Chapter 3. Water Quality

INTRODUCTION

Seawater samples are collected and analyzed as part of the South Bay Ocean Outfall (SBOO) monitoring program to characterize water quality conditions in the region and to identify possible impacts of wastewater discharge on the marine environment and along the shoreline. Various water chemistry parameters and densities of fecal indicator bacteria (FIB), including total coliforms, fecal coliforms, and enterococcus, are measured and evaluated along with data on local oceanographic conditions (see Chapter 2) to provide information about the movement and dispersion of wastewater discharged into the Pacific Ocean through the outfall. Evaluation of these data may also help to identify other point or non-point sources of bacterial contamination. In addition, the City's water quality monitoring program is designed to assess compliance with water contact standards as established in the California Ocean Plan (Ocean Plan), which defines bacterial water quality objectives and standards with the intent of protecting the beneficial uses of State ocean waters (SWRCB 2001, 2005).

Because there are multiple natural and anthropogenic sources that can impact water quality, distinguishing a wastewater plume from other sources of bacterial contamination in ocean waters is often challenging. This is especially true in the SBOO region. For example, previous studies in the area have shown that tidal exchange from San Diego Bay, outflows from the Tijuana River in U.S. waters and Los Buenos Creek in northern Baja California, storm water discharges, and runoff from local watersheds have a large impact on nearshore bacteria levels (Noble et al. 2003, Largier et al. 2004, Gersberg et al. 2008, Griffith et al. 2009, Terrill et al. 2009). Likewise, it has been shown that kelp and seagrass beach wracks, storm drains impacted by tidal flushing, and beach sediments can act as reservoirs, cultivating bacteria until high tide returns and/or other disturbances release them into nearshore waters (Gruber et al. 2005, Martin and Gruber 2005). Finally, the presence of birds and their droppings have been related to bacterial exceedances that may impact nearshore water quality (Grant et al. 2001, Griffith et al. 2009).

This chapter presents analyses and interpretations of bacterial densities and water chemistry data collected during 2010 at monitoring sites surrounding the SBOO. The primary goals are to: (1) evaluate overall water quality conditions in the SBOO monitoring region, (2) differentiate among various sources of bacterial contamination into the survey area, including the SBOO wastewater plume, (3) evaluate potential movement and dispersal of wastewater discharged via the SBOO, and (4) assess compliance with water contact standards as defined in the Ocean Plan. In addition, this chapter assesses remote sensing data to provide further insight into the transport potential in coastal waters surrounding the SBOO discharge site.

Materials and Methods

Field Sampling

Seawater samples for bacteriological analyses were collected at a total of 39 shore, kelp bed, or other offshore monitoring sites during 2010 (Figure 3.1). Sampling was performed weekly at 11 shore stations to monitor FIB concentrations in waters adjacent to public beaches. Eight of these stations (S4, S5, S6, S8, S9, S10, S11, S12) are located between the USA/Mexico border and Coronado, southern California and are subject to Ocean Plan water contact standards. The other three shore stations (S0, S2, S3) are located in Mexican waters off northern Baja California and are not subject to Ocean Plan requirements. Three stations located in nearshore waters within the Imperial Beach kelp forest were also monitored weekly to assess water quality conditions and Ocean Plan compliance in areas used for recreational activities such as SCUBA diving, surfing, fishing, and kayaking.

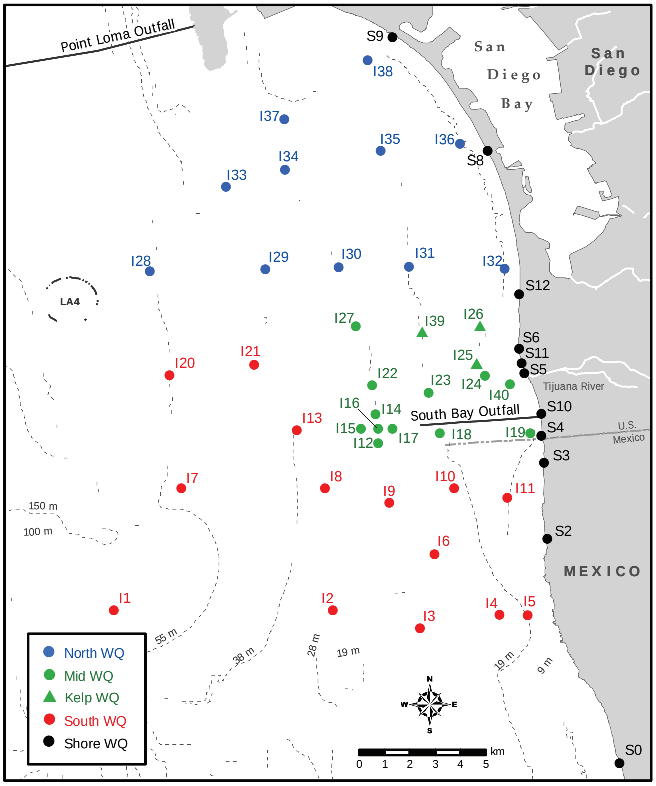

Figure 3.1
Water quality (WQ) monitoring stations for the South Bay Ocean Outfall Monitoring Program.

These include stations I25 and I26 located near the inner edge of the kelp bed along the 9-m depth contour, and station I39 located near the outer edge of the kelp bed along the 18-m depth contour. An additional 25 stations located further offshore in deeper waters were sampled once a month (except April due to a Bight'08 resource exchange) in order to monitor FIB levels and estimate the spatial extent of the wastewater plume. These offshore stations are arranged in a grid surrounding the discharge site distributed along the 9, 19, 28, 38, and 55-m depth contours (Figure 3.1). Sampling of these offshore stations generally occurs over a 3-day period each month (Appendix A.1).

Seawater samples for shore stations were collected from the surf zone in sterile 250-mL bottles. In addition, visual observations of water color, surf height, human or animal activity, and weather conditions were recorded at the time of collection. The samples were then transported on blue ice to the City of San Diego's Marine Microbiology Laboratory (CSDMML) and analyzed to determine FIB concentrations (i.e., total coliform, fecal coliform, and enterococcus bacteria).

Either an array of Van Dorn bottles or a rosette sampler fitted with Niskin bottles was used to collect seawater samples at each of the kelp bed and other offshore stations. Samples were collected at three discrete depths for the above FIBs and total suspended solids (TSS), whereas oil and grease (O&G) samples were only collected from surface waters. Aliquots for each analysis were drawn into appropriate sample containers. All bacterial seawater samples were refrigerated onboard ship and transported to the CSDMML for subsequent processing and analysis. TSS and O&G samples were taken to the City's Wastewater Chemistry Services Laboratory for analysis. Visual observations of weather and sea conditions, and human or animal activity were also recorded at the time of sampling. Monitoring of the SBOO area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging of Solana Beach, California (Svejkovsky 2011).

Laboratory Analyses

All bacterial analyses were performed within 8 hours of sample collection and conformed to standard membrane filtration techniques (APHA 1998). The CSDMML follows guidelines issued by the United States Environmental Protection Agency (USEPA) Water Quality Office, Water Hygiene Division, and the California State Department of Health Services (CDHS) Environmental Laboratory Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1998).

Procedures for counting colonies of indicator bacteria, calculation and interpretation of results, data verification and reporting all follow guidelines established by the USEPA (Bordner et al. 1978) and APHA (1998). According to these guidelines, plates with FIB counts above or below the ideal counting range were given greater than (>), less than (<), or estimated (e) qualifiers. However, these qualifiers

Box 3.1

Bacteriological compliance standards for water contact areas, 2001 California Ocean Plan (SWRCB 2001). CFU = colony forming units.

(a) *30-day Total Coliform Standard* — no more than 20% of the samples at a given station in any 30-day period may exceed a concentration of 1000 CFU per 100 mL.

(b) *10,000 Total Coliform Standard* — no single sample, when verified by a repeat sample collected within 48 hrs, may exceed a concentration of 10,000 CFU per 100 mL.

(c) *60-day Fecal Coliform Standard* — no more than 10% of the samples at a given station in any 60-day period may exceed a concentration of 400 CFU per 100 mL.

(d) *30-day Fecal Geometric Mean Standard* — the geometric mean of the fecal coliform concentration at any given station in any 30-day period may not exceed 200 CFU per 100 mL, based on no fewer than five samples.

Bacteriological compliance standards for water contact areas, 2005 California Ocean Plan (SWRCB 2005). CFU = colony forming units.

(a) *30-day Geometric Mean* — The following standards are based on the geometric mean of the five most recent samples from each site:
1) Total coliform density shall not exceed 1000 CFU/100 mL.
2) Fecal coliform density shall not exceed 200 CFU/100 mL.
3) Enterococcus density shall not exceed 35 CFU/100 mL.

(b) *Single Sample Maximum*:
1) Total coliform density shall not exceed 10,000 CFU/100 mL.
2) Fecal coliform density shall not exceed 400 CFU/100 mL.
3) Enterococcus density shall not exceed 104 CFU/100 mL.
4) Total coliform density shall not exceed 1000 CFU/100 mL when the fecal coliform:total coliform ratio exceeds 0.1.

were dropped and the counts treated as discrete values when calculating means and in determining compliance with Ocean Plan standards.

Quality assurance tests were performed routinely on seawater samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split bacteriological samples were processed according to method requirements to measure intra-sample and inter-analyst variability, respectively. Results of these procedures were reported in City of San Diego (2011).

Data Treatment

Densities of bacteria were summarized as monthly averages for each shore station and by depth contour for the offshore stations. Total suspended solids (TSS) were also summarized by month for the offshore stations. To assess temporal and spatial trends, bacteriological data were summarized as counts of samples in which FIB concentrations exceeded benchmark levels. For this report, water contact limits defined in the 2005 Ocean Plan for densities of total coliforms, fecal coliforms, and enterococcus in individual samples (i.e., single sample maximums; see Box 3.1 and SWRCB 2005) were used as reference points to distinguish elevated FIB values (i.e., benchmark levels). Concentrations of each FIB are identified by sample in Appendices B.1, B.2, and B.3. In addition, the 2005 Ocean Plan single sample maximum standard that states total coliform densities shall not exceed 1000 CFU/100 mL when the fecal coliform:total coliform (F:T) ratio exceeds 0.1 was considered as the criterion for contaminated waters. This condition is referred to as the fecal:total ratio (FTR) criterion herein. Finally, Pearson's Chi-Square analyses (χ^2)

were conducted to determine if the frequency of samples with elevated FIBs differed between wet versus dry seasons.

Compliance with Ocean Plan water-contact standards was summarized as the number of days that each of the shore stations north of the USA/Mexico border and all of the kelp bed stations exceeded various Ocean Plan standards during each month. Due to regulatory changes that became effective August 1, 2010, bacterial compliance was assessed using the water contact standards specified in the 2001 Ocean Plan (Box 3.1 and SWRCB 2001) between January 1 and July 31, 2010, whereas data collected after August 1, 2010 were assessed using water contact standards specified in the 2005 Ocean Plan (Box 3.1 and SWRCB 2005).

Results

Shore Stations

Concentrations of indicator bacteria generally were higher at the SBOO shore stations in 2010 than in 2009 (City of San Diego 2010), which likely reflects the higher levels of rainfall that occurred during the year (i.e. 16.3 inches in 2010 vs. 5.5 inches in 2009). During 2010, monthly FIB densities averaged from 8 to 16,000 CFU/100 mL for total coliforms, 2 to 10,400 CFU/100 mL for fecal coliforms, and 2 to 7400 CFU/100 mL for enterococcus (Table 3.1). As expected, the highest values for each parameter occurred during the wet season (January–April, October–December). In addition, 85% of the shore station samples with elevated FIBs and 89% of the samples that exceeded the FTR criterion were collected during these months, when rainfall totaled 16.2 inches (vs. 0.08 inches in the dry season; Table 3.2). Further, the proportion of samples that had elevated FIBs during the 2010 wet season was significantly greater than in the dry season [$\chi^2(1, N=540)=44.5$, $p<0.0001$]. This general relationship between rainfall and elevated bacteria levels has been evident over the past several years (Figure 3.2) and these data indicate that there is a 26% greater chance of collecting a sample with elevated FIBs during the wet season [$\chi^2(1, N=2267)=137.5$, $p<0.0001$].

In 2010, samples with elevated FIBs were collected primarily at shore stations close to the mouth of the Tijuana River (i.e., shore stations S4, S5, S10, S11) and further south (i.e., shore stations S0, S2, S3) (Table 3.2, Appendix B.1). High FIB counts at these stations tend to correspond with turbidity plumes from the Tijuana River and Los Buenos Creek (in Mexico), which have been observed repeatedly over the past several years following rain events (City of San Diego 2008–2010). For example, a MODIS satellite image taken February 10, 2010 showed turbidity plumes encompassing several of the shore stations, five of which had elevated total coliform concentrations on the previous day (Figure 3.3). While the image in this figure was not taken on the same day the bacterial samples were collected, the turbidity plume that is evident likely started earlier in the week due to a large storm that began February 5, 2010. Samples from some of these stations (e.g., S0, S2, S5) also had high levels of bacterial contamination during the warmer, dry conditions between May–September (Table 3.2). For example, 12 of the 15 samples with elevated FIB densities that were collected during the dry season occurred at stations S0 and S2, both of which are located south of the international border and bracket Los Buenos Creek. Historically, elevated FIB densities have occurred much more frequently at station S6 and other stations to the south than at stations S8, S9 and S12 located further north (City of San Diego 2007).

Kelp Bed Stations

On average, monthly FIB densities at the SBOO kelp bed stations were lower than those at the shore stations, ranging from 5 to 2208 CFU/100 mL for total coliforms, 2 to 717 CFU/100 mL for fecal coliforms, and 2 to 550 CFU/100 mL for enterococcus (Table 3.3). However, the highest concentrations of these parameters occurred during the wettest months of 2010, similar to the pattern described above for samples collected along the shore. For example, 96% of the kelp bed station

Table 3.1

Summary of rainfall and bacteria levels at SBOO shore stations during 2010. Total coliform, fecal coliform, and enterococcus densities are expressed as mean CFU/100 mL per month and for the entire year. Rain data are from Lindbergh Field, San Diego, CA. Stations are listed north to south from top to bottom; *n* = total number of samples.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Rain (in):		3.38	2.30	0.68	1.78	0.01	0.02	0.02	0.00	0.03	2.18	0.88	5.00
S9	*Total*	106	16	13	11	16	56	65	84	110	910	52	4014
	Fecal	8	7	2	2	2	2	3	11	7	245	3	222
	Entero	39	4	2	2	3	16	4	6	8	317	3	703
S8	*Total*	471	31	21	16	56	16	16	20	20	40	28	4021
	Fecal	26	2	2	2	15	2	2	2	2	4	12	354
	Entero	66	8	4	2	37	3	3	2	13	5	2	506
S12	*Total*	4086	8	20	16	70	48	35	20	25	40	13	4051
	Fecal	208	2	2	7	11	7	5	3	16	19	2	556
	Entero	1602	37	3	2	11	2	6	2	7	28	6	1576
S6	*Total*	4073	1764	7246	4016	20	52	20	16	61	475	52	4050
	Fecal	305	30	186	102	3	2	3	2	3	91	2	758
	Entero	1693	12	15	4	2	3	3	5	2	97	7	2521
S11	*Total*	4195	1195	2721	4085	4020	32	20	16	30	190	21	4156
	Fecal	711	29	33	46	67	2	3	2	5	74	6	3037
	Entero	775	7	6	4	5	2	7	4	4	51	7	3141
S5	*Total*	12,003	13,650	10,816	5160	4020	18	25	20	16	770	1376	4420
	Fecal	4851	6225	2788	3051	1152	2	5	2	2	121	38	3031
	Entero	5802	6011	2460	3024	552	3	4	3	3	32	34	3066
S10	*Total*	8235	12,900	12,400	7556	35	20	25	40	70	86	3408	5347
	Fecal	4204	1603	333	282	2	2	4	3	27	27	330	4001
	Entero	4008	462	702	25	2	2	20	2	17	19	12	1003
S4	*Total*	8004	9310	8320	5081	16	10	35	16	40	111	3428	5341
	Fecal	3551	721	500	112	2	2	5	4	7	25	144	668
	Entero	3802	111	319	8	2	2	4	2	4	12	6	82
S3	*Total*	8013	12,650	16,000	ns	20	44	63	105	213	293	1095	4225
	Fecal	1551	6555	10,400	ns	3	21	10	14	9	66	44	3010
	Entero	1810	5130	7400	ns	2	3	12	10	10	226	87	3021
S2	*Total*	4371	5502	16,000	ns	340	21	437	62	127	1800	740	4410
	Fecal	306	111	470	ns	15	4	86	9	3	35	36	921
	Entero	1758	83	490	ns	8	56	20	4	9	40	8	2138
S0	*Total*	4270	5915	8700	ns	1035	2536	5075	720	697	5420	1915	6625
	Fecal	198	815	235	ns	134	510	355	84	117	475	89	1885
	Entero	1023	1012	360	ns	154	250	314	52	94	324	131	3204
	n	44	44	46	32	44	55	44	55	41	41	52	42
Annual	*Total*	5257	5722	7478	3242	877	259	529	102	128	921	1103	4605
Means	*Fecal*	1447	1463	1359	450	128	51	44	12	18	107	64	1677
	Entero	2034	1170	1069	384	71	31	36	8	15	105	28	1905

ns = not sampled (no samples were collected at stations S0, S2, and S3 from March 16 to April 27 due to travel warnings issued by the U.S. Department of State regarding travel to northern Mexico)

Table 3.2

The number of samples with elevated bacteria densities collected at SBOO shore stations during 2010. Elevated FIB = the total number of samples with elevated FIB densities; contaminated = the total number of samples that meet the FTR criterion indicative of contaminated seawater; Wet = January–April and October–December; Dry = May–September; *n* = total number of samples. Rain data are from Lindbergh Field, San Diego, CA. Stations are listed north to south from top to bottom.

Station		Seasons		
		Wet	Dry	%Wet
S9	Elevated FIB	2	0	100
	Contaminated	1	0	100
S8	Elevated FIB	2	1	67
	Contaminated	0	0	—
S12	Elevated FIB	4	0	100
	Contaminated	1	0	100
S6	Elevated FIB	7	0	100
	Contaminated	2	0	100
S11	Elevated FIB	6	1	86
	Contaminated	2	0	100
S5	Elevated FIB	13	1	93
	Contaminated	11	1	92
S10	Elevated FIB	13	0	100
	Contaminated	5	0	100
S4	Elevated FIB	9	0	100
	Contaminated	4	0	100
S3	Elevated FIB	11	0	100
	Contaminated	7	0	100
S2	Elevated FIB	7	1	88
	Contaminated	1	1	50
S0	Elevated FIB	13	11	54
	Contaminated	5	3	63
	Rain (in)	16.20	0.08	
Total	Elevated FIB	87	15	85
Counts	Contaminated	39	5	89
	n	301	239	56

samples with elevated FIBs and 88% of the samples that met the FTR criterion occurred during the wet season (Table 3.4). Further, the proportion of samples from these stations that had elevated FIBs during the 2010 wet season was also significantly greater than in the dry season [$\chi^2(1, N = 540) = 17.6$, $p < 0.0001$], which is a relationship that has been evident over the past several years (Figure 3.4). Data collected from the kelp stations between 2007 and 2010 indicate that there is 26% greater chance of collecting a sample with elevated FIBs during the wet season [$\chi^2(1, N = 2160) = 68.4$, $p < 0.001$].

High FIB counts in the kelp bed during the rainy season also tended to correspond with turbidity plumes from the Tijuana River and Los Buenos Creek. For example, a MODIS satellite image taken January 24, 2010 showed turbidity plumes encompassing stations I25 and I26, both of which had slightly elevated total coliform concentrations on the following day (Figure 3.5). This turbidity plume likely started earlier in the week due to a large storm that occurred over several days between January 18 and 23, 2010, during which time a total of ~3 inches of rainfall occurred in the SBOO region. In contrast, only one seawater sample collected during the dry season from these stations contained elevated FIB levels (Table 3.4, Appendix B.2). The source of contamination for that sample is unclear.

Total suspended solids (TSS) and oil and grease (O&G) are also measured at the kelp bed stations as potential indicators of wastewater. However, previous analyses have demonstrated that these parameters have limited utility as indicators of the wastefield (City of San Diego 2007). Concentrations of TSS varied considerably during 2010, ranging between 0.2 and 30.9 mg/L per sample (Table 3.5); O&G was not detected in any samples. Of the 39 seawater samples with elevated TSS concentrations ≥8.0 mg/L, none corresponded to samples with elevated FIBs. It is more likely that these high TSS values were due to other sources, such as the re-suspension of bottom sediments when the CTD touched the sea floor, the presence of phytoplankton blooms, or runoff or wave action associated with storm activity that occurred around the time of sampling.

'Other' Offshore Stations

Elevated FIB concentrations were rare in samples collected from the 25 non-kelp bed ('other') offshore stations during 2010. Only 28 of 825 samples (~3.4%) collected at these sites had elevated FIBs and only 17 (2.1%) met the FTR criterion for contaminated waters (Table 3.4, Appendix B.3). The lack of samples with elevated FIBs reflects the low concentrations of bacteria, which ranged from 2 to 3350 CFU/100 mL for total coliforms, 2 to 946 CFU/100 mL for fecal coliforms, and 2 to 456 CFU/100 mL for enterococcus on average per

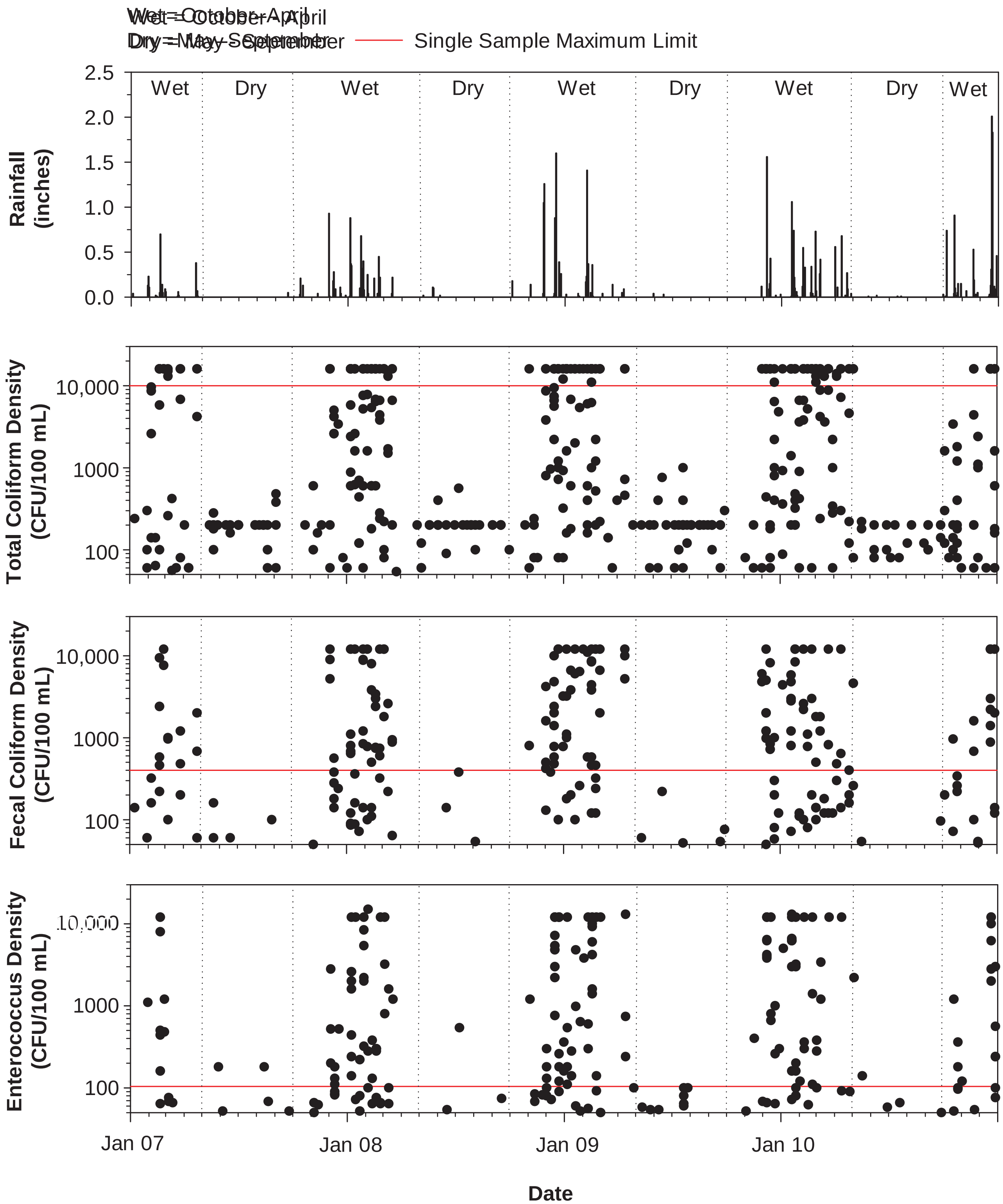

Figure 3.2
Comparison of bacteriological data from SBOO shore stations located north of the USA/Mexico border to rainfall between January 1, 2007 and December 31, 2010. Densities of bacteria have been limited to ≥50 CFU/100 mL for clearer data presentation.

month (Table 3.3). For stations located along the 9 and 19-m depth contours (i.e., I18, I19, I32, I36, I40), 100% of the samples with elevated FIBs were collected during the wet season. As with the shore and kelp stations, remote satellite images demonstrate that contaminants carried by turbidity plumes originating from the Tijuana River and Los Buenos Creek can extend into the offshore sampling region of the SBOO survey area. For example, a MODIS satellite image taken February 24, 2010 showed a turbidity plume associated with increased rainfall moving west and encompassing stations I19 and I40 (Figure 3.6). Samples collected on the previous day at these two stations had elevated total coliform densities, whereas the majority of samples collected farther offshore (i.e., stations I14, I16, I18, I22, I23, I24) had low FIB levels. This turbidity plume likely started earlier in the week due to a large storm that occurred over several days between February 19 and 22, 2010.

During 2010, a total of 14 samples with elevated FIB densities were collected at sites adjacent to the SBOO diffusers (i.e., stations I12 and I16; Table 3.4). Most of these samples were collected from a depth of 18 m or greater, and most also met the FTR criterion for contaminated waters (Appendix B.3). Consequently, it appears likely that these FIB densities were associated with wastewater discharge from the outfall. Further, three samples with elevated FIBs were collected in surface waters during the year. These three samples were collected at stations I12 and I16 in January and February and were likely associated with the surfacing of the wastewater plume in the winter. Aerial imagery results support this conclusion, as they indicated that the wastewater plume reached near-surface waters above the discharge site on several occasions between January and March, and again in December (Figure 2.4; Svejkovsky 2011).

Like the kelp bed stations, TSS and O&G are also measured at the 'other' offshore stations as potential indicators of wastewater. TSS were detected frequently at the offshore stations in 2010 at concentrations that varied considerably between 0.2 and 46.2 mg/L per sample (Table 3.5). In contrast, O&G was detected in only two samples from stations I24 and I36 at concentrations of 1.7 and 1.9 mg/L, respectively. Of the 208 seawater samples with elevated TSS concentrations (≥8.0 mg/L), only 15 corresponded to samples with elevated FIBs, three of which met the FTR criterion for contamination. The remaining elevated TSS values were more likely due to other sources described in the previous section.

California Ocean Plan Compliance

The overall compliance rate for 2010 was about 87%, indicating that compliance with the various Ocean Plan standards (Box 3.1) was relatively high at both shore and kelp stations. During the first half of the year (i.e., January–July), compliance with 2001 Ocean Plan standards along the shore ranged from 31 to 100% for the 30-day total coliform standard, 20 to 100% for the 60-day fecal coliform standard, and 63

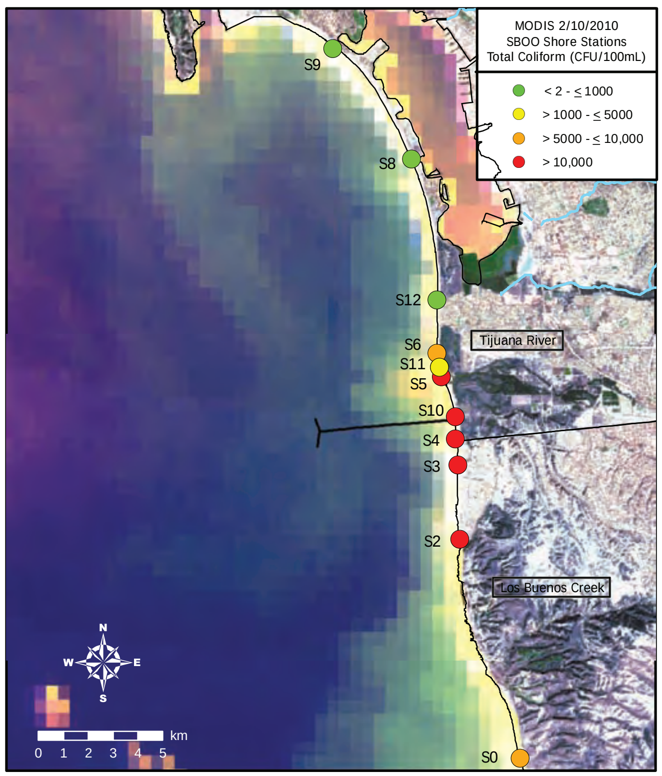

Figure 3.3
MODIS satellite image showing the SBOO monitoring region on February 10, 2010 (Ocean Imaging 2011) combined with total coliform concentrations at shore stations sampled on February 9, 2010. Turbid waters from the Tijuana River and Los Buenos Creek can be seen overlapping southern stations with higher levels of contamination.

Table 3.3

Summary of FIB densities (CFU/100 mL) at SBOO kelp bed and other offshore stations in 2010. Data are expressed as means for all stations along each depth contour by month; *n* = total number of samples per month.

Assay	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010 SBOO Kelp Bed Stations												
9-m Depth Contour (*n* = 30)												
Total	713	2208	106	305	20	6	5	7	14	1768	375	164
Fecal	20	66	10	25	2	2	2	2	2	717	34	19
Entero	114	34	13	5	3	2	2	2	2	550	14	107
19-m Depth Contour (*n* = 15)												
Total	1102	332	52	87	117	6	7	5	19	1102	13	6
Fecal	21	30	7	17	39	2	3	2	2	208	2	2
Entero	60	22	8	4	9	2	2	2	2	25	9	2
2010 SBOO 'Other' Offshore Stations												
9-m Depth Contour (*n* = 27)												
Total	24	1813	3350	ns	25	27	5	41	20	19	6	7
Fecal	2	45	228	ns	3	2	2	3	3	3	2	2
Entero	2	22	189	ns	2	2	2	2	3	2	2	2
19-m Depth Contour (*n* = 9)												
Total	29	33	77	ns	8	2	2	3	53	6	467	4
Fecal	2	6	8	ns	2	2	2	2	3	3	58	2
Entero	2	3	5	ns	2	2	2	2	5	2	37	2
28-m Depth Contour (*n* = 24)												
Total	1416	1717	1401	ns	15	844	1568	66	604	399	1395	19
Fecal	490	114	707	ns	2	500	946	22	239	105	275	2
Entero	335	13	224	ns	2	135	456	6	67	25	7	2
38-m Depth Contour (*n* = 9)												
Total	84	8	3	ns	2	28	2	10	2	96	2	2
Fecal	4	2	2	ns	2	2	2	2	2	11	2	2
Entero	9	3	2	ns	2	3	2	2	2	4	2	2
55-m Depth Contour (*n* = 6)												
Total	23	10	2	ns	15	125	2	8	2	3	5	2
Fecal	3	2	2	ns	2	9	2	2	2	2	2	2
Entero	3	3	2	ns	3	6	2	2	2	2	2	2

ns = not sampled (see text)

to 100% for the 30-day fecal geometric mean standard (Appendix B.4). In addition, the shore station samples were out of compliance with the 10,000 total coliform single sample maximum standard 15 times. During the second half of the year (i.e., August–December), compliance with the 2005 Ocean Plan standards at shore stations ranged from 95 to 100% for the 30-day total coliform geometric mean standard and from 88 to 99% for the enterococcus geometric mean standard; shore stations were 100% compliant with the fecal coliform geometric mean standard (Appendix B.5). In addition, the single sample maximum (SSM) standard for total coliforms was exceeded 20 times, while the SSM for fecal coliforms was exceeded 21 times, the SSM for enterococcus was exceeded 32 times, and the SSM based on the fecal:total coliform ratio was exceeded 18 times. Differences in compliance rates during the year generally reflected trends in elevated bacterial levels, with compliance being the lowest between the months of January–March and in December when rainfall was greatest.

Compliance rates for samples collected at the three kelp bed stations tended to be higher than at the

Table 3.4

The number of samples with elevated bacteria densities collected at SBOO kelp bed and other offshore stations during 2010. Elevated FIB = the total number of samples with elevated FIB densities; contaminated = the total number of samples that meet the FTR criterion indicative of contaminated seawater; Wet = January–April and October–December; Dry = May–September; Rain data are from Lindbergh Field, San Diego, CA. Offshore stations not listed had no samples with elevated FIB concentrations in 2010.

Station		Wet	Dry	% Wet
2010 SBOO Kelp Bed Stations				
Total No. of Samples		315	225	
Elevated FIBs		27	1	96
Contaminated		7	1	88
9-m Depth Contour				
I25	Elevated FIB	10	0	100
	Contaminated	2	0	100
I26	Elevated FIB	11	0	100
	Contaminated	3	0	100
19-m Depth Contour				
I39	Elevated FIB	6	0	100
	Contaminated	2	0	100
2010 SBOO 'Other' Offshore Stations				
Total No. of Samples		198	375	
Elevated FIBs		20	8	71
Contaminated		10	7	59
9-m Depth Contour				
I19	Elevated FIB	3	0	100
	Contaminated	0	0	—
I36	Elevated FIB	1	0	100
	Contaminated	0	0	—
I32	Elevated FIB	3	0	100
	Contaminated	1	0	100
I40	Elevated FIB	1	0	100
	Contaminated	0	0	—
19-m Depth Contour				
I18	Elevated FIB	1	0	100
	Contaminated	1	0	100
28-m Depth Contour				
I9	Elevated FIB	1	1	50
	Contaminated	1	1	50
I12	Elevated FIB	5	2	71
	Contaminated	2	2	50
I16	Elevated FIB	5	2	71
	Contaminated	5	2	71
I30	Elevated FIB	0	3	0
	Contaminated	0	2	0

shore stations, which reflects the lower levels of FIBs found in these samples. Compliance during the first half of 2010 with the 2001 Ocean Plan Standards at these sites ranged at from 75 to 99% for the 30-day total coliform standard and they were never out of compliance with the 60-day fecal coliform standard, the 30-day fecal geometric mean standard, or the 10,000 total coliform single sample maximum standard. As compared with the 2005 Ocean Plan Standards during the second half of the year, compliance with the 30-day enterococcus geometric mean standard ranged from 88 to 100%, whereas compliance with the 30-day total and 30-day fecal coliform geometric mean standards was 100%. The SSM standards were exceeded between 3 and 13 times at kelp stations.

Discussion

Overall water quality conditions in the SBOO monitoring region were good during 2010, as indicated by relatively high overall compliance (87%) with accepted water-contact bacterial standards. In addition, there was no evidence during the year that wastewater discharged to the ocean via the SBOO reached the shoreline or nearshore recreational waters. Although elevated FIBs were detected along the shore, and occasionally at the kelp bed or other nearshore stations, these results likely do not indicate shoreward transport of the SBOO wastewater plume, a conclusion consistently supported by the lack of shoreward movement of the plume evident in remote sensing images collected over several years (Svejkovsky 2010). Instead, analysis of FIB distributions and the results of satellite imagery data indicate that other sources such as outflows from the Tijuana River and Los Buenos Creek are more likely to have impacted water quality along the shore and in nearshore recreational waters in the South Bay outfall region. For example, the shore stations located near the Tijuana River and Los Buenos Creek have historically had higher numbers of contaminated samples than stations located farther to the north (City of San Diego 2007–2010). Further, long-term analyses of various water quality parameters have demonstrated that the general relationship between

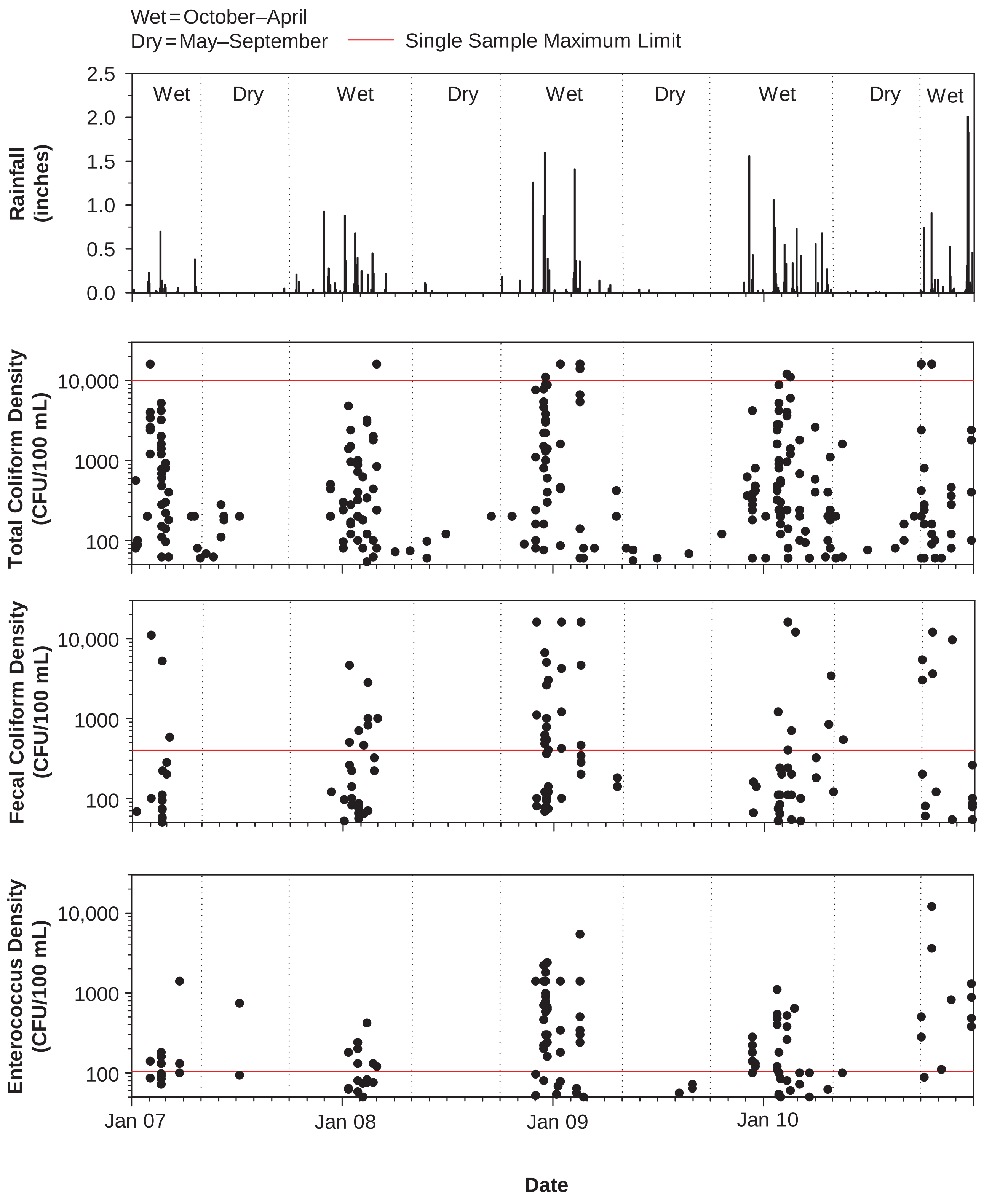

Figure 3.4
Comparison of bacteriological data from SBOO kelp stations to rainfall between January 1, 2007 and December 31, 2010. Densities of bacteria have been limited to ≥50 CFU/100 mL for clearer data presentation.

Table 3.5

Summary of total suspended solid (TSS) concentrations in samples collected from the SBOO kelp bed and other offshore stations in 2010. Data include the number of detected values (*n*), as well as minimum, maximum, and mean detected concentrations for each month. The method detection limit = 1.6 mg/L for TSS.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010 SBOO Kelp Bed Stations (*n* = 9)												
Min	5.18	5.38	2.51	ns	2.71	3.85	5.16	3.13	0.20	2.42	3.43	6.07
Max	8.32	30.90	10.70	ns	15.60	10.10	10.40	12.30	19.60	6.76	8.37	15.70
Mean	6.94	14.17	7.44	ns	7.15	6.99	7.37	6.28	9.60	4.80	5.45	11.03
2010 SBOO 'Other' Offshore Stations (*n* = 75)												
Min	3.55	3.44	0.20	ns	1.89	1.90	2.30	1.74	1.99	1.77	1.78	0.20
Max	14.60	46.20	23.90	ns	18.70	22.80	24.90	12.60	19.10	17.10	13.70	18.50
Mean	6.82	9.57	7.14	ns	7.19	5.80	5.46	5.67	6.66	5.74	5.67	6.24

ns = not sampled (see text)

rainfall and elevated FIB levels has remained consistent since ocean monitoring began in 1995, including the period prior to wastewater discharge (City of San Diego 2000). It is well established that contaminated waters originating from the Tijuana River and Los Buenos Creek are likely sources of bacteria during periods of increased flows in the SBOO region (e.g., during storms or extreme tidal exchanges) (Noble et al. 2003, Largier et al. 2004, Gersberg et al. 2008, Terrill et al. 2009). Such

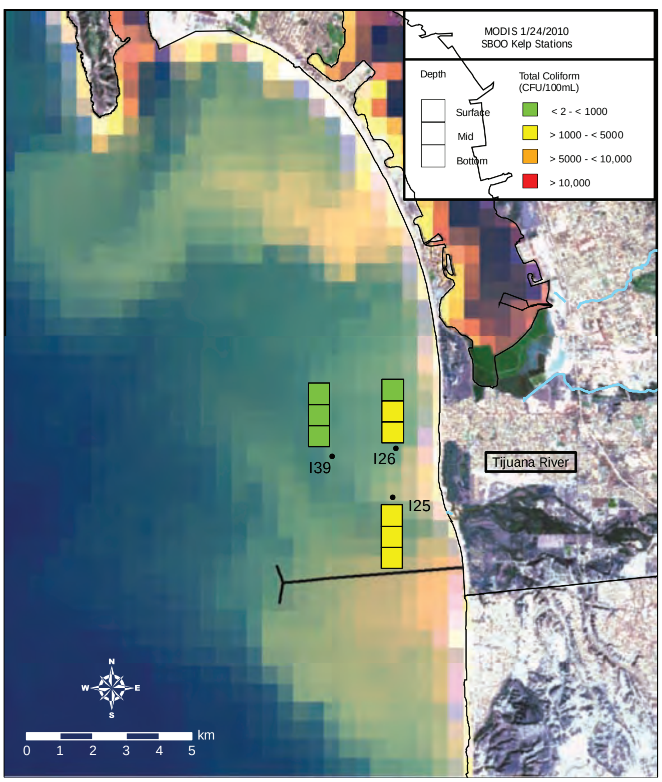

Figure 3.5

MODIS satellite image showing the SBOO monitoring region on January 24, 2010 (Ocean Imaging 2011) combined with total coliform concentrations at kelp stations sampled on January 25, 2010. Turbid waters from the Tijuana River can be seen overlapping the kelp bed stations.

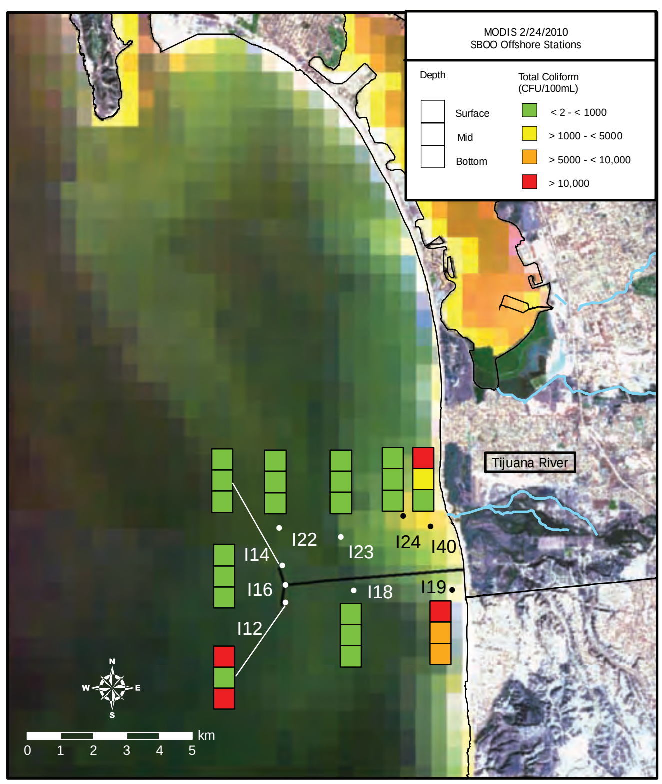

Figure 3.6

MODIS satellite image showing the SBOO monitoring region on February 24, 2010 (Ocean Imaging 2011) combined with total coliform concentrations at offshore stations sampled on February 23, 2010. Turbid waters from the Tijuana River can be seen overlapping stations where contamination was high nearshore.

contaminants may originate from various sources, including sod farms, surface runoff not captured by the canyon collection system, the Tijuana estuary (e.g., decaying plant material), and partially treated effluent from the San Antonio de los Buenos Wastewater Treatment Plant (SABWTP).

During 2010, the majority of elevated FIB densities not associated with rainfall events occurred at shore stations south of the border near known sources of contamination (e.g., the SABWTP) or at a few offshore sites located within 1000 m of the SBOO diffusers at a depth of 18 m or greater. Only three samples with elevated FIBs were collected at the surface near the SBOO during the year, although remote sensing observations did detect the signature of the wastewater plume in near-surface waters over the discharge site on several occasions during the winter. The low incidence of contaminated waters during winter at the surface and at depth may be due to chlorination of IWTP effluent, which typically occurs between November and April each year. The lack of elevated bacteria levels in surface waters during the summer is expected, as those are the months when the water column is well stratified and the wastefield remains trapped beneath the thermocline.

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