Utah Lake Water Quality Study
Science Panel Meeting
July 9, 2019
Salt Lake City, UT

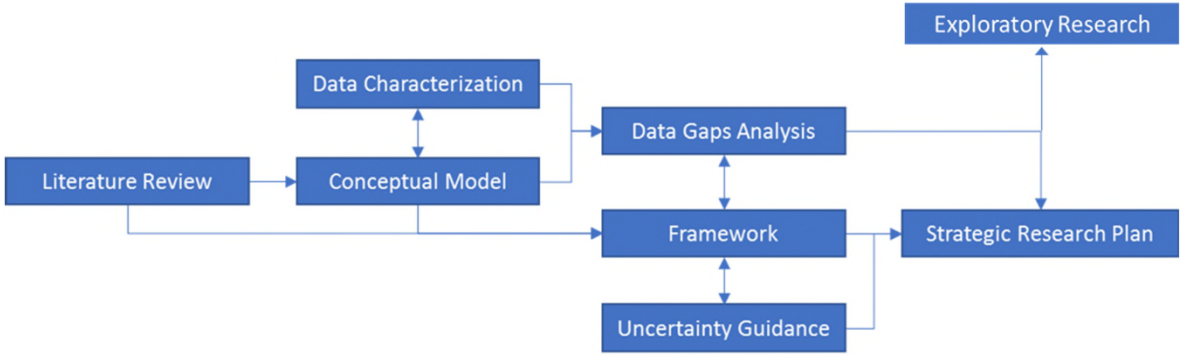
# Project team updates

Utah Lake Nutrient Criteria Development Technical Support

UTAH DEPARTMENT of ENVIRONMENTAL QUALITY

# Framework

- "develop a scientifically defensible approach for water quality criteria development"



# Framework

- Developing
- Overview and Background
  - Review
  - Conceptual Model
  - Data Characterization
  - Uncertainty
- Approach
  - Developing lines
  - Combining lines
  - Recommending values
  - Communicating

**Utah Lake Water Quality Study—Numeric Nutrient Criteria Technical Framework**

[DATE], 2019

**PRESENTED TO**

**Utah Department of Environmental Quality**
**Division of Water Quality**
PO Box 144870
Salt Lake City, UT 84114

**PREPARED BY**

**Tetra Tech**
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Cleveland, OH 44113

# Framework

- Approach:
  - Essentially lays out how the number will be derived
  - Lines of evidence,
    - How they are derived;
    - How they'll be combined into recommendation;
  - How uncertainty will be communicated
  - How the whole process will be communicated

# Framework

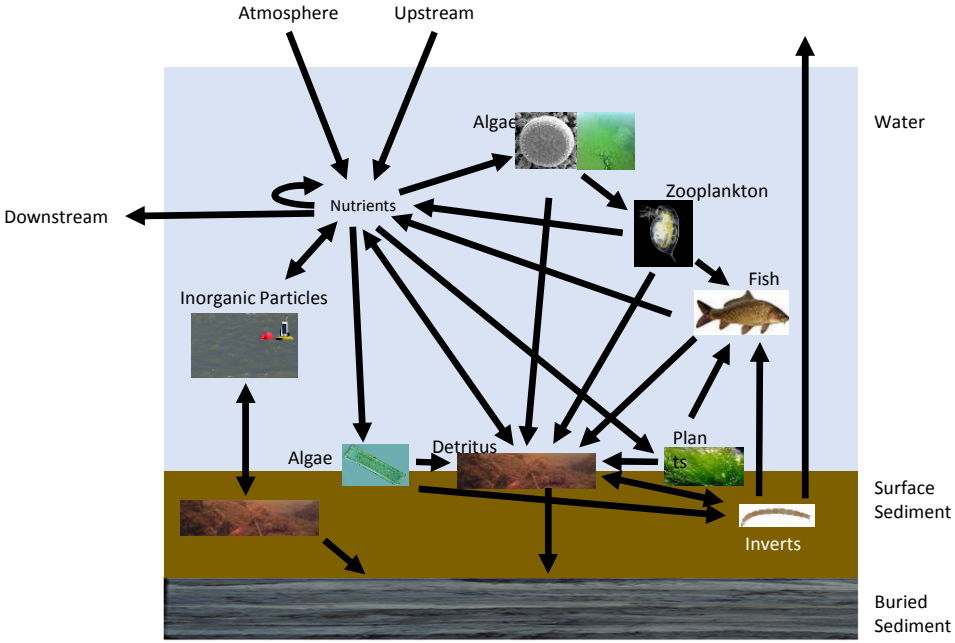
- Next Steps
  - Continue working on draft
  - Send out working draft in August

# Conceptual Models

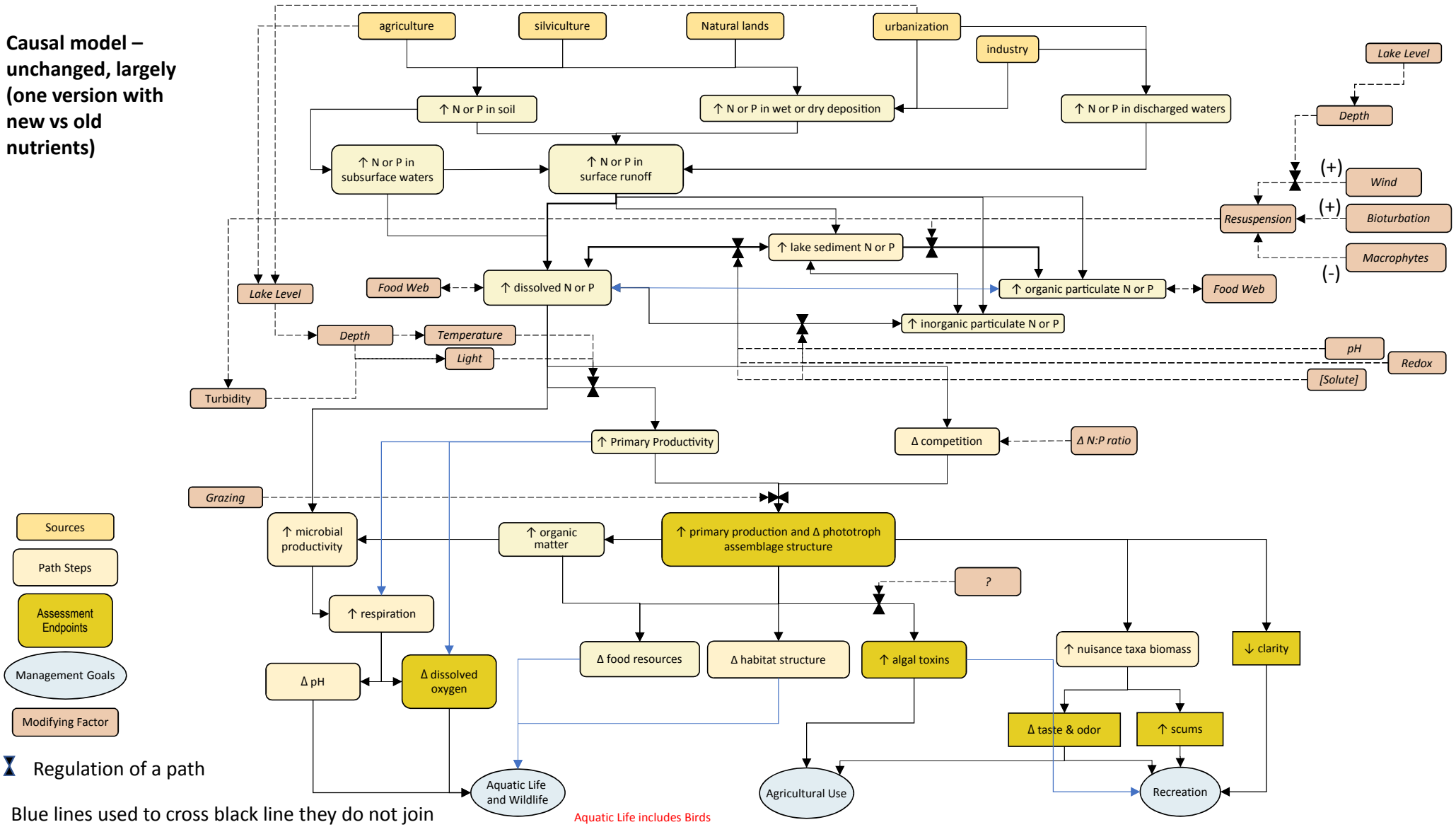
- Narrative sent out
  - Final models with description
  - Describes major pathways of each model
  - Language tailored to intended audience (for most part)
- Any feedback welcome –
  - Tried to address all of Mike's comments/questions

- Deadline for comments?

Simplified - unchanged

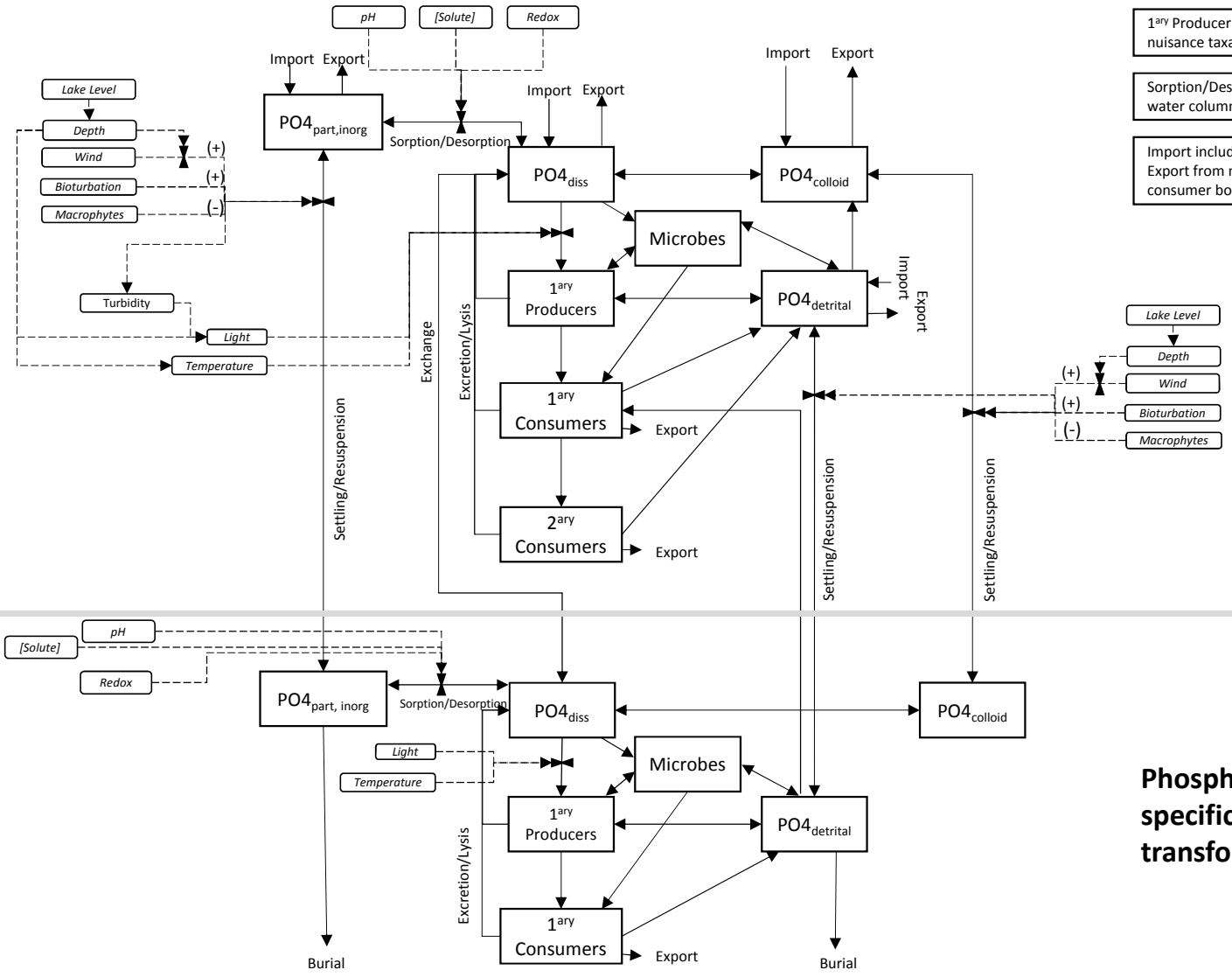


**Causal model – unchanged, largely (one version with new vs old nutrients)**




Blue lines used to cross black line they do not join

Aquatic Life includes Birds

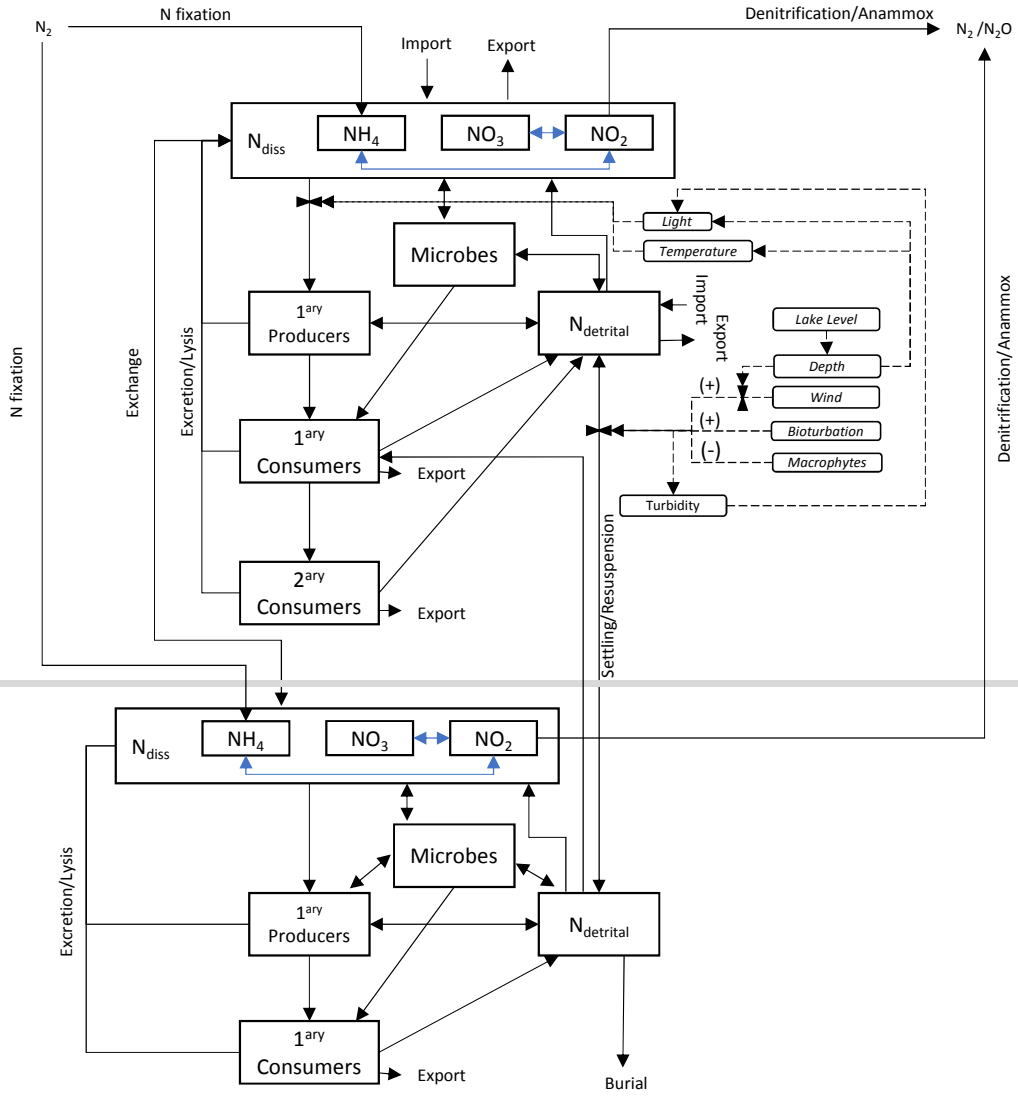



1ary Producer responses included shifts in species composition including to nuisance taxa (from competitive shifts) as well as increased biomass.

Sorption/Desorption includes calcite scavenging of dissolved P from the water column influenced by pH, etc.

Import includes tributary as well as atmospheric wet and dry deposition; Export from nutrient pools is largely downstream transport; Export from consumer boxes is emergence/harvest.

**Phosphorus model – beefed up specificity, external effects, transformations**



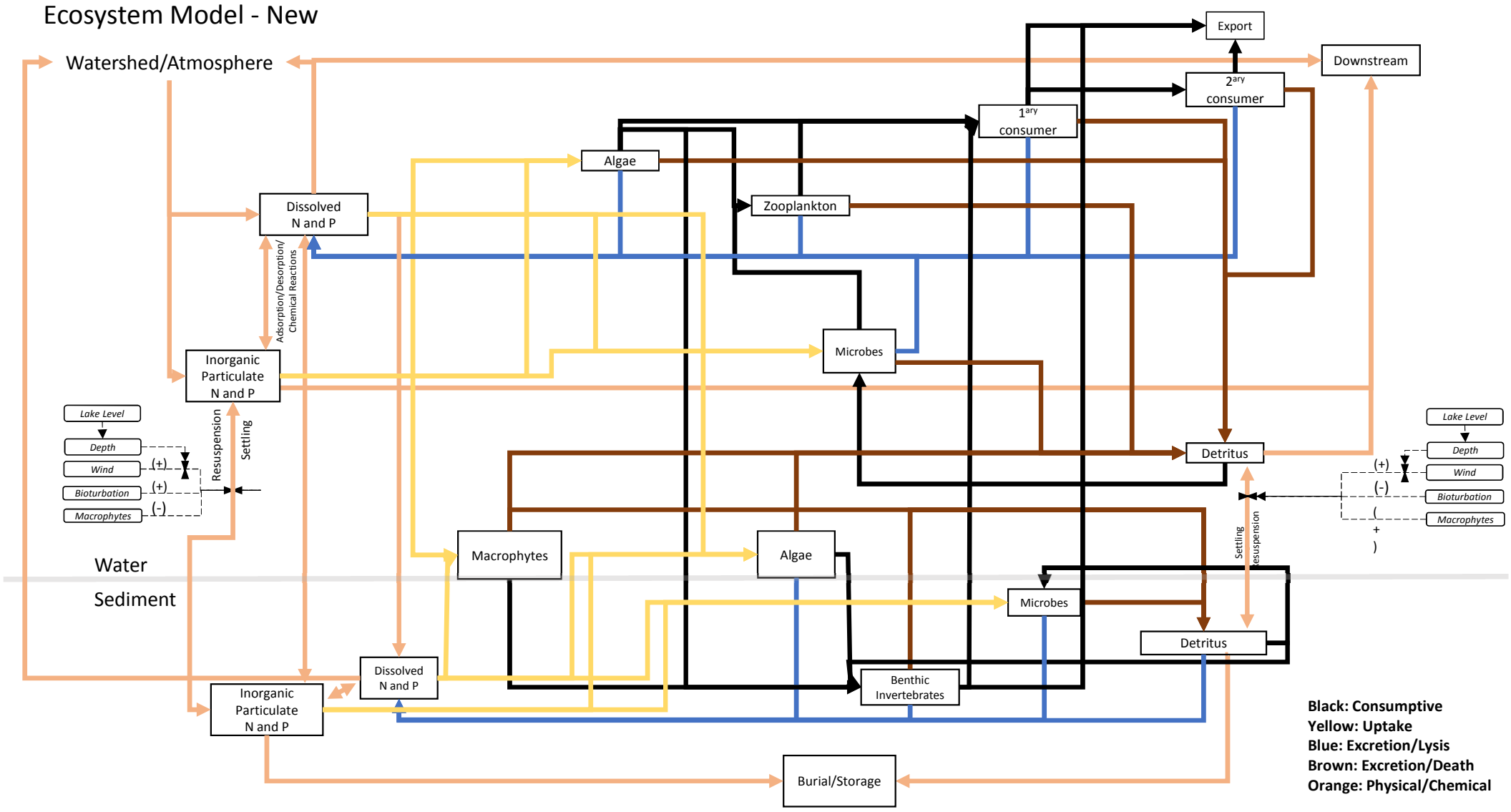

1ary Producer responses included shifts in species composition including to nuisance taxa (from competitive shifts) as well as increased biomass.

Blue arrows in $N_{diss}$ include several microbially mediated N transformations.

Import includes tributary as well as atmospheric wet and dry deposition; Export from nutrient pools is largely downstream transport; Export from consumer boxes is emergence/harvest.

Reactions within the $N_{diss}$ box including nitrification (ammonium oxidation and nitrite oxidation) and nitrate/nitrite reduction

**Nitrogen model – beefed up specificity, external effects, transformations**


Ecosystem Model - New
Watershed/Atmosphere
Export
Downstream
2ary consumer
1ary consumer
Algae
Zooplankton
Dissolved N and P
Adsorption/Desorption/ Chemical Reactions
Microbes
Inorganic Particulate N and P
Lake Level
Depth
Wind
Bioturbation
Macrophytes
(+)
(+)
(-)
Resuspension
Settling
Detritus
Water
Sediment
Macrophytes
Algae
Microbes
Detritus
Benthic Invertebrates
Dissolved N and P
Inorganic Particulate N and P
Burial/Storage
Black: Consumptive
Yellow: Uptake
Blue: Excretion/Lysis
Brown: Excretion/Death
Orange: Physical/Chemical

# Conceptual Models

- Next Steps:
  - Any Science Panel feedback?
  - We will look to finalize narratives and start incorporating models into framework and other documents.

# Data Characterization

- Scott and team sent data (1.3 GB)
  - Flow, Elevation, Meteorology
  - Chemistry, Sonde Data
  - Phytoplankton, HAB, Zooplankton, Macroinvertebrate, Fish
  - Wind
  - Shear Data
- Mark Fernandez and I continued implementing draft analysis plan
  - Any and all feedback always welcome
  - Major regret for my not being their in person
- Sent out midway analysis report on progress for you to review prior to meeting

# Data Analysis

- Eight Main Areas: Each tied to specific charge questions
  1. Carp excretion
  2. Algal cell count, and pigment relationships
  3. Sonde data analysis
  4. Plankton spatial and temporal analysis* (6 subareas)
  5. Diatom and macrophyte autecology
  6. Wind and turbidity
  7. Turbidity and macrophytes
  8. Light extinction

# Task 1. Carp Excretion

- Goal: Estimate potential excretion rates of carp
- Data:
  - Carp population density data
  - Excretion data (Mike Vanni excretion data – thanks to Ryan King)
- Methods:
  - Calculate excretion rate by size/individual, apply to population data

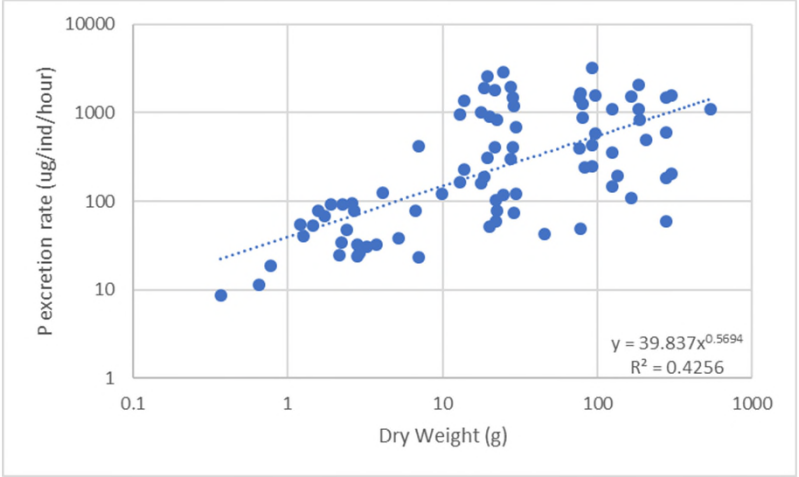
# Task 1. Carp Excretion

- Population Density
  - Pre-removal (SWCA 2005):
    - Population Size: 7.5 million adults (2+)
    - Average weight: 2.4 kg/ind (wet), 0.48 kg/ind (dry)
    - Total Biomass: 18m kg (wet), 3.6m kg (dry)

    - Younger carp: 100million (<2)
    - Ballpark size: 0.01 – 0.120 kg/ind (dry)

# Task 1. Carp Excretion

- Excretion
  - Mike Vanni dataset
    - *Cyprinus carpio*
    - 85 excretion estimates, developed curve
    - Multiplied by size estimates
    - Range:
      - Adults: 88,000 kg/y
      - Young: 129,000 to 532,000 kg/y
      - Total: 217,490 to 621,952 kg/y
    - 75 % reduction
      - Total: 54,373 to 155,238 kg/y



# Task 1. Carp Excretion

- Excretion
  - Mike Vanni dataset
    - 75 % reduction
      - Total: 54,373 to 155,238 kg/y
    - In context:
      - Total P inputs: 138,255 to 269,978 kg/y (Brett 2019, Merritt and Miller 2016, Psomas and SWCA 2007)
      - Carp excretion is from 20% to 112% of total inputs

# Task 1. Carp Excretion

- Questions:
  - Does this get us what we need?  If not, how do we get from this to estimating how much P is cycling through Carp?
  - And this is contribution to the budget via excretion, what about consumption, standing stock?
  - And how to attack the question of bioturbation?

# Task 2. Algal Cell Count and Pigment Relationship

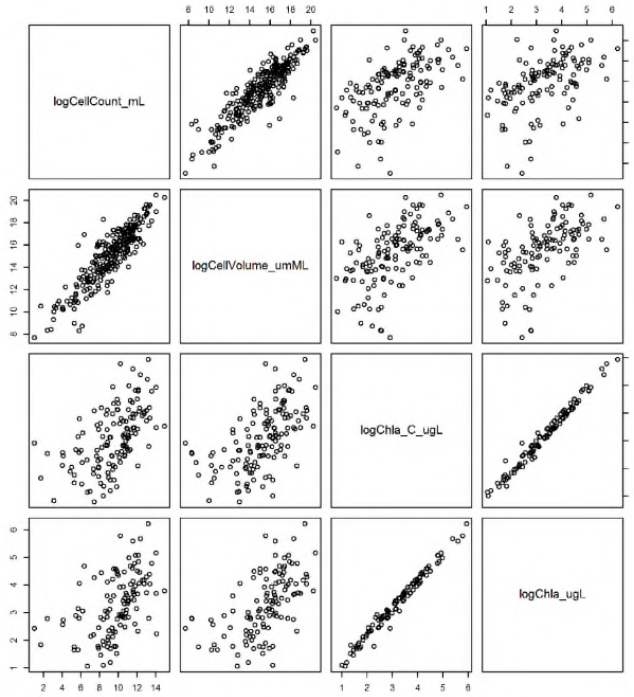
- Goal: Estimate relationships between cell count, biovolume, and pigment concentrations

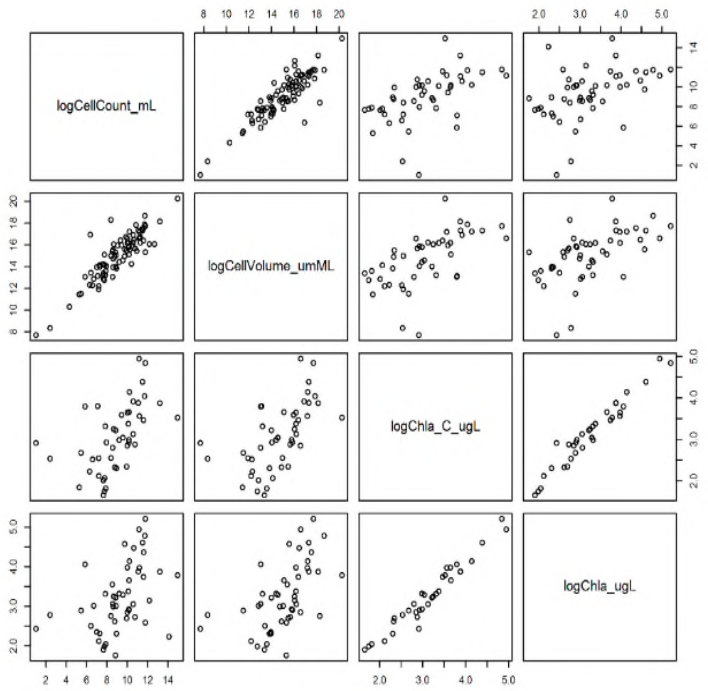
- Data:
  - Phytoplankton cell count and biovolume
  - Water quality chlorophyll a data (corrected and uncorrected – two methods)

- Methods:
  - Simple correlation/regression
  - Organized by grab (site-date), annual average (site-year), and long term averages run

# Task 2 Alaal Cell Count and Pigment Relationship

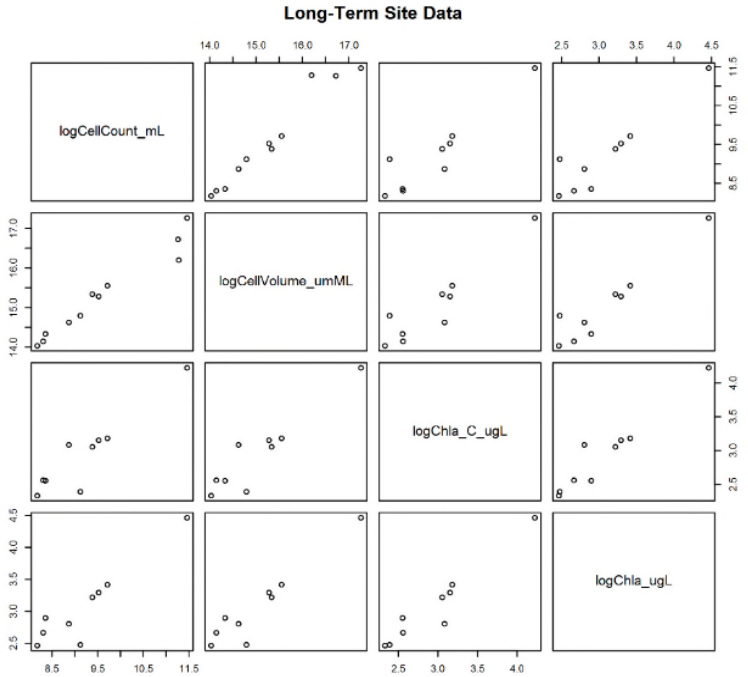
- Scatterplot
- Grab Data
  - Site-date (left)
  - Site-year (right)



# Task 2 Algal Cell Count and Pigment Relationship

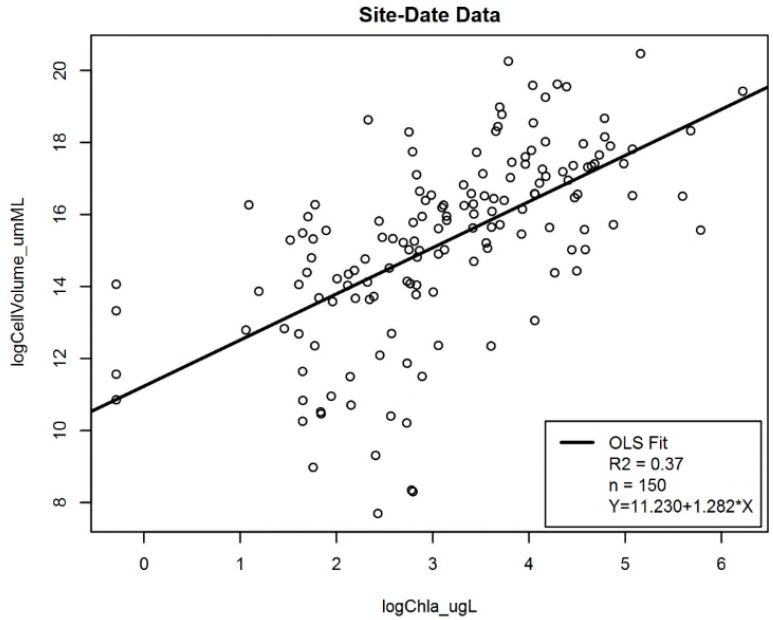
- Scatterplot
- Grab Data
  - Long-term averages



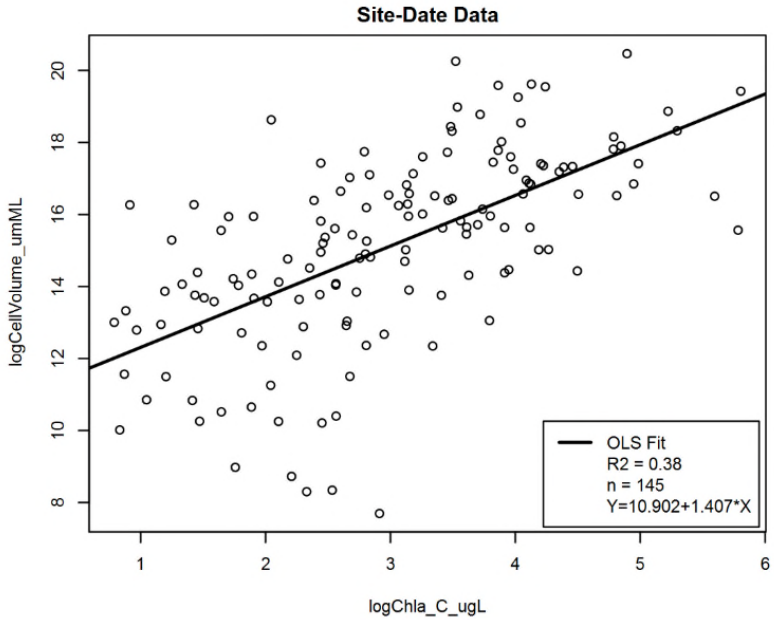
# Task 2. Algal Cell Count and Pigment Relationship

- Biovolume Results (grab):

Chl



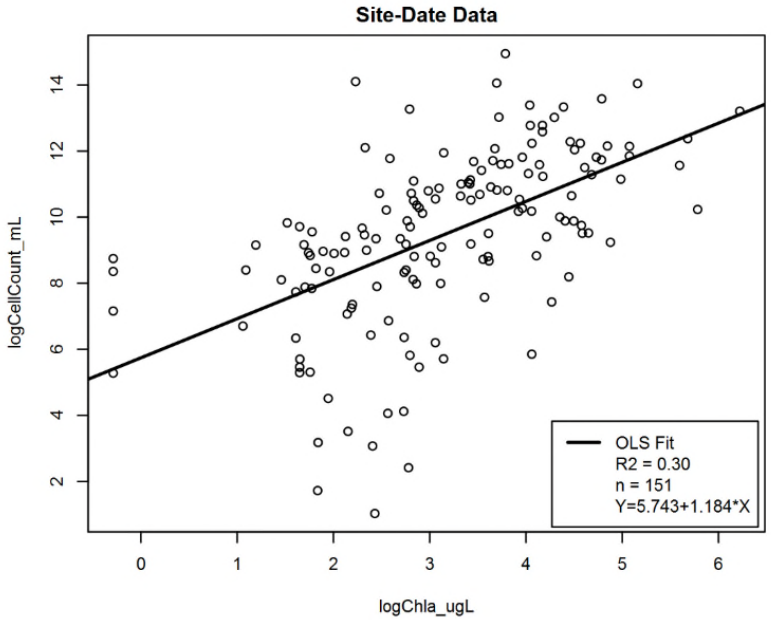

Corrected Chl



# Task 2. Algal Cell Count and Pigment Relationship

- Abundance Results (grab):

Chl

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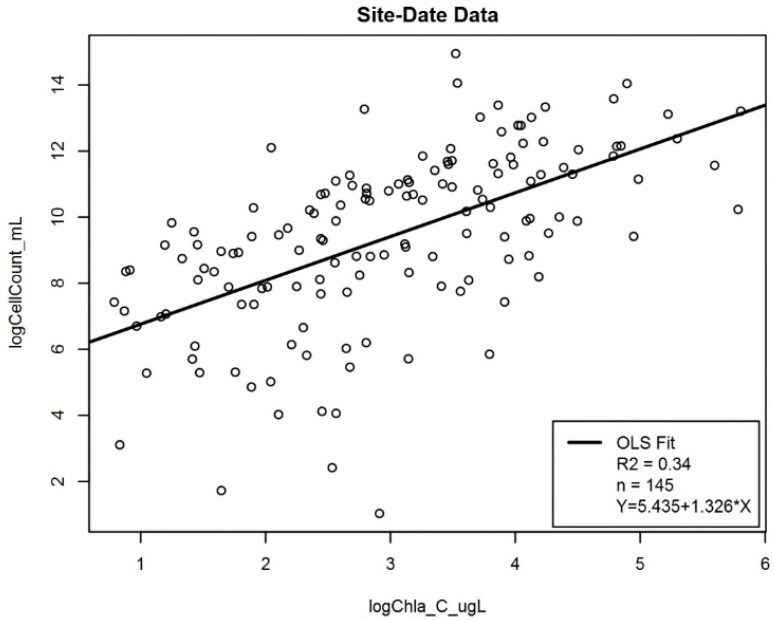
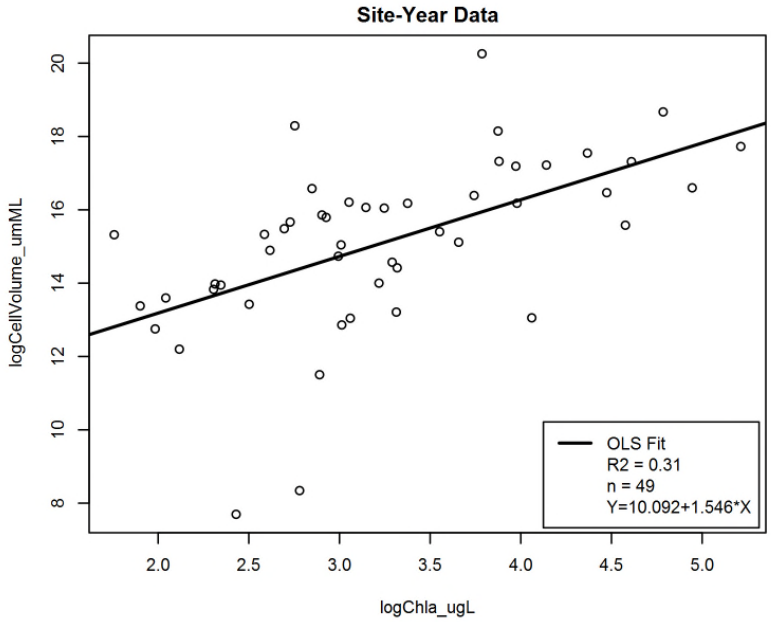


# Task 2. Algal Cell Count and Pigment Relationship

- Biovolume Results (annual):

Chl

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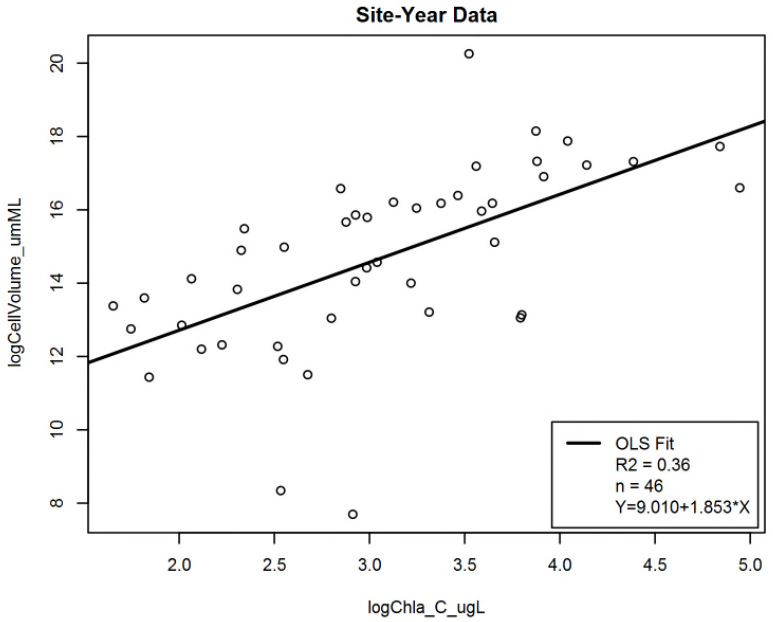
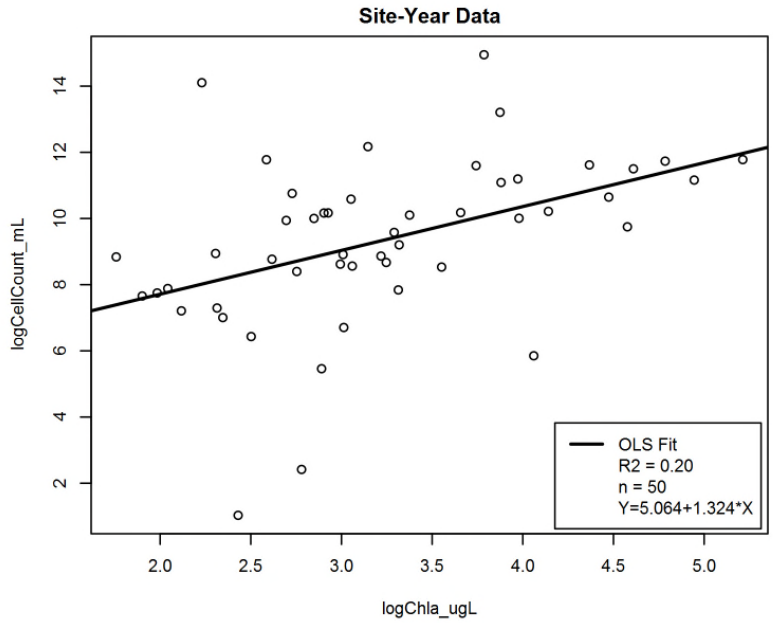


# Task 2. Algal Cell Count and Pigment Relationship

- Abundance Results (annual):

Chl

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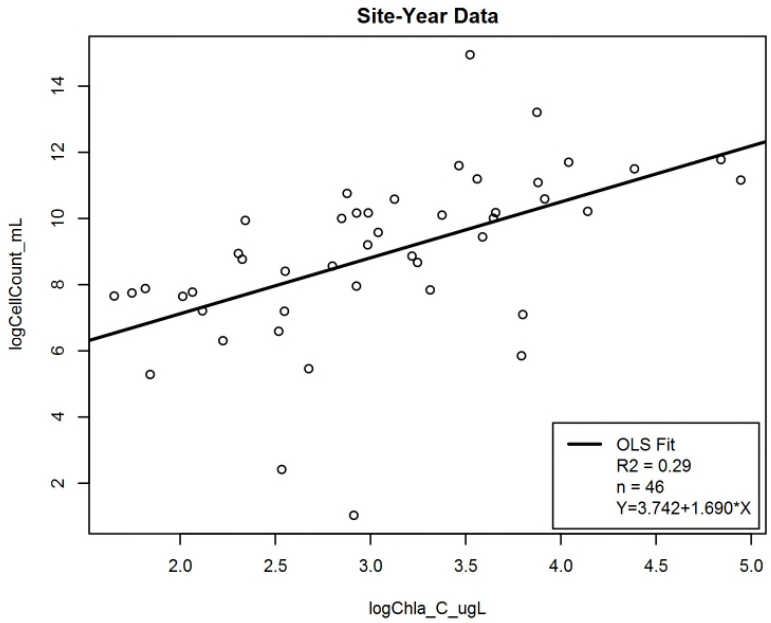
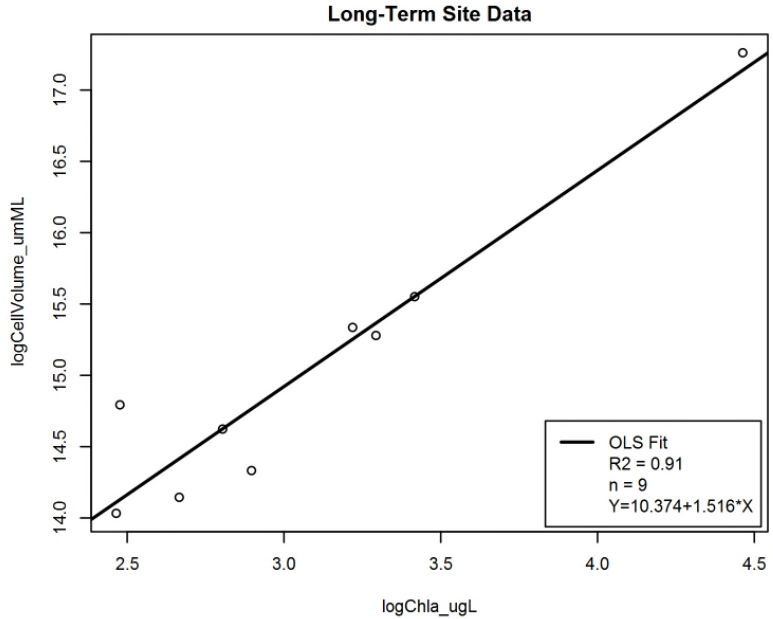


# Task 2. Algal Cell Count and Pigment Relationship

- Biovolume Results (long-term):

Chl

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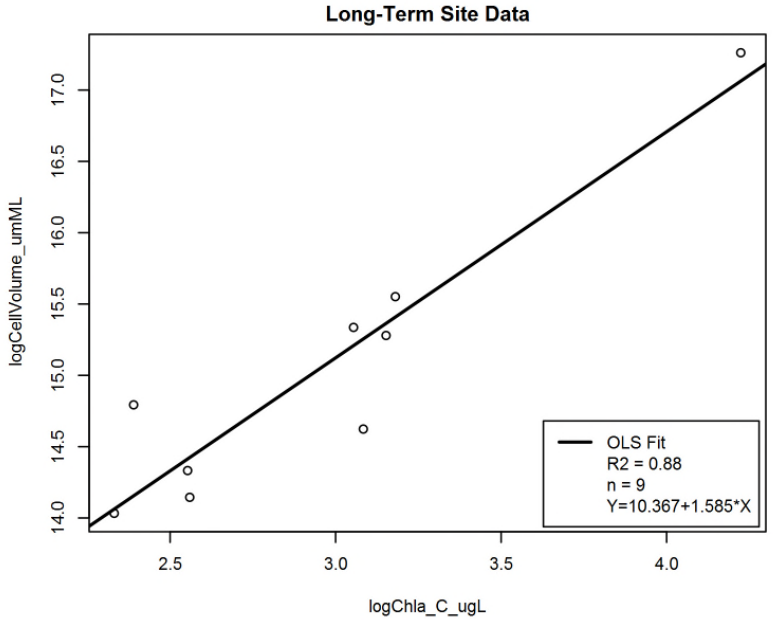
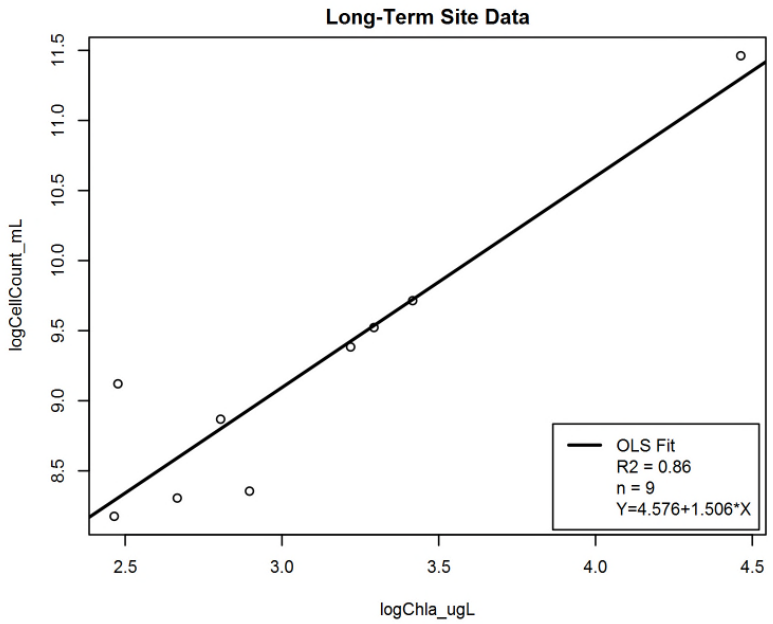


# Task 2. Algal Cell Count and Pigment Relationship

- Abundance Results (long-term):

Chl

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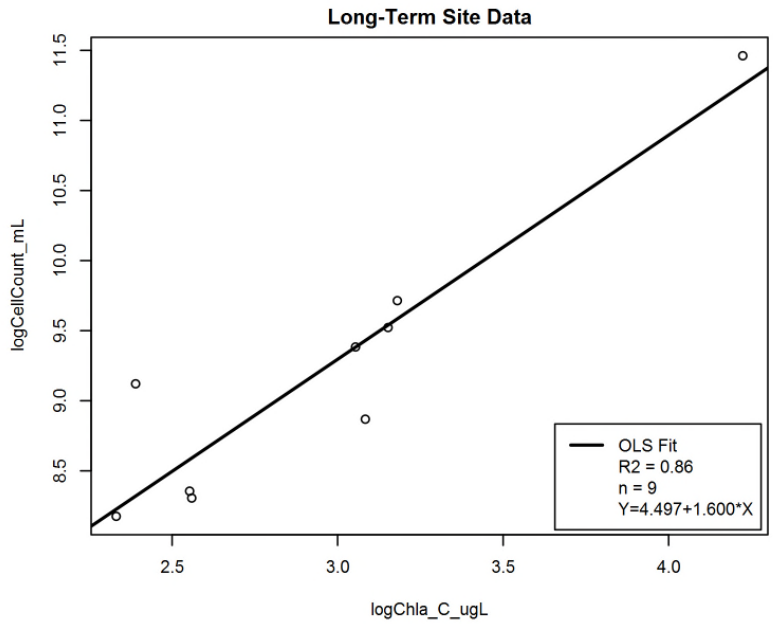


# Task 2. Algal Cell Count and Pigment Relationship

- Generally, abundance and biovolume track chlorophyll, which is well established and not particularly surprising
- Level of error may actually be surprising
- Questions:
  - Does this get us what we need?
  - The goals here were pretty straightforward, but we did not have all the context.
  - Is it worth chasing outliers?

# Task 3. Sonde Data Analysis

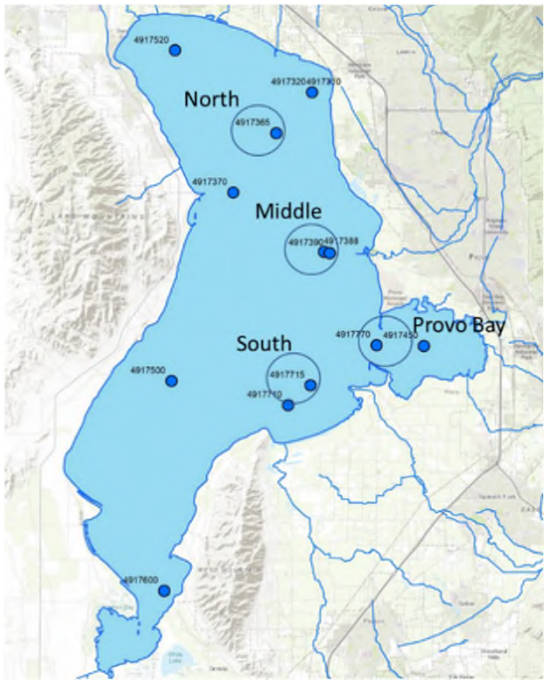
- Goal: Extract sonde data and examine relationships among sonde variables
- Clarified on June call: "run descriptive statistics on sonde data"

- We have 4 sonde locations (Phycocyanin, Chlorophyll, DO, pH, Conductivity, Temperature, Turbidity)

- Methods: Run descriptive stats (tables in report), correlation matrices, time series

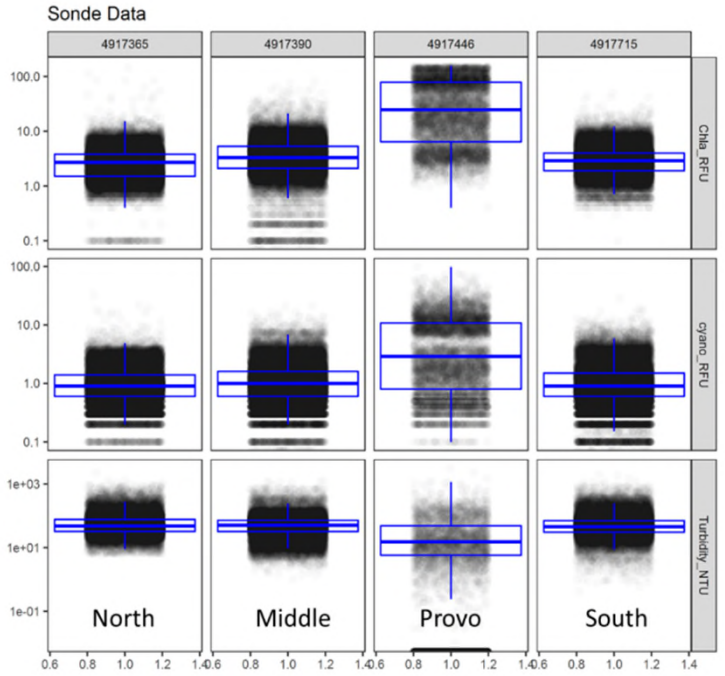
# Task 3. Sonde Data Analysis

- Locations:
  - North (~Aug 2016 – Oct 2018)
  - Middle (~Aug 2016 – Oct 2018)
  - *Provo Bay (July 2018 – Oct 2018
  - South (~Aug 2016 – Oct 2018)



# Task 3. Sonde Data Analysis

- Box and whiskers with jittered data
- Provo bay (third column) stands out



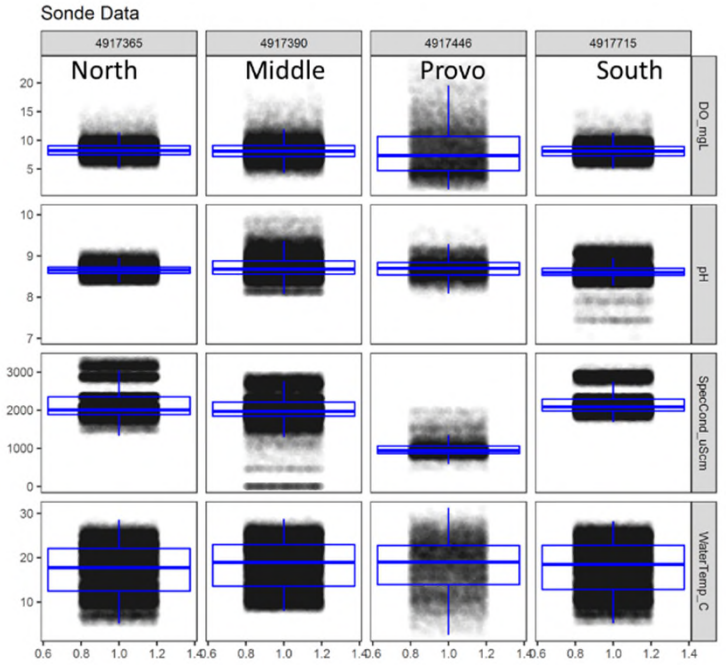

Chl

Cyano

Turbidity

# Task 3. Sonde Data Analysis

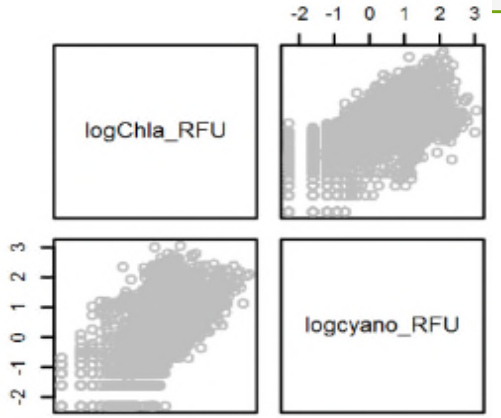
- Box and whiskers with jittered data
- Provo bay (third column) stands out



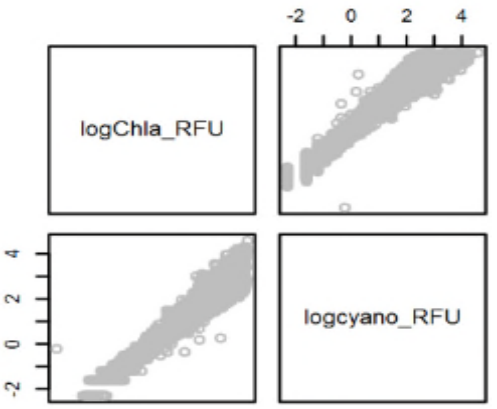
# Task 3. Sonde Data Analysis

- Correlation matrices unremarkable accept look how chl tracks cyanos in Provo vs other stations...but they do have less data and its only July-October.
- Something to watch for.

- Time series not particularly remarkable either – in report




Middle




Provo

# Task 3. Sonde Data Analysis

- Big Picture:
  - You have the descriptive stats you requested
  - Provo looks different, but less data
  - The rest look similar

- Questions:
  - Does this get us what we need?
  - Last meeting we were asked to run descriptive statistics and explore relationships among variables.

# Task 4. Plankton Temporal and Spatial Analysis

- Question: When do HABs most frequently start/occur? (Charge question 2.3.i) What are the temporal patterns in phytoplankton and zooplankton? What is the seasonal succession of phytoplankton and zooplankton? What is the typical pattern of phytoplankton and zooplankton, how do they wax and wane? (Attachment A ULWQS Science Panel Ideas for Studies, Experiments, and Literature Reviews question).

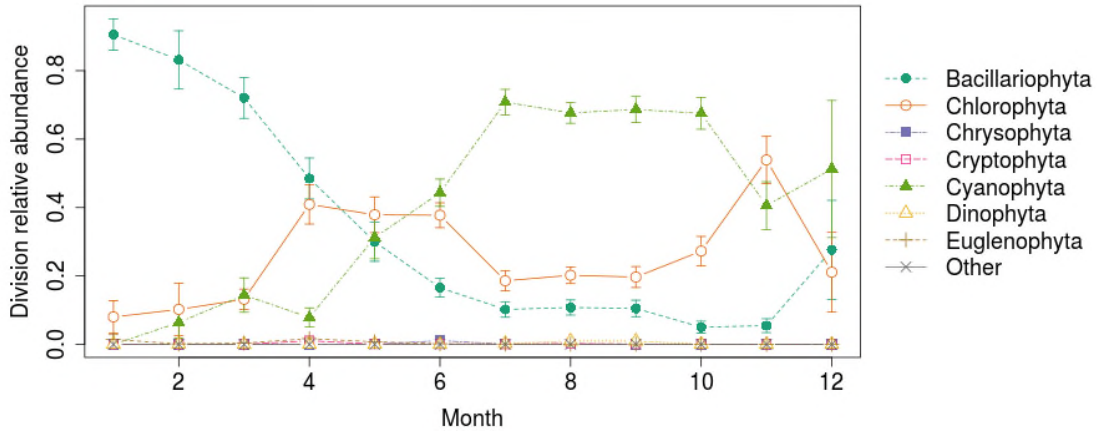
- Objective: Estimate temporal patterns in plankton, including HAB, assemblages.

- Data:
  - Phytoplankton cell count data (OTUs designated)
  - Site location information
  - Other water chemistry data

- Methods:
  - Scatterplots
  - Non-metric multidimensional scaling models
  - Overlays

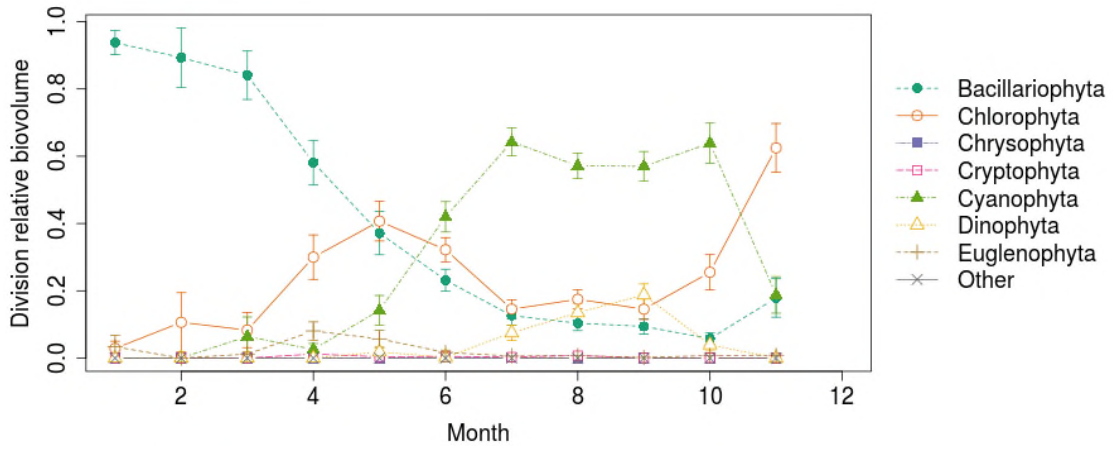
# Task 4. Plankton Temporal Analysis

- Results: Temporal (long-term average across station/years)
- Relative Abundance – pretty traditional pattern



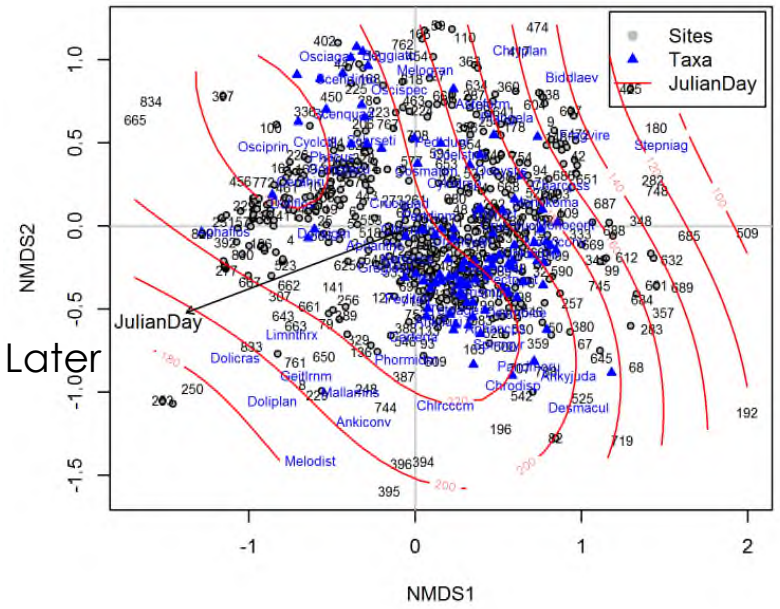
# Task 4. Plankton Temporal Analysis

- Results: Temporal (long-term average across station/years)
- Relative Biovolume - ditto



# Task 4. Plankton Temporal Analysis

- Results: Temporal – reflects the monthly pattern – algae change



# Task 4. Plankton Temporal Analysis

- When do HABs most frequently start/occur? (Charge question 2.3.i)
  - June
- What are the temporal patterns in phytoplankton and zooplankton?
  - Shown
- What is the seasonal succession of phytoplankton and zooplankton?
  - Shown
- What is the typical pattern of phytoplankton and zooplankton, how do they wax and wane?
  - Shown
- Questions:
  - Other ideas for temporal analysis?

# Task 4. Plankton Spatial Analysis

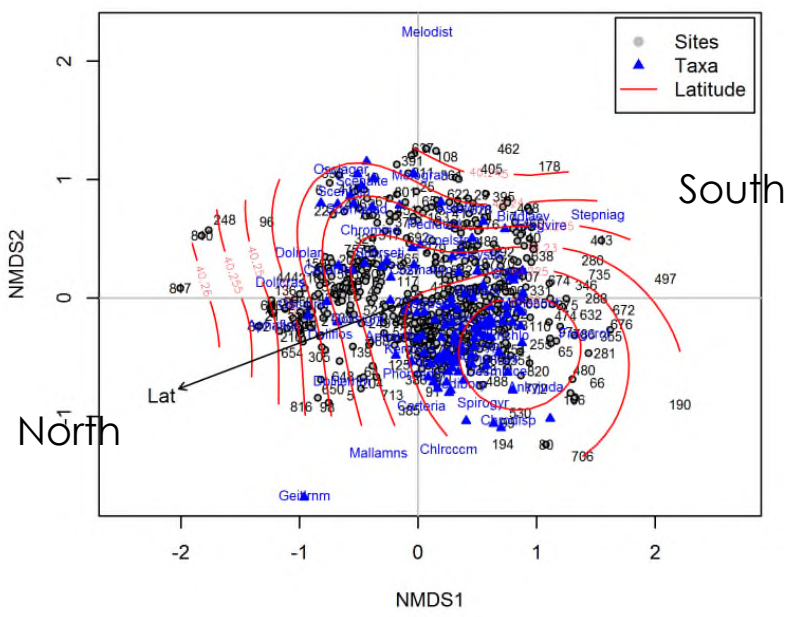
- Question: Are there hotspots and do they tend to occur near major nutrient sources? (Charge question 2.3.i) Do HABs generally begin near POTW outfalls? (Attachment A ULWQS Science Panel Ideas for Studies, Experiments, and Literature Reviews question).

- Objective: Estimate spatial patterns in plankton, including HAB, assemblages.

- Approach:
  - Use explorer
  - Complement with multivariate analysis of DWQ database

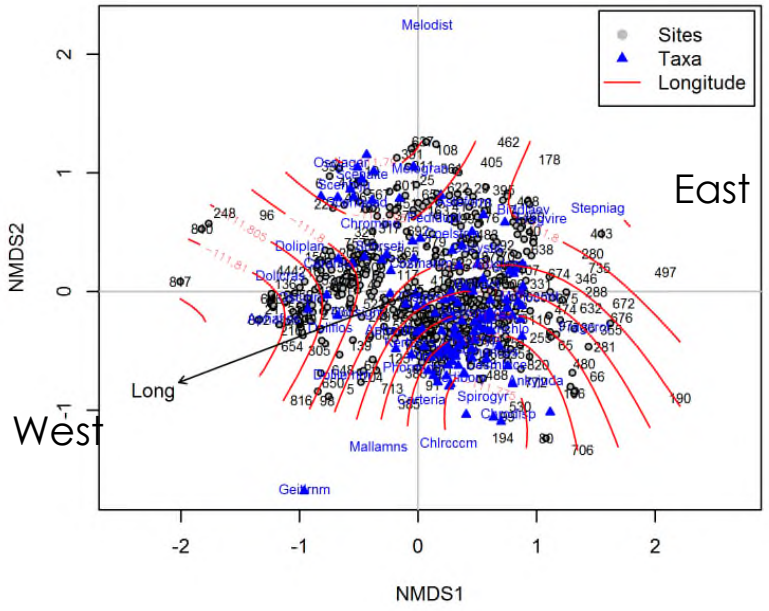
# Task 4. Plankton Spatial Analysis

- Results: Spatial




South

North



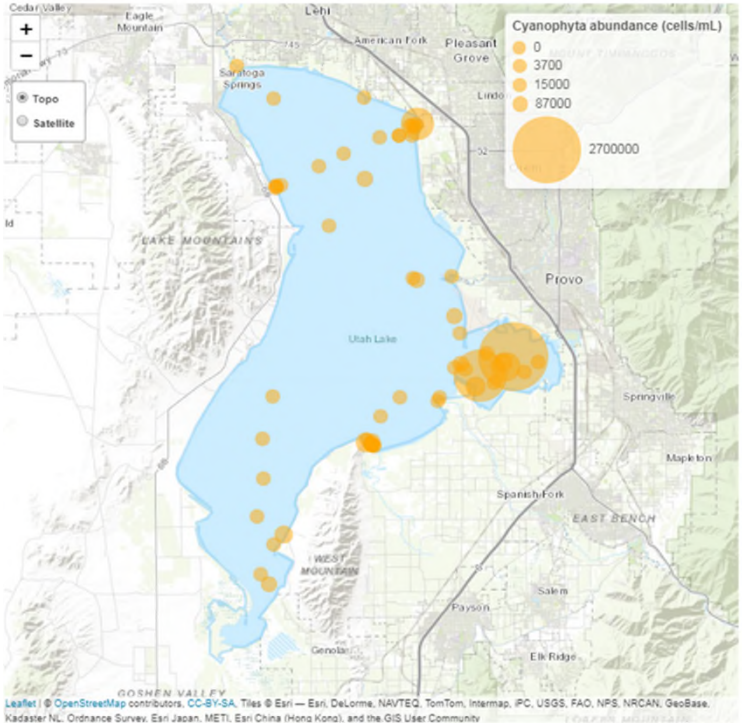

East

West

# Task 4. Plankton Spatial Analysis

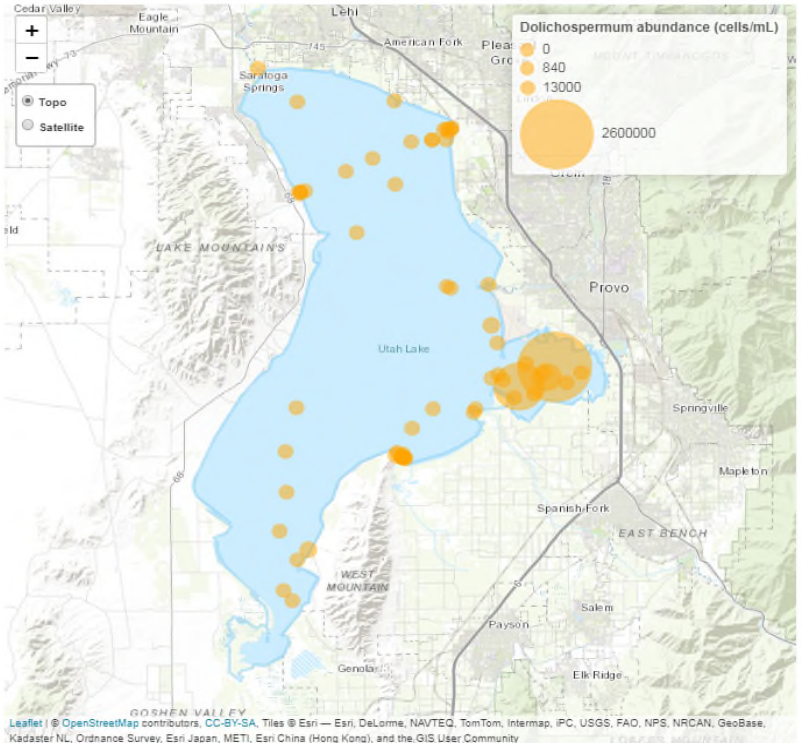
- Results: Spatial – are there hotspot locations  HABs?
- Report has list of HAB taxa and the toxins they can produce

- Cyanophytes combined
- Eastern hot spots



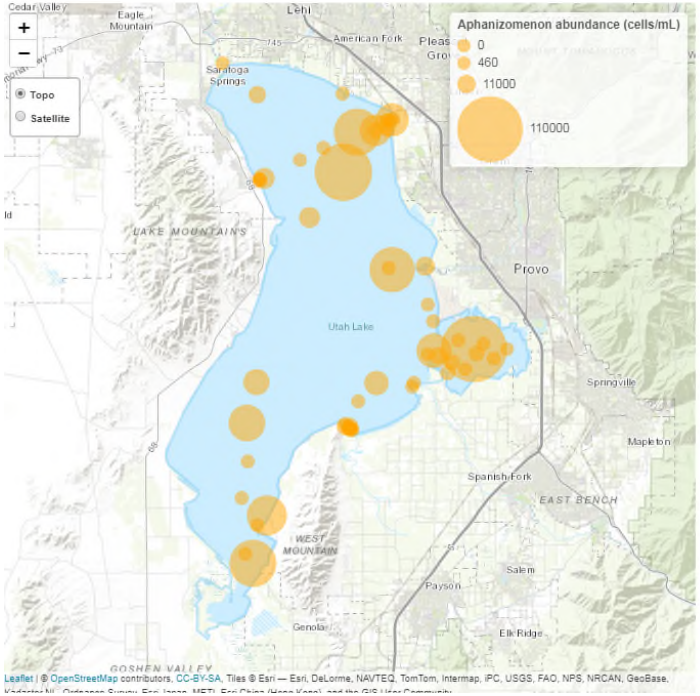
# Task 4. Plankton Spatial Analysis

- Dolly (what we used to call Annie)
- Eastern hot spots



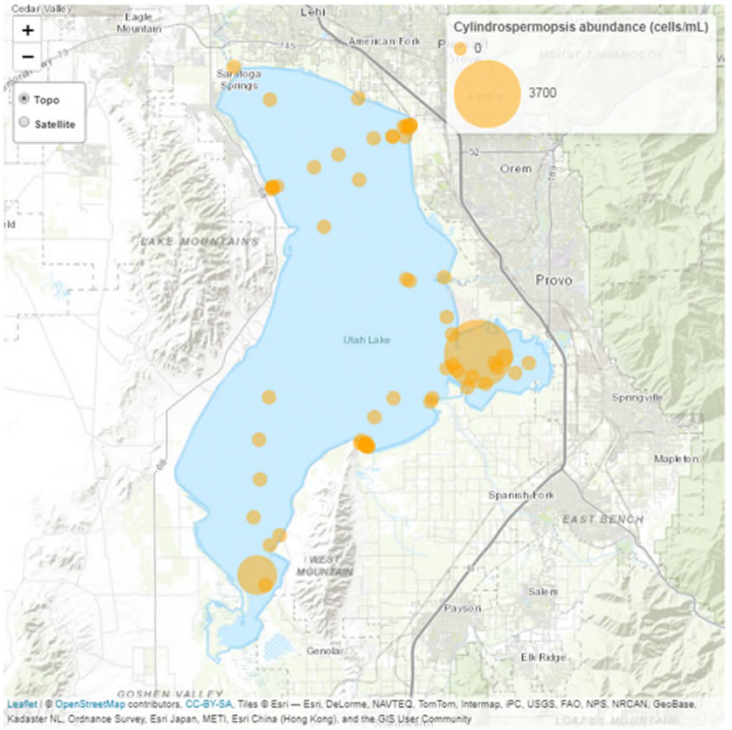
# Task 4. Plankton Spatial Analysis

- Fanny
- Eastern-ish hot spots



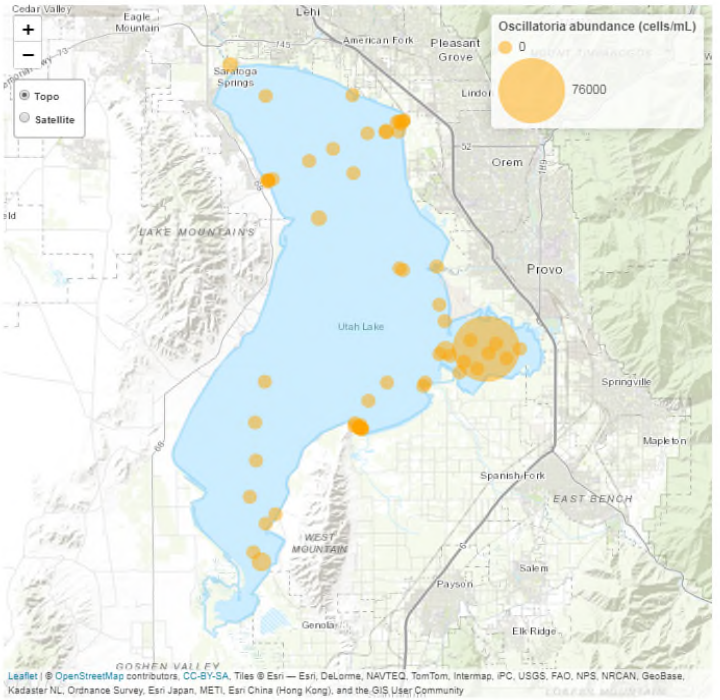
# Task 4. Plankton Spatial Analysis

- Cylindrospermopsis
- Eastern hot spots



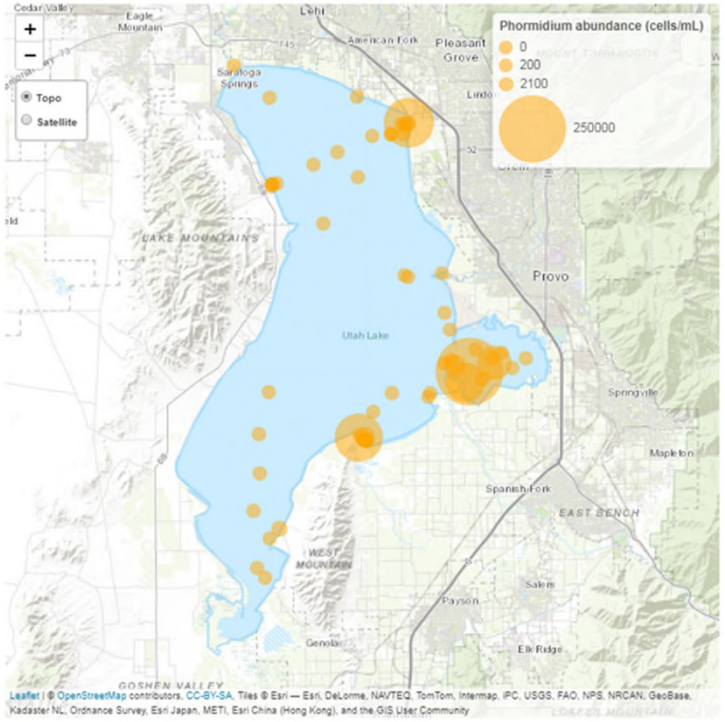
# Task 4. Plankton Spatial Analysis

- Oscillatoria
- Eastern hot spots



# Task 4. Plankton Spatial Analysis

- Phormidium
- Eastern hot spots



# Task 4. Plankton Spatial Analysis

- Are there hotspots and do they tend to occur near major nutrient sources? (Charge question 2.3.i)
  - Yes and not sure about POTWs – still to do
- Do HABs generally begin near POTW outfalls? (Attachment A ULWQS Science Panel Ideas for Studies, Experiments, and Literature Reviews question).
  - Initiation is hard to distinguish from these data

- Questions:
  - What else to do for this question?
  - Relation to POTW needs a POTW map and distance to each sampling location
  - We can then run HAB abundance (mean, max) versus distance to POTW outfall.

# Task 4. Plankton Spatial Analysis – To Nutrients

- Question: Which nutrients are actually controlling primary production and HABs and when? (Charge question 2.3.ii) If there are linkages between changes in nutrient regime and HABs?? (Charge question 2.3.iii)

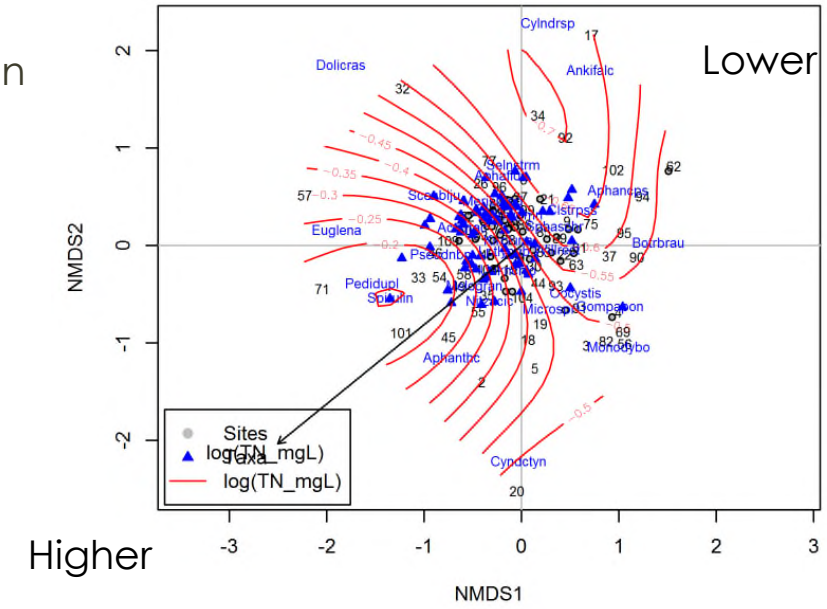
- Objective: Test for a relationship between nutrient concentrations and HAB abundances.

- Approach: Using the spatial analyses conducted in previous sub-analyses, test for relationships between nutrient concentration and algal abundances.

# Task 4. Plankton Spatial Analysis – To Nutrients

- Results: Miscellaneous Chemical
- Only paired chemistry and plankton

- TN

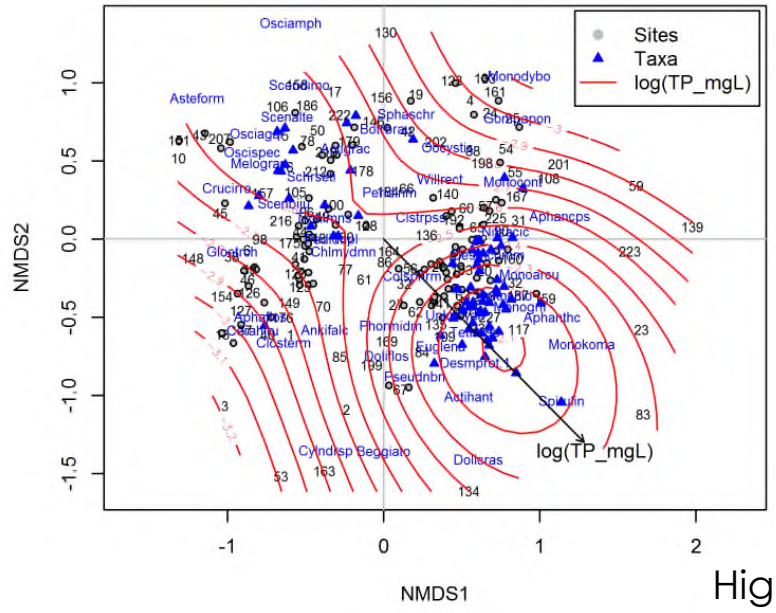


# Task 4. Plankton Spatial Analysis – To Nutrients

- Results: Miscellaneous Chemical
- Only paired chemistry and plankton

- TP

Lower




Higher

# Task 4. Plankton Spatial Analysis – To Nutrients

- Question: Which nutrients are actually controlling primary production and HABs and when? (Charge question 2.3.ii)
  - Both, but the bioassay research project will get at this better
- If there are linkages between changes in nutrient regime and HABs?? (Charge question 2.3.iii)
  - Unsure how this is addressable, only that literature would say yes,

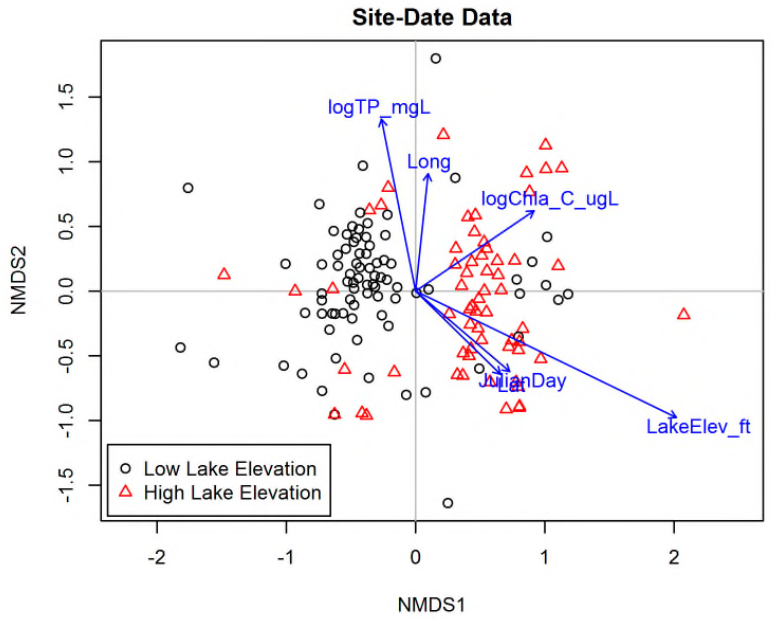
- Questions:
  - What more to add or do with this?
  - We plan to test NMS using the HAB taxa alone – or track them on plots

# Task 4. Plankton Spatial Analysis – Role of Lake Level

- Question: If there are linkages between changes in nutrient regime and HABs, what role if any does lake elevation change play? (Charge question 2.3.iii)
- Objective: Test for a relationship between lake level and HAB abundances.
- Approach: Using the spatial analyses conducted in previous sub-analyses, test for relationships between nutrient concentration and algal abundances.

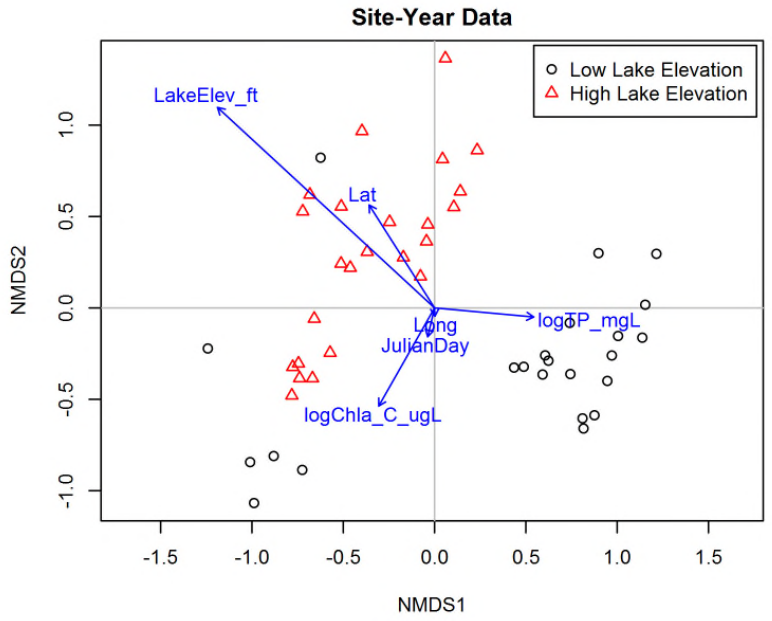
# Task 4. Plankton Spatial Analysis – Role of Lake Level

- Grab sample data



# Task 4. Plankton Spatial Analysis – Role of Lake Level

- Annual averaged data



# Task 4. Plankton Spatial Analysis – Role of Lake Level

- Taxa weighting on differences among lake level
- Many are HAB taxa discriminating low and high lake level years

| OTU | Importance | RelativeImportance |
|---|---|---|
| Aphanizomenon_flosaquae | 6.48 | 1.00 |
| Oocystis | 3.21 | 0.49 |
| Melosira_granulata | 2.76 | 0.43 |
| Dolichospermum_flosaquae | 2.05 | 0.32 |
| Oscillatoria_agardhii | 1.78 | 0.28 |
| Willea_rectangularis | 1.65 | 0.25 |
| Microcystis | 1.60 | 0.25 |
| Unknown_chlorophyte | 1.54 | 0.24 |
| Pediastrum_duplex | 1.32 | 0.20 |
| Ceratium_hirundinella | 1.29 | 0.20 |
| Scenedesmus_quadricauda | 1.18 | 0.18 |
| Aphanocapsa | 1.03 | 0.16 |
| Merismopedia | 1.00 | 0.15 |
| Chlamydomonas | 0.99 | 0.15 |
| Oscillatoria_species | 0.94 | 0.14 |
| Pteromonas | 0.86 | 0.13 |
| Dolichospermum_crassum | 0.84 | 0.13 |
| Ankistrodesmus_falcatus | 0.68 | 0.11 |
| Desmodesmus_communis | 0.67 | 0.10 |
| Euglena | 0.65 | 0.10 |

# Task 4. Plankton Spatial Analysis – Role of Lake Level

- If there are linkages between changes in nutrient regime and HABs, what role if any does lake elevation change play? (Charge question 2.3.iii)
  - So there does appear to be a nutrient/level relationship
  - That "role" is unclear from these data, but an obvious culprit is light and nutrient concentration (dilution is the solution to pollution)…
- Need to tease HAB taxa along NMS gradient more clearly
- Questions:
  - What else to do on this question?

# Task 5. Diatom and Macrophyte Autecology

- Questions:
  - Still want to relate just HAB taxa to this nutrient gradient – HAB taxa abundance versus nutrient concentrations.
  - Can highlight HAB taxa in the NMS plots as well
  - What else to do for this question?

# Task 6. Wind and Turbidity

- Goal: Identify wind condition necessary to entrain bottom sediments in Utah Lake.

- Data:
  - Wind speed
  - Sediment characteristics

- Methods:
  - Calculate critical shear stress
  - Compare to wind induced sheer stress

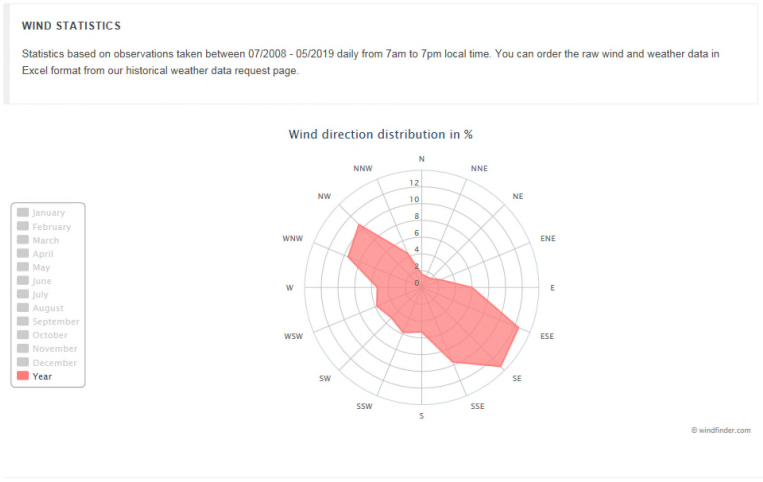
# Task 6. Wind and Turbidity

Windfinder.com

- Results:
  - Chao et al. 2008 (Shallow lake cohesive sediment transport, Adv in Wat Res)
  - Chung et al. 2009 (Sediment resuspension in a shallow lake, Wat Res Res)
  - Shear stress (Pascals or $N/m^2$):
    - $\tau_{wave} = 0.5\ \rho f_w U_w^2$
    - $\rho$ = water density; $f_w$ = bottom friction factor (2/sqrt(Reynolds number)); $U_w$ = amplitude of the orbital wave velocity
    - Need wave height, period, and length (Coastal Engineering Research Center 1984, Shore Protection Manual I)
    - $\tau_{velocity}$ data from Nick Van Stackelberg

# Task 6. Wind and Turbidity

- Results:
  - Wind speed: Provo airport, long-term data average = 2.63 m/s
  - Wind direction: Average =145.8 degrees (SSE/SE)
  - Other east and south sites similar; Saratoga from West
  - Fetch: at this direction is 15 miles


Windfinder.com

# Task 6. Wind and Turbidity

- Very Preliminary Results:
  - Wave Shear stress

| depth (m) | Wind speed (m/s) | $\tau_w$ (N/m2) |
|---|---|---|
| 1.5 | 2.63 | 0.106740 |
| 3 | 2.63 | 0.026731 |
| 6 | 2.63 | 0.001515 |

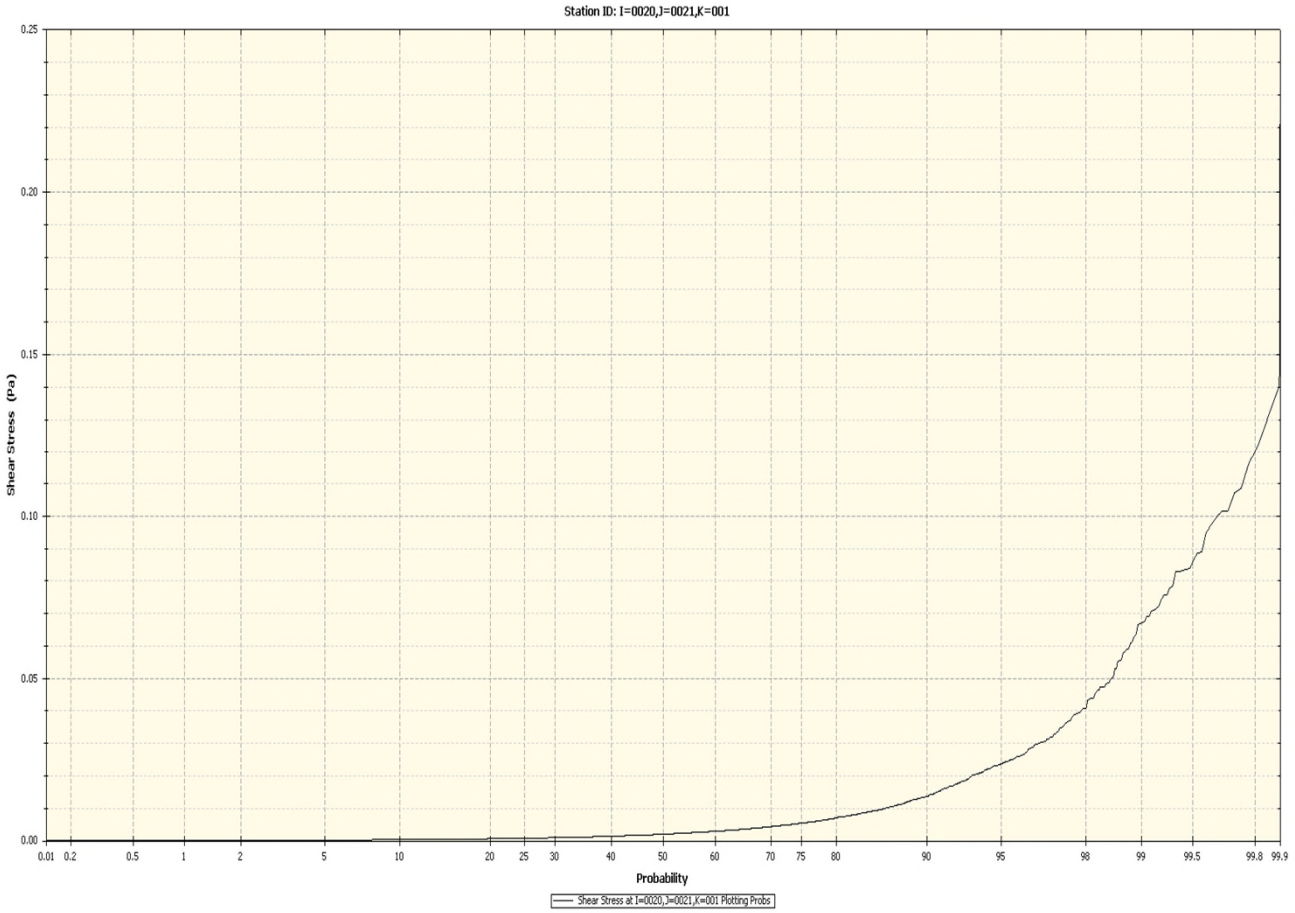
| depth (m) | Wind speed (m/s) | Fetch (m) | $\tau_w$ (N/m2) |
|---|---|---|---|
| 3 | 2.63 | 24140 | 0.026731 |
| 3 | 2.63 | 12070 | 0.023028 |
| 3 | 2.63 | 6035 | 0.018406 |

| depth (m) | Wind speed (m/s) | $\tau_w$ (N/m2) |
|---|---|---|
| 3 | 0.986 | Very low |
| 3 | 2.63 | 0.026731 |
| 3 | 4.67 | 0.188448 |

  - Sensitive to Depth and Wind Speed; Less to fetch
  - At average speeds, fetch, and depth: 0.026 N/m2

# Task 6. Wind and Turbidity

- Very Preliminary Results:
  - Current Shear Stress – from EFDC model (Nick)
  - If I read correctly, most of the time, current shear exceeds 0.14 to 0.23 N/m2
  - Need to check with Nick



# Task 6. Wind and Turbidity

- Results: Critical shear stress ($N/m^2$)
  - Easy: $\tau_{crit} = 0.06(g)(\rho s-\rho)D$ (for stream coarse beds)
  - Hard: Need to work on finding an appropriate method
  - Got median particle size data for Utah Lake (<0.005 mm); set to clay which is 0.002 mm
  - Bulk density: 600 kg/m3 (Goel lab); Literature particle density: 2000 kg/m3
  - 600 kg/m3 results in negative critical shear; 2000 kg/m3 = 1.17 N/m2
  - Literature based critical shear for cohesive sediments: 0.009 to 0.25 N/m2

# Task 6. Wind and Turbidity

- Results: Comparison
  - Wind shear: 0.027 N/m2 at average wind speed and depth and longest fetch
  - Current shear: 0.14 to 0.23 N/m2
  - Literature based critical shear for cohesive sediments: 0.009 to 0.25 N/m2
  - Likely winds are sufficient to move cohesive bottom sediments regularly, consistent with observations (proving the obvious).

# Task 6. Wind and Turbidity

- Questions:
  - What else to do on this question?
  - Do we want to look at any specific locations?
  - There are clearly some critical unknowns to resolve: particle density, particle diameter (core data all have median particle diameter at somewhere less than 0.005. But what it is it, then?
  - Do we want isopleths of shear versus wind speed; nomographs of wind, fetch, and depth? Etc.

  - Next will be to work on next question and try and model effects of macrophyte stem density on bottom velocity.

# Task 7. Turbidity and Macrophytes

- Goal: Identify the potential contribution of macrophytes to reducing turbidity.

- Data:
  - Effect of macrophytes on stabilizing sediments through reducing shear and holding sediments
  - Papers from Soren, Eric, and Janice – will look into how to calculate

- Methods:
  - TBD

# Task 8. Light extinction

- Goal: Identify the potential contribution of turbidity/TSS and algal biomass to turbidity.

- Data and Methods:
  - TSS, Secchi, Kd, VTSS
  - Empirical formulae for light attenuation
  - Calculate Utah Lake specific value (upcoming PAR data)
  - Calculate contribution of non-algal TSS and chlorophyll to $k_d$
  - Calculate light available at lake bottom across range of TSS and Chlorophyll values

- Results:
  - TBD

# Data Analysis

- Next Steps:
  - Heads down, keep at it
  - More in Fall after feedback

# Uncertainty Analysis

- Draft document sent out – but not really in time for your feedback in June...but it's July...
- Goal: "*characterize scientific uncertainty including confidence of scientific findings and quantified measures of uncertainty, where possible*"

## Utah Lake Water Quality Study—Uncertainty Guidance

June 5, 2019

**PRESENTED TO**

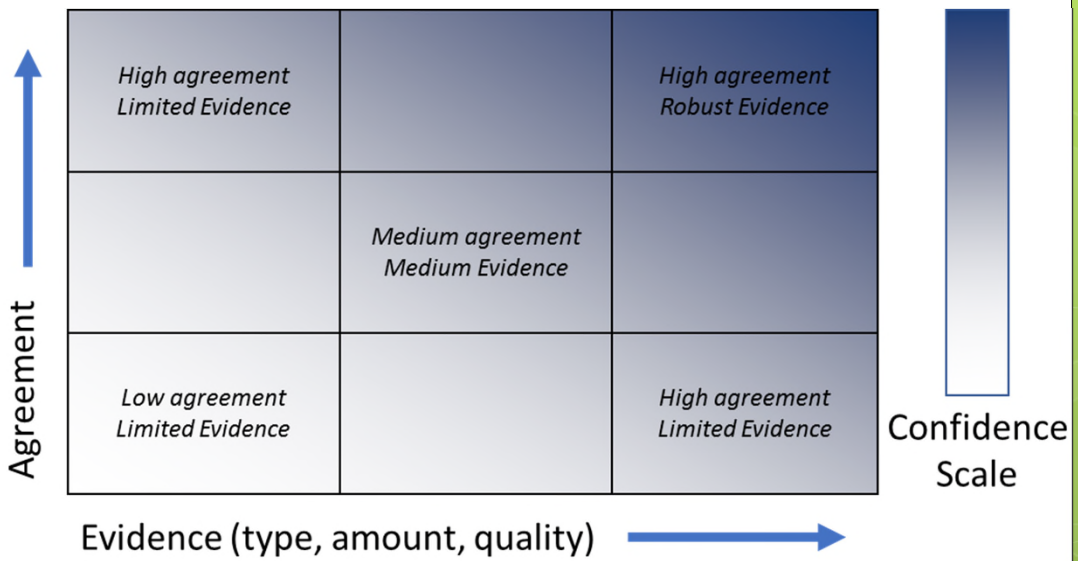
**Utah Department of Environmental Quality**
**Division of Water Quality**
PO Box 144870
Salt Lake City, UT 84114

**PREPARED BY**

**Tetra Tech**
1 Park Drive, Suite 200
Research Triangle Park, NC 2709

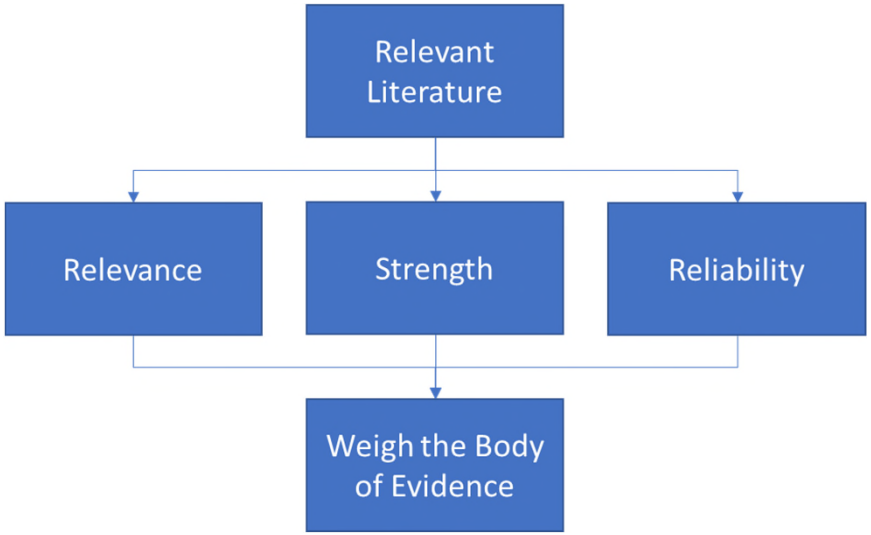
# Uncertainty Analysis

- Evaluation based on:
  - Evidence
  - Agreement
- Statements convey:
  - Confidence – not statistical
  - Likelihood – can be statistical
- Based on IPCC



# Uncertainty Analysis

- Evaluating different lines:
  - Empirical Analyses
  - Mechanistic Models
  - Literature
- Communication:
  - Traceable accounts




How to weigh literature – from USEPA 2016

# Uncertainty Analysis

- Next steps:
  - Mostly guiding principles – details will emerge with work
  - Feedback from Science Panel
  - Revise and Finalize

# Questions/Comments