North Coast Areas of Special Biological Significance Regional Monitoring Program: First Year Results

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Southern California Coastal Water Research Project

SCCWRP Technical Report 856

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ASBS REGIONAL MONITORING COMMITTEE

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EXECUTIVE SUMMARY

In northern California, over 123 km of shoreline have been designated as marine water quality protected areas, termed Areas of Special Biological Significance (ASBS). While the standard for water quality protection in an ASBS is "natural water quality", there are at least 106 documented coastal discharges in the north coast region 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 posed by ASBS regulation: 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. Thirteen locations encompassing 28 site-events were sampled immediately prior to (<48 hours), then during or immediately following (<2 hours) storm events ranging from 0.31 to 4.53 inches rainfall.

The following results and conclusions were gleaned from this study:

- **In its first year, the North Coast Regional Monitoring Program was able to demonstrate modest success and collect valuable information.**
  While all targeted site-events from reference receiving water locations were collected, only 50% of the discharge receiving water site-events were collected. Drought conditions were a possible reason for the delay in achieving success for discharge receiving water sites. However, there was an element of slow reactions resulting in lack of necessary funding and support to complete all of the required sampling.

- **The North Coast Regional Monitoring Program was successful at translating the narrative standard "natural water quality" into numerical guidelines.**
  Defining natural water quality was accomplished through the use of reference receiving water sites with minimal to no impact from human activities. We are confident that these sites were minimally impacted because none demonstrated toxicity to marine organisms, no site had quantifiable concentrations of man-made constituents (i.e., organophosphorus and pyrethroid pesticides), and outlier concentrations of naturally-occurring parameters (i.e., TSS, nutrients, trace metals) was extremely rare.

- **Regionally, constituent concentrations from north coast discharge and reference receiving waters were comparable.**
  The distributions of concentrations at reference and discharge receiving water sites overlapped one another and median concentrations differed by less than a factor of three between them. Total suspended solids (TSS) was the lone exception. Not only was the TSS concentrations significantly greater at discharge than reference receiving water sites, but there was a substantial increase in TSS concentrations in discharge receiving waters post-storm compared to pre-storm. A similar increase was not observed at reference sites.

- **The Saunders and Redwood ASBS had amongst the lowest exceedance rates of natural water quality guidelines at discharge receiving water sites statewide. In contrast, the Trinidad ASBS had the highest exceedance rate of any ASBS in California.**
  Cumulative across all parameters, Redwood and Saunders Reef ASBS had an exceedance rate of 12% and 9% respectively, which is less than what we would expect from the reference sites. Trinidad ASBS had a 40% exceedance rate of natural water quality guidelines. Based on limited data, the exceedance rate at Trinidad ASBS has been declining over time. The decline may be the result of new structural best management practices (BMPs) installed part way through the monitoring period. Alternatively, the decrease may be an artifact of sampling, which was conducted slightly differently in early years relative to later years. Only future monitoring will be able answer this question.

- **Total suspended solids appears to be the most problematic constituent at north coast ASBS and at Trinidad ASBS in particular.**
  TSS exceeded natural water quality guidelines in over 70% of the north coast samples, and the majority of these occurred at the Trinidad ASBS discharge receiving water site. The next most problematic constituents were PAHs and trace metals, both of which are known to adsorb to solids and were positively correlated with TSS concentrations. Ultimately, if TSS concentrations can be reduced, managers will likely see commensurate reductions in PAHs and metals, too.

- **The next year of data will be particularly important for the North Coast Regional Monitoring Program.**
  The final year of monitoring will provide data for the currently unsampled Kings Range ASBS, provide an extra year of data to help confirm the improving trend in water quality at the Trinidad ASBS, and corroborate the good water quality status at Redwood and Saunders Reef ASBS. Finally, the extra year of monitoring will demonstrate to the regional collaborative, including both regulated and regulatory parties, that coordinated monitoring does provide additional value and unique perspectives at a reduced cost compared to individualized monitoring efforts.

TABLE OF CONTENTS

INTRODUCTION

In the early to mid-1970's, the State Water Resources Control Board (SWRCB) created a series of water quality protected areas, termed Areas of Special Biological Significance (ASBS). These ASBS were designed to ensure the protection of California coastline endowed with unique flora and fauna. There are 34 ASBS statewide, seven of which are located along the northern coast of California (Figure 1). These seven ASBS encompass over 123 km of California's shoreline, over 21% of all ASBS coastline statewide.

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". 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 106 discharges, most of which are storm drain outfalls, emptying into northern California 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 due to increases in human activities. Human activities that lead to watershed development such as urbanization, agriculture or timber activities can result in habitat loss, flow modification, and pollutant inputs from surface runoff (Lyon and Stein 2009, Schiff and Sutula 2004, Tiefenthaler et al 2008).

In order to address the dilemma between state regulations for water quality protected areas and development in coastal watersheds, the goal of this study was to assess the water quality in northern 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.

METHODS

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.

Sampling

Thirteen sites were selected for wet weather sampling in this study (Table 1). Eight of the sampling locations were reference drainage sites (representing natural water quality) and five were ASBS discharge sites. Reference site selection followed five criteria: 1) the site must be an open beach with breaking waves (i.e., no enclosed bays); 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 (>95%) 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).

A total of 28 site-events were sampled (Table 1). Twenty-one site-events were sampled near reference drainage locations, and another seven site-events were sampled near ASBS discharge locations. Between zero and three site-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. Pre-storm samples were collected prior to (<48 hours) rainfall, and post-storm samples were collected either during or immediately following (<2 hours) rainfall. All 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.

In an effort to increase sample size, three receiving water samples at the Trinidad ASBS were collected during storm events between 2010 and 2012. In general, the sampling methods were comparable to the regional monitoring, with the following two exceptions: 1) composite samples consisting of 4 to 5 grab samples were collected during the duration of the storm event instead of a single grab sample; 2) no pre-storm sample was collected from the receiving water, and; 3) all of the same constituents measured in the regional monitoring samples were also measured in the historical sample events except for toxicity.

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), nitrite (NO2-N), ammonia (NH3-N), and ortho-phophate (PO4-P); 3) total [unfiltered] trace metals (arsenic, cadmium, chromium, copper, nickel, lead, silver, zinc); 3) pyrethroid (8 pyrethroids plus fipronyl) and organophosphorus (diazinon and chlorpyrifos) pesticides; 4) total polycyclic aromatic hydrocarbons (28 PAHs); and 5) three different short-term chronic toxicity tests using endemic species (purple sea urchin *Strongylocentrotus purpuratus*, germination and tube growth using the giant kelp (*Macrocycstis pyrefira*), and normal growth and development of the California mussel (*Mytilus californianus*). All sample analysis followed standard methods and/or EPA approved procedures (APHA 2006, US EPA 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; 97% success meeting data quality objectives (DQOs) for precision using laboratory duplicates; 98% success meeting DQOs for accuracy using spiked samples.

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 organophosphorus), 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 regional reference drainage sites to regional ASBS discharge sites. Differences between these concentrations were evaluated using the parametric studentized T-test or the non-parametric Mann-Whitney pairwise comparison test, depending on normal distribution and homogeneity of variance assumptions required of the parametric 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. For the historical data at Trinidad ASBS where no pre-storm data existed, the average pre-storm concentration from the remaining storms at that same site were used for applying the natural water quality algorithm. For any constituent that was not detected, concentrations were set to one-half the method detection limit.

RESULTS

There was a wide range of rainfall characteristics for the storms sampled across the north Coast region during the 2012-14 study (Table 3). Storm rainfall totals ranged from 0.31 to 4.53 inches per storm event, with an event median of 0.95 inches. The storm on March 5-6, 2013 was the storm that was sampled simultaneously in all four regions of the north coast. The range in rainfall among regions was nearly three-fold with the greatest precipitation in the north and the least to the south (0.88 to 2.42 inches). A second storm on February 8-9, 2014 was sampled in three of the four ASBS regions. In this case, the ASBS to the south had three-fold more rain than the northern ASBS (1.56 to 4.53 inches). Rainfall duration and rainfall intensity had similarly wide ranges among ASBS during sampled events. The historical data at Trinidad ASBS had rainstorms within the range of the storms sampled during this study.

Post-storm reference receiving water site concentrations were similar to post-storm ASBS discharge site receiving water concentrations (Table 4). Median concentrations varied by less than a factor three between reference and discharge sites for every one of the 18 parameters measured. In fact, median concentrations for half of the constituents were greater at reference than discharge receiving water sites. The constituent with the greatest difference in median concentration between reference and discharge receiving water sites was TSS; discharge sites were 2.5-fold greater than reference sites (71 vs. 29 mg/L). This difference between reference and discharge sites was statistically significant (p=0.03). Except for mercury and pyrethroid pesticides, no constituent was detectable at discharge and not reference receiving water sites. For mercury, three samples were detected at discharge receiving water sites and the maximum concentration was less than three times the detection limit. For pyrethroid pesticides, one sample was detected at discharge receiving water sites and the maximum concentration was less than two times greater than the detection limit.

There was not a consistent increase or decrease in concentrations pre- to post-storm at reference drainage or ASBS discharge sites (Figure 2). Except for TSS, there was no statistically significant increase in concentrations from pre- to post-storm at ASBS discharge receiving water sites. Similarly, the pre:post-storm ratio for every constituent except for TSS encompassed unity within its interquartile distribution indicating that pre- and post-storm concentrations were comparable. For TSS, the median increase from pre- to post-storm at reference sites was 1.6-fold while the median increase at discharge sites was 3.4-fold. The minimum pre:post-storm ratio for TSS was greater than unity at discharge sites indicating that every storm increased TSS concentrations. However, while pre:post-storm ratios were generally greater at discharge receiving water sites than reference sites, reference receiving water sites had the greatest pre:post-storm ratio observed during the study (maximum 10-fold post-storm increase at reference compared to maximum 6-fold increase at discharge receiving water sites).

There was no apparent relationship between any of the routinely detected constituents (i.e., nutrients and most trace metals) and rainfall characteristics (Table 5). No correlation coefficient between post-storm constituent concentrations and rainfall total, duration, or intensity was statistically significant. Six of the 18 constituents, including four trace metals (copper, nickel, lead, and zinc) were significantly correlated to TSS. Correlation coefficients for the four trace metals ranged from 0.79 to 0.97. However, TSS was not significantly correlated with any of the rainfall characteristics.

Exceedence of natural water quality guidelines ranged from 9 to 40% of all analyses at each ASBS (Figure 3, Appendix A). The Redwood and Saunders ASBS had 12 and 9% exceedance rates of natural water quality guidelines respectively, amongst the least of any ASBS in the state. The Trinidad ASBS not only had the greatest frequency of exceedences in the north coast, but the most of any ASBS in the state. This frequency of exceedance is greater than 15%, which is the exceedance frequency that would be expected at the study's reference sites (e.g., the reciprocal of the reference site 85th percentile).

TSS was the constituent with the greatest exceedance frequency in the north coast (Figure 4, Appendix A). Consistent with its greater mean concentrations and its greater pre:post-storm ratio, TSS exceeded natural water quality guidelines at approximately 71% of the samples. Similarly, total PAHs (43%), trace metals (33%), and nutrients (27%) also exceeded natural water quality guidelines. Pesticides (21%) exceeded natural water quality guidelines the least, although the natural water quality guideline was non-detectable. No toxicity was observed in any of the three test species from any sample located near an ASBS discharge during this study.

DISCUSSION

In its first year, the North Coast Regional Monitoring Program was able to demonstrate modest success and collect valuable information. For a group that rarely interacted and had never worked together, the regional collaborative coalesced to define their study questions and create a unified study design with performance-based quality assurance objectives. The resulting outcome was 100% success at collecting reference sites and just over 50% success at collecting discharge receiving water sites. While drought conditions were a possible reason for the delay in achieving success for discharge receiving water sites, there was an element of slow reactions resulting in lack of necessary funding and support to complete all of the required sampling. As the regional collaborative moves into its second year of sampling, it is clear that momentum has increased and samples from sites without any storms will be collected in the upcoming 2014-15 wet season.

The North Coast Regional Monitoring Program was successful at translating the narrative standard "natural water quality" into numerical guidelines. This was accomplished through the use of reference receiving water sites with minimal to no impact from human activities. We are confident that these sites were minimally impacted because none demonstrated toxicity to marine organisms and no site had quantifiable concentrations of man-made constituents such as pyrethroid or organophosphorus pesticides. Moreover, outlier concentrations of naturally-occurring parameters (i.e., TSS, nutrients, trace metals), which could be the result of human additions, was extremely rare. As called for in the SWRCB's Special Protections, the 85th percentile of the regional reference site distribution was selected as the natural water quality guideline.

Constituent concentrations from discharge and reference receiving waters were comparable. The distributions of concentrations at reference and discharge overlapped one another and, despite concentration ranges that frequently exceeded an order of magnitude or more, median concentrations were always less than a factor of three. TSS was the lone exception. Not only was the TSS significantly greater at discharge than reference receiving water sites, but there was a substantial increase in TSS concentrations in discharge receiving waters pre-storm to post-storm. A similar increase was not observed at reference sites.

The range of natural water quality exceedances varied widely amongst the three ASBS in the north coast. The Saunders and Redwood ASBS had amongst the lowest exceedance rates at discharge receiving water sites statewide. In contrast, Trinidad ASBS had a 40% exceedance rate of natural water quality guidelines cumulative for all constituents, the highest exceedance rate of any ASBS in California. Redwood and Saunders Reef ASBS had an exceedance rate of 9% and 12% for all constituents, less than what we might expect from the reference site population (e.g., 15% or the inverse of the 85th percentile).

The causes for the exceedance rates at Trinidad ASBS remain unclear because we combined regional monitoring from 2012-14 and historical data from 2010-12. The vast majority of the natural water quality guideline exceedences occurred in the historical data set. While reducing sample size and confidence, examining only the regional monitoring data at Trinidad ASBS resulted in an exceedance rate of 12% which is comparable to the Redwood ASBS and below the median exceedance rate at ASBS statewide. The reduction in exceedance rate between the historical and regional monitoring data could be real or it could be an artifact. The historical data was collected prior to constructing a number of best management practices (BMPs) at Trinidad ASBS and the regional monitoring occurred after construction. If the reduction in exceedance rate is real, then this would be an excellent example of effective BMP implementation. However, there was also a difference in sample collection methods between the historical and regional monitoring, which could also explain the difference in exceedance rates. Composite samples were collected historically, where up to five grab samples from receiving waters were composited over the course of a single storm event. The regional monitoring protocol only called for a single grab sample. Composite samples can integrate small-scale temporal and spatial variability, which can be significant during a storm event, but require more effort than single grab samples. While no study of composite versus grab samples exists for post-storm receiving water samples, composite:grab sample comparisons do exist for storm discharge samples (Leecaster et al 2002). In that study, grab samples generated more variability, but the bias was not uniformly lesser (or greater) than composite samples.

Regardless of the reason for exceeding the natural water quality guidelines, TSS appears to be the most problematic constituent in northern California ASBS and at Trinidad ASBS in particular. Over 70% of all samples exceeded for TSS. Eighty percent of these exceedences occurred in the discharge receiving water at Trinidad ASBS. The next two constituent groups with the highest exceedance rates were PAHs and trace metals, both of which are known to adsorb to solids and were positively correlated with TSS concentrations. Ultimately, if TSS concentrations can be reduced, managers will see commensurate reductions in PAH and metals, too.

Despite Trinidad ASBS having the greatest frequency of natural water quality guideline exceedences, there was little evidence of associated biological impacts. No sample from Trinidad ASBS induced toxicity to sensitive life stages tested in all three marine species. In addition, subsequent studies of rocky intertidal biological communities at Trinidad ASBS (or the other north coast ASBS) did not generate demonstrably different community composition or abundance than those observed at reference sites (Raimondi et al 2015). Finally, bioaccumulation of toxic compounds, such as pesticides or trace metals, were not substantially greater at the Trinidad ASBS than at regional reference sites (Dodder and Schiff 2015).

The final year of data will be particularly important for the North Coast Regional Monitoring Program. It will provide data for the Kings Range ASBS and two regulated parties (Humboldt County Public Works and Humboldt Bay Harbor, Recreation and Conservation District) that do not have any information. In addition, the extra year of data will help confirm the improving trend in water quality at the Trinidad ASBS and the good quality status at Redwood and Saunders Reef ASBS. Finally, the extra year of monitoring will demonstrate to the regional collaborative, including both regulated and regulatory parties, that coordinated monitoring does provide additional value and unique perspectives at a reduced cost compared to individualized monitoring efforts.

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Figure 1. Map of northern California Areas of Special Biological Significance.

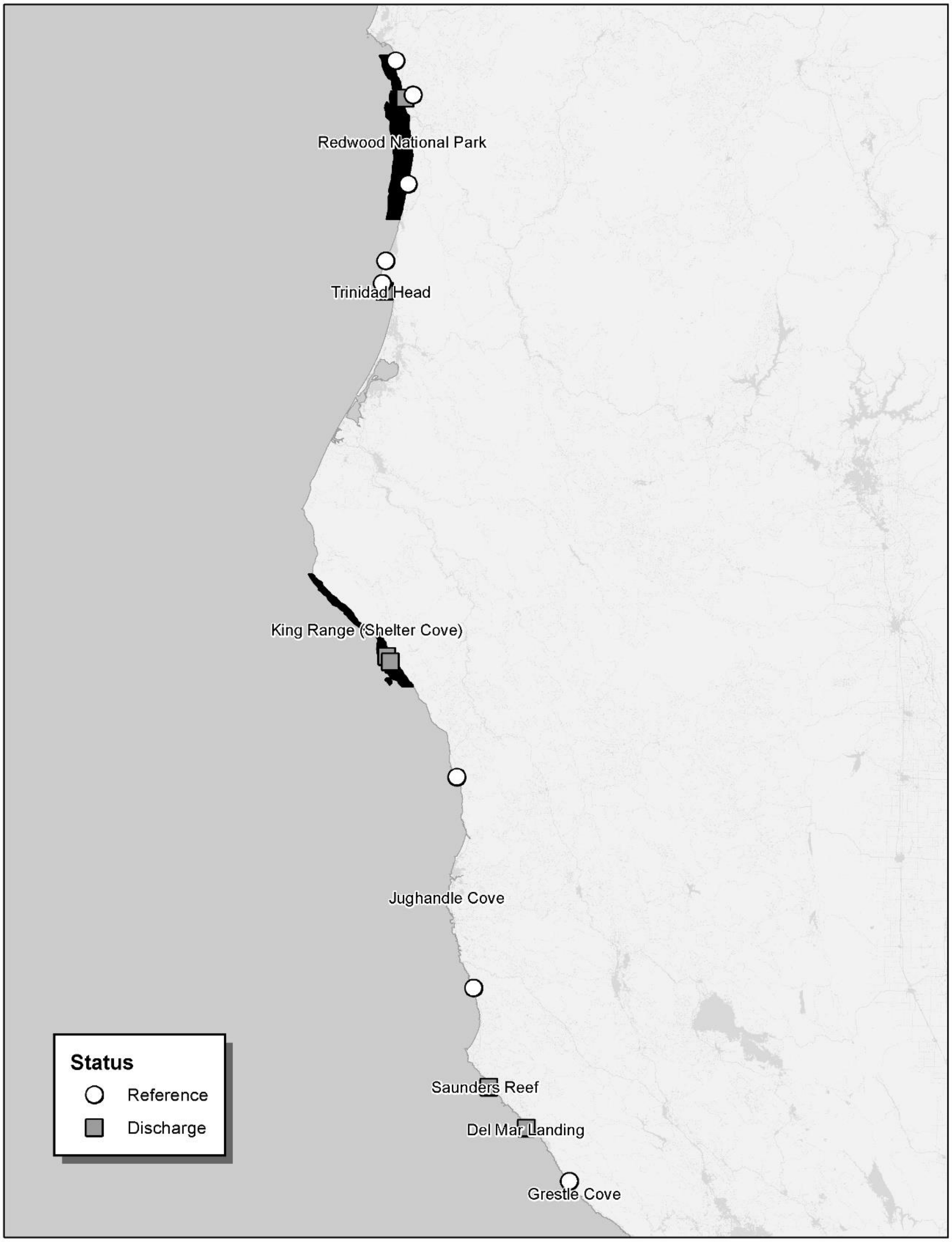


Table 1. List of sample sites and sampling inventory from North Coast Regional ASBS monitoring (2012-14).

ASBS Number	ASBS Name	Site Name	Latitude	Longitude	Responsible Party	Reference or Discharge	Number Targeted Storms	Number Pre-Storm Samples	Number Post-Storm Samples
2	Del Mar Landing	Del Mar Landing	38.7411	-123.5097	Sea Ranch Assoc	Discharge	3	-[a]	- [a]
5	Saunders Reef	Saunders Reef	38.8518	-123.6490	Caltrans	Discharge	0[e]	1	1
6	Trinidad Head	Launchers Beach[f]	41.0566	-124.1466	City Trinidad Humboldt State Univ Trinidad Rancheria	Discharge Discharge Discharge	1 1 1	1 1 0	1+3 [b] 1 0
7	Kings Range	Dolphin Drive Launch Ramp Road	40.0386 40.0242	-124.0794 -124.0664	Humboldt Co Public Wk Humboldt Bay Harb Dist	Discharge Discharge	3 3	0 [d] 0	0 [d] 0
8	Redwood	False Klamath Cove	41.5966	-124.1013	Caltrans	Discharge	3	1	1
6	Trinidad Head	Agate Creek	41.1411	-124.1459	SWRCB	Reference	3	3	3
8	Redwood	Epsa Creek	41.3580	-124.0766	SWRCB	Reference	-	1 [c]	1 [c]
5	Saunders Reef	Greenwood Creek	39.1258	-123.7181	SWRCB	Reference	3	3	3
7	Kings Range	Hardy Creek	39.7108	-123.8082	SWRCB	Reference	3	3	3
2	Del Mar Landing	Kruze Creek	38.5972	-123.3507	SWRCB	Reference	3	3	3
6	Trinidad Head	Martin Creek	41.0776	-124.1551	SWRCB	Reference	3	3	3
8	Redwood	Nickel Creek	41.6999	-124.1419	SWRCB	Reference	3	3	3
8	Redwood	Squashan Creek	41.6067	-124.0713	SWRCB	Reference	3	2 [c]	2 [c]
		Total No. Reference Site-Events					21	21	21
		Total No. Discharge Site-Events					15	4	7
		Total No. Site-Events					36	25	28

[a] Discharged removed, so no sample required
[b] Three historical post-storm samples from 2010-2012 added to data set
[c] Epsa Creek substituted for Squashan Creek due to lack of flow
[d] No sample collected
[e] Site not listed in workplan
[f] All three responsible agencies discharge to the same site

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

Analyte	Reference Drainage Site Guidelines (85th Percentile)
Ammonia as N (mg/L)	0.01
Nitrate as N (mg/L)	2.84
Oil and Grease (mg/L)	0.5
Orthophosphate as P (mg/L)	0.09
Total Suspended Solids (mg/L)	42
Arsenic (µg/L)	1.7
Cadmium (µg/L)	0.06
Chromium (µg/L)	4.2
Copper (µg/L)	1.8
Lead (µg/L)	0.5
Mercury (µg/L)	0.0006
Nickel (µg/L)	4.5
Selenium (µg/L)	0.03
Silver (µg/L)	0.06
Zinc (µg/L)	9.7
Total PAHs (µg/L)	0.0474
Total Organophosphorus pesticides (µg/L)	0.006
Total Pyrethroid pesticides (µg/L)	0.00675

Table 3. Rainfall characteristics from sampled storm events by ASBS within northern California

ASBS (#)	Site Name	Receiving Water Type	Sampling Dates	Maximum Intensity (inches/hr)	Storm Total (inches)	Storm Duration (hr)
Del Mar Landing (2)	Kruse Creek	Reference	3/5/2013	0.21	0.88	6.3
Del Mar Landing (2)	Kruse Creek	Reference	2/9/2014	0.24	4.53	47.0
Del Mar Landing (2)	Kruse Creek	Reference	2/26/2014	0.20	0.73	8.5
Saunders Reef (5)	Greenwood Creek	Reference	3/6/2013	0.20	1.04	40.3
Saunders Reef (5)	Greenwood Creek	Reference	2/9/2014	0.22	3.40	43.5
Saunders Reef (5)	Greenwood Creek	Reference	2/26/2014	0.40	0.70	7.5
Trinidad (6)	Launcher's Beach [a]	Discharge	10/3/2011	0.15	0.95	23.8
Trinidad (6)	Launcher's Beach [a]	Discharge	1/20/2012	0.31	2.13	34.8
Trinidad (6)	Launcher's Beach [a]	Discharge	4/13/2012	0.16	0.43	6.9
Trinidad (6)	Agate Creek	Reference	2/19/2013	0.28	0.48	7.5
Trinidad (6)	Martin Creek	Reference	2/19/2013	0.28	0.52	14.5
Trinidad (6)	Agate Creek	Reference	3/6/2013	0.16	1.76	26.0
Trinidad (6)	Martin Creek	Reference	3/6/2013	0.16	1.76	27.2
Trinidad (6)	Martin Creek	Reference	1/11/2014	0.24	0.68	6.3
Trinidad (6)	Launcher's Beach	Discharge	1/11/2014	0.17	0.31	3.7
Trinidad (6)	Agate Creek	Reference	2/8/2014	0.16	1.56	53.0
Trinidad (6)	Launcher's Beach	Discharge	3/26/2014	0.18	0.34	7.1
Kings Range (7)	Hardy Creek	Reference	3/6/2013	0.22	1.12	42.0
Kings Range (7)	Hardy Creek	Reference	2/9/2014	0.20	3.40	47.8
Kings Range (7)	Hardy Creek	Reference	2/27/2014	0.65	0.93	19.0
Redwood (8)	Nickel Creek	Reference	2/19/2013	0.17	0.56	11.0
Redwood (8)	Squashan Creek	Reference	2/19/2013	0.20	0.48	9.5
Redwood (8)	Nickel Creek	Reference	3/6/2013	0.30	2.42	28.0
Redwood (8)	Squashan Creek	Reference	3/6/2013	0.16	1.72	23.5
Redwood (8)	Nickel Creek	Reference	11/19/2013	0.36	1.45	18.0
Redwood (8)	Epsa Creek	Reference	2/12/2014	0.20	0.72	6.5
Redwood (8)	Redwood Nat Park	Discharge	2/14/2014	0.24	2.58	59.6
			Min	0.15	0.31	3.7
			Max	0.65	4.53	59.6
			Median	0.20	0.95	19.0

[a] historical data

Table 4. Summary statistics for North Coast Regional Monitoring of Areas of Special Biological Significance.

Analyte Name	Reference (N=21)					Discharge (N=7)				
	% Non-detects	Minimum	Maximum	Median	Mean	% Non-detects	Minimum	Maximum	Median	Mean
General (mg/L)										
Ammonia as N	100	0.01	0.01	0.01	0.01	86	0.01	0.07	0.02	0.02
Nitrate as N	5	0.005	3.14	0.96	1.4	29	0.10	5	0.33	1.62
Oil and Grease	100	0.5	0.5	0.5	0.5	100	0.4	0.65	0.5	0.53
Ortho-Phosphate as P	14	0.005	0.12	0.06	0.06	0	0.02	0.07	0.06	0.05
Total Suspended Solids	0	9.3	59.4	28.6	31.1	0	18.4	120.0	71.0	70.7
Metals (µg/L)										
Arsenic	0	0.38	2.16	1.29	1.33	0	1.4	2.0	1.5	1.6
Cadmium	0	0.02	0.07	0.04	0.04	0	0.04	0.10	0.06	0.06
Chromium	0	0.73	5.41	1.98	2.68	0	1.3377	6.6763	3.51	3.71
Copper	0	0.51	3.62	1.12	1.28	0	0.425	2.9	2.25	1.96
Lead	0	0.07	1.09	0.28	0.35	0	0.1377	1.1	0.61	0.62
Mercury	100	0.0006	0.0006	0.0006	0.0006	57	0.0006	0.013	0.0006	0.0006
Nickel	0	0.78	5.4	2.4	2.6	0	1.3	7.3	5.3	4.6
Selenium	29	0.00	0.04	0.02	0.02	29	0.02	0.30	0.02	0.06
Silver	67	0.01	0.13	0.01	0.03	57	0.005	0.27	0.01	0.05
Zinc	0	1.41	13.28	5.68	5.81	0	1.79	6.4	5.40	4.61
Organics (µg/L)										
Organophosphorus Pest	100	0.003	0.006	0.006	0.005	100	0.003	0.123	0.003	0.024
Total PAH	52	0.007	0.402	0.013	0.054	86	0.0065	3.11	0.03	0.80
Pyrethroid Pesticide	100	0.0068	0.0068	0.0068	0.0068	86	0.0045	0.0068	0.0067	0.01

Figure 2. Box plot of post/pre-storm concentration ratios at reference (grey) and ASBS discharge (white) receiving water sites.

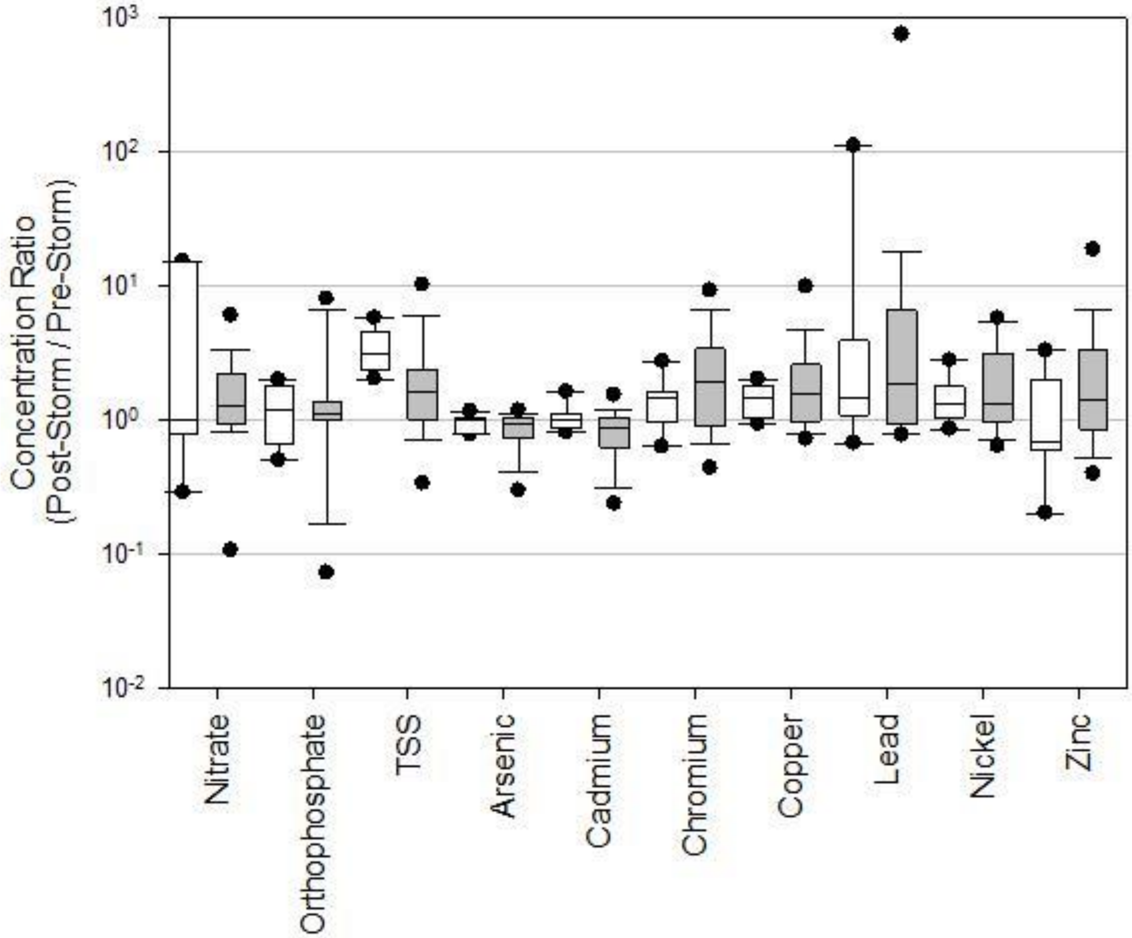


Table 5. Relationships (correlation coefficients (r) between storm characteristics or conservative tracers [total suspended solids (TSS)] and pollution concentrations at northern California discharge sites. Bold values are statistically significant ($p \leq 0.05$).

Analyte	Storm Total	Storm Intensity	Storm Duration	TSS
Ammonia	*0.543*	*-0.487*	*0.412*	**0.842**
Nitrate	*0.306*	*0.324*	*0.216*	*0.342*
OilandGrease	*0.020*	*0.238*	*-0.022*	*0.296*
Orthophosphate	*-0.400*	*0.392*	*-0.400*	**-0.982**
TSS	*0.679*	*-0.142*	*0.573*	-
Arsenic	*0.126*	*-0.100*	*-0.275*	*-0.225*
Cadmium	*0.071*	*-0.334*	*-0.134*	*0.522*
Chromium	*0.143*	*-0.150*	*0.201*	*0.543*
Copper	*0.179*	*-0.524*	*0.286*	**0.791**
Lead	*0.357*	*-0.212*	*0.368*	**0.965**
Mercury	*0.473*	*-0.164*	*0.273*	*0.600*
Nickel	*0.357*	*-0.323*	*0.300*	**0.925**
Selenium	*0.487*	*0.036*	*0.541*	*0.090*
Silver	*0.090*	*0.216*	*0.252*	*-0.198*
Zinc	*0.321*	*-0.371*	*0.340*	**0.891**
Organophosphate	*0.020*	*0.299*	*-0.100*	*0.159*
PAH	*0.234*	*-0.288*	*0.126*	*0.613*
Pyrethroid	*0.037*	*0.704*	*0.074*	*-0.482*

Figure 3. Exceedence of reference site based natural water quality guidelines by ASBS throughout California. The north coast ASBS include Redwood National Park, Trinidad Head, and Saunders Reef. The 15% reference line is the expected exceedance rate for reference sites.

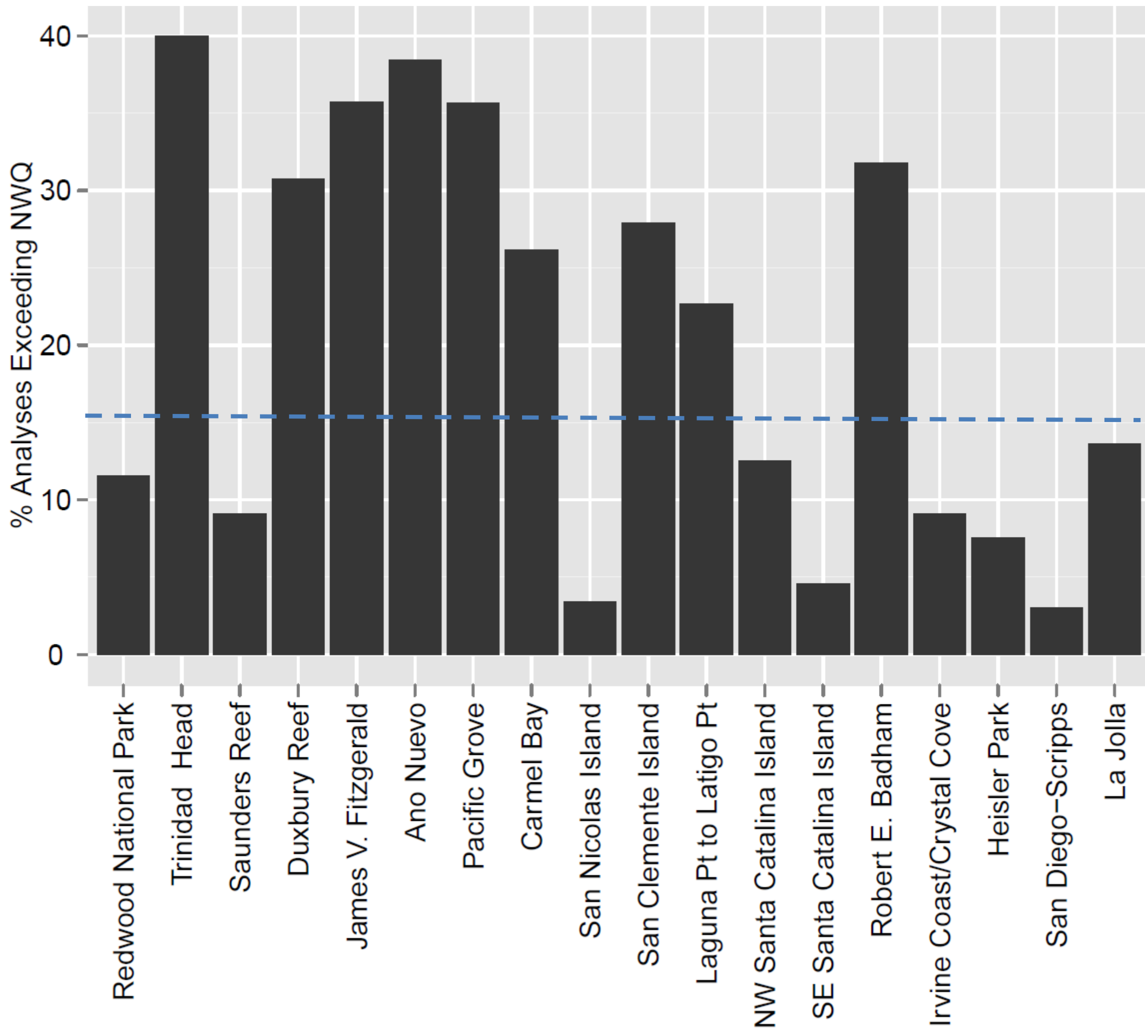
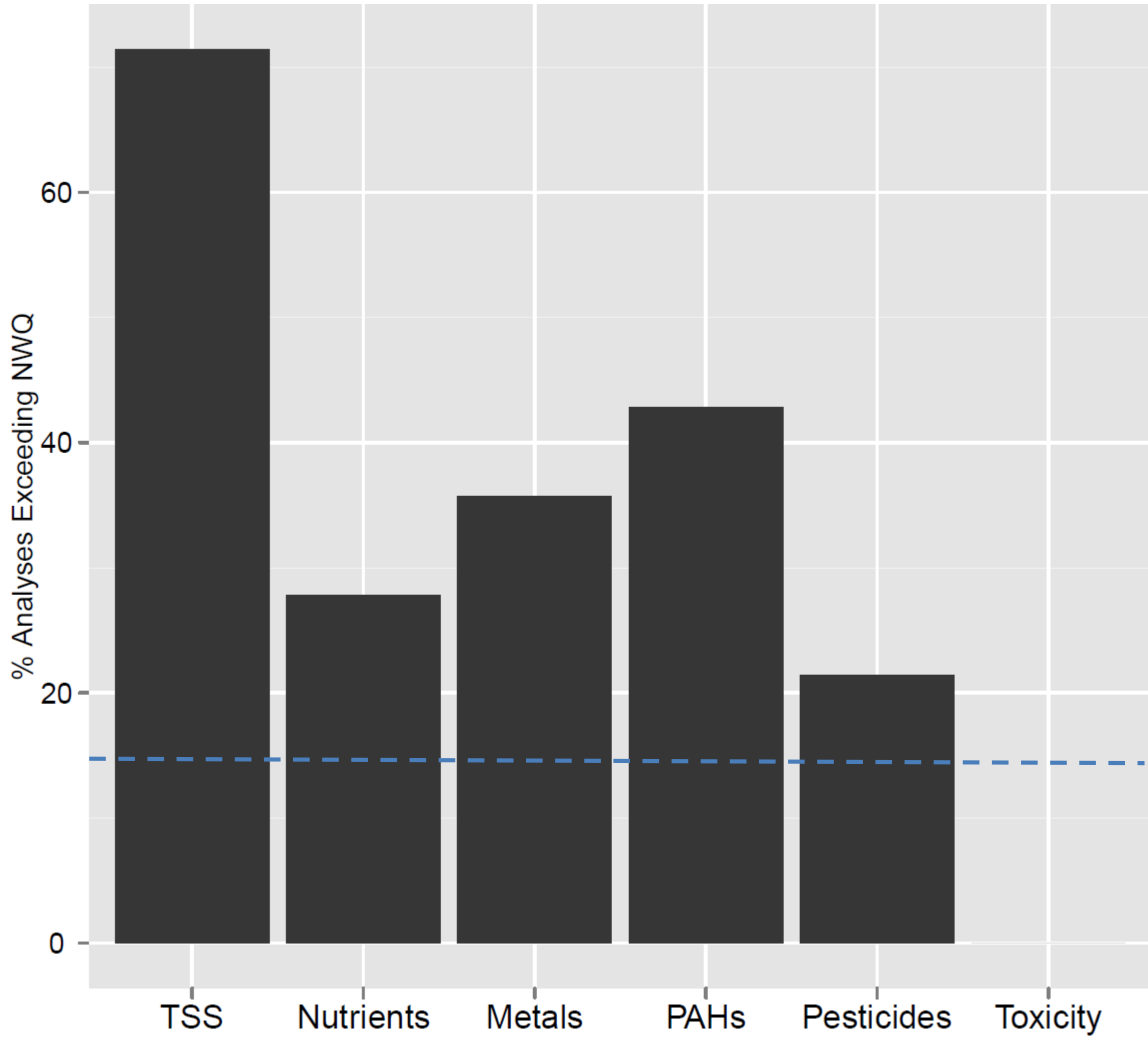
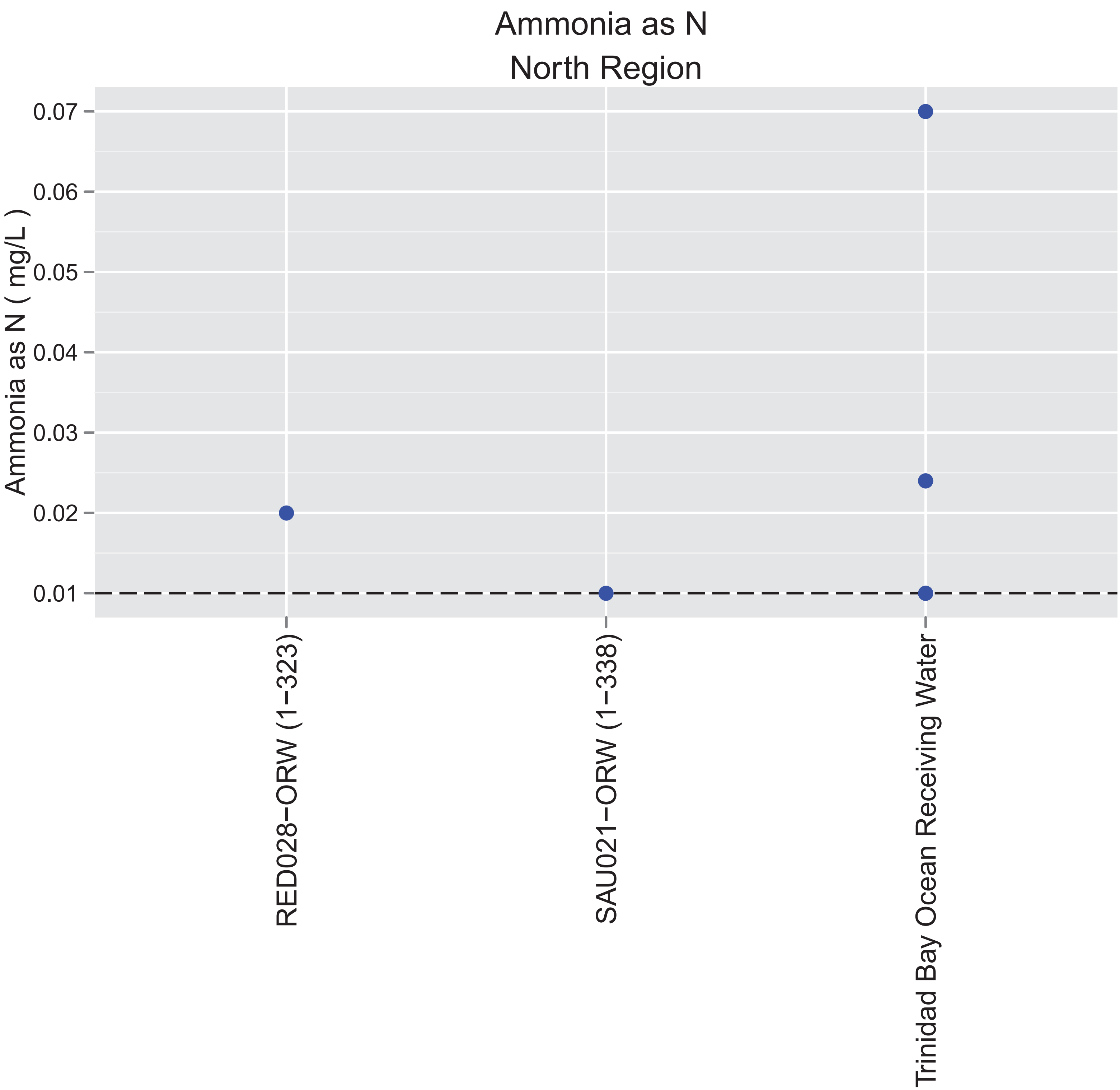


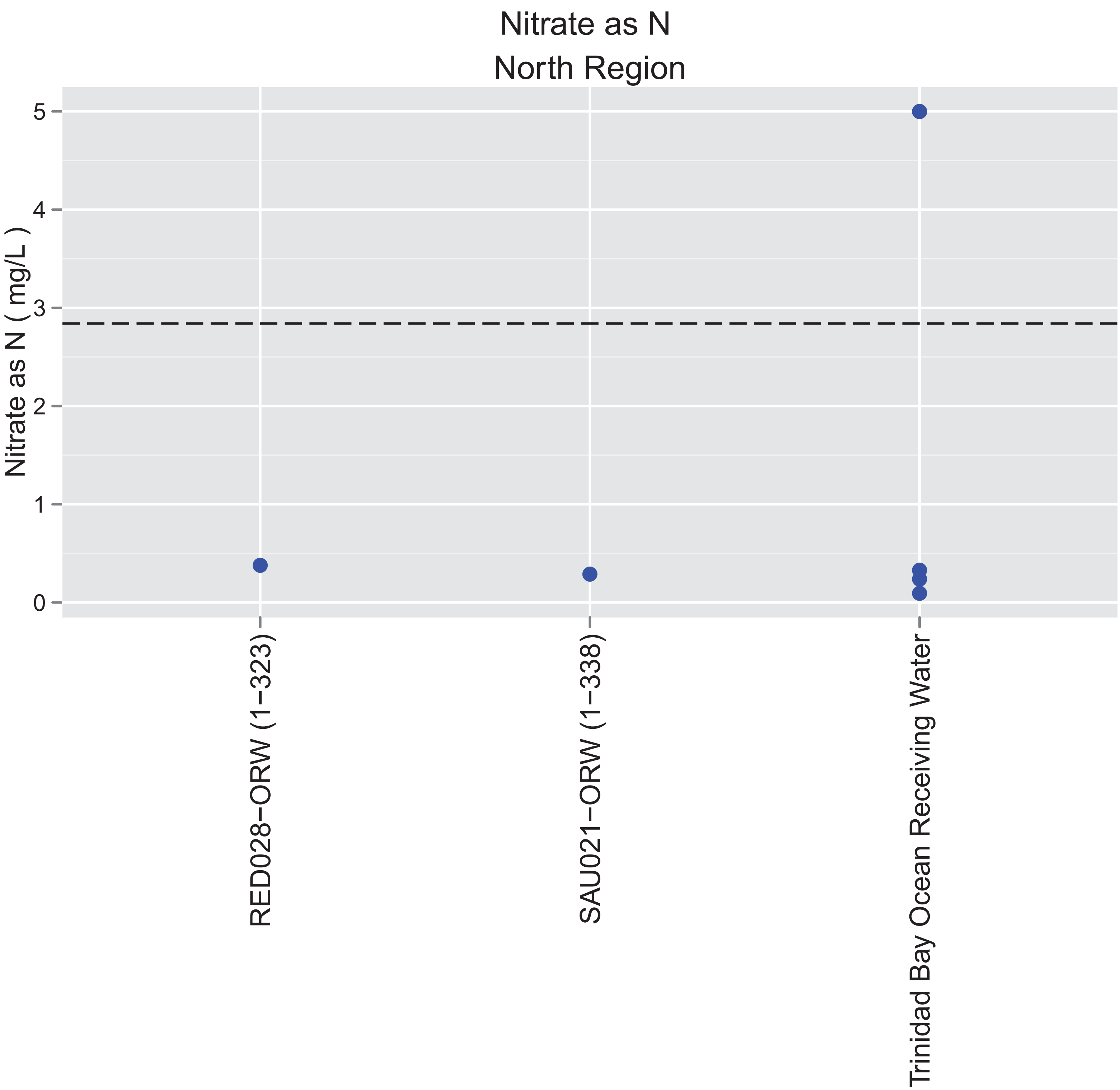
Figure 4. Exceedence of reference site based natural water quality guidelines by parameter group. The 15% reference line is the expected exceedance rate for reference sites.

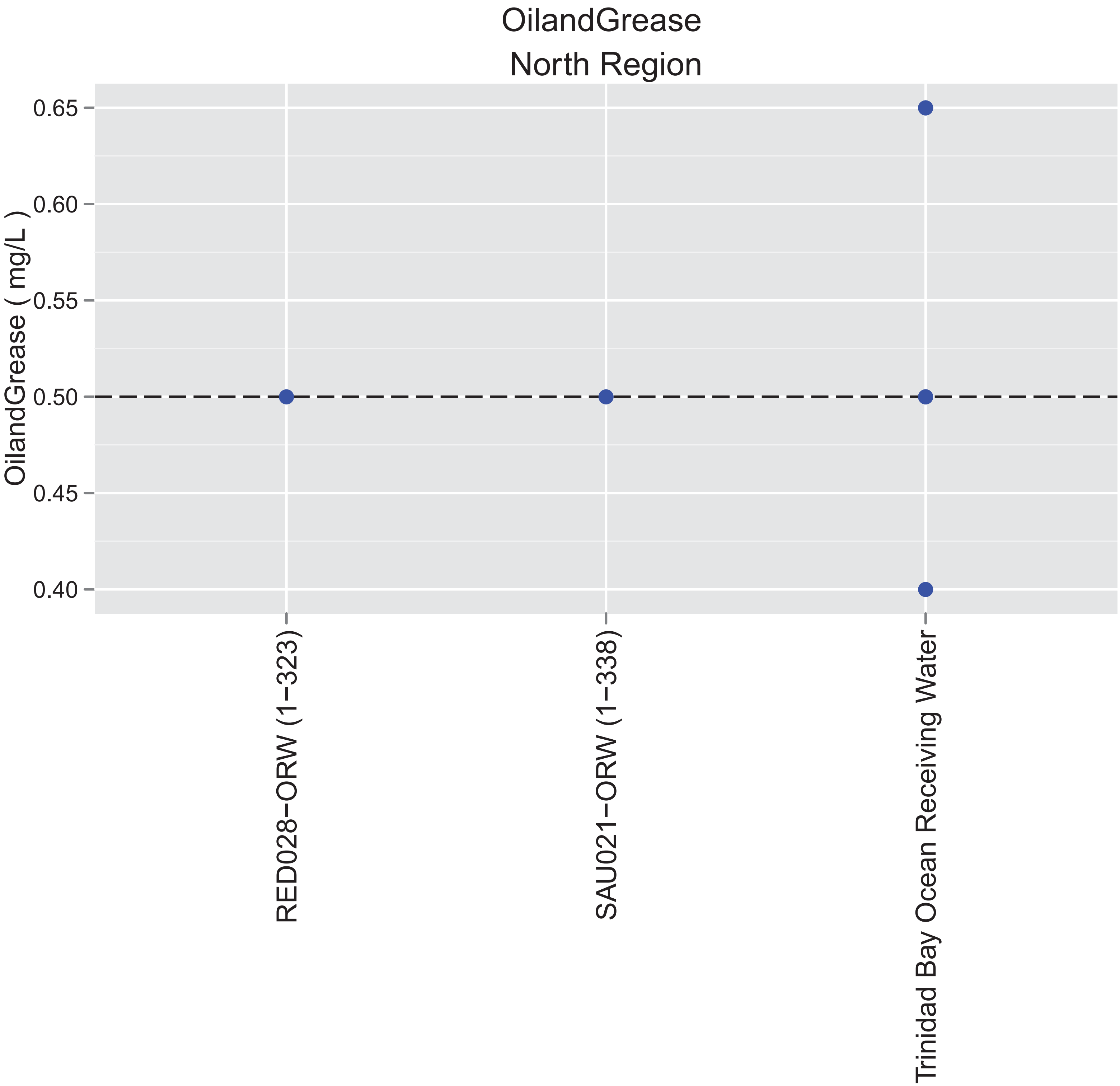


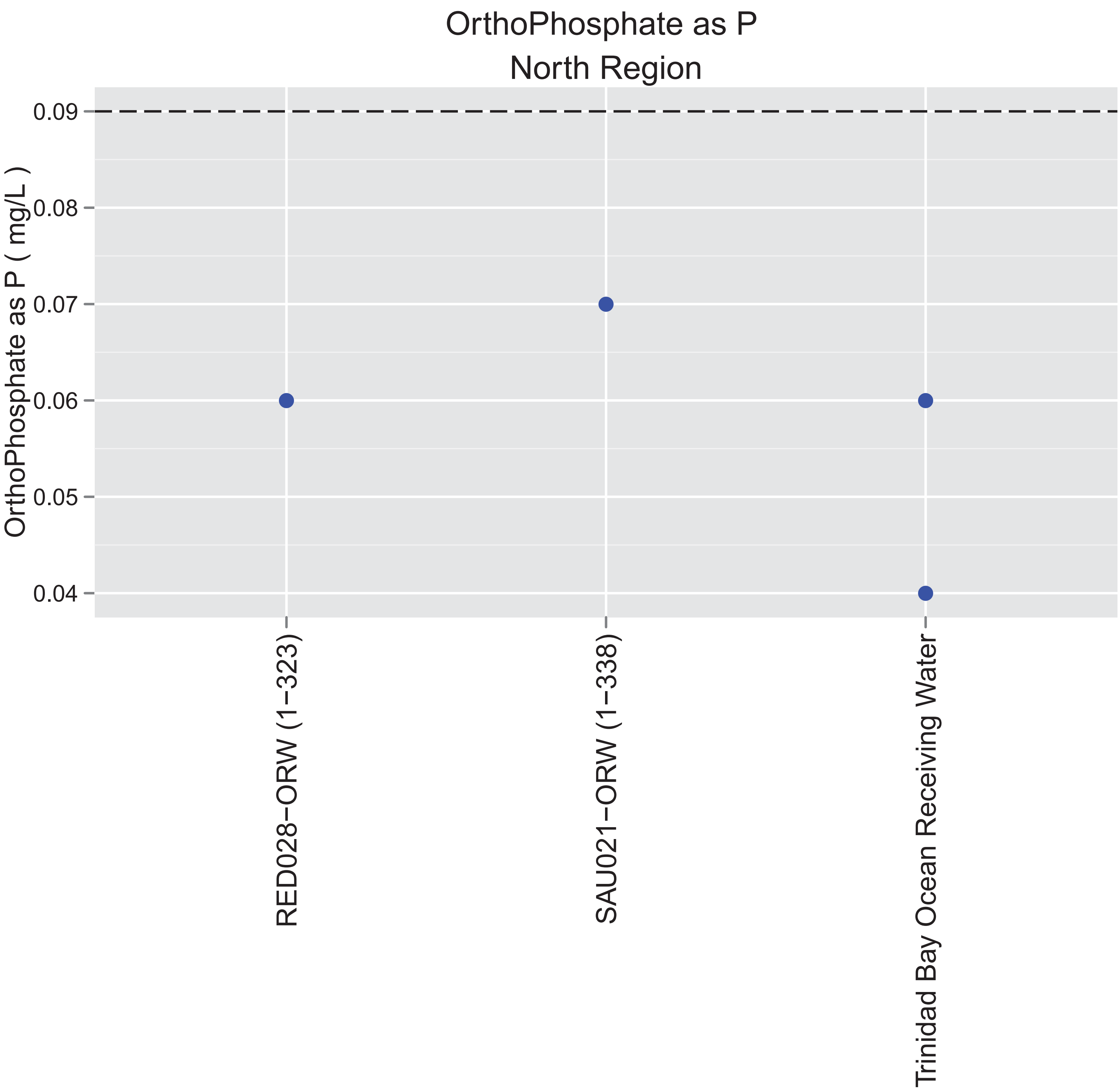
APPENDIX A: CONCENTRATIONS BY SITE



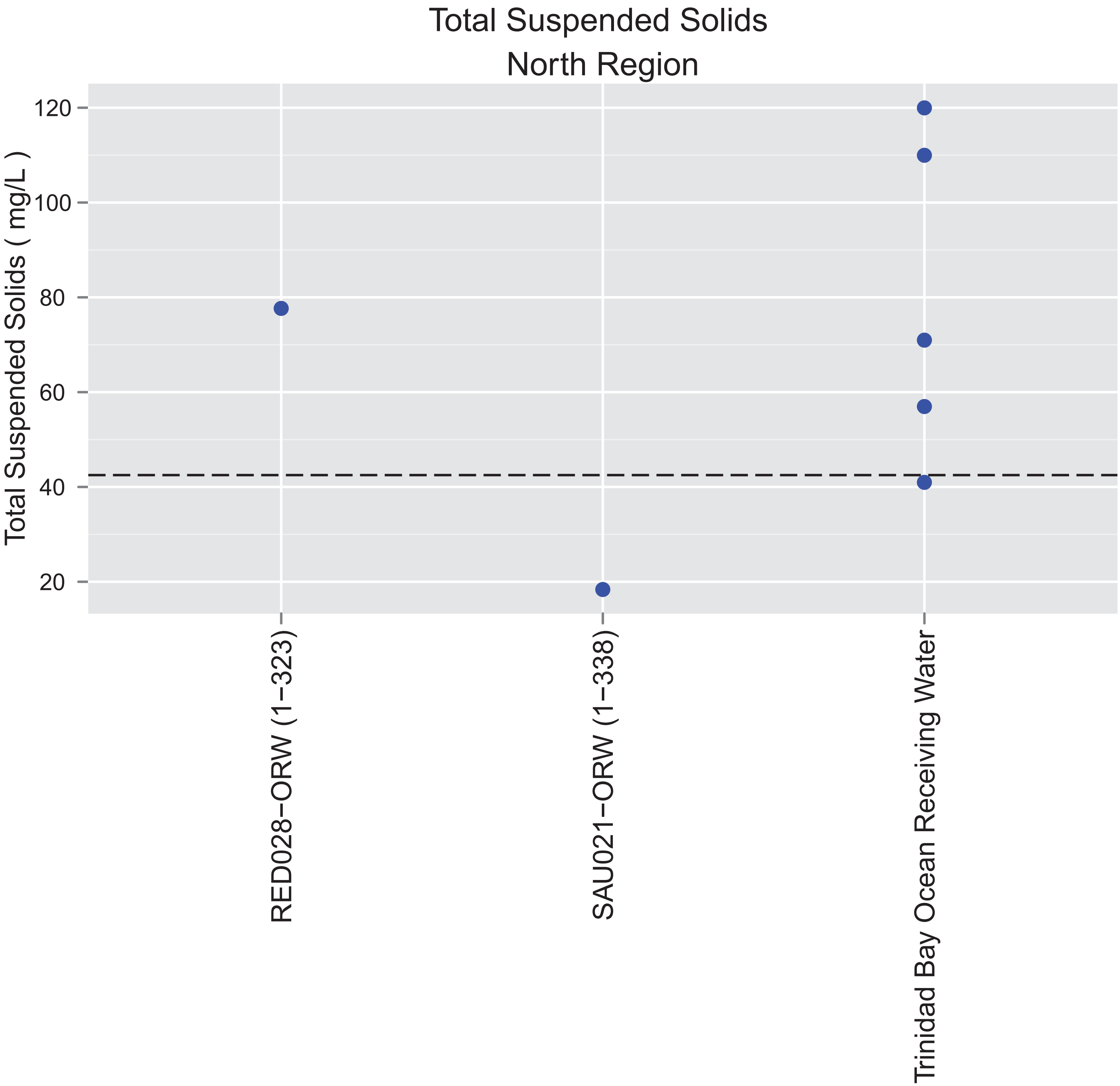
Ammonia as N
North Region
Ammonia as N (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water


Nitrate as N
North Region
Nitrate as N (mg/L)
0
1
2
3
4
5
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

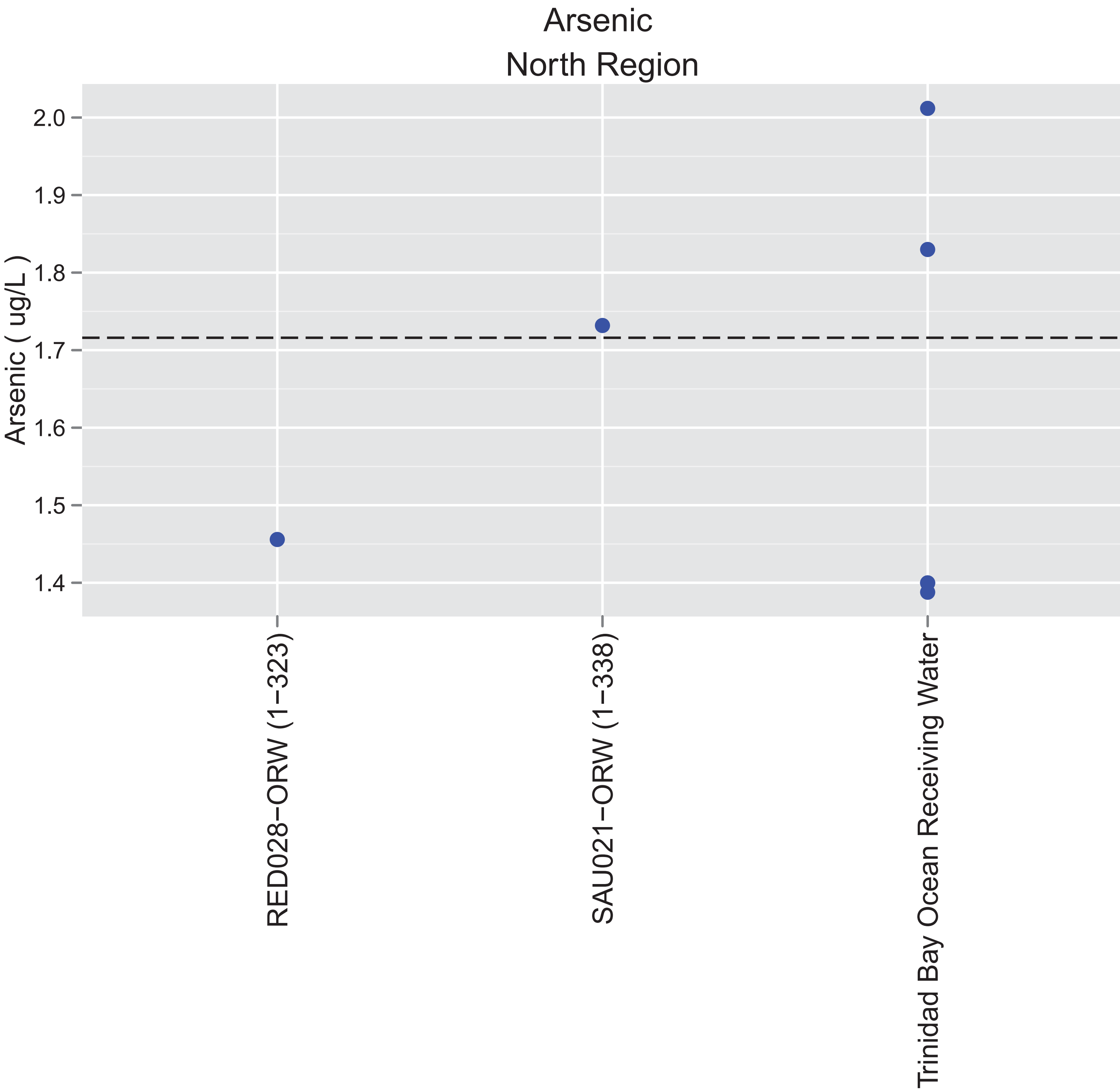

OilandGrease
North Region
OilandGrease (mg/L)
0.65
0.60
0.55
0.50
0.45
0.40
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

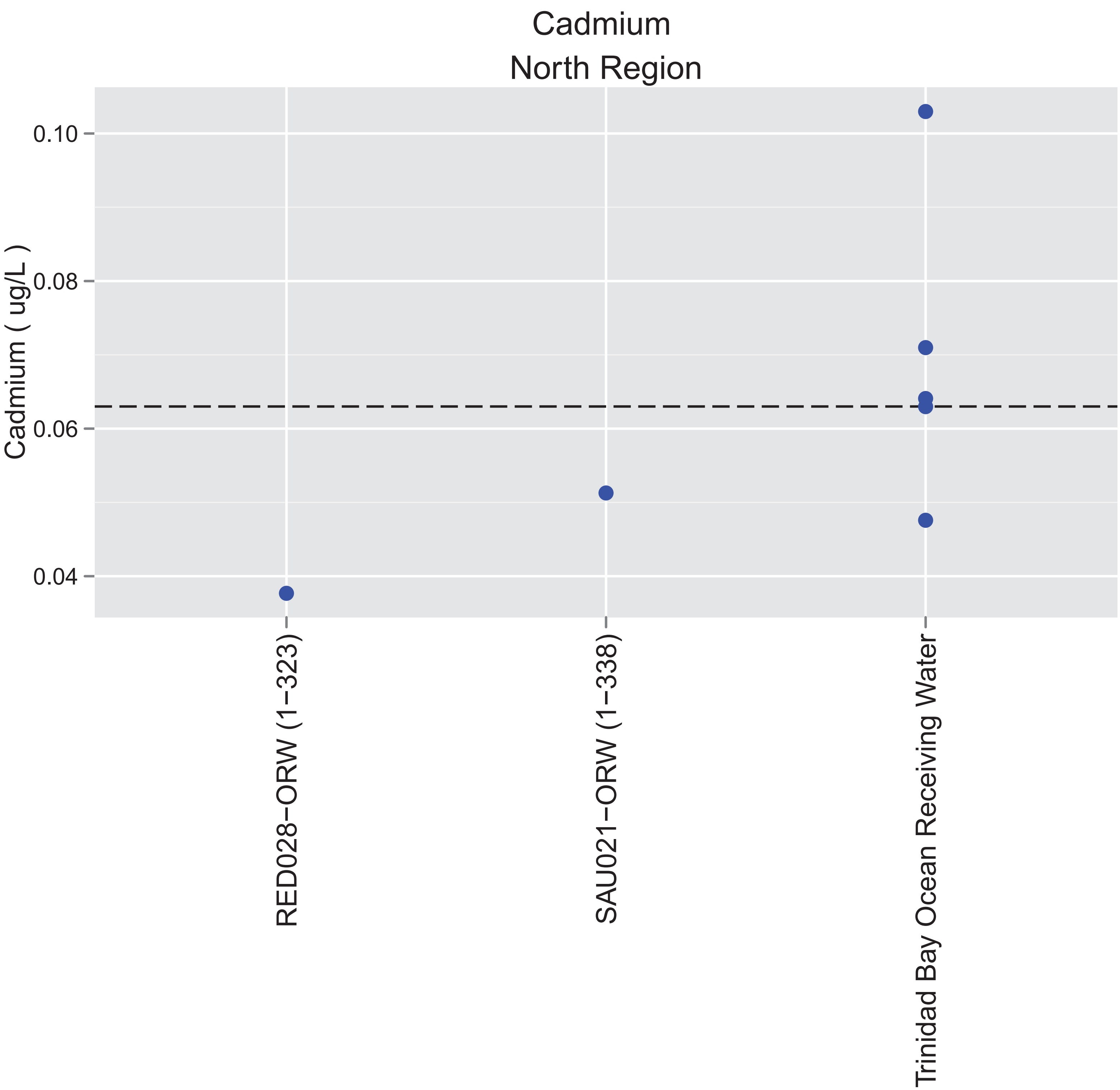


OrthoPhosphate as P
North Region
OrthoPhosphate as P (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

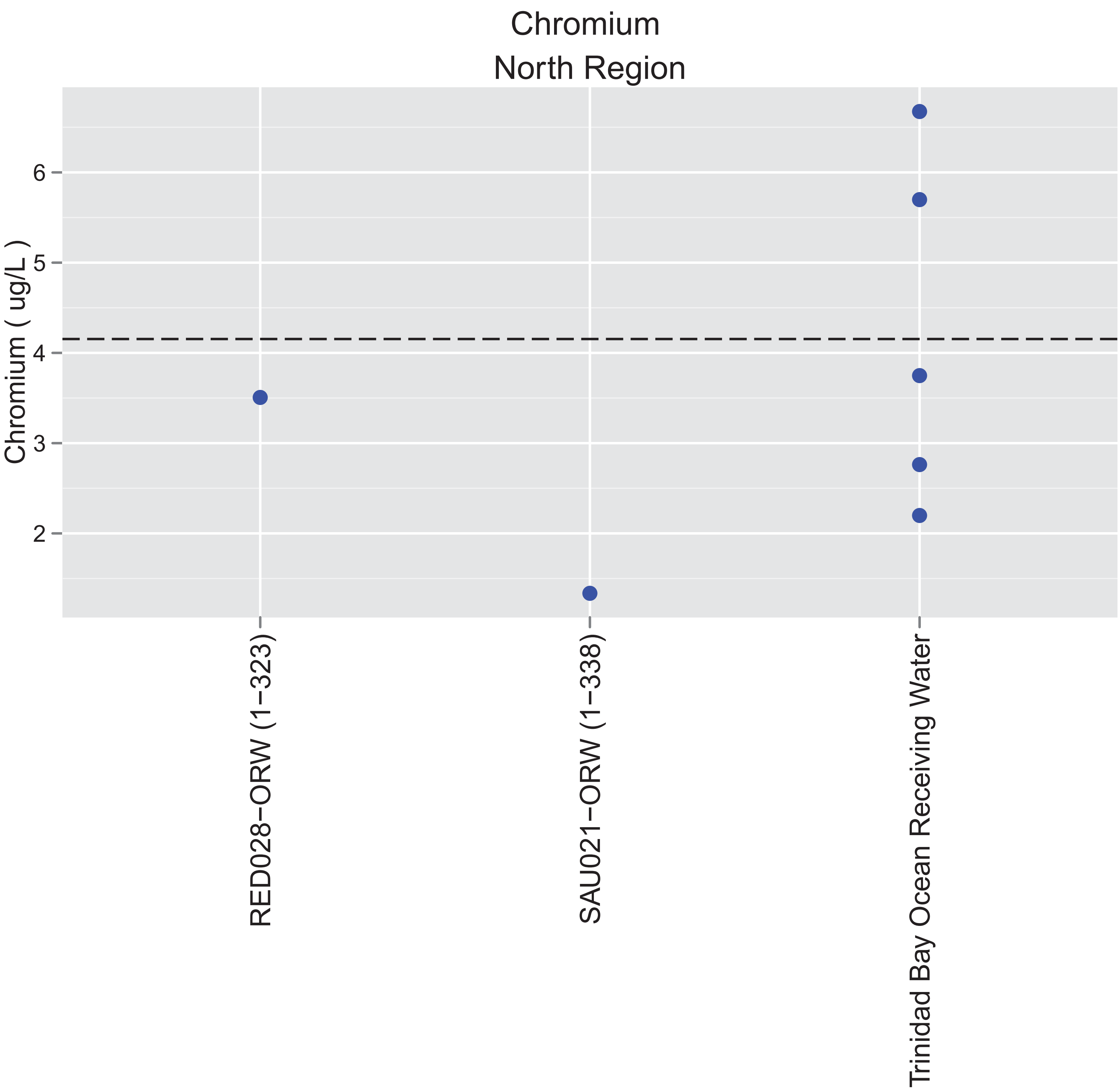


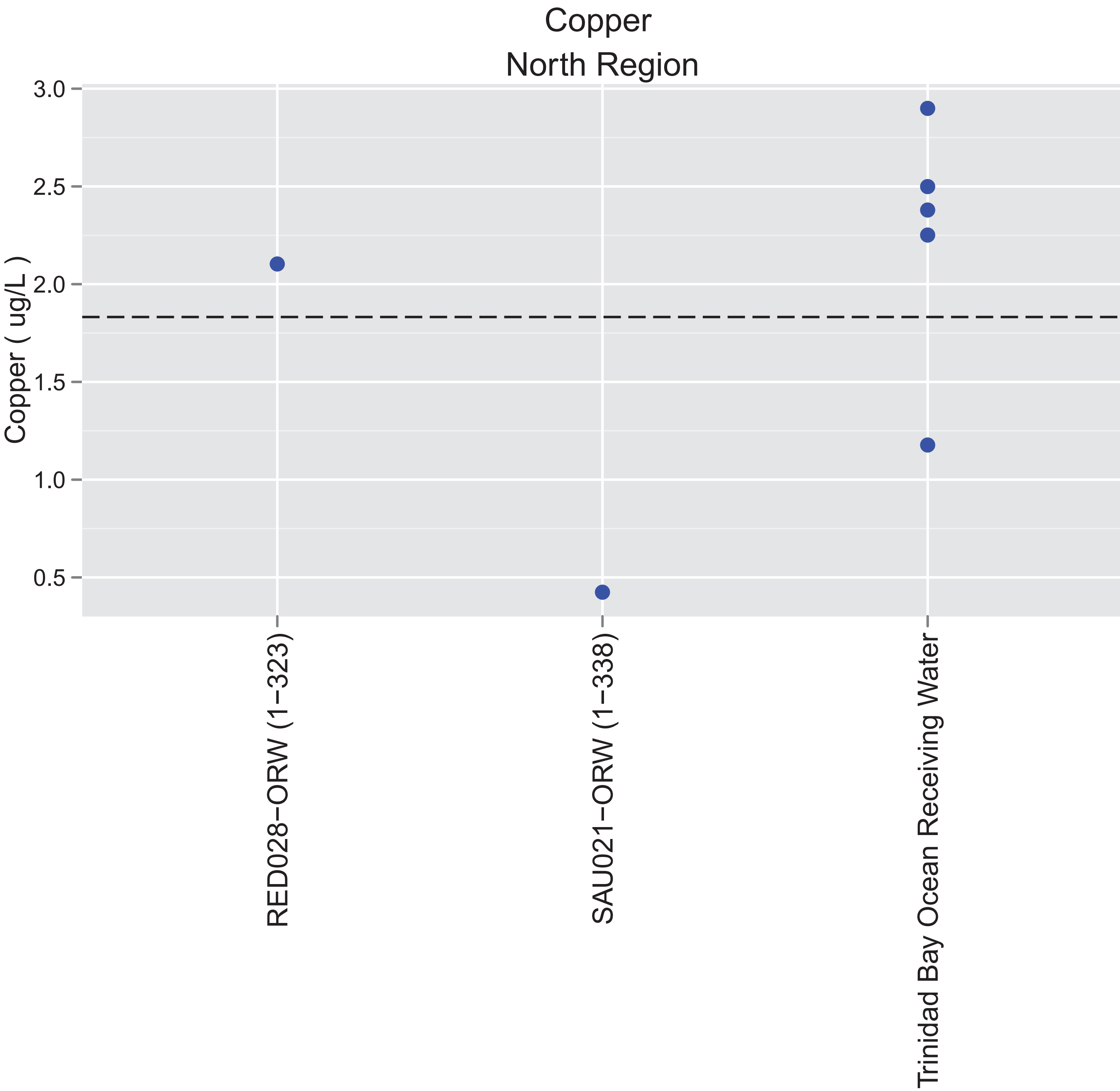
Total Suspended Solids
North Region
Total Suspended Solids (mg/L)
120
100
80
60
40
20
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

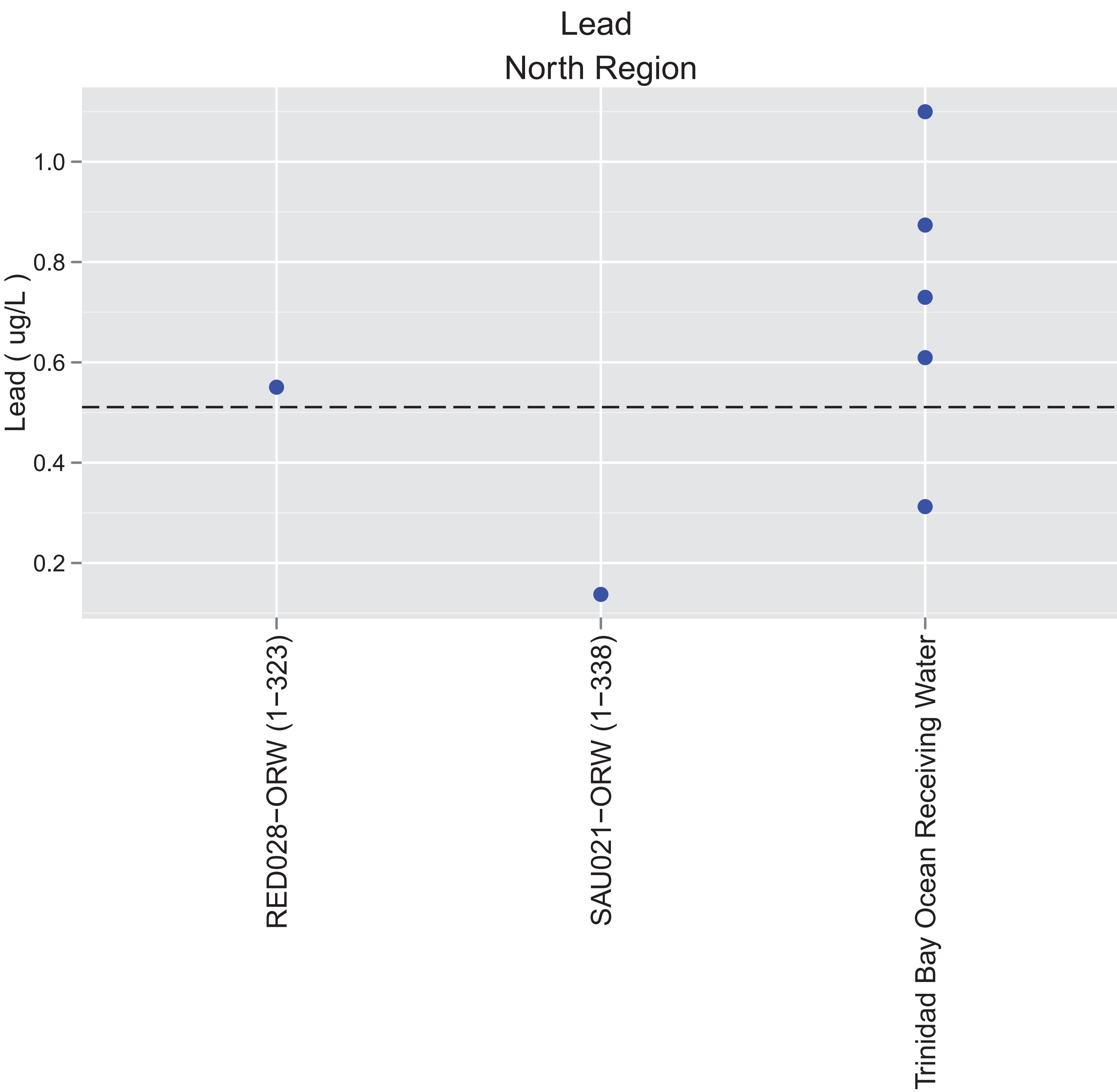

Arsenic
North Region
Arsenic (ug/L)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water



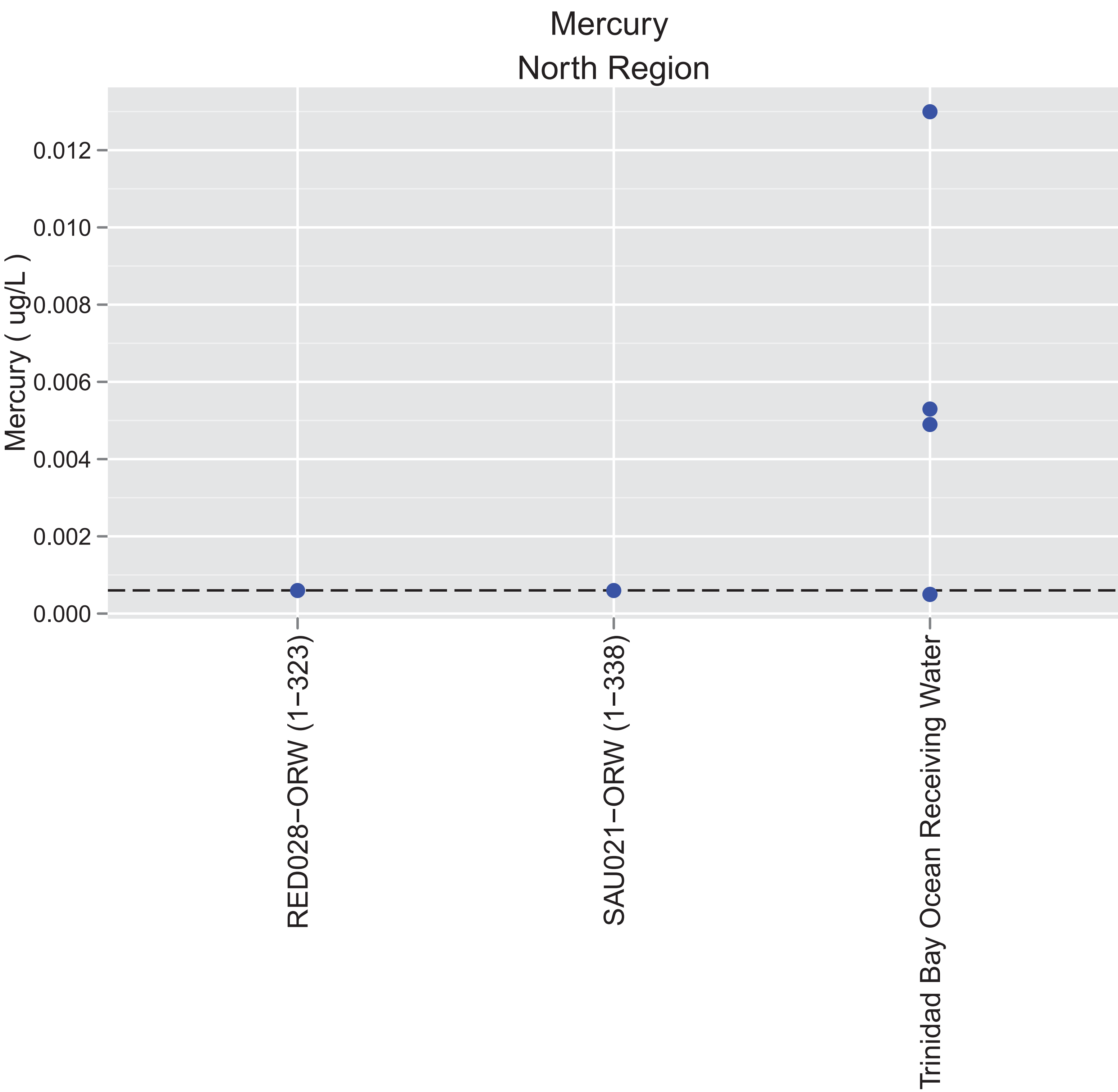
Cadmium
North Region
Cadmium (ug/L)
0.10
0.08
0.06
0.04
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water


Chromium
North Region
Chromium (ug/L)
6
5
4
3
2
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

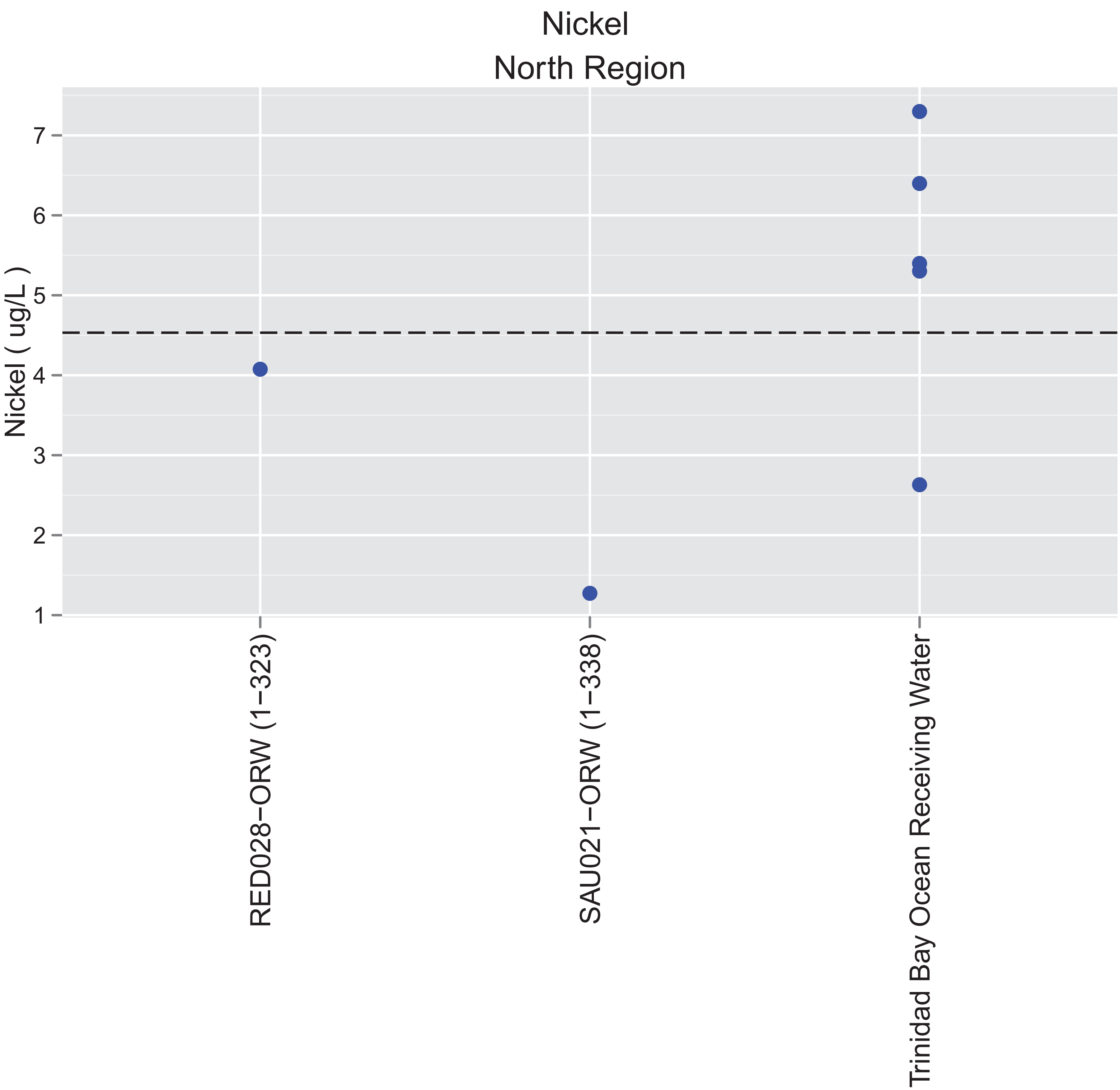

Copper
North Region
Copper (ug/L)
3.0
2.5
2.0
1.5
1.0
0.5
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

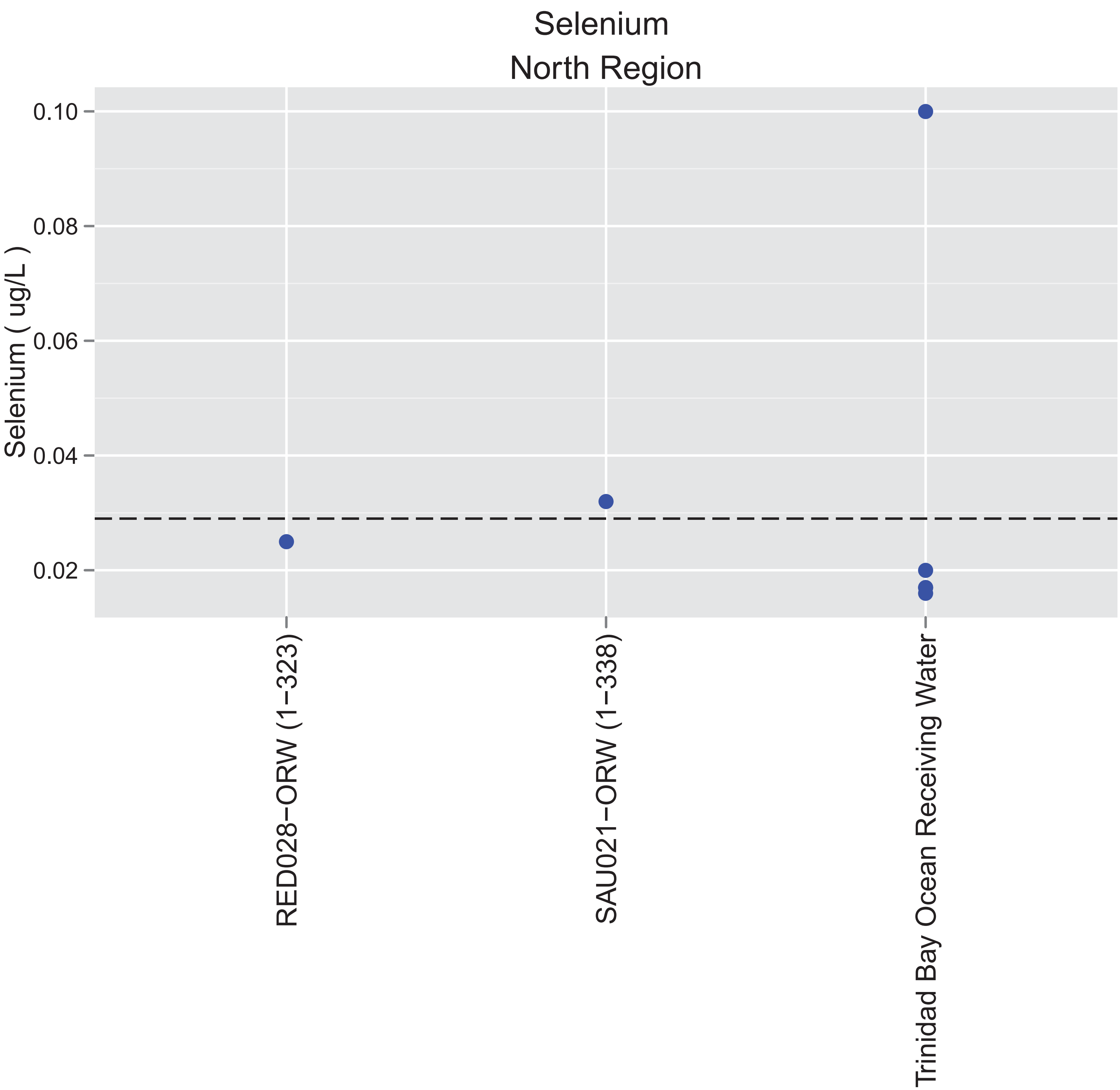


Lead
North Region
Lead (ug/L)
1.0
0.8
0.6
0.4
0.2
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

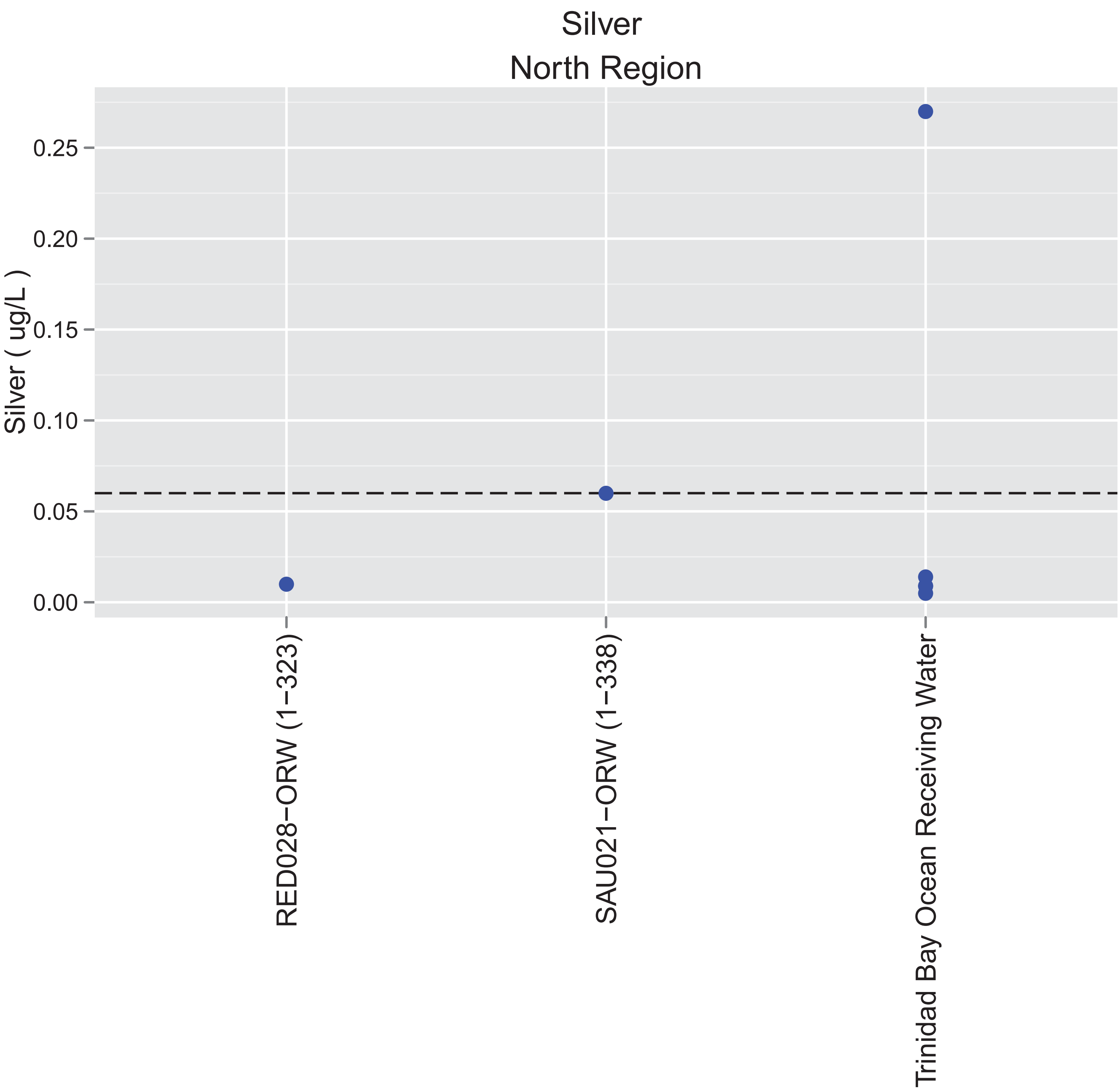


Mercury
North Region
Mercury (ug/L)
0.012
0.010
0.008
0.006
0.004
0.002
0.000
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

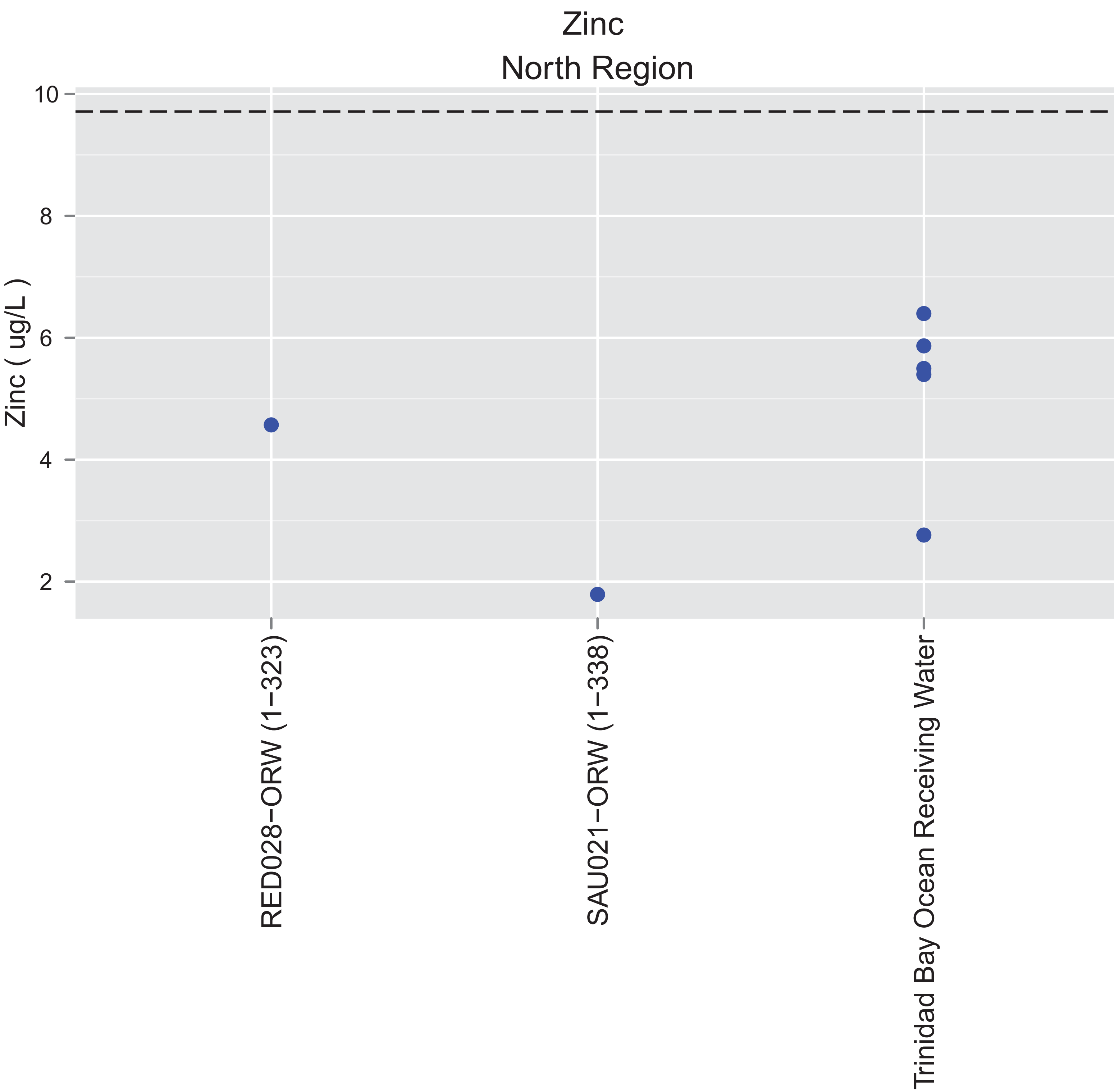

Nickel
North Region
Nickel (ug/L)
7
6
5
4
3
2
1
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water



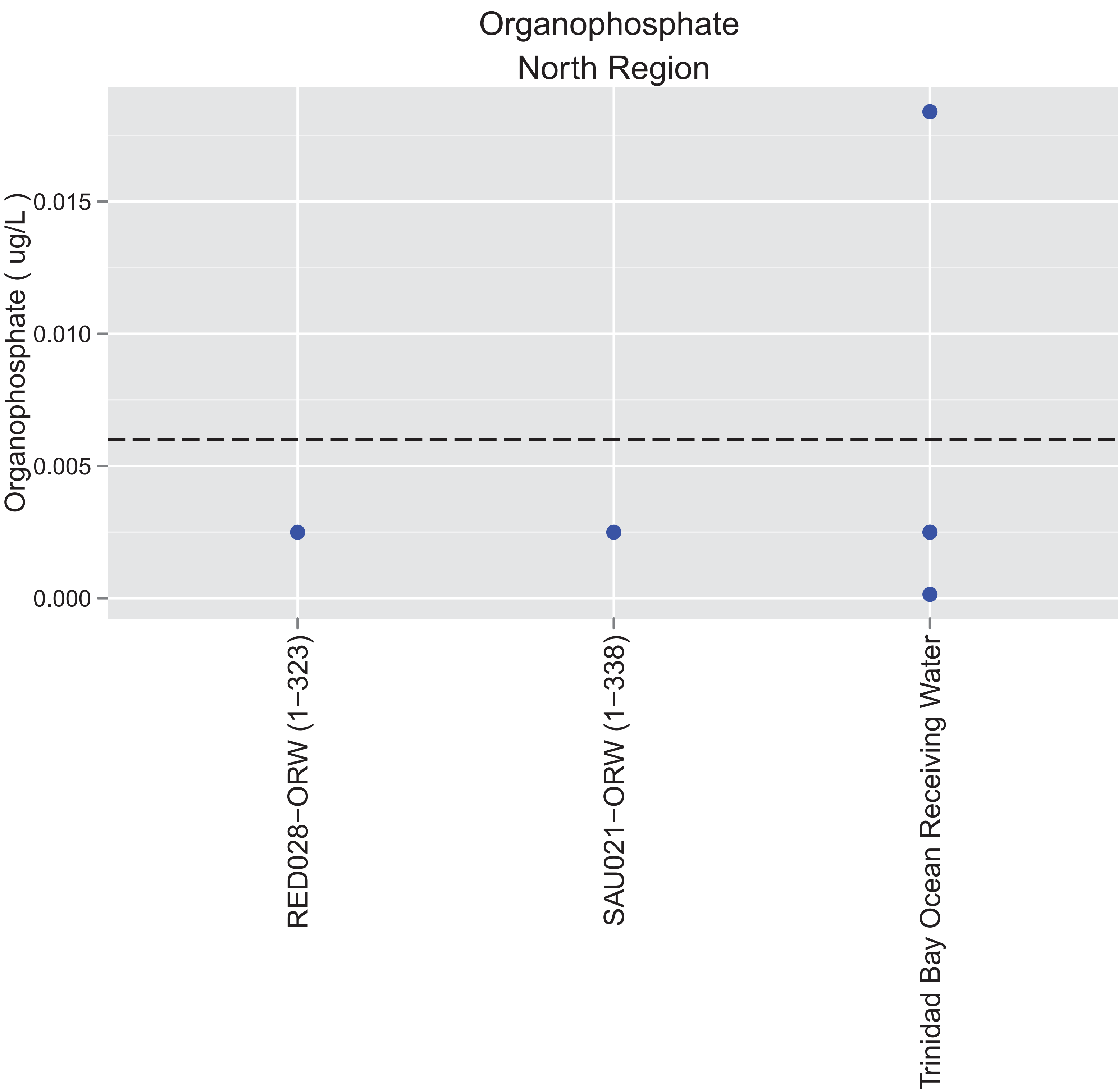
Selenium
North Region
Selenium (ug/L)
0.10
0.08
0.06
0.04
0.02
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

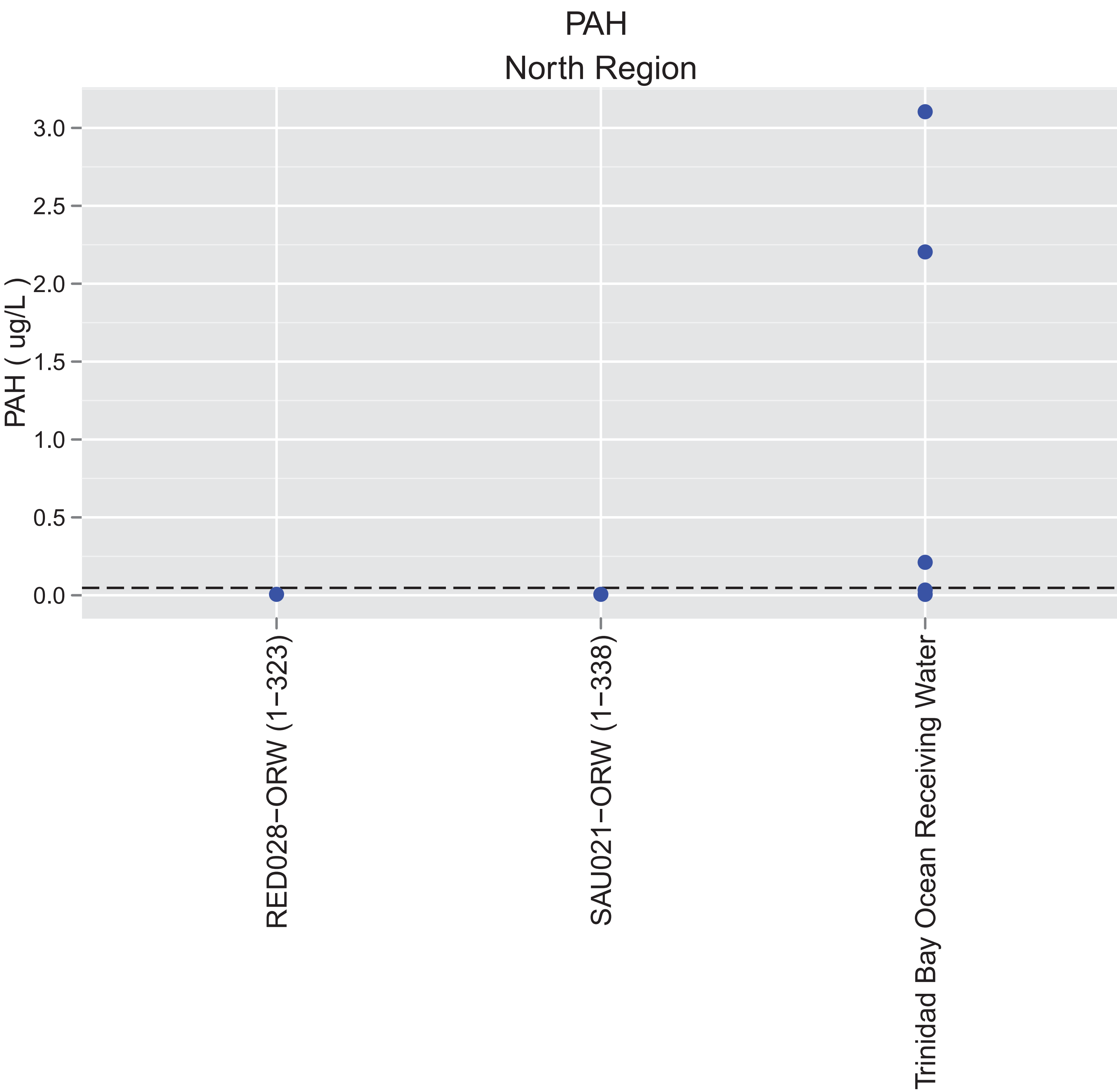


Silver
North Region
Silver (ug/L)
0.25
0.20
0.15
0.10
0.05
0.00
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

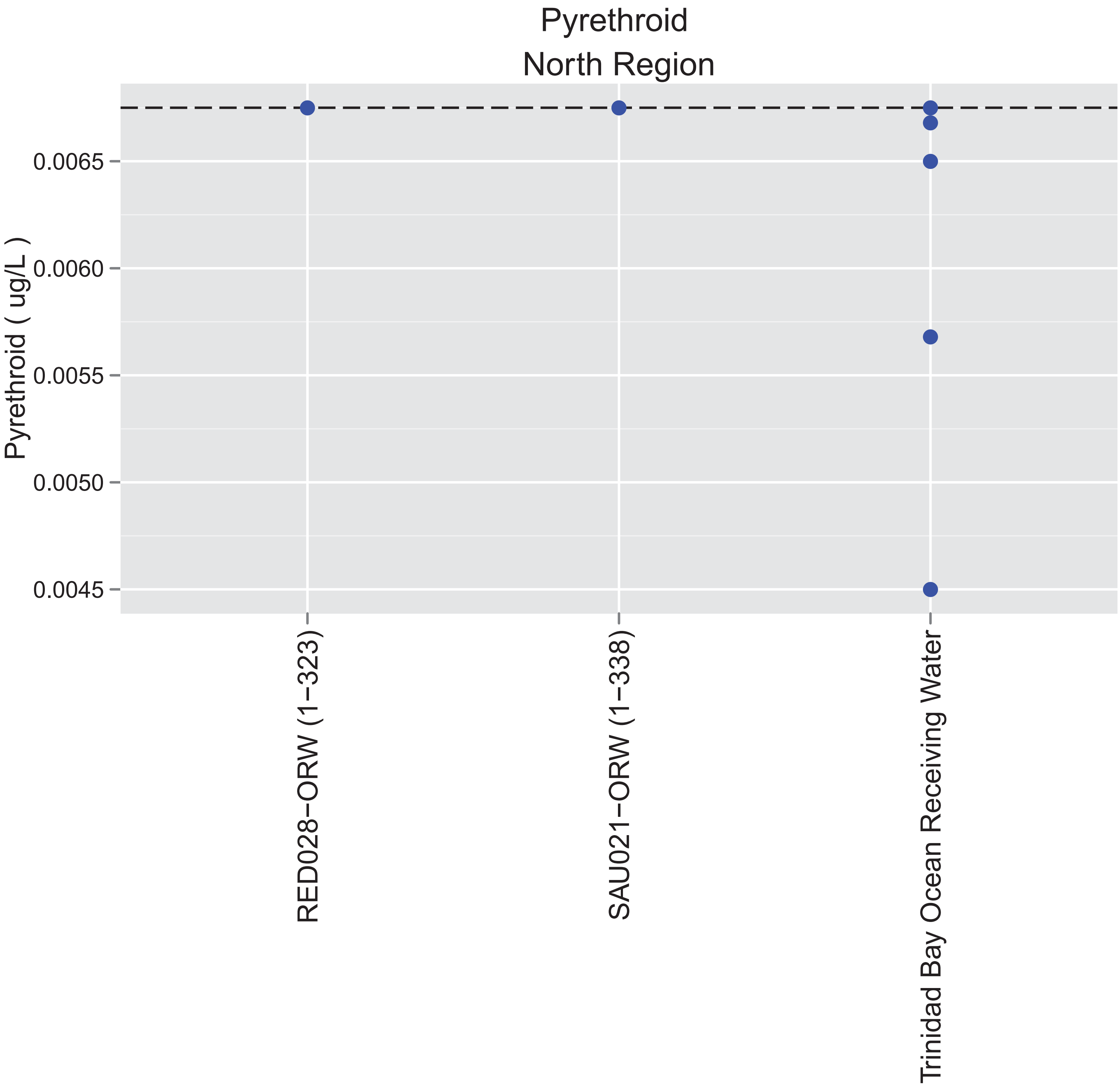


Zinc
North Region
Zinc (ug/L)
10
8
6
4
2
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

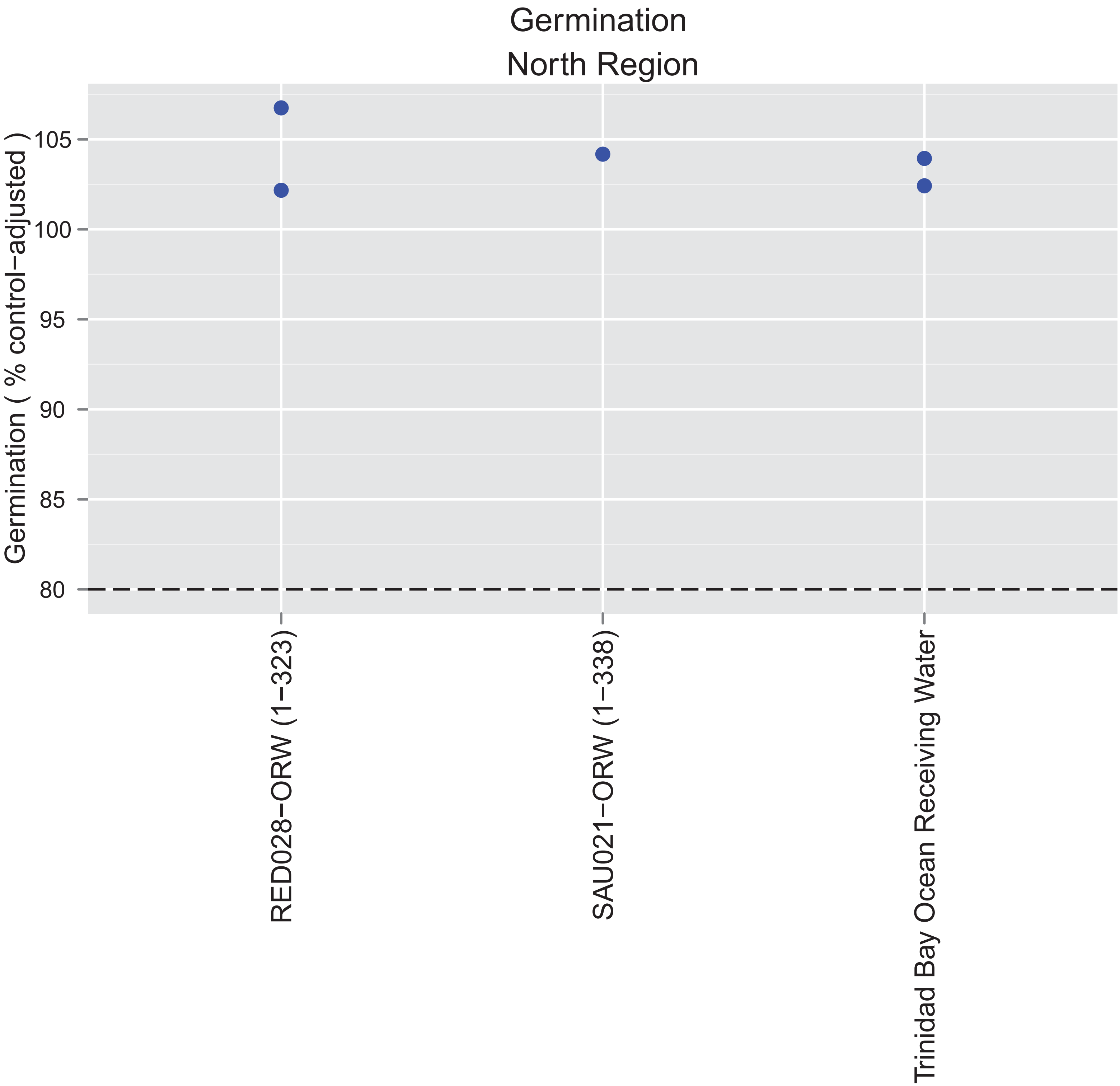

Organophosphate
North Region
Organophosphate (ug/L)
0.015
0.010
0.005
0.000
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water



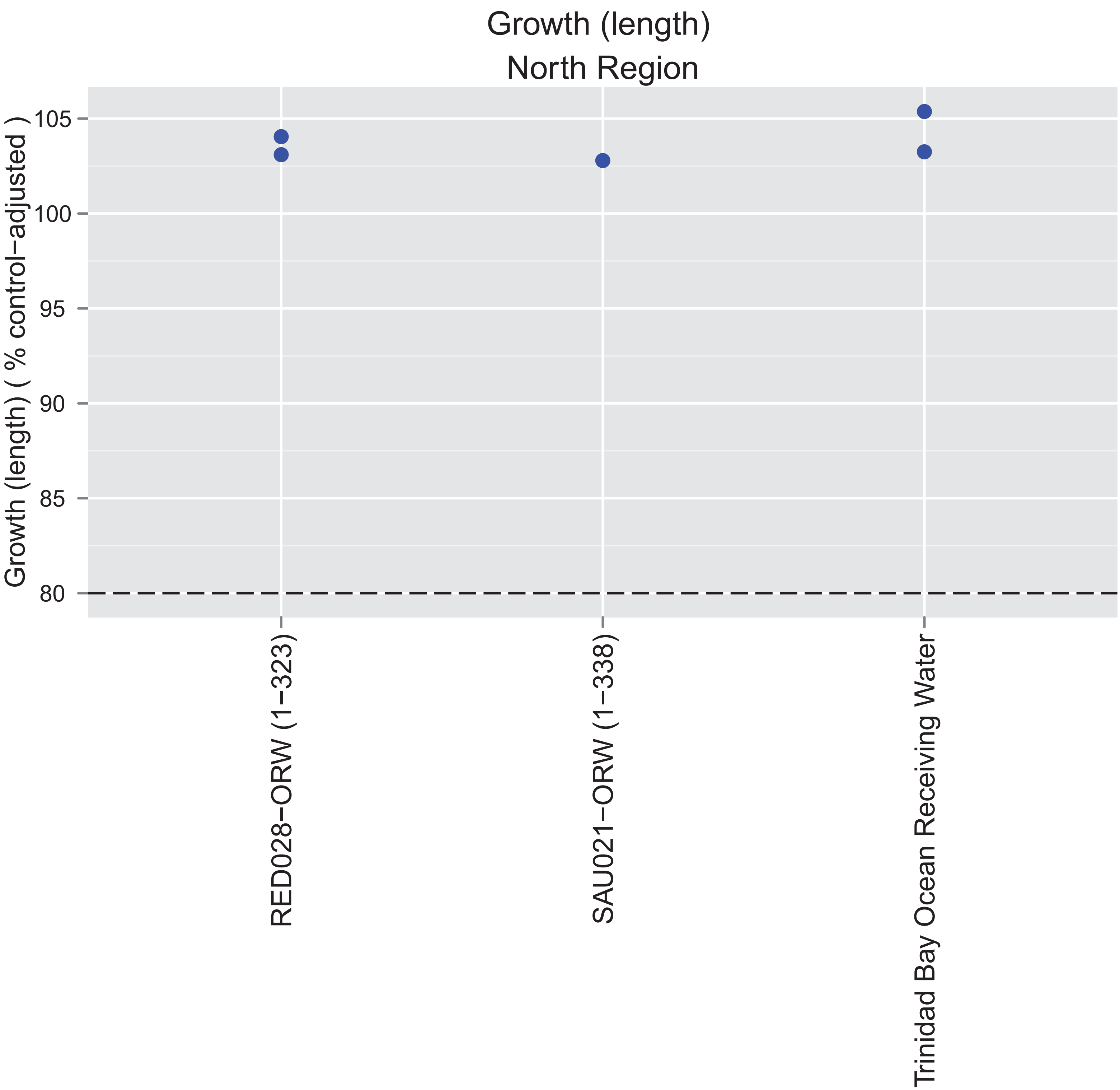
PAH
North Region
PAH (ug/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water



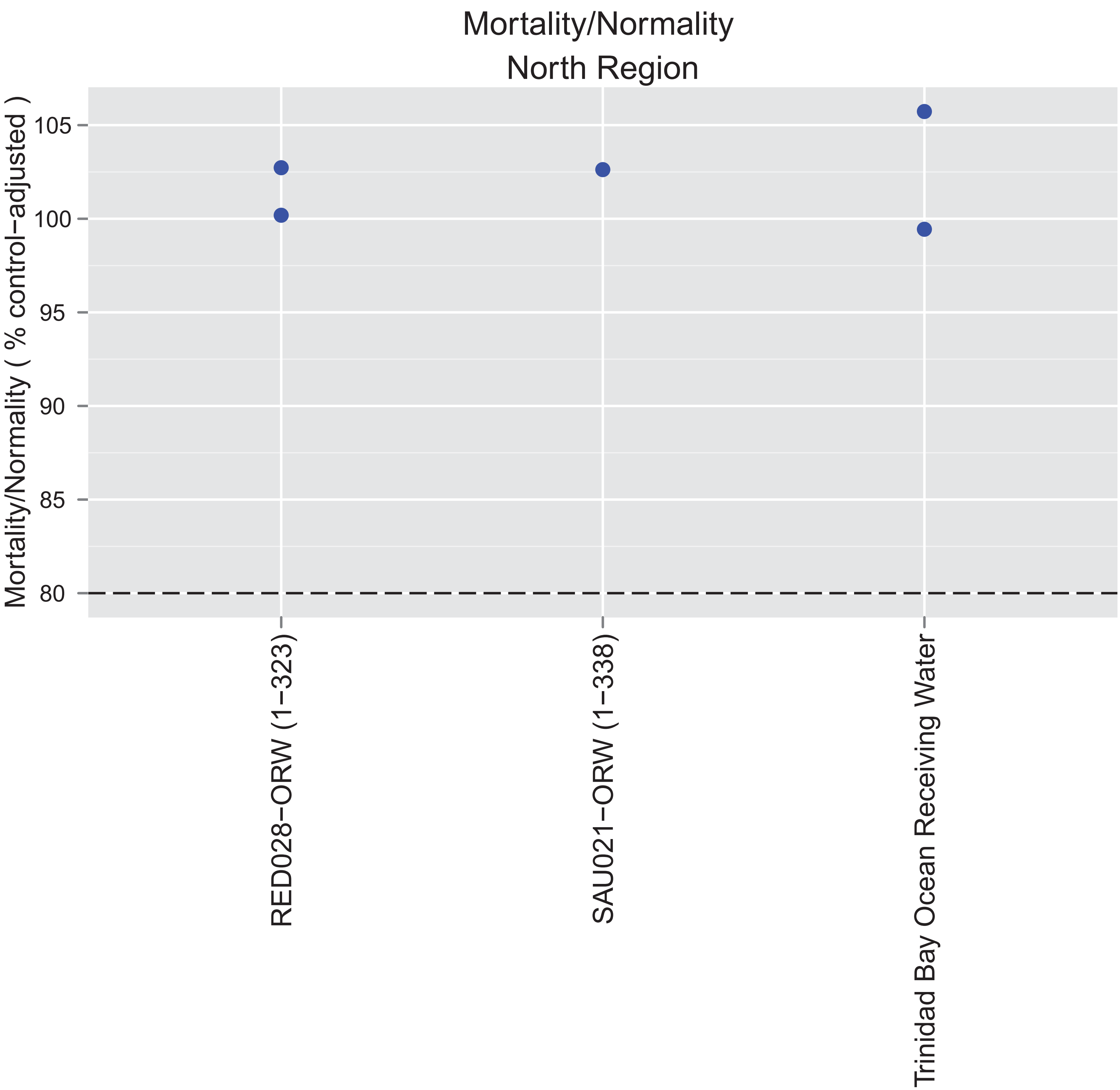
Pyrethroid
North Region
Pyrethroid (ug/L)
0.0065
0.0060
0.0055
0.0050
0.0045
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water

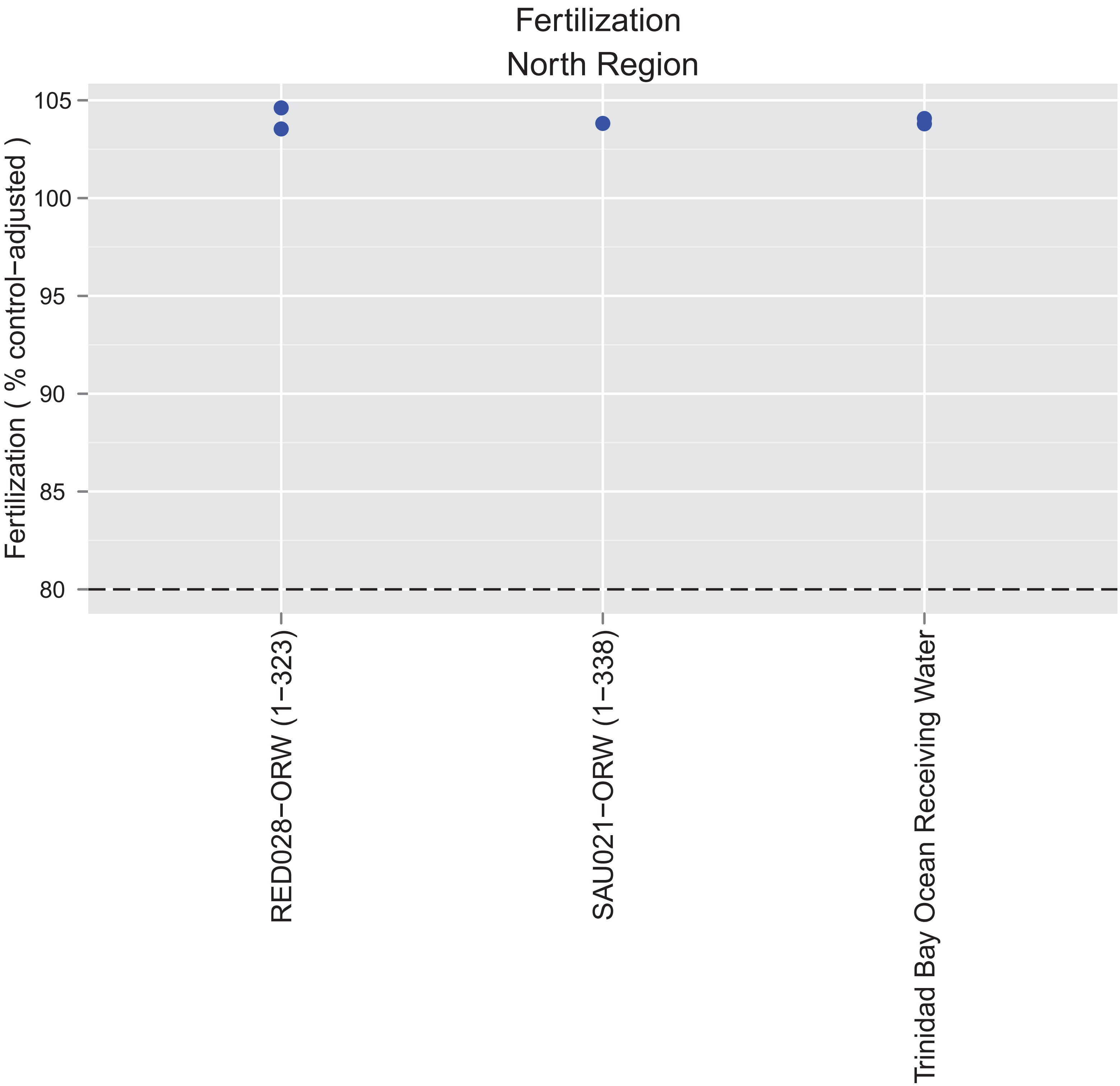


Germination
North Region
Germination (% control−adjusted)
105
100
95
90
85
80
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water



Growth (length)
North Region
Growth (length) (% control−adjusted)
105
100
95
90
85
80
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water


Mortality/Normality
North Region
Mortality/Normality (% control−adjusted)
105
100
95
90
85
80
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water



Fertilization
North Region
Fertilization (% control−adjusted)
105
100
95
90
85
80
RED028−ORW (1−323)
SAU021−ORW (1−338)
Trinidad Bay Ocean Receiving Water