Chapter 3. Microbiology

INTRODUCTION

The City of San Diego performs shoreline and water column bacterial monitoring in the region surrounding the Point Loma Ocean Outfall (PLOO). This program is designed to assess general water quality conditions, evaluate patterns in movement and dispersal of the wastewater plume, and monitor compliance with the 2001 California Ocean Plan (SWRCB 2001). The final results of bacteriological and individual station compliance data are submitted to the San Diego Regional Water Quality Control Board in the form of monthly receiving waters monitoring reports. Overall bacteriological densities (total coliforms, fecal coliforms, enterococcus), together with oceanographic data (see Chapter 2), are evaluated to provide information about the movement and dispersion of wastewater discharged through the outfall. Analyses of these data may also implicate point or non-point sources other than the outfall as contributing to bacterial contamination events in the region. This chapter summarizes and interprets patterns in bacterial concentration data collected for the Point Loma region during 2005.

MATERIALS AND METHODS

Field Sampling

Water samples for bacteriological analyses were collected at fixed shore and offshore sampling sites throughout the year (**Figure 3.1**). Weekly sampling was performed at 8 shore stations (D4, D5, D7–D12) to monitor bacterial levels along public beaches. Eight stations located in the Point Loma kelp bed were also monitored to assess water quality conditions in areas used for water contact sports (e.g., SCUBA and kayaking). These stations include 3 sites (stations C4, C5, C6) located near the inner edge of the kelp bed along the 9-m depth contour, and 5 sites (stations A1, A6, A7, C7, C8) located near the outer edge of the kelp bed along the 18-m depth contour. Samples were taken at 3 fixed depths for each kelp station (**Table 3.1**). The kelp stations were sampled weekly, such that each day of the week was represented over a 2-month period. Additional samples were collected at shore stations D5, D7, and D8 on October 7 in response to elevated enterococcus densities reported at station D5 on October 6. The data from this sampling event is included in the mean calculations.

Thirty-six offshore stations (F01–F36) were sampled quarterly (January, April, July, October) to estimate the spatial extent of the wastewater plume at these times. Sampling at these 36 sites usually takes place over a 3-day period. Three of these stations (F01–F03) are located along the 18-m depth contour, while 33 sites (11 per transect) are located along the

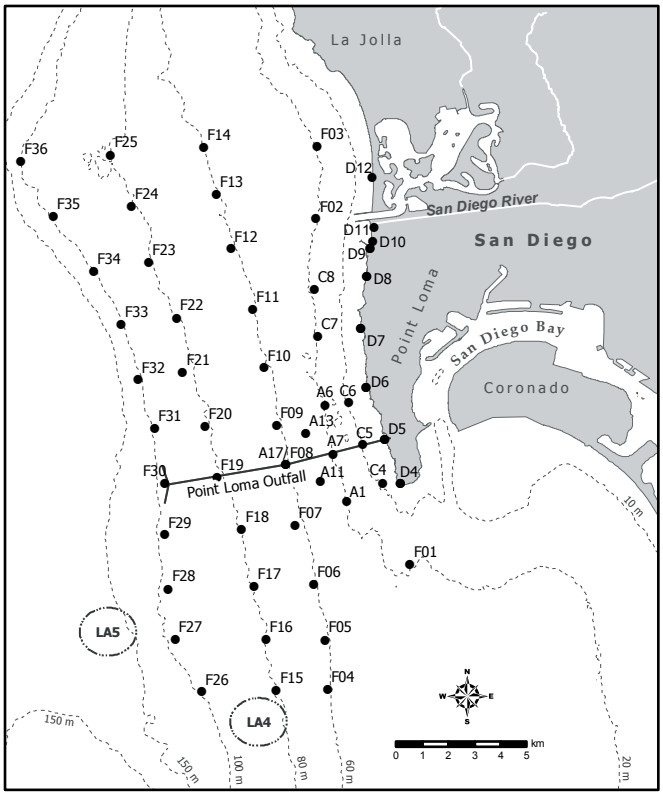

Figure 3.1
Water quality monitoring stations where bacteriological samples were collected, Point Loma Ocean Outfall Monitoring Program.

Table 3.1
Depths at which bacteriological samples are collected at the PLOO kelp and quarterly offshore stations.

	Sample depth (m)								
Station transect	1	3	9	12	18	25	60	80	98
9-m Kelp bed	x	x	x						
18-m Kelp bed	x			x	x				
18-m Quarterly	x			x	x				
60-m Quarterly	x					x	x		
80-m Quarterly	x					x	x	x	
98-m Quarterly	x					x	x	x	x

60-m (stations F04–F14), the 80-m (stations F15–F25), and the 98-m (stations F26–F36) contours. The number of samples collected at each station was depth-dependent and ranged from 3 to 5 fixed depths (Table 3.1).

Seawater samples were collected from the surf zone at each station and stored in sterile 250-mL bottles. Visual observations of water color and clarity, surf height, human or animal activity, and weather conditions were recorded at the time of sample collection. The seawater samples were then transported on ice to the City's Marine Microbiology Laboratory and analyzed to determine concentrations of total coliform, fecal coliform, and enterococcus bacteria.

Seawater samples from the kelp bed and quarterly offshore stations were also analyzed for total coliforms, fecal coliforms, and enterococcus. These samples were collected using either a series of Van Dorn bottles or a rosette sampler fitted with Niskin bottles. Aliquots for each analysis were drawn into appropriate sample containers. The samples were refrigerated aboard ship and then transported to the City's Marine Microbiology Laboratory for bacteriological analysis. Visual observations of weather and water conditions were also recorded for each sampling event.

Monitoring of the San Diego area and neighboring coastline also included aerial and satellite image analysis performed by Ocean Imaging Corporation (OI). All usable images captured during 2005 by the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite were downloaded, and several quality Landsat Thematic Mapper (TM) images were purchased. Aerial images were collected with OI's DMSC-MKII digital multispectral sensor (DMSC). Its 4 channels were configured to a specific wavelength (color) combination which, according to OI's previous research, maximizes the detection of the PLOO plume's turbidity signature by differentiating between the wastewater plume and coastal turbidity. Such data helps distinguish between bacterial contamination events caused by the PLOO discharge and those attributable to other point and non-point sources (e.g., river and bay discharges). The depth penetration of the imaging varies between 8 and 15 meters, depending on overall water clarity. The spatial resolution of the data is dependent upon aircraft altitude, but is typically maintained at 2 meters. Several aerial overflights were performed each month for a total of 11 flights from January through April and November through December, and 6 flights from May through October.

Laboratory Analyses and Data Treatment

All bacterial analyses were performed within 8 hours of sample collection and conformed to the membrane filtration techniques outlined in the City's Quality Assurance Plan (City of San Diego in prep). The Marine Microbiology Laboratory follows guidelines issued by the EPA Water Quality Office, Water Hygiene Division and the California State Department of Health Services (CDHS) Environmental Laboratory Accreditation Program with respect to sampling and analytical procedures (Bordner et al. 1978, Greenberg et al. 1992).

Box 3.1

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

(1) *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.

(2) *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.

(3) *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.

(4) *geometric mean* — 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.

Colony counting, calculation of results, data verification, and reporting all follow EPA guidelines (see Bordner et al. 1978). Plates with bacterial counts above or below the ideal counting range were given greater than (>), less than (<) or estimated (e) qualifiers. However, these qualifiers were dropped and the counts treated as discrete values during the calculation of compliance with 2001 California Ocean Plan (COP) water contact standards and means/values.

Shore and kelp bed station compliance with COP standards (see **Box 3.1**) were summarized according to the number of days that each station was out of compliance. Bacteriological data for offshore stations are not subject to COP standards, but were used to examine spatio-temporal patterns in the dispersion of the waste field. Such patterns were determined from mean densities of total coliform, fecal coliform, and enterococcus bacteria. These data were calculated for each station by month, station, and depth. Monthly rainfall data (Lindbergh Field, San Diego, CA), oceanographic conditions (see Chapter 2), as well as other events (e.g., storm water flows, nearshore and surface water circulation patterns) identified through remote sensing data were evaluated relative to the bacterial data. COP bacteriological benchmarks were used as reference points to distinguish elevated bacteriological values in receiving water samples discussed in this report. These benchmarks are a) ≥1000 CFU/ 100 mL for total coliform, b) ≥400 CFU/100 mL for fecal coliforms, and c) ≥104 CFU/100 mL for enterococcus. Furthermore, "contaminated" water samples were identified as samples that had total coliform concentrations ≥1000 CFU/ 100 mL and a fecal:total (F:T) ratio ≥0.1 (see CDHS 2000). Samples from offshore monthly water quality stations that met these criteria were used as indicators of the PLOO waste field.

Quality assurance tests were performed routinely on water samples to ensure that sampling variability did not exceed acceptable limits. Duplicate and split field samples were collected according to method requirements and processed by laboratory personnel to measure intra-sample and inter-analyst variability, respectively. Results of these procedures were reported in the Quality Assurance Report (City of San Diego 2006b).

Maps to show the distribution of the PLOO waste field as estimated from bacterial densities were created using total coliform counts from the offshore quarterly stations. Bacterial densities from samples shallower than 60 m were not used because contaminated water was only detected in 1 sample taken shallower than 60 m at station F01. The maps were generated using the Spatial Analyst extension for ArcGIS 9.0. The Inverse Distance

Weighting algorithm was used with the power set to 3, a neighborhood of 5, and default values for all other parameters. Interpolations of deep water total coliform concentrations are meant for simplified data visualization purposes only and were not statistically significant.

RESULTS AND DISCUSSION

Approximately 2485 bacteriological samples were collected in 2005, including 490 from the shoreline stations, 1431 at the kelp stations, and 564 at the quarterly offshore stations. Of all the samples collected, only 87 had total coliform concentrations ≥ the 1000 CFU/100 mL benchmark. Twelve of these samples were collected at the shore stations, 8 at the kelp stations, and 67 at the offshore stations. One kelp bed sample and 64 offshore samples had F:T ratios ≥0.1, which could be indicative of wastewater. These samples were used to evaluate possible patterns in plume movement.

Spatial and Temporal Trends – Shore Stations

Bacterial densities from the shore stations in 2005 were generally low despite the relatively large amounts of rain that fell from January through March (**Table 3.2**). For example, monthly total coliform densities during the year averaged from 3 to 1733 CFU/100 mL. Most of the high densities occurred during the wet months (e.g., January, February, and October). The highest mean total coliform and enterococcus densities occurred in January as a result of samples collected along the shore on January 3 and 9, when 3.2 inches of rain accumulated over a 7-day period (see NOAA/NWS 2006). However, only 6 out of 12 samples with total coliforms ≥1000 CFU/100 mL occurred in January and February during rain events (**Table 3.3)**. Only 1 of these 6 samples contained bacterial levels that exceeded the benchmark values for fecal coliforms and enterococcus (400 and 104 CFU/100 mL, respectively) and was indicative of wastewater. This sample, collected from station D8 on January 3, had an F:T ratio ≥0.1 and densities of fecal coliforms and enterococcus above their benchmark values (400 and 104 CFU/100 mL, respectively). In contrast, samples from stations D8 and D11 on June 26, and station D11 on December 29 had total and fecal coliform densities well above their respective benchmark values but occurred when there was no recorded rainfall. Potential sources of contamination that may have contributed to these elevated bacterial densities include dogs, which were present at station D11 on June 26, and kelp, which was present at station D8 on June 26 and station D11 on December 29 (City of San Diego 2005b, 2006a). The beach around station D11 is unique in that it is a designated area for people to walk their dogs. In addition, contamination may have resulted from a population of transient people living upstream of station D11. High counts of indicator bacteria have also been present during dry periods at station D8 in previous years (City of San Diego 2005c).

Spatial and Temporal Trends – Kelp Bed and Offshore Stations

Most of the bacteriological samples collected from the kelp bed and offshore stations in 2005 were not indicative of contaminated waters. Only 3% (n=65) of the samples had total coliform densities ≥1000 CFU/100 mL and an F:T ratio ≥0.1 (**Appendix A.1**). Total coliform densities in shallow waters (1–25 m) ranged from 0 to 2600 CFU/100 mL throughout the year, while densities of fecal coliforms ranged from 0 to 500 CFU/100 mL. All but 2 of the samples indicative of contaminated water came from sample depths greater than 25 m. The highest mean indicator bacterial densities came from depths of 60 m and greater (**Figure 3.2A**), suggesting that the stratified water column restricted the plume to mid- and deep-water depths throughout the year (see Chapter 2).

There was little evidence that the wastewater plume reached nearshore waters in 2005. Mean bacterial densities were highest at stations along the 80 and 98-m transects (Figure 3.2B), with 60 of the 65 samples indicative of contaminated water collected from these sites. The other 5 samples came from stations A1 and F01 (18-m depth contour) and

Table 3.2

Shore station bacterial densities and rainfall data for the PLOO region during 2005. Mean total coliform, fecal coliform, and enterococcus bacterial densities are expressed as CFU/100 mL. Rainfall is expressed in inches as measured at Lindbergh Field, San Diego, CA. Sample size (n) for each station is given in parenthetically and includes resamples.

Month (Rainfall)		D4 (60)	D5 (62)	D7 (62)	D8 (62)	D9 (61)	D10 (61)	D11 (61)	D12 (61)	All Stations
Jan	Total	1733	405	369	968	45	184	348	80	517
(4.49)	Fecal	60	45	37	164	14	37	34	9	50
	Entero	113	27	24	332	24	28	42	15	75
Feb	Total	254	42	52	264	84	132	64	34	112
(5.83)	Fecal	18	2	22	17	12	10	11	8	12
	Entero	120	2	2	12	40	11	6	5	22
Mar	Total	12	12	85	86	66	115	140	30	67
(2.12)	Fecal	2	6	4	20	5	144	36	15	29
	Entero	2	2	8	28	10	103	38	20	26
Apr	Total	6	6	6	118	18	41	46	9	31
(0.59)	Fecal	6	6	2	6	6	10	22	3	8
	Entero	2	2	46	6	6	8	12	3	11
May	Total	6	8	36	68	14	32	228	6	50
(0.12)	Fecal	4	6	10	6	4	10	80	3	15
	Entero	2	2	3	9	3	8	27	5	7
Jun	Total	10	14	292	260	10	38	316	6	118
(0.02)	Fecal	2	5	2	186	5	14	242	4	57
	Entero	2	2	7	2	4	3	4	2	3
Jul	Total	44	15	50	66	10	10	35	22	31
(0.01)	Fecal	2	3	2	4	3	6	11	2	4
	Entero	2	2	6	4	2	3	4	4	4
Aug	Total	9	6	160	87	4	66	81	11	53
(0.00)	Fecal	2	3	23	70	3	24	49	3	22
	Entero	5	3	7	8	2	17	14	4	8
Sep	Total	13	12	96	116	14	50	24	21	43
(0.10)	Fecal	6	2	6	33	4	10	4	19	11
	Entero	3	2	2	8	9	3	3	2	4
Oct	Total	13	747	111	480	89	152	280	53	255
(0.46)	Fecal	2	71	60	99	4	18	189	9	58
	Entero	4	241	5	127	102	22	64	7	75
Nov	Total	6	6	13	209	9	12	8	7	34
(0.16)	Fecal	2	2	5	56	2	11	3	6	11
	Entero	2	2	2	26	2	2	4	6	6
Dec	Total	3	54	20	339	43	20	310	8	100
(0.25)	Fecal	4	28	18	43	21	9	161	3	36
	Entero	2	5	4	9	4	6	26	3	7
Annual Means										
	Total	172	119	108	256	33	70	155	24	
	Fecal	9	16	17	60	7	25	70	7	
	Entero	20	28	10	48	17	18	20	6	

Table 3.3

Elevated total coliform, fecal coliform, and enterococcus bacterial (Entero) densities (CFU/100 mL) at PLOO shore stations in 2005. Fecal to total coliform ratios (F:T) ≥0.1 are bolded. Rainfall (in inches) was measured at Lindbergh Field, San Diego, CA.

Date	72-Hour Rain	Station	Total	Fecal	Entero	F:T
January 3	1.08	D7	1600	160	52	**0.10**
		D8	3000	580	1300	**0.19**
January 9	1.53	D4	8400	280	480	0.03
		D5	1600	120	74	0.08
		D8	1400	110	280	0.08
February 14	0.25	D8	1000	16	16	0.02
June 26	0.00	D11	1300	1100	2	**0.85**
		D8	1200	900	2	**0.75**
October 6	0.00	D5	4200	20	1300	0.00
October 12	0.00	D8	1200	6	2	0.01
December 11	0.00	D8	1200	12	16	0.01
December 29	0.00	D11	1400	760	30	**0.54**

stations F08, F09, and F10 (60-m depth contour). Mean bacterial densities were generally highest at the 98 m stations in January and July, while the 60 and 80 m stations had high bacterial densities in April (**Table 3.4**). The kelp bed and 18 m offshore stations had similar bacterial densities for 3 of the 4 quarters (April, July, October). The higher mean value for the 18 m offshore stations in January was caused by 1 surface water sample collected at station F01 (see Appendix 1).

The spatial distribution of the waste field appeared to vary by quarter in 2005 (**Figure 3.3**). Interpolation of the bacteriological data from 60 m and below indicates: (a) a predominantly northward flow in January, (b) an isolated area in the northern part of the sampling grid that appears to be a result of northward flow in October, and (c) a south-east flow in April. The wastefield appeared to have moved eastward along the PLOO in April, but was not detected at special study stations A11 and A13 or at the kelp bed stations (City of San Diego 2005a). MODIS imagery indicated that surface waters were also flowing south in April (Ocean Imaging 2005). The July data suggests that there were no strong currents forcing the wastefield in either direction, and the wastefield was spread out equally north and south of the PLOO. Contaminated water was detected up to 12.5 km (7.8 mi) north of the PLOO (stations F36 and F25) in July and October and 7.3 km (4.5 mi) to the south (station F26) in April.

Compliance with California Ocean Plan Standards – Shore and Kelp Bed Stations

Despite heavy rainfall that periodically affected nearshore water quality (see Chapter 2), compliance with COP bacterial standards for the shore and kelp stations was generally high in 2005 (**Tables 3.5, 3.6**). For example, compliance with the 30-day total coliform standard at the shore stations ranged from 92 to 100% in 2005, with only 3 stations below 100% compliance. This is similar to 2004, another year of heavy rains, when compliance ranged

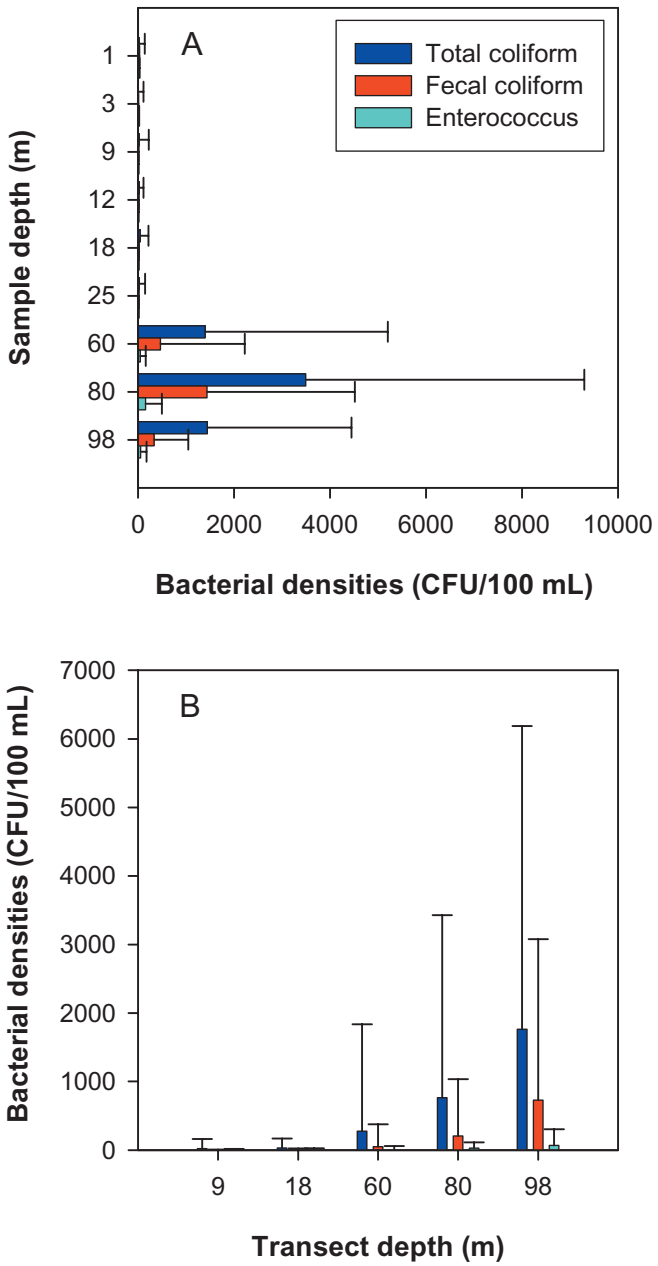

Figure 3.2

Kelp and quarterly offshore station bacterial densities for the PLOO region during 2005. Total coliform, fecal coliform, and enterococcus bacterial densities (mean±SD; CFU/100 mL) by (A) sample depth and (B) transect depth.

Table 3.4

Mean bacterial densities (CFU/100 mL) for January, April, July, and October 2005 sampling at PLOO offshore and kelp bed stations. Bacterial densities from all sample depths for each contour were used to calculate the means.

Month	Contour	n	Total	Fecal	Entero
Jan	9-m kelp bed	45	81	7	19
	18-m kelp bed	75	71	6	22
	18-m quarterly	9	195	61	27
	60-m quarterly	33	114	10	17
	80-m quarterly	44	265	57	36
	98-m quarterly	55	2004	814	135
Apr	9-m kelp bed	45	2	2	3
	18-m kelp bed	75	8	3	3
	18-m quarterly	9	8	4	4
	60-m quarterly	33	917	172	29
	80-m quarterly	44	1982	580	60
	98-m quarterly	55	1168	257	20
Jul	9-m kelp bed	45	27	2	2
	18-m kelp bed	72	21	3	3
	18-m quarterly	9	27	2	2
	60-m quarterly	33	37	7	3
	80-m quarterly	44	503	107	14
	98-m quarterly	55	2762	1241	94
Oct	9-m kelp bed	45	4	2	2
	18-m kelp bed	75	27	3	2
	18-m quarterly	9	5	2	2
	60-m quarterly	33	39	11	3
	80-m quarterly	44	305	80	10
	98-m quarterly	55	1130	603	29

from 89 to 100% and only 2 stations had <100% compliance. The few exceedances of the 30-day total coliform standard along the shoreline occurred at stations D4, D7, and D8 during the wettest months of January and February. Station D8 was the only shore station that exceeded the 60-day fecal coliform standard. Compliance with the 60-day fecal coliform standard at station D8 in 2005 (85%) was similar to compliance in 2004 (83%). All shore stations were 100% compliant with the 10,000 total coliform and 30-day fecal coliform geometric mean standards.

Levels of compliance for the kelp stations were slightly lower in 2005 compared to 2004.

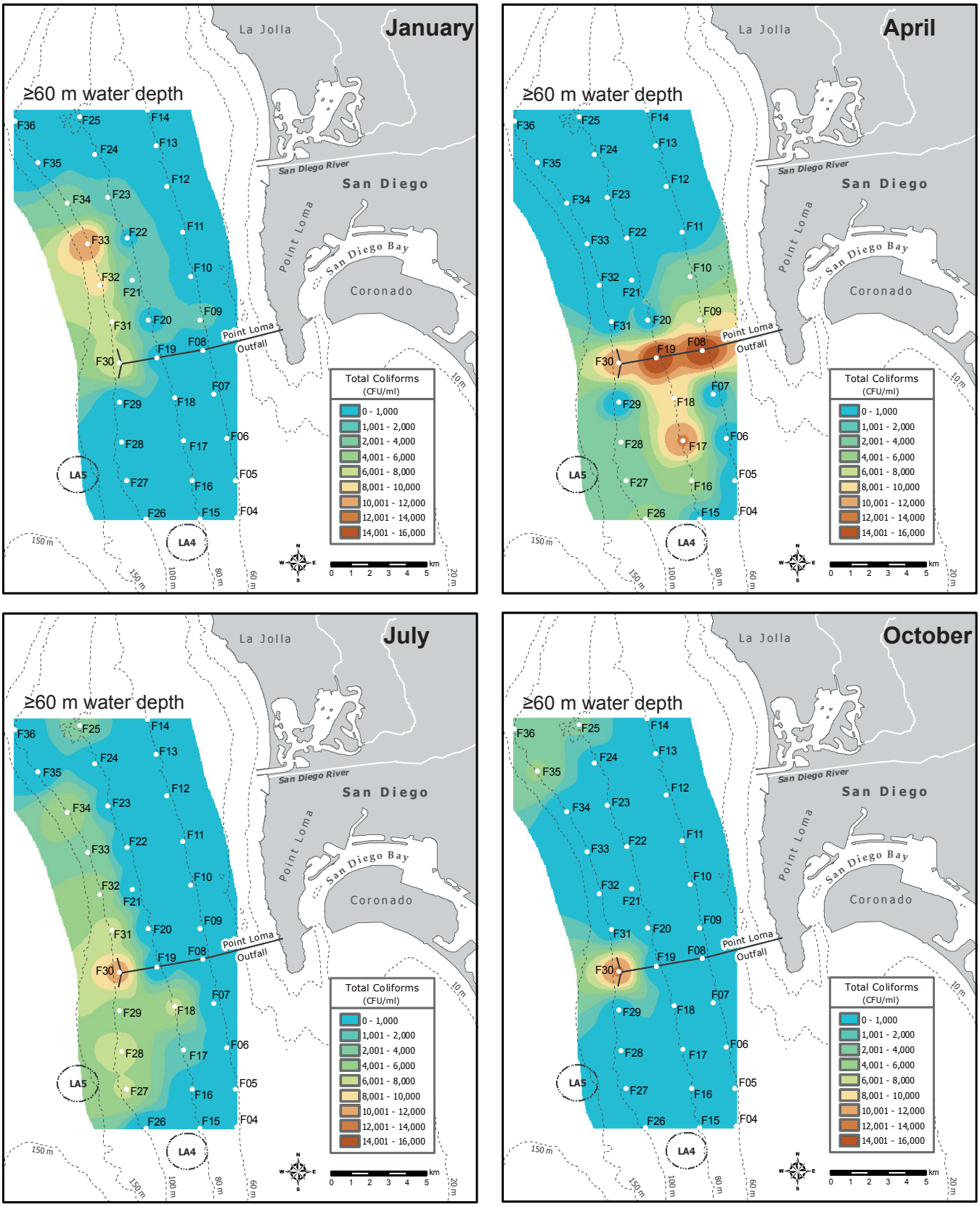

Figure 3.3

Distribution of mean total coliform counts from depths of 60 m and below collected during quarterly offshore sampling in 2005: (A) January, (B) April, (C) July, and (D) October. Contaminated water (see text) was generally not detected in samples shallower than 60 m depth.

Table 3.5

Summary of compliance with California Ocean Plan water contact standards for PLOO shore stations during 2005. The values reflect the number of days that each station exceeded the 30-day total and 60-day fecal coliform standards. Shore stations are listed left to right from south to north.

30-Day total coliform standard

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
January	31	0	0	24	29	0	0	0	0
February	28	6	0	0	1	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Compliance (%)		98%	100%	93%	92%	100%	100%	100%	100%

60-Day fecal coliform standard

Month	# days	D4	D5	D7	D8	D9	D10	D11	D12
January	31	0	0	0	31	0	0	0	0
February	28	0	0	0	25	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Compliance (%)		100%	100%	100%	85%	100%	100%	100%	100%

Compliance with the 30-day total coliform standard at these stations ranged from 92 to 100% in 2005 compared to 96 to 100% in 2004. The exceedances of the 30-day total coliform standard occurred only in January. Stations C4 and C5 were the only kelp stations out of compliance with the 60-day fecal coliform standard. Elevated total and fecal coliform levels from the end of December 2004 caused the initial exceedances in the beginning of 2005. All kelp stations were 100% compliant with the 10,000 total coliform and 30-day fecal coliform geometric mean standards.

SUMMARY AND CONCLUSIONS

Record rainfall in 2005 had little affect on water quality conditions surrounding the Point Loma

Table 3.6

Summary of compliance with California Ocean Plan water contact standards for PLOO kelp bed stations during 2005. The values reflect the number of days that each station exceeded the 30-day total and 60-day fecal coliform standards. Kelp stations are listed left to right from south to north and by depth contour.

30-Day total coliform standard

		9-m stations			18-m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	28	28	18	18	1	0	0	11
February	28	0	0	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Compliance (%)		92%	92%	95%	95%	100%	100%	100%	97%

60-Day Fecal Coliform Standard

		9-m stations			18-m stations				
Month	**# days**	**C4**	**C5**	**C6**	**A1**	**A7**	**A6**	**C7**	**C8**
January	31	31	15	0	0	0	0	0	0
February	28	27	17	0	0	0	0	0	0
March	31	0	0	0	0	0	0	0	0
April	30	0	0	0	0	0	0	0	0
May	31	0	0	0	0	0	0	0	0
June	30	0	0	0	0	0	0	0	0
July	31	0	0	0	0	0	0	0	0
August	31	0	0	0	0	0	0	0	0
September	30	0	0	0	0	0	0	0	0
October	31	0	0	0	0	0	0	0	0
November	30	0	0	0	0	0	0	0	0
December	31	0	0	0	0	0	0	0	0
Compliance (%)		84%	91%	100%	100%	100%	100%	100%	100%

Ocean Outfall (PLOO). Values from the shore and kelp bed stations that exceeded the COP bacterial standards were limited primarily to January and February and appear to have been caused by contamination from river discharge during and after storm events. Bacterial concentrations and information from satellite images indicate that water discharge from the San Diego River, San Diego Bay, and other non-point source runoff are all more likely than the PLOO to critically impact the water quality at shore and nearshore stations.

It is unlikely that the wastewater plume from the PLOO ever reached surface waters in 2005. Elevated

bacterial densities within the kelp bed and along the shoreline were primarily limited to periods of heavy rainfall and river discharge that occurred in January and February. The exceptions occurred at shore stations D8 and D11 in June, and D11 in December. These stations are subject to heavy recreational use, which may have been the source of the elevated bacterial counts. Bacteriological evidence of contaminated water at the offshore stations was predominantly limited to samples collected from depths of 60 m and deeper. Additionally, the only sample indicative of contaminated water found inshore of the 60-m depth contour was taken at the surface (1 m) at offshore station F01 in January, and may have been due to storm-derived outflow from the San Diego Bay.

The depth of the discharge site (~98 m) may be the dominant factor that keeps the plume from reaching the surface. Wastewater is released into cold, dense sea water that does not appear to mix with the top 25 m of the water column. Physical parameters suggest that the water column is strongly stratified during the spring through fall months (see Chapter 2). The absence of evidence for bacteriological contamination in the surface waters during the winter months, when the water column is well mixed, suggests that stratification is not the only factor limiting the depth of the plume to 60 m and deeper.

The direction of the flow of the waste field from the PLOO varied spatially in 2005. High bacterial densities were detected at the northern limits of the quarterly sampling grid in July and October and at the southern limits in April. There was evidence that the plume moved inshore to the 60-m depth contour in April. It also appears that the plume may have dispersed further offshore than most of the sampling stations, such as in October, when contaminated water was only detected at the northwestern sampling sites. Overall, there did not appear to be one predominant pattern for the distribution of the wastefield.

Although rainfall was heavy in 2005, compliance rates with the COP standards were generally high. The levels of compliance for shore stations in 2005 was similar to that in 2004, another year with heavy rainfall, while the kelp station compliance levels were slightly lower in 2005. Shore station water quality samples were compliant with the 30-day total coliform standard over 90% of the time. Only 3 stations were compliant less than 100%. Similarly, station D8 was the only station not 100% compliant with the 60-day fecal coliform standard. All shoreline water quality samples were 100% compliant with both the 10,000 total coliform and 30-day fecal coliform geometric mean standards.

Kelp station compliance rates with the COP standards were generally high as well. Kelp station water quality samples were compliant with the 30-day total coliform standard over 90% of the time. Station C4 was the only site that was less than 90% compliant with the 60-day fecal coliform standard. All kelp water quality samples were 100% compliant with both the 10,000 total coliform and 30-day fecal coliform geometric mean standards.

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