Section 4
Results – Water Quality

Precipitation

The winter of 2001-2002 was unusually dry. Total rainfall at Sea World between November 6 2001 and November 5 2002 was 3.49" (archived data were acquired from http://www.wrh.noaa.gov/sandiego/climate/rtp/seaworld.html), well below the annual average for this area. However, San Diego received considerably more rain during the winter of 2003-2003, and Sea World recorded 10.38" between November 6 2002 and May 6 2003 (Figure 6). The substantial difference in rainfall between these two winters provides an excellent opportunity to evaluate the effects of precipitation during an unusually dry winter in comparison to a more "normal" winter.

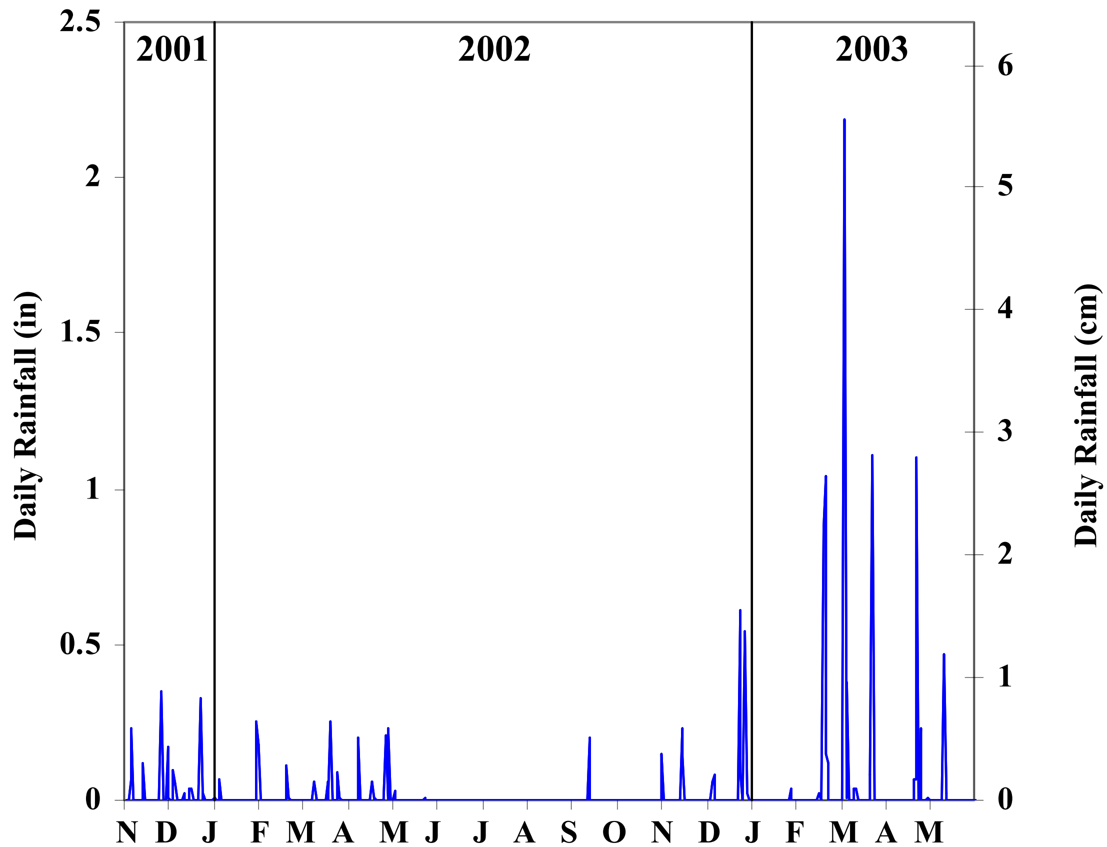

Figure 6. Daily rainfall totals for Sea World between November 1 2001 and May 31 2003.

Hydrography

During the summer, sea surface temperatures in the back bay consistently were higher than temperatures in the front bay (Figure 7). During the winter, surface temperatures varied little throughout the bay, with occasional periods characterized by cooler water in the back bay than near the mouth. Periods during which surface waters in the back bay were cooler than those in the front bay typically followed a rain event, indicating that the temperature trends may have resulted from the input of cool, fresh water from the watershed.

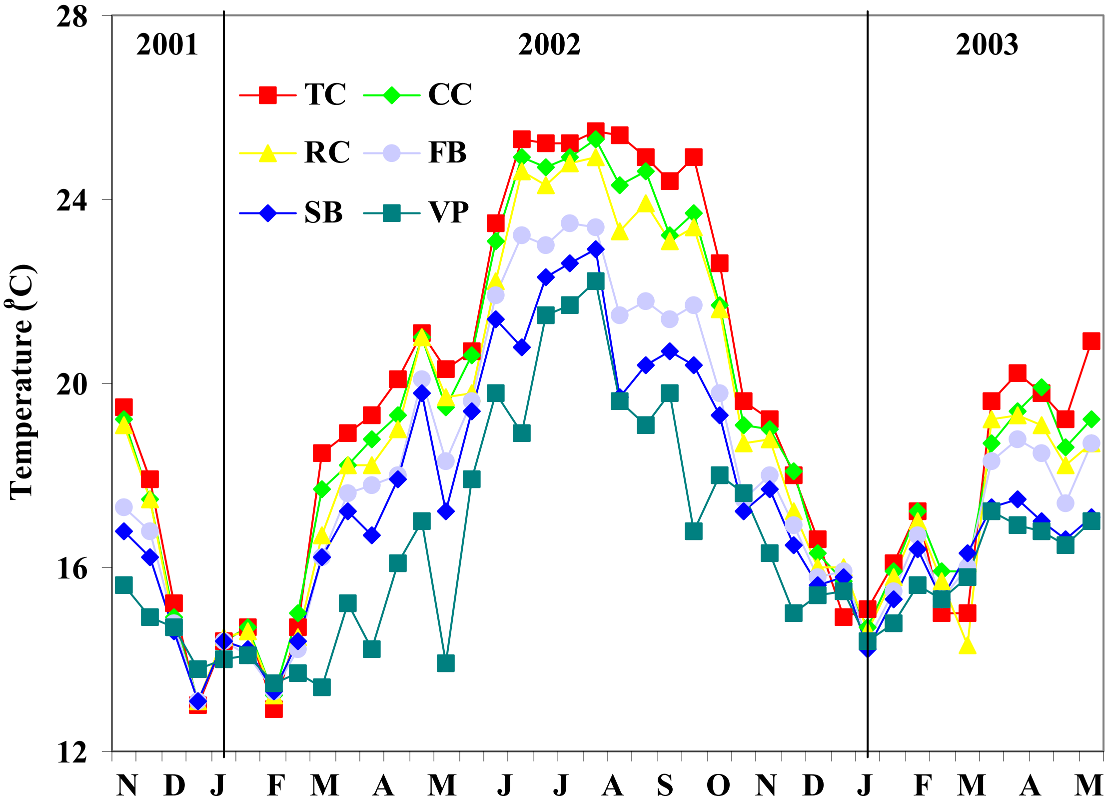

Figure 7. Sea surface temperature measured between November 2001 and May 2003 at six sampling sites within Mission Bay. Each data point represents a single biweekly sample. Letters on the X-axis indicate the first sampling date within a calendar month. Site abbreviations: TC – Tecolote Creek inlet, CC – Cudahy Creek inlet, RC – Rose Creek inlet, FB – Fiesta Bay, SB – Sail Bay, VP – Ventura Point.

Surface salinity typically was higher in the back bay during the summer compared to the winter (Figure 8). Individual inputs of fresh water to the back bay resulted in distinctly lower salinity, e.g. from rainfall events during the winter. Sharply lower surface salinity was apparent in the back bay following several rainfall events during the winter of 2002-2003. Events of this type were virtually absent and of much lower magnitude during the winter of 2001-2002.

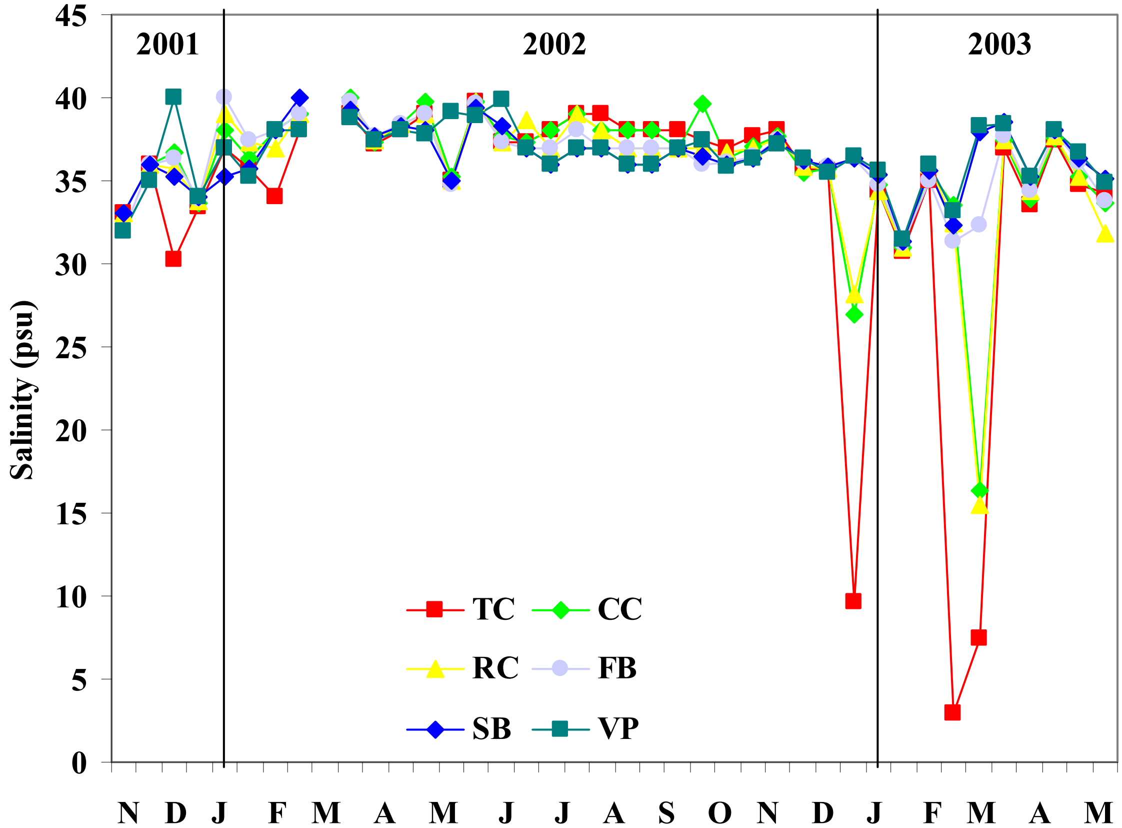

Figure 8. Sea surface salinity measured between November 2001 and May 2003 at six sampling sites within Mission Bay. Each data point represents a single biweekly sample. Letters on the X-axis indicate the first sampling date within a calendar month. Site abbreviations are the same as for Figure 7.

Sea surface salinity was correlated positively and statistically significantly with temperature in the back bay and Sail Bay (Table 3). The strength of this correlation generally decreased with distance from the inlet of Tecolote Creek. Surprisingly, temperature and salinity were not correlated significantly at the Rose Creek inlet but were correlated significantly in Sail Bay.

These results suggest that Sail Bay may experience substantial heating and evaporation during the summer on time scales that are long relative to the flushing rate. By contrast, the inlet of Rose Creek may be relatively well flushed, compared to the residence time. Addition of more data for the time period from May – November 2003 might resolve this trend.

	Spearman Correlation (R)		
Site	**Temp. vs. Salinity**	**Temp. vs. O_2**	**Salinity vs. O_2**
Tecolote Creek Inlet	**0.55***	**-0.64***	-0.30
Cudahy Creek Inlet	**0.36**	**-0.48**	-0.41
Rose Creek Inlet	0.30	**-0.48**	-0.29
Fiesta Bay	0.21	-0.36	**-0.63***
Sail Bay	**0.36**	0.18	-0.24
Ventura Point	0.042	0.034	-0.35

Table 3. Spearman rho correlation between sea surface temperature, sea surface salinity and sea surface dissolved oxygen concentration between November 2001 and May 2003 at six sampling sites within Mission Bay. 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.

Concentrations of dissolved oxygen in surface waters displayed a seasonal cycle, with higher values in the winter and lower values in the summer (Figure 9). This pattern is not surprising, given the reduction in oxygen solubility as water temperature increases. Although the oxygen data for the winter of 2001-2002 are incomplete, the existing data suggest that dissolved oxygen levels were lower during this dry winter than during the considerably wetter winter of 2002-2003.

Pronounced rainfall events visually seem to be associated with increases in dissolved oxygen concentrations, but this impression is not supported by statistical relationships between surface salinity and dissolved oxygen. However, significant negative correlations were observed between surface temperature and dissolved oxygen at all three back bay sites (Table 3). These relationships may have been driven most strongly by warming during the summer and the concomitant decrease in oxygen levels that accompanies reduced oxygen solubility at elevated temperatures.

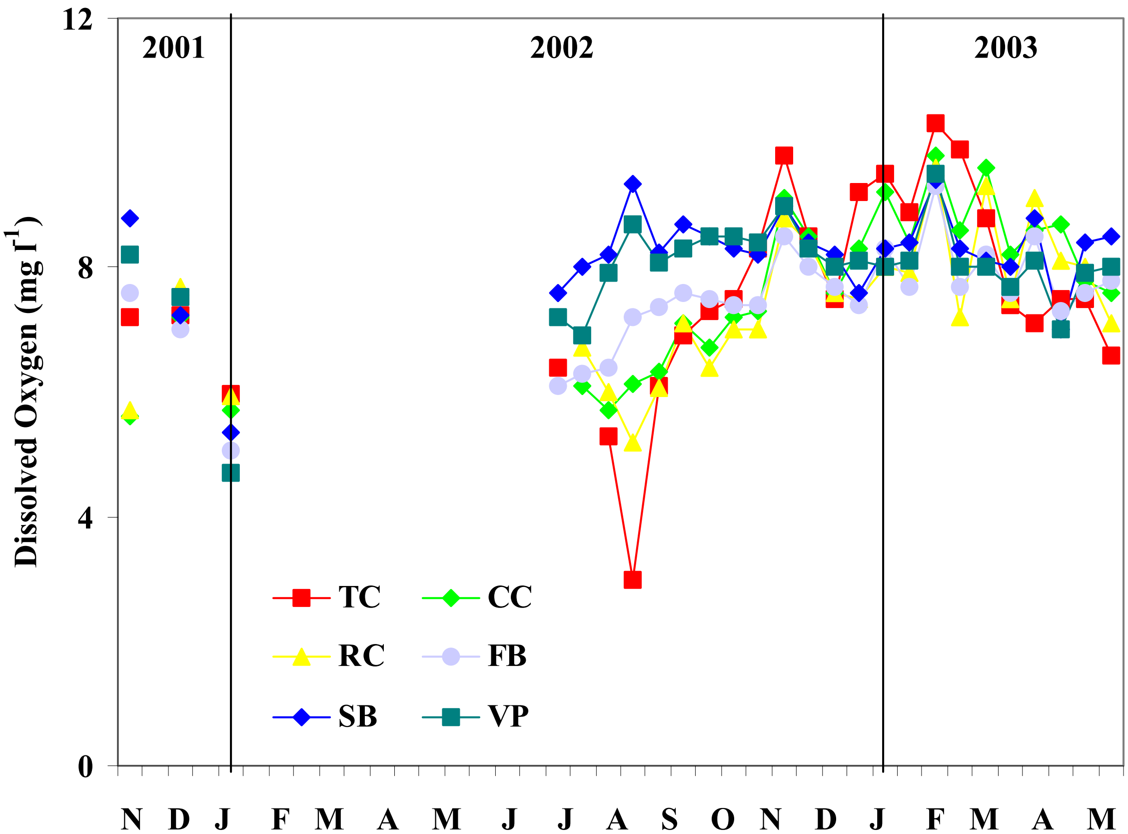

Figure 9. Dissolved oxygen concentrations measured near the surface of the water between November 2001 and May 2003 at six sampling sites within Mission Bay. Each data point represents a single biweekly sample. Missing data during early 2002 were the result of persistent equipment problems. Letters on the X-axis indicate the first sampling date within a calendar month. Site abbreviations are the same as for Figures 7-8.

Nutrients

Nitrate

Concentrations of dissolved nutrients in surface waters varied throughout the 18-month sampling period. Nitrate levels were variable and displayed no consistent seasonal patterns (Figure 10). Concentration peaks seemed to occur throughout the bay synchronously, in many cases, perhaps reflecting high variability in the processes responsible for furnishing nitrate to and removing nitrate from the bay.

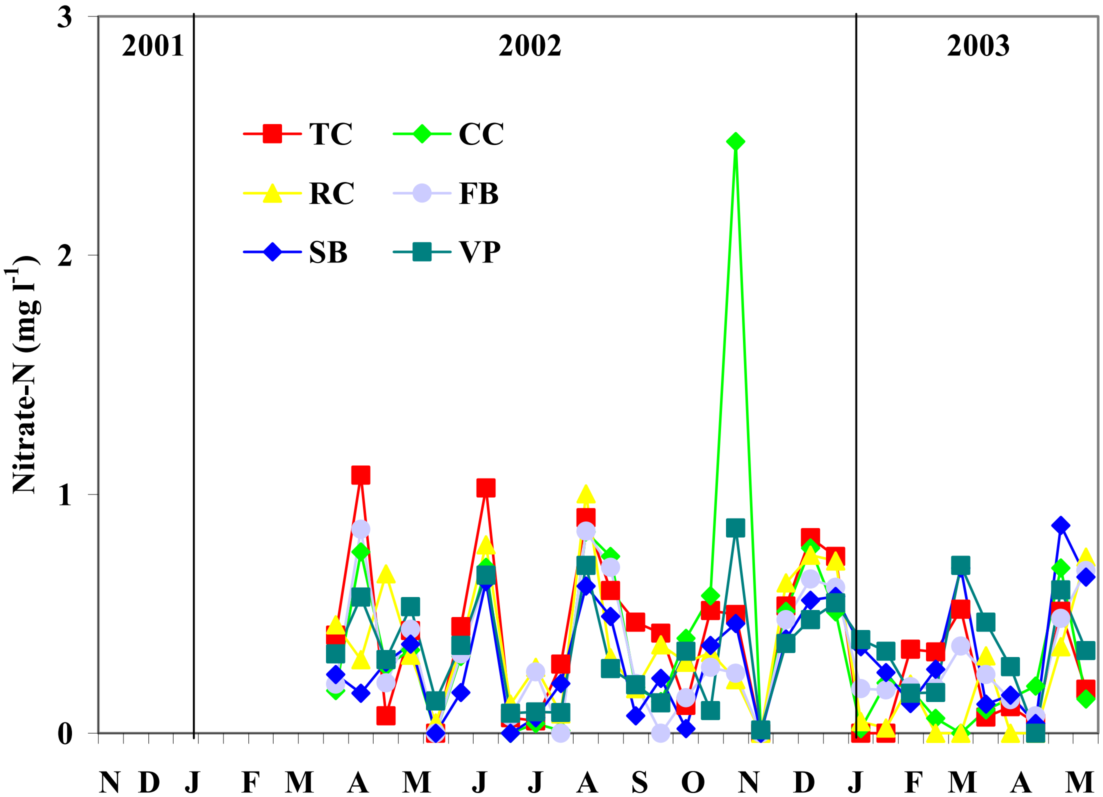

Figure 10. Dissolved nitrate-nitrogen concentrations measured near the surface of the water between November 2001 and May 2003 at six sampling sites within Mission Bay. Each data point represents a single biweekly sample. Missing data during 2001 and early 2002 were the result of analytical problems. Letters on the X-axis indicate the first sampling date within a calendar month. Site abbreviations are the same as for Figures 7-9.

Phosphate

Concentrations of dissolved phosphate displayed a seasonal cycle, with higher values in the summer and winter, and lower values in the spring and fall (Figure 11). These patterns were especially evident in the back bay. During the dry winter of 2001-2002, phosphate levels consistently were low, however several noticeable phosphate peaks were observed during the much wetter winter of 2002-2003. Large peaks in phosphate concentrations during the winter seemed to accompany large rainfall events, suggesting that substantial amounts of phosphate enter Mission Bay with runoff from winter storms. However, rainfall events would not seem to account for the elevated phosphate concentrations measured during the summer.

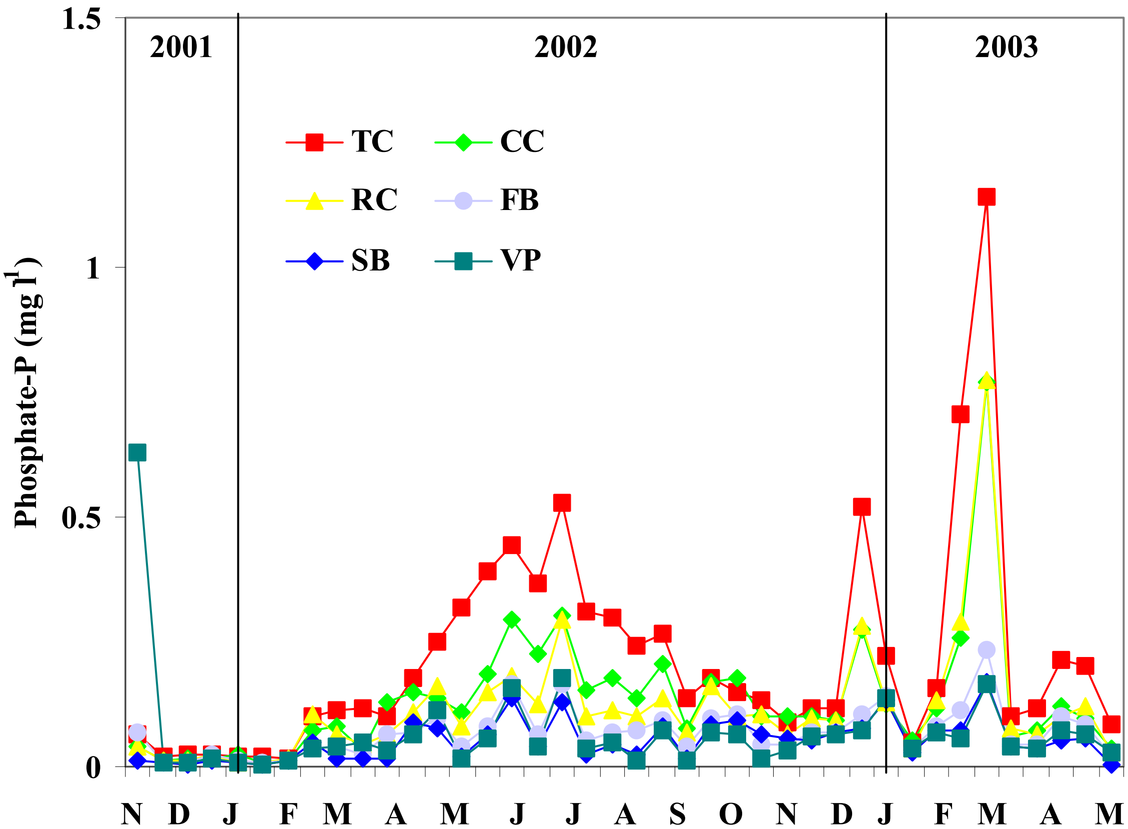

Figure 11. Dissolved phosphate-phosphorus concentrations measured near the surface of the water between November 2001 and May 2003 at six sampling sites within Mission Bay. Each data point represents a single biweekly sample. Letters on the X-axis indicate the first sampling date within a calendar month. Site abbreviations are the same as for Figures 7-10.

Silica

Concentrations of dissolved silica also displayed a seasonal cycle, with higher values in the late summer through winter and lower values in the spring (Figure 12). These temporal trends were especially pronounced in the back bay and much less evident at the front bay sites. During the dry winter of 2001-2002, silica levels were relatively high, not unlike levels observed during the winter of 2002-2003. In addition, peaks in silica concentration during the winter of 2003-2003 seemed to accompany large rainfall events, however rainfall can't account for the elevated silica concentrations during the late summer and fall or the dry winter of 2001-2002.

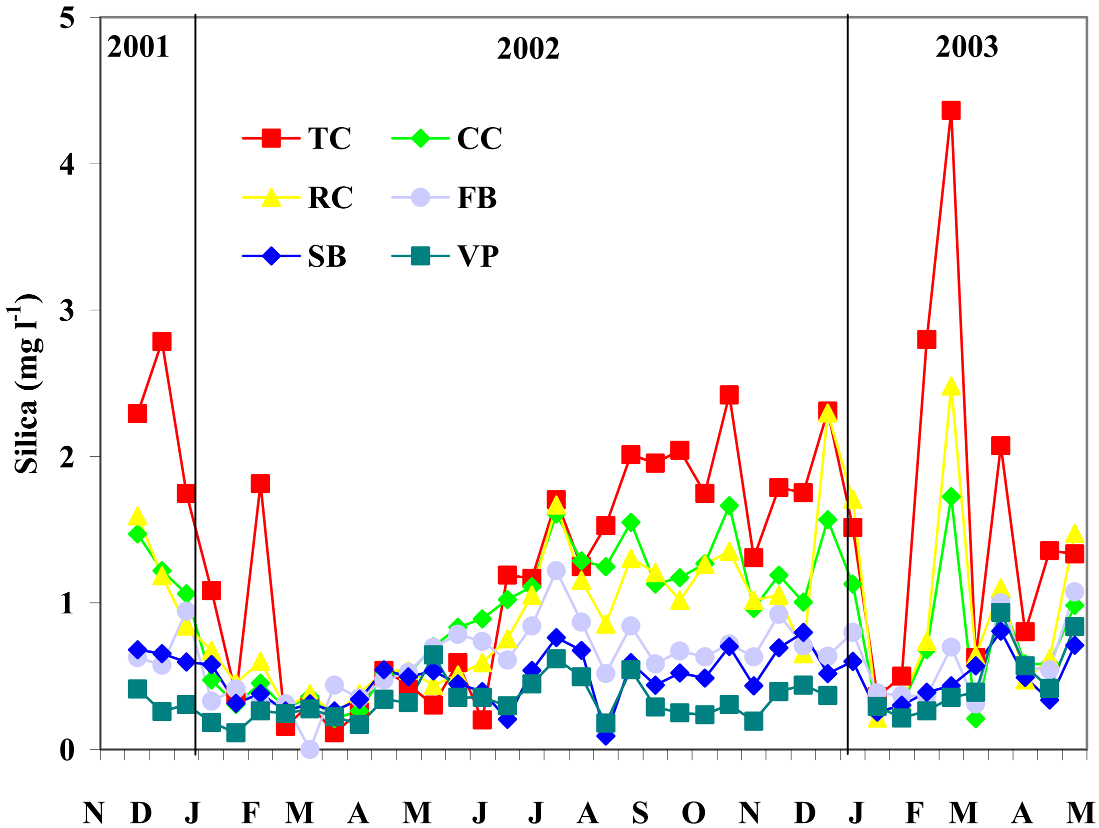

Figure 12. Dissolved silica concentrations measured near the surface of the water between November 2001 and May 2003 at six sampling sites within Mission Bay. Each data point represents a single biweekly sample. Letters on the X-axis indicate the first sampling date within a calendar month. Site abbreviations are the same as for Figures 7-11.

Correlations

Concentrations of nitrate did not correlate significantly with hydrographic parameters at any site in Mission Bay. Phosphate concentrations were correlated positively and significantly with sea surface temperature at all six sites (Table 4). Correlation coefficients generally decreased from back bay to front bay. A similar relationship was not apparent for silica, however silica correlated positively and significantly with sea surface temperature in Fiesta Bay and Ventura Point, the two sites with the most extensive flushing. Surface salinity did not correlate well with phosphate levels, however a negative correlation was observed between salinity and silica concentrations at all sites and significantly in Fiesta Bay.

Site	Spearman Correlation (R)			
	Surface Temperature		Surface Salinity	
	Phosphate-P	Silica	Phosphate-P	Silica
Tecolote Creek Inlet	**0.50***	-0.09	**0.56***	-0.30
Cudahy Creek Inlet	**0.56***	0.32	0.31	-0.11
Rose Creek Inlet	**0.37**	0.17	0.22	-0.31
Fiesta Bay	**0.38**	**0.42**	-0.13	**-0.35**
Sail Bay	**0.34**	0.08	0.31	-0.31
Ventura Point	**0.31**	**0.37**	-0.003	-0.08

Table 4. Spearman rho correlation between sea surface temperature, sea surface salinity and near-surface nutrient concentration between November 2001 and May 2003 at six sampling sites within Mission Bay. 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.

Metals

Concentrations of cadmium and lead were below detection limits at all sites for all five time periods when metals were assayed (November 2001, February, May, August, November 2002). Zinc was detected only during February 2002, and the highest levels were measured in samples from Sail Bay (Table 5).

Copper was detected in February, May and August 2002. The highest copper concentrations were measured in May 2002, with a maximum of 26.6 μg l^{-1} measured at the Tecolote Creek inlet. Trends based on the other two sampling periods were less clear.

	Zinc	Copper		
Site	**Feb 2002**	**Feb 2002**	**May 2002**	**Aug 2002**
Tecolote Creek Inlet	10.0	8.14	26.6	5.89
Cudahy Creek Inlet	ND	6.88	14.7	9.79
Rose Creek Inlet	10.3	6.16	ND	9.79
Fiesta Bay	ND	7.56	17.5	ND
Sail Bay	46.8	8.54	15.4	ND
Ventura Point	17.3	6.86	16.0	7.86

Table 5. Concentrations of metals in surface waters, measured between November 2001 and November 2002 at six sampling sites within Mission Bay. All concentrations in μg l^{-1}. "ND" = "Not Detectable".