South Coast Areas of Special Biological Significance Regional Monitoring Program Year 2 Results

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Southern California Coastal Water Research Project

SCCWRP Technical Report 852

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EXECUTIVE SUMMARY

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? Previous monitoring of southern California ASBS in 2008-09 was able to produce natural water quality guidelines, and ASBS water quality was generally comparable to these guidelines without widespread, dramatic alterations. The work detailed in this report, describes a second survey in 2012-14, which aims to increase confidence in the natural water quality guidelines and confirm the lack of demonstrative impacts to water quality in ASBS.

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. Twenty-seven locations encompassing 57 site-events were sampled immediately prior to (<48 hours), then immediately following (<24 hours) storm events ranging from 0.09 to 2.58 inches rainfall. Mean concentrations of total suspended solids (TSS), nutrients (ammonia, nitrate, nitrite, total phosphorus), total trace metals (arsenic, cadmium, chromium, copper, nickel, lead, silver, and zinc), pyrethroid and organophosphorus pesticides, 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 was <10%. Concentrations of pesticides were infrequent and post-storm samples rarely exhibited significant toxicity despite testing with three different endemic species. 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, duration, intensity) or stormwater tracers (i.e., salinity, TSS), decreasing the utility of these tools for predicting impacts. A reference drainage site 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. 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 PAHs, pesticides, and nutrients.

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INTRODUCTION

Environmental managers face a tremendous challenge trying to maintain water quality in the face of urban development. Nowhere is this more apparent than in southern California. Population in the three coastal counties has increased from roughly 10 million in 1970 to 24 million in 2010; an increase of 140% in just 40 years (US Census 2009). Along with this increase in urban development, are commensurate increases in habitat loss, flow modification, and pollutant inputs from surface runoff (Lyon and Stein 2009, Schiff and Sutula 2004, Tiefenthaler *et al.* 2008).

In the early to mid-1970's, perhaps in anticipation of the urbanizing coastline, the State Water Resources Control Board (SWRCB) created a series of water quality protected areas, termed Areas of Special Biological Significance (ASBS). The language in the SWRCB's Ocean Plan (2010) states that ASBS shall not have any "discharge of waste" and shall maintain "natural water quality". There are 14 ASBS in southern California covering approximately 280 km of shoreline in southern California (Figure 1).

Since the mid-1970's, the SWRCB has effectively prevented the construction of treated municipal or industrial wastewater outfalls in ASBS. However, there are at least 271 storm drain outfalls that discharge to ASBS (SCCWRP 2003). These storm drain outfalls likely discharge natural constituents (i.e., suspended solids, nutrients or trace metals) as well as the possibility of anthropogenic pollutant contributions of these natural constituents and some human synthesized pollutants (i.e., pesticides).

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? 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.

In 2008-09, the dischargers to ASBS in southern California and their state regulators collaborated on a first-of-its-kind regional monitoring program in an attempt to answer these questions (Schiff *et al.* 2011). After collecting 35 storm-event samples in the ocean from Malibu to San Diego, the water quality measured in ASBS receiving water near storm drain discharges was similar to the water quality at reference locations. However, one of the primary limitations from that study was a concern that the data set was too sparse. The regional monitoring collaborative recommended collecting additional data to capture the range of variability inherent between storms, between wet seasons, and between additional sites. The goal of this study fulfills these recommendations, collecting additional storms to quantify the range of variability from reference locations and near ASBS discharges, and to confirm that water quality in ASBS is being protected.

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.

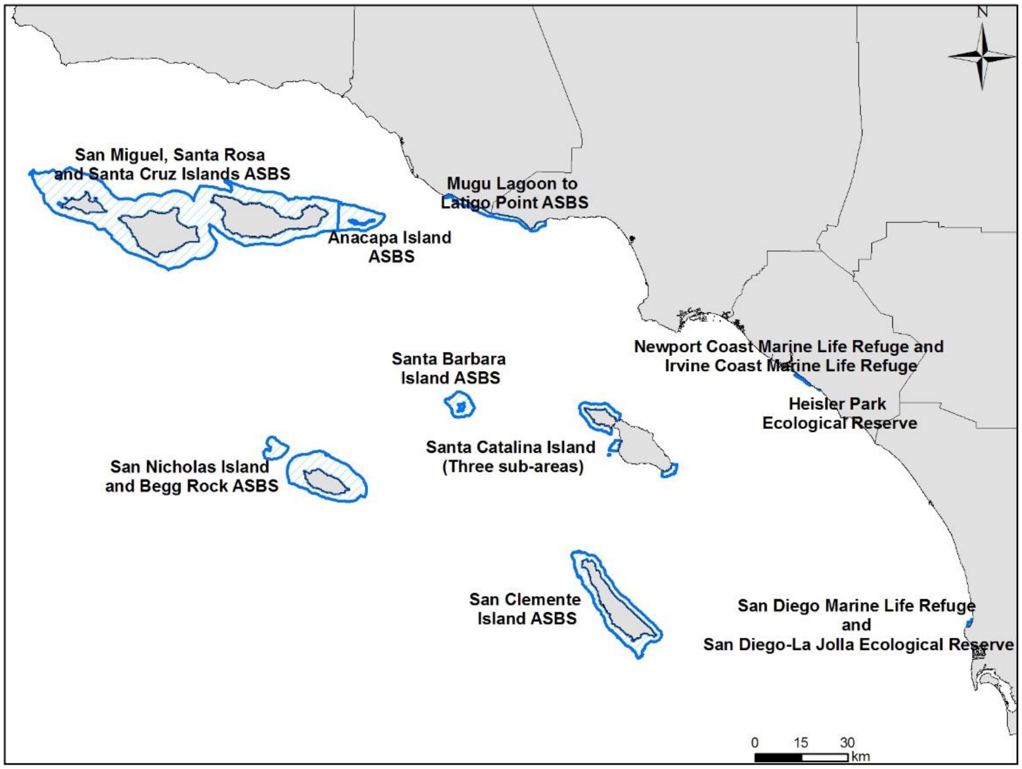

Figure 1. Southern California Areas of Special Biological Significance.

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 a focus on wet weather. Dry weather was not addressed in this study assuming that all non-storm discharges are, or soon will be, remediated.

Sampling

Twenty-seven sites were selected for wet weather sampling in this study (Table 1). Fourteen of the sampling locations were reference drainage sites (representing natural water quality) and 13 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 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.

Table 1. Sampling sites and sample inventory.

ASBS Number	ASBS Name	Site Name (Survey year, if changed between years)	Latitude	Longitude	Reference or Discharge	Number Pre-Storm Samples	Number Post-Storm Samples
21	San Nicolas Island	North end of San Nicholas Island (2013)	33.26797	-119.5	Reference	2	3
21	San Nicolas Island	North end of San Nicholas Island (2014)	33.27969	-119.52117	Reference	1	1
21	San Nicolas Island	San Nicolas Island (2008/2009)	37.26600	-119.49828	Reference	2	2
21	San Nicolas Island	Barge Landing	33.21961	-119.44736	Discharge	3	3
23	San Clemente Island	San Clemente Island (2013/14)	32.98083	-118.53815	Reference	1	1
23	San Clemente Island	San Clemente Island (2008/09)	32.98083	-118.53815	Reference	1	1
23	San Clemente Island	San Clemente Island (Outfall 30)	33.0049	-118.5569	Discharge	2	3
24	Laguna Pt to Latigo Pt	Broad Beach	34.0331	-118.851	Discharge	1	1
24	Laguna Pt to Latigo Pt	Deer Creek	34.0622	-118.986	Reference	2	2
24	Laguna Pt to Latigo Pt	Escondido Beach	34.0256	-118.76	Discharge	3	3
24	Laguna Pt to Latigo Pt	MUG283RW (7-369)	34.0249	-118.766	Discharge	1	1
24	Laguna Pt to Latigo Pt	Nicholas Canyon (2013/14)	34.0423	-118.915	Reference	2	2
24	Laguna Pt to Latigo Pt	Nicholas Canyon (2008/09)	34.04172	-118.91574	Reference	3	3
24	Laguna Pt to Latigo Pt	Zuma Beach	34.019	-118.828	Discharge	3	1
25	NW Santa Catalina Island	Catalina Express Pier (TH1-SW)	33.4418	-118.498	Discharge	2	2
28	SE Santa Catalina Island	Connolly Pacific	33.3178	-118.303	Discharge	3	3
29	La Jolla	Avenida De La Playa (SDL062)	32.8549	-117.26	Discharge	3	3
30	Heisler Park	Heisler Pk	33.3235	-117.472	Discharge	3	3
31	San Diego-Scripps	SIO Headwall (OF002)	32.8656	-117.254	Discharge	3	3
32	Robert E. Badham	Shorecliffs (NEW018OP)	33.5885	-117.868	Discharge	3	3
33	Irvine Coast/Crystal Cove	El Morro Canyon (2013/14)	33.5608	-117.822	Reference	3	3
33	Irvine Coast/Crystal Cove	El Morro Canyon (2008/09)	33.56033	-117.82205	Reference	3	3
33	Irvine Coast/Crystal Cove	Irvine Coast (12-351)	33.5642	-117.829	Discharge	1	1
-	-	Goat Harbor, Catalina Island	33.4162	-118.395	Reference	2	2
-	-	Italian Gardens, Catalina Island (2013/14)	33.4097	-118.382	Reference	2	2
-	-	Italian Gardens, Catalina Island (2009)	33.41011	-118.38176	Reference	1	1
-	-	San Onofre Creek	33.38056	-117.57722	Reference	1	1
		Total No. Reference Site-Events				**26**	**27**
		Total No. Discharge Site-Events				**33**	**30**
		Total No. Site-Events				**59**	**57**

A total of 57 site-events were sampled (Table 1). Twenty-seven site-events were sampled near reference drainage locations, and another 30 site-events were sampled near ASBS discharge locations. Up to three storm events were sampled 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 0.09 to 2.58 inches. Pre-storm samples were collected prior to (<48 hours) rainfall, and post-storm samples were collected immediately following (<24 hours) rainfall, with most post-storm samples collected less than 6 hours after rainfall cessation. All post-storm samples 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 filling pre-cleaned intermediate container just below the water surface and then pouring sequential aliquotes into sample containers to ensure homogeneity.

Laboratory Analysis

All water samples were analyzed for 18 parameters: 1) general constituents including total suspended solids (TSS), oil and grease, and salinity; 2) nutrients including nitrate (NO3-N), ammonia (NH3-N), and ortho-phophate (PO4-P); 3) total [unfiltered] trace metals (arsenic, cadmium, chromium, copper, mercury, nickel, lead, selenium, silver, zinc); 3) pyrethroid (8 pyrethroids) and organophosphorus (2 OPs) pesticides; 4) total polycyclic aromatic hydrocarbons (28 PAHs); and 5) three different short-term chronic toxicity tests using endemic species (successful egg fertilization of purple sea urchin *Strongylocentrotus purpuratus*, normal germination and tube growth using the giant kelp *Macrocycstis pyrifera*, and normal growth and development of the California mussel *Mytilus californianus*). All sample analysis followed standard methods and/or EPA approved procedures (APHA 2006, USEPA 1995). Trace metals were prepared for analysis using ammonium pyrrolidine dithiocarbamate (APDC), a chelation method that concentrates trace metals and removes matrix interferences (USEPA 1996).

The project focused on performance-based measures of quality assurance. In general, laboratory data quality was quite good: 100% sample completeness, no laboratory blank samples were greater than the method detection limit; 90% success meeting data quality objectives (DQOs) for precision using laboratory duplicates; 96% success meeting DQOs for accuracy using spiked samples. All toxicity tests indicated 100% success meeting DQOs for negative and positive control response.

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., synthetic pesticides such as pyrethroids and fipronyl), 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, TSS and salinity concentrations were correlated with all of the post-storm chemical concentrations. For the final data analysis, a reference site based threshold was used as a proxy for distinguishing differences from natural water quality (Table 2). 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.

Table 2. Reference drainage site based thresholds (85th percentile of reference drainage site distribution) used as proxies of natural water quality in south coast areas of special biological significance.

Analyte	Reference Drainage Site Thresholds (85th Percentile)
Ammonia as N (mg/L)	0.015
Nitrate as N (mg/L)	0.34
Oil and Grease (mg/L)	0.5
Orthophosphate as P (mg/L)	0.10
Total Suspended Solids (mg/L)	48
Arsenic (µg/L)	1.8
Cadmium (µg/L)	0.15
Chromium (µg/L)	1.9
Copper (µg/L)	1.5
Lead (µg/L)	0.5
Mercury (µg/L)	0.0006
Nickel (µg/L)	1.3
Selenium (µg/L)	0.0025
Silver (µg/L)	0.08
Zinc (µg/L)	18.6
Total PAHs (µg/L)	0.0125
Total Organophosphorus pesticides (µg/L)	0.006
Total Pyrethroid pesticides (µg/L)	0.00675

Minimum detection limits for each compound are listed in Appendix B. For all calculations, one-half the detection limit was used when samples were non-detectable. Organic analyses flagged as quantifiable estimates below the reporting level, but above the detection limit, were used as reported.

RESULTS

There was a wide range of rainfall characteristics of the storms sampled across the Southern California region during the 2013-14 study year (Table 3). Storm rainfall totals ranged from 0.09 to 2.58 inches per storm event, with an event median of 0.16 inches. The greatest rainfall generally occurred in the north. For example, Malibu had triple the amount of rain measured at San Onofre on March 1, 2014 (2.58 vs. 0.91 inches) and double the amount of rain measured at Laguna on February 27, 2014 (0.79 vs. 0.32 inches). Storm rainfall intensity ranged from 0.06 to 0.66 inches per hour, with a median of 0.16. In general, the islands tended to have the least intense rainfall, never exceeding 0.27 inches per hour and the majority of storm events less than 0.11 inches per hour. Storm durations ranged from 2.9 to 50 hours, with a median of 9.4 hours. Except for Laguna, every site had at least one storm that exceeded 20 hours.

Table 3. Rainfall by region within southern California.

Region	Sampling Dates	Maximum Intensity (inches/hr)	Storm Total (inches)	Storm Duration (hr)
Malibu	2/19/2013	0.14	0.20	2.9
	3/8/2013	0.20	0.33	33.3
	2/27/2014	0.28	0.79	8.7
	3/1/2014	0.53	2.58	20.0
Laguna	2/19/2013	0.66	0.30	11.5
	3/8/2013	0.64	0.36	3.6
	2/27/2014	0.29	0.32	4.0
San Onofre	3/1/2014	0.15	0.91	50.0
La Jolla	1/25/2013	0.10	0.43	22.3
	2/8/2013	0.11	0.19	6.5
	2/20/2013	0.16	0.37	8.5
Catalina Island	2/20/2013	0.11	0.20	4.0
	3/8/2013	0.11	0.17	4.1
	2/28/2014	0.27	1.08	32.8
San Nicolas Island	1/25/2013	0.06	0.33	32.0
	2/20/2013	0.07	0.09	8.0
	3/8/2013	0.13	0.22	8.0
	2/28/2014	0.25	0.41	10.0
San Clemente Island	1/25/2013	0.07	0.21	26.2
	2/28/2014	0.17	0.91	32.0
	Min	0.06	0.17	2.9
	Max	0.66	2.58	50.0
	Median	0.16	0.33	9.4

Post-storm reference drainage site concentrations were similar to post-storm ASBS discharge site concentrations (Table 4). For 18 parameters (including TSS, nutrients, total PAH, total pyrethroids, and total trace metals), none were significantly different between reference and discharge sites following storm events ($p < 0.05$). No constituent differed by more than an order of magnitude between mean reference and discharge site concentration; half of the constituents differed by less than a factor of two. The two largest differences were for mercury, where 95% of all samples were below detection limits and TSS, which had roughly three times greater concentration at reference drainage sites than ASBS discharge sites.

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Table 4. Summary statistics for regional monitoring of southern California Areas of Special Biological Significance.

Analyte	Reference					Discharge				
	% Non-detects	Minimum	Maximum	Median	Mean	% Non-detects	Minimum	Maximum	Median	Mean
General (mg/L)										
Ammonia as N	85	0.01	0.38	0.010	0.03	80	0.010	0.13	0.010	0.026
Nitrate as N	59	0.01	0.84	0.005	0.13	30	0.005	3.0	0.19	0.37
Oil and Grease	94	0.50	1.60	0.50	0.56	90	0.50	1.3	0.50	0.58
Ortho-Phosphate as P	53	0.01	1.00	0.005	0.09	48	0.005	0.2	0.03	0.04
TSS	11	0.25	1692	7.70	132.7	3	0.25	680	12.0	45.6
Metals (µg/L)										
Arsenic	4	0.0025	14.08	1.49	2.00	3	0.003	4.1	1.5	1.6
Cadmium	4	0.0013	0.95	0.030	0.10	3	0.0013	0.36	0.02	0.06
Chromium	7	0.0063	30.55	0.37	2.25	7	0.006	5.0	0.52	0.93
Copper	4	0.0025	63.99	0.44	3.28	3	0.003	21.1	0.60	1.9
Lead	11	0.0013	71.26	0.08	3.14	3	0.0013	4.0	0.19	0.4
Mercury	100	0.0006	0.0006	0.0006	0.0006	90	0.0005	0.026	0.0006	0.002
Nickel	4	0.0013	15.84	0.44	1.76	3	0.0013	4.3	0.43	0.79
Selenium	76	0.0025	0.89	0.0025	0.06	57	0.003	0.155	0.0025	0.026
Silver	52	0.0050	0.13	0.0100	0.04	67	0.005	0.18	0.005	0.03
Zinc	7	0.0013	129.3	1.92	10.28	3	0.0013	79.6	6.6	13.5
Organics (µg/L)										
Organophosphate	100	0.0015	0.006	0.006	0.004	100	0.0005	0.136	0.006	0.011
PAH	77	0.011	1.85	0.013	0.09	77	0.007	1.96	0.013	0.12
Pyrethroid	100	0.007	0.007	0.007	0.01	90	0.007	0.058	0.007	0.010

In general, there was no consistent increase or decrease in concentrations pre- to post-storm at reference drainage or ASBS discharge sites (Figure 2). Pre:Post-storm concentration 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, with over 75% of the ASBS discharge site distribution greater than 1. This would indicate that receiving water concentrations of copper increased following storm events. However, the maximum pre:post storm ratio at reference drainage sites was greater than the ratio at ASBS discharge sites.

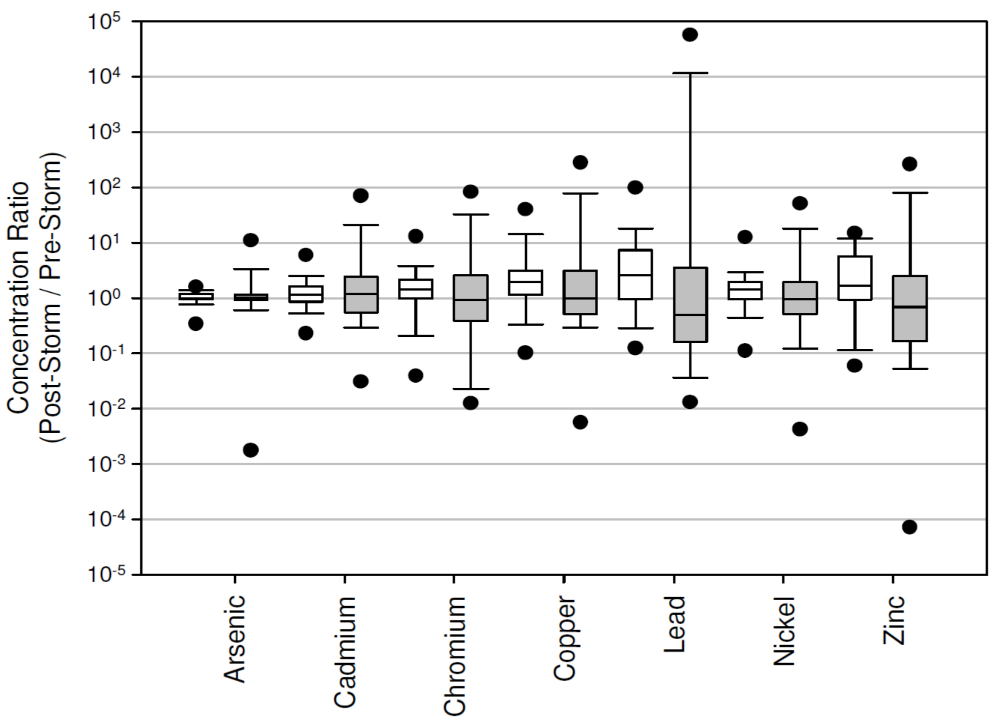

Figure 2. Box plot of pre/post-storm concentrations at reference drainage (grey) and ASBS discharge (white) sites for total trace metals.

Most relationships of discharge post-storm concentrations with storm characteristics were poor (Table 5). Correlation coefficients of constituent concentrations with storm characteristics were generally low and most were non-significant. No significant correlation was observed between storm duration and receiving water concentration. Three of 16 constituents had significant relationships with rainfall quantity, with correlation coefficients ranging from -0.37 to 0.40. Zinc concentrations increased with increasing rainfall, while nitrate and oil and grease had decreased with increasing rainfall. Eight of 16 constituents had significant relationships between constituent concentration and rainfall intensity. While most significantly correlated constituents had positive relationships with rainfall intensity, correlation coefficients ranged from -0.39 to 0.61.

Table 5. Relationships (correlation r-values) between storm characteristics or conservative tracers [salinity and total suspended solids (TSS)] and pollution concentrations at southern California discharge sites. Bold values are significant (p <0.05).

Analyte	Average Intensity	Storm Rainfall	Storm Duration	Salinity	TSS
TSS	0.12	0.07	0.10	-0.24	
Ammonia as N	-0.22	0.05	0.15	-0.14	-0.12
Nitrate as N	-0.01	**-0.37**	-0.19	0.05	0.18
Oil and Grease	**-0.39**	**-0.40**	-0.09	0.01	0.28
Ortho-Phosphate as P	0.33	0.26	0.19	0.03	0.20
Arsenic	0.12	0.14	0.07	-0.28	0.20
Cadmium	**0.61**	0.11	-0.14	0.03	**0.50**
Chromium	**0.39**	0.28	0.00	-0.24	0.25
Copper	**0.49**	0.18	0.17	-0.13	**0.43**
Lead	0.23	0.17	0.13	-0.15	**0.42**
Mercury	-0.08	0.17	0.26	0.22	0.34
Nickel	**0.38**	0.25	0.05	-0.13	**0.54**
Selenium	**0.50**	0.24	0.01	-0.01	**0.48**
Silver	0.05	0.30	0.28	0.27	0.01
Zinc	**0.40**	**0.42**	0.18	0.21	0.19
Organophosphate	0.07	-0.24	-0.09	**0.38**	0.09
PAH	0.00	-0.29	-0.09	**0.47**	0.21
Pyrethroid	**0.38**	-0.02	-0.13	0.09	0.05

Salinity, a conservative marker of freshwater inputs, was not well correlated with constituent concentrations. Only organophosphorus pesticides and PAHs were significantly correlated, but both relationships were positive indicating runoff plumes were not the source of these constituents. Perhaps the strongest and most consistently correlated parameters were between TSS and constituent concentrations, particularly for trace metals that ranged from 0.44 to 0.54

Exceedance of reference drainage site based thresholds ranged from 35 to 32% of all analyses at each ASBS (Figure 3). ASBS 32 (Robert Badham) had the greatest proportion of analyses that were greater than reference site based thresholds (33% of all analyses). ASBS 31 (San Diego-Scripps) had the smallest proportion of analyses that were greater than reference site based thresholds (3% of all analyses). Cumulatively across all ASBS, 14% of all analyses were greater than reference site based thresholds.

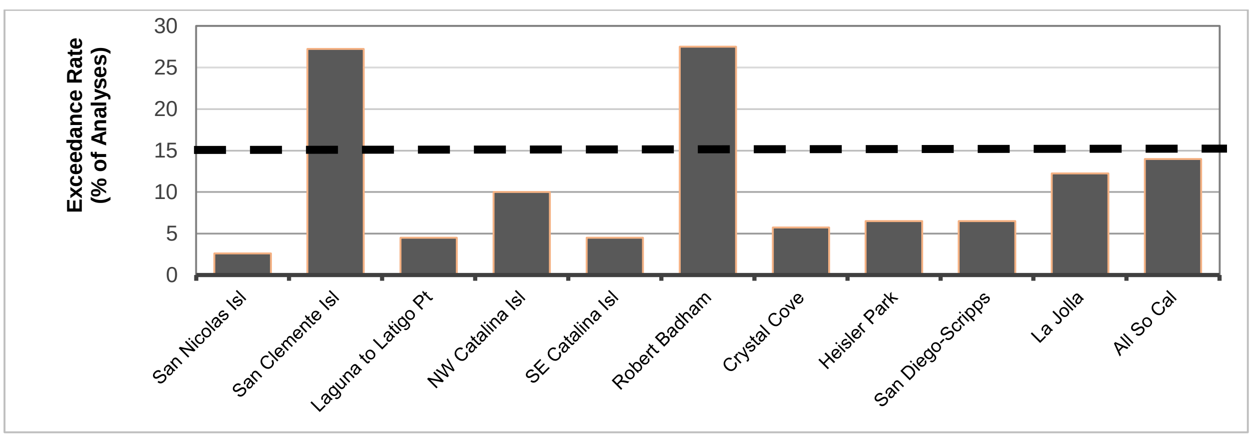

Figure 3. Exceedance of reference site based thresholds by ASBS. The 15% reference line is the expected exceedance rate for reference sites.

There were relatively minor differences in exceedance rate among constituent types (Figure 4). Total PAH (19% of all analyses) and nutrients (17% of all analyses) exceeded reference site based thresholds most frequently. TSS exceeded reference site based thresholds least frequently (10% of all analyses). Significant toxicity was rarely observed during this study. No toxicity was observed with either the mussel embryo development or sea urchin fertilization tests. Only three ASBS discharge samples exhibited toxicity utilizing the kelp germination and growth test, and none of these appeared correlated with maximum contaminant concentrations (see Appendix A).

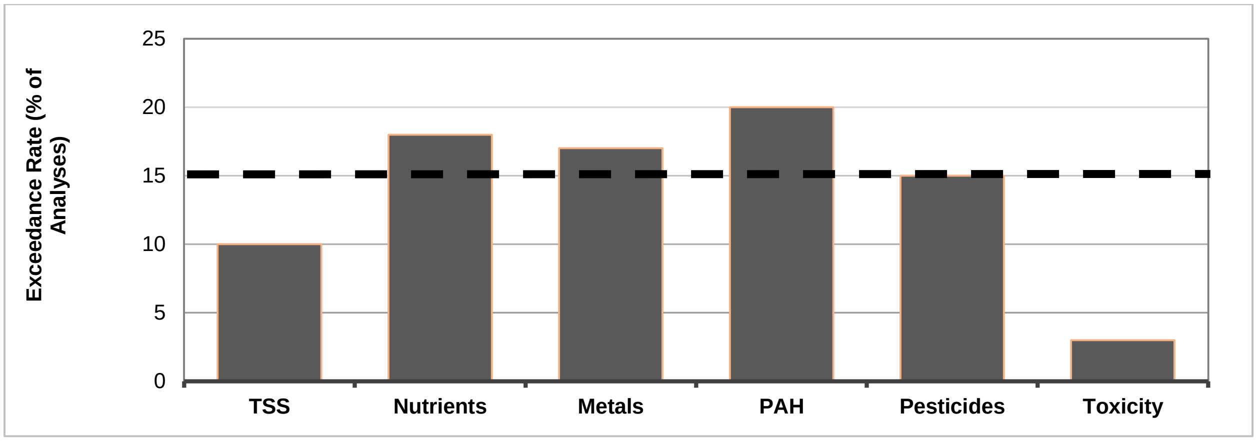

Figure 4. Exceedance of reference site based thresholds by parameter group. The 15% reference line is the expected exceedance rate for reference sites.

DISCUSSION

Based on the data reported in this study, water quality in southern California ASBS was generally comparable to 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. When comparing cutpoint exceedances, which focused on the 85th percentile of the reference site distribution, the southern California ASBS discharge sites cumulatively exceeded these thresholds 14% of the time for all chemical and toxicological analysis. This is similar to the 15% expected from a reference drainage site distribution (e.g., inverse of the 85th percentile). Moreover, few relationships with storm characteristics such as rainfall quantity, or with conservative tracers in the receiving water such as salinity or TSS, were observed in large part because pollutant concentrations were so low. Furthermore, synthetic anthropogenic contaminants such as organophosphorus and pyrethroid pesticides were not detectable across the wide variety of reference drainage sample locations in ASBS, and were infrequently detectable at discharge sites in ASBS. Moreover, toxicity in post-storm samples collected near ASBS discharges was rare even though multiple species were tested.

Although ASBS on average were maintaining natural water quality, there were some individual ASBS sites that appeared to have anthropogenic contributions. ASBS 32 (Robert Badham) had an unusually large proportion of analyses that were greater than reference site based thresholds. This site recently had a large structural BMP installed to help reduce constituent concentrations including a large infiltration gallery and a small restoration project near the terminus of the discharge. As a result, samples collected from the discharge to the ASBS during storm events should be examined to assess the potential for local and direct stormwater discharges to cause or contribute to the exceedances of reference site thresholds. These results should also be compared to other nearby sources that could be impacting the ASBS. For example, a recent study identified that this site potentially receives influence from the nearby Newport Harbor (Rogowski *et al.* 2014), which includes several 303d listed waterbodies. However, Newport Harbor does not discharge directly to ASBS 32 and is not subject to ASBS Special Protection regulatory requirements.

Supplementary studies examining bioaccumulation have largely supported the finding that natural water quality is being supported in southern California ASBS (Dodder *et al.* 2014). Bioaccumulation measurements were taken in mussels (*Mytilus californianus*), often considered a sentinel organism by state and federal agencies (Sericano *et al.* 1995, O'Connor 1998). Samples were collected at reference sites (to generate reference based thresholds similar to the water column sampling study design) and then compared to mussels collected near ASBS discharges. The results indicated that the number and magnitude of reference threshold exceedances were quite small. Interestingly, only San Clemente Island exceeded reference drainage site bioaccumulation and water column chemistry thresholds. This site drains a naval installation with limited development including municipal and industrial land uses, and exceeded reference based thresholds for several contaminants in mussel tissues. The exceedances could be a result of runoff from these land-based activities, or they could be associated with local geology associated with naturally high levels of metals (Weigand 1994). Repeated mussel sampling is being conducted at San Clemente Island to confirm these results.

Supplementary studies examining biodiversity have also supported the general finding that natural water quality is being supported in southern California ASBS (Raimondi *et al.* 2014). Similar in study design to the water column and tissue chemistry, rocky intertidal habitats were quantitatively surveyed near reference and ASBS discharges following the wet season. Results indicated that these biological communities, which are perhaps the habitat most at risk from direct storm drain discharges, were largely similar to reference site communities. Where sites near ASBS discharges did appear to be different from reference sites, resampling has indicated that these differences are relatively short-lived.

This study in 2012-14 was not the first regional survey of water concentrations in ASBS of southern California. The previous regional survey in 2008-09 listed several recommendations that the current study has addressed (Schiff *et al.* 2011). The primary recommendation was to increase sample size to confirm and provide greater confidence in the reference-based thresholds. Interestingly, reference-based thresholds changed little even though the sample size more than doubled, and included new sites and a wider range of storm conditions. The second recommendation from 2008-09 was to better define the extent and magnitude of exceedances at ASBS discharge locations. In 2008-09, the cumulative exceedance rate was 15% of all chemical and toxicological analysis. In 2012-14, the same cumulative exceedance rate was 14%. The similarities of these results, separated by five years, should provide managers with added confidence for making environmental decisions.

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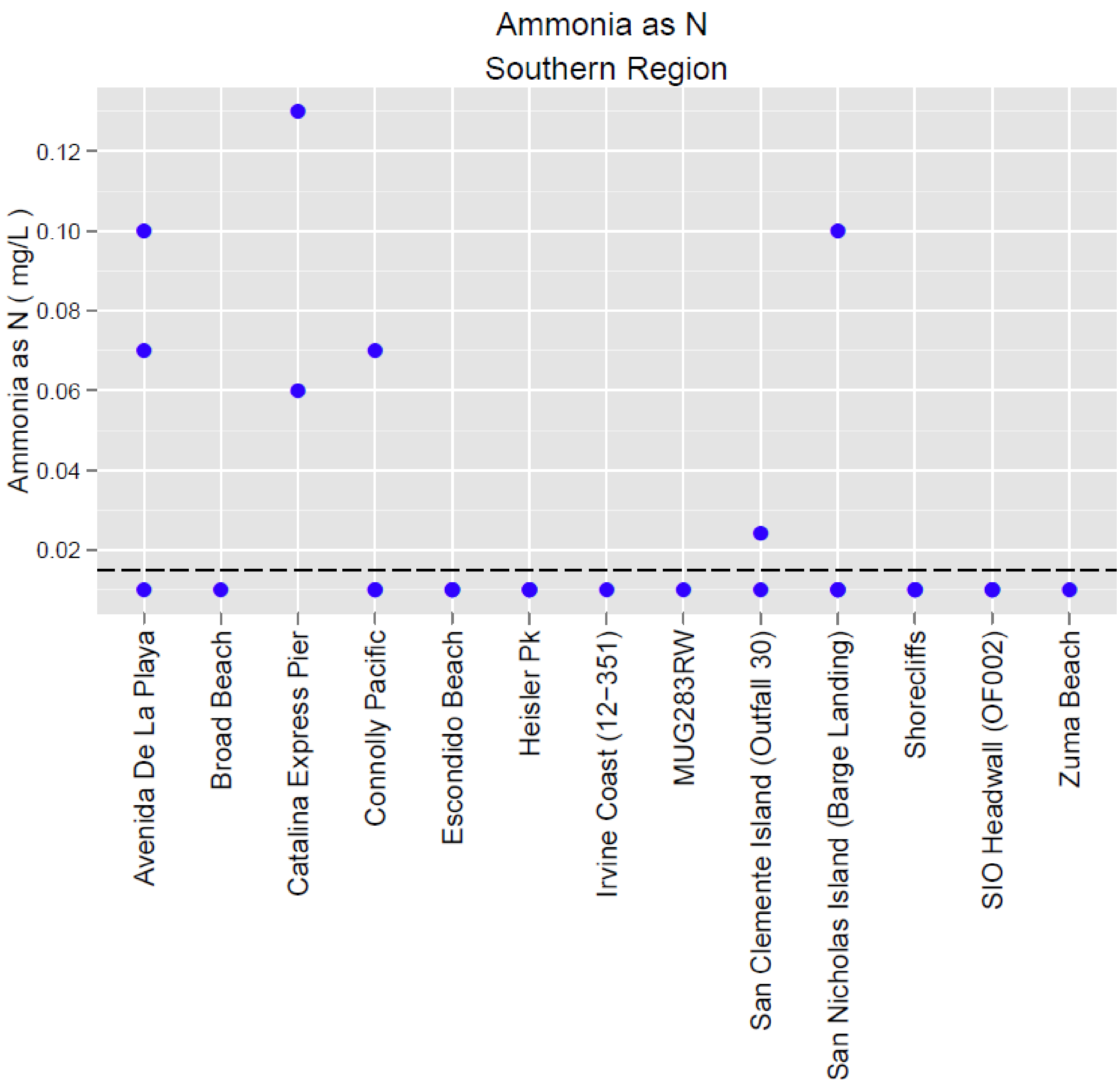
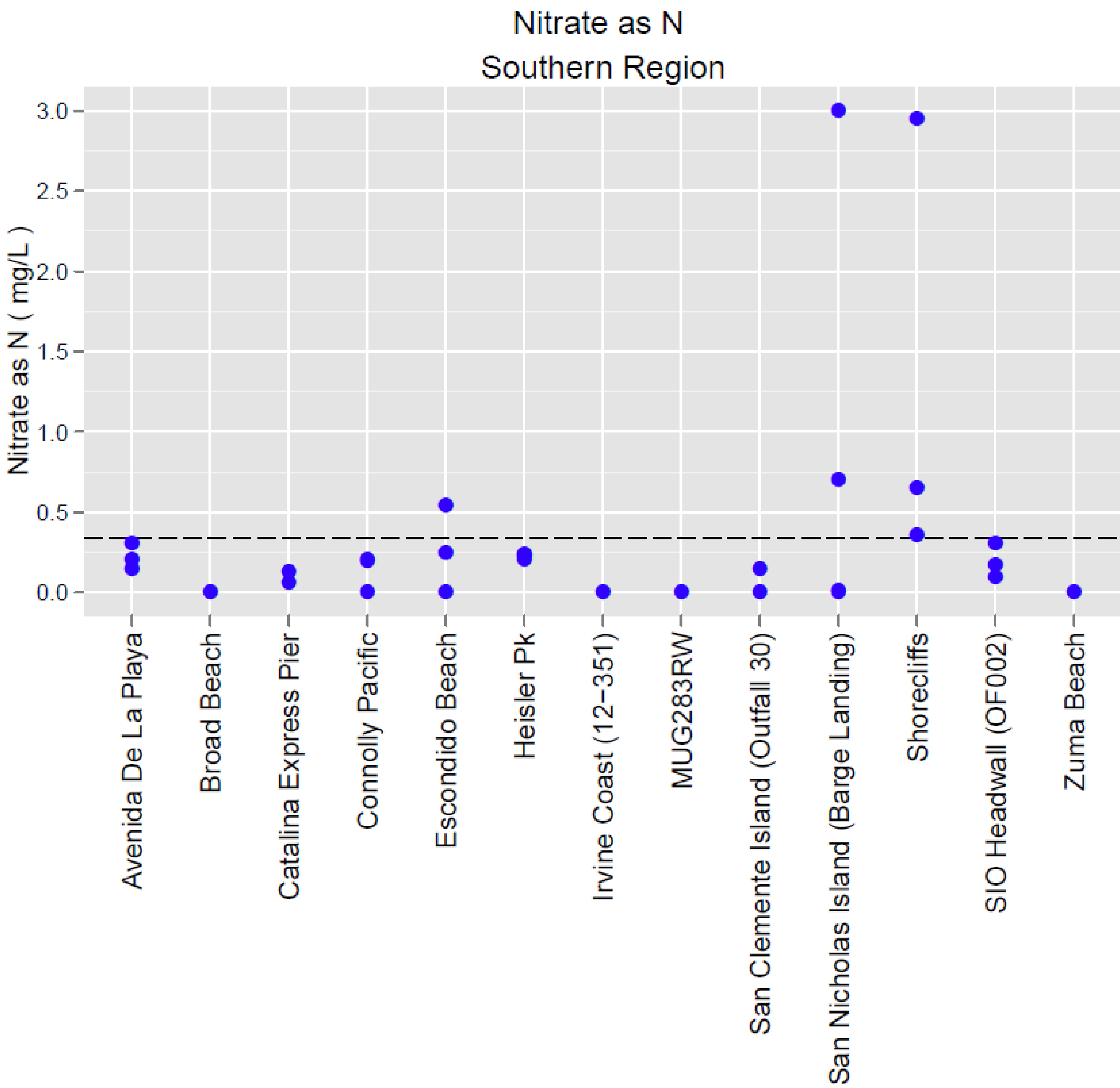
APPENDIX A – POST-STORM CONCENTRATION PLOTS FOR SOUTHERN REGION ASBS AT DISCHARGE RECEIVING WATER SITES

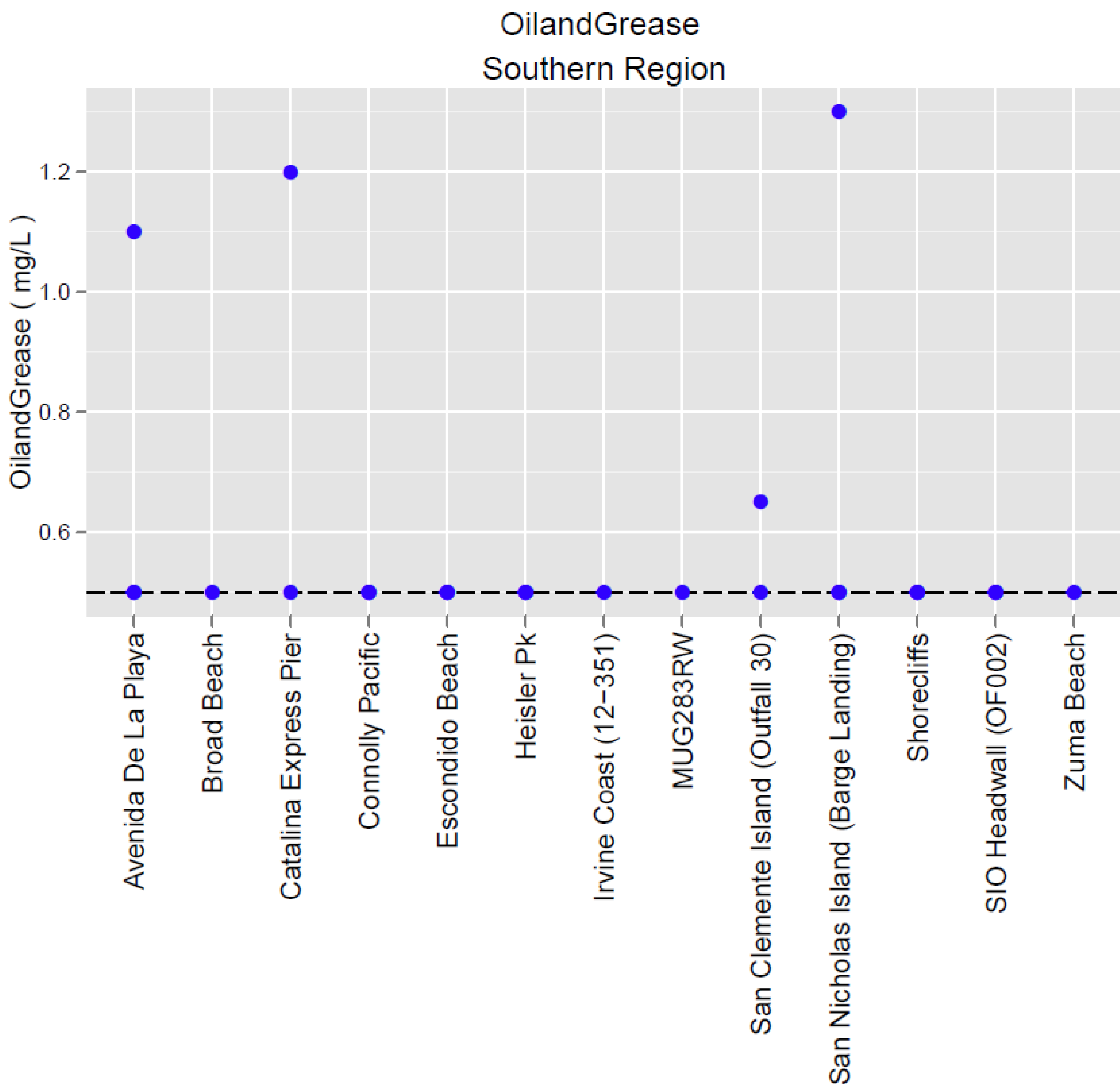


Ammonia as N
Southern Region
Ammonia as N (mg/L)
0.12
0.10
0.08
0.06
0.04
0.02
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

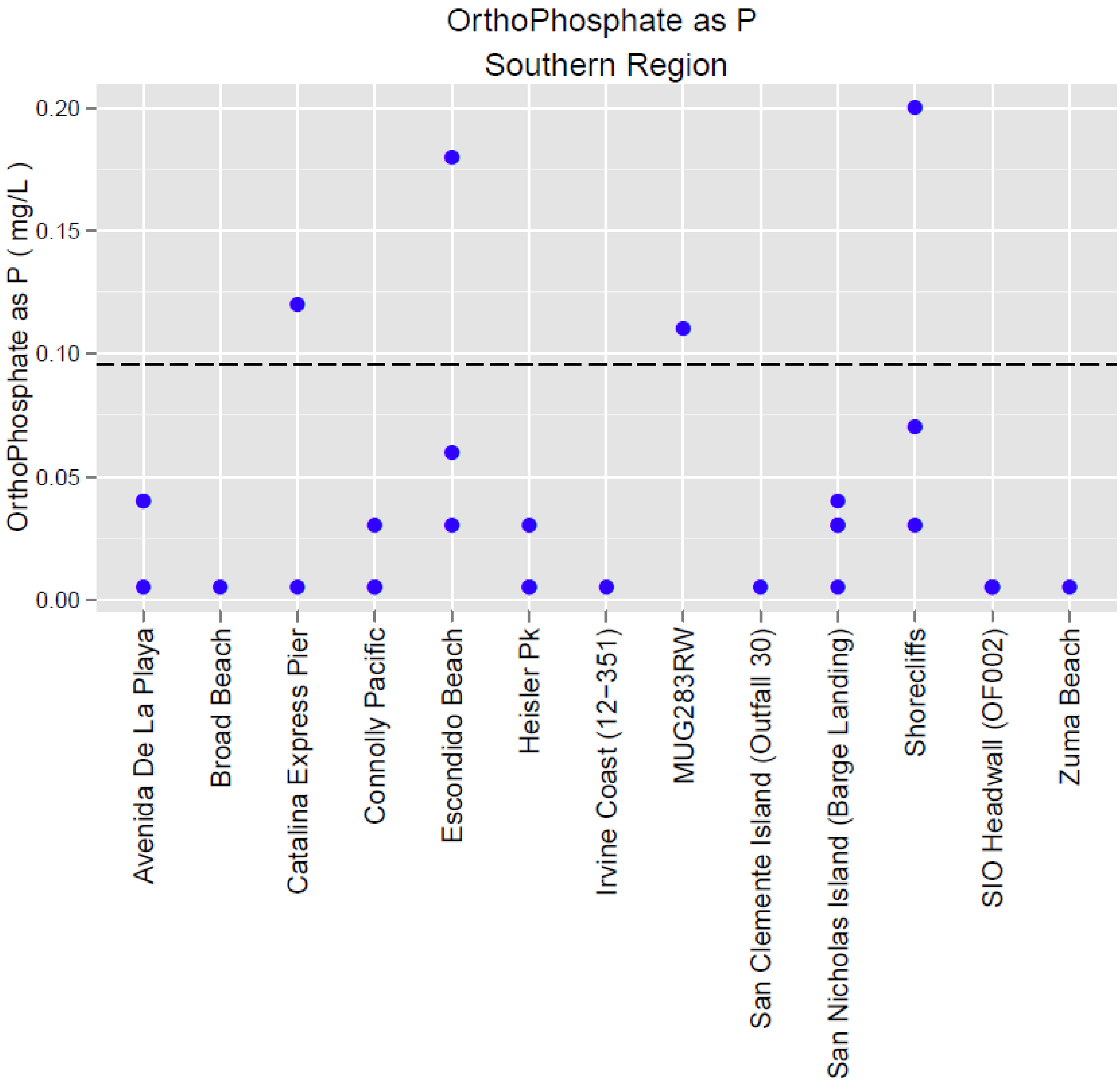
Ammonia as N


Nitrate as N
Southern Region
Nitrate as N (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

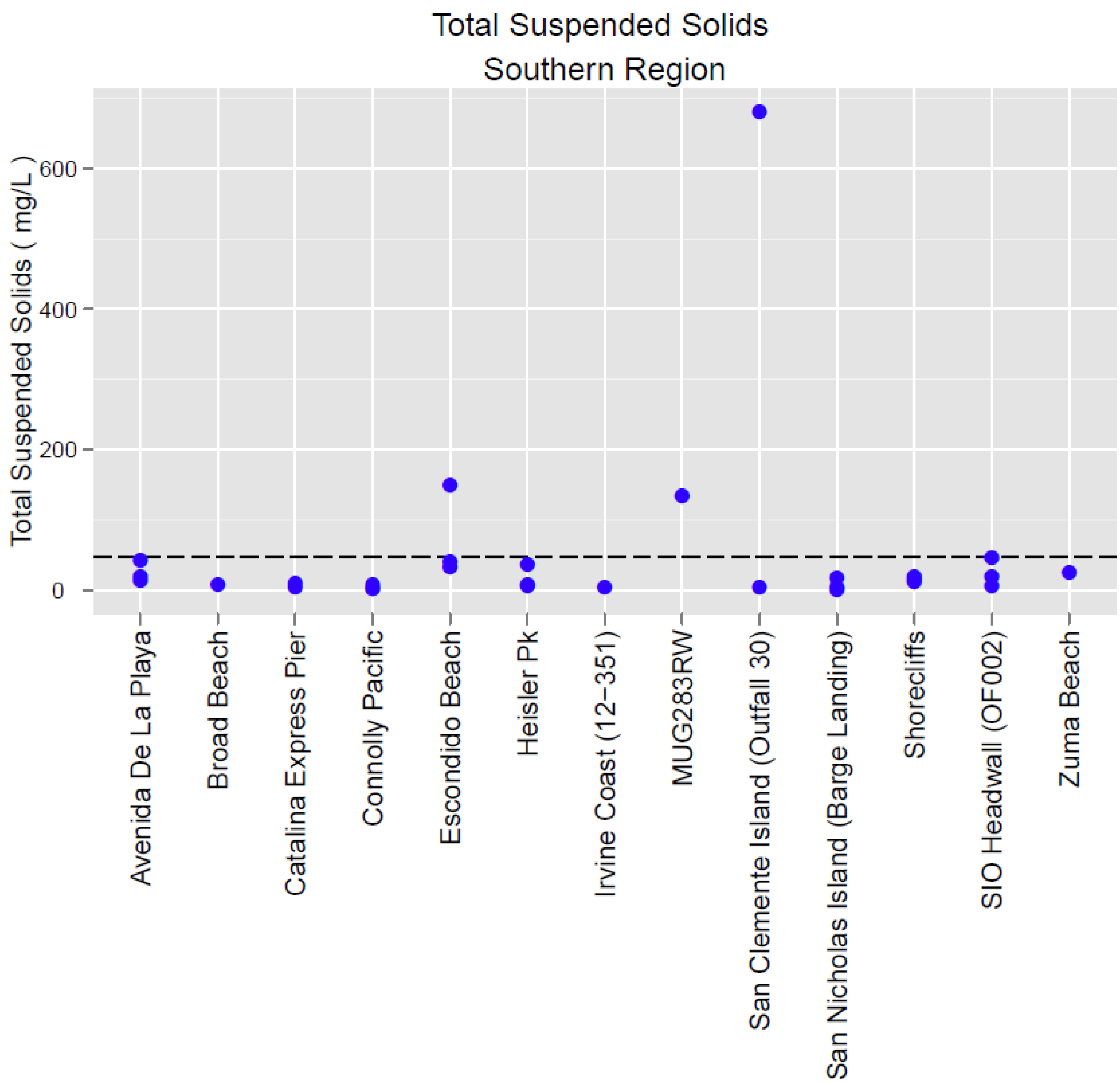
Nitrate as N



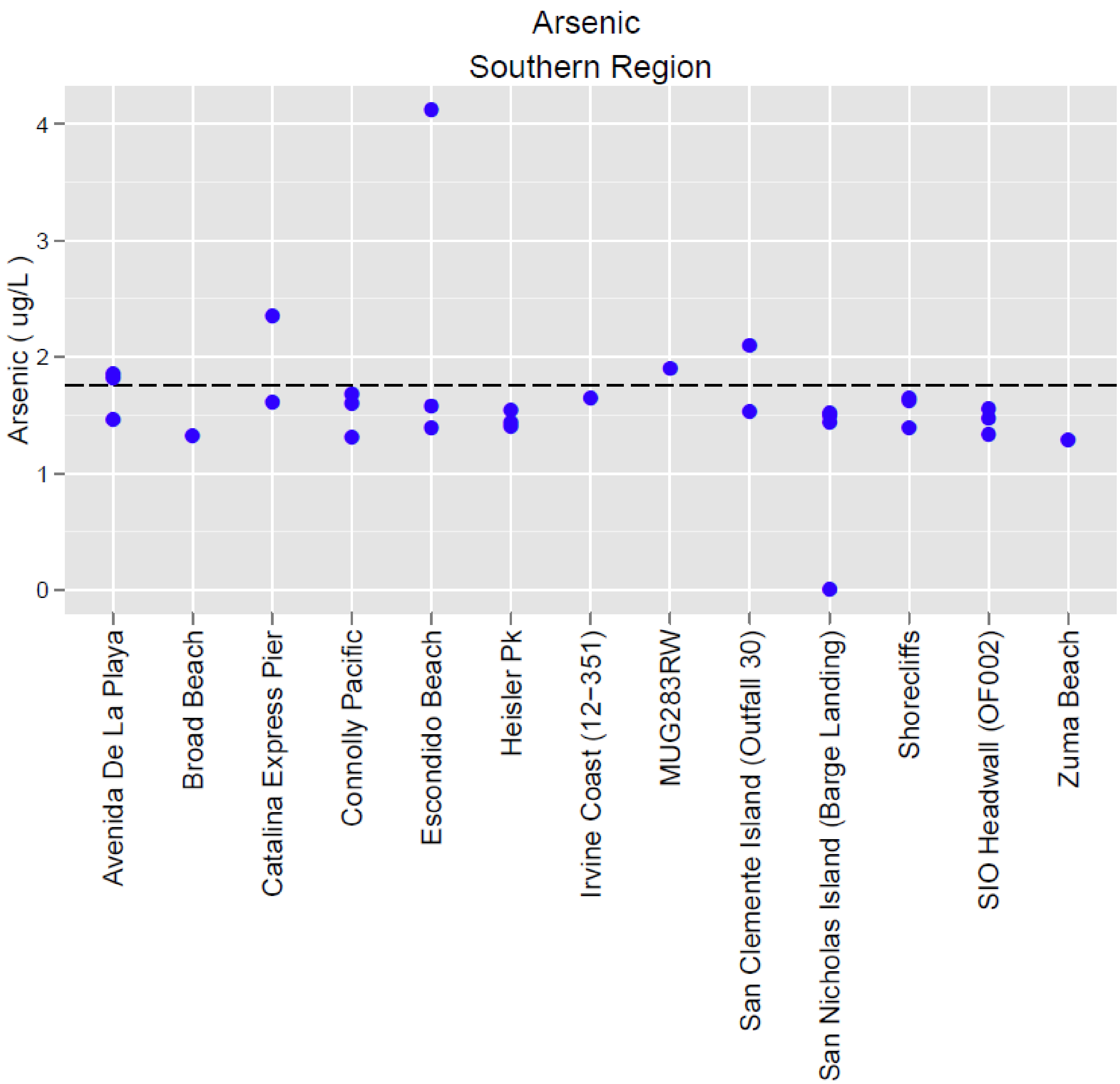
Oil and Grease



Ortho-phosphate as P

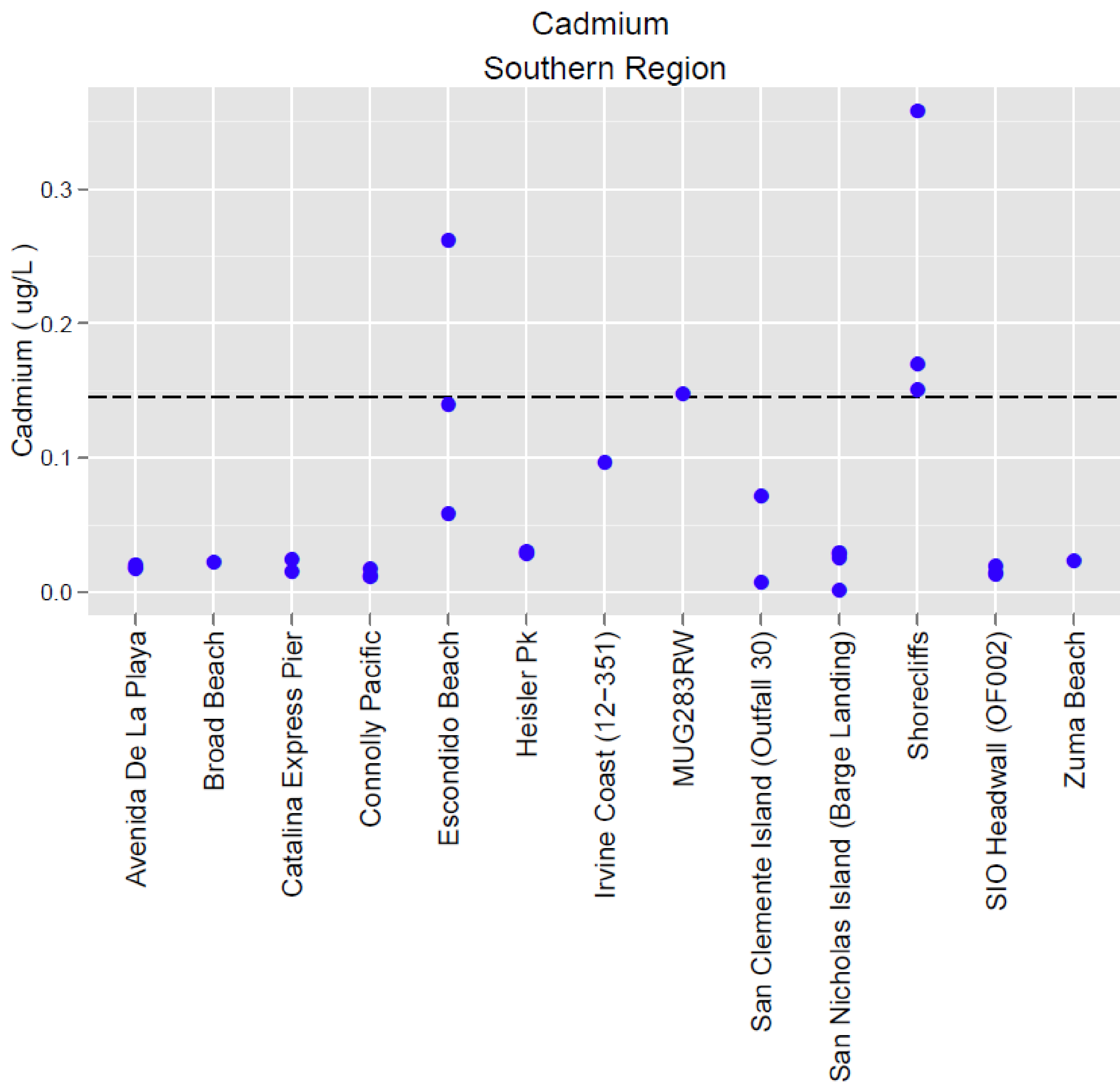


Total Suspended Solids



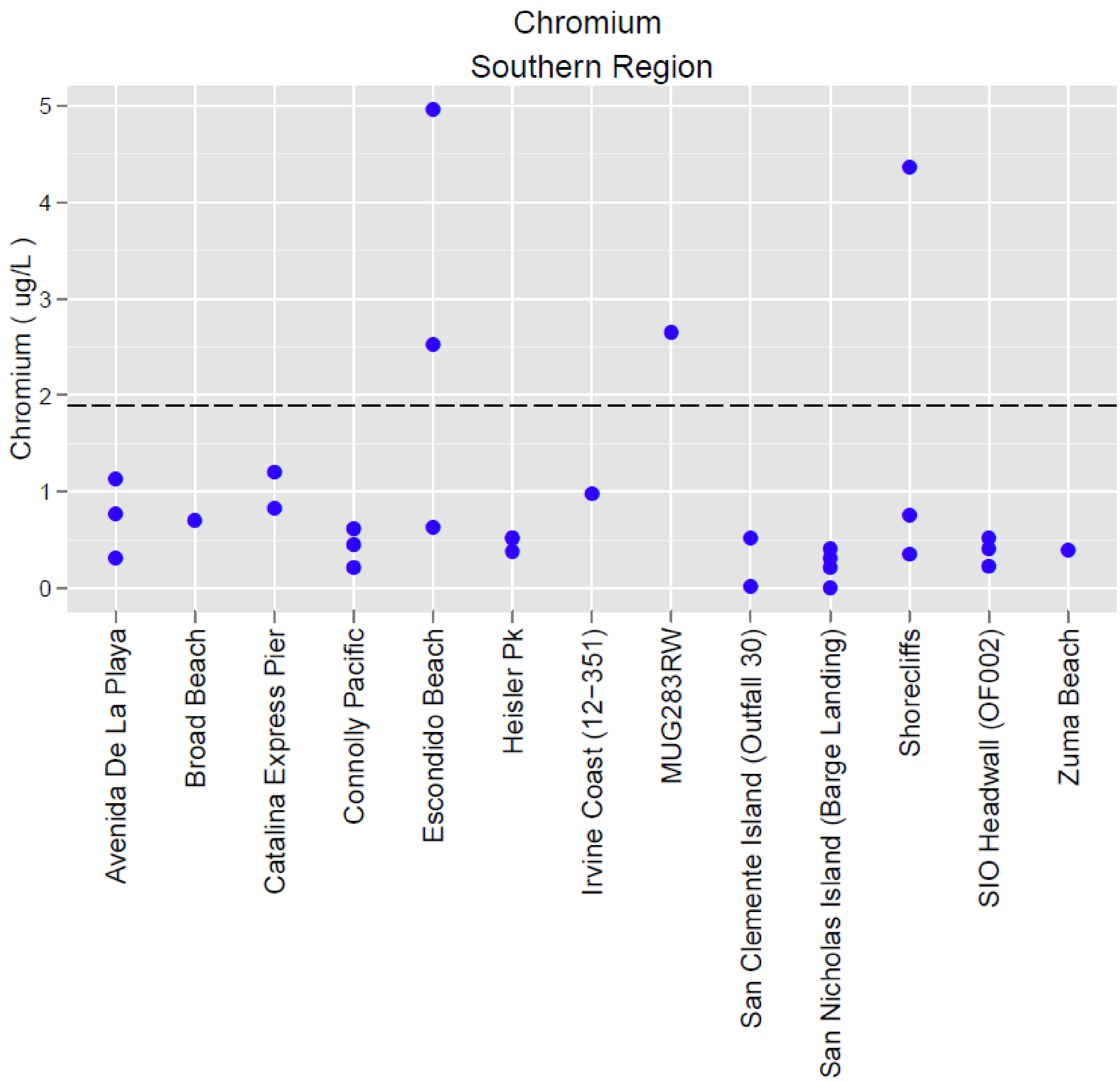
Arsenic
Southern Region
Arsenic (ug/L)
0
1
2
3
4
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

Arsenic

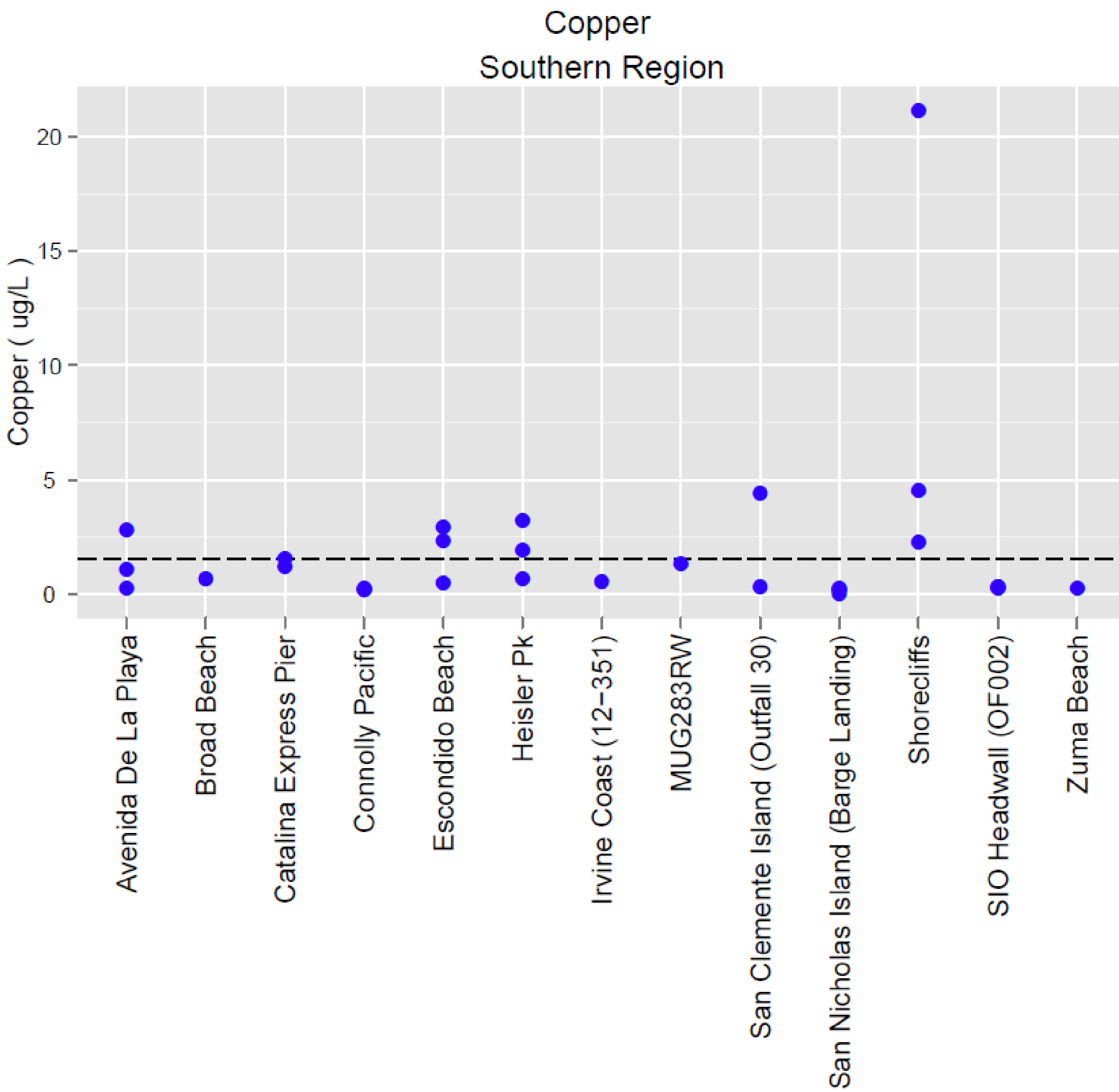


Cadmium
Southern Region
Cadmium (ug/L)
0.0
0.1
0.2
0.3
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

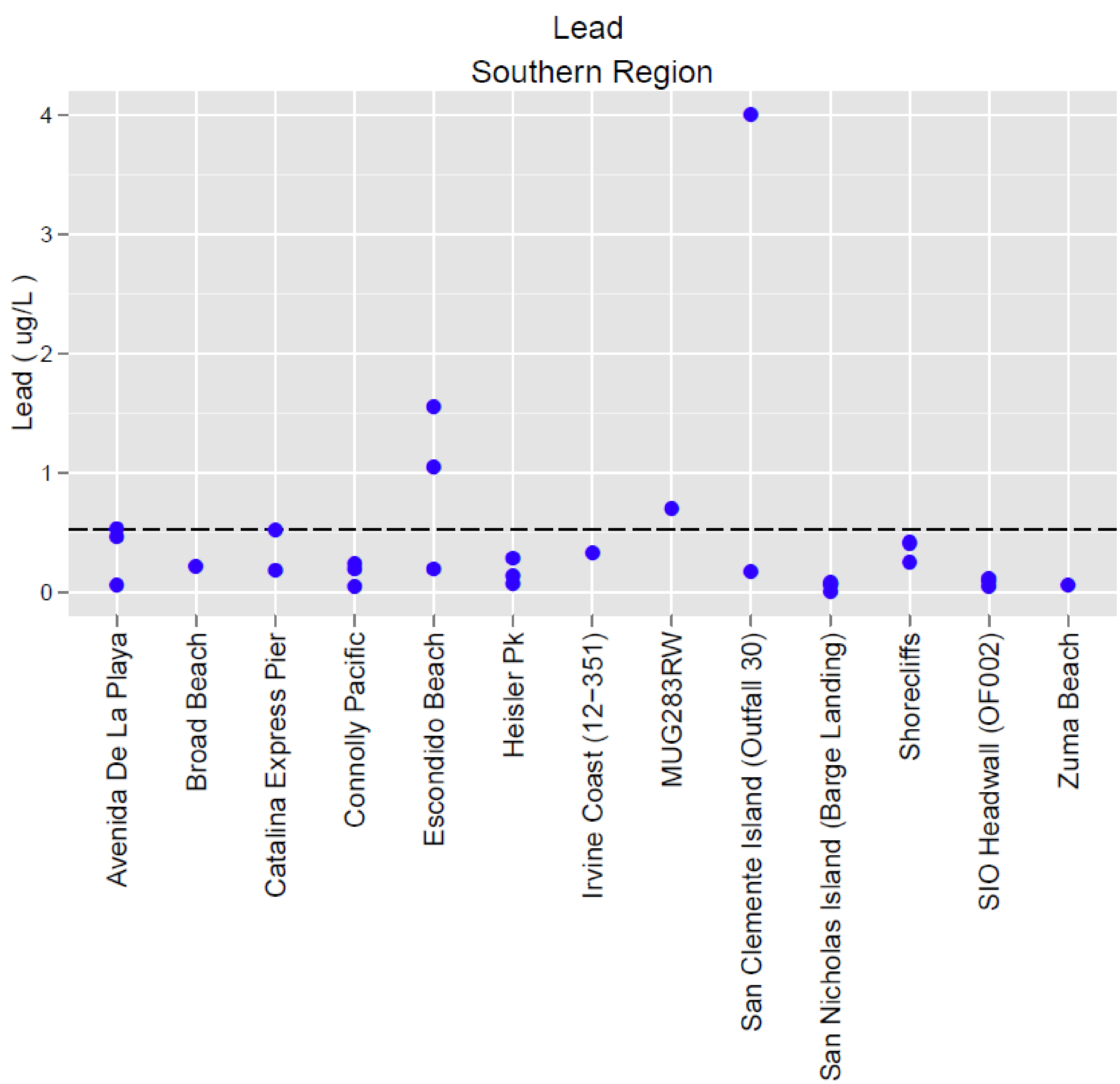
Cadmium


Chromium
Southern Region
Chromium (ug/L)
5
4
3
2
1
0
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

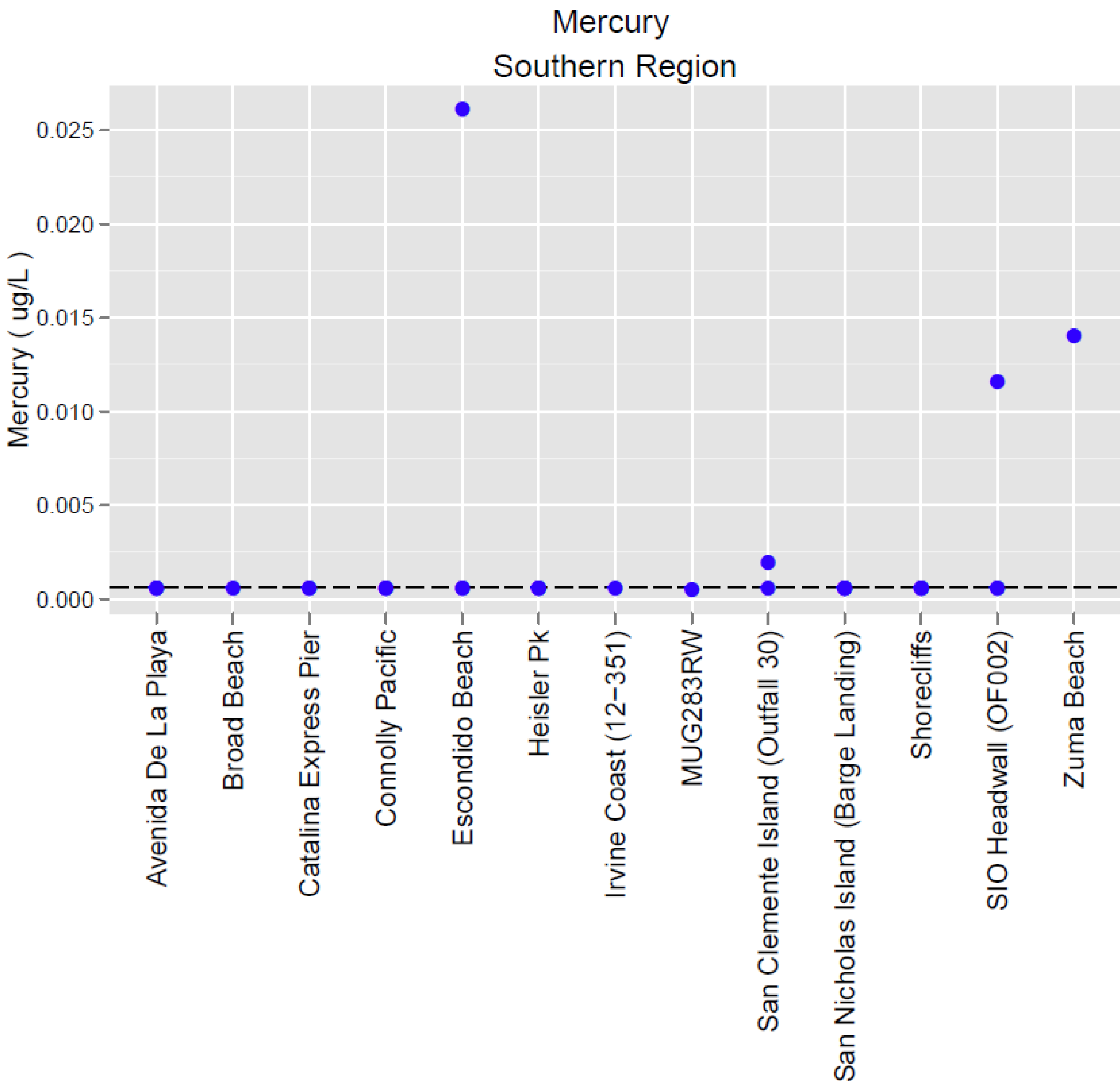
Chromium


Copper
Southern Region
Copper (ug/L)
20
15
10
5
0
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

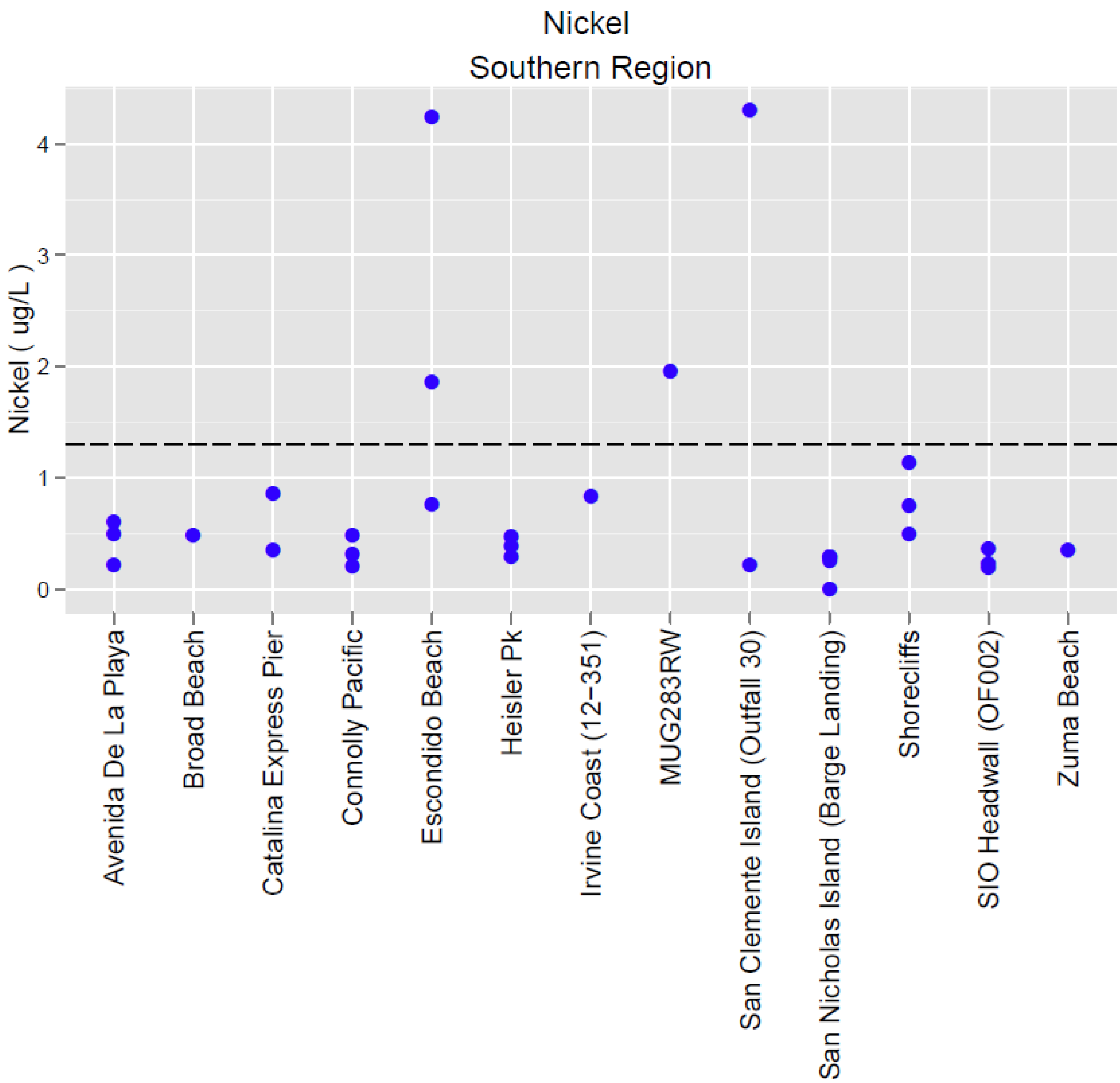
Copper


Lead
Southern Region
Lead (ug/L)
4
3
2
1
0
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

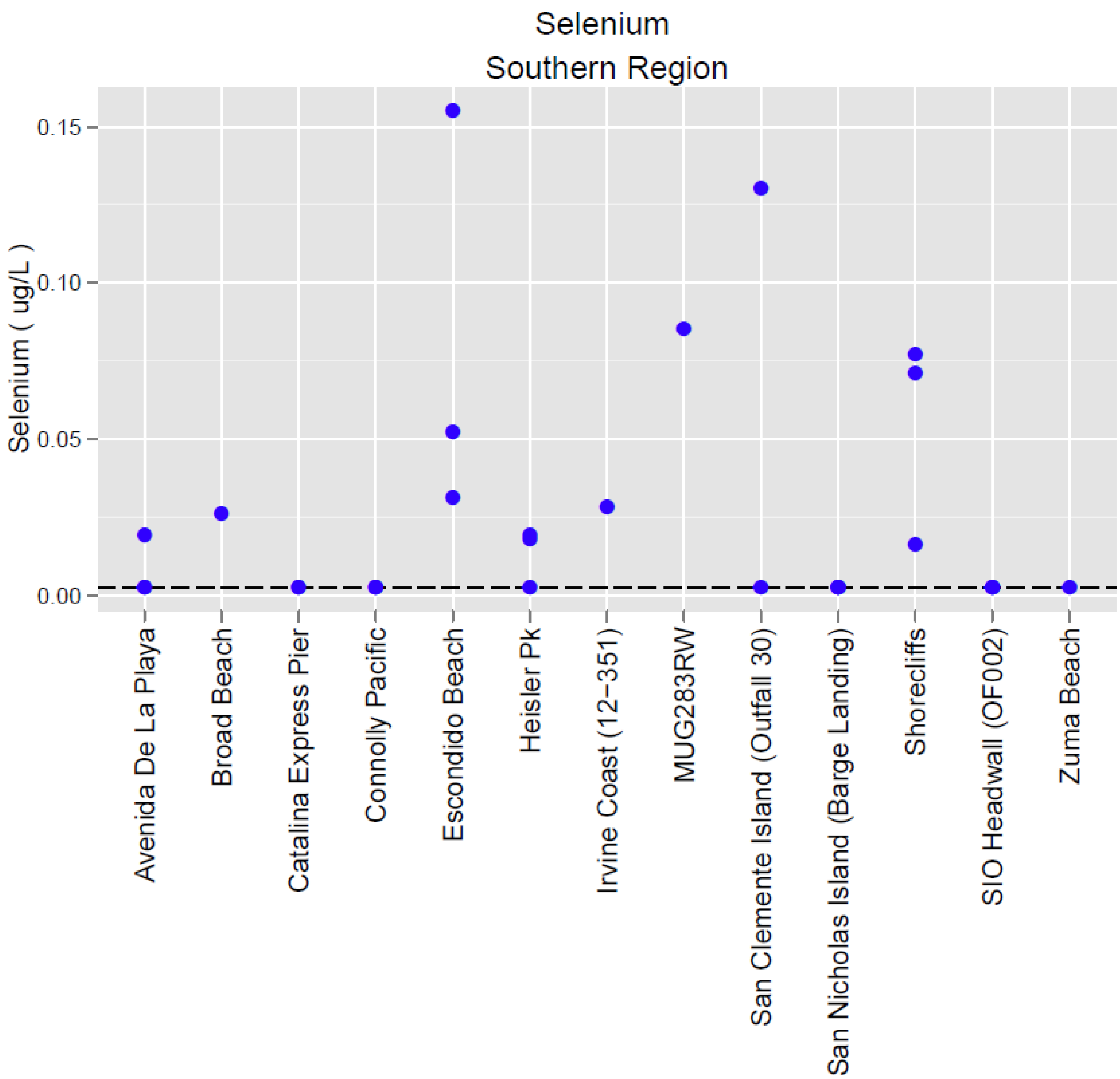
Lead


Mercury
Southern Region
Mercury (ug/L)
0.025
0.020
0.015
0.010
0.005
0.000
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

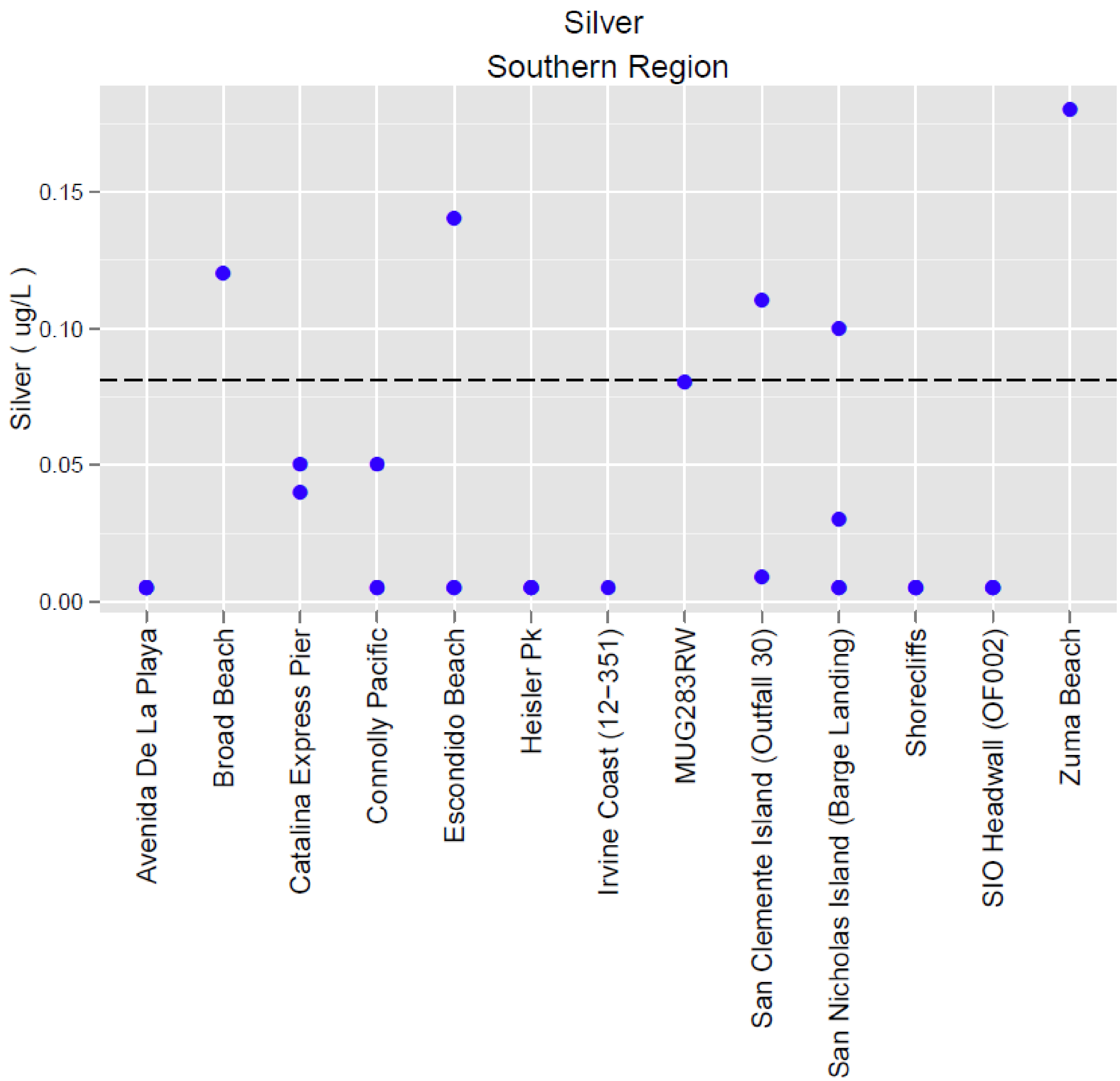
Mercury


Nickel
Southern Region
Nickel (ug/L)
0
1
2
3
4
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

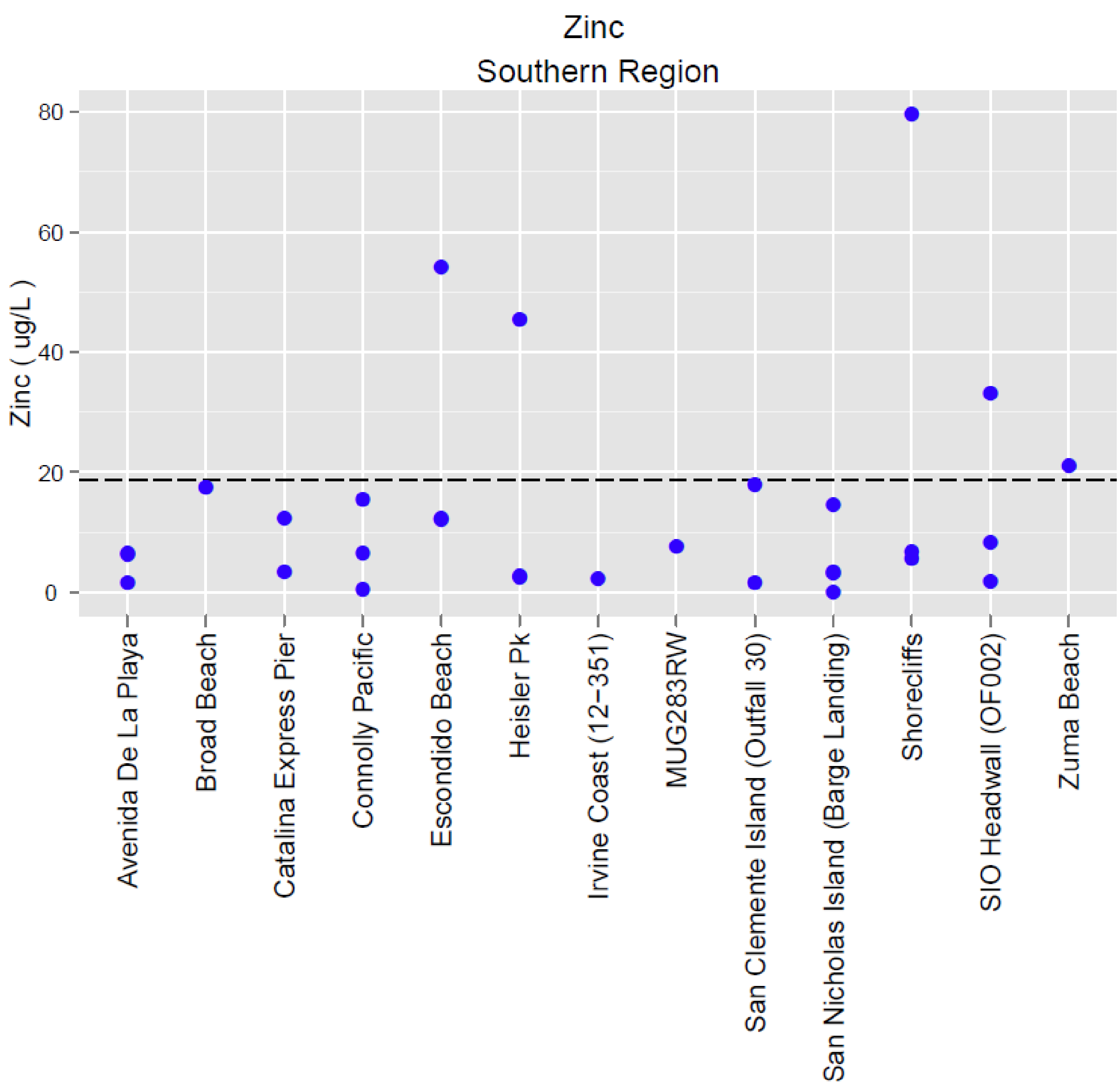
Nickel


Selenium
Southern Region
Selenium (ug/L)
0.15
0.10
0.05
0.00
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

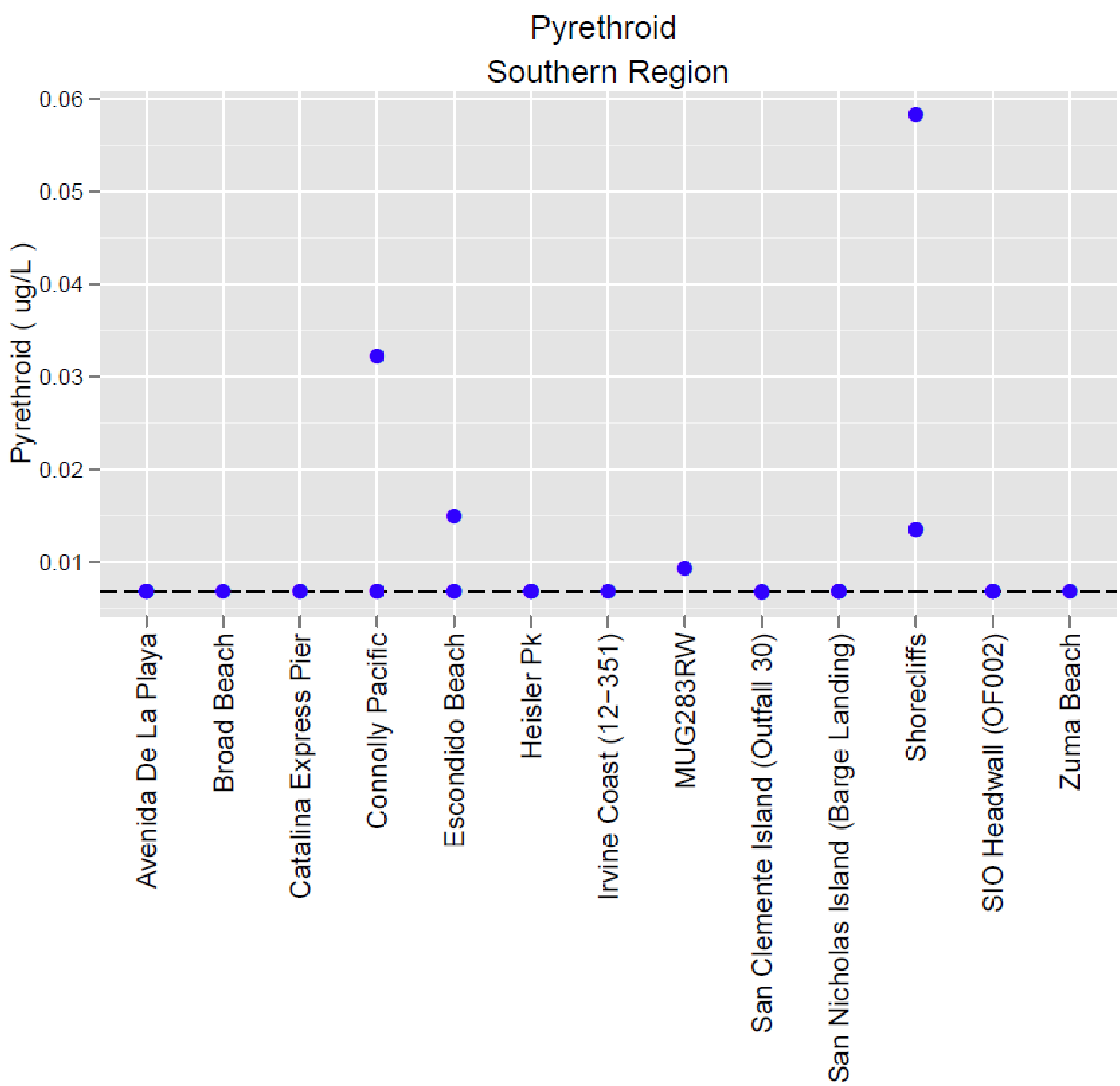
Selenium


Silver
Southern Region
Silver (ug/L)
0.15
0.10
0.05
0.00
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

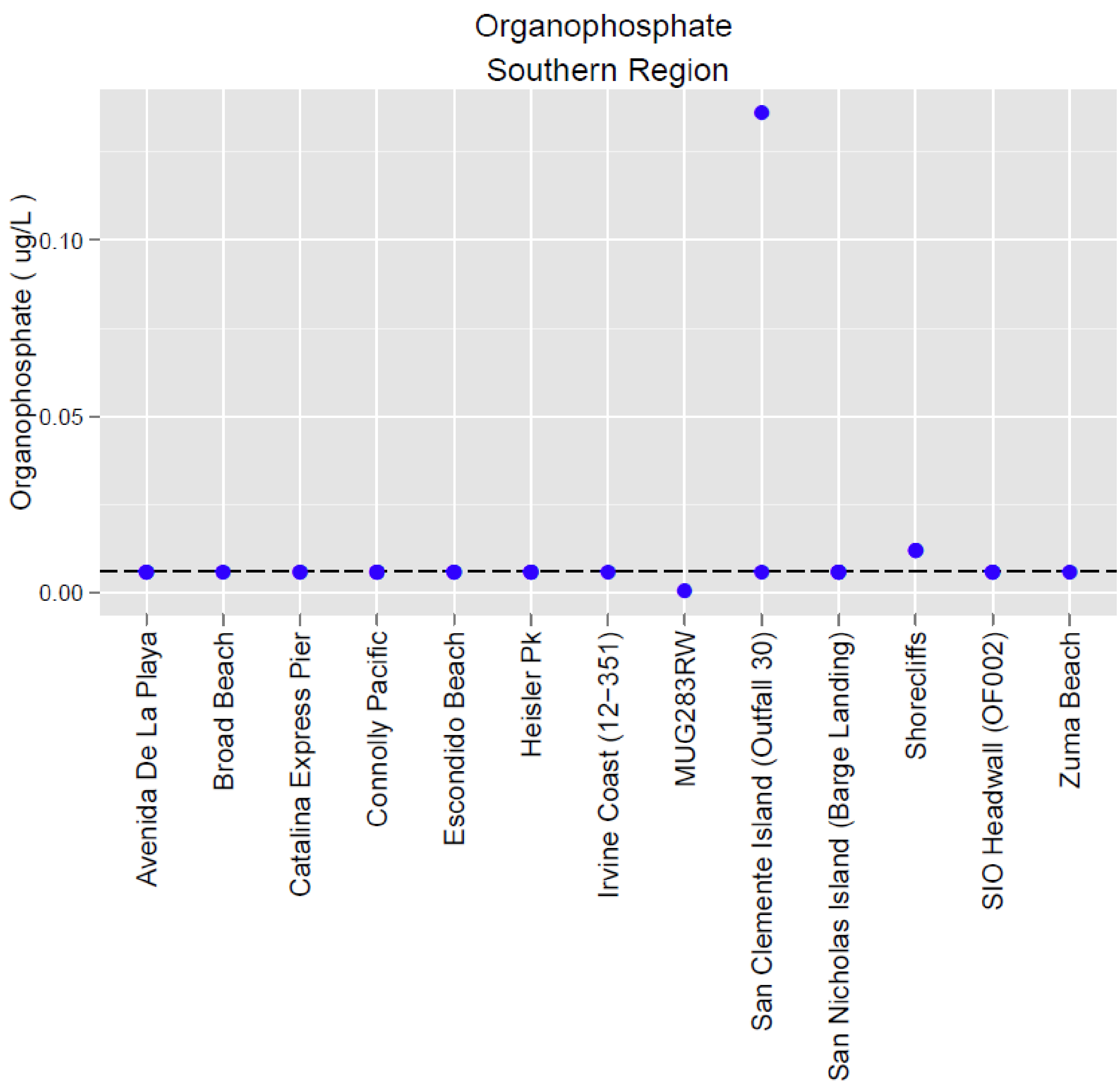
Silver


Zinc
Southern Region
Zinc (ug/L)
80
60
40
20
0
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

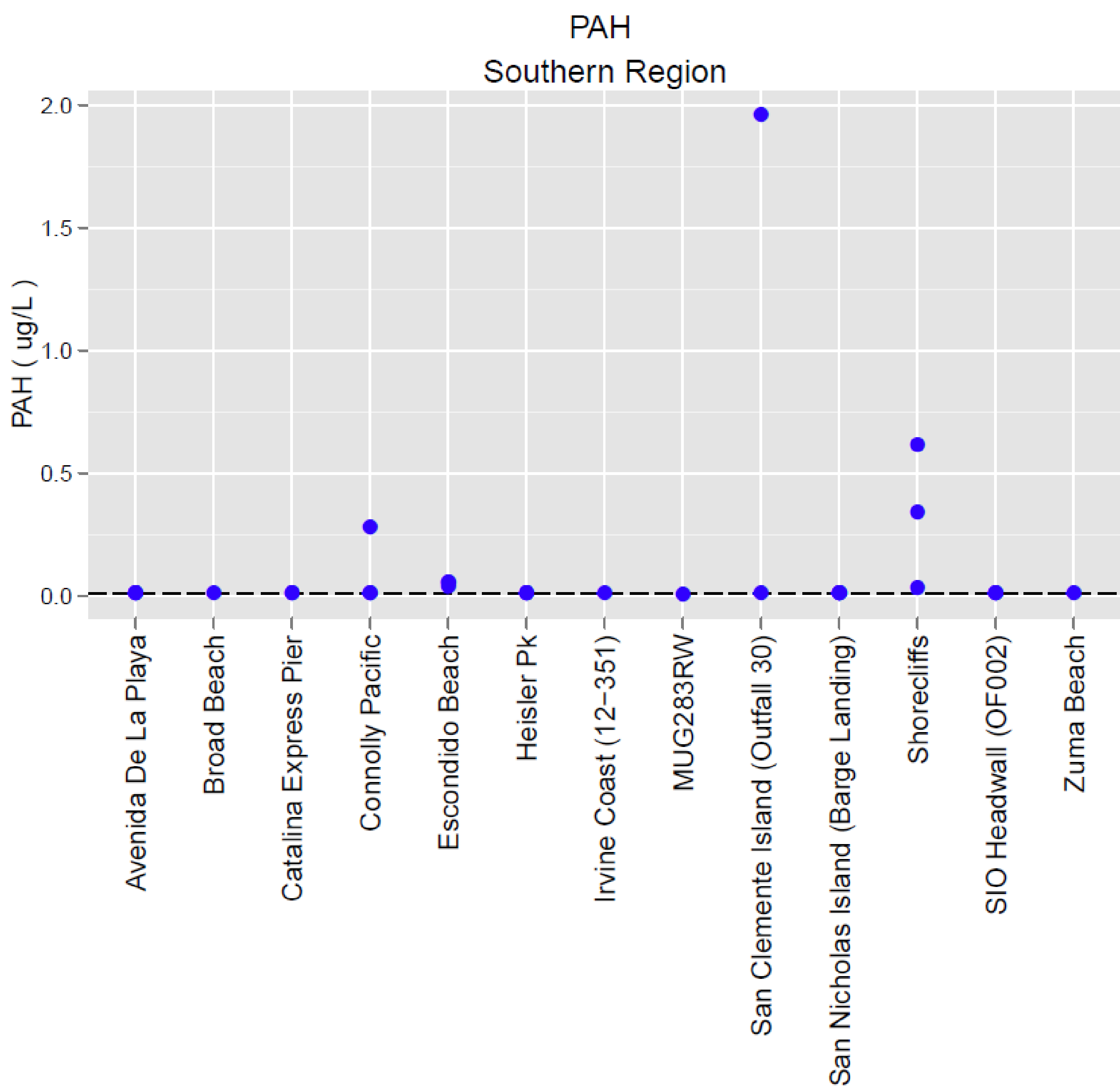
Zinc



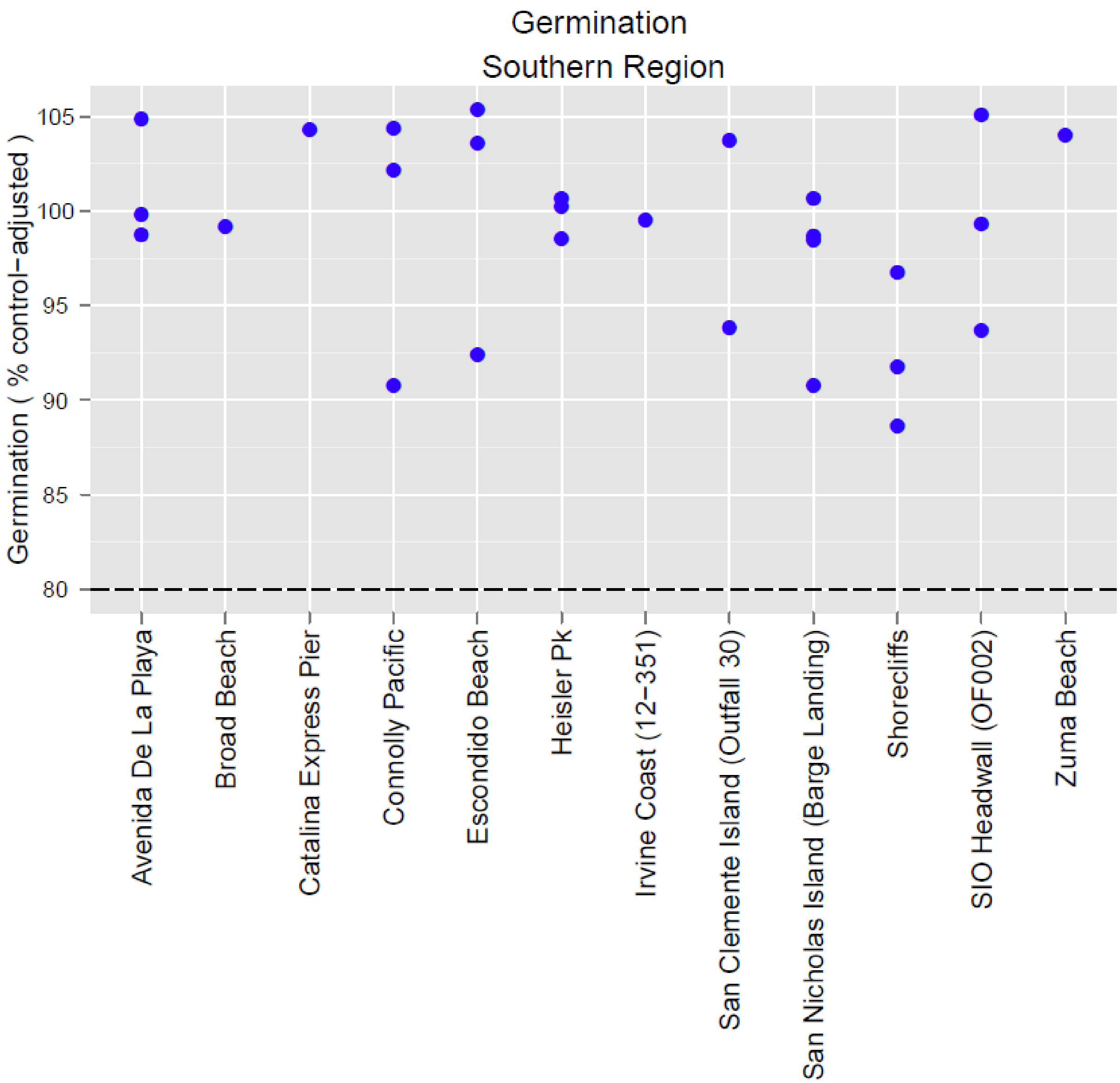
Pyrethroid pesticides



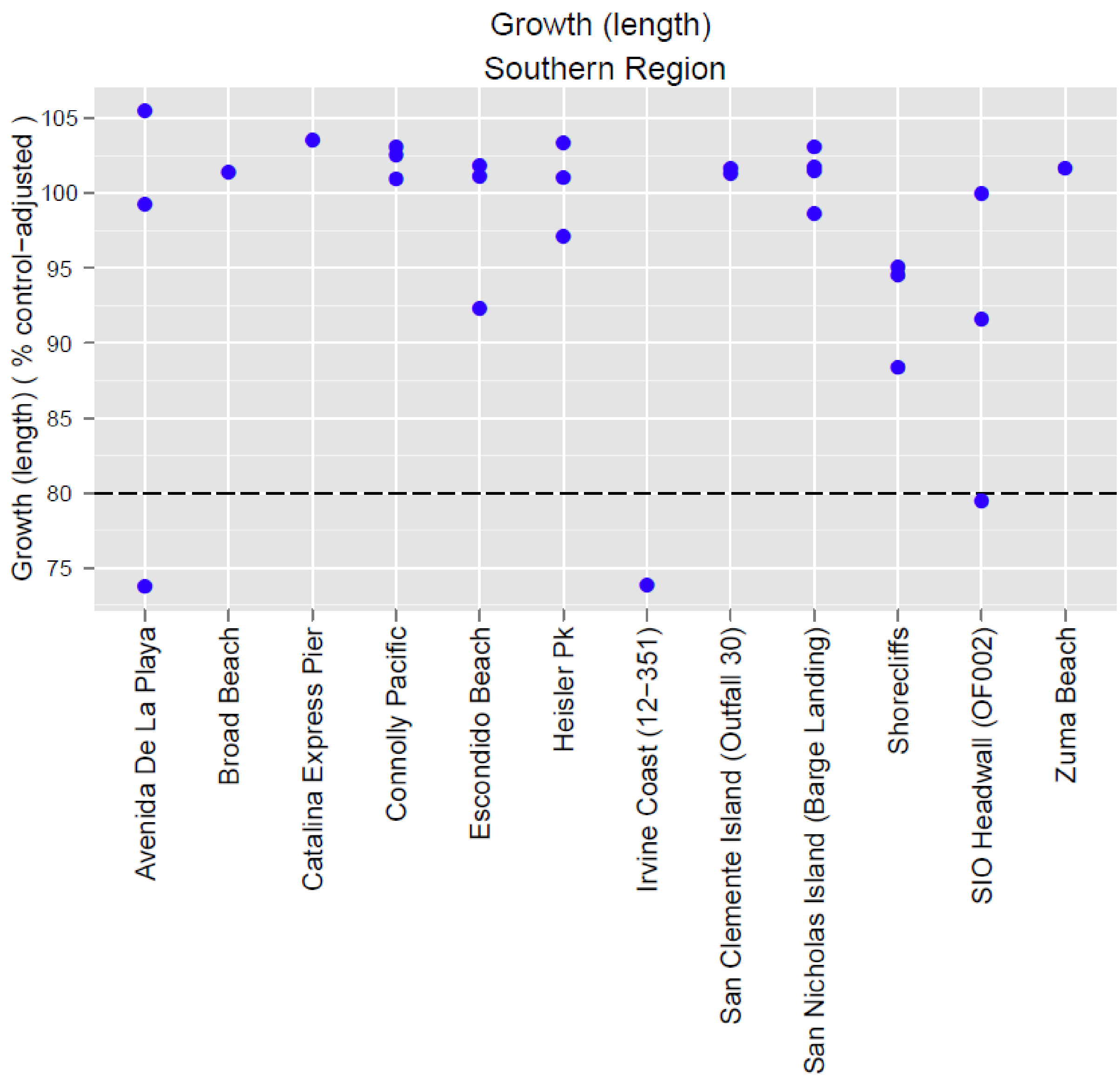
Organophosphate pesticides


PAH
Southern Region
PAH (ug/L)
2.0
1.5
1.0
0.5
0.0
Avenida De La Playa
Broad Beach
Catalina Express Pier
Connolly Pacific
Escondido Beach
Heisler Pk
Irvine Coast (12−351)
MUG283RW
San Clemente Island (Outfall 30)
San Nicholas Island (Barge Landing)
Shorecliffs
SIO Headwall (OF002)
Zuma Beach

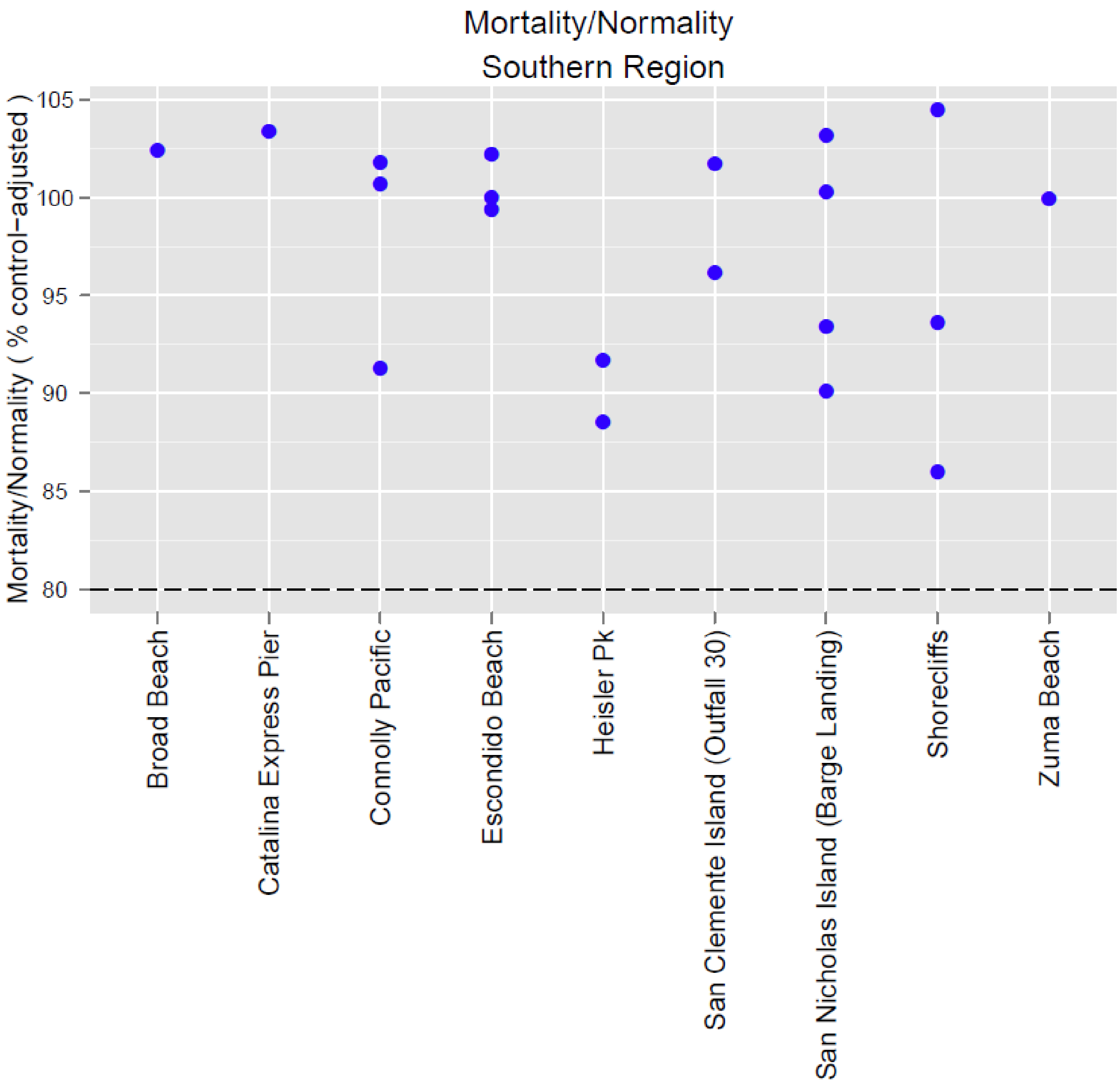
Total PAH



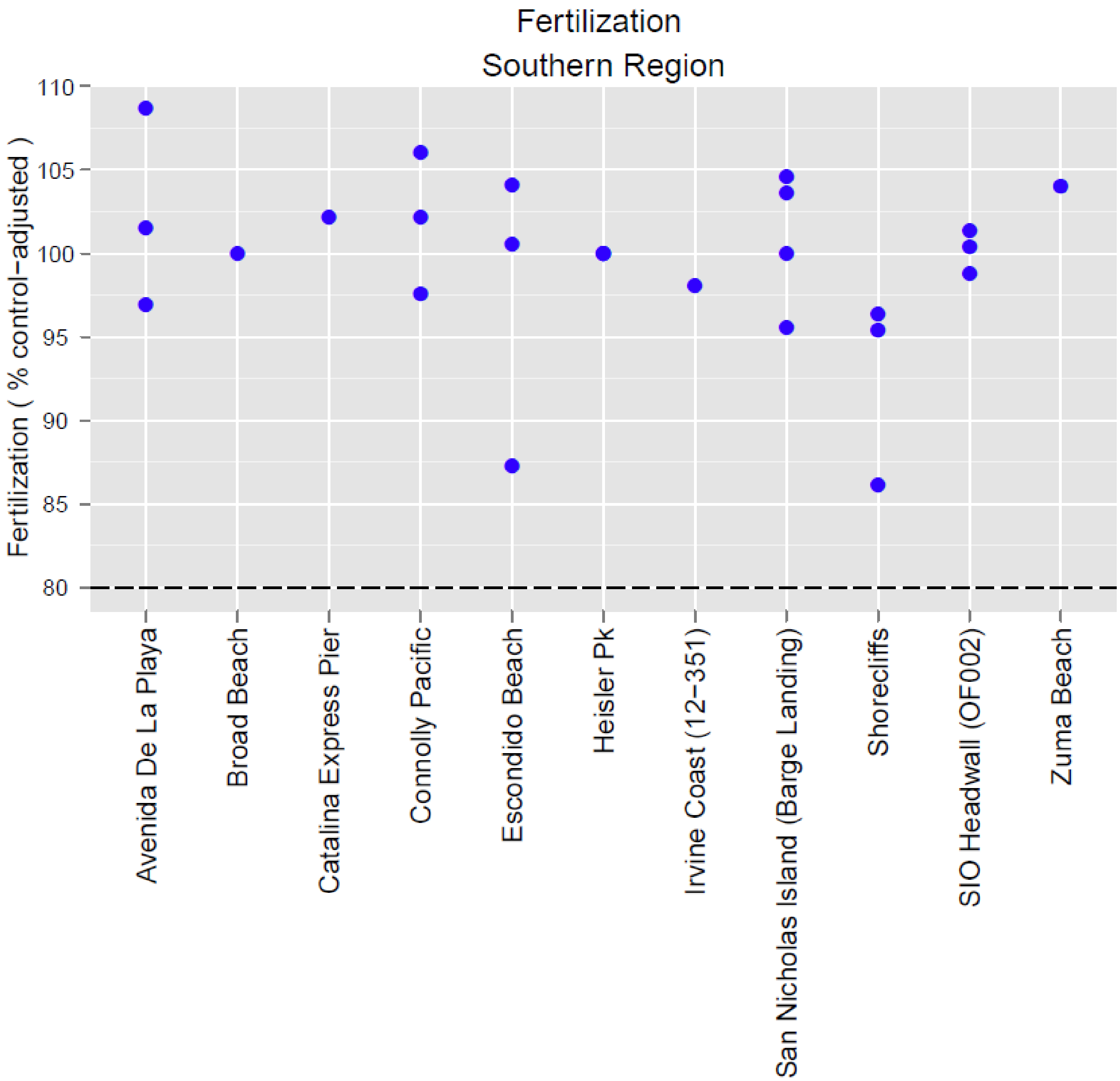
Kelp Germination



Kelp Growth (Length)



Mussel Enbryo Mortality/Normality



Sea Urchin Egg Fertilization

APPENDIX B - ANALYTES AND MINIMUM DETECTION LIMITS

Analyte (units)	Range of Minimum Detection Limits
Ammonia as N (mg/L)	0.02, 0.03
Nitrate as N (mg/L)	0.01
Oil and Grease (mg/L)	1
Orthophosphate as P (mg/L)	0.01
Total Suspended Solids (mg/L)	0.5
Arsenic (µg/L)	0.005, 0.01
Cadmium (µg/L)	0.0025, 0.005
Chromium (µg/L)	0.0125, 0.025
Copper (µg/L)	0.005, 0.01
Lead (µg/L)	0.0025, 0.005
Mercury (µg/L)	0.0012
Nickel (µg/L)	0.0025, 0.005
Selenium (µg/L)	0.005
Silver (µg/L)	0.01, 0.02
Zinc (µg/L)	0.0025, 0.005
Total PAHs (µg/L)	0.021, 0.025
Total Organophosphorus pesticides (µg/L)	0.006, 0.024
Total Pyrethroid pesticides (µg/L)	0.013, 0.0135