The Health Effects of Swimming in Ocean Water Contaminated by Storm Drain Runoff

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Waters adjacent to the County of Los Angeles (CA) receive untreated runoff from a series of storm drains year round. Many other coastal areas face a similar situation. To our knowledge, there has not been a large-scale epidemiologic study of persons who swim in marine waters subject to such runoff. We report here results of a cohort study conducted to investigate this issue. Measures of exposure included distance from the storm drain, selected bacterial indicators (total and fecal coliforms, enterococci, and *Escherichia coli*), and a direct measure of enteric viruses. We found higher risks of a broad range of symptoms, including both upper respiratory and gastrointestinal, for subjects swimming (a) closer to storm drains, (b) in water with high levels of single bacterial indicators and a low ratio of total to fecal coliforms, and (c) in water where enteric viruses were detected. The strength and consistency of the associations we observed across various measures of exposure imply that there may be an increased risk of adverse health outcomes associated with swimming in ocean water that is contaminated with untreated urban runoff. (Epidemiology 1999;10:355–363)

Keywords: environmental epidemiology, gastrointestinal illness, ocean, recreational exposures, sewage, storm drains, waterborne illnesses, waterborne pathogens.

Runoff from a system of storm drains enters the Santa Monica Bay adjacent to Los Angeles County (CA). Even in the dry months of summer 10–25 million gallons of runoff (or non-storm water discharge) per day enter the bay from the storm drain system. Storm drain water is not subject to treatment and is discharged directly into the ocean. Total and fecal coliforms, as well as enterococci, are sometimes elevated in the surf zone adjacent to storm drain outlets; pathogenic human enteric viruses have also been isolated from storm drain effluents, even when levels of all commonly used indicators, including F2 male-specific bacteriophage, were low.[1]

Approximately 50–60 million persons visit Santa Monica Bay beaches annually. Concern about possible adverse health effects due to swimming in the bay has been raised by numerous interested parties.[2] Previous reports indicate that swimming in polluted water (for example, due to sewage) increases risks of numerous adverse health outcomes (Pruss[3] provides a recent review of this literature). To our knowledge, however, there has never been a large epidemiologic study of persons who swim in marine waters contaminated by heavy urban runoff.

These circumstances provided the motivation to study the possible health effects of swimming in the bay. We present here the main results from a large cohort study of people that addressed the issue of adverse health effects of swimming in ocean water subject to untreated urban runoff.

Methods

Design and Subjects

The exposures of interest were distance swimming from storm drains, levels of bacterial indicators (total coli-

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forms, fecal coliforms, enterococcus, *Escherichia coli*) for pathogens that potentially produce acute illness, and human enteric viruses. We studied three beaches located in Santa Monica Bay (CA) that exhibited a wide range of pathogen indicator counts and a high density of swimmers (Santa Monica, Will Rogers, and Surfrider).

Persons who immersed their heads in the ocean water were potential subjects for this study. There was no restriction based on age, sex, or race. We excluded anyone who swam at the study beaches or in heavily polluted areas (that is, Mothers' Beach in Marina del Rey or near the Santa Monica Pier) within 7 days before the study date, or between the date of the beach interview and the telephone follow-up interview. We excluded subjects who swam on multiple days, as one of our primary questions was whether risk of health outcomes was associated with levels of indicator organisms on the specific day a subject entered the water. We targeted persons bathing within 100 yards upcoast or downcoast of the storm drain and persons bathing greater than 400 yards beyond a storm drain.

For this study, 22,085 subjects were interviewed on the beach from June 25 to September 14, 1995, to ascertain eligibility and willingness to participate. We found that 17,253 of these subjects were eligible and able to participate (that is, had a telephone and were able to speak English or Spanish). Of these, 15,492 (90% of the eligible subjects) agreed to participate. They were interviewed about their age, residence, and swimming, particularly immersion of the head into ocean water. The interviewer noted distance from the storm drain (within the categories 0, 1–50, 51–100, or 400 yards), gender, and race of the subject. (Distances from each drain were marked with inconspicuous objects such as beach towels and umbrellas.)

Nine to 14 days after the beach interview, subjects were interviewed by telephone to ascertain the occurrence(s) of: fever, chills, eye discharge, earache, ear discharge, skin rash, infected cuts, nausea, vomiting, diarrhea, diarrhea with blood, stomach pain, coughing, coughing with phlegm, nasal congestion, and sore throat. For this study we defined *a priori* three groupings of symptoms indicative of gastrointestinal illness or respiratory disease. In particular, following Cabelli *et al*,[4] subjects were classified as having highly credible gastrointestinal illness 1 (HCGI 1) if they experienced at least one of the following: (1) vomiting, (2) diarrhea and fever, or (3) stomach pain and fever. We also classified subjects as having highly credible gastrointestinal illness 2 (HCGI 2) if they had vomiting and fever. Finally, we classified subjects as having significant respiratory disease (SRD) if they had one of the following: (1) fever and nasal congestion, (2) fever and sore throat, or (3) coughing with phlegm.

We were able to contact and interview 13,278 subjects (86% follow-up). Of those interviewed, 1,485 were found to be ineligible because they swam (and immersed their heads) at a study beach or in heavily polluted waters between the day of the beach interview and the telephone follow-up. We excluded 107 subjects because they did not confirm immersing their faces in ocean water, leaving 11,686 subjects. One subject had a missing value for age, which we imputed (as the median value among all subjects) for inclusion in the adjusted analyses (discussed below). For the bacteriological analyses, we excluded an additional 1,227 subjects who had missing values, leaving 10,459 subjects. In the virus analyses we included only the 3,554 subjects who swam within 50 yards of the drain on days when viruses were measured (as the samples were collected only at the storm drain).

Collection and Analysis of Samples for Bacterial Indicators

Samples were collected on days that subjects were interviewed on the beaches. Each day, ankle depth samples were collected from each location (0 yards, 100 yards upcoast and downcoast of the drain, and one sample at 400 yards). One duplicate sample per site was collected daily. Samples were collected in sterile 1 liter polypropylene bottles and transferred on ice to the microbiology laboratory. All samples were analyzed for total coliforms, fecal coliforms, enterococcus, and *E. coli*. Densities of total and fecal coliforms and enterococci were determined using the appropriate membrane filtration techniques in Ref 5. *E. coli* densities were determined by membrane filtration using Hach Method 10029 for m-ColiBlue24 Broth.

Collection and Analysis of Samples for Enteric Viruses

For looking at enteric viruses, we collected samples from the three storm drain sites on Fridays, Saturdays, and Sundays, using Method 9510 C g of Ref 5. Ambient pH, temperature, conductivity, and total dissolved solids were measured. Samples as large as 100 gallons chosen to minimize the impacts of seawater dilution were filtered through electropositive filters at ambient pH. Adsorption filters were eluted in the field with 1 liter of sterile 3% beef extract adjusted to pH 9.0 with sodium hydroxide. Field eluates were reconcentrated in the laboratory using an organic reflocculation procedure.[6] All final concentrates were detoxified before analysis.[7]

All samples were analyzed for infectious human enteric viruses in Buffalo green monkey kidney cells (BGMK) by the plaque assay technique. Ten percent of the final concentrate was tested in this manner to determine whether there were a quantifiable number of viruses present. The remaining concentrate volume was divided in half and analyzed using the liquid overlay technique known as the cytopathic effect (CPE) assay.[8] The CPE assay generally detects a greater number of viruses than the plaque assay, but it is not quantitative. Flasks that did not exhibit CPE were considered to be negative for detectable infectious virus. We further examined any flask exhibiting CPE by the plaque-forming unit method to confirm the presence of infectious viruses.

Statistical Analysis

Our analysis addressed two main questions. First, are there different risks of specific outcomes among subjects swimming 0, 1–50, 51–100, and 400 or more yards from a storm drain? If pathogens in the storm drain result in increased acute illnesses, one would expect higher risks among swimmers closer to the drain. Second, are risks of specific outcomes associated with levels of specific bacterial indicators or enteric viruses?

To address the second question, we estimated risks arising from exposure to levels within categories defined *a priori* by existing standards or expert consensus. Specifically, for total coliforms we defined categories using 1,000 and 10,000 colony-forming units (cfu) per 100 ml as cutpoints, which are based on the California Code of Regulations (S.7958 in Title 17).[9] For fecal coliforms we created categories using cutpoints of 200 and 400 cfu per 100 ml, which reflect criteria set by the State Water Resources Control Board.[10] For enterococcus we used cutpoints of 35 and 104 cfu per 100 ml of water, which were established by the U.S. Environmental Protection Agency.[11] Finally, categories for *E. coli* were selected in meetings with staff from the Santa Monica Bay Restoration Project (SMBRP), Heal the Bay, and the Los Angeles County Department of Health Services. These meetings resulted in initially selecting categories based on cutpoints of 35 and 70 cfu per 100 ml, and then subsequently adding categories using cutpoints of 160 and 320 cfu per 100 ml; the latter were added because it is believed that *E. coli* comprises about 80% of the fecal coliforms. Using these knowledge-based categories, however, assumes a homogeneous risk between cutpoints. This might not be a reasonable assumption because the adequacy of these cutpoints is unclear, and because a large percentage of the subjects were in a single (that is, the lowest) category. Therefore, we further explored the bacteriological relations using categories defined by deciles.

In addition to considering total and fecal coliforms separately, we investigated the potential effect of the ratio of total to fecal coliforms. Motivation for this arose from our expectation that the risk of adverse health outcomes might be higher when the ratio is smaller, indicating a relatively greater proportion of fecal contamination. We used categories of this ratio defined by a cutpoint of 5 (where 5 corresponds to there being 5 times as much total as fecal coliform in the water). The human enteric virus exposure was reported as a dichotomous (that is, virus detected *vs* not detected) measure.

We first calculated simple descriptive statistics giving the number of subjects with each adverse health outcome who swam (1) at the prespecified distances from the drain or (2) in water with the prespecified levels of pathogens. From these counts we estimated the crude risk associated with each exposure. We then used logistic regression to estimate the adjusted relative risks of each outcome. For each exposure/outcome combination, we fit a separate model. All models adjusted for the potential confounding of: age (three categories: 0–12 years, 13–25 years, >25 years); sex; beach; race (four categories: white, black, Latino/a, and Asian/multiethnic/other); California *vs* out-of-state resident; and concern about potential health hazards at the beach (four categories: not at all, somewhat, a little, and very).

Results

Table 1 presents results for each of the adverse health outcomes by distance swimming from the storm drain. Across all distances, risks ranged from about 0.001 (that is, 1 per 1,000) for diarrhea with blood to about 0.1 for runny nose. The risk of numerous outcomes was higher for people who swam at the drain (0 yards away), in comparison with those who swam 1–50, 51–100, or >400 yards from the drain. In particular, we observed increases in risk for fever, chills, ear discharge, coughing with phlegm, HCGI 2, and SRD. In addition, the risks for eye discharge, earache, sore throat, infected cut, and HCGI 1 were also slightly elevated. A handful of outcomes exhibited small increased risks among swimmers at 1–50 yards (skin rash) or at 51–100 yards (cough, cough with phlegm, runny nose, and sore throat). Adjusted estimates of relative risk (RR) comparing swimmers at 0, 1–50, or 51–100 yards from the drain with swimmers at least 400 yards away from the drain showed similar relations as the aforementioned patterns of risks (Table 1). Among the positive associations for swimmers at the drain, RRs ranged in magnitude from about 1.2 (eye discharge, sore throat, HCGI 1) to 2.3 (earache), with varying degrees of precision; most of these RRs ranged from 1.4 to 1.6.

In Table 2 we see that the risk of skin rash increased for the highest prespecified category of total coliforms (that is, >10,000 cfu). Furthermore, the adjusted RR comparing swimmers exposed at this level *vs* those exposed to levels ≤1,000 cfu was 2.6. Whereas the RR for diarrhea with blood also suggested a positive association, this result was based on a single adverse health event (as evinced by the wide 95% CIs). When looking at deciles, in relation to the lowest exposure level (that is, the lowest 10%), we observed increased risks of skin rash at all other levels (Figure 1). The adjusted RRs ranged from 1.6 to 6.2, with five of the nine RRs in the 2–3 range. In addition, there were increased risks of HCGI 2 for all deciles except one (the eighth); the corresponding adjusted RRs ranged from 1.4 to 4.7, with varying levels of precision (Figure 1).

When looking at fecal coliforms, we again observed among those in the highest category (that is, >400 cfu) an increased risk for skin rash (Table 3). There were also *slight* increased risks for infected cut, runny nose, and diarrhea with blood in the highest category, as well as for nausea, vomiting, coughing, sore throat, and HCGI 2 in the middle category (200–400 cfu). The adjusted RRs also indicated positive associations for these outcomes (Table 3). When we used deciles to categorize subjects, however, in comparison with the lowest decile, we only observed marginal increased risks for infection and skin rash (not shown). In our investigation of the ratio of

TABLE 1. Adverse Health Outcomes by Distance Swimming from Drain: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	Distance from Drain (in Yards)										
	>400 (N = 3030)*		51–100 (N = 3311)			1–50 (N = 4518)			0 (N = 827)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR (95% CI)†	No. Ill	Risk	RR (95% CI)†	No. Ill	Risk	RR (95% CI)†
Fever	138	0.046	158	0.048	1.06 (0.84–1.34)	208	0.046	1.07 (0.85–1.33)	59	0.071	1.61 (1.16–2.24)
Chills	72	0.024	85	0.026	1.07 (0.77–1.47)	108	0.024	1.05 (0.77–1.42)	31	0.037	1.60 (1.03–2.50)
Eye discharge	61	0.020	59	0.018	0.88 (0.61–1.27)	73	0.016	0.77 (0.55–1.09)	19	0.023	1.15 (0.67–1.98)
Earache	116	0.038	116	0.035	0.89 (0.68–1.16)	136	0.030	0.81 (0.63–1.04)	38	0.046	1.34 (0.91–1.98)
Ear discharge	21	0.007	19	0.006	0.78 (0.42–1.46)	25	0.006	0.80 (0.45–1.44)	13	0.016	2.09 (1.01–4.33)
Skin rash	23	0.008	30	0.009	1.16 (0.67–2.01)	53	0.012	1.50 (0.91–2.46)	4	0.005	0.62 (0.21–1.83)
Infected cut	17	0.006	16	0.005	0.79 (0.40–1.58)	37	0.008	1.51 (0.84–2.69)	6	0.007	1.48 (0.57–3.87)
Nausea	133	0.044	115	0.035	0.77 (0.60–1.00)	143	0.032	0.75 (0.59–0.95)	40	0.048	1.13 (0.78–1.65)
Vomiting	57	0.019	58	0.018	0.97 (0.67–1.40)	63	0.014	0.76 (0.53–1.09)	25	0.030	1.40 (0.85–2.31)
Diarrhea	204	0.067	163	0.049	0.70 (0.56–0.86)	202	0.045	0.69 (0.56–0.84)	53	0.064	1.04 (0.75–1.44)
Diarrhea with blood	7	0.002	2	0.001	0.26 (0.05–1.26)	3	0.001	0.27 (0.07–1.06)	2	0.002	0.87 (0.15–4.57)
Stomach pain	206	0.068	194	0.059	0.85 (0.70–1.05)	271	0.060	0.93 (0.77–1.12)	61	0.074	1.11 (0.82–1.51)
Cough	209	0.069	263	0.079	1.18 (0.97–1.42)	296	0.066	0.98 (0.82–1.18)	55	0.067	1.01 (0.73–1.38)
Cough and phlegm	90	0.030	114	0.034	1.16 (0.88–1.54)	143	0.032	1.09 (0.83–1.43)	39	0.047	1.65 (1.11–2.46)
Runny nose	273	0.090	351	0.106	1.18 (1.00–1.40)	371	0.082	0.95 (0.80–1.12)	74	0.089	1.10 (0.84–1.46)
Sore throat	190	0.063	244	0.074	1.17 (0.96–1.43)	304	0.067	1.12 (0.93–1.35)	59	0.071	1.25 (0.92–1.71)
HCGI 1	102	0.034	96	0.029	0.88 (0.66–1.17)	121	0.027	0.84 (0.64–1.10)	35	0.042	1.21 (0.81–1.82)
HCGI 2	26	0.009	28	0.008	1.04 (0.61–1.79)	32	0.007	0.90 (0.53–1.53)	15	0.018	1.64 (0.84–3.21)
Significant respiratory disease	139	0.046	177	0.053	1.18 (0.94–1.49)	205	0.045	1.03 (0.82–1.23)	63	0.076	1.78 (1.29–2.45)

The total number of swimmers in each category is given in parentheses (N). HCGI1, highly credible gastrointestinal illness with vomiting, diarrhea and fever or stomach pain and fever. HCGT2, highly credible gastrointestinal illness with vomiting and fever only. Significant respiratory disease, fever and nasal congestion, fever and sore throat or coughing with phlegm.
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

total to fecal coliforms, we observed a consistent pattern of higher risks for diarrhea and HCGI 2 as the ratio category became lower (not shown, but available in Ref 12). Because any effect of this lower ratio should be stronger when there was a higher degree of contamination, indicated by total coliform counts in excess of 1,000 or 5,000 cfu, we then restricted our analysis to subjects swimming in water above these levels. In the first case, increased risks with decreasing cutpoints were observed for nausea, diarrhea, and HCGI 2.[12] When we restricted our investigation to subjects in water in which the total coliforms exceeded 5,000 cfu, we observed

TABLE 2. Adverse Health Outcomes by Total Coliform Levels: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	Total Coliforms (cfu/100ml)							
	≤1,000 (N = 7,574)*		>1,000–10,000 (N = 1,988)			>10,000 (N = 757)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR†	No. Ill	Risk	RR†
Fever	368	0.049	88	0.044	0.92 (0.72–1.17)	42	0.055	1.23 (0.87–1.73)
Chills	193	0.025	51	0.026	1.03 (0.75–1.42)	9	0.012	0.51 (0.26–1.01)
Eye discharge	151	0.020	21	0.011	0.46 (0.29–0.74)	15	0.020	0.81 (0.47–1.41)
Earache	270	0.036	66	0.033	0.96 (0.72–1.27)	21	0.028	0.86 (0.54–1.38)
Ear discharge	51	0.007	15	0.008	1.22 (0.67–2.23)	2	0.003	0.46 (0.11–1.93)
Skin rash	65	0.009	14	0.007	0.75 (0.41–1.36)	19	0.025	2.59 (1.49–4.53)
Infected cut	49	0.006	11	0.006	0.97 (0.49–1.91)	3	0.004	0.82 (0.25–2.72)
Nausea	292	0.039	69	0.035	0.94 (0.72–1.24)	18	0.024	0.71 (0.43–1.16)
Vomiting	137	0.018	34	0.017	0.90 (0.61–1.33)	9	0.012	0.64 (0.32–1.29)
Diarrhea	434	0.057	85	0.043	0.80 (0.63–1.03)	33	0.044	0.95 (0.65–1.39)
Diarrhea with blood	8	0.001	2	0.001	1.08 (0.22–5.35)	1	0.001	1.73 (0.19–15.88)
Stomach pain	487	0.064	125	0.063	1.05 (0.85–1.29)	29	0.038	0.69 (0.47–1.02)
Cough	546	0.072	133	0.067	0.90 (0.73–1.10)	51	0.067	0.94 (0.69–1.28)
Cough and phlegm	267	0.035	58	0.029	0.81 (0.60–1.09)	27	0.036	1.03 (0.68–1.57)
Runny nose	703	0.093	170	0.086	0.93 (0.78–1.12)	67	0.089	1.06 (0.81–1.40)
Sore throat	534	0.071	116	0.058	0.83 (0.67–1.03)	47	0.062	0.95 (0.69–1.30)
HCGI 1	242	0.032	54	0.027	0.84 (0.62–1.14)	17	0.022	0.74 (0.44–1.23)
HCGI 2	72	0.010	16	0.008	0.89 (0.51–1.55)	5	0.007	0.83 (0.32–2.12)
Significant respiratory disease	396	0.052	84	0.042	0.80 (0.62–1.02)	42	0.055	1.11 (0.79–1.55)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

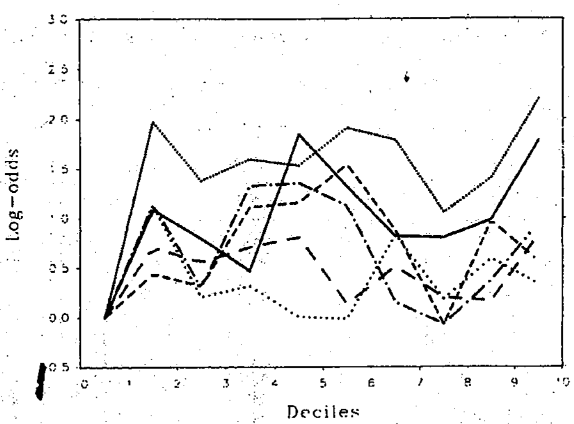

FIGURE 1. Log odds of adverse health outcomes by deciles of exposure for selected bacterial exposures. —, Total coliform and skin rash; – – – ·, total coliform and HCGI 2; · · ·, Enterococci and infected cut; — — —, *E coli* and eye discharge; ···, *E coli* and skin rash; · — ··, *E coli* and infected cut. HCGI 2 = highly credible gastrointestinal illness with vomiting and fever only.

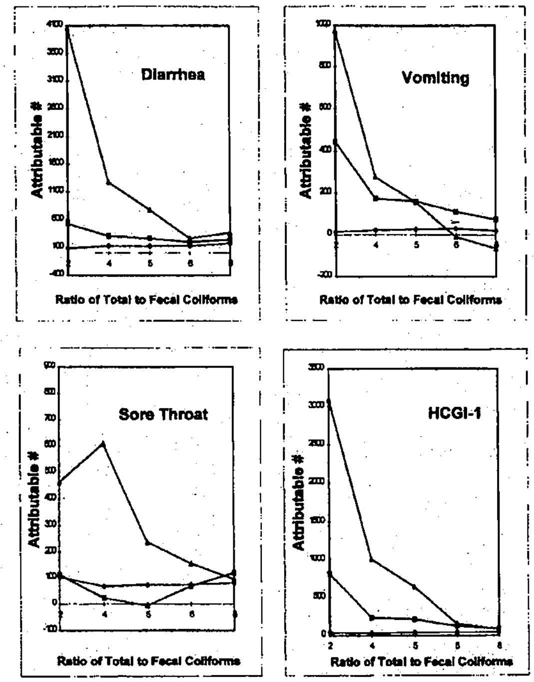

FIGURE 2. Selected attributable numbers/10,000 exposed subjects for total to fecal coliforms. ◆, All days; ■, >1000; ▲, > 5000. HCGI 1 = highly credible gastrointestinal illness with vomiting, diarrhea and fever or stomach pain and fever.

increased risks with eye discharge, ear discharge, skin rash, nausea, diarrhea, stomach pain, nasal congestion, HCGI 1, and HCGI 2.[12] There was a consistent pattern of stronger risk ratios as the cutpoint became lower (when the analyses were restricted to times when total coliforms exceeded 1,000 or 5,000 cfu), with the strongest effects generally observed with the cutpoint of 2, as illustrated in Figure 2 for diarrhea, vomiting, sore throat, and HCGI 1.

Table 4 gives results for the relation among enterococci and the adverse health outcomes. Again, we observed an increased risk of skin rash among those in the highest category (that is, >104 cfu). In addition, comparing the highest to other categories of exposure, there

TABLE 3. Adverse Health Outcomes by Fecal Coliform Levels: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	Fecal Coliforms (cfu/100ml)							
	≤200 (N = 8,005)*		>200–400 (N = 768)			>400 (N = 1,636)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR†	No. Ill	Risk	RR†
Fever	381	0.048	39	0.051	1.04 (0.74–1.46)	80	0.049	1.02 (0.80–1.32)
Chills	197	0.025	24	0.031	1.14 (0.74–1.76)	34	0.021	0.78 (0.54–1.14)
Eye discharge	149	0.019	11	0.014	0.70 (0.38–1.31)	30	0.018	0.97 (0.65–1.46)
Earache	275	0.034	26	0.04	0.93 (0.62–1.41)	57	0.035	1.00 (0.75–1.35)
Ear discharge	53	0.007	8	0.010	1.29 (0.60–2.73)	7	0.004	0.56 (0.25–1.24)
Skin rash	69	0.009	5	0.007	0.64 (0.26–1.60)	26	0.016	1.86 (1.17–2.95)
Infected cut	47	0.006	2	0.003	0.40 (0.10–1.65)	15	0.009	1.50 (0.83–2.74)
Nausea	289	0.036	38	0.049	1.29 (0.91–1.84)	57	0.035	0.93 (0.69–1.24)
Vomiting	133	0.017	18	0.023	1.33 (0.81–2.21)	31	0.019	1.07 (0.71–1.60)
Diarrhea	425	0.053	50	0.065	1.17 (0.86–1.60)	81	0.050	0.90 (0.70–1.15)
Diarrhea with blood	7	0.001	1	0.001	1.22 (0.15–10.01)	3	0.002	1.69 (0.42–6.75)
Stomach pain	495	0.062	51	0.066	1.04 (0.77–1.41)	103	0.063	0.98 (0.78–1.23)
Cough	551	0.069	70	0.091	1.34 (1.03–1.74)	117	0.072	1.06 (0.86–1.31)
Cough and phlegm	265	0.033	31	0.040	1.16 (0.79–1.70)	60	0.037	1.10 (0.82–1.47)
Runny nose	722	0.090	72	0.94	1.03 (0.79–1.33)	160	0.098	1.11 (0.93–1.34)
Sore throat	527	0.066	70	0.091	1.40 (1.07–1.82)	106	0.065	0.99 (0.80–1.24)
HCGI 1	239	0.030	28	0.036	1.18 (0.79–1.77)	50	0.031	0.99 (0.72–1.36)
HCGI 2	65	0.008	11	0.014	1.63 (0.85–3.12)	17	0.010	1.13 (0.65–1.95)
Significant respiratory disease	399	0.050	42	0.055	1.08 (0.77–1.50)	85	0.052	1.04 (0.81–1.33)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California vs out-of-state resident, and concern about potential health hazards at the beach.

TABLE 4. Adverse Health Outcomes by Enterococci Levels: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	Enterococci (cfu/100ml)							
	≤35 (N = 7,689)*		>35–104 (N = 1,863)			>104 (N = 857)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR†	No. Ill	Risk	RR†
Fever	371	0.048	84	0.045	0.91 (0.71–1.16)	45	0.053	1.00 (0.72–1.40)
Chills	198	0.026	33	0.018	0.67 (0.46–0.97)	24	0.028	0.94 (0.60–1.48)
Eye discharge	149	0.019	25	0.013	0.69 (0.45–1.07)	16	0.019	1.01 (0.58–1.75)
Earache	270	0.035	57	0.031	0.82 (0.61–1.11)	31	0.036	0.88 (0.59–1.31)
Ear discharge	52	0.007	12	0.006	0.85 (0.45–1.62)	4	0.005	0.53 (0.19–1.51)
Skin rash	74	0.010	13	0.007	0.71 (0.39–1.30)	13	0.015	1.72 (0.89–3.31)
Infected cut	46	0.006	12	0.006	0.95 (0.49–1.82)	6	0.007	0.90 (0.37–2.18)
Nausea	271	0.035	72	0.039	1.07 (0.82–1.41)	41	0.048	1.19 (0.84–1.70)
Vomiting	130	0.017	34	0.018	1.13 (0.77–1.67)	18	0.021	1.20 (0.71–2.04)
Diarrhea	398	0.052	101	0.054	0.99 (0.78–1.25)	57	0.067	1.01 (0.75–1.36)
Diarrhea with blood	8	0.001	0	—	—	3	0.004	2.90 (0.66–12.68)
Stomach pain	464	0.060	126	0.068	1.09 (0.89–1.35)	59	0.069	0.97 (0.72–1.30)
Cough	554	0.072	121	0.065	0.91 (0.73–1.12)	63	0.074	1.00 (0.75–1.34)
Cough and phlegm	266	0.035	59	0.032	0.91 (0.68–1.22)	31	0.036	1.03 (0.69–1.54)
Runny nose	704	0.092	165	0.089	0.96 (0.80–1.15)	85	0.099	1.01 (0.79–1.30)
Sore throat	533	0.069	118	0.063	0.89 (0.72–1.10)	52	0.061	0.80 (0.59–1.09)
HCGI 1	230	0.030	51	0.027	0.92 (0.67–1.26)	36	0.042	1.31 (0.89–1.92)
HCGI 2	67	0.009	14	0.008	0.82 (0.46–1.48)	12	0.014	1.30 (0.67–2.51)
Significant respiratory disease	397	0.052	84	0.045	0.86 (0.67–1.11)	45	0.053	0.98 (0.70–1.37)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

were increased risks of nausea, vomiting, diarrhea with blood, HCGI 1, and HCGI 2. Our adjusted RRs suggested similar positive associations, except for diarrhea; although the risk increased from 0.05 to 0.07, the adjusted RR comparing the highest to lowest category was 1.0 (Table 4). When comparing the lowest to higher deciles, we observed increased risks in most categories for infected cut and skin rash (Figure 1). Other adverse health outcomes—infected cut, nausea, diarrhea, diarrhea with blood, HCGI 1, and HCGI 2—exhibited increased risks only in particular quantiles. In comparison with the lowest decile, the risk of each of these outcomes was higher in the 10th decile. For example, the risk for HCGI 2 was 0.007 in the first decile, but 0.015 in the 10th.

Table 5 presents results for *E. coli.* We once again found an increased risk of skin rash in the highest prespecified category (that is, >320 cfu). Furthermore, we observed slight increased risks in this highest category for eye discharge, earache, stomach pain, coughing with phlegm, runny nose, and HCGI 1 (Table 5). In our decile-based analysis, however, we only observed materially increased risks for eye discharge, skin rash, and infection (Figure 1).

Numerous adverse health outcomes exhibited higher risks among subjects swimming on days when samples were positive for viruses (Table 6). In particular, the risk of fever, eye discharge, vomiting, sore throat, HCGI 1, and HCGI 2, and to a lesser extent, chills, diarrhea, diarrhea with blood, cough, coughing with phlegm, and SRD were higher on days when viruses were detected. Our adjusted RR estimates showed similar relations, most ranging from 1.3 to 1.9 (Table 6). Additionally, adjusting for each bacterial indicator (one-at-a-time) also left these results essentially unchanged.[12] As expected, there was an association between presence of virus and fecal coliforms within 50 yards of the drain. The mean density of fecal coliforms when no virus was detected was 234.8 cfu (SD 542.5 cfu); whereas it was 2,233.8 (SD 2,634.1) when viruses were detected (N = 386). The median values were 47.8 and 452.6 cfu, respectively.

Discussion

We observed differences in risk for a number of outcomes when we compared subjects swimming at 0 yards *vs* 400+ yards. Most of the relative risks suggested an approximately 50% increase in risk. Furthermore, as evinced by both the risks and RRs, there is an apparent threshold of increased risk occurring primarily at the drain: no dose response is evinced with increasing closeness to the drain, but there is a jump in risk for many adverse health outcomes among those swimming at the drain. We also found that distance is a reasonably good surrogate for bacterial indicators, with higher levels observed closer to the drain.[12]

For bacterial indicators, we observed a relation among numerous higher exposures and adverse health outcomes. These increases were mostly restricted to the highest knowledge-based categories (no effect was observed below any existing standards). When looking at quantiles, we found higher risks of skin rash and infection at fairly low levels. In contrast with what one might expect, however, there was no clear dose-response pattern across increasing levels of bacteriological exposures.

TABLE 6. Number Ill, Risks, and Adjusted Relative Risk (RR) Estimates of Adverse Health Outcomes by Virus

	Viruses				
	No (N = 3,168)*		Yes (N = 386)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR (95% CI)†
Fever	126	0.040	23	0.060	1.56 (0.98–2.50)
Chills	65	0.021	10	0.026	1.25 (0.63–2.50)
Eye discharge	36	0.011	8	0.021	1.86 (0.85–4.09)
Earache	93	0.029	10	0.026	0.92 (0.47–1.80)
Ear discharge	15	0.005	0		
Skin rash	32	0.010	4	0.010	0.97 (0.34–2.82)
Infected cut	31	0.010	2	0.005	0.57 (0.13–2.40)
Nausea	101	0.032	12	0.031	0.93 (0.50–1.73)
Vomiting	44	0.014	10	0.026	1.86 (0.92–3.80)
Diarrhea	130	0.041	21	0.054	1.27 (0.78–2.07)
Diarrhea with blood	2	0.001	1	0.003	5.82 (0.45–75.72)
Stomach pain	191	0.060	23	0.060	0.92 (0.58–1.45)
Cough	181	0.057	28	0.073	1.22 (0.80–1.86)
Cough and phlegm	92	0.029	13	0.034	1.20 (0.66–2.18)
Runny nose	246	0.078	32	0.083	1.01 (0.68–1.49)
Sore throat	198	0.063	32	0.083	1.38 (0.93–2.06)
HCGI 1	72	0.023	15	0.039	1.69 (0.95–3.01)
HCGI 2	22	0.007	6	0.016	2.32 (0.91–5.88)
Significant respiratory disease	133	0.042	21	0.054	1.34 (0.83–2.18)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California *vs* out-of-state resident, and concern about potential health hazards at the beach.

When looking at the ratio of total to fecal coliforms using the entire dataset, no consistent pattern emerged.[12] This is not entirely surprising inasmuch as an analysis of all data points treats all ratios of similar numerical value equally. Thus, for example, even though a ratio of 5 when the total coliforms are very low may not increase risk, the same ratio may be associated with increased risks when the density of total coliforms is above 1,000 or 5,000 cfu. When the analysis was restricted to swimmers exposed to total coliform densities above 1,000 or 5,000 cfu, a consistent pattern emerged, with higher risks associated with low ratios.[12]

This is the first large-scale epidemiologic study that included measurements of viruses. A number of adverse health effects were reported more often on days when the samples were positive, suggesting assays for viruses may be informative for predicting risk. Norwalk-like viruses are a plausible cause of gastroenteritis.[4,13] Enteroviruses, the most common viruses in sewage effluent, can cause respiratory symptoms. Not only are viruses responsible for many of the symptoms associated with swimming in ocean water but also they die off at slower rates in sea water than do bacteria, and they can cause infection at a much lower dose.[14]

Our design substantially reduced the potential for confounding by restricting the study entirely to swimmers and making comparisons between groups of swimmers (for example, defined by distance from the drain) to estimate relative risks. Previous studies looking at the effects of exposure to polluted recreational water (for example, due to sewage outflows) have been criticized for comparing risks in swimmers with risks in nonswimmers.[4,14,15] In these earlier studies, background risks among subjects who swim *vs* those choosing not to swim may differ because there are many other (potentially noncontrollable) exposures/pathways that can produce the symptoms under investigation. By restricting the present study to swimmers, we have reduced potential differences between the background risks of exposed *vs* unexposed subjects (for example, swimmers choosing to swim at the drain *vs* those swimming at the same beach but farther away from the drain). Furthermore, we were able to adjust our relative risk estimates for a number of additional factors (listed above) that could confound the observed relations. Of course, this does not exclude the possibility that residual confounding in these factors, or other unknown factors, might have confounded the observed relations.

Nevertheless, any actual (that is, causal) effects may be higher than we observed in this study because both distance and pathogenic indicators are proxy measures of the true pathogenic agents. Also, recall that we excluded subjects who frequently entered the water at these beaches. If there is a dose-response relation such that higher cumulative exposures are associated with increased risk, then one may infer that persons who frequently enter the water and immerse their heads (for example, surfers) may have a higher risk of adverse health outcomes than the relatively infrequent swimmers included in this study.

In summary, we observed positive associations between adverse health effects and (1) distance from the drain, (2) bacterial indicators, and (3) presence of enteric viruses. Taken together, these results imply that there may be an increased risk of a broad range of adverse health effects associated with swimming in ocean water subject to urban runoff. Moreover, attributable numbers—that is, estimates of the number of new cases of an adverse health outcome that is attributable to the exposure of interest—reached well into the 100s per

TABLE 5. Adverse Health Outcomes by E. coli Levels: Number Ill, Acute Risks, Adjusted Relative Risk (RR) Estimates and 95% Confidence Intervals (CI)

	E. coli (cfu/100ml)													
	≤35 (N = 6,104)*		>35–75 (N = 1,620)			>75–160 (N = 1,145)			>160–320 (N = 518)			>320 (N = 991)		
Outcome	No. Ill	Risk	No. Ill	Risk	RR†	No. Ill	Risk	RR†	No. Ill	Risk	RR†	No. Ill	Risk	RR†
Fever	274	0.045	89	0.055	1.22 (0.95–1.56)	61	0.053	1.20 (0.90–1.60)	29	0.056	1.22 (0.81–1.84)	45	0.045	0.98 (0.70–1.37)
Chills	145	0.024	41	0.025	1.00 (0.70–1.44)	28	0.024	1.00 (0.66–1.52)	18	0.035	1.38 (0.82–2.33)	22	0.022	0.79 (0.49–1.26)
Eye discharge	116	0.019	30	0.019	0.99 (0.65–1.49)	14	0.012	0.65 (0.37–1.15)	6	0.012	0.61 (0.26–1.43)	23	0.023	1.36 (0.84–2.19)
Earache	214	0.035	45	0.028	0.75 (0.54–1.04)	33	0.029	0.78 (0.53–1.14)	18	0.035	0.91 (0.55–1.50)	47	0.047	1.25 (0.89–1.77)
Ear discharge	42	0.007	8	0.005	0.60 (0.28–1.28)	5	0.004	0.57 (0.22–1.46)	6	0.012	1.28 (0.52–3.15)	6	0.0066	0.67 (0.27–1.62)
Skin rash	57	0.009	15	0.009	1.01 (0.56–1.80)	7	0.006	0.66 (0.30–1.46)	6	0.012	1.21 (0.49–2.98)	15	0.015	2.04 (1.11–3.76)
Infected cut	42	0.007	7	0.004	0.53 (0.24–1.20)	3	0.003	0.33 (0.10–1.06)	3	0.006	0.66 (0.20–2.19)	9	0.009	1.02 (0.48–2.19)
Nausea	216	0.035	74	0.046	1.22 (0.93–1.61)	34	0.030	0.80 (0.55–1.16)	18	0.035	0.88 (0.53–1.46)	42	0.042	1.03 (0.73–1.47)
Vomiting	107	0.018	31	0.019	1.09 (0.72–1.64)	16	0.014	0.82 (0.48–1.40)	8	0.015	0.87 (0.41–1.85)	20	0.020	1.05 (0.63–1.74)
Diarrhea	310	0.051	101	0.062	1.14 (0.90–1.44)	63	0.055	1.00 (0.75–1.33)	25	0.048	0.80 (0.52–1.23)	56	0.057	0.91 (0.67–1.23)
Diarrhea with blood	5	0.001	3	0.002	2.06 (0.48–8.89)	1	0.001	1.03 (0.12–9.01)	2	0.004	3.98 (0.68–23.21)	0	—	—
Stomach pain	353	0.058	124	0.077	1.28 (1.03–1.59)	70	0.061	1.02 (0.78–1.33)	31	0.060	0.95 (0.64–1.40)	70	0.071	1.06 (0.80–1.40)
Cough	444	0.073	96	0.059	0.81 (0.64–1.02)	86	0.075	1.04 (0.82–1.33)	29	0.056	0.77 (0.51–1.14)	82	0.083	1.14 (0.88–1.48)
Cough and phlegm	226	0.037	41	0.025	0.66 (0.47–0.92)	34	0.030	0.78 (0.54–1.12)	11	0.021	0.53 (0.28–1.00)	43	0.043	1.12 (0.79–1.59)
Runny nose	566	0.093	136	0.084	0.87 (0.71–1.06)	105	0.092	0.96 (0.77–1.20)	38	0.073	0.76 (0.53–1.08)	108	0.109	1.12 (0.89–1.41)
Sore throat	417	0.068	99	0.061	0.86 (0.68–1.08)	82	0.072	1.02 (0.80–1.31)	29	0.056	0.78 (0.52–1.17)	75	0.076	1.04 (0.80–1.37)
HCGI 1	183	0.030	51	0.031	1.03 (0.75–1.42)	30	0.026	0.88 (0.59–1.30)	17	0.033	1.06 (0.63–1.80)	36	0.036	1.12 (0.76–1.64)
HCGI 2	48	0.008	21	0.013	1.55 (0.92–2.64)	8	0.007	0.85 (0.40–1.81)	6	0.012	1.25 (0.51–3.03)	10	0.010	1.04 (0.51–2.13)
Significant respiratory disease	319	0.052	71	0.044	0.82 (0.62–107)	58	0.051	0.96 (0.72–1.28)	21	0.041	0.74 (0.47–1.18)	56	0.057	1.03 (0.76–1.40)

The total number of swimmers in each category is given in parentheses (N).
* Referent category (RR = 1.0).
† Adjusted for age, sex, beach, race, California vs out-of-state resident, and concern about potential health hazards at the beach.

10,000 exposed subjects for many of the positive associations observed here.[12] This finding implies that these risks might not be trivial when we consider the millions of persons who visit these beaches each year. Furthermore, the factors apparently contributing to the increased risk of adverse health outcomes observed here are not unique to Santa Monica Bay (similar levels of bacterial indicators are observed at many other beaches). Consequently, the prospect that untreated storm drain runoff poses a health risk to swimmers is probably relevant to many beaches subject to such runoff, including areas on the East, West, and Gulf coasts of North America, as well as numerous beaches on other continents.

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EXECUTIVE SUMMARY

A cohort study was conducted to investigate the possible adverse health effects of bathing in Santa Monica Bay and whether the risks of ill health outcomes were associated with urban runoff from storm drains. Exposures of primary interest were pathogens that produced acute illnesses (for reasons discussed in our original proposal, chronic health effects were not studied).

Three beaches with a wide range of indicator counts and high density of bathers were studied. The beaches were Santa Monica Beach (near the Ashland Avenue storm drain), Will Rogers Beach (Santa Monica Canyon Channel or storm drain) and Surfrider Beach (near Malibu Creek).

Persons who bathed and immersed their heads in the ocean water were potential subjects for this study. There were no restrictions based on age, sex, or race. Persons who had bathed at the study beaches, Mothers' Beach in Marina del Rey or near the Santa Monica Pier within seven days of the study date were excluded, as were subjects who bathed at the study beaches (or Mothers Beach or near the Santa Monica Pier) between the date of the beach interview and the telephone follow-up. Subjects who bathed on multiple days had to be excluded since one of our primary research questions was whether risk of health outcomes was associated with levels of specific indicator organisms on the day a subject entered the water. Given the range of incubation periods for the outcomes of interest and that the counts were quite variable from day to day, it would have been impossible to link subjects' experiences with specific counts on a given day if they were in the water on numerous days. Persons bathing within 100 yards upcoast or downcoast of the storm drain and persons bathing greater than 400 yards beyond a storm drain were targeted for this study.

For this study, 22,085 subjects were interviewed on the beach to ascertain eligibility and willingness to participate. Of these, 17,253 subjects were found to be eligible and able to participate (had a telephone and were able to speak English or Spanish). Of these, 15,492 agreed to participate. Eligible subjects who agreed to participate were then interviewed about basic demographic data and about their bathing, including type of bathing activity (particularly immersion of the head into ocean water). Distance from the storm drain, gender, age, and race of the subject were noted by the interviewer.

On the same days that subjects were recruited, morning water samples were collected at ankle depth at 0, 100 yards north and south of the storm drain, and 400 yards north or south (depending on which area was used as a "control" area). Samples were analyzed for total and fecal coliforms, enterococci, and *E. coli*. In addition, one sample each Friday, Saturday, and Sunday of the study was taken in the storm drain (0 yards) at each study beach and analyzed for enteric viruses.

Nine to fourteen days after the interview date, subjects were interviewed by telephone to ascertain the occurrence(s) of fever, chills, eye discharge, earache, ear discharge, skin rash, infected cut, nausea, vomiting, diarrhea, diarrhea with blood, stomach pain, coughing, coughing with phlegm, nasal congestion, sore throat, and a group of symptoms indicative of highly credible gastrointestinal illness (HCGI) and significant respiratory disease (SRD). Of the 15,492 subjects interviewed on the beach, we were able to contact and interview 13,278 (86% follow-up). Of these 13,278, 1,485 were found to be ineligible because they bathed (and immersed their heads) at a study beach between the day of the beach interview and the telephone follow-up. This left 11,793 eligible subjects who provided data that were analyzed for this study. Of these, 107 were excluded because they reported not immersing their faces in the ocean water, leaving 11,686 subjects for analysis.

Analyses addressed the following two questions: 1) What are the relative risks of specific adverse health outcomes in subjects bathing at 0, 1-50, and 51-100 yards from a storm drain compared to subjects bathing at the same beach, but beyond 400 yards from a storm drain? 2) Are risks of specific outcomes (e.g. highly credible gastrointestinal illness; ear, eye and sinus infections; upper respiratory infections; skin rashes and lesions) among subjects associated with levels of the bacterial indicators (or viruses) mentioned above.

As a measure of strength of association, we relied initially on the risk ratio (RR), which expresses the risk (proportion of subjects who report a given symptom) among subjects who bathed, for example, in front of the drain (0 yards) versus the risk among subjects who bathed 400+ yards from the drain. Comparing subjects who swam at 0 versus 400+ yards from the drain for all three beach sites combined, statistically significant increases in risk were observed for fever, where the RR=1.57 (95% C.L. = 1.17-2.10), chills RR=1.58 (1.04-2.39), ear discharge RR=2.27 (1.14-4.51), vomiting RR=1.61 (1.01-2.56), coughing with phlegm RR=1.59 (1.10-2.29), a group of symptoms we labeled highly credible gastrointestinal illness (HCGI 2) RR=2.11 (1.12-3.97), and a group of symptoms indicative of significant respiratory disease (SRD) RR=1.66 (1.25-2.21). These increases in risk were observed predominantly at the distance of 0 yards.

A second set of analyses was completed, restricted to days when the total coliforms to fecal coliforms ratio was greater than 5 for the water samples taken at 400 yards. The rationale was to exclude days when the plume from the drain or some other source of high counts apparently reached the 400 yard area, making this less than an ideal "control" zone. The relative risks for the seven outcomes cited above all increased. In addition, some significant increases in risk were observed for adverse health effects at distances of 1-50 and 51-100 yards from the drain, compared to 400+ yards from the drain.

The results for distance did not change when adjusted for age, beach, gender, race, California versus out-of-state resident, socioeconomic status, and worry about potential health hazards at the beach. Distance results also did not change substantially when controlled for each bacterial indicator.

A number of approaches to analyzing the effects of bacterial indicators were taken. We first calculated risk ratios for the lower and higher cutpoints described in the text (e.g. 200 and 400 colony forming units, or cfu, for fecal coliforms). Very few associations were observed when these cutpoints were used. None were detected for *E. coli* at lower cutpoints (35 or 70 cfu). Earache RR= 1.46(1.06-2.00) and runny nose RR=1.24(1.00-1.53) were associated with *E. coli* at the highest cutpoint of 320 cfu. Only skin rash was associated with total and fecal coliforms using the cutpoints of 10,000 and 400 cfu, respectively. Diarrhea with blood RR=4.23 (1.12-15.91) and HCGI 1 RR=1.44 (1.03-2.03) were associated with enterococci, using the higher cutpoint of 106 cfu.

It is conceivable that real increases in risk might have been missed with these cutpoints, particularly since they were not based on data that were generated by previous studies of Santa Monica Bay, so we also calculated odds ratios from categorical models using quintiles (of bacterial indicator levels) and from continuous models. For the continuous linear (on logistic scale) models, the odds ratios correspond to a unit increase equal to the difference between the 90th and 10th percentiles (i.e. the difference between the midpoints of the fifth and first quintiles). In general, results from the categorical models resembled results using the cutpoints (to define dichotomies) described above. The continuous models yielded a number of positive associations. For *E. coli*, small but statistically significant associations were seen for skin rash and stomach pain. Only skin rash was associated with total coliforms. Fever, skin rash, and HCGI 1 and 2 were associated with fecal coliforms. For enterococci, significant positive associations were noted for fever, skin rash, nausea, diarrhea, stomach pain, coughing, runny nose, HCGI 1, HCGI 2, and SRD.

In addition to investigating single bacterial indicators, associations between adverse health effects and the ratio of total to fecal coliforms, and the ratio of total coliforms to enterococci were investigated. For the total to fecal ratio, we initially used a cutpoint of 5.0, assuming the risk may be higher when the ratio is smaller. For the entire data set, significant associations were observed for diarrhea RR=1.28 (1.08-1.51) and HCGI 2 RR=1.87 (1.20-2.90). We then estimated effects of this ratio restricted to subjects in water where the total coliforms exceeded 1,000 cfu. Significant effects were observed for nausea RR=1.48 (1.08-2.04), diarrhea RR=1.40 (1.07-1.85), and HCGI2 RR=3.12 (1.60-6.07). We also conducted a similar analysis restricted to subjects in water where the total coliforms exceeded 5,000 cfu. Significant effects were observed for fever, eye discharge, skin rash, nausea, diarrhea, stomach pain, nasal congestion, HCGI 1, and SRD. Risk ratios ranged from 2-7. We then conducted a similar analysis restricted to subjects in water where the total coliforms exceeded 10,000 cfu. Here we observed significant associations with eye discharge, ear discharge, skin rash, nausea, diarrhea, stomach pain, nasal congestion, HCGI 1, and HCGI 2. The significant RR's ranged from 2-39. All the effects noted above became consistently stronger as the analyses were increasingly restricted to occasions with higher counts of total coliforms. Since this ratio appeared to be informative, a range of cutpoints (2, 4, 6, 8) was subsequently investigated. There was a consistent pattern of stronger risk ratios as the cutpoint became lower (when the analyses were restricted to times when total coliforms exceeded 1,000 or 5000 cfu), with the strongest effects generally observed when the cutpoint of 2 was used. The consistency of the results suggests the observed associations are real.

None of the bacterial results changed when adjusted for age, beach, gender, race, California versus out-of-state resident, socioeconomic status, and worry about potential health hazards at the beach. They also did not change when we adjusted the bacterial results for distance from the drain.

The analysis of samples for enteric viruses yielded seventeen samples (taken in the storm drain) that were positive for enteric viruses. This number of positive samples did not enable us to conduct many analyses; however, we were able to compare the frequency of outcomes reported by subjects who were swimming within 50 yards of the drain on days when samples were tested for viruses and found to be negative versus days when the samples were positive for viruses. Results are presented in Table 73. Although based on small numbers, a number of outcomes were reported more often on days when the samples were positive for viruses, including fever (RR=1.53, 95% CI 0.97-2.42, p=value 0.07); vomiting (RR=1.89, 0.94-3.78), HCGI-1 (RR=1.74, 0.99-3.06) and HCGI-2 (RR=2.26, 0.91-5.60). Results remained essentially unchanged when adjusted for covariates or for each bacterial indicator. Research with gene probes is ongoing and will be presented in an addendum at a later date.

The attributable number for noteworthy distance and bacterial indicator results was also calculated. This attributable number is an estimate of the number of new cases of a specific adverse health outcome that is attributable to the exposure (distance or bacterial indicator) of interest. For a number of outcomes, the attributable number ranged into the indicator) of interest. For a number of outcomes, the attributable number ranged into the 100's of new cases per 10,000 exposed subjects (complete results are presented in Tables 65-70).

In summary, both sets of results (the positive associations between adverse health effects and a) distance from the drain and b) bacterial indicators and presence of enteric viruses) taken together strongly suggest that there is an increased risk of a relatively broad range of symptoms caused by swimming in ocean water at the beach sites included in this study, particularly close to the drains and when indicator densities increase or ratios between selected indicators decrease.