Chapter 3. Water Quality

Introduction

The City of San Diego analyzes seawater samples collected along the shoreline and in offshore coastal waters surrounding both the Point Loma and South Bay Ocean Outfalls (PLOO and SBOO, respectively) to characterize water quality conditions in the region and to identify possible impacts of wastewater discharge on the marine environment. Densities of fecal indicator bacteria (FIB), including total coliforms, fecal coliforms and enterococcus are measured and evaluated in context with oceanographic data (see Chapter 2) to provide information about the movement and dispersion of wastewater discharged into the Pacific Ocean through the outfalls. Evaluation of these data may also help to identify other sources of bacterial contamination. In addition, the City's water quality monitoring efforts are designed to assess compliance with the water contact standards specified in the 2005 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 2005).

In the SBOO region, multiple natural and anthropogenic point and non-point sources of potential bacterial contamination exist in addition to the outfall. Therefore, being able to separate the impacts associated with a wastewater plume from other sources of contamination in ocean waters is often challenging. Examples of other local, but non-outfall sources include San Diego Bay, the Tijuana River and Los Buenos Creek in northern Baja California (Largier et al. 2004, Nezlin et al. 2007, Gersberg et al. 2008, Terrill et al. 2009). Likewise, storm water discharges and wet-weather runoff from local watersheds can also flush contaminants seaward (Noble et al. 2003, Reeves et al. 2004, Griffith et al. 2010, Sercu et al. 2009). Moreover, beach wrack (e.g., kelp, seagrass), storm drains impacted by tidal flushing, and beach sediments can act as reservoirs, cultivating bacteria until release into nearshore waters by a returning tide, rainfall, and/or other disturbances (Gruber et al. 2005, Martin and Gruber 2005, Noble et al. 2006, Yamahara et al. 2007, Phillips et al. 2011). The presence of birds and their droppings have also been associated with bacterial exceedances that may impact nearshore water quality (Grant et al. 2001, Griffith et al. 2010).

This chapter presents analyses and interpretations of the microbiological and water chemistry data collected during 2011 at fixed water quality monitoring stations surrounding the SBOO. The primary goals are to: (1) document overall water quality conditions in the region during the year, (2) distinguish between the SBOO wastewater plume and other sources of bacterial contamination, (3) evaluate potential movement and dispersal of the plume, and (4) assess compliance with water contact standards defined in the 2005 Ocean Plan. Results of remote sensing data are also evaluated to provide insight into wastewater transport and the extent of significant events in surface waters during the year (e.g., turbidity plumes).

Materials and Methods

Field Sampling

Shore stations

Seawater samples were collected weekly at 11 shore stations to monitor FIB concentrations in waters adjacent to public beaches (Figure 3.1). Of these, stations S4–S6 and S8–S12 are located in California waters between the USA/Mexico border and Coronado and are subject to Ocean Plan water contact standards (see Box 3.1). The other three stations (i.e., S0, S2, S3) are located in northern Baja California, Mexico and are not subject to Ocean Plan requirements. Seawater samples for shore stations were collected from the

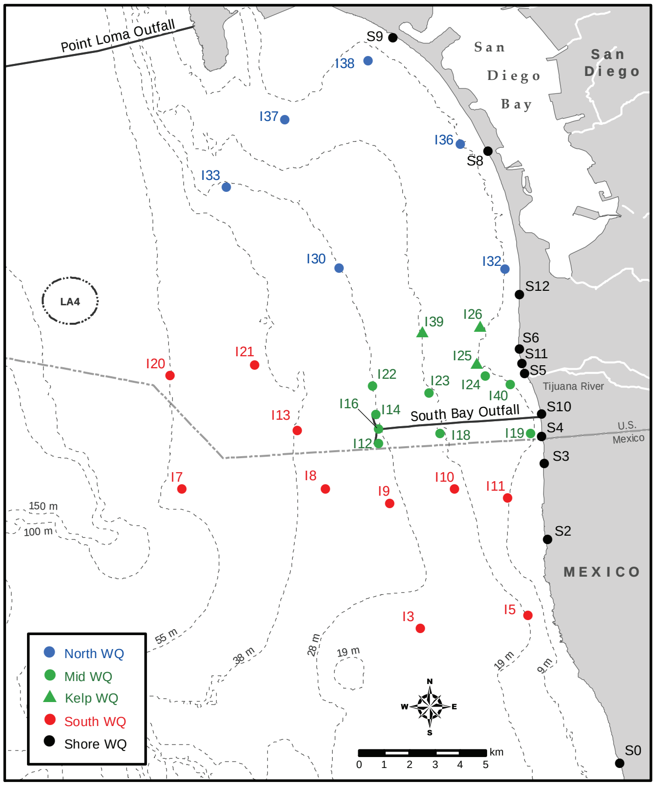

Figure 3.1
Water quality (WQ) monitoring station locations sampled around the South Bay Ocean Outfall as part of the City of San Diego's Ocean Monitoring Program.

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 concentrations of total coliform, fecal coliform, and enterococcus bacteria.

Kelp bed and other offshore stations

Three stations located in nearshore waters within the Imperial Beach kelp forest were monitored five times a month to assess water quality conditions and Ocean Plan compliance in areas used for recreational activities such as SCUBA diving, surfing, fishing, and kayaking. These included two stations located near the inner edge of the kelp bed along the 9-m depth contour (I25 and I26), and one station located near the outer edge of the kelp bed along the 18-m depth contour (I39). An additional 25 stations located further offshore in deeper waters were sampled once a month to monitor FIB levels and estimate the spatial extent of the wastewater plume. These non-kelp 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 occurred over a 3-day period within each month (see Chapter 2).

Seawater samples were collected at each of the kelp bed and non-kelp bed offshore stations using either an array of Van Dorn bottles or a rosette sampler fitted with Niskin bottles at three discrete depths for FIBs and total suspended solids (TSS). Additional samples for oil and grease (O&G) analysis were collected from surface waters only. Aliquots for each analysis were drawn into appropriate sample containers. All bacterial seawater samples were refrigerated onboard ship and transported to the CSDMML for 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 and/or animal activity were also recorded at the time of sampling.

Laboratory Analyses

The CSDMML follows guidelines issued by the United States Environmental Protection Agency (USEPA) Water Quality Office and the California Department of Public Health (CDPH) Environmental Laboratory Accreditation Program (ELAP) with respect to sampling and analytical procedures (Bordner et al. 1978, APHA 1995, CDPH 2000, USEPA 2006). All bacterial analyses were performed within eight hours of sample collection and conformed to standard membrane filtration techniques (APHA 1995).

Enumeration of FIB density was performed and validated in accordance with USEPA (Bordner et al. 1978, USEPA 2006) and APHA (1995) 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 were dropped

Box 3.1

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.

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 under separate cover (City of San Diego 2012).

Data Analyses

Densities of bacteria were summarized as monthly averages for each shore station and by depth contour for the kelp bed and non-kelp bed offshore stations. TSS concentrations 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 maxima, 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. Bacterial densities were compared to rain data from Lindbergh Field, San Diego, CA (see NOAA 2012). Remote sensing images of the SBOO region were provided by Ocean Imaging of Solana Beach, California (Svejkovsky 2012) and were used to aid in the analysis and interpretation of water quality data (see Chapter 2 for remote sensing details). Fisher's Exact Tests (FET) were conducted to determine if the frequency of samples with elevated FIBs differed at shore and kelp bed stations between wet (January–April and October–December) versus dry (May–September) seasons. Finally, compliance with Ocean Plan water-contact standards was summarized as the number of times per month that each of the eight shore stations located north of the USA/Mexico border and all three of the kelp bed stations exceeded the various standards.

Results

Distribution of Fecal Indicator Bacteria

Shore stations

During 2011, FIB densities at the individual shore stations averaged from 7 to 12,000, 2 to 6048, and 2 to 4236 CFU/100 mL per month for total coliforms, fecal coliforms, and enterococcus, respectively (Table 3.1). The highest values for each of these indicators occurred during the wet season. In addition, 88% of the shore station samples with elevated FIBs were collected during

Table 3.1

Summary of rainfall and bacteria levels at SBOO shore stations during 2011. 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):		0.30	2.10	1.46	0.26	0.36	0.03	0.00	0.00	0.13	0.46	3.12	0.86
S9	*Total*	11	7	1772	20	20	60	110	92	35	16	68	20
	Fecal	2	2	130	8	2	6	6	3	7	6	2	2
	Entero	12	2	54	4	5	4	8	4	15	5	2	2
S8	*Total*	16	12	2610	12	20	16	20	20	16	60	1456	7
	Fecal	2	2	154	2	2	2	2	4	2	4	86	2
	Entero	3	2	90	2	2	2	2	3	12	9	7	6
S12	*Total*	122	35	3216	1512	14	45	20	56	70	16	1140	126
	Fecal	2	2	202	246	2	4	6	6	6	8	70	26
	Entero	20	8	162	19	3	4	2	3	14	12	7	10
S6	*Total*	335	481	3220	485	64	16	20	16	36	20	544	4015
	Fecal	11	18	602	62	5	7	2	3	22	2	30	1053
	Entero	12	11	204	2	6	2	2	2	8	2	12	3006
S11	*Total*	645	480	5068	4225	488	56	20	13	16	7	3164	3010
	Fecal	16	30	938	258	26	2	3	3	2	2	297	82
	Entero	10	29	442	26	2	2	4	2	2	2	15	192
S5	*Total*	4250	2018	6416	9000	3476	60	20	16	20	12	7008	1960
	Fecal	3012	36	4801	6048	1300	8	2	3	2	6	4825	92
	Entero	3754	32	2426	3253	167	5	2	2	3	6	3006	3004
S10	*Total*	9400	4130	8108	8010	157	460	16	48	66	14	6924	4856
	Fecal	5332	3013	1572	2205	14	22	2	4	4	8	1845	176
	Entero	1859	626	160	452	2	12	2	2	2	12	234	116
S4	*Total*	5650	4086	6844	4012	58	2370	20	114	110	16	3231	1501
	Fecal	282	3003	644	55	12	34	2	7	9	4	1448	141
	Entero	71	458	59	2	2	18	2	2	8	8	60	122
S3	*Total*	5300	930	3002	4063	292	3760	16	94	18	58	4096	4026
	Fecal	160	22	174	305	26	136	2	9	13	20	162	456
	Entero	59	26	64	2	2	202	3	5	36	62	54	362
S2	*Total*	2530	1690	1341	556	1534	1265	16	137	221	13	2765	861
	Fecal	245	109	49	21	66	22	2	10	4	8	99	38
	Entero	240	21	21	46	14	29	2	2	5	3	45	74
S0	*Total*	2235	8365	1616	425	784	1158	760	44	155	246	1732	12,000
	Fecal	170	2013	276	78	125	112	29	3	10	56	112	3330
	Entero	68	3370	190	198	130	77	70	2	14	28	44	4236
	n	44	44	55	44	55	44	44	55	44	44	55	44
Annual	*Total*	2772	2021	3928	2938	628	842	94	59	69	43	2921	2944
Means	*Fecal*	840	750	867	844	144	32	5	5	8	11	816	491
	Entero	555	417	352	364	30	33	9	3	11	14	317	1012

these wet months when rainfall totaled 8.56 inches (versus 0.52 inches in the dry season; Table 3.2). This general relationship between rainfall and elevated bacterial levels has been evident since water quality monitoring in the South Bay outfall region began (Figure 3.2, Appendix B.4). These data indicate that collecting a sample with elevated FIBs was significantly more likely during the wet season than during the dry (22% versus 7%, respectively; $n = 9960$, $p < 0.0001$, FET).

Samples collected during the wet season with elevated FIBs were taken primarily at the shore stations close to the mouth of the Tijuana River (S4, S5, S10, S11) and farther south (S0, S2, S3; Table 3.2, Appendix B.1). Samples from some of these stations (e.g., S0, S2, S3, S5) also had high levels of bacterial contamination during dry conditions between May–September. For example, four of the nine dry weather samples with elevated FIB densities were collected at station S0 that is located south of the international border and is the station closest to Los Buenos Creek. Analyses of historical data, including from years prior to wastewater discharge, corroborated this finding (Appendix B.4). Over the past several years, high FIB counts at these stations have consistently corresponded to turbidity flows from the Tijuana River and Los Buenos Creek, typically

Table 3.2

The number of samples with elevated bacteria densities collected at SBOO shore stations during 2011. 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.

	Seasons		
Station	**Wet**	**Dry**	**% Wet**
S9	1	0	100
S8	2	0	100
S12	2	0	100
S6	2	0	100
S11	5	0	100
S5	9	2	82
S10	12	0	100
S4	9	0	100
S3	7	2	78
S2	8	1	89
S0	12	4	75
Rain (in)	8.56	0.52	
Total Counts	69	9	88
n	330	242	

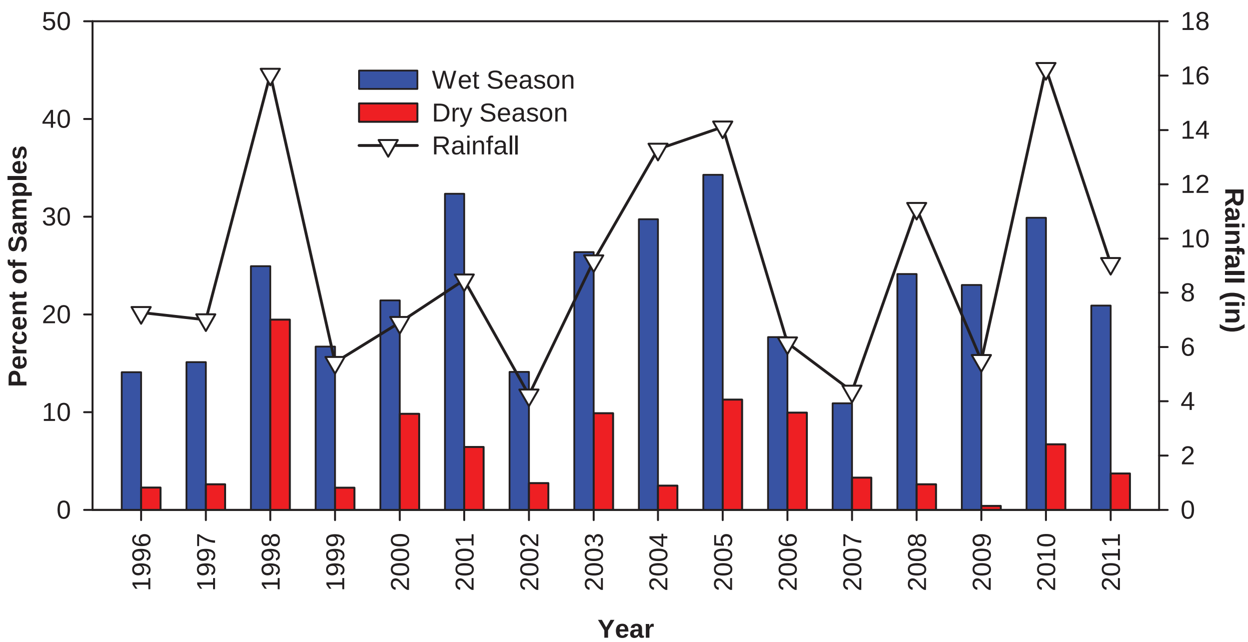

Figure 3.2

Comparison of annual rainfall to the percent of samples with elevated FIB densities in wet versus dry seasons at SBOO shore stations between 1996 and 2011. Wet = January–April and October–December; Dry = May–September. Rain data are from Lindbergh Field, San Diego, CA. Data from 1995 were excluded as sampling did not occur the entire year.

Figure 3.3
Rapid Eye satellite image showing the SBOO region on March 24, 2011 (Ocean Imaging 2012) combined with bacteria levels at shore stations sampled on March 22, 2011. Turbid waters from the Tijuana River and Los Buenos Creek can be seen overlapping stations with elevated FIBs (indicated by red circles).

after rain events (City of San Diego 2008–2011). At times, however, impacts from these two sources can extend beyond these seven stations. For example, a satellite image taken March 24, 2011 showed turbidity plumes encompassing all of the shore stations, nine of which had elevated FIB concentrations two days prior (Figure 3.3). While the image in this figure was taken after the contaminated samples were collected, the plumes that are evident likely originated earlier in the week due to significant runoff caused by a rainstorm that began March 20, 2011.

Kelp bed stations
On average, FIB densities at the SBOO kelp bed stations were lower than those at the shore stations, ranging between 2 and 1312, 2 and 71, and 2 and 42 CFU/100 mL per month for total coliforms, fecal coliforms, and enterococcus, respectively (Table 3.3). The highest concentrations of these bacteria occurred during the wettest months of 2011, similar to the pattern exhibited at the shore stations. For example, 87% of kelp bed samples with elevated FIBs were collected during the wet season (Table 3.4, Appendix B.2). These results are consistent with historical water quality monitoring data from the South Bay outfall region (Figure 3.4, Appendix B.5). These data indicate that collecting a sample with elevated FIBs was significantly more likely during the wet season than during the dry (8% versus 1%, respectively; $n = 7376$, $p < 0.0001$, FET).

High bacteria counts in the kelp bed during the wet season also appeared to correspond with turbidity plumes from the Tijuana River. For example, another satellite image taken January 1, 2011 shows plumes that persisted throughout the SBOO region during January and into February following heavy rainfall in late December, plus additional rainfall in January, which caused large volumes of runoff from the river (Figure 3.5; Ocean Imaging 2012, Svejkovsky 2012). This image demonstrates how these plumes encompassed stations I25 and I26, both of which had elevated FIBs during this period (Appendix B.2). The kelp bed stations had a higher rate of elevated FIB detection than most of the other offshore stations, including their closest neighbors, because they were sampled more often and therefore had a greater chance of being sampled during (or following) rain events (Figure 3.6).

Oil and grease and total suspended solids were also measured at the kelp bed stations as potential indicators of wastewater. None of the samples collected during 2011 contained detectable levels of O&G (detection limit = 0.2 mg/L). In contrast, TSS were detected 100% of the time at concentrations ranging between 1.49–22.80 mg/L per sample (Table 3.5). Of the 26 seawater samples with elevated TSS concentrations (≥8.0 mg/L), none co-occurred with elevated FIB levels.

Non-kelp bed stations
Concentrations of bacteria were also low in samples collected from the 25 non-kelp bed offshore stations during 2011, averaging from 2 to 2203, 2 to 202, and 2 to 49 CFU/100 mL per month for total coliforms, fecal coliforms,

Table 3.3

Summary of bacteria levels at SBOO kelp bed and other offshore stations during 2011. Total coliform, fecal coliform, and enterococcus densities are expressed as mean CFU/100 mL for all stations along each depth contour by month; *n* = total number of samples per month.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011 Kelp Bed Stations												
9-m Depth Contour (*n* = 30)												
Total	729	244	1312	18	471	19	4	3	7	3	79	1144
Fecal	53	19	39	3	54	2	2	2	2	2	6	71
Entero	32	6	23	3	6	2	2	2	2	2	8	42
19-m Depth Contour (*n* = 15)												
Total	313	7	339	37	26	3	19	6	4	2	254	166
Fecal	18	2	15	4	7	2	3	2	2	2	18	12
Entero	13	3	32	2	2	2	2	2	2	2	7	12
2011 Non-Kelp Bed Stations												
9-m Depth Contour (*n* = 27)												
Total	1749	1054	1813	703	3	14	10	3	3	3	787	2
Fecal	56	68	75	24	2	2	2	2	2	2	39	2
Entero	42	14	16	10	2	2	2	2	2	2	12	2
19-m Depth Contour (*n* = 9)												
Total	180	110	2203	5	98	3	4	2	2	5	17	2
Fecal	9	4	202	2	33	2	2	2	2	2	3	2
Entero	10	2	49	2	3	2	2	2	2	2	2	2
28-m Depth Contour (*n* = 24)												
Total	80	199	55	32	69	6	187	39	4	4	30	6
Fecal	11	13	4	3	33	2	27	10	2	3	8	2
Entero	5	3	2	2	6	2	9	4	2	2	3	2
38-m Depth Contour (*n* = 9)												
Total	3	17	57	2	26	3	2	2	2	2	4	2
Fecal	2	2	4	2	2	2	2	2	2	2	2	2
Entero	2	2	3	2	2	2	2	2	2	2	2	2
55-m Depth Contour (*n* = 6)												
Total	2	2	141	2	2	2	2	3	2	2	2	2
Fecal	2	2	7	2	2	2	2	2	2	2	2	2
Entero	2	2	6	2	2	2	2	3	2	2	2	2

and enterococcus, respectively (Table 3.3). Only about 1.3% (n = 12) of the 900 samples collected at these sites contained elevated FIBs (Table 3.4, Appendix B.3). For stations located along the 9 and 19-m depth contours (i.e., I10, I11, I19, I24, I32, I40), 100% of the samples with elevated FIBs were collected during the wet season. As with the shore and kelp bed stations, satellite imagery showed turbidity flows originating from the Tijuana River can extend into the offshore sampling region around the SBOO. For example, the plumes depicted in the image taken on January 1, 2011 also encompassed stations relatively close to the mouth of the river (I10, I11, I19, I24, I32, I40), many of which had elevated FIBs during the same period discussed above (Figure 3.5, Appendix B.3). In combination with the kelp bed stations, these sites had the highest elevated FIBs detection rates throughout the year (Figure 3.6).

The proportion of samples from the 28-m offshore stations with elevated FIBs was much lower in 2011 than previous years (Figure 3.7). Only one sample with high bacteria counts was collected from these stations; the sample was taken from I12 at 18 m (Table 3.4, Figure 3.6, Appendix B.3).

Table 3.4

The number of samples with elevated bacteria collected at SBOO kelp bed and other offshore stations during 2011. Wet = January–April and October–December; Dry = May–September; *n* = total number of samples. Rain data are from Lindbergh Field, San Diego, CA. Missing offshore stations had no samples with elevated FIB concentrations in 2011.

	Wet	Dry	% Wet
2011 Kelp Bed Stations			
9-m Depth Contour			
I25	4	0	100
I26	8	2	80
19-m Depth Contour			
I39	1	0	100
Total Counts	13	2	87
n	315	225	
2011 Non-Kelp Bed Stations			
9-m Depth Contour			
I11	1	0	100
I19	5	0	100
I24	1	0	100
I32	1	0	100
I40	1	0	100
19-m Depth Contour			
I10	1	0	100
28-m Depth Contour			
I12	0	1	0
I22	0	1	0
Total Counts	10	2	83
n	525	375	

Historically, samples with elevated bacterial levels have been collected more often at the two stations closest to the SBOO south diffuser leg (i.e., stations I12 and I16) when compared to other stations along the 28-m depth contour; most of these samples were collected from a depth of 18 m or greater (Figure 3.7). Consequently, it appears likely that these FIB densities were associated with wastewater discharge from the outfall.

Oil and grease and total suspended solids were also measured at the non-kelp bed stations as potential indicators of wastewater. None of the samples collected during 2011 contained detectable levels of O&G, whereas TSS were detected at a rate of 94%. Concentrations of TSS ranged from 1.74 to 49.00 mg/L per sample (Table 3.5). Of the 155 seawater samples with elevated TSS concentrations (≥8.0 mg/L), only 7 corresponded to samples with elevated FIBs.

California Ocean Plan Compliance

Overall compliance with Ocean Plan standards was 91% during 2011. Compliance at the shore stations ranged from 63 to 100% for the 30-day total coliform geometric mean standard, from 73 to 100% for the fecal coliform geometric mean standard, and from 59 to 100% for the enterococcus geometric mean standard (Appendix B.6). In addition, the single sample maximum (SSM) standards for total coliforms, fecal coliforms, enterococcus, and the FTR criterion were exceeded 63, 61, 65 and 44 times, respectively, at these sites. Compliance at the three kelp stations was 100% with the 30-day total and 30-day fecal coliform geometric mean standards, and ranged from 92 to 100% for the 30-day enterococcus geometric mean standard. The SSM standards were exceeded from 2 to 10 times across all kelp bed stations. Since compliance rates reflect the presence of elevated FIBs, rates were lowest between the months of January–April and November–December when rainfall was greatest.

Discussion

Water quality conditions in the South Bay outfall region were excellent during 2011. Overall compliance with 2005 Ocean Plan water-contact standards was 91%, which was slightly higher than the 87% compliance observed during the previous year (City of San Diego 2011). This improvement likely reflects lower rainfall, which totaled about 9.1 inches in 2011 versus 16.3 inches in 2010. Additionally, only about 5% (*n* = 105) of all water samples analyzed in 2011 had elevated FIBs, of which about 88% (*n* = 92) occurred during the wet season. Most of these high counts (*n* = 69) were from samples collected at the shore stations. This pattern of relatively higher contamination along the shore during the wet season is similar to that observed during previous years (e.g., City of San Diego 2011). The few samples with high bacteria counts taken during dry weather periods

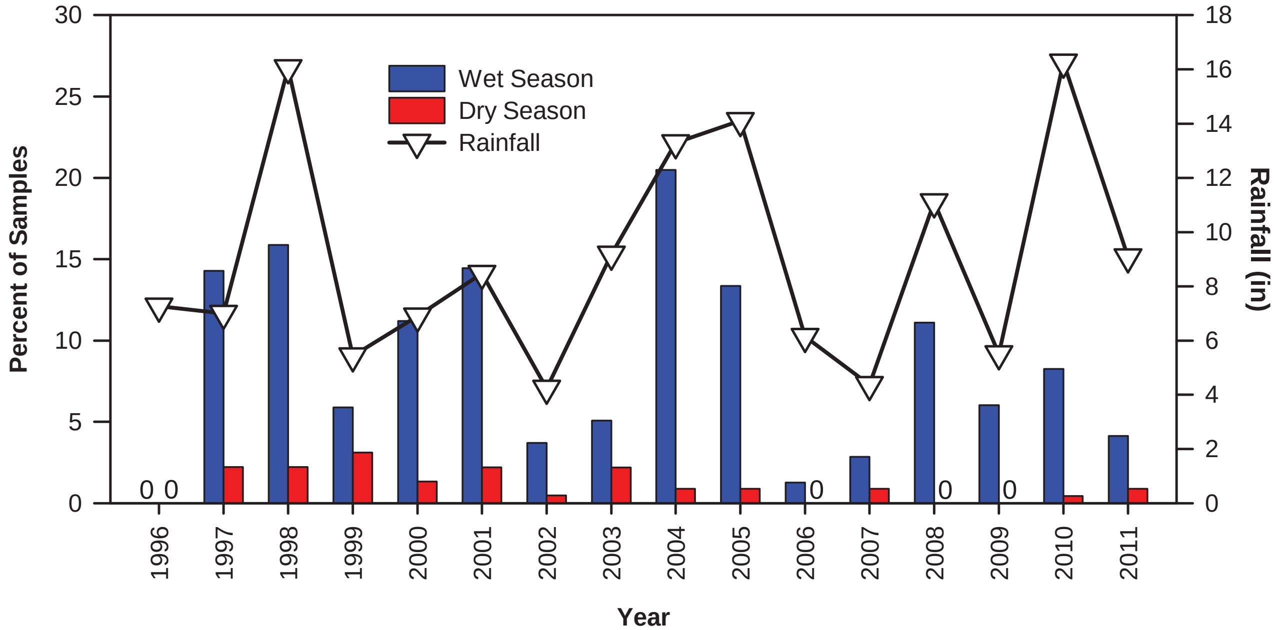

Figure 3.4

Comparison of annual rainfall to the percent of samples with elevated FIB densities in wet versus dry seasons at SBOO kelp bed stations between 1996 and 2011. Wet = January–April and October–December; Dry = May–September. Rain data are from Lindbergh Field, San Diego, CA. Data from 1995 were excluded as sampling did not occur the entire year.

tended to occur at shore stations located south of the border near other known sources of coastal contamination (see below).

There was no evidence that wastewater discharge to the ocean via the SBOO reached the shoreline or nearshore recreational waters during the year. Although elevated FIBs were detected along the shore and occasionally at kelp bed or other nearshore stations, these results did not indicate shoreward transport of the wastewater plume, a conclusion consistently supported by remote sensing observations (e.g., Svejkovsky 2010, 2011, 2012). Instead, comparisons of FIB distribution patterns with corresponding satellite images suggest that other sources such as outflows (turbidity plumes) from rivers and creeks are more likely to impact coastal water quality in the South Bay outfall region, especially during the wet season. For example, the shore stations located near the mouths of 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 2008–2011). It is also well established that sewage-laden discharges from the Tijuana River and Los Buenos Creek are likely sources of bacteria during storms or other periods of increased flows (Svejkovsky and Jones 2001, Noble et al. 2003, Gersberg et al. 2004, 2006, 2008, Largier et al. 2004, Terrill et al. 2009, Svejkovsky 2010). Further, the general relationship between rainfall and elevated bacterial levels in the SBOO region existed before wastewater discharge began in 1999 (see also City of San Diego 2000).

Finally, bacterial contamination in offshore waters was very low in the SBOO region during 2011, with about 1.3% (n = 12) of all samples collected having elevated FIBs. These high counts included 10 samples from the wet season and two samples from dry season. Only a single sample with elevated FIBs was collected near the discharge site (i.e., at station I12 near the tip of the southern diffuser leg). The lack of bacteriological contamination detected near the outfall is likely due to chlorination of IWTP effluent (typically between November–April), and to initiation of full secondary treatment at the IWTP beginning

Table 3.5

Summary of total suspended solid (TSS) concentrations in samples collected from the SBOO kelp bed and other offshore stations in 2011. Data include the number samples per month (*n*) and detection rate, as well as the minimum, maximum, and mean of detected concentrations for each month. The method detection limit = 0.2 mg/L for TSS.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011 Kelp Bed Stations (*n* = 9)												
Detection Rate (%)	100	100	100	100	100	100	100	100	100	100	100	100
Min	7.74	4.52	1.77	2.16	3.26	7.64	1.98	2.60	3.73	1.49	3.43	2.53
Max	18.80	21.60	13.40	6.78	22.80	22.50	4.81	6.44	7.62	3.71	7.75	4.81
Mean	13.37	11.50	7.05	4.79	10.15	10.80	3.51	4.53	5.07	2.67	4.83	3.85
2011 Non-Kelp Bed Stations (*n* = 75)												
Detection Rate (%)	96	99	100	100	99	100	100	99	100	79	99	60
Min	nd	nd	1.74	1.85	nd	2.23	1.58	nd	1.57	nd	nd	nd
Max	21.50	26.80	49.00	20.00	20.60	20.50	10.90	9.53	12.20	15.50	8.29	9.11
Mean	7.92	7.04	6.98	5.17	5.39	7.83	3.94	4.00	4.21	3.35	3.90	3.60

nd = not detected

in January 2011. Consequently, bacteriological data may no longer be useful for plume tracking in this region. Instead, remote sensing observations may prove more useful. For example, satellite images captured during 2011 were able to detect the signature of the SBOO wastewater plume in near-surface waters over the discharge site on several occasions between January–March and October–December (Svejkovsky 2012). These findings have been supported by other high resolution satellite images that suggest the wastewater plume typically remains within approximately 700 m of the outfall, and analyses of oceanographic data collected by the City's ocean monitoring program for the past several years (see Chapter 2).

Literature Cited

[APHA] American Public Health Association. (1995). Standard Methods for the Examination of Water and Wastewater, 19th edition. A.E. Greenberg, L.S. Clesceri, and A.D. Eaton (eds.). American Public Health Association, American Water Works Association, and Water Pollution Control Federation.

Bordner, R., J. Winter, and P. Scarpino, eds. (1978). Microbiological Methods for Monitoring the Environment: Water and Wastes, EPA Research and Development, EPA-600/8-78-017.

[CDPH] California State Department of Health Services. (2000). Regulations for Public Beaches and Ocean Water-Contact Sports Areas. Appendix A: Assembly Bill 411, Statutes of 1997, Chapter 765. http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Beaches/APPENDIXA.pdf.

City of San Diego. (2000). International Wastewater Treatment Plant Final Baseline Ocean Monitoring Report for the South Bay Ocean Outfall (1995–1998). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2008). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2007. City of San Diego Ocean Monitoring Program, Metropolitan

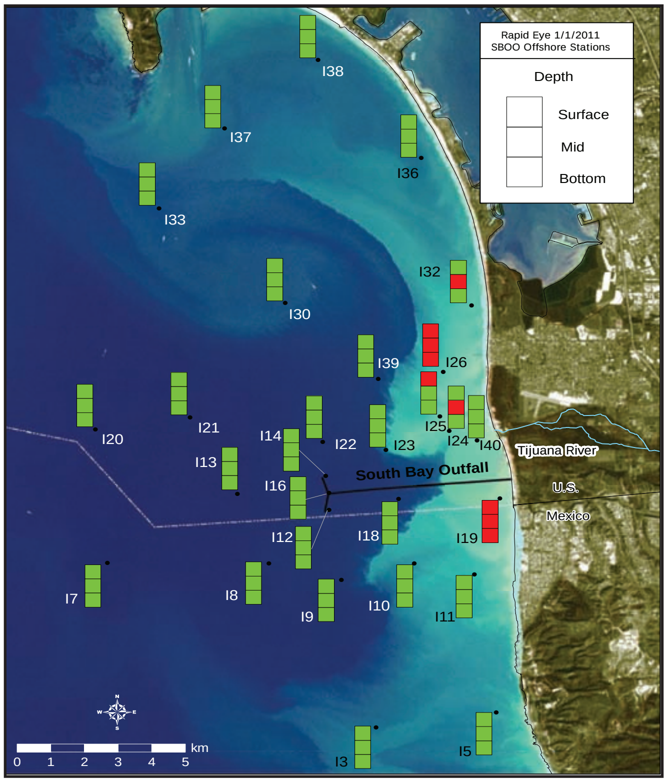

Figure 3.5
Rapid Eye satellite image showing the SBOO region on January 1, 2011 (Ocean Imaging 2012) combined with bacteria levels at kelp bed and other offshore stations sampled between the first of the year and February 1, 2011. Red squares indicate at least one sample was collected during this period with elevated FIBs (see Appendix B.2, B.3); these correspond to turbid waters that persisted throughout the month and into February (Ocean Imaging 2012, Svejkovsky 2012).

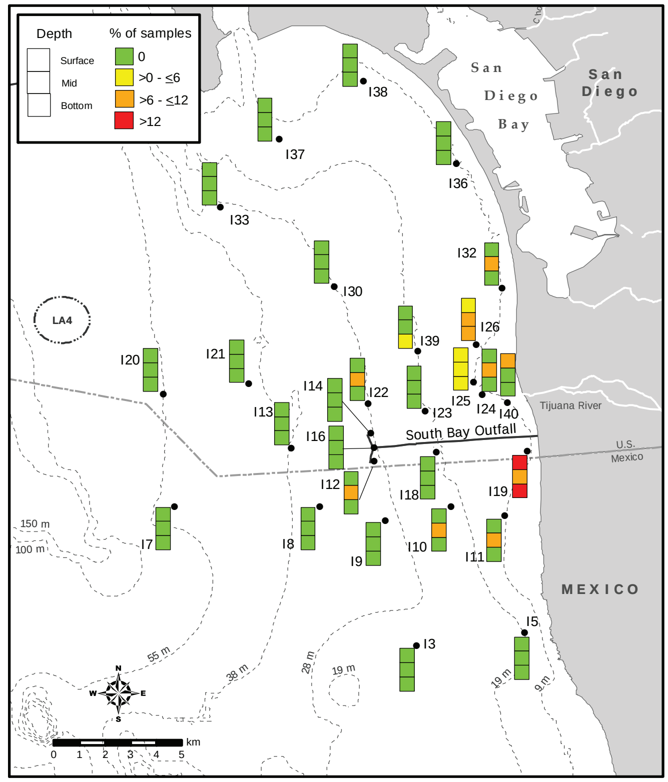

Figure 3.6
Distribution of seawater samples with elevated FIBs at kelp bed and other offshore stations during 2011. Data are the percent of samples that contained elevated bacteria densities. See text and Table 2.1 for sampling details.

Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2009). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2008. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2010). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2009. City of San Diego Ocean Monitoring Program, Public Utilities Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2011). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall (South Bay Water Reclamation Plant), 2010. City of San Diego Ocean Monitoring Program, Public Utilities Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2012). EMTS Division Laboratory Quality Assurance Report, 2011. City of San Diego Ocean Monitoring Program, Public Utilities Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Gersberg, R.M., D. Daft, and D. Yorkey. (2004). Temporal pattern of toxicity in runoff from

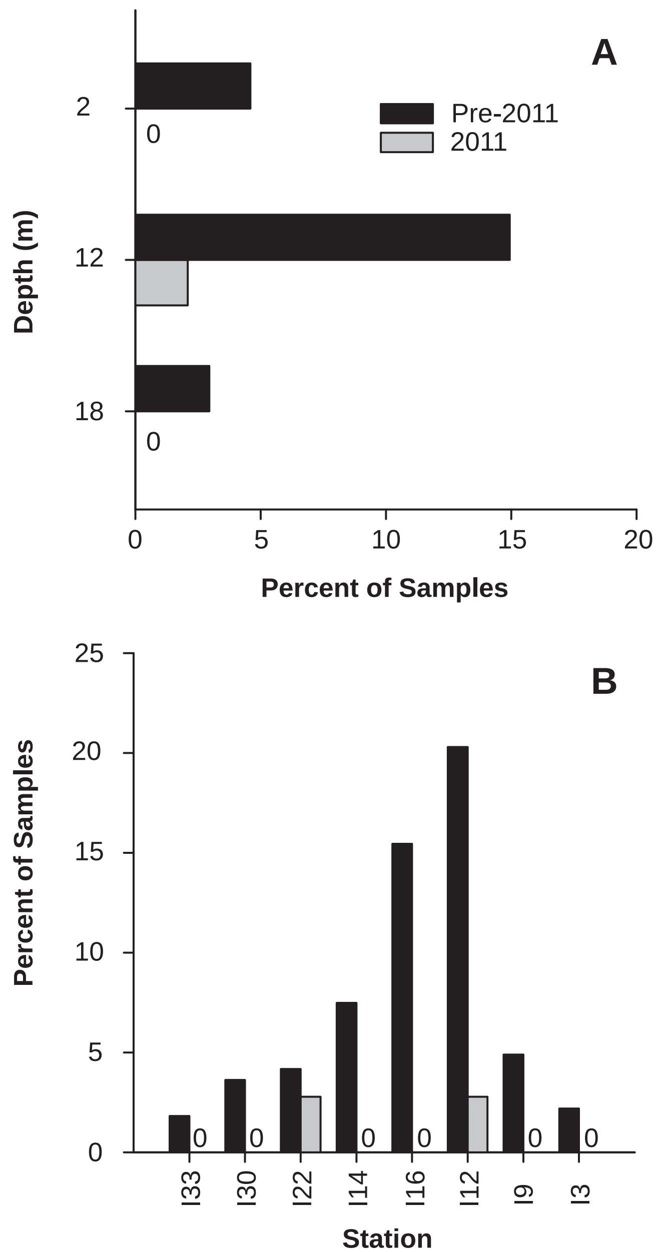

Figure 3.7
Percent of samples collected from SBOO 28-m offshore stations with elevated bacteria densities. Samples from 2011 are compared to those collected between 1995–2010 by (A) sampling depth and by (B) station.

the Tijuana River Watershed. Water Research, 38: 559–568.

Gersberg, R.M., M.A. Rose, R. Robles-Sikisaka, and A.K. Dhar. (2006). Quantitative detection of hepatitis a virus and enteroviruses near the United States-Mexico Border and correlation with levels of fecal indicator bacteria. Applied and Environmental Microbiology, 72: 7438–7444.

Gersberg, R., J. Tiedge, D. Gottstein, S. Altmann, K. Watanabe, and V. Luderitz. (2008). Effects of the South Bay Ocean Outfall (SBOO) on beach water quality near the USA-Mexico border. International Journal of Environmental Health Research, 18, 149–158.

Grant, S.B., B.F. Sanders, A.B. Boehm, J.A. Redman, J.H. Kim, R.D. Mrse, A.K. Chu, M. Gouldin, C.D. McGee, N.A. Gardiner, B.H. Jones, J. Svejkovsky, G.V. Leipzig, and A. Brown. (2001). Generation of enterococci bacteria in a coastal saltwater marsh and its impact on surf zone water quality. Environmental Science Technology, 35: 2407–2416.

Griffith, J.F., K. C. Schiff, G.S. Lyon, and J.A. Fuhrman. (2010). Microbiological water quality at non-human influenced reference beaches in southern California during wet weather. Marine Pollution Bulletin, 60: 500–508.

Gruber, S., L. Aumand, and A. Martin. (2005) Sediments as a reservoir of indicator bacteria in a coastal embayment: Mission Bay, California, Technical paper 0506. Westin Solutions, Inc. Presented at StormCon 2005. Orlando, FL, USA. July 2005.

Largier, J., L. Rasmussen, M. Carter, and C. Scearce. (2004). Consent Decree–Phase One Study Final Report. Evaluation of the South Bay International Wastewater Treatment Plant Receiving Water Quality Monitoring Program to determine its ability to identify source(s) of recorded bacterial exceedences. Scripps Institution of Oceanography, University of California, San Diego, CA.

Martin, A. and S. Gruber. (2005). Amplification of indicator bacteria in organic debris on southern California beaches. Technical paper 0507. Weston Solutions, Inc. Presented at StormCon 2005. Orlando, FL, USA. July 2005.

Nezlin, N.P., P.M. DiGiacomo, S.B. Weisberg, D.W. Diehl, J.A. Warrick, M.J. Mengel, B.H. Jones, K.M. Reifel, S.C. Johnson, J.C. Ohlmann, L. Washburn, and E.J. Terrill. (2007). Southern California Bight 2003 Regional Monitoring Program: V. Water Quality. Southern California Coastal Water Research Project. Costa Mesa, CA.

[NOAA] National Oceanic and Atmospheric Administration. (2012). National Climatic Data Center. http://www7.ncdc.noaa.gov/CDO/cdo.

Noble, R.T., D.F. Moore, M.K. Leecaster, C.D. McGee, and S.B. Weisberg. (2003). Comparison of total coliform, fecal coliform, and enterococcus bacterial indicator response for ocean recreational water quality testing. Water Research, 37: 1637–1643.

Noble, M.A., J.P. Xu, G.L. Robertson, and K.L. Rosenfeld. (2006). Distribution and sources of surfzone bacteria at Huntington Beach before and after disinfection of an ocean outfall – A frequency-domain analysis. Marine Environmental Research, 61: 494–510.

Phillips, C.P., H.M. Solo-Gabriele, A.J.H.M. Reneiers, J.D. Wang, R.T. Kiger, and N. Abdel-Mottaleb. (2011). Pore water transport of enterococci out of beach sediments. Marine Pollution Bulletin, 62: 2293–2298.

Reeves, R.L., S.B. Grant, R.D. Mrse, C.M. Copil Oancea, B.F. Sanders, and A.B. Boehm. (2004). Scaling and management of fecal indicator bacteria in runoff from a coastal urban watershed in southern California. Environmental Science and Technology, 38: 2637–2648.

Sercu, B., L.C. Van de Werfhorst, J. Murray, and P.A. Holden. (2009). Storm drains are sources of human fecal pollution during dry weather in three urban southern California watersheds. Environmental Science and Technology, 43: 293–298.

Svejkovsky, J. (2010). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/ Tijuana Region: Annual Summary Report, 1 January, 2009–31 December, 2009. Ocean Imaging, Solana Beach, CA.

Svejkovsky, J. (2011). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/ Tijuana Region: Annual Summary Report, 1 January, 2010–31 December, 2010. Ocean Imaging, Solana Beach, CA.

Svejkovsky, J. (2012). Satellite and Aerial Coastal Water Quality Monitoring in the San Diego/ Tijuana Region: Annual Summary Report, 1 January, 2011–31 December, 2011. Ocean Imaging, Solana Beach, CA.

Svejkovsky, J. and B. Jones. (2001). Detection of coastal urban stromwater and sewage runoff with synthetic aperture radar satellite imagery. Eos, Transactions, American Geophysical Union, 82, 621–630.

[SWRCB] California State Water Resources Control Board. (2005). California Ocean Plan, Water Quality Control Plan, Ocean Waters of California. California Environmental Protection Agency, Sacramento, CA.

Terrill, E., K. Sung Yong, L. Hazard, and M. Otero. (2009). IBWC/Surfrider – Consent Decree Final Report. Coastal Observations and Monitoring in South Bay San Diego. Scripps Institution of Oceanography, University of California, San Diego, CA.

[USEPA] United States Environmental Protection Agency. (2006). Method 1600: Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI). EPA Document EPA-821-R-06-009. Office of Water (4303T), Washington, DC.

Yamahara, K.M., B.A. Layton, A.E. Santoro, and A.B. Boehm. (2007). Beach sands along the California coast are diffuse sources of fecal bacteria to coastal waters. Environmental Science and Technology, 41: 4515–4521.

This page intentionally left blank