Section 6
Results - Sediments

Grain Size Distribution

Sediment grain size was variable among sites, among subsites within a site at a single time point, and between time points at a single site. In general, sediments in the back bay were fine, compared to those in the front bay (Table 6). Median particle diameters were 20-35 μm in most of the samples collected at Tecolote, Cudahy and Rose Creek in February and March 2002. The exceptions to this rule were samples from Tecolote Creek B, Cudahy Creek B and Cudahy Creek C. Tecolote Creek B and Cudahy Creek B were in relatively shallow water and had sandy sediments, typical of the beaches in the vicinity of each inlet and quite different from sediments elsewhere at each site. Sediments in Fiesta Bay and Sail bay typically were coarser than in the back bay, with median particle diameters in the range of 30-50 μm. The coarsest sediments were collected near Ventura Point and had median particle diameters of 130μm and larger (Table 6).

Site	February 2002		March 2002	
	Mean ± S.D.	Median	Mean ± S.D.	Median
Tecolote Creek A	55.3 ± 99.1	22.4	48.4 ± 87.8	19.3
Tecolote Creek B	212 ± 280	108	415 ± 286	419
Tecolote Creek C	81.6 ± 123	33.0	174 ± 265	53.9
Cudahy Creek A	77.3 ± 120	30.2	110 ± 192	33.6
Cudahy Creek B	349 ± 306	287	296 ± 263	239
Cudahy Creek C	139 ± 202	60.0	143 ± 220	56.5
Rose Creek A	75.0 ± 118	33.5	52.2 ± 83.6	24.1
Rose Creek B	77.5 ± 145	25.5	100 ± 191	27.7
Rose Creek C	134 ± 250	29.0	106 ± 198	21.9
Fiesta Bay A	112 ± 167	48.0	108 ± 179	42.0
Fiesta Bay B	77.1 ± 122	32.3	108 ± 192	36.7
Fiesta Bay C	87.7 ± 136	37.3	76.4 ± 113	37.4
Sail Bay A	NA	NA	130 ± 175	76.3
Sail Bay B	92.9 ± 165	33.8	132 ± 223	45.4
Sail Bay C	121 ± 188	52.2	122 ± 163	84.2
Ventura Point A	182 ± 194	142	157 ± 131	135
Ventura Point B	156 ± 151	129	162 ± 162	130
Ventura Point C	247 ± 154	229	285 ± 169	259

Table 6. Selected sediment grain size statistics from samples collected at 18 locations throughout Mission Bay in February and March 2002. All measurements are given in μm. NA = Not Available.

Tecolote Creek

Sediments collected near the Tecolote Creek inlet were poorly sorted, with the exception of the relatively well sorted sandy sediments sampled at subsite B in March (Figure 30). Profiles from subsite A, in the center of the channel formed by the mouth of Tecolote Creek, were fairly consistent between February and March. Profiles from subsites B and C were less similar between sampling events, most likely because of gradients in sediment type closer to the sides of the channel.

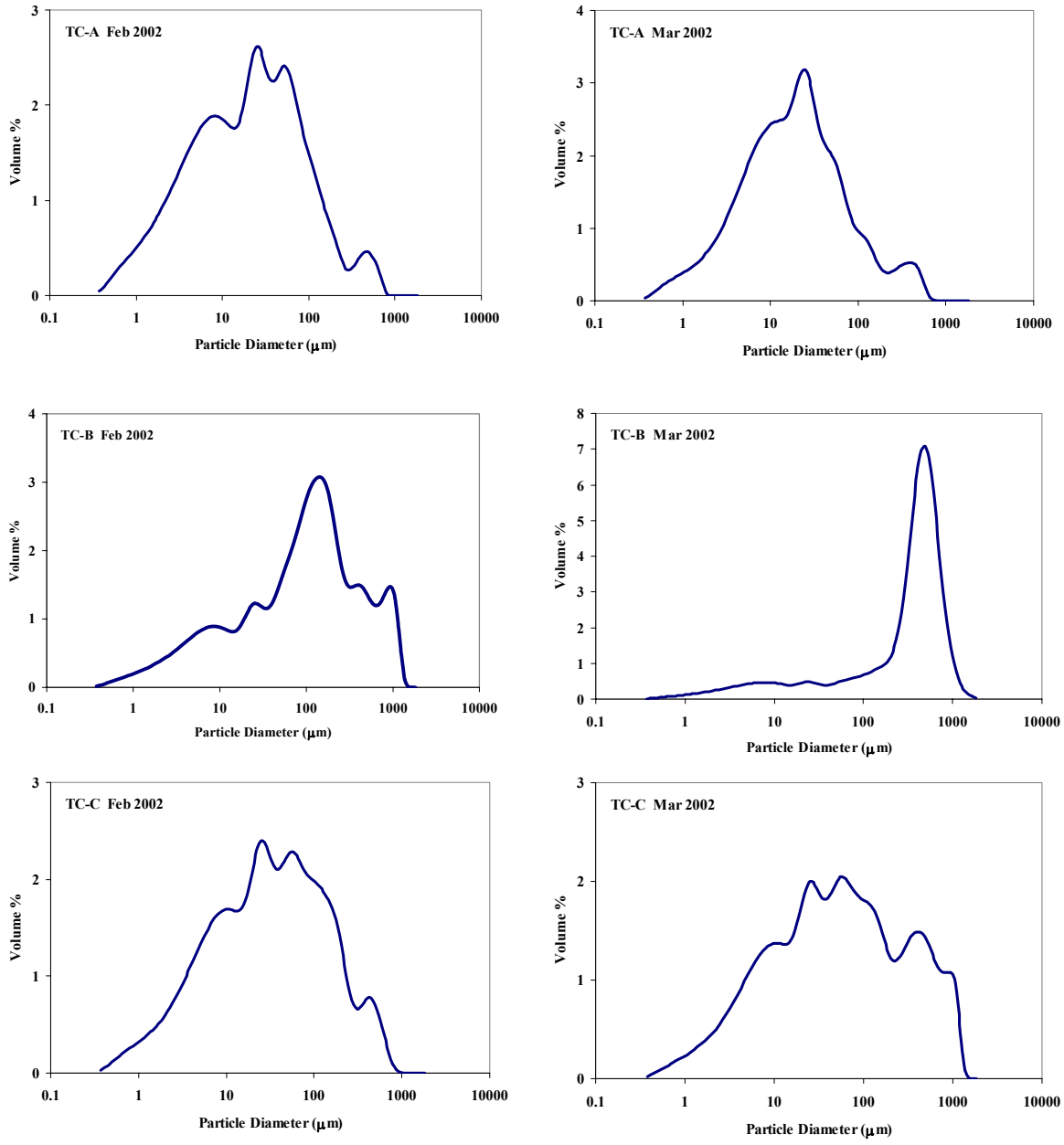

Figure 30. Grain size distributions from sediment samples collected at three subsites near the Tecolote Creek inlet in February and March 2002. Note differences in Y-axis scales among panels.

Cudahy Creek

Sediments from subsites A and C were poorly sorted, compared to those from subsite B (Figure 31), although sediments at subsite B included fine particles in low proportions.

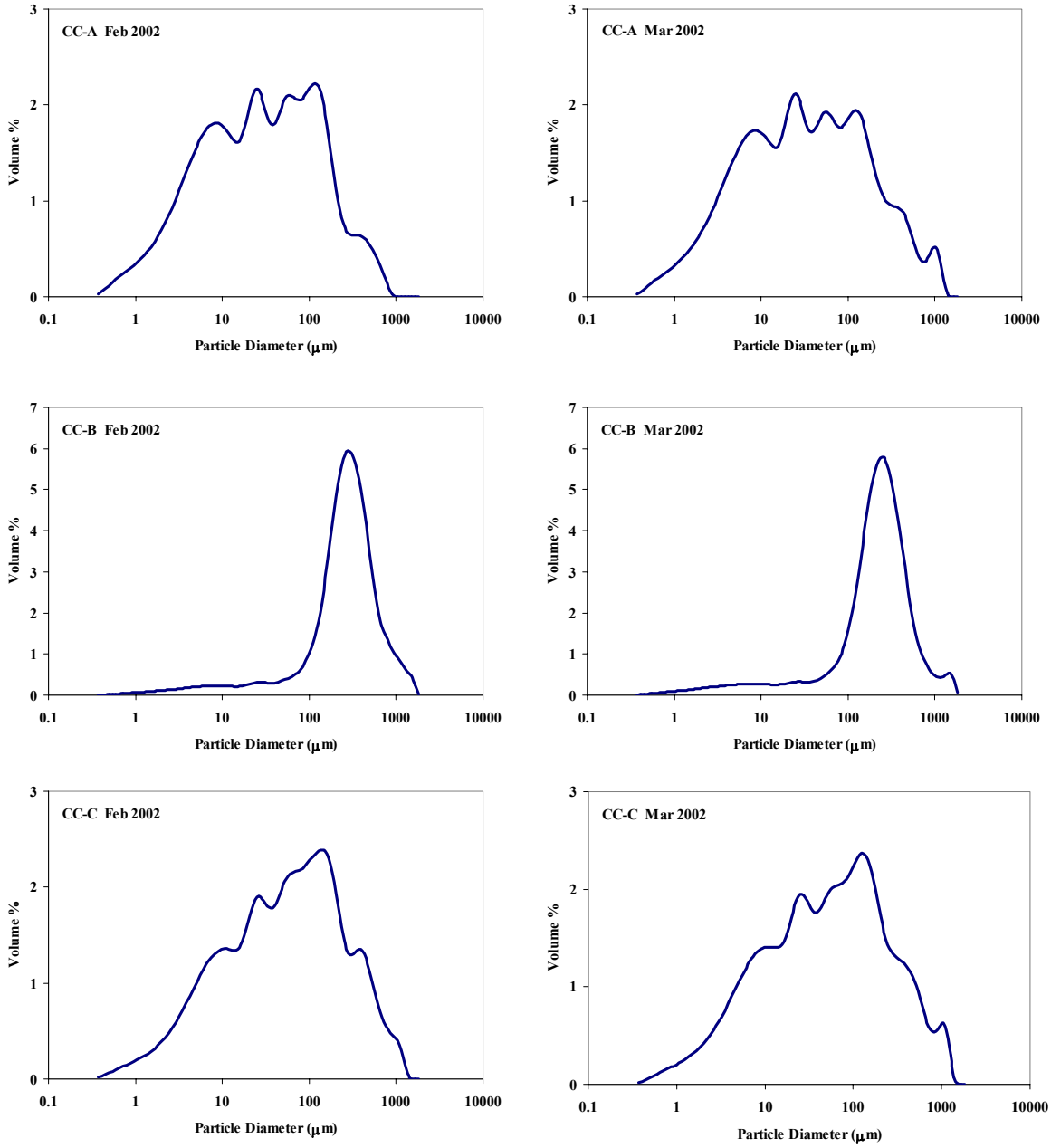

Figure 31. Grain size distributions from sediment samples collected at three subsites near the Cudahy Creek inlet in February and March 2002. Note differences in Y-axis scales among panels.

Rose Creek

Sediments collected near the Rose Creek inlet consistently were the finest and most poorly sorted, compared to sediments from the other five sites (Figure 32). All three subsites were near the center of the inlet from Rose Creek to Fiesta Bay, well away from shallow water and sandy sediments of the type that were collected at Tecolote Creek and Cudahy Creek.

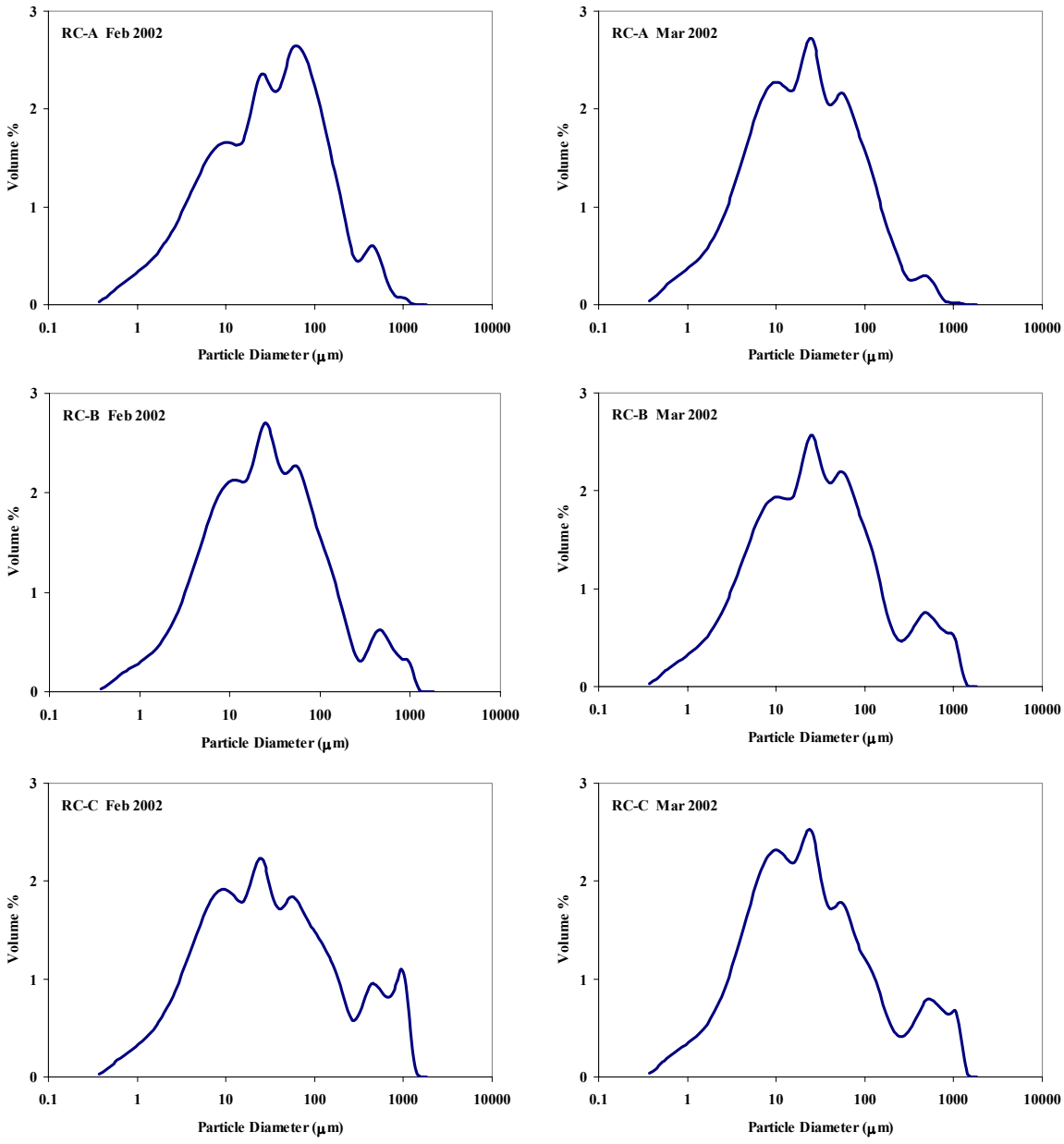

Figure 32. Grain size distributions from sediment samples collected at three subsites near the Rose Creek inlet in February and March 2002.

Fiesta Bay

Sediments collected in Fiesta Bay were poorly sorted and coarser than most of the sediments in the back bay (Figure 33). Size distributions displayed similar features in both February and March 2002.

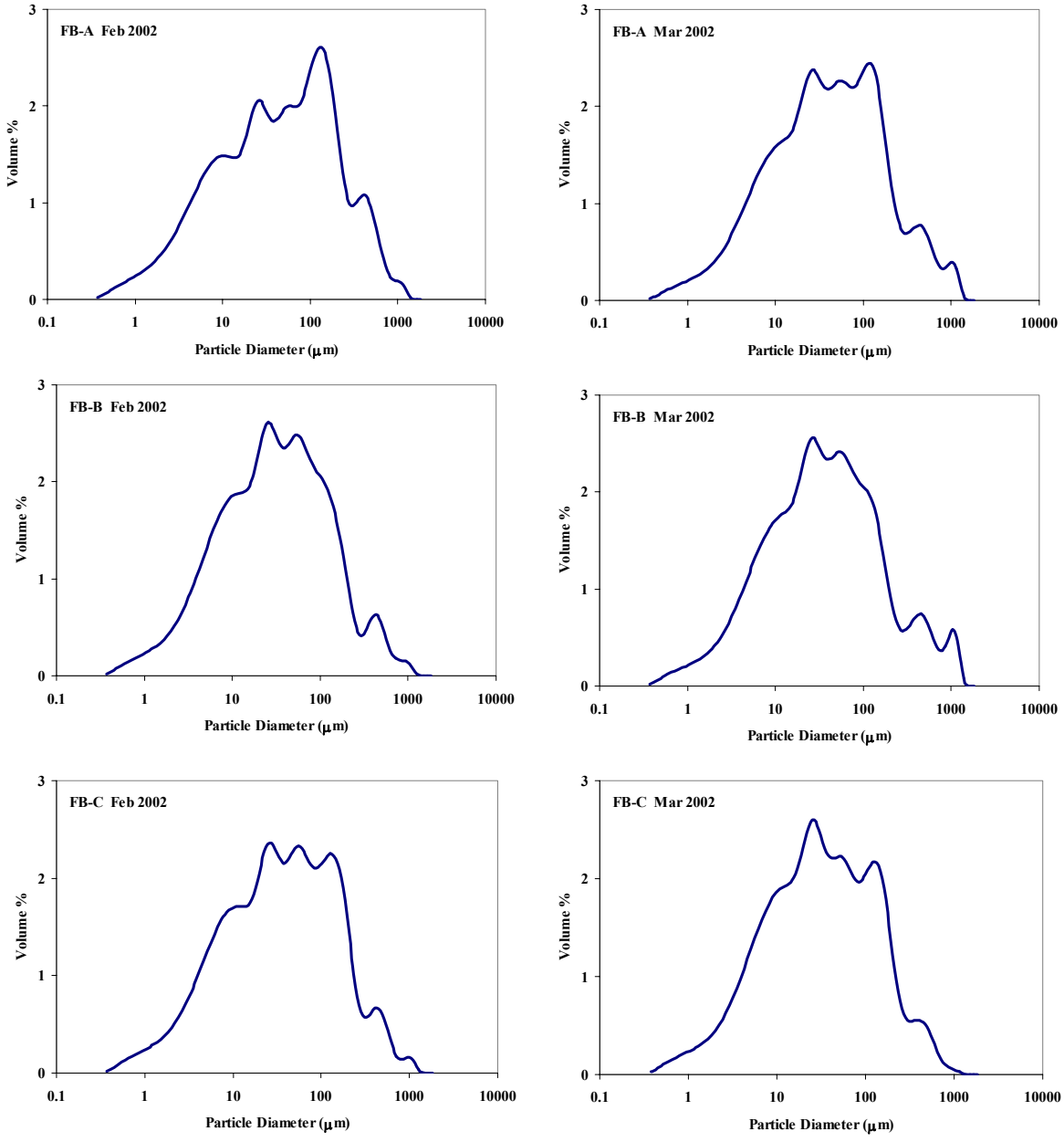

Figure 33. Grain size distributions from sediment samples collected at three subsites in Fiesta Bay in February and March 2002.

Sail Bay

Sediments from Sail Bay were coarser than those in Fiesta Bay. Subsite B had relatively fine sediments, compared to those collected at subsites A and C (Figure 34). Sediments from subsites A and C were poorly sorted and contained particles covering a broad size range, with a distinct peak near the mean particle diameter.

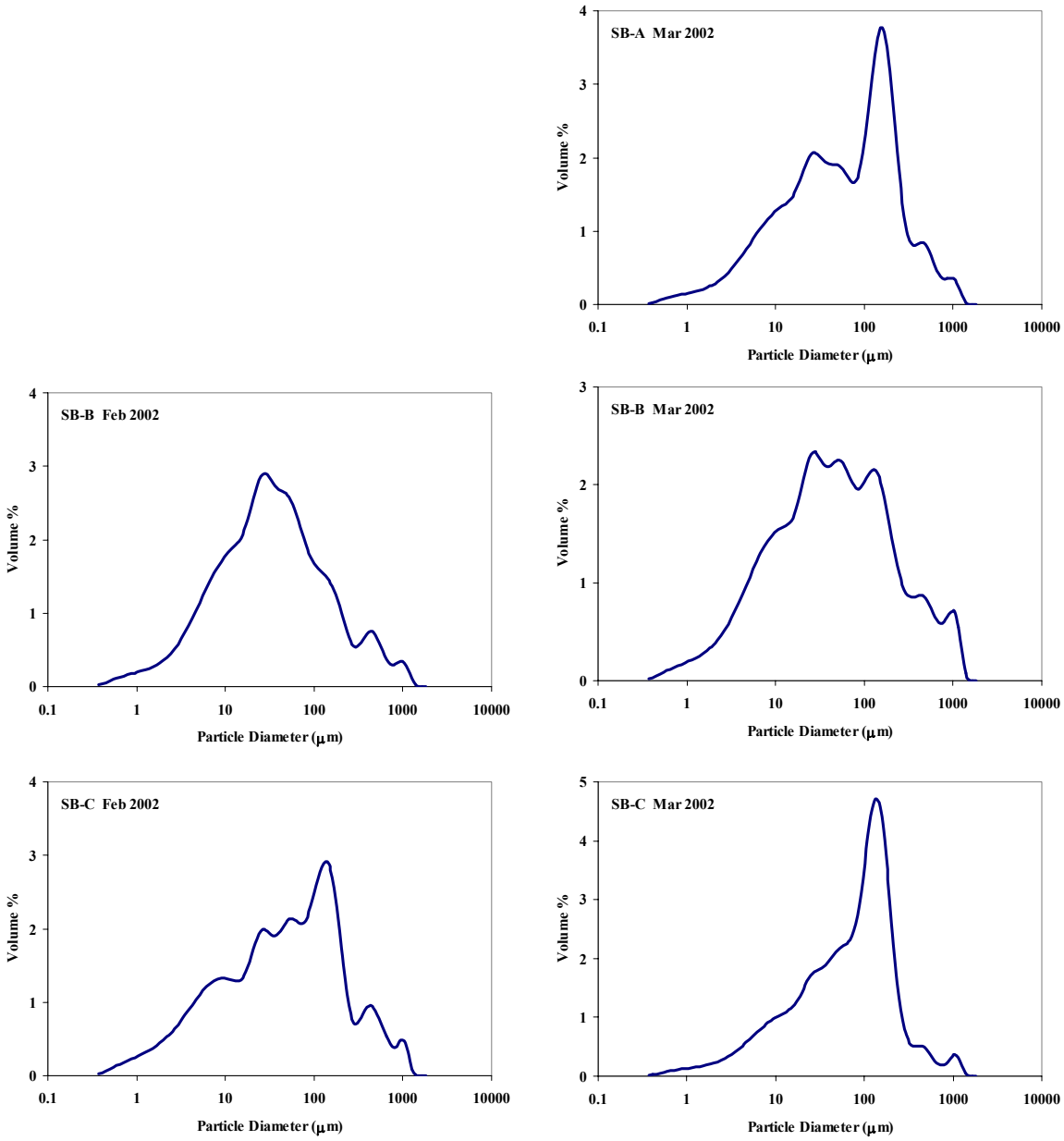

Figure 34. Grain size distributions from sediment samples collected at three subsites in Sail Bay in February and March 2002.

Ventura Point

Sediments collected near Ventura Point were coarse, sandy and well sorted compared to sediments from other sites in Mission Bay (Figure 35). Subsite C had especially well sorted sediments, as indicated by the low standard deviation compared to mean particle size.

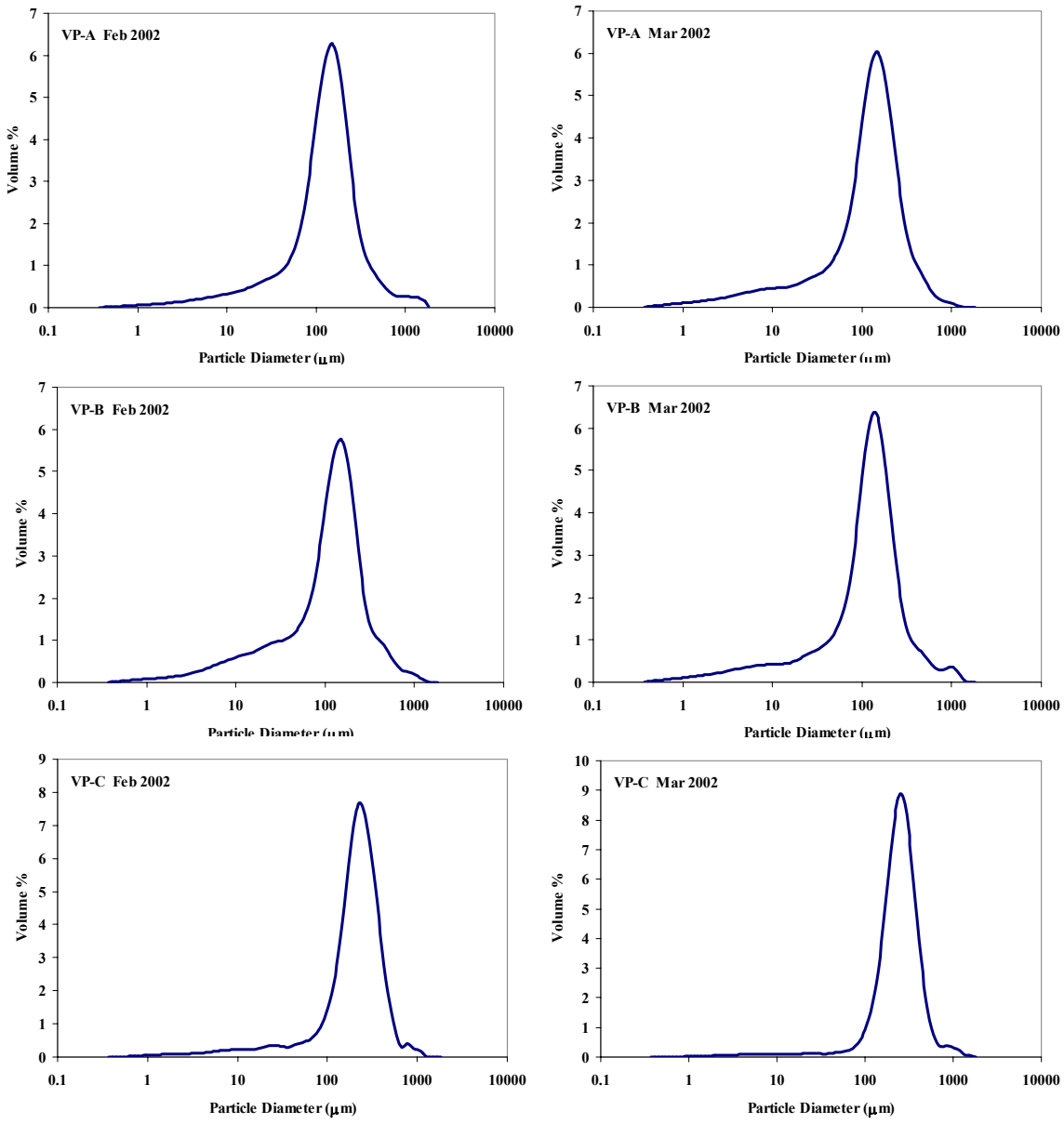

Figure 35. Grain size distributions from sediment samples collected at three subsites near Ventura Point in February and March 2002. Note differences in Y-axis scales among panels.

Water Content

Sediment water content was lowest at Ventura Point and highest at Rose Creek (Table 7). Water content varied inversely with particle diameter, and the coarsest sediments typically had a lower water content than the finest sediments (Figure 36). Sediments with median particle diameters in excess of 200 μm were made up of approximately 30% water, whereas the finest sediments had water contents over 50% and as high as 64.1% at Rose Creek subsite C.

Site	% Water Mean ± S.D.	Site	% Water Mean ± S.D.
Tecolote Creek A	51.0 ± 3.55	**Fiesta Bay A**	58.4 ± 10.9
Tecolote Creek B	33.7 ± 9.14	**Fiesta Bay B**	57.8 ± 11.0
Tecolote Creek C	46.6 ± 9.50	**Fiesta Bay C**	55.7 ± 13.4
Cudahy Creek A	52.5 ± 4.64	**Sail Bay A**	56.5 ± 12.2
Cudahy Creek B	30.6 ± 11.4	**Sail Bay B**	54.4 ± 3.52
Cudahy Creek C	45.8 ± 21.6	**Sail Bay C**	43.4 ± 6.24
Rose Creek A	58.1 ± 5.65	**Ventura Point A**	41.2 ± 15.9
Rose Creek B	58.6 ± 7.49	**Ventura Point B**	42.5 ± 14.1
Rose Creek C	64.1 ± 10.4	**Ventura Point C**	31.9 ± 17.8

Table 7. Water content from samples collected at 18 locations throughout Mission Bay between November 2001 and August 2002. All measurements are given as percent water content.

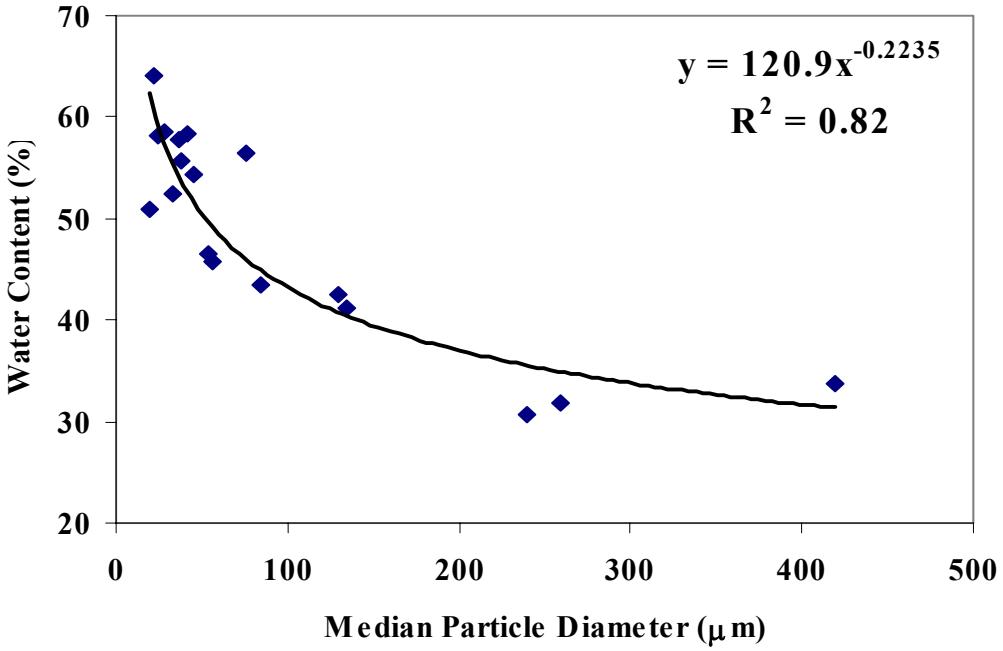

Figure 36. Water content vs. median particle diameter at 18 sampling sites in Mission Bay. Samples for water content were collected monthly from November 2001 – November 2002. Median particle diameter data were determined from samples collected in March 2002.

Sediment Chemistry

Total Organic Carbon (TOC)

Total organic carbon values for sediments within Mission Bay varied within sites, among sites and among time points. For example, based on analysis of sediments collected in November 2002, Tecolote Creek subsite B had a relatively low sediment organic content, compared to subsites A and C (Figure 37), and Cudahy Creek subsite A had a relatively high organic content, compared to subsites B and C. Qualitatively, sediment from Tecolote Creek subsites A and C often contained terrestrial plant debris and other forms of organic detritus. TOC values were highest at Rose Creek and lowest at Ventura Point, although low values for individual subsites were detected at Tecolote Creek and Cudahy Creek.

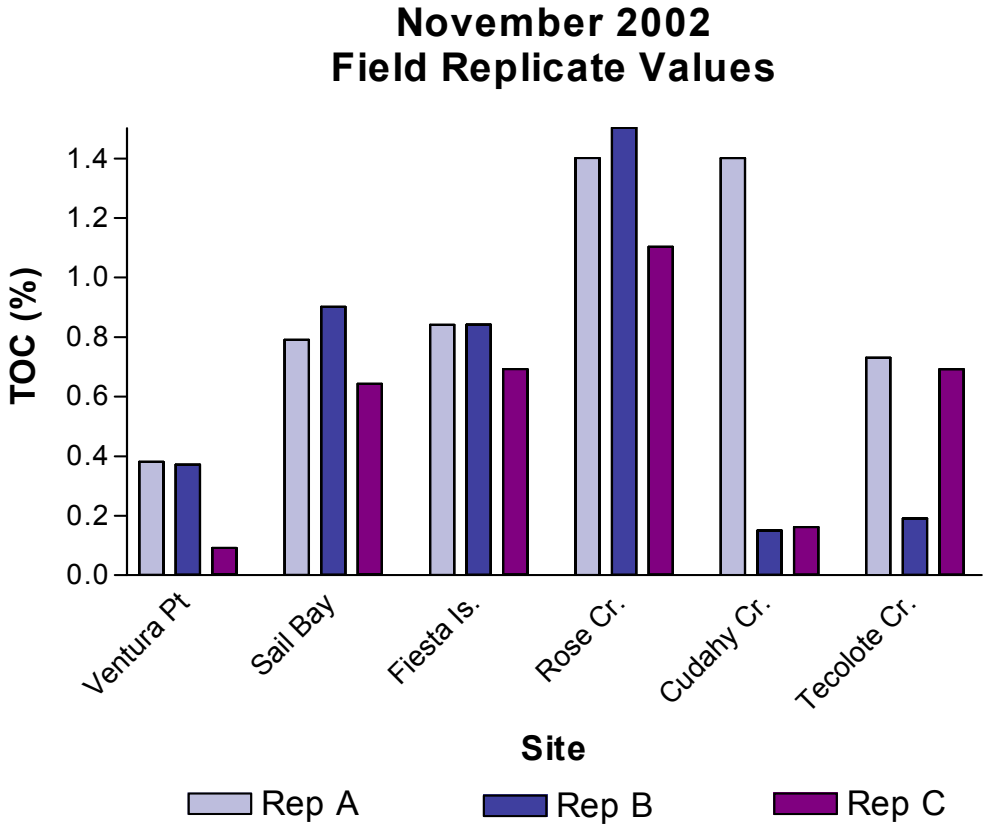

Figure 37. Total Organic Carbon (TOC) in sediments collected from six sites (three subsites or "field replicates" per site) in Mission Bay during November 2002.

Examined over the year from November 2001 – November 2002, two basic patterns were seen (Figure 38). At four of the six sites, maximum TOC values were detected in February, with lower values in May and increased levels in August (Fiesta Bay) or November (Sail Bay, Cudahy Creek, Tecolote Creek). At the other two sites, TOC levels were low in the spring and highest in August (Ventura Point) or November (Rose Creek). The two sites displaying peak sediment TOC values in the late summer and fall also displayed the highest densities of eel grass (*Zostera marina*). Eel grass beds were extensive at both sites during the summer but diminished substantially during the late summer and fall. TOC levels at all sites were higher in November 2002 than in November 2001, possibly reflecting long0term accumulation of organic material in the sediments.

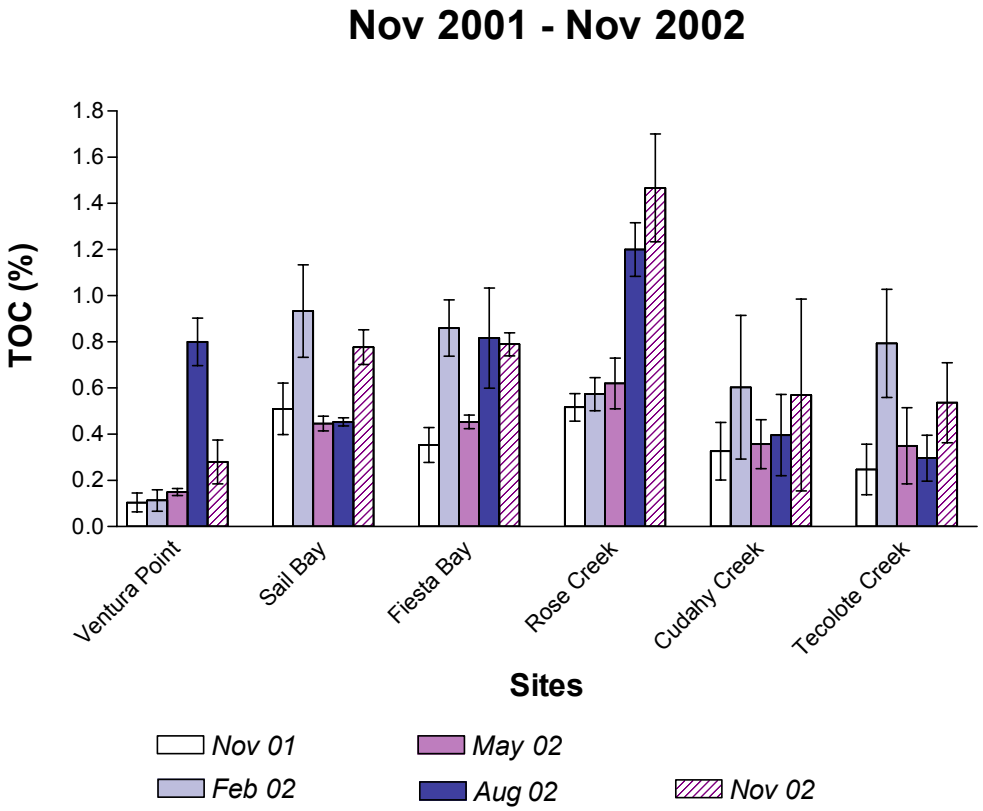

Figure 38. Total Organic Carbon (TOC) in sediments collected from six sites (three subsites per site) in Mission Bay between November 2001 and November 2002. Each bar represents the mean of measurements from all subsites at each time point. Error bars indicate one standard deviation.

Total organic carbon exhibited an inverse relationship with median grain size (Figure 39). Fine sediments typically had a higher TOC content than coarse sediments, a common pattern in the marine environment. Fine, organic-rich sediments also have a greater tendency than coarse sediments to complex with contaminants, including organic pesticides and heavy metals.

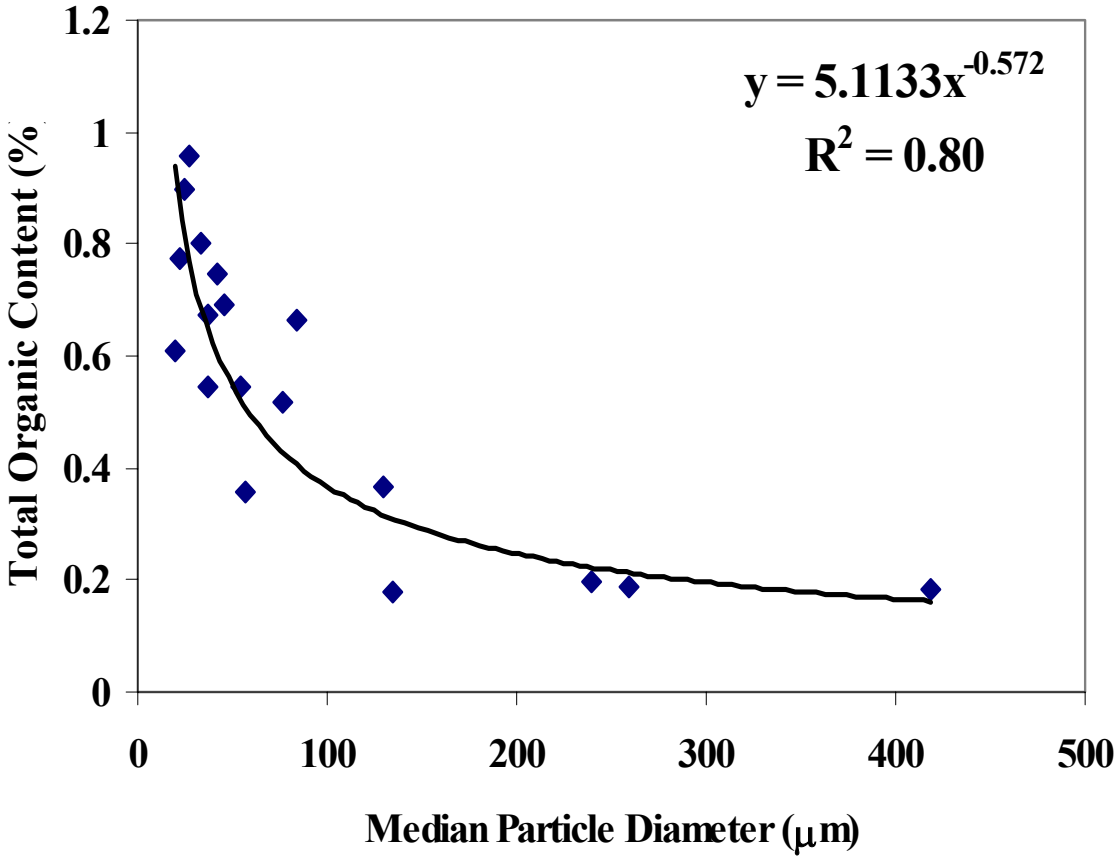

Figure 39. Mean total organic content (TOC) vs. median particle diameter at 18 sampling sites in Mission Bay. Samples for TOC were collected quarterly from November 2001 – November 2002. Median particle diameter data were determined from samples collected in March 2002.

Copper

Sediment copper concentrations displayed a similar pattern to TOC, with highest values at Rose Creek and lowest at Ventura Point. Low values for individual subsites were detected at Tecolote Creek and Cudahy Creek, as was a single high value of 1590 mg kg^{-1} at Tecolote Creek subsite A in November 2001 (not shown).

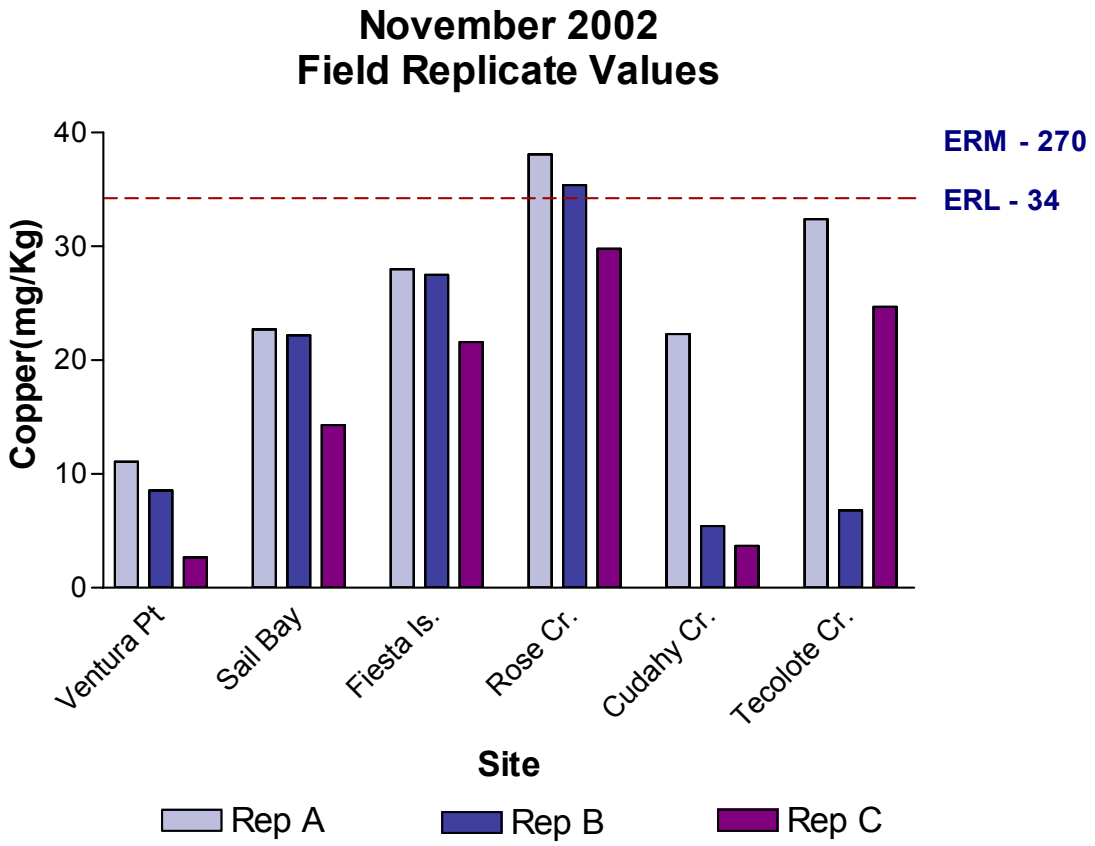

Figure 40. Concentrations of copper in sediments collected from six sites (three subsites or "field replicates" per site) in Mission Bay during November 2002.

Copper concentrations in the sediments were correlated positively and significantly with concentrations of total organic carbon (Table 8). Considering the inverse relationship between TOC and median particle diameter, copper concentrations should be highest in the finest-grained, most organic-rich sediments (Figure 41), a prediction that is supported by the data.

Parameter	Copper	Lead	Zinc	TRPH	PAH
TOC	**0.72*** (n=89)	**0.55*** (n=90)	**0.56*** (n=90)	0.018 (n=84)	0.013 (n=72)
Copper		**0.88*** (n=89)	**0.87*** (n=89)	**0.28*** (n=83)	**0.37*** (n=71)
Lead			**0.91*** (n=90)	**0.48*** (n=84)	**0.54*** (n=72)
Zinc				**0.43*** (n=84)	**0.38*** (n=72)
TRPH					**0.49*** (n=66)

Table 8. Spearman rho correlations between pairs of sediment parameters measured quarterly in samples collected at 18 locations throughout Mission Bay between November 2001 and November 2002. P-values in red indicate a statistically significant correlation at an alpha level of 0.05. Asterisks indicate statistical significance at an alpha level of 0.01.

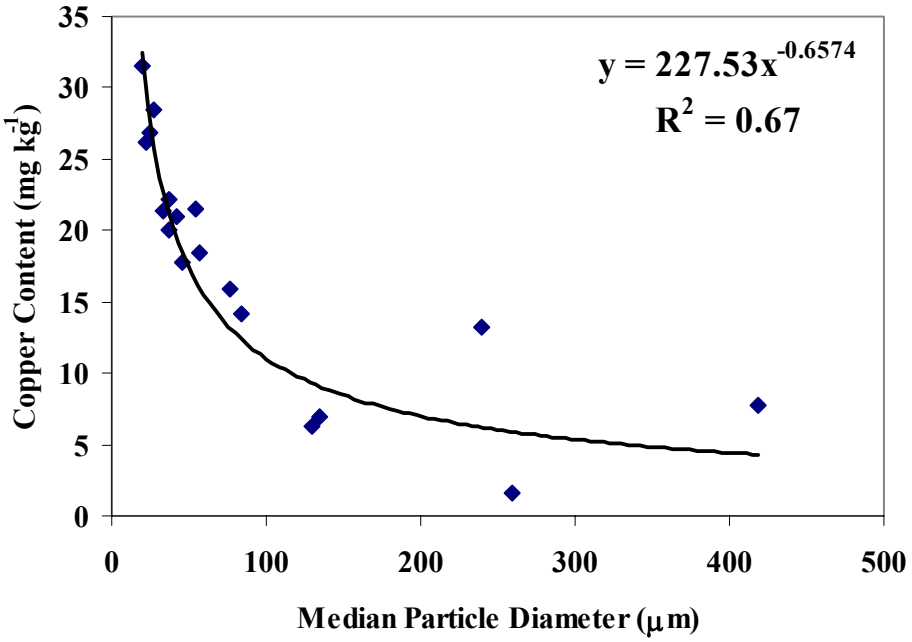

Figure 41. Mean copper concentration vs. median particle diameter at 18 sampling sites in Mission Bay. Samples for copper analysis were collected quarterly from November 2001 – November 2002. Median particle diameter data were determined from samples collected in March 2002. A single extremely high value of 1590 mg kg^{-1} measured in November 2001 at Tecolote Creek subsite A was omitted from this analysis

At almost all sites, the lowest concentrations of copper in the sediments were measured in May 2002 (Figure 42). During the summer and fall of 2002, sediment copper concentrations increased progressively, reaching maximum values in November 2002 at all sites except Tecolote Creek and Cudahy Creek. At these two sites, maximum copper concentrations were measured in February, possibly indicating inputs of copper during the winter.

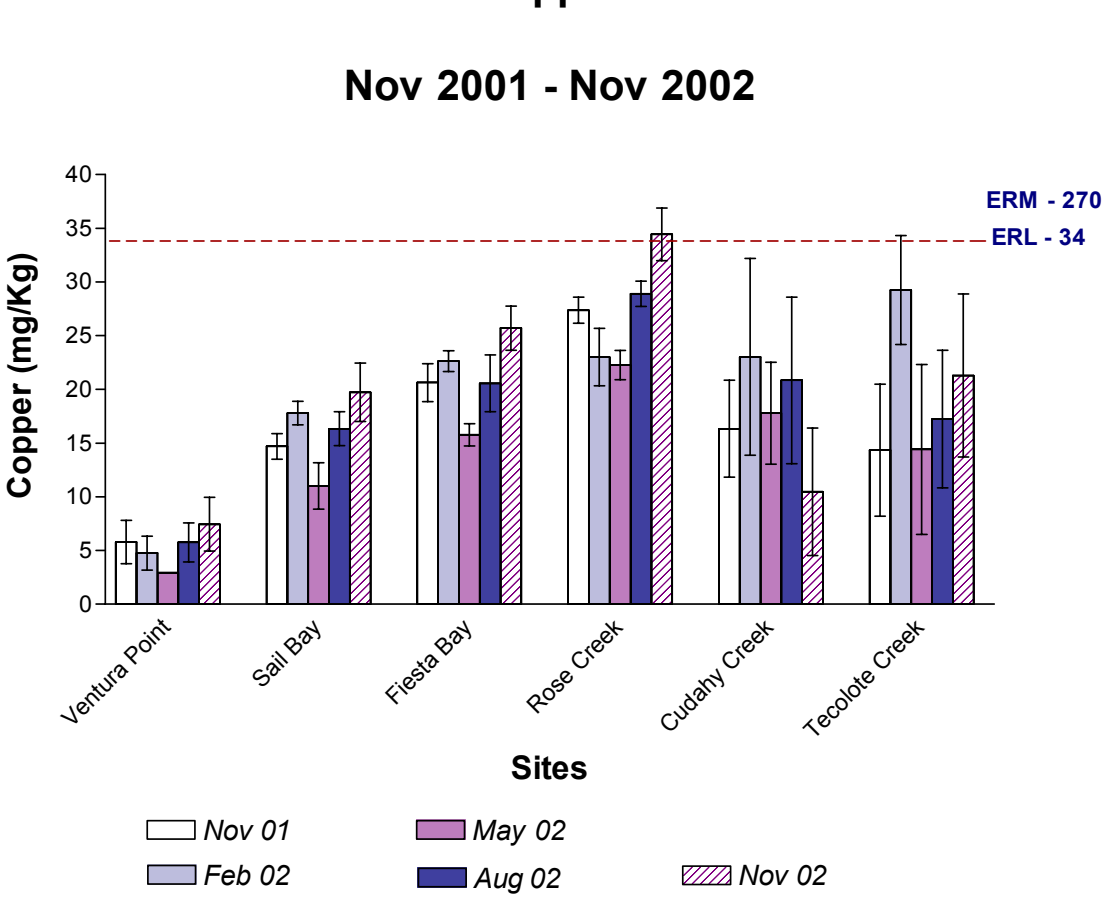

Figure 42. Copper in sediments collected from six sites (three subsites per site) in Mission Bay between November 2001 and November 2002. Each bar represents the mean of measurements from all subsites at each time point. Error bars indicate one standard deviation.

Lead

As would be expected from the high degree of correlation with copper concentrations, sediment inventories of lead displayed highest values at Rose Creek and lowest at Ventura Point (Figure 43). Low values for individual subsites were detected at Cudahy Creek. Lead concentrations exhibited an inverse relationship with median particle diameter that was similar to that shown for copper (Figure 41) and is not shown in this report.

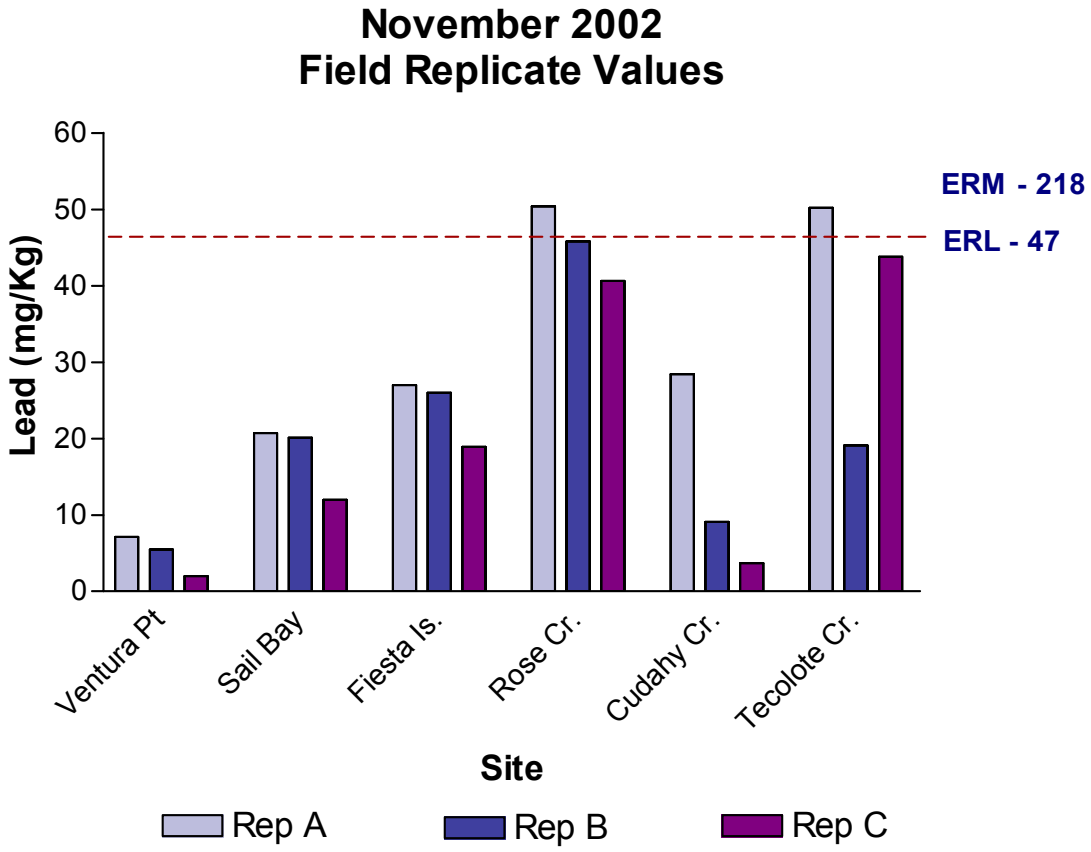

Figure 43. Concentrations of lead in sediments collected from six sites (three subsites or "field replicates" per site) in Mission Bay during November 2002.

Trends in lead concentrations over time differed somewhat from those detected for copper. For copper, minimum concentrations were measured in May at almost all sites, however elevated levels of lead were seen in May at Ventura Point, Sail Bay, Fiesta Bay and Rose Creek (Figure 44). At the two back bay sites, highest levels of lead in the sediments occurred in February, a pattern similar to that observed for copper and perhaps indicative of inputs during the winter.

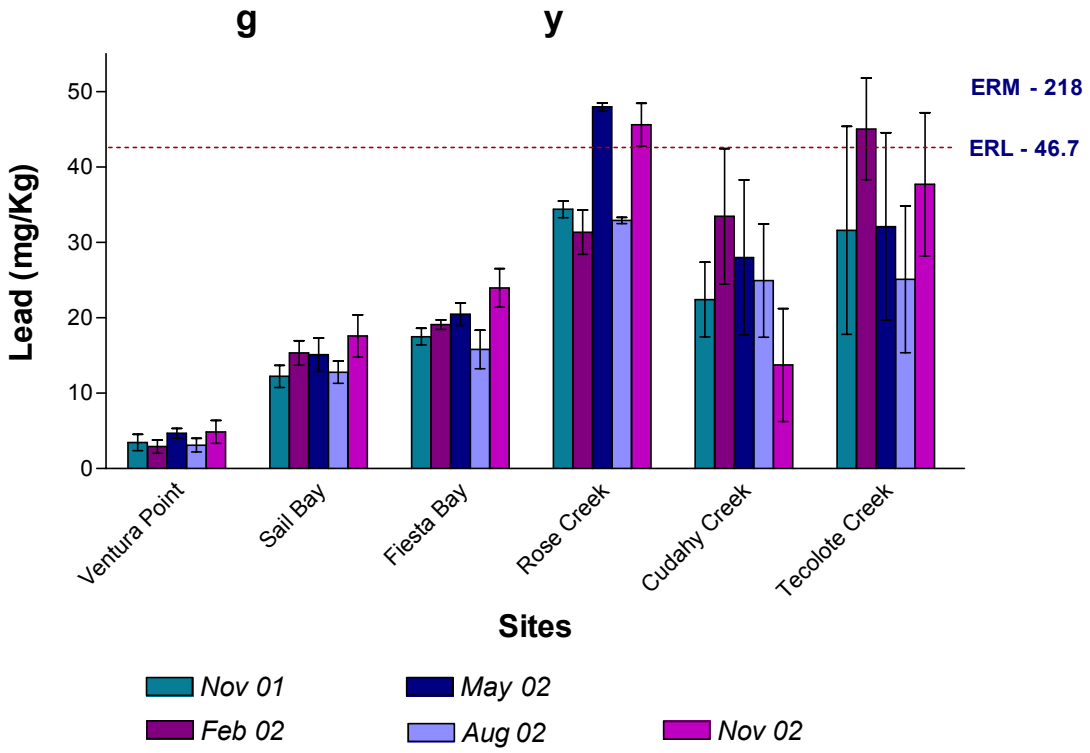

Figure 44. Lead in sediments collected from six sites (three subsites per site) in Mission Bay between November 2001 and November 2002. Each bar represents the mean of measurements from all subsites at each time point. Error bars indicate one standard deviation.

Zinc

Sediment concentrations of zinc were highest at Rose Creek and lowest at Ventura Point (Figure 45), a pattern similar to those for copper and lead. Low values for individual subsites were detected at Cudahy Creek. Zinc concentrations were related inversely to median particle diameter in a manner similar to that shown for copper (Figure 41) and lead.

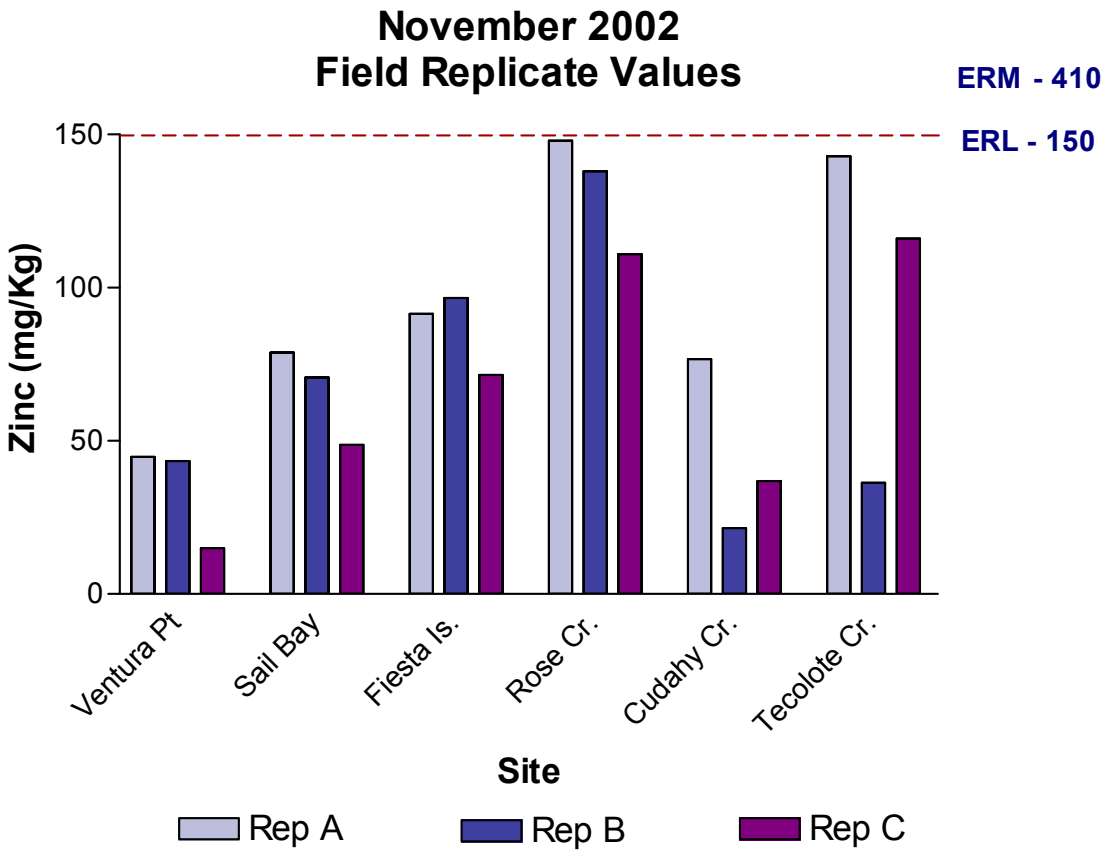

Figure 45. Concentrations of zinc in sediments collected from six sites (three subsites or "field replicates" per site) in Mission Bay during November 2002.

Trends in zinc concentrations over time differed from those detected for copper and lead. Elevated levels of zinc were seen in May at Sail Bay, Fiesta Bay and Rose Creek, with an exceptionally high concentration of zinc in sediments from Rose Creek (Figure 46). This high mean value at Rose Creek was based on high levels of zinc in two of the three subsites. As with lead and copper, highest levels of zinc in the sediments occurred in February at the two back bay sites.

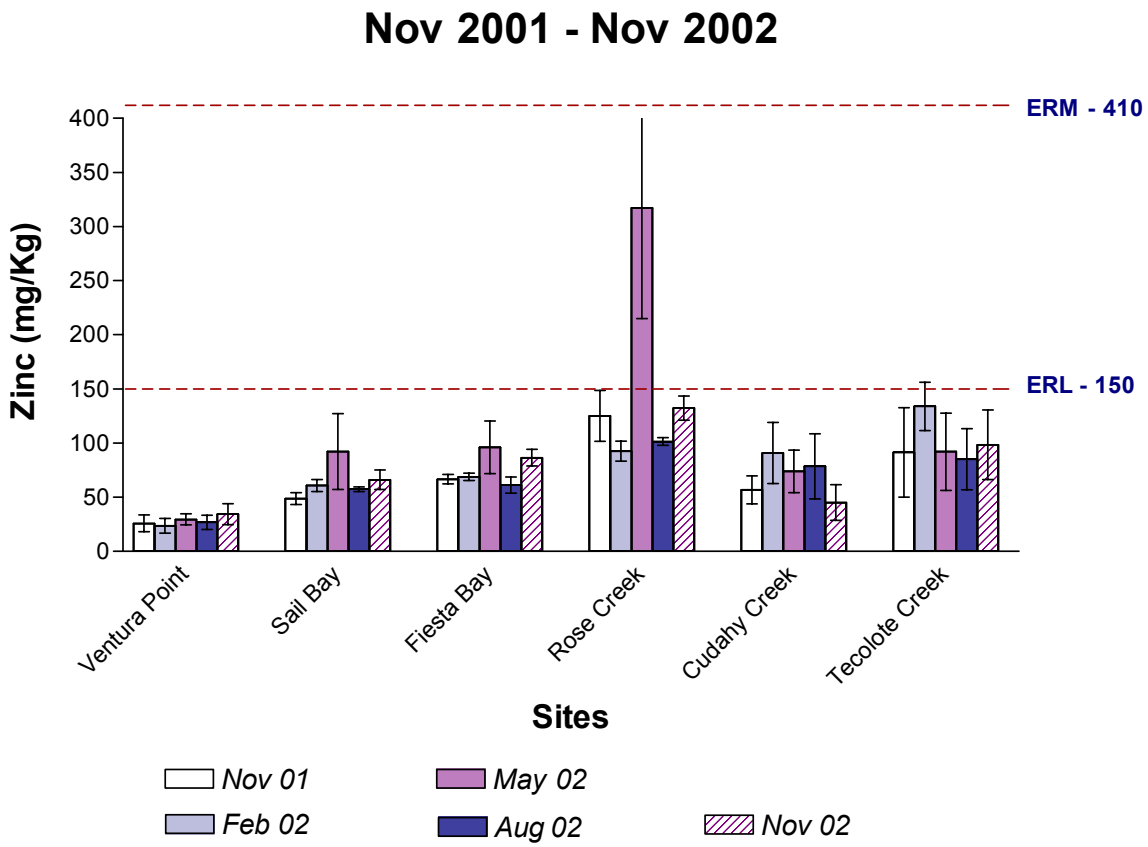

Figure 46. Zinc in sediments collected from six sites (three subsites per site) in Mission Bay between November 2001 and November 2002. Each bar represents the mean of measurements from all subsites at each time point. Error bars indicate one standard deviation.

Total Recoverable Petroleum Hydrocarbons (TRPH)

Sediment concentrations of TRPH were highest in the back bay at Cudahy Creek and Tecolote Creek (Figure 47). Individual subsites displayed variable TRPH levels at all three creek sites and Ventura Point in November 2002, whereas concentrations were consistent among subsites in Fiesta bay and Sail Bay.

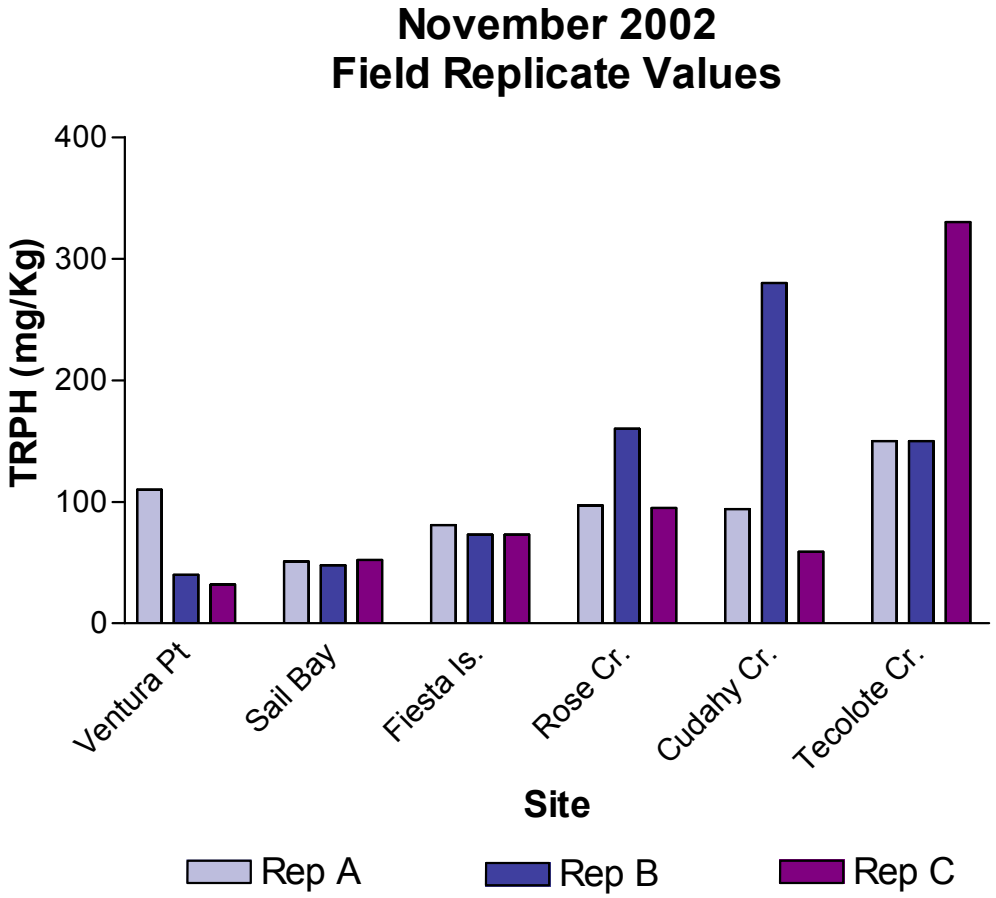

Figure 47. Concentrations of total recoverable petroleum hydrocarbons (TRPH) in sediments collected from six sites (three subsites or "field replicates" per site) in Mission Bay during November 2002.

Minimum concentrations of TRPH were detected in February 2002, and maximum levels were measured in May 2002 at all sites (Figure 48). This pattern suggests an input of TRPH (e.g. from boat fuel or oil) in early spring at all sites.

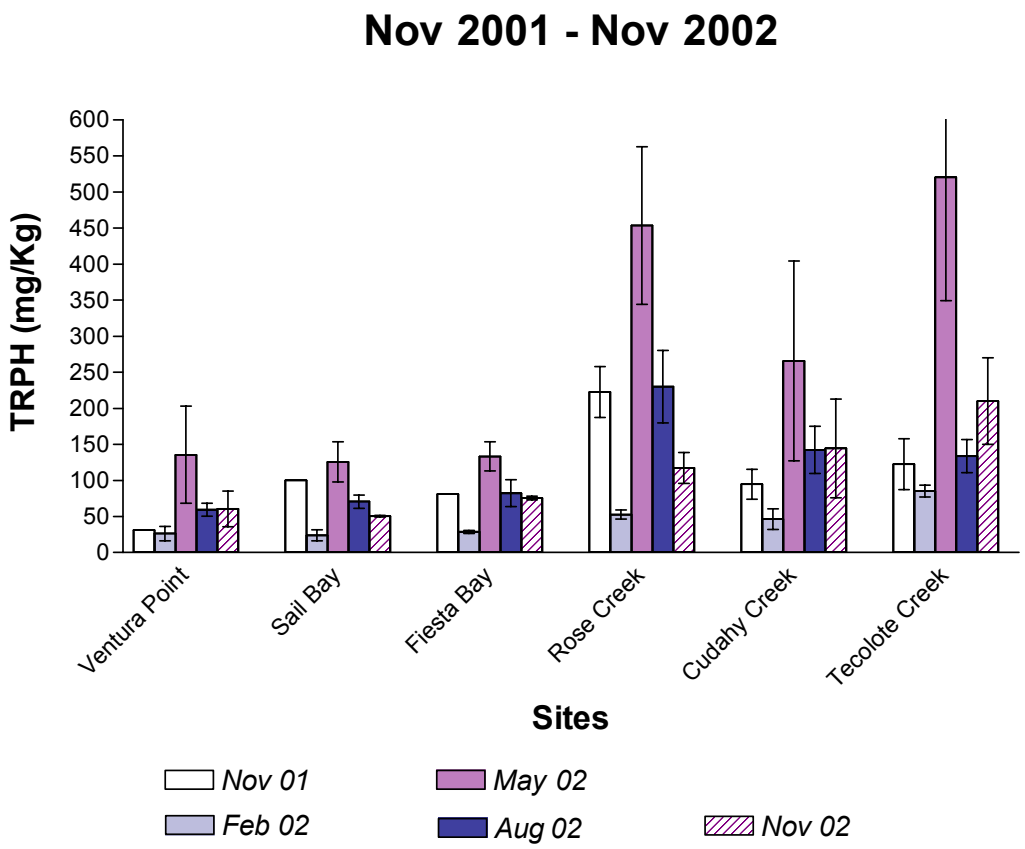

Figure 48. Total recoverable petroleum hydrocarbons (TRPH) in sediments collected from six sites (three subsites per site) in Mission Bay between November 2001 and November 2002. Each bar represents the mean of measurements from all subsites at each time point. Error bars indicate one standard deviation.

Polynuclear Aromatic Hydrocarbons (PAH)

Sediment concentrations of PAH in November 2002 were variable among subsites at all sites, except Fiesta Bay (Figure 49). Highest concentrations were detected at the inlets of the three creeks, and lowest levels were measured in Fiesta Bay.

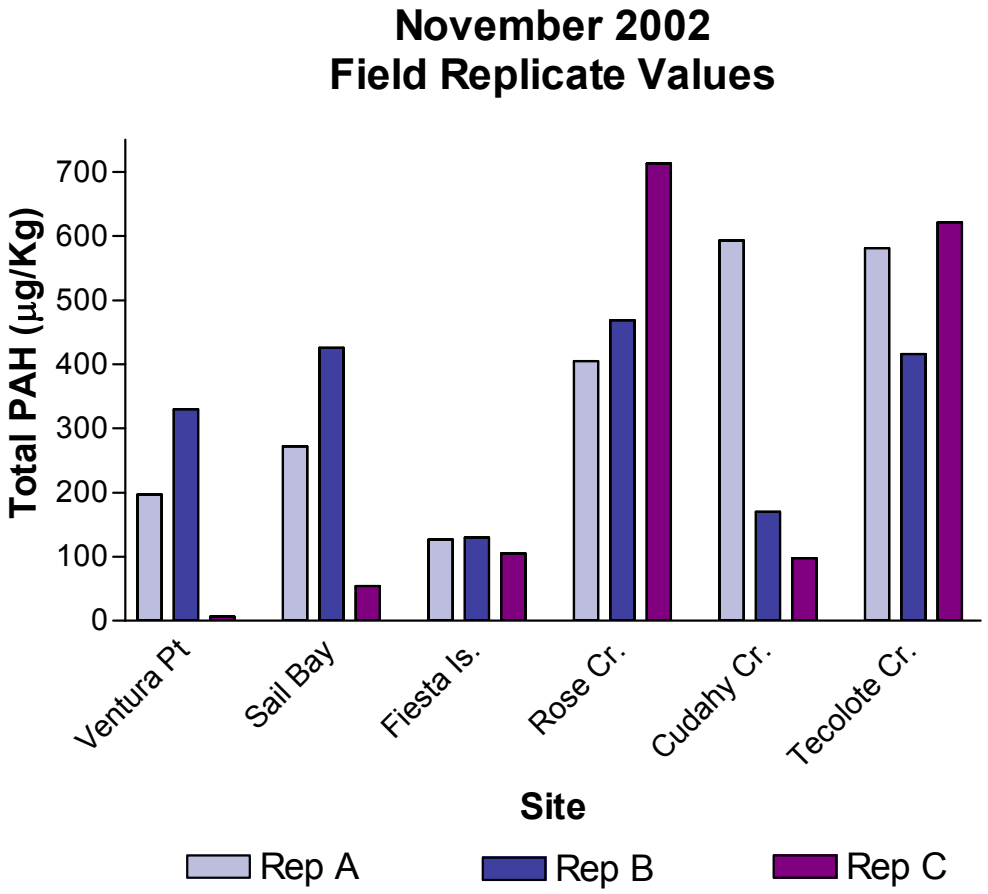

Figure 49. Concentrations of polynuclear aromatic hydrocarbons (PAH) in sediments collected from six sites (three subsites or "field replicates" per site) in Mission Bay during November 2002.

Maximum levels of sediment PAH were measured at the three creek sites (Figure 50), with the highest concentrations detected at Cudahy Creek in August 2002. A possible source of PAH at this site is creosote from treated wood railroad ties that pass near Cudahy Creek just upstream from where it enters Mission Bay. The railroad tracks also passes near or over Tecolote Creek and Rose Creek, possibly furnishing PAH to those sites as well. Although absolute levels of PAH were low at Ventura Point, Sail Bay and Fiesta Bay, highest concentrations at all these sites were measured in November 2001, suggesting a discrete input event that affected all three sites.

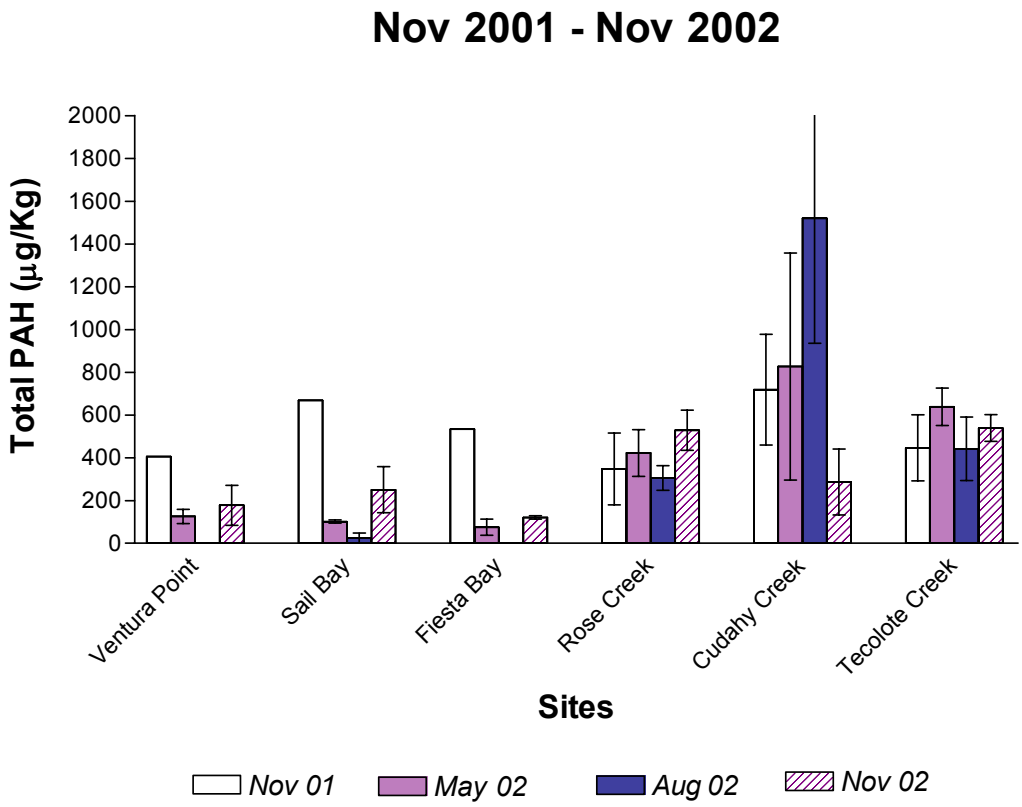

Figure 50. Polynuclear aromatic hydrocarbons (PAH) in sediments collected from six sites (three subsites per site) in Mission Bay between November 2001 and November 2002. Each bar represents the mean of measurements from all subsites at each time point. Error bars indicate one standard deviation.

Chlordane

The pesticide chlordane was detected only at Tecolote Creek in November 2002 (Figure 51). Concentrations at all three subsites were substantial, well above the levels predicted to affect organisms in the environment.

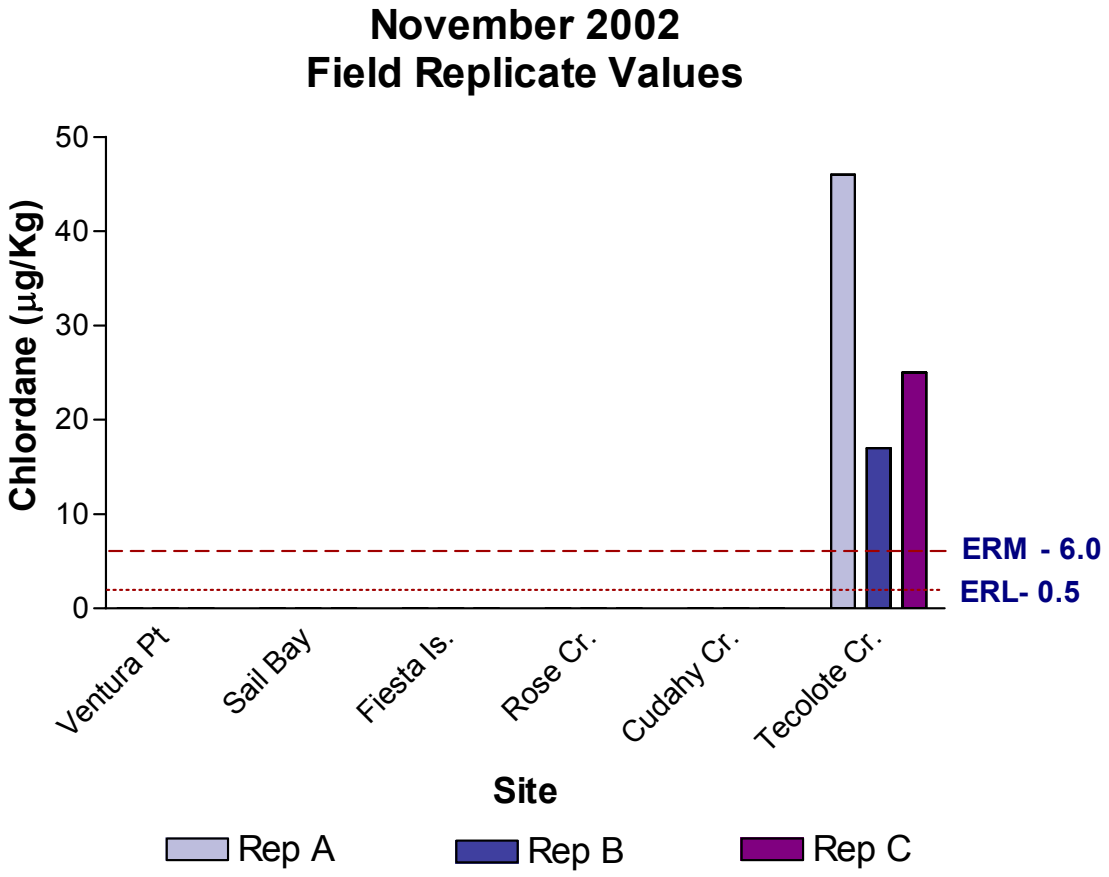

Figure 51. Concentrations of the pesticide chlordane in sediments collected from six sites (three subsites or "field replicates" per site) in Mission Bay during November 2002.

Chlordane was detected at the creek sites but never at Ventura Point, Sail Bay or Fiesta Bay (Figure 52). Highest concentrations were measured in November 2001 at all three sites where chlordane was detected, and sediments at Tecolote Creek displayed elevated concentrations in both November samples, relative to May and August 2002. This pattern suggests that chlordane may be entering the sediments at Tecolote Creek during the fall or early winter.

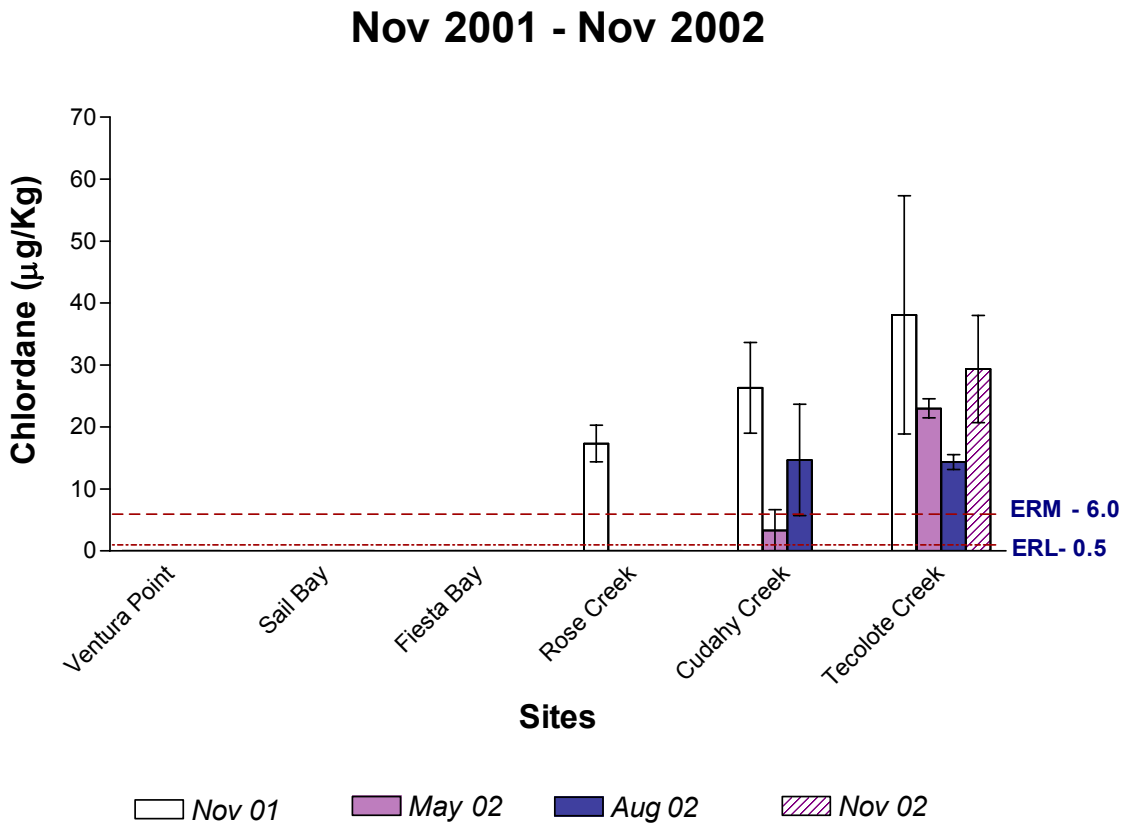

Figure 52. Chlordane in sediments collected from six sites (three subsites per site) in Mission Bay between November 2001 and November 2002. Each bar represents the mean of measurements from all subsites at each time point. Error bars indicate one standard deviation.