Table 8. Mean densities and standard error of higher taxonomic groups at each site in San Diego Bay. Total area sampled (0.04m2) at each site was from 5 replicate cores.

SITES	ID ORG #	Polychaetes mean #/m2 ± SE	Mollusks mean #/m2 ± SE	Crustaceans mean #/m2 ± SE	Echinoderms mean #/m2 ± SE
10 Swartz (West Basin)	837	4,986.5 ± 481.8	2,213.3 ± 1,211.5	5,199.9 ± 792.2	
11 Swartz (East Basin)	840	5,599.9 ± 1,654.0	640.0 ± 319.4	7,946.5 ± 2,605.1	26.7 ± 26.7
14 Swartz (Downtown Piers)	846	4,213.2 ± 822.5	2,453.3 ± 1,865.5	1,146.6 ± 449.4	
15 Swartz (G St Pier Marina)	849	4,106.6 ± 694.6	1,040.0 ± 508.4	1,120.0 ± 123.6	
16 Swartz (Intercont. Marina)	818	3,893.2 ± 824.5	1,146.6 ± 629.1	2,853.3 ± 905.9	
23 Swartz (Naval Base 07)	865	5,119.9 ± 1,427.1	106.7 ± 77.7	373.3 ± 154.3	
25 Swartz (Naval base/ SY 010)	887	2,639.9 ± 932.7	53.3 ± 53.3	53.3 ± 32.7	
27 Swartz (Naval Base /SH 013)	890	2,373.3 ± 268.0	133.3 ± 73.0	293.3 ± 165.5	
28 Swartz (7th St Channel Q1)	893	2,000.0 ± 944.7	80.0 ± 53.3	26.7 ± 26.7	
31 Swartz (Marine Terminal R3)	896	4,373.2 ± 1,827.4	746.6 ± 225.5	853.3 ± 466.8	
32 Swartz (Sweetwater Ch)	875	5,066.5 ± 1,224.2	213.3 ± 181.8	1,013.3 ± 459.2	
34 Swartz (CV Yacht Basin)	824	10,426.4 ± 2,264.4	373.3 ± 154.3	800.0 ± 332.0	
35 Swartz (Coronado Cays)	843	4,986.5 ± 1,506.5	320.0 ± 171.8	3,199.9 ± 370.0	26.7 ± 26.7
37 Swartz (Marina)	815	4,399.9 ± 1,141.5	426.7 ± 160.0	1,626.6 ± 351.2	
41 Swartz (Glorietta Bay)	821	10,106.4 ± 532.3	5,066.5 ± 2,724.3	1,493.3 ± 816.9	
K Swartz (Naval Base 04)	862	2,799.9 ± 480.7	906.6 ± 208.3	853.3 ± 293.9	
NSB-M1 (Sub Base C2)	871	4,266.6 ± 668.0	1,013.3 ± 149.7	1,146.6 ± 200.4	53.3 ± 53.3
P Swartz (Naval Base 012)	868	4,799.9 ± 808.8	533.3 ± 279.7	533.3 ± 245.8	
SDNI- N5 (Carrier Base V2)	899	7,733.1 ± 2,003.5	1,946.6 ± 512.2	2,000.0 ± 511.2	
12 Swartz (Downtown Anch)	878	3,893.2 ± 760.6	1,333.3 ± 865.1	2,159.9 ± 586.3	
Mission Bay A3	853	1,600.0 ± 152.0	1,440.0 ± 330.4	533.3 ± 242.2	640.0 ± 216.6
Mission Bay A4	859	2,186.6 ± 422.9	213.3 ± 149.7	933.3 ± 467.6	53.3 ± 32.7
Mission Bay A8	856	11,573.0 ± 761.7	320.0 ± 90.4	3,599.9 ± 1,096.2	213.3 ± 53.3
San Diego River B1	881	2,426.6 ± 1,062.0	26.7 ± 26.7	800.0 ± 173.8	
Stormdrain EM (Grape St.)	827	4,239.9 ± 534.0	53.3 ± 53.3	3,813.2 ± 1,345.6	

Table 9. Macrobenthic community variables at sites in San Diego bay. Biological parameters derived from 5 replicate samples per site Physical measurements are from an average of the 3 stations.

SITES	depth (m)	silt:clay (%)	TOC	Total no. of species	Mean no. indiv./m2	Simpson's diversity D	inverse (1/D) diversity	V' evennness	Shannon-W diversity H'	J' evenness	habitat
32 Swartz (Sweetwater Ch)	6	64.49	0.97	31	6,426.5	0.161	6.211	0.005	3.514	0.709	E-sandy
11 Swartz (East Basin)	3	52.71	1.33	35	14,586.3	0.124	8.065	0.004	3.719	0.725	S,Sb
16 Swartz (Intercont. Marina)	4	59.68	1.04	32	8,106.5	0.086	11.628	0.003	4.037	0.807	S,Sb
37 Swartz (Marina)	3	92.77	1.45	29	6,586.5	0.101	9.901	0.003	3.833	0.789	S,Sb
Stormdrain EM (Grape St.)	8	82.47	1.97	33	8,239.8	0.071	14.085	0.002	4.152	0.823	E,Sb
10 Swartz (West Basin)	3	75.36	1.46	34	12,399.7	0.094	10.638	0.003	3.910	0.769	S,Sb
14 Swartz (Downtown Piers)	11	54.59	1.30	37	7,919.8	0.088	11.364	0.002	4.112	0.789	E
15 Swartz (G St Pier Marina)	5	77.25	4.08	33	6,586.5	0.074	13.514	0.002	4.194	0.831	E
41 Swartz (Glorietta Bay)	5	50.00	1.05	28	16,879.6	0.163	6.135	0.006	3.296	0.686	S,Sb
K Swartz (Naval Base 04)	5	62.79	2.23	21	4,586.6	0.129	7.752	0.006	3.481	0.793	E,N
SDNI- N5 (Carrier Base V2)	7	65.80	1.81	46	11,839.7	0.075	13.333	0.002	4.342	0.786	E,N
12 Swartz (Downtown Anch)	5	73.73	1.83	31	7,439.8	0.094	10.638	0.003	3.985	0.804	E
23 Swartz (Naval Base 07)	8	55.09	1.74	29	5,706.5	0.124	8.065	0.004	3.621	0.745	E,N
25 Swartz (Naval base/ SY 010)	9	71.89	1.92	20	2,799.9	0.141	7.092	0.007	3.324	0.769	E,N
27 Swartz (Naval Base /SH 013)	10	71.16	1.90	21	2,826.6	0.111	9.009	0.005	3.631	0.827	E,N
31 Swartz (Marine Terminal R3)	6	61.51	1.58	32	6,079.8	0.142	7.042	0.004	3.634	0.727	E
34 Swartz (CV Yacht Basin)	3	90.40	1.39	33	11,866.4	0.368	2.717	0.011	2.474	0.490	S
35 Swartz (Coronado Cays)	3	82.29	1.39	30	8,613.1	0.103	9.709	0.003	3.847	0.784	S,N
NSB-M1 (Sub Base C2)	10	62.67	1.64	43	6,746.5	0.101	9.901	0.002	4.087	0.753	E,N
P Swartz (Naval Base 012)	10	69.63	2.07	28	5,866.5	0.108	9.259	0.004	3.744	0.779	E,N
Mission Bay A4 REF	2	65.70	1.63	37	3,599.9	0.069	14.493	0.002	4.460	0.856	M
28 Swartz (7th St Channel Q1)	7	45.97	1.73	15	2,159.9	0.178	5.618	0.012	3.156	0.808	nd
Mission Bay A8 REF	5	36.99	0.89	44	15,866.3	0.085	11.765	0.002	4.109	0.753	M
Mission Bay A3 REF	3	93.21	2.98	27	5,653.2	0.130	7.692	0.005	3.516	0.739	M
San Diego River B1 REF	1	76.19	2.31	9	3,466.6	0.332	3.012	0.037	2.081	0.656	M
					Value range=	0-1	1-s	0-1	<5, max=log S	0-1	

E=exposed, S=sheltered, Sb=small boats, N=navy, C=channel, M=Mission Bay

shown by the evenness index (J'=0.490). This was due to an abundance of *Mediomastus californiensis* and *Leitoscoloplos pugettensis* polychaetes. Compared to all other sites, Chula Vista had a significantly lower density of crustaceans. The Mission Bay A4 site had moderately high species diversity but comparatively low species abundance.

Cluster and Ordination Analyses

Cluster analyses produced the dendrogram (Figure 15) of station affinities, based on mean root-root transformed abundance of the 198 macrobenthic species, using Pearson's correlation of similarity and group-average sorting. A root-root transformation, reduced the weighting of abundant species (Field *et al.*, 1982). The similarity level, although arbitrary, was designated somewhat conservatively near 50%. The resulting classification of assemblages reflect general patterns of benthic species composition, domination, and evenness (*e.g.*, sites along the 0.00 line would be identical in species composition and abundance). Six major groups were delineated from the hierarchical clusters, which were defined by an overall dominant species. Group I, which included only a single site (32 Swartz, Sweetwater Channel) was co-dominated by the tube-building tanaid *Zuexo normandi* and polychaete worm *Leitoscoloplos pugettensis*. Groups IV, V and VI were all dominated by the polychaete worm species *L. pugettensis*, *Prionospio heterobranchia*, and co-dominants *P. heterobranchia* and oligochaetes, respectively. Amphipods (*Acuminodeutopus heteruropus*) were the most abundant group in cluster II. The seemingly ubiquitous bivalve *Musculista senhousei* was the numerically important species in Group III. When plotted, these biologically-based clusters provide a qualitative assessment of the pattern of physical data and visually demonstrate the relationship of one site to another. To put the relationship of samples into a more general perspective, the level of similarity found between San Diego Bay site samples and those from Los Angeles Harbor was between 5-10% (Figure 16), revealing the benthos of these northerly areas should not be used comparatively, due to differences in habitats and biotic response. Although tidally influenced, the species composition of the San Diego River B1 site was also found to be highly dissimilar to other San Diego Bay samples, presumably due to habitat differences.

In addition to conventional methods, non-metric multi-dimensional scaling (MDS) using a weighted Spearman rank correlation coefficient dissimilarity matrix was used to determine similarity in species composition between stations. Non-metric MDS can handle large numbers of zeros, missing data, and unequal replication. MDS seeks a representation of individuals in a space of low dimensionality where the distances between individuals in ordination space optimally represent their dissimilarities in variable space (Kenkel and Orloci, 1986). Typically, transformed biotic and abiotic data are initially analyzed separately, then combined to assess common MDS spatial patterns. The resulting ordination for biotic variables is demonstrated here.

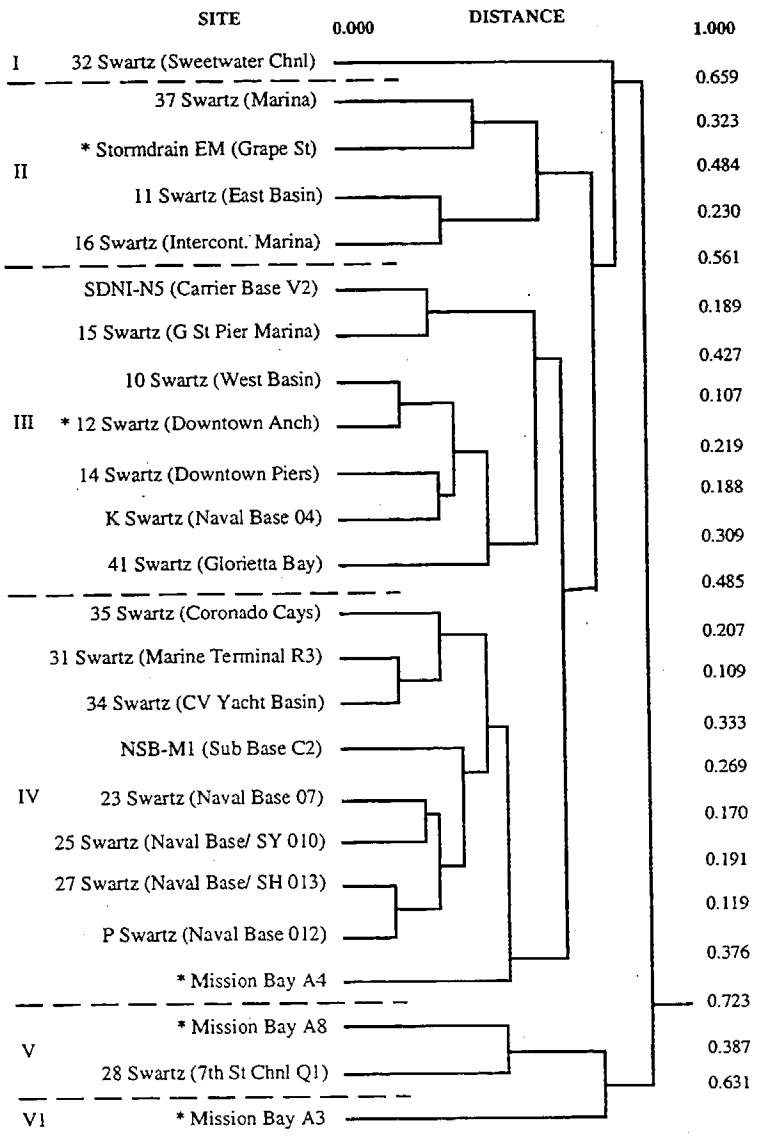


Figure 15. Numerical classification of mean abundance data of 198 macrobenthic species. Clusters are derived from Pearson correlation matrix data and group-average sorting. Six major clusters are shown, each dominated by 1-2 species.

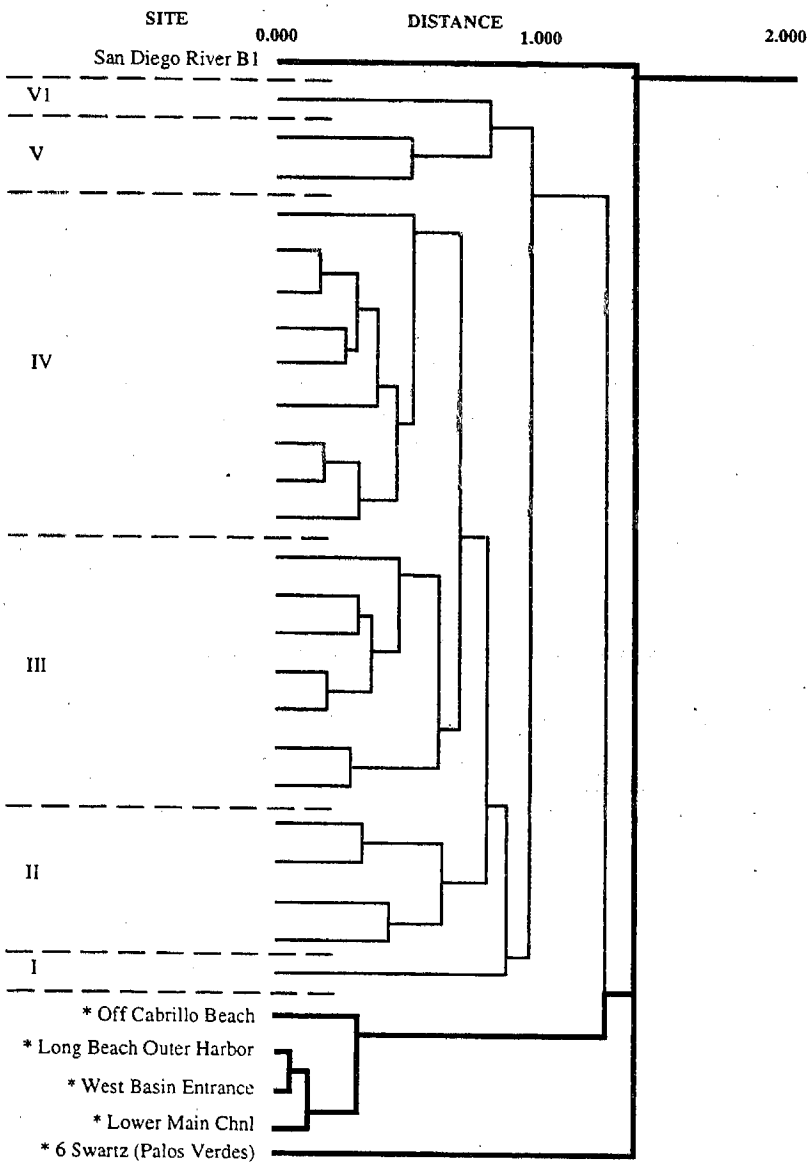


Figure 16. Numerical classification of mean abundance data from San Diego Bay and vicinity and Los Angeles Harbor.

PLOT	VARIABLE/SITE	CORRELATION CLUSTER NO.	PLOT	VARIABLE/SITE	CORRELATION CLUSTER NO.
A	West Basin, Swartz 10	III	N	Marina, Swartz 37	II
B	East Basin, Swartz 11	II	O	Glorietta Bay, Swartz 41	III
C	Downtown Piers, Swartz 14	III	P	Naval Base 04, Swartz K	III
D	G St Pier Marina, Swartz 15	III	Q	Sub Base C2, NSB-M1	IV
E	Intercont. Marina, Swartz 16	II	R	Naval Base 012, Swartz P	IV
F	Naval Base 07, Swartz 23	IV	S	Carrier Base V2, SDNI-N5	III
G	Naval Base/ SY 010, Swartz 25	IV	T	San Diego River B1	nd
H	Naval Base/ SH 013, Swartz 27	IV	U	Stormdrain EM, Grape St	II
I	7th Channel Q1, Swartz 28	V	V	Downtown Anch, Swartz 12	III
J	Marine Terminal R3, Swartz 31	IV	W	Mission Bay A3	VI
K	Sweetwater Channel, Swartz 32	I	X	Mission Bay A4	IV
L	CV Yacht Basin, Swartz 34	IV	Y	Mission Bay A8	V
M	Coronado Cays, Swartz 35	IV			

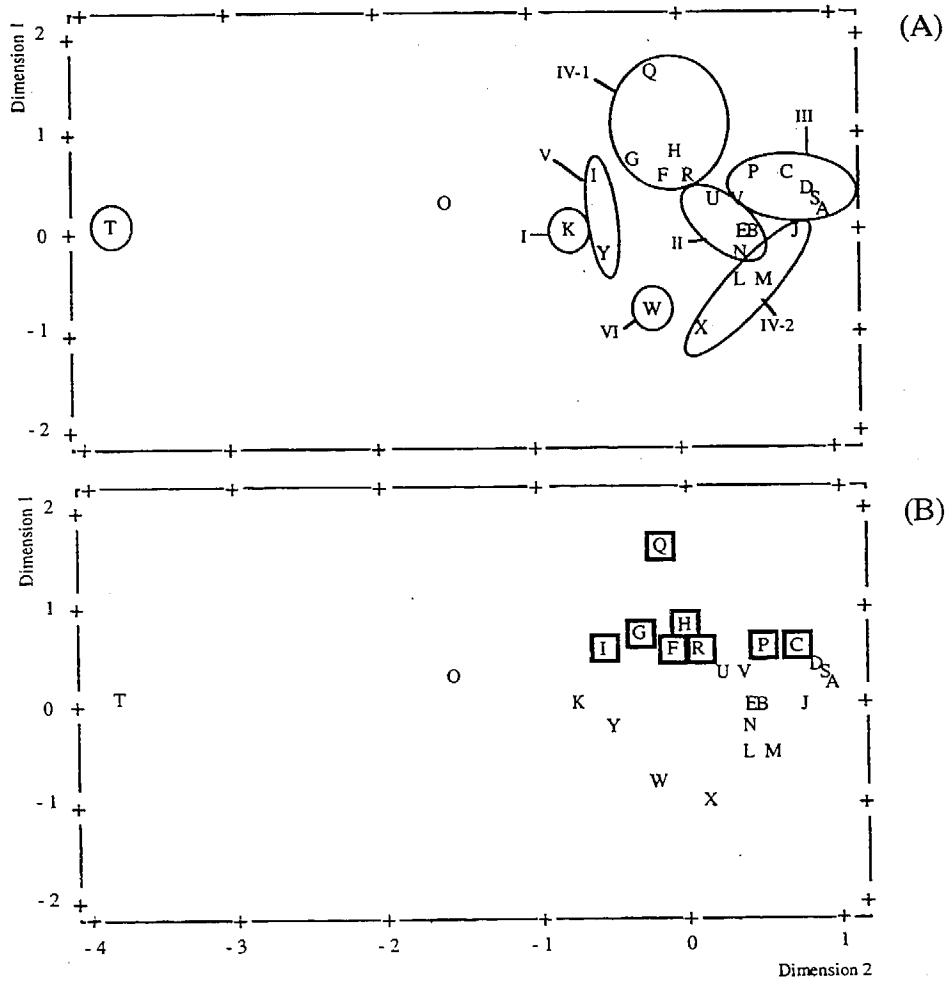


Figure 17. Multidimensional scaling (ms) ordination of site samples from San Diego Bay based on the abundance matrix of 198 macrobenthic species. (A) Clusters deliniated and numbered in Figure 15 dendogram are shown here as circled groups. (B) Qualitative assessment of the relation of chemistries >ERM levels (site codes surrounded by boxes) to ms biotic configuration.

displays the 2-dimensional representation resulting from multidimensional scaling, using the same matrix data applied to classification analysis. Letters surrounded by each circle represent the partitioned cluster groups delineated in the cluster hierarchy. The configuration was not altered when the outlier (T) was removed. The x- and y-axes represent scores for the first and second ordination axes. These scores are based on species diversity data and abundance and composition data.

When sites with chemistry values which exceeded ERM levels were assessed on the MDS plot in a qualitative, cursory manner as shown in Figure 17b (shown with squares), the sites clustered together. When interpreted along the axis gradient, these data suggested dimension 1 likely defined the pollution gradient, where the top quadrant within the plot identified the most contaminated sites (*i.e.*, Q or H). This is assuming the plot configuration is affected by toxic pollution alone and not by any organic enrichment. The y-axis may represent responses to a salinity gradient or change in sediment grain size. These analyses are especially revealing when environmental variables (*e.g*, TOC, grain size, water depth, total PAHs, individual metals, etc.) and biota are scaled together to determine which variables influence the configuration. However, even in the absence of these parallel plots, patterns are apparent from the correlations illustrated in other sections of this report.

Indicator Species

Despite the numerous studies performed in San Diego Bay, there have been no analyses of the fauna as bioindicators (SCCWRP-Diener, personal communication). Indicator species are assessed to determine which species are responsible for the separation of groups in classification and ordination analyses (Field *et al.*, 1982). Indicator species used in this study were selected on the basis of overall abundance in the San Diego Bay data set, literature review which determined distribution, known life histories and habitat preference, and discussions with ecologists experienced with Southern California marine biota and marine habitats. Species indicative of control or reference sites were derived from frequency of occurrence data. The presence or absence of specific polychaetes in sediments provided one valuable indication of the condition or health (Pocklington and Wells, 1992) of the benthic communities in San Diego Bay. The presence of *Capitella capitata* or *Streblospio benedicti*, in the absence of other species, is widely accepted as pollution indicators. Sensitive species like *Harmothoe imbricata* are represented at sites Carrier Base V2 and Mission Bay A8, and are typically found in uncontaminated areas. Additionally, *Nereidae* are accepted as indicators of early successional phases of environmental recovery (Pearson and Rosenberg, 1978) and are evident at site Carrier Base V2. *Mediomastus* polychaetes are found throughout the bay and have been considered to be identifiers of environmentally stressed areas. However, this species was found at the majority of sites. Another common species found in 16 out of 25 station samples was *Diplocirrus* sp.

which had not been found in previous studies in San Diego Bay (SCCWRP, personal communication). *Dipolocirrus* sp. was significantly ($p>0.05$) abundant at the Mission Bay A8 site. This unusual species is thought to have been introduced from the arctic region (G. Ruff, personal communication).

The benthic index discussed later was used to rank and calculate site partitions using the following indicator species: *Capitella capitata* (polychaete), *Armandia brevis* (polychaete), *Dorvillea longicornis* (polychaete), *Heterophoxus oculatus* (gammarid amphipod), and *Diastylis* sp. (cumacean). The polychaete worm *C. capitata* is widely accepted as a pollution indicator. *Diastylis* sp. ("sand-licker") feeds on nutrients adhered to sand grains and its presence indicates a relatively clean sample. Although it can tolerate moderately contaminated sediments, *H. oculatus* is a burrower and is considered an indicator of clean sediment.

One of the limitations in benthic community assessment is that patterns are more apparent where there is a strong gradient of pollutants, or when samples are selected from areas with distinctively low and high pollutant signals. There are limitations to what can be surmised from analyses of abundance of specific species, and selection of indicator species are highly site specific (Swartz *et al.*, 1985). However, these species, combined with information from ordination and other supplemental analyses, make it apparent that these are important as ecologically relevant data. Many species used to assess environmental quality are used because they respond quickly to changes in environmental conditions. (Pocklington and Wells, 1992). Therefore, a station designated in the initial phases of sample collection as a having reference conditions, based on toxicity test or chemical analysis results, could be removed from the reference station list based on subsequent benthic community analyses.

Benthic Index

Benthic communities, and occasionally single benthic species, have been used to elucidate the severity of human disturbance to nearshore marine and estuarine environments. It is possible to develop a comparable disturbance classification for species and use a simple numerical infaunal index with these species. Distinct pollution gradients are rare in most embayments because of confounding environmental gradients and historical changes. Still, an index has the best potential to quantitatively assess benthic community responses to disturbance. Some benthic indices are based on *a priori* information and are developed using test sites representing the extremes within a range of environmental conditions which adversely affect benthos. In contrast, the index developed and used in this study was based solely on information which characterized the benthic community, such as specific indicator species and community parameters (species richness, abundance, presence of pollution indicator species, etc.). This elementary index approach may be best for this study because San Diego Bay encompasses a variety of habitats, each of which may

require a very specific set of index variables (SCCWRP-Diener, personal communication). Note that identification of degraded and undegraded sites here resulted from evaluation of a limited data set, without site comparison to an existing known reference. The index was used within this limited data set to designate the partition between degraded, undegraded and transitional areas.

Site and Station Application of Benthic Index

Table 10 shows the results of benthic index application to data from sampling sites in legs 20-23. Sites (25 sites with 5 replicates each) were ranked and partitioned into 9 degraded, 3 undegraded and 13 transitional sites using 8 biotic parameters. Due to spatial differences in sampling of the benthic replicates at the 25 sites, the benthic index was also applied to individual stations (n=75). When benthic community structure was evaluated "by site", 5 replicates were used. Replicates 1, 2 and 3 were sampled at numbered stations locations (Table 6) where associated toxicity and chemistry data could be directly compared. When later analyses were expanded to a "by station" evaluation, the 4th and 5th replicates were not included in the per station assessment. These replicates were randomly sampled within the "site" for benthic community analysis only and did not receive synoptic chemistry and toxicity analysis. While the results did not alter the degraded and undegraded determination of sites assessed "by site", it did separate stations within the initial "transitional" status into one of the three categories (*e.g.*, degraded, transitional or undegraded). Station analyses heavily emphasized benthic index, amphipod abundance, species diversity and crustacean numbers.

As part of analytical procedure, the BPTCP Scientific Planning and Review Committee (SPARC) recommended additional emphasis on the use of amphipod abundance and overall species diversity as indicators of degraded and undegraded areas. These parameters were assessed and incorporated into the "station evaluation" versions of the benthic index. Species number and abundance of amphipods were calculated from the proportions of total species and total individuals, respectively. The resultant categorization of stations into one of the three partitions (*e.g.*, degraded, transitional, undegraded) did not change, so the assessment of amphipods further supported the partition derived from previous analyses. The density of all amphipods was significantly more abundant at the following stations: West Basin (90050, 93199, 93200), East Basin (90001, 93201), Downtown Anchorage (93221, 93222), Coronado Cays (90053, 93203), Sweetwater Channel (93220), Mission Bay A8 (93112), Carrier Base V2 (90025) and Grape St. Stormdrain (90037). No amphipods were found at stations 14 Downtown Piers (90003), Naval Base O7 (93212), Naval Base/SY O10 (93223, 93224), Naval Base/SH O13 (93225, 93226), 7th St. Channel Q1 (90009, 93227, 93228), Marine Terminal R3 (93229), K Swartz Naval Base O4 (93210), Sub Base C2 (93216, 93217), and Naval Base O12 (93215). Stations with abundant amphipods but dominated by *Grandidierella japonica* were evaluated with caution, because *G. japonica* has been found to be tolerant of high

Table 10. Results of Benthic Index application on San Diego Bay data. Benthic community condition based on mean abundance of 5 replicate samples per site. Community status indicates allocation of a station to an Index partition: 2-undegraded sites, 1=transitional sites, 0=degraded sites.

SITES (5 replicates)	Community Status	SITES (5 replicates)	Community Status
10 Swartz (West Basin)	1	35 Swartz (Coronado Cays)	1
11 Swartz (East Basin)	2	37 Swartz (Marina)	2
12 Swartz (Downtown Anch)	1	41 Swartz (Glorietta Bay)	1
14 Swartz (Downtown Piers)	0	K Swartz (Naval Base 04)	1
15 Swartz (G St Pier Marina)	1	Mission Bay A3	1
16 Swartz (Intercont. Marina)	1	Mission Bay A4	1
23 Swartz (Naval Base 07)	0	Mission Bay A8	2
25 Swartz (Naval base/ SY 010)	0	NSB-M1 (Sub Base C2)	0
27 Swartz (Naval Base /SH 013)	0	P Swartz (Naval Base 012)	0
28 Swartz (7th St Channel Q1)	0	San Diego River B1	0
31 Swartz (Marine Terminal R3)	1	SDNI- N5 (Carrier Base V2)	1
32 Swartz (Sweetwater Ch)	1	Stormdrain EM (Grape St.)	1
34 Swartz (CV Yacht Basin)	0		

sediment toxicity (Slattery and Swartz, personal communication). Final benthic community evaluation of 75 stations (Table 11) resulted in the designation of 23 undegraded, 43 degraded and 9 transitional stations. A map of the distribution of degraded, transitional and undegraded stations is shown in Figure 18(a-d). Degraded stations were found at the submarine base in North San Diego Bay. Commercial shipping, storm drainages and the naval shipyard waterfronts all had degraded communities in the Mid San Diego Bay. In South San Diego Bay, industrial and small boat locations exhibited benthic community degradation. In Mission Bay the stations near Rose Inlet and in the San Diego River were found to be degraded.

Chemically clean sites, as determined by ERM and PEL summary quotients and lack of ERM and PEL guideline exceedances, were reexamined to expand the undegraded list from possible "borderline" transitional stations. Stations 93194 and 93231 appropriately fit this category (Table 4) and were used as undegraded stations in the construction of the reference envelope for toxicity determination, discussed earlier.

As shown earlier in Figure 14, the relationship between benthic community conditions and elevated chemical conditions (as determined by using ERM and PEL Summary Quotients) was quite dramatic. Benthic communities were always found to be degraded when chemical levels were elevated (ERMQ>0.85), where both analyses were performed at a station.

Distribution Of Toxicity

The results of all toxicity tests conducted as part of this study are presented in tables in Appendix D. These tables show means and standard deviations for each toxicity test response (e.g. percent survival of amphipods; percent normal development of larval sea urchins) for three to five replicates of each sample tested. Associated ammonia and hydrogen sulfide concentrations are also presented in Appendix D.

Toxicity Testing Quality Assurance/Quality Control Evaluation

All toxicity test data produced for this report were evaluated for acceptability using the Quality Assurance guidelines described in the BPTCP Quality Assurance Project Plan (QAPP; Stephenson *et al.*, 1994). Toxicity data reported here met all test acceptability standards for each protocol, with the following exceptions. Of the solid phase tests with amphipods, two samples (Station 93120- IDORG# 702 and Station 93107- IDORG# 721) were tested with only one laboratory replicate, due to a lack of sufficient sample volume. Survival in those two samples was 90% and 85%, respectively, indicating a lack of toxicity. All amphipod samples tested in Leg 15 (Appendix D) have the following QA qualification. The test protocol requires five replicates of a control sample to be tested concurrently with test samples. In some early sampling legs of this study, 15 laboratory replicates of the control sediment were tested, to

Table 11. Benthic Index results showing the recalculation of San Diego Bay data based on individual stations. Replicates 4 and 5 in the site evaluation were not included (see text). Community status indicates allocation of a station to an Index partition: 2=undegraded stations, 1=transitional stations, 0=degraded stations.

IDORG	Station #	Station name	Community Status	IDORG	Station #	Station name	Community Status	IDORG	Station #	Station name	Community Status
837	90050	10 Sw (West Basin)	2	892	93226	27 Sw (Naval Base /SH 013)	0	854	93107	Mission Bay A3	0
838	93199	10 Sw (West Basin)	2	893	90009	28 Sw (7th St Channel Q1)	0	855	93107	Mission Bay A3	1
839	93200	10 Sw (West Basin)	2	894	93227	28 Sw (7th St Channel Q1)	0	859	93108	Mission Bay A4	1
840	90001	11 Sw (East Basin)	2	895	93228	28 Sw (7th St Channel Q1)	0	860	93108	Mission Bay A4	2
841	93201	11 Sw (East Basin)	2	896	90010	31 Sw (Marine Terminal R3)	0	861	93108	Mission Bay A4	1
842	93202	11 Sw (East Basin)	2	897	93229	31 Sw (Marine Terminal R3)	0	856	93112	Mission Bay A8	2
878	90002	12 Sw (Downtown Anch)	0	898	93230	31 Sw (Marine Terminal R3)	0	857	93112	Mission Bay A8	2
879	93221	12 Sw (Downtown Anch)	2	875	90052	32 Sw (Sweetwater Ch)	1	858	93112	Mission Bay A8	2
880	93222	12 Sw (Downtown Anch)	2	876	93219	32 Sw (Sweetwater Ch)	1	871	90028	NSB-M1 (Sub Base C2)	0
846	90003	14 Sw (Downtown Piers)	0	877	93220	32 Sw (Sweetwater Ch)	0	872	93216	NSB-M1 (Sub Base C2)	0
847	93205	14 Sw (Downtown Piers)	0	824	90012	34 Sw (CV Yacht Basin)	0	873	93217	NSB-M1 (Sub Base C2)	0
848	93206	14 Sw (Downtown Piers)	0	825	93196	34 Sw (CV Yacht Basin)	0	868	90022	P Sw (Naval Base 012)	0
849	90004	15 Sw (G St Pier Marina)	0	826	93197	34 Sw (CV Yacht Basin)	0	869	93214	P Sw (Naval Base 012)	0
850	93207	15 Sw (G St Pier Marina)	0	843	90053	35 Sw (Coronado Cays)	2	870	93215	P Sw (Naval Base 012)	0
851	93208	15 Sw (G St Pier Marina)	0	844	93203	35 Sw (Coronado Cays)	2	881	93116	San Diego River B1	0
818	90051	16 Sw (Intercont. Marina)	1	845	93204	35 Sw (Coronado Cays)	0	882	93116	San Diego River B1	0
819	93192	16 Sw (Intercont. Marina)	1	815	90013	37 Sw (Marina)	2	883	93116	San Diego River B1	0
820	93193	16 Sw (Intercont. Marina)	1	816	93190	37 Sw (Marina)	2	899	90025	SDNI- N5 (Carrier Base V2)	2
865	90006	23 Sw (Naval Base 07)	0	817	93191	37 Sw (Marina)	2	1000	93231	SDNI- N5 (Carrier Base V2)	2
866	93212	23 Sw (Naval Base 07)	0	821	90015	41 Sw (Glorietta Bay)	1	1001	93232	SDNI- N5 (Carrier Base V2)	2
867	93213	23 Sw (Naval Base 07)	0	822	93194	41 Sw (Glorietta Bay)	2	827	90037	Stormdrain EM (Grape St.)	0
887	90007	25 Sw (Naval base/ SY 010)	0	823	93195	41 Sw (Glorietta Bay)	2	828	90037	Stormdrain EM (Grape St.)	0
888	93223	25 Sw (Naval base/ SY 010)	0	862	90021	K Sw (Naval Base 04)	0	829	90037	Stormdrain EM (Grape St.)	2
889	93224	25 Sw (Naval base/ SY 010)	0	863	93210	K Sw (Naval Base 04)	0				
890	90008	27 Sw (Naval Base /SH 013)	0	864	93211	K Sw (Naval Base 04)	0				
891	93225	27 Sw (Naval Base /SH 013)	0	853	93107	Mission Bay A3	0				

Figure 18a
Benthic Community Analyses
North San Diego Bay

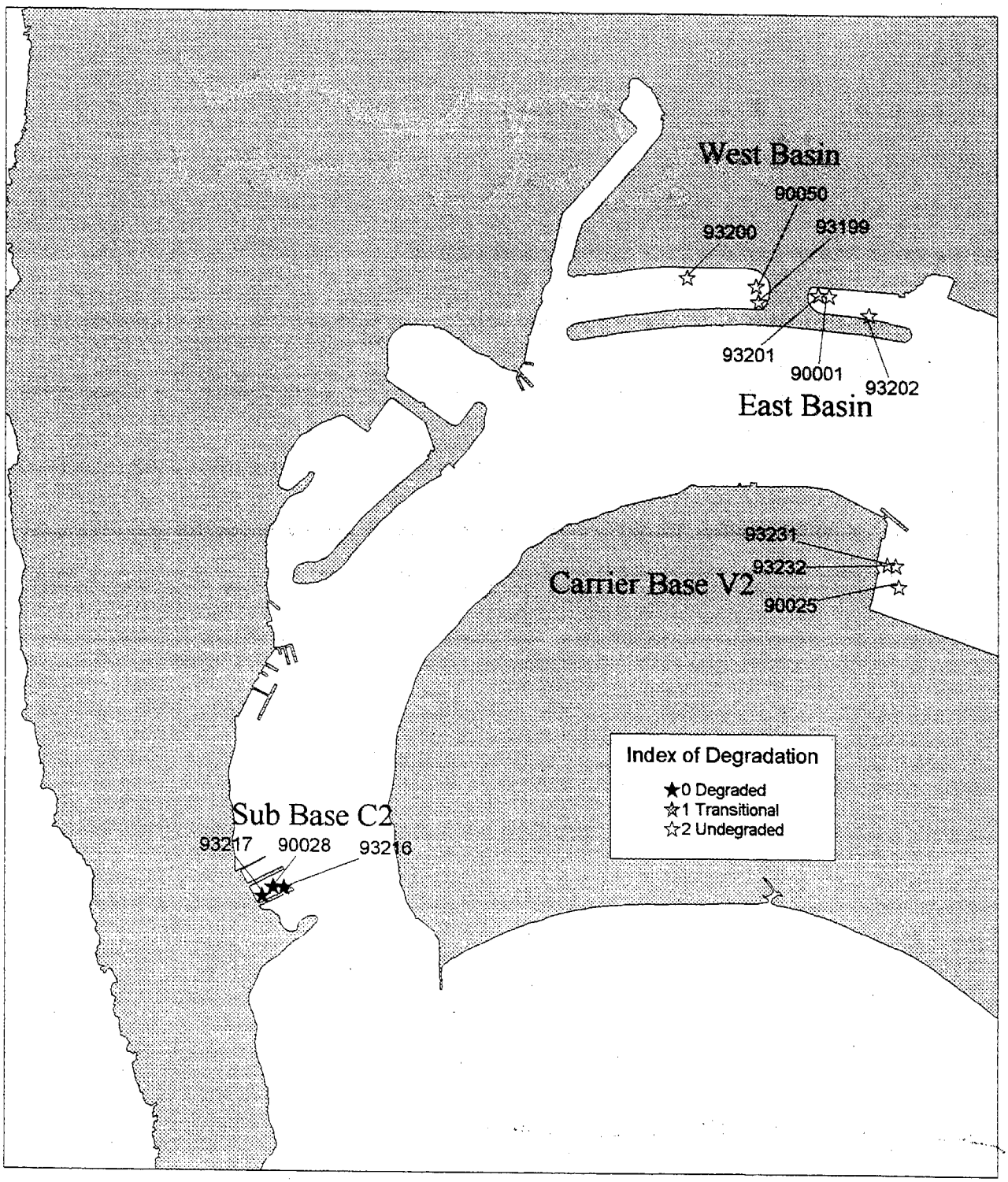


Figure 18b
Benthic Community Analyses
Mid San Diego Bay

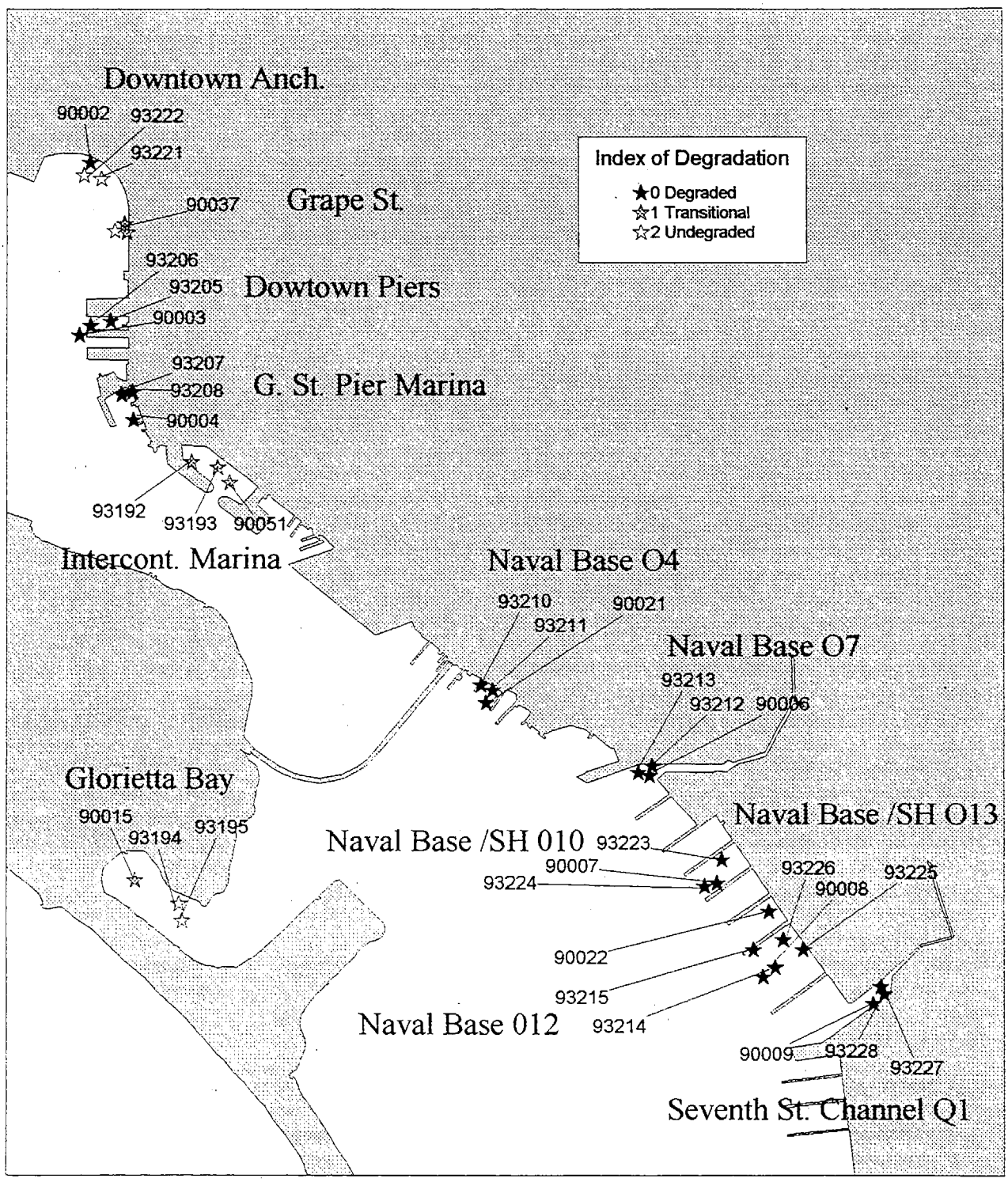


Figure 18c
Benthic Community Analyses
South San Diego Bay

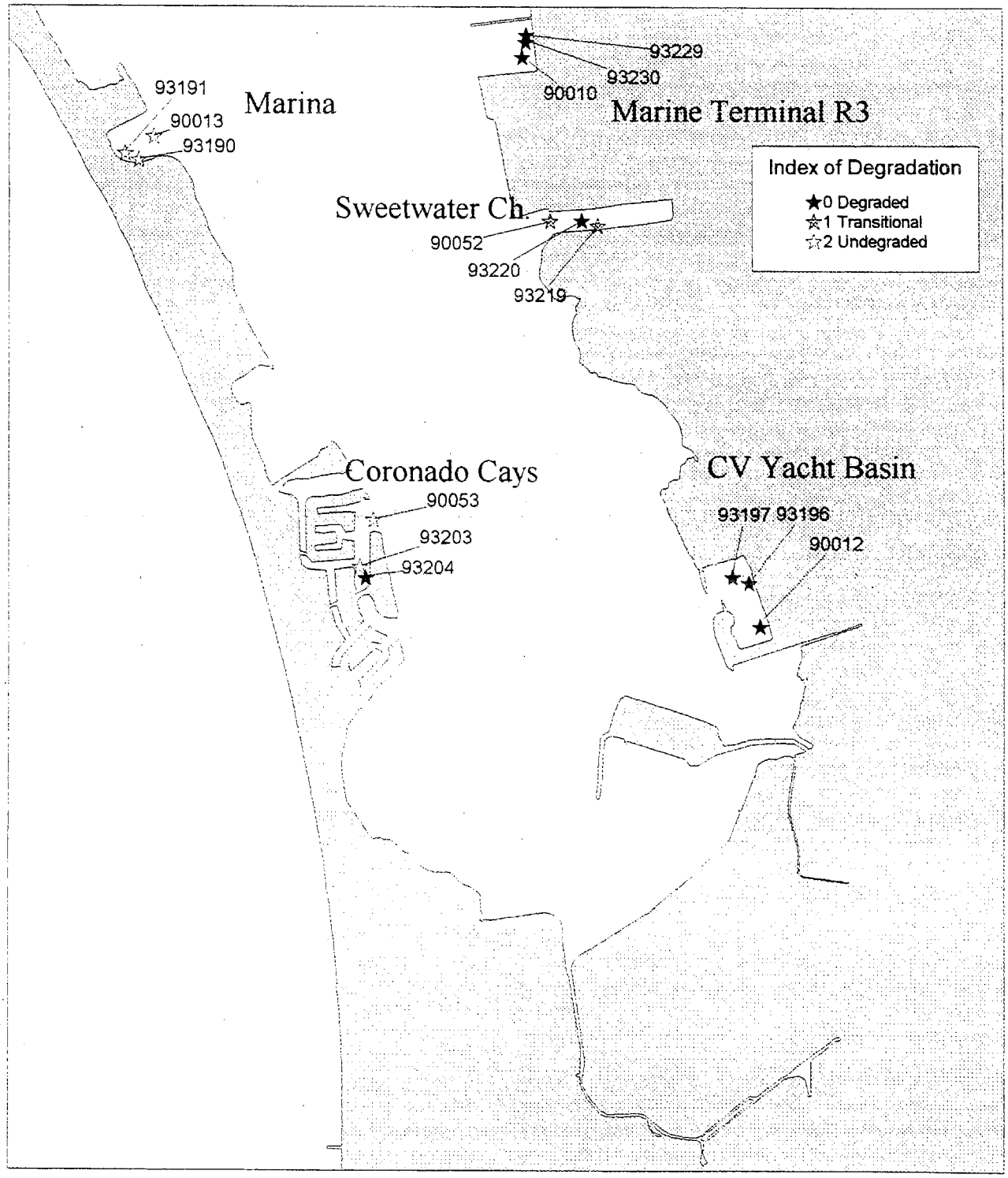
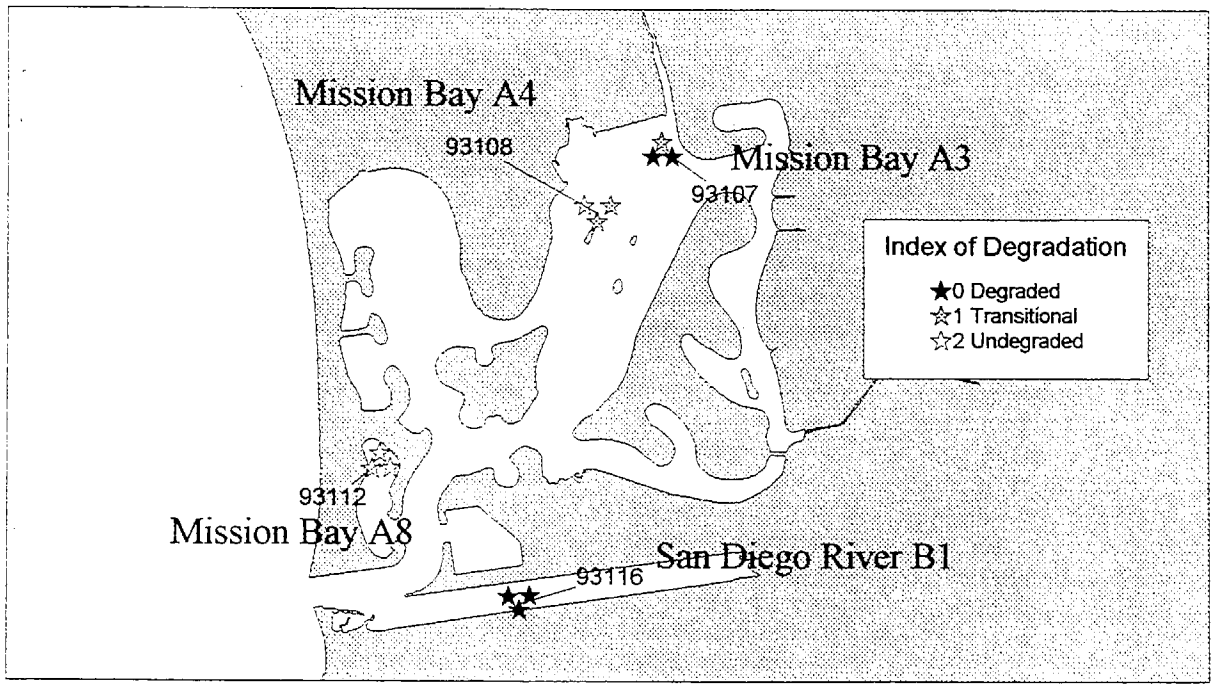


Figure 18d
Benthic Community Analyses
Mission Bay and San Diego River Estuary



allow use of alternative statistical procedures. Of the fifteen control replicates in Leg 15, two had 75% survival, which is below the 80% criterion given in the protocol. In tests using the *Neanthes arenaceodentata* (hereafter *Neanthes*) protocol on solid phase sediments, all samples tested in Leg 21 used sediment that was held in the laboratory three days beyond the fourteen-day specified holding time. These QA exceptions in solid phase tests have been judged by the toxicity project officers to not adversely affect interpretation of toxicity results. These and lesser departures from acceptable standards are recorded in the Quality Assurance Evaluative Reports accompanying each dataset for this study. Quality Assurance Evaluative Reports for toxicity testing are available for review from the SWRCB. Minor departures not mentioned above included elevated dissolved oxygen measurements in overlying water and other variations in water quality measurement that were considered to have little probability of affecting the outcome of the respective toxicity test.

There were no deviations from quality assurance criteria, other than minor deviations in measurement of water quality parameters as cited above, in any of the abalone, mussel, or sea urchin larval development tests in pore water or water column samples (subsurface water).

Sea urchin fertilization tests were conducted on over 300 pore water samples. Many of these were retested because of poor response in brine controls. Bay *et al.* (1993) discussed commonly observed problems using the *Strongylocentrotus purpuratus* (hereafter *Strongylocentrotus*) fertilization test in samples requiring salinity adjustment with hypersaline brine. Through numerous repeated tests, acceptable brine control results were produced for all but one sample. However, as described in BPTCP QA reports to the SWRCB, an additional control for the storage effects of frozen pore water samples in Teflon bottles was included in later tests. These additional controls, which were not required by the original QAPP, indicated that toxicity may be associated with frozen sample storage in Teflon bottles. Because all pore water samples for fertilization tests were stored frozen in Teflon bottles, we have no assurance the data from any of these fertilization tests is truly indicative of sample toxicity. Any toxicity observed in the fertilization tests may be wholly or partially due to storage effects. For this reason, we retested all samples from legs 15-23 with the sea urchin larval development test, unless those samples had already been tested with the development test. The urchin larval development test has been unaffected by storage artifacts, as indicated by response in frozen storage bottle controls. While sea urchin fertilization data are reported in Appendix D, they were not used in any further data analysis for this report. The use of fertilization data, for determination of toxicity, was therefore not considered prudent considering the possibility of false positive results related to sample storage.

Areal Extent of Toxicity Based on the EMAP Approach

The Cumulative Distribution Frequency (CDF) analyses indicated that 56% of the total area sampled was toxic to *Rhepoxynius abronius* (hereafter *Rhepoxynius*) (Table 12, Figure 19). The sea urchin larval development test of undiluted (100%), 50%, and 25% pore water indicated 74%, 54%, and 29% percent of the total study area was toxic, respectively (Table 12, Figure 20). A number of samples were toxic to both sea urchins and amphipods. Samples representing 36%, 27%, or 14% of the study area were toxic to *Rhepoxynius* in solid phase sediment and to sea urchin larvae in 100%, 50%, or 25% pore water, respectively. The percentage of area toxic was based on comparisons with laboratory controls using the EMAP statistical approach described in the methods section. These analyses utilized data from random stations within the stratified sampling blocks, and did not include data from stations utilizing the non-random, directed sampling design (Figure 21a-d, Figure 22a-d).

The curves on the CDF plots indicate the magnitude of toxicity throughout the Region. Each point on the CDF plot represents a single sample. The distribution of the amphipod data (Figure 19) show there were few samples with survival less than 40%, a greater number of samples with survival between 40% and 80%, and about half of all samples with survival greater than 80%. NOAA surveys of Tampa Bay, Florida and EMAP surveys of the Mid-Atlantic coast region (Virginian Province) produced CDF curves for amphipod mortality data further right on the scale and much steeper than the San Diego Bay Region plot, and had more than 90% of samples with greater than 90% survival in both regions (Long *et al.*, 1994; Schimmel *et al.*, 1991).

The CDF plot of San Diego Bay Region sea urchin larval development test data (Figure 20) shows a cluster of samples with 0% normal larval development, a smaller number of samples with intermediate response, and a cluster of samples with percent normal development roughly equal to that observed in controls. The 25% pore water dilutions had a majority of samples resulting in percent normal larval development roughly equal to controls. As pore water concentration increased to 50% and 100% pore water, the distribution of samples shifted toward the more toxic end of the scale, and the 100% pore water tests had a majority of samples resulting in 0% normal larval development. A similar pattern was observed in sea urchin fertilization tests of pore water from Tampa Bay, Florida (NOAA, 1994). As with the amphipod data, the San Diego distribution is shifted further to the left, indicating higher overall toxicity observed from San Diego Bay Region samples.

Toxicity Based on Reference Envelope Approach

Using the *Rhepoxynius* data and a p-value of 1%, a lower reference envelope tolerance bound of 48% survival was calculated, indicating that samples with survival values below 48% are significantly more toxic than samples representative of less

Table 12. Percent of total area sampled determined to be toxic with each toxicity test protocol. Sample toxicity is based on the EMAP statistical approach using two criteria for any given sample: significant difference from the control using a separate variance t-test and an alpha of 0.05 and a sample mean value less than 80% of the control value. Calculations for cumulative distribution frequency (CDFs) used to compute the percent of area toxic are explained in text and presented in Appendix F. Total study area was 47 square kilometers.

Toxicity Test and Pore Water Dilution	**Percent of Total Area Determined to be Toxic**
Rhepoxynius abronius Survival in Solid Phase	56%
Strongylocentrotus purpuratus Development in:	
100% (undiluted) Pore Water	74%
50% Pore Water	54%
25% Pore Water	29%

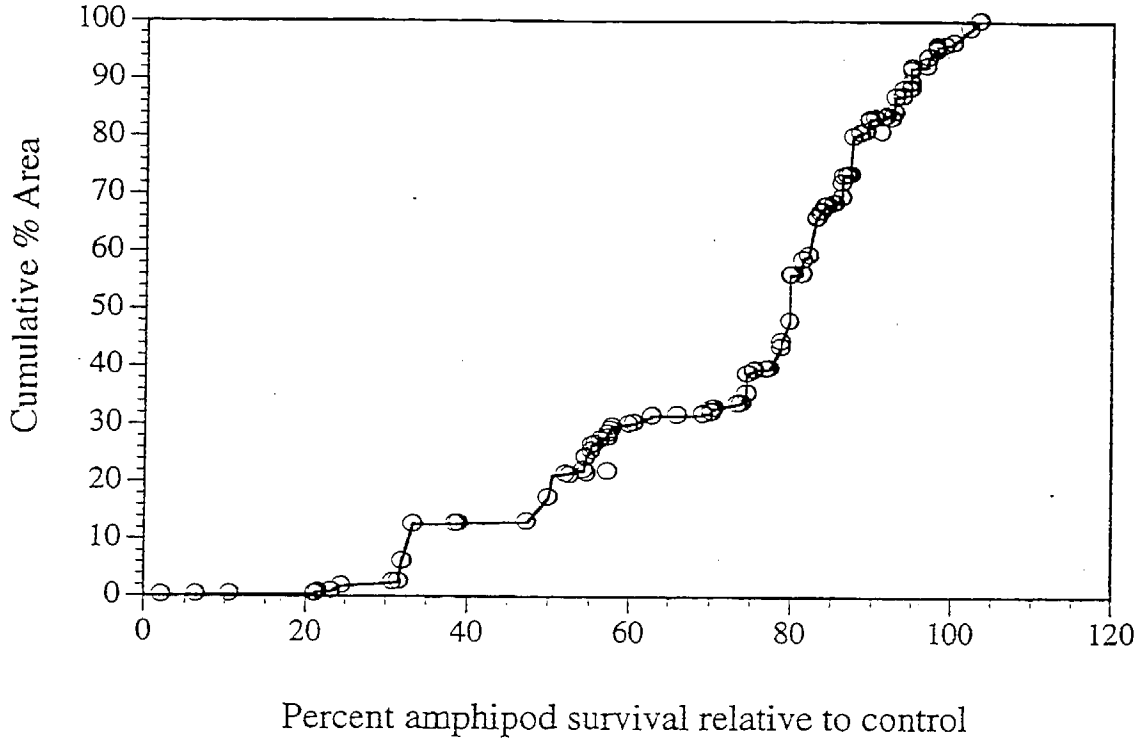


Figure 19. Cumulative distribution frequency of percent *Rhepoxynius* survival against percent of total area sampled. Data points correspond to individual samples.

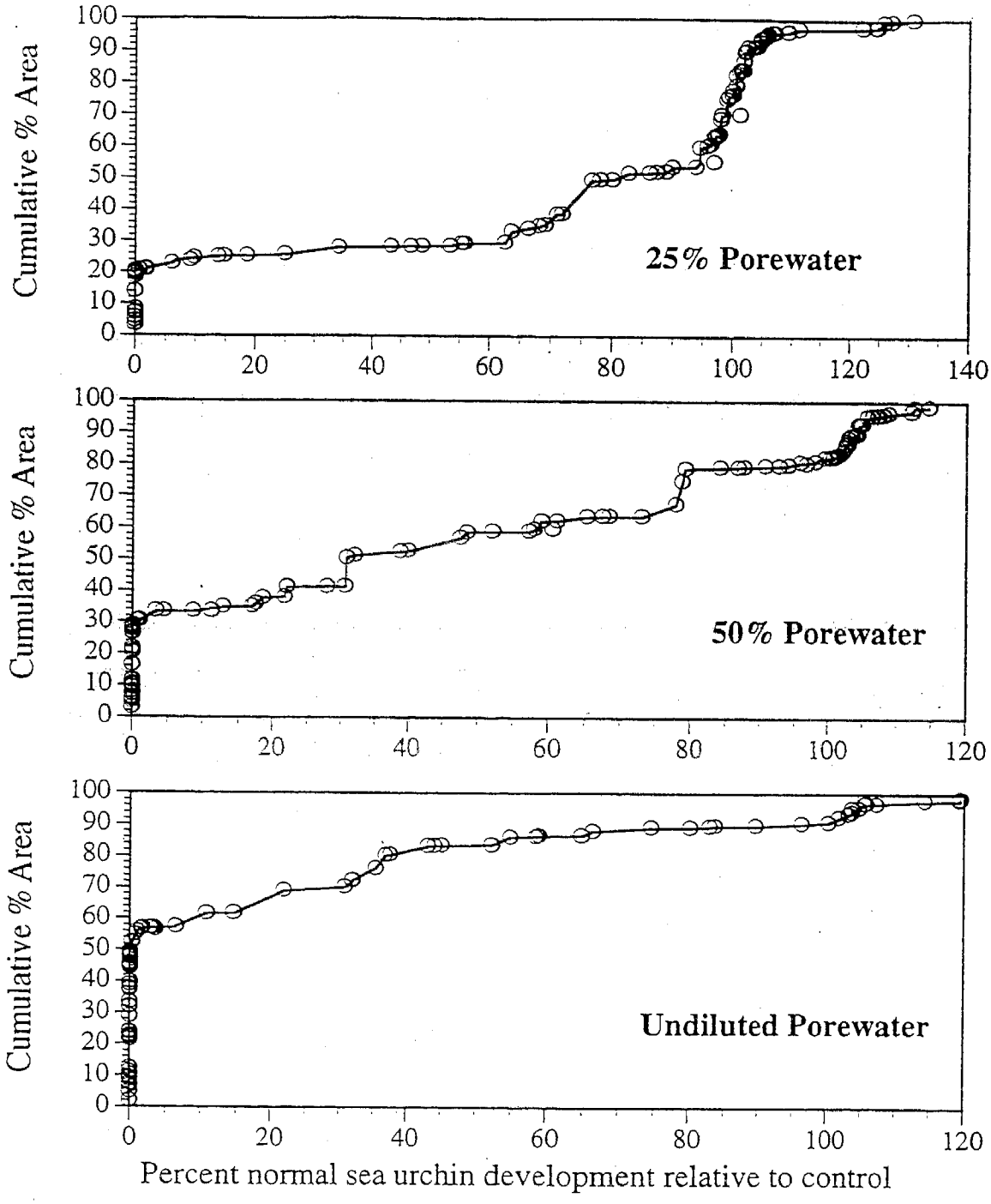


Figure 20. Cumulative distribution frequency of percent normal sea urchin larval development in 25%, 50%, and undiluted porewater against percent of total area sampled. Data points correspond to individual samples.

Figure 21a
Amphipod Toxicity Using Lab Controls for Randomly Sampled Stations North San Diego Bay

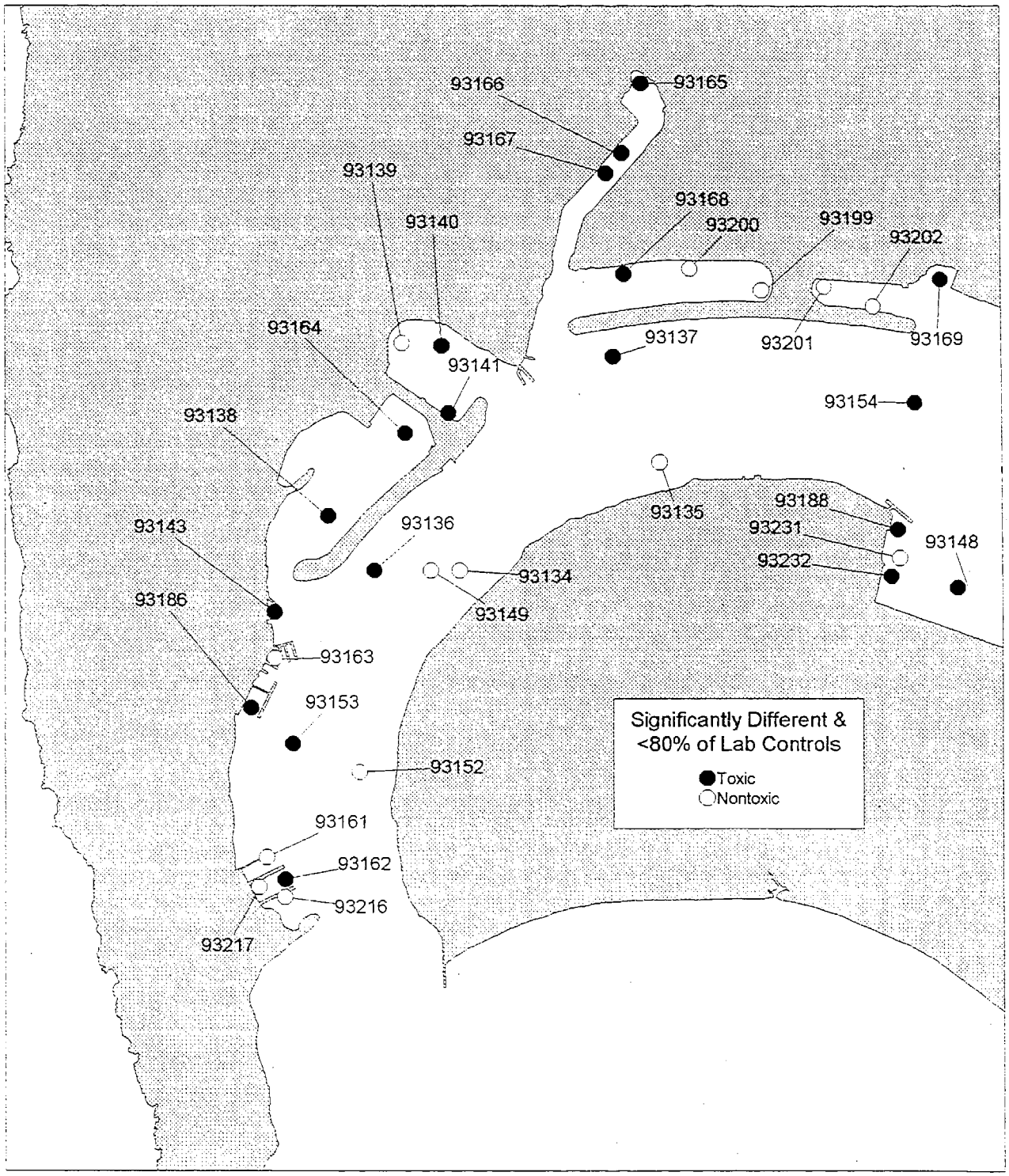


Figure 21b
Amphipod Toxicity Using Lab Controls for Randomly Sampled Stations Mid San Diego Bay

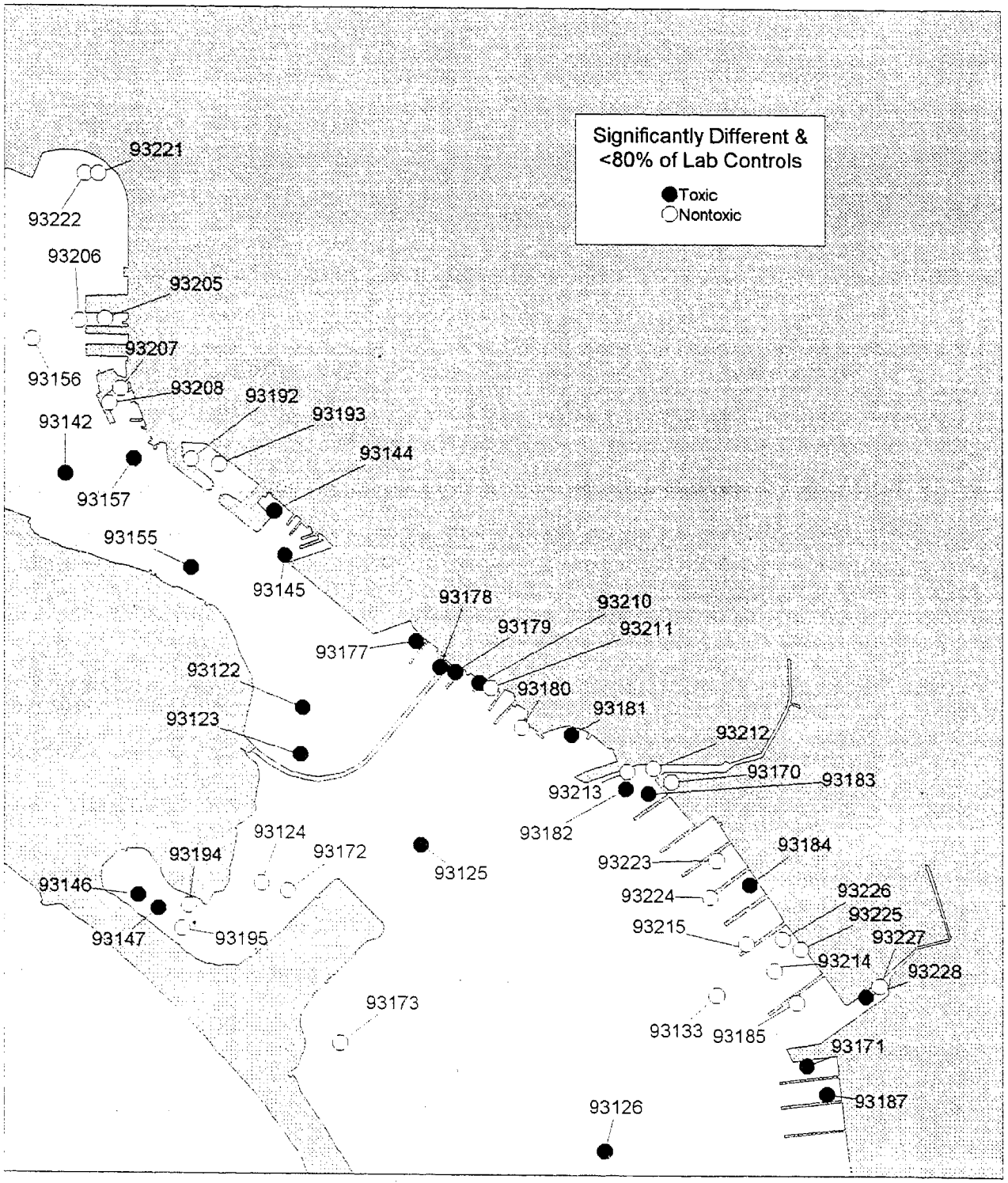


Figure 21c
Amphipod Toxicity Using Lab Controls for Randomly Sampled Stations South San Diego Bay

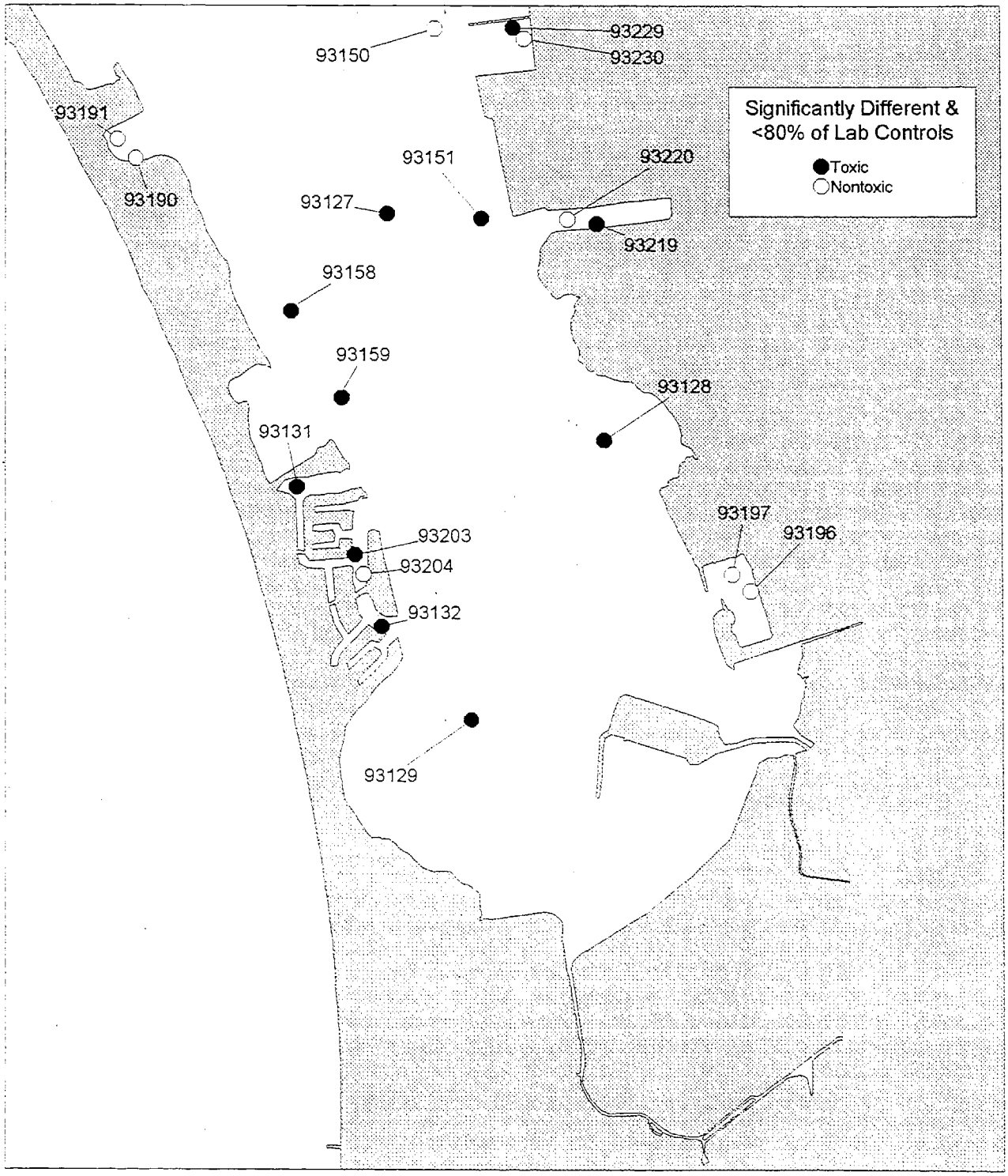
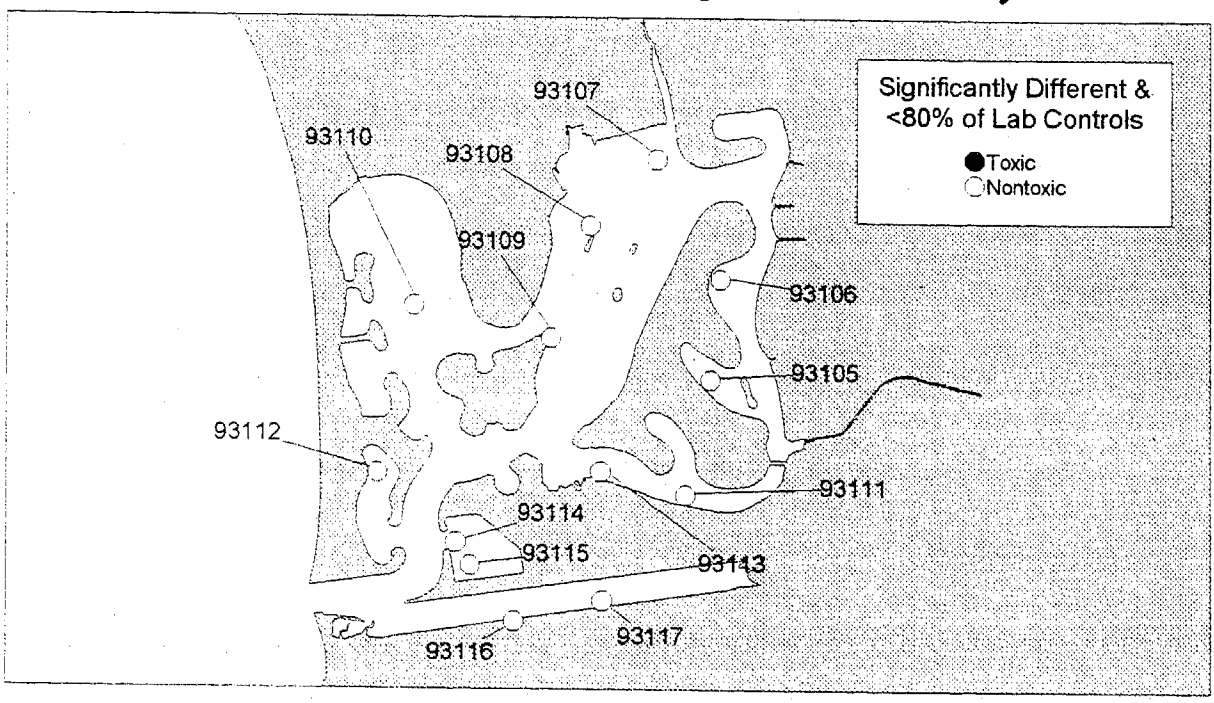


Figure 21d
Amphipod Toxicity Using Lab Controls for Randomly Sampled Stations Mission Bay and San Diego River Estuary



Tijuana River Estuary

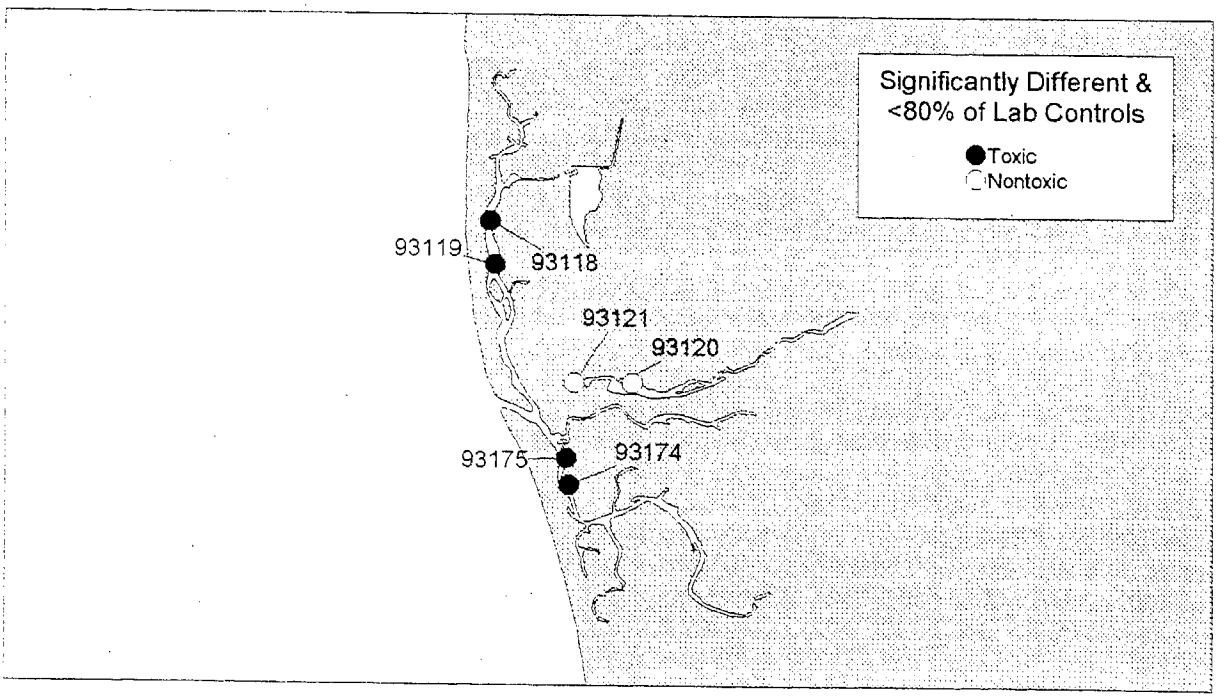


Figure 22a
Urchin Development Toxicity Using Lab Controls for Randomly Sampled Stations North San Diego Bay

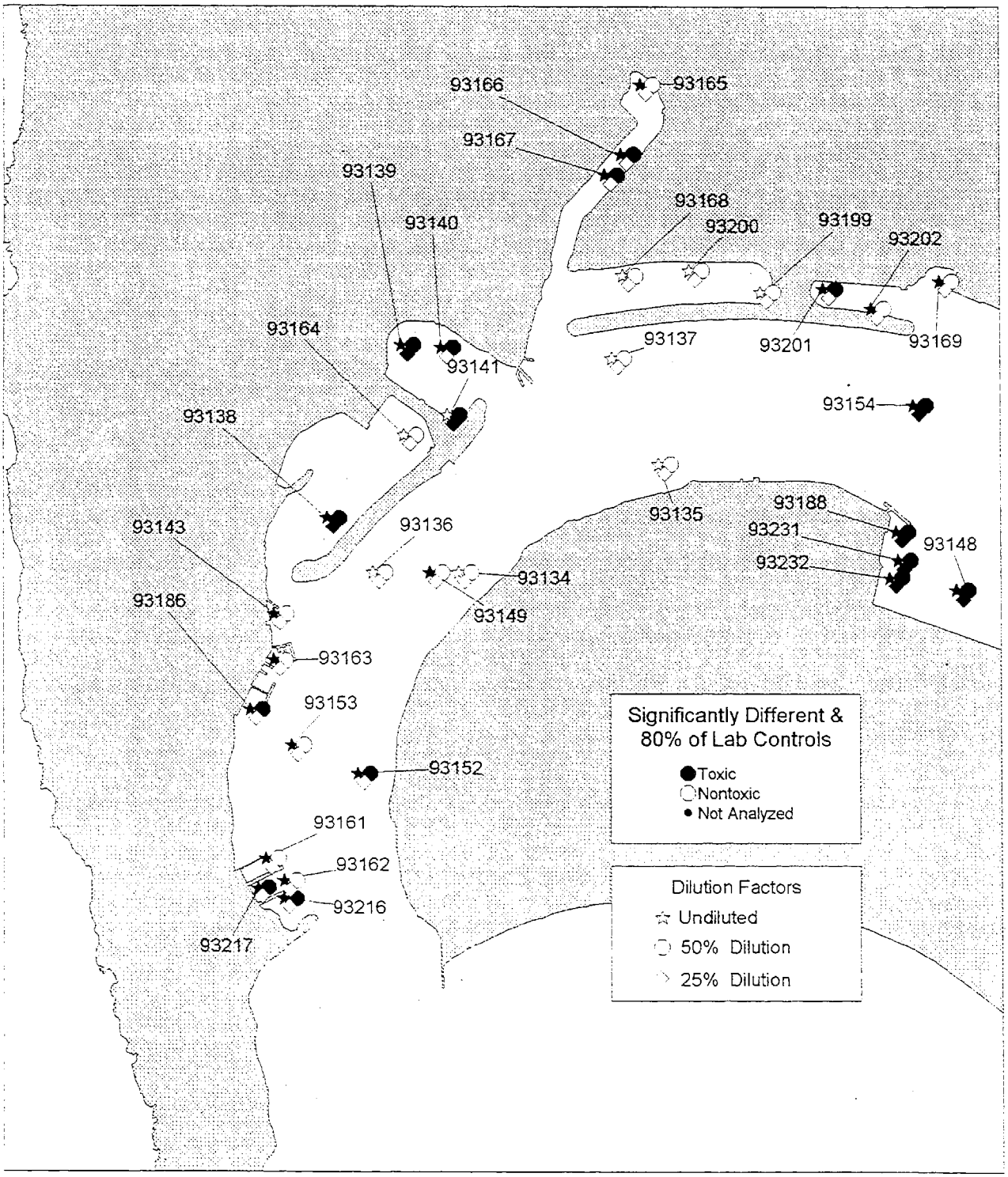


Figure 22b
Urchin Development Toxicity Using Lab Controls for Randomly Sampled Stations Mid San Diego Bay

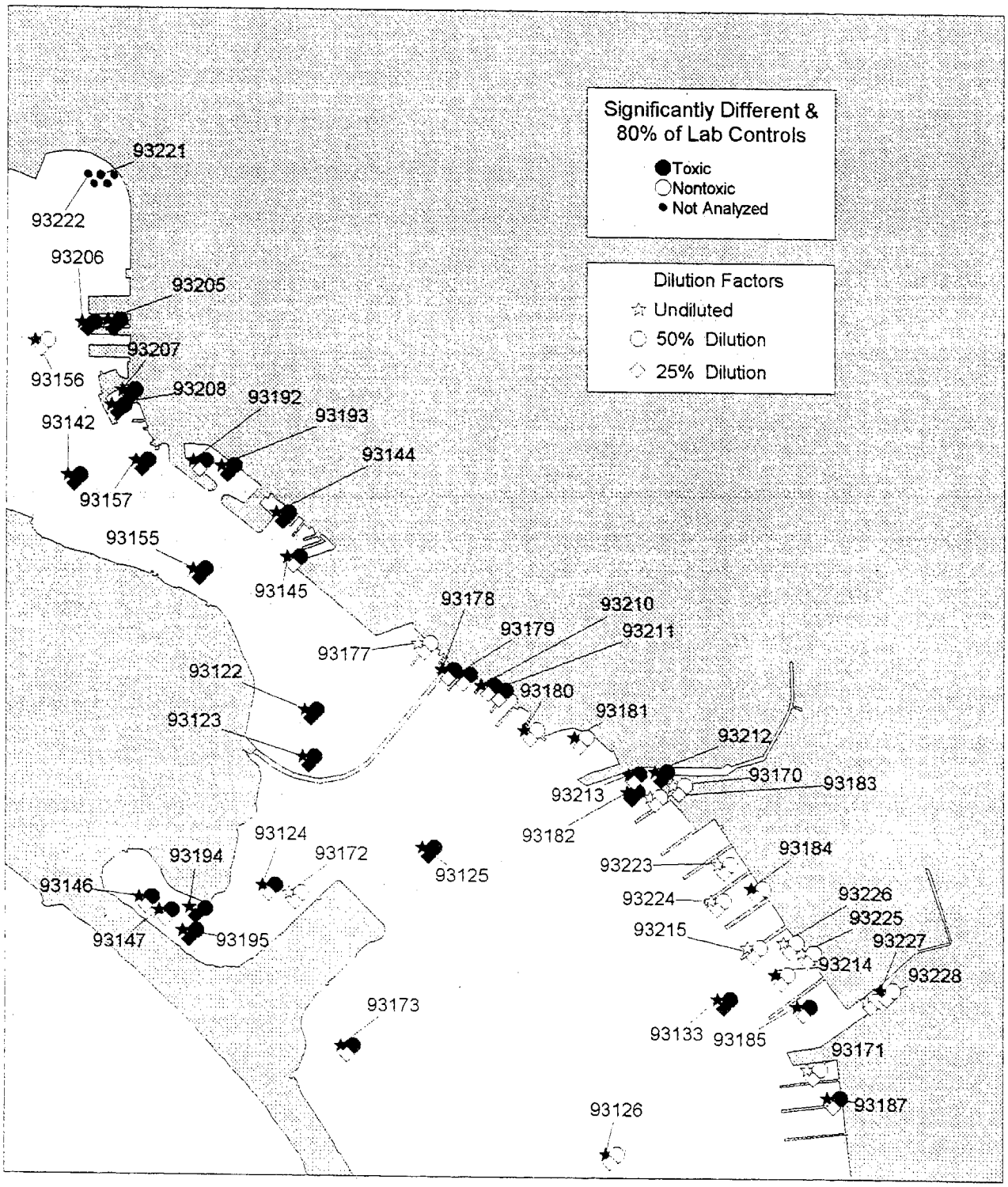


Figure 22c
Urchin Development Toxicity Using Lab Controls for Randomly Sampled Stations South San Diego Bay

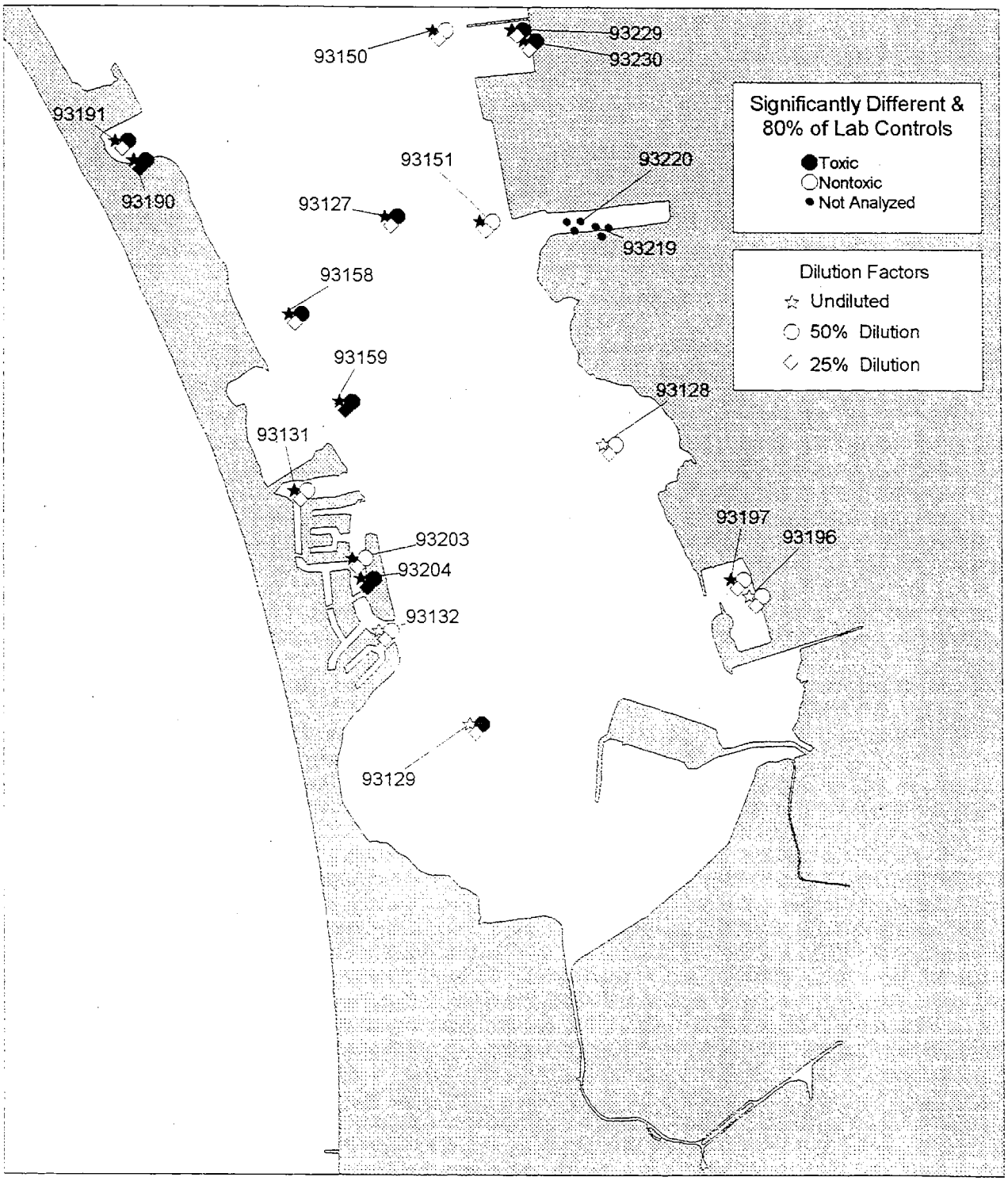
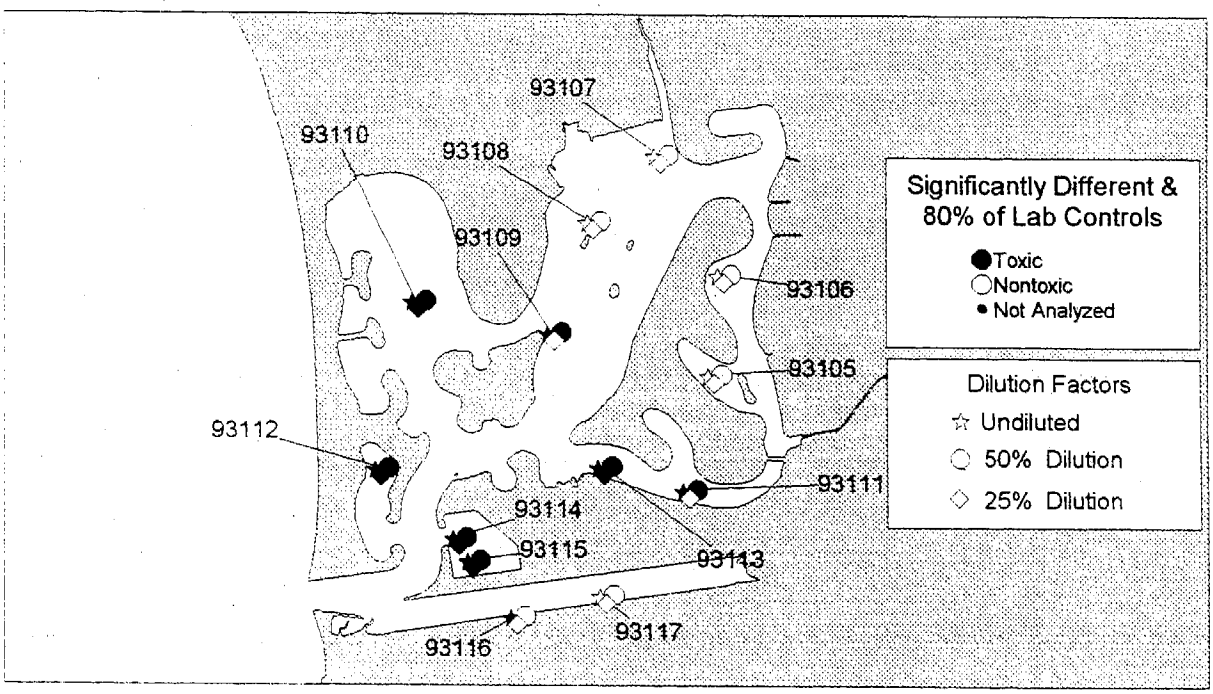
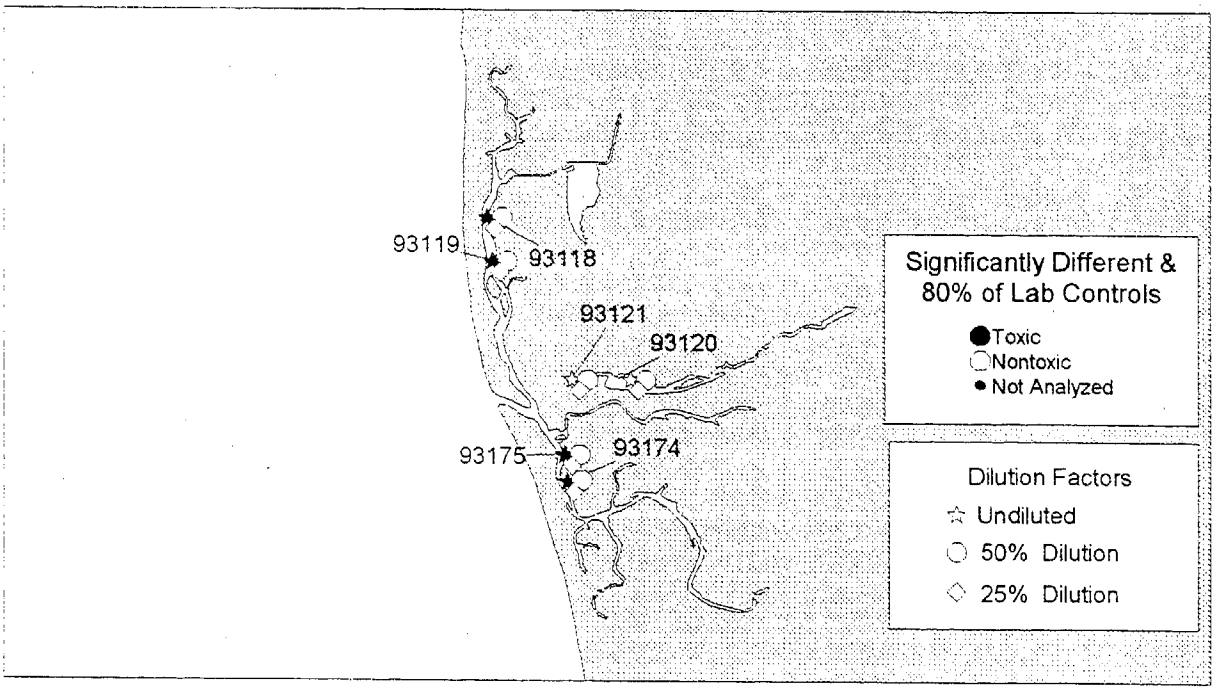


Figure 22d
Urchin Development Toxicity Using Lab Controls for Randomly Sampled Stations Mission Bay and San Diego River Estuary



Tijuana River Estuary



contaminated ambient conditions in the San Diego Bay Region. There is a 95% probability that samples with survival values less than 48% are more toxic than the most toxic 1% of samples from the reference site population. Of 350 samples tested with the *Rhepoxynius* test (from both random and non-randomly selected stations), 61 samples were found to be toxic using the reference envelope analysis (Figure 23a-d). Toxicity based on the reference envelope approach is used later in this report for prioritizing stations of concern.

Strongylocentrotus pore water data from reference stations produced a lower mean value and greater variability than was found for the amphipod solid phase data (Table 4). The variability in pore water data from sea urchin larval development tests produced a reference site distribution extending across the range from 0 to 100% normal development. A p-value of 1% (see Methods Section) produced a tolerance bound (reference envelope edge) which was below zero, indicating no distinctions could be made between reference and toxic stations. The high degree of variability in the pore water results from the reference sites may be related to the sensitivity of this test to measured or unmeasured toxicants, and/or may reflect artifacts related to pore water extraction and handling. Potential artifacts and sources of variability related to pore water testing are discussed below.

Comparison of Toxicity Test Protocols

Solid phase toxicity tests using the amphipod *Rhepoxynius* provided a wide range of response, from 0 to 98% survival. Amphipod survival ranged from 68-98 % for the eleven reference stations, suggesting that relatively high *Rhepoxynius* survival is a consistent feature of sites with relatively low chemical concentrations and undegraded benthic communities. The *Rhepoxynius* test identified multiple toxic samples, which indicated adequate sensitivity. Of the two solid phase protocols used in this study, the *Rhepoxynius* test provided the best test performance in terms of convenience, consistency, and sensitivity.

Solid phase toxicity tests which used the polychaete *Neanthes* were less sensitive than the *Rhepoxynius* test, and usually indicated no toxicity in samples that were toxic to test organisms using other protocols. In all instances where a sediment sample was toxic to *Neanthes* (survival or growth - relative to controls), it was also toxic to *Rhepoxynius*, whereas many samples that were toxic to *Rhepoxynius* were not toxic to *Neanthes* test. Because the *Neanthes* test demonstrated considerably less sensitivity than the *Rhepoxynius* test, the *Neanthes* test was not recommended for continued use in this program.

Two pore water tests, using *Strongylocentrotus* fertilization and larval development protocols, were performed on three concentrations of pore water samples to evaluate their usefulness

Figure 23a
Amphipod Toxicity Using Reference Envelope for All Stations North San Diego Bay

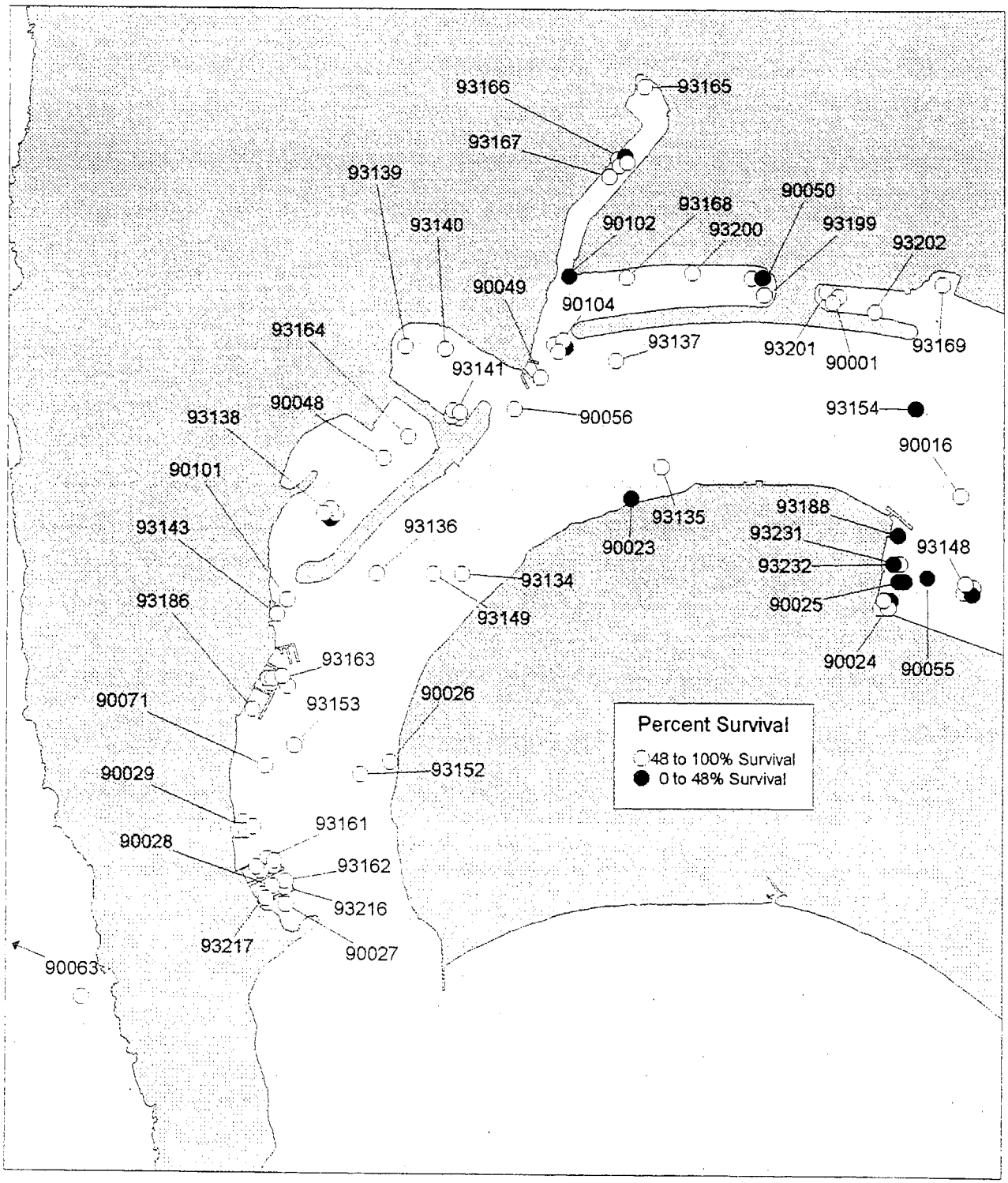


Figure 23b
Amphipod Toxicity Using Reference Envelope for All Stations Mid San Diego Bay

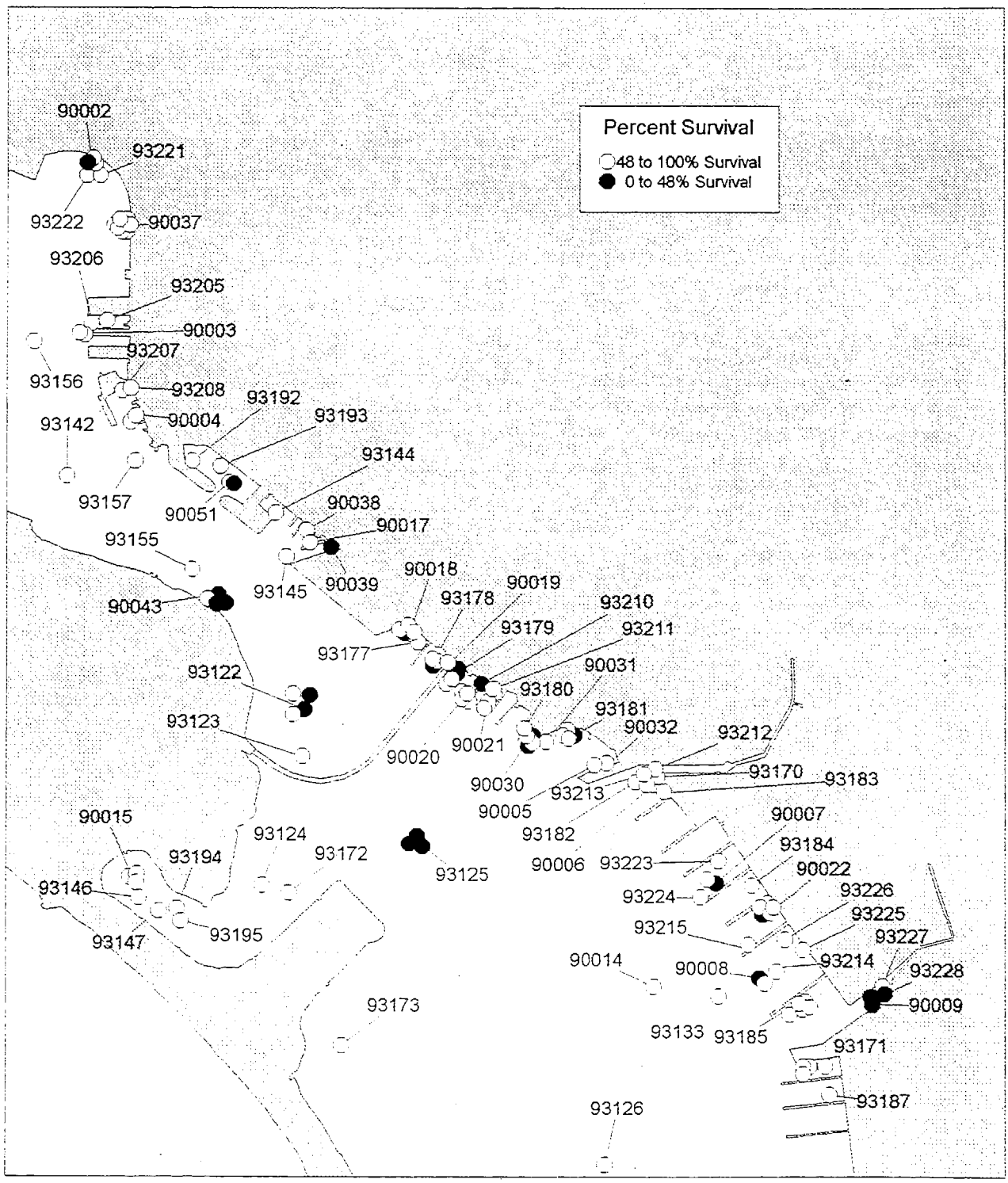


Figure 23c
Amphipod Toxicity Using Reference Envelope for All Stations South San Diego Bay

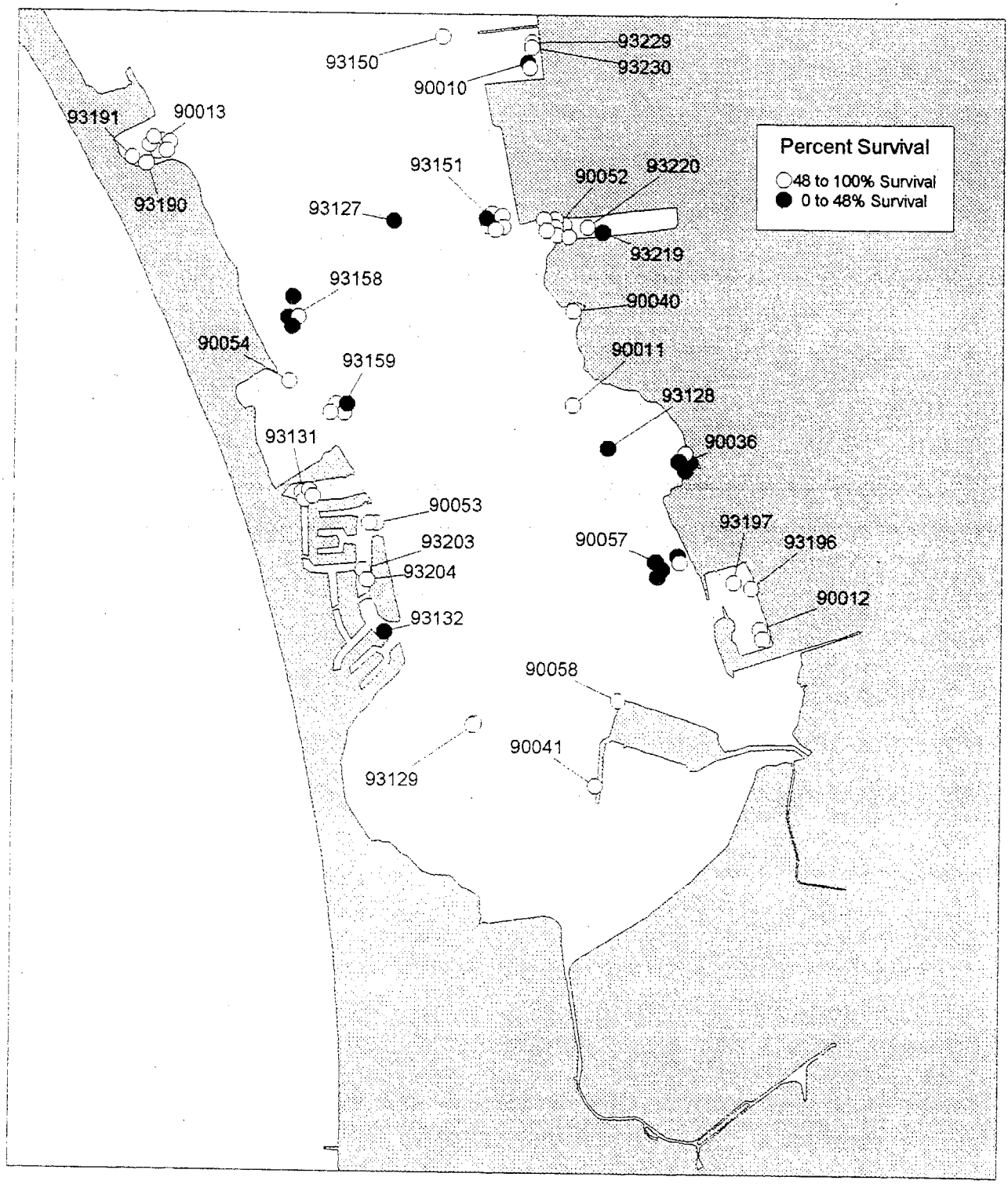
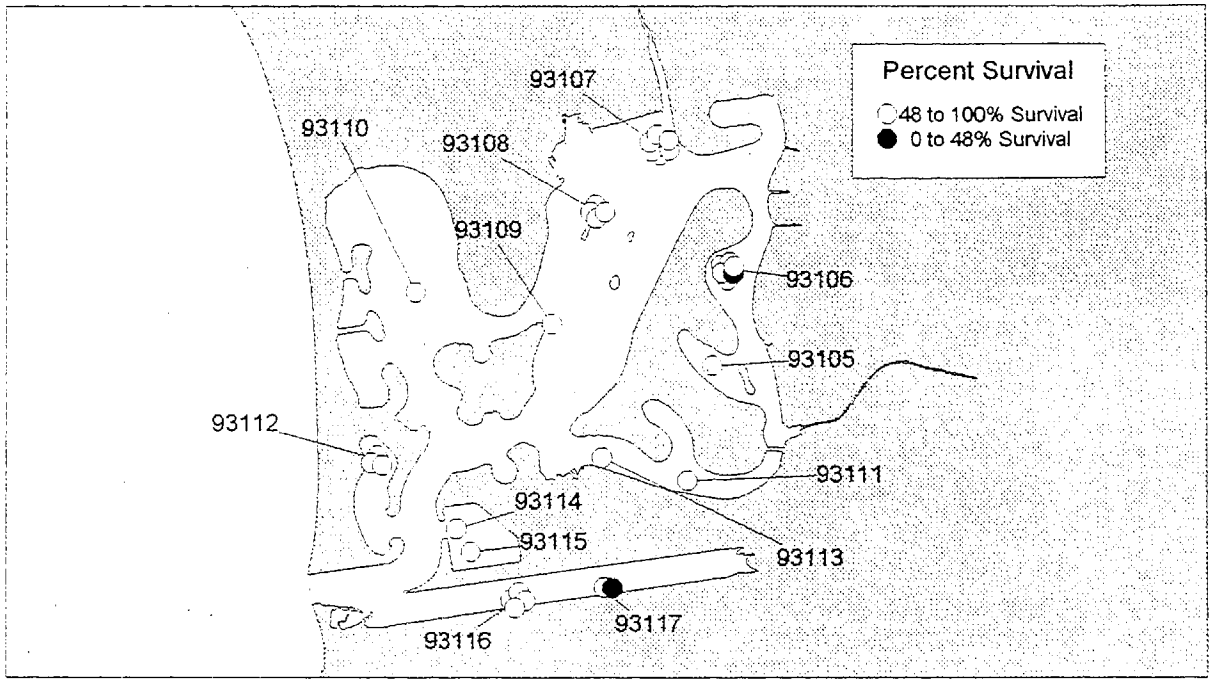
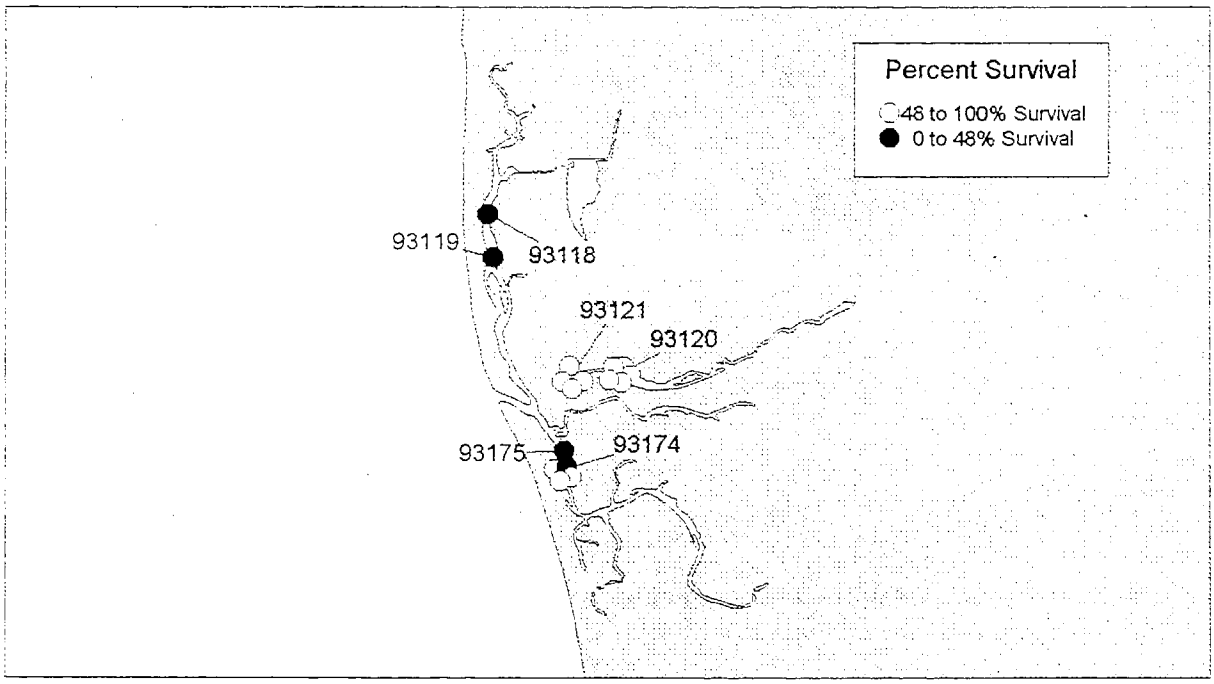


Figure 23d
Amphipod Toxicity Using Reference Envelope for All Stations Mission Bay and San Diego River Estuary



Tijuana River Estuary



as components of the BPTCP. Results indicated these tests were extremely sensitive to pollutants and/or other pore water constituents in the study area, particularly at the 100% porewater concentration. It is reasonable to expect that pore water sea urchin tests, which measure sublethal effects on sensitive early life stages, would be more sensitive than the amphipod solid phase tests, which measure adult mortality. It is also likely that all three protocols respond differently to different contaminants. The high sensitivity of the sea urchin protocols has been observed in other studies assessing pore water toxicity (Burgess *et al.*, 1993; Carr and Chapman, 1992; Long *et al.*, 1990).

Rhepoxynius solid phase test results agreed with *Strongylocentrotus* development (100% and 50%) pore water results in 61 of 117 concurrently tested samples (52%). For the 25% pore water dilution, results agreed in 48% of samples. The three dilutions for the *Strongylocentrotus* tests agreed with each other 56% of the time. In all but two cases, *Strongylocentrotus* results differed from each other because samples were less toxic as pore water was increasingly diluted. In one case the 50% pore water was toxic when the 100% and 25% were not, and in another case, the 50% and 25% were toxic when the 100% was not.

Carr and Chapman (1992) noted that sensitive toxicity test protocols are necessary to adequately characterize the toxicity of potentially contaminated sediments. Pore water tests provide the following advantages: allow the use of a variety of sensitive sublethal toxicity test protocols which have not yet been developed for solid phase tests; eliminate interference from physical factors such as sediment grain size; and allow test organisms to be directly exposed to the aqueous sediment fraction, the probable primary route of pollutant exposure to organisms (Adams *et al.*, 1985; DiToro, 1990). In addition, pore water is currently the only sediment matrix suitable for toxicity identification evaluations that may be useful in identifying toxicants responsible for observed sediment toxicity.

Despite the need to evaluate pore water toxicity, logistical issues of pore water extraction and handling are still a focus of current research (Carr *et al.*, 1995). Among the samples associated with high toxicity in the sea urchin pore water tests were a number from the selected reference stations. These stations had non-degraded benthic communities, relatively low concentrations of pollutants, and ammonia concentrations below levels expected to have an observable effect. The wide range in pore water toxicity at the reference stations was unexpected, and prevented identification of toxic sites using the reference envelope approach. Pore water properties and sampling manipulations that may have affected pore water test results are discussed later.

Samples of water collected one meter above the sediment surface were tested for toxicity at a number of stations. These subsurface water samples were tested as one of the suite of

screening bioassays conducted on suspected areas of water quality impairment. Sixty-five subsurface water samples were tested with the red abalone (*Haliotis rufescens*) larval shell development protocol. Of these, eleven samples were significantly toxic, indicating degradation of the water column in 17% of the stations tested. Water column testing has not been a consistent component of the BPTCP, and will probably be reserved for special investigations. The abalone test appears appropriate for this application.

The bivalve (*Mytilus sp.*) larval shell development test was used to test eight subsurface water samples and three pore water samples. This test was used only in cases where salinity was less than 30 or 26 parts per thousand, the low end of salinity ranges for abalone and sea urchin larval development tests, respectively. Because seawater salinities in the San Diego Bay region were usually in the acceptable range for abalone and sea urchins, the bivalve test was used sparingly. None of the subsurface water samples tested with mussels were significantly toxic, and one of three pore water samples tested with mussels was significantly toxic. This protocol is well established as a sensitive test method, and has the advantage of a relatively wide salinity range. In situations where the salinity range precludes the use of abalone or sea urchins, the bivalve test is an acceptable alternative.

The presence of mitotic aberrations in anaphase cells (cytogentic abnormalities) of *Strongylocentrotus* were determined in some samples. Cells undergoing mitosis were analyzed for chromosomal abnormalities. This porewater test is appropriate for identifying samples containing genotoxic compounds, which may affect reproductive capacity in a wide variety of organisms. Though the test is useful for specific applications, it proved time-consuming for assessing large numbers of samples. Most porewater samples that demonstrated increased aberration rates also were significantly toxic in larval development tests. Since the larval development test was considerably easier to quantify and was being used routinely as part of the study, the mitotic aberration endpoint was discontinued for logistical reasons. It would be useful in specific applications where the effects of genotoxic compounds must be assessed.

Evaluation of Utilization of Pore Water as a Test Medium for the BPTCP

The diffusive flux of dissolved chemicals through the sediment water interface into the overlying water column is a major component of sediment diagenesis and chemical cycles. Bioassay testing of the filtered pore water is an attempt to address exposure of animals living in the sediment matrix, or near the sediment/water interface, to chemicals not associated with the particulate phase. Equilibrium-partitioning theory predicts pore water is the controlling exposure medium in the toxicity of sediments to infaunal organisms (Adams *et al.*, 1985; DiToro, 1990). To accurately interpret pore water test results, it is

important to determine how manipulations of pore water during extraction and handling may have affected observed toxicity. The BPTCP utilized a low pressure (<200psi) squeezing extraction technique with filtration to 0.45 um, and subsequent freezing of pore water samples, prior to testing. There has been some debate regarding appropriate pore water extraction methods and sample manipulations for the purposes of toxicity testing (Carr et al., 1995; Schults et al., 1992). Squeezing techniques allow pore water to be selectively filtered, thus eliminating particulates.

Suspected artifacts from the squeezing technique may include chemical disequilibria through physical disruption of weakly charged ion/particulate associations or lysing of cell walls with resultant changes in concentration of dissolved and particulate organic carbon or other organic components. There is also concern that filtration has a profound effect on observed toxicity. Pore size and filter material can cause variability in measured chemical concentrations (Schults, *et al.*, 1992). Many scientists are now using centrifugation to obtain pore water from sediment for toxicity testing, because this method may be less subject to toxicity artifacts than squeezing (Lange *et al.*, 1992; Giesy *et al.*, 1990).

Toxicity has been observed to decrease in bedded sediments which are tested after freezing and thawing, with observed changes assumed to be related to the release of soluble organic carbon through disruption of natural lattices, clay aggregates and organic matter (Schuytema *et al.*, 1989). Although solids are removed from pore water samples, there remain some soluble organic carbon concerns due to disruption of colloidal aggregations in the pore water, however centrifugation of pore water samples prior to freezing helps minimize this effect (Carr and Chapman, 1995). There are other unresolved concerns related to the toxicity testing of sediment pore waters which require additional study. These include sediment sample handling and storage conditions prior to testing, oxygen contamination, storage time of pore water samples prior to testing (Lange *et al.*, 1992) and sorption kinetics in toxicity test containers and extraction devices (Pittinger, 1988).

Dose responses from the three pore water dilutions demonstrate decreasing toxicity with increasing pore water dilution, confirming that some factor associated with pore water was causing toxicity. However, considering the uncertainty of introduced artifacts during sample manipulations, the ability to discriminate more severely impacted sediments from less severely impacted sediments (a primary goal of the BPTCP) is clearly compromised. As a result of this uncertainty, toxicity testing using pore water as the test medium was suspended in August, 1993, pending further method evaluation. Pore water extraction methods and pore water sample handling have been under evaluation by the BPTCP since that time, with preliminary results indicating that centrifugation and refrigerated (not frozen) sample storage may be the preferable methods when testing this matrix. Recent method comparison research of Carr and Chapman (1995) supports

the use of squeezing technique yet concludes that in situations where hydrophobic organic compounds are a concern (as they are in this program), centrifugation is the method of choice for maximizing the sensitivity of the toxicity test. Sample storage and holding times were critical for all methods evaluated and require further investigation (Schults *et al.*, 1992).

As pore water test methods, test organism selection, and the interpretation of results continue to evolve, they will be evaluated for use by the BPTCP. Because test sensitivity is necessary for accurate sediment characterization, the *Strongylocentrotus* pore water larval development toxicity test protocol should continue to be included in BPTCP. At present, pore water toxicity data by themselves are difficult to interpret. If pore water toxicity tests are used in conjunction with solid phase toxicity tests, chemical measurements and benthic community evaluations, they can provide useful additional information when using a weight of evidence approach toward site characterization.

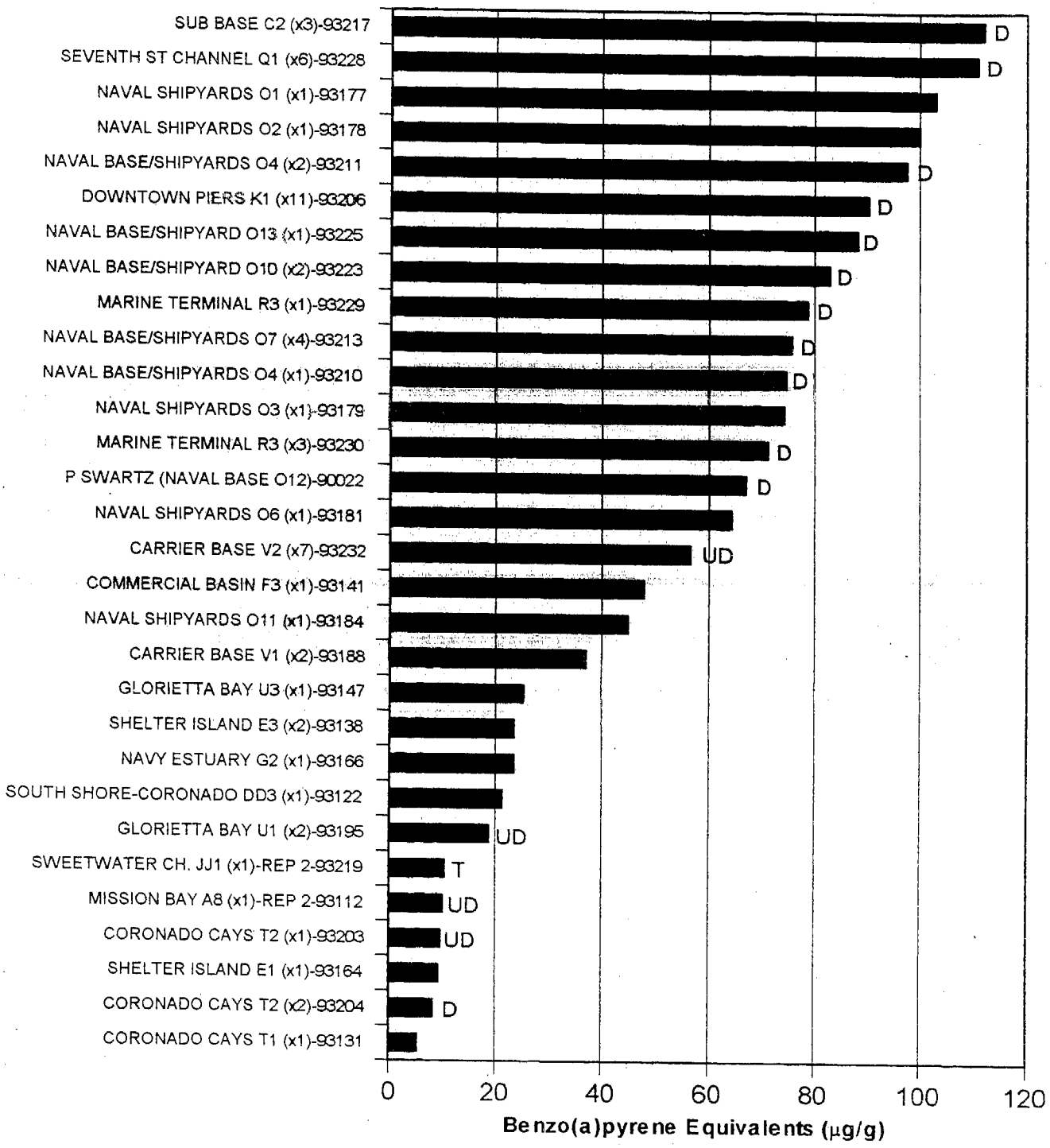
Distribution of P450 Reporter Gene System Response

Induction of the CYP1A1 gene on the human chromosome is produced by such compounds as dioxins, furans, dioxin-like PCB congeners (coplanar), and several high molecular weight polycyclic aromatic hydrocarbons. This induction and resulting production of the detoxifying enzyme, P450, infers that these xenobiotics are present at levels that are potentially toxic, carcinogenic, or mutagenic to organisms. The P450 Reporter Gene System (RGS) assay can measure the response of human (101L) cells to organic extracts when a firefly plasmid at the CYP1A1 site produces the enzyme luciferase. A luminometer is used to quantify the luciferase as a function of concentration and potency of the organics in the extract. Solvent extracts (using standard extraction methods EPA 3510, 3450 or 3550) of water, aquatic sediments, soils and tissues can be tested in the assay system, with a measured response in 16 hours (Anderson *et al.*, 1996).

Findings of the P450 Reporter Gene System (RGS) assay of sediment extracts from 30 stations are summarized in Figure 24, where the RGS responses (in 101L cells) are expressed as $\mu g/g$ (ppm) of benzo(a)pyrene equivalents (BaPEq). The Mission Bay A8 (93112) station, Coronado Cays T2 (93203, 93204) stations, Shelter Island E1 & E3 (93138, 63164) and the Sweetwater Channel stations produced baseline responses in the range of 5.3 to 10.4 $\mu g/g$ BaPEq. Figure 24 shows that all Naval Shipyard stations, the Commercial Basin station, the Marine Terminal and Downtown piers, as well as Seventh Street and the Sub Base stations all produced strong RGS responses. These responses suggest that benthic fish and invertebrates living in contact with these sediments have a high probability of P450 enzyme levels above background, which could result in chronic toxicity, and/or damage to tissues and reproductive potential.

Examination of the relationship between RGS response to sediment extracts and total PAHs concentration in sediments demonstrates

Figure 24. P450 Responses to Extracts of Sediments From San Diego Bay



P450-RGS response (expressed as benzo(a)pyrene equivalents) and benthic community index. Stations with degraded benthic communities are shown with a "D" label. Undegraded are shown with "UD," and transitional stations are shown with "T." Benthic community analysis was not performed on unlabeled stations.

a strong correlation (r^2= 0.86) between the two measures (Figure 25). This is expected, because samples significantly contaminated with PAHs and/or other compounds (coplanar PCBs) have been shown to produce induction of the CYP1A1 gene and the RGS response (Anderson *et al.*, 1995).

Figures 9a-d show stations with high molecular weight PAHs at the PEL (6676 ng/g) and above in black. Examination of these data demonstrated that RGS responses above 60 µg/g BaPEq were always associated with total PAHs at levels above the PEL. This comparison with the PEL suggested that sediment samples with RGS responses above 60 µg/g BaPEq also had a high probability of demonstrating a toxic biological effect, based on sediment quality guidelines. Interestingly, stations identified by RGS to contain significant amounts of inducing organic compounds (> 60µg/g BaPEq) were also found to have degraded benthic communities, at all stations where both analyses were performed. Toxicity test results did not demonstrate a similar strong association with the RGS response.

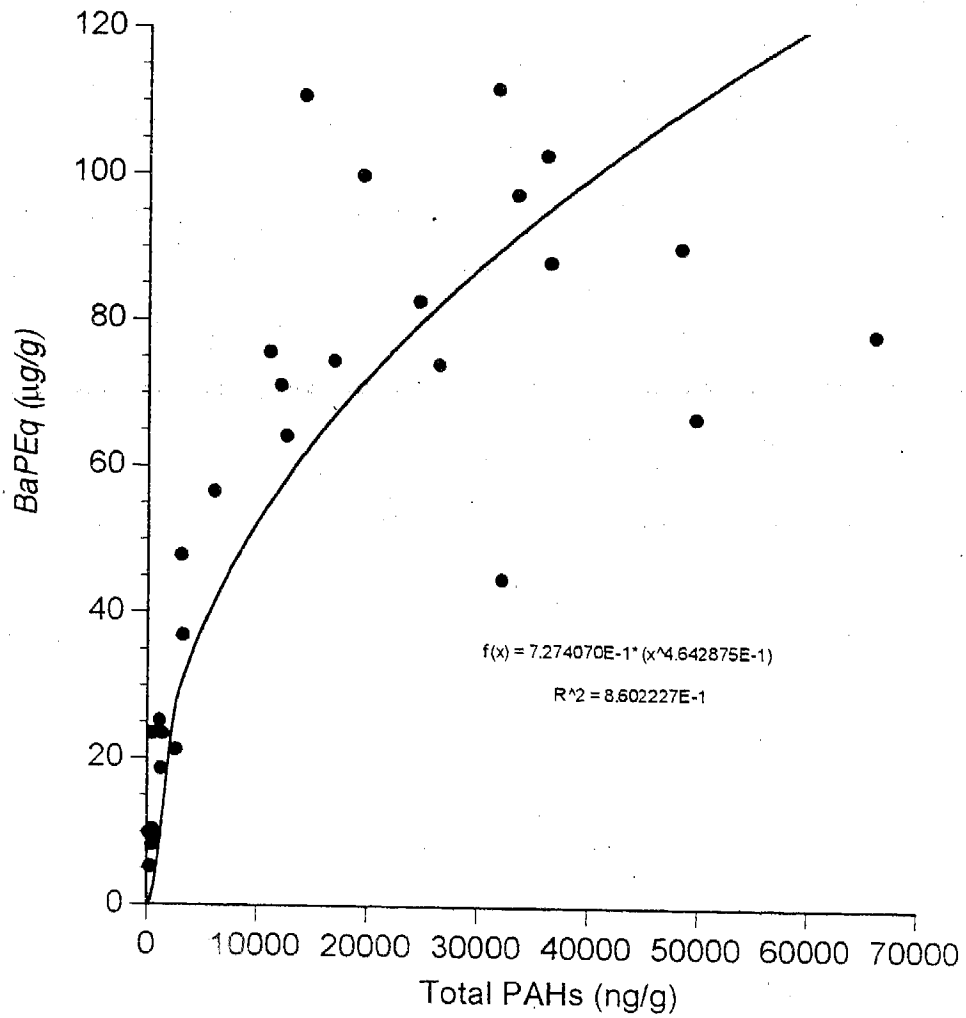
The P450 Reporter Gene System proved to be effective for rapidly (16 hr test) and inexpensively assessing the magnitude of PAHs at selected stations in the San Diego Bay Region. It further proved useful by demonstrating a RGS response threshold above which benthic community degradation was expected. This method may be appropriate as a screening test at additional locations when benthic community degradation and contamination from multiple PAHs, coplanar PCBs, dioxins and furans is suspected. The bioeffects branch of NOAA has utilized this assay in investigations of coastal studies in southern California, Charleston Harbor, S.C., Sabine Lake and Galveston Bay, Texas, and Biscane Bay Florida. In concert with other chemical and biological measures, this method provides additional convincing evidence for the assessment of overall pollution at sites of chemical concern.

Determination of Relationships Between Toxicity and Chemistry

Linear regression was used to describe the relationship between toxicity and chemical concentrations. The dependent variable values are assumed to be normally distributed around the predicted values on the regression line. If this assumption has been met, then a significance test evaluating the null hypothesis (slope of the regression equation is equal to zero), is performed. In addition to a significant probability ($p< 0.05$), the coefficient of determination (r^2) is also an indication of regression strength. The coefficient of determination value represents the proportion of total variance of the dependent variable which can be explained by the independent variable, with a r^2 value of greater than 0.60 being significant. Regression is preferable to non-parametric tests because there is greater power to detect significant relationships with this method (Zar, 1984).

Linear regressions were used to assess the relationship between *Rhepoxynius* (amphipod) mean survival and chemical concentration.

Figure 25. Total PAHs vs P450-RGS Response Expressed as Benzo(a)pyrene Equivalents



Systat® v.5.04 was used for all analyses. The arcsine (square root) transformation is utilized to equalize variance over the entire range of proportions. Chemistry data were checked for normality and transformed using Log(x+1), when necessary (Zar, 1984). Examination of residuals reveal homogeneity of variances exists when these transformations are performed and therefore, the statistical assumptions of a regression can be met. The coefficient of determination (r^2) was reported only when the linear regression was significant ($p<0.05$).

Regressions using amphipod data and chemical concentrations for all stations were analyzed. Testing the degree of dependence of amphipod survival on individual chemical concentrations yielded several regressions which are significant, however, there were no r^2 values greater than 0.072 (Table 13).

To investigate dependence of amphipods on chemistry within specific areas of the Bay, all stations were grouped into one of six specific areas (Appendix B). Groupings were performed to combine stations with similar physical characteristics or uses. These six groups were military use areas (Navy), commercial basins for shipping and industrial activities, small boat harbors and marinas, Mission Bay, rivers (San Diego and Tijuana), and "other" stations, which generally were in open areas removed from San Diego Bay shorelines. The area into which each station was grouped is reported in Appendix B. These regressions were used to test the degree of relationship between amphipod survival and specific areas in the San Diego Bay Region.

Regressions using the navy station group were significant for some chemical groups although no regression had an r^2 value greater than 0.272 (Table 14). In commercial basins, low and high molecular weight PAHs, several metals and one PCB compound were significant, but all had low r^2 values (Table 15). In the small boat harbor group, several PAH and PCB compounds and one pesticide were significant, however, no r^2 values were greater than 0.167 (Table 16). In river stations low molecular weight PAHs were strongly correlated with amphipod survival (Table 17), producing the most significant regressions of the statistical analysis. These regression results from the river stations were somewhat misleading, however, because PAH levels were low relative to most stations in San Diego Bay and to ERM guidelines. For regressions using the "other" station designations, several metals and PCB compounds and one PAH, were significant (Table 18) yet, r^2 values were never better than 0.265. When testing the six station groups, there were no significant regressions for chemistry or amphipods within the Mission Bay group. This was expected because of the low chemical concentrations, therefore no table is shown.

Ammonia, hydrogen sulfide and grain size are suspected non-anthropogenic contributors to toxicity, and have been discussed previously by Ankley *et al.*(1990), Knesovich *et al.* (In Press), and DeWitt *et al.* (1988). To investigate whether these natural

Table 13. Linear regression of amphipod survival dependence on chemistry concentrations for all stations (chemistry with * and all PCB and PAH compounds were Log (1+x) transformed, r^2 is presented when $p<0.05$, ns=not significant).

Metal	n	p	r^2	Pesticide	n	p	r^2	PCB	n	p	r^2	PAH	n	p	r^2
Aluminum	217	0.000	0.047	ALDRIN	229	ns		PCB8	229	0.008	0.031	ACY	198	ns	
Antimony	217	0.015	0.027	CCHLOR*	229	ns		PCB15	78	ns		ACE	229	ns	
Arsenic	217	ns		TCHLOR*	198	ns		PCB18	229	0.001	0.049	ANT	229	ns	
Cadmium*	217	0.000	0.06	ACDEN	217	ns		PCB27	78	ns		BAA	229	ns	
Chromium	217	ns		GCDEN	186	ns		PCB31	78	0.018	0.072	BAP	229	ns	
Copper	217	ns		CLPYR	165	0.011	0.039	PCB44	229	ns		BBF	198	ns	
Iron*	217	ns		Total CHLR	229	ns		PCB49	78	ns		BKF	198	ns	
Manganese	217	ns		DACTH	186	0.000	0.049	PCB52	229	ns		BGP	198	ns	
Nickel	217	ns		OPDDD	229	0.000	0.060	PCB66	229	ns		BEP	229	ns	
Silver	217	0.023	0.024	PPDDD	229	0.000	0.057	PCB70	78	ns		BPH	229	ns	
Selenium	217	ns		OPDDE	229	ns		PCB74	78	ns		CHR	229	ns	
Tin	217	0.000	0.049	PPDDE	229	ns		PCB87	109	ns		DBA	229	ns	
Zinc	217	ns		OPDDT	229	ns		PCB95	78	ns		DMN	229	0.012	0.028
				Total DDT	229	ns		PCB97	78	ns		FLA	229	ns	
				DICLB	186	ns		PCB99	78	ns		FLU	229	ns	
				DIELDRIN	229	ns		PCB101	229	ns		IND	198	ns	
				HCHG	229	ns		PCB105	229	ns		MNP1	229	ns	
				HEPTACHL	229	0.000	0.068	PCB110	78	ns		MNP2	229	ns	
				HCB	229	ns		PCB118	229	ns		MPH1	229	ns	
				METHOXY	217	0.04	0.020	PCB128	229	ns		NPH	198	ns	
				MIREX	229	ns		PCB132	78	ns		PHN	229	ns	
				CNONA	186	ns		PCB138	229	ns		PER	229	ns	
				TNONA	217	ns		PCB149	78	ns		PYR	229	ns	
				TBT	217	ns		PCB153	229	ns		LMW PAH	229	ns	
								PCB156	78	ns		HMW PAH	229	ns	
								PCB157	78	ns		Total PAH	229	ns	
								PCB158	78	ns					
								PCB170	229	ns					
								PCB174	78	ns					
								PCB177	78	ns					
								PCB180	229	ns					
								PCB183	78	ns					
								PCB187	78	ns					
								PCB194	78	ns					
								PCB195	229	ns					
								PCB201	78	ns					
								PCB203	78	ns					
								PCB206	229	ns					
								PCB209	229	ns					
								Total PCB	229	ns					

Navy Stations

Table 14. Linear regression of amphipod survival dependence on chemistry concentrations in navy stations (all chemistry data were Log (1+x) transformed, r^2 is presented when $p<0.05$, ns=not significant). All PAH compound regressions were not significant and therefore not shown.

Metal	n	p	r^2	Pesticide	n	p	r^2	PCB	n	p	r^2
Aluminum	65	0.024	0.078	ALDRIN	65	ns		PCB 15	25	ns	
Antimony	65	ns		CCHLOR	65	ns		PCB 18	65	0.024	0.078
Arsenic	65	ns		OPDDD	65	ns		PCB 27	25	ns	
Cadmium	65	0.021	0.082	PPDDD	65	ns		PCB 31	25	0.007	0.272
Chromium	65	ns		TCHLOR	57	ns		PCB 44	65	ns	
Copper	65	ns		OPDDE	65	ns		PCB 49	25	ns	
Iron	65	ns		PPDDE	65	ns		PCB 52	65	ns	
Lead	65	0.014	0.092	OPDDT	65	ns		PCB 66	65	0.026	0.077
Manganese	65	ns		PPDDT	65	0.011	0.098	PCB 70	25	0.017	0.222
Mercury	65	0.022	0.081	Total DDT	65	ns		PCB 74	25	0.013	0.240
Silver	65	ns		ACDEN	65	ns		PCB 87	33	ns	
Nickel	65	ns		Total CHLR	65	ns		PCB 97	25	ns	
Selenium	65	ns		DIELDRIN	65	ns		PCB 95	25	ns	
Tin	65	0.000	0.215	HCHG	65	ns		PCB 99	25	ns	
Zinc	65	ns		HEPTACH	65	0.001	0.168	PCB 101	65	ns	
				HCB	65	ns		PCB 105	65	0.020	0.084
				METHOXY	65	ns		PCB 110	25	ns	
				CNONA	57	ns		PCB 118	65	ns	
				TNONA	65	ns		PCB 128	65	0.029	0.073
				TBT	65	ns		PCB 132	25	ns	
								PCB 138	65	ns	
								PCB 149	25	ns	
								PCB 153	65	ns	
								PCB 156	25	ns	
								PCB 158	25	ns	
								PCB 170	65	ns	
								PCB 174	25	ns	
								PCB 177	25	ns	
								PCB 180	65	ns	
								PCB 183	25	ns	
								PCB 187	25	ns	
								PCB 194	25	ns	
								PCB 195	65	ns	
								PCB 201	25	ns	
								PCB 203	25	ns	
								PCB 206	65	ns	
								PCB 209	65	ns	
								TTLPCB	65	ns	

Commercial Basin Stations

Table 15. Linear regression of amphipod survival dependence on chemistry concentrations in commercial basin stations (all chemistry data were Log (1+x) transformed, r^2 is presented when $p<0.05$, ns=not significant). All pesticide compound regressions were not significant and therefore not shown.

Metal	n	p	r^2	PAHs	n	p	r^2	PCBs	n	p	r^2
Aluminum	44	0.000	0.266	ACY	37	0.024	0.137	PCB 8	44	ns	
Antimony	44	ns		ACE	44	0.016	0.130	PCB 15	19	ns	
Arsenic	44	0.007	0.163	ANT	44	0.001	0.216	PCB 18	44	ns	
Cadmium	44	0.006	0.168	BAA	44	0.018	0.127	PCB 31	19	ns	
Chromium	44	0.026	0.112	BAP	44	0.010	0.146	PCB 44	44	ns	
Copper	44	ns		BBF	37	0.008	0.187	PCB 49	19	ns	
Iron	44	ns		BKF	37	0.009	0.180	PCB52	44	ns	
Lead	44	ns		BGP	37	0.009	0.180	PCB 66	44	ns	
Manganese	44	ns		BEP	44	0.020	0.123	PCB 70	19	ns	
Mercury	44	ns		BPH	44	ns		PCB 74	19	ns	
Nickel	44	ns		CHR	44	0.016	0.130	PCB 87	26	ns	
Silver	44	ns		DBA	44	0.014	0.135	PCB 95	19	ns	
Selenium	44	ns		DMN	44	ns		PCB 99	19	ns	
Tin	44	ns		FLA	44	0.025	0.114	PCB 101	44	ns	
Zinc	44	ns		FLU	44	0.008	0.158	PCB 105	44	ns	
				IND	37	0.005	0.207	PCB 110	19	ns	
				MNP1	44	ns		PCB118	44	ns	
				MNP2	44	0.013	0.137	PCB 128	44	ns	
				MPH1	44	0.039	0.097	PCB 132	19	ns	
				NPH	37	0.004	0.218	PCB 138	44	ns	
				PHN	44	0.023	0.116	PCB 149	19	ns	
				PER	44	0.019	0.124	PCB 153	44	ns	
				PYR	44	0.025	0.114	PCB 156	19	ns	
				TMN	37	ns		PCB 157	19	ns	
				HMW PAH	44	0.008	0.156	PCB 170	44	ns	
				LMW PAH	44	0.007	0.158	PCB 174	19	ns	
				Total PAH	44	0.006	0.168	PCB 177	19	ns	
								PCB 180	44	ns	
								PCB 183	19	ns	
								PCB 194	19	ns	
								PCB 195	44	ns	
								PCB 201	19	ns	
								PCB 203	19	ns	
								PCB 206	44	ns	
								PCB 209	44	0.000	0.091
								Total PCB	44	ns	

Small Boat Stations

Table 16. Linear regression of amphipod survival dependence on chemistry concentrations in small boat stations (all chemistry data were Log (1+x) transformed, r^2 is presented when $p<0.05$, ns=not significant). All metal concentration regressions were not significant and therefore not shown.

PAHs	n	p	r^2	PCBs	n	p	r^2	Pesticide	n	p	r^2
ACY	39	ns		PCB 5	22	ns		CCHLOR	44	ns	
ACE	44	ns		PCB 18	44	ns		TCHLOR	39	ns	
ANT	44	ns		PCB 31	22	ns		Total CHLR	44	ns	
BAA	44	ns		PCB 44	44	ns		OPDDD	44	ns	
BAP	44	ns		PCB 49	22	ns		PPDDD	44	ns	
BBF	39	ns		PCB 52	44	ns		OPDDE	44	ns	
BKF	39	ns		PCB 66	44	ns		PPDDE	44	ns	
BGP	39	0.015	0.150	PCB 70	22	ns		OPDDT	44	ns	
BEP	44	0.038	0.099	PCB 74	22	ns		PPDDT	44	ns	
CHR	44	ns		PCB 87	27	ns		Total DDT	44	ns	
DBA	44	0.043	0.094	PCB 95	22	ns		CNONA	39	ns	
FLA	44	0.009	0.153	PCB 97	22	ns		TNONA	44	0.047	0.091
FLU	44	0.034	0.102	PCB 101	44	ns		TBT	44	ns	
IND	39	0.035	0.114	PCB 105	44	ns					
MNP2	44	ns		PCB 110	22	ns					
MPH1	44	ns		PCB 118	44	ns					
NPH	39	ns		PCB 128	44	ns					
PHN	44	0.040	0.097	PCB 132	22	ns					
PER	44	ns		PCB 138	44	0.036	0.100				
PYR	44	0.006	0.167	PCB 149	22	ns					
LMW PAH	44	0.050	0.089	PCB 153	44	0.041	0.096				
HMW PAH	44	0.030	0.108	PCB 156	22	ns					
Total PAH	44	0.030	0.108	PCB 157	22	ns					
				PCB 170	44	ns					
				PCB 174	22	ns					
				PCB 177	22	ns					
				PCB 180	44	ns					
				PCB 183	22	ns					
				PCB 187	22	ns					
				PCB 194	22	ns					
				PCN 195	44	ns					
				PCB 201	22	ns					
				PCB 203	22	ns					
				PCB 206	44	ns					
				Total PCB	44	0.049	0.089				

River Stations

Table 17. Linear regression of amphipod survival dependence on chemistry concentrations in river stations (all chemistry data were Log (1+x) transformed, r^2 is presented when $p<0.05$, ns=not significant). All metal, pesticide, and PCB compound regressions were not significant and therefore not shown.

PAHs	n	p	r2
ACY	18	ns	
ACE	20	0.028	0.240
ANT	20	ns	
BAA	20	ns	
BAP	20	ns	
BBF	18	ns	
BKF	18	ns	
BGP	18	ns	
BEP	20	ns	
BPH	20	0.000	0.646
CHR	20	ns	
DBA	20	ns	
DMN	20	0.000	0.672
FLA	20	ns	
FLU	20	0.000	0.692
IND	18	ns	
MNP1	20	0.000	0.669
MNP2	20	0.000	0.634
MPH1	20	0.000	0.714
NPH	18	ns	
PHN	20	0.005	0.358
PER	20	ns	
PYR	20	ns	
TMN	18	0.000	0.591
LMW PAH	20	0.000	0.607
HMW PAH	20	ns	
Total PAH	20	ns	

"Other" Stations

Table 18. Linear regression of amphipod survival dependence on chemistry concentrations in "other" stations (all chemistry data were Log (1+x) transformed, r^2 is presented when $p<0.05$, ns=not significant). All pesticide compound regressions were not significant and therefore not shown.

Metal	n	p	r^2	PAHs	n	p	r^2	PCBs	n	p	r^2
Aluminum	35	ns		ACY	28	ns		PCB 5	37	ns	
Antimony	35	0.002	0.255	ACE	37	ns		PCB 18	37	ns	
Arsenic	35	ns		ANT	37	ns		PCB 44	37	ns	
Cadmium	35	ns		BAA	37	ns		PCB 52	37	ns	
Chromium	35	0.017	0.161	BAP	37	ns		PCB 66	37	ns	
Copper	35	0.023	0.147	BBF	28	ns		PCB 87	9	ns	
Iron	35	0.009	0.188	BKF	28	ns		PCB 101	37	0.033	0.124
Lead	35	0.019	0.155	BGP	28	ns		PCB 105	37	ns	
Manganese	35	ns		BEP	37	ns		PCB 118	37	0.033	0.124
Mercury	35	ns		BPH	37	ns		PCB 128	37	ns	
Nickel	35	ns		CHR	37	ns		PCB 138	37	ns	
Silver	35	0.003	0.232	DBA	37	ns		PCB 153	37	0.017	0.151
Selenium	35	ns		DMN	37	ns		PCB 170	37	ns	
Tin	35	0.046	0.159	FLA	37	ns		PCB 180	37	ns	
Zinc	35	0.003	0.232	FLU	37	ns		PCB 195	37	ns	
				IND	28	ns		PCB 206	37	ns	
				MNP1	37	ns		PCB 209	37	ns	
				MNP2	37	ns		Total PCB	37	0.049	0.106
				MPH1	37	ns					
				NPH	28	0.005	0.265				
				LPHN	37	ns					
				PER	37	ns					
				PYR	37	ns					
				TMN	28	ns					
				LMW PAH	37	ns					
				HMW PAH	37	ns					
				Total PAH	37	ns					

factors influenced the effects of anthropogenic chemicals in test sediments from the San Diego Bay Region, data were adjusted to exclude tests where unionized ammonia was greater than 0.4 mg/L in overlying water and/or hydrogen sulfide was greater than 0.06 mg/L. The 0.4 mg/L ammonia threshold value is based on the NOEC value for the EPA test protocols for marine amphipods (USEPA, 1994) and the 0.06 mg/L hydrogen sulfide threshold value is based on data presented by Knesovich *et al.* (In Press). A general trend is seen by DeWitt *et al.* (1988), in which survival decreases with increasing fines. However, because this trend was not apparent in the San Diego Bay Region and no clear cutoff has been conclusively demonstrated, data were not adjusted to exclude samples with a high percentage of fines. NH_3 and H_2S adjusted amphipod data were compared to the thirty two chemicals or chemical groups, for which PEL values have been derived, and to ERM and PEL summary quotients. Regressions were significant for cadmium, chromium, copper, nickel, silver, zinc, DDT, dieldrin, acenapthene, and the ERM and PEL summary quotients (Table 19). By eliminating high ammonia concentrations (>0.4 mg/L) and high hydrogen sulfide concentrations (0.06 mg/L), regressions do improve slightly, however r^2 values are generally low. It is prudent though to recognize that these natural factors may confound interpretation of toxicity results and that caution should be exercised when elevated ammonia or hydrogen is noted.

In summary, simple linear regressions provide few clues to understanding the relationship between amphipod survival in the toxicity tests and measured single chemical concentrations. When viewing scatter plots, it remains difficult to convincingly argue that there is, or should be, a linear toxic response to increasing chemical concentrations in natural settings. In industrialized settings such as San Diego Bay, where multiple pollutants are common, co-variation and possible synergistic effects within a group of multiple pollutants further confound the separation of effects to single pollutants. A single multiple regression or a variable selection technique may statistically better describe the relationship between toxicity and multiple chemicals, but these were not performed in this analysis.

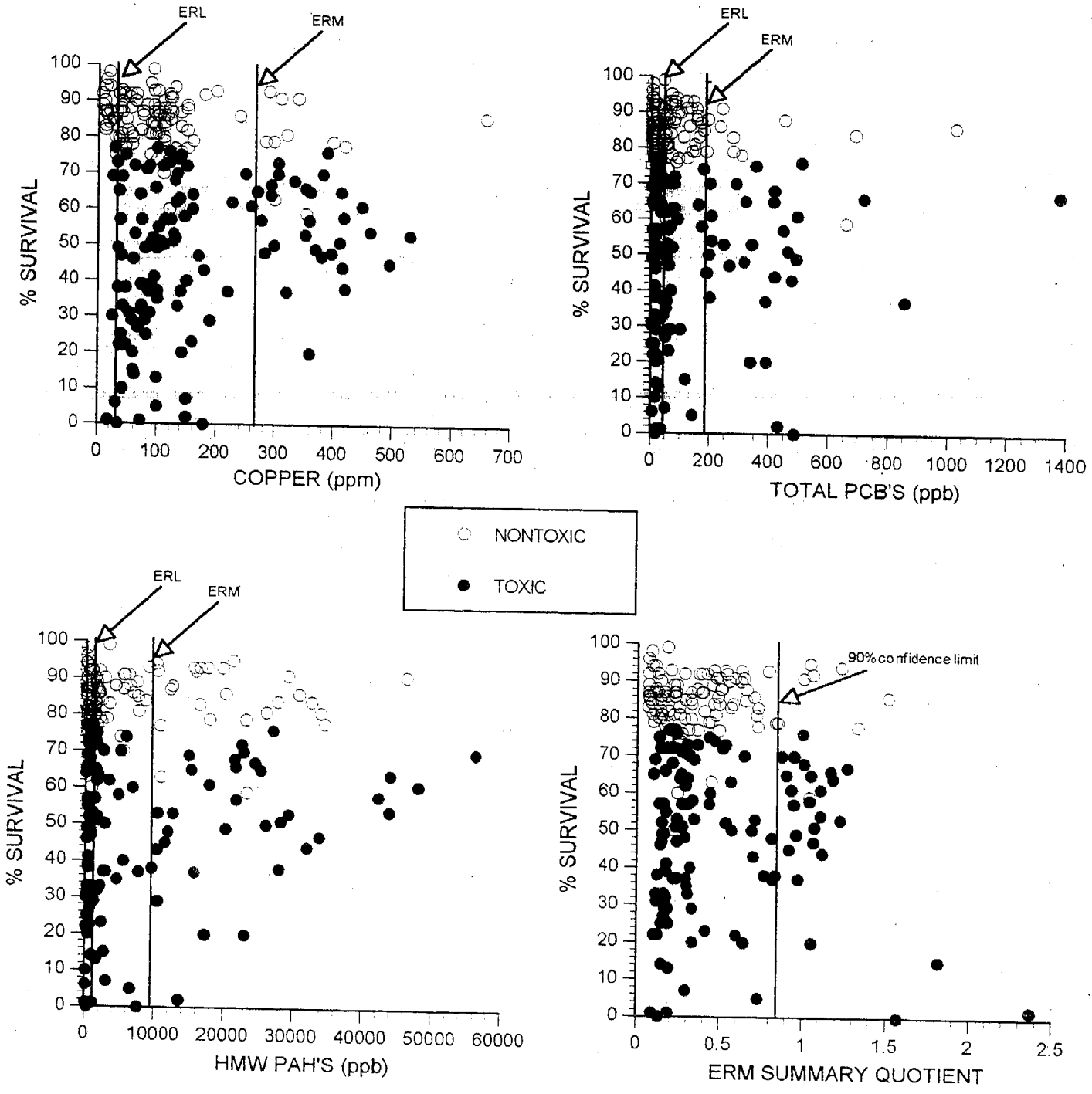
Figure 26 is typical of chemical vs. toxicity scatter plots seen throughout the region, with considerable scatter at low chemical concentrations and a gradual decrease in survival at elevated chemical concentrations. Because regressions did not generally support a linear toxic response to chemical pollutants, it is suspected that most organisms are tolerant of pollutants until a threshold is exceeded. This threshold effect appears well demonstrated in the San Diego Bay Region's benthic communities setting, as illustrated in Figure 14.

Although it was less evident for acute toxicity tests, where high amphipod survival was observed even at elevated chemical levels (Figure 26), a distinct response pattern still emerges. When the EMAP approach for determination of toxicity (significantly different from controls and less than 80% of controls) was used, 28 of 39 (72%) sediment samples were toxic when copper

Table 19. Linear regression of amphipod survival dependence on chemical analytes for which PEL levels have been developed. Amphipod data has overlying unionized ammonia values >0.4 ppm and hydrogen sulfide values >0.06 ppb removed (all chemical data are Log (x+1) transformed. r^2 is presented when $p<0.05$, ns= not significant).

ANALYTE	n	p	r2
Metal			
Arsenic	193	ns	
Cadmium	193	0.000	0.074
Chromium	193	0.028	0.025
Copper	193	0.014	0.031
Lead	176	ns	
Nickel	193	0.003	0.044
Mercury	193	ns	
Silver	193	0.008	0.036
Zinc	193	0.001	0.057
Pesticide			
Total Chlordane	193	ns	
PPDDE	193	ns	
PPDDT	193	0.000	0.068
Total DDT	193	0.008	0.036
Dieldrin	193	0.023	0.027
Lindane	193	ns	
PAH			
ACY	170	ns	0.031
ACE	193	ns	
ANT	193	ns	
BAA	193	ns	
BAP	193	ns	
CHR	193	ns	
DBA	193	ns	
FLA	193	ns	
FLU	193	ns	
MNP2	193	ns	
NPH	170	ns	
PHN	193	ns	
PYR	193	ns	
LMW PAH	193	ns	
HMW PAH	193	ns	
Total PAH	193	ns	
PCB			
Total PCB	193	ns	
Summary Quotients			
PELQ	184	0.050	0.020
ERMQ	184	0.014	0.033

Figure 26. Amphipod Survival vs ERM Summmary Quotient or Chemical Level



concentrations exceeded the ERM value whereas only about 7 of 28 samples (25%) were toxic when copper concentrations were below the ERL value. This was also seen with total PCBs with 73% of the samples being toxic when PCB concentrations exceeded the ERM value and only 53% toxic below the ERL. Because it is suspected that toxicity in urban bays is caused by exposure to complex mixtures of chemicals comparisons to ERM summary quotients (multiple chemical indicators) were made. The highest incidence of toxicity (>78%) is found in samples with elevated ERM summary quotients (>0.85), supporting the theory that the effects of elevated levels of multiple pollutants may elucidate the toxic response. This pattern of increased incidence of toxicity when chemical concentrations exceed established sediment quality guidelines or the summary quotient 90% confidence interval seems to support the threshold response theory for amphipod bioassays in the San Diego Bay Region.

Guideline thresholds are quantitatively estimated from large national or statewide data sets, as described earlier, but the applicability of calculated values may be limited in specific water bodies. Use of unique guidelines for the San Diego Bay Region, which account for local physical, chemical and biological conditions, would be optimal when evaluating data. However, without substantial additional data, chemical specific thresholds for the San Diego Bay region cannot be accurately determined. Currently the most useful tools for addressing the relationship between toxicity and chemical concentration appears to be threshold approaches, such as the ERM/ERL and TEL/PEL guidelines.

Station Specific Sediment Quality Assessments

One of the primary goals of the BPTCP is to establish state guidelines under which contaminated or toxic stations can be designated "toxic hot spots". These guidelines are currently being developed based on data collected throughout the state. Although final guidelines are contingent upon further data analysis, the "toxic hot spot" definition currently utilized by the BPTCP, requires that one or more of the following criteria must be met:

1. The water or sediment exhibits toxicity associated with toxic pollutants, based on toxicity tests acceptable to the SWRCB or the RWQCB. To determine whether toxicity exists, recurrent measurements (at least two separate sampling dates) should demonstrate an effect.

2. Significant degradation in biological populations and/or benthic communities associated with presence of elevated levels of toxic pollutants.

3. The site exceeds water or sediment quality objectives for toxic pollutants which are contained in appropriate water quality control plans, or exceeds water quality criteria promulgated by the U.S. Environmental Protection Agency.

4. The tissue toxic pollutant levels of organisms collected from the site exceed levels established by the United States Food and Drug Administration (FDA) for protection of human health, or the National Academy of Sciences (NAS) for the protection of human health or wildlife.

Because tissue residues were not analyzed in this study, criteria are limited to the first three. Satisfying any one of these criteria can designate a site a "toxic hot spot". Satisfying more than one criterion and the severity demonstrated within each criterion determines the weighting for which qualitative rankings can be made. In this report, stations were not designated as "toxic hot spots", because this designation is still under evaluation and development by the BPTCP. Instead, stations were prioritized for further evaluation for hot spot status. This priority was classified as high, moderate, low, or no action and may be used by State and Regional Water Board staff to direct further investigations at these stations. Each station receiving a high to low priority ranking meets one or more of the first three criteria established above. Those meeting all three criteria were designated as the highest priority for further action.

Stations were evaluated for repeat toxicity (criterion 1) using the reference envelope method, the most conservative measure developed. Only those stations which demonstrated amphipod survival less than 48% in repeated tests, without confounding ammonia, hydrogen sulfide or grain size effects, were considered to exhibit repeat toxicity hits. Because only one critical value could be determined for any of the dilutions of the pore water bioassays, pore water toxicity results were not evaluated for repeat toxicity when prioritizing stations.

Stations with repeat toxicity and elevated chemistry and/or degraded benthic communities, were assigned a moderate or high priority. Stations with repeat toxicity, but lacking elevated chemistry or degraded benthic communities, were assigned a low priority (Tables 20 and 21- REPEAT TOXICITY HITS).

Stations with only a single toxicity hit were also considered a moderate or high priority, when associated with elevated chemistry and/or degraded benthic communities. Stations with a single toxicity hit, but lacking elevated chemistry or degraded benthic communities, were assigned a low priority. (Tables 20 and 21- SINGLE TOXICITY HITS).

Nineteen stations demonstrated repeat or single toxicity hits but were given a "no action" recommendation at this time (Tables 20 and 21). These stations had measured hydrogen sulfide or ammonia concentrations which confounded interpretation of the bioassay test results. Chemistry levels were low, or not analyzed, and the benthic community was undegraded or transitional, where sampled. These results provided little or no evidence that these stations should be prioritized for hot spot status. A toxicity identification evaluation (TIE) should be considered for these

TABLE 20

FUTURE INVESTIGATION PRIORITY LIST FOR THE SAN DIEGO BAY REGION

Stations With Synoptic Chemical, Toxicological and Benthic Community Analyses

STANUM	STATION	IDORG	LEG	H2S	NH3	% AMPHI. SURVIVAL	>4X ERM OR >5.9X PEL	ERMQ	PELQ	BENTHICS	COMMENTS	PRIORITY
	REPEAT TOXICITY											
90009.0	28 SWARTZ (7TH ST CHANNEL O1)	893	23	nd	0.016	5.00	Chlordane	0.732	0.990	DEGRADED	TOXICITY, ELEVATED CHEM, BENTHIC HIT	HIGH
93228.0	SEVENTH ST CHANNEL Q1 (x6)	895	23	nd	0.010	2.00	Chlordane	2.373	3.082	DEGRADED	TOXICITY, ELEVATED CHEM, BENTHIC HIT	HIGH
90025.0	SDNI-N5 (CARRIER BASE V2)	899	23	nd	0.643	37.00		0.294	0.454	UNDEGRADED	NH3>0.4	NO ACTION
93232.0	CARRIER BASE V2 (x7)	1001	23	nd	0.773	35.00		0.300	0.481	UNDEGRADED	NH3>0.4	NO ACTION
	SINGLE TOXICITY											
90002.0	12 SWARTZ(DOWNTOWN ANCH)-REP 1	878	22	nd	1.836	15.00	Chlordane	1.818	2.444	DEGRADED	TOXICITY (NH3>0.4), ELEVATED CHEM, BENTHIC HIT	HIGH
93210.0	NAVAL BASE/SHIPYARDS O4 (x1)	863	22	0.0023	0.775	37.00		0.975	1.157	DEGRADED	TOXICITY (NH3>0.4), ELEVATED CHEM, BENTHIC HIT	HIGH
90051.0	16 SWARTZ (INTERCONT. MARINA)	818	20	0.0010	3.340	1.00		0.190	0.301	TRANSITIONAL	NH3>0.4	LOW
93219.0	SWEETWATER CH. JJ1 (x1)-REP 2	876	22	nd	0.319	31.00		0.115	0.188	TRANSITIONAL		LOW
	DEGRADED BENTHICS											
90007.0	25 SWARTZ (NAVAL BASE/SY O10)	887	23	nd	0.014	86.00		0.702	1.025	DEGRADED		LOW
93223.0	NAVAL BASE/SHIPYARD O10 (x2)	888	23	nd	0.016	79.00		0.847	1.308	DEGRADED	ELEVATED CHEM	MODERATE
93224.0	NAVAL BASE/SHIPYARD O10(x6)	889	23	nd	0.010	90.00	Zinc	0.623	0.994	DEGRADED	ELEVATED CHEM	MODERATE
93211.0	NAVAL BASE/SHIPYARDS O4 (x2)	864	22	nd	0.158	86.00	Antimony, Copper, PCB	1.509	1.945	DEGRADED	ELEVATED CHEM	MODERATE
90021.0	K SWARTZ (NAVAL BASE O4)	862	22	nd	0.060	93.00		0.626	0.961	DEGRADED		LOW
90006.0	23 SWARTZ (NAVAL BASE O7)	865	22	nd	0.054	92.00	Chlordane	1.056	1.487	DEGRADED	ELEVATED CHEM	MODERATE
93212.0	NAVAL BASE/SHIPYARDS 07 (x1)	866	22	nd	0.026	91.00	Chlordane	0.589	0.847	DEGRADED	ELEVATED CHEM	MODERATE
93213.0	NAVAL BASE/SHIPYARDS O7 (x4)	867	22	nd	0.010	94.00	Chlordane	1.230	1.730	DEGRADED	ELEVATED CHEM	MODERATE
93227.0	SEVENTH ST CHANNEL Q1 (x5)	894	23	nd	0.076	79.00	Chlordane	0.837	1.175	DEGRADED	ELEVATED CHEM	MODERATE
93206.0	DOWNTOWN PIERS K1 (x11)	848	21	nd	0.048	95.00	PAHs	1.042	1.956	DEGRADED	ELEVATED CHEM	MODERATE
90004.0	15 SWARTZ (G ST. PIER MARINA)	849	21	nd	0.220	77.00		0.494	0.736	DEGRADED		LOW
93207.0	G ST. PIER MARINA L1 (x4)	850	21	nd	0.173	89.00		0.454	0.674	DEGRADED		LOW
90022.0	P SWARTZ (NAVAL BASE O12)	868	22	nd	0.061	91.00	PAHs	1.001	1.522	DEGRADED	ELEVATED CHEM	MODERATE
93214.0	NAVAL BASE/SHIPYARDS O12 (x3)	869	22	nd	0.031	93.00		0.465	0.710	DEGRADED		LOW
93215.0	NAVAL BASE/SHIPYARDS O12 (x4)	870	22	nd	0.017	88.00		0.361	0.578	DEGRADED		LOW
90008.0	27 SWARTZ (NAVAL BASE/SH O13)	890	23	nd	0.008	92.00		0.419	0.665	DEGRADED		LOW
93225.0	NAVAL BASE/SHIPYARD O13 (x1)	891	23	0.0213	0.013	81.00		0.719	1.130	DEGRADED		LOW
93226.0	NAVAL BASE/SHIPYARD O13 (x3)	892	23	nd	0.019	91.00		0.642	1.033	DEGRADED		LOW
90010.0	31 SWARTZ (MARINE TERMINAL R3)	896	23	nd	0.077	86.00		0.145	0.254	DEGRADED		LOW
93229.0	MARINE TERMINAL R3 (x1)	897	23	nd	0.109	70.00	PAHs	0.876	1.504	DEGRADED	ELEVATED CHEM	MODERATE
93230.0	MARINE TERMINAL R3 (x3)	898	23	nd	0.056	63.00		0.449	0.737	DEGRADED		LOW
93116.0	SAN DIEGO RIVER B1 (x4)-REP 1	881	22	nd	0.216	92.00		0.282	0.381	DEGRADED		LOW
93116.0	SAN DIEGO RIVER B1 (x4)-REP 2	882	22	nd	0.098	92.00	Chlordane	0.540	0.770	DEGRADED	ELEVATED CHEM	MODERATE
93116.0	SAN DIEGO RIVER B1 (x4)-REP 3	883	22	nd	0.162	78.00	Chlordane	0.728	1.026	DEGRADED	ELEVATED CHEM	MODERATE
90028.0	NSB-M1 (SUB BASE C2)	871	22	nd	0.078	84.00	PAHs	0.577	1.038	DEGRADED	ELEVATED CHEM	MODERATE
93216.0	SUB BASE C2 (x1)	872	22	nd	0.079	93.00		0.201	0.351	DEGRADED		LOW
93217.0	SUB BASE C2 (x3)	873	22	nd	0.074	81.00		0.472	0.818	DEGRADED		LOW
90012.0	34 SWARTZ (C.V. YACHT BASIN)	824	20	0.0002	0.334	57.00		0.135	0.243	DEGRADED		LOW
93196.0	CHULA V. YACHT BASIN S1 (x1)	825	20	0.0003	0.260	76.00		0.236	0.426	DEGRADED		LOW
93197.0	CHULA V. YACHT BASIN S1 (x3)	826	20	0.0003	0.165	79.00		0.177	0.308	DEGRADED		LOW
90003.0	14 SWARTZ (DOWNTOWN PIERS)	846	21	nd	0.084	70.00		0.314	0.483	DEGRADED		LOW
93205.0	DOWNTOWN PIERS K1 (x9)	847	21	nd	0.167	84.00	PAHs	0.329	0.552	DEGRADED	ELEVATED CHEM	MODERATE
93107.0	MISSION BAY A3 (x1)-REP 1	853	21	nd	0.075	57.00		0.311	0.429	DEGRADED		LOW
93107.0	MISSION BAY A3 (x1)-REP 2	854	21	nd	0.046	77.00		0.364	0.483	DEGRADED		LOW
93204.0	CORONADO CAYS T2 (x2)	845	21	nd	0.062	82.00		0.140	0.234	DEGRADED		LOW
93220.0	SWEETWATER CH. JJ1 (x8)-REP 3	877	22	nd	0.129	81.00		0.088	0.150	DEGRADED		LOW
93208.0	G ST. PIER MARINA L1 (x5)	851	21	nd	0.064	83.00		0.726	1.047	DEGRADED		LOW
	CHEMISTRY-Individual Chemicals											
93107.0	MISSION BAY A3 (x1)-REP 3	855	21	nd	0.145	73.00	Chlordane	0.535	0.724	TRANSITIONAL	ELEVATED CHEM	MODERATE
93221.0	DOWNTOWN ANCH. J1 (x1)-REP 2	879	22	nd	0.143	83.00	Chlordane	0.564	0.803	UNDEGRADED	ELEVATED CHEM	LOW

TABLE 21

FUTURE INVESTIGATION PRIORITY LIST FOR THE SAN DIEGO BAY REGION

Stations Without Synoptic Chemical, Toxicological and Benthic Community Analyses

STANUM	STATION	IDORG	LEG	H2S	NH3	% AMPHI. SURVIVAL	>4X ERM OR >5.9X PEL	ERMQ	PELQ	BENTHICS	COMMENTS	PRIORITY
	REPEAT TOXICITY											
90009.0	28 SWARTZ	158	7	not analyzed	0.002	0.00	Chlordane, DDT	**1.570**	**1.839**	not analyzed	ELEVATED CHEM, SITE DEGRADED IN LEG 23	HIGH
93179.0	NAVAL SHIPYARDS O3 (x1)	797	19	not analyzed	**0.539**	20.00		**1.056**	**1.534**	not analyzed	ELEVATED CHEM, ADJACENT SITE DEGRADED	HIGH
93179.0	NAVAL SHIPYARDS O3 (x1)-REP 1	1122	27	0.0003	0.059	44.00		**1.119**	**1.525**	not analyzed	ELEVATED CHEM, ADJACENT SITE DEGRADED	HIGH
90043.0	CORONADO WHARF	192	12	not analyzed	**0.684**	29.00		0.169	0.249	not analyzed	NH3>0.4	NO ACTION
90043.0	CORONADO WHARF-REP 1	1156	28	0.0016	**0.423**	33.00		0.113	0.187	not analyzed	NH3>0.4	NO ACTION
90043.0	CORONADO WHARF-REP 2	1157	28	0.0030	0.224	43.00		0.703	0.996	not analyzed		LOW
90030.0	BF SCHROEDER SITE F	179	12	not analyzed	0.066	47.00	PAHs	**1.067**	**1.768**	not analyzed	ELEVATED CHEM	MODERATE
90030.0	BF SCHROEDER SITE F	749	16	not analyzed	0.204	43.00		not analyzed	not analyzed	not analyzed		LOW
93122.0	SOUTH SHORE-CORONADO DD3 (x1)	725	16	not analyzed	**0.740**	23.00		0.416	0.617	not analyzed	NH3>0.4	NO ACTION
93122.0	S.S.- CORONADO DD3 (x1) REP 1	1013	24	nd	**0.463**	33.00		0.306	0.471	not analyzed	NH3>0.4	NO ACTION
90036.0	STORM DRAIN- ROHR CHANNEL	185	5	not analyzed	**0.894**	27.00		0.162	0.253	not analyzed	NH3>0.4	NO ACTION
90036.0	STORMDRAIN EA (ROHR CH.) REP 3	1024	24	nd	0.119	1.00		0.090	0.144	not analyzed		LOW
90036.0	STORMDRAIN EA (ROHR CH.) REP 1	1022	24	**0.0679**	0.136	0.00		0.131	0.174	not analyzed	H2S> 0.06	NO ACTION
93125.0	SILVER STRAND FF4 (x4) REP 1	1016	24	nd	**0.514**	38.00		0.121	0.199	not analyzed	NH3>0.4	NO ACTION
93125.0	SILVER STRAND FF4 (x4) REP 2	1017	24	nd	**0.720**	22.00		0.102	0.171	not analyzed	NH3>0.4	NO ACTION
93125.0	SILVER STRAND FF4 (x4) REP 3	1018	24	**1.2744**	**0.484**	22.00		0.125	0.210	not analyzed	H2S> 0.06, NH3>0.4	NO ACTION
93158.0	SOUTH BAY GG1 (x1) REP 1	1035	24	nd	0.043	33.00		0.163	0.265	not analyzed		LOW
93158.0	SOUTH BAY GG1 (x1) REP 2	1036	24	nd	0.108	39.00		0.175	0.277	not analyzed		LOW
93158.0	SOUTH BAY GG1 (x1) REP 3	1037	24	nd	0.072	46.00		0.141	0.233	not analyzed		LOW
90024.0	SDNI-N1	173	7	not analyzed	**0.684**	40.00		0.323	0.506	not analyzed	NH3>0.4, SITE UNDEGRADED IN LEG 23	NO ACTION
90025.0	SDNI-N5	174	7	not analyzed	**0.925**	7.00		0.295	0.489	not analyzed	NH3>0.4, SITE UNDEGRADED IN LEG 23	NO ACTION
93188.0	CARRIER BASE V1 (x2)	806	19	not analyzed	**2.593**	37.00		0.220	0.349	not analyzed	NH3>0.4 SITE UNDEGRADED IN LEG 23	NO ACTION
90057.0	5 SDG&E	206	12	not analyzed	0.011	25.00		0.147	0.249	not analyzed		LOW
90057.0	5 SDG&E REP 1	1019	24	nd	0.046	41.00		0.176	0.290	not analyzed		LOW
90057.0	5 SDG&E REP 2	1020	24	0.0132	0.011	39.00		0.172	0.283	not analyzed		LOW
90057.0	5 SDG&E REP 3	1021	24	nd	0.032	31.00		0.169	0.281	not analyzed		LOW
	SINGLE TOXICITY											
90007.0	25 SWARTZ	156	7	not analyzed	0.004	37.00	Mercury	0.820	1.088	not analyzed	ELEVATED CHEM, SITE DEGRADED IN LEG 23	MODERATE
90008.0	27 SWARTZ	157	7	not analyzed	0.010	29.00		0.333	0.564	not analyzed	SITE DEGRADED IN LEG 23	MODERATE
90022.0	P SWARTZ	171	7	not analyzed	0.008	38.00		0.771	1.207	not analyzed	SITE DEGRADED IN LEG 22	MODERATE
93181.0	NAVAL SHIPYARDS O6 (x1)	799	19	not analyzed	0.042	45.00		**0.920**	**1.382**	not analyzed	ELEVATED CHEM	MODERATE
90010.0	31 SWARTZ	159	6	not analyzed	**1.291**	39.00		not analyzed	not analyzed	not analyzed	NH3>0.4, SITE DEGRADED IN LEG 23	LOW
90039.0	CL	188	12	not analyzed	0.090	38.00	Chlordane, DDT	0.835	1.156	not analyzed	ELEVATED CHEM	MODERATE
93178.0	NAVAL SHIPYARDS O2 (x1)	796	19	not analyzed	0.350	20.00		0.647	0.936	not analyzed		LOW
93166.0	NAVY ESTUARY G2 (x1)	779	18	not analyzed	**1.129**	20.00		0.336	0.501	not analyzed	NH3>0.4	NO ACTION
93118.0	TIJUANA R. ESTUARY HH1 (x2)	713	15	0.0005	0.187	30.00	DDE	not analyzed	not analyzed	not analyzed	ELEVATED CHEM	MODERATE
90018.0	D DE LAPPE	748	16	not analyzed	0.039	19.00		not analyzed	not analyzed	not analyzed		LOW
90023.0	NM SANDBAG	172	7	not analyzed	0.378	32.00		0.173	0.302	not analyzed		LOW
90050.0	10 SWARTZ	199	7	not analyzed	0.004	47.00		0.240	0.416	not analyzed		LOW
90055.0	43 SWARTZ	204	7	not analyzed	0.075	37.00		0.238	0.372	not analyzed		LOW
90102.0	HARBOR BRIDGE 71A	256	7	not analyzed	0.113	14.00		0.149	0.243	not analyzed		LOW
90104.0	WEST BASIN ENTRANCE (71C) REF	275	12	not analyzed	**1.046**	13.00		0.192	0.314	not analyzed	NH3>0.4	NO ACTION
93106.0	MISSION BAY A2 (x1)-REP 2	1102	27	0.0007	0.106	25.00		0.190	0.275	not analyzed		LOW
93117.0	SAN DIEGO RIVER B2 (x2)	1029	24	0.0125	0.110	0.00		not analyzed	not analyzed	not analyzed		LOW
93119.0	TIJUANA R. ESTUARY HH1 (x1)	714	15	0.0015	0.224	22.00	DDE, DDT	0.599	0.726	not analyzed	ELEVATED CHEM	MODERATE
93127.0	SOUTH BAY GG2 (x1)	1028	24	nd	0.096	47.00		not analyzed	not analyzed	not analyzed		LOW
93128.0	SOUTHBAY GG5 (x1)	1033	24	nd	0.031	27.00		not analyzed	not analyzed	not analyzed		LOW
93132.0	CORONADO CAYS T3 (x1)	1025	24	nd	0.004	47.00		not analyzed	not analyzed	not analyzed		LOW
93138.0	SHELTER ISLAND E3 (x2)	741	16	not analyzed	0.020	29.00		0.185	0.282	not analyzed		LOW
93148.0	CHANNEL-CORONADO Y1 (x2)	751	16	not analyzed	**0.525**	47.00		0.151	0.225	not analyzed	NH3>0.4	NO ACTION
93154.0	NORTH SHORE-MOUTH CC4 (x1)	763	17	not analyzed	**0.836**	31.00		not analyzed	not analyzed	not analyzed	NH3>0.4	NO ACTION
93159.0	SOUTH BAY GG3 (x1)	768	17	not analyzed	**0.675**	21.00		not analyzed	not analyzed	not analyzed	NH3>0.4	NO ACTION
93174.0	TIJUANA R. ESTUARY HH3 (x2)	787	18	not analyzed	0.282	6.00		not analyzed	not analyzed	not analyzed		LOW
93175.0	TIJUANA R. ESTUARY HH3 (x3)	788	18	not analyzed	0.141	10.00	DDE, DDT	not analyzed	not analyzed	not analyzed	ELEVATED CHEM	MODERATE

sites to confirm the source of toxicity as non-anthropogenic. Stations were evaluated for benthic community condition using the benthic index discussed earlier (Table 11). Stations determined to be degraded, with elevated chemistry and/or toxicity, were assigned a moderate or high priority. Stations determined to be degraded, but which did not demonstrate elevated chemistry or toxicity, were assigned a low priority. Transitional and undegraded stations were not considered a priority unless chemical or toxicity results initially prioritized the stations. (Table 20- DEGRADED BENTHICS)

Stations were evaluated for elevated chemistry (criterion 3) using an ERM Summary Quotient >0.85 or a PEL Summary Quotient >1.29. In the earlier discussion of ERM and PEL summary quotients, it was determined these values are statistically above the 90% confidence interval of summary quotients from all stations analyzed. These quotients were used to identify stations where multiple pollutants were near or above established ERM and PEL guidelines (Table 22-CHEMISTRY-Summary Quotients). As shown in Figure 14, 100% of the stations analyzed for benthics were found to be degraded when chemical analysis demonstrated an ERMQ above 0.85. Although the eighteen stations in Table 22 (CHEMISTRY-Summary Quotients) did not have benthic community analysis performed, it is likely these stations will demonstrate degraded benthic communities, when analyzed. In consideration of this concern, all stations with elevated chemistry, based on ERM summary quotients above 0.85, were assigned a moderate priority ranking.

In situations where high summary quotient values were not found, but where any single chemical concentration exceeded four times (4x) its associated ERM or 5.9 times (5.9x) its associated PEL, the station was also considered to exhibit elevated chemistry. The 4x and 5.9x cutoffs were not statistically determined using the 90% confidence interval as they were with the summary quotients. Values for individual chemical quotients were not normally distributed and transformations did not improve distributions, so statistical determination of confidence limits was not appropriate. Instead, a qualitative examination of the data set indicated that only in the top 10th percentile of chemical measurements do values exceed four times their respective ERM or 5.9 times their respective PEL (Tables 20 and 22- CHEMISTRY-Individual Chemicals). These cutoffs were used to help identify stations where any single chemical was extremely elevated. Stations with elevated individual chemical quotients and evidence of benthic community degradation were assigned a moderate ranking. Stations which exhibited elevated chemistry, but showed no biological effects, were assigned a low priority.

Stations which satisfied all three of the criteria were considered a triad hit and are given the highest priority ranking. These stations demonstrated toxicity in the bioassay tests, benthic community degradation and elevated chemistry. Four stations (representing three sites) fell in this category: the Seventh Street Channel (90009-leg 23 and 93228), 12 Swartz

TABLE 22

FUTURE INVESTIGATION PRIORITY LIST FOR THE SAN DIEGO BAY REGION

Stations Without Synoptic Chemical, Toxicological and Benthic Community Analyses

STANUM	STATION	IDORG	LEG	H2S	NH3	% AMPHI SURVIVAL	>4X ERM OR >5.9X PEL	ERMQ	PELQ	BENTHICS	COMMENTS	PRIORITY
	CHEMISTRY-Summary Quotients											
90020.0	G DE LAPPE	169	12	not analyzed	0.020	49.00		0.964	1.255	not analyzed	ELEVATED CHEM	MODERATE
90020.0	G DE LAPPE-REP 1	1104	27	0.0006	0.086	65.00		1.051	1.411	not analyzed	ELEVATED CHEM	MODERATE
90020.0	G DE LAPPE-REP 2	1105	27	0.0007	0.087	59.00		1.043	1.401	not analyzed	ELEVATED CHEM	MODERATE
90020.0	G DE LAPPE-REP 3	1106	27	0.0009	0.049	57.00		0.947	1.293	not analyzed	ELEVATED CHEM	MODERATE
90030.0	BF SCHROEDER SITE F-REP 1	1144	28	0.0012	0.192	70.00		0.948	1.419	not analyzed	ELEVATED CHEM	MODERATE
90030.0	BF SCHROEDER SITE F-REP 2	1145	28	0.0025	0.616	76.00	PAHs	1.000	1.537	not analyzed	ELEVATED CHEM	MODERATE
90030.0	BF SCHROEDER SITE F-REP 3	1146	28	0.0013	0.017	68.00		1.007	1.438	not analyzed	ELEVATED CHEM	MODERATE
93178.0	NAVAL SHIPYARDS O2 (x1)-REP 1	1119	27	0.0022	0.185	61.00		0.934	1.294	not analyzed	ELEVATED CHEM	MODERATE
93178.0	NAVAL SHIPYARDS O2 (x1)-REP 2	1120	27	nd	0.145	66.00	PCBs	1.170	1.618	not analyzed	ELEVATED CHEM	MODERATE
93178.0	NAVAL SHIPYARDS O2 (x1)-REP 3	1121	27	0.0007	0.168	67.00	PCBs	1.269	1.851	not analyzed	ELEVATED CHEM	MODERATE
90022.0	P SWARTZ-REP 1	1107	27	0.0003	0.061	58.00	PAHs	1.042	1.549	not analyzed	ELEVATED CHEM	MODERATE
90022.0	P SWARTZ-REP 2	1108	27	0.0008	0.073	61.00	PAHs	1.109	1.770	not analyzed	ELEVATED CHEM	MODERATE
90022.0	P SWARTZ-REP 3	1109	27	0.0008	0.038	54.00	PAHs	1.107	1.724	not analyzed	ELEVATED CHEM	MODERATE
93179.0	NAVAL SHIPYARDS O3 (x1)-REP 2	1123	27	nd	0.049	51.00		1.071	1.482	not analyzed	ELEVATED CHEM	MODERATE
93179.0	NAVAL SHIPYARDS O3 (x1)-REP 3	1124	27	nd	0.115	78.00	Antimony	1.330	1.658	not analyzed	ELEVATED CHEM	MODERATE
93184.0	NAVAL SHIPYARDS O11 (x1)	802	19	not analyzed	0.070	53.00	DDT	1.226	1.774	not analyzed	ELEVATED CHEM	MODERATE
90017.0	C DELAPPE	166	6	not analyzed	0.840	64.00	PAHs	1.183	1.943	not analyzed	ELEVATED CHEM	MODERATE
93181.0	NAVAL SHIPYARDS O6 (x1)-REP 3	1112	27	0.003	0.037	65.00		0.904	1.362	not analyzed	ELEVATED CHEM	MODERATE
	CHEMISTRY-Individual Chemicals											
93162.0	SUB BASE C3 (x1)	775	18	not analyzed	0.585	53.00	PAHs	0.347	0.596	not analyzed	ELEVATED CHEM	LOW
90037.0	STORMDRAIN EM(GRAPE ST.)-REP 3	1161	29	0.0012	0.290	85.00	Chlordane	0.656	0.934	not analyzed	ELEVATED CHEM	LOW
93141.0	COMMERCIAL BASIN F3 (x1)-REP 3	1170	29	0.0004	0.057	70.00	Mercury	0.650	0.905	not analyzed	ELEVATED CHEM	LOW
93116.0	SAN DIEGO RIVER B1 (x4)	711	15	0.0893	0.137	88.00	Chlordane	0.659	0.913	not analyzed	ELEVATED CHEM, SITE DEGRADED IN LEG 22	MODERATE
93120.0	TIJUANA R. ESTUARY HH2 (x1)	715	15	0.0002	0.087	85.00	DDE	0.321	0.358	not analyzed	ELEVATED CHEM	LOW
93121.0	TIJUANA R. ESTUARY HH2 (x5)	716	15	0.0016	0.010	85.00	DDE	0.287	0.314	not analyzed	ELEVATED CHEM	LOW
93174.0	TIJUANA R. EST. HH3 (x2)-REP 3	1152	28	0.0044	0.084	80.00	DDE	0.325	0.395	not analyzed	ELEVATED CHEM	LOW
93177.0	NAVAL SHIPYARDS O1 (x1)	795	19	not analyzed	0.023	50.00	PAHs	0.694	1.204	not analyzed	ELEVATED CHEM	LOW

Downtown Anchorage (90002) and Naval Base/Shipyards 04 (93210). Three stations were given a high priority ranking although not all conditions of the triad were met (Seventh Street Channel (90009-leg 7) and Naval Shipyards 03 (93179- legs 19 & 27)). These stations demonstrated repeated toxicity and elevated chemistry but no benthic analyses were performed. However, benthic data for stations analyzed in the same proximity, or later sampling of the station, led to the concern that these sites would have been found degraded, if analyzed. In addition, chemical summary quotients at these three stations were at levels which suggest probable benthic community degradation, as discussed earlier. These concerns warranted upgrading these three stations from a moderate priority to a high priority. Forty three stations were given moderate priorities and 57 were given low priorities, based on the methods of prioritization previously discussed. Prioritized stations are mapped in Figure 27(a-d).

Stations were prioritized to assist SWRCB and RWQCB staff in meeting sediment quality management objectives for San Diego Bay. These recommendations were based on scientific evaluation of data collected between 1992 and 1994. They are intended to focus future efforts toward scientifically and economically responsible characterization of locations which have a high probability of causing adverse effects to aquatic life. This report should be evaluated in conjunction with all available information and additional research when management and policy decisions are made by SWRCB and RWQCB staff.

Possible Sources of Pollutants at Prioritized Stations

A brief description is given, where additional information was available, of factors which may have contributed to elevated chemical levels, toxicity, or benthic community degradation at the prioritized stations. Descriptions are given in order of geographic distribution, proceeding from north (Mission Bay) to south (Tijuana River Estuary).

In Mission Bay only one location was given the moderate priority ranking (station 93116). This station was located in the San Diego River flood control channel and demonstrated high total chlordane concentrations (36.1 ppb). Chlordane is not expected to undergo significant hydrolysis, oxidation, or direct photolysis in water, thus it may persist in soils for extended periods of time (Howard, 1991). Cohen *et al.* (1990) conducted a study on chlordane in soil samples near golf courses and found unusually high concentrations of chlordane (4.75-4310 ppb). Station 93116 is located directly down river from a golf course, therefore, runoff from this facility could be a chlordane source. Station 93107, in the mouth of Rose Inlet (northern Mission Bay), received a moderate priority listing, based on high chlordane concentrations. Its location is also near a golf course.

One site in North San Diego Bay (Point Loma area) received a moderate priority recommendation; stations 90028 (Submarine Base). This station had degraded benthic communities, high

Figure 27a
Future Investigation Priority List
North San Diego Bay

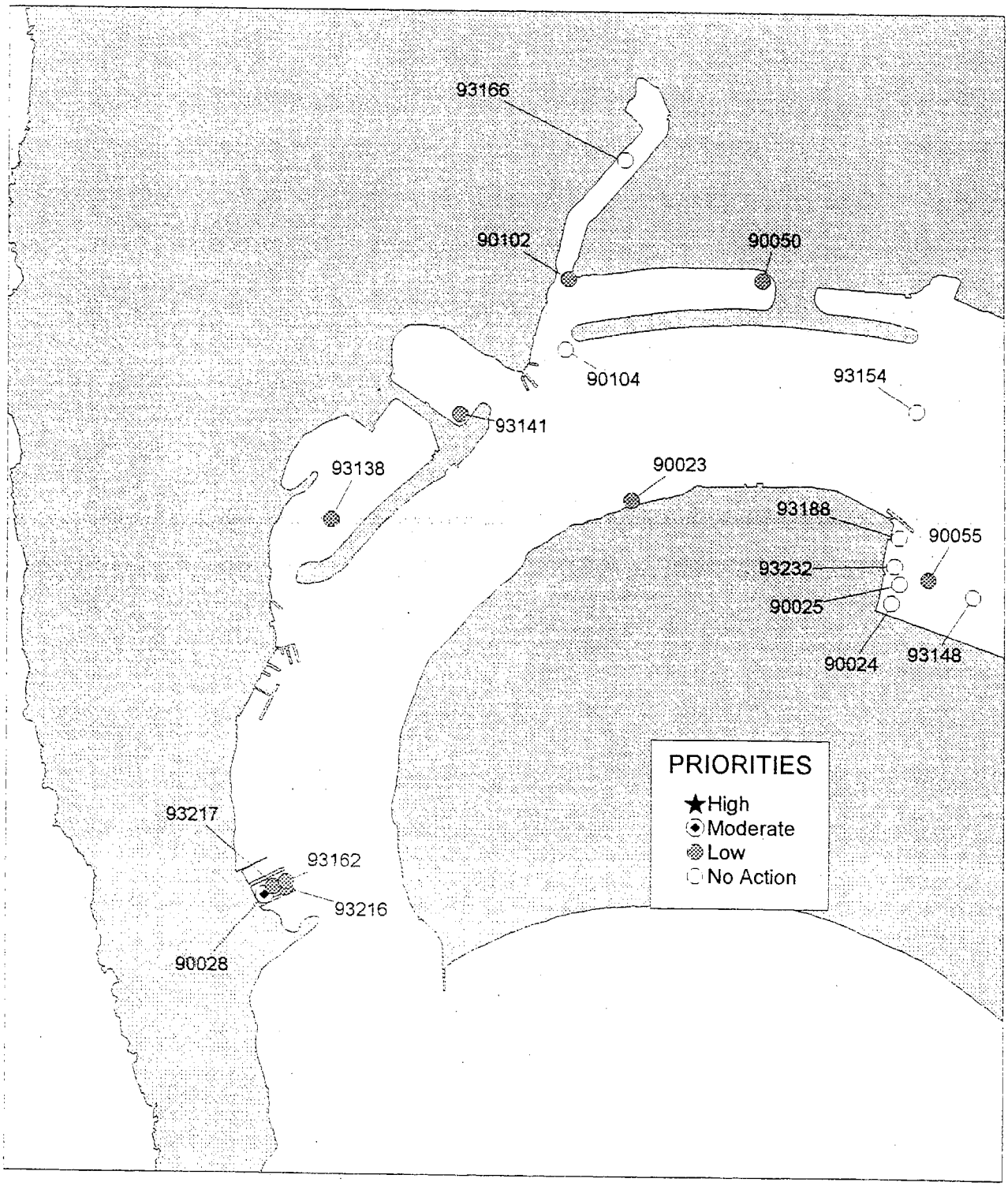


Figure 27b
Future Investigation Priority List
Mid San Diego Bay

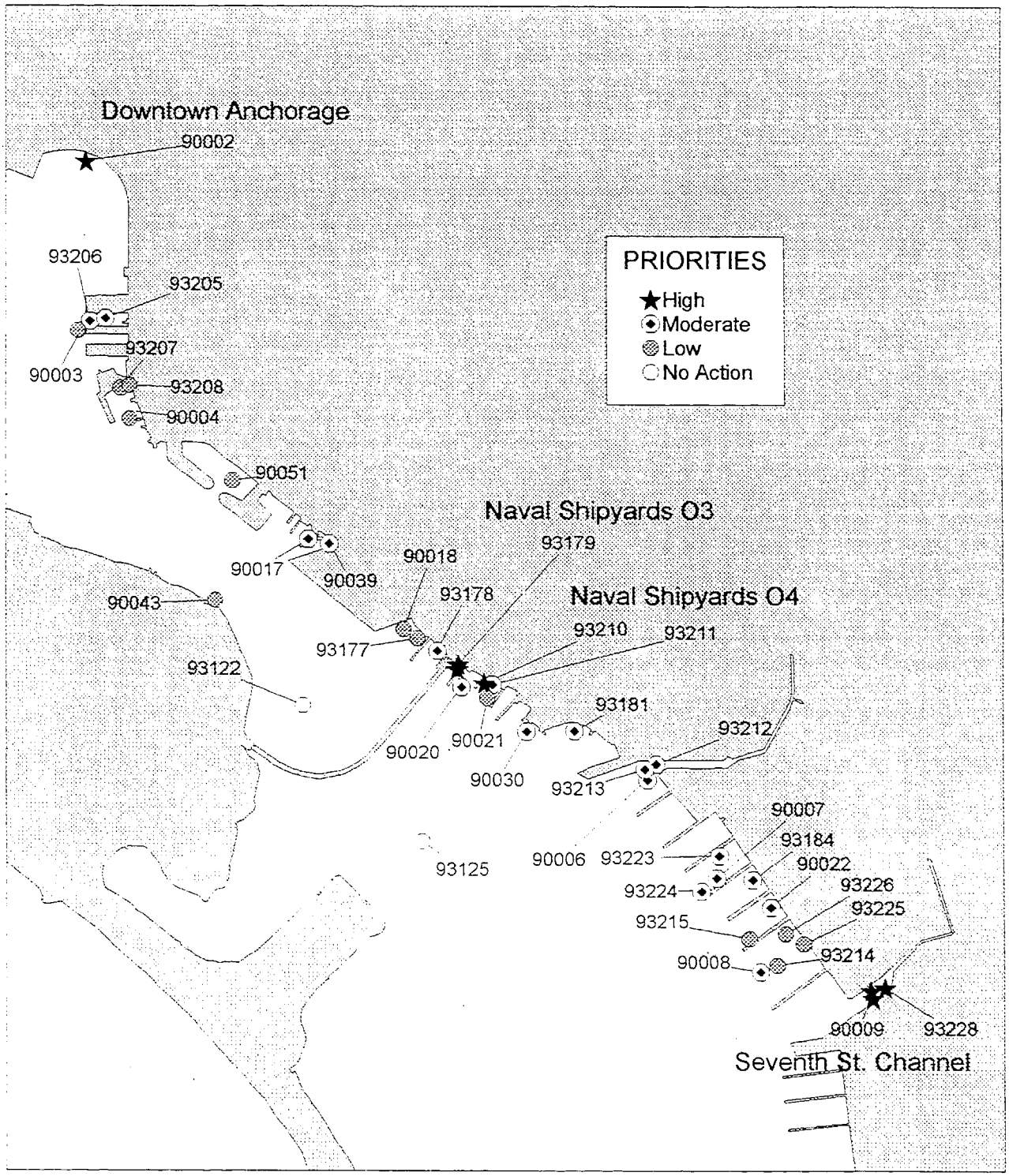


Figure 27c
Future Investigation Priority List
South San Diego Bay

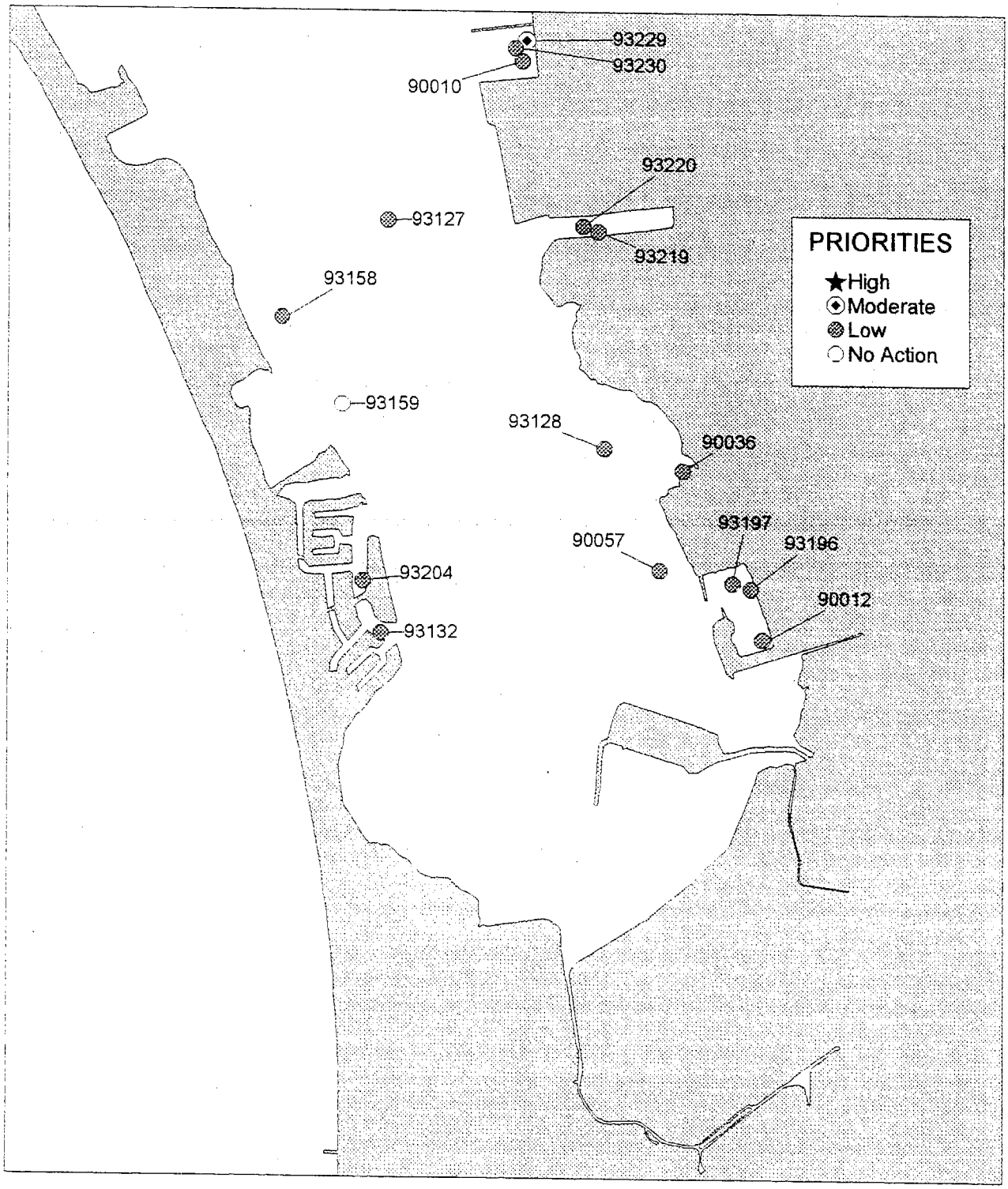
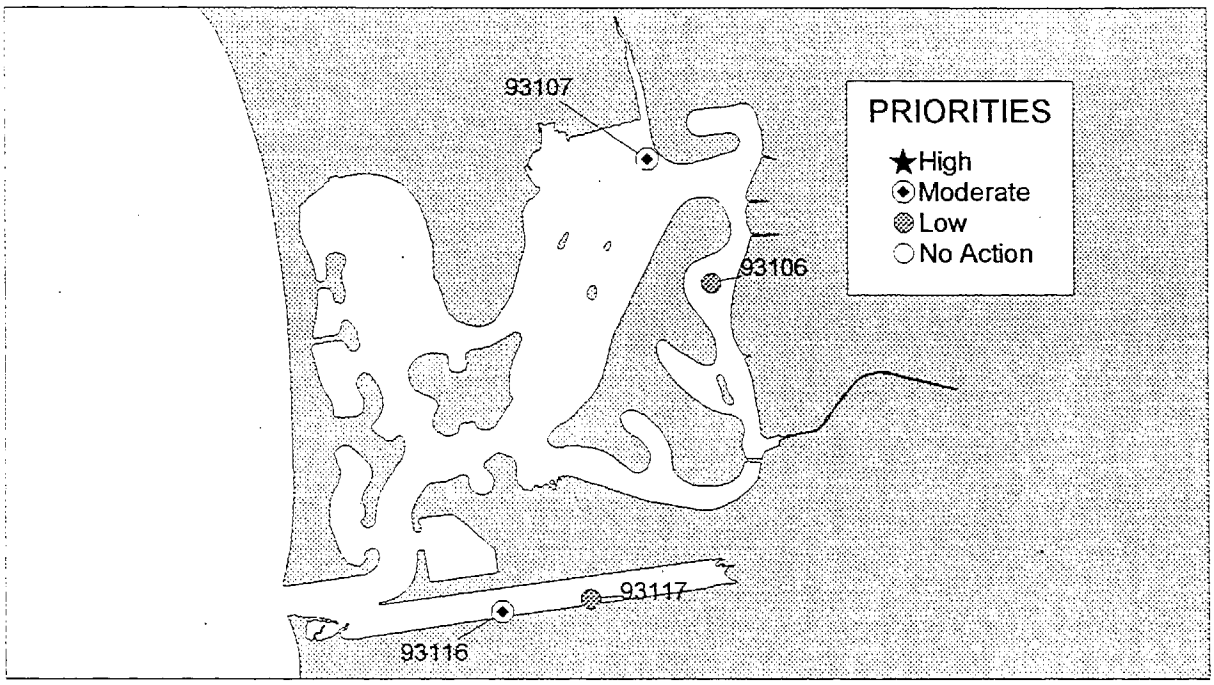
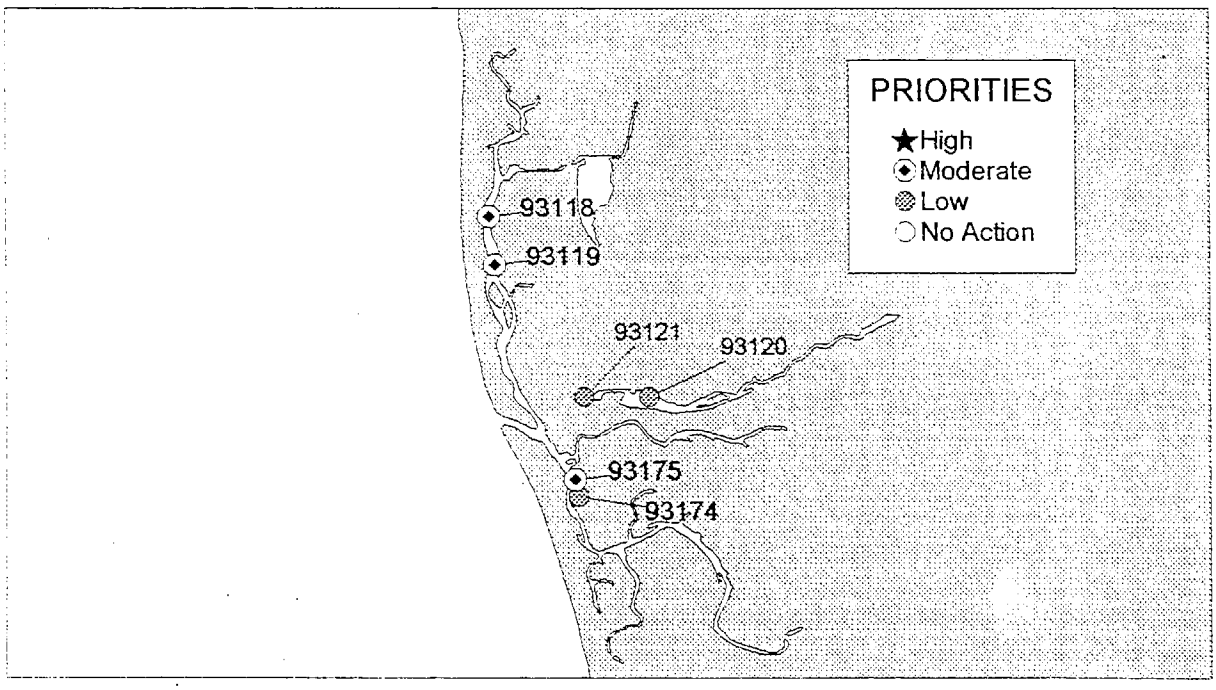


Figure 27d
Future Investigation Priority List
Mission Bay and San Diego River Estuary



Tijuana River Estuary



concentrations of low and high molecular weight PAHs, and moderate levels of metals. Historically the Naval Complex at Point Loma has received plating waste, sewage, and sludge containing high concentrations of metals and chlorinated hydrocarbons (Johnston *et al.*, 1989). Although it is difficult to identify the source of high concentrations of PAHs at these stations, Lung (1983) suggests ground water gradients promote groundwater flow towards San Diego Bay, thus potentially allowing PAHs in the nearby soil to migrate to the Bay. A number sites investigated by the Navy (Eakes and Smith, 1986), which were previously used for waste oil and drum disposal, are located onshore adjacent to and immediately north of stations 93216, 93217 and 90028. Migration of pollutants from these onshore sites is likely. Minor spills during fueling operations at the submarine base are also possible.

Station 90002 (Downtown Anchorage), located in the northern end of mid San Diego Bay, was one of the stations which received a high priority recommendation. High concentrations of metals and chlordane were present, as well as a degraded benthic community. This station also had a low survival for *Rhepoxynius* in solid phase toxicity tests. Perhaps the most obvious explanation for these data would be the presence of a large storm drain and numerous smaller storm drains, which empty into the Bay near this station. These storm drains drain parking lots, light industrial and commercial areas (Conway and Gilb, 1990). Another possible source for observed toxicity and chemistry is runoff from nearby San Diego International Airport. Results from the State Mussel Watch Program 1987-1993 indicate elevated levels of both metals and pesticides in mussel tissue and sediments in this area. Elevated levels of metals could have originated from anti-fouling paints on private boats anchored near the station (90002). The area around this station becomes a modified eddy during ebb tide and may serve to recirculate pollutants, creating a pollutant sink and preventing chemicals from being flushed out of the area (Peeling, 1974).

Located just south of station 90002, stations 93205 and 93206 (Downtown Piers) were given moderate priority ratings based on high chlordane and PAHs concentrations, and degraded benthic communities. Located between the B street pier and the Broadway pier, elevated levels of pollutants can most likely be attributed to sources similar to those described above. Commercial shipping is likely an additional contributor to the observed PAH signal in this area.

Two stations, 90017 and 90039 (located immediately north of the 10th avenue marine terminal), were assigned moderate priority rankings based on high concentrations of chlordane, metals, and PAHs at each of these stations. Campbell Industries operate five ship repair piers and four dry-docking facilities in this area. Sandblasting, painting, and other ship repair activities are probably the cause of the elevated levels of copper, zinc and mercury. High concentrations of metals have historically been detected at this site (Barry, 1972). The 10th avenue Marine

Terminal berths 1 and 2 are also located in this area (station 90039). Ships are loaded and unloaded at this site and supplied with fuel from four steel storage tanks located near the berths. Increased levels of PAHs and metals detected in this area may be related to the cargo transfer facility.

In addition to the ship repair facilities and cargo transfer areas, there is a large storm drain system which is directly south of the 10th and Imperial Trolley station. The system drains approximately eleven square kilometers of residential (including Balboa Park) and industrial areas before emptying into the Bay. The elevated levels of chlordane and PAHs at both of the sites could have additional sources from within this drainage system.

Immediately south of the Coronado Bridge was station 93179 (Naval Shipyards-03) which was designated as a high priority site for future investigations. To the north and south of this site are numerous stations assigned a moderate prioritization. The predominant activity in this area is ship building and repair (NASSCO, Continental Maritime, Southwest Marine), thus indicating the probable source of high levels of metals, PCBs and PAHs found at stations sampled in this area. A stormdrain, which drains an industrial area and empties into the Bay immediately adjacent to the bridge, is the likely chlordane source to the area. Runoff from the bridge itself could also be viewed as a potential source of PAHs and metals in the Bay. The California State Mussel Watch Program (1995) has sampled extensively in this area of San Diego Bay and found chemistry values for mussels and sediment to be comparable to the current study. This area has also been extensively sampled in other studies resulting in similar conclusions (de Lappe, 1989; Martin, 1985; Anderson, 1989). Toxicity, chemical pollution and benthic community degradation are extensive in this area and warrant further site characterizations.

Stations 93212, 93213, and 90006 (Naval Shipyards-07) were located near the 28th Street pier and were each given a moderate priority ranking. Chollas Creek empties into the Bay near this site, carrying with it runoff from a large urban area. This creek is believed to carry high concentrations of PAHs into the Bay (McCain *et al.*, 1992) and is the likely source of high chlordane levels at the site.

Numerous low, moderate and high priority sites were located in the Naval Station between the 28th Street pier and 7th Street channel. This area demonstrated toxicity, high metal and chemistry concentrations and degraded benthic communities. The area is predominantly used for ship repair, outfitting, and conversion. Sand blasting, painting, and the changing of zinc electrolysis plates are some of the specific activities conducted in this area and are likely the main sources of metals found in the sediments.

Station 93227 was located in the 7th Street Channel at the southern end of the San Diego Naval Station. This site was given

the high priority ranking based on high metal, chlordane and PAH concentrations, as well as toxicity and degraded benthic communities. Repeated sampling of this site resulted in similar findings. Paleta Creek runs directly into 7th Street channel with numerous drains located in the immediate area emptying into the creek and bay. Also, a large stormdrain is present which drains a residential area east of Interstate 5 and the Naval station adjacent to the channel.

The Navy has used 7th Street channel and the surrounding area for a variety of activities. Excess materials (solid waste, ships stores, and waste hydraulic fluids) from decommissioned ships were disposed of in the ship repair basins. Overflow from salvage yards, lube and hydraulic oil wastes, and paint sludge from nearby Naval repair facilities were often taken to the area's wet docks for disposal. In the late 1970's trucks and heavy equipment returning form Vietnam were routinely decontaminated by spraying with diesel fuel and dunking (by crane) into Paleta Creek. It is estimated that approximately 75,000 to 360,000 gallons of petroleum based material were disposed of at this site during its period of operation (1945-1973).

The 7th Street channel is located near a Navy salvage yard which has stormdrains emptying directly into the channel. In 1976, soil samples retrieved from the area contained PCB concentrations high enough to result in the upper eight inches of soil being removed as contaminated waste and the entire area paved. Although the Navy has attempted to deal with this historic pollution in the area, further investigations were requested by a Naval initial assessment team in 1986 (Eakes and Smith, 1986). Furthermore, the California State Mussel Watch program has stations located in the area and concluded 7th Street channel had some of the highest chemical concentrations in San Diego Bay (State Mussel Watch Program, 1995).

The Marine terminal site (stations 90010, 93230 and 93229) demonstrated elevated copper and PAH levels and a degraded benthic community. Moderate and low priorities were assigned to these stations even though a portion of this area is currently undergoing cleanup activities. Due to the large amount ore spillage at the PACO copper loading facility, this area should continue to be monitored after cleanup activities are completed.

The southern portion of San Diego Bay, from 7th Street channel to the Otay River, did not receive any moderate or high priority rankings. Although this result could give the impression south San Diego Bay is in not polluted, it is important to note some stations still demonstrated high metals concentrations. The Sweetwater channel area (station 93220), and other sites in the South San Diego Bay had high concentrations of copper, most likely reflecting the input from the copper ore loading facility (Martin, 1985). Three stations in the Chula Vista area and one in Coronado Cays received low priority rankings due to elevated levels of metals and degraded benthic communities. Each of these stations were located within marinas where numerous private boats

are berthed. Increased levels of metals detected in this area are probably from anti-fouling paint scrapings or zinc electrolysis blocks used on virtually all boats. Few studies have concentrated sampling in the South San Diego Bay, presumably due to reduced shipping activity and population.

Stations from the Tijuana River Estuary demonstrated elevated concentrations of DDT and DDE, as well as toxicity to amphipods. This resulted in a number of stations receiving moderate and low prioritizations. The presumed sources of this pesticide were wastewater discharges from Mexico, into the Tijuana River (California State Coastal Conservancy, 1989).

Comparison of Pollution with Other Water Bodies

Numerous studies comparing San Diego Bay with other bays and harbors have been conducted (NOAA, 1991; Grovenhoug *et al.*, 1987; Goldberg *et al.*, 1978). In one such study, Robertson (1989) analyzed sediments for a number of organic pollutants at approximately 200 sites around the coasts of the United States. Results ranked San Diego Bay seventh highest in the country for total concentrations of PCBs. Interestingly, San Diego Bay did not rank high in comparison to the rest of the country for any other organic pollutant, although results from the current study clearly showed elevated concentrations (relative to ERMs and PELs) of total PAHs, chlordane, and certain trace metals throughout the Bay.

In a similar study, Johnston (1990) evaluated 367 waste disposal sites at 58 Navy and Marine Corps bases located throughout the country. Each of the bases, or areas of activity, were located in the coastal zone and were reviewed to characterize the pollutants, disposal methods, and potential impact to the surrounding aquatic environment. Four sites were chosen in San Diego Bay: Naval Station San Diego (located immediately south of the seventh street channel), Naval Amphibious Base (near Glorietta Bay), Naval Training Center, and Naval Complex Point Loma. Although these sites were not ranked or compared with sites in other parts of the country, the types of contamination listed were somewhat similar for each of the sites described. Paint, oil, and solvent contamination was reported at all of the sites in addition to some site specific forms of contamination(*i.e.* sandblasting grit disposal area at the Naval Amphibious Base and drum disposal area at the Naval Complex Point Loma).

San Diego Bay has also been compared to other bodies of water on a regional scale. In a SCCWRP project funded by the State Board, Anderson and Gossett (1987) analyzed PAHs in sediments collected at stations between Santa Monica Bay and San Diego Bay and found the Seventh Street (Paleta Creek) and Chollas Creek stations to contain the highest levels of these hydrocarbons. In a follow-up State Board/SCCWRP study Anderson *et al.* (1988) compared ten coastal sites in southern California for concentrations of trace metals, PAHs, chlorinated hydrocarbons and toxicity. Samples from San Diego Bay were shown to have the highest concentrations of

metals, PAHs, and hydrocarbons of all stations sampled, and were the most toxic in two out of three toxicity tests used. Anderson *et al.* (1988) identified the Seventh Street Channel station as the most polluted area in the San Diego Bay Region. This conclusion is corroborated by the current study which also found sampling stations in the Seventh Street Channel to be the most polluted and most toxic stations in the region.

Flegal and Sanudo-Wilhelmy (1993) showed total dissolved trace metal (Ag, Cd, Co, Cu, Ni, and Pb) concentrations in San Diego Bay are comparable to levels of trace element pollution in south San Francisco Bay. Specifically, copper was found in elevated concentrations in both bays. The current study found copper to be the predominant trace element pollutant in San Diego Bay. Flegal and Sanudo-Wilhelmy concluded that unlike south San Francisco Bay, elevated trace metal concentrations in San Diego Bay could not be directly linked to point-source inputs, because all wastewater discharges to San Diego Bay were terminated in 1964. Copper based anti-fouling paints and urban runoff are currently the most likely sources of copper. Elevated concentrations of copper in San Diego Bay have also been reported in other studies (Zirino *et al.*, 1978).

It is also important to analyze available site specific data within San Diego Bay from previous studies. In the current study, commercial and naval shipyards located near the Coronado Bridge consistently demonstrated high concentrations of pollutants, a high incidence of toxicity, and benthic community degradation. Shipbuilding activity, in addition to storm drains and creeks, appear to be the primary sources of organic and trace metal pollutants in these areas (Conway and Gilb, 1990). Secondary sources of contamination may include runoff from the Coronado Bridge (San Diego Interagency Water Quality Panel, 1989) and polluted fill in the area (Peter Michael, San Diego Regional Water Quality Control Board, personal communication). This is supported by the conclusions of McCain (1992) who found several major sources of pollutants in the central portion of San Diego Bay.

Specific organic pollutants such as PCBs have been historically identified in certain parts of the bay. In one of the earliest studies of PCBs in San Diego Bay, Young and Heesen (1977) identified PCBs in mussel tissues. The highest measured concentrations occurred in Commercial Basin (Shelter Island). Subsequent studies have also shown elevated levels of PCBs in the Shelter Island area, as well as near Harbor Island and numerous other spots throughout the Bay (Stephenson *et al.*, 1980; Martin, 1985). Similar results were obtained from sediment samples in the current study in which high concentrations of PCBs were reported from areas near the Coronado Bridge, west Commercial Basin and East Basin near Harbor Island. The Regional Water Quality Control Board has identified a 60 inch storm drain as the main source of PCBs into the East Basin site. Cleanup and Abatement Orders, regarding PCBs, have been issued to boatyards in and around Shelter Island and Harbor Island (San Diego Interagency Water Quality Panel, 1994).

Tributyltin (TBT), an organic based biocide, was widely used as an antifoulant on ships and small craft until 1988 (Richard and Lillebo, 1988). Although TBT is highly efficient at killing fouling organisms it is also acutely toxic to non-target organisms, making it a continuing concern in the San Diego Bay Region. Toxic effects have been observed in concentrations as low as 1 ng/L (Henderson, 1988). Long term monitoring of U.S. harbors indicates that among naval bases, San Diego has relatively low concentrations of TBT (Kram *et al.*, 1989; Seligman *et al.*, 1990). These studies focused on comparisons between U.S. Naval facilities (i.e. Pearl harbor, Norfolk harbor) where use of TBT anti-fouling paints is not restricted on vessels over 25 meters in length (Organotin Antifouling Paint Control Act, 1988). Because San Diego Bay is a multi-use port, where smaller non-naval vessels must conform to the 1988 legislation, TBT values are expectedly lower than harbors which solely contain large naval vessels. In the current study, TBT values were highest in naval and commercial basin areas, similar to the findings of Seligman *et al.* (1990). Although both studies found elevated levels of TBT in commercial and naval sites, data from the current study indicates an overall decline in TBT sediment concentrations at these locations. This is most likely a reflection of restrictive legislation on TBT use in antifouling paints. Given the historical use of antifouling paints in San Diego Bay, continued monitoring is recommended, although results from the current study were encouraging.

Limitations

The two step sampling design of this study relied on an initial "screening phase" to give a broad assessment of toxicity in the San Diego Bay Region. Subsequent toxicity test, chemical analysis and benthic community analysis were performed only on selected stations (≈ 40% of the screened stations) which demonstrated toxicity during the screening phase, or were considered candidates as reference stations. The remaining stations, from the screening phase, did not receive additional testing or analysis. Therefore, statistical analyses, comparisons to chemical specific screening values, identification of undegraded and degraded habitats, and prioritized rankings could not be performed on all stations sampled. Currently these stations fall under a no action recommendation, but it should be understood that for these stations a weight-of-evidence evaluation was not performed, due to the absence of chemical and/or benthic community data.

In determination of toxicity for the reference envelope approach, values must be chosen for alpha and the percentile (p) to calculate the edge of the reference envelope (L) using the following equation:

$$L = X_r - [\ g_{a,p,n} * S_r\ ]$$

The values of alpha and p are chosen to express the degree of certainty desired when classifying a sample as toxic. In this study values of alpha=.05 and p=1 were used to distinguish the most toxic samples which have a 95% certainty of being in the most toxic 1% (Figure 4). This calculation resulted in a determination of toxicity for the *Rhepoxynius* test when samples had a mean survival of less than 48%. If the value of p was chosen to equal 10% (*i.e.*, a 95% certainty of being in the most toxic 10%) the determination of toxicity (edge of the reference envelope) would have been at 63% survival. Obviously, a choice of p=10% would broaden the range of samples which would be classified as "toxic". It must be recognized the 48% level used in this study was chosen as a conservative guideline to identify only the most toxic stations for setting priorities for future work. The 48% survival cutoff used in this study should be recognized as a statistical determination which may or may not reflect the certainty desired by SWRCB and RWQCB staff for sediment quality management purposes.

There is a necessary caution to the ecological applicability of data collected from studies such as reported here. Although measures of toxicity and chemical concentration are used extensively in this study, they can only be used as indicators of possible adverse effects to indigenous communities. Benthic community assessment is the only tool used in this study which can demonstrate actual effects to resident biological communities. In combination, these three measures provide a strong weight of evidence for the conditions found at a particular sampling location. However, it is recommended these lines of evidence be supported with an ecological risk assessment during subsequent investigations of stations of concern.

CONCLUSIONS

The major conclusions of this study were:

1. Two sets of sediment quality guidelines were useful in demonstrating chemical pollution: The ERL/ERM thresholds developed by NOAA (Long and Morgan, 1990; Long *et al.*, 1995) and the TEL/PEL thresholds used in Florida (MacDonald, 1993; MacDonald, 1994). Copper, mercury, zinc, total chlordane, total PCBs, and PAHs were most often found to exceed critical ERM or PEL values. These were considered the major chemicals or chemical groups of concern in the San Diego Bay Region. ERM and PEL summary quotients were developed as chemical indices for evaluating pollution of sediments with multiple chemicals. An ERM summary quotient >0.85 or a PEL summary quotient >1.29 was indicative of sites where multiple chemicals were significantly elevated. Stations with any chemical concentration >4 times its respective ERM or >5.9 times its respective PEL were considered to exhibit elevated chemistry.

2. The identification of degraded and undegraded habitat was determined by macrobenthic community structure, using a cumulative, weight-of-evidence approach. Analyses of the 75

stations sampled for benthic community structure identified 23 undegraded stations, 43 degraded and 9 transitional stations. All sampled stations with an ERM quotient>0.85 were found to have degraded communities. All sampled stations with P450 responses above 60 μg/g BaPEq. were found to have degraded benthic communities.

3. Exceedances of toxicity thresholds were determined using two approaches: the reference envelope approach and laboratory control comparison approach. The reference envelope approach was the more conservative of the two, indicating toxicity for the *Rhepoxynius* (amphipod) sediment test was significant when survival was less than 48%, in samples tested. No reference envelope was determined for the *Strongylocentrotus* (urchin) fertilization or development tests. High variability in pore water data from reference stations produced a lower confidence boundary for the reference envelope below 0% survival. This indicates no significant distinction in toxicity could be made between reference stations and other stations for these pore water tests.

4. Using the EMAP definition of toxicity, 56% of the total area sampled in the San Diego Bay Region was toxic to *Rhepoxynius*. For *Strongylocentrotus* development test, percent of total area toxic was 29%, 54%, and 72% respectively for 25%, 50%, and undiluted pore water concentrations. Samples representing 36%, 27%, or 14% of the study area were toxic to both *Rhepoxynius* in solid phase sediment and to *Strongylocentrotus* larvae in 100%, 50%, or 25% pore water, respectively. Spatial extent of toxicity was not determined using the reference envelope definition of toxicity.

5. Linear regression analyses failed to reveal strong correlations between amphipod survival and chemical concentration. It is suspected instead of a linear response to chemical pollutants, most organisms are tolerant of pollutants until a threshold is exceeded. Comparisons to established sediment quality guideline thresholds demonstrate an increased incidence of toxicity for San Diego Bay Region samples with chemical concentrations exceeding the ERM or PEL values. It is further suspected toxicity in urban bays is caused by exposure to complex mixtures of chemicals. Comparisons to ERM summary quotients (multiple chemical indicators) demonstrate that the highest incidence of toxicity (>78%) is found in samples with elevated ERM summary quotients (>0.85).

Statistical analyses of the P450 Reporter Gene System responses versus the PAHs in sediment extracts demonstrated that this biological response indicator was significantly correlated ($r^2 = 0.86$) with sediment PAH (total and high molecular weight) concentrations.

6. Stations requiring further investigation were prioritized based on combined evidence from toxicity, chemical and benthic community data. Prioritizations were developed to help direct

future investigations by State and Regional Water Board staff at these stations. Each station receiving a high, moderate, or low priority ranking meets one or more of the criteria under evaluation for determining hot spot status in the Bay Protection and Toxic Cleanup Program. Those meeting all criteria were given the highest priority for further action.

Seven stations (representing four sites) were given a high priority ranking, 43 stations were given a moderate priority ranking, and 57 stations were given a low priority ranking. The seven stations receiving the high priority ranking were in the Seventh Street channel area, two naval shipyard areas near the Coronado Bridge, and the Downtown Anchorage area west of the airport. The majority of stations given moderate rankings were associated with commercial areas and naval shipyard areas in the vicinity of the Coronado Bridge. Low priority stations were interspersed throughout the San Diego Bay Region.

7. A review of historical data supports the conclusions of the current research. Possible sources for pollution at prioritized stations are given. Recommendations are made for complementary investigations which could provide additional evidence for further characterizing stations of concern.

RECOMMENDATIONS

Given the supporting evidence of previous studies, the patterns of chemical pollution and bioeffects observed during this assessment of the San Diego Bay Region are convincing. There are additional avenues of investigation though which would complement the results of this study. The results also should be confirmed with further studies before any adverse ecological impacts can be conclusively demonstrated.

Due to the large number of elevated chemicals at the majority of the prioritized sampling stations, toxic biological responses can only be associated with overall chemical pollution, rather than a particular chemical. However, stations on the priority list, where the number of ERM or PEL exceedances is low and the exceedance for a particular chemical is high, are excellent candidates for toxicity identification evaluations (TIE). The ability to distinguish between causative factors of toxicity is enhanced when multiple chemicals are not involved. Stations Naval Base 07(x1), 12 Swartz (Downtown Anchorage), and the San Diego River, where high chlordane concentrations are found, are well suited for TIE manipulations which would attempt to test this organic pesticide as the causative toxicity agent. The Naval Base/Shipyard 010(x6) station, which only demonstrates ERM or PEL exceedances for trace metals, is well suited for manipulations which could remove metal toxicity (*e.g.*, EDTA additions).

Several chemicals of concern identified in the San Diego Bay region have been shown to bioconcentrate and biomagnify in the

tissues of marine species. A tissue contamination study for lipophilic compounds such as PCBs, chlordane, and possibly methylmercury is recommended to address human health concerns due to consumption of impacted resident species. This line of investigation seems necessary considering tissue contamination is the only BPTCP criterion not investigated during this study.

Although specific stations are identified as having a high probability of causing adverse effects, no attempt can be made to define the boundaries of the impacted area. Sampling specifically designed to quantify areal extent of an impacted area must be addressed during intensive site characterizations.

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Appendix A

Data Base Description

APPENDIX A

DATA BASE DESCRIPTION

for the

SWRCB/NOAA COOPERATIVE PROJECT
SAN DIEGO BAY

A Report prepared for the

California State Water Resources Control Board
Bays and Estuaries Unit
Bay Protection and Toxic Cleanup Program

by the

California Department of Fish and Game
Marine Pollution Studies Laboratories
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September, 1996

I. OVERVIEW OF THE BAY PROTECTION PROGRAM

The California State Water Resources Control Board (SWRCB) has contracted the California Department of Fish and Game (CDFG) to coordinate the scientific aspects of the Bay Protection and Toxic Cleanup Program (BPTCP), a SWRCB program mandated by the California Legislature. The BPTCP is a comprehensive, long-term effort to regulate toxic pollutants in California's enclosed bays and estuaries. The program consists of both short-term and long-term activities. The short-term activities include the identification and priority ranking of toxic hot spots, development and implementation of regional monitoring programs designed to identify toxic hot spots, development of narrative sediment quality objectives, development and implementation of cleanup plans, revision of waste discharge requirements as needed to alleviate impacts of toxic pollutants, and development of a comprehensive database containing information pertinent to describing and managing toxic hot spots. The long-term activities include development of numeric sediment quality objectives; development and implementation of strategies to prevent the formation of new toxic hot spots and to reduce the severity of effects from existing toxic hot spots; revision of water quality control plans, cleanup plans, and monitoring programs; and maintenance of the comprehensive database.

Actual field and laboratory work is performed under contract by the California Department of Fish and Game (CDFG). The CDFG subcontracts the toxicity testing to Dr. Ron Tjeerdema at the University of California at Santa Cruz (UCSC) and the laboratory testing is performed at the CDFG toxicity testing laboratory at Granite Canyon, south of Carmel. The CDFG contracts the majority of the sample collection activities to Dr. John Oliver of San Jose State University at the Moss Landing Marine Laboratories (MLML) in Moss Landing. Dr. Oliver also is subcontracted to perform the TOC and grain size analyses, as well as to perform the benthic community analyses. CDFG personnel perform the trace metals analyses at the trace metals facility at Moss Landing Marine Laboratories in Moss Landing. The synthetic organic pesticides, PAHs and PCBs are contracted by CDFG to Dr. Ron Tjeerdema at the UCSC trace organics facility at Long Marine Laboratory in Santa Cruz. MLML currently maintains the Bay Protection and Toxic Cleanup Database for the SWRCB. Described below is a description of that database system.

II. DESCRIPTION OF COMPUTER FILES

The sample collection/field information, chemical, and toxicity data are stored on hard copy, computer disks and on a 486DX PC at Moss Landing Marine Laboratories. Access is limited to Russell Fairey. Contact Russell Fairey at (408) 633-6035 for copies of data. The data are stored in a dBase 4 program and can be exported to a variety of formats. There are three backups of this database stored in two different laboratories. The data are entered into 1 of 2 files. REG9CHEM.DBF file contains all the collection and chemical data. REG9TOX.DBF file contains all the collection and toxicity test data. A hardcopy printout of the dBase database structure is attached, showing precise characteristics of each field.

The REG9CHEM.DBF file is the chemistry data file which contains the following fields (the number at the start of each field is the field number):

1. STANUM. This numeric field is 7 characters wide with 1 decimal place and contains the CDFG station numbers that are used statewide. The format is YXXXX.Z where Y is the Regional Water Quality Control Board Region number and XXXX is the number that corresponds to a given location or site and Z is the number of the station within that site. An example is West Basin in San Diego Harbor where the STANUM is 90050.0. The 9 indicates Region 9. The 0050 indicates that it is Site 50 and the .0 is the replicate (if any) at the station within Site 50.

2. STATION. This character field is 30 characters wide and contains the exact name of the station.

3. IDORG. This numeric field is 8 characters wide and contains the unique i.d. organizational number for the sample. For each station collected on a unique date, an idorg sample number is assigned. This should be the field that links the collection, toxicity, chemical, and other data bases.

4. DATE. This date field is 8 characters long and is the date that each sample was collected in the field. It is listed as MM/DD/YY.

5. LEG. This numeric field is 6 characters wide and is the leg number of the project in which the sample was collected.

6. LATITUDE. This character field is 12 characters wide and contains the latitude of the center of the station sampled. The format is a character field as follows: XX,YY,ZZ, where XX is in degrees, YY is in minutes, and ZZ is in seconds or hundreds.

7. LONGITUDE. This character field is 14 characters wide and contains the longitude of the center of the station sampled. The format is a character field as follows: XX,YY,ZZ, where XXX is in degrees, YY is in minutes, and ZZ is in seconds or hundreds.

8. GISLAT. This numeric field is 12 characters wide with 8 decimal places and contains the latitude of the station sampled in Geographical Information System format. The format is a numeric field as follows: XX.YYYYYYYY, where XX is in degrees and YYYYYYYY is a decimal fraction of the preceding degree.

9. GISLONG. This character field is 14 characters wide with 8 decimal places and contains the longitude of the station sampled. The format is a character field as follows: XXXX.YYYYYYYY where XXXX is in degrees and YYYYYYYY is a decimal fraction of the preceding

degree.

10. HUND_SECS. This character is 1 character wide and contains the designation "h" if the latitude and longitude are given in degrees, minutes and hundredths of a minute. The designation "s" is given when latitude and longitude are given in degrees, minutes and seconds.

11. DEPTH. This character field is 4 characters wide and contains the depth at which the sediment sample was collected, in meters to the nearest one half meter.

12. METADATA. This is an index directing the user to tables or files of ancillary data pertinent to associated test. Character field, width 12.

TRACE METALS IN SEDIMENT are presented in fields 13 through 32. All sediment trace metal results are reported on a dry weight basis in parts per million (ppm).

A. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed.
B. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected.

Sediment trace metals are numeric fields of varying character width, and including the following elements, listed by field number, then field name as it appears in the database, then numeric character width and number of decimal places:

13. TMMOIST. 6.2
14. ALUMINUM. 9.2
15. ANTIMONY. 7.3
16. ARSENIC. 6.3
17. CADMIUM. 7.4
18. CHROMIUM. 8.3
19. COPPER. 7.2
20. IRON. 7.1
21. LEAD. 6.3
22. MANGANESE. 7.2
23. MERCURY. 7.4
24. NICKEL. 7.3
25. SILVER. 7.4
26. SELENIUM. 6.3
27. TIN. 8.4
28. ZINC. 9.4
29. ASBATCH. 5.1
30. SEBATCH. 5.1
31. TMBATCH. The Batch number that the sample was digested in, numeric character width 5 and 1 decimal places.
32. TMDATAQC. Data qualifier codes are notations used by data reviewers to briefly describe, or qualify data and the systems producing data, numeric character width 3. Data qualifier codes are as follows:

A. When the sample meets or exceeds the control criteria

requirements, the value is reported as "-4".

B. When the sample has minor exceedances of control criteria but is generally usable for most assessments and reporting purposes, the value is reported as "-5". For samples coded "-5" it is recommended that if assessments are made that are especially sensitive or critical, QA evaluations should be consulted before using the data.
C. When QA samples have major exceedances of control criteria requirements and the data are not usable for most assessments and reporting purposes, the value is reported as "-6".
D. When the sample has minor exceedances of control criteria and is unlikely to affect assessments, the value is reported as -3.

SYNTHETIC ORGANICS are presented in fields 33 through 147. All synthetic organic results are reported on a dry weight basis in parts per billion (ppb or ng/g).

A. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed.
B. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected.

Synthetic organics are reported on a dry weight basis in parts per billion (ppb or ng/g) and are numeric fields of varying character width, and include the following compounds, listed by field number, then field name as it appears in database (and followed by the compound name if not obvious), and then finally, the numeric character width and number of decimal places is given:

33. SOWEIGHT. This numeric field is 6 characters wide with 2 decimal places and contains the weight of the sample extracted for analysis.
34. SOMOIST. This numeric field is 6 characters wide with 2 decimal places and contains the percent moisture of the sample extracted.
35. ALDRIN. 9.3
36. CCHLOR. cis-Chlordane. 9.3
37. TCHLOR. trans-Chlordane. 9.3
38. ACDEN. alpha-Chlordene. 9.3
39. GCDEN. gamma-Chlordene. 9.3
40. CLPYR. Chlorpyrifos. 8.2
41. DACTH. Dacthal. 9.3
42. OPDDD. o,p'-DDD. 8.2
43. PPDDD. p,p'-DDD. 9.3
44. OPDDE. o,p'-DDE. 8.2
45. PPDDE. p,p'-DDE. 8.2
46. PPDDMS. p,p'-DDMS. 8.2
47. PPDDMU. p,p'-DDMU. 8.2
48. OPDDT. o,p'-DDT. 8.2
49. PPDDT. p,p'-DDT. 8.2
50. DICLB. p,p'-Dichlorobenzophenone. 8.2
51. DIELDRIN. 9.3
52. ENDO_I. Endosulfan I. 9.3

53. ENDO_II. Endosulfan II. 8.2
54. ESO4. Endosulfan sulfate. 8.2
55. ENDRIN. 8.2
56. ETHION. 8.2
57. HCHA. alpha HCH 9.3
58. HCHB. beta HCH 8.2
59. HCHG. gamma HCH (Lindane) 9.3
60. HCHD. delta HCH 9.3
61. HEPTACHLOR. 9.3
62. HE. Heptachlor Epoxide. 9.3
63. HCB. Hexachlorobenzene. 9.3
64. METHOXY. Methoxychlor. 8.2
65. MIREX. 9.3
66. CNONA. cis-Nonachlor. 9.3
67. TNONA. trans-nonachlor. 9.3
68. OXAD. Oxadiazon. 8.2
69. OCDAN. Oxychlordane. 9.3
70. TOXAPH. Toxaphene. 7.2
71. PESBATCH.The batch number that the sample was extracted in, numeric character width 6 and 2 decimal places.
72. TBT. tributyltin. 8.4
73. TBTBATCH.The batch number that the sample was extracted in, numeric character width 5 and 1 decimal place.
74. PCB5. 9.3
75. PCB8. 9.3
76. PCB15. 9.3
77. PCB18. 9.3
78. PCB27. 9.3
79. PCB28. 9.3
80. PCB29. 9.3
81. PCB31. 9.3
82. PCB44. 9.3
83. PCB49. 9.3
84. PCB52. 9.3
85. PCB66. 9.3
86. PCB70. 9.3
87. PCB74. 9.3
88. PCB87. 9.3
89. PCB95. 9.3
90. PCB97. 9.3
91. PCB99. 9.3
92. PCB101. 9.3
93. PCB105. 9.3
94. PCB11O. 9.3
95. PCB118. 9.3
96. PCB128. 9.3
97. PCB132. 9.3
98. PCB137. 9.3
99. PCB138. 9.3
100. PCB149. 9.3
101. PCB151. 9.3
102. PCB153. 9.3
103. PCB156. 9.3
104. PCB157. 9.3
105. PCB158. 9.3
106. PCB170. 9.3
107. PCB174. 9.3
108. PCB177. 9.3

109. PCB180. 9.3
110. PCB183. 9.3
111. PCB187. 9.3
112. PCB189. 9.3
113. PCB194. 9.3
114. PCB195. 9.3
115. PCB201. 9.3
116. PCB203. 9.3
117. PCB206. 9.3
118. PCB209. 9.3
119. PCBBATCH. The batch number that the sample was extracted in, numeric character width 6 and 2 decimal place.
120. ARO5460. 9.3
121. ACY. Acenaphthylene. 8.2
122. ACE. Acenaphthene. 8.2
123. ANT. Anthracene. 8.2
124. BAA. Benz[a]anthracene. 8.2
125. BAP. Benzo[a]pyrene. 8.2
126. BBF. Benzo[b]fluoranthrene. 8.2
127. BKF. Benzo[k]fluoranthrene. 8.2
128. BGP. Benzo[ghi]perylene. 8.2
129. BEP. Benzo[e]pyrene. 8.2
130. BPH. Biphenyl. 8.2
131. CHR. Chrysene. 8.2
132. DBA. Dibenz[a,h]anthracene. 8.2
133. DMN. 2,6-Dimethylnaphthalene. 8.2
134. FLA. Fluoranthrene. 8.2
135. FLU. Fluorene. 8.2
136. IND. Indo[1,2,3-cd]pyrene. 8.2
137. MNP1. 1-Methylnaphthalene. 8.2
138. MNP2. 2-Methylnaphthalene. 8.2
139. MPH1. 1-Methylphenanthrene. 8.2
140. NPH. Naphthalene. 8.2
141. PHN. Phenanthrene. 8.2
142. PER. Perylene. 8.2
143. PYR. Pyrene. 8.2
144. TMN. 2,3,4-Trimethylnaphthalene. 8.2
145. PAHBATCH. The batch number that the sample was extracted in, numeric character width 6 and 2 decimal places.
146. SOBATCH. The batch number that the sample was extracted in, numeric character width 6 and 2 decimal places.
147. SODATAQA. Data qualifier codes are notations used by data reviewers to briefly describe, or qualify data and the systems producing data, numeric character width 3. Data qualifier codes are as follows:
   A. When the sample meets or exceeds the control criteria requirements, the value is reported as "-4".
   B. When the sample has minor exceedances of control criteria but is generally usable for most assessments and reporting purposes, the value is reported as "-5". For samples coded "-5" it is recommended that if assessments are made that are especially sensitive or critical, the QA evaluations should be consulted before using the data.
   C. When QA samples have major exceedances of control criteria requirements and the data are not usable for most assessments and reporting purposes, the value is reported as "-6".

D. When the sample has minor exceedances of control criteria and is unlikely to affect assessments, the value is reported as -3.

SEDIMENT PARTICULATE SIZE ANALYSES DATA. Field 148, with a field name of "FINES", represents the sediment particulate size ("grain size") analyses data for each station. The grain size results are reported as percent fines.

148. FINES. Sediment grain size (percent fines) for each station. Numeric field, width 5 and 2 decimal places.
   A. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed.
   B. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected.
149. FINEBATCH. The batch number that the sample was analyzed in, numeric field character width 4.
150. FINEDATAQC. Data qualifier codes are notations used by data reviewers to briefly describe, or qualify data and the systems producing data, numeric character width 3. Data qualifier codes are as follows:
   A. When the sample meets or exceeds the control criteria requirements, the value is reported as "-4".
   B. When the sample has minor exceedances of control criteria but is generally usable for most assessments and reporting purposes, the value is reported as "-5". For samples coded "-5" it is recommended that if assessments are made that are especially sensitive or critical, QA evaluations should be consulted before using the data.
   C. When QA samples have major exceedances of control criteria requirements and the data are not usable for most assessments and reporting purposes, the value is reported as "-6".
   D. When the sample has minor exceedances of control criteria and is unlikely to affect assessments, the value is reported as -3.

SEDIMENT TOTAL ORGANIC CARBON (TOC) ANALYSES DATA. Field 151 presents the levels of total organic carbon detected in the sediment samples at each station. All TOC results are reported as percent of dry weight.

151. TOC. Total Organic Carbon (TOC) levels (percent of dry weight) in sediment, for each station. Numeric field, width 6 and 2 decimal places.
   A. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed.
   B. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected.
152. TOCBATCH. The batch number that the sample was analyzed in, numeric field character width 4.
153. TOCDATAQC. Data qualifier codes are notations used by data reviewers to briefly describe, or qualify data and the systems producing data, numeric character

width 3. Data qualifier codes are as follows:

A. When the sample meets or exceeds the control criteria requirements, the value is reported as "-4".
B. When the sample has minor exceedances of control criteria but is generally usable for most assessments and reporting purposes, the value is reported as "-5". For samples coded "-5" it is recommended that if assessments are made that are especially sensitive or critical, the QA evaluations should be consulted before using the data.
C. When QA samples have major exceedances of control criteria requirements and the data are not usable for most assessments and reporting purposes, the value is reported as "-6".
D. When the sample has minor exceedances of control criteria and is unlikely to affect assessments, the value is reported as -3.

The REG9TOX.DBF file is the toxicity data file which contains the following fields (the number at the start of each field is the field number:

1. STANUM. This numeric field is 7 characters wide with 1 decimal place and contains the CDFG station numbers that are used statewide. The format is YXXXX.Z where Y is the Regional Water Quality Control Board Region number and XXXX is the number that corresponds to a given location or site and Z is the number of the station within that site. An example is West Basin in San Diego Harbor where the STANUM is 90050.0. The 9 indicates Region 9. The 0050 indicates that it is Site 50 and the .0 is the replicate (if any) at the station within Site 50.
2. STATION. This character field is 30 characters wide and contains the exact name of the station.
3. IDORG. This numeric field is 8 characters wide with 1 decimal place and contains the unique i.d. organizational number for the sample. For each station collected on a unique date, an idorg sample number is assigned. This should be the field that links the collection, toxicity, chemical, and other data bases.
4. DATE. This date field is 8 characters long and is the date that each sample was collected in the field. It is listed as MM/DD/YY.
5. LEG. This numeric field is 6 characters wide and is the leg number of the project in which the sample was collected.
6. TYPE. This character field is 7 characters wide and describes whether the sample was a field sample, replicate or control.
7. METADATA. This is an index directing the user to tables or files of ancillary data pertinent to associated test. Character field, width 12.
8. CTRL. This character field is 5 characters wide and describes the type of control being used.
9. LATITUDE. This character field is 12 characters wide and contains the latitude of the center of the station

sampled. The format is a character field as follows: XX,YY,ZZ, where XX is in degrees, YY is in minutes, and ZZ is in seconds or hundreds.

10. LONGITUDE. This character field is 14 characters wide and contains the longitude of the center of the station sampled. The format is a character field as follows: XX,YY,ZZ, where XXX is in degrees, YY is in minutes, and ZZ is in seconds or hundreds.
11. GISLAT. This numeric field is 12 characters wide with 8 decimal places and contains the latitude of the station sampled in Geographical Information System format. The format is a numeric field as follows: XX.YYYYYYYY, where XX is in degrees and YYYYYYYY is a decimal fraction of the preceding degree.
12. GISLONG. This character field is 14 characters wide with 8 decimal places and contains the longitude of the station sampled. The format is a character field as follows: XXXX.YYYYYYYY where XXXX is in degrees and YYYYYYYY is a decimal fraction of the preceding degree.

AMPHIPOD SURVIVAL TOXICITY TEST DATA. The following are descriptions of the field headings for the amphipod (Rhepoxynius abronius (RA), presented in fields 13 through 24.

13. RA_MN. Station mean percent survival. Numeric field, width 6 and 2 decimal places.
14. RA_SD. Station standard deviation of percent survival. Numeric field, width 6 and 2 decimal places.
15. RA_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
16. RASITE_MN. Station mean percent survival for replicate of three, when appropriate. Numeric field, width 6 and 2 decimal places.
17. RASITE_SD. Station standard deviation of percent survival for replicate of three, when appropriate. Numeric field, width 6 and 2 decimal places.
18. RASITE_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
19. RA_OTNH3. Total ammonia concentration (mg/L in water) in overlying water (water above bedded sediment used for amphipod tests) for each station analyzed using amphipod toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 7 and 3 decimal places.
20. RA_OUNH3. Unionized ammonia concentration (mg/L in water) in overlying water (water above bedded sediment

used for amphipod tests) for each station analyzed using amphipod toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 7 and 3 decimal places.

21. RA_OH2S. Hydrogen sulfide concentration (mg/L in water) in overlying water (water above bedded sediment used for amphipod tests) for each station analyzed using amphipod toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 7 and 4 decimal places.
22. RA_ITNH3. Total ammonia concentration (mg/L in water) in interstitial water (water above bedded sediment used for amphipod tests) for each station analyzed using amphipod toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 10 and 3 decimal places.
23. RA_IUNH3. Unionized ammonia concentration (mg/L in water) interstitial water (water within bedded sediment used for amphipod tests) for each station analyzed using amphipod toxicity tests. When the value is missing or not analyzed, the value is reported as "9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 10 and 3 decimal places.
24. RA_IH2S. Hydrogen sulfide concentration (mg/L in water) in interstitial water (water within bedded sediment used for amphipod tests) for each station analyzed using amphipod toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 10 and 4 decimal places.
25. RABATCH. The batch number that the sample were run in, numeric character width 10.
26. RADATAQC. Data qualifier codes are notations used by data reviewers to briefly describe, or qualify data and the systems producing data, numeric character width 4. Data qualifier codes are as follows:

A. When the sample meets or exceeds the control criteria requirements, the value is reported as "-4".
B. When the sample has minor exceedances of control criteria but is generally usable for most assessments and reporting purposes, the value is reported as "-5". For samples coded "-5" it is recommended that if assessments are made that are especially sensitive or critical, the QA evaluations should be consulted before using the data.

C. When the QA sample has major exceedances of control criteria requirements and the data is not usable for most assessments and reporting purposes, the value is reported as "-6".
D. When the sample has minor exceedances of control criteria and is unlikely to affect assessments, the value is reported as -3.

ABALONE LARVAL SHELL DEVELOPMENT TOXICITY TEST DATA. The following are descriptions of the field headings for the larval (Haliotis rufescens) shell development toxicity tests, presented in fields 27 through 30. Results are given for undiluted subsurface water (100%).

27. HRS100_MN. Station mean percent normal development in 100% subsurface water. Numeric field, width 6 and 2 decimal places.
28. HRS100_SD. Station standard deviation of percent normal development in 100% subsurface water. Numeric field, width 6 and 2 decimal places.
29. HRS100_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
30. HRS100_NH3. Unionized ammonia concentration (mg/L in water) in subsurface water for each station analyzed in abalone toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 6 and 3 decimal places.

The following are descriptions of the field headings for the sea urchin (Strongylocentrotus purpuratus) fertilization toxicity tests, presented in fields 31 through 41. Results are given for undiluted pore water (100% pore water), pore water that is diluted with Granite Canyon seawater to a 50% of original concentration (50% pore water), and pore water that is diluted with Granite Canyon seawater to a 25% of original concentration (25% pore water).

31. SPPF100_MN. Station mean percent fertilization in 100% pore water. Numeric field, width 6 and 2 decimal places.
32. SPPF100_SD.Station standard deviation of percent fertilization in 100% pore water. Numeric field, width 6 and 2 decimal places.
33. SPPF100_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
34. SPPF100NH3. Unionized ammonia concentration (mg/L in water) in pore water samples (100%). When the value

is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 7 and 3 decimal places.

35. SPPF100H2S. Hydrogen sulfide concentration (mg/L in water) in pore water samples (100%). When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0"= not detected. Numeric field, width 7 and 4 decimal places.
36. SPPF50_MN. Station mean percent fertilization in 50% pore water. Numeric field, width 6 and 2 decimal places.
37. SPPF50_SD. Station standard deviation of % fertilization in 50% pore water. Numeric field, width 6 and 2 decimal places.
38. SPPF50_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
39. SPPF25_MN. Station mean percent fertilization in 25% pore water. Numeric field, width 6 and 2 decimal places.
40. SPPF25_SD. Station standard deviation of percent fertilization in 25% pore water. Numeric field, width 6 and 2 decimal places.
41. SPPF25_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.

The following are descriptions of the field headings for the sea urchin embryo (Strongylocentrotus purpuratus) development tests, presented in fields 42 through 54. Results are given for undiluted pore water (100% pore water), pore water that is diluted with Granite Canyon seawater to a 50% of original concentration (50% pore water), and porewater that is diluted with Granite Canyon seawater to a 25% of original concentration (25% pore water).

42. SPPD100_MN. Station mean percent normal development in 100% pore water. Numeric field, width 6 and 2 decimal places.
43. SPPD100_SD. Station standard deviation of percent normal development in 100% pore water. Numeric field, width 6 and 2 decimal places.
44. SPPD100_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.

45. SPPD100NH3. Unionized ammonia concentration (mg/L in water) in pore water samples (100%). When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 7 and 3 decimal places.
46. SPPD100H2S. Hydrogen sulfide concentration (mg/L in water) in pore water samples (100%). When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0"= not detected. Numeric field, width 7 and 4 decimal places.
47. SPPD50_MN. Station mean percent normal development in 50% pore water. Numeric field, width 6 and 2 decimal places.
48. SPPD50_SD. Station standard deviation of percent normal development in 50% pore water. Numeric field, width 6 and 2 decimal places.
49. SPPD50_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
50. SPPD25_MN. Station mean percent normal development in 25% pore water. Numeric field, width 6 and 2 decimal places.
51. SPPD25_SD. Station standard deviation of percent normal development in 25% pore water. Numeric field, width 6 and 2 decimal places.
52. SPPD25_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
53. SPPDBATCH. The batch number that the samples were analyzed in, numeric character width 10.
54. SPPDQC. Data qualifier codes are notations used by data reviewers to briefly describe, or qualify data and the systems producing data, numeric character width 3. Data qualifier codes are as follows:
    A. When the sample meets or exceeds the control criteria requirements, the value is reported as "-4".
    B. When the sample has minor exceedances of control criteria but is generally usable for most assessments and reporting purposes, the value is reported as "-5". For samples coded "-5" it is recommended that if assessments are made that are especially sensitive or critical, the QA evaluations should be consulted before using the data.
    C. When the QA sample has major exceedances of control criteria requirements and the data is not usable for most assessments and reporting purposes, the value is reported as "-6".
    D. When the sample has minor exceedances of control

criteria and is unlikely to affect assessments, the value is reported as -3.

The following are descriptions of the field headings for the sea urchin embryo (Strongylocentrotus purpuratus) cytogenetic tests, presented in fields 55 through 59. Results are given for undiluted pore water (100% pore water).

55. SPPC100_MN. Station mean percent normal mitosis in 100% pore water. Numeric field, width 6 and 2 decimal places.
56. SPPC100_SD. Station standard deviation of percent normal mitosis in 100% pore water. Numeric field, width 6 and 2 decimal places.
57. SPPC100_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 6.
58. SPPC100NH3. Unionized ammonia concentration (mg/L in water) in pore water samples (100%). When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 6 and 3 decimal places.
59. SPPC100H2S. Hydrogen sulfide concentration (mg/L in water) in pore water samples (100%). When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0"= not detected. Numeric field, width 7 and 4 decimal places.

MUSSEL LARVAL SHELL DEVELOPMENT TOXICITY TEST DATA. The following are descriptions of the field headings for the larval (Mytilus edulis) shell development toxicity tests, presented in fields 60 through 63. Results are given for undiluted subsurface water (100%).

60. MES100_MN. Station mean percent normal development in 100% subsurface water. Numeric field, width 6 and 2 decimal places.
61. MES100_SD. Station standard deviation of percent normal development in 100% subsurface water. Numeric field, width 6 and 2 decimal places.
62. MES100_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
63. MES100_NH3. Unionized ammonia concentration (mg/L in water) in subsurface water. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as

"-8.0" = not detected. Numeric field, width 6 and 3 decimal places.

The following are descriptions of the field headings for the larval (Mytilus edulis) shell development toxicity tests, presented in fields 64 through 68. Results are given for undiluted pore water (100% pore water).

64. MEP100_MN. Station mean percent normal development in 100% pore water. Numeric field, width 6 and 2 decimal places.
65. MEP100_SD. Station standard deviation of percent normal development in 100% pore water. Numeric field, width 6 and 2 decimal places.
66. MEP100_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
67. MEP100_NH3. Unionized ammonia concentration (mg/L in water) in pore water samples (100%). When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 6 and 3 decimal places.
68. MEP100_H2S. Hydrogen sulfide concentration (mg/L in water) in pore water samples (100%). When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0"= not detected. Numeric field, width 7 and 4 decimal places.

POLYCHAETE SURVIVAL TOXICITY TEST DATA. The following are descriptions of the field headings for the polychaete worm (Neanthes arenaceodentata) survival toxicity tests, presented in fields 69 through 71.

69. NASURV_MN. Station mean percent survival. Numeric field, width 6 and 2 decimal places.
70. NASURV_SD. Station standard deviation of % survival. Numeric field, width 6 and 2 decimal places.
71. NASURV_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.

POLYCHAETE WEIGHT TOXICITY TEST DATA. The following are descriptions of the field headings for the polychaete worm (Neanthes arenaceodentata) weight toxicity tests, presented in fields 72 through 80.

72. NAWT_MN. Station mean weight (gm). Numeric field, width 6 and 2 decimal places.

73. NAWT_SD. Station standard deviation of weight (gm). Numeric field, width 6 and 2 decimal places.
74. NAWT_SG. Station statistical significance, representing the significance of the statistical test between the home sediment and the sample. A single * represents significance at the .05 level, and double ** represents significance at the .01 level. ns = not statistically significant. Character field, width 5.
75. NA_OTNH3. Total ammonia concentration (mg/L in water) in overlying water (water above bedded sediment used for polychaete tests) for each station analyzed using polychaete toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 7 and 3 decimal places.
76. NA_OUNH3. Unionized ammonia concentration (mg/L in water) in overlying water (water above bedded sediment used for polychaete tests) for each station analyzed using polychaete toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 7 and 3 decimal places.
77. NA_OH2S. Hydrogen sulfide concentration (mg/L in water) in overlying water (water above bedded sediment used for polychaete tests) for each station analyzed using polychaete toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 9 and 4 decimal places.
78. NA_ITNH3. Total ammonia concentration (mg/L in water) in interstitial water (water above bedded sediment used for polychaete tests) for each station analyzed using polychaete toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 9 and 3 decimal places.
79. NA_IUNH3. Unionized ammonia concentration (mg/L in water) in interstitial water (water within bedded sediment used for polychaete tests) for each station analyzed using polychaete toxicity tests. When the value is missing or not analyzed, the value is reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 9 and 3 decimal places.
80. NA_IH2S. Hydrogen sulfide concentration (mg/L in water) in interstitial water (water within bedded sediment used for amphipod tests) for each station analyzed using amphipod toxicity tests. When the value is missing or not analyzed, the value is

reported as "-9.0" = not analyzed. When the value is less than the detection limit of the analytical test, the value is reported as "-8.0" = not detected. Numeric field, width 9 and 4 decimal places.