



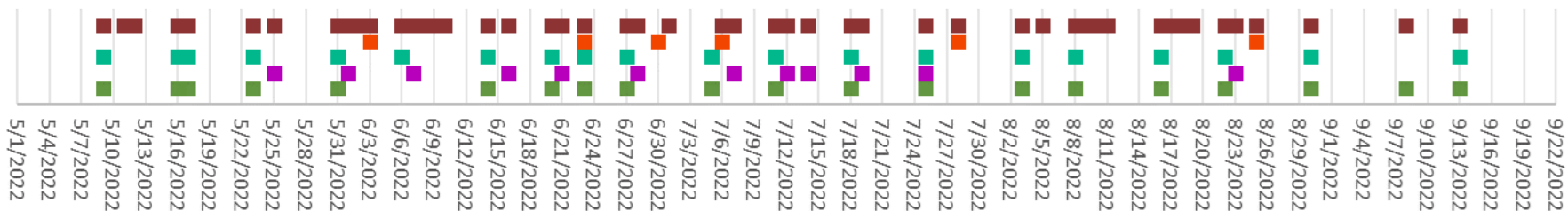
## 2022 TSSD Utah Lake Nutrient Cycling Experiments Summer Field Campaign Observations



# 2022 Field Sampling Summary

Deep Corrals (6-10) Active

Shallow Corrals (1-5) Active



■ Probe Single Points

■ Probe Vertical Profiles

■ Surface Water Samples

■ Data Tracks

■ Drone Images

# 2022 Data summary

TSSD	
Analyte	# Data Points
Nitrite (NO2-N)	191
Nitrate (NO3-N)	191
Ammonia (NH4-N)	191
Unfiltered Reactive P (PO4-P)	191
Filtered Reactive P (PO4-P)	191
Total P (P)	191
COD	191
TSS	191
VSS	190
TDS	191
Unfiltered TOC	79

BYU Environmental Analytical Laboratory (EAL)			
Analyte	# Data Points	Analyte	# Data Points
Dissolved Al	154	Total Al	137
Dissolved As	154	Total As	137
Dissolved B	154	Total B	137
Dissolved Ba	154	Total Ba	137
Dissolved Ca	154	Total Ca	137
Dissolved Cd	154	Total Cd	137
Dissolved Co	154	Total Co	137
Dissolved Cr	154	Total Cr	137
Dissolved Cu	154	Total Cu	137
Dissolved Fe	154	Total Fe	137
Dissolved K	154	Total K	137
Dissolved Mg	154	Total Mg	137
Dissolved Mo	154	Total Mo	137
Dissolved Na	154	Total Na	137
Dissolved Ni	154	Total Ni	137
Dissolved P	154	Total P	137
Dissovled S	154	Total S	137
Dissolved Pb	154	Total Pb	137
Dissovled S	154	Total S	137
Dissolved Se	154	Total Se	137
Dissovled Si	154	Total Si	137
Dissolved Sr	154	Total Sr	137
Dissolved Ti	154	Total Ti	137
Dissolved Zn	154	Total Zn	137

YSI Sondes	
Analyte	# Data Points
Pressure (psi a)	8699
Conductivity (uS/cm)	8696
Specific Conductance (uS/cm)	8696
Salinity (psu)	8696
nLFCCond (uS/cm)	8696
TDS (mg/L)	8696
Temperature (C)	8696
Resisitivity (ohms-cm)	8696
Sigma-T (s t)	8696
Sigma (s)	8699
Chlorophyll (RFU)	3936
Chlorophyll (ug/L)	3936
PC (RFU)	3936
PC (ug/L)	3936
Turbidity (FNU)	4763
TSS (mg/L)	4763
ODO (% Saturation)	4763
ODO (mg/L)	4763
pH	3936
pH (mV)	3936
ORP (mV)	3936

Miscellaneous	
Analyte	# Data Points
PAR	20
PAR (Air)	10
PAR (Water)	10
Secchi disk depth	163

679 water samples, 516 probe measurements, 600+ drone images: 143,345 data points on Utah Lake

# Students

## Current (14)

- Kaylee Tanner (PhD)
- Rachel Valek (U/MS)
- Cristian Dorrett (MS)
- Becca Butters (MS)
- Anna Cardall (U)
- Marypaz Cuessy (U)
- Megan Jones (U)
- Samuel Cuessy (U)
- Blake Markham (U)
- Samuel Quispe (U)
- Amber Gurecki (U)
- Isabel Logan (U)
- Hannah Smith (U)

## Past (9)

- Heather Siddoway (U)
- Madi Pollei (U)
- Arianna Kee (U)
- Kamden Peterson (U)
- Brooklyn Beard (U)
- Hannah Keen (U)
- Naomi Welling (U)
- Emily Walmer (U)
- Blair Hanson (U)

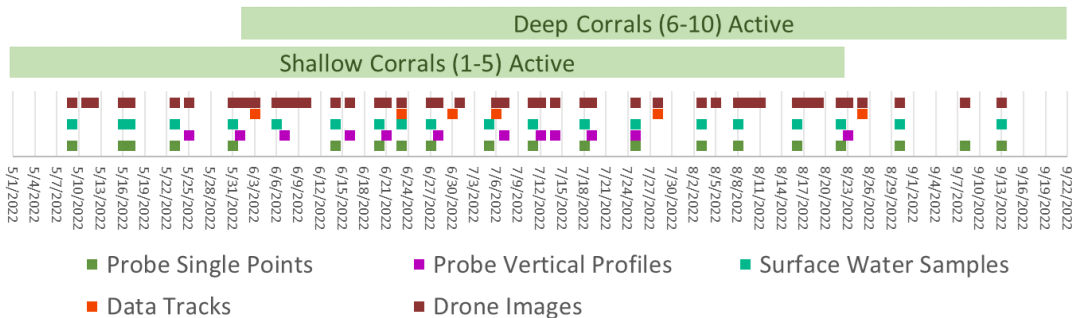
## Related Students (Wasatch Front)

- Jacob Taggart (Ph.D.)
- Justin Teffler (MS)
- Mitch Brown (MS)



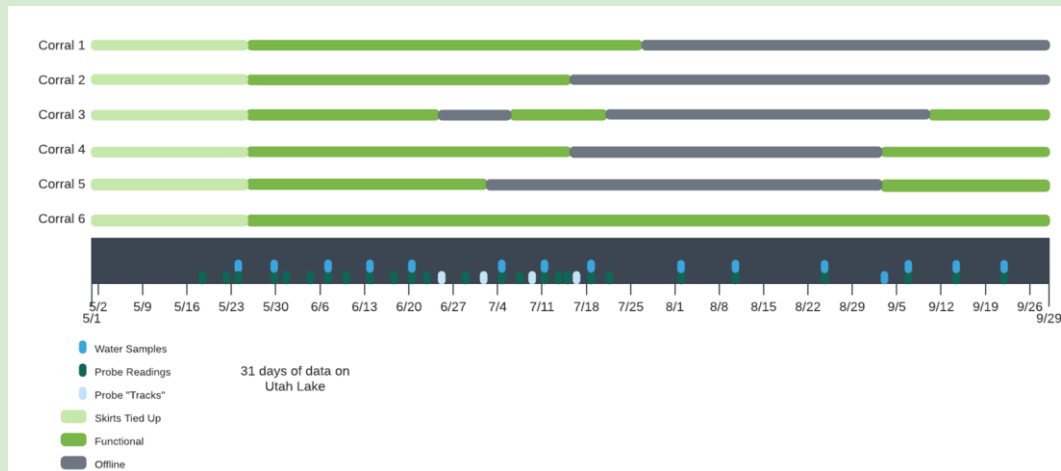
2022

### 2022 Field Sampling Summary



- 55 days with data
- 679 water samples
- 516 probe measurements
- 600+ drone images

2021



- 31 days with data
- ~132 water samples
- ~192 probe measurements
- 200+ drone images

# Field Observations from Rachel

- ❖ Corrals were often clearer than the lake (secchi disk, drone image, seeing the probes in the water)
- ❖ Carp jumping in and out of the corrals
  - Suggest putting up netting around the poles just wrapping so that it would be easier to sample
  - Or lay fine net over the top of the corrals (something that floats)
- ❖ Baby carp
- ❖ Ducks, cranes, and pelicans seemed to enjoy the shallow water corrals
- ❖ Corral 1 turned dark brown
- ❖ A lot of algal growth on skirts, especially 7 and 10 — slightly pink
- ❖ No noticeable algal bloom after phosphorus spike!
- ❖ Turbidity highly correlated with wind/storms
- ❖ Water got really low really fast
- ❖ Minks really like the pontoon boat



# Improved Corral Design

- ❖ No spokes– great choice
- ❖ Poles to help pull the tarp down
  - Compare locations with 10 poles and locations with 5
  - Suggest put poles in corners next year (better for nets)
  - Sandbags for next year?
- ❖ Some rips in tarp (looks like from wear and tear) – check before we put them back in next year
- ❖ Corrals would ride on top of poles after a storm – not huge deal but hard to put back down
- ❖ We added double screws to each corral (need to use locktight next year)
- ❖ Occasional zip ties broke (we just replaced them)

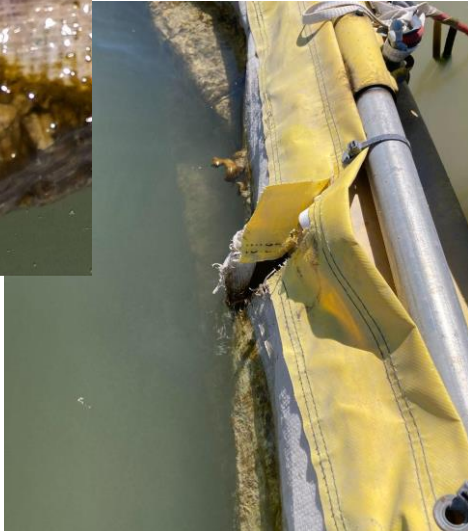


# Corral Damage



Skirt rips

- ❖ We should look at the tarps once the corrals are taken out.
- ❖ We can clean and repair them for next year.



Broken zip ties

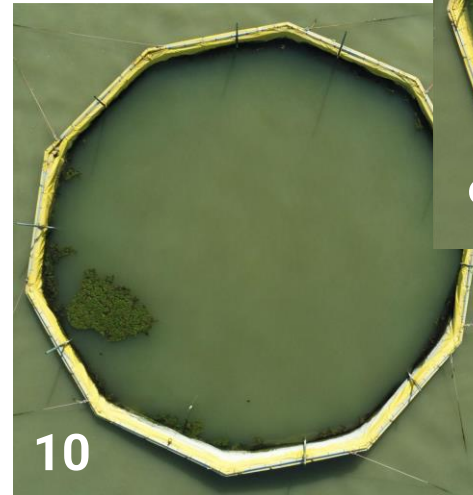
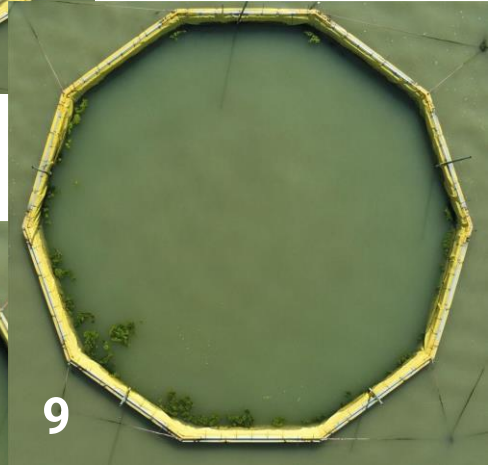
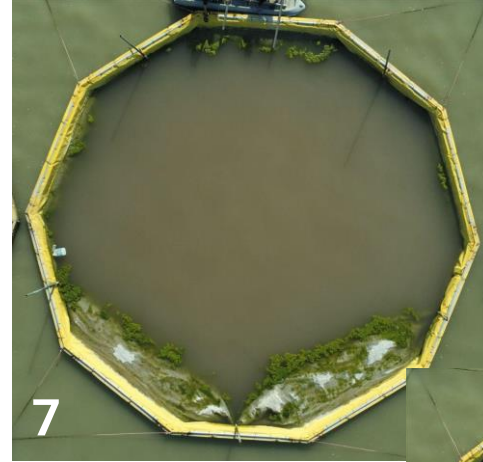
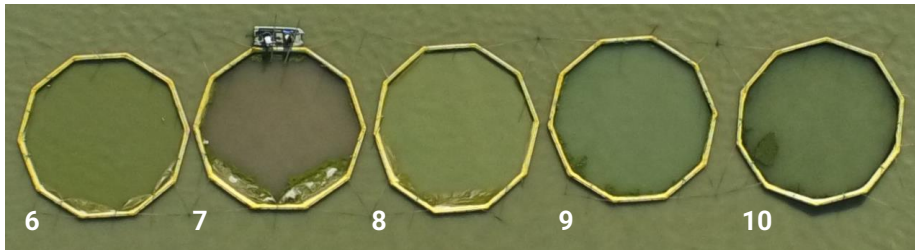


Loose screw

# Algae in the corrals

- Algal growth in the corrals increased over the summer, at its highest right now
- 7 is pink (no rhodamine)
- Corrals with algae are clearer

Corral	6	7	8	9	10
9/8/2022 Secchi Depth (cm)	8	20	8	16	23

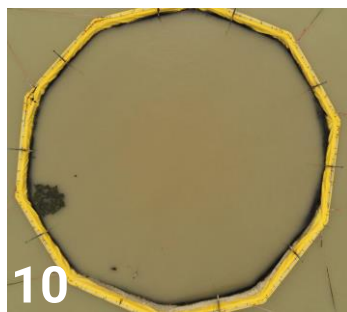


Pictures taken  
9/8/2022

# Current State of Corrals

- Sampling crew got stuck multiple times heading out of the marina
- Algae has changed since last week
  - Corral 7 - less algae
  - Corral 9 - a little more algae
  - Corral 10 - algae has turned brownish-purple

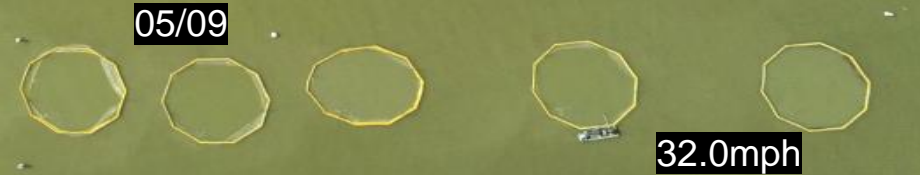
Location	Depth
Marina dock	1' 3"
Marina	8"
Corral 6	1' 8" in
Corral 7	2' 4" in
Corral 8	1' 3" in
Corral 9	2' 8" in
Corral 10	2' 9" in
Lake DW	2' 5" in

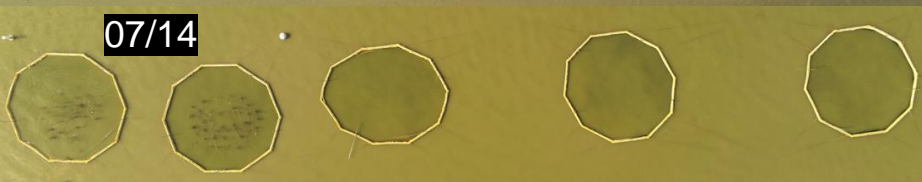


# Limnocorral Timelapse

- ★ All corrals were structurally sound
- ★ Observed different algal growth throughout sampling season
- ★ Stopped doing SW samples due to drop in water level

# Shallow Corrals







# Deep Corrals

06/07



06/20



06/08



06/21



06/09



06/23



06/10



06/27



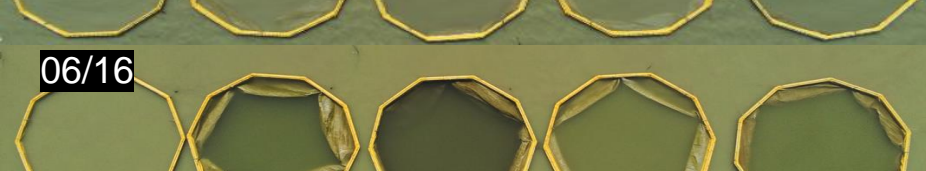
06/14



06/29



06/16



07/01



07/06



07/19



07/07



07/21



07/11



07/25



07/12



07/28



07/14



08/10



07/18



08/16



08/30



09/08



09/14



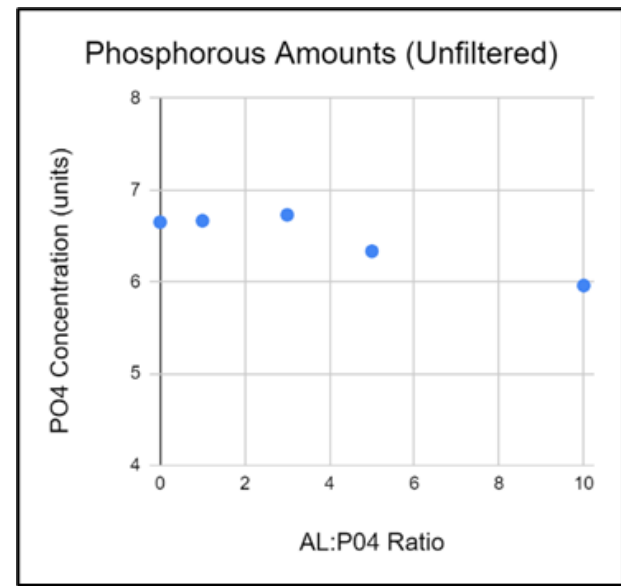
# Experiments

- Aluminum Dosing
  - 8/9/2022
- Phosphorus Addition (x2)
  - 8/3/2022
  - 8/17/2022
- Rhodamine
  - 6/8/2022
  - 8/3/2022
  - 8/9/2022
- Corral stirring
  - 8/24/2022
- Whole-lake sampling
  - 9/6/2022
- Serial Filtration
  - 7/15/2022
- Mesh bottom



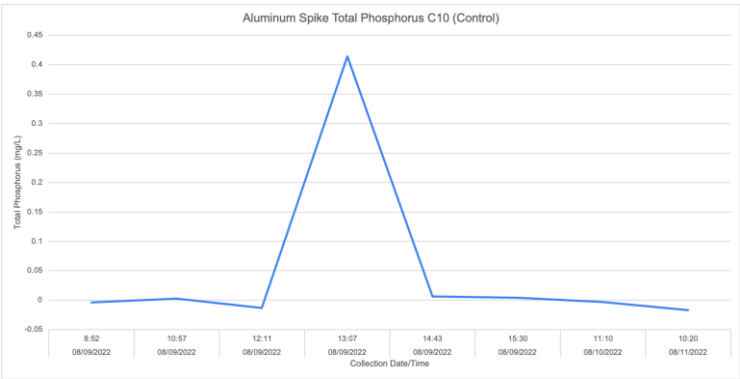
# Aluminum dosing

- Jar test
  - Tested Al:P ratios 1,2,3,5 and a control
  - 150 ml of lake water treated with lugol's was dosed with the appropriate amount for the ratio. Then each flask was shaken on the shaker table for 30 minutes. The flocs started to form and sank to the bottom of the flask, we took the samples from the top of the water,
  - We determined a 4:1 Al:P ratio would be best for dosing the corrals
- 166.4 ml of Aluminum Solution and 10 ml of Rhodamine in a 2 gallon fertilizer sprayer filled with DI water, was sprayed into corral 7
- Mixed for approximately 15-20 minutes
- Water samples were taken ever hour after initial dose and dosed with 3 ml of Lugols, single point probe readings were also taken every hour on the first day. One water sample and one probe reading were taken for 2 days after
- A strange foam formed while we were spraying

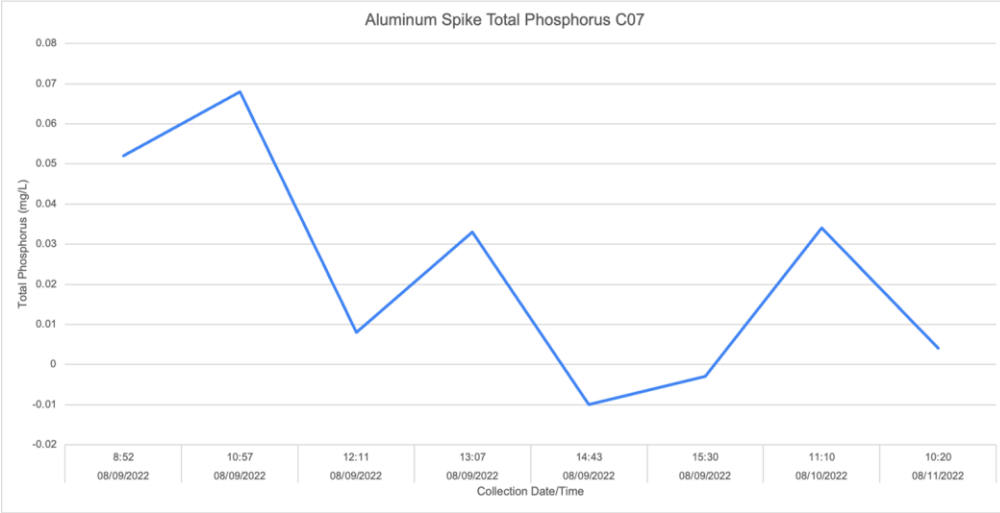
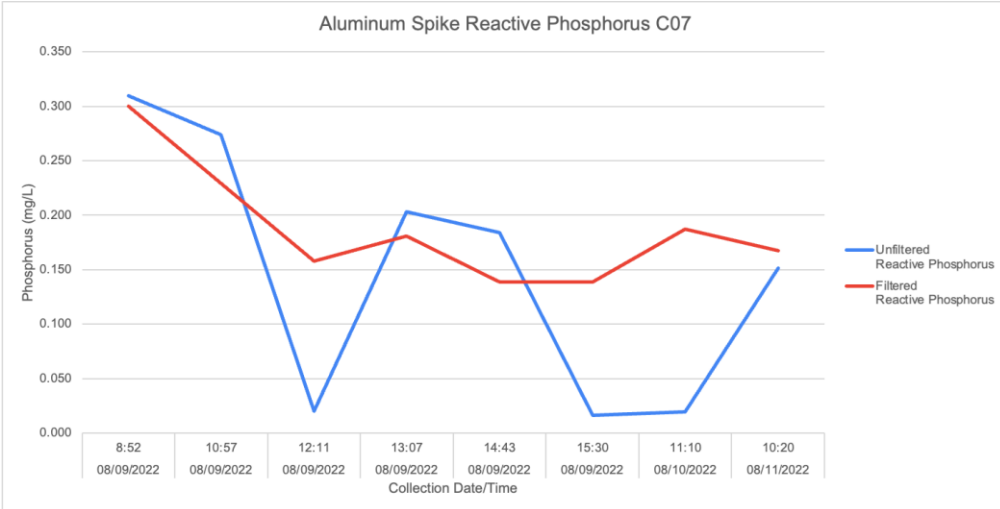


# Aluminum Dosing Lab Results

- Lugol's Solution (Iodine) may have interfered with total phosphorus results



- All QC and control corral results looked normal, except for one high outlier for total phosphorus
- All reactive phosphorus results had to be divided by a factor of 3, since the kits used measured PO4 instead of PO4-P



# Phosphorus Spike

- Hypothesis: Utah Lake sediment and water column act as a buffer system that maintains consistent phosphate concentrations in the water column.
- Bench-Scale Test
  - Tested action of phosphate added to lakewater and DI water when shaken with sediment at a consistent temperature. We examined two factors in this process:
    - Concentration of phosphate
    - Duration of exposure to soil
  - Our results indicated the action of processes other than the sorption of excess P to solids and P precipitation into lakebed sediments. Potential actors that will need to be accounted for include Iron that could interact with the excess P.

Table 1: Treated lake water bench-scale experimental treatments

Flask #	Soil added (g)	Fertilizer added (g)	Phosphate added (g)	Water volume treated (mL)	Concentration (ppm)	Time Shaken (hrs)
1A	50	None	None	200	0.09736*	1
2A	50	0.005	0.00241	200	9.736*	1
3A	50	0.053	0.02432	200	97.36*	1
4A	50	None	None	200	0.09736*	24
5A	50	0.005	0.00241	200	9.736*	24
6A	50	0.053	0.02432	200	97.36*	24

\*Estimates based on baseline lake phosphate concentration determined by past ICP data for corral 7 – more exact values to be determined before and after shaking

Table 2: Treated DI water bench-scale experimental treatments

Flask #	Soil added (g)	Fertilizer added (g)	Phosphate added (g)	Water volume treated (mL)	Concentration (ppm)	Time Shaken (hrs)
1B	50	None	None	200	0	1
2B	50	0.005	0.00243	200	9.736	1
3B	50	0.053	0.0243	200	97.36	1
4B	50	None	None	200	0	24
5B	50	0.005	0.00243	200	9.736	24
6B	50	0.053	0.0243	200	97.36	24

Table 3: Untreated lake water bench-scale experimental concentrations

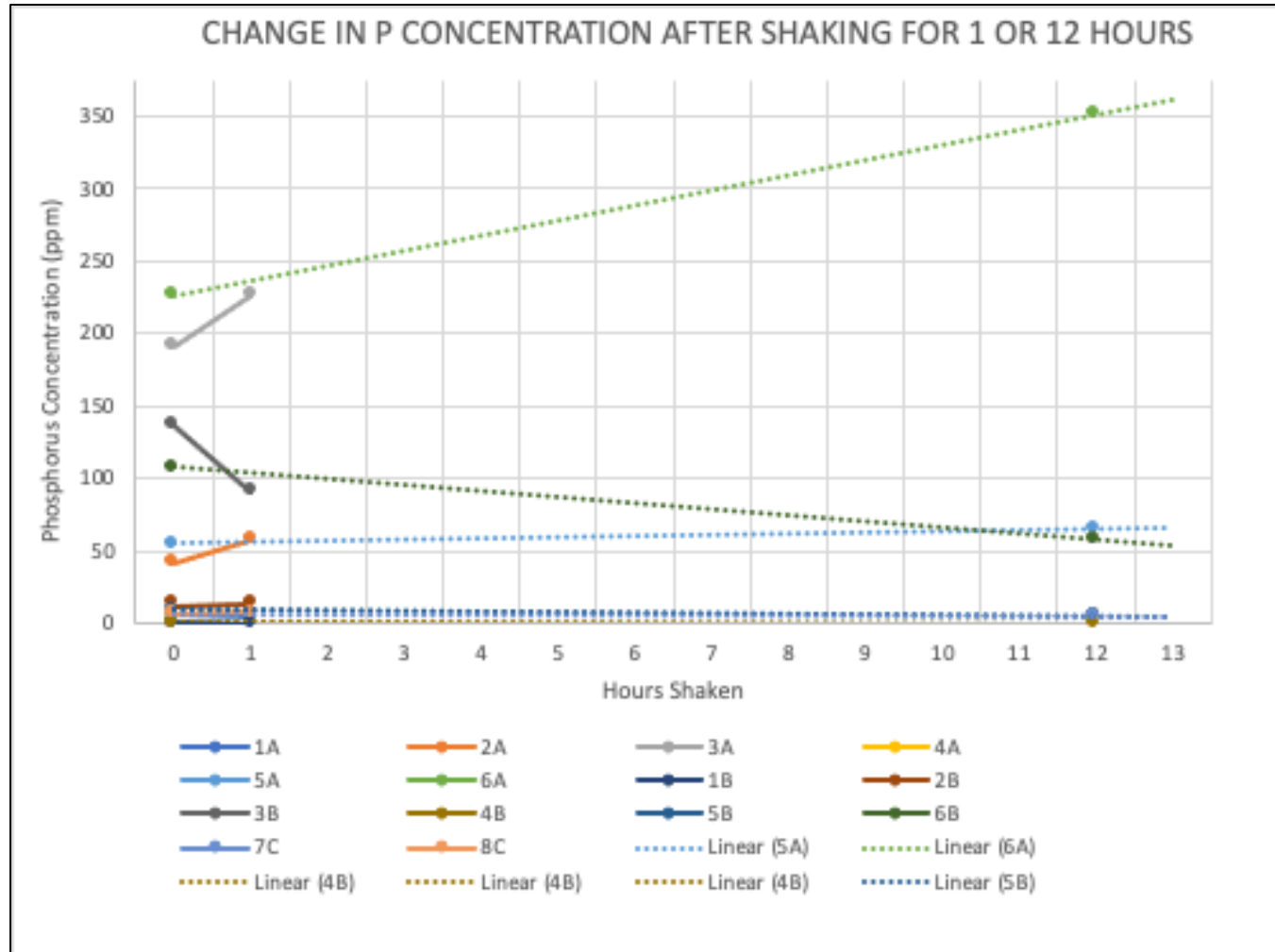
Flask #	Soil added (g)	Fertilizer added (g)	Phosphate added (g)	Water volume (mL)	Concentration (ppm)	Time Shaken (hrs)
1	0	None	None	200	Unknown	1
2	--	--	--	--	--	--
3	--	--	--	--	--	--
4	0	None	None	200	Unknown	24
5	--	--	--	--	--	--
6	--	--	--	--	--	--

# P-Spike Bench-Scale Results

We expected to see a decline in P concentration in all lakewater (A) samples except for 1 & 4, which would remain constant. Instead, we saw an increase in 2 & 5 and in 3 & 6, with a higher increase in the higher-dosed flasks.

We expected to see a decline in P concentration in all DI (B) samples except for 1 & 4, which would increase, but instead we saw relative stability in 1 & 4, and subtle increase in 2 & 5.

Interestingly, for all flasks, those with the same P concentration and type of water increased or decreased together whether shaken for 1 hour or 12 hours. We must develop further tests to understand this phenomenon.



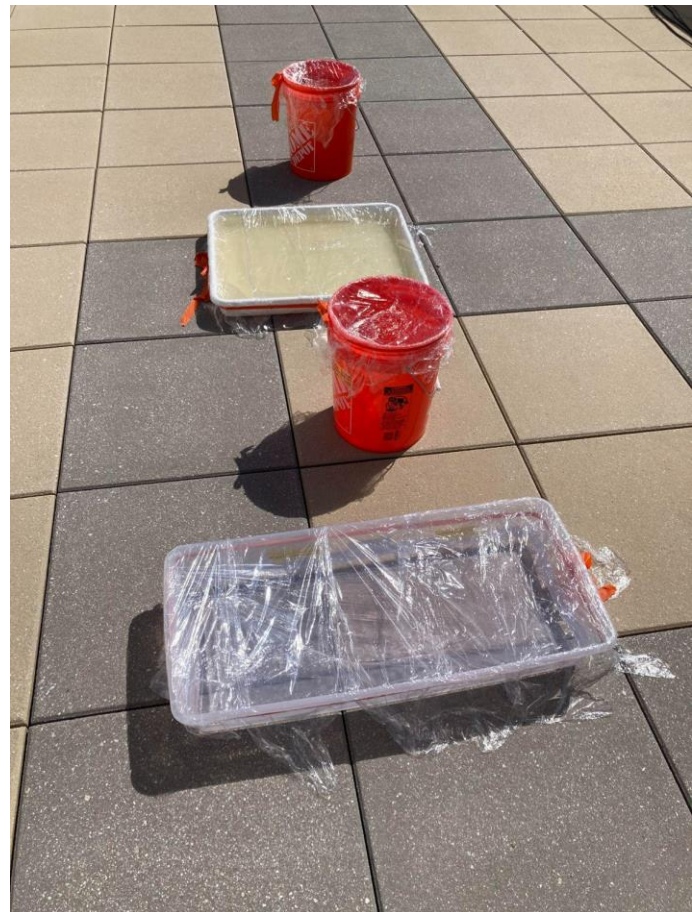
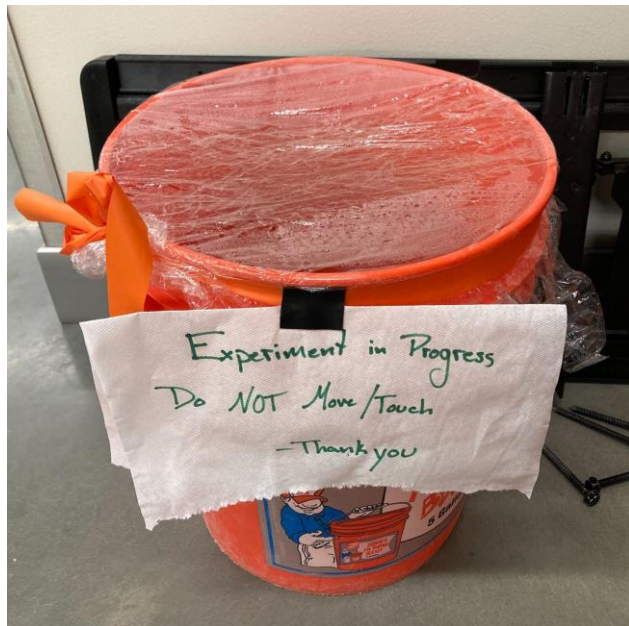
# Phosphorus Spike

- Hypothesis: Utah Lake sediment and water column act as a buffer system that maintains consistent phosphate concentrations in the water column.
- Field Test
  - We dosed lakewater in corral 7 with Phosphate and took hourly .5 L samples for one day after, then frequent samples for the next 2 days. We dosed all samples with 4 mL Lugol's Iodine solution to prevent further algal growth that could alter our results after sample collection
  - Based on averaging measured Phosphorus levels in corral 7, we determined that usual P levels are about .097 ppm. We chose to dose the corral with enough Phosphate to artificially increase the concentration by two orders of magnitude (to 10mg/L).
    - We added 1500g of 46% P fertilizer, dissolved in about 6 L water
  - We used corral 10, which has comparable background P concentrations to corral 7, as a control.
  - Our samples and data are currently mid-analysis, but some preliminary results indicate that Phosphorus reacts with Iodine during heat-involving testing. In the future, we may need to adjust our sampling methods to limit algal growth without the use of Iodine.

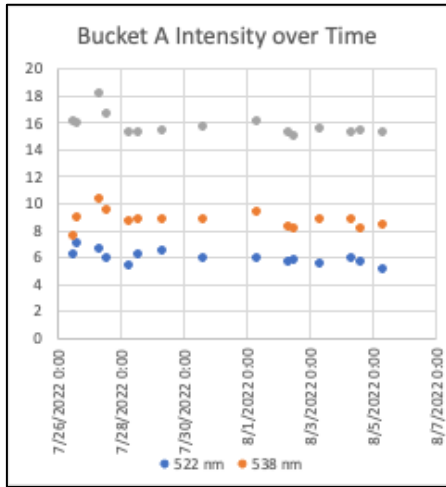
# Rhodamine Bench-Scale Tests

- Purpose: Understand the rate of rhodamine degradation by sunlight for application to our study on the rate of movement of water through the limnocorrals as demonstrated by the movement of rhodamine.
- Bench-Scale Tests
  - We conducted several bench-scale tests by dosing buckets of water with sufficient rhodamine to create an identical concentration of rhodamine in the buckets as in the dosed corrals.
  - We collected samples from the buckets twice daily and ran them on the fluorometer as we did with the lake samples.
  - We used these data to understand the potential depletion rate of rhodamine in response to sunlight exposure. In all of our bench-scale tests, each bucket was paired, so one was protected from light exposure in the basement, and the other was exposed to full sunlight on the roof.
  - We found that rhodamine does decline in concentration in response to direct sunlight in both lakewater, tap water, and DI water.
  - We are currently working to quantify and apply this decline to our field data to gain an accurate estimate of rhodamine depletion in the corrals due to movement of the water through the corral.

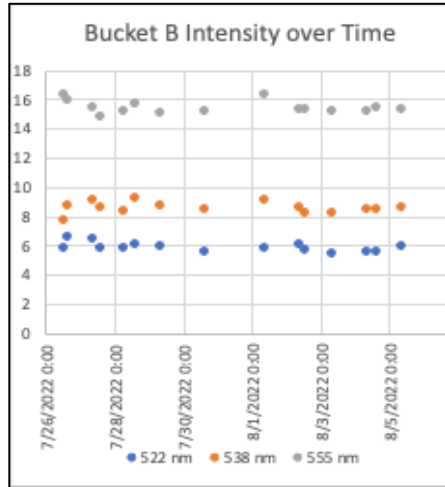
# Rhodamine Bench-Scale Tests



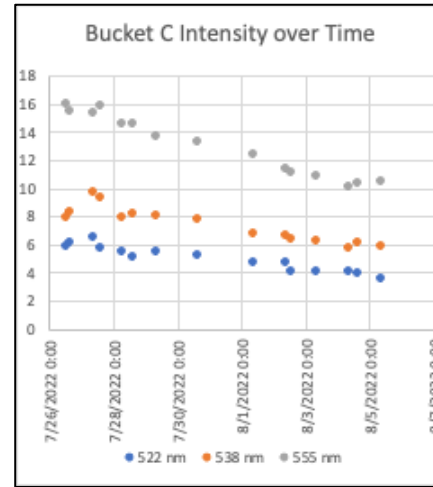
# Rhodamine Bench-Scale Tests (tap water)



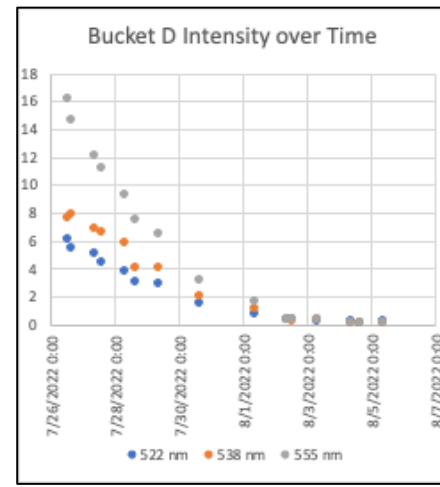
The intensity measured by the fluorometer stayed nearly constant in Bucket A, indicating that the rhodamine concentration did not decline during the experimental period. Bucket A is a covered bucket in the basement. These data do not contradict our prediction that rhodamine degrades in response to sunlight.



The intensity measured by the fluorometer stayed nearly constant in Bucket B, indicating that the rhodamine concentration did not decline during the experimental period. Bucket B is a covered bucket in the basement. These data do not contradict our prediction that rhodamine degrades in response to sunlight.



The intensity measured by the fluorometer declined in Bucket C, indicating that the rhodamine concentration declined during the experimental period. Bucket C is a bucket apparatus on the roof. These results are consistent with our prediction that rhodamine degrades in response to sunlight.



The intensity declined rapidly in Bucket D, indicating that the rhodamine concentration declined rapidly during the experimental period. Bucket D is a shallow tray on the roof. These data are consistent with our predictions that rhodamine degrades in response to sunlight, and that the tray apparatus would display quicker degradation of rhodamine, likely due to increased sun exposure.

# Rhodamine Field Experiment

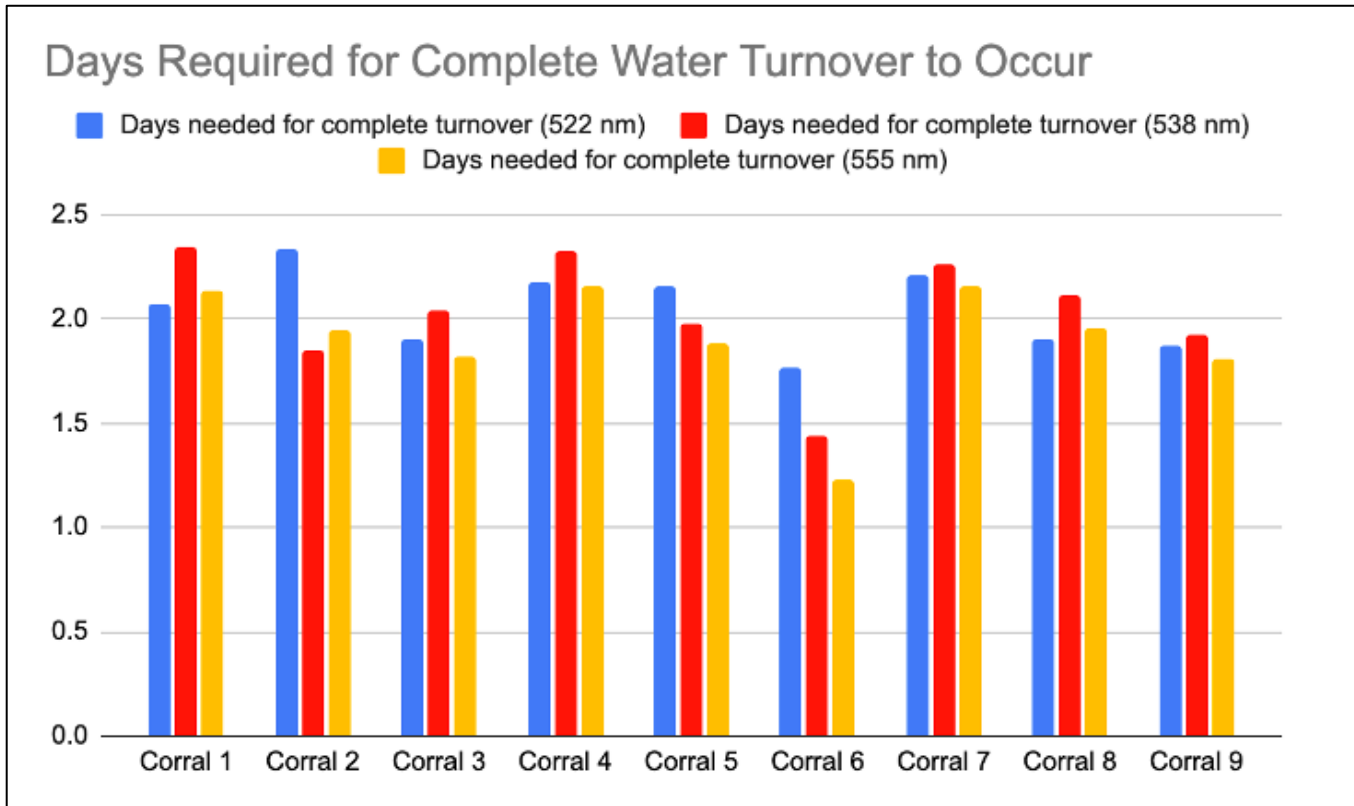
- Purpose: Understand the rate of water turnover in limnocorrals as demonstrated by the movement of rhodamine dye.
- Field Experiment
  - We sprayed 10 mL of rhodamine dye, diluted in 2 gallons of water, over the surface of each limnocorral. We took frequent samples of the water from the corrals over the course of 2 weeks and stored the samples in a cool, dark fridge.
  - We measured the amount of rhodamine present in each sample with a fluorometer and compared the rate of decline in measured intensity with our previously developed calibration curves based on known rhodamine concentrations.
  - We found that on average, corral water turnover occurs in two days. We recently replicated our experiment and are analyzing those data as well, and must account for our bench-scale data on sunlight depletion, so this number may change.

# Rhodamine Field Tests

**Table 3 Flow Rate in each corral based on three data sets collected at wavelengths of 522nm, 538 nm, and 555 nm.**

	<b>Flow rate (522) L/hr</b>	<b>Flow rate (538) L/hr</b>	<b>Flow rate (555) L/hr</b>
Corral 1	4030.574464	3555.523552	3903.757225
Corral 2	3565.44431	4515.539971	4286.281902
Corral 3	4392.15391	4085.538473	4586.210096
Corral 4	3829.219283	3580.302417	3869.145511
Corral 5	3859.355987	4207.681093	4425.504316
Corral 6	4713.327611	5802.184977	6790.916814
Corral 7	3775.222552	3682.553996	3864.784309
Corral 8	4386.430086	3937.569055	4263.845084
Corral 9	4447.710253	4328.408695	4608.747838

# Rhodamine Field Tests



# Corral Stirring Turbidity Experiment

8/24/22 10 am



8/24/22 12 pm



22 cm (v)

23 cm (v)

30 cm (v)

24 cm

23 cm

8/25/22 10 am



21 cm

18 cm

20 cm

19.5 cm

18 cm

08/25/22 5 pm



7.4 cm (v)

8.5 cm (v)

11 cm

9 cm

10.5 cm

8/26/22 10 am



11.5 cm

12 cm

12 cm

8.5 cm

10.5 cm

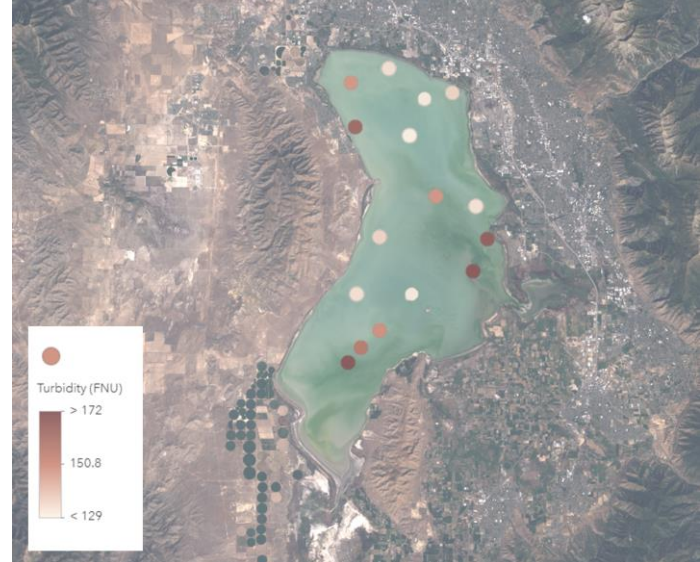
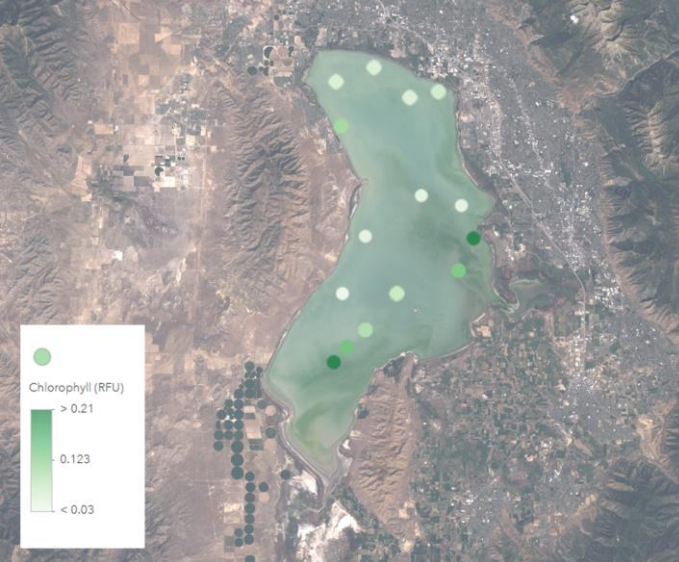
# Whole-lake sampling

## Methods

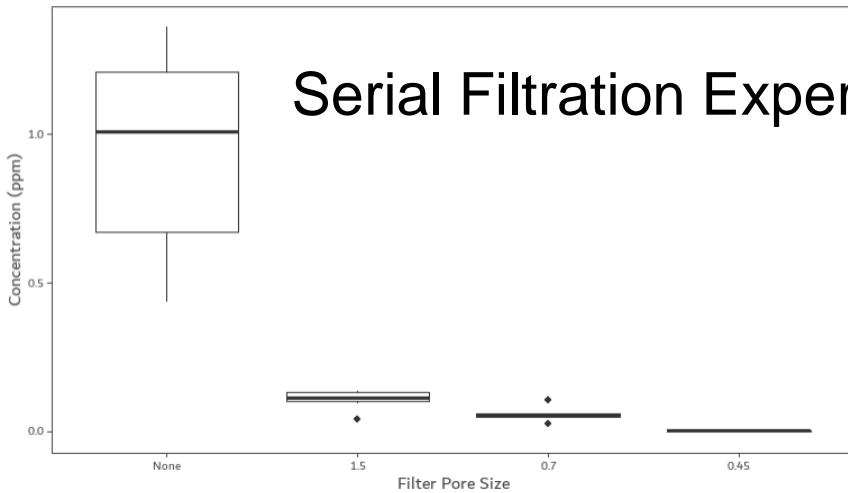
- 8:30am-5pm, Landsat overpass occurred at 10:30
- Collected single-point probe readings, multispectral drone images, sediment samples, and secchi readings

## Preliminary Observations

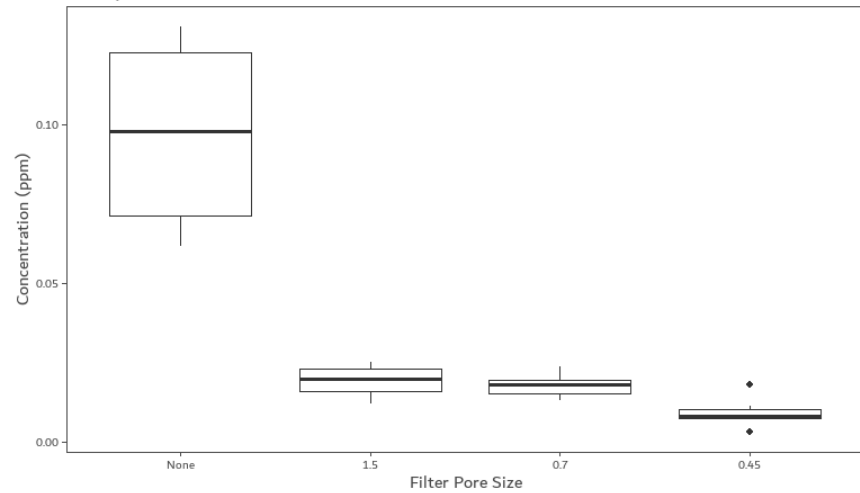
- Large blooms at south end of lake and flowing out of Provo Bay
- Depth at center of lake was a little over 2 meters
- Significant variability in several parameters



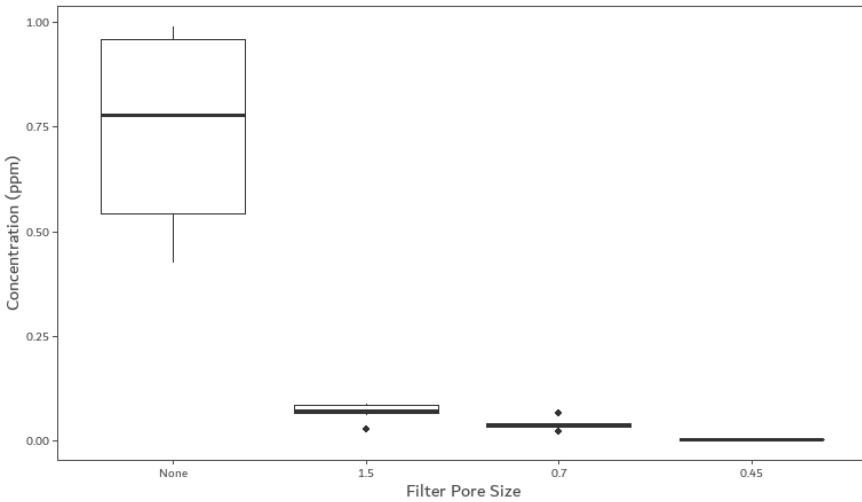
Aluminum



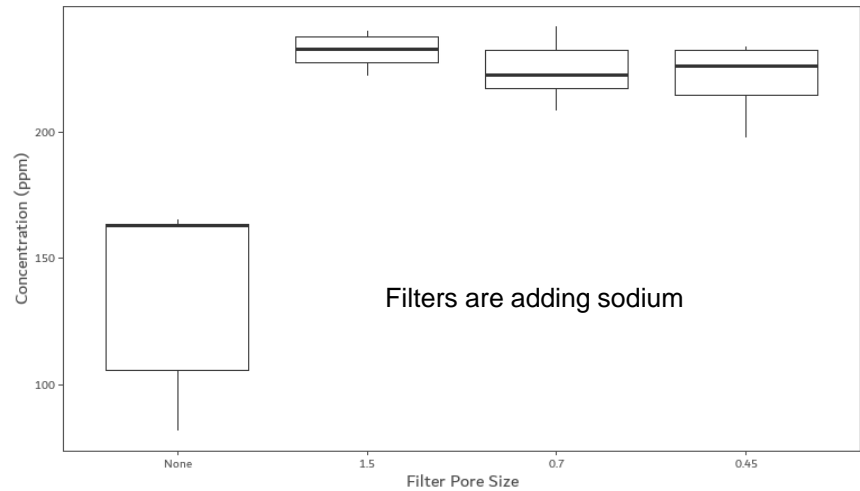
Phosphorus



Iron



Sodium



# Data tracks

- Probes were put in the water taking a measurement every 10 seconds
- We drove a specific route around the corrals
- Generic background image -- not taken on the day of data collection





# Next Year Experiments

- ❖ Phosphorus Spike -Becca
- ❖ Light Limitation
  - Alginator in Corrals
  - PAR Measurements in the Corrals
- ❖ Baseline Samples
  - Water Samples
  - Single Point Probe
  - Vertical Profile Probe
  - Drone Photos
- ❖ Aluminum Dosing?
- ❖ Sediment Phosphorus Flux (not currently part of project)

# Proposed Papers

- Light limitation of algal growth in Utah Lake--data from PAR and field tests
- Metals in Utah Lake
- Utah Lake as a buffered system for phosphorus sorption
- Analysis of multispectral drone imagery of Utah Lake and limnocorrals
- Analysis of settling rates in corals using multispectral drone imagery
- Potential for addition of fresh aluminum to sequester phosphorus from Utah Lake
- Nutrients in Utah Lake (2021 Lake data)
- Weather correlations with nutrients and turbidity in Utah Lake

# Data Analysis



# Principal Components

Parameter <chr>	PC1 <dbl>
Ca3179-D	-0.2172954745
pH	0.2070871415
Ba4554-D	-0.2070073716
Pb2203-D	-0.1949095720
Ti3088-D	-0.1829675564
Sr4077-D	-0.1810465243
ug/L_pc	0.1741835728
Mn2576-D	-0.1721793597
rfu_pc	0.1719452933
Al1670-D	-0.1702327598

Parameter <chr>	PC2 <dbl>
Sr4077-F	0.2452812444
Mg2852-F	0.2385987466
V_3093-F	0.2382515973
S_1820-F	0.2197872667
K_7664-F	0.2189829750
Na5895-F	0.2110652430
B_2497-F	0.2069650174
cond.y	0.2016959556
temp.x	0.2011699147
avg_temp...101	0.2009927347

Parameter <chr>	PC3 <dbl>
cond.x	0.249891527
sp_cond.x	0.249442120
tds.x	0.249442061
sal.x	0.246194901
resistivity.x	-0.234955819
filtered_toc	-0.210307022
max_temp	-0.206344397
V_3093-D	0.187645492
tss	0.180582825
Zn2138-D	-0.178871607

Parameter <chr>	PC4 <dbl>
P-1782-D	0.3264312223
P_1782-F	0.2873906675
rfu_chla	0.2747155262
ug/L_chla	0.2731868834
ammonia	0.2524435100
cod	0.2483760802
total_P	0.2469529678
rfu_pc	0.2091698068
unfiltered_toc	0.2089302834
ug/L_pc	0.2044124271

Parameter <chr>	PC7 <dbl>
Cu3247-D	0.3932155739
Ni2316-D	0.3755705937
Zn2138-F	-0.2973480401
Fe2382-D	0.2733886060
Mn2576-F	-0.2140667149
Al1670-F	-0.2064112427
Mn2576-D	0.1722240640
nitrite	-0.1568731240
B_2497-D	-0.1546310103
Ni2316-F	-0.1545495788