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Nutrient Atmospheric Deposition on Utah Lake and Great Salt Lake Locations 2020, including Effects of Sampler Type

Statistical Analyses and Results

DRAFT

To
Wasatch Front Water Quality Council
Salt Lake City, UT

By
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August 2, 2022, Note:
These analyses were made in August 2021 based on limited time and funding constraints and knowledge of AD at the time. Additional understanding of AD science has been accruing since then. The statistical methods and results presented in this report are valid however, additional refinements can be made that may increase precision (e.g., decrease error estimates).

Title Page Image: Atmospheric deposition sampler located on Bird Island, SW Utah Lake. Photo by David Richards.

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Introduction

Understanding and quantifying sources of nutrient loading is essential if we are to effectively manage Utah Lake's ecosystem, including the increasing effects of cultural eutrophication on food webs, water quality, and subsequent direct and indirect intensification of potentially harmful cyanobacteria blooms (Utah Lake Science Panel (ULSP) 2021). This is especially important for large shallow Utah Lake where sediments, water column, and atmospheric deposition interactions are continuous and inseparable (Scheffer et al. multiple years; Richards and Miller 2017, 2019). Nutrient loading and cycling in Utah Lake is dependent on four major abiotic pathways: 1) Point source tributary inputs and 2) outputs, 3) non-point transfer between sediments and the water column, and 4) non-point atmospheric deposition (AD). Point source nutrient inputs and outputs are relatively easily identified and quantified with good precision and are near completion by the ULSP, whereas interactions within the sediment -water column cycle have been less studied in the lake and were not as easily quantified, characteristically resulting in greater uncertainty (Hogsett and Goel 2013; Hogsett et al. 2019; ULSP). Much less understood and rarely accurately quantified is the water column-atmospheric deposition (AD) nutrient cycle and associated effects on chemical and ecological interactions in Utah Lake (ULSP 2021).

Very few watershed or lake-specific atmospheric deposition (AD) data have been routinely collected and monitored on Utah Lake, other than that recently initiated and sponsored by Wasatch Front Water Quality Council (WFWQC). Although regional AD models are becoming more widely available, their relevance to local conditions on Utah Lake is questionable (ULSP 2021). Therefore, accurate spatial and temporal atmospheric nutrient deposition rates do not exist for the lake, without which useful nutrient cycling and predictive models cannot be developed. In addition, there are no standards for design and implementation of AD samplers, as AD monitoring is in its infancy. Subsequently, management of cultural eutrophication and development of site specific, science-based water quality criteria is hindered without accurate estimates of local AD rates, which is of concern to water quality managers and scientists working on Utah Lake's ecosystem.

Goals

The central goals of these analyses were to:

1. Estimate total annual AD of total phosphorus, TP, soluble reactive phosphorus SRP, and dissolved inorganic nitrogen, DIN on Utah Lake in 2020.
2. Test differences in AD nutrient accumulation in low vs. high type samplers.
3. Test differences in AD nutrient accumulation in screened non-NADP vs. unscreened NADP type samplers.
4. Compare and contrast local spatial and temporal AD rates.

Methods

Utah Lake

Utah Lake is a slightly saline- eutrophic to hypereutrophic- alkaline-turbid- shallow-temperate lake with an average depth of about 1.5 to 2.8 m. It is about 40 km long by 21 km wide, with a surface area of about

384 km^2. Although Utah Lake historically functioned as a natural shallow lake ecosystem, it is now managed as a water storage reservoir and has undergone what are known as ecological hysteresis (Nikanorov and Sukhorukov 2008, Beisner et al. 2003) and catastrophic ecosystem shifts (Scheffer et al. 2001, Beisner et al. 2003) over the last century and a half. This has resulted in dramatic transitions known as 'alternative stable states', primarily driven by human activity (Richards and Miller 2019; ULSP 2021). See Richards and Miller 2017, 2019 for more detailed descriptions of Utah Lake's ecosystem.

Data Used

We obtained nutrient atmospheric deposition (AD) data collected by BYU graduate student Seth Barrus that were the core of his MS thesis. Data were collected from several locations in Utah County along Utah Lake and Salt Lake County near Great Salt Lake in 2020 using three types of samplers for comparison (**Error! Reference source not found.**). Funding for research was provided by Wasatch Front Water Quality Council.

Sampler Design

See Barrus et al. 2021 and Miller 2021 for a description of AD sampler design and locations.

Statistical Methods

Atmospheric depositional (AD) nutrient data that were collected and recorded as parts per million (ppm) were transformed as mg m^{-2} prior to obtaining data for these analyses. We used data collected weekly from May to December 2020 to generate time series graphs of TP, SRP, and DIN from paired high and low samplers at two locations, Central Davis and Ambassador. We also conducted parametric correlations (*r)* along with associated p-values between low and high samplers for all three nutrients.

Histograms were then generated and examined for data distributional patterns. Box plots of TP, SRP, and DIN data comparing sites and types of samplers used were also made. Plots included medians, 25th and 75th quantiles and interquartile ranges. Outliers were not plotted. Nonparametric Kruskal-Wallis rank tests were made for these comparisons without adjusting for temporal effects[1].

Different combinations of categorical independent predictor variables vs. untransformed and transformed nutrient concentration (mg m^{-2}) dependent response variables were modeled using simple and multi-level mixed effects linear regressions with interactions and then evaluated. We categorized the data into monthly bins as our temporal predictor variable and modeled it as a random effect for each regression model. Although monthly categories are somewhat arbitrary temporal delineations, there were too few samples (i.e., small sample size) collected on a weekly basis to develop valid models using weekly estimates. In most instances the monthly categorical random effects variable significantly improved model fit based on likelihood ratio tests. Final best-fit regression models were selected based on lowest log likelihood, Akaike information criteria (AIC), and Bayesian information criteria (BIC). Two types of mixed effects regression models provided the best fits, 1) negative binomial models using

[1] Because AD data analyzed in this report were not conducted by the original authors, more appropriate preplanned comparisons were not made in testing the two sampler type hypotheses (see Goals).

untransformed data and 2) linear models using log_{10} transformed data, as did simple linear regressions on log_{10} transformed response variables. Negative binomial regression is used for count data (non-integer values are suitable) that are produced by a Poisson-like process but are over-dispersed (StataCorp 2019). Because nutrient data were collected and recorded as ppm (i.e., count data) and were over-dispersed, in most instances we considered mixed effects negative binomial regression models to be the most appropriate, however log_{10} transformed mixed effects models sometimes provided superior estimates, particularly for estimating total annual nutrient AD on Utah Lake. Incidence-rate ratios (IRR) were reported to help interpret mixed effects negative binomial regression model results. IRR is the rate (proportion) of change in nutrient concentrations resulting from one unit of change in the baseline categorical predictor variable. We also created mean and 95% CI graphs of predicted nutrient concentrations in response to predictor variables using best-fit model results. Tables of predicted means, standard errors (Std. Err.), and 95% CIs of TP and DIN for each sampler type and site were derived from regression results and are also presented. All statistical analyses were conducted using Stata16.1 (StataCorp 2019).

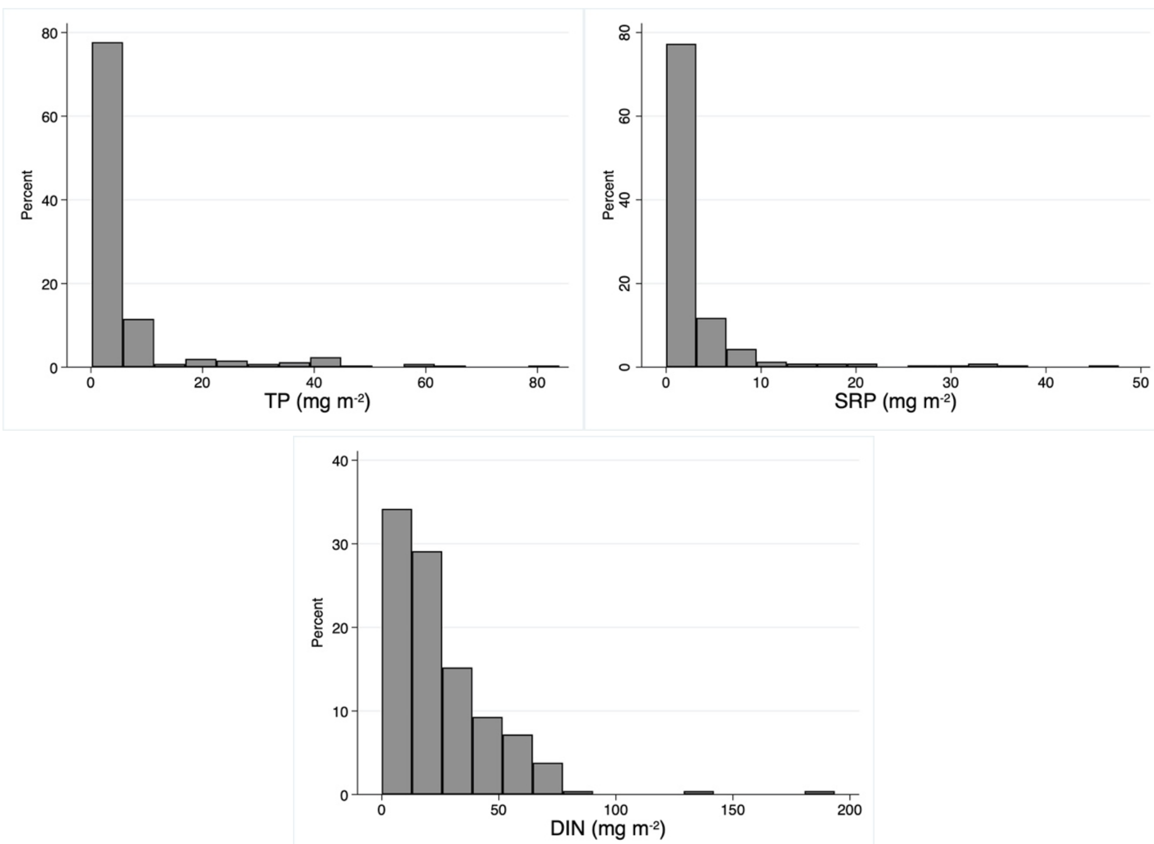
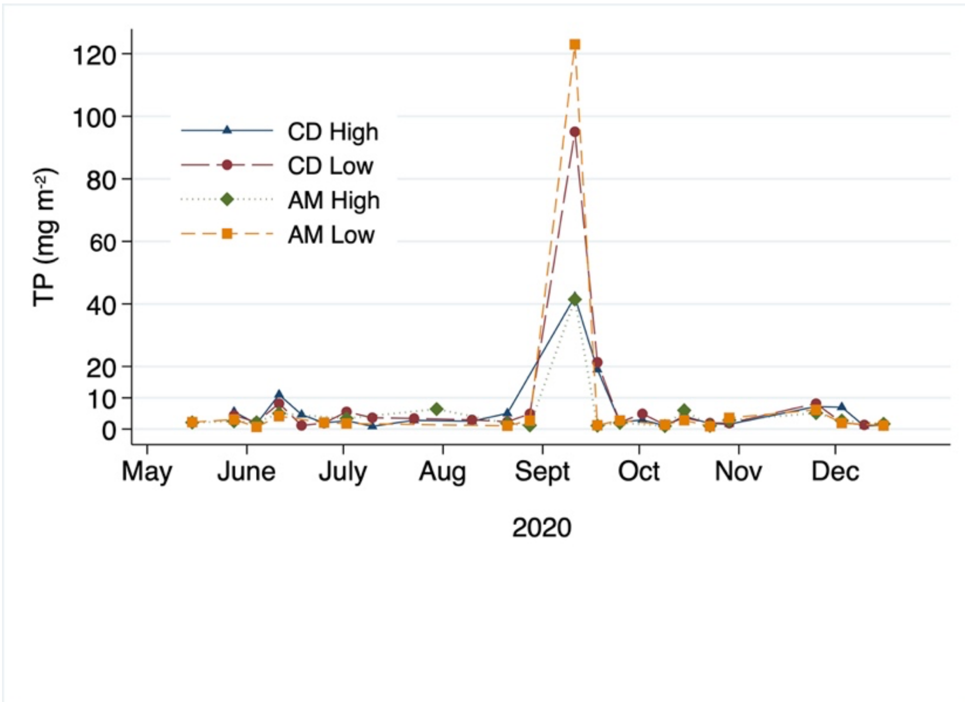


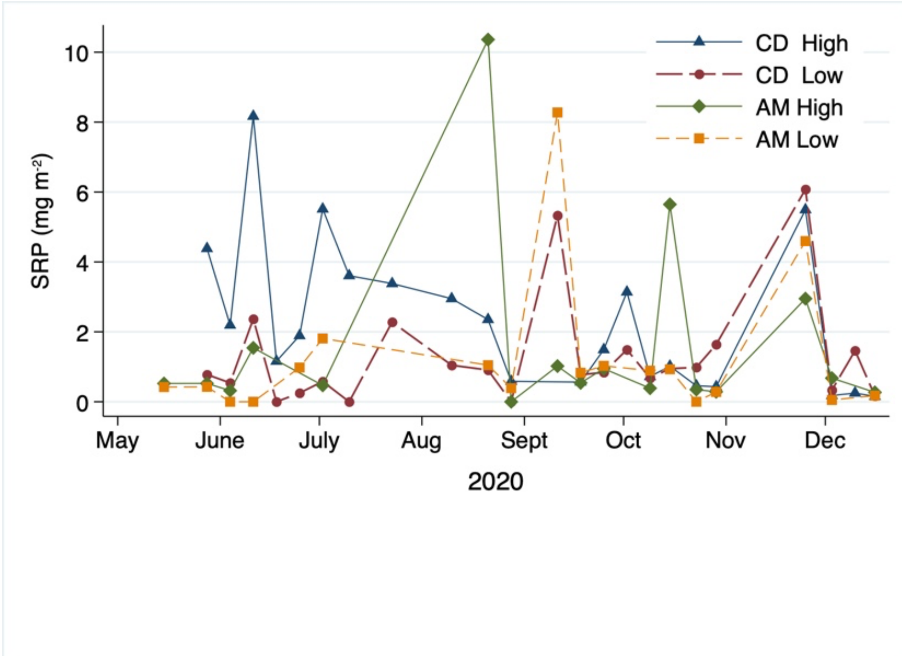
Figure 1. Histograms of TP, SRP, and DIN showing non normal distribution with overdispersion suggesting development and evaluation of negative binomial distribution-based regression models.

Results

Temporal Patterns

Pseudo-time series of TP, SRP, DIN (mg m^{-2}) comparing Central Davis and Ambassador sites and low and high samplers varied but generally were similar (Figure 2). High and low sampler TP concentrations were significantly correlated ($r = 0.70$, $P < 0.01$) as were DIN high and low concentrations ($r = 0.69$, $p < 0.01$). High and low sampler SRP concentrations were not significantly correlated ($r = 0.23$, $P = 0.15$).





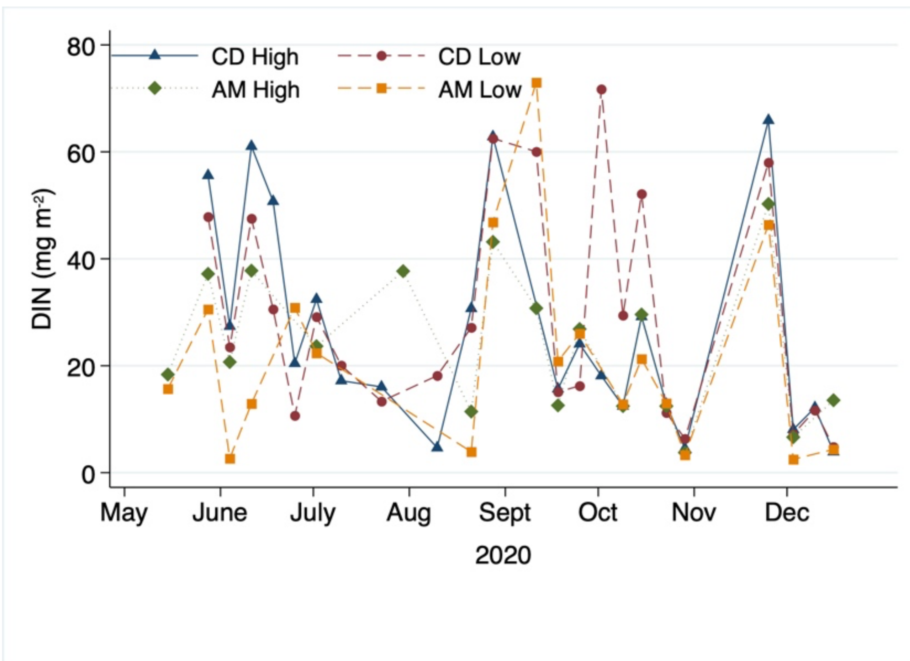


Figure 2. Comparison of TP (top panel), SRP (middle panel), and DIN (bottom panel) from May to December 2020 from paired high and low tables at two different sites, Central Davis (CD) and Ambassador (AM).

Total Phosphorus, TP

Low vs. High Samplers

TP concentrations were higher at Central Davis than Ambassador but not significantly perhaps because of their relative proximity to each other compared to locations on Utah Lake (Figure 3, Figure 4, and Table 1). TP concentrations were also not significantly different between high and low tables demonstrating that sampler height was not an important factor (Figure 3, Figure 4, and Table 1). For every unit of increase in TP at Central Davis, TP was predicted to change by 0.74 (0.17 Std. Err.) at Ambassador and for every unit of increase in TP in the high tables, TP was predicted to change by only 0.94 (0.22 Std. Err.) in the low elevation samplers (Table 1). Predicted means, std. errs., and 95% CIs of TP for high and low samples from Central Davis and Ambassador based on results of regression model (Table 1) are in Table 2.

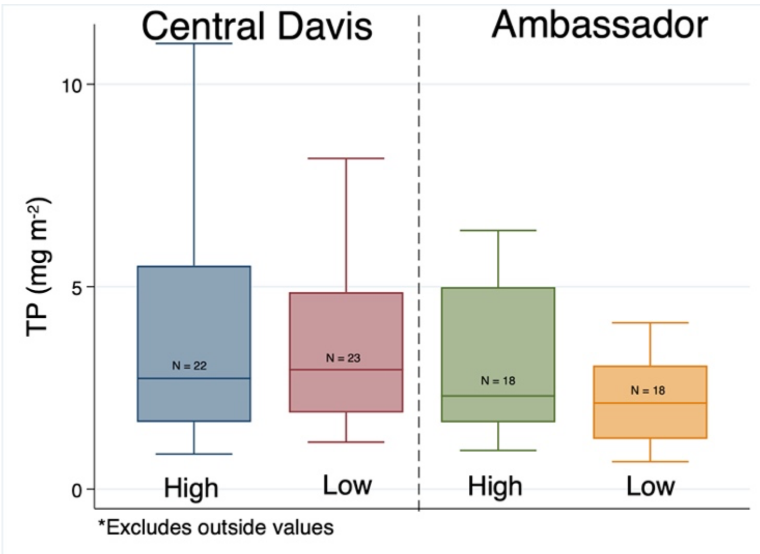


Figure 3. Comparison of TP between high and low elevation sampler data at Central Davis and Ambassador sites.

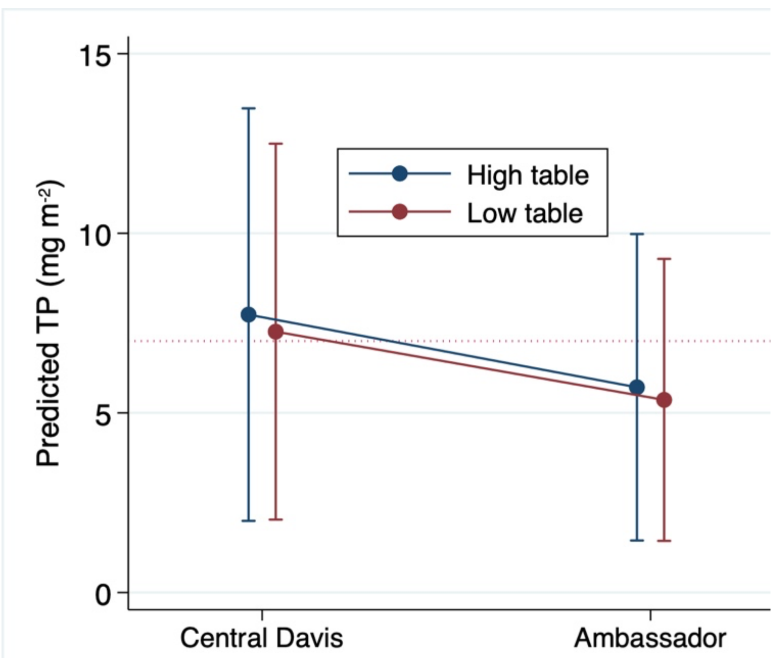


Figure 4. Predicted mean and 95% CIs of TP (mg m^{-2}) at high and low samplers at Central Davis and Ambassador sites. Predicted values based on regression results in Table 1. Red dashed line is overall mean.

Table 1. Multilevel mixed-effects negative binomial regression results for TP at Central Davis vs Ambassador sites and high vs. low samplers. Month was modeled as a random effect. Likelihood ratio test $\chi^2 = 38.99$, $p < 0.001$ confirmed that a mixed effects model using month as a categorical random effect was appropriate.

tp	IRR	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
Central Davis	**1.00**	(base)				
Ambassador	**0.74**	**0.17**	**-1.32**	**0.186**	**0.47**	**1.16**
highlowcode						
High	**1.00**	(base)				
Low	**0.94**	**0.22**	**-0.28**	**0.783**	**0.60**	**1.47**
_cons	**5.76**	**1.92**	**5.26**	**0.000**	**3.00**	**11.07**
/lnalpha	**-0.33**	**0.18**			**-0.69**	**0.02**
monthcode						
var(_cons)	**0.59**	**0.34**			**0.19**	**1.80**

Table 2. TP (mg m^{-2}) predicted means, std. errs., and 95% CIs (truncated at zero) for high and low samplers from Central Davis and Ambassador based on results of regression model in Table 1. Std. errs. were estimated by allowing for sampling of covariates.

	TP (mg m^{-2})			
Sampler	**Mean**	**Std. Err.**	**95% CIs**	
Central Davis	7.52	3.49	0.67	14.36
Ambassador	5.49	2.92	0.00	11.22
High	6.90	2.75	1.50	12.29
Low	6.35	3.71	0.00	13.61
Central Davis-High	8.24	3.89	0.61	15.86
Central Davis-Low	6.81	3.68	0.00	14.02
Ambassador-High	5.22	2.06	1.18	9.26
Ambassador-Low	5.76	3.79	0.00	13.19

non-NADP vs. NADP Samplers

TP (mg m^{-2}) at the Central Davis and Orem sites were significantly different likely because of the distance between sites and concentrations were significantly different between non-NADP (screened) and NADP (not screened) samplers (Figure 5, Figure 6, and Table 3, Table 4). For every unit of increase in TP (mg m^{-2}) at Central Davis, TP was predicted to increase by 2.05 (0.49 Std. Err.) (mg m^{-2}) at Orem (Table 3) suggesting strong localized environmental effects between valleys. For every unit of increase in TP (mg

m^{-2}) in the NADP samplers, TP (mg m^{-2}) in the non-NADP tables was predicted to increase by 0.53 (0.13 Std. Err.) (mg m^{-2}) (Table 3) primarily reflecting the reduction of AD accumulation in the collection buckets by screens. Predicted means, std. errs., and 95% CIs of TP for non-NADP and NADP samples from Central Davis and Orem based on results of regression model (Table 3) are in Table 4.

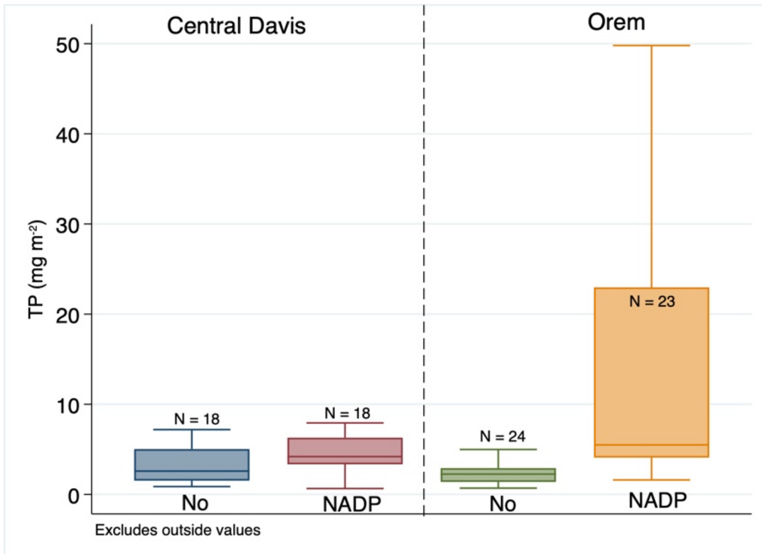


Figure 5. Comparison of TP between Central Davis and Orem sites and non-NADP (screened) vs. NADP (not screened) samplers.

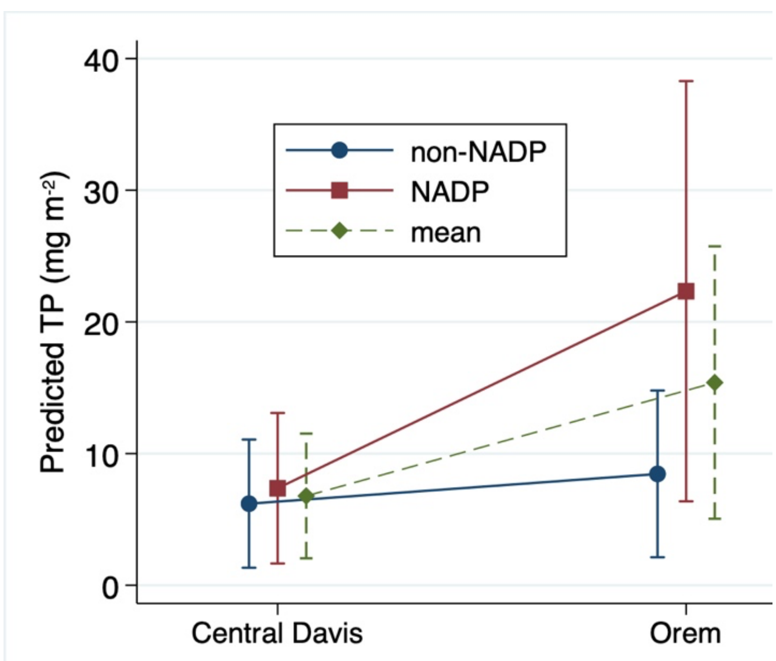


Figure 6. Predicted mean and 95% CIs of TP (mg m^{-2}) at non-NADP (screened) and NADP (not screened) samplers at Central Davis and Orem sites. Predicted values based on regression results shown in Table 3.

Table 3. Multilevel mixed-effects negative binomial regression results for TP at Central Davis vs Orem sites and non-NADP vs. NADP tables. Month was modeled as a random effect. Likelihood ratio text $\chi^2 = 23.36$, $p < 0.001$ confirming that a mixed effects model was appropriate.

tp	IRR	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
Central Davis	1.00	(base)				
Orem	2.05	0.49	3.02	0.003	1.29	3.27
nadpcode						
non-NADP	0.53	0.13	-2.67	0.008	0.34	0.85
_cons	7.38	2.60	5.68	0.000	3.70	14.73
/lnalpha	-0.09	0.16			-0.41	0.23
MonthCode						
var(_cons)	0.50	0.32			0.15	1.73

Table 4. TP (mg m^{-2}) predicted means, std. errs., and 95% CIs of from non-NADP and NADP samples from Central Davis and Orem based on results of regression model in Table 3. Std. errs. were estimated allowing for sampling of covariates.

	TP (mg m^{-2})			
Sampler	**Mean**	**Std. Err.**	**95% CIs**	
Central Davis	6.78	2.30	2.95	11.28
Orem	15.39	6.50	2.37	28.14
non-NADP (screened)	7.49	2.31	3.25	12.01
NADP (not screened)	15.92	7.59	2.10	30.79
Central Davis # non-NADP	6.20	2.44	2.53	10.99
Central Davis # NADP	7.37	2.60	2.83	12.47
Orem # nonNADP	8.46	2.87	2.94	14.08
Orem # NADP	22.33	11.72	1.90	45.30

Soluble Reactive Phosphorus, SRP

Low vs. High Samplers

SRP concentrations were higher at Central Davis than Ambassador but not significantly perhaps because of relative proximity compared to each other than locations on Utah Lake (Figure 7 and Table 5). However, SRP concentrations were significantly different between high and low samplers (Figure 7 and Table 5) (see Discussion for more on SRP value concerns). For every unit of change in SRP at Central

Davis, TP was predicted to change by 1.07 (0.28 Std. Err.) at Ambassador and for every unit of change in TP in the high tables, TP was predicted to change by 0.50 (0.22 Std. Err.) in the low elevation samplers (Table 5) Predicted means, std. errs., and 95% CIs of TP for non-NADP and NADP samples from Central Davis and Orem based on results of regression model (Table 3) are in Table 4.

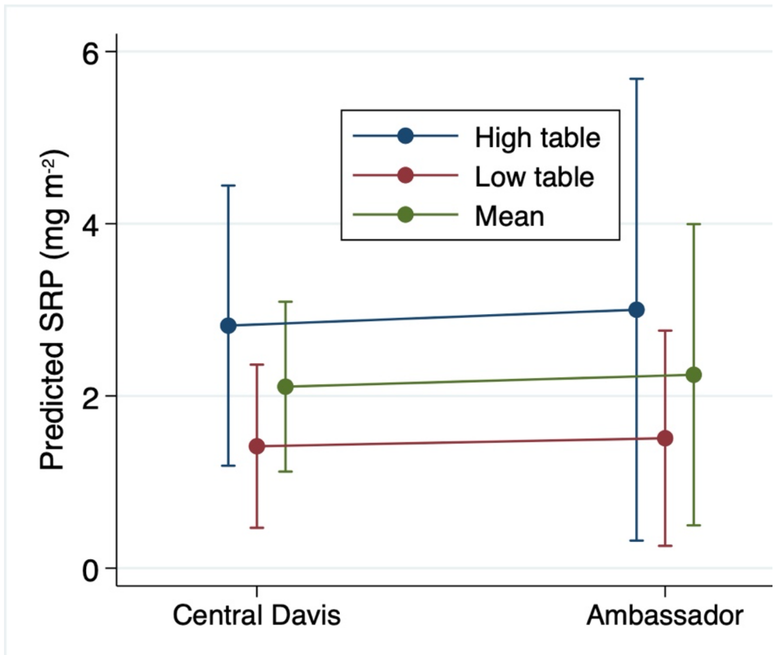


Figure 7. Predicted mean and 95% CIs of SRP (mg m^{-2}) at high and low samplers at Central Davis and Ambassador sites. Predicted values based on regression results in Table 5.

Table 5. Multilevel mixed-effects negative binomial regression results for SRP at Central Davis vs Ambassador sites and low vs. high samplers. Month was modeled as a random effect. Likelihood ratio text $\chi^2 = 10.29$, $p < 0.001$ confirming that a mixed effects model was appropriate.

SRP	IRR	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
CentralDavis	1.00	(base)				
Ambassador	1.07	0.28	0.24	0.812	0.63	1.80
highlowcode						
High	1.00	(base)				
Low	0.50	0.14	-2.50	0.012	0.29	0.86
_cons	2.34	0.73	2.75	0.006	1.28	4.30
/lnalpha	-0.32	0.27			-0.86	0.21
monthcode						
var(_cons)	0.37	0.28			0.08	1.68

Table 6. SRP (mg m^{-2}) predicted means, std. errs., and 95% CIs of from high and low sampler from Central Davis and Ambassador based on results of regression model in Table 5. Std. Errs. were estimated allowing for sampling of covariates.

	SRP (mg m^{-2})			
	Mean	Std. Err.	95% CIs	
Central Davis	2.11	0.66	0.81	3.40
Ambassador	2.25	0.71	0.86	3.63
High	2.90	0.89	1.15	4.65
Low	1.46	0.47	0.54	2.38
Central Davis # High	2.82	0.95	0.96	4.68
Central Davis # Low	1.42	0.49	0.46	2.37
Ambassador # High	3.00	1.00	1.03	4.97
Ambassador # Low	1.51	0.53	0.47	2.55

Non-NADP vs. NADP Samplers

SRP (mg m^{-2}) at the Central Davis and Orem sites were significantly different likely because of the distance between sites and concentrations were significantly different between non-NADP and NADP samplers (Figure 8and Table 7). For every unit of change in SRP (mg m^{-2}) at Central Davis, SRP was predicted to change by 2.46 (0.64 Std. Err.) (mg m^{-2}) at Orem (Table 7) suggesting strong localized environmental effects between valleys. For every unit of change in SRP (mg m^{-2}) in the NADP samplers, SRP (mg m^{-2}) in the non-NADP tables was predicted to change by 0.33 (0.09 Std. Err.) (mg m^{-2}) (Table 7) primarily reflecting the reduction of AD accumulation in the collection buckets by screens. Predicted means, Std. Errs., and 95% CIs of SRP for non-NADP and NADP samples from Central Davis and Orem based on results of regression model (Table 7) are in Table 9

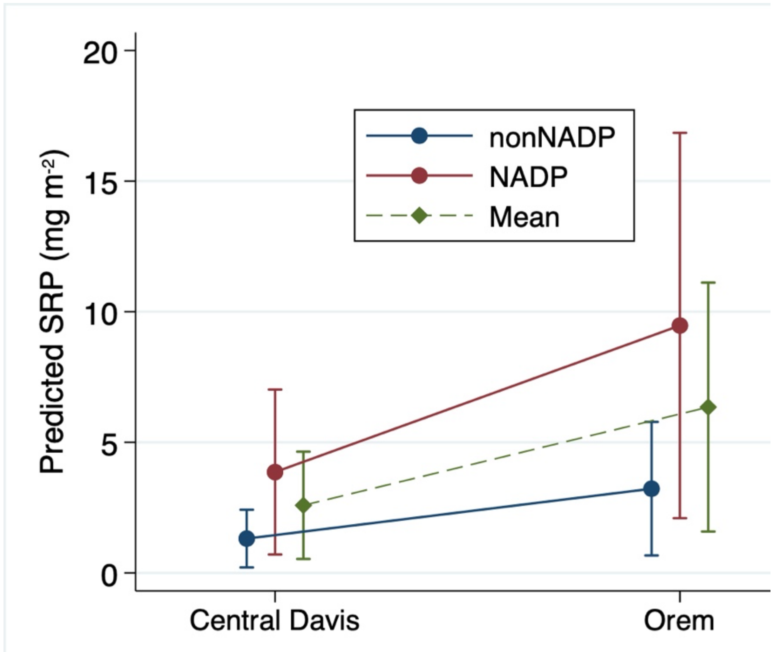


Figure 8. Predicted mean and 95% CIs of SRP (mg m⁻²) at non-NADP and NADP tables at Central Davis and Orem sites. Predicted values based on regression results shown in Table 7.

Table 7. Multilevel mixed-effects negative binomial regression results for SRP at Central Davis vs Orem sites and non-NADP vs. NADP samplers. Month was modeled as a random effect. Likelihood ratio text $\chi^2 = 13.94$, $p < 0.001$ confirming that a mixed effects model was appropriate.

SRP	IRR	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
CentralDavis	**1.00**	(base)				
Orem	**2.46**	**0.64**	**3.48**	**0.000**	**1.48**	**4.08**
nadpcode						
nonNADP	**0.33**	**0.09**	**-4.21**	**0.000**	**0.20**	**0.56**
NADP	**1.00**	(base)				
_cons	**0.33**	**0.13**	**-2.85**	**0.004**	**0.15**	**0.71**
ln(monthcode)	**1.00**	(exposure)				
/lnalpha	**-0.19**	**0.21**			**-0.59**	**0.22**
monthcode						
var(_cons)	**0.68**	**0.46**			**0.18**	**2.58**

Table 8. SRP (mg m-2) predicted means, std. errs., and 95% CIs of from non-NADP and NADP samplers from Central Davis and Orem based on results of regression model in Table 5. Std. Errs. were estimated allowing for sampling of covariates.

	SRP (mg m-2)			
	Mean	**Std. Err.**	**95% CIs**	
Central Davis	2.59	1.05	0.53	4.64
Orem	6.35	2.43	1.58	11.11
Non-NADP	2.41	0.95	0.54	4.27
NADP	7.07	2.74	1.71	12.43
Central Davis # non-NADP	1.31	0.56	0.21	2.42
Central Davis # NADP	3.86	1.61	0.70	7.02
Orem # non-NADP	3.22	1.30	0.67	5.78
Orem # NADP	9.47	3.76	2.09	16.85

Dissolved Inorganic Nitrogen, DIN

Low vs. High Samplers

DIN (mg m-2) concentrations were significantly different between Ambassador and Central Davis but not high and low samplers (Figure 9, Figure 10, and Table 9). For every unit of change in DIN at Central Davis, DIN was predicted to change by 0.77 (0.10 Std. Err.) at Ambassador, which we attribute to Ambassador site being further away from urbanized centers than Central Davis (Table 9). For every unit of change in DIN in the high tables DIN in the low tables was not predicted to change (IRR = 1.00, Std. Err. = 0.16) (Table 9). Predicted means, std. errs., and 95% CIs of DIN for high and low samples from Central Davis and Ambassador based on results of regression model (Table 9) are in Table 10.

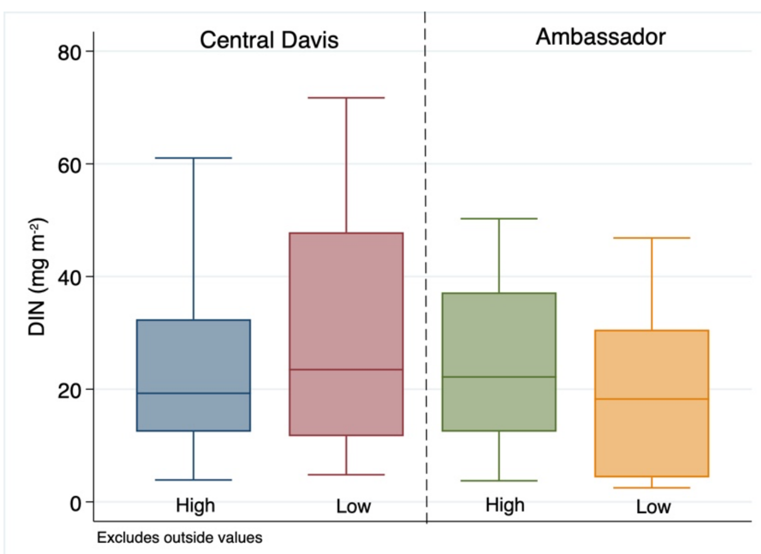


Figure 9. Comparison of DIN between Central Davis and Ambassador sites and high vs. low samplers.

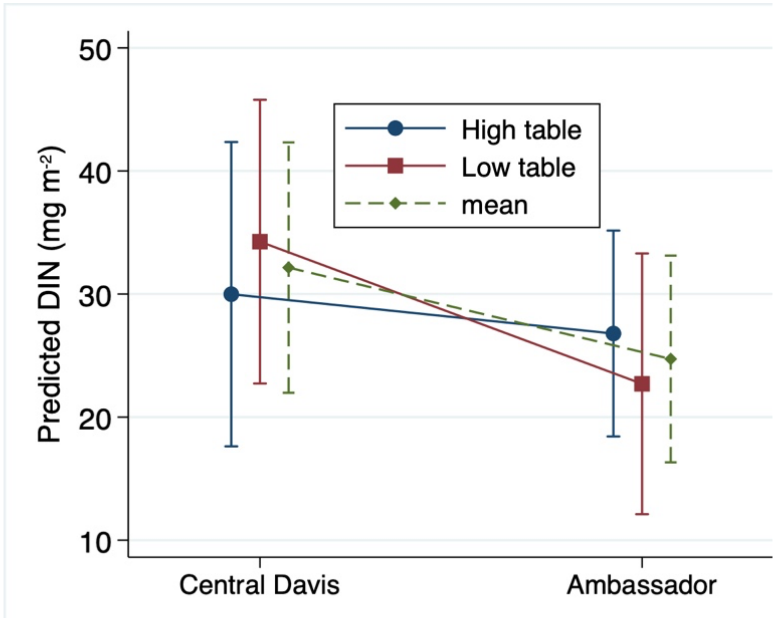


Figure 10. Predicted means and 95% CIs of DIN (mg m-2) at high and low tables at Central Davis and Ambassador sites and means. Predicted values based on regression results shown in Table 9. Mean and 95% CIs shown.

Table 9. Multilevel mixed-effects negative binomial regression results for DIN at Central Davis vs Ambassador sites and high vs. low samplers. Month was modeled as a random effect. Likelihood ratio text $\chi^2 = 29.28$, $p < 0.001$ confirming that a mixed effects model was appropriate.

DIN	IRR	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
Central Davis	1.00	(base)				
Ambassador	0.77	0.11	-1.85	0.065	0.58	1.02
highlowcode						
High	1.00	(base)				
Low	1.00	0.14	-0.02	0.987	0.76	1.32
_cons	3.52	0.94	4.71	0.000	2.09	5.94
ln(monthcode)	1.00	(exposure)				
/lnalpha	-1.06	0.18			-1.41	-0.70
monthcode						
var(_cons)	0.44	0.25			0.15	1.33

Table 10. DIN (mg m-2) predicted means, std. errs., and 95% CIs from high and low samples from Central Davis and Ambassador based on results of regression model in Table 9. Std. errs. were estimated allowing for sampling of covariates.

	DIN (mg m^{-2})			
Sampler	**Mean**	**Std. Err.**	**95% CIs**	
Central Davis	32.15	5.20	21.96	42.33
Ambassador	24.72	4.28	16.34	33.11
High	28.57	5.22	18.34	38.80
Low	29.12	4.60	20.11	38.14
Central Davis # High	29.99	6.31	17.62	42.35
Central Davis # Low	34.26	5.88	22.73	45.79
Ambassador # High	26.79	4.27	18.43	35.16
Ambassador # Low	22.70	5.40	12.11	33.30

Non-NADP vs. NADP samplers

DIN concentrations at the Orem and Central Davis sites were not significantly different, however, concentrations between non-NADP and NADP samplers were significantly different (Figure 11, Figure 12, and Table 11). For every unit of change in DIN at Central Davis, DIN was predicted to change by only 0.96 (0.14 Std. Err.) at Orem perhaps in response to close proximity to urbanization in both areas (Table 11). For every unit of change in TP in the NADP samples, DIN in the non-NADP (screened) samples was predicted to change by 0.49 (0.07 Std. Err.) (Table 11) primarily reflecting the reduction on AD accumulation in the collection buckets by screens. Predicted means, std. errs., and 95% CIs of DIN for non-NADP and NADP samples from Central Davis and Orem based on results of regression model (Table 11) are in Table 10.

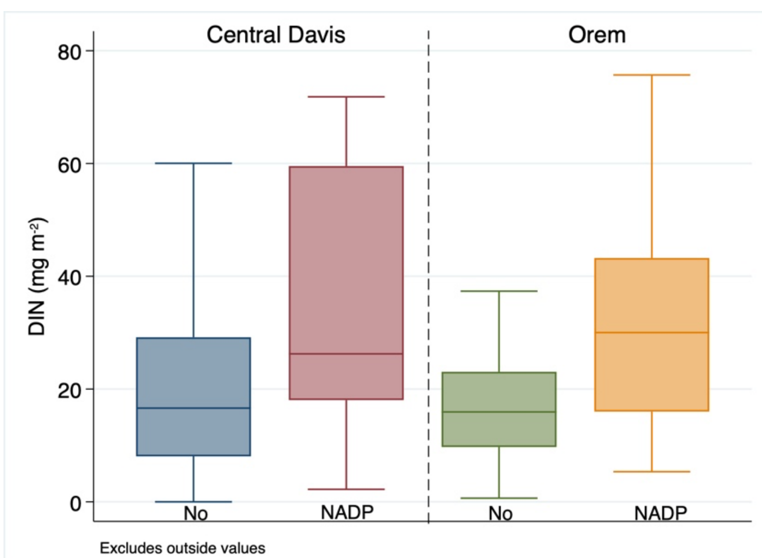


Figure 11. Comparison of DIN (mg m^{-2}) between Central Davis and Orem sites, and non-NADP vs. NADP sampler data.

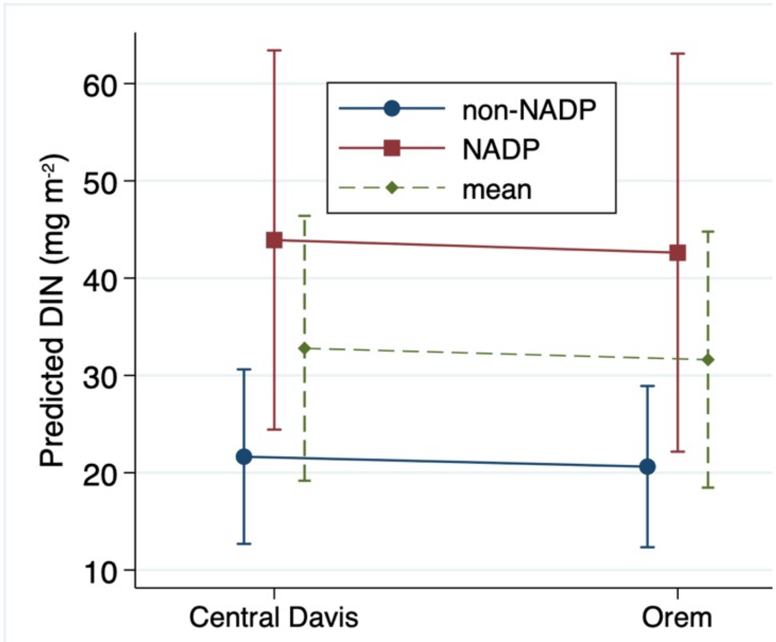


Figure 12. Predicted means and 95% CIs of DIN (mg m⁻²) at non-NADP and NADP tables at Central Davis and Orem sites and means. Predicted values based on regression results shown in Table 11.

Table 11. Multilevel mixed-effects negative binomial regression results for DIN at Central Davis vs Orem sites and non-NADP vs. NADP tables. Month was modeled as a random effect. Likelihood ratio text $\chi^2 = 30.44$, $p < 0.001$ confirming that a mixed effects model was appropriate.

din	IRR	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
Central Davis	**1.00**	(base)				
Orem	**0.96**	**0.14**	**-0.26**	**0.795**	**0.72**	**1.29**
nadpcode						
non-NADP	**0.49**	**0.07**	**-4.86**	**0.000**	**0.37**	**0.65**
_cons	**33.98**	**10.37**	**11.56**	**0.000**	**18.69**	**61.80**
/lnalpha	**-0.95**	**0.18**			**-1.31**	**-0.59**
monthcode						
var(_cons)	**0.52**	**0.31**			**0.16**	**1.66**

Table 12. Predicted means, std. errs., and 95% CIs for DIN from non-NADP and NADP samples from Central Davis and Orem based on results of regression model in Table 11. Std. errs. were estimated allowing for sampling of covariates.

	DIN (mg m^{-2})			
Sampler	**mean**	**Std. Err.**	**95% CIs**	
Central Davis	32.79	7.00	19.07	46.51
Orem	31.62	6.78	18.33	44.91
non-NADP	21.07	3.44	14.32	27.81
NADP	43.18	9.20	25.16	61.20
Central Davis-nonNADP	21.66	4.57	12.69	30.62
Central Davis-NADP	43.92	9.94	24.43	63.41
Orem-nonNADP	20.63	4.23	12.34	28.91
Orem-NADP	42.62	10.44	22.16	63.07

Temporal (Monthly) Patterns of AD Nutrients

TP

The best fit regression model for temporal (monthly) effects on TP was a linear model using $\log_{10}$ transformation that included Utah Lake and Great Salt Lake area sample data.

Table 13. Best fit regression model for temporal (month) patterns of TP. TP was $\log_{10}$ transformed. Months were modeled as categorical predictors and September was used as the baseline to make comparisons.

Source	SS	df	MS			
				Number of obs	=	238
				F(7, 230)	=	6.12
Model	8.25147404	7	1.17878201	Prob > F	=	0.0000
Residual	44.2800544	230	.192521975	R-squared	=	0.1571
				Adj R-squared	=	0.1314
Total	52.5315284	237	.221652019	Root MSE	=	.43877

logAdjTP	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
monthcode						
May	-0.25	0.19	-1.31	0.19	-0.63	0.13
June	-0.28	0.13	-2.15	0.03	-0.54	-0.02
July	-0.26	0.11	-2.42	0.02	-0.47	-0.05
Aug	-0.10	0.10	-0.99	0.32	-0.30	0.10
Oct	-0.38	0.09	-4.21	0.00	-0.56	-0.20
Nov	-0.02	0.11	-0.19	0.85	-0.24	0.20
Dec	-0.55	0.10	-5.21	0.00	-0.75	-0.34
_cons	1.02	0.07	14.64	0.00	0.88	1.15

Table 14. Predicted mean and 95% CI estimates of TP (mg m^{-2}) by month based on linear regression model presented in Table 13.

TP (mg m^{-2})

Month	mean	Lower 95% CI	Upper 95% CI
May	5.80	2.57	13.08
June	5.44	3.31	8.96
July	5.74	3.99	8.25
Aug	8.22	5.87	11.51
Sept	10.36	7.56	14.19
Oct	4.28	3.28	5.60
Nov	9.86	6.62	14.69
Dec	2.94	2.06	4.21

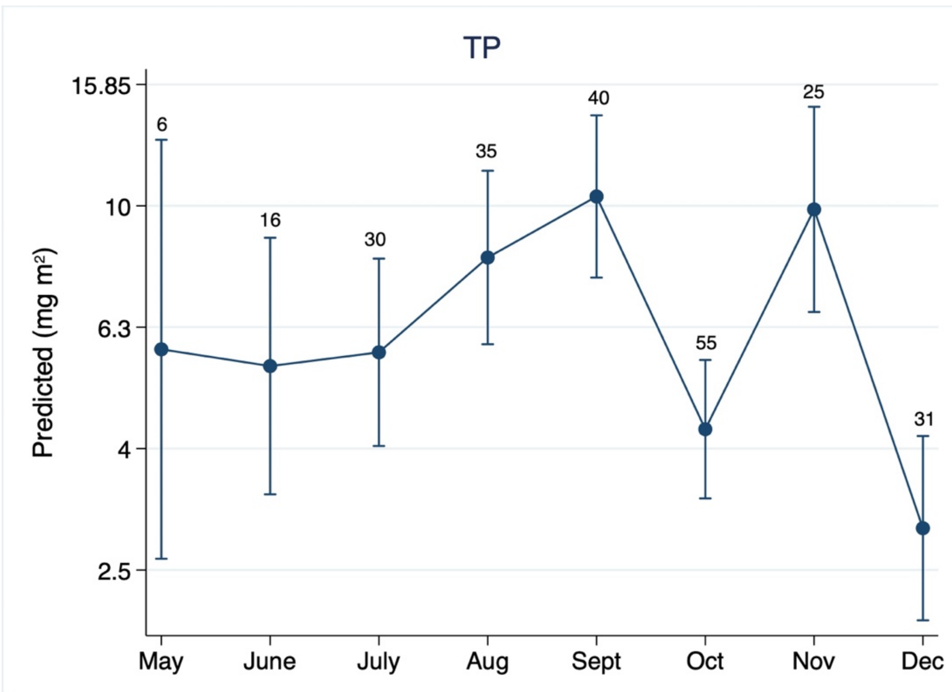


Figure 13. Predicted mean and 95% CI estimates of TP (mg m^{-2}) by month based on linear regression model presented in Table 13. Numbers above upper CIs are sample size. Year 2020.

Table 15. Post hoc pairwise comparisons of TP by month. Based on linear regression model presented in Table 13. Unadjusted for multiple comparisons.

	Contrast	Delta-method Std. Err.	Unadjusted t	P>|t|
monthcode				
June vs May	-0.03	0.21	-0.13	0.90
July vs May	-0.00	0.20	-0.03	0.98
Aug vs May	0.15	0.19	0.78	0.44
Sept vs May	0.25	0.19	1.31	0.19
Oct vs May	-0.13	0.19	-0.70	0.49
Nov vs May	0.23	0.20	1.16	0.25
Dec vs May	-0.29	0.20	-1.51	0.13
July vs June	0.02	0.14	0.17	0.87
Aug vs June	0.18	0.13	1.35	0.18
Sept vs June	0.28	0.13	2.15	0.03
Oct vs June	-0.10	0.12	-0.84	0.40
Nov vs June	0.26	0.14	1.84	0.07
Dec vs June	-0.27	0.14	-1.98	0.05
Aug vs July	0.16	0.11	1.43	0.15
Sept vs July	0.26	0.11	2.42	0.02
Oct vs July	-0.13	0.10	-1.27	0.20
Nov vs July	0.24	0.12	1.98	0.05
Dec vs July	-0.29	0.11	-2.58	0.01
Sept vs Aug	0.10	0.10	0.99	0.32
Oct vs Aug	-0.28	0.09	-2.98	0.00
Nov vs Aug	0.08	0.11	0.69	0.49
Dec vs Aug	-0.45	0.11	-4.12	0.00
Oct vs Sept	-0.38	0.09	-4.21	0.00
Nov vs Sept	-0.02	0.11	-0.19	0.85
Dec vs Sept	-0.55	0.10	-5.21	0.00
Nov vs Oct	0.36	0.11	3.42	0.00
Dec vs Oct	-0.16	0.10	-1.65	0.10
Dec vs Nov	-0.53	0.12	-4.45	0.00

SRP

The best fit regression model for temporal (monthly) effects on SRP was a linear model using $\log_{10}$ transformation that included Utah Lake and Great Salt Lake area sample data.

Table 16. Best fit regression model for temporal (month) patterns of SRP. SRP was $\log_{10}$ transformed. Months were modeled as categorical predictors and November was used as the baseline to make comparisons.

```
Linear regression                               Number of obs     =        218
                                                F(7, 210)         =      11.33
                                                Prob > F          =     0.0000
                                                R-squared         =     0.2540
                                                Root MSE          =     .46804

------------------------------------------------------------------------------
             |               Robust
   logAdjSRP |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   monthcode |
        May  |      -0.49        0.19    -2.58    0.01        -0.87      -0.12
       June  |      -0.27        0.17    -1.62    0.11        -0.61       0.06
       July  |      -0.19        0.15    -1.28    0.20        -0.48       0.10
     August  |      -0.11        0.15    -0.70    0.48        -0.40       0.19
  September  |      -0.19        0.14    -1.39    0.16        -0.46       0.08
    October  |      -0.34        0.14    -2.38    0.02        -0.62      -0.06
   December  |      -0.91        0.14    -6.31    0.00        -1.19      -0.63
             |
       _cons |       0.76        0.12     6.28    0.00         0.52       1.00
------------------------------------------------------------------------------
```

Table 17. Predicted mean and 95% CI estimates of SRP (mg m^{-2}) by month based on linear regression model presented in Table 16.

	SRP (mg m^{-2})		
Month	**Mean**	**Lower 95% CI**	**Upper 95% CI**
May	1.86	0.95	3.64
June	3.08	1.80	5.28
July	3.75	2.56	5.50
Aug	4.55	3.04	6.80
Sept	3.74	2.81	4.97
Oct	2.68	1.93	3.71
Nov	5.80	3.34	10.08
Dec	0.72	0.50	1.02

Table 18. Post hoc pairwise comparisons of TP by month. Based on linear regression model presented in Table 16. Unadjusted for multiple comparisons.

	Contrast	Delta-method Std. Err.	Unadjusted t	P>|t|
monthcode				
June vs May	0.22	0.19	1.16	0.25
July vs May	0.30	0.17	1.79	0.07
August vs May	0.39	0.17	2.25	0.03
September vs May	0.30	0.16	1.89	0.06
October vs May	0.16	0.16	0.96	0.34
November vs May	0.49	0.19	2.58	0.01
December vs May	-0.41	0.17	-2.49	0.01
July vs June	0.09	0.15	0.59	0.56
August vs June	0.17	0.15	1.14	0.25
September vs June	0.08	0.13	0.62	0.53
October vs June	-0.06	0.14	-0.44	0.66
November vs June	0.27	0.17	1.62	0.11
December vs June	-0.63	0.14	-4.49	0.00
August vs July	0.08	0.12	0.69	0.49
September vs July	-0.00	0.11	-0.01	0.99
October vs July	-0.15	0.11	-1.32	0.19
November vs July	0.19	0.15	1.28	0.20
December vs July	-0.72	0.11	-6.30	0.00
September vs August	-0.09	0.11	-0.79	0.43
October vs August	-0.23	0.11	-2.02	0.04
November vs August	0.11	0.15	0.70	0.48
December vs August	-0.80	0.12	-6.84	0.00
October vs September	-0.15	0.10	-1.52	0.13
November vs September	0.19	0.14	1.39	0.16
December vs September	-0.72	0.10	-7.22	0.00
November vs October	0.34	0.14	2.38	0.02
December vs October	-0.57	0.11	-5.42	0.00
December vs November	-0.91	0.14	-6.31	0.00

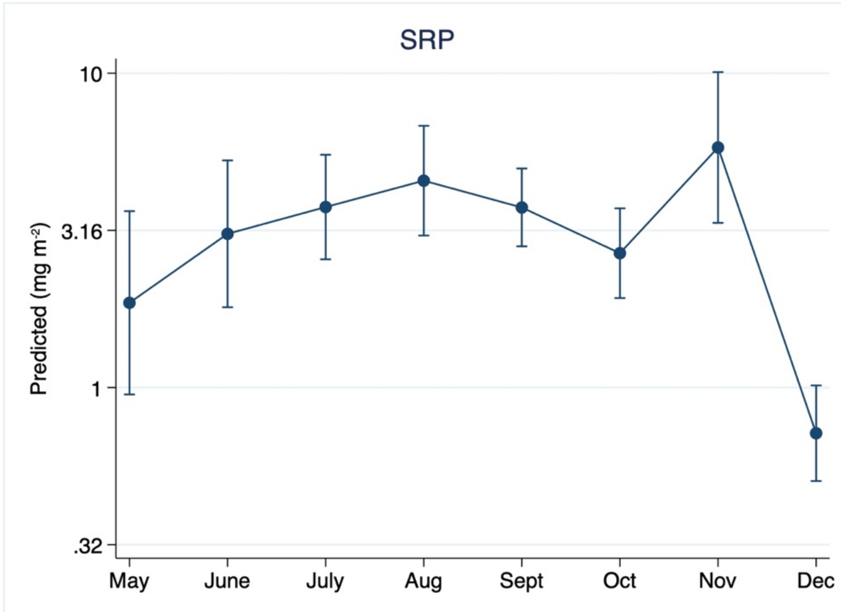


Figure 14. Predicted mean and 95% CI estimates of SRP (mg m^{-2}) by month based on linear regression model presented in Table 16.

SRP/TP

Note: SRP results are questionable, and no further analyses have been conducted until these data are further evaluated for quality.

DIN

The best fit regression model for temporal (monthly) effects on DIN was a mixed effects model using log_{10} transformation that included Utah Lake and Great Salt Lake area sample data. Site was modeled as a random factor.

Table 19. Best fit regression mixed effects model for temporal (month) patterns of DIN. DIN was log_{10} transformed. Months were modeled as categorical predictors and sites were modeled as a random variable.

logAdjustDIN	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
monthcode						
August	**0.13**	**0.14**	**0.93**	**0.35**	**-0.14**	**0.40**
September	**0.07**	**0.13**	**0.49**	**0.62**	**-0.20**	**0.33**
October	**-0.28**	**0.13**	**-2.15**	**0.03**	**-0.53**	**-0.03**
November	**-0.45**	**0.14**	**-3.21**	**0.00**	**-0.73**	**-0.18**
December	**-0.80**	**0.15**	**-5.53**	**0.00**	**-1.09**	**-0.52**
_cons	**1.34**	**0.12**	**11.35**	**0.00**	**1.11**	**1.57**

Random-effects Parameters	Estimate	Std. Err.	[95% Conf.	Interval]
sitecode: Identity				
var(_cons)	**0.01**	**0.01**	**0.00**	**0.07**
var(Residual)	**0.11**	**0.02**	**0.08**	**0.14**

LR test vs. linear model: chibar2(01) = **3.31** Prob >= chibar2 = **0.0345**

Table 20. Predicted mean and 95% CI estimates of DIN (mg m^{-2}) by month based on linear regression model presented in Table 19.

Month	Mean	Lower 95% CI	Upper 95% CI
May	21.98	12.89	37.46
June	29.56	19.19	45.53
July	25.58	17.07	38.31
Aug	11.54	7.93	16.79
Sept	7.79	4.99	12.14
Oct	3.45	2.14	5.56
Nov	21.98	12.89	37.46
Dec	29.56	19.19	45.53

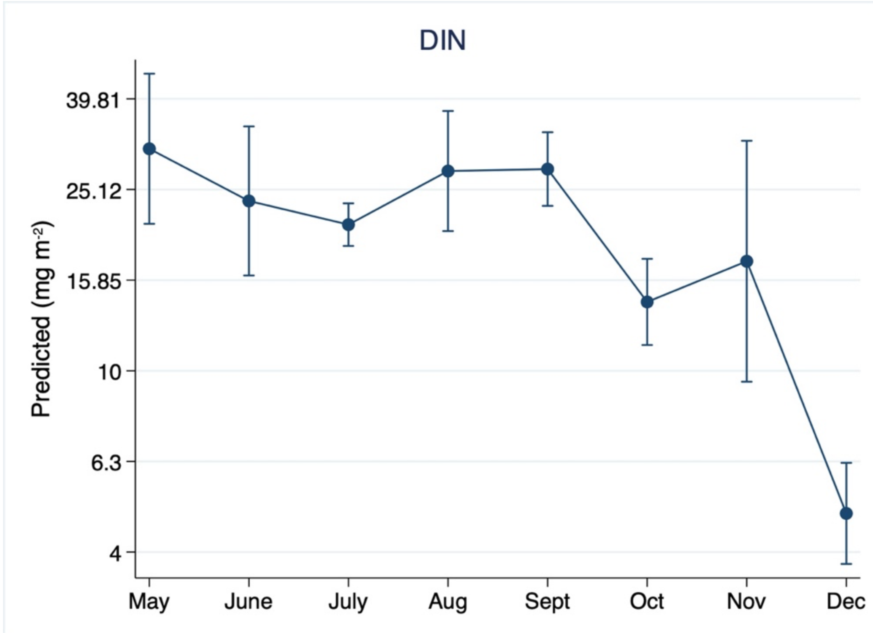


Figure 15. Predicted mean and 95% CI estimates of DIN (mg m^{-2}) by month based on mixed effects regression model presented in Table 19.

Table 21. Post hoc pairwise comparisons of TP by month. Based on linear regression model presented in Table 19. Unadjusted for multiple comparisons.

	Contrast	Std. Err.	t	Unadjusted P>|t|
monthcode				
June vs May	-0.12	0.12	-0.97	0.33
July vs May	-0.17	0.09	-1.92	0.06
August vs May	-0.05	0.11	-0.46	0.65
September vs May	-0.04	0.09	-0.48	0.63
October vs May	-0.34	0.10	-3.49	0.00
November vs May	-0.25	0.16	-1.56	0.12
December vs May	-0.80	0.10	-7.94	0.00
July vs June	-0.05	0.09	-0.60	0.55
August vs June	0.07	0.11	0.62	0.54
September vs June	0.07	0.09	0.76	0.45
October vs June	-0.22	0.10	-2.31	0.02
November vs June	-0.13	0.16	-0.84	0.40
December vs June	-0.69	0.10	-6.83	0.00
August vs July	0.12	0.07	1.66	0.10
September vs July	0.12	0.05	2.57	0.01
October vs July	-0.17	0.05	-3.17	0.00
November vs July	-0.08	0.14	-0.59	0.56
December vs July	-0.64	0.06	-10.37	0.00
September vs August	0.00	0.08	0.06	0.96
October vs August	-0.29	0.08	-3.49	0.00
November vs August	-0.20	0.15	-1.32	0.19
December vs August	-0.76	0.09	-8.59	0.00
October vs September	-0.29	0.06	-4.62	0.00
November vs September	-0.20	0.14	-1.44	0.15
December vs September	-0.76	0.07	-10.85	0.00
November vs October	0.09	0.14	0.63	0.53
December vs October	-0.47	0.07	-6.27	0.00
December vs November	-0.56	0.15	-3.80	0.00

Utah Lake Spatial (Site) Patterns

We adjusted TP and DIN (mg m^{-2}) data for screen effects demonstrated in regression models presented in Table 3 and Table 11. TP values from screened sample were divided by 0.53 and DIN values from screened samples were divided by 0.49 based on the IRRs (Table 3, Table 11). SRP values from screened samplers were divided by 0.50 and not IRR results because those results appeared to be too extreme (IRR = 0.33) and not representative of our understanding on screen effects.

Differences in overall TP, SRP, and DIN among Utah Lake sites were evaluated using nonparametric Kruskall-Wallis ranks test on screen adjusted data. We then conducted mixed-effects linear regression on $\log_{10}$ transformed screen adjusted TP, SRP, and DIN data using month as a random effect. We used Bird Island as the baseline site to compare with other sites in the mixed effects model. We also computed pairwise comparisons among sites based on results of the regression model. The rank test showed that

TP, SRP, and DIN differed significantly among sites (Figure 16, Figure 17, and Figure 18) Regression models and pairwise comparisons showed that Bird Island nutrients typically were significantly greater than other sites (Table 22, Table 23, Table 24, Table 25, Table 26, and Table 27).

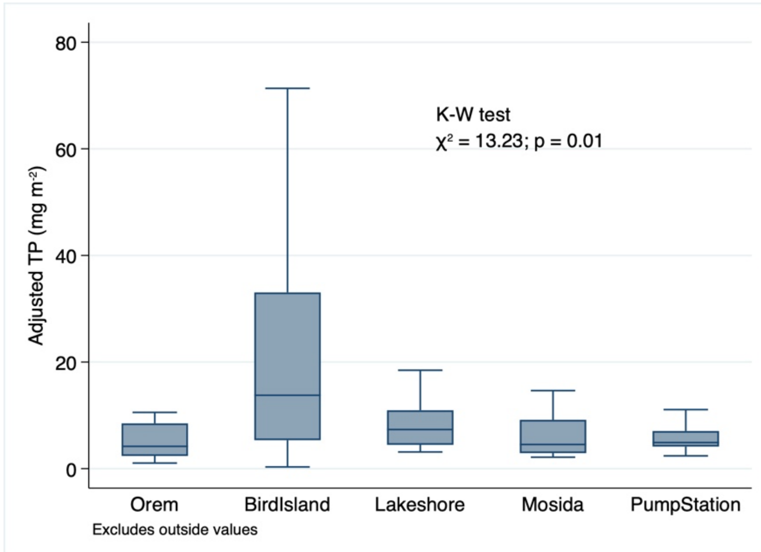


Figure 16. Comparison of TP concentrations (mg m^{-2}) among Utah Lake sites including Kruskal-Wallis rank tests without adjusting for temporal effects.

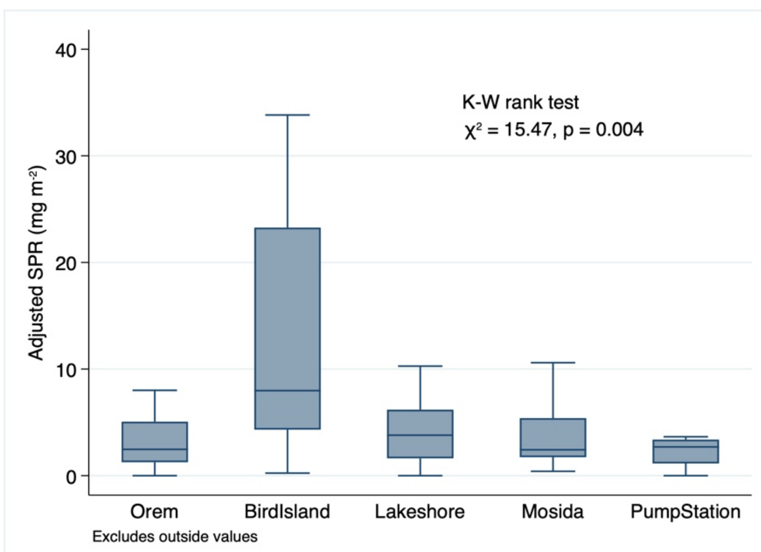


Figure 17. Comparison of SRP concentrations (mg m^{-2}) among Utah Lake sites including Kruskal-Wallis rank tests without adjusting for temporal effects.

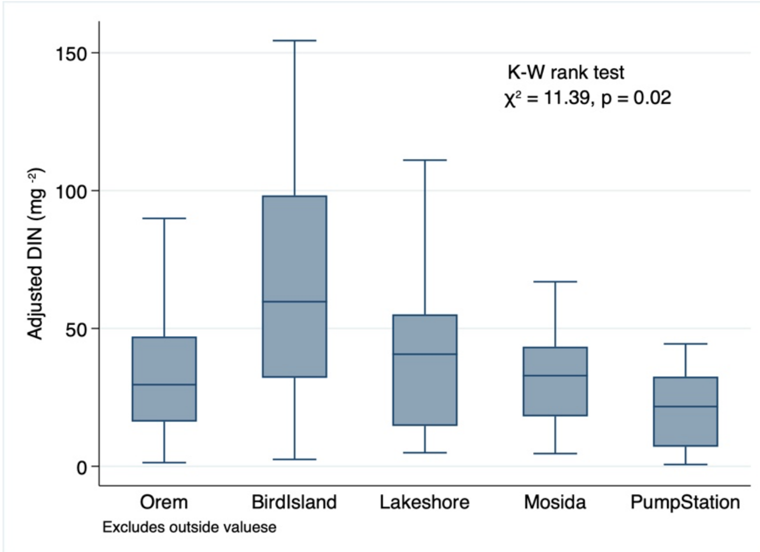


Figure 18. Comparison of DIN concentrations (mg m-2) among Utah Lake sites including Kruskal-Wallis rank tests without adjusting for temporal effects.

Table 22. Mixed-effects regression model results for Utah Lake sites TP log_{10} transformed. Month was modeled as random factor. Likelihood ratio test $\chi^2 = 4.71$, $p = 0.015$ confirming that a mixed effects model with month as a random factor was appropriate.

logAdjTP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
Orem	**-0.32**	**0.13**	**-2.44**	**0.015**	**-0.58**	**-0.06**
BirdIsland	**0.00**	(base)				
Lakeshore	**-0.21**	**0.17**	**-1.28**	**0.202**	**-0.54**	**0.11**
Mosida	**-0.36**	**0.16**	**-2.23**	**0.026**	**-0.67**	**-0.04**
PumpStation	**-0.26**	**0.16**	**-1.68**	**0.092**	**-0.57**	**0.04**
_cons	**1.08**	**0.13**	**8.23**	**0.000**	**0.82**	**1.34**

Random-effects Parameters	Estimate	Std. Err.	[95% Conf.	Interval]
monthcode: (empty)				
monthcode: Identity				
var(_cons)	**0.02**	**0.02**	**0.00**	**0.10**
var(Residual)	**0.21**	**0.03**	**0.17**	**0.27**

Table 23. Post hoc pairwise comparisons of TP concentrations among Utah Lake sites based on regression results summarized in Table 22.

	Contrast	Delta-method Std. Err.	Unadjusted z	P>|z|
sitecode				
BirdIsland vs Orem	.3215545	.1316844	2.44	0.015
Lakeshore vs Orem	.1095721	.1278203	0.86	0.391
Mosida vs Orem	-.0334956	.1195837	-0.28	0.779
PumpStation vs Orem	.056755	.1169046	0.49	0.627
Lakeshore vs BirdIsland	-.2119824	.1660165	-1.28	0.202
Mosida vs BirdIsland	-.3550501	.1591426	-2.23	0.026
PumpStation vs BirdIsland	-.2647995	.1572587	-1.68	0.092
Mosida vs Lakeshore	-.1430677	.1559426	-0.92	0.359
PumpStation vs Lakeshore	-.0528171	.1540312	-0.34	0.732
PumpStation vs Mosida	.0902506	.146923	0.61	0.539

Table 24. Mixed-effects regression model results for Utah Lake sites SRP log_{10} transformed. Month was modeled as random factor. Likelihood ratio test $\chi^2 = 9.26$, $p = 0.001$ confirming that a mixed effects model with month as a random factor was appropriate.

logAdjSRP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
Orem	-0.34	0.14	-2.52	0.012	-0.61	-0.08
BirdIsland	0.00	(base)				
Lakeshore	-0.28	0.17	-1.64	0.102	-0.61	0.06
Mosida	-0.42	0.16	-2.62	0.009	-0.73	-0.11
PumpStation	-0.53	0.16	-3.26	0.001	-0.85	-0.21
_cons	0.86	0.14	5.98	0.000	0.58	1.14

Random-effects Parameters	Estimate	Std. Err.	[95% Conf.	Interval]
monthcode: Identity				
var(_cons)	0.04	0.03	0.01	0.16
var(Residual)	0.21	0.03	0.16	0.28

Table 25. Post hoc pairwise comparisons of SRP concentrations among Utah Lake sites based on regression results summarized in Table 24.

	Contrast	Delta-method Std. Err.	Unadjusted z	P>|z|
sitecode				
BirdIsland vs Orem	.3436887	.1361818	2.52	0.012
Lakeshore vs Orem	.0655452	.1350465	0.49	0.627
Mosida vs Orem	-.0755275	.1238448	-0.61	0.542
PumpStation vs Orem	-.1851698	.1259176	-1.47	0.141
Lakeshore vs BirdIsland	-.2781435	.1701081	-1.64	0.102
Mosida vs BirdIsland	-.4192162	.160232	-2.62	0.009
PumpStation vs BirdIsland	-.5288585	.1624217	-3.26	0.001
Mosida vs Lakeshore	-.1410727	.1597136	-0.88	0.377
PumpStation vs Lakeshore	-.2507149	.1613377	-1.55	0.120
PumpStation vs Mosida	-.1096422	.1518069	-0.72	0.470

Table 26. Mixed-effects regression model results for Utah Lake sites DIN log_{10} transformed. Month was modeled as random factor. Likelihood ratio test $\chi^2 = 35.70$, $p < 0.001$ confirming that a mixed effects model with month as a random factor was appropriate.

logAdjustDIN	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
sitecode						
Orem	-0.16	0.11	-1.44	0.150	-0.39	0.06
BirdIsland	0.00	(base)				
Lakeshore	-0.07	0.12	-0.56	0.576	-0.30	0.17
Mosida	-0.06	0.12	-0.54	0.592	-0.29	0.16
PumpStation	-0.36	0.11	-3.19	0.001	-0.59	-0.14
_cons	1.25	0.15	8.16	0.000	0.95	1.56

Random-effects Parameters	Estimate	Std. Err.	[95% Conf.	Interval]
monthcode: Identity				
var(_cons)	0.10	0.06	0.03	0.33
var(Residual)	0.11	0.02	0.08	0.15

Table 27. Post hoc pairwise comparisons of DIN concentrations among Utah Lake sites based on regression results summarized in Table 26 .

	Contrast	Delta-method Std. Err.	Unadjusted z	P>|z|
sitecode				
BirdIsland vs Orem	.1635624	.1137025	1.44	0.150
Lakeshore vs Orem	.0962014	.1109665	0.87	0.386
Mosida vs Orem	.101797	.1057273	0.96	0.336
PumpStation vs Orem	-.1992607	.104236	-1.91	0.056
Lakeshore vs BirdIsland	-.067361	.1204516	-0.56	0.576
Mosida vs BirdIsland	-.0617654	.1152498	-0.54	0.592
PumpStation vs BirdIsland	-.3628232	.1137025	-3.19	0.001
Mosida vs Lakeshore	.0055956	.1124994	0.05	0.960
PumpStation vs Lakeshore	-.2954622	.1109665	-2.66	0.008
PumpStation vs Mosida	-.3010577	.1057273	-2.85	0.004

Nutrient Atmospheric Deposition on Utah Lake 2020

We conducted regression analyses to evaluate differences between Utah Lake and Great Salt Lake area (Central Davis and Ambassador) samplers to determine if all data could be combined to estimate annual nutrient atmospheric deposition on Utah Lake to increase sample size and predictability. The best fit models were mixed effects models using month as a random predictor variable on $\log_{10}$ transformed TP, SRP, and DIN (mg m^{-2}). TP and DIN concentrations were not significantly different between Utah Lake and GSL sites (Table 28 and Table 29), therefore we were able to justify the use of both Utah Lake and Great Salt Lake area TP and DIN data, effectively almost doubling our sample size. However, SRP concentrations were significantly different between Utah Lake and Great Salt Lake samplers (Table 30), therefore we only used Utah Lake sample data to determine annual SRP deposition in 2020.

Table 28. Mixed-effects regression model results for comparison between $\log_{10}$ transformed TP Utah Lake and Great Salt Lake sites. Month was modeled as random factor. Likelihood ratio text $\chi^2 = 20.25$, $p < 0.001$ confirming that a mixed effects model was appropriate.

logAdjTP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ulgslcode						
UtahLake	0.00	(base)				
GSL	-0.02	0.06	-0.36	0.717	-0.14	0.10
_cons	0.80	0.07	11.18	0.000	0.66	0.94

Random-effects Parameters	Estimate	Std. Err.	[95% Conf.	Interval]
monthcode: Identity				
var(_cons)	0.03	0.02	0.01	0.09
var(Residual)	0.19	0.02	0.16	0.23

Table 29. Mixed-effects regression model results for comparison between log_{10} transformed SRP Utah Lake and Great Salt Lake sites. Month was modeled as random factor. Likelihood ratio text $\chi^2 = 39.20$, $p < 0.001$ confirming that a mixed effects model was appropriate.

logAdjSRP	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ulgslcode						
UtahLake	0.00	(base)				
GreatSaltLake	-0.13	0.07	-2.05	0.04	-0.26	-0.01
_cons	0.52	0.10	5.23	0.00	0.33	0.72

Random-effects Parameters	Estimate	Std. Err.	[95% Conf.	Interval]
monthcode: Identity				
var(_cons)	0.06	0.03	0.02	0.18
var(Residual)	0.21	0.02	0.18	0.26

Table 30. Mixed-effects regression model results for comparison between log_{10} transformed DIN Utah Lake and Great Salt Lake sites. Month was modeled as random factor. Likelihood ratio test $\chi^2 = 61.05$, $p < 0.001$ confirming that a mixed effects model with month as a random factor was appropriate.

```
 logAdjustDIN |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
--------------+----------------------------------------------------------------
    ulgslcode |
     UtahLake |       0.00  (base)
GreatSaltLake |       0.09       0.05     1.78    0.07       -0.01        0.18
              |
        _cons |       1.22       0.09    13.53    0.00        1.04        1.39
```

```
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
monthcode: Identity          |
                  var(_cons) |       0.05       0.03          0.02        0.16
-----------------------------+------------------------------------------------
               var(Residual) |       0.13       0.01          0.11        0.15
```

Subsequently, we used a simplified formula to estimate annual deposition (metric tons) of TP, SRP, and DIN on Utah Lake in 2020:

[Antilog of log_{10} TP, SRP, or DIN from best fit models predicted means and 95% CIs (mg m^{-2} $week^{-1}$) **x** *52 (weeks $year^{-1}$)* **x** *380,000,000 (estimated Utah Lake area m^2)] / $1x10^9$ (mg to metric tons)*

We also estimated annual deposition for 2020 using geometric means (with 95% CIs) and using medians with 25^{th} and 75^{th} percentiles. Estimates are in Table 31.

Table 31. Estimated weekly and annual atmospheric nutrient deposition on Utah Lake in 2020. All data adjusted for screen effects.

	Model	**(Mg m^{-2} $week^{-1}$)**	**Metric tons $week^{-1}$**	**Metric tons $year^{-1}$**
TP	Best-fit linear regression[2]	6.34 (5.28, 7.61)	2.41 (2.01, 2.89)	125.26 (104.38, 150.30)
	Geometric Mean	6.34 (5.24, 7.67)	2.41 (1.99, 2.91)	125.26 (103.51, 151.58)
	Median (25^{th}, 75^{th} percentiles)	4.78 (3.12, 10.13)	1.81 (1.19, 3.85)	94.37 (61.69, 200.18)
	Model	**(Mg m^{-2} $week^{-1}$)**	**Metric tons $week^{-1}$**	**Metric tons $year^{-1}$**
SRP	Linear regression[2]	3.32 (2.72, 4.05)	1.26 (1.03, 1.54)	65.57 (53.67, 80.10)
	Geometric Mean	3.32 (2.67, 4.13)	1.26 (1.01, 1.57)	65.57 (52.70, 81.57)
	Median (25^{th}, 75^{th} percentiles)	3.03 (1.45, 5.39)	1.15 (0.55, 2.05)	59.95 (53.67, 80.10)

	Model	(Mg m^{-2} week^{-1})	Metric tons week^{-1}	Metric tons year^{-1}
DIN	Mixed effects linear regression[1]	18.10 (12.28, 26.67)	6.88 (4.67, 10.14)	357.57 (242.60, 527.04)
	Geometric Mean	31.29 (27.62, 35.44)	11.89 (10.50, 13.47)	618.29 (545.77, 700.29)
	Median (25th, 75th percentiles)	34.39 (19.30, 59.69)	13.07 (7.33, 22.68)	679.55 (381.37, 1179.47)

[1] $\log_{10}$ transformed, mixed effects linear regression model, random effect = site

[2] $\log_{10}$ transformed, linear regression model, only month as predictor

Discussion

Analyses presented in this draft were only preliminary analyses given time and funding constraints. Results however were similar to other researcher results available at the time of these analyses. Additional analyses using the statistical methods in this report are recommended pending further input for other experts.

Analyses presented in this report did not explicitly model AD spatial autocorrelation[2], which undoubtably occurs on Utah Lake and consequently may have somewhat biased our conclusions[3] (Isaak et al. 2014; Legendre 1993; Dale and Fortin 2009; Ver Hoef et al. 2001). AD is wind driven and varies spatially and temporally across the lake such that locations closer to each other in space and time likely had similar AD rates (i.e., spatial autocorrelation). In spatial data analysis terminology this spatial and temporal variation is known as 'non-stationarity' or 'anisotropy'. Sophisticated geospatial mapping methods such as Universal Kriging based on best fit (semi)variograms for AD on Utah Lake can account for non-stationarity and anisotropy including estimating model uncertainty, but unfortunately in our opinion there were too few data points (n = 5) for these methods to be considered useful. Typically, the recommended minimum number of sample locations to accurately detect significant spatial autocorrelation is around thirty (ASTM D5922-18; Legendre and Fortin 1989; Fortin 1999; Fortin et al 1989) and fifty to one hundred sampling locations are needed to create useful variograms and kriging maps (Dale and Fortin 2014; Webster and Oliver 1992, 2014). If in the future, researchers are interested in understanding fine scale AD spatial patterns across the lake, many more sample locations will be needed. Until then, only best professional inference of AD spatial patterns on the lake based on correlations between a handful of sites and wind patterns, local geology, and nutrient sources will suffice, although the application of decay functions derived from other regional locations do not seem appropriate for Utah Lake.

[2] Spatial autocorrelation (structure) is part of what is known as the first law of geography: 'Everything is related to everything else, but near things are more related than distant things' (Tobler 1970).

[3] By not being able to model spatial autocorrelation due to too few sample locations, the assumption of independence between sites may have been violated resulting in error estmates being too small with too liberal tests of significance (i.e. p-values and Type I error rates)(Isaak et al. 2014; Legendre 1993; Dale and Fortin 2009).

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