
Assessing water quality conditions in southern California's areas of special biological significance

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ABSTRACT

Over 280 km of shoreline have been designated as marine water quality protected areas, termed Areas of Special Biological Significance (ASBS), in southern California, USA. While the standard for water quality protection in an ASBS is “natural water quality”, there are at least 271 documented coastal discharges that potentially threaten this important ecological resource. The goal of this study was to assess the water quality status of ASBS by answering two questions: 1) What is the range of natural water quality near reference drainage locations? and 2) How does water quality near ASBS discharges compare to the natural water quality near reference drainage locations? The sample design focused exclusively on receiving water (not effluents) and wet weather, which are the locations and times where natural and anthropogenic contributions can mix making pollutants difficult to identify and control. Sixteen locations encompassing 35 site-events were sampled immediately prior to (<48 hours), then immediately following (<24 hours) storm events ranging from 0.1 to 9.8 cm rainfall. Concentrations of total suspended solids (TSS), nutrients (ammonia, nitrate, nitrite, total nitrogen, total phosphorus), total and dissolved trace metals (arsenic, cadmium, chromium, copper, nickel, lead, silver, and zinc), and polycyclic aromatic hydrocarbons (PAH) from post-storm samples were similar at reference drainage and ASBS discharge sites. The average concentration difference between post-storm geometric mean concentrations at reference drainage vs. ASBS discharge sites across all parameters (except chlorinated hydrocarbons) was 3%. Concentrations of chlorinated

hydrocarbons were almost entirely nondetectable and no post-storm sample exhibited significant toxicity to the purple sea urchin *Strongylocentrotus purpuratus*. In addition, there was no consistent increase from pre- to post-storm concentrations at either reference drainage or ASBS discharge locations. Most post-storm concentrations did not correlate well with storm parameters (i.e., rainfall quantity, antecedent dry period) or stormwater tracers (i.e., salinity, dissolved organic carbon), decreasing the utility of these tools for predicting impacts. A reference-based threshold was used as a proxy for distinguishing differences from natural water quality. The reference-based threshold included a two-step process that was used to determine if water quality near ASBS discharges differed from natural water quality: 1) was the individual chemical post-storm discharge concentration greater than the 85th percentile of the reference drainage site post-storm concentrations; and then 2) was the individual post-storm discharge concentration greater than the pre-storm concentration for the same storm event. While the concentrations near ASBS discharges were on average similar to reference site concentrations, there were some individual ASBS discharge sites that were greater than the reference site based threshold. Cumulatively across all ASBS, the constituents that were most frequently greater than the reference site-based threshold were nutrients and general constituents, followed by dissolved or total trace metals.

INTRODUCTION

Coastal municipalities and other agencies subjected to nearshore water quality regulation face a

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difficult task. The public demands equal access to the shoreline and, at the same time, mandates protection of water quality to maintain the integrity of marine ecosystems. Public access, especially in highly populated urban centers is almost always to the detriment of coastal marine life. This is routinely observed in terms of habitat loss (Boesch *et al.* 2001), harvesting of seafood and other marine resources (Cohen 1997), and the introduction of pollutants (O'Connor 1998, Schiff *et al.* 2000). Almost by definition, natural water quality is in the absence of coastal development and public access (Halpern *et al.* 2008).

Southern California epitomizes this conundrum. Approximately 17.5 million people live within an hour's automobile drive to the beach and is home to the sprawling urban centers of Los Angeles and San Diego, two of the nation's eight largest cities (US Census Bureau 2009). Over 1.5 billion gallons of treated wastewater are discharged to the ocean every day (Lyon and Stein 2009). In a typical rainy season, over double this volume is discharged via surface runoff (Ackerman and Schiff 2003). Surface runoff following storm events will carry the accumulated anthropogenic pollutants from urban activities such as residential application of fertilizers and pesticides (Schiff and Sutula 2004), trace metals from brake and tire wear (Davis *et al.* 2001), and atmospheric fallout from mobile and non-mobile sources (Sabin *et al.* 2006). Exacerbating these potential threats to the environment, sanitary and stormwater systems are separate in southern California. Therefore, stormwater runoff receives virtually no treatment prior to entering the ocean (Lyon and Stein 2009).

The dilemma between water quality protection and urbanization reaches a climax in southern California at areas of special biological significance (ASBS). The ASBS are marine water quality protected areas whose standard is "no discharge of waste" and maintenance of "natural water quality" (SWRCB 2005). More than 280 km of shoreline in southern California is designated as ASBS. While state regulatory agencies have been effective at minimizing point source discharges into ASBS, there are at least 271 storm drain discharges. These storm drains can discharge urban runoff, but also natural runoff from undeveloped portions of their respective watersheds. Nutrients, trace metals, and some organic constituents found in urban runoff are also natural components of the ecosystem (Yoon and Stein 2006). The dichotomy between natural versus anthro-

pogenic inputs ultimately clashes because the state regulatory structure does not numerically define natural water quality.

In order to address the dilemma between water quality protected areas and development in the coastal zone, the goal of this study was to assess the water quality in southern California ASBS. Specifically, the study was designed to answer two questions: 1) what is the range of natural water quality near reference drainage locations? and 2) how does water quality near ASBS discharges compare to the natural water quality at reference drainage locations? These two questions address the primary lack of information faced by both ASBS dischargers and regulators that stymies management actions, if they are necessary. The first question aims to quantify what is meant by "natural water quality" by visiting locations presumptively free of anthropogenic contributions. The second question compares the natural water quality levels derived from the first question to water quality near ASBS discharges to determine the level of existing water quality protection.

METHODS

There are 34 ASBS in California, 14 of which occur in southern California (Figure 1). The majority (78%) of ASBS shoreline in southern California surrounds the offshore Channel Islands, but a significant fraction (35 km) occur along the six mainland ASBS.

This study had two primary design elements. The first design element was a focus on receiving water. All samples were collected in receiving waters near reference drainage or ASBS discharges; no effluent discharge samples were collected as part of this study. The second design element was to focus on wet weather. Dry weather was not addressed in this study.

Sampling

Sixteen sites were selected for wet weather sampling in this study (Table 1). Six of the sampling locations were reference drainage sites (representing natural water quality) and 10 were ASBS discharge sites. Reference site selection followed five criteria: 1) the site must be an open beach with breaking waves (i.e., no embayments); 2) the beach must have drainage from a watershed that produces flowing surface waters during storm events; 3) the reference watershed should be similar in size to the watersheds that discharge to ASBS; 4) the watershed must be



Figure 1. Map of Areas of Special Biological Significance (ASBS) in Southern California.

comprised of primarily (>90%) open space; and 5) neither the shoreline nor any segment within the contributing watershed can be on the State’s 2006 list of impaired waterbodies (e.g., §303d list). All but one of the reference drainage sites was located within an ASBS. At least one discharge site was selected in

each southern California ASBS. Each site was selected based on three criteria: 1) greater than 1m diameter outfall; 2) the discharge catchment contained amongst the most land use development in that ASBS; and 3) local knowledge of potential impact to receiving water.

Table 1. Reference drainage and ASBS discharge sites, and their respective sampling effort, collected immediately prior to and immediately following storm events in southern California.

ASBS Number	ASBS Name	SiteName	Latitude	Longitude	Reference or Discharge	Number Pre-Storm Samples	Number Post-Storm Samples	
ASBS 21	San Nicolas Island	Barge Landing	33.21967	-119.44728	Discharge	2	2	
ASBS 21	San Nicolas Island	Cissy Cove	33.21448	-119.48459	Discharge	1	1	
ASBS 21	San Nicolas Island	Reference Site	37.26600	-119.49828	Reference	2	2	
ASBS 21	San Nicolas Island	Reverse Osmosis site	33.24281	-119.44433	Discharge	1	1	
ASBS 24	Malibu	Solstice Beach	34.03255	-118.74216	Reference	1	1	
ASBS 24	Malibu	Arroyo Sequit	34.04441	-118.93393	Reference	1	1	
ASBS 24	Malibu	Broad Beach	34.03339	-118.85090	Discharge	3	3	
ASBS 24	Malibu	Nicholas Canyon	34.04172	-118.91574	Reference	3	3	
ASBS 24	Malibu	Westward Beach	34.01030	-118.81721	Discharge	2	2	
ASBS 25	Santa Catalina Island	Two Harbors Pier	33.44194	-118.49821	Discharge	1	2	
-	-	Italian gardens	33.41011	-118.38176	Reference	1	2	
ASBS 29	San Diego	Avienda de la Playa	32.85466	-117.25899	Discharge	3	3	
ASBS 31	La Jolla	San Diego Marine Life Refuge	32.86632	-117.25469	Discharge	1	3	
ASBS 32	NewportCoast/CrystalCove	NewportCoast/CrystalCove	33.58867	-117.86759	Discharge	3	3	
ASBS 33	Heisler Park	El Moro Canyon	33.56033	-117.82205	Reference	3	3	
ASBS 33	Heisler Park	Heisler Park	33.54301	-117.78958	Discharge	3	3	
						Discharge	20	23
						Reference	11	12
						Total	31	35

A total of 35 site-events were collected (Table 1). Twelve site-events were collected near reference drainage locations and another 23 site-events were collected near ASBS discharge locations. Up to three storm events were monitored per site. A storm was defined as any wet weather event that resulted in surface flow across the beach into the ocean receiving water. Rainfall during sampled events ranged from 0.1 to 9.8 cm. Pre-storm samples were collected prior to (<48 hour) rainfall, and post-storm samples were collected immediately following (<24 hour) rainfall, with most post-storm samples collected less than 6 h after rainfall cessation. Eighty nine percent of all post-storm site-events also had a pre-storm sample collected. Samples were collected in the ocean at the initial mixing location in the receiving water. Both pre- and post-storm samples were collected by direct filling of pre-cleaned sample containers just below the water surface. With the exception of one ASBS (Catalina Island), all samples were collected from shore without the use of boats.

Laboratory Analyses

All water samples were analyzed for 93 parameters: 1) general constituents including total suspended solids (TSS), dissolved organic carbon (DOC), and salinity; 2) nutrients including nitrate (NO₃-N), nitrite (NO₂-N), ammonia (NH₃-N), total nitrogen (TN), total phosphorus (TP), and ortho-phosphate (PO₄-P); 3) dissolved and total trace metals (arsenic, cadmium, chromium, copper, nickel, lead, silver, zinc); 3) chlorinated hydrocarbons including total PCB (sum of congeners 18, 28, 37, 44, 49, 52, 66, 70, 74, 77, 81, 87, 99, 101, 105, 110, 114, 118, 119, 123, 126, 128, 138, 149, 151, 153, 156, 157, 158, 167, 168, 169, 170, 177, 180, 183, 187, 189, 194, 201, 206) and total DDT (sum of *o,p'*- and *p,p'*-DDT, DDE, and DDD); 4) total polycyclic aromatic hydrocarbons (28 PAHs); and 5) short-term chronic toxicity. All sample analysis followed standard methods and/or EPA approved procedures (APHA 2006). Trace metals were prepared for analysis using ammonium pyrrolidine dithiocarbamate (APDC), a chelation method that concentrates trace metals and removes matrix interferences (US EPA 1996). Toxicity of the receiving water was evaluated by performing an egg fertilization test using the endemic purple sea urchin *S. purpuratus* (USEPA 1995).

The project focused on performance-based measures of quality assurance. In general, laboratory data quality was quite good: no laboratory blank samples

were greater than the method detection limit; there was 96% success meeting data quality objectives (DQOs) for precision using laboratory duplicates; and there was 91% success meeting DQOs for accuracy using spiked samples. The lowest accuracy success rate was for cadmium (12 of 15 batches) and zinc (8 of 16 batches) where the requirement of 75-125% recovery from seawater was not met. This was due, in part, to the APDC chelation method that has lower affinities for extracting cadmium and zinc.

Data Analysis

Data analysis followed four steps. The first step was determining the validity of reference drainage site selection. This was achieved by examining the data for known anthropogenic contamination (i.e., chlorinated hydrocarbons such as DDTs and PCBs), testing for outlier samples in the reference drainage data set, and the presence of toxicity. The second data analysis step compared the average concentration of post-storm ambient concentrations at reference drainage sites to ASBS discharge sites. Differences between these concentrations were evaluated using a studentized T-test. The third data analysis step examined potential relationships among parameters looking for explanatory variables that derive differences both within reference drainage sites and between reference drainage and ASBS discharge sites. Rainfall quantity, antecedent dry period, TSS and DOC concentrations were correlated with all of the post-storm chemical concentrations and with the relative change in concentration between pre- and post-storm concentrations after log-transformation for data normalization. For the final data analysis, a reference based threshold was used as a proxy for distinguishing differences from natural water quality. The reference based threshold included a two-step process: 1) was the individual chemical post-storm discharge concentration greater than the 85th percentile of the reference drainage site post-storm concentrations; and then 2) was the individual post-storm discharge concentration greater than the pre-storm concentration for the same storm event. For ASBS discharge sites that did not have a matching pre-storm concentration, the pre-storm concentration from the previous storm at that site for which data was available, was used.

RESULTS

Post-storm reference drainage site concentrations were similar to post-storm ASBS discharge site concentrations (Figure 2). For 13 parameters (including

TSS, nutrients, total PAH and total trace metals), none were significantly different between reference drainage and discharge sites following storm events ($p < 0.05$). Of the minor differences between reference drainage and ASBS discharge site results, post-storm geometric mean concentrations were greater for nine of 13 constituents at reference drainage sites. No detectable concentrations of total DDT or total PCB were observed at reference drainage sites. However, detectable quantities of chlorinated hydrocarbons (*p,p'*-DDE), while extremely rare, did occur at certain ASBS discharge sites. The average difference between geometric mean concentrations at reference drainage vs. ASBS discharge sites across all parameters (except chlorinated hydrocarbons) was 3%; no parameter differed by more than a factor of 70%.

In general, there was no consistent increase or decrease in concentrations pre- to post-storm at reference drainage or ASBS discharge sites (Figure 3). Pre:Post-storm ratios were not significantly different between reference drainage and ASBS discharge sites for any of the trace metals. Nearly every trace metal, whether from reference drainage or ASBS discharge sites, encompassed unity within its interquartile distribution indicating that pre- and post-storm concentrations were similar. The only exception was copper that, despite having similar reference drainage and discharge site concentrations, had roughly 75% of their respective distributions greater than unity. This

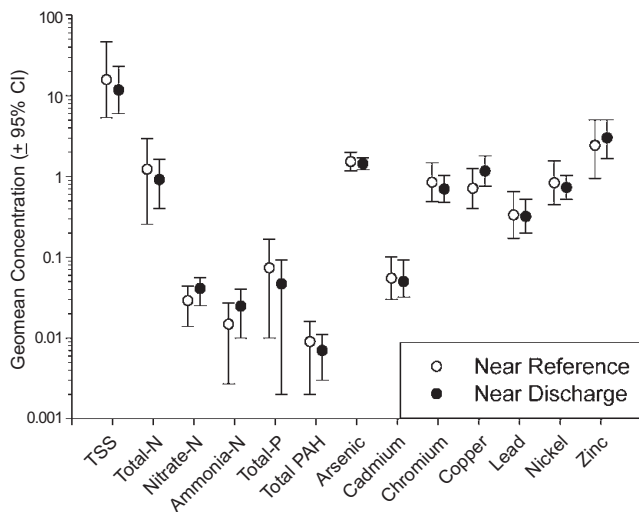


Figure 2. Comparison of geometric mean (\pm 95% confidence interval) concentrations in ambient near-shore receiving waters following storm events at reference drainage and ASBS discharge sites. Total suspended solids (TSS) and nutrients in mg/L; Total Polycyclic Aromatic Hydrocarbons (Total PAHs) and total trace metals in $\mu\text{g/L}$.

would indicate that receiving water concentrations of copper increased following storm events.

Most relationships of discharge post-storm concentrations with storm characteristics were poor (Table 2). Correlation coefficients with storm size ranged from -0.2 to 0.25 across all constituents, none of which were significant. Correlation coefficients with antecedent dry days were marginally better, ranging from -0.45 to 0.34 across all constituents; only salinity and total P were statistically significant. Other potential explanatory variables such as salinity, TSS, or DOC concentrations provided limited insight. Salinity was negatively correlated with most of the total trace metals; cadmium, chromium, and copper were statistically significant. In contrast, TSS was positively correlated with most of the total trace metals; arsenic, chromium, lead and nickel were statistically significant. Despite the statistically significant correlation for a subset of metals for both salinity and TSS, no correlation explained more than 45% of the variability in parameter concentrations observed in ASBS receiving waters. In fact, roughly one-third of the parameters had correlation coefficients less than 0.30.

Differences from reference water quality were relatively infrequent at ASBS discharge sites (Figure 4; Table 3). ASBS 25 (Northwest Santa Catalina Island) had the greatest proportion of analyses that were greater than reference site based thresholds

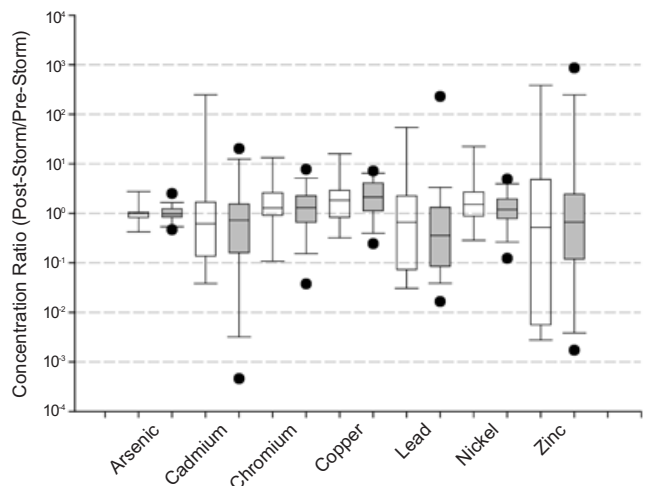


Figure 3. Distribution of post-storm relative to pre-storm trace metal concentrations in ambient near-coastal waters at reference drainage (in white) and ASBS discharge (in grey) sites. Box plots indicate the 5th, 25th, 50th, 75th, and 95th percentile of the data distribution.

Table 2. Correlation coefficients between storm characteristics (rainfall quantity, antecedent dry days) or conservative tracers (total suspended solids, salinity, dissolved organic carbon) and chemical parameters of interest. Bolded numbers are statistically significant at $p < 0.05$.

	Rainfall	Ant Dry	Salinity	TSS	DOC
Salinity	0.20	-0.43			
TSS	0.19	0.23	0.02		
DOC	0.08	-0.11	0.50	0.05	
Ammonia-N	0.08	0.29	-0.34	-0.11	0.26
Nitrate-N	-0.05	0.05	0.00	-0.08	0.41
Total N	-0.20	0.22	-0.07	0.15	0.09
Total P	-0.07	0.34	0.03	0.07	-0.21
Arsenic	-0.04	-0.04	0.13	0.46	0.17
Cadmium	-0.01	-0.01	-0.34	-0.09	0.03
Chromium	0.25	0.25	-0.34	0.67	0.21
Copper	0.07	0.07	0.02	0.27	0.24
Lead	0.13	0.13	-0.06	0.37	0.15
Nickel	0.14	0.14	-0.19	0.55	0.32
Zinc	0.02	0.02	-0.44	0.31	-0.10
Total PAH	0.16	0.16	-0.03	0.03	0.11

(35% of all analyses). ASBS 29 (La Jolla) had the smallest proportion of analyses that were greater than reference site based thresholds (5% of all analyses). Cumulatively across all ASBS, 15% of all analyses were greater than reference site based thresholds. Nutrients and general constituents were greater than reference site based thresholds most frequently (24 and 23% of all analyses, respectively; Figure 5). For both total and dissolved metals, differences from natural water quality occurred in approximately 19% of all samples were greater than reference site based thresholds. Total PAH were

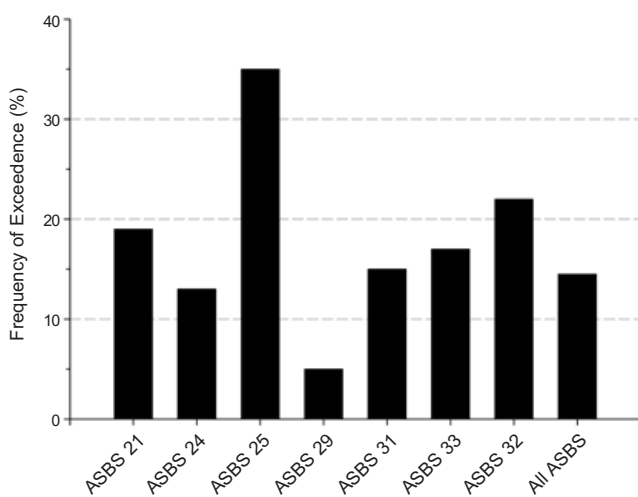


Figure 4. Frequency of reference site based thresholds exceedences for all parameters during all storm events at each Area of Special Biological Significance (ASBS) in southern California.

greater than reference site based thresholds least frequently (2% of all analyses).

Significant toxicity was not observed during this study. Sea urchin fertilization in all post-storm samples ranged from 88 to 100% of laboratory control responses, indicating a lack of statistically significant effect in both the reference drainage and ASBS discharge samples. However, samples from ASBS 25, the site that differed most from natural water quality, had no toxicity data.

DISCUSSION

Based on the data collected during this study, ASBS in southern California are consistently protective of natural water quality following storm events. On average, the range of post-storm pollutant concentrations in receiving waters sampled near ASBS discharge sites were not significantly different from post-storm concentrations at reference drainage sites, which included stormwater inputs free of (or minimally influenced by) anthropogenic sources. No conservative tracer could be used to track natural constituents such as salinity, TSS, or DOC, in large part because pollutant concentrations were so low. Furthermore, synthetic anthropogenic contaminants such as total DDT or total PCB were not detectable across the wide variety of reference drainage sample locations in ASBS, and were rarely detectable at discharge sites in ASBS. Moreover, no post-storm samples collected near ASBS discharges exhibited toxicity.

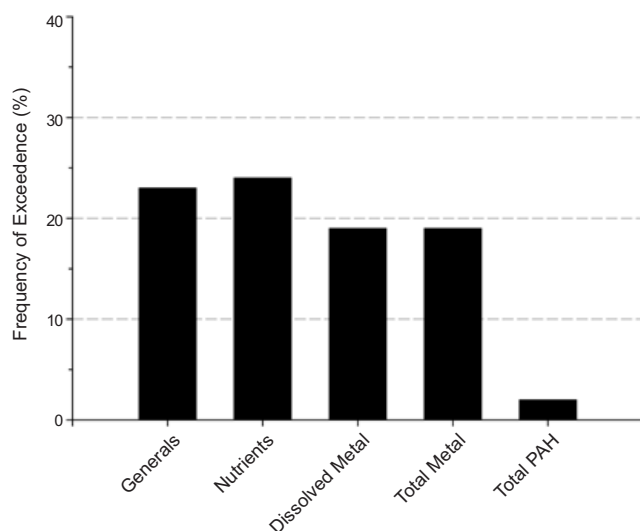


Figure 5. Frequency of reference site based thresholds exceedences by parameter group for all storm events and all Areas of Special Biological Significance (ASBS) in southern California.

Table 3. Natural water quality exceedence frequency near discharges into Areas of Special Biological Significance (ASBS) following storm events in southern California.

Parameter	Natural Water Quality		Discharge Site Comparison		
	85th Percentile of Reference Data	Units	Total No. Post-Storm Samples	Pct Samples > Reference 85th Percentile	Pct of Samples > Reference 85th Percentile and greater than Pre-Storm Concentration
Total Suspended Solids	16.5	mg/L	23	35	22
Dissolved Organic Carbon	0.80	mg/L	21	24	19
Ammonia-N	0.03	mg/L	23	30	26
Nitrate-N	0.05	mg/L	23	26	13
Nitrite-N	0.01	mg/L	23	0	0
Total Nitrogen	4.0	mg/L	21	10	5
Total Phosphorus	0.10	mg/L	23	9	9
Arsenic-Dissolved	1.48	ug/L	19	32	32
Arsenic-Total	1.9	ug/L	23	13	4
Cadmium-Dissolved	0.05	ug/L	19	21	16
Cadmium-Total	0.14	ug/L	23	26	17
Chromium-Dissolved	0.21	ug/L	19	5	5
Chromium-Total	1.6	ug/L	23	17	13
Copper-Dissolved	0.45	ug/L	19	47	42
Copper-Total	2.2	ug/L	23	26	26
Iron-Dissolved	1.7	ug/L	19	11	11
Iron-Total	813	ug/L	23	13	13
Lead-Dissolved	0.02	ug/L	19	26	21
Lead-Total	1.1	ug/L	23	13	17
Nickel-Dissolved	0.32	ug/L	19	32	26
Nickel-Total	1.5	ug/L	23	17	17
Silver-Dissolved	ND	ug/L	19	0	0
Silver-Total	0.0	ug/L	23	13	9
Zinc-Dissolved	2.88	ug/L	19	5	5
Zinc-Total	8.6	ug/L	23	30	30
TotalPAH	19.6	ug/L	23	9	9

Although ASBS on average were maintaining natural water quality, there were some individual ASBS sites that appeared to have anthropogenic contributions. ASBS 25 (Catalina Island) had an unusually large proportion of analyses that greater than reference site based thresholds. This is not wholly unexpected as this site is subject to pollutant inputs via stormwater runoff from a developed community as well as a vessel mooring field. ASBS 21 (San Nicolas Island), 32 (Newport Coast), and 33 (Heisler Park), all of which receive discharges from municipal and/or industrial (military) stormwater runoff, were the next three water quality protected areas to exceed reference site based thresholds. While no stormwater discharge information was collected just upstream of the ASBS during our storm events, other studies have identified pollutants such as nutrients and trace metals widespread in municipal (Tiefenthaler *et al.* 2008) and industrial (Lee *et al.* 2007) stormwater. Trace metals and nutrients were also two groups of constituents that had the greatest proportion of samples greater than the reference site based thresholds in this study.

The reference drainage sites in this study were used to as a proxy for establishing natural water quality thresholds. The algorithm selected for the natural water quality threshold, while not arbitrary, is not an exclusive approach to utilizing the reference drainage site information. In this case, the 85th percentile of the reference site distribution was selected as a primary threshold. Because of the similarities to the reference site data, approximately 15 percent of the ASBS discharge data distribution also exceeded this threshold. As a test of sensitivity, differing reference thresholds were used to assess the ASBS discharge site information. Regardless of whether the thresholds were empirically based (i.e., 95th percentile) or statistically based (i.e., 95th prediction interval), a concomitant decrease in ASBS discharge site difference from natural water quality followed (i.e., 5%). This once again emphasizes that, despite a few samples with high magnitude concentrations that exceeded reference site maxima, the reference and discharge data were similar in their distribution.

Turbulent mixing and advection associated with breaking waves likely plays a large role in reducing concentrations in coastal stormwater plumes. Mixing and advection were the primary forces associated with shoreline dilution of dye and bacteria near flowing storm drains in Santa Monica Bay (Clarke *et al.* 2007). In these examples, dilution fac-

tors of 10^3 to 10^6 were observed at distances of 25 m from the discharge mixing zone during dry weather. While the increased flows from dry to wet weather could overwhelm nearshore mixing and advection, wave energy also increases during storm events. Similarly detailed studies at the shoreline during wet weather have not been conducted.

The data in this study represent some of the first near-shore seawater concentrations at reference drainage sites located on the Pacific coast of the United States that are influenced by stormwater inputs. The concentrations were generally low overall with many parameters very close to, or less than, method detection limits (i.e., DDTs, PCBs, PAHs). The trace metal concentrations measured in these nearshore waters were in the same range as concentrations measured from reference freshwater streams in the southern California coastal range (Yoon and Stein 2008). However, the trace metal concentrations measured in this study were greater than typical open ocean concentrations cited by the State of California as reference conditions (Klapow and Lewis 1979) suggesting that these open ocean concentrations are not representative of near-coastal conditions.

Despite this new source of information, many data gaps remain in regards to natural water quality and these data gaps limit our ability to definitively assess water quality in ASBS. The data gaps fall into five categories. First, the reference data set that was used to derive natural water quality is limited. While this study produced one of the most complete data sets to date on ambient seawater concentrations near reference drainages during wet weather, it was only comprised of 12 site-events. Undoubtedly, this is insufficient to capture the wide range of natural conditions associated with watershed size and composition, storm size and intensity, or receiving water dynamics associated with waves and currents. Without a good grasp of natural water quality following storm events, it will be uncertain whether those ASBS discharges that were similar to reference drainage conditions actually lacked measurable anthropogenic enhancements. The second data gap is associated with those ASBS discharges that were dissimilar from reference drainage sites. While it appeared clear, even from our limited reference data set, that some ASBS discharge sites contained anthropogenic contributions, the magnitude, duration, and ultimate source of anthropogenic contributions, the thresholds we evaluated are not currently regulatory compliance measures. Additional infor-

mation on the magnitude and duration of anthropogenic contributions is crucial before state regulators or regulated ASBS managers can rank or prioritize discharges for remediation. The third data gap addresses sources of anthropogenic inputs to ASBS discharges. Sites that appeared dissimilar from natural water quality may be attributable to non-anthropogenic site-specific causes (i.e., marine mammal defecation of nutrients). Alternatively, large unmonitored anthropogenic sources outside of the ASBS may be transported into the ASBS. This gap is best addressed through follow-on site-specific investigations. The fourth data gap addresses all of the non-sampled ASBS discharges. Only 10 ASBS discharges were targeted in this study and, while these may have been the largest and perceived greatest risk to the ASBS, they are only a small fraction of the 271 discharges to the southern California ASBS. The last data gap to evaluate for natural water quality is non-water quality threats. Risks posed by poaching, trampling, or invasive species are equally, or perhaps even more, threatening to the health of ASBS. To compliment this chemical and toxicity testing effort, the State of California and stakeholders are currently addressing this data gap by conducting intertidal and subtidal biological surveys of ASBS.

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