ECOLOGICAL HEALTH ASSESSMENT OF MISSION BAY, SAN DIEGO, CA - TEMPORAL AND SPATIAL VARIABILITY EFFECTS ON DATA INTERPRETATION

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ABSTRACT

At over 4,000 acres, Mission Bay Park is the West Coast's largest aquatic park and represents one of San Diego's unique treasures. In addition to its recreational value, Mission Bay Park also hosts a diverse assemblage of species indigenous to the southern California coastline and is home to several wildlife preserves. In order to better understand and address Mission Bay's ecological health issues, a comprehensive two-year study of water quality, sediment quality, and pelagic and benthic communities is currently in progress. A portion of the chemical and toxicological data for the first year of monitoring is presented here. The sampling program consists of six key sites, one each near the three major sources of fresh water input to eastern Mission Bay, two representative of large regions in the center of the bay, and one reference site located near the mouth. The analysis of both small-scale spatial variability and temporal trends are evaluated in this assessment. Results to date indicate that observable biological impacts and elevated levels of chemical inputs appear to be related to areas near the creek drainages, however, both spatial and temporal variability is high. Results indicate ecological health studies in shallow marine estuaries without multiple sampling events and field replication can easily lead to erroneous conclusions.

INTRODUCTION

A comprehensive, first of its kind study of water quality, sediments, and pelagic and benthic communities of Mission Bay was initiated November 2001. This presentation summarizes chemical and toxicological results from the first year of sampling. Year one (November 2001 - November 2002) was funded by the City of San Diego. The current second year of the program is funded by a 319(h) grant. The goals of the Mission Bay Watershed Evaluation are to:

1. Develop baseline water quality, sediment, and benthic community monitoring data and begin the process of analyzing the relationships between monitoring data and environmental factors in the watershed and spatial and temporal variability;

2. Provide the City of San Diego, regulatory agencies, and other stakeholders with the necessary data to make informed decisions and to develop and implement an effective Watershed Management Plan and other pollution prevention strategies (e.g. development of Total Maximum Daily Loads); and

3. Utilize the citizen-monitoring aspect of the project as a means to educate students and the general public about the environmental and human health impacts of urban runoff and other pollution sources.

Mission Bay Watershed Evaluation Participants and tasks

City of San Diego – Funding, program and data review

University of San Diego (MES, Chemistry)
- Hydrography (temperature, salinity, turbidity, dissolved oxygen)
- Water quality (nitrate, phosphate, silica)
- Planktonic community (abundance, composition)
- Sediment quality (grain size, organic content)
- Benthic community (abundance, composition)

AMEC Earth & Environmental, Inc.
- Field study management and execution
- Sediment chemistry (organics, metals)
- Sediment and pore water toxicity

San Diego BayKeeper
- Water quality (organics, metals)

MATERIALS AND METHODS

Following is a summary of data collected and sampling frequency for the entire program:

Water Column Metrics

Biweekly
- Nutrients (N, P, Si)
- Plankton community

Quarterly
- Metals (Cd, Cu, Pb, and Zn)
- Toxicity (bivalve embryo development - *Mytilus galloprovincialis*)

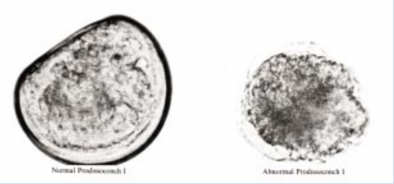
Sediment Metrics

Monthly
- Grain size
- Total organic carbon
- Benthic community

Quarterly
- Metals (Cd, Cu, Pb, and Zn)
- Organic pollutants (PAHs, TRPH, organophosphate and organochlorine pesticides, PCBs)
- Toxicity

1) 10-day amphipod survival - *Eohaustorius estuarius, Ampelisca abdita**
2) Solid-phase 48-hr bivalve embryo development – Blue mussel *Mytilus galloprovincialis*

*tested November 2001 only



Normal and abnormal bivalve embryo

Sediments were collected using a .038 m2 Birge-Eckman stainless steel box core

Eohaustorius estuarius

Amphipod Test Chambers

Sampling Design

Samples were collected at six sites within Mission Bay (Figure 1). Three sites were located in the eastern portion of the bay near each of the major fresh water input point sources: Tecolote Creek Inlet (TC), Cudahy Creek Inlet (CC), and Rose Creek Inlet (RC). Two sites were located in large central portions of the bay: Fiesta Bay (FB) and Sail Bay (SB). One site was located in the western portion of the bay Ventura Point (VP). Ventura Point was representative of an in-bay control location due to its proximity to the ocean entrance and high degree of flushing. At each of the six sampling sites, sediments were collected at three field replicate locations spaced in linear relation approximately 20 to 30 meters apart. Field replicates were treated as distinct samples for all analyses. Water samples were collected at each middle replicate location. Plankton was collected along three replicate transects parallel to the field sediment replicate locations at each site.

**Figure 1.
Mission Bay Sampling Locations**

Ventura Point and Sail Bay

Fiesta Bay

Rose Creek

Tecolote Creek

Cudahy Creek

RESULTS

Sediment Characteristics and Chemistry:

Mean concentrations and value ranges for selected measurements are included in Table 1. In summary, contaminant levels were low relative to those measured in industrially-impacted regions within neighboring San Diego Bay. Concentrations of measured constituents were elevated among the three creek inlet sites located in the east portion of the bay relative to those measured in the central and outer bay. With the exception of chlordane and DDT, chemical concentrations for those analytes measured are well below biological effects range median (ER-M) screening levels developed by Long and Morgan (1995). Chlordane was well above ER-M screening levels in all samples from the Tecolote Creek inlet, and several samples from Cudahy and Rose Creek inlets. Effects range low (ER-L) values were exceeded for several PAHs, organochlorine pesticides, and trace metals, most often in the eastern creek inlet locations.

Mean grain size distribution and total organic carbon content was comparable among all sites with the exception of Ventura Point. Due to its proximity to the entrance, sediments at VP are coarser with lower TOC than other sites selected in this study.

Table 1. Mean values and ranges of measurements of selected parameters at each site across all sampling events.

Site		Amphipod % Surv	Bivalve % Surv/Norm	Cadmium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	TRPH (mg/kg)	Total PAHs (µg/kg)	4-4'-DDE (µg/kg)	4-4'-DDT (µg/kg)	Chlordane (µg/kg)	Dieldrin (µg/kg)	TOC (%)	% Sand	Mean Grain Size (µm)
Ventura Point	Mean	90	87	0.31	5.0	3.8	28	73	201	ND	ND	ND	ND	0.15	83	195
	Low	85	42	0.20	0.1	1.1	10	31	6.6	ND	ND	ND	ND	0.02	75	156
	High	96	124	0.41	11	7.1	45	270	406	ND	ND	ND	ND	0.38	91	247
Sail Bay	Mean	81	79	0.43	16	15	65	75	212	ND	ND	ND	ND	0.62	45	123
	Low	68	48	0.23	7	10	41	24	54	ND	ND	ND	ND	0.3	44	121
	High	88	121	0.64	23	21	162	180	669	ND	ND	ND	ND	1.3	46	124
Fiesta Bay	Mean	81	80	0.63	21	19	76	80	146	ND	ND	ND	ND	0.65	38	92
	Low	67	45	0.27	15	11	47	26	11	ND	ND	ND	ND	0.22	33	77
	High	93	121	0.83	28	27	144	170	534	ND	ND	ND	ND	1.2	44	112
Rose Creek	Mean	74	69	0.83	27	38	154	215	401	1.1	ND	**17**	ND	0.88	32	96
	Low	57	34	0.32	18	27	75	40	33	0.9	ND	**13**	ND	0.43	27	75
	High	91	107	1.24	38	50	**468**	600	713	1.5	ND	**23**	ND	1.9	35	134
Cudahy Creek	Mean	80	73	0.57	18	25	69	139	838	1.7	ND	**24**	1.3	0.45	58	188
	Low	65	34	0.20	3.7	3.7	22	30	98	0.5	ND	**10**	1.1	0.03	35	77
	High	89	123	0.95	37	48	136	540	2258	3.1	ND	**36**	1.5	1.4	91	349
Tecolote Creek	Mean	60	77	0.58	19	34	100	214	516	2.8	3.5	**26**	1.4	0.44	40	116
	Low	6	30	0.27	2.5	5.9	14	53	146	0.6	0.6	**8.3**	0.57	0.03	23	55
	High	88	124	1.45	37	56	168	860	786	9.0	**7.5**	**74**	3.6	1.2	63	212
ER-L [a]				1.2	34	46.7	150			2.2	1.0	0.5	0.02			
ER-M [a]				9.6	270	218	410			27	7.0	6.0	8.0			

[a] Long and Morgan (1995)

Bold Exceeds ER-M screenin levels for biolo ical effects.

Spatial Relationships at Each Site:

Concentrations of selected analytes at each replicate location during one sampling period, November 2002, are depicted in Figures 2-5. Total organic carbon, grain size, and mean concentrations of a number of constituents often varied dramatically between sampling locations at each site, primarily in the east bay locations. Visual heterogeneity at each site was often dramatic. In shallow back-bay locations, clear boundaries between uniform sandy areas and depressed regions loaded with organic debris and fine black sediments may span < 0.1 meter. Despite little rainfall during the sampling period, these boundaries were dynamic and changed throughout the year. Variations in grain size, TOC, and chemical concentrations reflect the high degree of heterogeneity observed between replicates in the eastern portions of the bay. Benthic coverage of eelgrass, macroalgae, sponges, and *Musculista senhousia* mussel beds is also heterogeneous at most of the sites in Mission Bay.

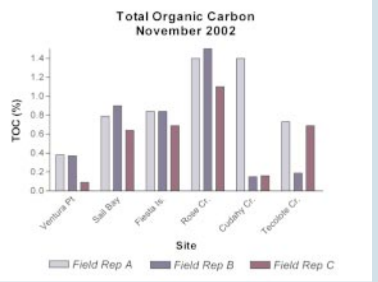
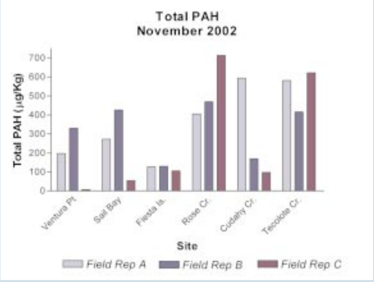


Figure 2



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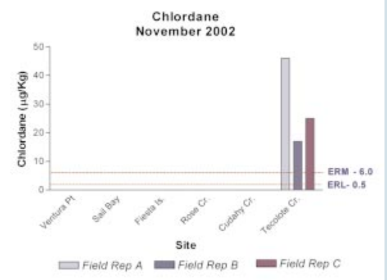

Figure 4

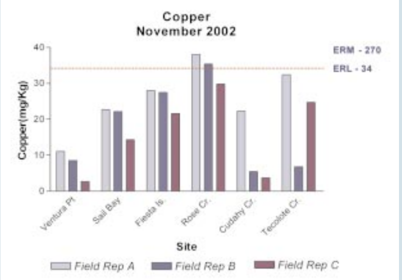

Figure 5

Figures 2-5. Concentrations of selected parameters at each field replicate location - November 2002 sampling event. * Note the strong correspondence between TOC and the three chemicals presented here.

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Temporal Relationships:

Mean concentrations of selected analytes across replicates (n=3) for each sampling event are shown in Figures 6-9. Total organic carbon and mean concentrations of a number of constituents often varied dramatically between sampling periods. Concentrations of organics varied much more, on average, than trace metals. Due to the observed heterogeneity of Mission Bay, it is not yet clear what proportion of the variation in concentrations between sampling periods is temporal versus spatial. Variations may be partly attributable to slightly different sample grab locations during each sampling period and/or analytical variability. The second year of sampling will help answer these questions.

The biology of Mission Bay appears to have a strong influence on surface sediment composition. Temporal variations in the distribution and density of eelgrass beds, macroalgae, and *Musculista* mussel beds were dramatic throughout Mission Bay. Eelgrass was absent at Site VP from November 2001 through February 2002. Dense beds then appeared May 2002 reaching a peak density by August 2002 before dying off again. Eelgrass density varied but was always present at all Site SB field replicates. Sediment composition within eelgrass beds is typically much finer and organic-rich relative to surrounding areas. *Musculista* create thick mucous mats, often several inches thick, which also accumulates fine organic-rich material. *Musculista* beds also appeared to have the greatest density during the summer and fall of 2002, however, their distribution was patchy.

It is anticipated that rain events may contribute significant chemical loads to Mission Bay sediments during the winter months, however, the 2001-2002 rainy season in San Diego was one of the driest on record with < 3 inches of rain total. Future sampling events will attempt to address stormwater inputs.

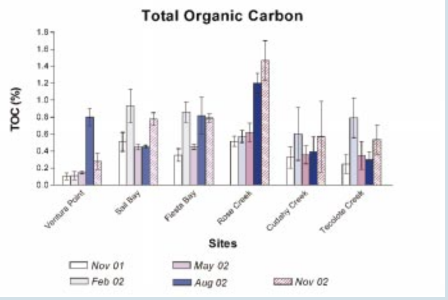

Figure 6

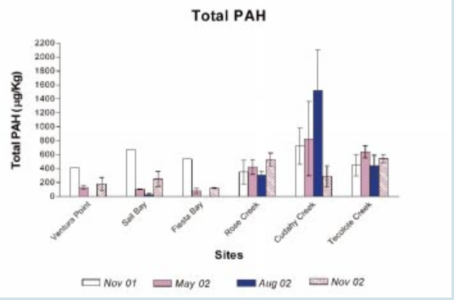

Figure 7

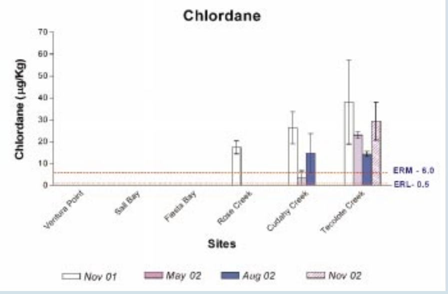

Figure 8

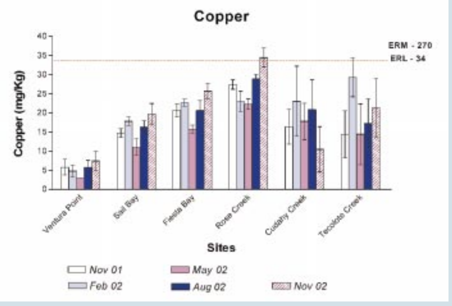

Figure 9

Figures 6-9. Mean concentrations of selected parameters at each site for all sampling events.

Toxicity:

In summary, most samples collected from Mission Bay were not significantly toxic to bivalve larvae or amphipods. When present, however, toxicity was greatest at the three locations in the eastern portion of the bay near the major freshwater inputs. A strong temporal relationship appeared to exist for both species, however, as with chemistry, additional data is needed to confirm this. Toxicity to amphipods and bivalve larvae was greatest at all locations relative to the control site, Ventura Point, during the months of February and May. Toxicity to amphipods was more pronounced than that to bivalves with greatest effects consistently occurring in sediments from Tecolote Creek inlet. Mean survival of *E. estuarius* in Tecolote Creek sediment ranged from 29% in Feb. 02 to 80% in November 2002.

Similar to chemical and physical parameters, a high degree of variability in toxicity among replicates was often present at sites in the eastern portion of Mission Bay. For example, mean survival of amphipods in Tecolote Creek sediment ranged from 6 to 61% among the three field replicates collected February 2002 (Figure 10).

Spatial Relationships of Toxicity at Each Site and Between Sites
February 2002 Sampling Event:

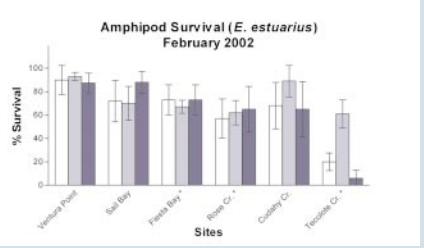

Figure 10

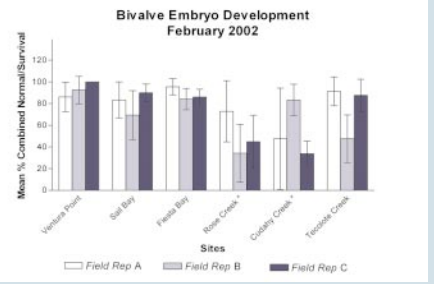

Figure 11

Figures 10-11. Mean field replicate toxicity results (± 95% CI, n=5)
*** - Statistically different from VP (p< 0.05).**

Temporal Relationships of Toxicity

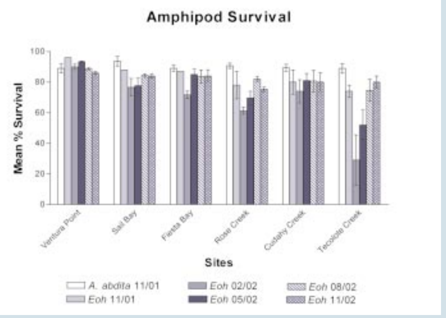

Figure 12A

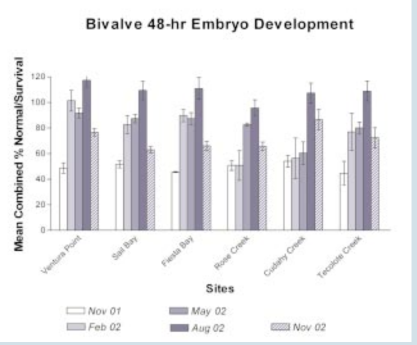

Figure 13

Figures 12-13. Mean toxicity tests results for each sampling event (± 95% CI, n=3, field replicates pooled)

CONCLUSIONS

Results to date indicate that observable biological impacts and elevated levels of chemical inputs in Mission Bay appear to be related primarily to areas near the creek drainages. Overall ecological conditions, based on measurements taken during this initial portion of study, indicate that the majority of Mission Bay, including the large central portions and regions near the entrance, are relatively clean and supportive of healthy natural biological populations. Impacts to biological communities due to physical habitat disturbance from boating recreation, rather than chemical input, may be a primary impact in central and outer portions of Mission Bay affecting existing biological communities.

A single chemical, the organochlorine pesticide chlordane, stood out from the rest due to levels well above screening levels expected to cause toxic effects near the three creek inlets. The relationship between chlordane and biological impacts in Mission Bay needs further investigation. Toxicity identification evaluation (TIE) studies are proposed for Tecolote Creek sediments to address this issue.

Substantial variations in physical, chemical, biological, and toxicological measurements were observed both spatially and temporally in Mission Bay. Additional data is needed to confirm the role of temporal variation on chemical and toxicological measurements. This high degree of variability observed provides strong evidence that ecological health studies in shallow coastal estuaries without multiple sampling events and field replication can easily lead to erroneous conclusions. As an example, approximately 57% (8) of the 14 samples collected at the Tecolote Creek inlet over the duration of the study were toxic to *E. estuarius*. Toxicity was dependant on both location within a site at any given sampling period and timing of collection during the year. Likewise, numerous chemical constituents including the primary known chemical of concern, chlordane, varied substantially depending on where and when samples were taken. Chlordane levels ranged from 7.3 to 74 µg/Kg in Tecolote Creek sediments. At Cudahy Creek, chlordane was detected in five of 14 samples, all above the ER-M screening value of 6 µg/Kg. Results from a single sample taken from any of the creek inlet locations could erroneously conclude that the entire area is toxic and elevated in chlordane and vice versa.

REFERENCES CITED

Long E.R., DD. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management Vol 19, No 1, pp 81-97.