)	(145-247)	(0.40-0.62)	(180-420)	(44-193)	(nd-7300)	(2347-3003)	(9900-24200)
C	4.3	54	78	0.23	143	24	1337	194	nd
	(3.0-10.3)	(33-75)	(39-200)	(0.10-0.33)	(81-232)	(17-46)	(nd-2100)	(nd-457)	
D	6.8	43	92	0.40	143	36	3200	2183	30640
	(3.3-11.2)	(12-78)	(18-252)	(nd-0.79)	(38-314)	(11-83)	(nd-3200)	(nd-10768)	(nd-123800)
E	4.2	68	139	**0.89**	160	32	780	283	nd
	(3.6-4.8)	(41-91)	(58-220)	(0.40-1.69)	(83-216)	(13-47)	(nd-780)	(nd-735)	
F	11.6	37	61	0.28	103	24	nd	548	1500
	(10.9-13.1)	(17-56)	(31-95)	(0.11-0.46)	(64-157)	(14-37)		(nd-1285)	(nd-1500)
G	11.0	64	70	0.30	125	24	nd	1929	13250
	(5.2-13.3)	(46-80)	(28-118)	(0.12-0.69)	(64-180)	(7-42)		(nd-5925)	(nd-16200)
ERL	.	.	34	0.15	150	46.7	1580	4022	22700
ERM	.	.	270	0.70	410	218.0	46100	44792	180000

Classification of Benthic Assemblages

Ordination and classification analyses separated the San Diego Bay stations into seven major cluster groups or types of assemblages based on differences in species composition and the relative abundances of specific taxa (see Figure 3.2). These cluster groups appeared to separate along gradients of tidal flushing and anthropogenic impact (see Figures 3.2 and 3.3, Table 3.3).

Cluster group A represented samples collected from three stations located in different regions of the Bay, but which may be linked by similar histories of human impact (see Fairey et al. 1996). For example, relatively high levels of contaminants were measured in the sediments at these sites, including the highest average value for PCBs (see Table 3.3). Polychaete worms were the dominant taxa in this assemblage, although the bivalve *Musculista senhousia* was also common (Table 3.4). The most abundant polychaetes included juveniles and unidentified members of the family Lumbrineridae, followed by the capitellid *Mediomastus* sp, the spionid *Prionospio heterobranchia*, and the syllid *Exogone lourei*.

Cluster group B represented samples from sites located in a region where human impact has been documented previously (e.g., Fairey et al.1996, USDoN, SWDIV and SDUPD 2000), and where sediments averaged the

Table 3.4

Numerically dominant taxa composing cluster groups A-G from the 1998 benthic survey of San Diego Bay. Data are included for the 10 most abundant taxa in each group and are expressed as mean abundance per sample (no./0.1m^2). The three most abundant taxa per cluster group are shown in bold type.

Species (Taxon)	Higher Taxa Code *	Cluster Groups A	B	C	D	E	F	G
Lumbrineris sp[1]	A	.	12.5	35.0	7.5	2.7	.	8.6
Exogone lourei	A	**46.0**	2.5	11.1	24.0	**112.3**	6.0	1.3
Pseudopolydora paucibranchiata [2]	A	4.3	.	4.4	91.5	**300.8**	4.3	9.1
Oligochaeta [1]	A	14.3	1.0	4.3	1.4	7.0	0.3	3.9
Musculista senhousia [2]	M	37.3	10.5	**114.1**	**155.7**	61.2	6.3	6.1
***Mediomastus* sp**[1]	A	**65.7**	**22.0**	**196.2**	**162.3**	14.3	32.0	46.0
Prionospio heterobranchia	A	**46.0**	**19.0**	30.2	32.9	18.0	61.8	21.7
***Lumbrineris* sp C**	A	22.7	**21.5**	**67.3**	15.0	16.3	11.5	34.0
Pista agassizi	A	3.3	16.5	24.0	43.1	22.5	13.5	23.9
Leitoscoloplos pugettensis	A	2.3	6.0	26.8	20.7	56.2	6.5	**54.4**
Euphilomedes carcharodonta	C	18.7	12.0	1.7	10.6	7.2	18.3	0.4
Euchone limnicola	A	18.0	1.5	37.6	**175.7**	48.2	**107.0**	21.0
Lumbrineridae [1]	A	**87.7**	.	42.8	45.3	38.5	33.3	47.9
Fabricinuda limnicola	A	1.3	1.0	1.8	61.7	0.5	4.0	0.3
Solen rostiformis	M	0.3	.	11.8	4.2	.	8.5	11.8
Synaptotanais notabilis	C	8.7	.	.	0.8	**235.7**	.	.
Theora lubrica [2]	M	1.0	12.0	8.1	20.5	16.2	29.5	**79.1**
Diplocirrus sp SD1[2]	A	.	6.5	2.7	3.7	25.0	1.8	21.3
Amphideutopus oculatus	C	3.3	.	3.3	30.3	26.2	**115.5**	**50.1**
Lyonsia californica	M	1.7	1.5	2.0	8.4	10.3	**99.5**	24.6
Crucibulum spinosum	M	8.0	.	0.3	0.3	.	37.0	.
Tagelus subteres	M	.	1.0	0.1	2.8	1.2	19.5	25.1

*A = Annelida C = Crustacea M = Mollusca
1 = unidentified juveniles and/or damaged specimens; 2 = nonindigenous species

highest concentrations of many contaminants of concern during the present study (see Chapter 2 and Table 3.3). Overall, the group B assemblage was characterized by fewer species and lower abundances than found elsewhere in the Bay (Table 3.5). *Mediomastus* sp was the most abundant taxon at these sites, followed by two other polychaetes, *Lumbrineris* sp C and *Prionospio heterobranchia* (Table 3.4).

Cluster group C included samples from nine south-bay stations that had the lowest exposure to tidal flushing. Largier (1995) referred to this part of San Diego Bay as the "Estuarine Region;" where the waters are subject to occasional freshwater inputs, and are characterized by residence times that can exceed one month. *Mediomastus* sp and *Musculista senhousia* were by far the two most abundant taxa in this group (Table 3.4).

Cluster group D comprised samples from 15 stations that were generally located in a hydrodynamic region of the Bay described as seasonally hypersaline (Largier 1995). In addition, a number of stations within this group had sediments containing relatively high levels of contaminants (see Chapter 2). Therefore, the benthic community characteristic of these sites may reflect the combined influences of lower exposure to tidal flushing and a history of human impact. The three numerically dominant species were the polychaetes *Euchone limnicola* and *Mediomastus* sp, and the bivalve *Musculista senhousia* (Table 3.4).

Table 3.5

Summary of major benthic community parameters for San Diego Bay cluster groups A-G. Data are expressed as means (no./0.1 m^2) and include: species richness (SR); abundance (Abun); diversity (H'); evenness (J'); Swartz dominance (Dom). Ranges of values for individual samples are shown in parentheses.

Cluster Group	SR	Abun	H'	J'	Dom
A (n=3)	37 (31-44)	441 (391-536)	2.4 (2.1-2.7)	0.7 (0.6-0.7)	7 (5-9)
B (n=2)	28 (25-30)	170 (102-237)	2.7 (2.6-2.7)	0.8 (0.8-0.8)	8 (8-8)
C (n=9)	36 (28-50)	701 (384-1117)	2.3 (1.8-2.7)	0.6 (0.5-0.7)	5 (3-8)
D (n=15)	46 (28-76)	1030 (237-2263)	2.4 (1.7-3.3)	0.6 (0.5-0.8)	7 (3-15)
E (n=6)	51 (40-79)	1146 (383-3149)	2.5 (1.8-2.9)	0.6 (0.5-0.8)	7 (3-10)
F (n=4)	60 (38-78)	783 (327-1502)	2.9 (2.8-3.1)	0.7 (0.6-0.8)	11 (8-14)
G (n=7)	62 (44-96)	680 (251-1672)	3.1 (2.8-3.4)	0.8 (0.7-0.8)	12 (9-16)
Overall	47 (25-96)	830 (102-3149)	2.5 (1.7-3.4)	0.7 (0.5-0.8)	8 (3-16)

Cluster group E included samples from six stations located in marinas in the northern portion of the Bay. These marinas likely represent a unique habitat, reflecting influences such as human impact and hydrodynamic conditions. For example, sediments here had relatively high levels of mercury (see Chapter 2 and Table 3.3). In addition, tidal flushing is reduced in these areas (see Figure 3.3). The most abundant species in this assemblage were the nonindigenous polychaete *Pseudopolydora paucibranchiata*, the tanaid *Synaptotanais notabilis*, and the polychaete *Exogone lourei* (Table 3.4). The high numbers of *S. notabilis* in these marinas are especially notable, since this animal was nearly absent elsewhere in the Bay.

Cluster group F represented the assemblage present at four mid-channel stations in the north-central region of the Bay. This area receives relatively frequent tidal flushing as illustrated by the model in Figure 3.3. The amphipod *Amphideutopus oculatus* was the numerically dominant species in this assemblage, followed by the polychaete *Euchone limnicola*, and the bivalve *Lyonsia californica* (Table 3.4).

Cluster group G represented the macrobenthic assemblage most directly influenced by tidal flushing. This assemblage was characterized by the highest species richness, the highest diversity, and the lowest dominance of any in the Bay (Table 3.5). The nonindigenous bivalve *Theora lubrica* was the most abundant species in this group, followed by the polychaete *Leitoscoloplos pugettensis*, and the amphipod *Amphideutopus oculatus* (Table 3.4).

Table 3.6

Comparison of San Diego Bay with other SCB embayments in terms of abundance and occurrence of the dominant benthic organisms collected during 1998. SD=San Diego Bay; N=Newport Bay; MDR=Marina Del Rey; LALB=Los Angeles/Long Beach Harbor; MB=Mission Bay; CI=Channel Island Harbor; DP=Dana Point; A=Anaheim Bay; p = taxa present in bay, though not among the ten most abundant. n = total number of stations sampled per embayment.

Ten Most Abundant	**Rank Abundance per Embayment**							
	SD	MB	DP	N	A	LALB	MDR	CI
Species (Taxa)	(n=46)	(n=3)	(n=3)	(n=11)	(n=3)	(n=36)	(n=7)	(n=4)
Mediomastus sp	1	p	p	6	1	p	3	7
Musculista senhousia [1]	2	10	.	4	p	p	p	.
Euchone limnicola	3	p	5	1	5	p	2	5
Pseudopolydora paucibranchiata [1]	4	6	1	5	9	1	1	4
Lumbrineridae	5	p	7	10	4	9	p	p
Amphideutopus oculatus	6	p	p	p	p	3	10	p
Synaptotanais notabilis	7	9	4	p	.	8	p	3
Prionospio heterobranchia	8	p	p	p	8	p	5	p
Lumbrineris sp C	9	p	p	p	7	p	9	10
Leitoscoloplos pugettensis	10	p	6	2	6	p	8	p

Ten Most Widespread	**Percent Occurrence per Embayment**							
	SD	MB	DP	N	A	LALB	MDR	CI
Species (Taxa)	(n=46)	(n=3)	(n=3)	(n=11)	(n=3)	(n=36)	(n=7)	(n=4)
Mediomastus sp	100%	67%	67%	91%	100%	64%	57%	75%
Prionospio heterobranchia	100%	100%	67%	91%	67%	11%	86%	25%
Lumbrineris sp C	98%	67%	100%	91%	100%	11%	71%	75%
Musculista senhousia [1]	96%	100%	0%	82%	33%	3%	29%	0%
Pista agassizi	96%	100%	67%	64%	67%	44%	14%	0%
Leitoscoloplos pugettensis	94%	100%	100%	91%	100%	64%	100%	75%
Theora lubrica [1]	87%	100%	67%	91%	66%	100%	43%	25%
Glycera americana	87%	67%	0%	18%	33%	69%	0%	0%
Euchone limnicola	85%	33%	67%	91%	67%	33%	71%	50%
Exogone lourei	85%	100%	67%	36%	33%	8%	0%	50%

1 = nonindigenous species

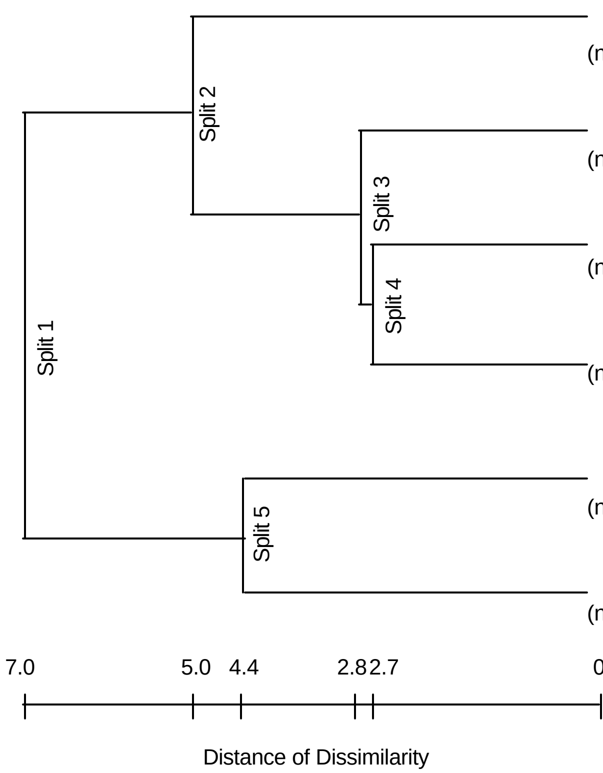
Comparison of San Diego Bay to Other Embayments

Most of the animals common in San Diego Bay were also present in all other bays sampled during Bight'98 (Table 3.6). In addition, many of the most abundant taxa in San Diego were also found in high numbers in the other bays. For example, the nonindigenous polychaete *Pseudopolydora paucibranchiata* was the most abundant species in three embayments (Dana Point Harbor, Los Angeles/Long Beach Harbor, Marina Del Rey) and among the numerically dominant animals in the other bays as well. Furthermore, species that were widespread in San Diego Bay had similar broad distributions in the other embayments. Such species included *Leitoscoloplos pugettensis*, *Mediomastus* sp, and *Theora lubrica*, all of which occurred at around 80% of stations sampled throughout the SCB.

Ordination and classification analyses separated the SCB bay macrofauna into six major types of assemblages (see Figure 3.4, cluster groups A-F). None of these assemblages was restricted to any single embayment, and most bays had more than one assemblage type present (see Figure 3.5). Cluster groups A-D included some stations from every bay sampled during the survey. These groups all had relatively high abundances of the polychaete *Pseudopolydora paucibranchiata*. All of the San Diego

Bay stations were associated with cluster group C, which represented a macrobenthic community characterized by high numbers of the nonindigenous bivalve *Musculista senhousia.* This community was also present at three stations in Newport Bay and one station in Mission Bay. Cluster groups E and F were primarily composed of stations located in Los Angeles/Long Beach (LA/LB) Harbor, and were dominated by the nonindigenous bivalve *Theora lubrica*.

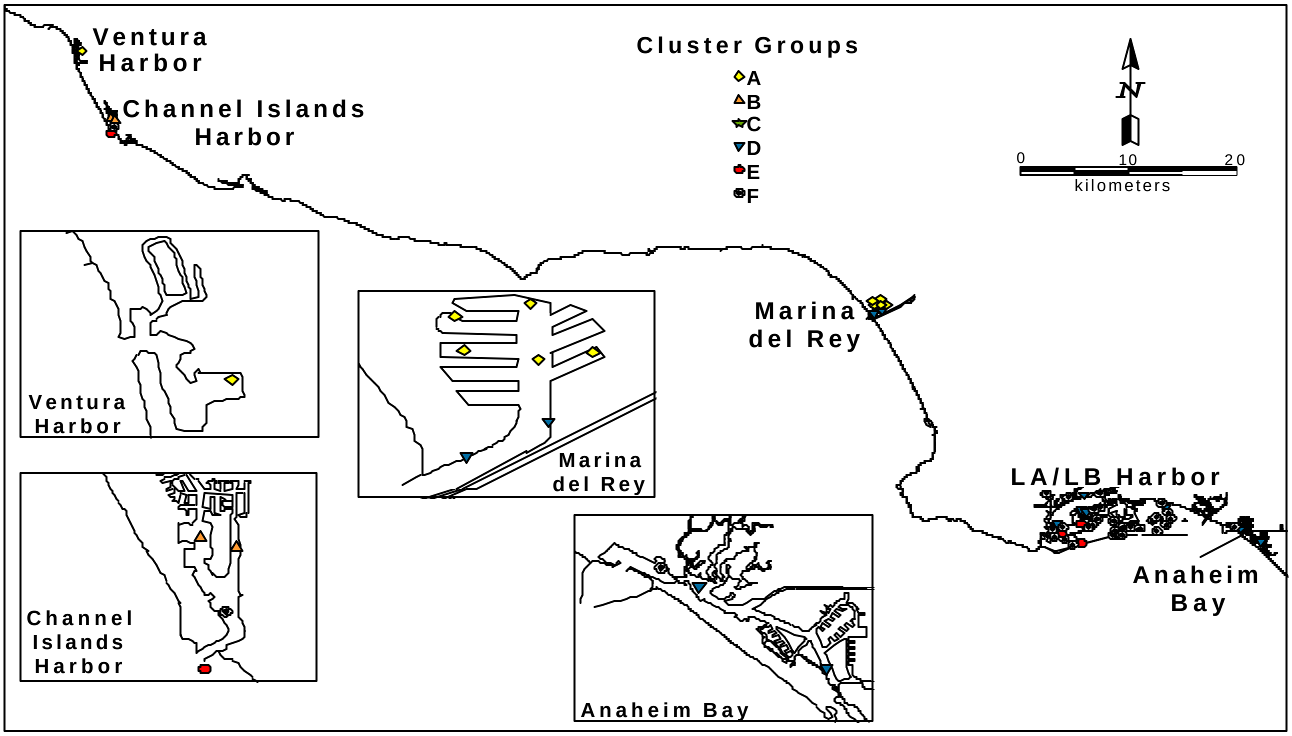
The cluster groups appeared to separate based on multiple environmental and biological factors, including different hydrodynamic conditions, anthropogenic impact, and the presence of dominant, habitat altering species. For example, two stations located near the mouth of Marina Del Rey clustered together with stations from a similar hydrodynamic region in Newport Harbor (see Figure 3.5). Classification analyses of these individual bays revealed a distinct zonation of assemblages along gradients from the open ocean to the headwaters of both Marina Del Rey and Newport Harbor. The separation of cluster groups A and E may be explained by anthropogenic impacts. Group A was characterized by the highest average values for most contaminants of concern, while group E included three sites in LA/LB Harbor that were dredged just prior to sampling. These groups had low abundances and low diversity, with each averaging fewer than 80 individuals and less than 12 taxa per grab.



Cluster Group	Bays	Top Three Taxa
A (n=6)	Ventura Harbor (n=1) Marina del Rey (n=5)	*Pseudopolydora paucibranchiata* * *Aphelochaeta* sp *Leitoscoloplos pugettensis*
B (n=7)	Channel Islands Harbor (n=2) Dana Point Harbor (n=3) Mission Bay (n=2)	*Caecum californicum* *Barleeia subtenuis* *Pseudopolydora paucibranchiata* *
C (n=50)	Newport Bay (n=3) Mission Bay (n=1) San Diego Bay (n=46)	*Mediomastus* sp *Musculista senhousia* * *Euchone limnicola*
D (n=17)	Marina del Rey (n=2) LA/LB Harbor (n=5) Anaheim Bay (n=2) Newport Bay (n=8)	*Pseudopolydora paucibranchiata* * *Euchone limnicola* *Mediomastus* sp
E (n=4)	Channel Islands Harbor (n=1) LA/LB Harbor (n=3)	*Theora lubrica* * *Capitella capitata* *Rhepoxynius lucubrans*
F (n=30)	Channel Islands Harbor (n=1) LA/LB Harbor (n=28) Anaheim Bay (n=1)	*Theora lubrica* * *Cossura candida* *Amphideutopus oculatus*

Figure 3.4

Cluster results of macrofaunal abundance data for Bight'98 embayment stations sampled during July and August, 1998. Included are the major cluster groups chosen to represent benthic assemblages, the bays in which each assemblage occurred and the top three taxa by mean abundance per $0.1 m^2$ for each assemblage (n = # of stations). Nonindigenous species are indicated by an *.



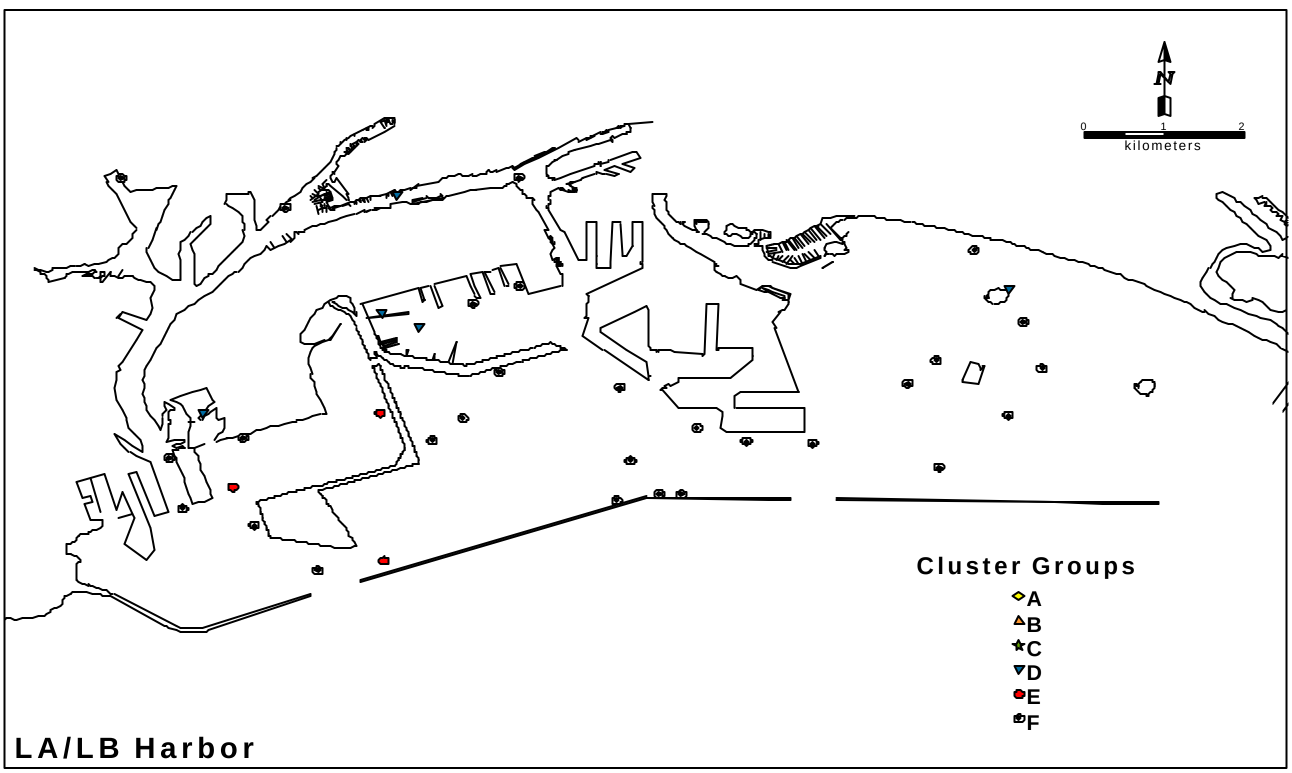
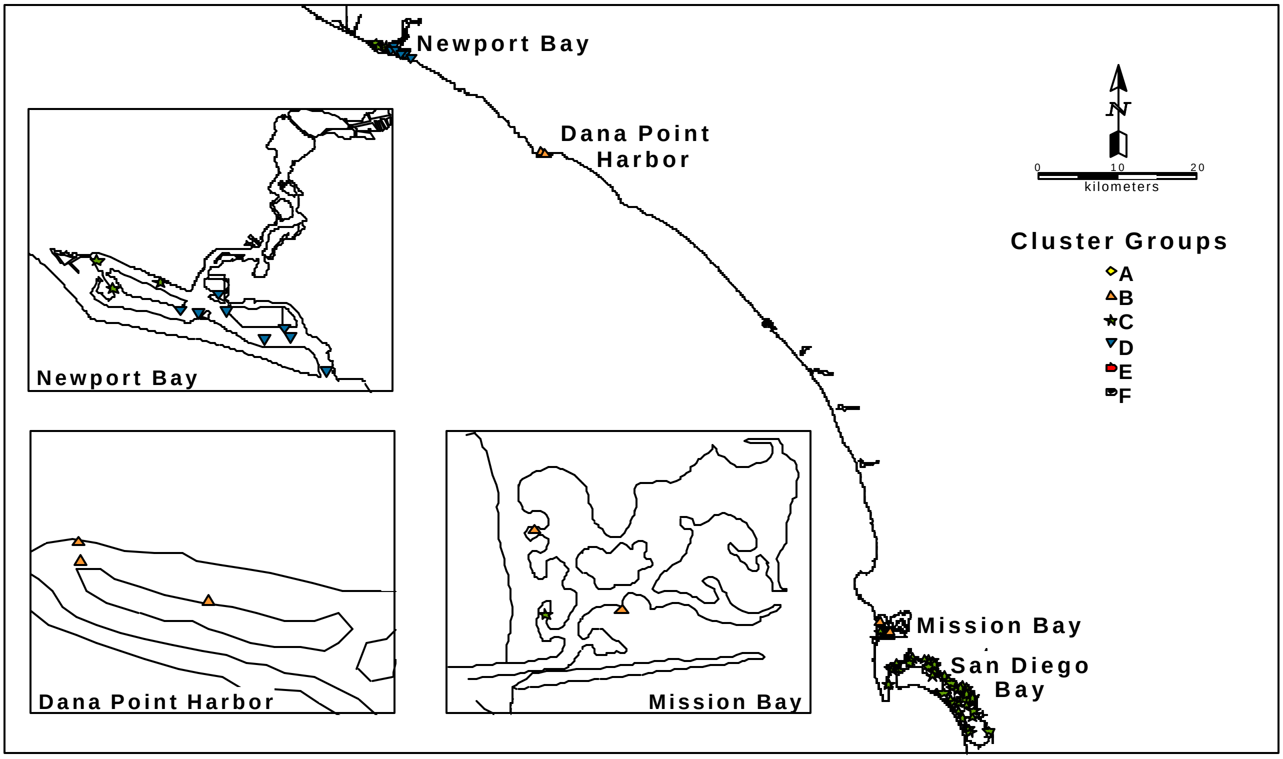


Figure 3.5

Benthic station locations for the nine embayments sampled during the Bight'98 survey. Stations are color-coded to represent affiliation with macrofaunal clusters.



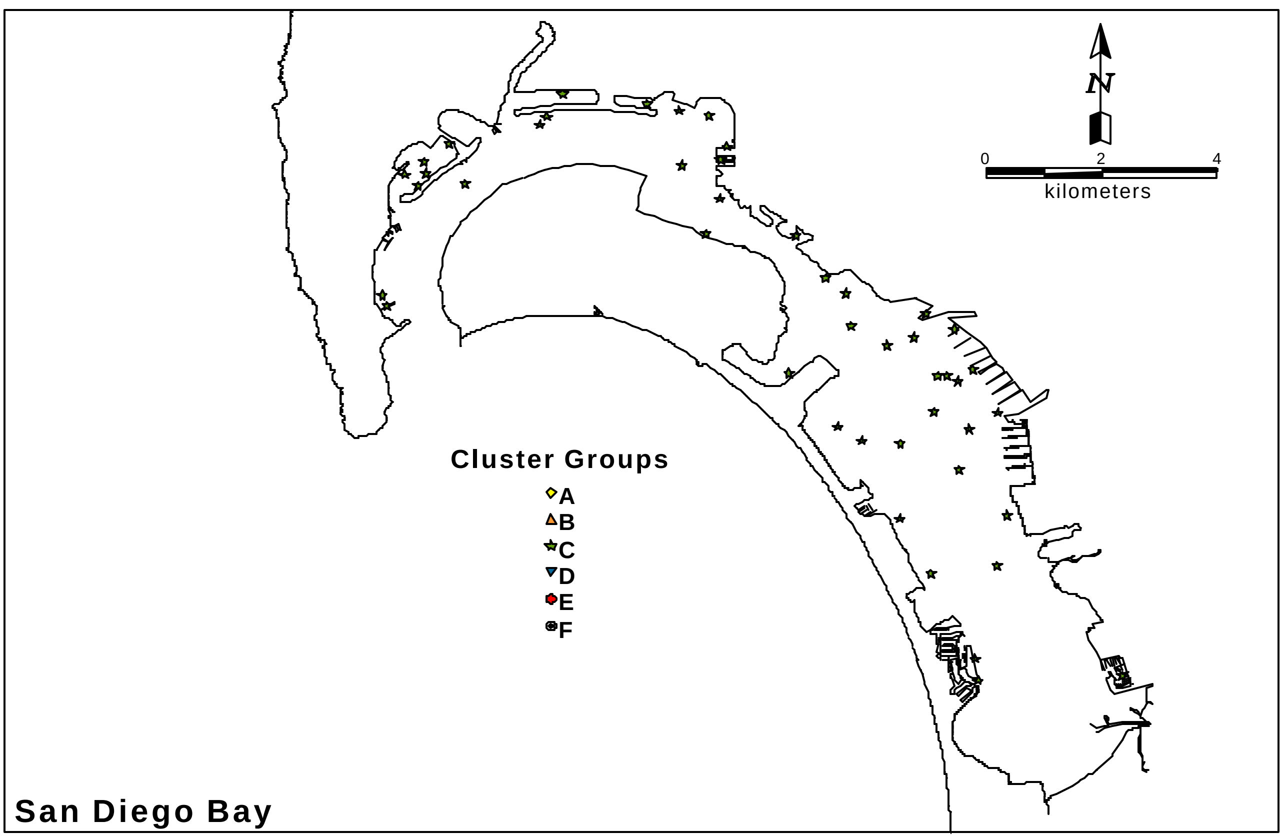


Figure 3.5 (continued)

SUMMARY & DISCUSSION

The macrobenthic community of San Diego Bay consisted of several unique assemblages distributed throughout different regions of the Bay. Most of the animals composing these assemblages belonged to a relatively small number of species, which reflects the unstable habitat typical of many embayments (Sumich 1992). Polychaete worms were the most abundant taxa followed by molluscs and crustaceans. These three taxa often dominate marine macrobenthic assemblages. Polychaetes were also the most diverse and widely occurring animals in the Bay.

Hydrodynamic conditions appeared to be the primary factor influencing the distribution of macrobenthic assemblages in San Diego Bay. For example, the distribution of assemblages found during 1998 resemble models of tidal exchange described previously by Largier (1995) and Sutton and Helly (2002). In addition, there was a pattern of increasing numbers of species (i.e., species richness) when moving from the backwaters towards the mouth of the Bay. This biological "zonation" was also apparent when considering populations of certain individual species. Some animals such as the bivalve *Musculista senhousia* and the polychaete *Mediomastus* sp were far more abundant in parts of the Bay where tidal flushing was less frequent, while others such as the bivalve *Theora lubrica* and the amphipod *Amphideutopus oculatus* were more common in areas of high tidal flushing. Similar patterns relative to hydrodynamic gradients have been reported for Mission Bay (Dexter and Crooks 2000), and are typical of estuarine benthic communities in general (Sumich 1992).

Anthropogenic impact may represent a secondary factor that influenced the distribution of the benthic macrofauna. For example, species richness was typically low in regions of the Bay that have well-documented histories of anthropogenic impact (e.g., see Fairey et al.1996, USDoN, SWDIV and SDUPD 2000). One such region is near the NASSCO shipyard, located between Las Chollas Creek and La Poleta Creek, where the macrobenthic assemblage (cluster group B) was characterized by few taxa and low abundance. This assemblage was only present at two sites, one of which had some of the highest concentrations of contaminants of any station in the Bay (i.e., station 2264).

Some evidence suggests that the overall composition of San Diego Bay's macrofauna has been affected by anthropogenic impacts. For example, several of the dominant species collected during this survey are not native to southern California. These nonindigenous species were probably introduced to the Bay through human activities, and are now among the most ecologically important members of the benthic community. One such animal, *Musculista senhousia*, was the second most abundant species collected during this survey. This exotic bivalve builds habitat-altering mats, and can have considerable influence on the species composition of benthic communities (Crooks 1996).

The various embayments sampled throughout southern California during 1998 generally had similar benthic communities. Results from multivariate analyses revealed that the benthos of the individual bays typically included multiple types of macrobenthic assemblages. As in San Diego Bay, these assemblages varied along environmental gradients. Although the same assemblage rarely occurred throughout a single embayment, all assemblage types were found in more than one bay. This zonation was such that the assemblages present in one region of a bay were often more similar to assemblages occurring in other bays than to those in adjacent regions of the same bay.

San Diego Bay was also similar to other bays in terms of dominant taxa. Earlier studies have shown similar results, with a small group of taxa dominating most bay assemblages throughout the SCB (Dexter 1983, Thompson et al. 1993). For example, Dexter (1983) found that three of the 13 most abundant species collected in Mission Bay were also reported from six other bays in southern California and northern Baja California. Six other species were also found in at least 50% of the bays. The presence of these ubiquitous organisms reflects the similarity of conditions in SCB bays and harbors. In contrast, most of the dominant species from San Diego Bay are not common on the mainland shelf off San Diego (see City of San Diego 2001). Despite the general similarity among SCB bays, however, the benthic community in San Diego Bay could be distinguished from most other embayments. This was mainly due to the large numbers of *Musculista senhousia* that were found in San Diego. Although *M. senhousia* is not dominant throughout the other southern California bays, other nonindigenous species were represented among the dominant taxa in all bays sampled.

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