Section 8
Results – Toxicity

Summary of Toxicity Test Results

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 (RC, CC, and TC). A temporal relationship appeared to exist for both species tested, however additional data are needed to confirm this. Toxicity to amphipods and bivalve larvae was greatest at all locations during February and May, relative to the reference site, Ventura Point. Toxicity to amphipods was more pronounced than bivalves, with the greatest effects consistently observed in Tecolote Creek sediments. A summary of t-test results between VP and all other sites for each sampling period is shown in Table 10.

Toxicity often exhibited a high degree of variability among field replicates in samples collected from the eastern portion of Mission Bay. Similarly, physical and chemical characteristics also were highly variable among some of the subsites in the back bay.

Sample Period	Amphipod	Bivalve
November 2001	None	None
February 2002	TC, RC, FB	CC, RC
May 2002	TC, CC, RC, SB	CC
August 2002	TC, RC, SB	RC
November 2002	RC	RC, FB, SB

Table 10. Summary of statistically significant comparisons of toxicity between sediments from Ventura Point and those from the other five sampling sites in Mission Bay. Sites with a statistically significant reduction in response are displayed (n=3 for each comparison; $p \leq 0.05$).

<u>Amphipod Results</u>

Cumulative mean survival of *Eohaustorius estuarius* among all samples tested during the one-year study ranged from 60 % in sediment from Tecolote Creek to 90 % in sediment from Ventura Point (Figure 59). The range of values for all samples tested was 6 % in February 2002 TC subsite C sediment to 96 % in sediment from VP.

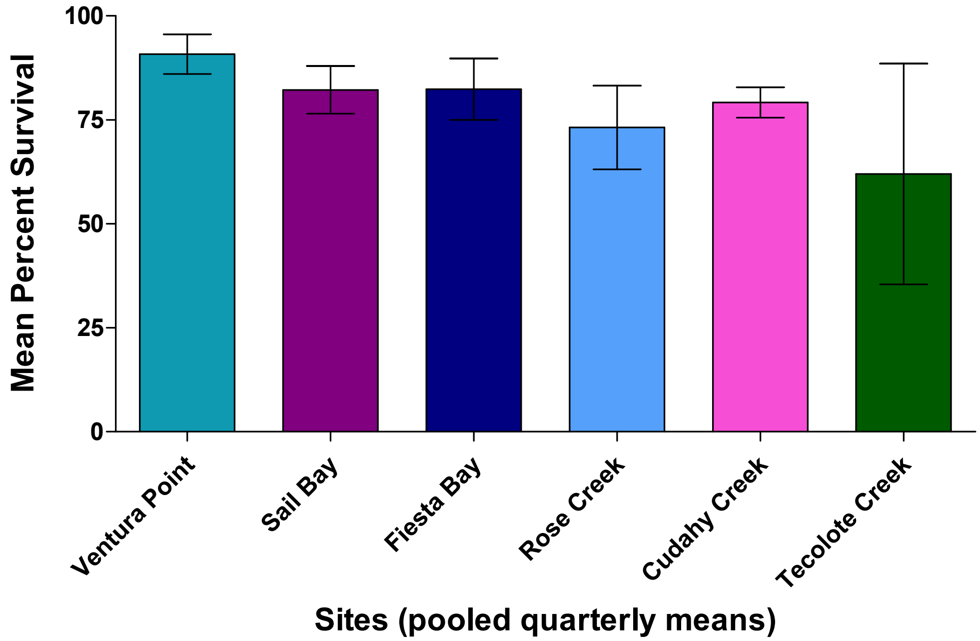

Figure 59. Mean percent survival of the amphipod *Eohaustorius estuarius* in sediments from six sites in Mission Bay between November 2001 and November 2002. Error bars indicate one standard deviation from the mean.

The amphipod *Ampelisca abdita* was tested only during the November 2001 sampling event and showed no effect following exposure to any of the test sediments. Mean survivorship values for this species ranged from 83 to 100 % among all sediments tested. *Ampelisca* create tough mucous lined tubes that they subsequently inhabit while filtering overlying water. *Eohaustorius*, on the other hand, are free burrowers and do not build tubes. A free burrowing amphipod has greater exposure to pore water and potential toxicants in the sediment than stationary tube dwellers. Two species of *Eohaustorius* (*E. washingtonianus* and *E. sencillus*) have been identified in sediments from Mission Bay (Dexter 1983). One *Ampelisca* species (*A. cristata*) also has been recorded in Mission Bay sediments by Dexter (1983). Based on the potential for exposure to contaminants and presence of the genus in Mission Bay, *E. estuarius* was chosen for use during all subsequent monitoring events. *E. estuarius* also is the amphipod species chosen for bight-wide evaluations of sediment quality every five years off the coast and in embayments throughout Southern California by the Southern California Coastal Water Research Project (SCCWRP).

As an example of temporal variability, mean survival of *E. estuarius* in sediments from all subsites at the mouth of Tecolote Creek ranged from 29 % in February 2002 to 80 % in November 2002 (Figure 60).

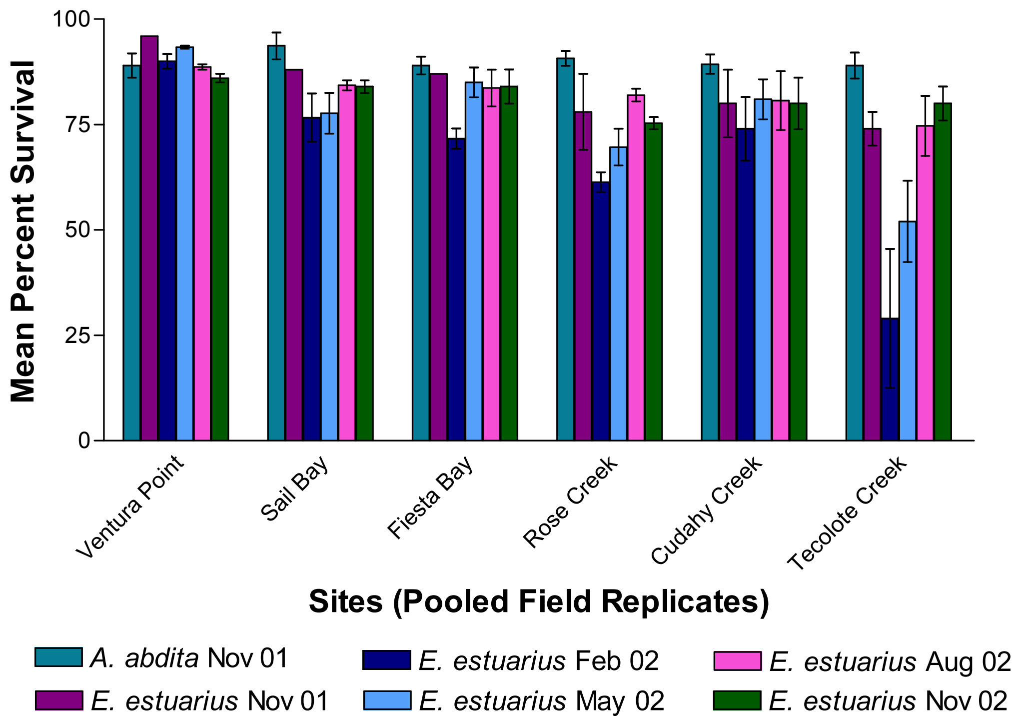

Figure 60. Mean percent survival of the amphipods *Ampelisca abdita* and *Eohaustorius estuarius* in sediments from six sites in Mission Bay between November 2001 and November 2002. Error bars indicate one standard deviation from the mean.

Spatial variability also was high on several dates at some of the eastern bay locations. For example, in February 2002 mean survival of amphipods exposed to sediments from Tecolote Creek ranged from 6 to 61 % among the three subsites (field replicates). Mean survival of amphipods in sediment from each subsite for each sampling event is displayed in Figures 61-66.

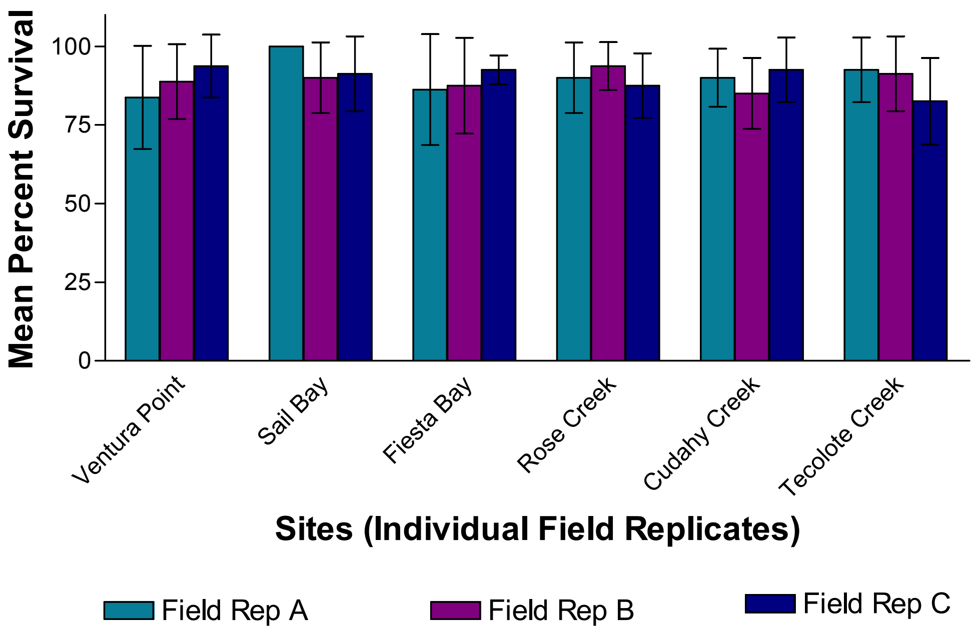

Figure 61. Mean percent survival of the amphipod *Ampelisca abdita* in sediments from 18 subsites (field replicates) at six sites in Mission Bay during November 2001. Error bars indicate one standard deviation from the mean.

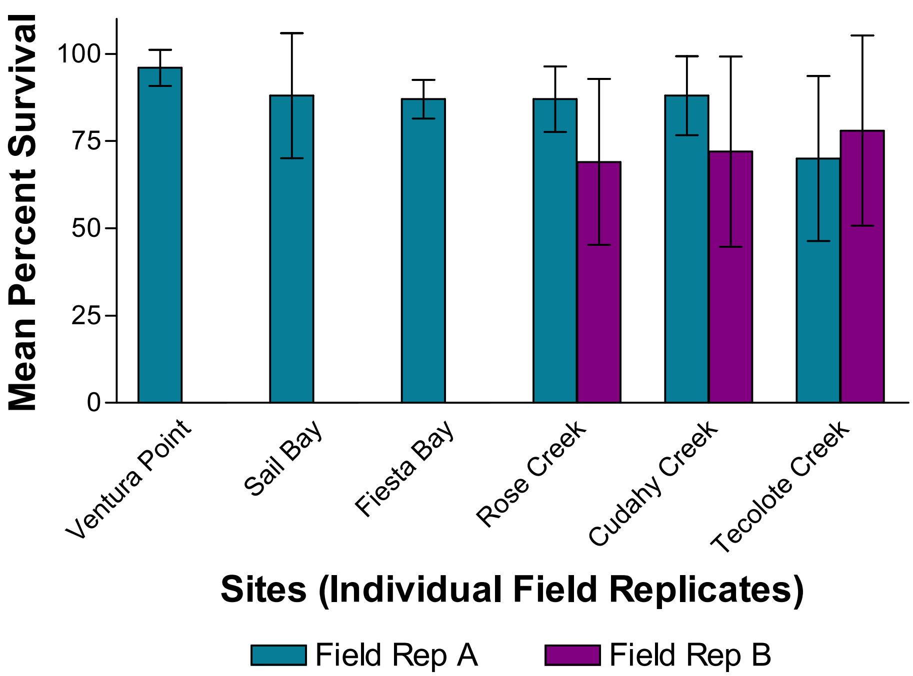

Figure 62. Mean percent survival of the amphipod *Eohaustorius estuarius* in sediments from 18 subsites (field replicates) at six sites in Mission Bay during November 2001. Error bars indicate one standard deviation from the mean.

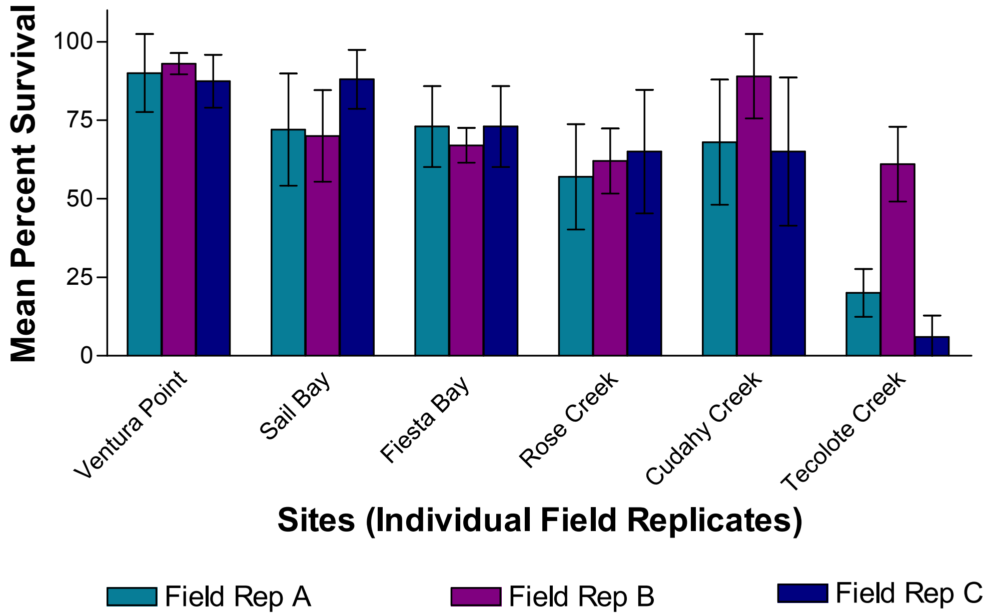

Figure 63. Mean percent survival of the amphipod *Eohaustorius estuarius* in sediments from 18 subsites (field replicates) at six sites in Mission Bay during February 2002. Error bars indicate one standard deviation from the mean.

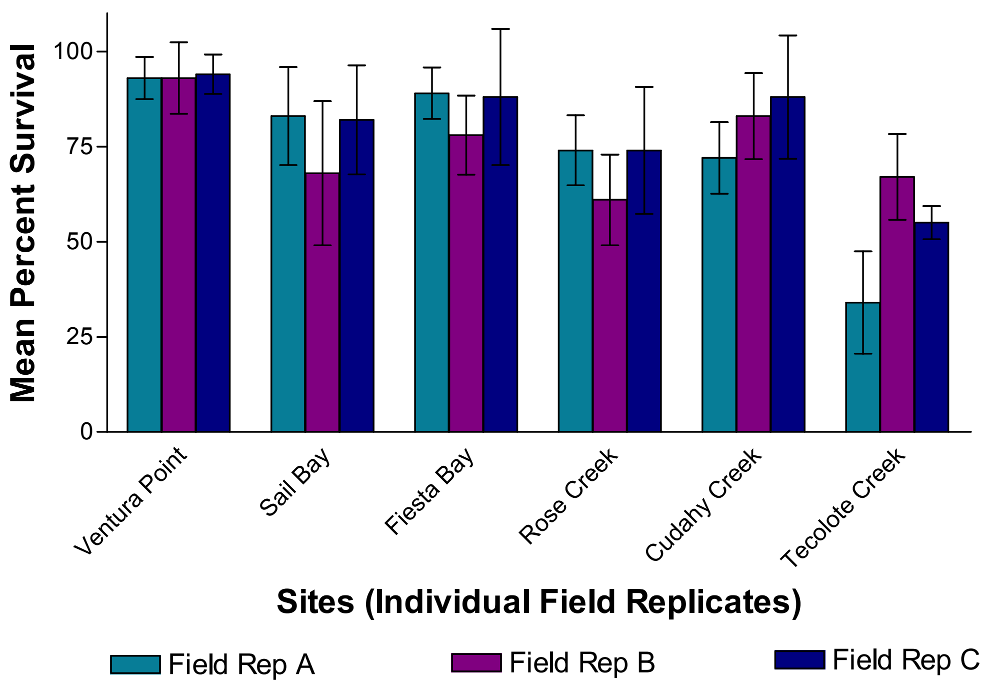

Figure 64. Mean percent survival of the amphipod *Eohaustorius estuarius* in sediments from 18 subsites (field replicates) at six sites in Mission Bay during May 2002. Error bars indicate one standard deviation from the mean.

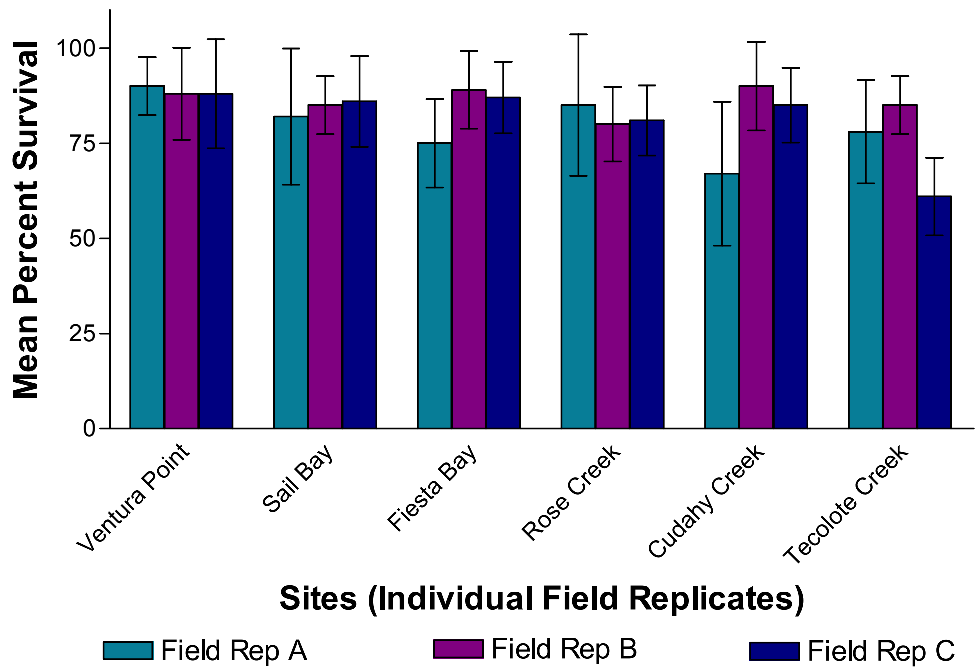

Figure 65. Mean percent survival of the amphipod *Eohaustorius estuarius* in sediments from 18 subsites (field replicates) at six sites in Mission Bay during August 2002. Error bars indicate one standard deviation from the mean.

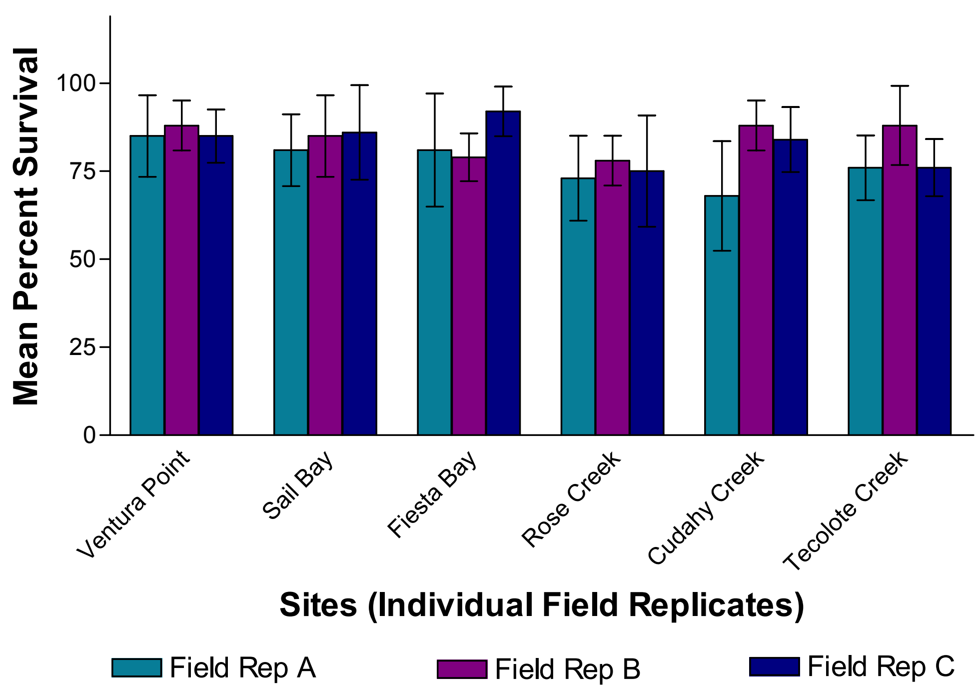

Figure 66. Mean percent survival of the amphipod *Eohaustorius estuarius* in sediments from 18 subsites (field replicates) at six sites in Mission Bay during November 2002. Error bars indicate one standard deviation from the mean.

Bivalve Results

Sediment Tests

A combined normality/survival endpoint (effective survival) was calculated for the bivalve embryo development test for all laboratory and field replicates. This calculation was derived by dividing the number of normal embryos by the mean total number of surviving embryos in the controls. This endpoint is useful in that it considers abnormal yet surviving larvae as unviable and therefore only takes into account normal larvae that can be expected to develop into viable adults.

Cumulative mean effective survival among all samples tested during the one-year study ranged from 69 % in sediment from Rose Creek to 87 % in sediment from Ventura Point (Figure 67).

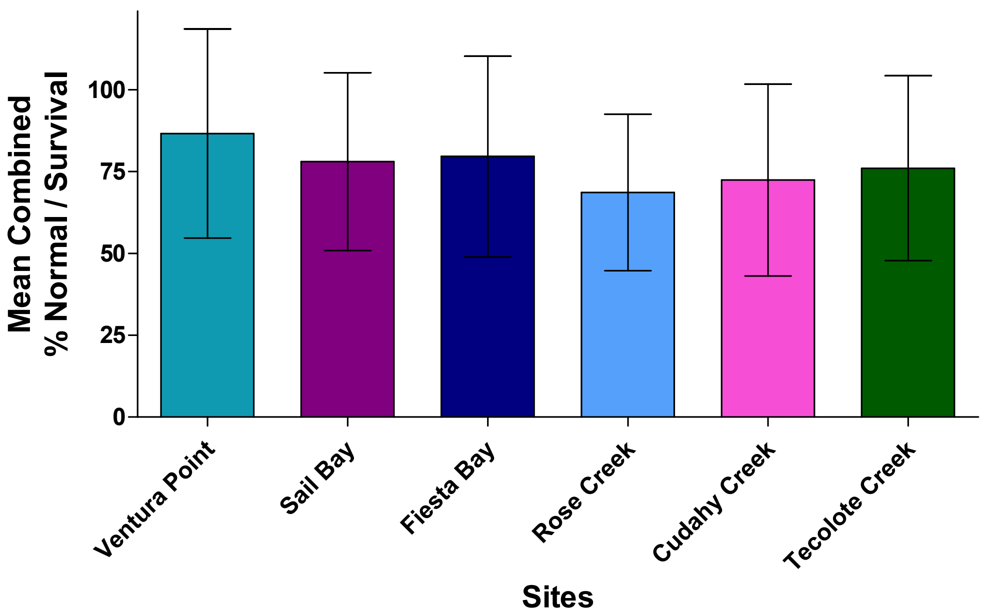

Figure 67. Mean effective survival of larval bivalves (*Mytilus galloprovincialis*) exposed to sediments from six sites in Mission Bay between November 2001 and November 2002. Error bars indicate one standard deviation from the mean.

As an example of temporal variability, mean effective survival of bivalve larvae exposed to Tecolote Creek sediment ranged from 45 % in November 2001 to 109 % in August 2002 (Figure 68).

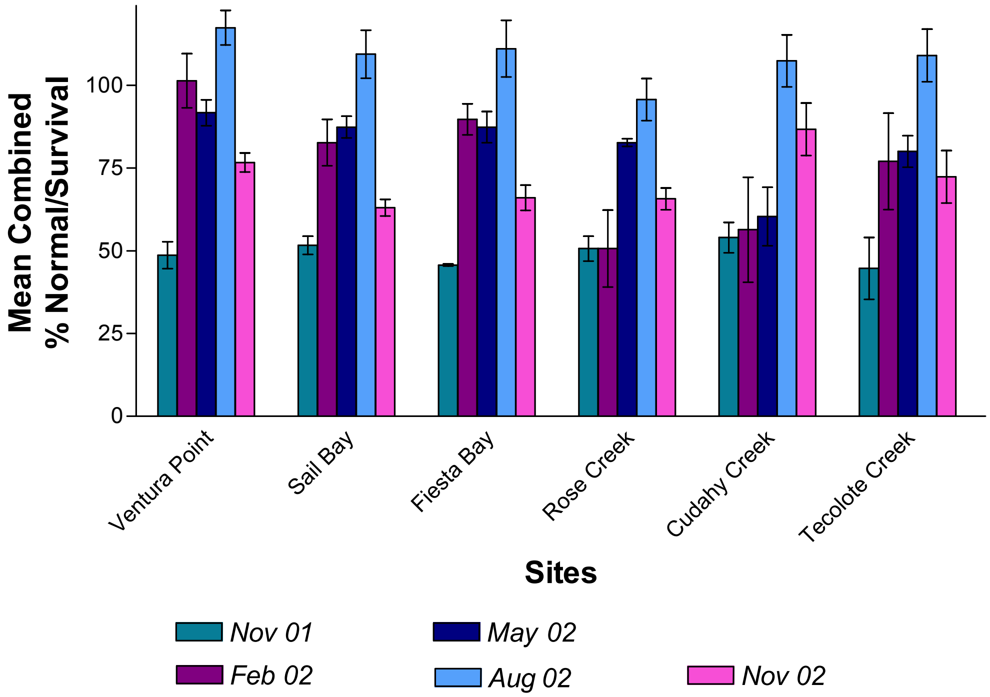

Figure 68. Mean effective survival of larval bivalves (*Mytilus galloprovincialis*) exposed to sediments from six sites in Mission Bay between November 2001 and November 2002. Error bars indicate one standard deviation from the mean.

Spatial variability of bivalve larvae also was high on several dates at some back bay locations. For example, in February 2002 mean effective survival of bivalves exposed to sediments from Rose Creek ranged from 34 to 73 % among the three subsites. Mean effective survival of bivalves exposed to sediment from each subsite for each sampling event is displayed in Figures 69-73.

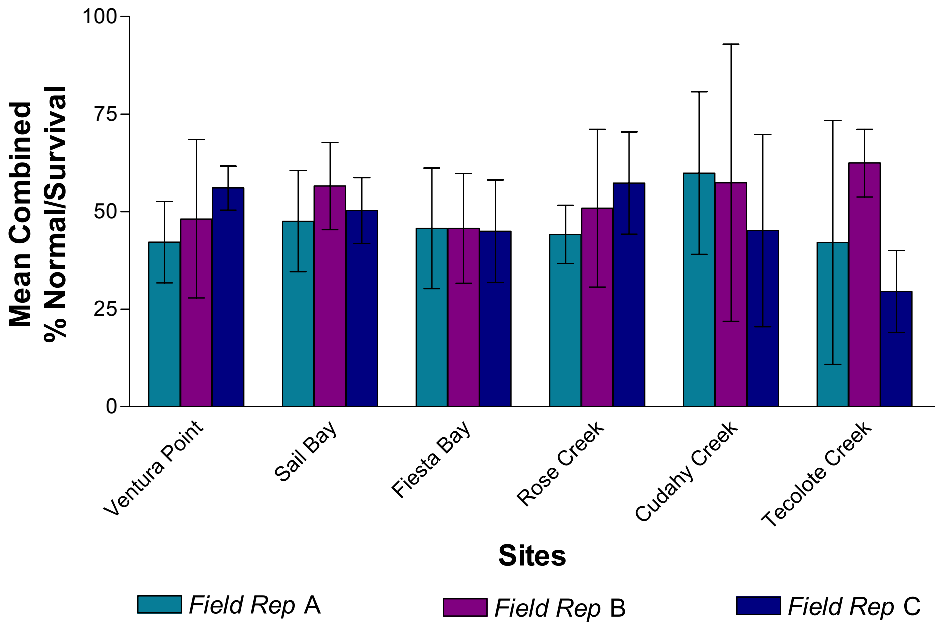

Figure 69. Mean effective survival of larval bivalves (*Mytilus galloprovincialis*) exposed to sediments from 18 subsites (field replicates) at six sites in Mission Bay during November 2001. Error bars indicate one standard deviation from the mean.

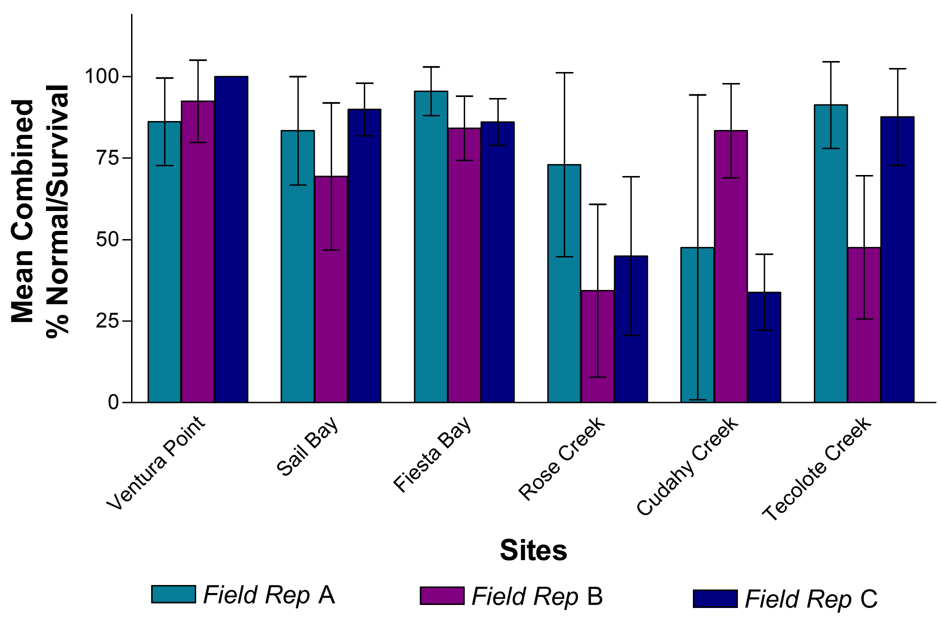

Figure 70. Mean effective survival of larval bivalves (*Mytilus galloprovincialis*) exposed to sediments from 18 subsites (field replicates) at six sites in Mission Bay during February 2002. Error bars indicate one standard deviation from the mean.

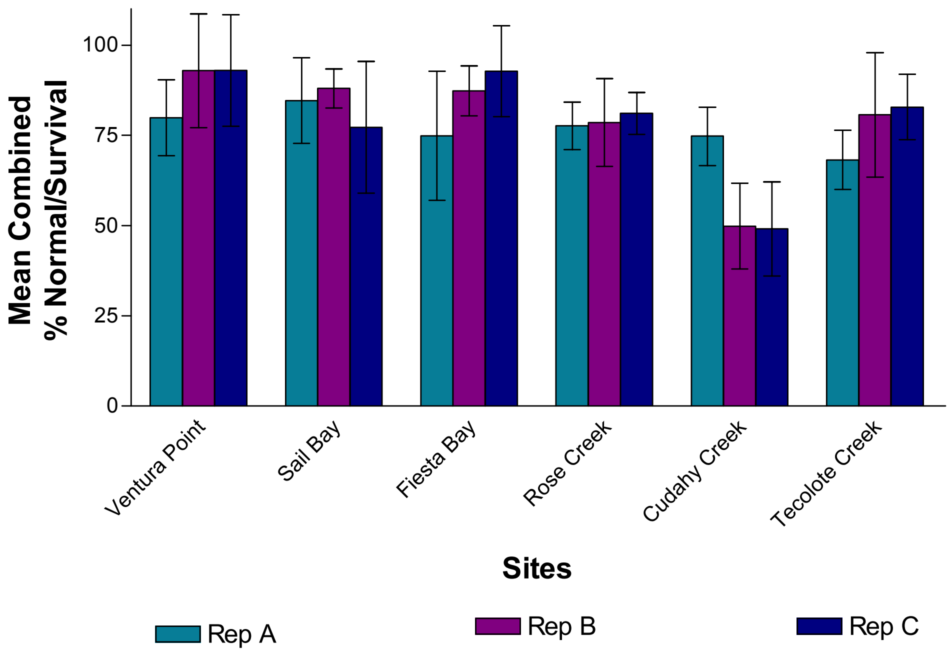

Figure 71. Mean effective survival of larval bivalves (*Mytilus galloprovincialis*) exposed to sediments from 18 subsites (field replicates) at six sites in Mission Bay during May 2002. Error bars indicate one standard deviation from the mean.

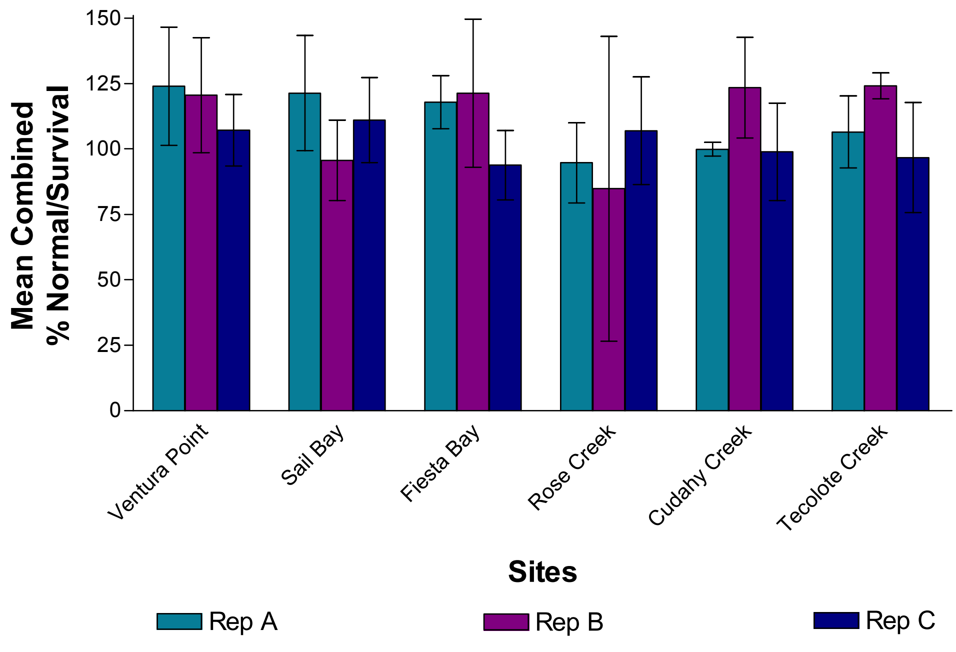

Figure 72. Mean effective survival of larval bivalves (*Mytilus galloprovincialis*) exposed to sediments from 18 subsites (field replicates) at six sites in Mission Bay during August 2002. Error bars indicate one standard deviation from the mean.

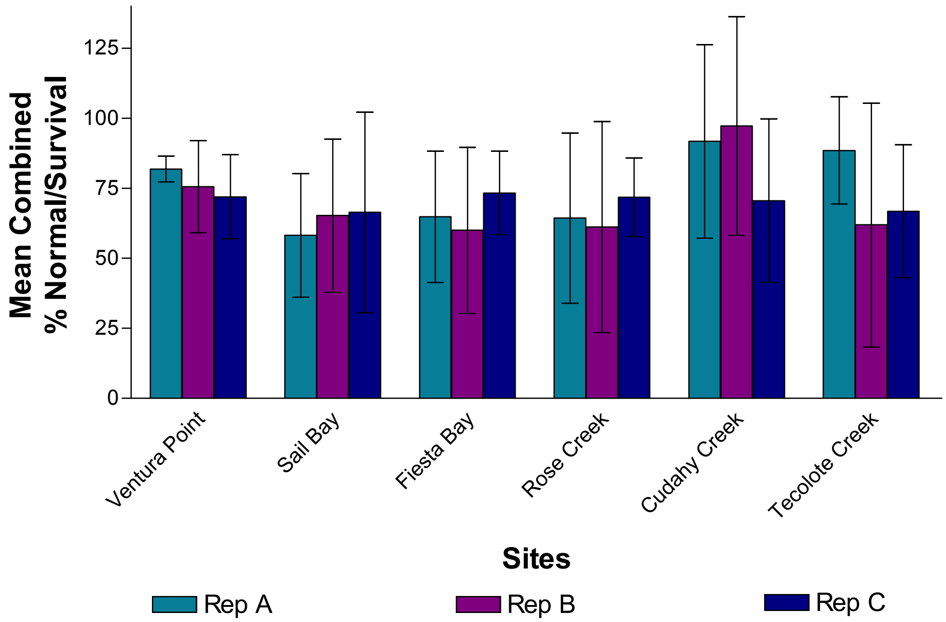

Figure 73. Mean effective survival of larval bivalves (*Mytilus galloprovincialis*) exposed to sediments from 18 subsites (field replicates) at six sites in Mission Bay during November 2002. Error bars indicate one standard deviation from the mean.

Site Overlying Water

Mean effective survival in overlying water from the reference site (VP) ranged from 73 to 91 % among all sample dates. Mean effective survival among all test sites in overlying water ranged from 66 % at Cudahy Creek in November 2002 to 99 % at the same site in February 2002 (Figure 74). Statistical evaluation of exposures to site overlying water showed that there was no significant difference between the reference site and all test sites. When compared to the laboratory control, however, one sample, collected in November 2002 from Cudahy Creek exhibited a statistically significant reduction in the effective survival endpoint.

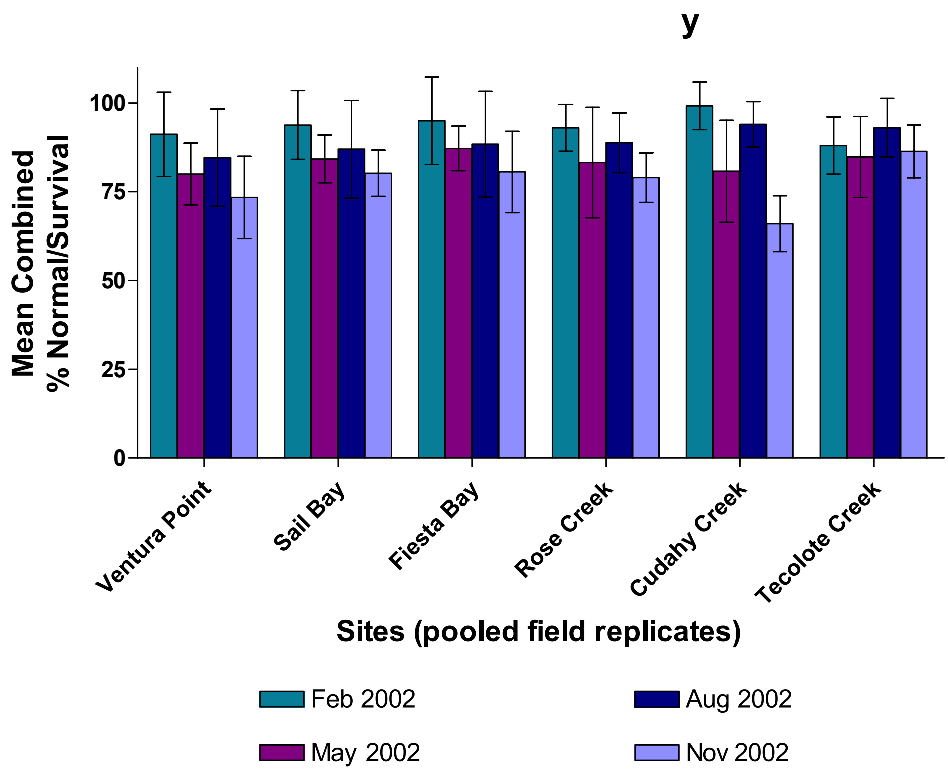

Figure 74. Mean effective survival of larval bivalves (*Mytilus galloprovincialis*) exposed to overlying water from 18 subsites (field replicates) at six sites in Mission Bay between February and November 2002. Error bars indicate one standard deviation from the mean.

Ammonia

Ammonia did not appear to be a confounding toxicant of concern in Mission Bay sediments tested in this study. Levels of total interstitial pore water ammonia in all samples collected were well below those (30-60 mg l^{-1}) reported to be toxic to amphipods (Dillon et al. 1993, Kohn et al. 1994). Levels of total ammonia in the overlying water for all bivalve larvae tests also were below the concentration of 4.0 mg l^{-1} reported to affect bivalve embryos (Tang 1997).

Sediment Characteristics and Toxicity

Contaminant levels in Mission Bay were low relative to industrially impacted sites in neighboring San Diego Bay. Concentrations of measured constituents were elevated among the three creek inlet sites in the eastern portion of the bay, relative to those measured in the central and outer bay. With the exception of chlordane and DDT, chemical concentrations for the analytes measured were well below biological effects range median (ER-M) screening levels developed by Long et al. (1995). Chlordane was well above ER-M screening levels near Tecolote Creek and, to a lesser extent, Cudahy Creek and Rose Creek. Effects range low (ER-L) values were exceeded for several PAHs, organochlorine pesticides, and trace metals, most often in the back bay locations.

Grain size may affect survival of several amphipod species, including *Eohaustorius* (ASTM 1993). A series of side-by-side control sediment tests with *E. estuarius* in both medium to coarse-grained and fine-grained sediments, however, indicates that this species is tolerant of finer grained sediments similar to those found in much of Mission Bay. Mean control values of 92 and 87 % have been obtained for medium to coarse-grained and fine-grained sediments, respectively. Four of these comparisons were performed with the Mission Bay samples and reported quarterly.

Toxicity and Chemical Relationships

Statistically significant relationships were obtained between amphipod survival and concentrations of copper, lead, zinc, total PAH, pyrene, 4,4'-DDE, TOC, and percent fine sediments (silt + clay; Table 11). The strongest relationships were obtained for the three trace metals. Although statistically significant, R^2 values were less than 0.3 for each metal, indicating that a large portion of the variation in survivorship was not explained by these individual relationships.

Statistically significant relationships also were obtained between bivalve effective survival and the concentrations of copper, lead and dieldrin. Correlations between survival and the two metals were weaker than for *E.* estuaries, with R^2 values of only 0.05 to 0.07. A relatively high R^2 value of 0.6 was obtained for dieldrin.

	Amphipod Survival			Bivalve Effective Survival		
Parameter	**Pearson r**	**p-value**	**n**	**Pearson r**	**p-value**	**n**
Copper	-0.393	**0.0004**	78	-0.215	**0.042**	90
Lead	-0.522	**<0.0001**	78	-0.255	**0.015**	90
Zinc	-0.477	**<0.0001**	78	-0.180	0.090	90
TRPH	-0.156	0.178	76	-0.022	0.843	82
Total PAH	-0.321	**0.020**	52	-0.027	0.831	63
Naphthalene	-0.249	0.113	42	-0.144	0.329	48
Acenaphthene	0.191	0.514	14	-0.345	0.137	20
Fluorene	0.562	0.324	5	-0.640	0.171	6
Phenanthrene	-0.245	0.170	33	0.119	0.469	39
Anthracene	-0.318	0.121	25	-0.037	0.850	28
Fluoranthene	-0.184	0.306	33	0.247	0.135	38
Pyrene	-0.458	**0.007**	34	0.238	0.140	40
4,4'-DDD	0.466	0.352	6	-0.492	0.215	8
4,4'-DDE	-0.532	**0.028**	17	-0.081	0.720	22
Chlordane	-0.284	0.325	14	-0.280	0.232	20
Dieldrin	0.322	0.597	5	-0.776	**0.024**	8
TOC	-0.320	**0.004**	78	-0.045	0.671	90
%Sand	0.641	**0.010**	15	0.407	0.105	17
%Fines	-0.650	**0.009**	15	-0.409	0.103	17

Table 9. Pearson correlations between amphipod and bivalve survival and properties of the sediments in Mission Bay. P-values in red indicate a statistically significant correlation at an alpha level of 0.05. Nondetect sediment chemistry data were excluded from this analysis.

Levels of copper, lead, zinc, 4,4'-DDE, and dieldrin exceeded effects-range low values in some cases but never exceeded effects-range median values published by Long et al. (1995). Pyrene never exceeded these benchmark values. Although relationships for these chemicals were observed, the current dataset lacks the resolution to identify any particular chemical causing toxicity. Multivariate statistical analysis may be useful when more data are available. Toxicity may also be a function of some combination of these chemicals and/or other chemicals not measured during this study.

A statistically significant relationship was not obtained between survival of amphipods and effective survival of bivalve larvae. This result suggests that these two species are responding to different chemicals present in Mission Bay sediments.

Interestingly, relationships between toxicity and chlordane, the one chemical that consistently exceeded ER-M benchmark values in eastern Mission Bay, were not statistically significant for either amphipods or bivalves.

Identification and confirmation of specific causes of toxicity may be performed in the future by conducting toxicity identification evaluation (TIE) studies.