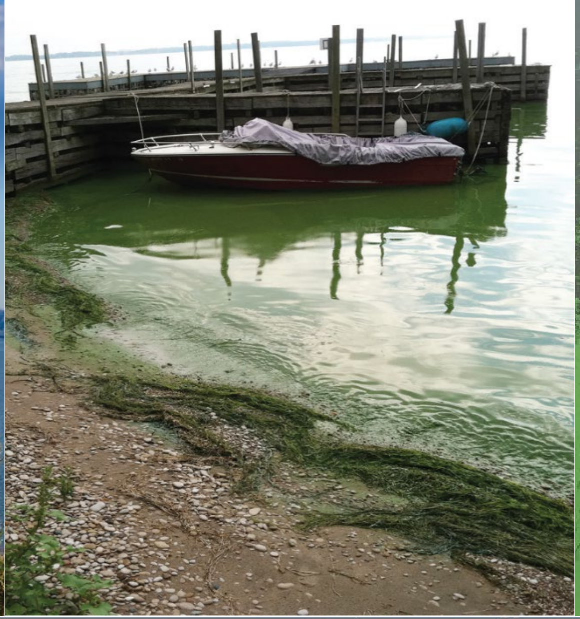
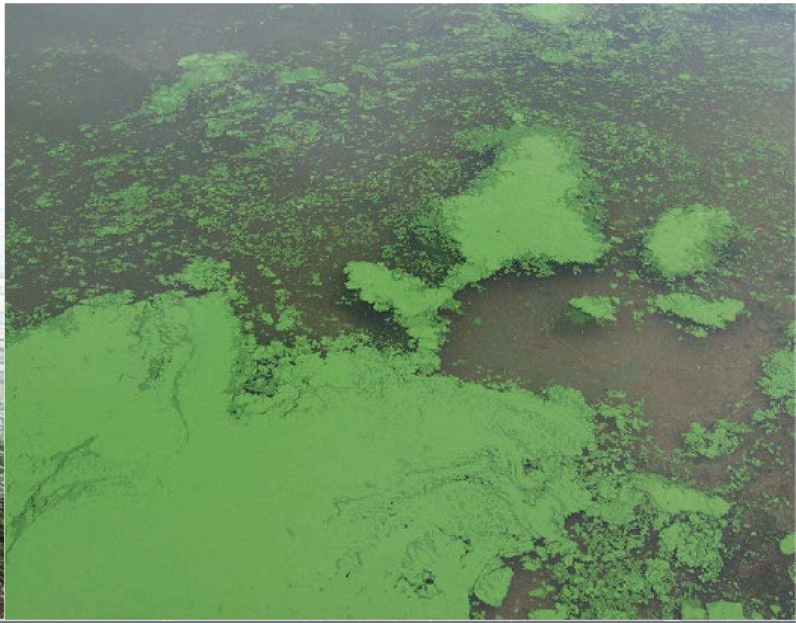
Technical Support Document Overview

Science Panel Meeting | March 2, 2023

Purpose of the Technical Support Document

- Provide the technical basis for the development of numeric nutrient criteria (NNC) to protect aquatic life and recreation uses
- Conduct analyses to support multiple lines of evidence in the NNC framework


Utah Lake Water Quality Study—Numeric Nutrient Criteria Technical Framework

FINAL REPORT

September 1, 2021
Version 9.0

Lines of Evidence

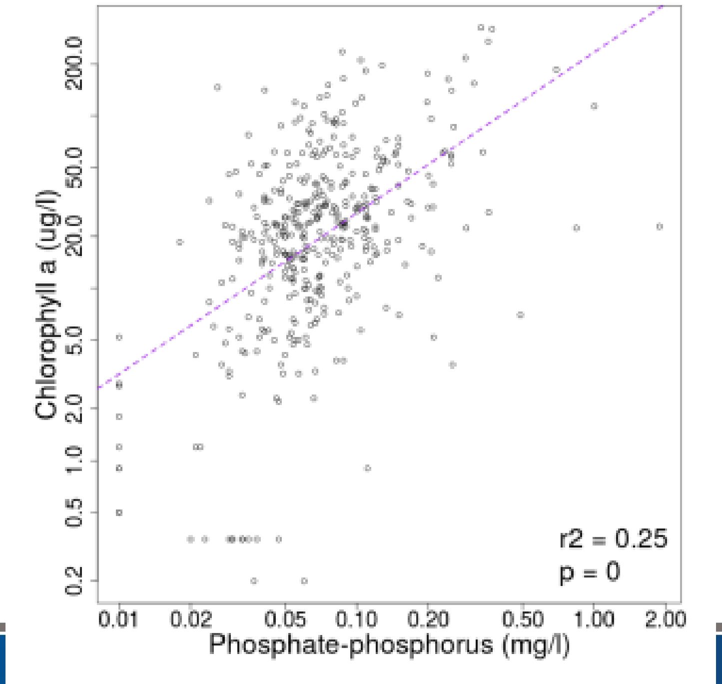
1. **Reference-based**
   - Results from paleolimnological studies
   - Utah Lake Nutrient Model prediction/extrapolation of reference conditions
2. **Stressor-response analysis**
   - Utah Lake Nutrient Model output
   - Statistical models
3. **Scientific literature**
   - Scientific studies of comparable/related lake ecosystems
   - Support/supplement other lines of evidence

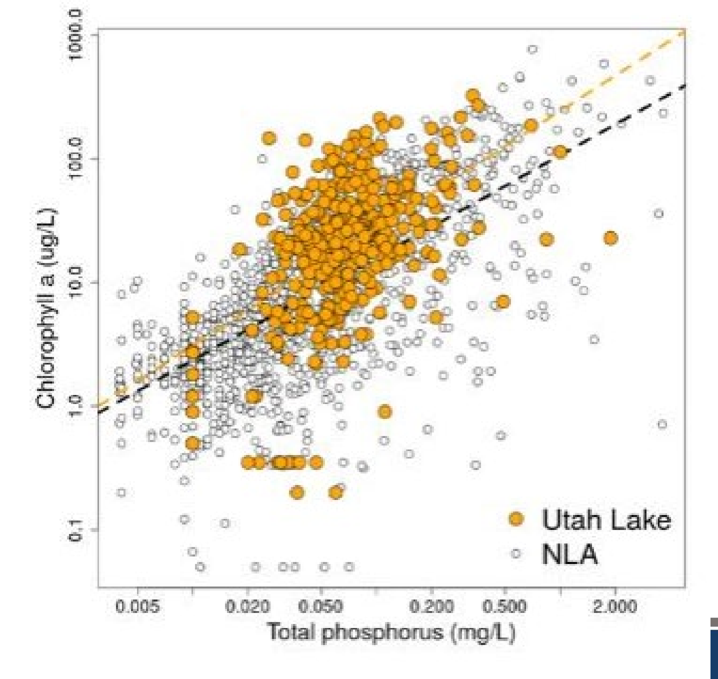
Reference-Based Analysis

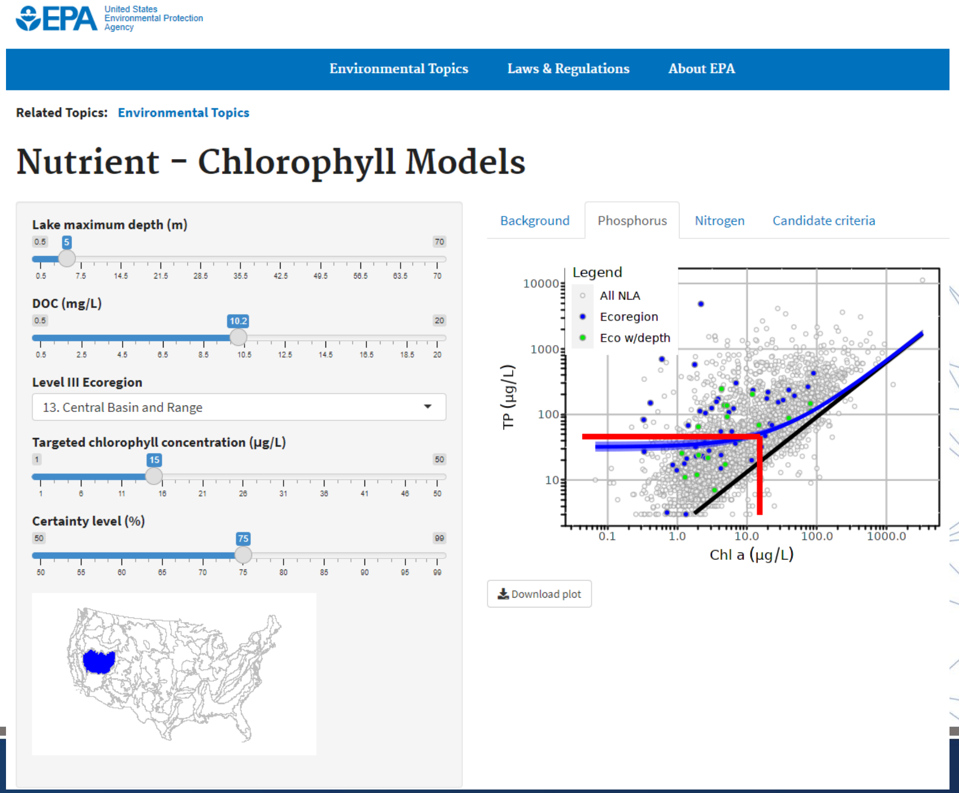
- **Paleolimnological reconstruction of past conditions**
  - Quantify pre-settlement nutrient conditions and how they have changed over time
  - SC charge questions include paleo topics: historic trophic state, water quality, & nutrient regime
- **Model-based prediction**
  - Watershed model run under a “reference conditions” scenario → watershed nutrient loading
  - Pre-EuroAmerican land cover, removal of water withdrawals/releases and irrigation, removal of nutrient point sources
  - Dams, stream hydraulics, sub-basin boundaries, weather maintained
- **Intended to set a “floor” and add context**

Stressor-Response Analysis

- Output from the Utah Lake Nutrient model (current and reduced nutrient loading)
- In-lake monitoring data for water quality variables
- Application of EPA's Ambient Water Quality Criteria nutrient models







Stressor-Response Analysis

Use	Assessment Endpoint	Stressor	Response	Empirical S-R Data Available	Mechanistic Model Output
Recreation, Aquatic Life, Agriculture, Drinking Water	Algal toxins	Chlorophyll a	Microcystin concentration	Yes	No
Recreation, Aquatic Life, Agriculture, Drinking Water	Algal toxins	Cyanobacterial abundance	Microcystin concentration	Yes	No
Recreation	Algal blooms	Chlorophyll a	Cyanobacterial abundance	Yes	Yes
Recreation, Aquatic Life	pH	Chlorophyll a	pH	Yes	Yes
Recreation	Lake visitation	Chlorophyll a	Annual visitation	Yes	No
Recreation	Lake visitation	Cyanobacterial abundance	Annual visitation	Yes	No
Recreation	Lake visitation	K_d, Secchi depth	Annual visitation	Yes	No
Recreation	Public perception	Chlorophyll a	Public perception	User perception	No
Recreation	Public perception	Cyanobacteria abundance	Public perception	User perception	No
Recreation	Public perception	K_d, Secchi depth	Public perception	User perception	No
Aquatic Life	DO	Chlorophyll a	DO	Yes	Yes
Aquatic Life	Food resources	Chlorophyll a	Zooplankton:Phytoplankton	National Model	No
Aquatic Life	Food resources	Chlorophyll a	Proportion cyanobacteria	Yes	Yes
Aquatic Life	Light	Chlorophyll a	K_d, Secchi depth	Yes	Yes
Criteria Setting		TN & TP	Chlorophyll a	Yes	Yes
Criteria Setting		TN & TP	Cyanobacterial abundance	Yes	Yes
Criteria Setting		TN & TP	K_d, Secchi depth	Yes	Yes

Aggregation for Stressor-Response Analyses

- Growing/recreation season
- Depths to represent surface
- Period of interest
- Extent: break lake into regions or take a lakewide average?
  - If lake is broken into regions, may end up with different targets

Scientific Literature

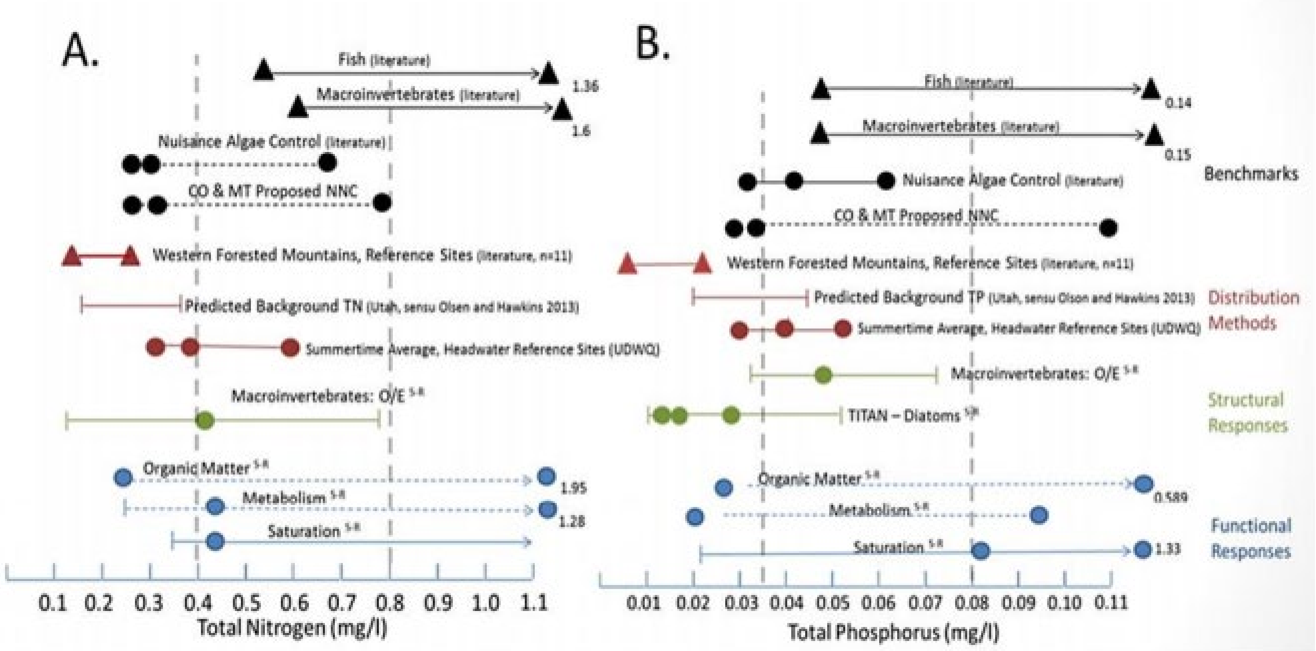
- **Comparison with nutrient levels in other lakes**
- **Could include:**
  - Similar lakes worldwide
  - NLA data
  - Reference waterbodies in ecoregion

Evaluating Numeric Targets

- **Magnitude**
  - "the maximum amount of the contaminant that may be present in a water body that supports the designated use"
  - This value is most readily identified from analyses
- **Frequency**
  - "the number of times the contaminant may be present above the magnitude over the specified period (duration)"
  - Examples: not to be exceeded, x exceedances in a season, x exceedances in y years
- **Duration**
  - "the period over which the magnitude is calculated"
  - Examples: grab (single date), seasonal central tendency
- **Some parameters already have these defined (e.g., microcystin, DO, pH)**

Weight of Evidence

- **Ranges of nutrients deemed protective of uses across lines of evidence**
- **How to distill these lines of evidence into a recommendation?**
  - Statistical distributions of endpoints
  - Interpret endpoints in the context of their uncertainty → weigh lines against each other by their relevance, strength, and reliability



Questions and Discussion

Utah Lake Bioassay Final Report-Nutrient Limitation of Phytoplankton, Cyanobacteria and Cyanotoxins

Professors in order of overall contribution

PI: Dr. Zachary T. Aanderud, Brigham Young University (BYU)

Co-PI: Dr. Michelle A. Baker, Utah State University (USU)

Co-PI: Dr. Ben Abbott, BYU

Graduate Students in order of overall contribution

Gabriella M. Lawson, BYU, MS

Dr. Erin F. Jones, BYU, PhD

Samuel P. Bratsman, BYU, MS

Rachel Buck, USU, PhD

List of Reviewers from the Utah Lake Quality Study Science Panel

Scott Daly, Utah Department of Environmental Quality-Water Quality

Dr. Kateri Salk-Gunderen, Tetra Tech

Dr. Hans W. Paerl, University of North Carolina at Chapel Hill

Dr. Ryan King, Baylor University

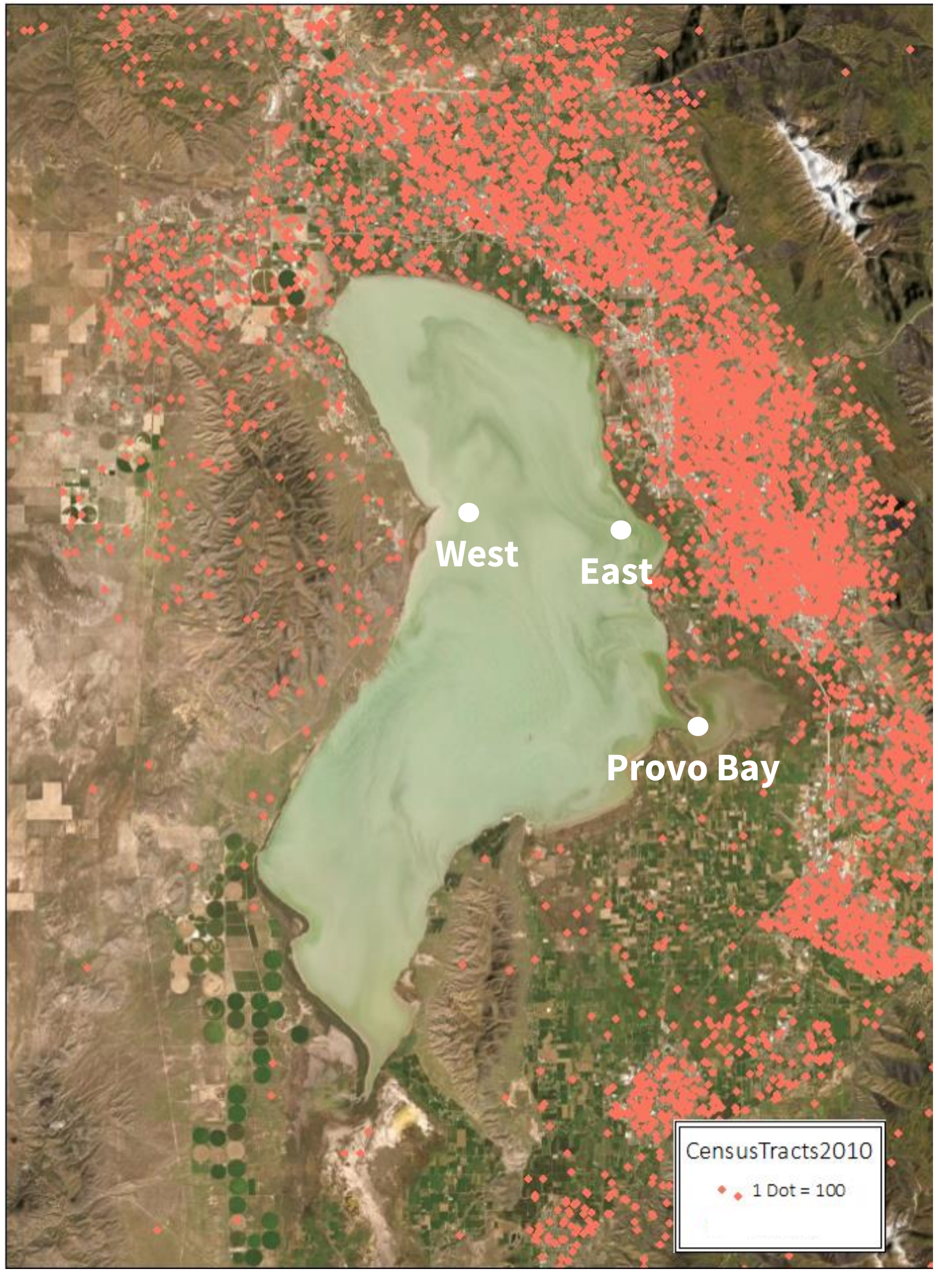
Dr. Michael J. Paul Tetra Tech

Dr. Mitch Hogsett, Forsgren Associates Inc.

Methods

SPRING	MAY
EARLY SUMMER	JUN
SUMMER	JUL
LATE SUMMER	AUG
FALL	OCT

- P amendment = 0.10 mg-P/L above background concentrations added as K_2HPO_4,
- N amendment = 0.72 mg-N/L added as NH_4NO_3 to achieve a
- 16:1 molar ratio of DIN:SRP
- ΔR = mean chlorophyll-a treatment/mean chlorophyll-a control)



PUBLISH ABOUT BROWSE SEARCH advanced search

PLOS ONE

OPEN ACCESS PEER-REVIEWED
RESEARCH ARTICLE

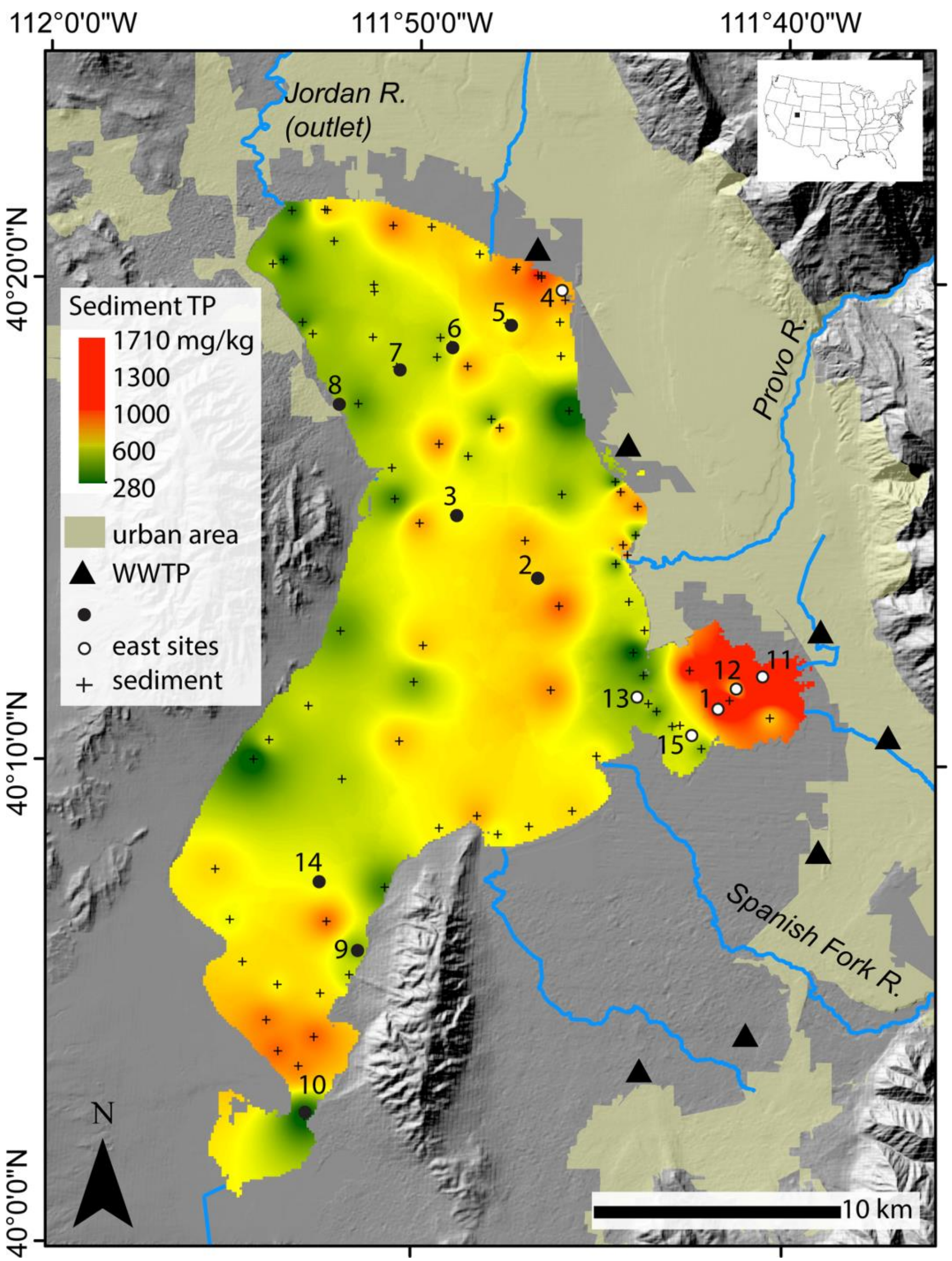
Sediment potentially controls in-lake phosphorus cycling and harmful cyanobacteria in shallow, eutrophic Utah Lake

Matthew C. Randall, Gregory T. Carling, Dylan B. Dastrup, Theron Miller, Stephen T. Nelson, Kevin A. Rey, Neil C. Hansen, Barry R. Bickmore, Zachary T. Aanderud

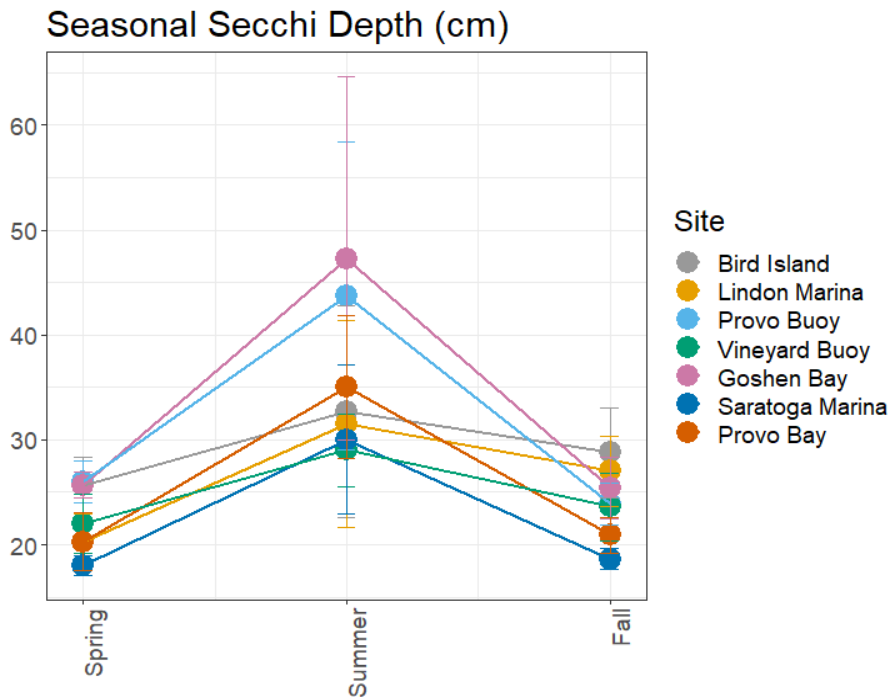
Published: February 14, 2019 • https://doi.org/10.1371/journal.pone.0212238

Table 1 Cyanobacterial species distribution across Utah Lake

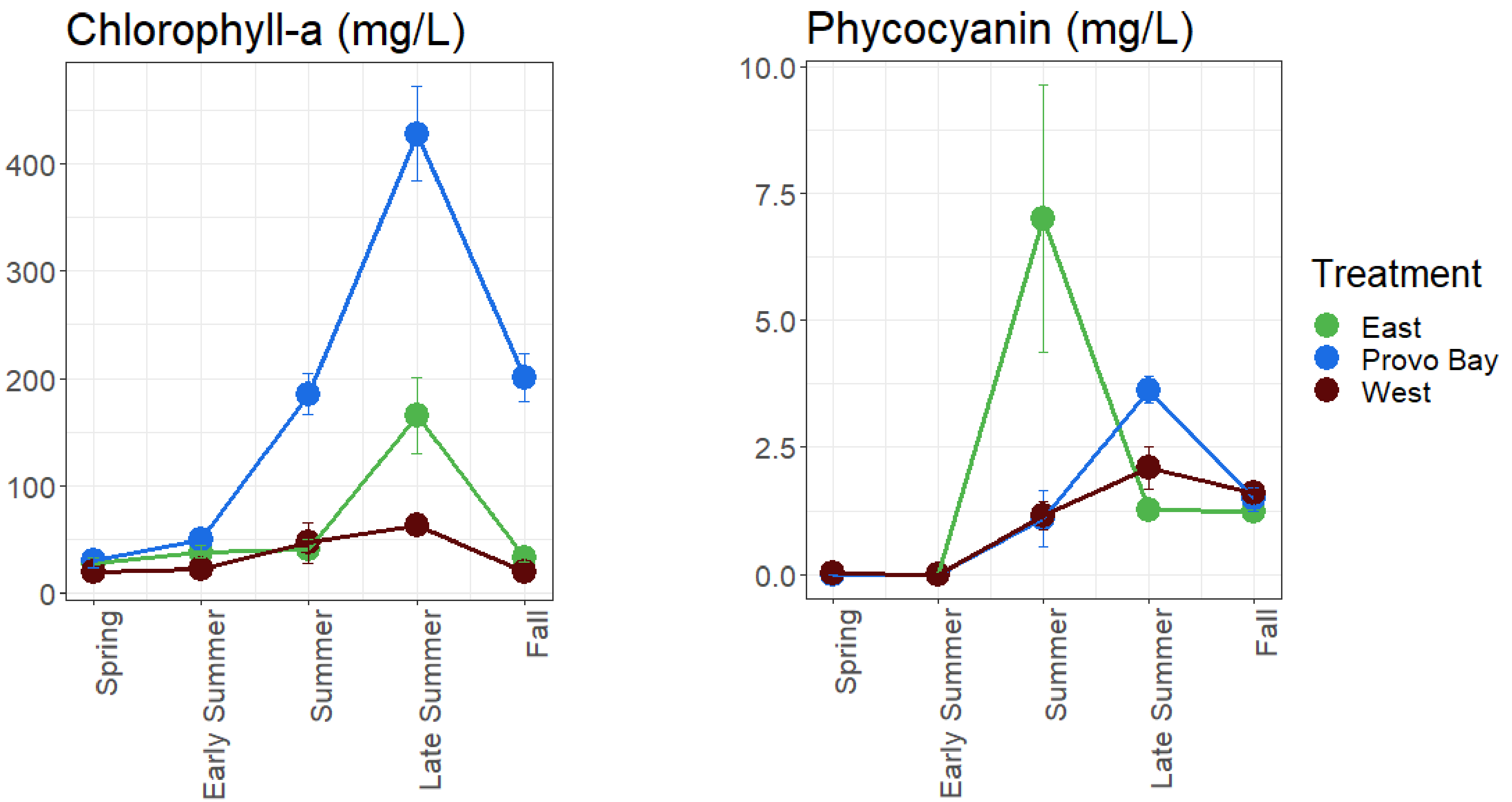
	EAST						WEST						PROVO BAY					
	counts (#)	richness = 18					counts (#)	richness = 15					counts (#)	richness = 12				
Species		SP	ES	S	LS	F		SP	ES	S	LS	F		SP	ES	S	LS	F
Aphanizomenon flosaquae	47,463-234,076						5,466-81,833						100,476-344,058					
Aphanocapsa grevillei	728																	
Aphanocapsa holsatica	3,528																	
Aphanocapsa planctonica	1,568-10,662						314-627											
Aphanocapsa species	2,394-10,591						532-8,512						1,862-46,075					
Calothrix species	157																	
Chroococcus species							62											
Chrococcus dispersus													3,240					
Chroococcus limeticus	101												101					
Coelosphaerium species							45						1,440					
Cyanodictyon planctonicum	336-2,688						2,520						2,700-54,000					
Dolichospermum circinalis	645-74,650						946-3,830						1,125-630,157					
Dolichospermum species													6,413					
Gomphosphaeria aponina	5,018																	
Leptolyngbya species	3,928-9,565						3,007						7,515-17,763					
Merismopedia glauca	3,472-48,288						5,555						6,535-65,596					
Microcystis aeruginosa	686						392											
Microcystis species	2,688-3,584						6,272						12,600					
Phormidium species	1,456-2,058						2,464						1,456-12,555					
Phormidium species 3	168-8,623																	
Planktothrix species	826-19,936						9,390-15,680						5,376-36,000					
Pseudanabaena species	162-1,217						324-1,966						1,620-3,035					
Snowella lacustris	784						2,867											



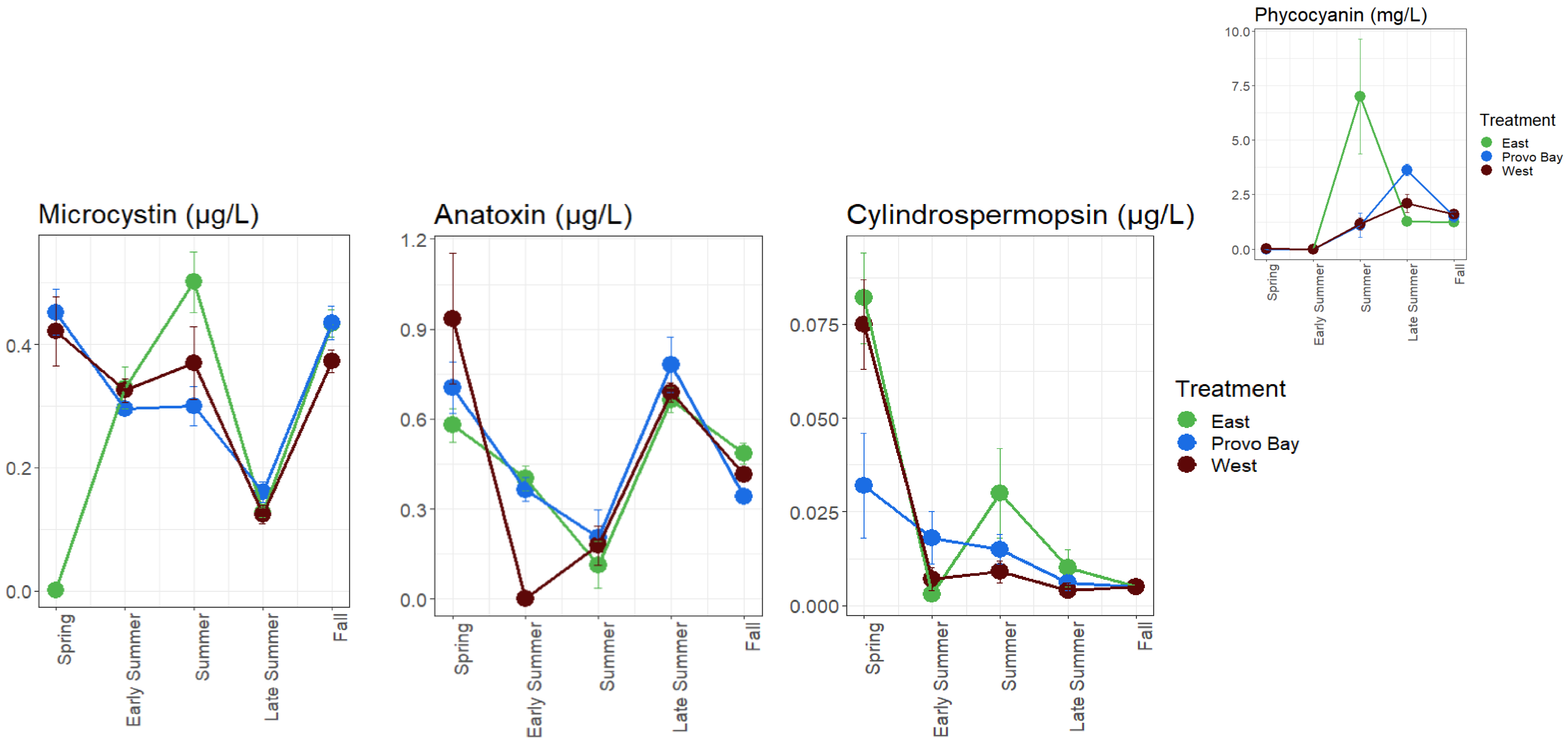
Sunlight is available to phytoplankton



- Shade covers reduced light by 30% / Plastic cubitainers reduced light by 15%

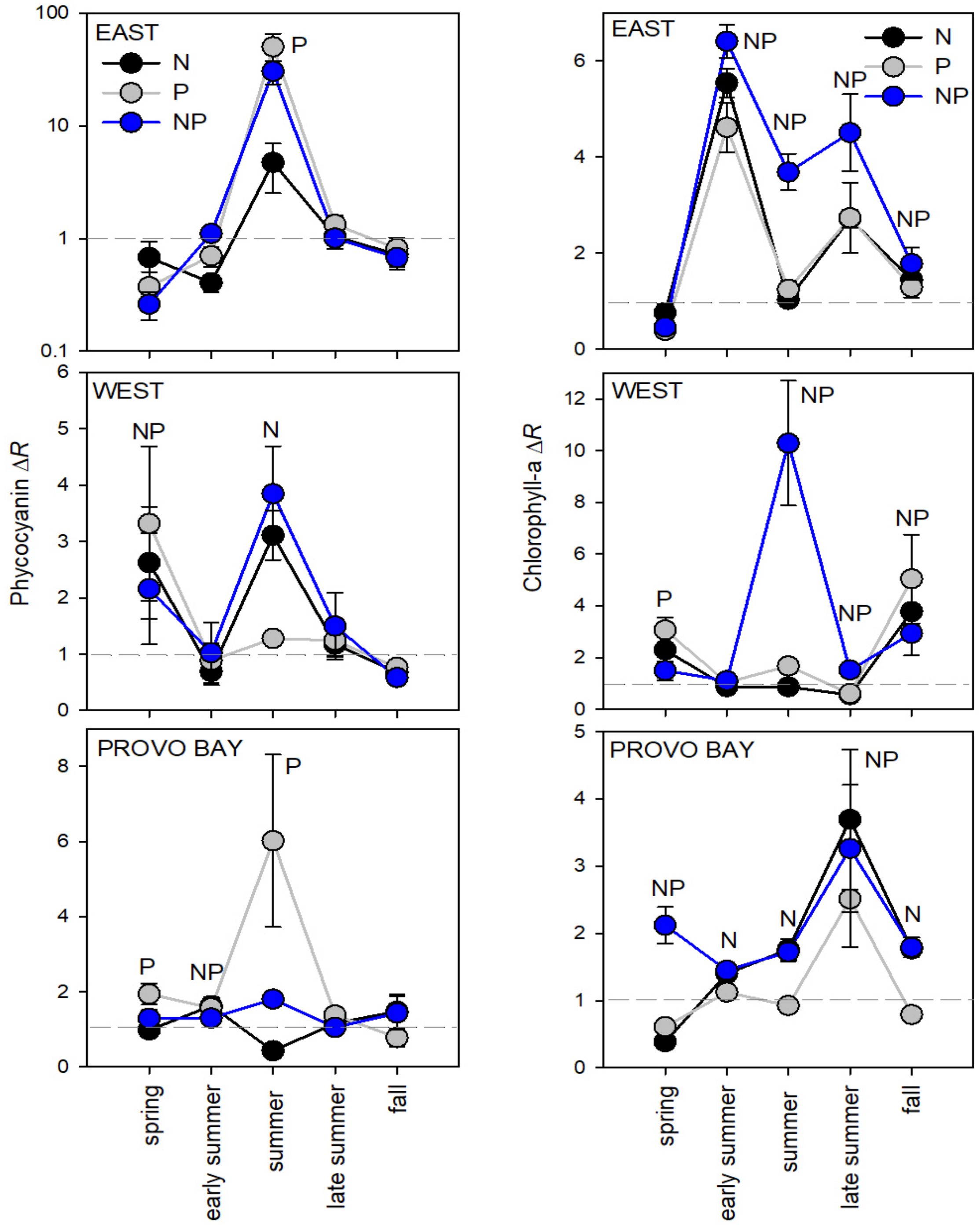


- phytoplankton as all prokaryotic or eukaryotic organism containing chlorophyll-a (e.g., chlorophytes, diatoms, and cyanobacteria)



- Cyanotoxins demonstrated a seasonal signal that was not dependent on the cell density of cyanobacteria
- Anatoxin-a concentration was generally higher in the spring, late summer, and fall
- Cylindrospermopsin concentration was highest in the spring

- N or P limited cyanobacteria in the summer across all three locations.
- P limited cyanobacterial responses in East and Provo Bay water, while N limited cyanobacteria in West water
- Cyanobacteria were not limited by either N or P in the late summer and fall
- Nutrient colimitation of phytoplankton occurred in the summer, late summer, and fall
- In the relatively nutrient rich Provo Bay that supported orders of magnitude more phytoplankton biomass than the main body, phytoplankton was limited during every season with N limiting phytoplankton responses when a co-limitation was not present



- In the summer, total phytoplankton growth was generally higher in the first 24 hours of the 96-hour time series in the main body of the lake
- Increases in cyanobacterial growth were dependent on the nutrient addition and location in the lake
- In the main body, cyanobacterial growth was stimulated by nutrient addition (i.e., P and N+P addition in the East, and any treatment in the West) in the first 24 hours
- There was no clear and consistent growth pattern in the bay during the incubation
- See final report for growth of individual species

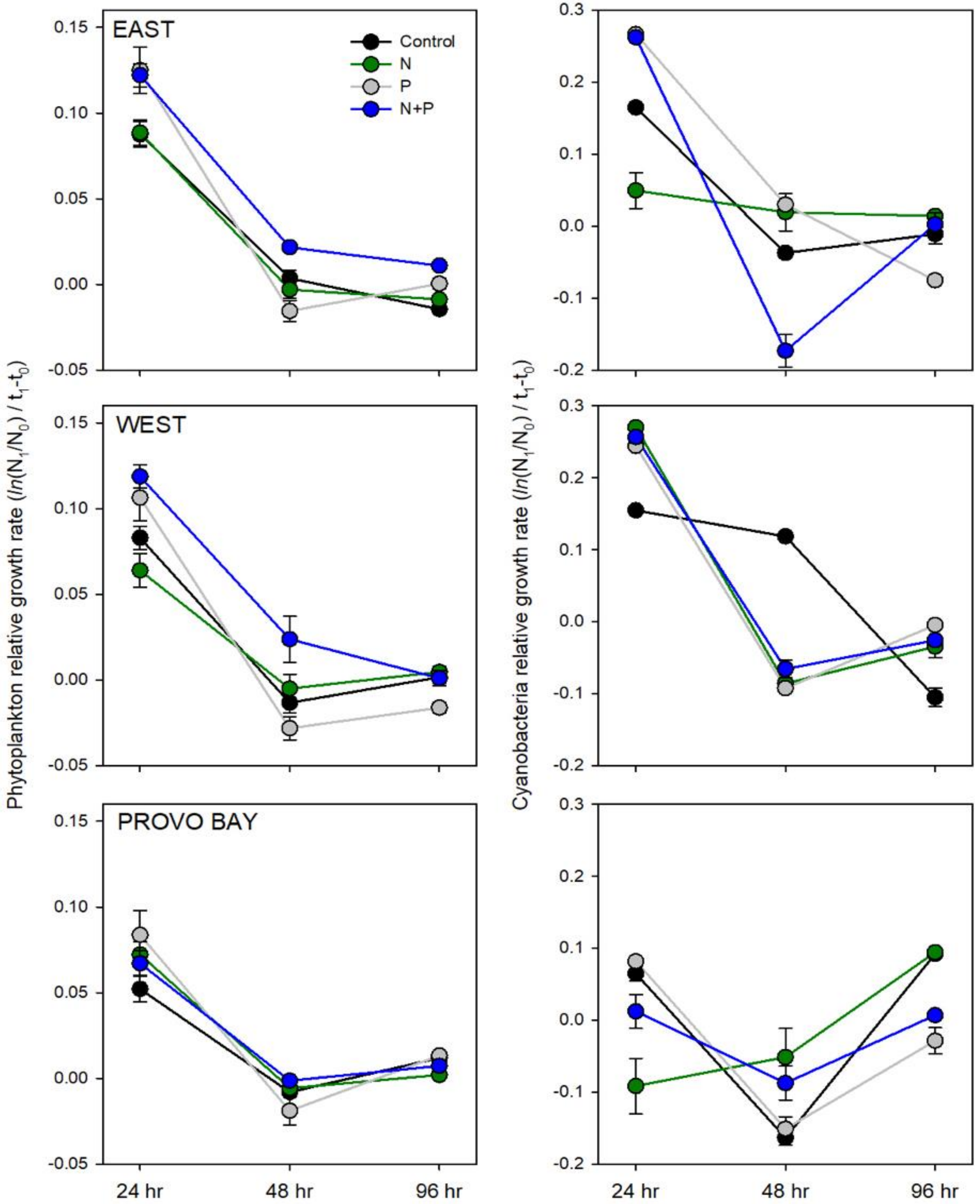


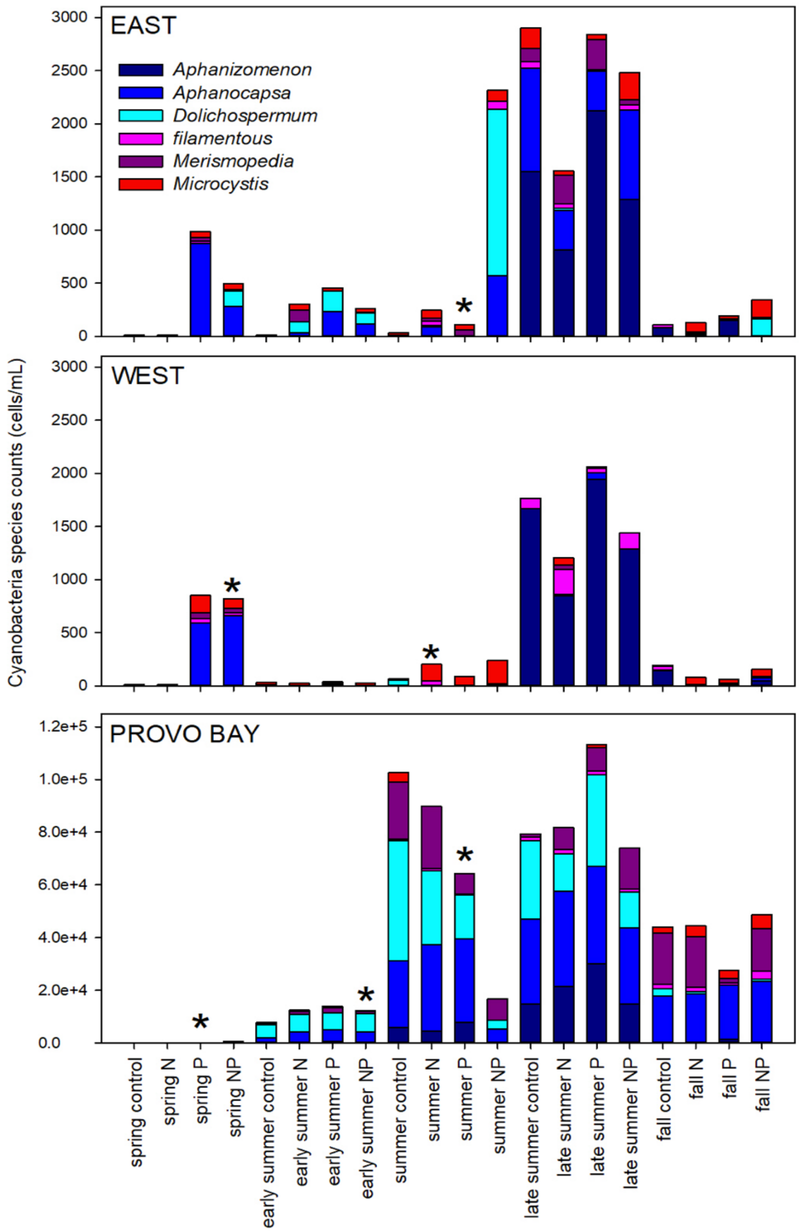
Table 2 Summary of Nutrient Limitation

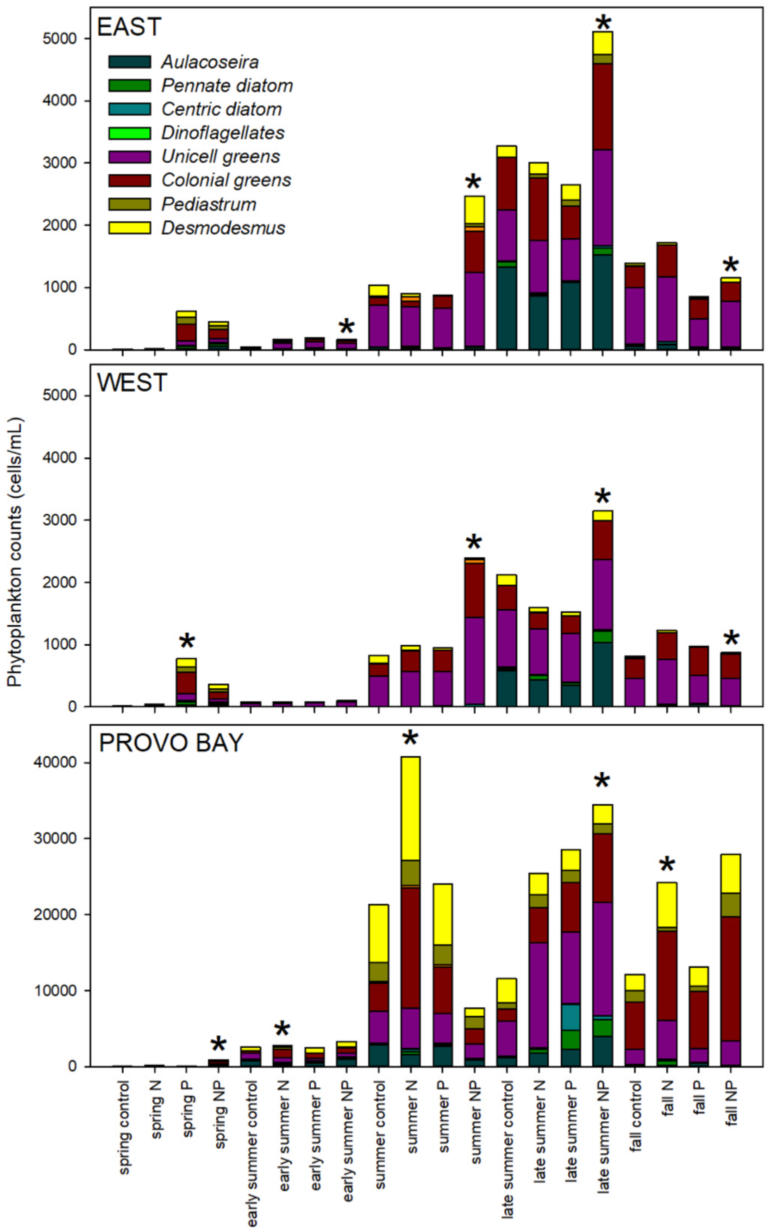
Variable and Location	spring	early summer	summer	late summer	fall
Cyanobacteria nutrient limitation					
East	No limitation	No limitation	P	No limitation	No limitation
West	N+P	No limitation	N	No limitation	No limitation
Provo Bay	P	N+P	P	No limitation	No limitation
Total phytoplankton nutrient limitation					
East	No limitation	N+P	N+P	N+P	N+P
West	P	No limitation	N+P	N+P	N+P
Provo Bay	N+P	N	N	N+P	N

- The DIN and SRP was biologically available to the cyanobacteria and phytoplankton
- Concentrations of DIN and SRP consistently declining in treatments—the addition of N resulted in lower P concentrations and the addition of P leading to lower N concentrations
- During the summer seasons, across all locations, the ratio of DIN to SRP in the N+P addition remained close to 16:1 indicating that phytoplankton and/or cyanobacteria were still utilizing N and P even under excessive nutrient conditions
- Biogeochemically co-limited instead of community-level co-limited

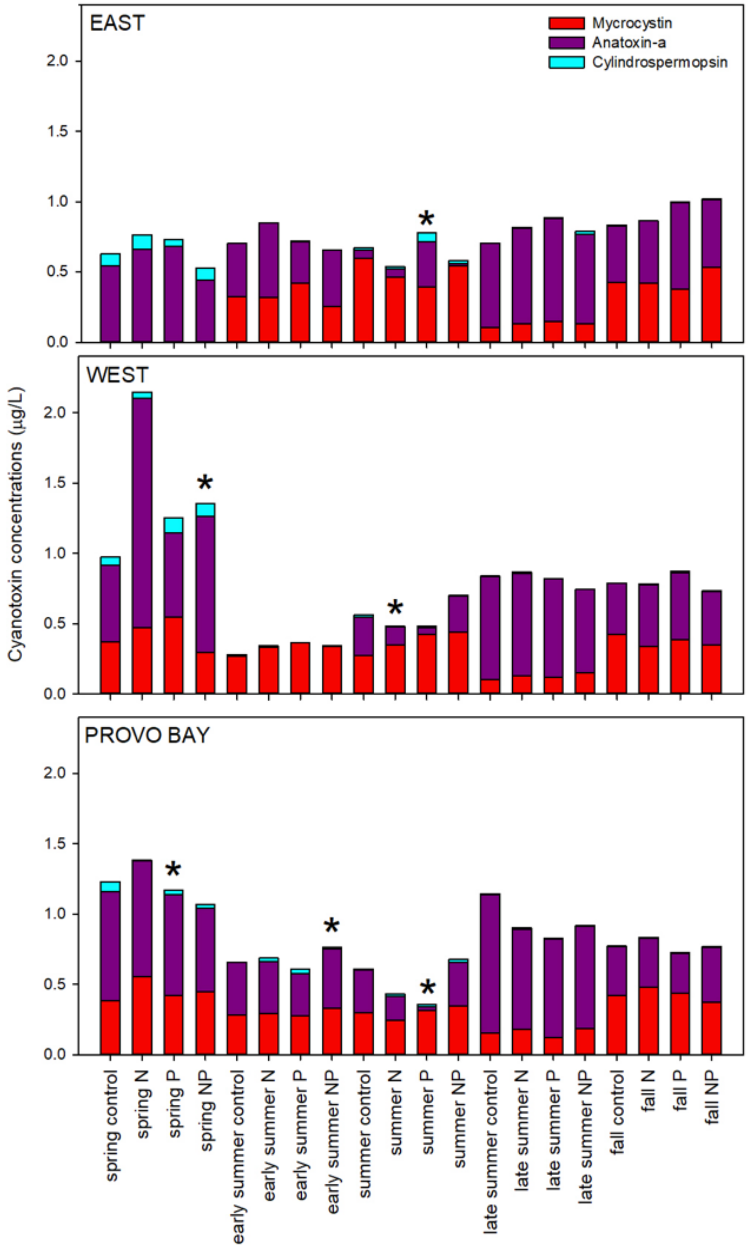
Table 3 SRP and DIN concentrations and molar ratios in nutrient additions treatments

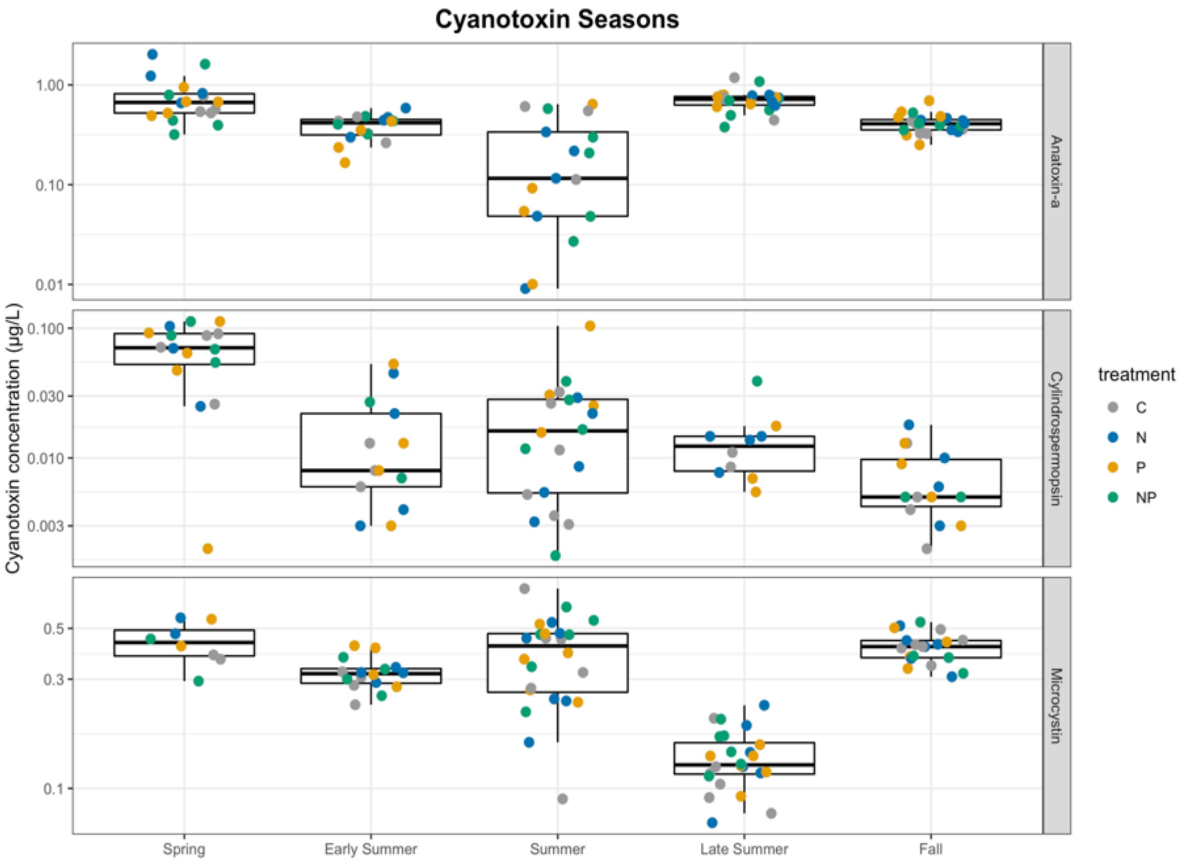
Location	Treatment	Treatment	SRP (mg/L)	DIN (mg/L)	DIN:SRP (mole:mole)
EAST	spring	N	0.013 ±0.002	0.05 ±0.02	9.22 ±3.33
		P	0.029 ±0.015	0.26 ± 0.01	32.6 ±12.8
		N+P	0.016 ±0.004	0.49 ± 0.33	55.5 ±25.5
	early summer	N	0.005 ±0.001	0.19 ±0.01	117 ±4.88
		P	0.008 ±0.003	0.07 ±0.06	16.2 ±8.66
		N+P	0.007 ±0.001	0.02 ± 0.001	5.30 ±1.25
	summer	N	0.004 ±0.002	0.86 ±0.08	800 ± 405
		P	0.100 ±0.001	0.06	1.33
		N+P	0.096 ±0.20	0.70 ±0.15	16.2 ±0.614
	late summer	N	0.031 ±0.012	0.39 ±0.06	33.5 ±7.72
		P	0.067 ±0.033	0.02 ±0.01	8.49 ±7.95
		N+P	0.037 ±0.033	0.17 ±0.06	94.1 ±53.2
	fall	N	0.008 ±0.004	1.00 ±0.06	122 ±61.5
		P	0.140 ±0.020	0.29 ±0.06	4.58 ±0.365
		N+P	0.123 ±0.021	1.18 ±0.38	12.0 ±6.45
WEST	spring	N	0.022 ±0.021	0.14 ±0.07	104 ±93.8
		P	0.084 ±0.026	0.06 ± 0.04	1.36 ±0.469
		N+P	0.117 ±0.043	0.25 ± 0.23	3.17 ±2.33
	early summer	N	0.005 ±0.002	0.28 ±0.01	372 ±278
		P	0.006 ±0.001	0.03 ±0.01	11.2 ±4.12
		N+P	0.009 ±0.002	0.23± 0.001	75.0
	summer	N	0.003 ±0.002	1.0 ±0.13	2859 ±1764
		P	0.094 ±0.002	0.14	3.43
		N+P	0.068 ±0.003	0.63 ±0.04	20.3 ±0.962
	late summer	N	0.065 ±0.037	0.75 ±0.04	13.0 ±7.78
		P	0.020 ±0.014	0.08 ±0.02	49.0 ±39.2
		N+P	0.037 ±0.021	0.50 ±0.09	19.7 ±14.3
	fall	N	0.009 ±0.006	0.96 ±0.11	913 ±712
		P	0.141 ±0.009	0.34 ±0.04	5.41 ±0.263
		N+P	0.106 ±0.003	0.96 ±0.06	20.0 ±0.836
PROVO BAY	spring	N	0.024 ±0.006	0.30 ±0.16	34.5 ±24.7
		P	0.015 ±0.002	0.31 ± 0.02	45.1 ±1.55
		N+P	0.021 ±0.006	0.14 ± 0.04	18.9 ±8.72
	early summer	N	0.012 ±0.002	0.30 ±0.16	31.4 ±14.6
		P	0.010 ±0.002	0.31 ±0.02	2.42
		N+P	0.010 ±0.002	0.14 ±0.04	17.7 ±14.1
	summer	N	0.008 ±0.001	0.14 ±0.06	41.0 ±29.1
		P	0.246 ±0.020	0.37 ±0.31	3.68 ±3.13
		N+P	0.074 ±0.018	0.26 ±0.12	11.1 ±7.11
	late summer	N	0.021 ±0.005	0.09 ±0.06	16.9 ±13.9
		P	0.114 ±0.010	0.19 ±0.06	3.72 ±1.08
		N+P	0.056 ±0.032	0.19 ±0.07	3.84 ±1.66
	fall	N	0.009 ±0.001	0.09 ±0.07	26.9 ±19.8
		P	0.084 ±0.006	0.01 ±0.001	0.257 ±0.129
		N+P	0.010 ±0.001	0.11 ±0.05	29.5 ±16.4





- During the summer, Microcystis sp. was associated with cyanobacterial nutrient limitation in the East and West. In the bay, Aphanocapsa, Dolichospermum, Merismopedia, and Aphanizomenon spp. were associated with nutrient limitation in the early summer and summer.
- Aulacoseira and Desmodesmus spp. and two taxonomical categories of algae (i.e., unicellular and colonial green algae) were primarily associated with the phytoplankton nutrient limitations across Utah Lake regardless of season.

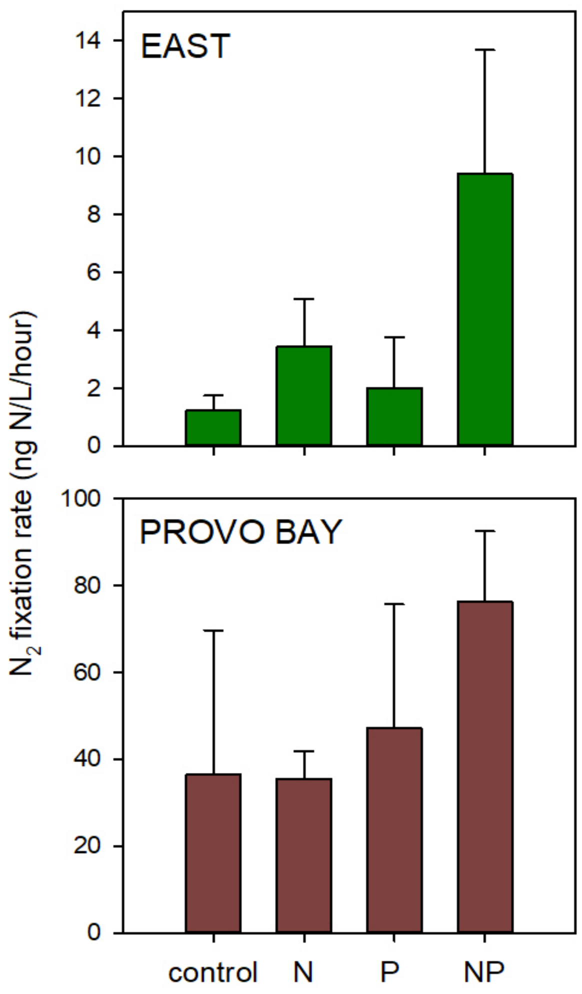


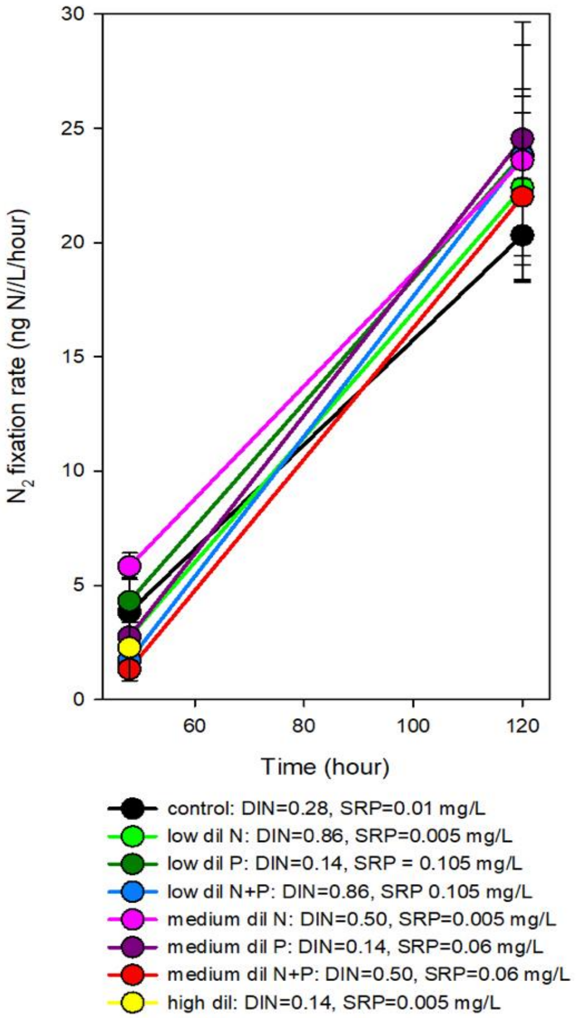


- Microcystin was most prevalent in the early summer and summer, regardless of nutrient treatment or a specific nutrient limitation to phytoplankton.

- In the early summer, N+P additions increased N_2 fixation 7.7-fold (N+P=9.41 ng N/L/hour ±4.27, control=1.23 ng N/L/hour ±0.523) in East water. In Provo Bay, N_2 fixation rates were at least 4-times higher than in East but were not influenced by nutrient addition. N_2 fixation was non-detectable in West water

- Regardless of treatment, N_2 fixation dramatically increased at least 5.5-fold from 48 to 120 hours (mean of all treatments: 48 hours=3.33 ±0.442 and 120 hours=22.9 ±1.08 ng N/L/hour



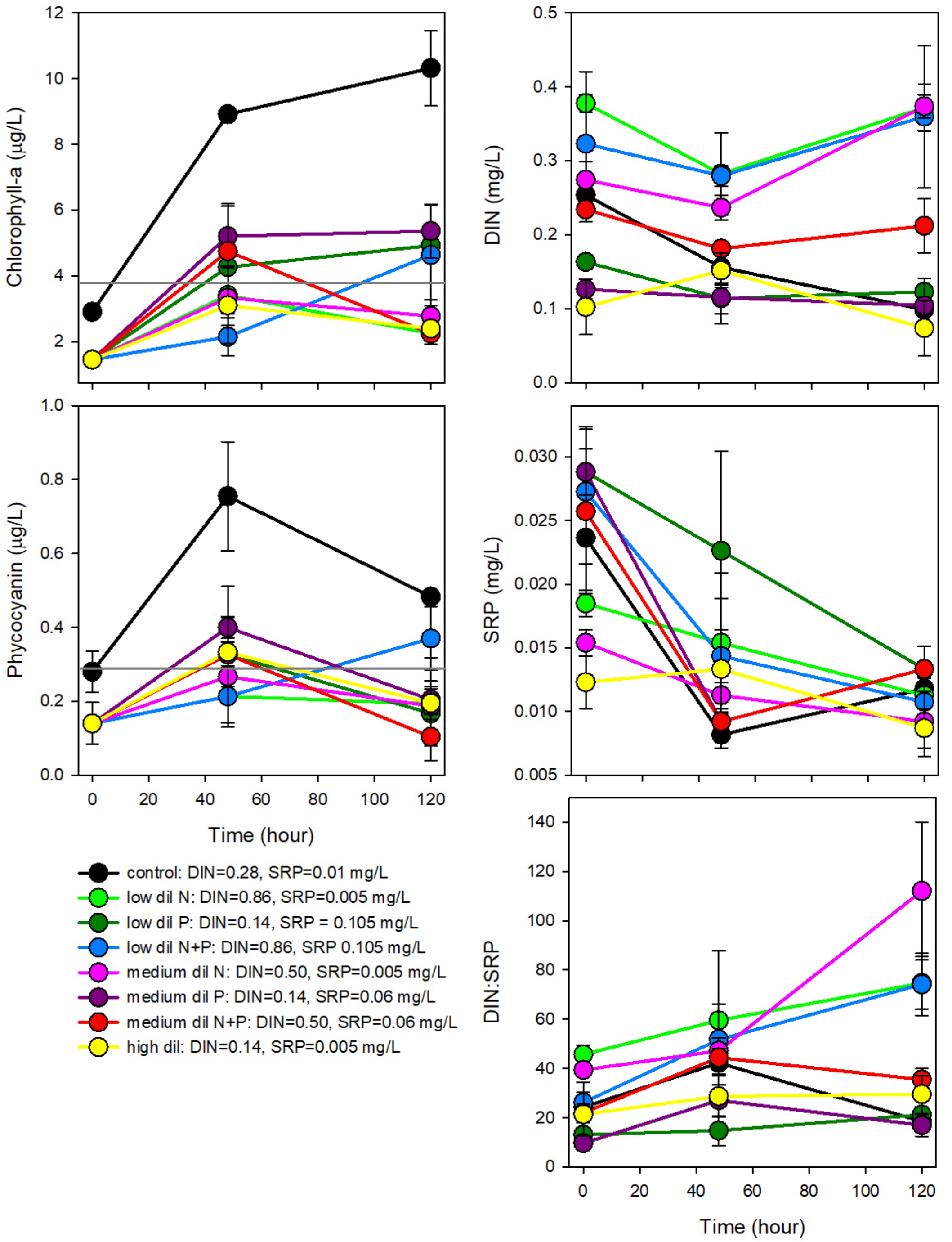


- In the spring, the nutrient levels needed to curb phytoplankton was a DIN concentration < 0.14 mg/L combined with an SRP concentration < 0.06 mg/L

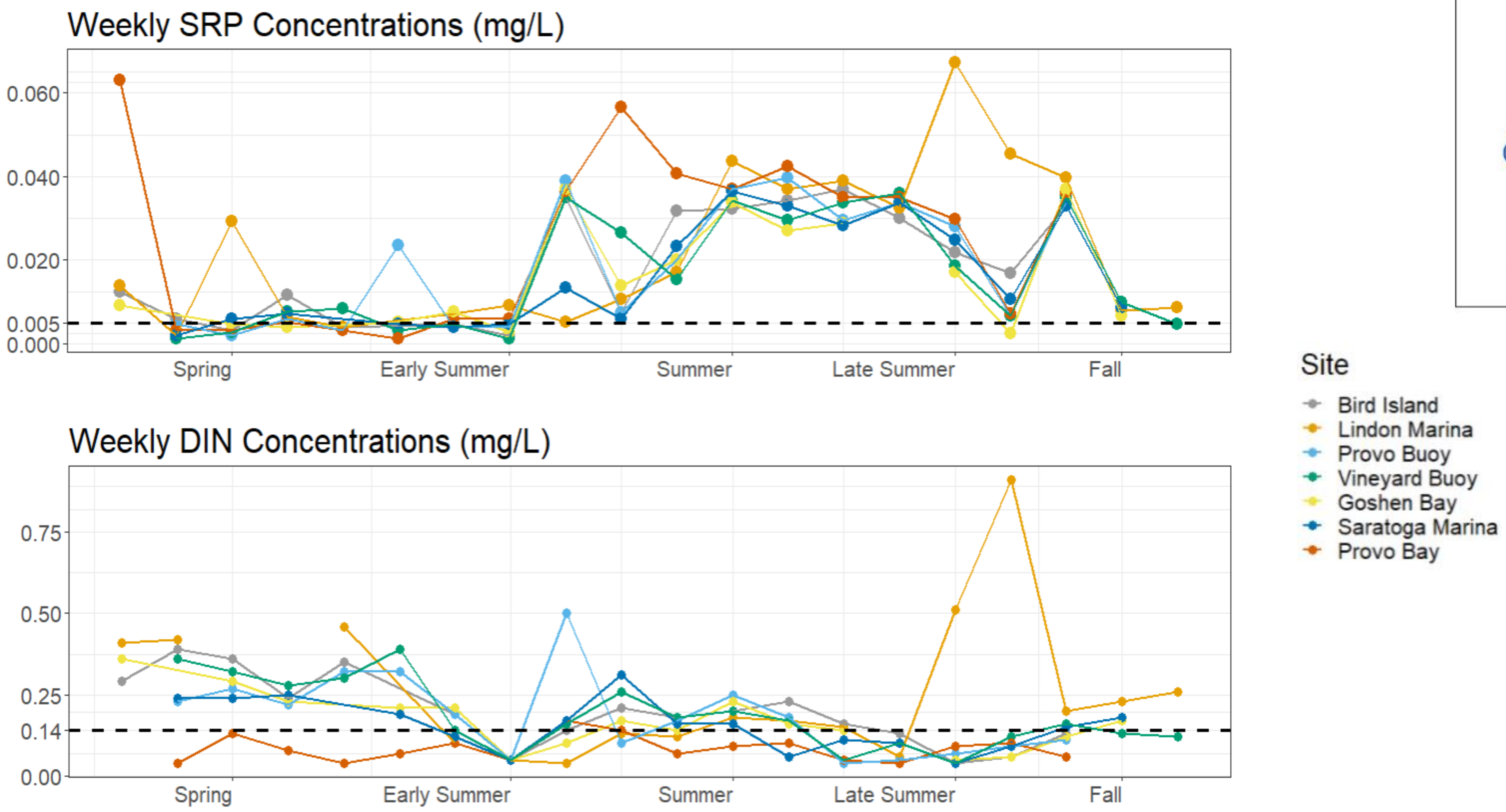
- The nutrient level needed to curb cyanobacteria was a SRP concentration < 0.005 mg/L

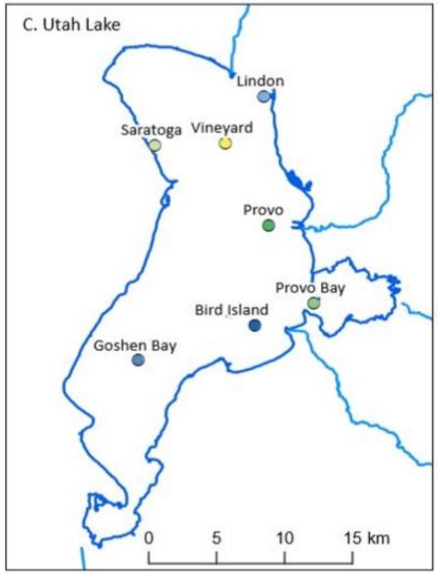
Table 4 Synthetic Utah Lake water recipe

Chemical form	Final concentration of the major ion solution used to dilute the assays (mg/L or element)
Si^{4+} as Na2 SiO3 9H2O	0.037
Ca^{2+} as CaCl2 2H2O	44.0
Mg^{2+} as MgSO4 7H2O	77.0
Na^{+} as Na2SO4	50.0
K^{+} as K2 SO4	10.6
SO42- as MgSO4 7H2O	304
Cl^{-} as CaCl2 2H2O	165



Are We Exceeding These Thresholds?





- Dual-nutrient management strategy maintaining DIN concentrations and reducing SRP (especially SRP)
- We strongly suggest that management goals focus on DIN in the spring and SRP in summer and late summer
- However, many measurements are completed as TN or TP
- Our thresholds in terms of TN and TP are: TN: < 1.3 mg/L, TP: < 0.11 mg/L

- In the main body of the lake, in the early summer, microzooplankton grazed total phytoplankton and cyanobacteria, but in the bay, microzooplankton grazers demonstrated a selective feeding preference for cyanobacteria
- In the main body of the lake, microzooplankton grazed cyanobacteria, measured as phycocyanin concentrations, to almost non-detectable levels
- In Provo Bay water, the inclusion of microzooplankton led to an increase in chlorophyll-a concentrations across all treatments and the control.

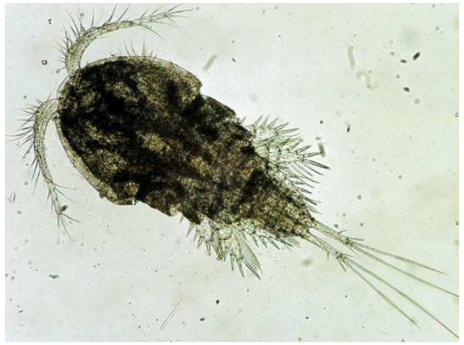
Table 5 Impact of grazers on chlorophylla-a and phycocyanin concentrations

		Chlorophyll-a		Phycocyanin	
Location	Treatment	plus grazers	minus grazers	plus grazers	minus grazers
EAST	Control	2.28 ±0.870	8.72 ±0.344	0.01 ±0.005	0.540 ±0.56
	N	2.48 ±1.07	48.2 ±4.81	0	2.62 ±0.254
	P	4.84 ±3.44	40.2 ±8.84	0.01 ±0.035	2.08 ±0.344
	N+P	3.90 ±2.49	55.8 ±5.64	0.01 ±0.045	2.64 ±0.333
WEST	Control	2.56 ±1.17	21.5 ±0.558	0.01 ±0.01	0.960 ±0.051
	N	2.41 ±1.01	18.4 ±0.649	0.01 ±0.005	0.870 ±0.006
	P	4.49 ±3.09	22.1 ±2.51	0.01 ±0.055	0.953 ±0.087
	N+P	3.97 ±2.57	23.6 ±4.78	0.01 ±0.050	0.990 ±0.107
PROVO BAY	Control	78.2 ±10.4	41.5 ±5.57	3.27 ±0.340	5.21 ±2.00
	N	101 ±12.9	55.7 ±2.61	4.26 ±0.645	7.71 ±0.254
	P	76.5 ±12.1	44.8 ±2.13	3.22 ±0.390	7.26 ±0.155
	N+P	89.3 ±0.660	57.7 ±2.61	3.76 ±0.145	7.09 ±0.274

Calanoida (Calanoids)

Phyllopoda
(Diplostraca, Notostraca)

Diplostraca
(Cladocera)



Cycolopoida (Cyclopoids)

Monogononta (Rotifers)

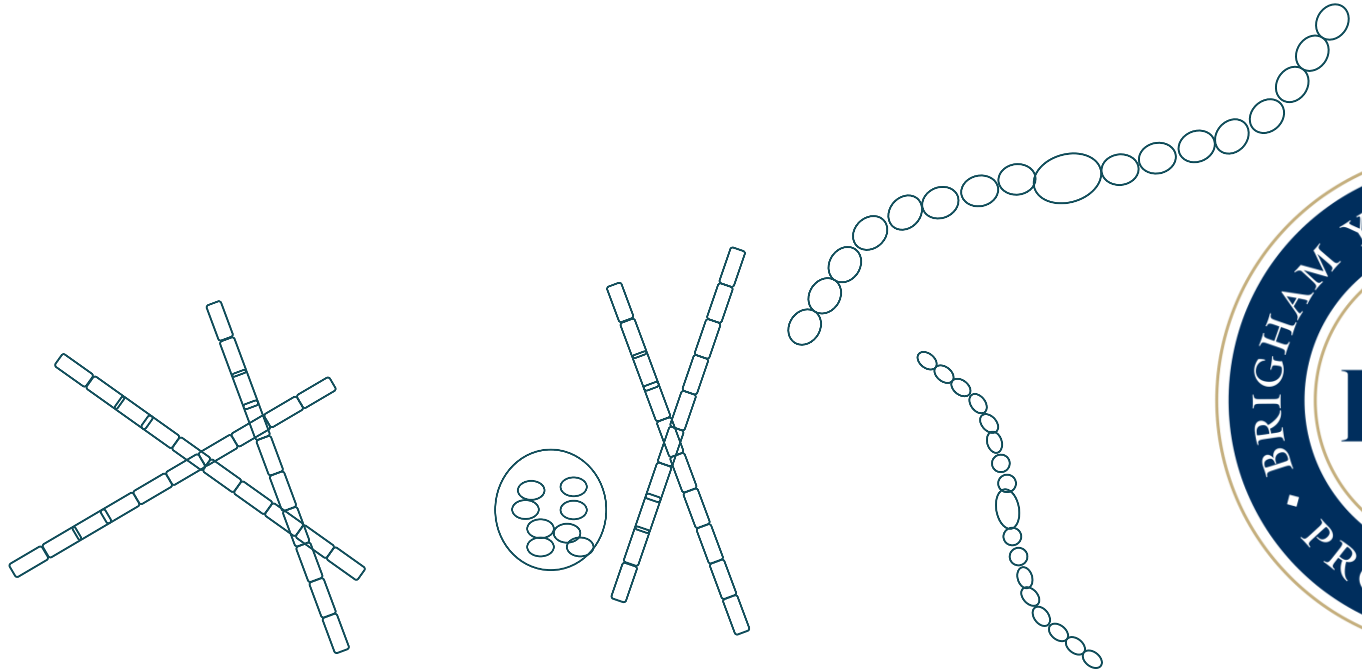
Ploimida (Rotifers)

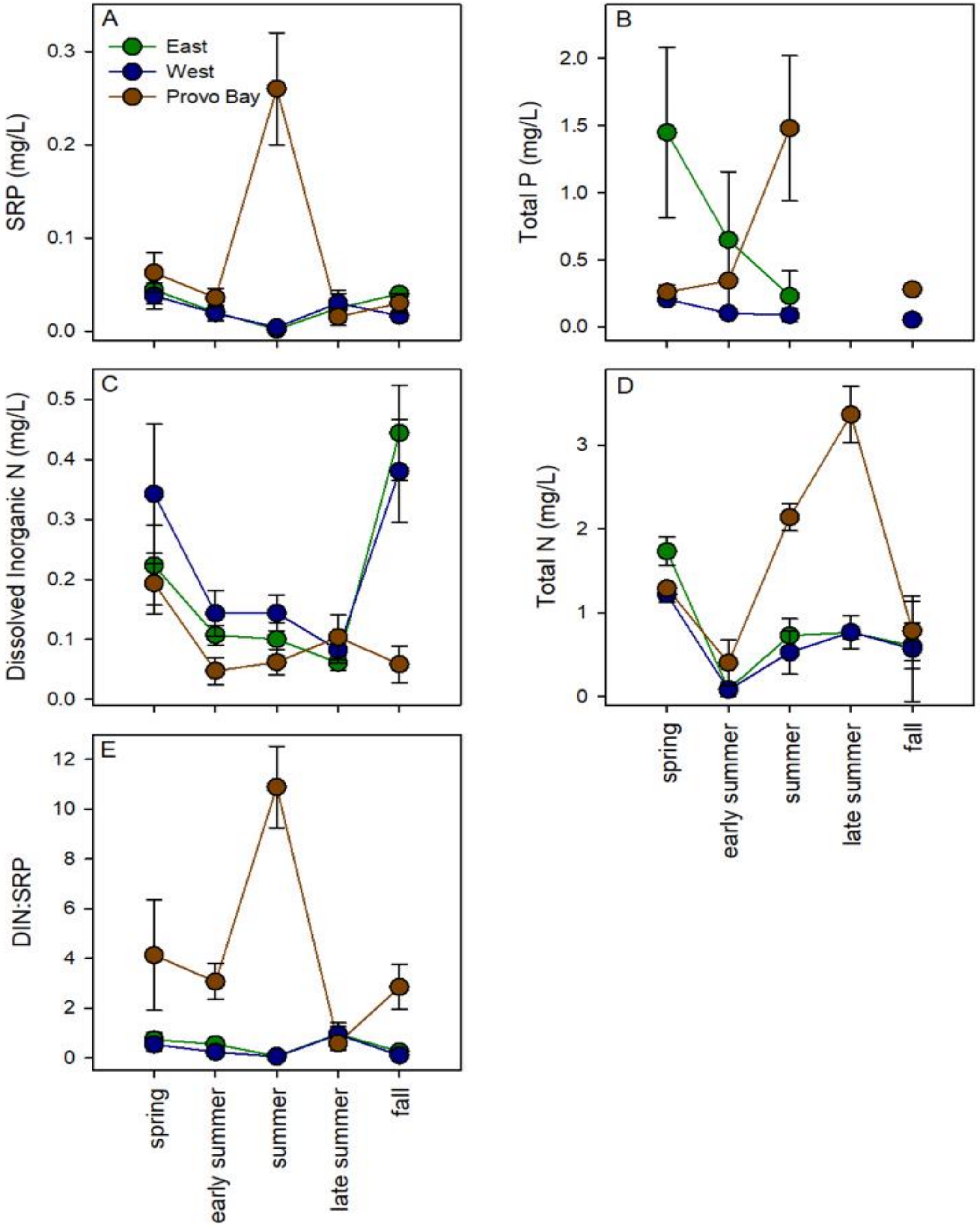
Acknowledgements

- Utah Department of Environmental Quality - Scott Daly
- Dr. Hans Paerl - University of North Carolina at Chapel Hill
- Dr. Ryan King - Baylor University
- Dr. Erin Jones - Brigham Young University
- Dr. Michael J. Paul - Tetra Tech
- Dr. Mitch Hogsett – PhD
- Rachel Buck - PhD, Utah State University
- Timpanogos Nation

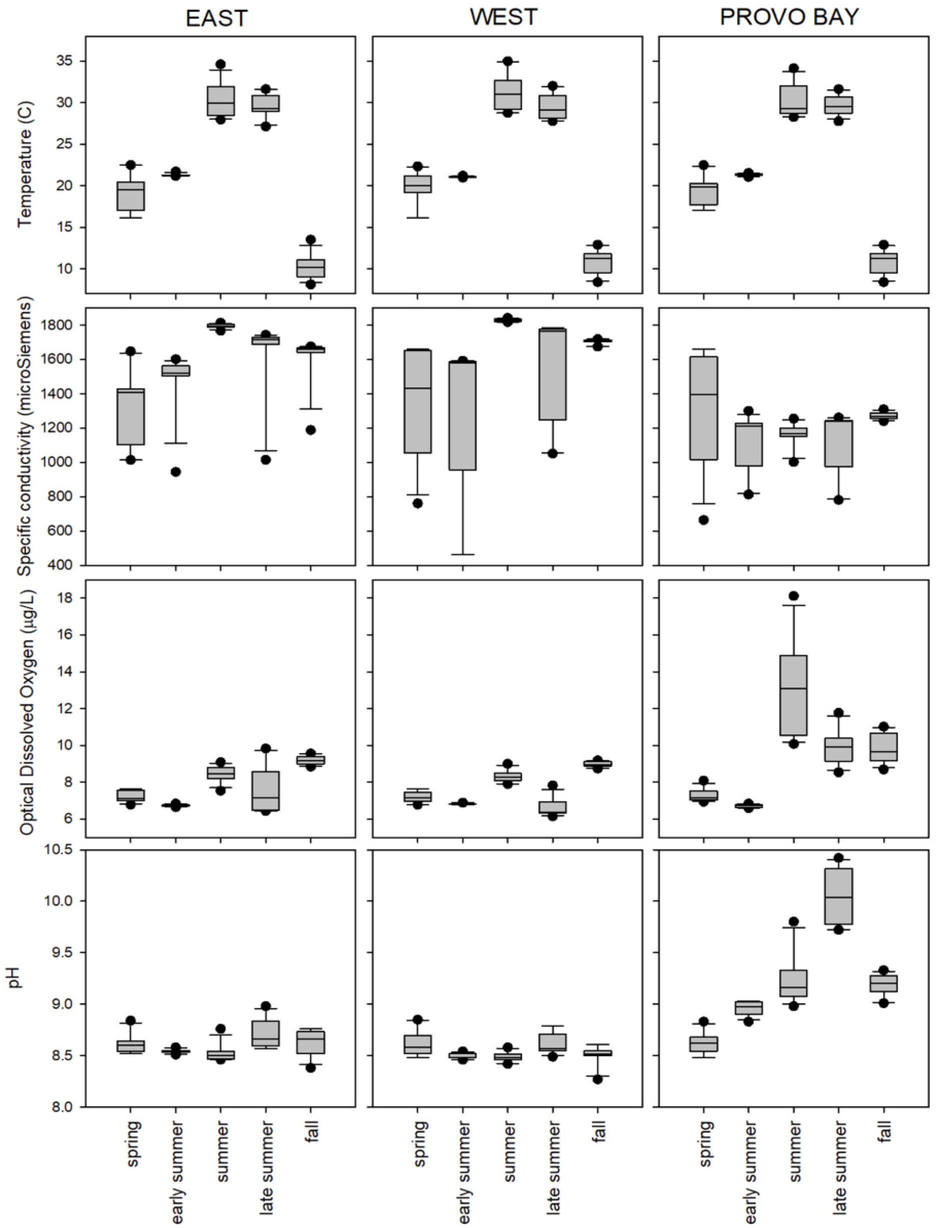
BYU Graduates / Undergraduates:

- Jonathan Daniels, Elizabeth Mclaughlin, Madeleine Malmfeldt, Maddie Armond, Detiare Leifi, Sara Schenk, Jacquelyn Land, Kevin Torgerson, Chelsea Abrahamian, Sierra Curtis Nichols, Alison Barnett Fischer





A
East
West
Provo Bay
SRP (mg/L)
0.0
0.1
0.2
0.3
B
Total P (mg/L)
0.0
0.5
1.0
1.5
2.0
C
Dissolved Inorganic N (mg/L)
0.0
0.1
0.2
0.3
0.4
0.5
D
Total N (mg/L)
0
1
2
3
E
DIN:SRP
0
2
4
6
8
10
12
spring
early summer
summer
late summer
fall


EAST
WEST
PROVO BAY
Temperature (C)
Specific conductivity (microSiemens)
Optical Dissolved Oxygen (µg/L)
pH
spring
early summer
summer
late summer
fall

Utah Lake Littoral Sediment Study: An Assessment of C, N, and P Dynamics in the Utah Lake Littoral Zone

PI: Dr. Erin Rivers, USU

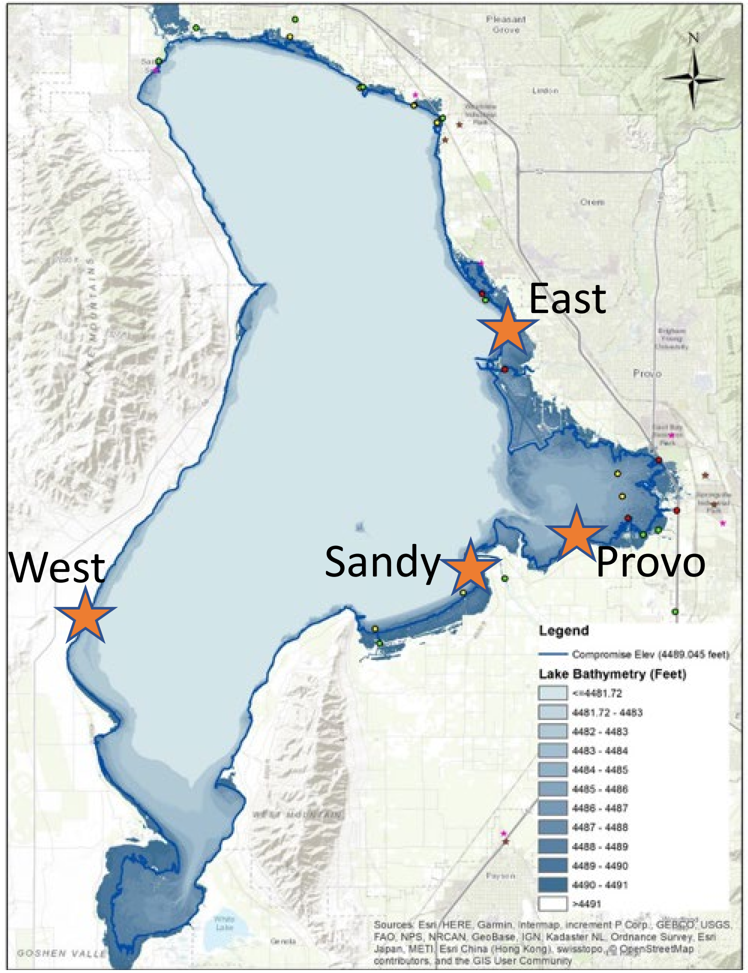
Co-PI: Dr. Zachary Aanderud, Western States Water and Soil & BYU

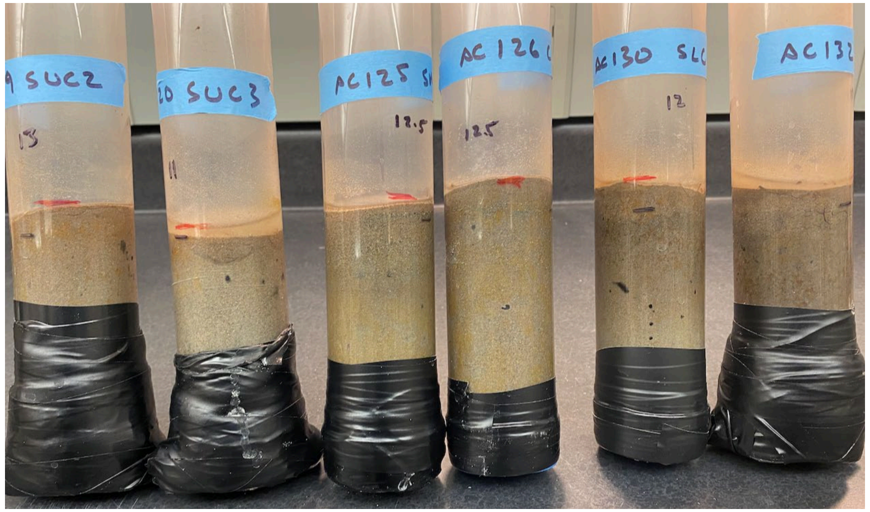
Co-PI: Dr. Greg Carling, Western States Water and Soil & BYU

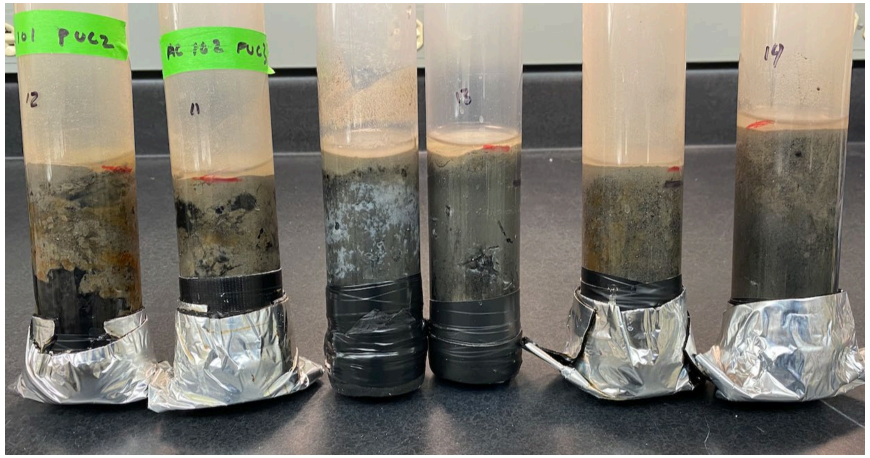
UTAH DEPARTMENT *of* ENVIRONMENTAL QUALITY
WATER QUALITY

Task 1: Frequency and Duration of Sediment Drying-Rewetting on Nutrient Release and Oxygen Demand

Experimental Design

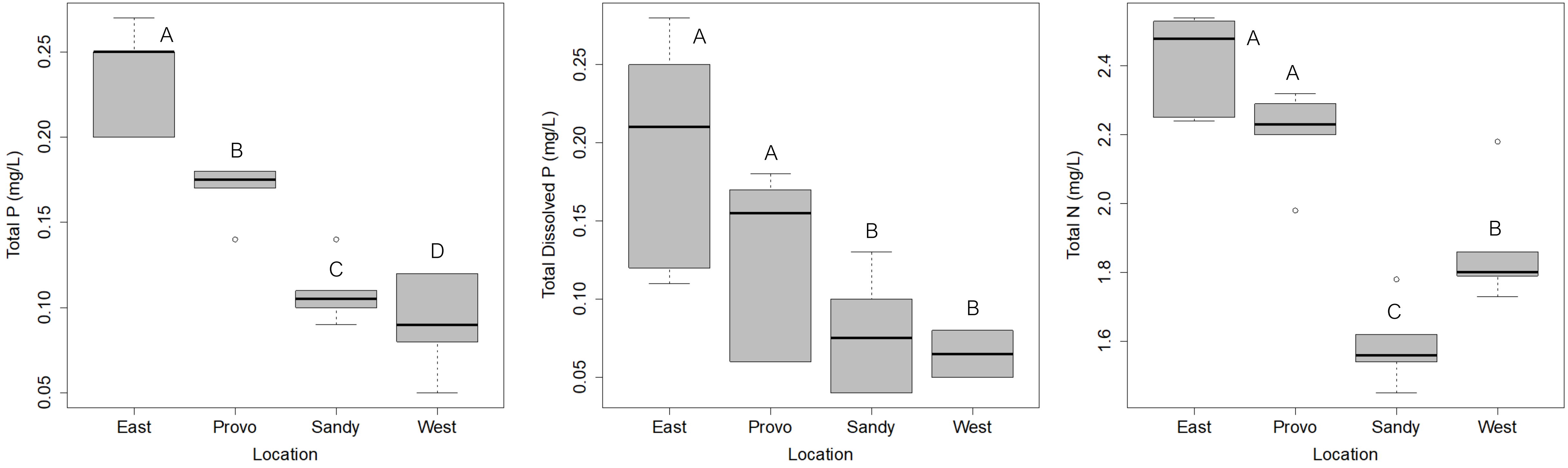






Four lake locations with three sediment types (i.e., lake, margin, and upland) expose sediments to constant water and drying-re-inundation regimes and estimate N and P release from sediments and P sink potential of sediments

Baseline water chemistry



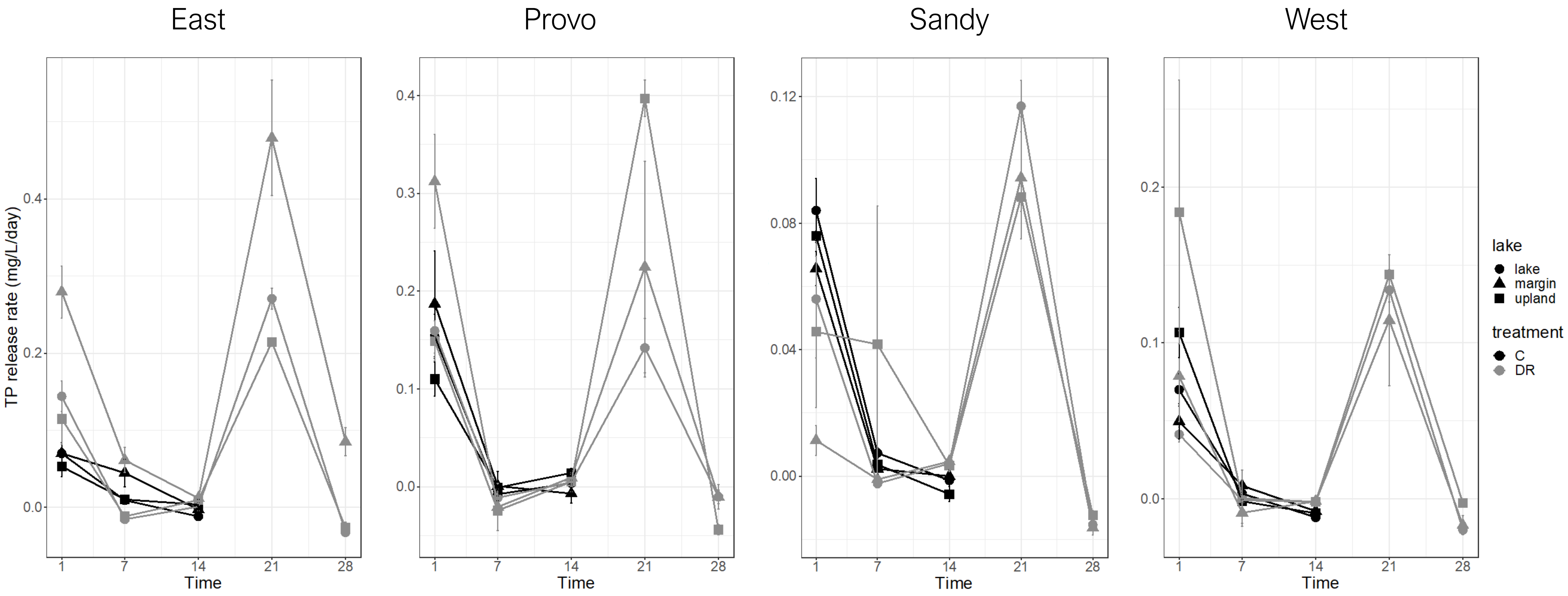
one-way ANOVA with mean, standard error mg/L:

SRP = 0.14, 0.02; Particulate P = 0.04, 0.01; Dissolved Organic P = 0.01, 0.00;

NO3-N = 0.69, 0.11; NH4+N = 0.19, 0.05; Total Dissolved N = 0.64. 0.05; Total Dissolved Organic N = 0.06, 0.02;

DOC = 4.56, 0.26

TP release rates



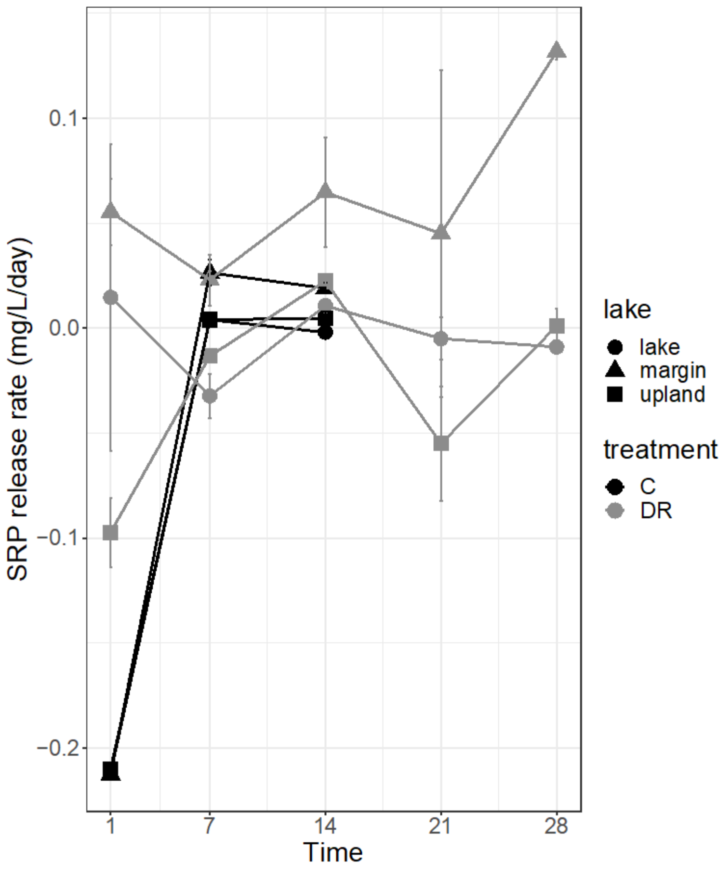
RM three-way ANOVA
treatment, F=7.6 *P*=0.007 df=1
lake location, F=3.5 *P*=0.04 df=2
margin highest rewetting

RM three-way ANOVA
treatment, F=3.6 *P*=0.06 df=1
margin highest upland highest
second rewetting

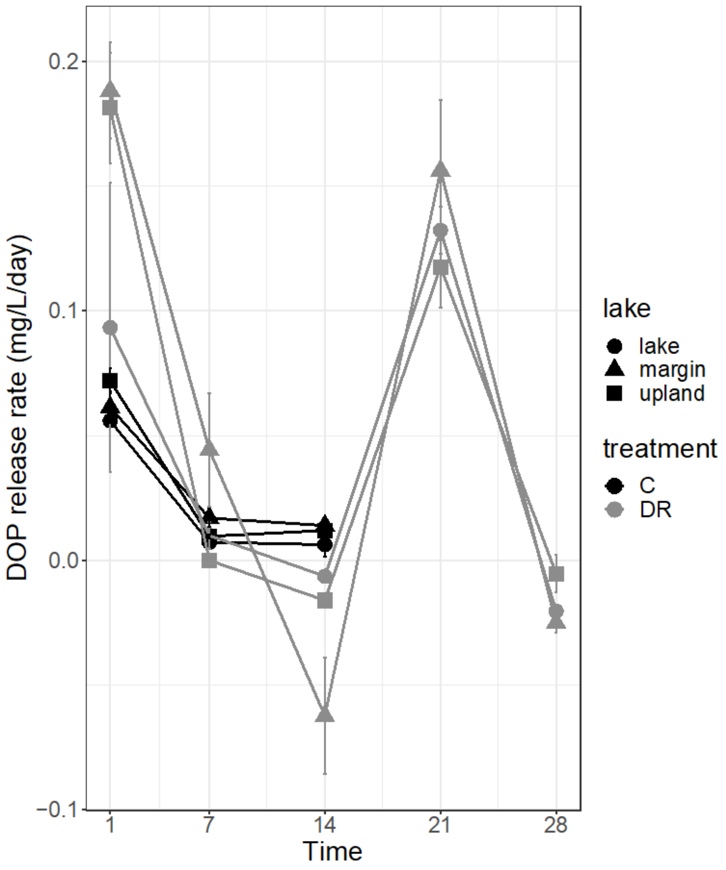
RM three-way ANOVA
treatment*time, F=11, *P*=0.001
df=1
lowest release with lake highest

RM three-way ANOVA
treatment*time, F=4.1, *P*=0.05
df=1
upland highest

East SRP and DOP release rates



RM three-way ANOVA
treatment*time, F=40, *P*<0.001
df=1
margin highest upland highest
second rewetting



RM three-way ANOVA
treatment, F=6.6, *P*=0.01 df=1
rewetting highest

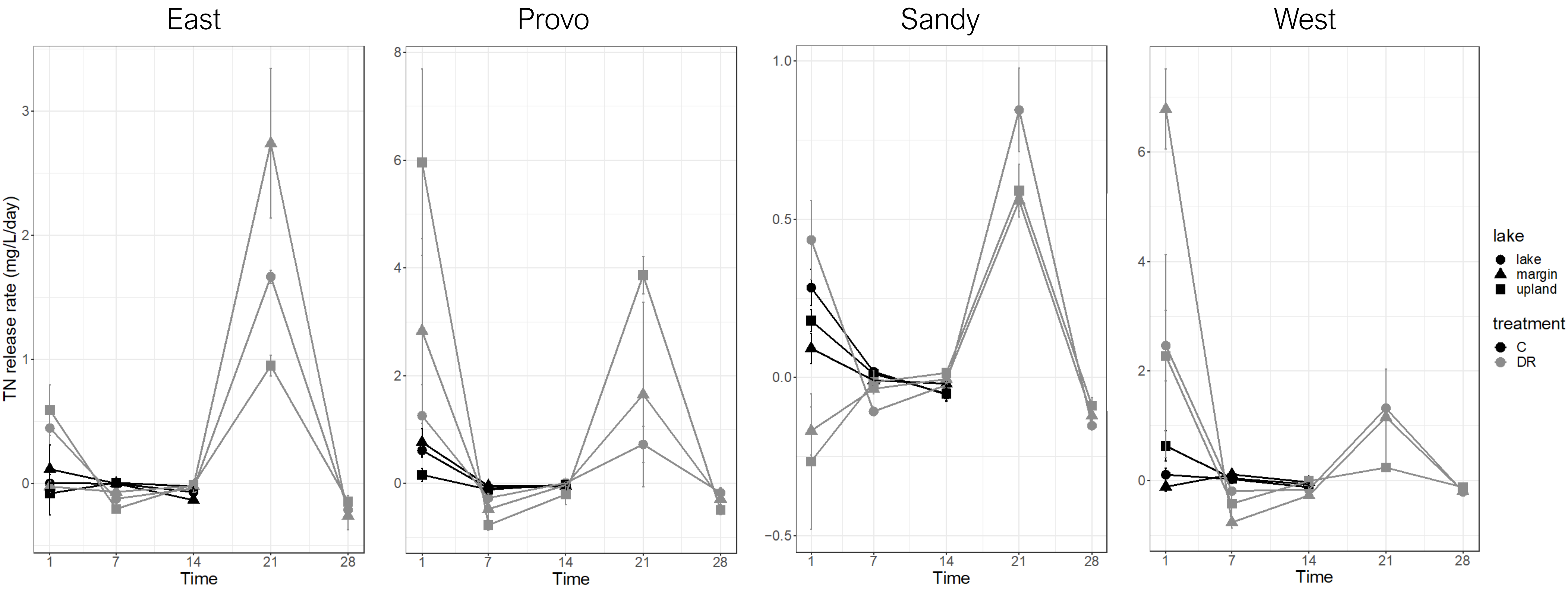
Table 1. P species release rates (grams P/m2 sediment/day) from four Utah Lake locations across three sediment types under continuous water conditions (control) and exposed to drying and rewetting cycles (DR 1). Values are means (n: control = 6, DR 1 = 9) with standard error.

location	sediment	treatment	TP		TDP		PP		SRP		DOP	
			mean	sterr	mean	sterr	mean	sterr	mean	sterr	mean	sterr
east beach	upland	control	0.002	0.000	0.004	0.000	-0.002	0.001	0.001	0.000	0.003	0.000
east beach	margin	control	0.005	0.003	0.009	0.001	-0.003	0.002	0.005	0.001	0.004	0.001
east beach	lake	control	0.000	0.001	0.002	0.001	-0.002	0.001	0.000	0.000	0.001	0.000
provo bay	upland	control	0.002	0.001	0.004	0.001	-0.002	0.001	0.002	0.000	0.001	0.000
provo bay	margin	control	-0.001	0.002	0.020	0.019	-0.021	0.019	0.001	0.000	0.019	0.019
provo bay	lake	control	0.000	0.001	0.002	0.001	-0.002	0.000	0.001	0.000	0.001	0.000
sandy beach	upland	control	0.000	0.001	0.001	0.000	-0.001	0.000	0.000	0.000	0.001	0.000
sandy beach	margin	control	0.000	0.000	0.001	0.000	-0.001	0.000	0.000	0.000	0.001	0.000
sandy beach	lake	control	0.001	0.001	0.002	0.001	-0.001	0.000	0.000	0.000	0.001	0.001
west beach	upland	control	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000
west beach	margin	control	0.000	0.001	0.001	0.000	-0.001	0.001	0.000	0.000	0.001	0.000
west beach	lake	control	-0.001	0.001	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000
east beach	lake	DR 1	0.010	0.006	0.011	0.007	-0.001	0.002	-0.001	0.005	0.008	0.005
east beach	margin	DR 1	0.029	0.011	0.031	0.012	-0.002	0.001	0.012	0.003	0.014	0.010
east beach	upland	DR 1	0.009	0.005	0.012	0.007	-0.003	0.002	-0.007	0.004	0.014	0.008
provo bay	lake	DR 1	0.011	0.006	0.011	0.006	0.000	0.000	-0.002	0.002	0.012	0.006
provo bay	margin	DR 1	0.022	0.012	0.017	0.010	0.005	0.003	0.004	0.004	0.011	0.007
provo bay	upland	DR 1	0.009	0.006	0.012	0.006	0.000	0.000	-0.003	0.002	0.011	0.006
sandy beach	lake	DR 1	0.004	0.002	0.004	0.002	0.000	0.001	-0.006	0.003	0.008	0.004
sandy beach	margin	DR 1	0.001	0.000	0.001	0.001	-0.001	0.001	-0.006	0.003	0.006	0.003
sandy beach	upland	DR 1	0.177	0.210	0.003	0.002	0.174	0.210	-0.006	0.003	0.007	0.004
west beach	lake	DR 1	0.002	0.001	0.003	0.002	0.000	0.001	-0.002	0.002	0.005	0.003
west beach	margin	DR 1	0.004	0.003	0.005	0.003	0.000	0.001	-0.003	0.002	0.007	0.004
west beach	upland	DR 1	0.011	0.007	0.012	0.008	-0.001	0.001	0.004	0.004	0.007	0.004

Table 2. Range of TP release rates (grams P/m2 sediment/day) from four Utah Lake locations across three sediment types under continuous water conditions (control) and exposed to drying and rewetting cycles (DR 1 and DR 2). Values are means (n: control = 6, DRs = 9) with standard error.

sediment	treatment	TP low		TP high	
		mean	sterr	mean	sterr
upland	control	-0.001	0.000	0.002	0.000
margin	**control**	**0.000**	**0.000**	**0.005**	**0.003**
lake	control	0.000	0.001	0.001	0.001
lake	DR 1	0.002	0.001	0.011	0.006
margin	DR 1	0.001	0.000	0.029	0.011
upland	**DR 1**	**0.009**	**0.005**	**0.177**	**0.210**
lake	DR 2	0.010	0.006	0.026	0.015
margin	**DR 2**	**0.008**	**0.005**	**0.068**	**0.022**
upland	DR 2	0.008	0.005	0.039	0.022

TN release rates



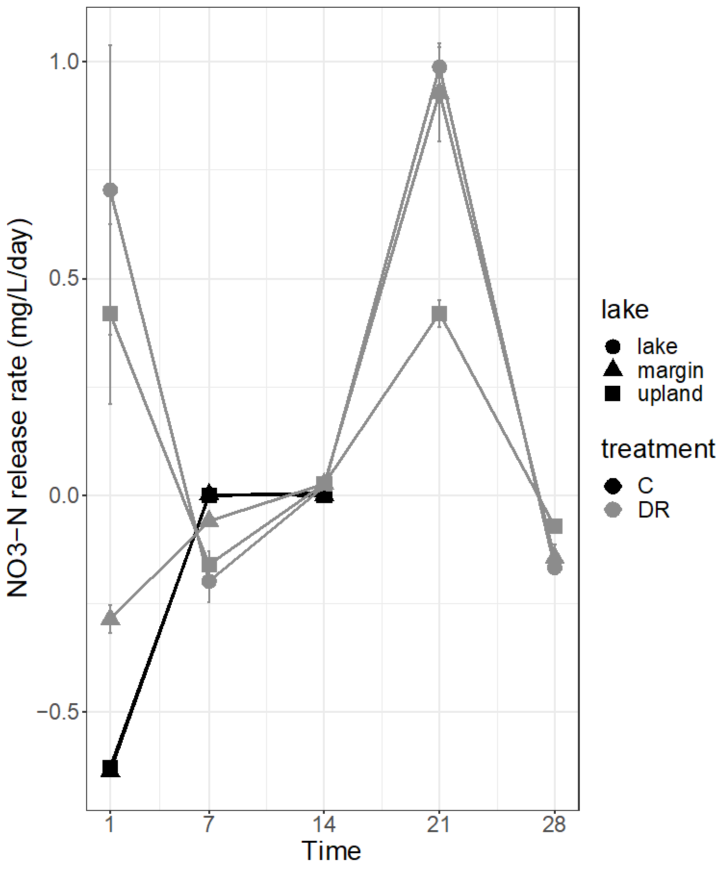
Second rewetting highest in margin

RM three-way ANOVA
treatment, F=7.2, *P*=0.01 df=1
Drying-rewetting highest
highest second rewetting

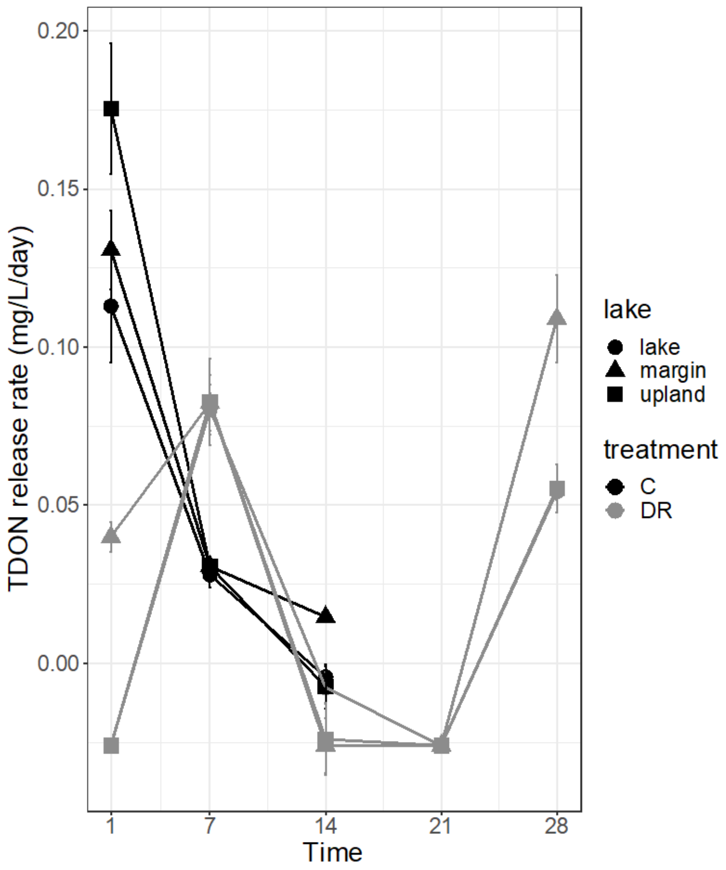
RM three-way ANOVA
treatment*time, F=11, *P*=0.001 df=1
Lowest release and lake highest

RM three-way ANOVA
treatment*time, F=4.1, *P*=0.05 df=1
Rewetting and margin highest

East NO3-N and DON release rates



RM three-way ANOVA
treatment*time, F=9.5, *P*=0.002
df=1
rewetting highest

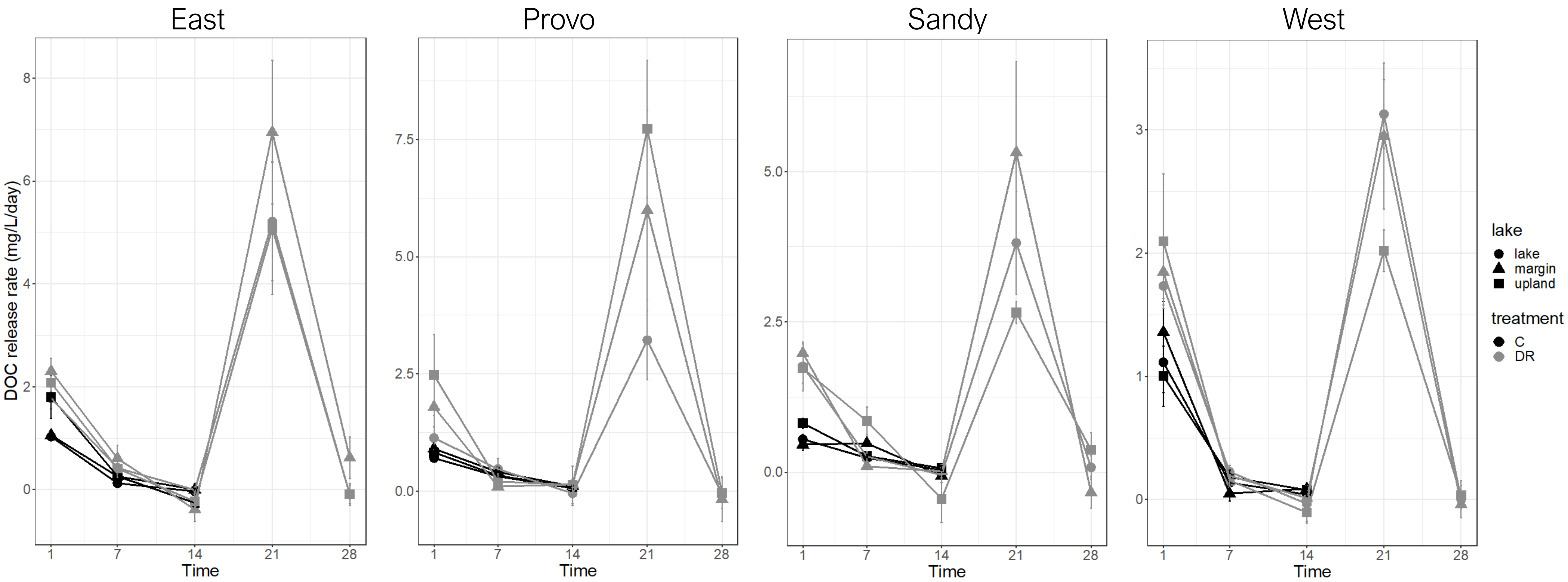


RM three-way ANOVA
treatment, F=37, *P*<0.001 df=1

Table 3. Range of TN release rates (grams N/m2 sediment/day) from four Utah Lake locations across three sediment types under continuous water conditions (control) and exposed to drying and rewetting cycles (DR 1 and DR 2). Values are means (n: control = 6, DRs = 9) with standard error.

sediment	treatment	TN low		TN high	
		mean	sterr	mean	sterr
upland	control	-0.015	0.005	-0.002	0.003
margin	**control**	**-0.016**	**0.008**	**0.009**	**0.008**
lake	control	-0.015	0.003	-0.004	0.004
upland	DR 1	-0.019	0.016	0.375	0.275
margin	DR 1	-0.019	0.016	0.373	0.240
lake	**DR 1**	**0.023**	**0.021**	**0.125**	**0.083**
upland	**DR 2**	**0.011**	**0.017**	**0.373**	**0.217**
margin	**DR 2**	**0.047**	**0.033**	**0.298**	**0.169**
lake	DR 2	0.011	0.017	0.101	0.063

DOC release rates



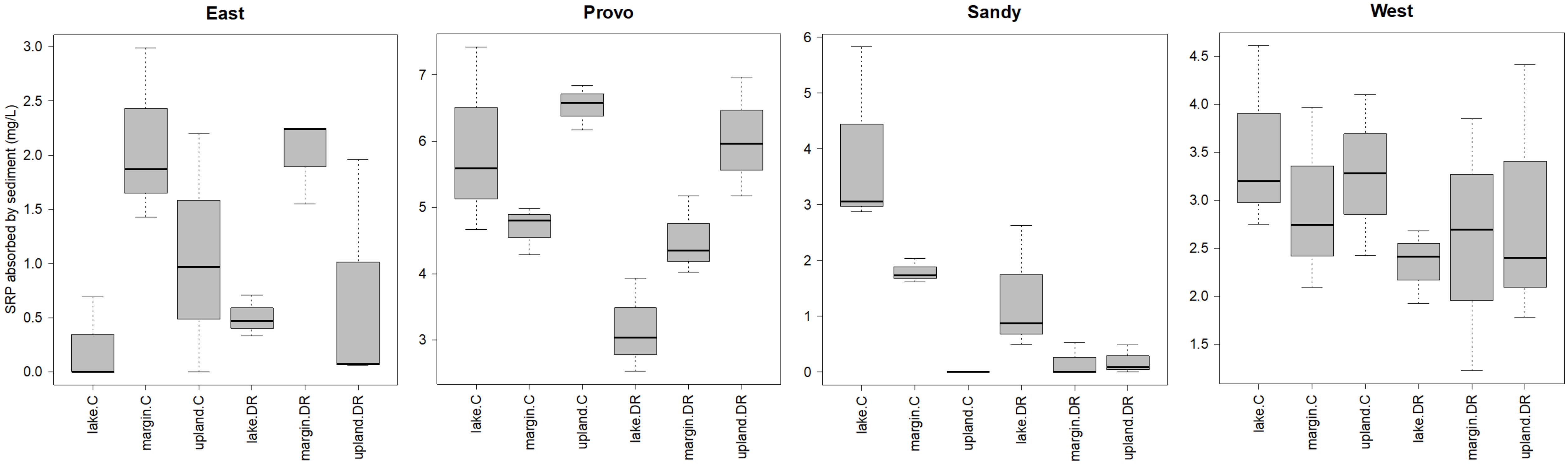
RM three-way ANOVA
treatment, F=4.6, *P*=0.04 df=1
margin highest rewetting and
upland highest constant

RM three-way ANOVA
treatment, F=3.3, *P*=0.08 df=1
drying-rewetting highest highest
second rewetting

RM three-way ANOVA
treatment, F=5.5, *P*=0.02 df=1
drying-rewetting highest highest
second rewetting

RM three-way ANOVA
treatment, F=6.2, *P*=0.02 df=1
drying-rewetting highest highest
second rewetting

Sediment SRP absorption



two-way ANOVA
sediments, F=7.9, *P*=0.007, df=2
margin highest regardless of treatment but lowest absorption

two-way ANOVA
sediments*treatment, F=4.5, *P*=0.04, df=2
upland highest and lake constant water

two-way ANOVA
sediments*treatment, F=4.2, *P*=0.04, df=2
lake constant highest

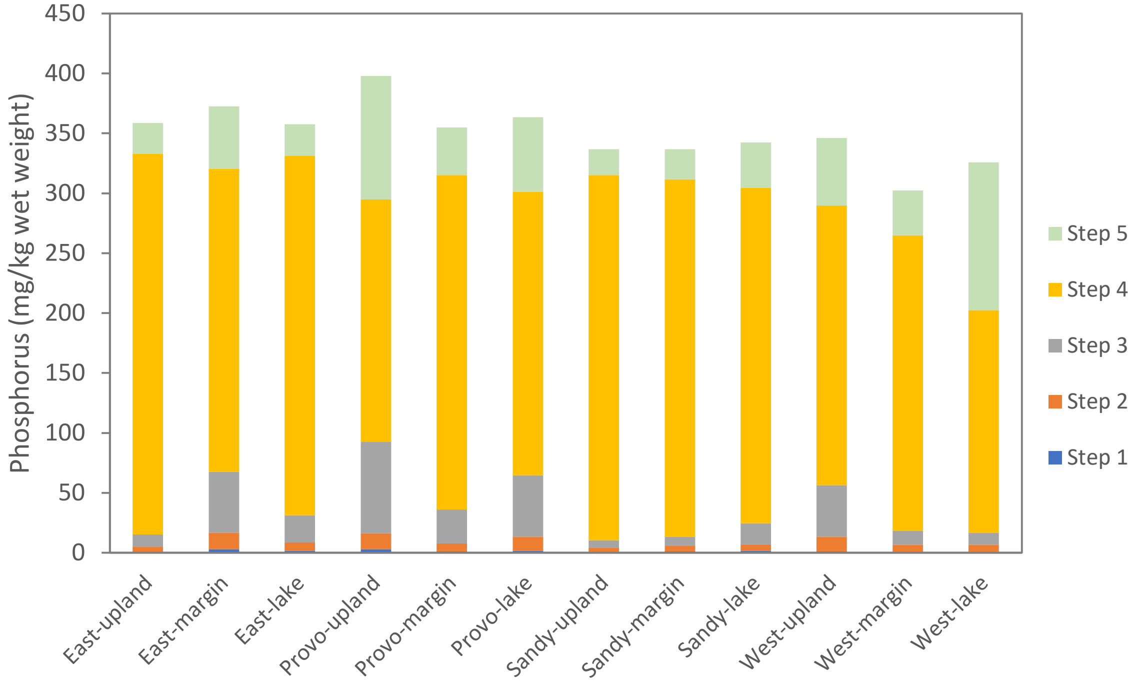
Investigate relationships between P absorption and P already in sediments 10 mg-P L^{-1} as K_2HPO_4 to saturate the water column with available P

Sediment SRP absorption continued

Table 4. SRP adsorption rate by sediments (grams P/m2 sediment/day) and % SRP adsorbed by sediments from four Utah Lake locations across three sediment types under continuous water conditions (control) and exposed to drying and rewetting cycles (DR). Values are means (n: control = 3 and DR = 6) with standard error.

location	sediment	treatment	rate SRP adsorbed by sediments		% adsorbed by sediments	
			mean	sterr	mean	sterr
east beach	upland	control	0.033	0.020	10.54	6.35
east beach	margin	control	0.065	0.014	20.96	4.63
east beach	lake	control	0.007	0.007	2.31	2.31
provo bay	upland	control	0.203	0.006	65.31	1.95
provo bay	margin	control	0.146	0.006	46.92	2.06
provo bay	lake	control	0.183	0.025	58.89	8.08
sandy beach	upland	control	0.000	0.000	0.00	0.00
sandy beach	margin	control	0.056	0.004	18.00	1.25
sandy beach	lake	control	0.122	0.030	39.27	9.55
west beach	upland	control	0.101	0.015	32.66	4.87
west beach	margin	control	0.091	0.017	29.31	5.50
west beach	lake	control	0.109	0.017	35.19	5.62
east beach	upland	DR	0.022	0.020	6.98	6.31
east beach	margin	DR	0.062	0.007	20.10	2.29
east beach	lake	DR	0.016	0.003	5.03	1.11
provo bay	upland	DR	0.187	0.016	60.30	5.20
provo bay	margin	DR	0.140	0.011	45.13	3.44
provo bay	lake	DR	0.098	0.013	31.69	4.10
sandy beach	upland	DR	0.006	0.005	1.93	1.50
sandy beach	margin	DR	0.005	0.005	1.76	1.76
sandy beach	lake	DR	0.041	0.020	13.34	6.57
west beach	upland	DR	0.089	0.025	28.62	7.94

Phosphorus sequential extractions in sediment



Sequential extractions suggest that phosphorus is primarily bound to calcite (step 4) with a small, but important, mobile fraction (steps 1-3).

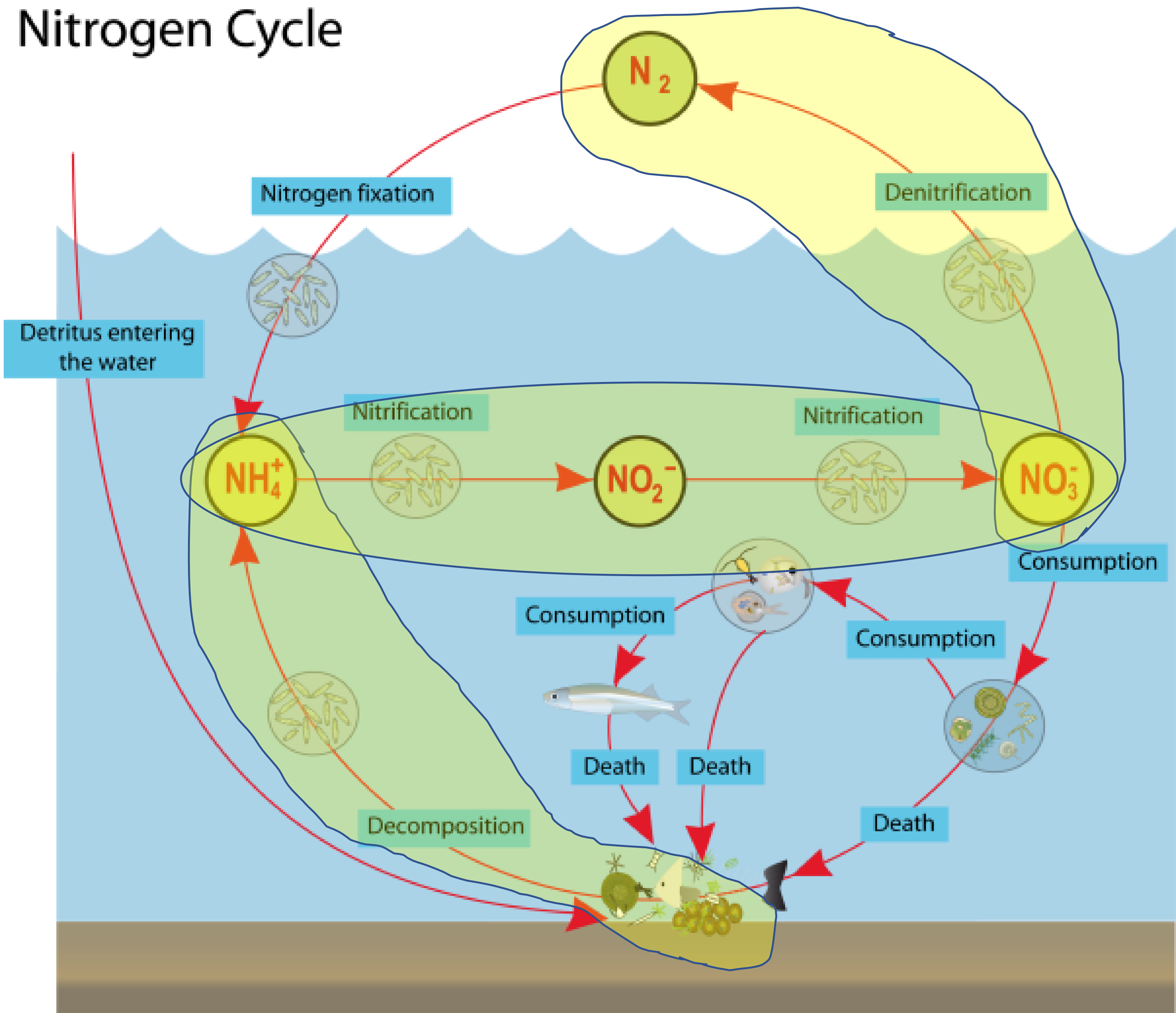
Other sediment observational data:

- Mineralogy
- Total P, Total N, TOC
- Metals

Task 2: Rate and Magnitude of Nutrient Fluxes from Drying, Dry, and Rewetting Sediments

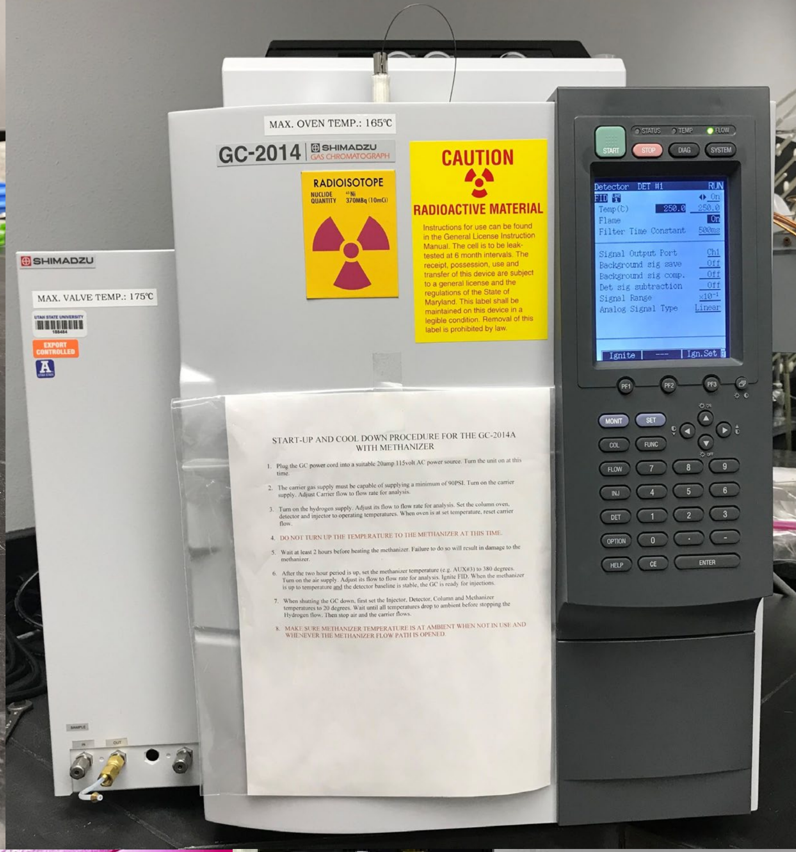
Nitrogen cycle

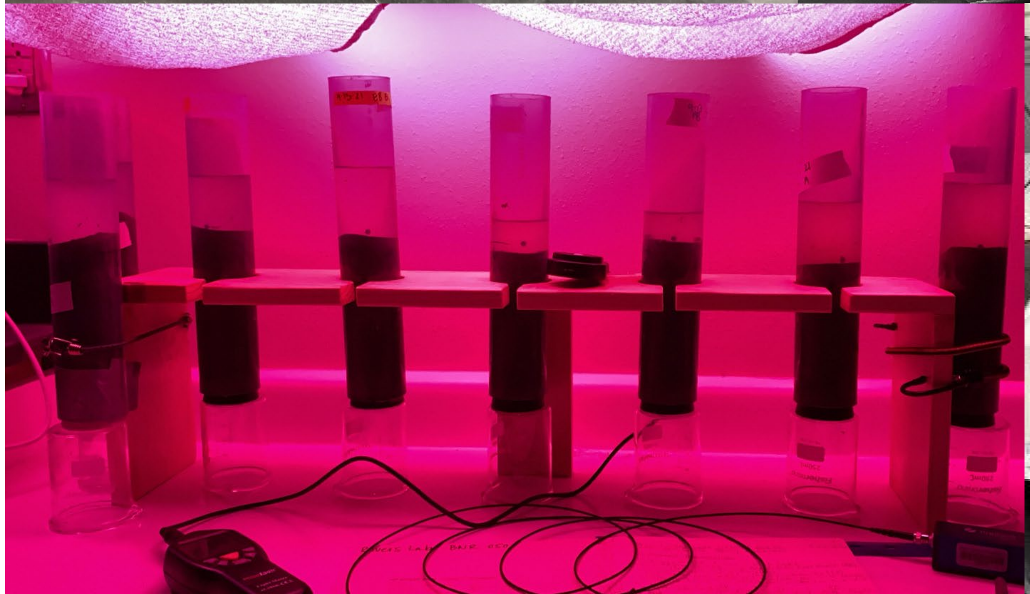
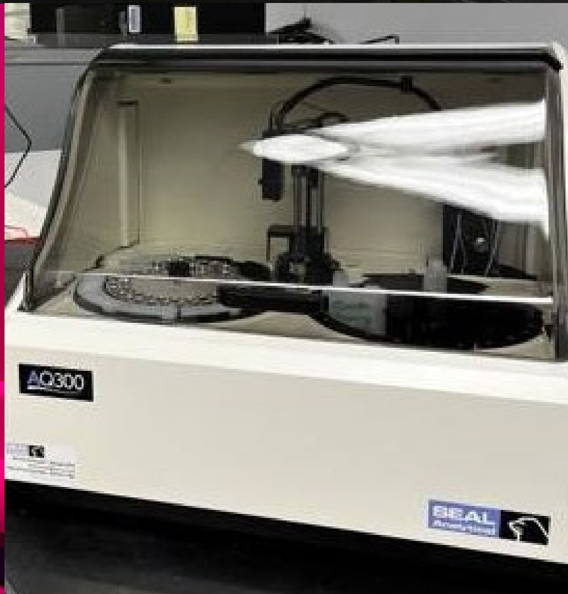
- Sources
  - Mineralization
  - Microbial biomass turnover
- Sinks
  - Denitrification- only permanent removal
- Internal cycling
  - Nitrification



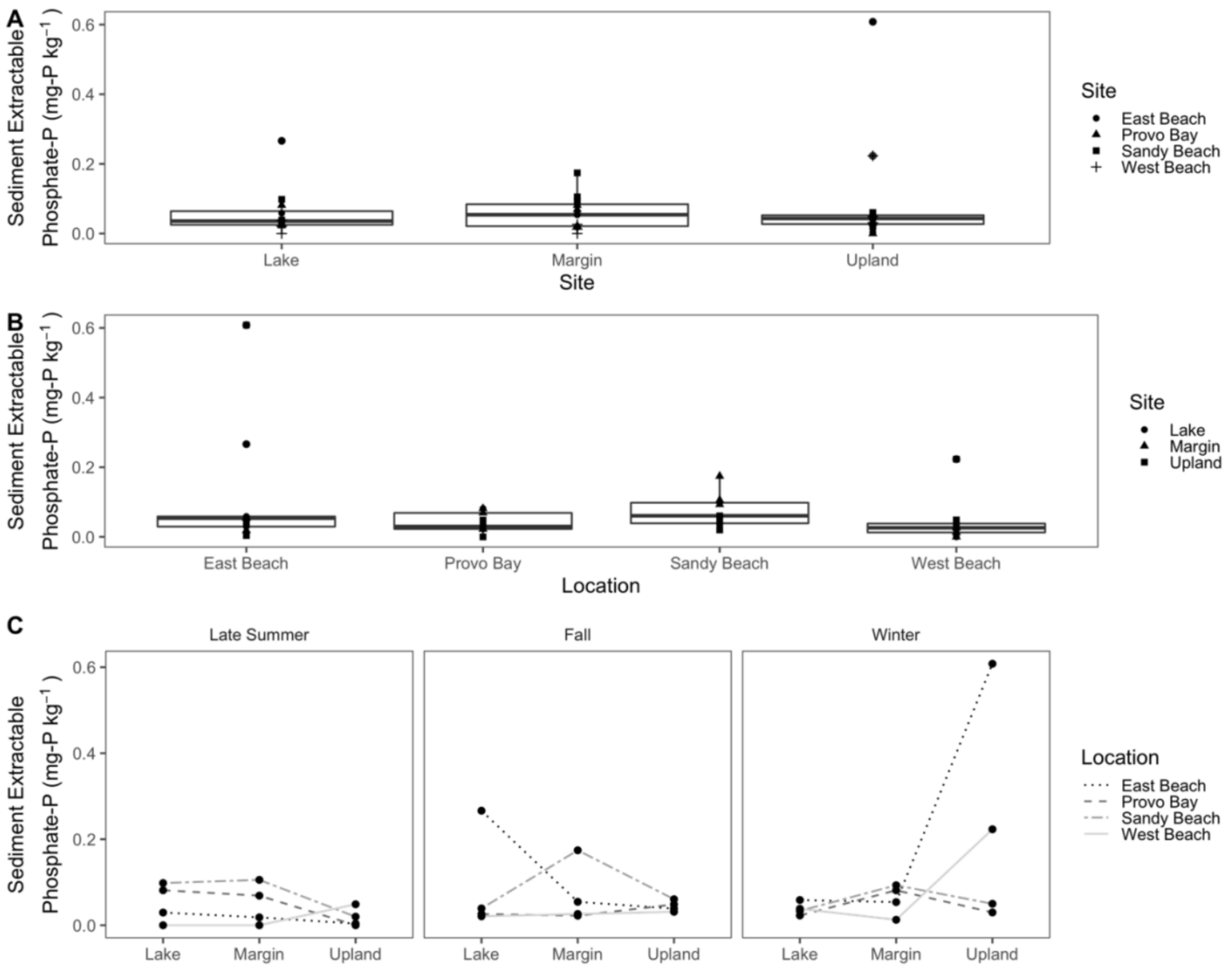
Lab Tests

- Benthic primary production
- Bulk density, moisture content, pH, and loss on ignition
- Microbial biomass N and C
- Nitrification
- Mineralization
- Denitrification

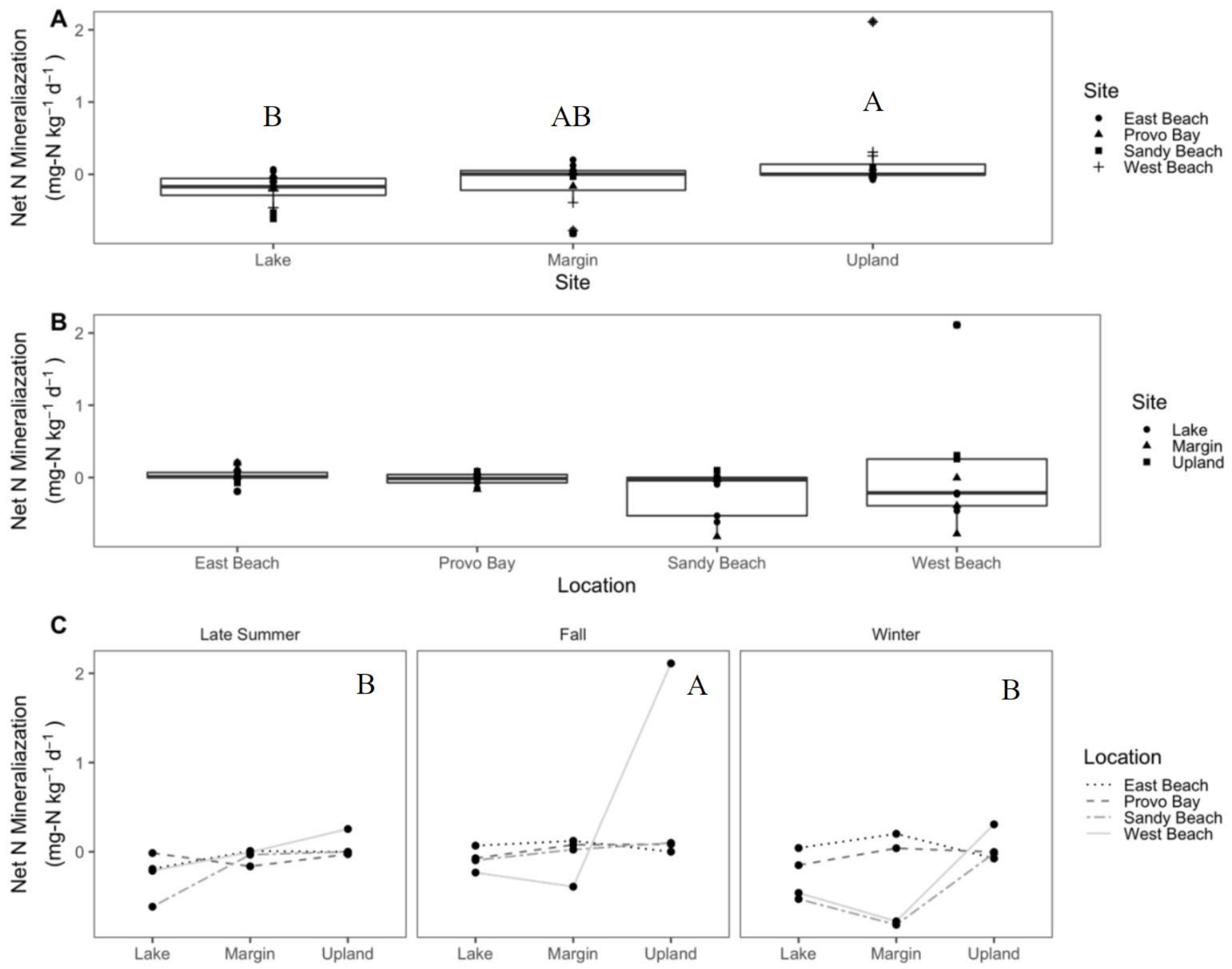
No effects on PO_4



Effect of zone on sediment nitrogen

moderate mineralization potential in littoral zone

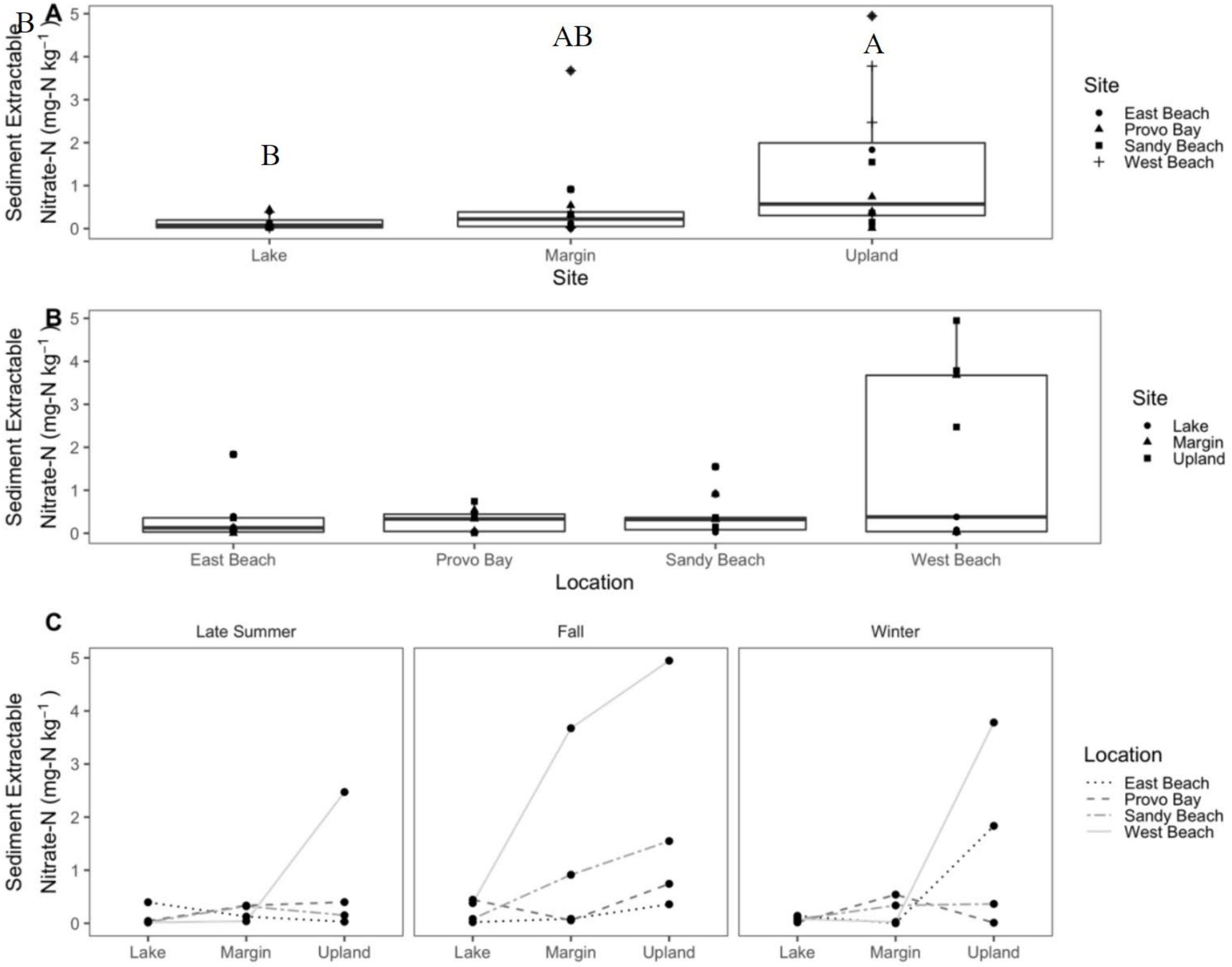
Variable	P-value
Mineralization	**0.03413**
Nitrification	0.3224
Respiration	0.2894
Sediment Nitrate	**0.003073**
Sediment Ammonium	0.1703
Sediment DIN	0.1281
MBC	0.2681
MBN	0.1475
OMC	0.4296



Effect of zone on sediment nitrogen

moderate mineralization potential in littoral zone

Variable	P-value
Mineralization	**0.03413**
Nitrification	0.3224
Respiration	0.2894
Sediment Nitrate	**0.003073**
Sediment Ammonium	0.1703
Sediment DIN	0.1281
MBC	0.2681
MBN	0.1475
OMC	0.4296



Mineralization and nitrification ~ sediment nitrogen, all zones

Site	Variables	Mineralization	Nitrification	Respiration	MBN	MBC
Lake	Sediment NO3	-0.3148953	**-0.6879581****	-0.3671524	-0.0283665	-0.0283665
	Sediment NH4	-0.4110991	0.1936905	**-0.6660403***	-0.5217204	-0.5217204
	Sediment DIN	-0.3030544	0.2876234	**-0.6644532***	-0.5637952	-0.5637952
	OMC	**0.6444089***	0.5679792	0.1405453	-0.1908367	-0.1908367
	MBC	0.3746627	0.226647	0.5671072		
	MBN	-0.3220327	-0.4718987	**0.8450628*****		
Littoral	Sediment NO3	-0.1396186	**-0.6337979***	-0.2518014	-0.4980386	-0.4980386
	Sediment NH4	**-0.5947243***	0.02223607	-0.1056993	0.5359337	0.5359337
	Sediment DIN	-0.5551523	-0.131581	-0.4977898	-0.004480036	-0.004480036
	OMC	-0.4305989	0.08672569	0.06752023	0.4671969	0.4671969
	MBC	**-0.7303059**	0.3356225	0.2224613		
	MBN	-0.5239152	0.2959826	**0.7473789****		
Upland	Sediment NO3	0.2027	0.2989981	0.1919603	0.227439	0.227439
	Sediment NH4	**-0.6730649****	0.264067	0.3890907	0.5392459	0.5392459
	Sediment DIN	-0.4463506	**0.5997574***	0.4766894	0.519176	0.519176
	OMC	-0.2567843	0.5768711	0.2538108	0.2591953	0.2591953
	MBC	0.1282074	**0.588944***	**0.7275784****		
	MBN	0.02935759	0.4085485	**0.8495313*****		

*p<0.10; **p<0.05; ***p<0.01; ****p<0.0001; not displayed: p>0.1

Mineralization ~ sediment organic matter, in-lake only

Site	Variables	Mineralization	Nitrification	Respiration	MBN	MBC
Lake	Sediment NO3	-0.3148953	**-0.6879581****	-0.3671524	-0.0283665	-0.0283665
	Sediment NH4	-0.4110991	0.1936905	**-0.6660403***	-0.5217204	-0.5217204
	Sediment DIN	-0.3030544	0.2876234	**-0.6644532***	-0.5637952	-0.5637952
	OMC	**0.6444089***	0.5679792	0.1405453	-0.1908367	-0.1908367
	MBC	0.3746627	0.226647	0.5671072		
	MBN	-0.3220327	-0.4718987	**0.8450628*****		
Littoral	Sediment NO3	-0.1396186	**-0.6337979***	-0.2518014	-0.4980386	-0.4980386
	Sediment NH4	**-0.5947243***	0.02223607	-0.1056993	0.5359337	0.5359337
	Sediment DIN	-0.5551523	-0.131581	-0.4977898	-0.004480036	-0.004480036
	OMC	-0.4305989	0.08672569	0.06752023	0.4671969	0.4671969
	MBC	**-0.7303059**	0.3356225	0.2224613		
	MBN	-0.5239152	0.2959826	**0.7473789****		
Upland	Sediment NO3	0.2027	0.2989981	0.1919603	0.227439	0.227439
	Sediment NH4	**-0.6730649****	0.264067	0.3890907	0.5392459	0.5392459
	Sediment DIN	-0.4463506	**0.5997574***	0.4766894	0.519176	0.519176
	OMC	-0.2567843	0.5768711	0.2538108	0.2591953	0.2591953
	MBC	0.1282074	**0.588944***	**0.7275784****		
	MBN	0.02935759	0.4085485	**0.8495313*****		

*p<0.10; **p<0.05; ***p<0.01; ****p<0.0001; not displayed: p>0.1

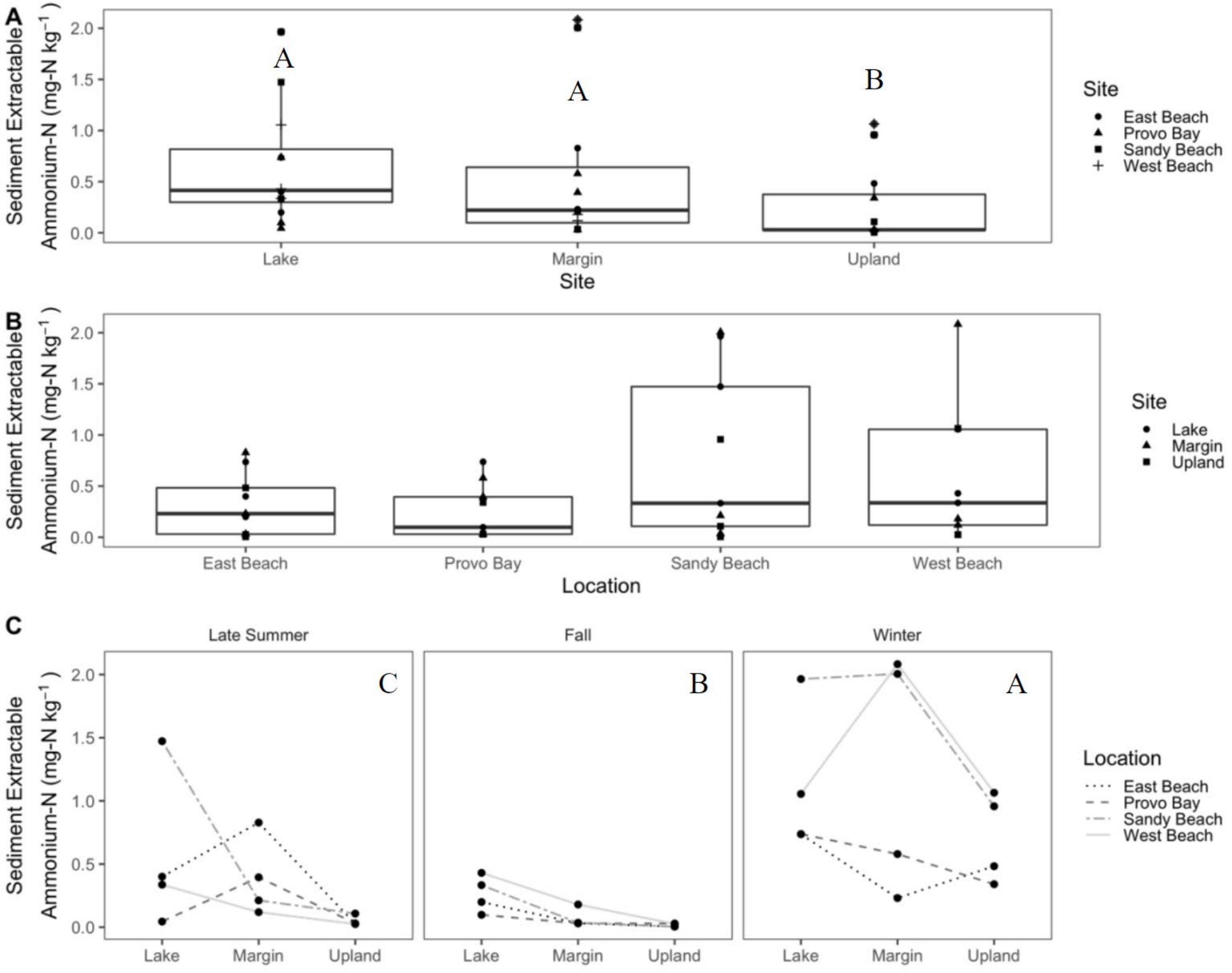
Mineralization and nitrification ~ microbial biomass, in-lake and littoral

Site	Variables	Mineralization	Nitrification	Respiration	MBN	MBC
Lake	**Sediment NO3**	-0.3148953	**-0.6879581****	-0.3671524	-0.0283665	-0.0283665
	Sediment NH4	-0.4110991	0.1936905	**-0.6660403***	-0.5217204	-0.5217204
	Sediment DIN	-0.3030544	0.2876234	**-0.6644532***	-0.5637952	-0.5637952
	OMC	**0.6444089***	0.5679792	0.1405453	-0.1908367	-0.1908367
	MBC	0.3746627	0.226647	0.5671072		
	MBN	-0.3220327	-0.4718987	**0.8450628*****		
Littoral	**Sediment NO3**	-0.1396186	**-0.6337979***	-0.2518014	-0.4980386	-0.4980386
	Sediment NH4	**-0.5947243***	0.02223607	-0.1056993	0.5359337	0.5359337
	Sediment DIN	-0.5551523	-0.131581	-0.4977898	-0.004480036	-0.004480036
	OMC	-0.4305989	0.08672569	0.06752023	0.4671969	0.4671969
	MBC	**-0.7303059**	0.3356225	0.2224613		
	MBN	-0.5239152	0.2959826	**0.7473789****		
Upland	**Sediment NO3**	0.2027	0.2989981	0.1919603	0.227439	0.227439
	Sediment NH4	**-0.6730649****	0.264067	0.3890907	0.5392459	0.5392459
	Sediment DIN	-0.4463506	**0.5997574***	0.4766894	0.519176	0.519176
	OMC	-0.2567843	0.5768711	0.2538108	0.2591953	0.2591953
	MBC	0.1282074	**0.588944***	**0.7275784****		
	MBN	0.02935759	0.4085485	**0.8495313*****		

*p<0.10; **p<0.05; ***p<0.01; ****p<0.0001; not displayed: p>0.1

Seasonal effect on sediment N

Zone	Variable	P-value
Lake	Mineralization	0.646
	Nitrification	0.318
	Respiration	**0.0456**
	Sediment Nitrate	0.589
	Sediment Ammonium	**0.0374**
	Sediment DIN	**0.0114**
	MBC	0.543
	MBN	**0.0114**
	OMC	0.317
Littoral	Mineralization	0.71
	Nitrification	0.862
	Respiration	0.103
	Sediment Nitrate	0.35
	Sediment Ammonium	**0.0101**
	Sediment DIN	0.0685
	MBC	0.664
	MBN	0.15
	OMC	0.763
Upland	Mineralization	0.198
	Nitrification	0.263
	Respiration	0.94
	Sediment Nitrate	0.646
	Sediment Ammonium	**3.87E-05**
	Sediment DIN	**0.0204**
	MBC	0.188
	MBN	0.611
	OMC	0.763



Seasonal effect on microbial N in lake

Zone	Variable	P-value
Lake	Mineralization	0.646
	Nitrification	0.318
	Respiration	**0.0456**
	Sediment Nitrate	0.589
	Sediment Ammonium	**0.0374**
	Sediment DIN	**0.0114**
	MBC	0.543
	MBN	**0.0114**
	OMC	0.317
Littoral	Mineralization	0.71
	Nitrification	0.862
	Respiration	0.103
	Sediment Nitrate	0.35
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Upland	Mineralization	0.198
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	Sediment Nitrate	0.646
	Sediment Ammonium	**3.87E-05**
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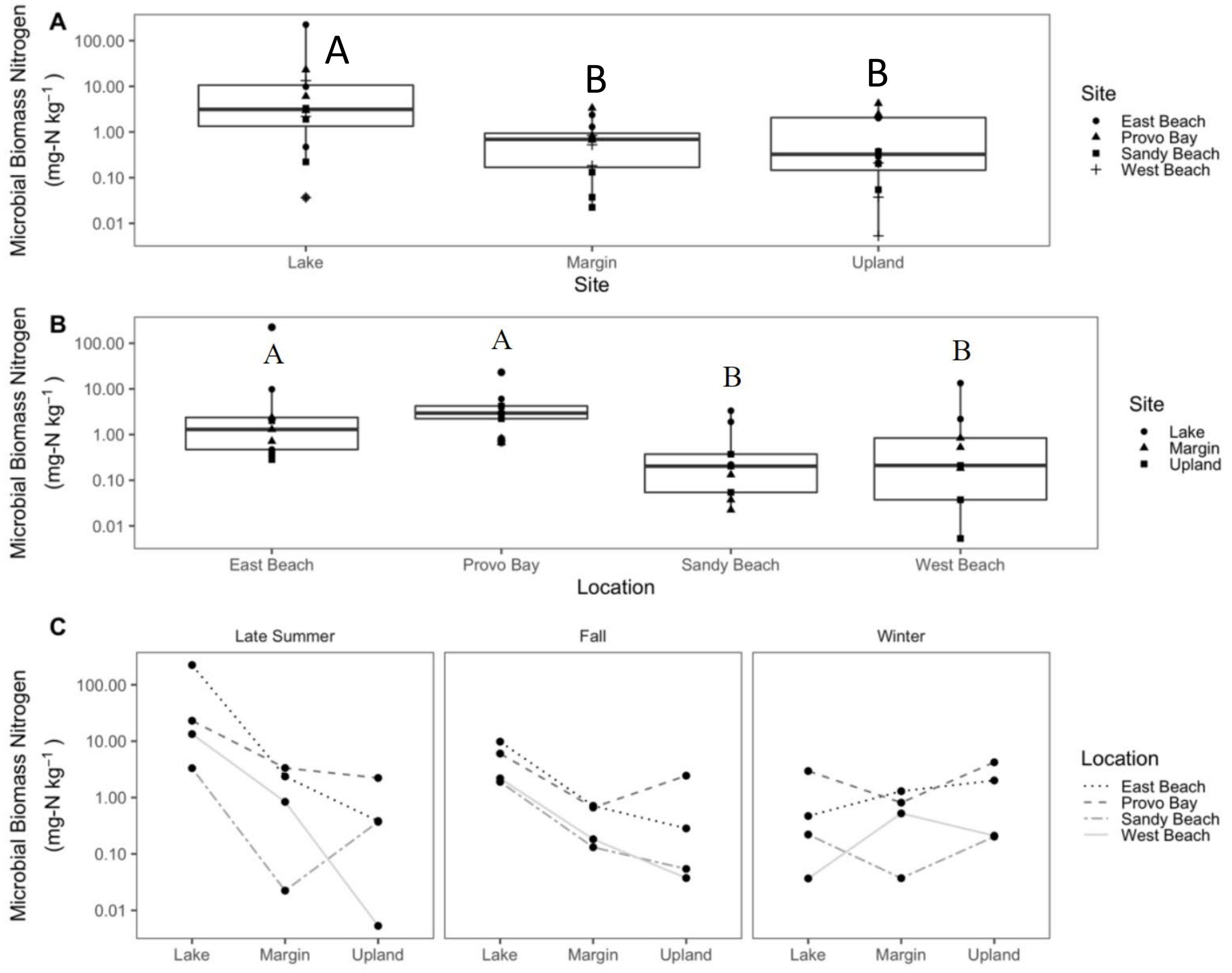

✗ Seasonal effect on mineralization or sediment organic matter

Zone	Variable	P-value
Lake	Mineralization	0.646
	Nitrification	0.318
	Respiration	**0.0456**
	Sediment Nitrate	0.589
	Sediment Ammonium	**0.0374**
	Sediment DIN	**0.0114**
	MBC	0.543
	MBN	**0.0114**
	OMC	0.317
Littoral	Mineralization	0.71
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	Respiration	0.103
	Sediment Nitrate	0.35
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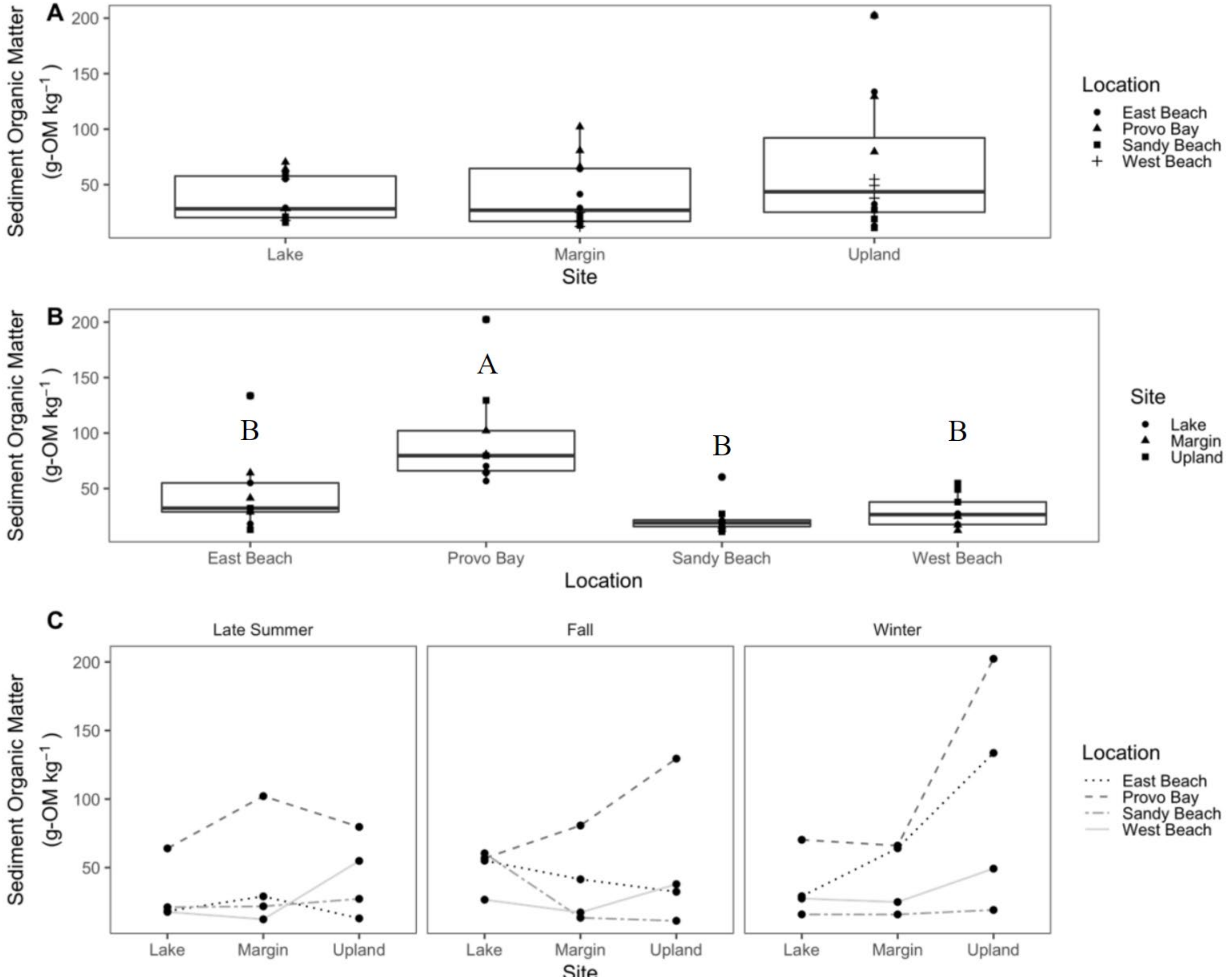
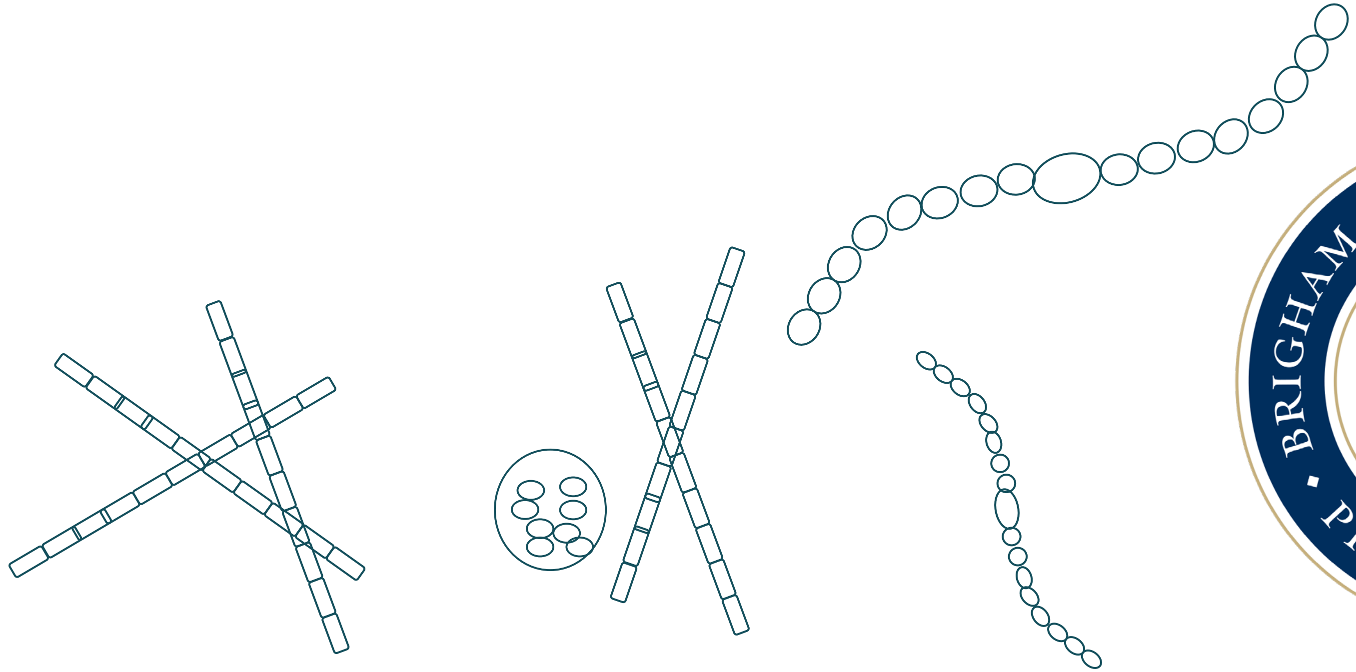


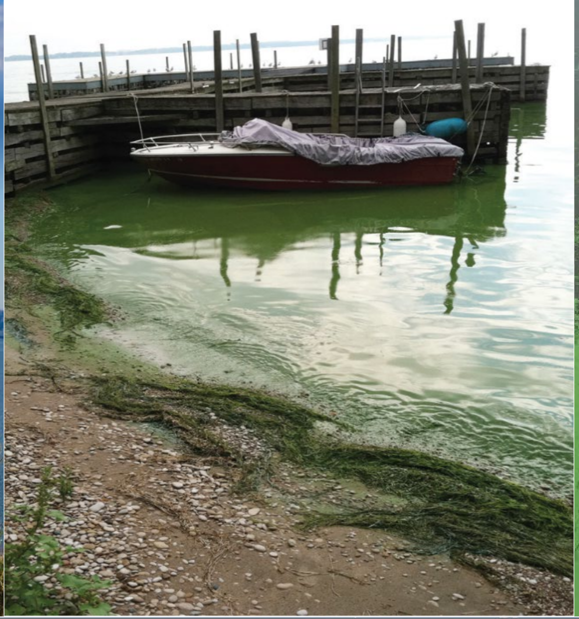
Acknowledgements

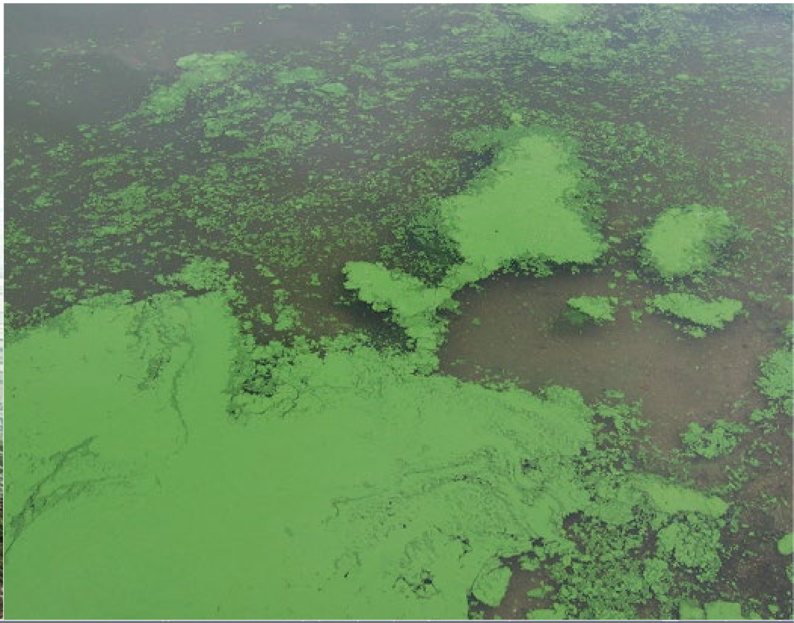
- Funded by the Utah Department of Environmental Quality, in partnership with Scott Daly
- This work was informed by a Science Panel subgroup that includes Janice Brahney, Michael Mills, Mitch Hogsett, and James Martin.
- BYU Graduates / Undergraduates: Niko Smiley
- USU Graduate student Emily Jainarain



Utah Lake Atmospheric Deposition Subgroup Report

Science Panel Meeting | March 2, 2023





AD Subgroup Objectives

1. Analyze available information and data to improve understanding of atmospheric deposition to Utah Lake
2. Work collaboratively toward a recommendation for atmospheric loading, ideally achieved through consensus
3. Document the SP's decision-making process for analyzing and evaluating evidence and working toward an atmospheric deposition recommendation

Data Summary and Review

- **Datasets**
  - Williams (2017-2020)
    [Olsen et al. 2018, Reidhead 2019, Barrus et al. 2021]
  - W. Miller (2017-2020)
- **Nutrients**
  - TP
  - SRP
  - DIN
  - Nitrate
  - Ammonium

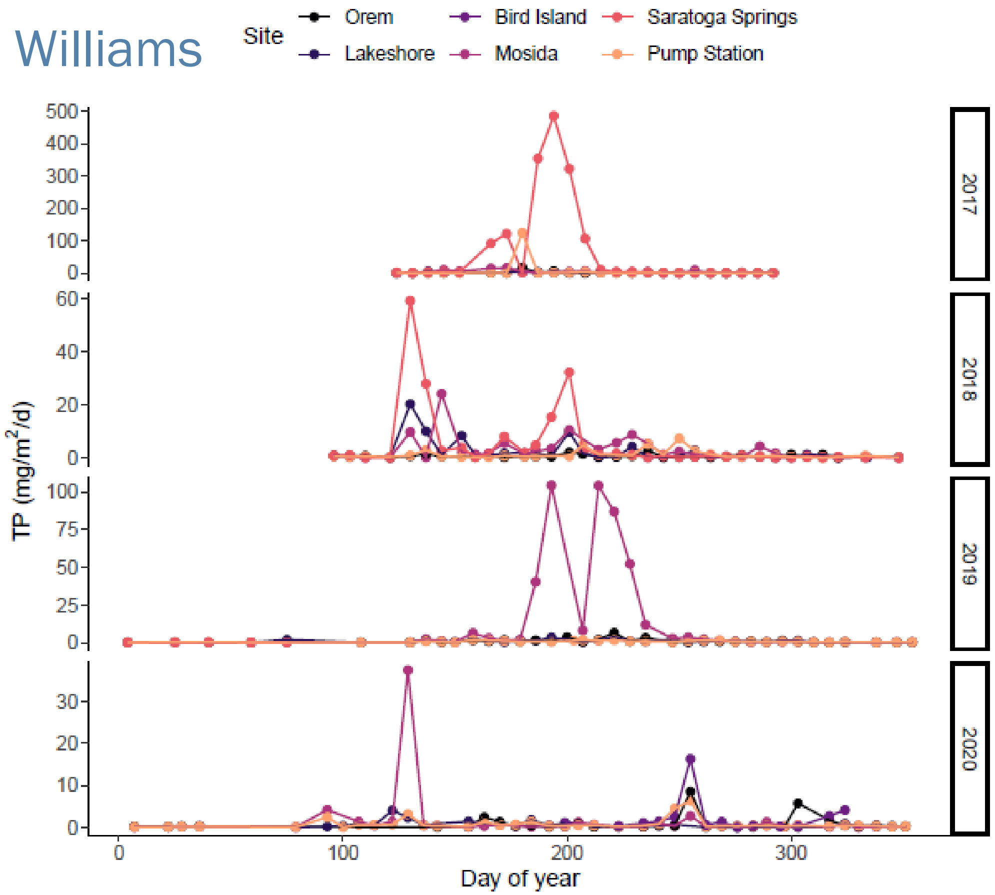
Data Summary and Review

- **Decision Point: Assigning non-detect values**
  - All subgroup members agreed to assign non-detect values at 0 mg/m^2
  - No method to convert non-detect concentrations to area-based fluxes
  - Very few values listed as 0 mg/m^2
- **Decision Point: Converting W. Miller volume-based fluxes (mg/L) to area-based fluxes (mg/m^2)**
  - Area-based fluxes based on W. Miller dataset was estimated using precipitation values from a single precipitation gauge
  - All subgroup members agreed to calculate area-based fluxes from W. Miller dataset using data from the nearest precipitation sampler

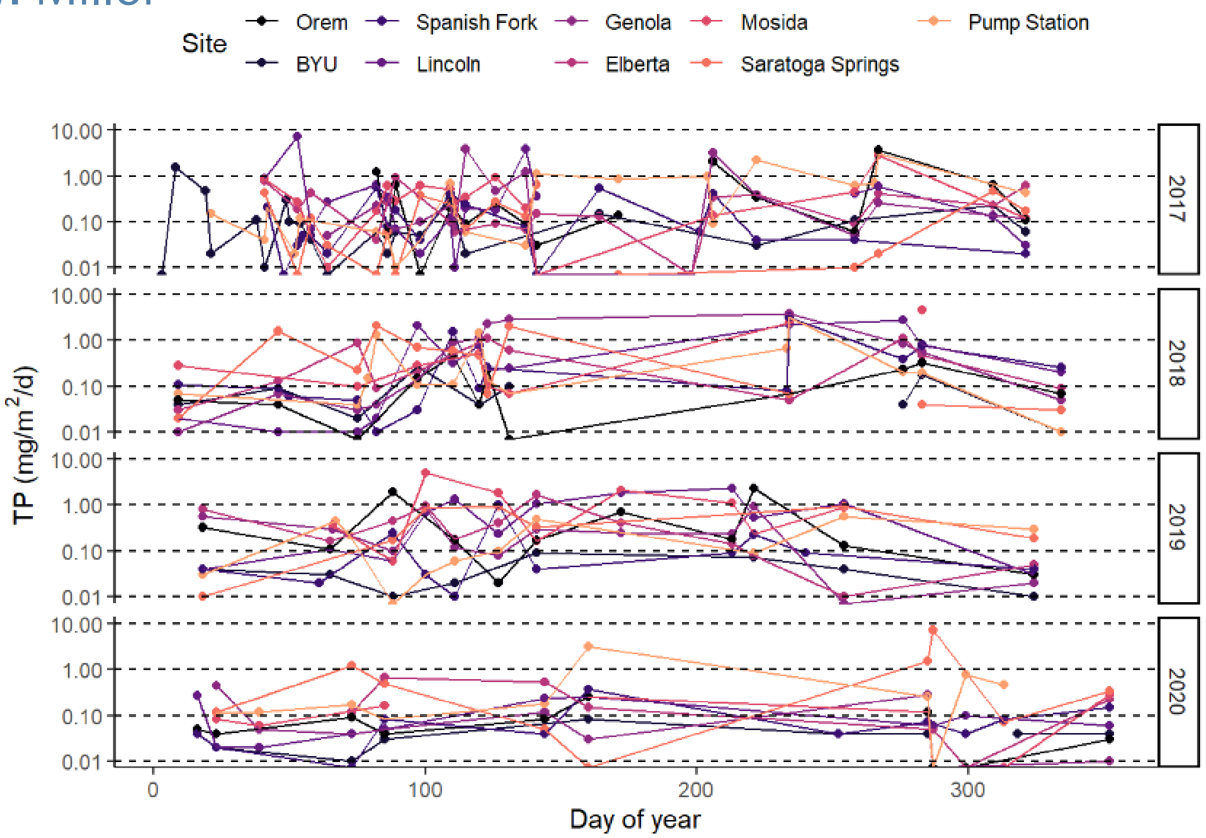
Data Summary and Review

Processed and visualized TP (and SRP) time series

Williams

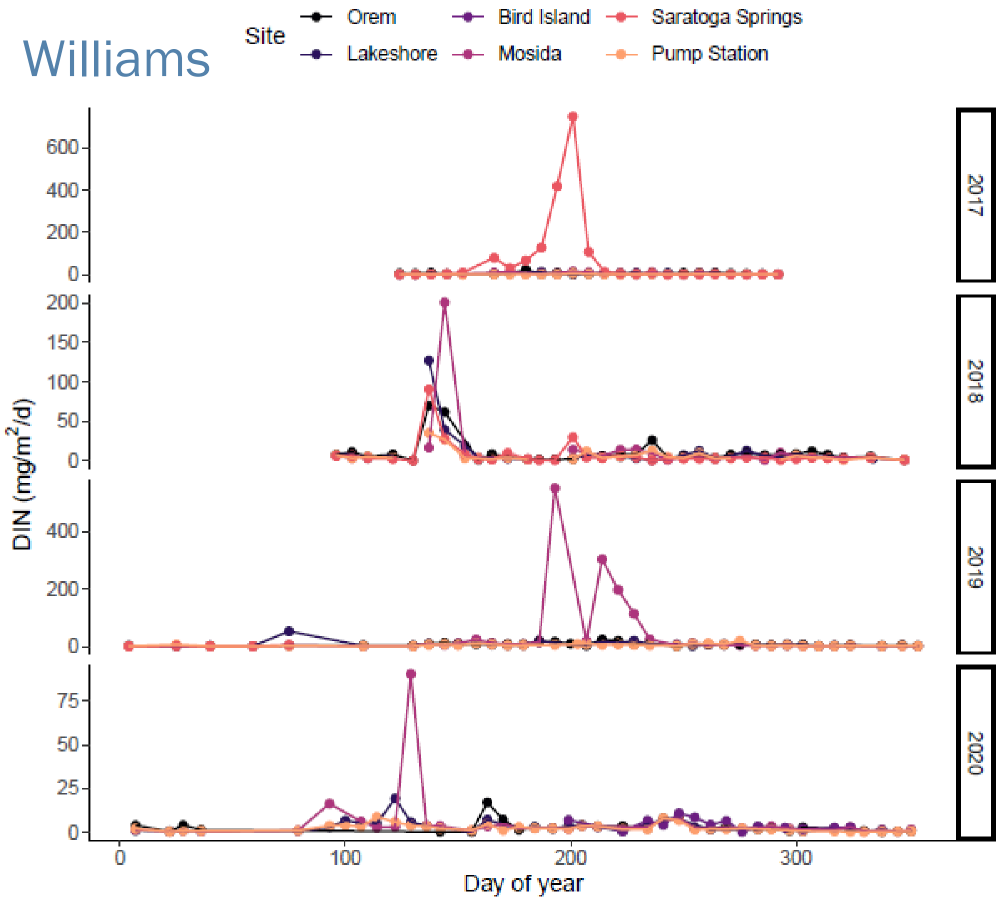


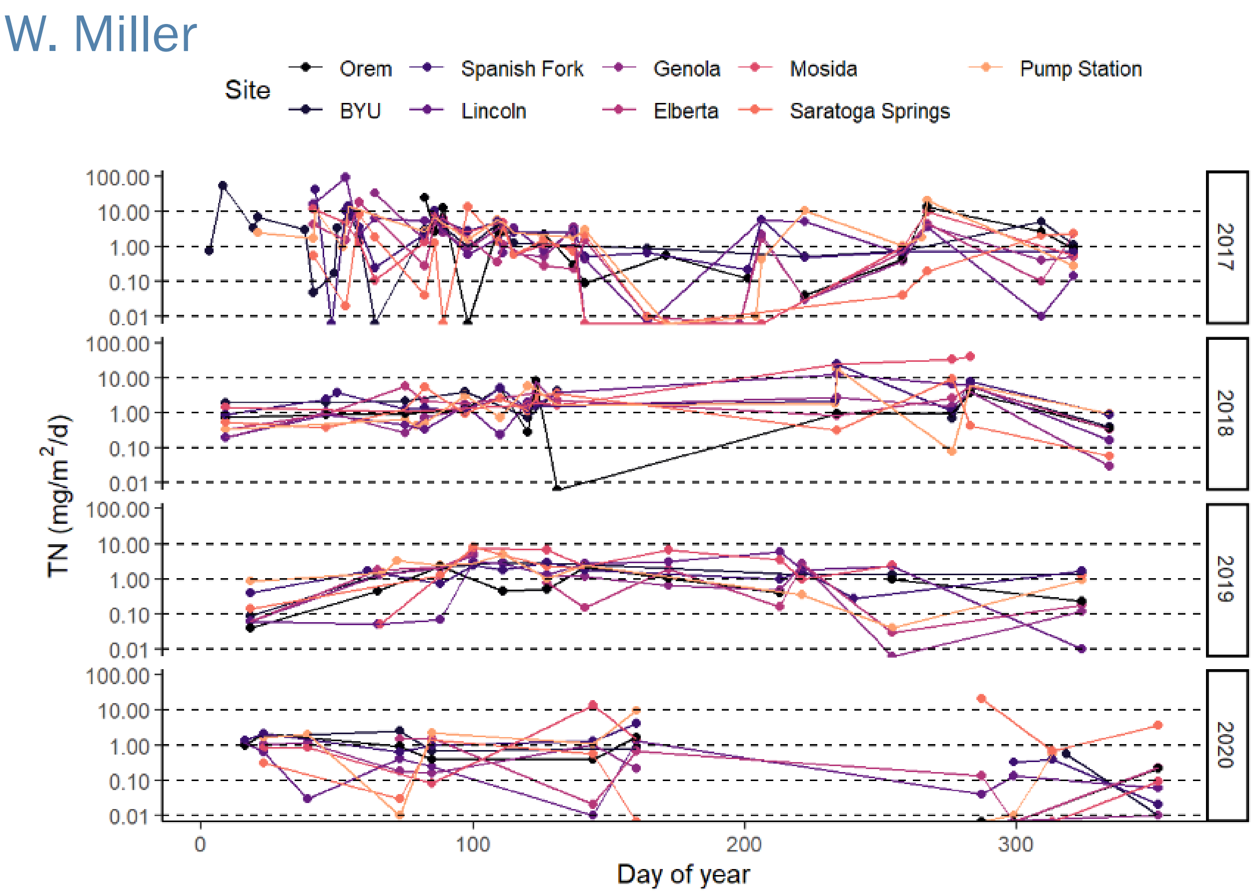
W. Miller



Data Summary and Review

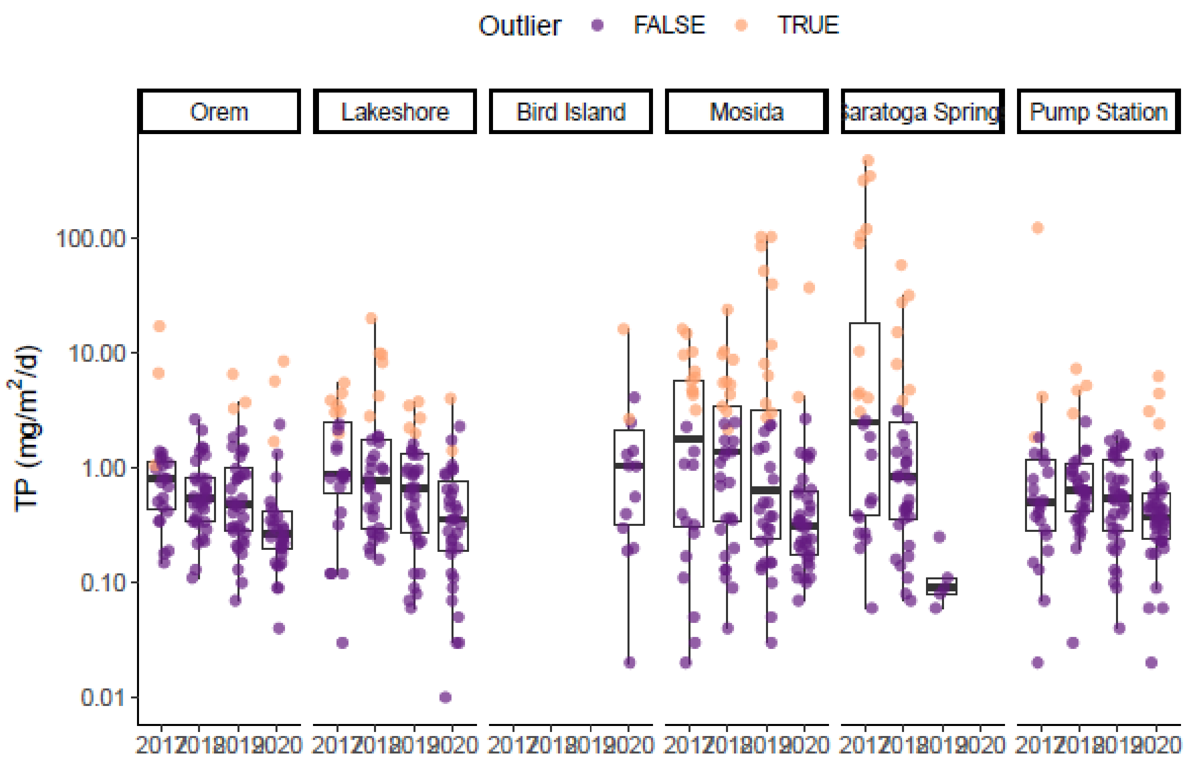
Processed and visualized DIN (and nitrate, ammonium) time series





Evaluating Outlier Samples for Potential Explanations

- **Outliers identified as 75th percentile + 1.5*IQR**
  - Exploratory approach
  - No low outliers found (25th – 1.5*IQR)
  - Simply identified, not removed!
- **Potential explanations for high outliers:**
  - Weather event
  - Local deposition source
  - Contamination
- **Decision Point: Identifying outliers**
  - All subgroup members agreed to use the IQR approach to identify outliers due to the distribution of the dataset



Evaluating Outlier Samples for Potential Explanations

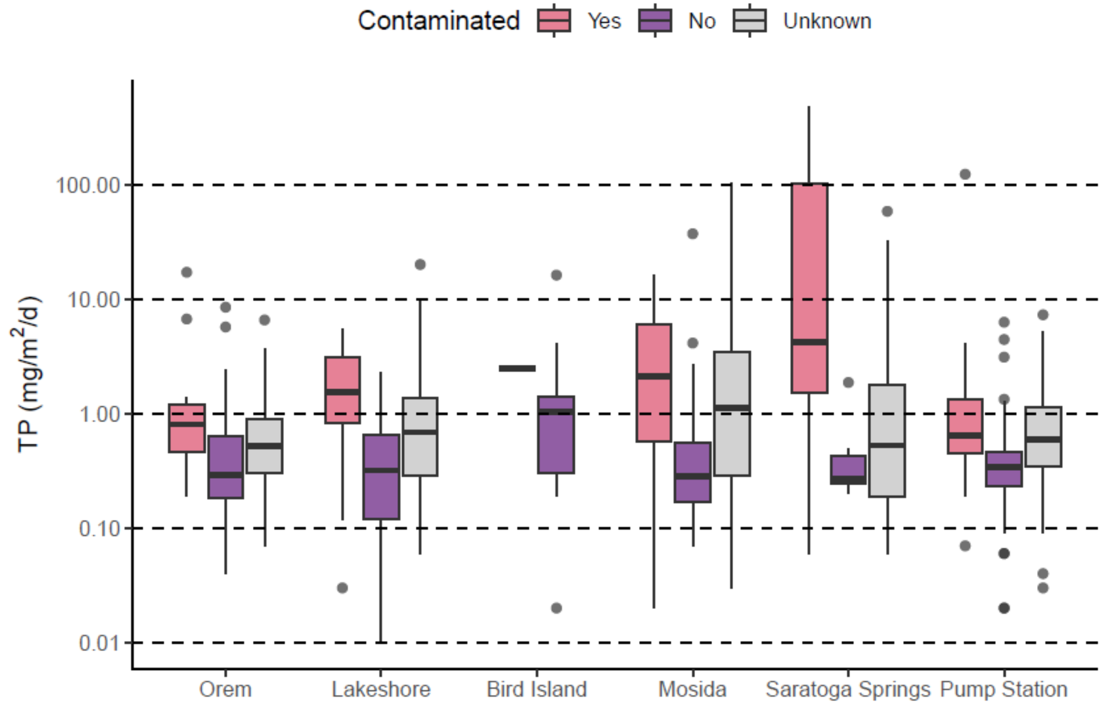
- **Insects observed in water-filled samplers**
- **Screens installed on samplers May 2020**
- **Decision Point: Should insects be considered AD or contamination?**
  - 3/4 subgroup members agreed that insects in sampling buckets should be considered contamination
  - Acknowledge that insects fall onto lakes, but as a separate source from AD. Samplers are not likely representative of their contribution to the lake
  - 1/4 subgroup member did not support this decision, with rationale that insects contribute to the nutrient budget of the lake

Evaluating Outlier Samples for Potential Explanations

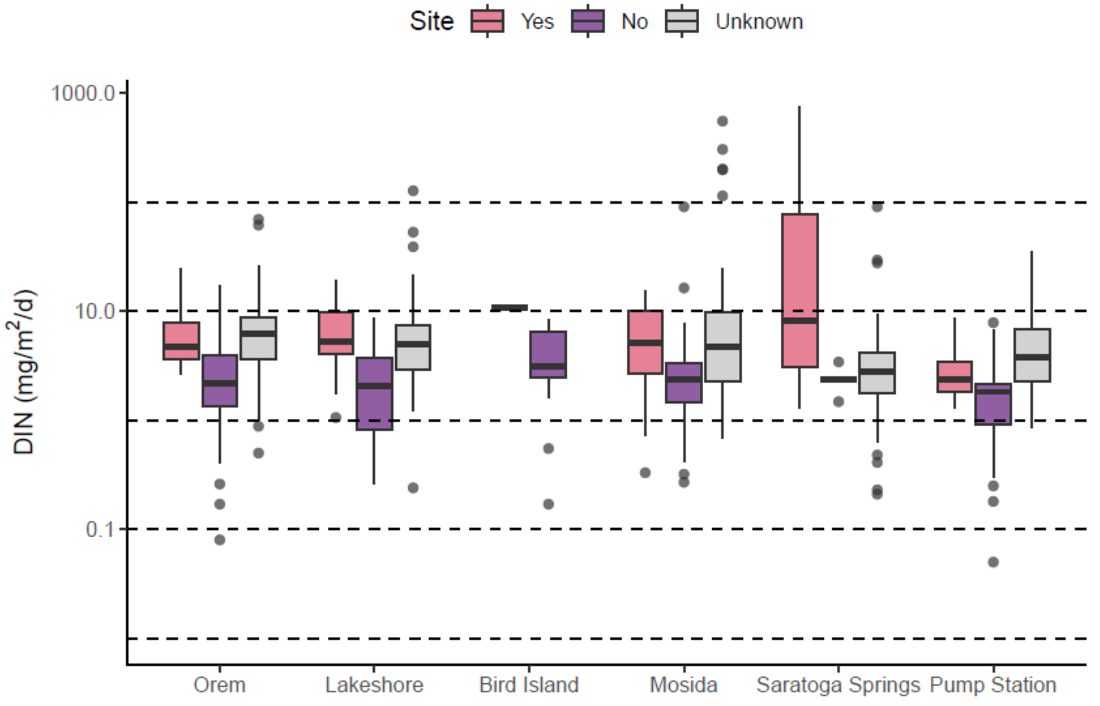
- **Decision Point: How to handle data without metadata**
  - Insofar as insects are considered contamination, subgroup members supported including:
    - Data collected from screened samplers
    - Data where metadata indicated the samples did not contain insects
  - Data from unscreened samplers without metadata or where metadata indicated the presence of insects were not used
  - Insect metadata available for 2017 and 2020 data

Evaluating Outlier Samples for Potential Explanations

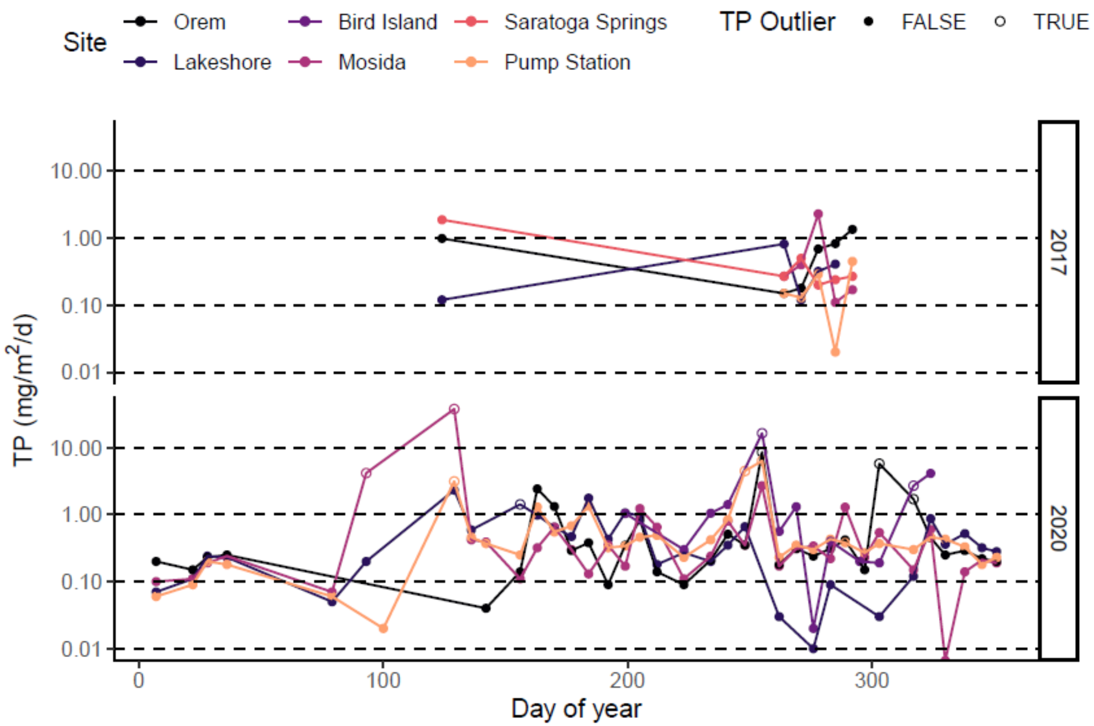
- **TP outliers**
  - 37 insect contamination
  - 11 uncontaminated
  - 47 unknown (no metadata)

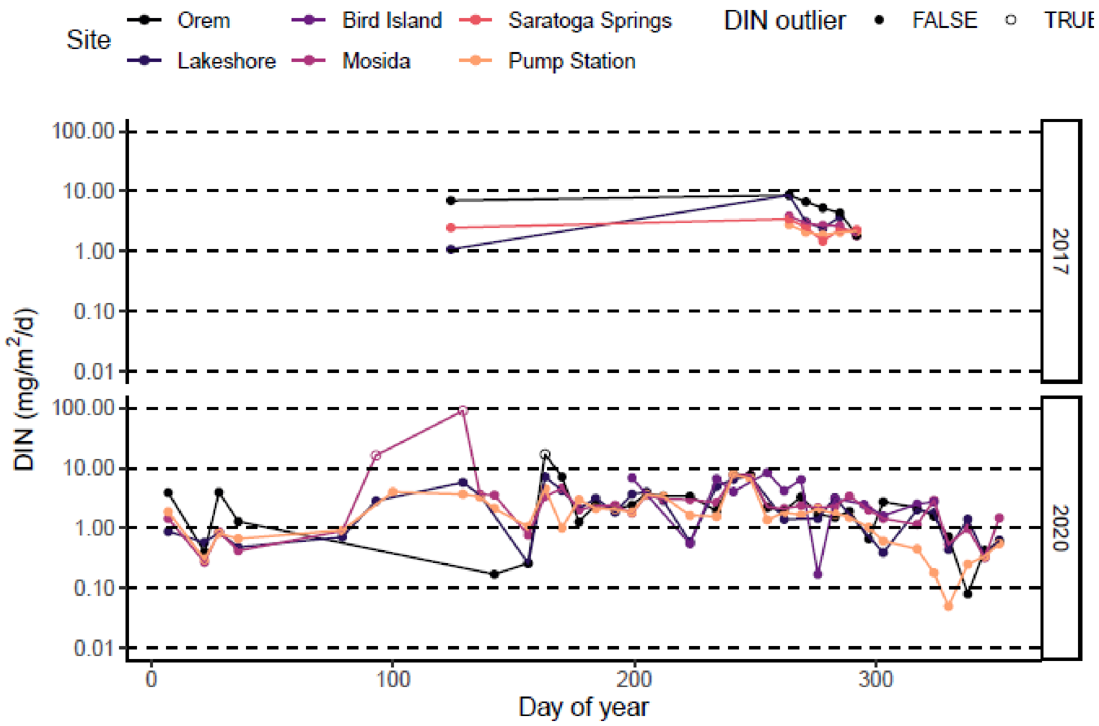


- **DIN**
  - 11 insect contamination
  - 3 uncontaminated
  - 32 unknown (no metadata)



Evaluating Outlier Samples for Potential Explanations

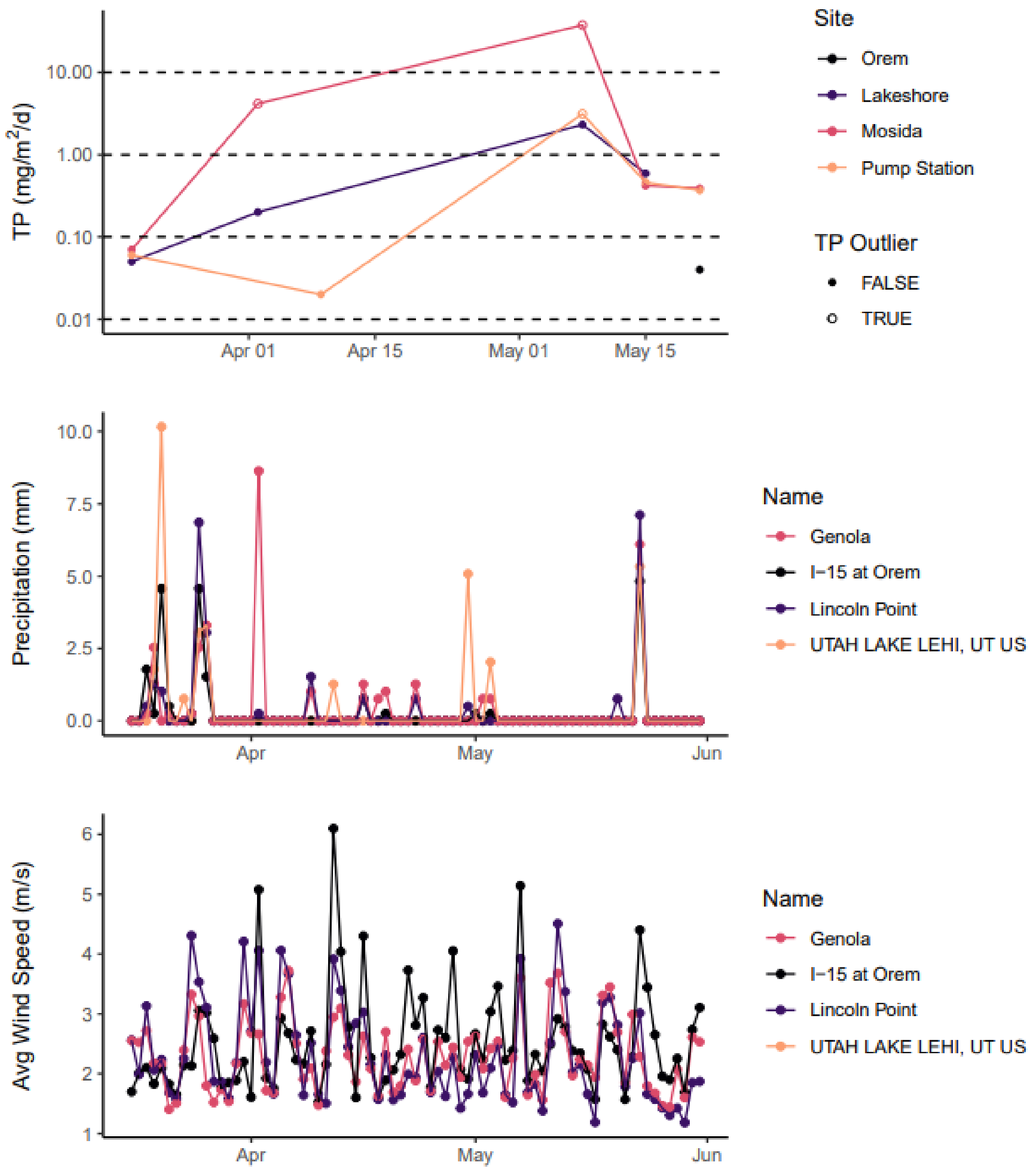




- 11 TP and 3 DIN uncontaminated samples were outliers → potential explanations include weather events and local sources
- Also need to impute fluxes on dates removed due to contamination

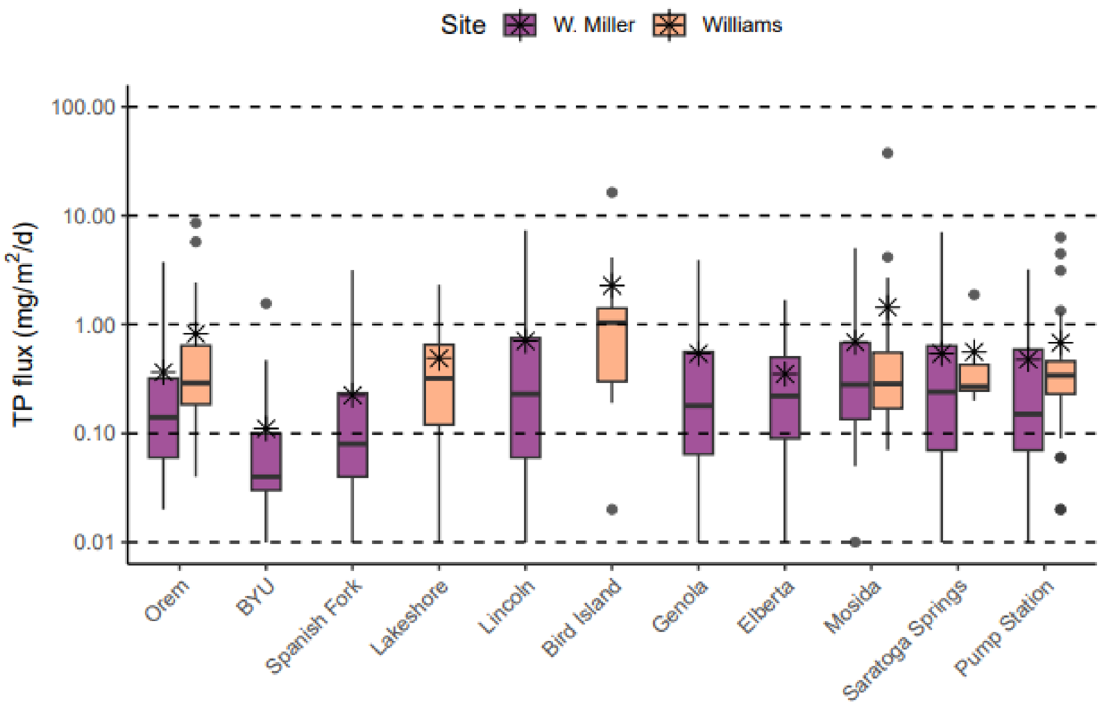
Imputing Missing Sampling Events

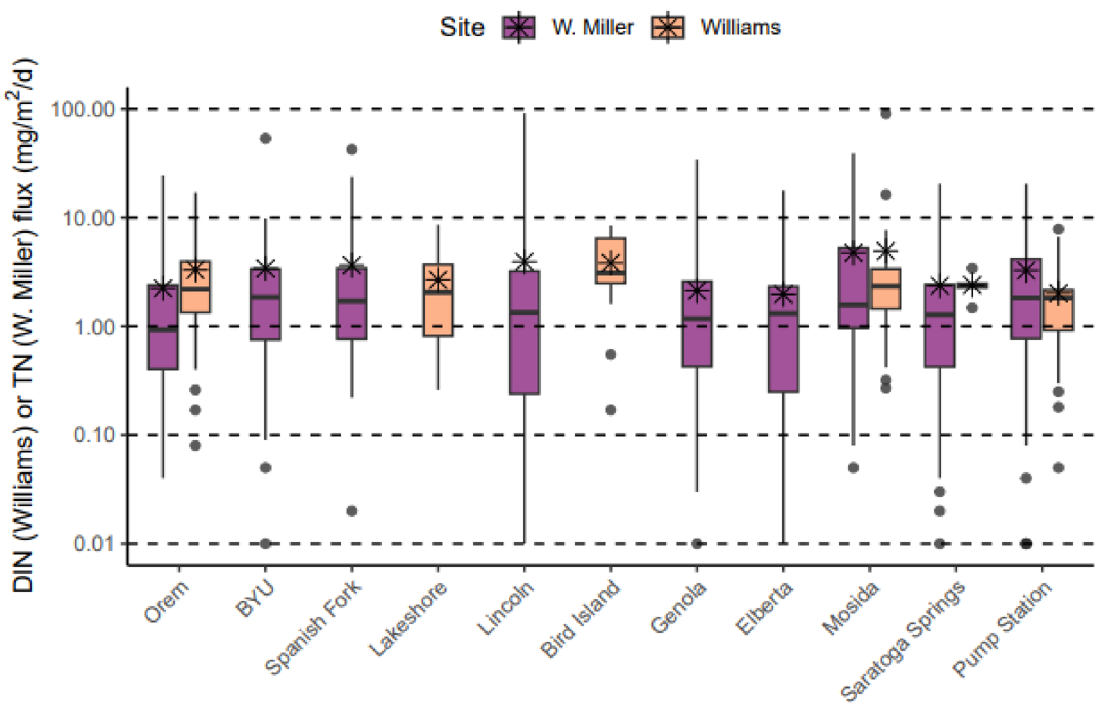
- **To compute cumulative annual load, need to fill in gaps in sampling dates**
- **Options**
  1. Impute via linear interpolation
  2. Impute via relationships with weather
- **Decision Point: Imputing fluxes for missing samples due to contamination**
  - All subgroup members agreed to use statistical relationships with weather
  - Linear interpolation assumes a predictable and consistent pattern, but AD in the basin is episodic



Comparing Samples Between Studies

- TP and DIN fluxes were significantly lower in W. Miller dataset than Williams dataset
- Comparison included several stations that were consistent between studies





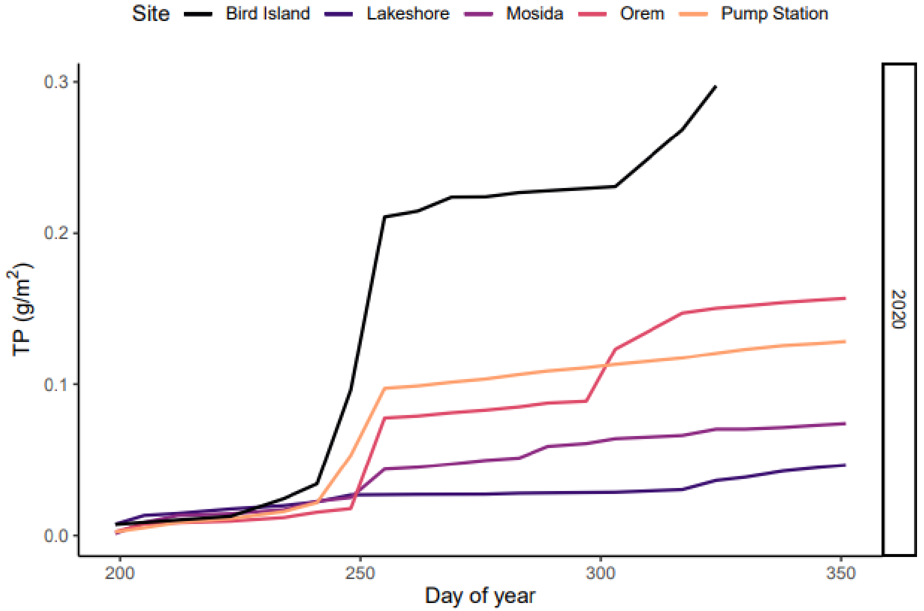
Comparing Samples Between Studies

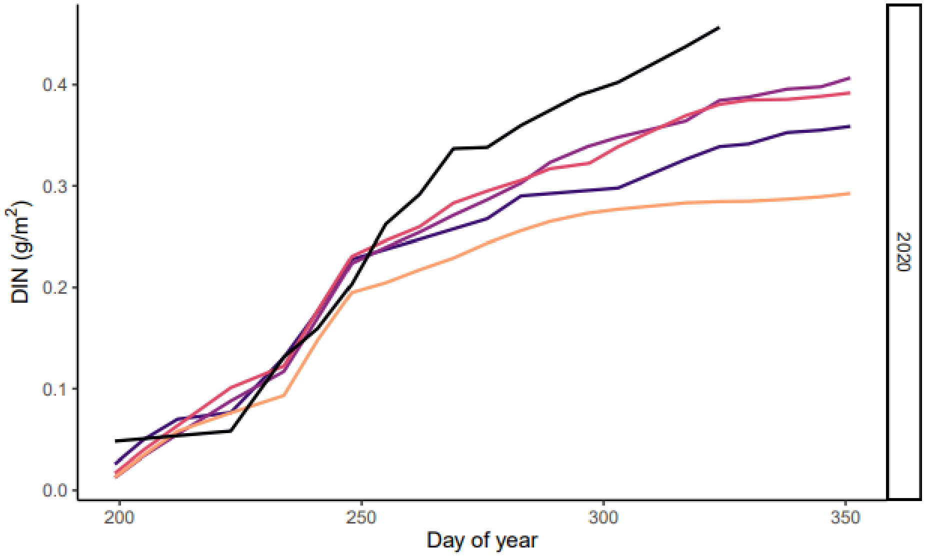
- **Decision Point: Interpreting W. Miller dataset**
  - All subgroup members agreed to use the Williams data as the primary line of evidence for calculating loading to Utah Lake
  - Several caveats with the W. Miller dataset that impact confidence:
    - **Evaporation** from sampling tube between sampling events → fluxes were concentration-based, so evaporation would lead to overestimate in flux
    - **Overflow** from funnel-shaped collector → precipitation event of >0.5 in would exceed sampler volume
    - **Loss of dry deposition** from dust blowing off shallow pan collector
    - **Sampler cleaning between samples** only conducted "now and then" by weather service
  - Several analyses conducted to evaluate impact of precipitation and evaporation, but no conclusive evidence for degree of impact

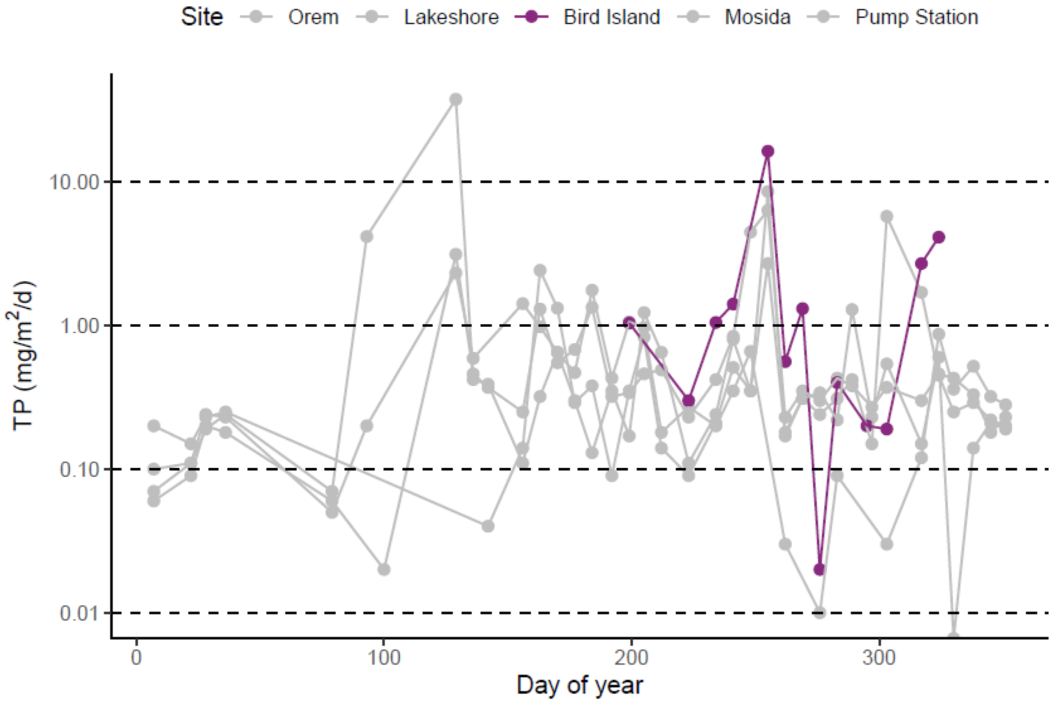
Evaluating Attenuation of Fluxes

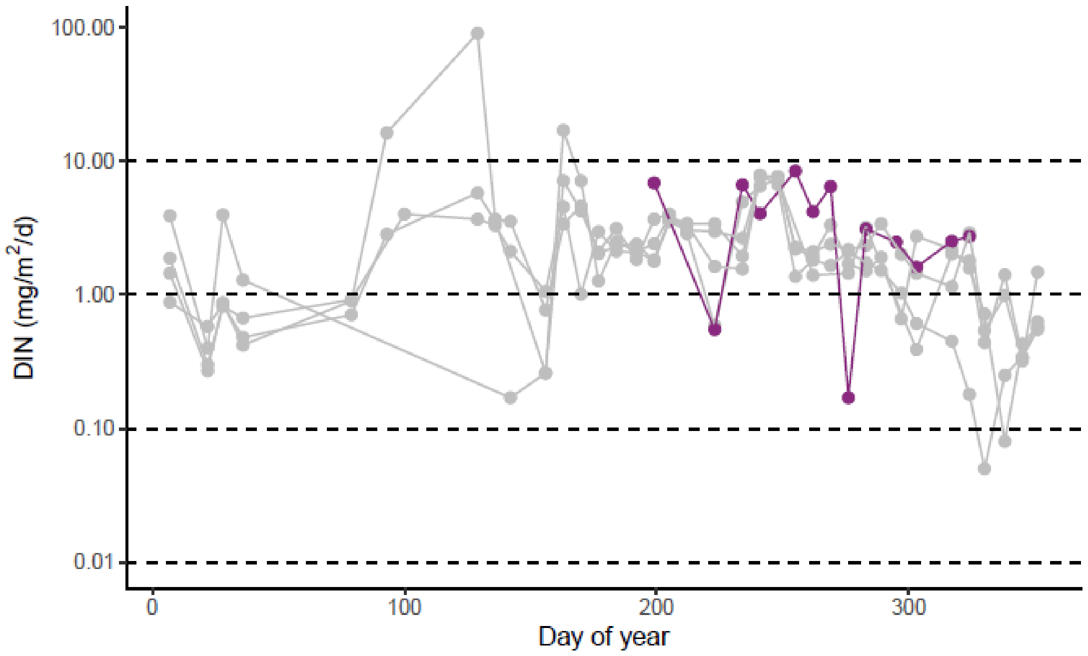
- **Previous studies assumed some flux decreased moving away from shore**
- **Sampler installed on Bird Island to quantify potential attenuation**
- **Hypotheses:**
  1. Attenuation occurs moving away from shore → Bird Island fluxes lower than shoreline fluxes
  2. Attenuation does not occur → Bird Island fluxes equivalent to shoreline fluxes

Evaluating Attenuation of Fluxes









Evaluating Attenuation of Fluxes

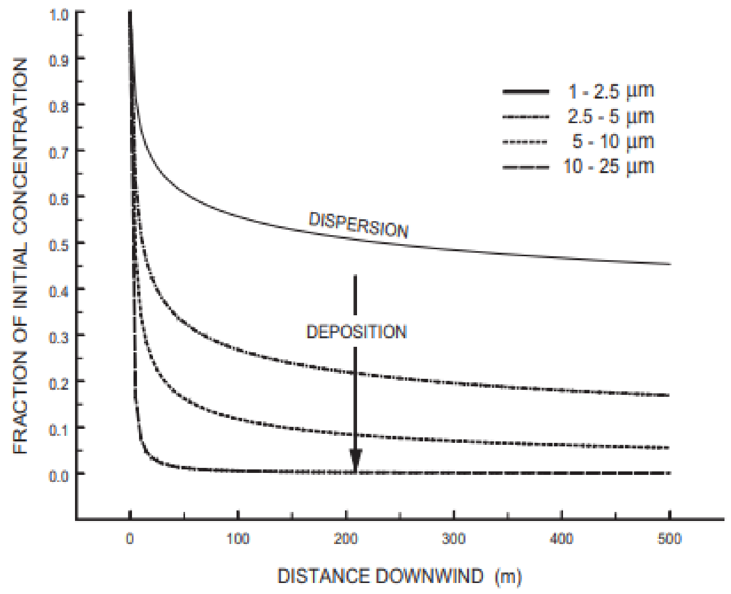
- **Hypotheses:**
  1. ~~Attenuation occurs moving away from shore → Bird Island fluxes lower than shoreline fluxes~~
  2. ~~Attenuation does not occur → Bird Island fluxes equivalent to shoreline fluxes~~
  3. Higher land-based flux not captured by current sampling array → Bird Island fluxes higher than shoreline fluxes
  4. Lake-based source of deposition to Bird Island sampler (e.g., bird droppings, aerosolized materials, lake spray) → Bird island fluxes higher than shoreline fluxes

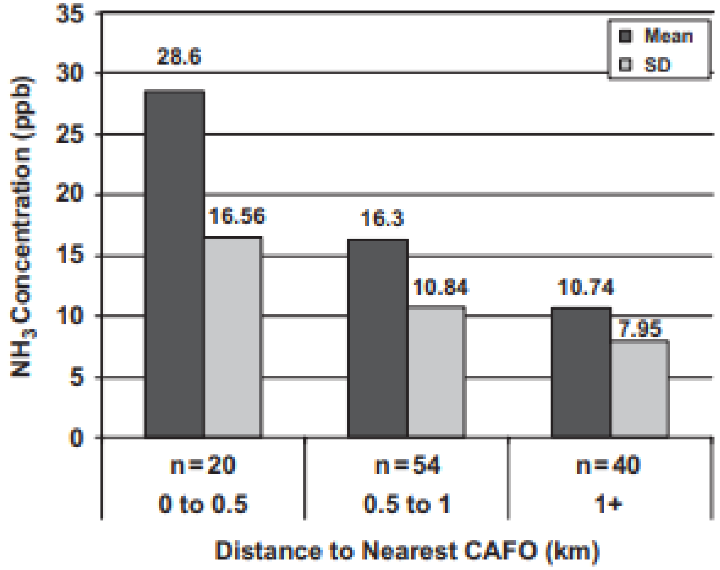
Evaluating Attenuation of Fluxes

- Hypothesis 3 evaluated using wind rose data, but this did not allow for a definitive identification of an additional nutrient source
- Hypothesis 4 could not be definitively ruled out using existing QA and field metadata
- Lack of conclusive support noted in David Gay review
- Decision Point: Bird Island data
  - 3/4 subgroup members supported excluding Bird Island from load calculations
  - Could not definitively rule in or out hypotheses 3 or 4
  - 1/4 subgroup members did not support this decision, stating support for hypothesis 3 and potential convergence of wind that would concentrate AD over the lake

Evaluating Attenuation of Fluxes

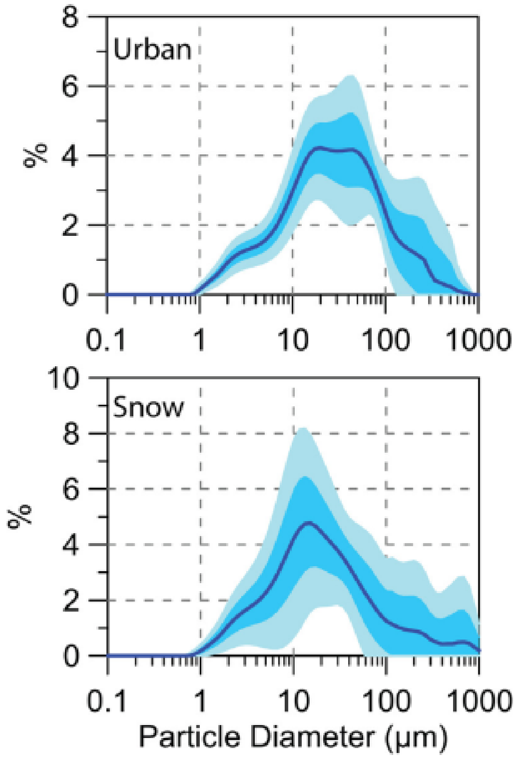
- **Explored observations from the literature on local & regional AD sources**
- **VanCuren et al. 2012 showed:**
  - Local AD attenuates moving away from the source
  - Attenuation of local AD dependent on grain size
  - Regional AD tends to be evenly distributed across lake area
- **Wilson and Serre 2007 showed:**
  - Local sources of ammonium (CAFOs) attenuate rapidly from 0-0.5 km and continue attenuating at a more gradual rate
  - Dominance of regional sources of ammonium beyond 2 km

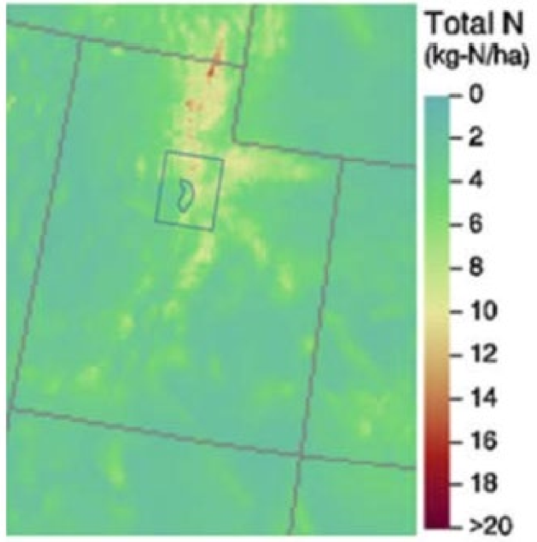




Evaluating Attenuation of Fluxes

- **Shoreline samplers capture local + regional flux**
- **How to quantify regional flux alone?**
- **TP: *Goodman et al. 2019***
  - Bulk samplers around Utah Lake, GSL, and Sevier Desert
  - Local dust sources had avg grain size of 20 µg → inform attenuation
  - Urban dust flux avg 30.5 g/m^2/yr
  - Urban dust was 91% regional → regional flux 27.8 g/m^2/yr
  - Consistent with *Putman et al. 2022* at Lehi (14.6-36.6 g/m^2/yr)
  - P content in regional dust is 1,344-4,340 mg/kg *[Carling 2022]*
  - Avg regional dust flux = **79 mg TP/m^2/yr**
- **DIN: Brahney 2019**
  - CMAQ model: avg **575 mg DIN/m^2/yr**
- **Decision Point: All subgroup members agreed on this approach**





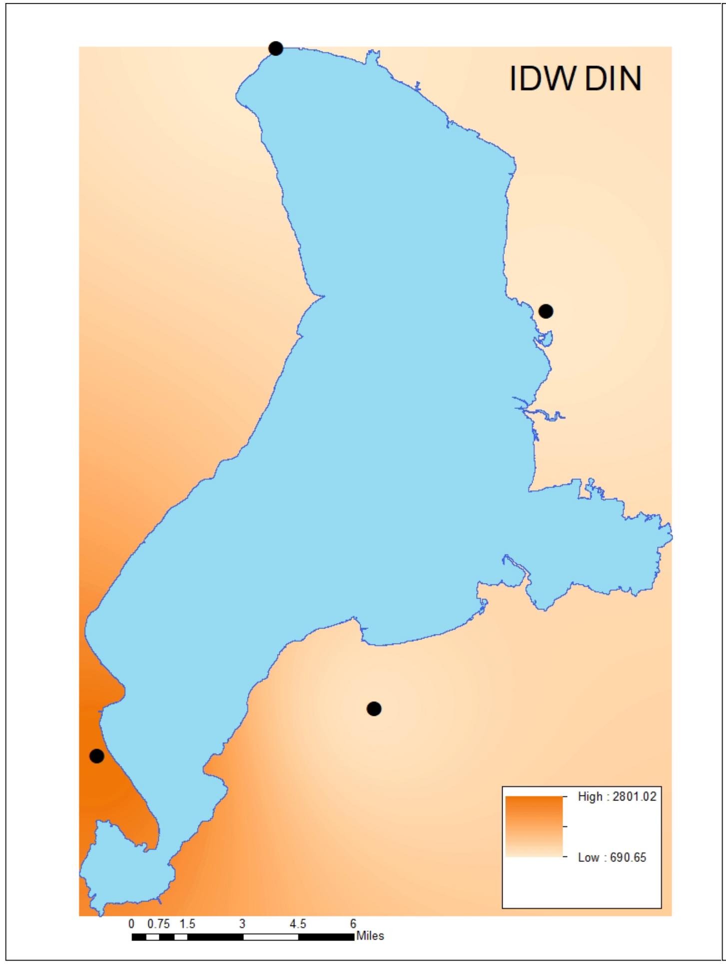
Evaluating Attenuation of Fluxes

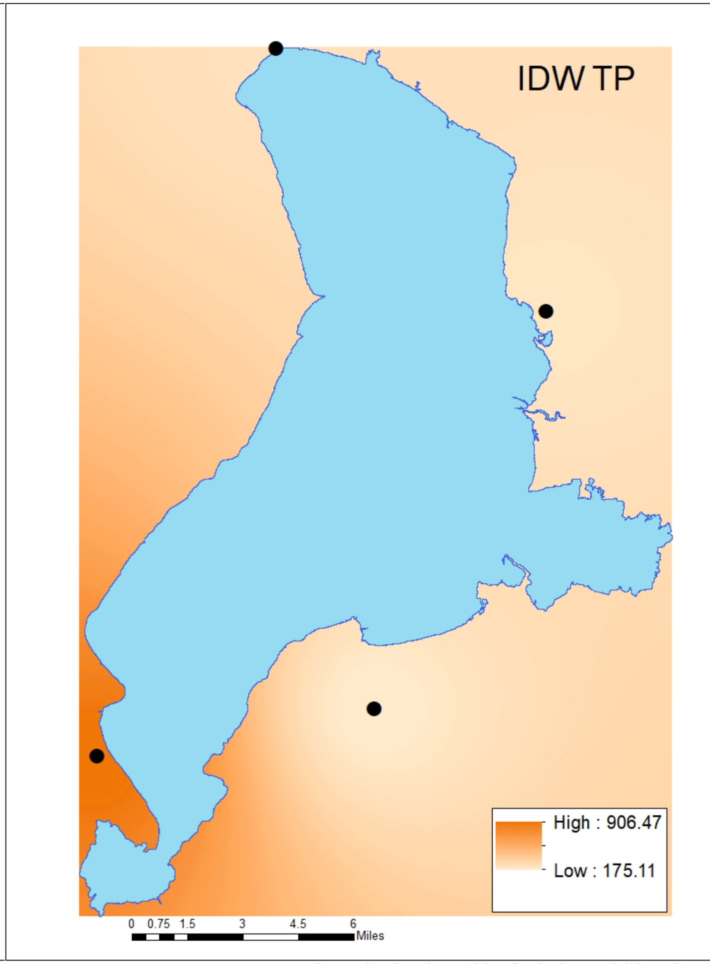
- **Decision Point: Attenuation Scenarios**
  - All subgroup members agreed that dust and aerosols attenuate as a function of distance
  - 3/4 subgroup members supported applying an attenuation rate to shoreline sampler fluxes and apply a regional flux beyond the attenuation distance
  - 1/4 subgroup member did not support attenuation and supported using Bird Island fluxes instead

Shoreline flux proportion	Regional flux proportion	100 m scenario (VanCuren et al. 2012)	200 m scenario (VanCuren et al. 2012, doubled to account for uncertainty)	2000 m scenario (Wilson and Serre 2007)
1.00	0.00	0 m	0 m	0 m
0.30	0.70	20 m	40 m	400 m
0.045	0.955	50 m	100 m	1000 m
0.026	0.974	100 m	200 m	2000 m

Determining Loading to Utah Lake

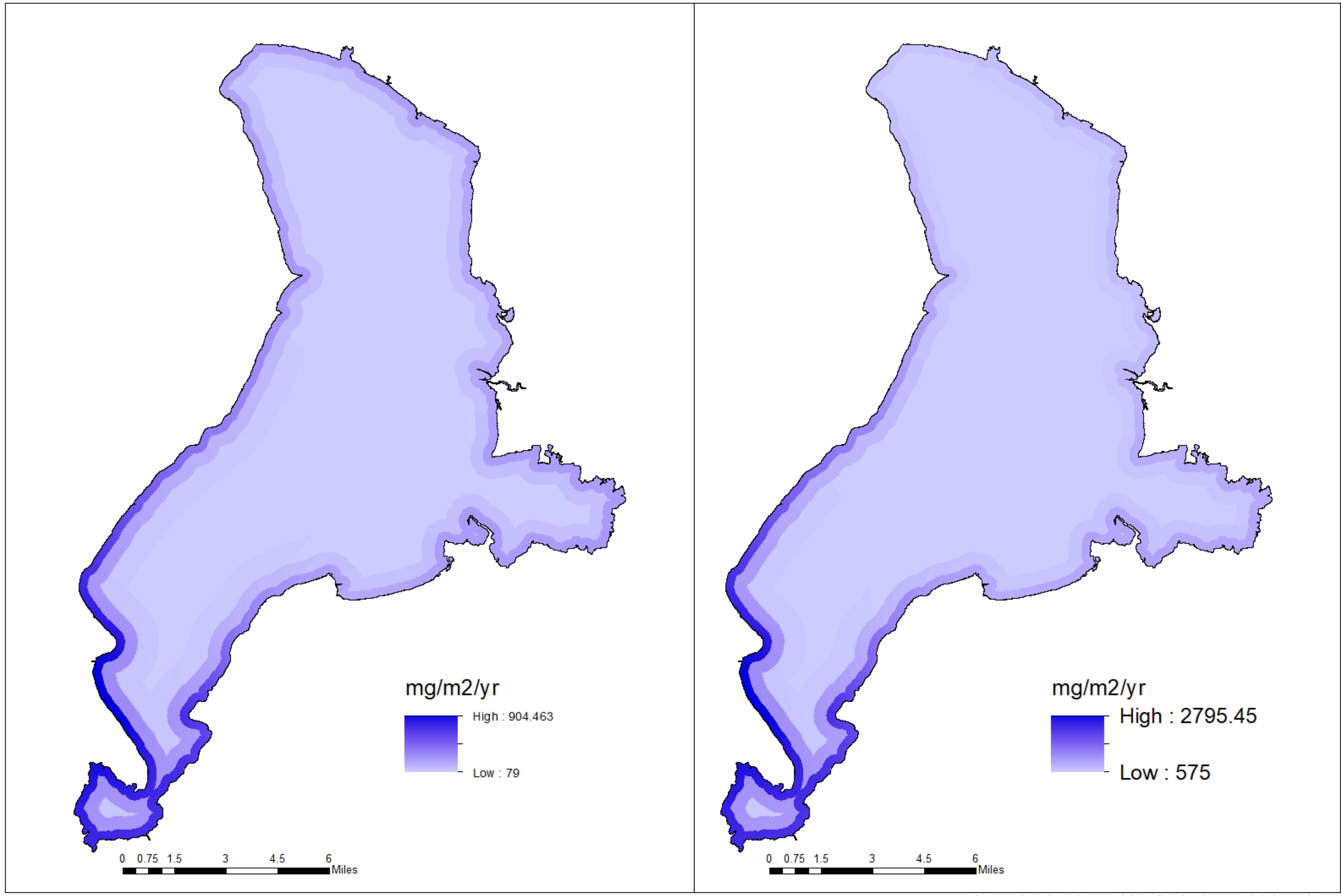
1. **Create a raster layer of shoreline fluxes around the edge of Utah Lake**
    - 4 shoreline samplers
    - Spatial interpolation via inverse distance weighted interpolation
    - Assumes conditions are more alike in locations close to one another
    - Plays out with Mosida location having an influence on the SW portion of the lake





Determining Loading to Utah Lake

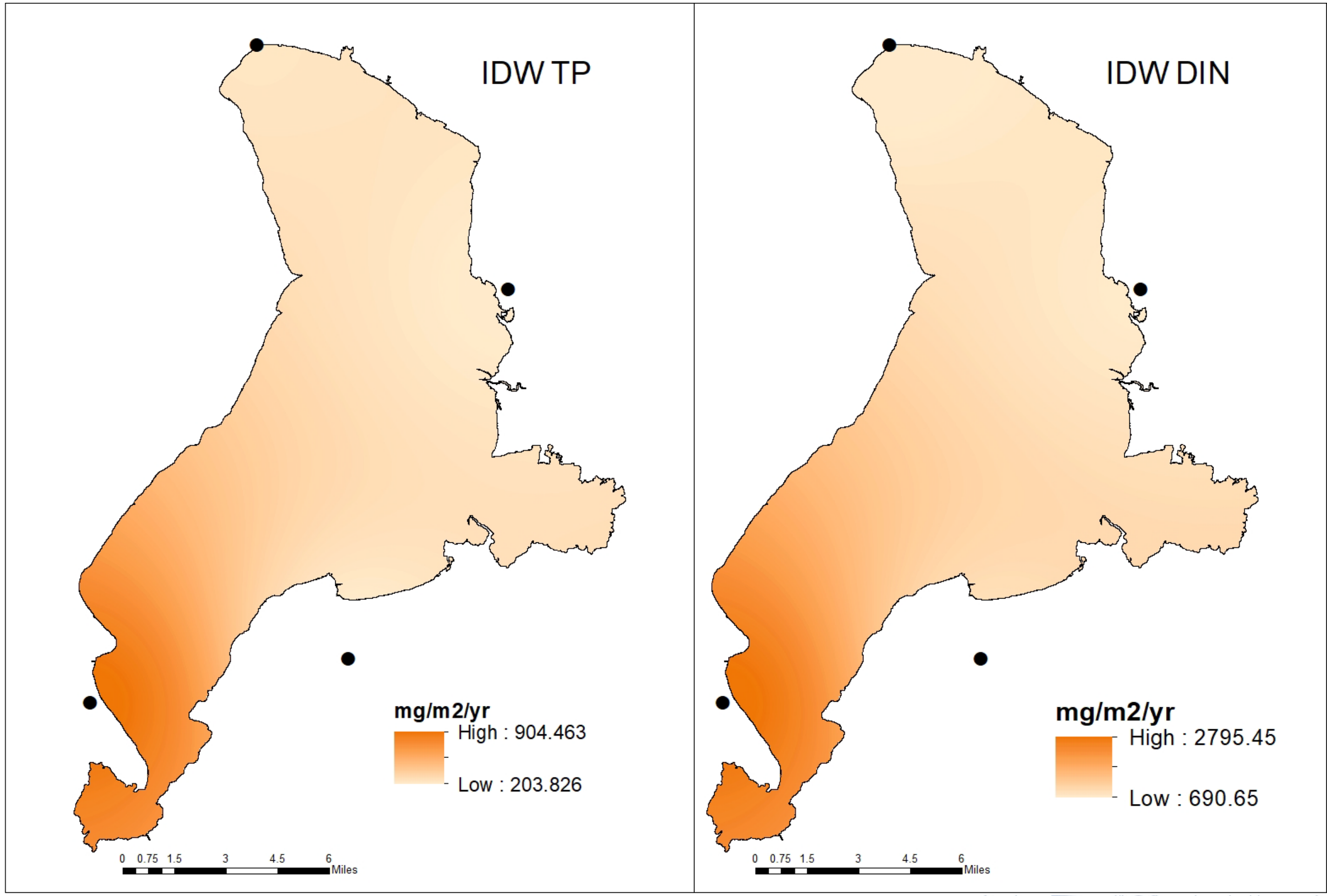
2. **Assign the decay rate of shoreline fluxes moving from shoreline to offshore**
   - 3 attenuation scenarios
3. **Assign the regional flux in areas of Utah Lake beyond the shoreline decay distance**
   - 79 mg TP/m^2/yr *[Goodman et al. 2019, Carling 2022, Putman et al. 2022]*
   - 575 mg DIN/m^2/yr *[Brahney 2019, CMAQ model]*



Determining Loading to Utah Lake

4. Fourth scenario: assume no attenuation

- Applied spatial interpolation via inverse distance weighted interpolation across the lake



Determining Loading to Utah Lake

Scenario	DIN (metric tons/yr)	TP (metric tons/yr)
Attenuation @ 100 m	**218**	**31**
Attenuation @ 200 m	**220**	**32**
Attenuation @ 2000 m	**249**	**45**
No attenuation	**351**	**93**
Carling 2022 (dust conversion, no attenuation)		57.5
Brahney et al. 2019	153-288	2-21
Brahney (mass balance)		33
Brett (mass balance)		60
Miller 2021 (assumed no attenuation)	257-409	50-104
Olsen et al. 2018 *(uncontaminated-contaminated)*	57-570	10-430
Reidhead et al. 2019 *(unscreened)*	637	193
Barrus et al. 2021 *(partially screened-unscreened)*	482-1052	133-262

Determining Loading to Utah Lake

- **Decision Point: Load recommendations**
  - Modeling team requested one primary recommendation and a range for sensitivity analysis
  - 3/4 subgroup members recommended:
    - 32 metric tons TP (31-45 range)
    - 220 metric tons DIN (218-249 range)
    - Based on 200-m attenuation scenario, with range based on 100-2000-m attenuation scenarios
  - 1/4 subgroup member recommended:
    - 150 metric tons TP (93-200 range)
    - Based on Williams data in its entirety with no samples removed due to contamination or Bird Island
    - Additional studies and comments provided

Evaluating Chemical Speciation

- **DIN constituents**
  - Avg 30.25% nitrate
  - Avg 69.75% ammonium
  - Consistent among sites except Mosida
- **TP constituents**
  - Avg 37.5% SRP
  - More consistent with regional dust than urban dust
- **Decision Point: Speciation**
  - All subgroup members supported these proportions
  - Additional specifics (org N and P) to be determined by the modeling team

Study	Site	NO3/DIN	NH4/DIN	SRP/TP
Williams data 2020	Orem	0.35	0.65	0.46
	Lakeshore	0.37	0.63	0.48
	Mosida	0.10	0.90	0.24
	Pump Station	0.39	0.61	0.27
Brahney 2019	Urban dust			0.75
	Regional dust			0.34
Reidhead 2019	Utah Lake shoreline sites			0.37
W. Miller 2021	Utah Lake shoreline sites			0.32

Questions and Discussion