UTAH LAKE RESEARCH 2016

Progress Report

A preliminary analysis of Utah Lake's unique foodweb with a focus on the role of nutrients, phytoplankton, zooplankton, and benthic invertebrates on HABs

Submitted to:
Wasatch Front Water Quality Council

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Forward

This progress report is a preliminary analysis of the critical role and interrelationships of nutrients, phytoplankton, zooplankton, and benthic macroinvertebrates in the foodweb of Utah Lake and how they affect cyanobacteria blooms (HABs). From our research, it is obvious that nutrients alone are not the sole cause of HABs. There is a wealth of information in this report however, it is just the beginning of much more intensive and informative statistical and ecological analyses pending continued data collection.

Acknowledgements

We are deeply indebted to the following that shared our vision of conducting the most intensive ecological analysis of Utah Lake to date: Dr. Sam Rushforth of Rushforth Phycology; Dr. Larry Gray at Utah Valley University; Brett Marshall at River Continuum Concepts; Mr. Dick Buhler most excellent air boat captain; the many technicians at Wasatch Front Water Quality Council; all of the POTWs associated with the Council and to the Wasatch Front Water Quality Council for funding this critically important work.

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Chapter 1

Utah Lake Phytoplankton Assemblages 2016

Summary

We collected more than 130 phytoplankton samples from Utah Lake in 2016 as part of our ongoing research focused on the role of nutrients in cyanobacteria dominated harmful algal blooms (HABs). An understanding of phytoplankton assemblages is a crucial link in this research. Results presented in this progress report are preliminary. We estimated that there were likely between 150 to 170 phytoplankton taxa occurring in Utah Lake in 2016, which by all standards is a highly diverse assemblage. Most taxa were uncommon with several taxa dominating, indicating potential cause and effect relationships. The phytoplankton assemblage clearly differed both spatially and temporally as did most individual taxa densities. These results are a critical first step in understanding Utah Lake's foodweb and the causes of HABs and their potential control.

Introduction

Almost nothing is known about phytoplankton spatial and temporal patterns in Utah Lake despite the critically important relationships between phytoplankton and; benthic and water column nutrient cycling, cyanobacteria blooms (**H**armful **A**lgal **B**looms)[1], benthic invertebrates, zooplankton, and the physico-chemical conditions in the benthos and water column. Phytoplankton-zooplankton-water column nutrient cycling has been well documented throughout the world and has been extensively studied by limnologists and ecologists for several generations. Phytoplankton obviously are the major link between water column nutrients (trophic level bottom up effects) and zooplankton grazers (top down trophic level effects). However, other interactions, including for example those between phytoplankton and the benthic component of the food web are less recognized and these interactions are likely important drivers of cyanobacteria blooms in Utah Lake. A simplified diagram of Utah Lake food web including water column nutrient cycling with phytoplankton at its core is shown in Figure 1.

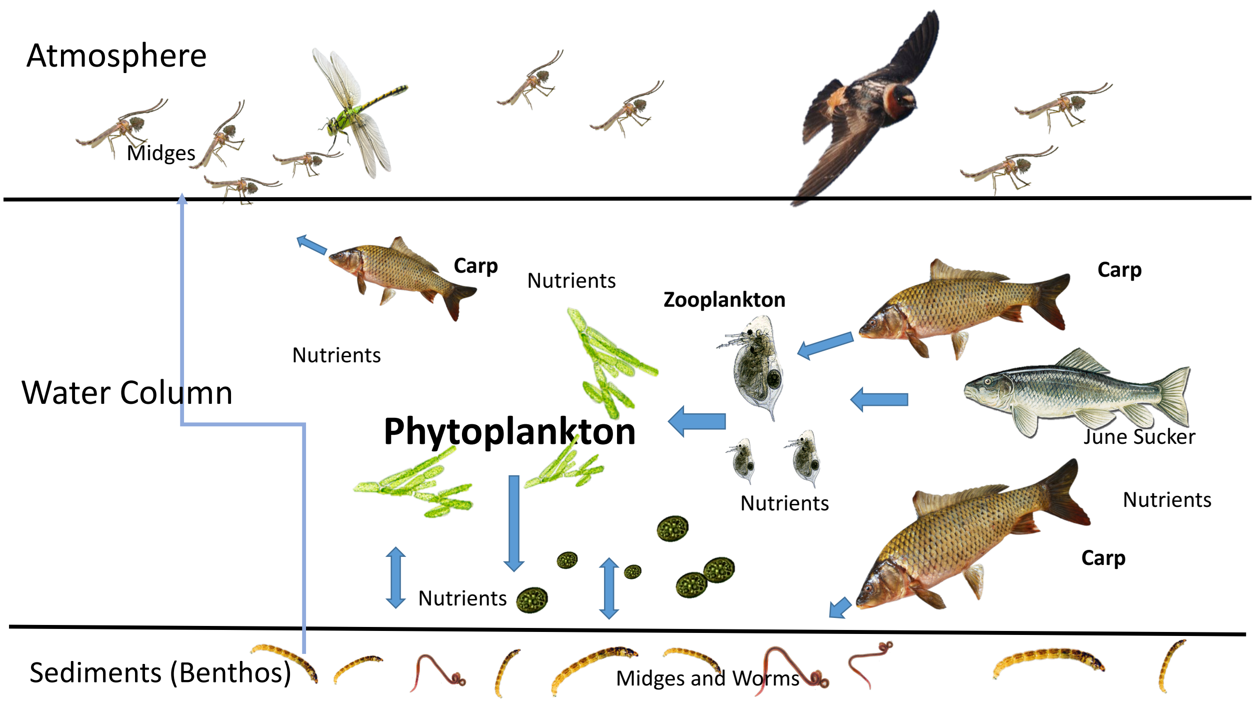


Figure 1. Simplified food web consisting of benthic invertebrates, phytoplankton, zooplankton, carp, other zooplankton grazers and predators, and nutrients in Utah Lake. Phytoplankton play the central role between sediment and water column nutrients and other components of Utah Lake's food web.

Many lake nutrient models fail to incorporate the water column foodweb component of phytoplankton, zooplankton, and fish or only use generalized attributes such as surrogate metrics (e.g. Chl A), or only include a handful of plankton taxa; hence they have poor predictive power

[1] Cyanobacteria are bacteria that can photosynthesize but they are not algae. Harmful Algal Blooms or HABs in Utah Lake are entirely comprised of cyanobacteria not algae.

and provide little understanding of the intricacies of this component. Critical information is lost by ignoring most of these primary producer phytoplankton taxa or by lumping them into superficial groups; information that could have been used to understand the role of nutrients and help alleviate cyanobacteria blooms in Utah Lake. There are dozens and dozens of within- and between- trophic level phytoplankton interactions, including inter and intraspecific phytoplankton interactions simultaneously co-occurring at spatial and temporal scales. These interactions critically need to be understood and need to be explicitly incorporated into Utah Lake nutrient models.

We are conducting the most intensive and extensive phytoplankton research on Utah Lake to date in order to understand their: spatial and temporal patterns, top down and bottom-up effects, and interactions and role in the food web. This research is specifically designed to better understand the role of nutrients in the foodweb and to predict and control cyanobacteria blooms in the lake, and to better understand the ecology of the unique Utah Lake ecosystem. This phytoplankton research is concurrent with our nutrient, benthic, and zooplankton research and is being conducted in collaboration with several other groups including; UDWQ, UDNR, USEPA, USU, BYU, UVU, and a consortium (Wasatch Front Water Quality Council) of several wastewater treatment facilities that discharge into Utah Lake, including the City of Provo, Timpanogos, City of Orem, and others.

Methods

Phytoplankton samples were collected from various locations in Utah Lake from February to December 2016 (Table 1). All phytoplankton samples were collected in the same locations and on the same dates as zooplankton samples (see Zooplankton chapter) and most were collected concomitantly with nutrient and water chemistry data (see Nutrient chapter).

Table 1. Dates, location description, and latitude and longitude of phytoplankton samples, Utah Lake 2016.

Date Collected	Location	Latitude	Longitude
February 10, 2016	Lindon Marina	40.32697645	111.7673372
February 10, 2016	Saratoga Springs Marina	40.304306	111.877623
March 9, 2016	Lindon Marina	40.32697645	111.7673372
March 9, 2016	Pelican Bay Marina	40.29059233	111.8686682
March 9, 2016	Utah Lake Outlet	40.35949026	111.8962022
March 10, 2016	Mid-lake, Pelican Point	40.258969	111.798406
March 10, 2016	Mid-Provo Bay	40.18649613	111.6981764
March 10, 2016	Mouth of Provo Bay	40.18708019	111.7299191
March 10, 2016	North End of Goshen Bay	40.121906	111.878705
March 10, 2016	South end of Goshen Bay	40.03406289	111.8897464
April 11, 2016	Lindon Marina	40.32697645	111.7673372
April 11, 2016	Provo Marina	40.24164098	111.7416926

April 11, 2016	Saratoga Springs Marina	40.304306	111.877623
April 24, 2016	1/2 Lindon Marina to Pelican Point transect	40.31100465	111.8188149
May 24, 2016	1/4 Lindon Marina to Pelican Point Transect	40.31873897	111.793439
May 24, 2016	3/4 Lindon Marina to Pelican Point Transect	40.30307211	111.8431384
May 24, 2016	Lindon Marina	40.32697645	111.7673372
May 24, 2016	Outlet	40.35949026	111.8962022
May 24, 2016	Pelican Point Marina	40.29059233	111.8686682
June 1, 2016	1/4 mile North of Goose Point	40.121906	111.878705
June 1, 2016	South end of Goshen Bay	40.121906	111.878705
June 14, 2016	1/2 Lindon Marina to Pelican Bay Transect	40.31100465	111.8188149
June 14, 2016	1/4 Lindon Marina to Pelican Bay	40.31873897	111.793439
June 14, 2016	3/4 Lindon Marina to Pelican Bay	40.30307211	111.8431384
June 14, 2016	Lindon Marina	40.32697645	111.7673372
June 14, 2016	Pelican Bay	40.29059233	111.8686682
June 14, 2016	Utah Lake Outlet	40.35949026	111.8962022
June 16, 2016	Goshen Bay, North Goose Point	40.092776	111.862278
June 16, 2016	Provo Bay East	40.189795	111.689438
June 16, 2016	Provo Bay Outlet	40.18708019	111.7299191
June 16, 2016	Jul	40.35949026	111.7299191
July 19, 2016	HAB	40.328195	111.7646
July 19, 2016	Lindon Marina Outside Jetty HAB	40.32697645	111.7673372
July 19, 2016	Lindon Marina 200m from Jetty HAB	40.32697645	111.7673372
July 19, 2016	Northeast corner of Lindon Marina HAB	40.328195	111.7646
July 19, 2016	Outlet HAB	40.35949026	111.8962022
July 28, 2016	1000 meters outside of Provo Bay	40.195214	111.767731
July 28, 2016	Lincoln Beach, 300 feet from shore	40.14410812	111.7983279
July 28, 2016	Mid Goshen Bay	40.08662632	111.8900758
July 28, 2016	Mouth of Provo Bay	40.18708019	111.7299191
July 28, 2016	Utah Lake Spanish Fork	40.168567	111.751162
July 29, 2016	Goshen Bay North	40.121906	111.878705
July 29, 2016	Lindon Marina	40.32697645	111.7673372
July 29, 2016	Sandy Beach	40.1702659	111.7479878
July 29, 2016	Utah Lake State Park	40.24164098	111.7416926
August 4, 2016	1/2 Way Between Lindon and Saratoga	40.31100465	111.8188149
August 4, 2016	1/4 distance from Lindon to Saratoga	40.31873897	111.793439
August 4, 2016	3/4 way on transect Bewteen Lindon and Saratoga	40.30307211	111.8431384
August 4, 2016	Lindon Marina; 100m from Jetty	40.32697645	111.7673372
August 4, 2016	Mouth of Provo Bay	40.18708019	111.7299191
August 4, 2016	Provo Bay Mid-bay	40.18649613	111.6981764

August 4, 2016	Saratoga Marina	40.304306	111.877623
August 11, 2016	1/2 way Lindon to Saratoga Transect	40.31100465	111.8188149
August 11, 2016	1/4 way Between Lindon to Saratoga Transect	40.31873897	111.793439
August 11, 2016	3/4 Along Lindon to Saratoga Transect	40.30307211	111.8431384
August 11, 2016	Goshen Bay	40.092776	111.862278
August 11, 2016	Lindon Marina	40.32697645	111.7673372
August 11, 2016	Utah Lake Mid-Provo Bay	40.18649613	111.6981764
August 15, 2016	American Fork	40.343223	111.804166
August 15, 2016	Lincoln Beach	40.141755	111.798205
August 15, 2016	Lindon Marina	40.32697645	111.7673372
August 15, 2016	Sandy Beach	40.1702659	111.7479878
August 15, 2016	Utah Lake @ State Park	40.24164098	111.7416926
August 18, 2016	1/2 Lindon to Saratoga	40.31100465	111.8188149
August 18, 2016	1/4 Lindon to Saratoga	40.31873897	111.793439
August 18, 2016	3/4 Lindon to Saratoga	40.30307211	111.8431384
August 18, 2016	Center of Provo Bay	40.18649613	111.6981764
August 18, 2016	Goshen Bay	40.092776	111.862278
August 18, 2016	Lindon Marina	40.32697645	111.7673372
August 18, 2016	Saratoga	40.304306	111.877623
August 31, 2016	1/2 Lindon to Saratoga	40.31100465	111.8188149
August 31, 2016	3/4 Lindon to Saratoga	40.30307211	111.8431384
August 31, 2016	Goshen Bay	40.092776	111.862278
August 31, 2016	Lincoln Harbor	40.14248556	111.8023818
August 31, 2016	Lincoln Harbor Shallow Skim	40.14248556	111.8023818
August 31, 2016	Lindon Marina	40.32697645	111.7673372
August 31, 2016	Pelican Bay	40.29059233	111.8686682
August 31, 2016	Provo Bay Center	40.18649613	111.6981764
August 31, 2016	1/4 Lindon to Saratoga	40.31873897	111.793439
September 8, 2016	1/2 Lindon to Pelican	40.31100465	111.8188149
September 8, 2016	1/4 Lindon to Pelican	40.31873897	111.793439
September 8, 2016	100m from Lindon Marina	40.121906	111.878705
September 8, 2016	3/4 Lindon to Pelican Point	40.30307211	111.8431384
September 8, 2016	Goshen Bay North	40.121906	111.878705
September 8, 2016	Provo Bay Mouth	40.18708019	111.7299191
September 8, 2016	Provo Bay Neck	40.181349	111.716983
September 8, 2016	Utah Lake Pelican Marina	40.29059233	111.8686682
September 8, 2016	Utah Lake Provo Bay Center	40.18649613	111.6981764
September 16, 2016	Goshen Bay	40.092776	111.862278
September 16, 2016	Lincoln Beach	40.141755	111.798205

September 16, 2016	Lindon Marina	40.32697645	111.7673372
September 16, 2016	Provo Airport	40.216144	111.736693
September 16, 2016	Sandy Beach	40.1702659	111.7479878
September 16, 2016	Sandy Beach Surface Skim	40.1702659	111.7479878
September 21, 2016	Goshen Bay North	40.144858	111.801088
September 21, 2016	Lincoln Beach North	40.144858	111.801088
September 21, 2016	Lindon Marina	40.32697645	111.7673372
September 21, 2016	Provo Airport	40.216144	111.736693
September 21, 2016	Sandy Beach	40.1702659	111.7479878
September 26, 2016	Goshen Bay North	40.121906	111.878705
September 26, 2016	Lincoln Beach	40.141755	111.798205
September 26, 2016	Provo Airport	40.216144	111.736693
September 26, 2016	Sandy Beach	40.1702659	111.7479878
October 3, 2016	Goshen Bay North	40.121906	111.878705
October 3, 2016	Lincoln Beach	40.141755	111.798205
October 3, 2016	Sandy Beach	40.1702659	111.7479878
October 6, 2016	1/2 Lindon to Pelican Point	40.31100465	111.8188149
October 6, 2016	1/4 Lindon to Pelican Point	40.31873897	111.793439
October 6, 2016	3/4 Lindon to Pelican Point	40.30307211	111.8431384
October 6, 2016	Lindon Marina	40.32697645	111.7673372
October 6, 2016	Pelican Bay	40.29059233	111.8686682
October 6, 2016	Provo Bay Center	40.18649613	111.6981764
October 6, 2016	Provo Bay Mouth	40.18708019	111.7299191
October 7, 2016	Goshen Bay North	40.121906	111.878705
October 7, 2016	Sandy Beach	40.1702659	111.7479878
October 20, 2016	1/2 distance Lindon to Pelican Point	40.31100465	111.8188149
October 20, 2016	1/4 distance Lindon to Pelican Bay	40.31873897	111.793439
October 20, 2016	3/4 Lindon to Pelican Bay	40.30307211	111.8431384
October 20, 2016	Lindon Marina	40.32697645	111.7673372
October 20, 2016	Pelican Marina	40.29059233	111.8686682
October 20, 2016	Provo Bay Center	40.18649613	111.6981764
November 4, 2016	Goshen Bay North	40.121906	111.878705
November 4, 2016	Lincoln Beach	40.141755	111.798205
November 4, 2016	Sandy Beach	40.1702659	111.7479878
November 10, 2016	1/2 Lindon to Pelican Bay	40.31100465	111.8188149
November 10, 2016	1/4 distance Lindon to Pelican Bay	40.31873897	111.793439
November 10, 2016	3/4 Lindon to Pelican Marina	40.30307211	111.8431384
November 10, 2016	Lindon Marina	40.32697645	111.7673372
November 10, 2016	Pelican Marina	40.29059233	111.8686682

November 10, 2016	Provo Bay Center	40.18649613	111.6981764
November 10, 2016	Provo Bay Mouth	40.18708019	111.7299191
December 4, 2016	Goshen Bay North	40.121906	111.878705
December 4, 2016	Lincoln Beach South	40.141755	111.798205
December 4, 2016	Lindon Marina South	40.32556293	111.7660461
December 4, 2016	Sandy Beach	40.1702659	111.7479878

Sample Collection

Phytoplankton samples were collected by inverting a small plastic bottle into the lake water down to elbow deep and then turning the bottle upright while bringing it to the surface. This insured that all the water column to elbow depth was collected equally. Samples were then placed in a cooler with ice and delivered within several hours of collection to Rushforth Phycology, Provo, Utah. If samples could not be delivered to their lab on the same day, then samples were preserved with several drops of Lugol's solution (usually 6-8 drops until water was 'tea colored') and delivered within two days. Samples were then processed by Rushforth Phycology using standard laboratory procedures. Taxa were counted as units/mL and then calculated by Rushforth to cells/mL using Utah Lake transformations specifically developed by Rushforth Phycology. Raw units/mL and transformed cells/mL results are in Appendix 1. We used cells/mL in all of our statistical analyses.

Statistics

Spatial and Temporal Patterns of Phytoplankton Assemblages: *Multivariate Models*

Non-metric multidimensional scaling (NMS) ordination was used to visually compare assemblage relationships between sites and months. Ordination techniques are often more informative than hypothesis-testing approaches for exploring relationships between multivariate ecological assemblages or communities (McCune and Grace 2002). In general, ordination is the ordering of objects along axes according to their (dis)similarities; the main objective of ordination is to reduce many-dimensional relationships into a small number of more easily interpretable dimensions (i.e., axes on a plot). The strongest correlation structure in the data is extracted and is then used to position objects in ordination space. Objects that are close in the ordination space are more similar than objects distant in ordination space (McCune and Mefford 2011).

NMS was used in these analyses because it has been shown to be robust and highly informative for understanding ecological relationships. NMS ordination is often more broadly applicable for ecological studies than other ordination techniques because it does not require relationships among variables to be linear (McCune and Mefford 2011; Peck 2010). NMS ordination permits the visualization of the multidimensional relationships of nutrients and other chemical variables into a more easily visualized, lower dimensional space. Dimensional reduction obviously creates some distortion in relationships between samples. The level of reduction in distortion is measured as ‘stress’; where lower stress values equal less distortion. NMS plots with stress values of 15% (0.15) or less are typically considered to be a good representation of the data and stress values lower than 10% (0.10) are considered excellent representations (McCune and Mefford 2011; Peck 2010).

NMS analyses of Utah Lake phytoplankton assemblage data was conducted using PC-ORD Version 6.0 (2011). A Sorensen (Bray-Curtis) distance measure was used in the NMS analysis and run for 250 iterations using the real data and 250 iterations in randomized Monte Carlo simulations. The Sorensen distance measure is based on pairwise comparisons between all sample pairs, therefore NMS ordinations were rotated using varimax rotation to maximize variation along the axes and extracted as univariate scores. Therefore, the final ordinations can be rotated either vertically or horizontally without effecting the results. The best model was chosen based on scree plots and final stress values. Centroid labels of sites were added to the ordinations to aid in the interpret the relationships. Post hoc proportion of variance represented by each axis was calculated based on the R^2 value between distance in the ordination space and distance in the original space.

MRPP (multi-response permutation procedure), a non-parametric multivariate method was used to formally test the hypothesis of no differences in assemblages between months and sites. MRPP has the advantage of not requiring distributional assumptions such as multivariate normality and homogeneity of variance and thus is often preferred over MANOVA for analyzing multivariate ecological data (McCune and Grace 2002). A Sorensen (Bray-Curtis) distance measure was used in the MRPP analyses. The chance-corrected within-group test statistic, *A* (and associated p-value) was used to evaluate the hypothesis of no difference in the spatial and temporal groupings (McCune and Grace 2002).

Individual Phytoplankton Taxa Spatial and Temporal Patterns

Additional statistical analyses including taxon specific: time series graphs (using means), boxplots, ANOVAs, and probit and negative binomial regressions are currently being conducted using Stata 14.2 (StatCorp 2015) and will be presented in future reports. Poisson probit and negative binomial regression methods were chosen because individual plankton taxa density estimates were count data that were truncated at zero and contained mostly zero counts. These types of data cannot be transformed to approximate normal Gaussian (normal) distributions using any transformation method, therefore linear models are not appropriate.

Results

Taxa

Phytoplankton taxonomists at Rushforth Phycology identified 124 phytoplankton taxa groups from our 2016 Utah Lake samples (N = 130 samples)(Table 2). We estimated that there were between 152 to 172 phytoplankton taxa in Utah Lake 2016 based on four species- area- curve estimators (first-order jackknife, second-order jackknife, and Chao classic and Chao bias corrected estimators (Chao 1987; Colwell and Coddington 1994; Palmer 1990; Palmer 1991; Heltshe and Forrester 1983; Burnham and Overton 1979;McCune and Mefford 2011)). Even though some of the taxa could not be identified to genus or species and were identified as unknown taxa groups; 150 to 170 phytoplankton taxa occurring in the lake is a remarkable number. Utah Lake is not only highly productive (eutrophic) but its phytoplankton assemblage is extremely diverse.

Table 2. Phytoplankton taxa identified from 130 Utah Lake 2016 samples. Taxonomy conducted by Rushforth Phycology, Provo, Utah.

Taxon
Actinastrum hantzschii
Acutidesmis obliquus
Acutidesmus dimorphus
Acutidesmus pectinatus
Anabaenopsis species
Ankistrodesmus falcatus
Ankyra judayi
Aphanizomenon flos-aquae
Aphanocapsa species
Aphanothece species
Asterionella formosa
Biddulphia laevis
Botryococcus braunii
Calothrix species
centric diatom species 2
centric diatoms
Ceratium hirundinella
Characiopsis species
Chlamydomonas species
Chroococcus dispersus
Chrysocapsa planktonica
Closteriopsis acicularis
Closteriopsis longissima
Closteriopsis longissima var. tropica
Coelastrum microporum
Coelastrum species
Coelosphaerum species
Crucigenia fenestrata
Crucigenia rectangularis

Crucigenia species
Crucigenia tetrapedia
Crucigeniella rectangularis
Cryptomonas species
Cryptomonas species 2
Cyanodictyon planktonicum
Cylindrospermopsis species
Cyllindarospermopsis catemaco
Cyllindarospermopsis catemca
Desmidium species
Desmodesmus aculeolatus
Desmodesmus bicellularis
Desmodesmus communis
Desmodesmus intermedius
Desmodesmus obtusus
Desmodesmus opoliensis
Desmodesmus protrubans
Desmodesmus species
Desodesmus bicellularis
Dinobryon divergens
Dolichospermum crassa
Dolichospermum flosaquae
Euglena species
Fragilaria crotonensis
Fragilaria virescens
Gomphosphaeria aponina
Gomphosphaeria lacustris
Gymnodinium species
Keratococcus species
Kirchneriella species
Kirchniella lunata
Lagerheimia species
Lepocinclis species
Leptolyngbya species
Leptolyngbya species 2
Melosira granulata
Melosira granulata var. angustissima
Melosira varians
Merismopedia glauca
Merismopedia species

Micractinium species
Microcystis aeruginosa
Microcystis incerta
Microcystis species
Microspora species
Monoraphidium arcuatum
Monoraphidium contortum
Monoraphidium convolutus
Monoraphidium dybowskii
Monoraphidium griffithii (Berkeley) Komarkova-Legnerova
Monoraphidium irregulare
Monoraphidium komarakovae
Monoraphidium species
Nitzschia acicularis
Nitzschia reversa
Oocystis borgei
Oocystis gigas
Oocystis species
Oocystis species 2
Oocystis species 3
Oscillatoria species
Pandorina morum
Pediastrum duplex
Pediastrum duplex var. clathratum
Pediastrum species
pennate diatoms
Perionella species
Phacus species
Phormidium formosum
Phormidium species
Phormidium species 3
Phormidium species 4
Pseudanabaena species
Quadrgigula lacustris
Quadrigula species
Scenedesmus arcuatus
Scenedesmus ellipticus
Scenedesmus obtusus
Scenedesmus species
Schroederia setigera

Sphaerocystis schroeteri
Spherical chlorophyta
Stephanodiscus niagarae
Tetraedron minimum
Trachellomonas species
Ulothrix species
Unknown colonial chlorophyte
Unknown colonial cyanophyte
Unknown colonial cyanophyte species 2
unknown elongate chlorophyte
unknown filamentous Cyanophyta species 2
Unknown filamentous cyanophyte 4
unknown spherical chlorophyta
unknown spherical chlorophyta 2
Unknown spherical chlorophyte 3

Many of the phytoplankton taxa were rare and only occurred in one or two samples (Table 3). Thirty-three taxa occurred as singletons, and 18 occurred as doubletons (Table 3).

Table 3. Rare and uncommon phytoplankton taxa collected from Utah Lake, 2016. We considered taxa to be rare and uncommon if they occurred in < 3 of the 130 samples. Several of these taxa were unidentifiable and thus may have been other already listed taxa or different species. Taxa in this table are also listed in Table 1.

Acutidesmis obliquus
Acutidesmus dimorphus
Anabaenopsis species
Ankyra judayi
Asterionella formosa
Calothrix species
Ceratium hirundinella
Characiopsis species
Chrysocapsa planktonica
Closteriopsis acicularis
Closteriopsis longissima
Crucigenia species
Crucigenia tetrapedia
Cryptomonas species
Cryptomonas species 2
Cylindrospermopsis species
Desmidium species
Desmodesmus aculeolatus

Desmodesmus intermedius
Desmodesmus protrubans
Dinobryon divergens
Fragilaria crotonensis
Gomphosphaeria lacustris
Keratococcus species
Kirchneriella species
Lagerheimia species
Lepocinclis species
Merismopedia species
Micractinium species
Microcystis incerta
Microcystis species
Microspora species
Monoraphidium griffithii (Berkeley) Komarkova-Legnerova
Monoraphidium irregulare
Nitzschia reversa
Oocystis gigas
Pandorina morum
Perionella species
Phormidium species 4
Quadrgigula lacustris
Quadrigula species
Scenedesmus arcuatus
Scenedesmus species
Spherical chlorophyta
Tetraedron minimum
Trachellomonas species
Unknown colonial cyanophyte
Unknown colonial cyanophyte species 2
unknown elongate chlorophyte
unknown filamentous Cyanophyta species 2
Unknown spherical chlorophyte 3

Descriptive statistics including proportional occurrences of the phytoplankton taxa are in Table 4.

Table 4. Descriptive statistics of phytoplankton taxa including means, standard deviations, sums, minima, maxima, and proportional occurrences. Proportional occurrence = number of samples a taxon occurred in divided by the total number of samples (N = 130).

Taxon	Mean	Std. Dev.	Sum	Min	Max	Proportional Occurrence
Actinastrum hantzschii	156.0	991.8	21210	0	9520	0.10
Acutidesmis obliquus	2.8	25.3	376	0	280	0.01
Acutidesmus dimorphus	0.2	2.1	24	0	24	0.01
Acutidesmus pectinatus	163.6	914.2	22248	0	10190	0.30
Anabaenopsis species	4.1	48.0	560	0	560	0.01
Ankistrodesmus falcatus	33.4	201.8	4538	0	2156	0.17
Ankyra judayi	0.0	0.5	6	0	6	0.01
Aphanizomenon flos-aquae	792.7	5206.2	107811	0	53840	0.13
Aphanocapsa species	1110.4	3590.1	151016	0	29600	0.32
Aphanothece species	81.7	447.1	11110	0	3100	0.05
Asterionella formosa	1.1	12.1	155	0	140	0.01
Biddulphia laevis	28.4	317.0	3868	0	3696	0.03
Botryococcus braunii	30.8	201.3	4184	0	1800	0.03
Calothrix species	27.4	319.0	3720	0	3720	0.01
centric diatom species 2	117.3	580.2	15953	0	5852	0.44
centric diatoms	825.3	3614.9	112238	0	35294	0.60
Ceratium hirundinella	4.7	55.0	641	0	641	0.01
Characiopsis species	0.5	6.0	70	0	70	0.01
Chlamydomonas species	6.2	31.2	840	0	224	0.05
Chroococcus dispersus	8.2	58.1	1112	0	600	0.03
Chrysocapsa planktonica	26.4	307.3	3584	0	3584	0.01
Closteriopsis acicularis	0.1	1.2	14	0	14	0.01
Closteriopsis longissima	0.0	0.3	3	0	3	0.01
Closteriopsis longissima var. tropica	132.7	1114.8	18052	0	11872	0.09
Coelastrum microporum	101.9	660.3	13864	0	6710	0.04
Coelastrum species	226.6	2226.6	30824	0	25500	0.02
Coelosphaerum species	9.5	103.0	1296	0	1200	0.02
Crucigenia fenestrata	73.8	511.7	10036	0	4480	0.02
Crucigenia rectangularis	56.1	370.2	7632	0	3360	0.05
Crucigenia species	28.1	309.2	3824	0	3600	0.01
Crucigenia tetrapedia	48.6	566.6	6608	0	6608	0.01
Crucigeniella rectangularis	703.8	3175.0	95715	0	31400	0.29
Cryptomonas species	0.5	6.0	70	0	70	0.01
Cryptomonas species 2	0.5	6.0	70	0	70	0.01
Cyanodictyon planktonicum	1227.7	5423.1	166970	0	51300	0.23
Cylindrospermopsis species	62.4	369.0	8488	0	2800	0.03
Cyllindarospermopsis catemaco	23.5	211.1	3196	0	2300	0.01

Cyllindarospermopsis catemca	24.8	189.4	3370	0	1740	0.02
Desmidium species	1.9	16.0	264	0	140	0.01
Desmodesmus aculeolatus	1.2	14.4	168	0	168	0.01
Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	330.5	2746.7	44950	0	27500	0.06
Desmodesmus communis	1936.0	16277.2	263299	0	189000	0.54
Desmodesmus intermedius	2.1	24.0	280	0	280	0.01
Desmodesmus obtusus	9.8	59.4	1335	0	420	0.04
Desmodesmus opoliensis	317.1	2350.9	43122	0	27040	0.24
Desmodesmus protrubans	21.3	248.7	2900	0	2900	0.01
Desmodesmus species	347.5	2747.5	47260	0	25830	0.07
Desodesmus bicellularis	28.7	130.2	3906	0	1014	0.15
Dinobryon divergens	92.6	1080.4	12600	0	12600	0.01
Dolichospermum crassa	57.8	368.4	7867	0	3080	0.05
Dolichospermum flosaquae	653.0	7132.7	88803	0	83160	0.04
Euglena species	49.8	434.1	6779	0	5051	0.18
Fragilaria crotonensis	11.1	101.5	1512	0	1120	0.01
Fragilaria virescens	880.5	9687.7	119752	0	113000	0.08
Gomphosphaeria aponina	124.8	827.4	16970	0	8400	0.04
Gomphosphaeria lacustris	200.7	1693.1	27300	0	16800	0.01
Gymnodinium species	1.2	9.4	168	0	84	0.02
Keratococcus species	3.5	28.5	472	0	236	0.01
Kirchneriella species	0.6	7.2	84	0	84	0.01
Kirchniella lunata	43.3	229.0	5882	0	2016	0.05
Lagerheimia species	0.6	7.2	84	0	84	0.01
Lepocinclis species	0.4	4.8	56	0	56	0.01
Leptolyngbya species	1721.0	7156.1	234054	0	69900	0.30
Leptolyngbya species 2	52.7	415.9	7162	0	4550	0.03
Melosira granulata	384.9	4128.6	52342	0	48160	0.10
Melosira granulata var. angustissima	2193.9	9979.8	298373	0	94245	0.43
Melosira varians	24.4	173.1	3324	0	1800	0.11
Merismopedia glauca	2751.4	8977.2	374188	0	56200	0.40
Merismopedia species	4.5	38.0	615	0	375	0.01
Micractinium species	8.2	96.0	1120	0	1120	0.01
Microcystis aeruginosa	873.3	4677.0	118770	0	35000	0.10
Microcystis incerta	12.5	102.7	1700	0	850	0.01
Microcystis species	16.0	150.0	2180	0	1680	0.01
Microspora species	2.6	30.0	350	0	350	0.01

Monoraphidium arcuatum	65.6	338.6	8925	0	2884	0.22
Monoraphidium contortum	68.6	447.1	9336	0	4805	0.16
Monoraphidium convolutus	7.6	46.4	1028	0	364	0.04
Monoraphidium dybowskii	385.4	3159.5	52414	0	26152	0.05
Monoraphidium griffithii (Berkeley) Komarkova-Legnerova	0.1	1.2	14	0	14	0.01
Monoraphidium irregulare	0.6	7.2	84	0	84	0.01
Monoraphidium komarakovae	5.7	24.9	773	0	182	0.08
Monoraphidium species	0.1	1.3	20	0	14	0.02
Nitzschia acicularis	288.3	1825.3	39204	0	16086	0.38
Nitzschia reversa	1.0	12.0	140	0	140	0.01
Oocystis borgei	61.2	231.2	8318	0	1450	0.15
Oocystis gigas	0.0	0.4	5	0	5	0.01
Oocystis species	248.3	630.5	33774	0	5400	0.60
Oocystis species 2	46.6	268.4	6340	0	2300	0.04
Oocystis species 3	4.3	33.0	587	0	345	0.02
Oscillatoria species	133.6	720.2	18174	0	5460	0.04
Pandorina morum	6.6	54.1	896	0	448	0.01
Pediastrum duplex	115.3	708.6	15682	0	7073	0.16
Pediastrum duplex var. clathratum	397.6	2907.3	54080	0	24000	0.03
Pediastrum species	79.7	534.9	10836	0	4872	0.04
pennate diatoms	804.7	2187.4	109435	0	11564	0.95
Perionella species	0.2	2.4	28	0	28	0.01
Phacus species	0.8	6.6	115	0	70	0.03
Phormidium formosum	497.7	2140.7	67684	0	16800	0.09
Phormidium species	561.2	2260.9	76319	0	13610	0.10
Phormidium species 3	371.3	2275.9	50494	0	18100	0.07
Phormidium species 4	31.7	369.5	4309	0	4309	0.01
Pseudanabaena species	150.0	716.2	20402	0	6696	0.07
Quadrgigula lacustris	0.1	1.5	18	0	18	0.01
Quadrigula species	0.3	2.2	36	0	18	0.01
Scenedesmus arcuatus	4.6	48.3	628	0	560	0.01
Scenedesmus ellipticus	261.4	2379.0	35553	0	27664	0.18
Scenedesmus obtusus	167.8	1112.5	22825	0	11757	0.13
Scenedesmus species	0.5	5.3	62	0	62	0.01
Schroederia setigera	22.8	240.2	3102	0	2800	0.05
Sphaerocystis schroeteri	823.0	8457.8	111926	0	98500	0.08
Spherical chlorophyta	0.0	0.3	3	0	3	0.01

Stephanodiscus niagarae	10.3	96.1	1406	0	1109	0.04
Tetraedron minimum	0.3	3.0	46	0	32	0.01
Trachellomonas species	0.2	1.7	28	0	14	0.01
Ulothrix species	18.2	130.6	2470	0	1210	0.02
Unknown colonial chlorophyte	230.0	890.8	31282	0	5600	0.13
Unknown colonial cyanophyte	0.7	7.7	90	0	90	0.01
Unknown colonial cyanophyte species 2	0.6	7.2	84	0	84	0.01
unknown elongate chlorophyte	28.4	308.1	3864	0	3584	0.01
unknown filamentous Cyanophyta species 2	78.2	842.9	10640	0	9800	0.01
Unknown filamentous cyanophyte 4	79.1	625.7	10760	0	5880	0.02
unknown spherical chlorophyta	72.5	202.6	9858	0	1092	0.29
unknown spherical chlorophyta 2	245.0	954.2	33318	0	5810	0.23
Unknown spherical chlorophyte 3	1.0	12.0	140	0	140	0.01

Phytoplankton assemblages: Spatial and Temporal Effects

Discerning phytoplankton assemblage patterns in Utah Lake 2016 was not straight forward because almost half of the taxa were rare and uncommon and many occurred in < 10% of the samples (Table 3, Appendix 1), which resulted in a large proportion (0.91) of the dataset containing zero counts. We removed the taxa that occurred in <10 samples out of the 130 samples to help reduce these effects in our multivariate assemblage analyses. We also had to resort to using Beal's smoothing transformation method to account for the remaining disproportionally large number of zero counts in the dataset. This transformation resulted in a loss of much of the quantitative information but not as severe of a loss of information as a presence/absence transformation would have caused. We used the Beal's smoothing formula:

$$b_y = \frac{1}{Si} \sum_k \left(\frac{Mjk}{Nk}\right)$$

where S is the number of species in sample i, M_{jk} is the number of samples with both species j and k, and N_k is the number of samples with species k. (McCune and Mefford 1999)

This transformation helped relieve the "zero-truncation problem" (Beals 1984; McCune 1994), which is most severe in heterogeneous community data sets that have most of the samples containing a fairly small proportion of the species (McCune and Mefford 1999). Beal's smoothing replaced presence/absence data with quantitative values that represented the "favorability" of each sample for each species, regardless of whether the species was present in the sample (McCune and Mefford 1999). The index evaluated the favorability of a given sample for species *i*, based on the whole data set, using the proportions of joint occurrences between the species that do occur in the sample and species *i*. (McCune and Mefford 1999). As with any numerical smoothing, Beals smoothing tended to reduce the noise in the data by enhancing the strongest patterns in the data. In this case, the signal that is smoothed is the pattern of joint occurrences in the data. This is an extremely powerful transformation that is particularly effective on heterogeneous or noisy data. However, because, like any smoothing function; Beal's transformation can produce the appearance of reliable, consistent trends even from a series of random numbers (McCune and Mefford 1999).

Data editing and transformations resulted in the inclusion of 21 taxa in the multivariate analyses. The final NMS ordination resulted in a 2-dimensional solution with a final stress of 15.13 (final instability < 0.00001 at 44 iterations). Axis 1 accounted for 58% of the phytoplankton assemblage variability and Axis 2 accounted for 32% of the assemblage variability. We then developed ordination graphs for location and months.

Assemblages by Location

The location ordination was loosely based on the following groupings: Pelican Marina, Lindon Marina, Goshen Bay, Provo Bay, Sandy Beach, Lincoln Beach, and the remaining sites were grouped as Utah Lake samples (Figure 1). For the most part, phytoplankton assemblages were similar given that the taxa used in the analyses were the most common. The major differences in phytoplankton assemblages was between Sandy Beach and Lincoln Beach with the other locations (Figure 1). Sandy Beach and Lincoln Beach are located close to each other in the southern end of Utah Lake and their assemblage similarity results are not surprising. However, Provo Bay assemblage did not appear to differ from the other locations (Figure 1). We expected Provo Bay phytoplankton assemblages to be more different from other locations than NMS showed because we consider it to be a sheetflow wetland as compared to other sites in Utah Lake which are typical lake environs; although MRPP suggested that Provo Bay was significantly different from the main sections of Utah Lake (Table 5). This result was likely because we grouped all Provo Bay sites together from the center of the bay to its confluence with Utah Lake (mouth of Provo Bay) and because this first set of site location ordinations included all month's sampled combined. We later conducted ordination on June –November, and then on August only to further explore these relationships.

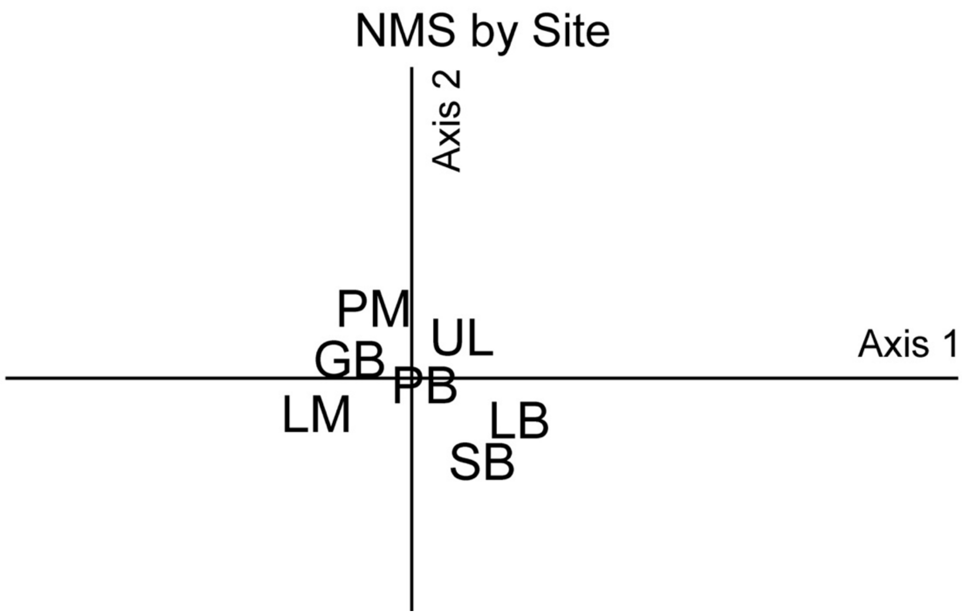


Figure 2. NMS Axis 1 and Axis 2 by site for all months. Site centroids shown. Overall phytoplankton assemblages appeared to be quite similar. Further analysis could separate sites better.

Multi-response permutation procedure suggested that overall, phytoplankton assemblages slightly significantly differed by sites (T = -2.09; A = 0.02; and P = 0.03). It appears that phytoplankton assemblages likely significantly differed between: Lindon Marina and Utah Lake; Lindon Marina and Lincoln Beach; Lindon Marina and Sandy Beach; Pelican Marina and Lincoln Beach; and Pelican Marina and Sandy Beach (Table 5). These results support our hypothesis that phytoplankton assemblages are not spatially uniform over the entire lake.

Table 5. MRPP pairwise comparisons for phytoplankton assemblages by site. Significant differences are highlighted in gray at P $\leq$ 0.06. Note: p values not corrected for multiple comparisons. T = test statistic; A = chance corrected within group agreement; P = probability of a smaller or equal delta. Site Codes: LM = Lindon Marina; PM = Pelican Marina; UL = Utah Lake; GB = Goshen Bay; PB = Provo Bay; LB = Lincoln Beach; SB = Sandy Beach.

Site			T	A	P
LM	vs.	PM	-0.09	0.00	0.35
LM	vs.	UL	-1.74	0.01	0.06
LM	vs.	PB	-0.05	0.00	0.36
LM	vs.	GB	0.07	0.00	0.42
LM	vs.	LB	-1.89	0.02	0.05
LM	vs.	SB	-1.84	0.02	0.06
PM	vs.	UL	0.19	0.00	0.45
PM	vs.	PB	-1.56	0.02	0.08

PM	vs.	GB	-0.43	0.01	0.25
PM	vs.	LB	-1.93	0.03	0.05
PM	vs.	SB	-1.87	0.03	0.06
UL	vs.	PB	-2.21	0.01	0.04
UL	vs.	GB	-0.47	0.00	0.24
UL	vs.	LB	-0.28	0.00	0.30
UL	vs.	SB	-1.02	0.01	0.14
PB	vs.	GB	-1.50	0.02	0.08
PB	vs.	LB	-0.80	0.01	0.18
PB	vs.	SB	0.06	0.00	0.42
GB	vs.	LB	-0.22	0.00	0.32
GB	vs.	SB	-1.05	0.01	0.13
LB	vs.	SB	0.78	-0.01	0.77

Assemblages by Month

Phytoplankton assemblages clearly differed by month/season with a major change in assemblages occurring between July and August (Figure 3). February, March, and April assemblages were more similar to each other; May, June, and July assemblages tended to be similar except July started to become more similar to August assemblages (Figure 3). The August assemblage was most similar to September assemblage; and October, November, December assemblages were similar to each other (Figure 3).

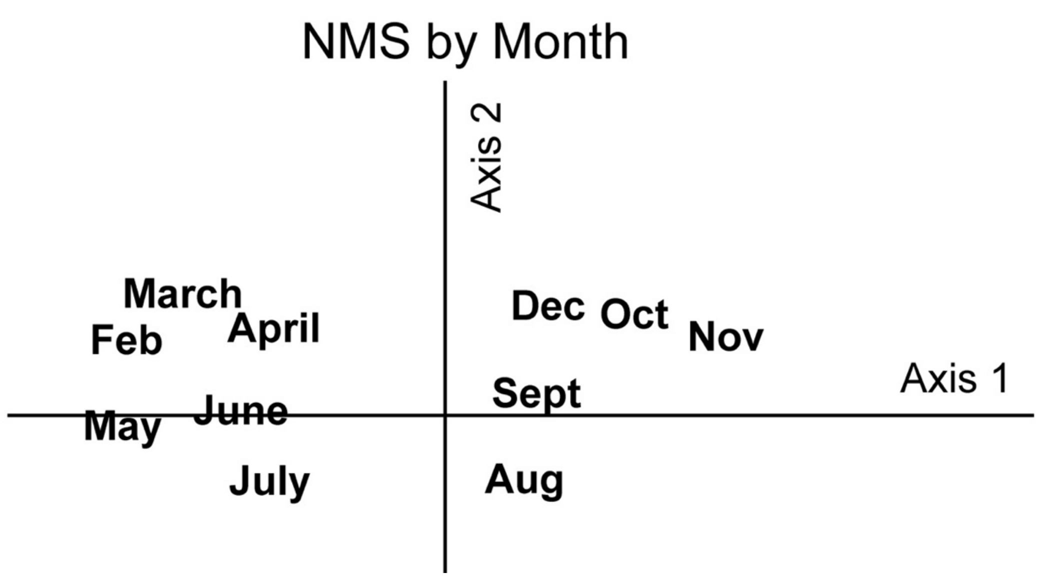


Figure 3. NMS Axis 1 and Axis 2 by months. Month centroids shown.

Table 6. Correlations between taxa and NMS Axis 1 and Axis 2 (Figure 3). Positive r -values in Axis 1 column are associated to the right of Figure 3 and negative values are associated to the left. Positive r -values in Axis 2 column are associated to the top of Figure 3 and negative values are associated to the bottom.

Axis 1		Axis 2	
Taxon	r	Taxon	r
Merismop	0.748	Pdiatoms	0.834
Cplanktn	0.704	Oocystis	0.695
Aphanoca	0.543	Pediastr	0.438
Microcys	0.224	Monoraph	0.324
Oocystis	0.060	Merismop	0.319
Pdiatoms	-0.009	Desodoes	0.309
Pediastr	-0.052	UCchloro	0.175
Phormidi	-0.055	Cdiatoms	0.089
Melosira	-0.133	Crucigen	0.084
Leptolyn	-0.161	Aphanoca	0.082
Acutides	-0.339	Acutides	0.073
Nacicula	-0.366	Euglena	0.065
Desodoes	-0.481	Cplanktn	0.063
Afalcatu	-0.617	Nacicula	0.015
Crucigen	-0.690	Scenedes	-0.085
Monoraph	-0.697	Uschloro	-0.126
Cdiatoms	-0.806	Leptolyn	-0.222
UCchloro	-0.821	Melosira	-0.604
Scenedes	-0.842	Afalcatu	-0.612
Euglena	-0.860	Phormidi	-0.796
Uschloro	-0.888	Microcys	-0.814

Multi-response permutation procedure showed that overall, phytoplankton assemblages significantly differed by months (A = 0.19; and P = <<0.00) (Table 7). It appears that phytoplankton assemblages likely significantly differed between most months but fewer samples collected in winter months (November, December, February) may have biased results. These results support our conclusion and most literature, that phytoplankton assemblages are not temporally uniform over the entire lake.

Table 7. MRPP pairwise comparisons for phytoplankton assemblages by month. Significant differences are highlighted in gray at P $\leq$ 0.06. Note: p values not corrected for multiple comparisons. *T* = test statistic; *A* = chance corrected within group agreement; *P* = probability of a smaller or equal delta.

Month			*T*	*A*	*P*
Feb	vs.	March	0.20	-0.01	0.55
Feb	vs.	April	0.53	-0.03	0.68
Feb	vs.	May	-1.54	0.12	0.08
Feb	vs.	June	-0.81	0.03	0.20
Feb	vs.	July	-2.68	0.10	0.01

Feb	vs.	Aug	-1.41	0.02	0.09
Feb	vs.	Sept	-2.85	0.04	0.01
Feb	vs.	Oct	-4.22	0.10	0.00
Feb	vs.	Nov	-5.62	0.26	0.00
Feb	vs.	Dec	-1.75	0.13	0.05
March	vs.	April	-0.39	0.01	0.32
March	vs.	May	-3.91	0.15	0.00
March	vs.	June	-3.24	0.06	0.01
March	vs.	July	-5.98	0.14	0.00
March	vs.	Aug	-7.93	0.08	0.00
March	vs.	Sept	-10.24	0.12	0.00
March	vs.	Oct	-11.24	0.21	0.00
March	vs.	Nov	-9.84	0.41	0.00
March	vs.	Dec	-3.83	0.17	0.01
April	vs.	May	-0.86	0.04	0.19
April	vs.	June	-0.16	0.00	0.37
April	vs.	July	-4.41	0.12	0.00
April	vs.	Aug	-3.96	0.04	0.00
April	vs.	Sept	-6.34	0.07	0.00
April	vs.	Oct	-8.16	0.16	0.00
April	vs.	Nov	-7.88	0.37	0.00
April	vs.	Dec	-2.67	0.16	0.01
May	vs.	June	-0.16	0.00	0.38
May	vs.	July	-4.59	0.17	0.00
May	vs.	Aug	-5.36	0.06	0.00
May	vs.	Sept	-8.82	0.11	0.00
May	vs.	Oct	-9.54	0.21	0.00
May	vs.	Nov	-8.21	0.43	0.00
May	vs.	Dec	-3.36	0.24	0.01
June	vs.	July	-5.25	0.09	0.00
June	vs.	Aug	-9.13	0.08	0.00
June	vs.	Sept	-13.07	0.13	0.00
June	vs.	Oct	-14.55	0.24	0.00
June	vs.	Nov	-12.60	0.39	0.00
June	vs.	Dec	-5.16	0.14	0.00
July	vs.	Aug	-7.34	0.07	0.00
July	vs.	Sept	-10.03	0.10	0.00
July	vs.	Oct	-13.04	0.22	0.00
July	vs.	Nov	-11.58	0.41	0.00

July	vs.	Dec	-5.43	0.16	0.00
Aug	vs.	Sept	-3.36	0.02	0.01
Aug	vs.	Oct	-8.25	0.06	0.00
Aug	vs.	Nov	-11.45	0.10	0.00
Aug	vs.	Dec	-0.27	0.00	0.32
Sept	vs.	Oct	-3.10	0.02	0.01
Sept	vs.	Nov	-10.90	0.10	0.00
Sept	vs.	Dec	0.82	-0.01	0.79
Oct	vs.	Nov	-3.73	0.05	0.00
Oct	vs.	Dec	0.56	-0.01	0.67
Nov	vs.	Dec	-2.57	0.07	0.02

Assemblages: June to November

Assemblages by location

We refined our multivariate phytoplankton assemblage to only include June to November samples. This resulted in the use of 21 taxa from 104 samples. The best fit NMS model was also a 2-dimensional model and had a final stress of 15.25 (< 0.00001 instability; 101 iterations). Axis was explained 65% of assemblage variability and Axis 2 explained 24% variability.
The phytoplankton assemblage near Pelican Marina was least similar to the Goshen Bay assemblage, however Goshen Bay assemblage was most closely similar to the Lindon Marina assemblage (Figure 4). This was likely due to the cyanobacteria blooms that were most intense in these two locations but not in Goshen Bay. Sandy Beach was somewhat different than the other locations but overall assemblages were fairly similar throughout the lake (Figure 4).

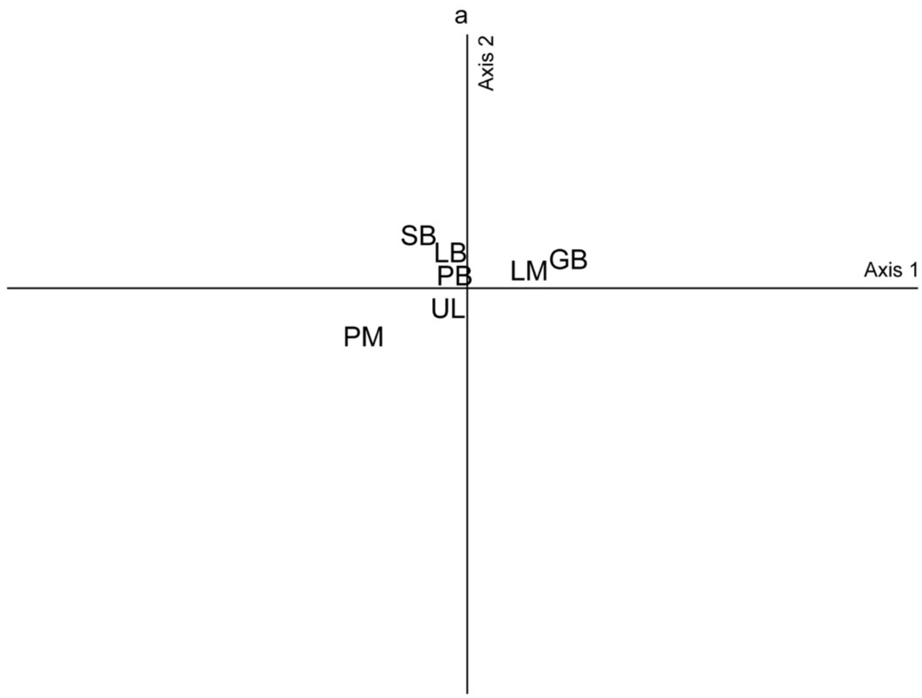


Figure 4. NMS Axis 1 and Axis 2 by sites. Month centroids shown. June to November data.

Assemblages by Month

Phytoplankton assemblages clearly differed by month with: June and July assemblages very similar to each other; August assemblages dissimilar to the other months and; October, September, and November somewhat similar to each other however, November was more dissimilar to October and September and was clearly dissimilar to June and July assemblages (Figure 5).

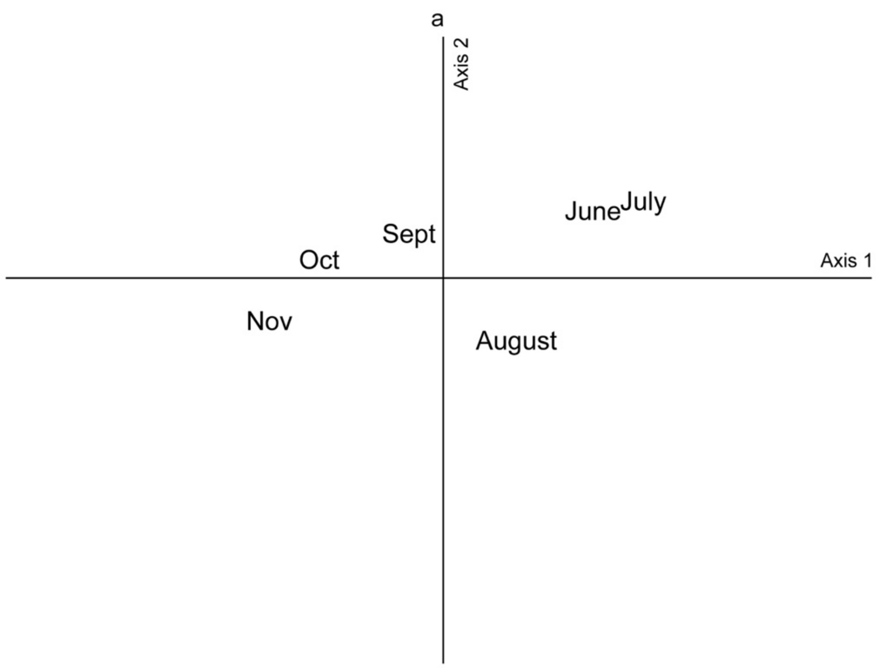


Figure 5. NMS Axis 1 and Axis 2 by months. Month centroids shown. June to November data.

Table 8. Correlations between taxa and NMS Axis 1 and Axis 2 (Figure 4). Positive r -values in Axis 1 column are associated to the right of Figure 4 and negative values are associated to the left. Positive r -values in Axis 2 column are associated to the top of Figure 4 and negative values are associated to the bottom.

Taxon	r	Taxon	r
Afalcatu	0.915	Monoraph	0.728
Uschloro	0.866	Desodoes	0.711
Scenedes	0.811	Pediastr	0.596
Phormidi	0.789	Acutides	0.541
Aflos-aq	0.732	Oocystis	0.539
Euglena	0.651	Crectang	0.464
Microcys	0.492	Nacicula	0.444
Cdiatoms	0.482	Euglena	0.433
Melosira	0.454	Merismop	0.417
Leptolyn	0.416	Cdiatoms	0.283
Nacicula	0.386	Scenedes	0.228
Crectang	0.279	Leptolyn	0.136
Monoraph	0.195	Uschloro	0.039
Acutides	0.172	Afalcatu	0.011

Desodoes	0.17	Pdiatoms	-0.04
Pediastr	0.01	Cplanktn	-0.127
Oocystis	-0.399	Aphanoca	-0.139
Pdiatoms	-0.402	Phormidi	-0.21
Aphanoca	-0.419	Aflos-aq	-0.401
Cplanktn	-0.613	Microcys	-0.421
Merismop	-0.744	Melosira	-0.626

Multi-response permutation procedure suggested that overall, phytoplankton assemblages did not significantly differ by sites between June and November (T = -1.42; A = 0.01; and P = 0.09) (Table 9), except Goshen Bay assemblage was significantly different than Sandy Beach assemblage (Table 9). This was likely because of the dominance of the phytoplankton assemblages by just a few taxa that occurred throughout the lake in summer. NMS showed that late autumn assemblages were clearly different than early and late summer assemblages (Figure 5).

Table 9. MRPP pairwise comparisons for phytoplankton assemblages by site. Significant differences are highlighted in gray at P ≤ 0.06. Note: p values not corrected for multiple comparisons. T = test statistic; A = chance corrected within group agreement; P = probability of a smaller or equal delta. Site Codes: LM = Lindon Marina; PM = Pelican Marina; UL = Utah Lake; GB = Goshen Bay; PB = Provo Bay; LB = Lincoln Beach; SB = Sandy Beach.

Site			T	A	P
GB	vs.	UL	-1.32	0.01	0.10
GB	vs.	LM	0.55	-0.01	0.64
GB	vs.	PB	-1.44	0.02	0.09
GB	vs.	LB	-0.06	0.00	0.37
GB	vs.	SB	-1.82	0.03	0.06
GB	vs.	PM	-1.13	0.02	0.12
UL	vs.	LM	-1.21	0.01	0.11
UL	vs.	PB	-1.42	0.01	0.09
UL	vs.	LB	-0.36	0.00	0.29
UL	vs.	SB	-0.77	0.01	0.18
UL	vs.	PM	0.76	-0.01	0.77
LM	vs.	PB	0.62	-0.01	0.68
LM	vs.	LB	-0.05	0.00	0.39
LM	vs.	SB	-1.23	0.02	0.11
LM	vs.	PM	-0.85	0.02	0.17
PB	vs.	LB	0.45	-0.01	0.60

PB	vs.	SB	0.22	0.00	0.49
PB	vs.	PM	-0.69	0.01	0.20
LB	vs.	SB	0.36	-0.01	0.58
LB	vs.	PM	-0.79	0.02	0.19
SB	vs.	PM	-0.17	0.00	0.35

Multi-response permutation procedure suggested that phytoplankton assemblages significantly differed by months (A = 0.16; and p-value << 0.001) (Table 10) and that phytoplankton assemblages significantly differed between all months. These results support our conclusion and most literature, that phytoplankton assemblages are not temporally uniform over the entire lake and that temporal effects on assemblages are much greater than spatial effects.

Table 10. MRPP pairwise comparisons for phytoplankton assemblages by month (June through November). All months were significant different from each other. Note: p values not corrected for multiple comparisons. T = test statistic; A = chance corrected within group agreement; P = probability of a smaller or equal delta.

Month			T	A	P
June	vs.	July	-4.321	0.069	0.001
June	vs.	Aug	-5.273	0.044	0.001
June	vs.	Sept	-9.444	0.098	0.000
June	vs.	Oct	-12.977	0.193	0.000
June	vs.	Nov	-12.054	0.344	0.000
July	vs.	Aug	-6.974	0.064	0.000
July	vs.	Sept	-11.291	0.137	0.000
July	vs.	Oct	-13.566	0.234	0.000
July	vs.	Nov	-11.389	0.420	0.000
Aug	vs.	Sept	-6.051	0.036	0.000
Aug	vs.	Oct	-9.827	0.071	0.000
Aug	vs.	Nov	-11.863	0.110	0.000
Sept	vs.	Oct	-2.318	0.018	0.028
Sept	vs.	Nov	-10.254	0.111	0.000
Oct	vs.	Nov	-3.816	0.048	0.003

Individual Phytoplankton Taxa

The Utah Lake 2016 phytoplankton assemblage was dominated by a handful of ubiquitous taxa and the remainder occurred rarely or uncommonly spatially and temporally. This is typical of most ecosystems: “rare is common and uncommon is rare”. The number of taxa (taxa richness) also varied seasonally and by location. Estimated taxa richness was typically greatest during summer months although estimates varied widely during this time (Figure 6). Low taxa richness estimates in the winter months (Figure 6) may have been affected by fewer samples collected during this time, 'the less you look, the less you find', although the species area curve estimates we calculated were adjusted for sample size and it is likely that taxa richness was indeed lower during winter months.

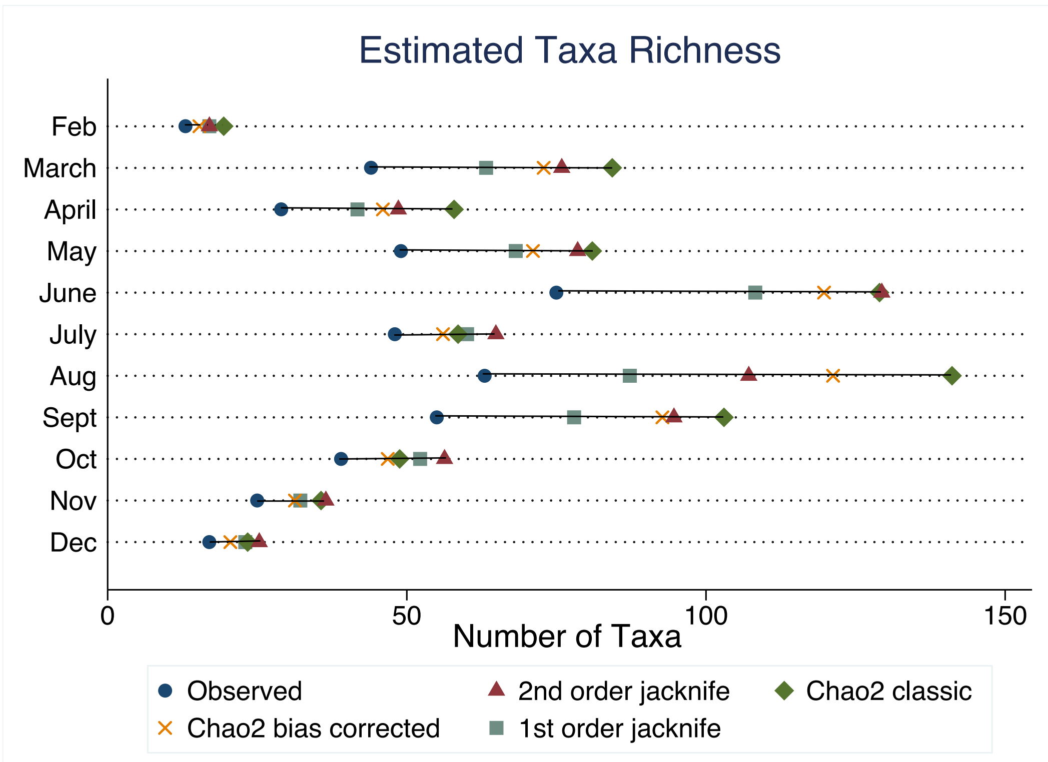
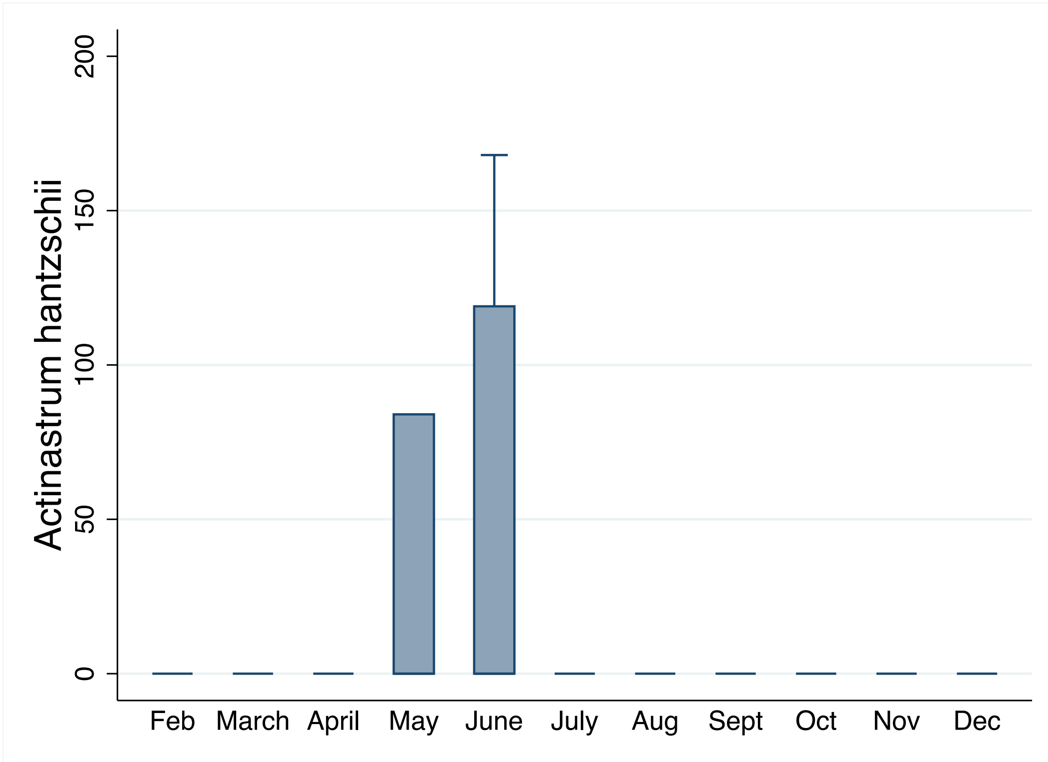


Figure 6. Estimated phytoplankton taxa richness by month in Utah Lake 2016. Estimates include observed and four species area curve based estimates: 1st order jackknife; 2nd order jackknife; Chao2 classic; and Chao2 bias corrected (McCune and Mefford 2011).

Box plots of monthly densities (cells/mL) of the fifty-seven most ubiquitous (spatially and temporally abundant) occurring taxa in Utah Lake 2016 are in the following figures. The box plots include; median, 25th, 75th percentiles and lower and upper adjacent values, and omit outside values. The adjacent values are defined as the lowest and highest observations that are still inside the region defined by the following limits: Lower Limit: Q1 − 1.5 × Interquartile range. Upper Limit: Q3 + 1.5 × Interquartile range.


Actinastrum hantzschii
0
50
100
150
200
Feb
March
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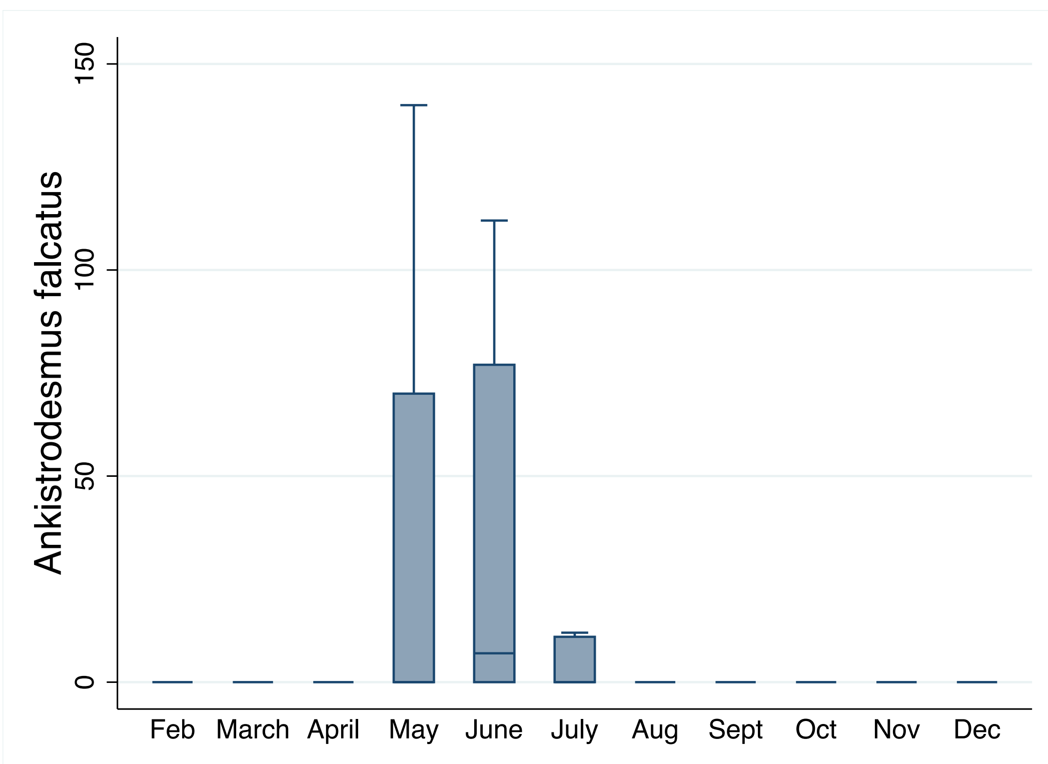
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100
150
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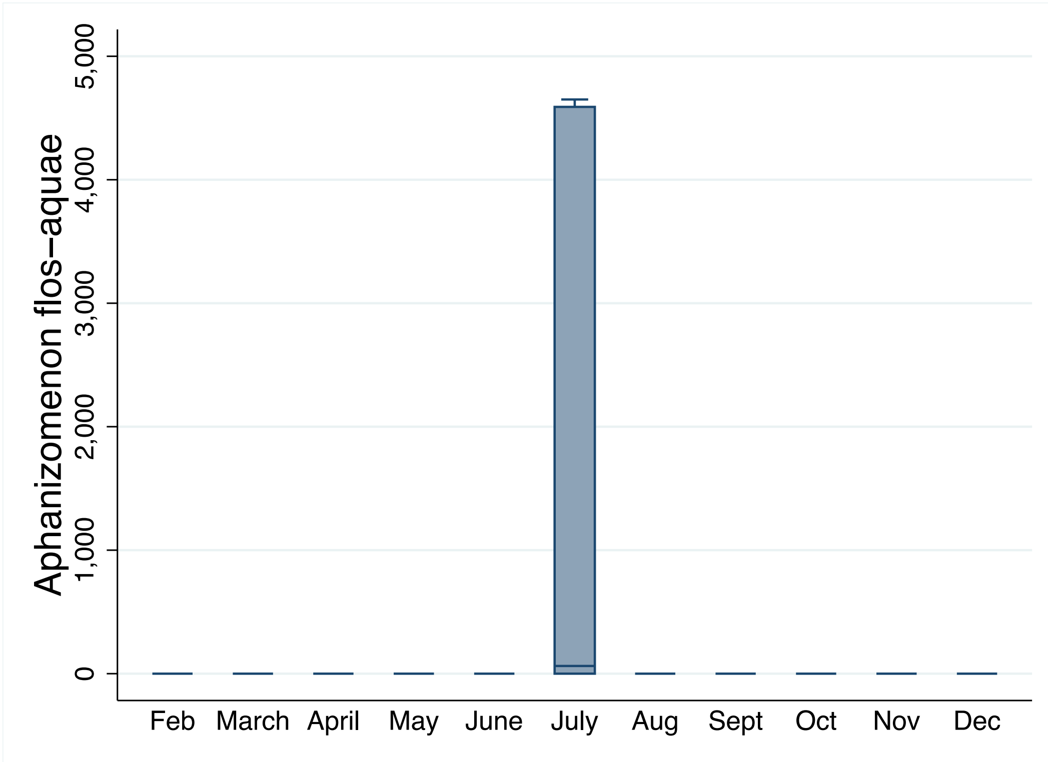
Aphanizomenon flos−aquae
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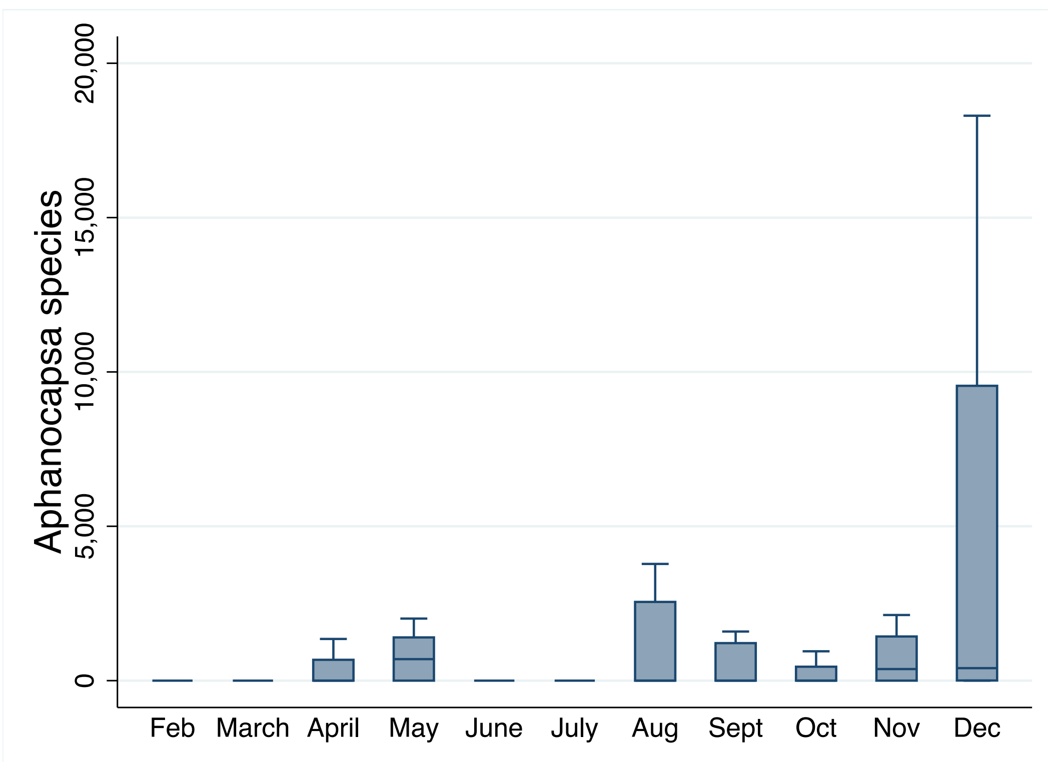
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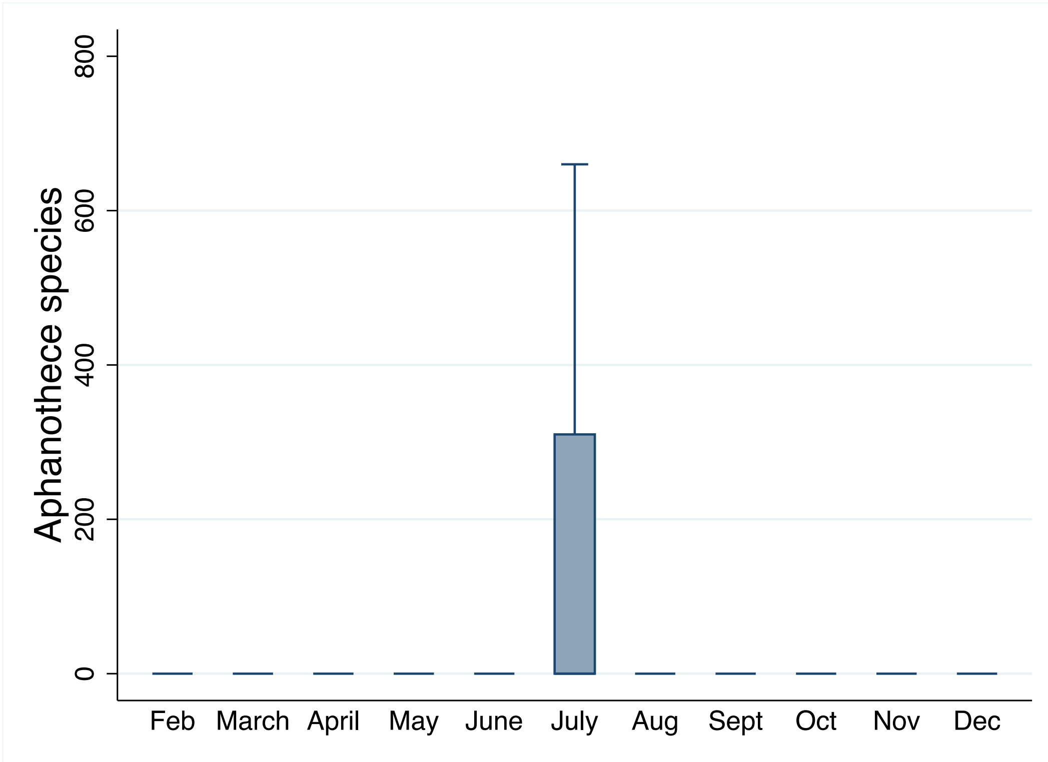
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400
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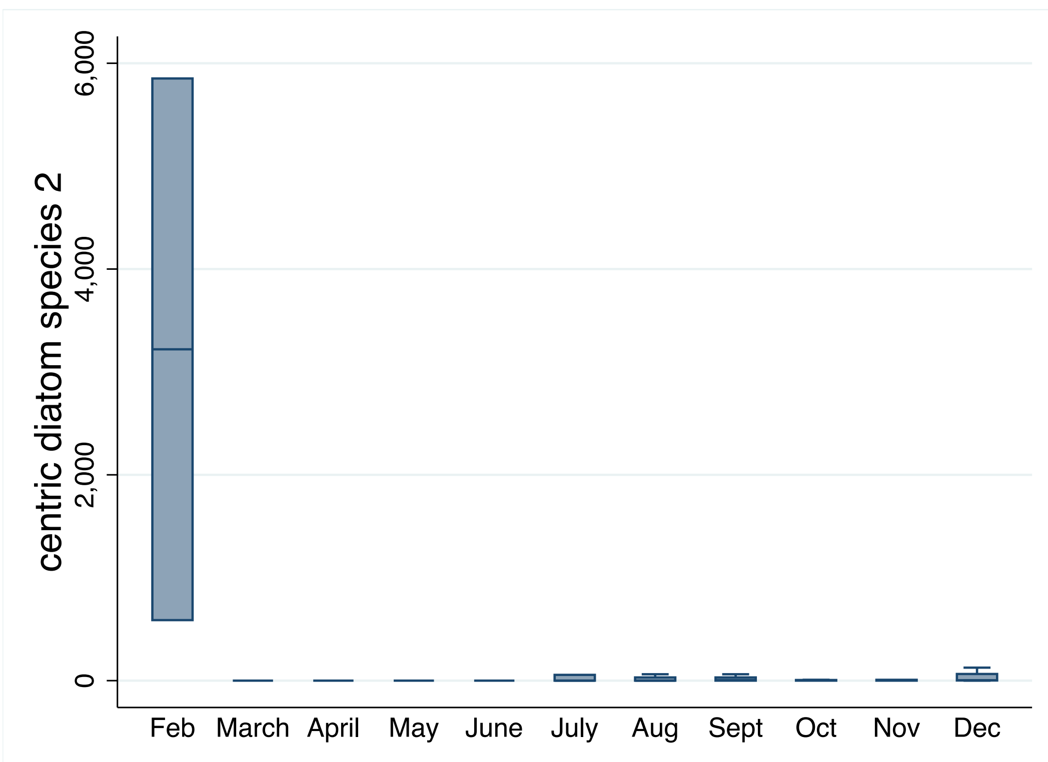
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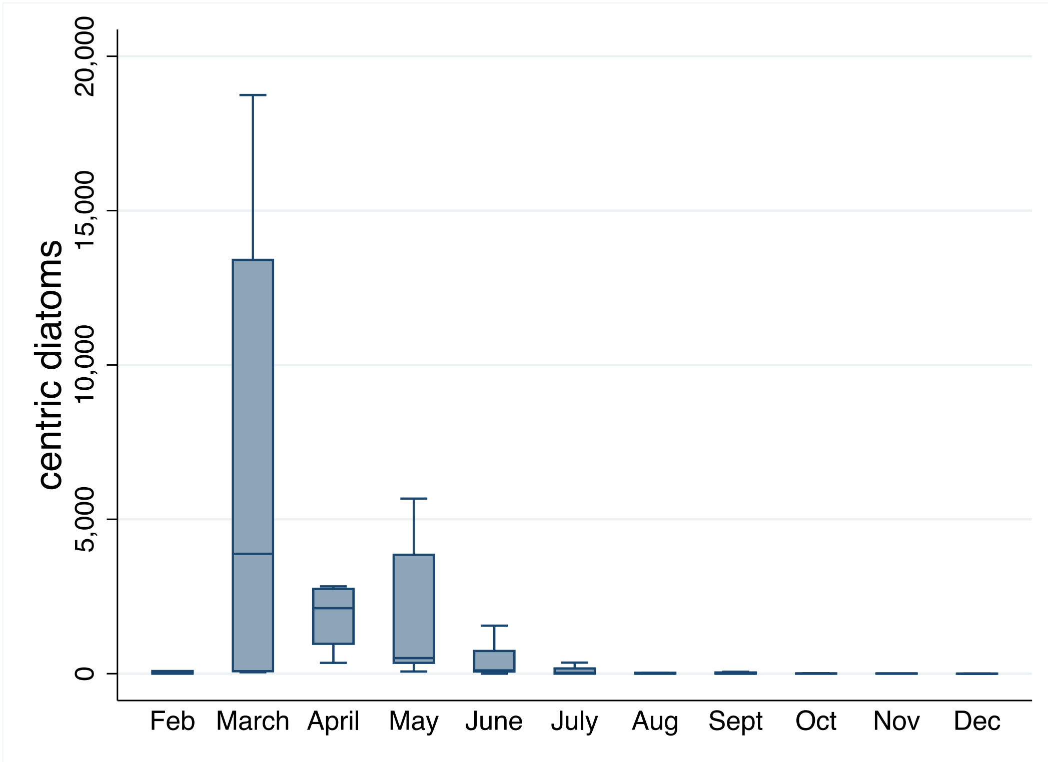
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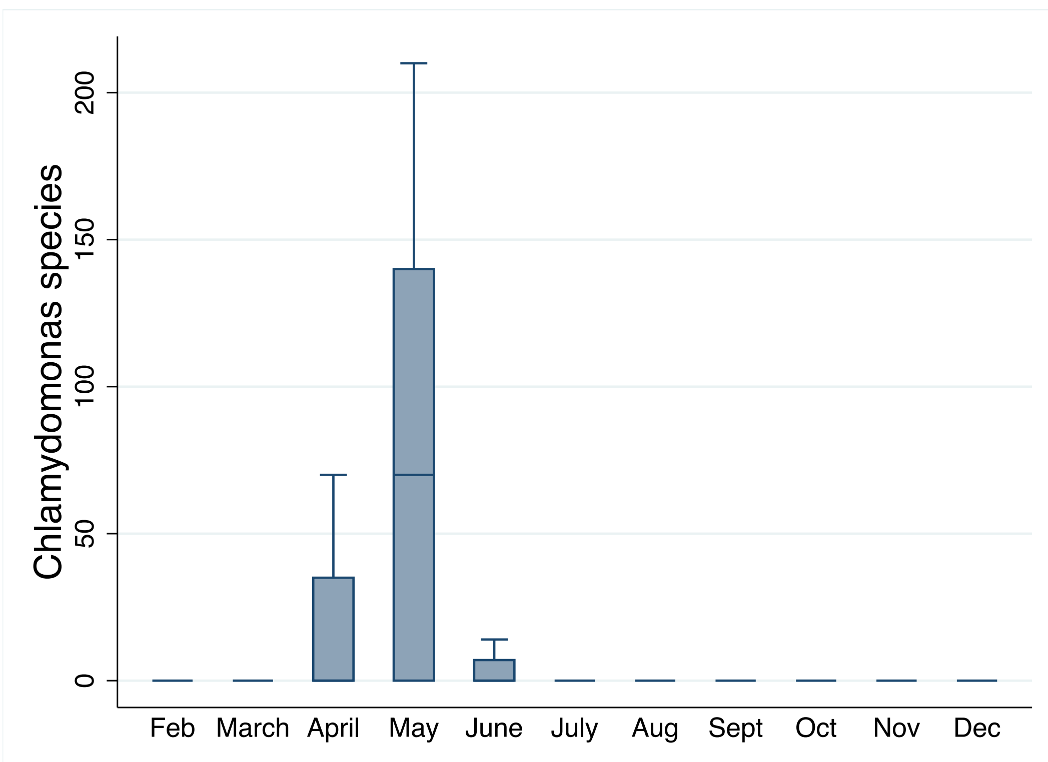
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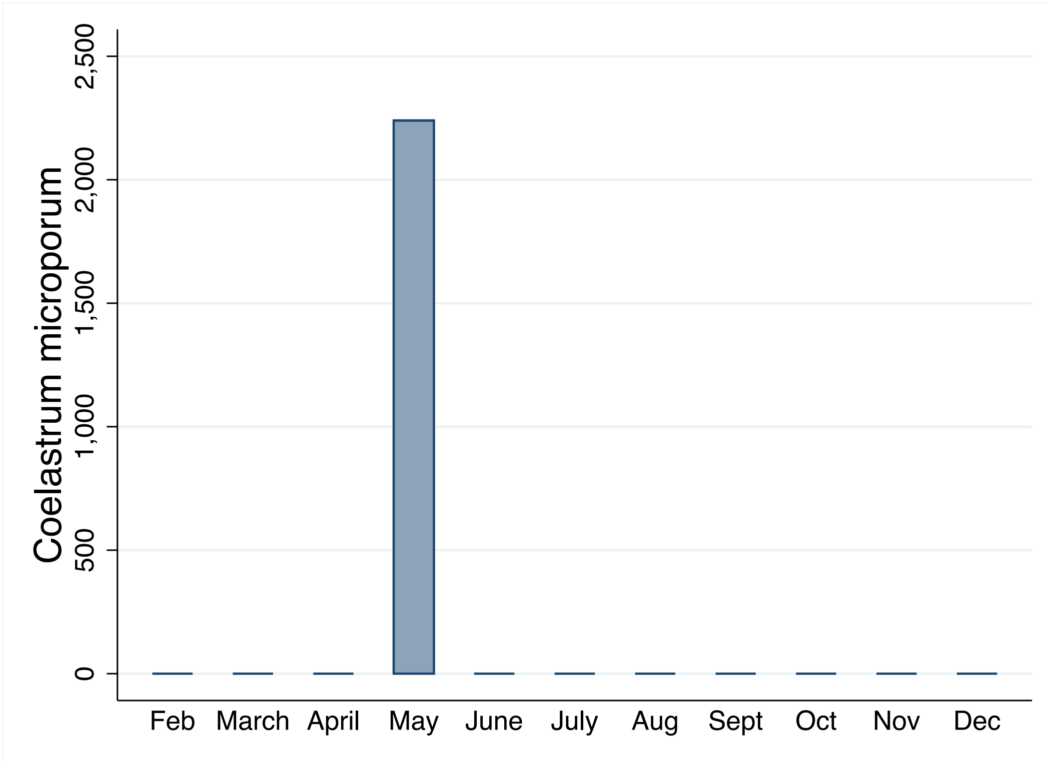
Coelastrum microporum
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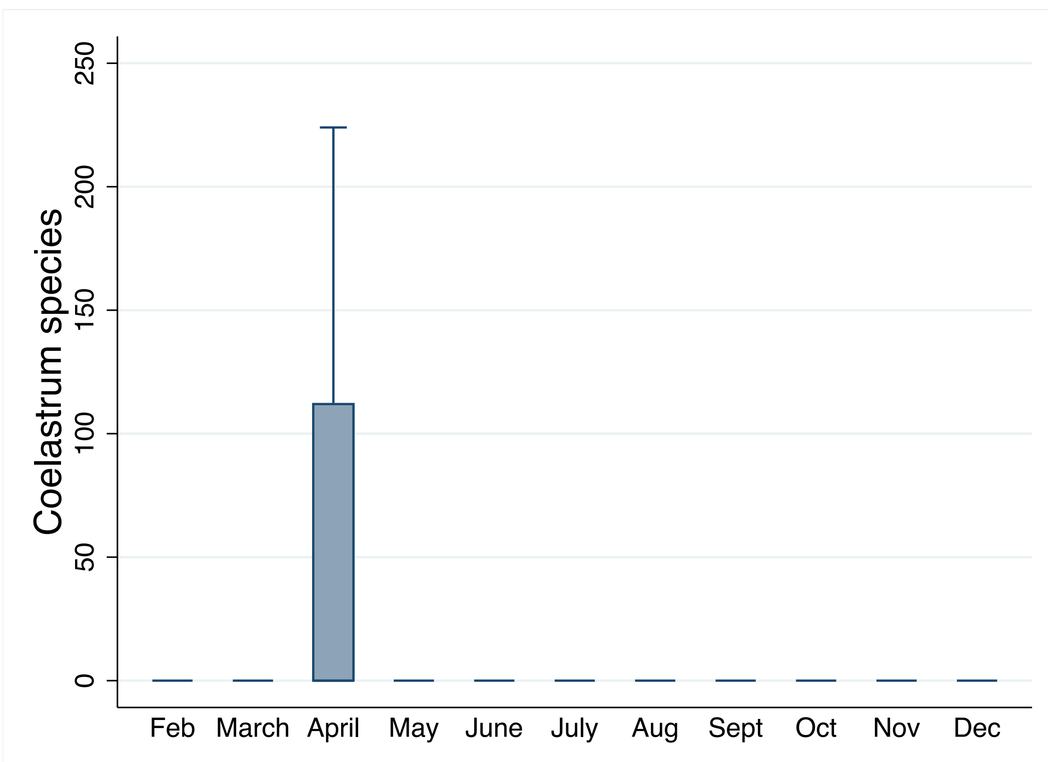
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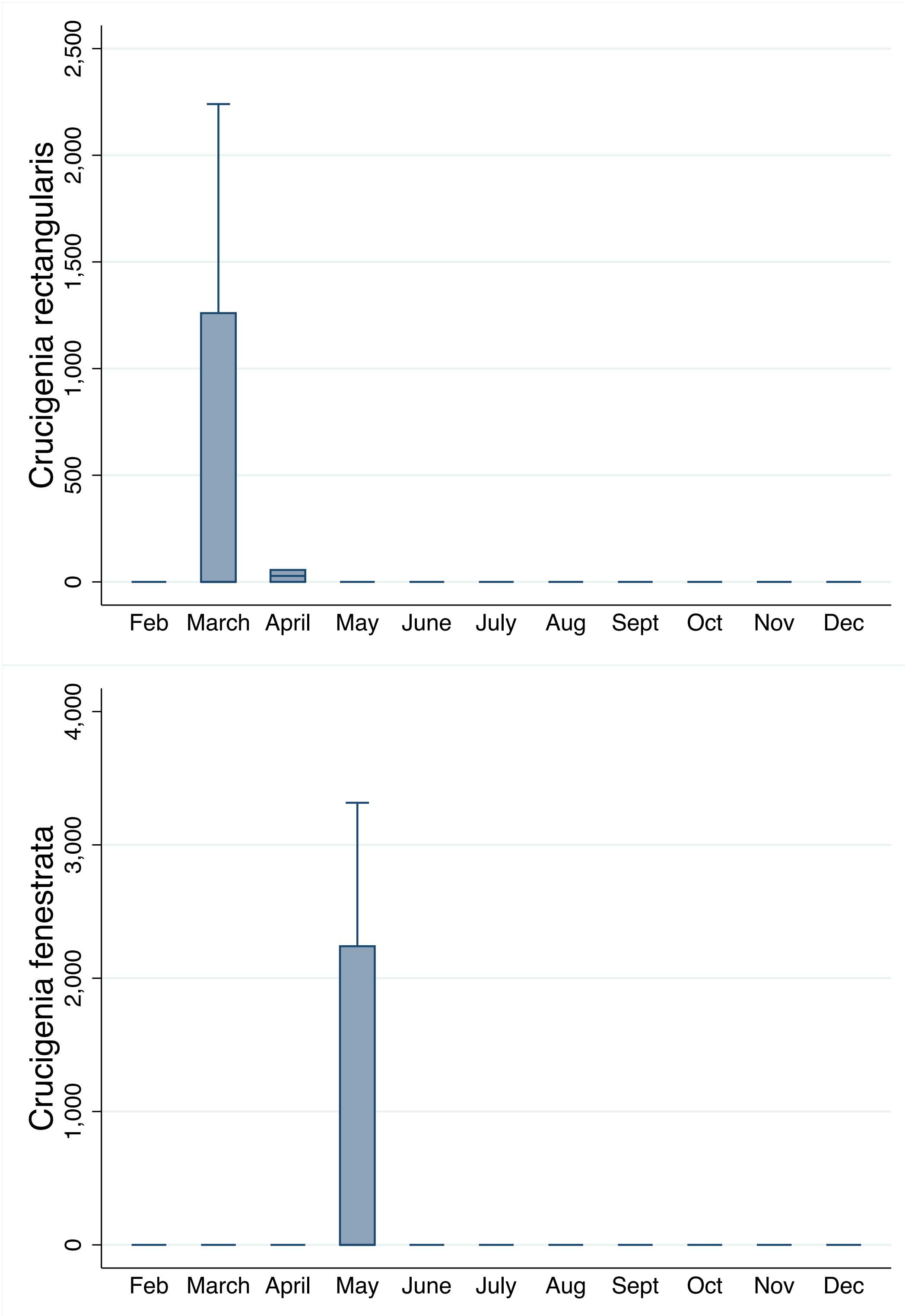
Crucigenia rectangularis
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Feb March April May June July Aug Sept Oct Nov Dec
Crucigenia fenestrata
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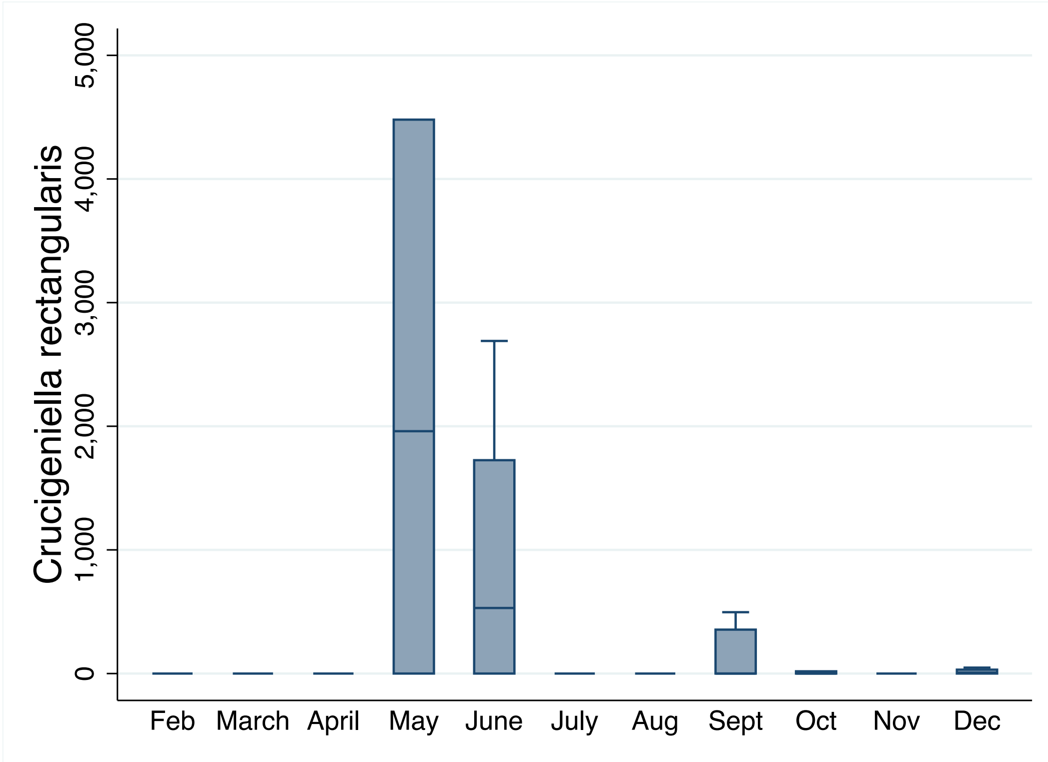
Feb March April May June July Aug Sept Oct Nov Dec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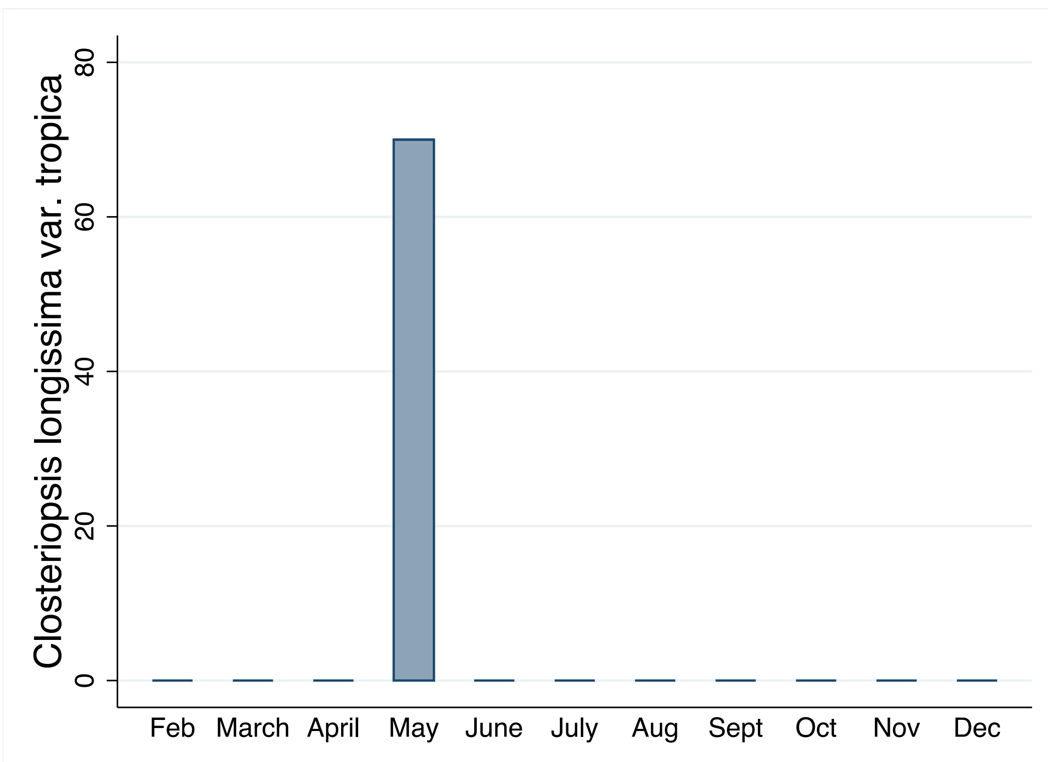
Closteriopsis longissima var. tropica
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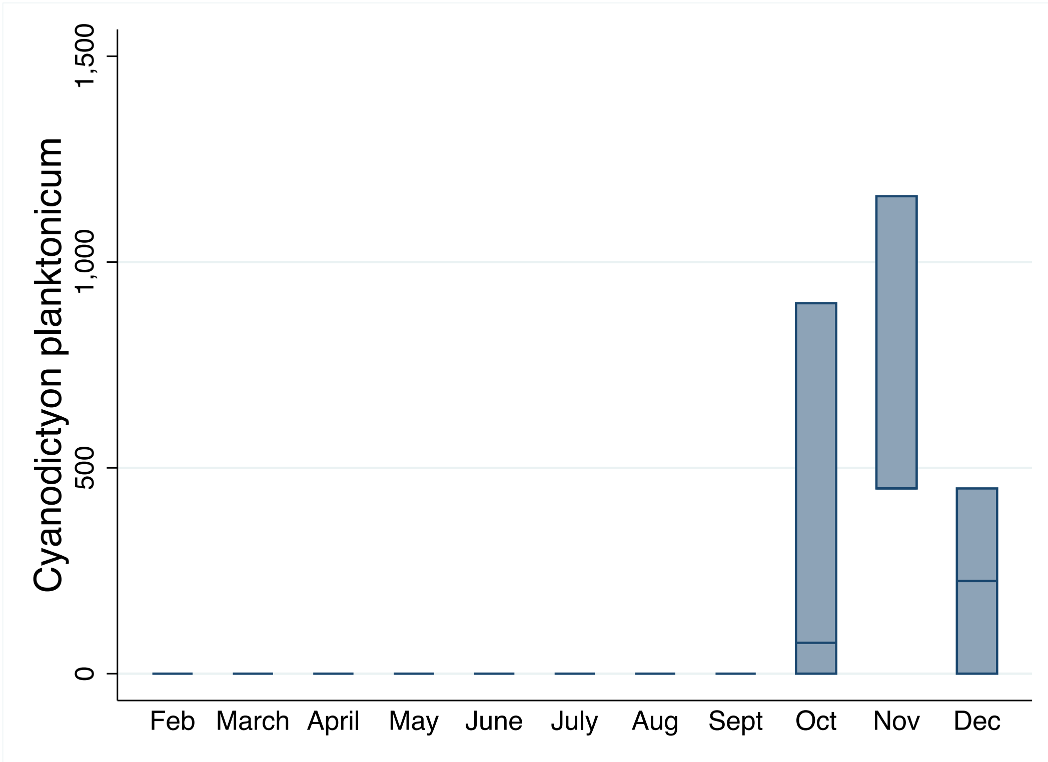
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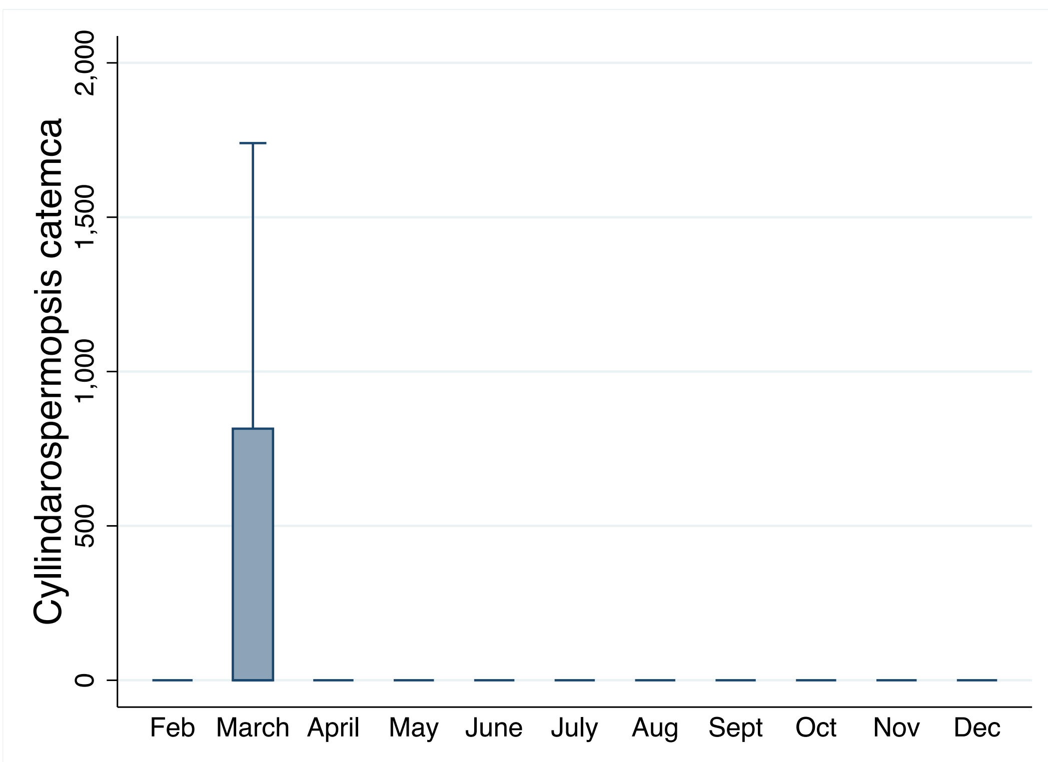
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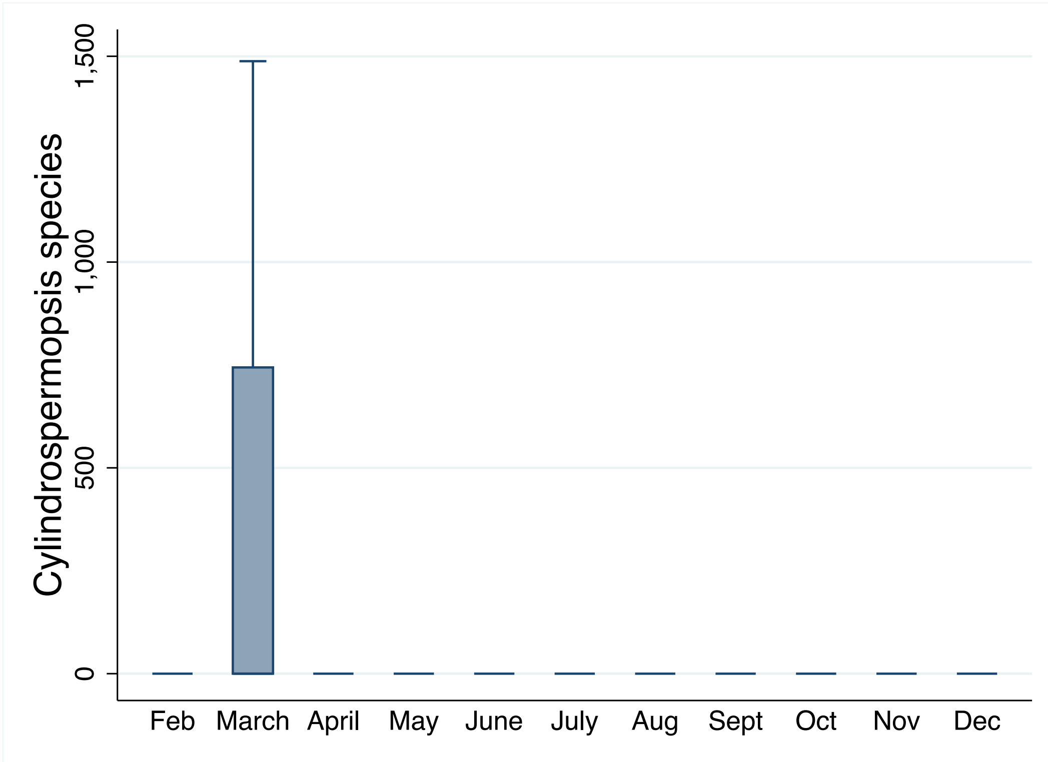
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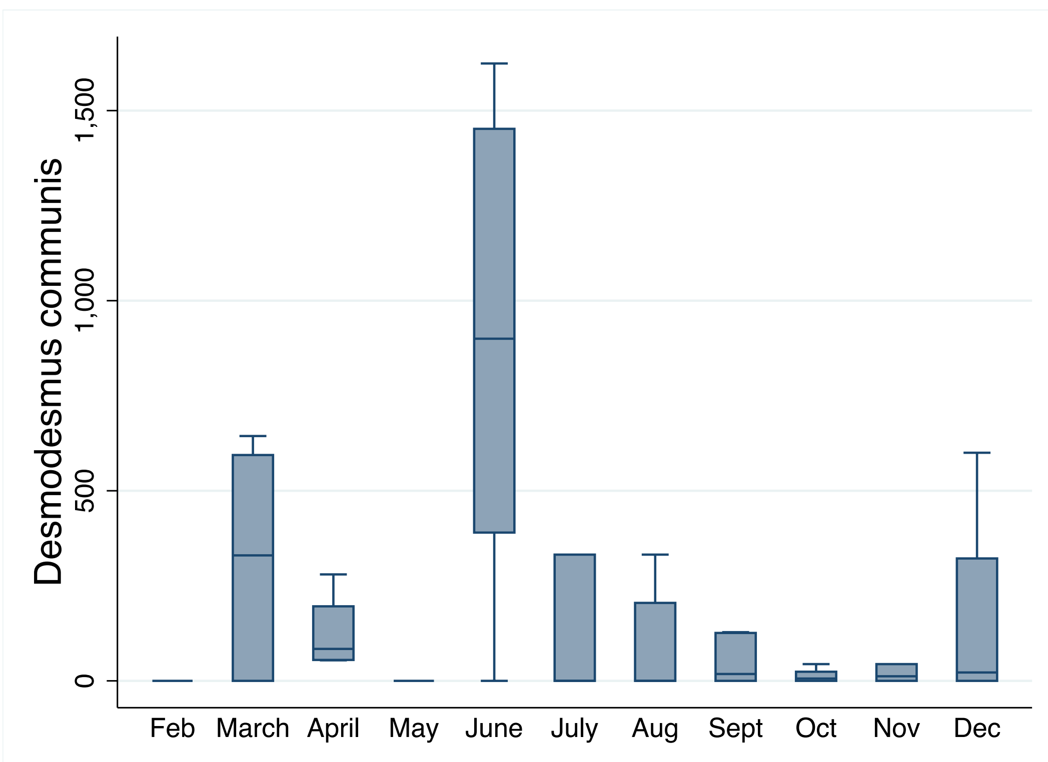
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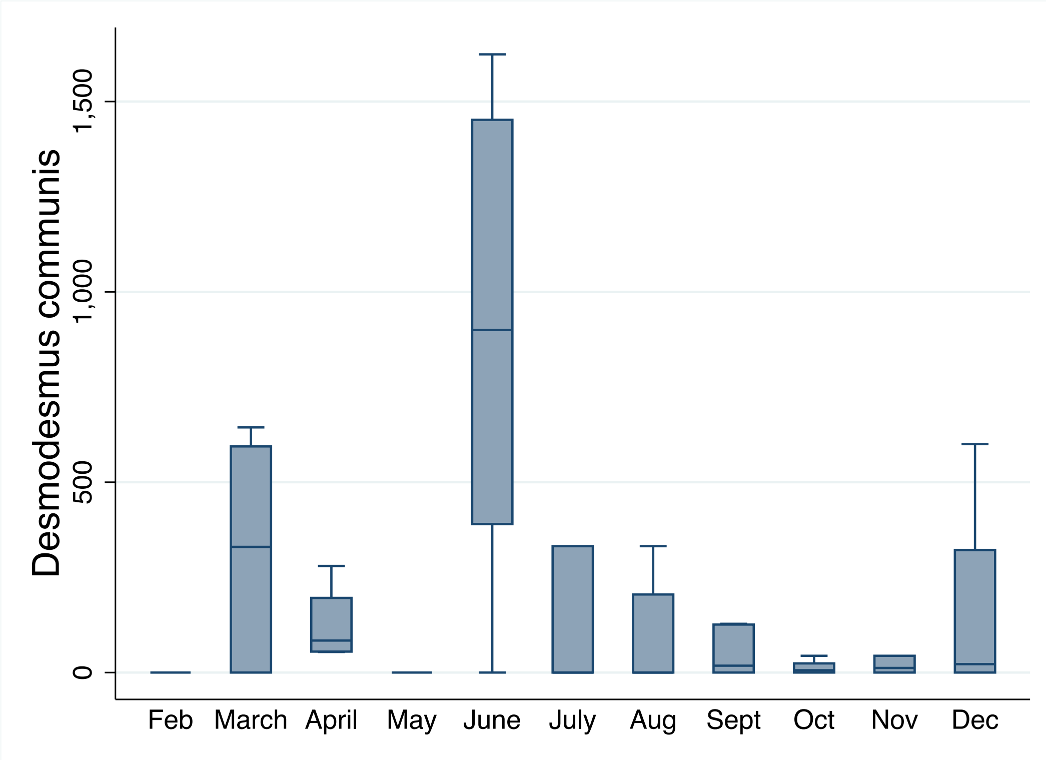
Desmodesmus communis
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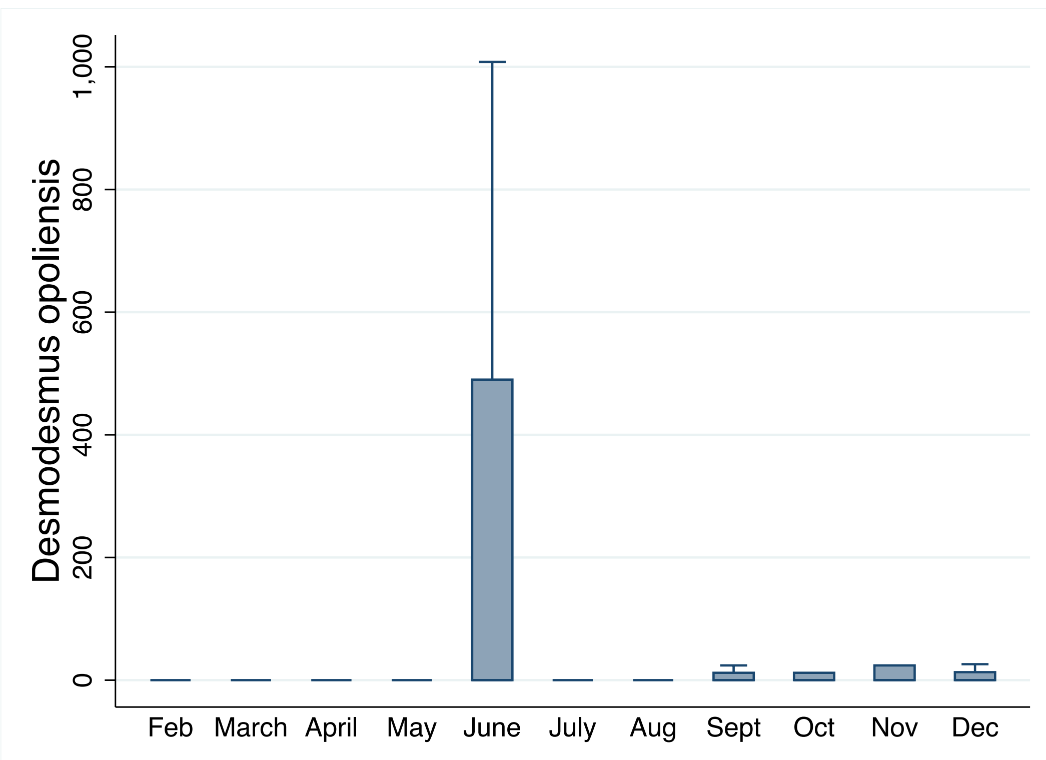
Desmodesmus opoliensis
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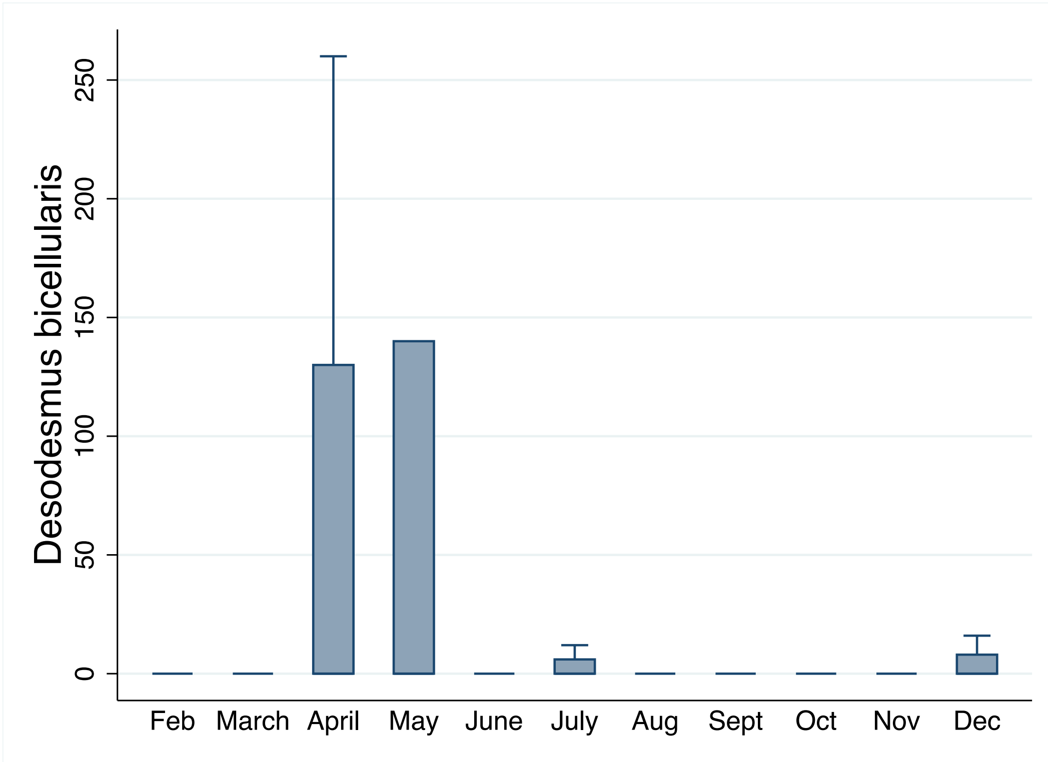
Desodesmus bicellularis
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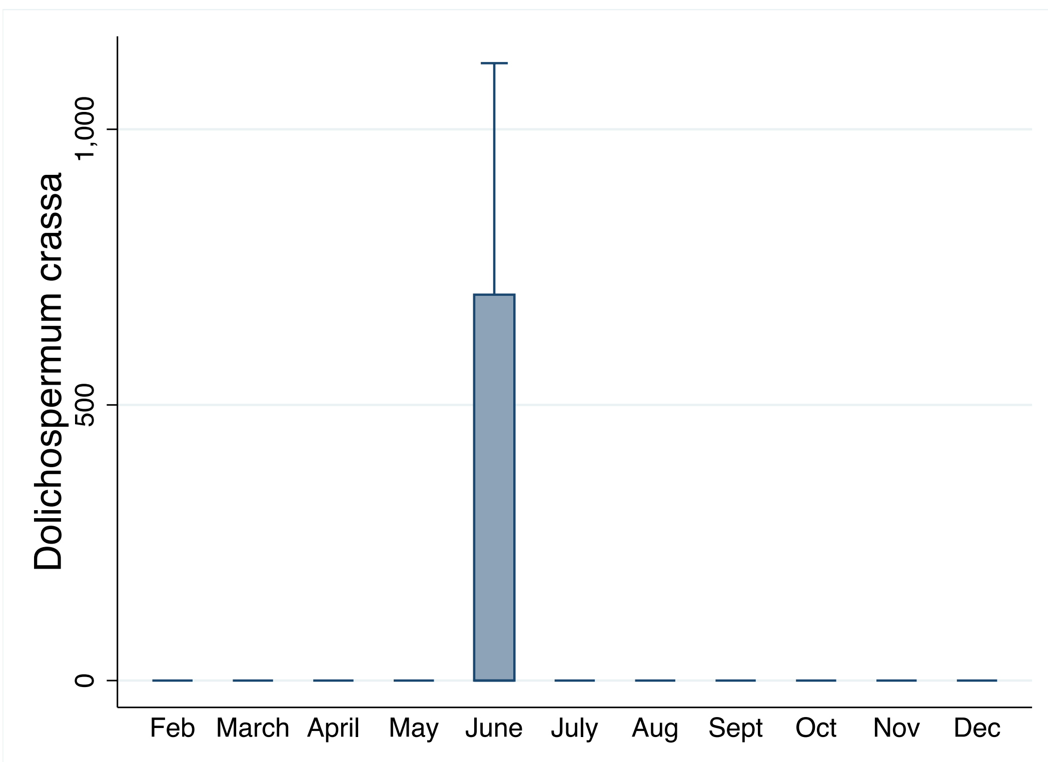
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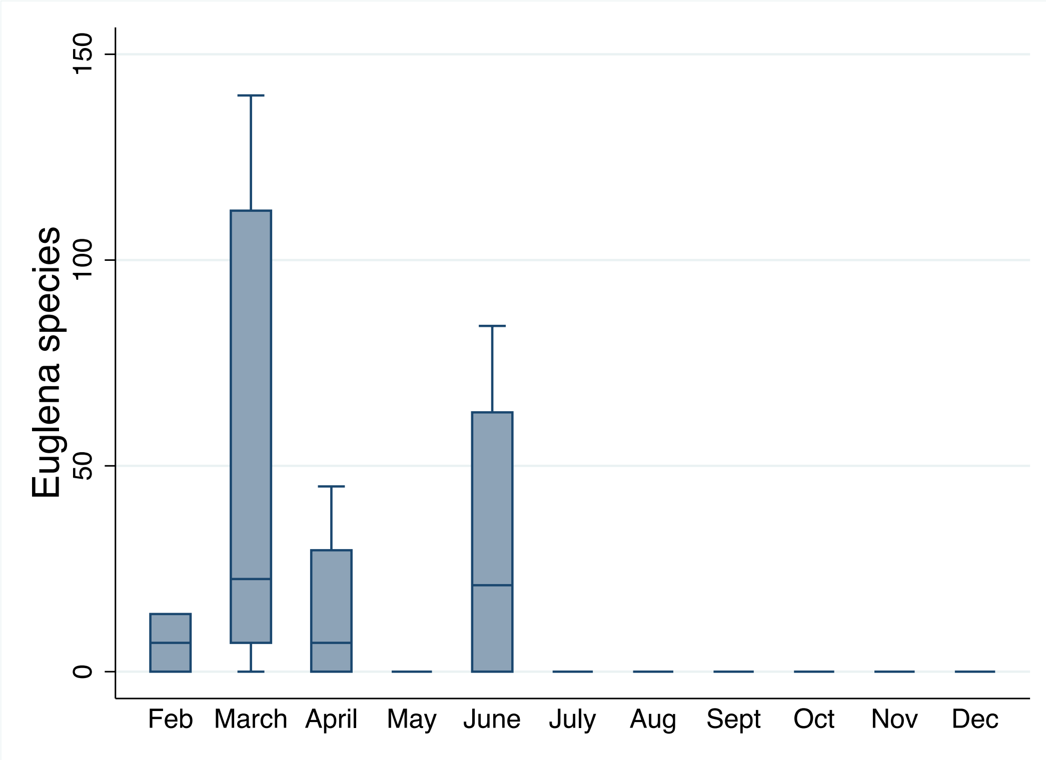
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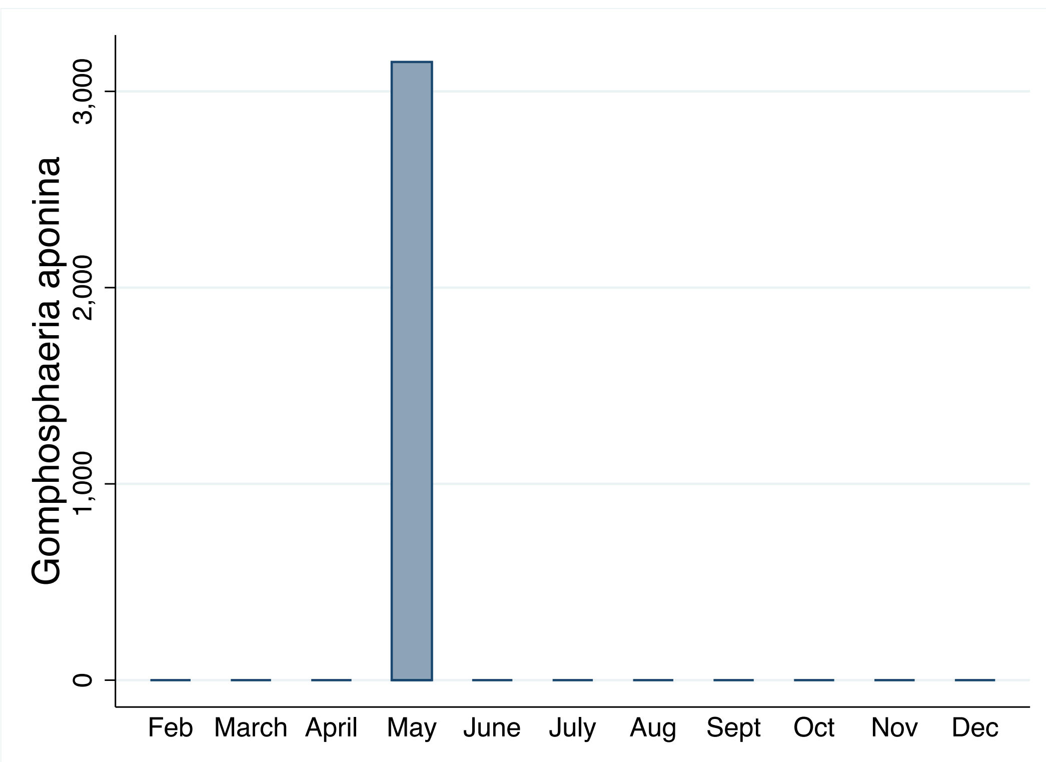
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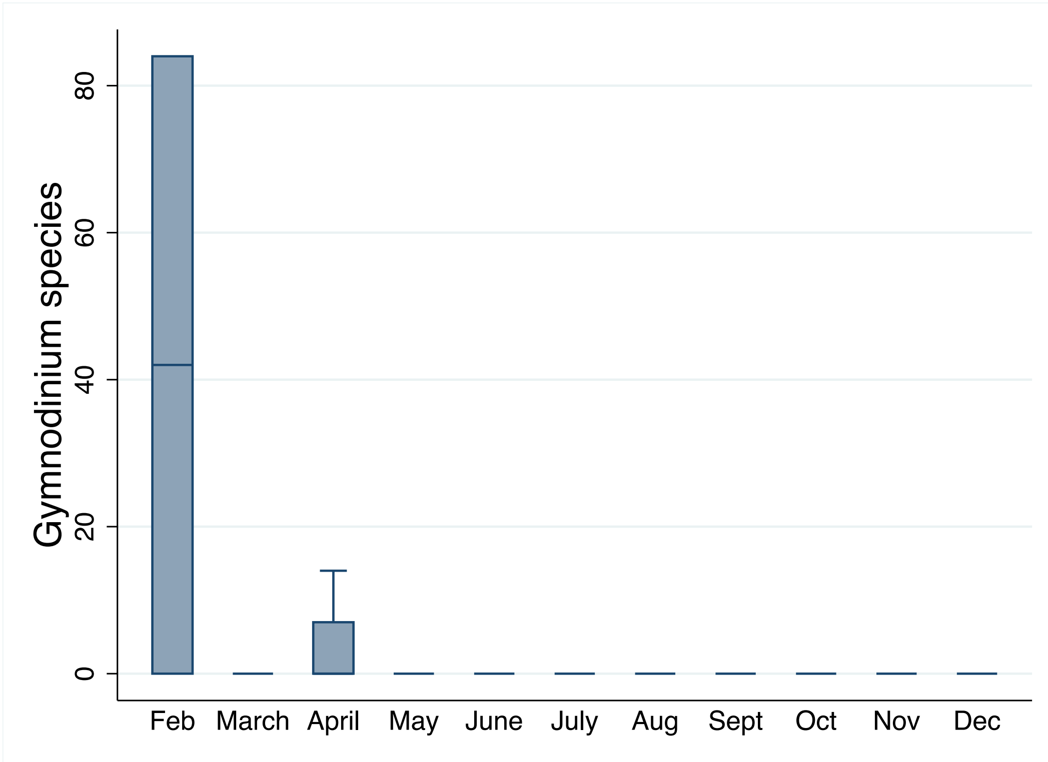
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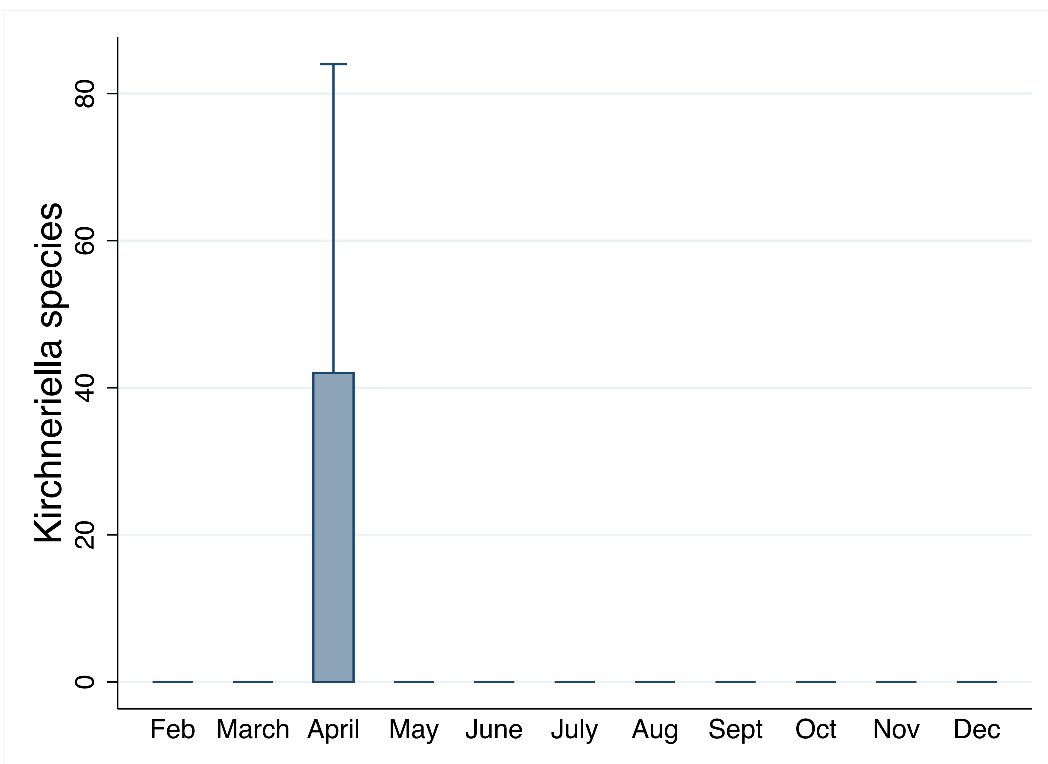
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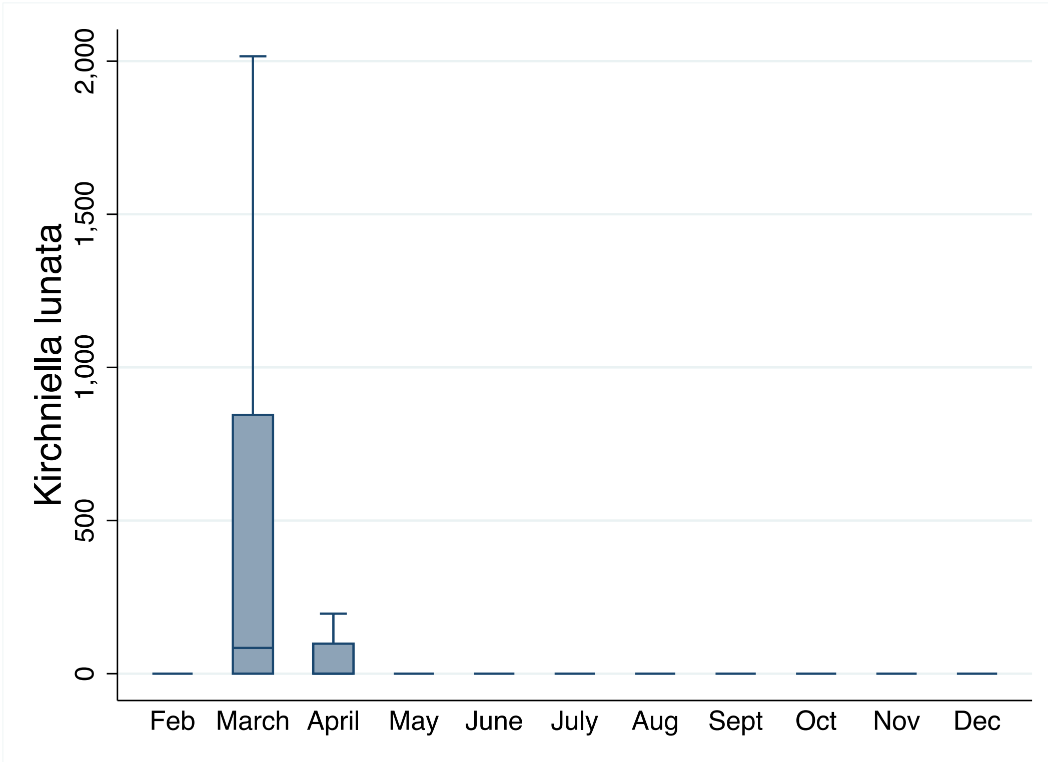

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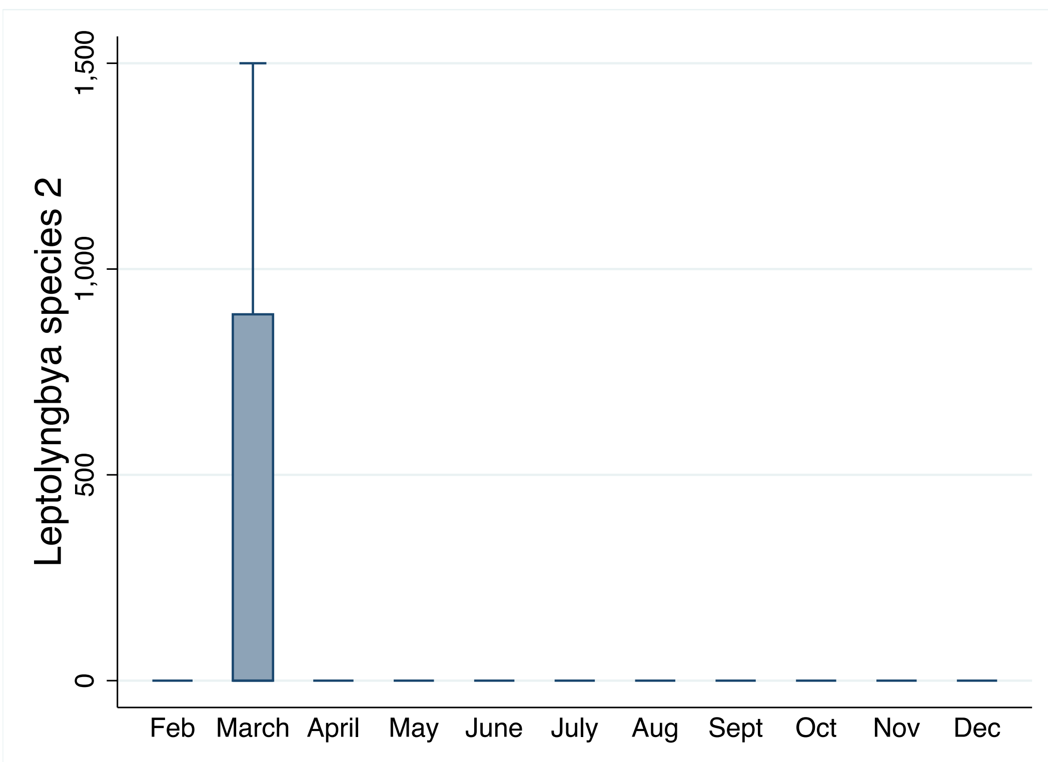

Leptolyngbya species 2
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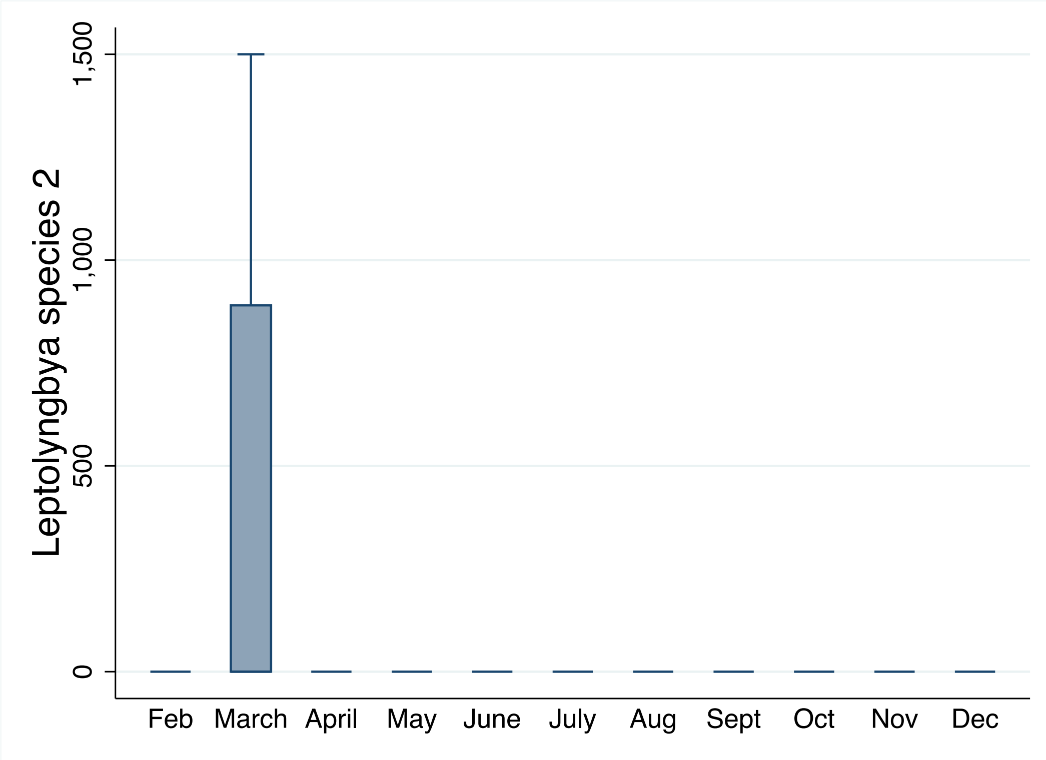
Leptolyngbya species 2
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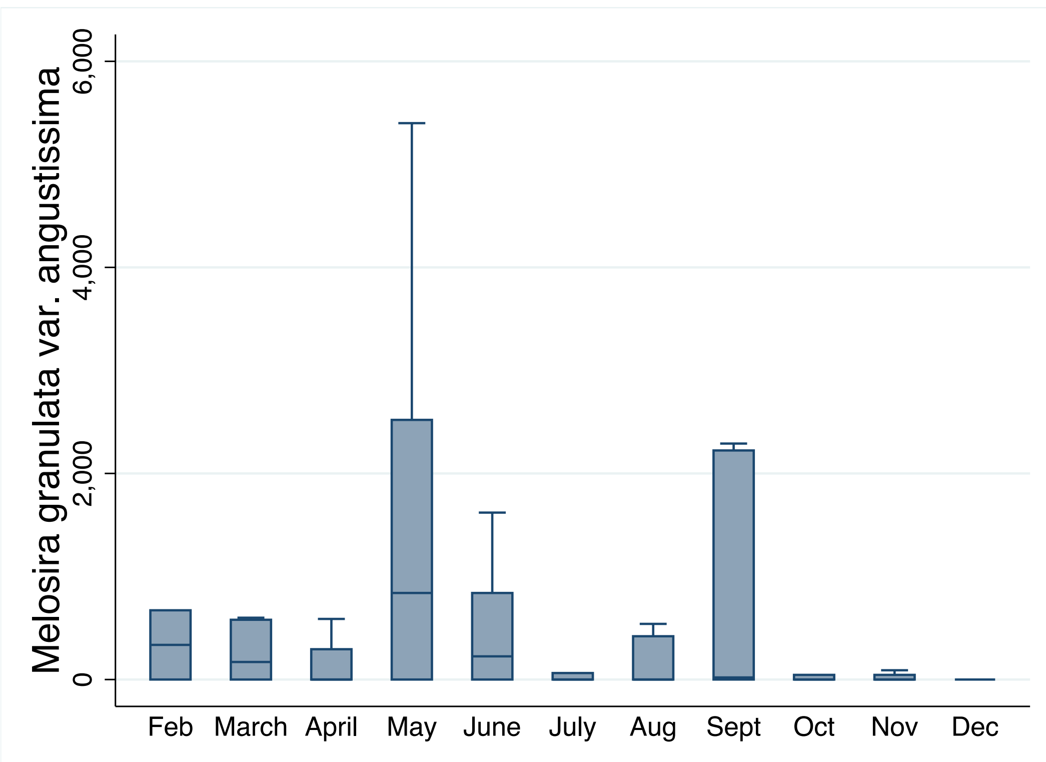
Melosira granulata var. angustissima
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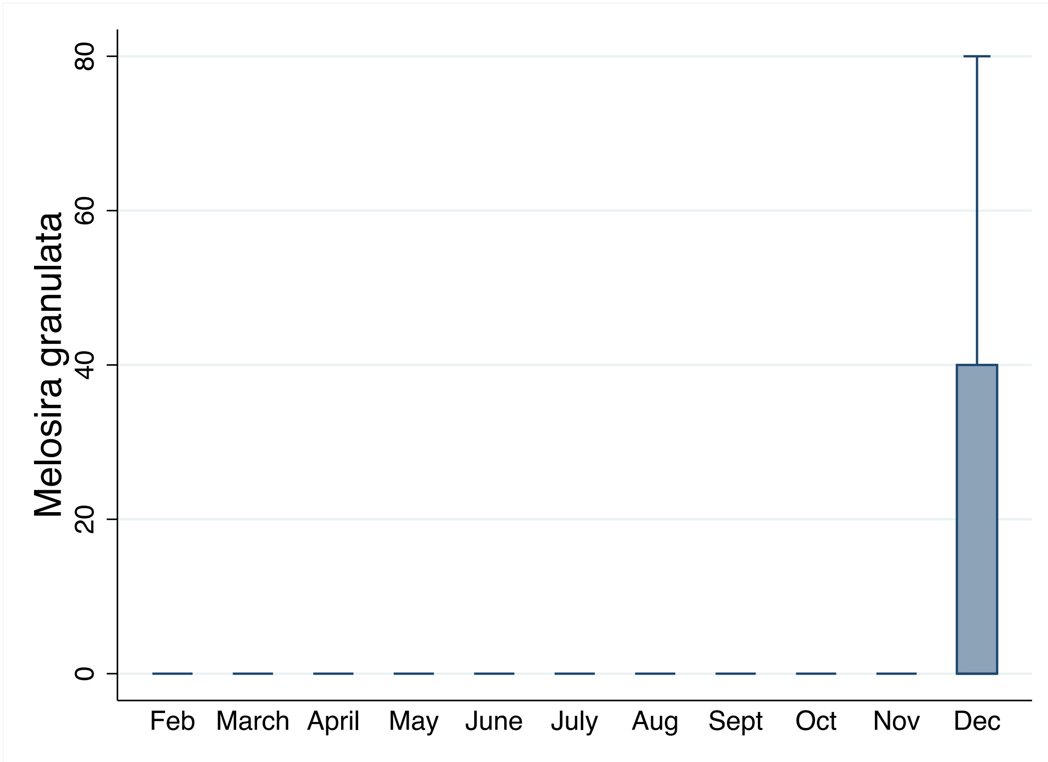
Dec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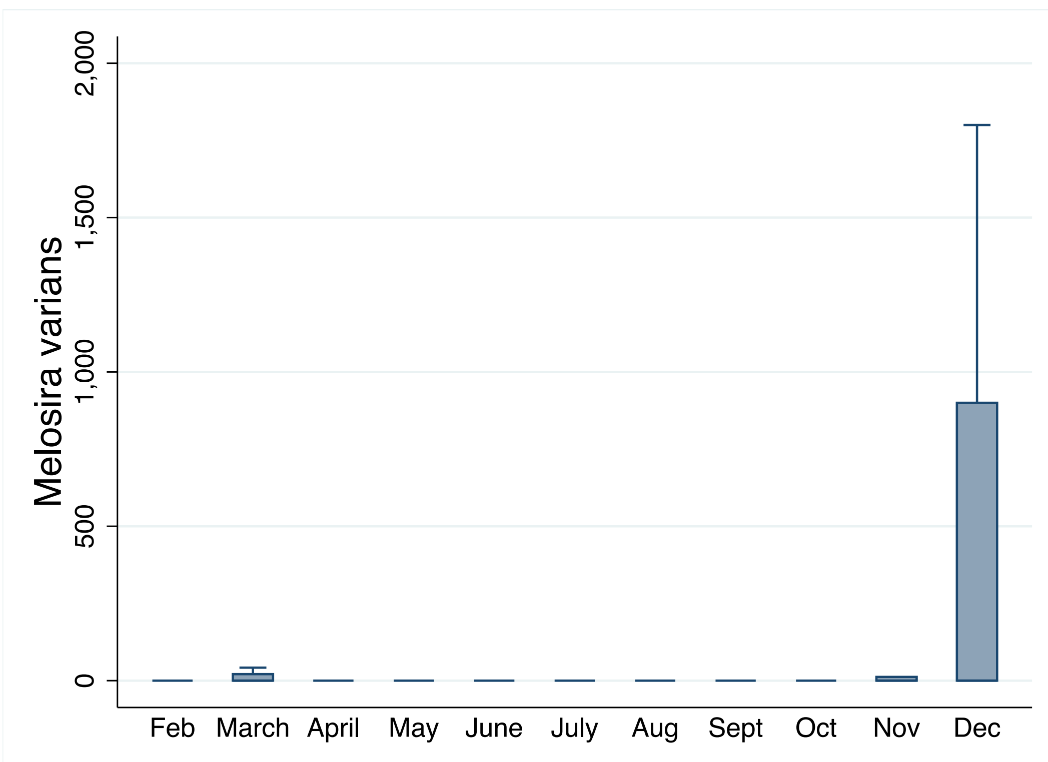
Melosira varians
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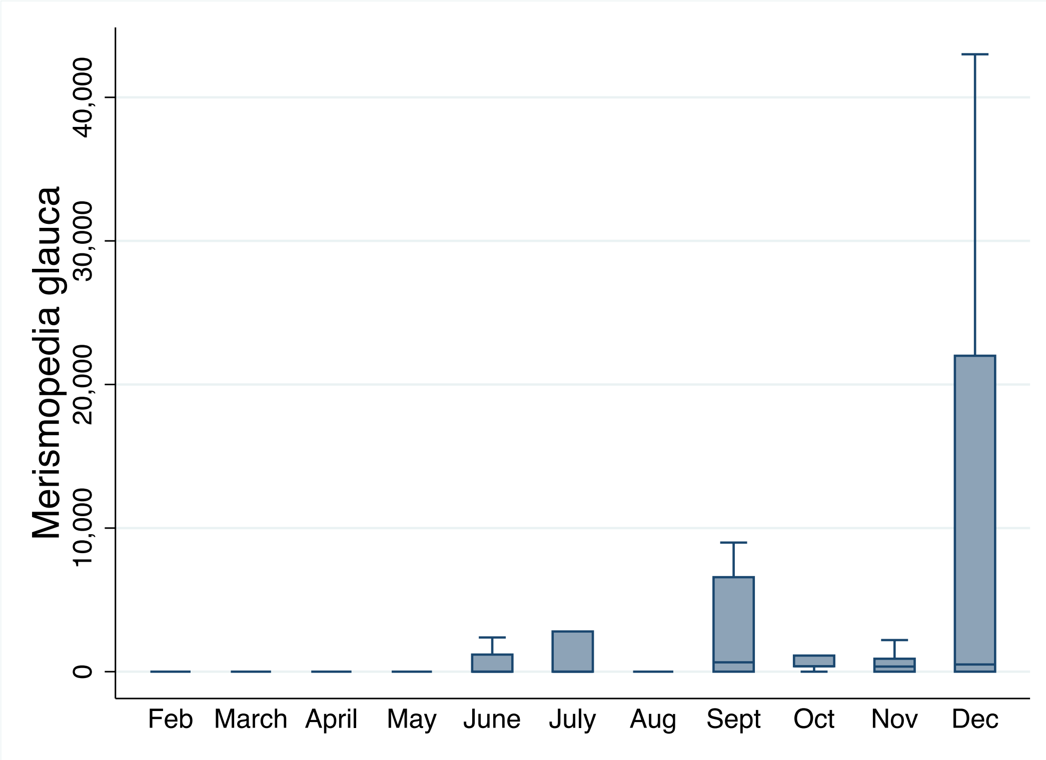
Merismopedia glauca
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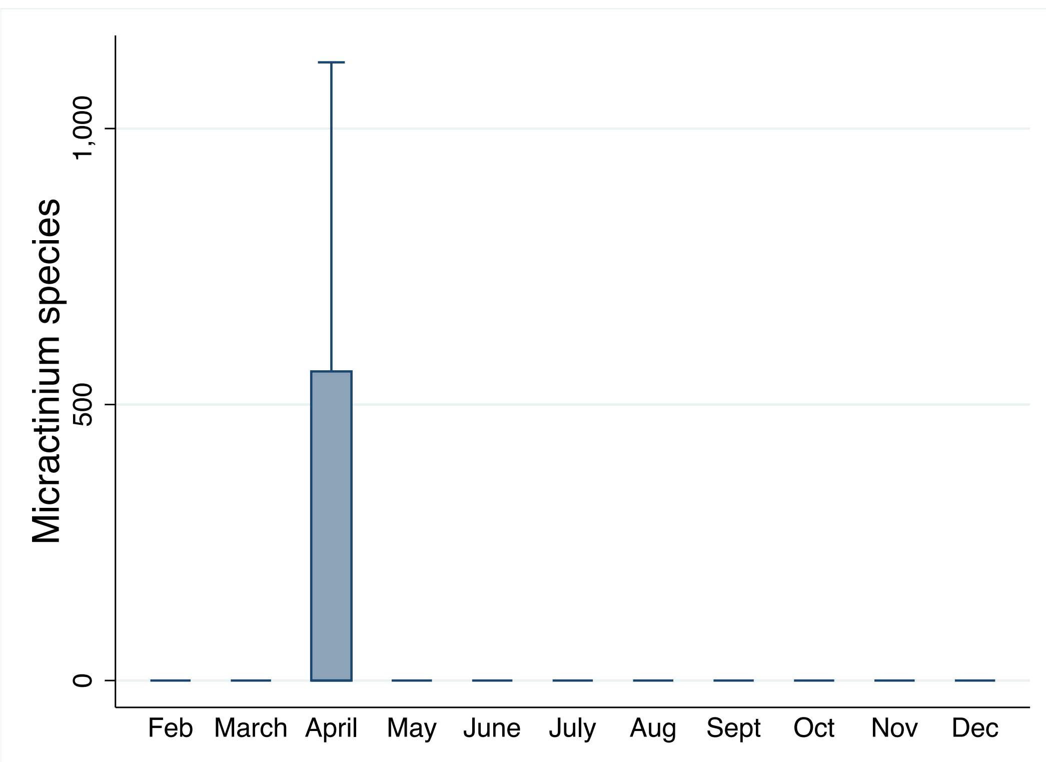
Micractinium species
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Feb
March
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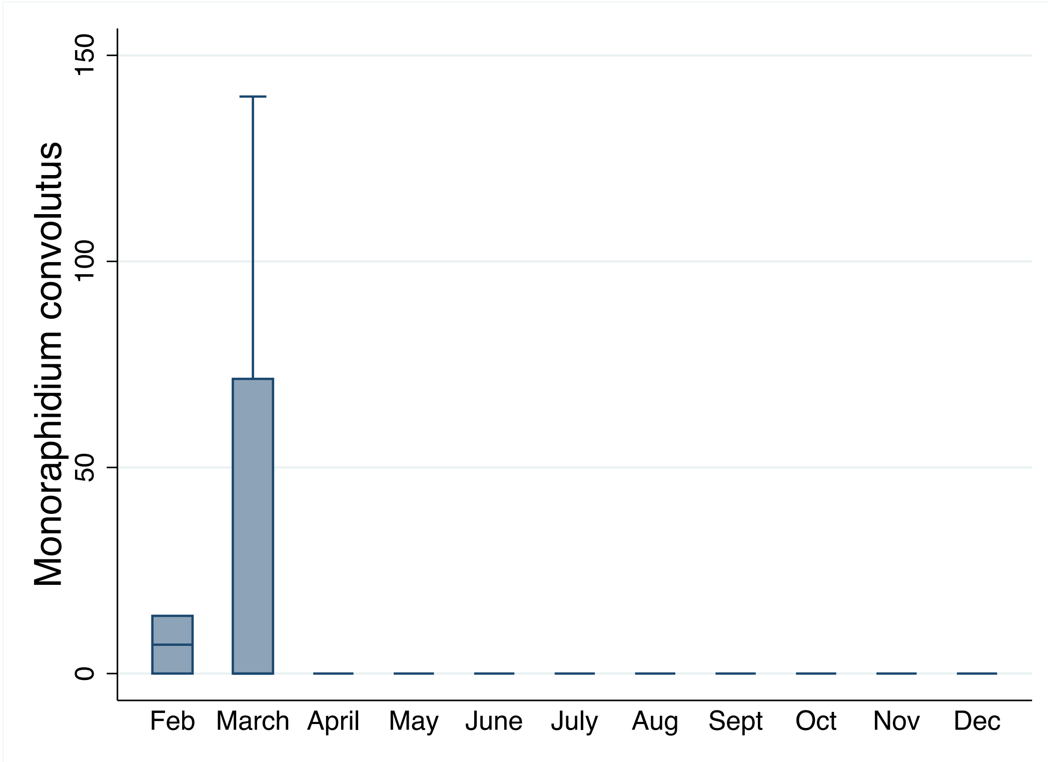
Monoraphidium convolutus
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150
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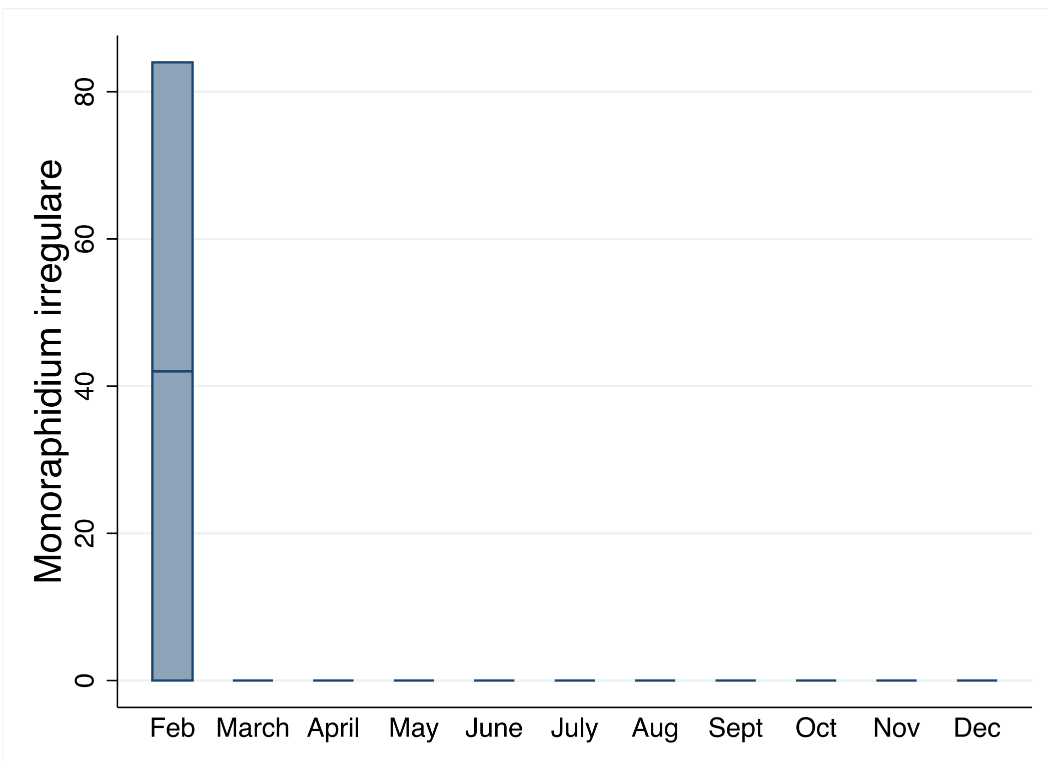
Nov
Dec


Monoraphidium irregulare
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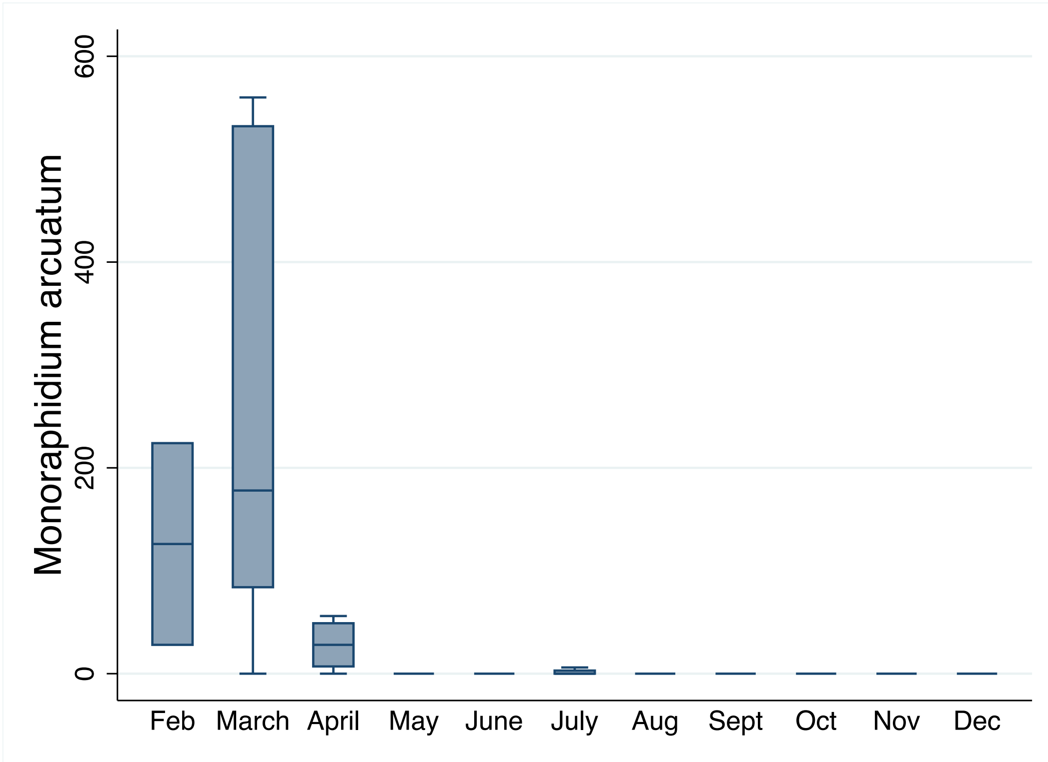
Monoraphidium arcuatum
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200
0
Feb
March
April
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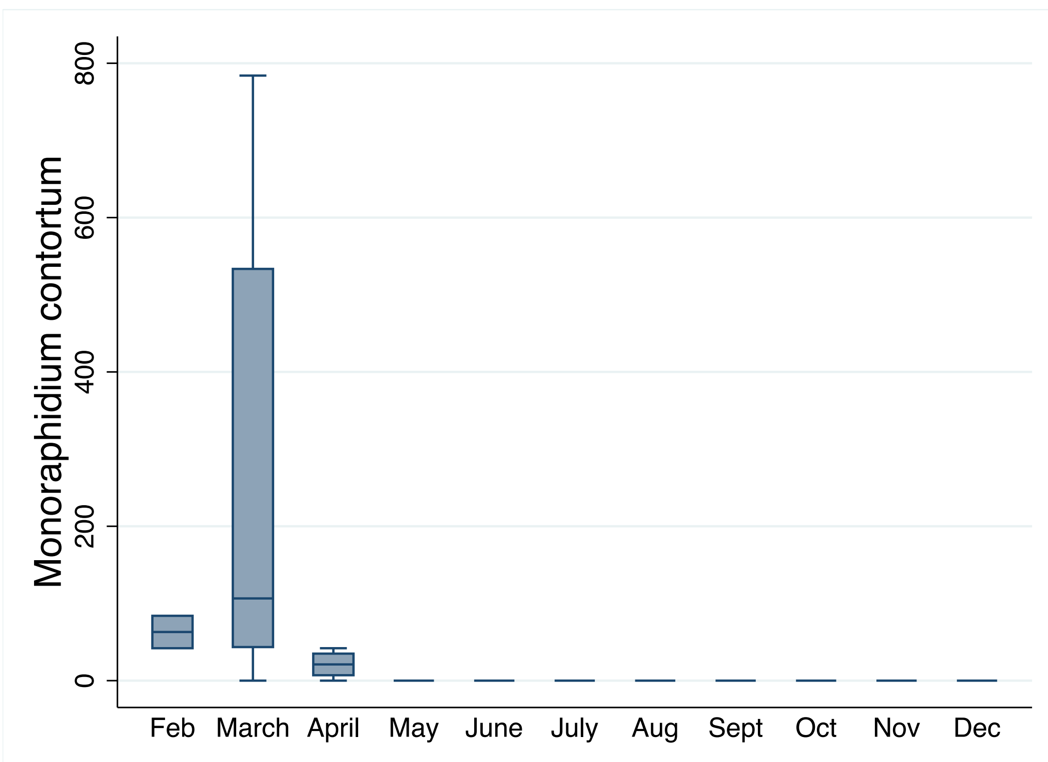
Nov
Dec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400
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March
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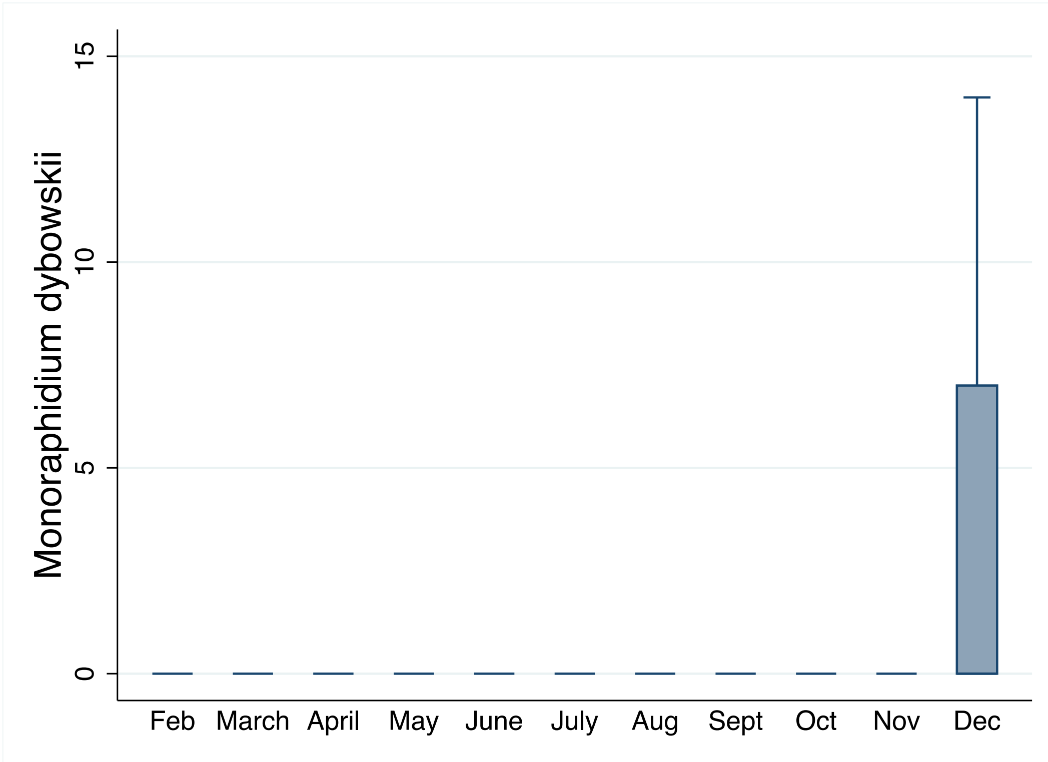
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10
15
Feb
March
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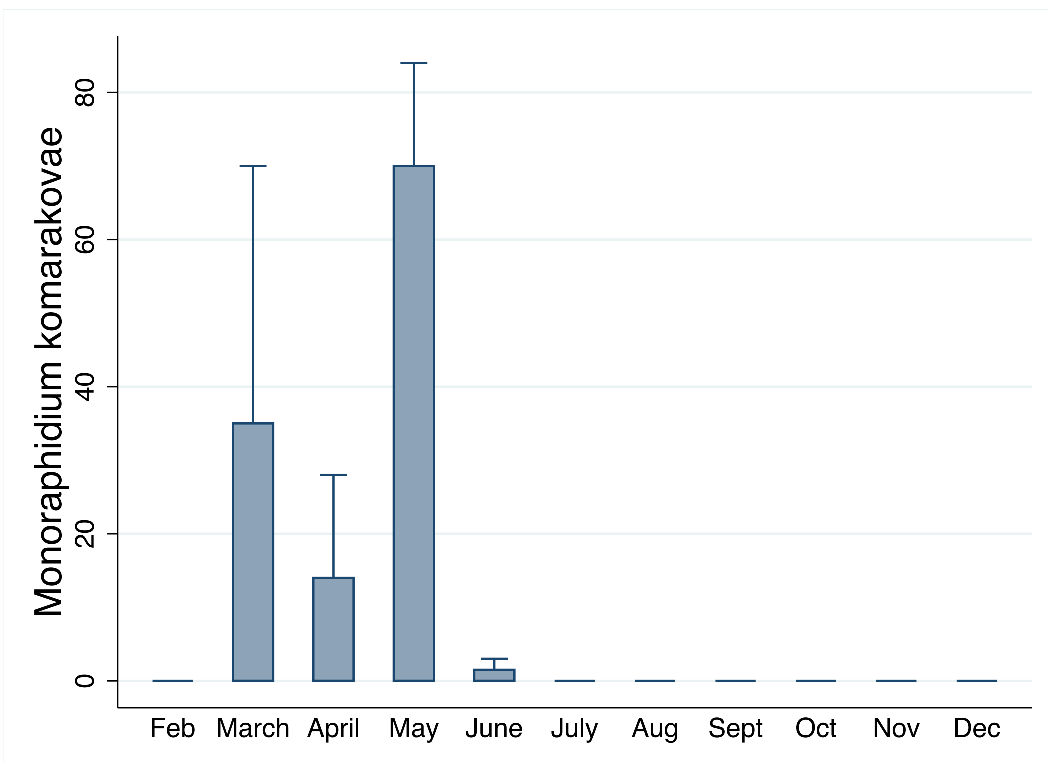
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40
60
80
Feb
March
April
May
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Nov
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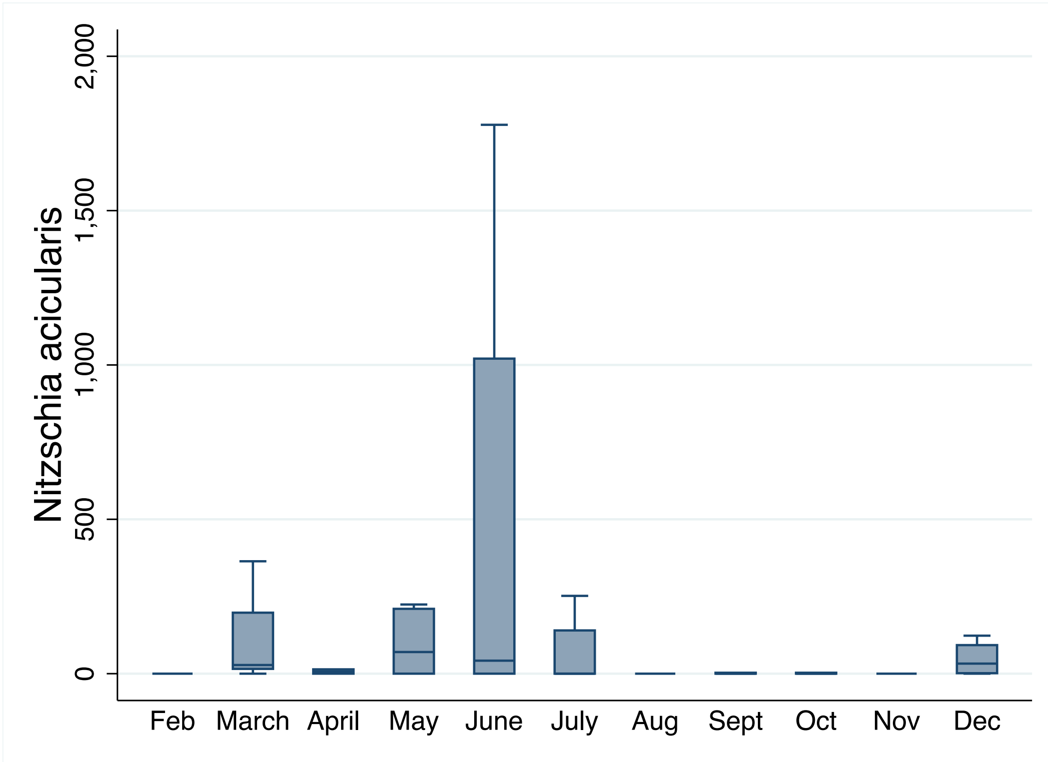
Nitzschia acicularis
0
500
1,000
1,500
2,000
Feb
March
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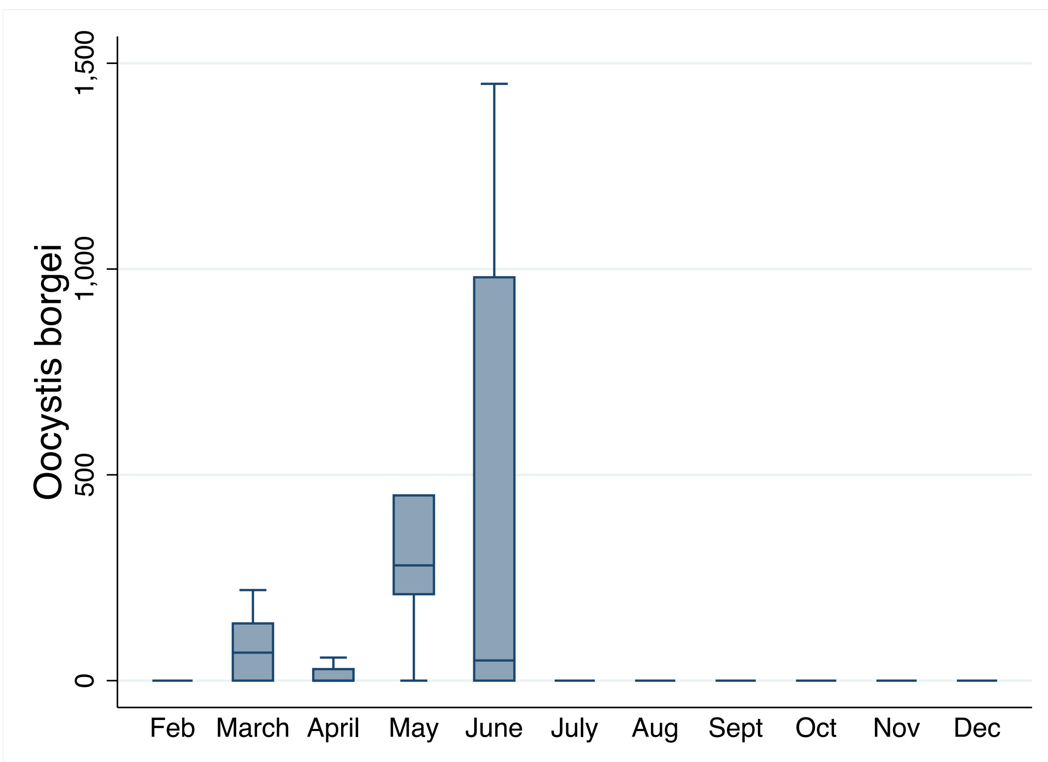
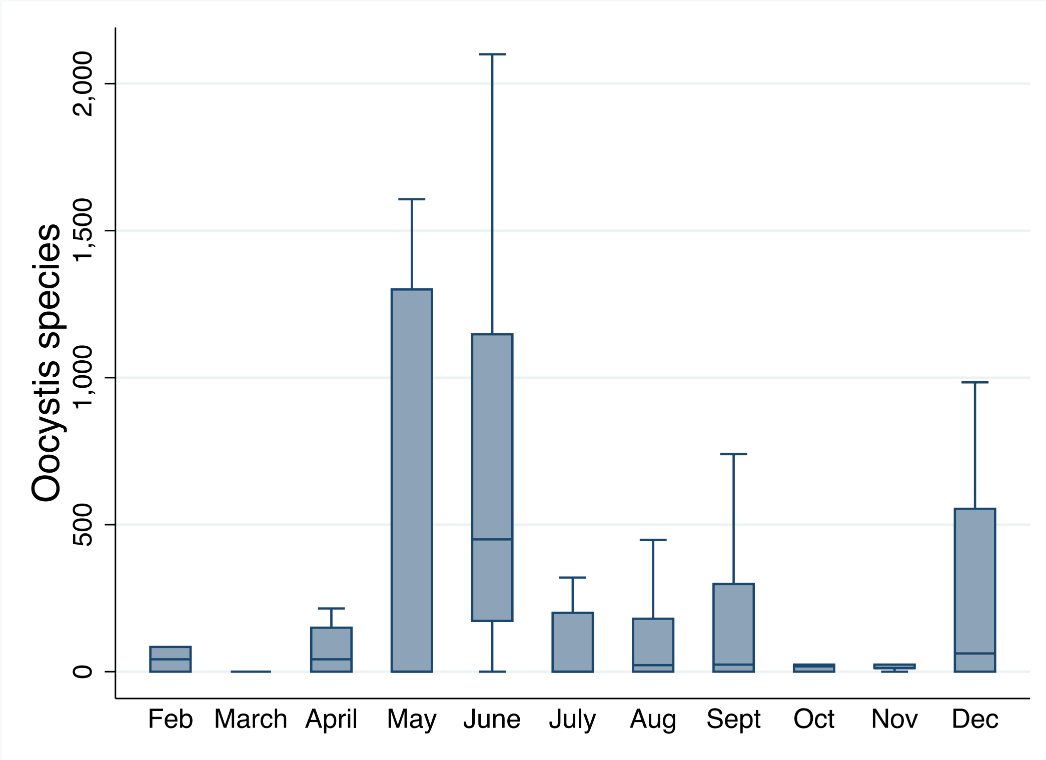
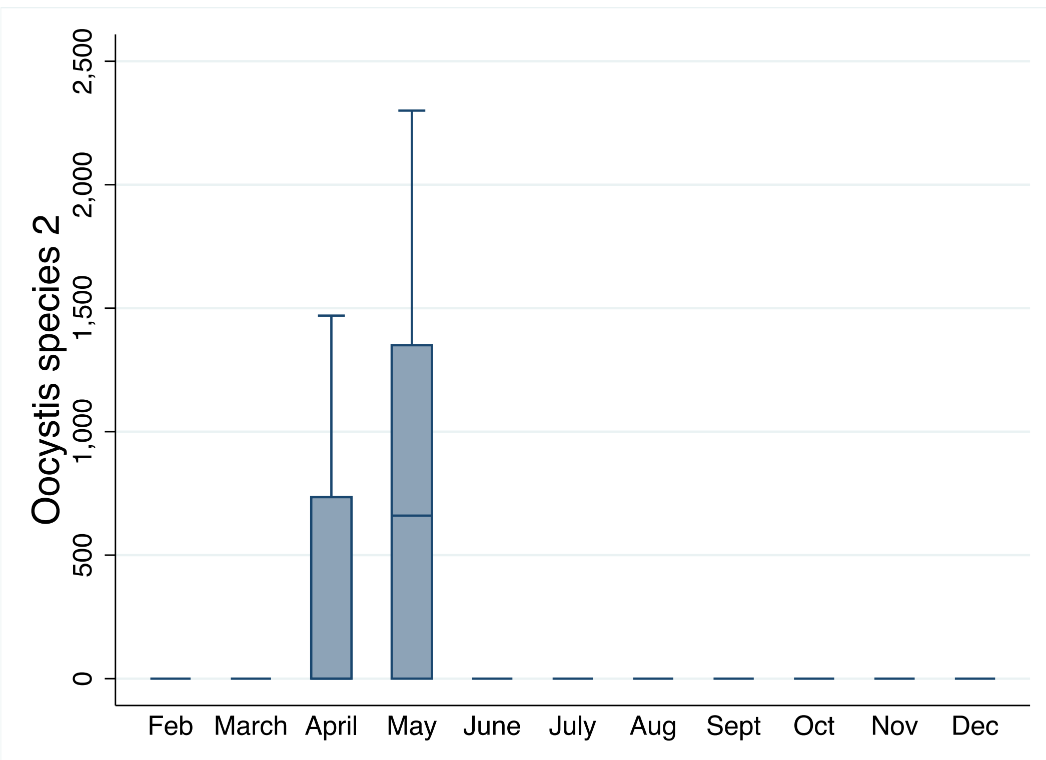
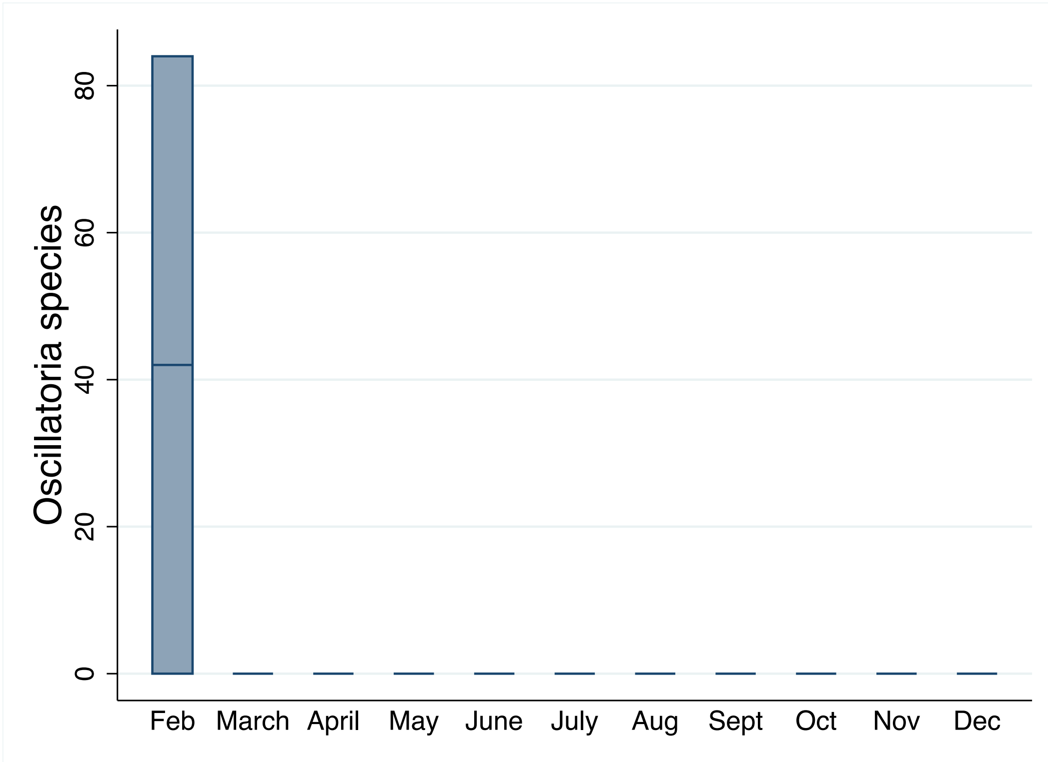
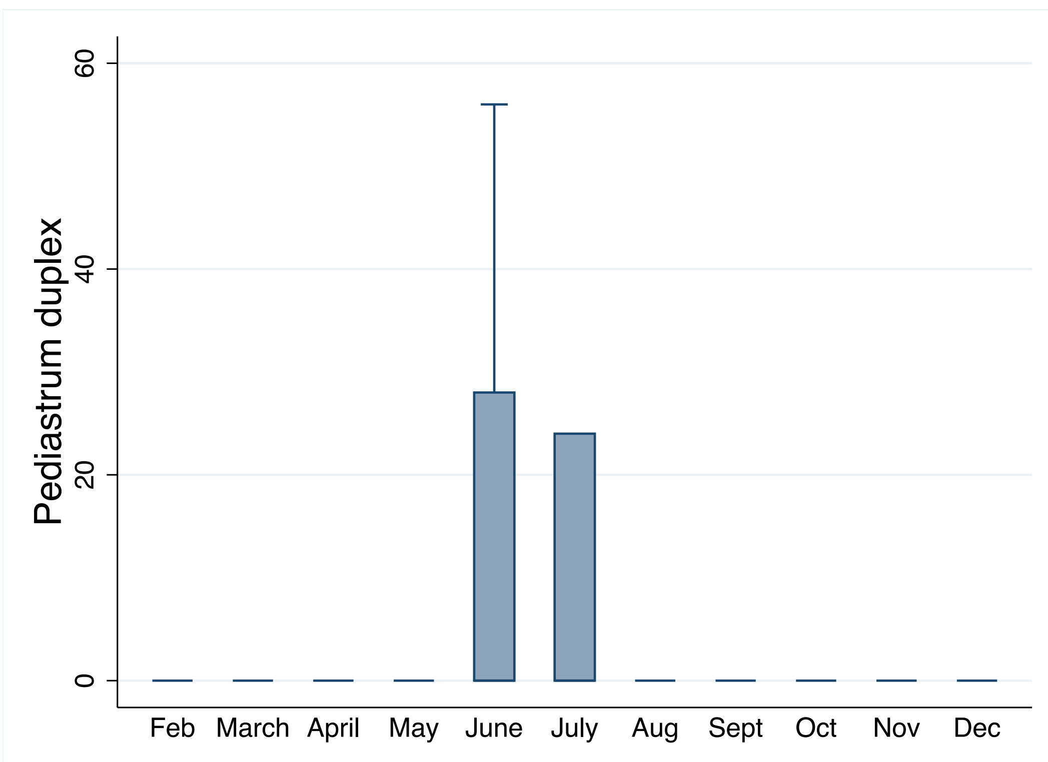
June
July
Aug
Sept
Oct
Nov
Dec

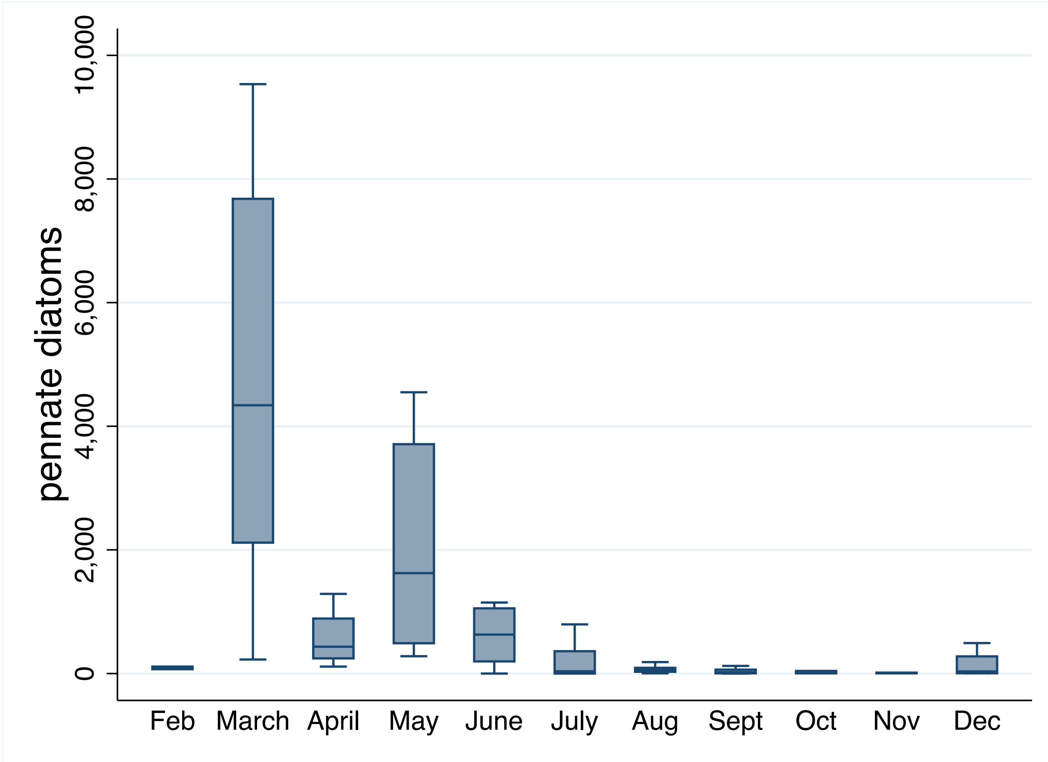

Oocystis borgei
0
500
1,000
1,500
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

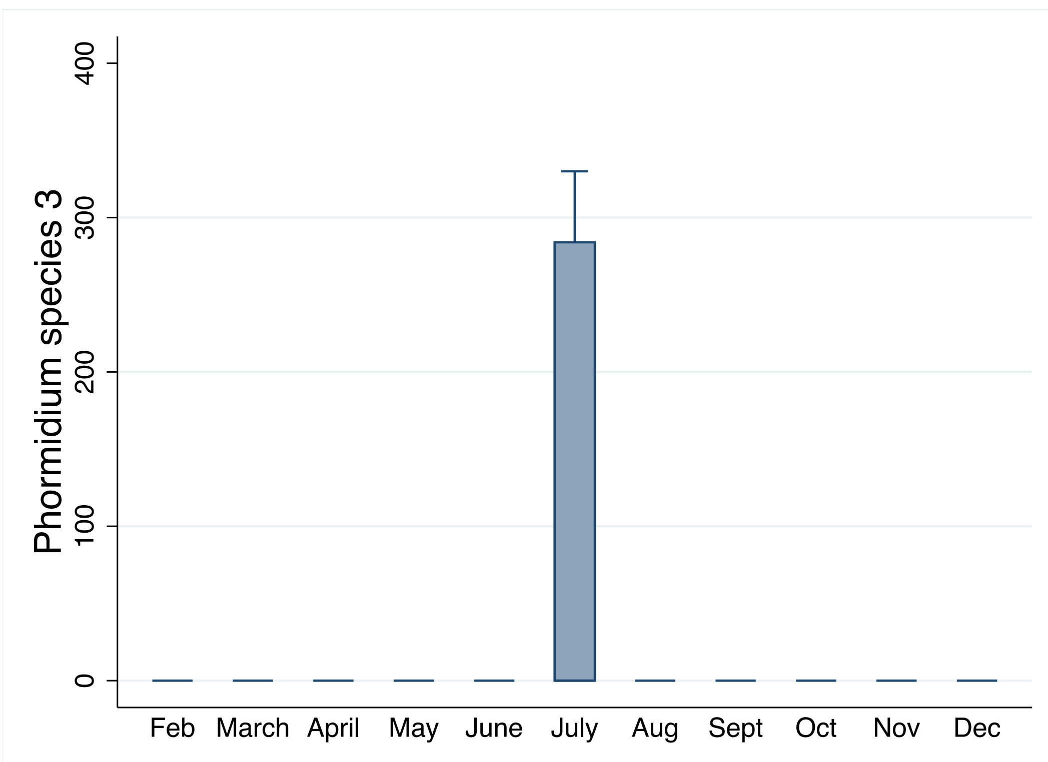

Oocystis species
0
500
1,000
1,500
2,000
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

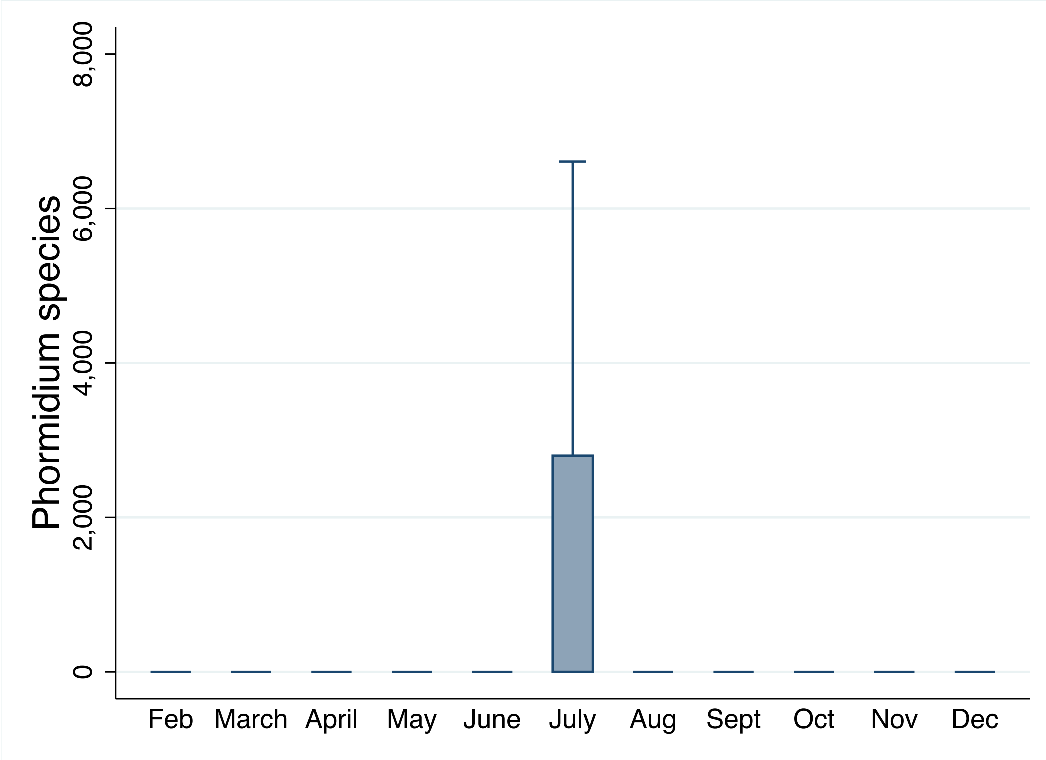

Oocystis species 2
0
500
1,000
1,500
2,000
2,500
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

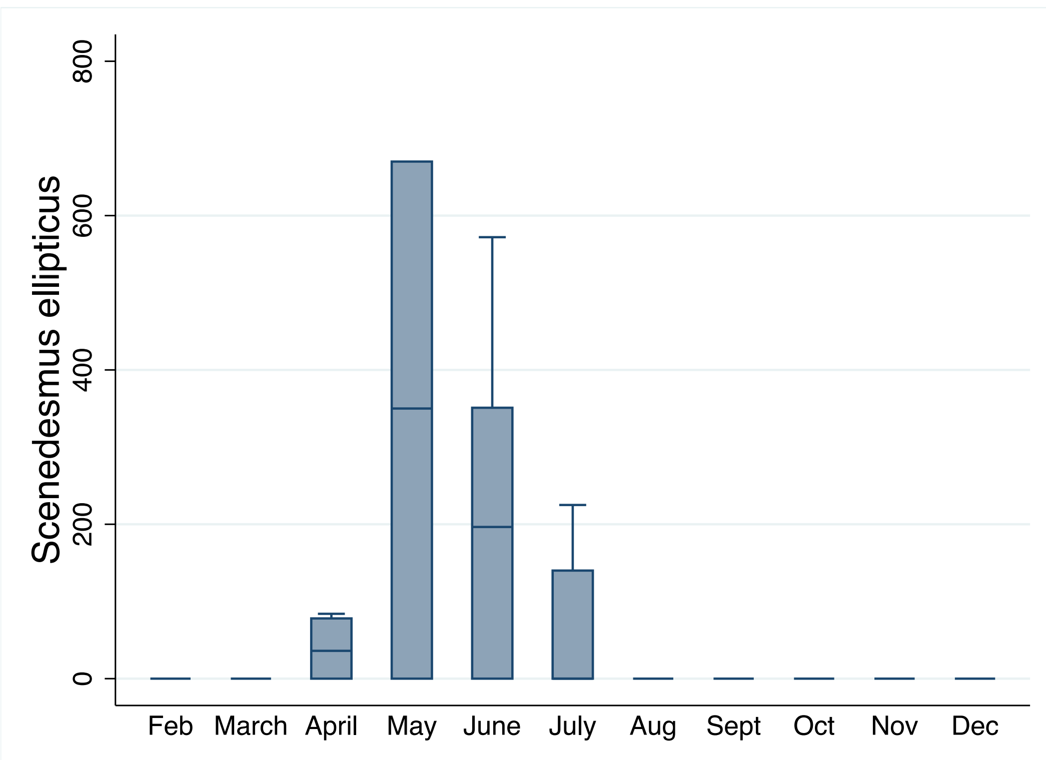

Oscillatoria species
0
20
40
60
80
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

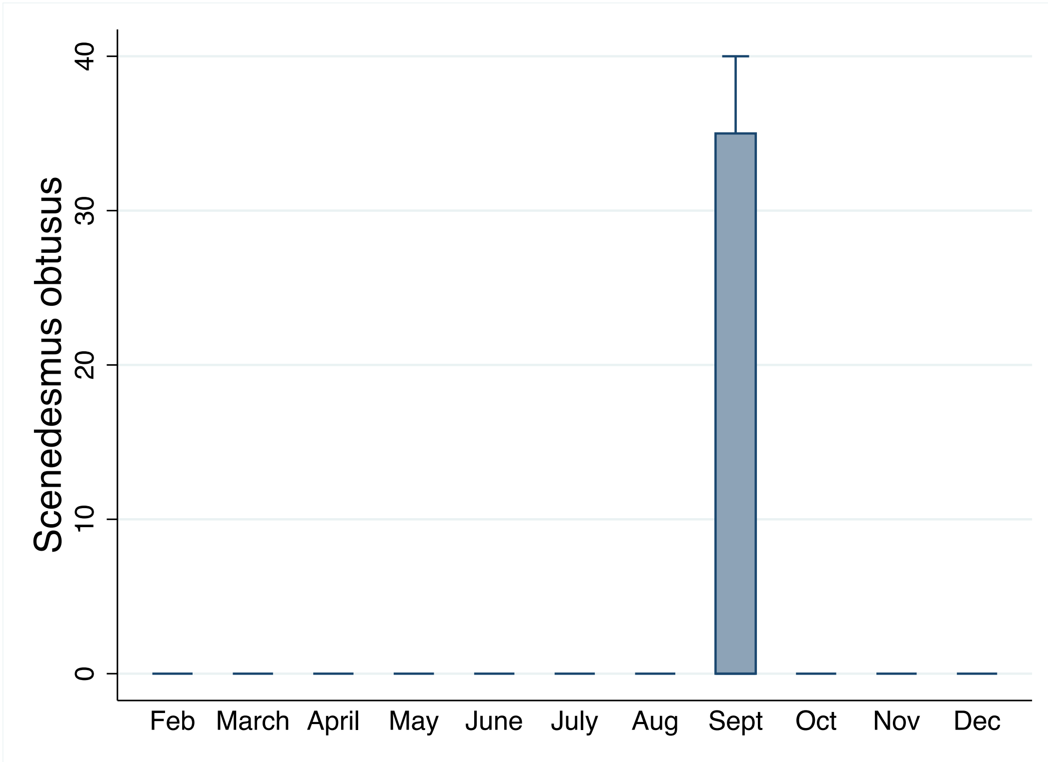

Pediastrum duplex
0
20
40
60
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

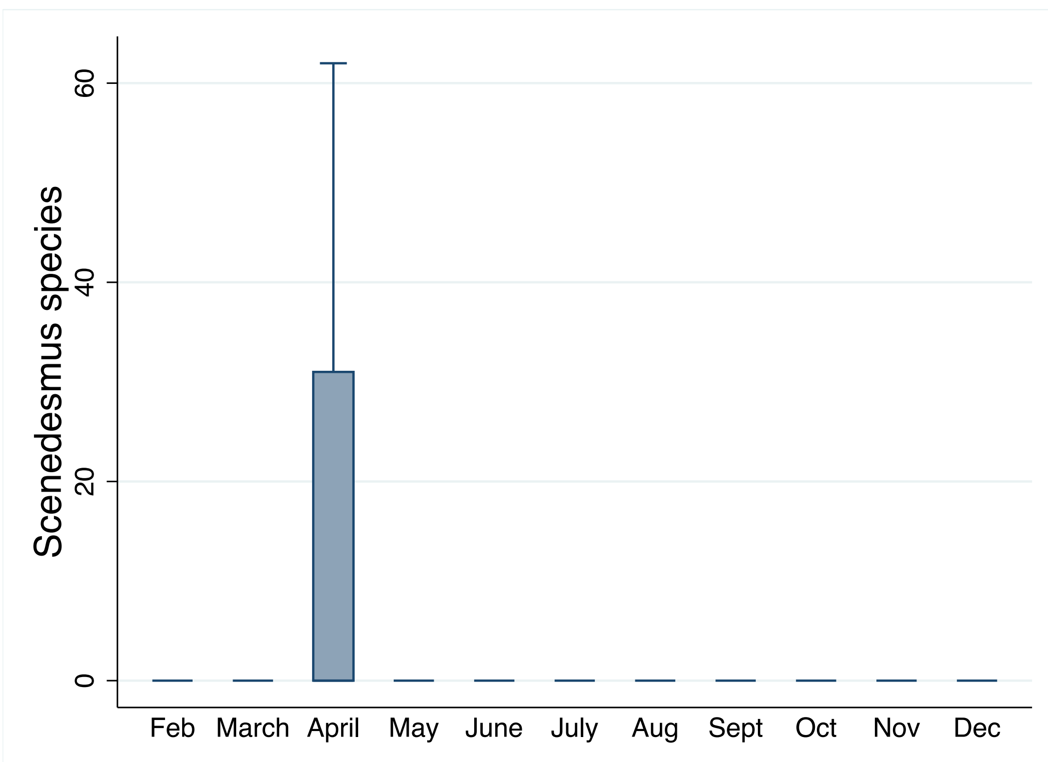

pennate diatoms
0
2,000
4,000
6,000
8,000
10,000
Feb March April May June July Aug Sept Oct Nov Dec

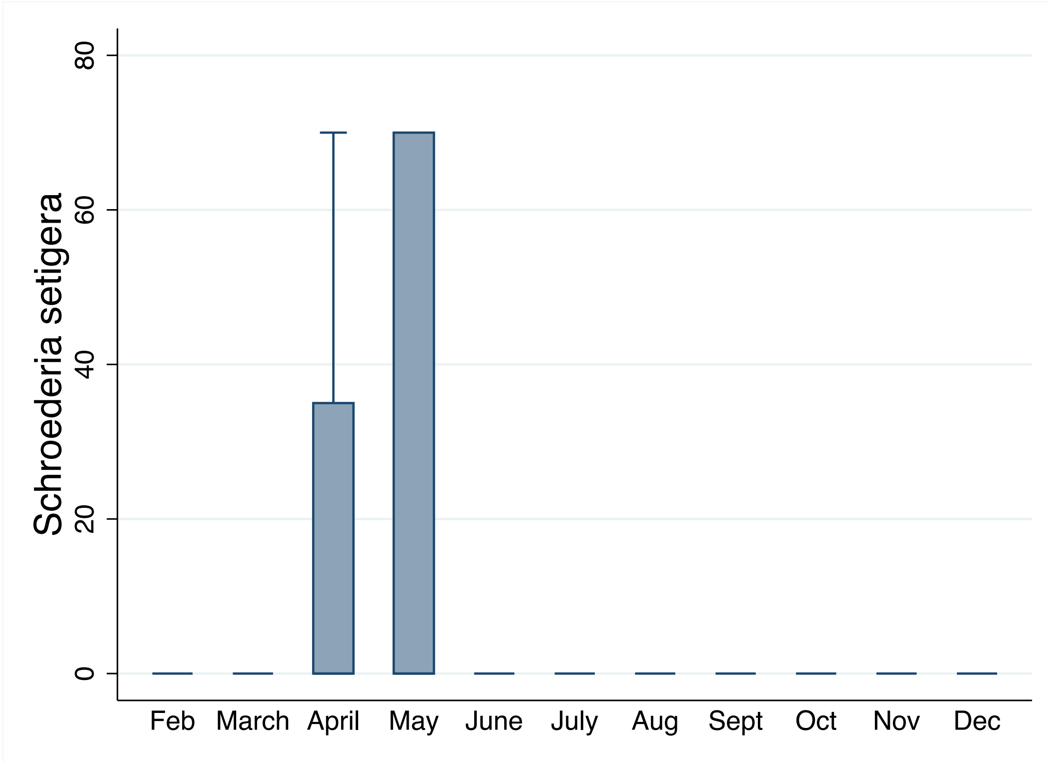

Phormidium species 3
0
100
200
300
400
Feb March April May June July Aug Sept Oct Nov Dec

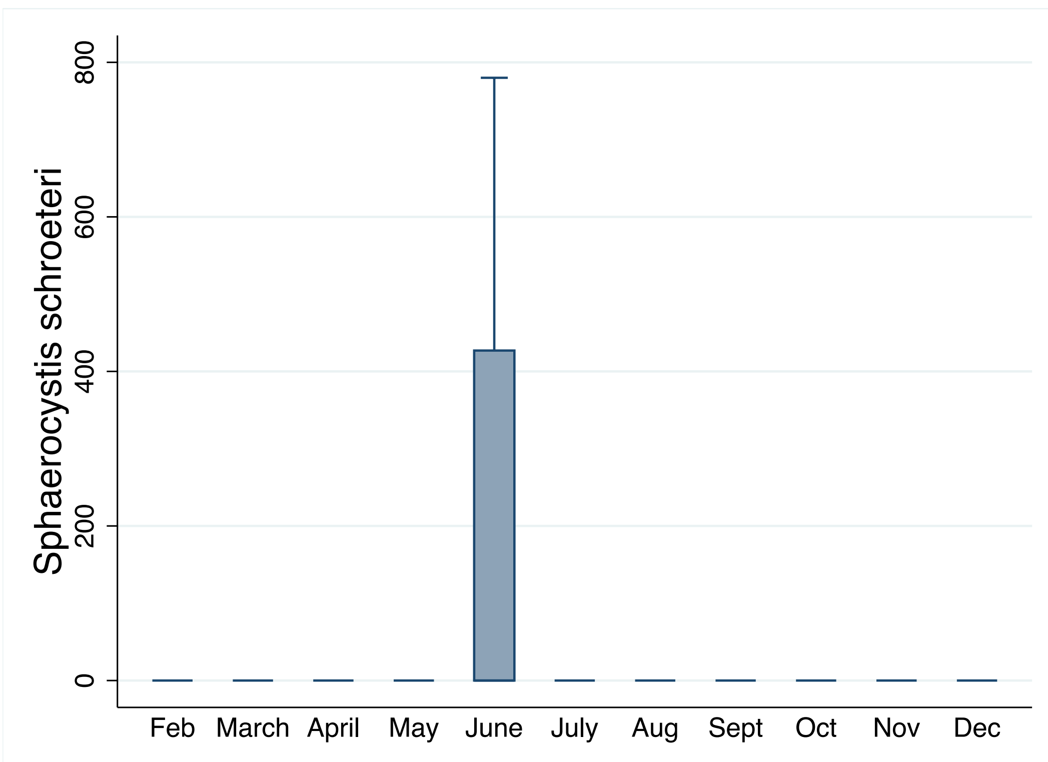

Phormidium species
0
2,000
4,000
6,000
8,000
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

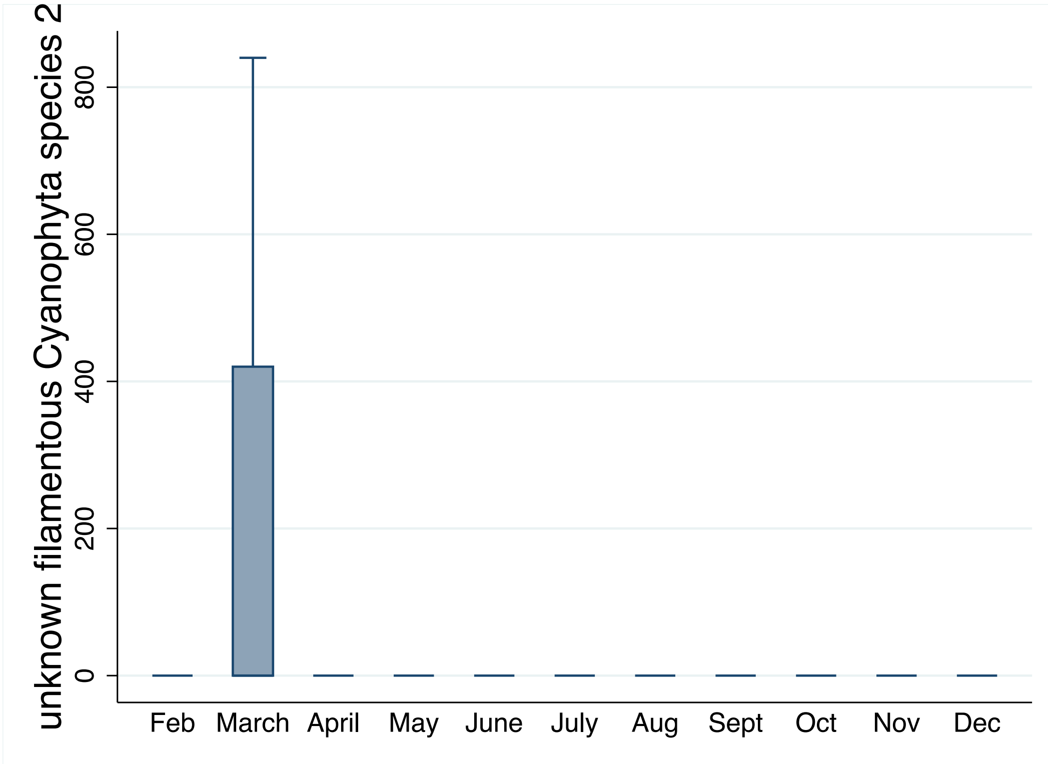

Scenedesmus ellipticus
0
200
400
600
800
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

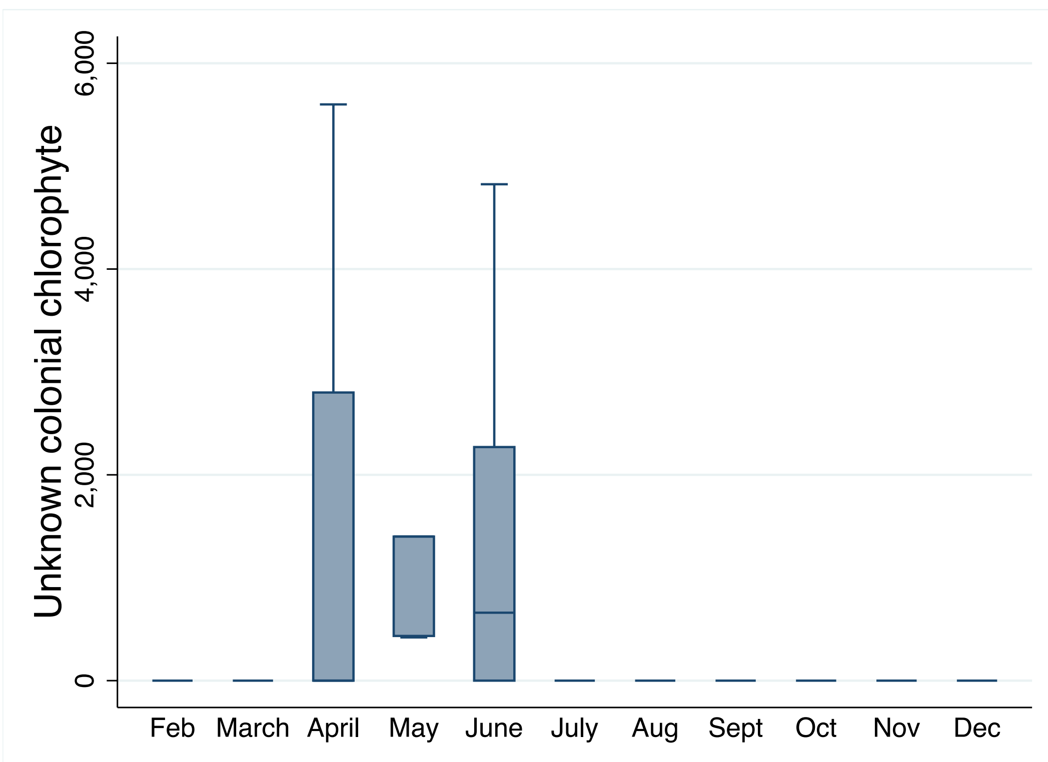

Scenedesmus obtusus
0
10
20
30
40
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

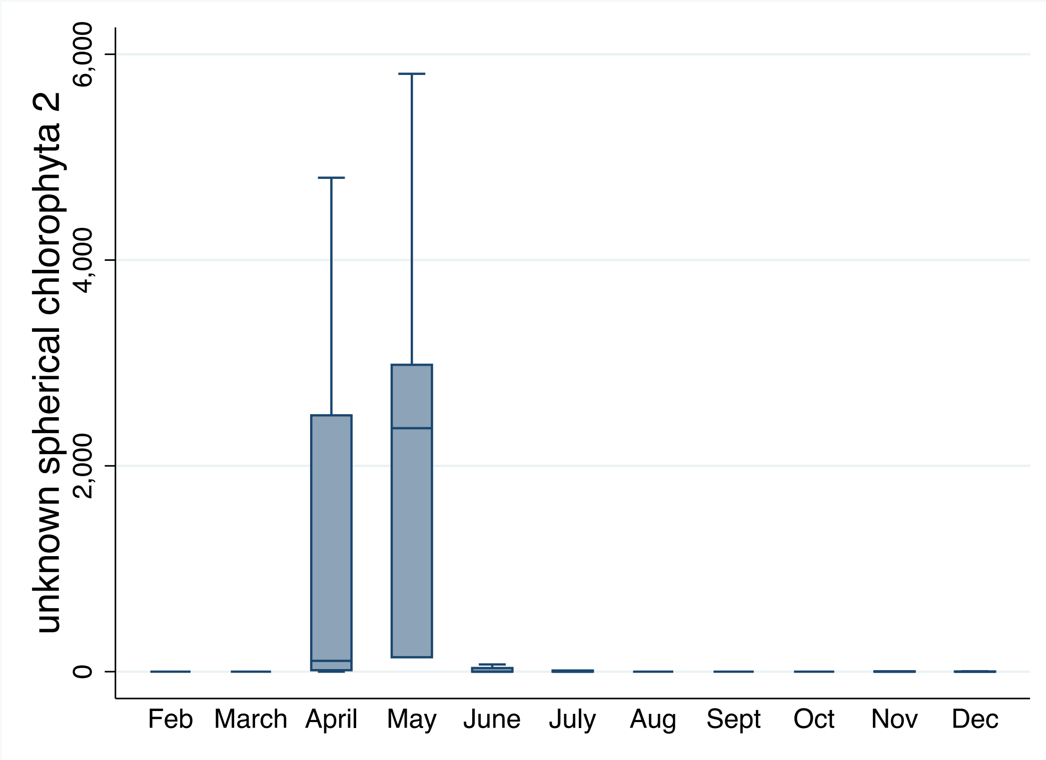

Scenedesmus species
0
20
40
60
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

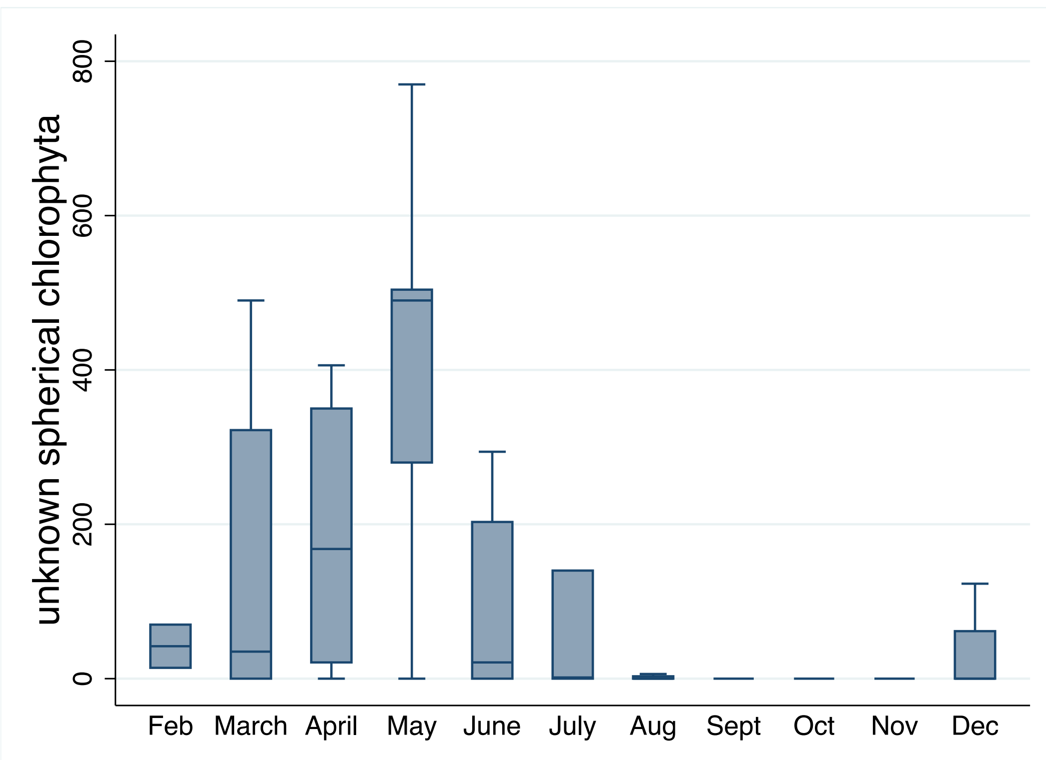

Schroederia setigera
0
20
40
60
80
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec


Sphaerocystis schroeteri
0
200
400
600
800
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec


unknown filamentous Cyanophyta species 2
0
200
400
600
800
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec


Unknown colonial chlorophyte
0
2,000
4,000
6,000
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec


unknown spherical chlorophyta 2
0
2,000
4,000
6,000
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec


unknown spherical chlorophyta
0
200
400
600
800
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov
Dec

Discussion

The results presented in this progress report are only preliminary findings. We are in the process of combining nutrients, phytoplankton, zooplankton, benthic invertebrate, and other physico-chemical data to determine interactions between these trophic levels of Utah Lake's foodweb to better understand the causes of cyanobacteria blooms and potential preventive measures. However, some important findings were presented in this report. For example, we have shown that phytoplankton assemblages vary temporally and spatially in Utah Lake. This has important implications for understanding HABs and their control. In addition, many phytoplankton were rare and uncommon both spatially and temporally. These taxa should not be considered unimportant players in the ecology of Utah Lake. Rare and uncommon often disproportionately affect food webs and their abundances can rebound quickly even after subtle shifts in food web dynamics or slight changes in environmental conditions and then they become the dominant players. In addition, rare and uncommon phytoplankton taxa may have occurred at low abundances in Utah Lake because they were a preferred food item for zooplankton. If zooplankton assemblage structure changes in the future these rare phytoplankton taxa may become dominant and in turn affect the prevalence and timing of HABs. Utah Lake's phytoplankton assemblage is rich and diverse and primary production is extremely high. Although this is typical of shallow, nutrient- rich lakes, Utah Lake appears to have a unique phytoplankton assemblage, which in turn results in a unique foodweb.

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Appendices

Appendix 1. Raw phytoplankton data from Rushforth Phycology.

Sample Location	Sample Date	Species	Taxa Units/ mL	Cells per mL
Lindon Marina	2/10/16	centric diatom species 2	5852	5852
Lindon Marina	2/10/16	centric diatoms	84	84
Lindon Marina	2/10/16	Gymnodinium species	84	84
Lindon Marina	2/10/16	Melosira granulata var. angustissima	84	672
Lindon Marina	2/10/16	Monoraphidium arcuatum	224	224
Lindon Marina	2/10/16	Monoraphidium contortum	84	84
Lindon Marina	2/10/16	Monoraphidium irregulare	84	84
Lindon Marina	2/10/16	Oocystis species	84	84
Lindon Marina	2/10/16	Oscillatoria species	84	84
Lindon Marina	2/10/16	pennate diatoms	70	70
Lindon Marina	2/10/16	unknown spherical chlorophyta	70	70
Saratoga Springs Marina	2/10/16	centric diatom species 2	588	588
Saratoga Springs Marina	2/10/16	Euglena species	14	14
Saratoga Springs Marina	2/10/16	Monoraphidium arcuatum	28	28
Saratoga Springs Marina	2/10/16	Monoraphidium contortum	42	42
Saratoga Springs Marina	2/10/16	Monoraphidium convolutus	14	14
Saratoga Springs Marina	2/10/16	pennate diatoms	112	112
Saratoga Springs Marina	2/10/16	unknown spherical chlorophyta	14	14
Saratoga Springs Marina	4/11/16	centric diatoms	2828	2828
Saratoga Springs Marina	4/11/16	Desmodesmus communis	14	56
Saratoga Springs Marina	4/11/16	Monoraphidium arcuatum	42	42
Saratoga Springs Marina	4/11/16	Monoraphidium contortum	28	28
Saratoga Springs Marina	4/11/16	Nitzschia acicularis	14	14
Saratoga Springs Marina	4/11/16	pennate diatoms	1288	1288
Saratoga Springs Marina	4/11/16	unknown spherical chlorophyta	42	42
Saratoga Springs Marina	4/11/16	unknown spherical chlorophyta 2	28	28
Lindon Marina	4/11/16	Acutidesmus pectinatus	14	56
Lindon Marina	4/11/16	centric diatoms	2660	2660
Lindon Marina	4/11/16	Coelastrum species	14	224
Lindon Marina	4/11/16	Crucigenia rectangularis	14	56
Lindon Marina	4/11/16	Desmodesmus communis	28	112
Lindon Marina	4/11/16	Euglena species	45	45

Lindon Marina	4/11/16	Gymnodinium species	14	14
Lindon Marina	4/11/16	Monoraphidium arcuatum	14	14
Lindon Marina	4/11/16	Monoraphidium contortum	14	14
Lindon Marina	4/11/16	Oocystis borgei	14	56
Lindon Marina	4/11/16	Oocystis species	28	84
Lindon Marina	4/11/16	pennate diatoms	378	378
Lindon Marina	4/11/16	Scenedesmus ellipticus	14	72
Lindon Marina	4/11/16	unknown spherical chlorophyta	294	294
Provo Marina	4/11/16	centric diatoms	1582	1582
Provo Marina	4/11/16	Crucigenia rectangularis	14	56
Provo Marina	4/11/16	Desmodesmus communis	14	54
Provo Marina	4/11/16	Euglena species	14	14
Provo Marina	4/11/16	Kirchneriella species	14	84
Provo Marina	4/11/16	Kirchniella lunata	28	196
Provo Marina	4/11/16	Melosira granulata var. angustissima	28	588
Provo Marina	4/11/16	Monoraphidium arcuatum	56	56
Provo Marina	4/11/16	Monoraphidium contortum	42	42
Provo Marina	4/11/16	Monoraphidium griffithii (Berkeley) Komarkova-Legnerova	14	14
Provo Marina	4/11/16	Monoraphidium komarakovae	28	28
Provo Marina	4/11/16	Nitzschia acicularis	14	14
Provo Marina	4/11/16	Oocystis species	70	215
Provo Marina	4/11/16	pennate diatoms	112	112
Provo Marina	4/11/16	Scenedesmus ellipticus	14	84
Provo Marina	4/11/16	Scenedesmus species	14	62
Provo Marina	4/11/16	unknown spherical chlorophyta	406	406
Provo Marina	4/11/16	unknown spherical chlorophyta 2	182	182
Outlet	5/24/16	Actinastrum hantzschii	14	84
Outlet	5/24/16	Acutidesmus pectinatus	14	56
Outlet	5/24/16	Aphanocapsa species	84	696
Outlet	5/24/16	centric diatoms	504	504
Outlet	5/24/16	Chlamydomonas species	140	140
Outlet	5/24/16	Closteriopsis longissima var. tropica	70	70
Outlet	5/24/16	Euglena species	14	14
Outlet	5/24/16	Gomphosphaeria aponina	70	3150
Outlet	5/24/16	Kirchniella lunata	98	1164
Outlet	5/24/16	Leptolyngbya species	70	3220
Outlet	5/24/16	Melosira granulata var. angustissima	140	2520
Outlet	5/24/16	Monoraphidium arcuatum	140	140

Outlet	5/24/16	Monoraphidium komarakovae	84	84
Outlet	5/24/16	Nitzschia acicularis	224	224
Outlet	5/24/16	Oocystis species	574	1607
Outlet	5/24/16	pennate diatoms	1624	1624
Outlet	5/24/16	Schroederia setigera	70	70
Outlet	5/24/16	Sphaerocystis schroeteri	14	672
Outlet	5/24/16	Unknown colonial chlorophyte	434	434
Outlet	5/24/16	unknown elongate chlorophyte	3584	3584
Outlet	5/24/16	unknown spherical chlorophyta	504	504
Outlet	5/24/16	unknown spherical chlorophyta 2	2366	2366
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Aphanocapsa species	280	2010
3/4 Lindon Marina to Pelican Point Transect	5/24/16	centric diatoms	3850	3850
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Chlamydomonas species	210	210
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Closteriopsis longissima var. tropica	70	70
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Coelastrum microporum	210	6710
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Crucigenia tetrapedia	140	6608
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Crucigeniella rectangularis	630	15120
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Cryptomonas species 2	70	70
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Desmodesmus species	70	280
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Desodesmus bicellularis	70	140
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Gomphosphaeria lacustris	140	16800
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Gymnodinium species	70	70
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Melosira granulata	70	420
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Monoraphidium dybowskii	70	70
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Monoraphidium komarakovae	70	70
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Nitzschia acicularis	70	70
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Oocystis borgei	420	1275
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Oocystis species 2	910	2300
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Pediastrum duplex	70	280
3/4 Lindon Marina to Pelican Point Transect	5/24/16	pennate diatoms	490	490
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Scenedesmus ellipticus	350	2450

3/4 Lindon Marina to Pelican Point Transect	5/24/16	Schroederia setigera	70	70
3/4 Lindon Marina to Pelican Point Transect	5/24/16	Unknown colonial chlorophyte	350	4150
3/4 Lindon Marina to Pelican Point Transect	5/24/16	unknown spherical chlorophyta	280	280
3/4 Lindon Marina to Pelican Point Transect	5/24/16	unknown spherical chlorophyta 2	2982	2982
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	Aphanocapsa species	70	1350
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	centric diatoms	350	350
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	Chlamydomonas species	70	70
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	Desmodesmus communis	70	280
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	Desodesmus bicellularis	140	260
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	Micractinium species	70	1120
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	Oocystis species 2	490	1470
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	pennate diatoms	490	490
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	Schroederia setigera	70	70
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	Unknown colonial chlorophyte	140	5600
1/2 Lindon Marina to Pelican Point tranhsect	4/24/16	unknown spherical chlorophyta 2	140	4800
1/4 Lindon Marina to Pelican Point Transect	5/24/16	Ankistrodesmus falcatus	140	140
1/4 Lindon Marina to Pelican Point Transect	5/24/16	centric diatoms	70	70
1/4 Lindon Marina to Pelican Point Transect	5/24/16	Closteriopsis longissima var. tropica	70	70
1/4 Lindon Marina to Pelican Point Transect	5/24/16	Crucigenia fenestrata	140	2240
1/4 Lindon Marina to Pelican Point Transect	5/24/16	Fragilaria crotonensis	70	1120
1/4 Lindon Marina to Pelican Point Transect	5/24/16	Melosira granulata var. angustissima	70	840
1/4 Lindon Marina to Pelican Point Transect	5/24/16	Oocystis borgei	70	280
1/4 Lindon Marina to Pelican Point Transect	5/24/16	Oocystis species 2	210	660
1/4 Lindon Marina to Pelican Point Transect	5/24/16	pennate diatoms	280	280
1/4 Lindon Marina to Pelican Point Transect	5/24/16	Unknown colonial chlorophyte	70	1400
1/4 Lindon Marina to Pelican Point Transect	5/24/16	unknown spherical chlorophyta 2	140	140
Pelican Point Marina	5/24/16	Ankistrodesmus falcatus	70	70
Pelican Point Marina	5/24/16	centric diatoms	350	350
Pelican Point Marina	5/24/16	Characiopsis species	70	70

Pelican Point Marina	5/24/16	Coelastrum microporum	70	2240
Pelican Point Marina	5/24/16	Crucigeniella rectangularis	70	1960
Pelican Point Marina	5/24/16	Desmodesmus obtusus	70	420
Pelican Point Marina	5/24/16	Desodesmus bicellularis	70	140
Pelican Point Marina	5/24/16	Monoraphidium contortum	70	70
Pelican Point Marina	5/24/16	Oocystis borgei	70	210
Pelican Point Marina	5/24/16	Oocystis species 2	350	1350
Pelican Point Marina	5/24/16	pennate diatoms	4550	4550
Pelican Point Marina	5/24/16	Scenedesmus ellipticus	70	350
Pelican Point Marina	5/24/16	Scenedesmus obtusus	70	280
Pelican Point Marina	5/24/16	Unknown colonial chlorophyte	70	420
Pelican Point Marina	5/24/16	unknown spherical chlorophyta	490	490
Pelican Point Marina	5/24/16	unknown spherical chlorophyta 2	140	140
Lindon Marina	5/24/16	Actinastrum hantzschii	70	1120
Lindon Marina	5/24/16	Acutidesmis obliquus	70	280
Lindon Marina	5/24/16	Acutidesmus pectinatus	210	840
Lindon Marina	5/24/16	Aphanocapsa species	70	1400
Lindon Marina	5/24/16	centric diatoms	5670	5670
Lindon Marina	5/24/16	Chlamydomonas species	70	70
Lindon Marina	5/24/16	Coelastrum microporum	70	2240
Lindon Marina	5/24/16	Crucigenia fenestrata	210	3316
Lindon Marina	5/24/16	Crucigeniella rectangularis	280	4480
Lindon Marina	5/24/16	Desmodesmus communis	420	1680
Lindon Marina	5/24/16	Gomphosphaeria aponina	140	8400
Lindon Marina	5/24/16	Melosira granulata var. angustissima	280	5400
Lindon Marina	5/24/16	Nitzschia acicularis	210	210
Lindon Marina	5/24/16	Oocystis borgei	140	450
Lindon Marina	5/24/16	Oocystis species	350	1300
Lindon Marina	5/24/16	Oscillatoria species	70	2100
Lindon Marina	5/24/16	pennate diatoms	3710	3710
Lindon Marina	5/24/16	Phacus species	70	70
Lindon Marina	5/24/16	Scenedesmus arcuatus	140	560
Lindon Marina	5/24/16	Scenedesmus ellipticus	140	670
Lindon Marina	5/24/16	Unknown colonial chlorophyte	70	1400
Lindon Marina	5/24/16	unknown spherical chlorophyta	770	770
Lindon Marina	5/24/16	unknown spherical chlorophyta 2	5810	5810
1/4 mile North of Goose Point	6/1/16	Dolichospermum crassa	140	2800
1/4 mile North of Goose Point	6/1/16	Aphanocapsa species	140	2880
1/4 mile North of Goose Point	6/1/16	centric diatoms	2968	2968

1/4 mile North of Goose Point	6/1/16	Crucigenia fenestrata	280	4480
1/4 mile North of Goose Point	6/1/16	Desmodesmus communis	280	960
1/4 mile North of Goose Point	6/1/16	Gomphosphaeria lacustris	140	10500
1/4 mile North of Goose Point	6/1/16	Oocystis borgei	574	1450
1/4 mile North of Goose Point	6/1/16	Oocystis species	840	3310
1/4 mile North of Goose Point	6/1/16	pennate diatoms	10808	10808
1/4 mile North of Goose Point	6/1/16	Scenedesmus obtusus	280	1680
1/4 mile North of Goose Point	6/1/16	Stephanodiscus niagarae	84	84
1/4 mile North of Goose Point	6/1/16	unknown elongate chlorophyte	280	280
1/4 mile North of Goose Point	6/1/16	unknown spherical chlorophyta	294	294
1/4 mile North of Goose Point	6/1/16	unknown spherical chlorophyta 2	4760	4760
South end of Goshen Bay	6/1/16	Ankistrodesmus falcatus	28	28
South end of Goshen Bay	6/1/16	Cylindrospermopsis species	28	1960
South end of Goshen Bay	6/1/16	Dinobryon divergens	28	12600
South end of Goshen Bay	6/1/16	Melosira granulata	28	350
South end of Goshen Bay	6/1/16	pennate diatoms	28	28
South end of Goshen Bay	6/1/16	unknown spherical chlorophyta	28	28
Lindon Marina	6/14/16	Acutidesmus pectinatus	84	336
Lindon Marina	6/14/16	Ankistrodesmus falcatus	154	2156
Lindon Marina	6/14/16	centric diatoms	84	84
Lindon Marina	6/14/16	Chlamydomonas species	224	224
Lindon Marina	6/14/16	Coelastrum microporum	70	2240
Lindon Marina	6/14/16	Crucigenia species	70	3600
Lindon Marina	6/14/16	Crucigeniella rectangularis	224	1334
Lindon Marina	6/14/16	Desmodesmus communis	294	1100
Lindon Marina	6/14/16	Desmodesmus obtusus	70	350
Lindon Marina	6/14/16	Desmodesmus opoliensis	224	1008
Lindon Marina	6/14/16	Euglena species	84	84
Lindon Marina	6/14/16	Melosira granulata var. angustissima	70	1120
Lindon Marina	6/14/16	Microspora species	70	350
Lindon Marina	6/14/16	Nitzschia acicularis	224	224
Lindon Marina	6/14/16	Oocystis borgei	294	1145
Lindon Marina	6/14/16	Oocystis species	644	1425
Lindon Marina	6/14/16	pennate diatoms	784	784
Lindon Marina	6/14/16	Scenedesmus ellipticus	70	420
Lindon Marina	6/14/16	Schroederia setigera	70	70
Lindon Marina	6/14/16	Ulothrix species	70	840
Lindon Marina	6/14/16	Unknown colonial chlorophyte	84	4824
1/4 Lindon Marina to Pelican Bay	6/14/16	Actinastrum hantzschii	154	1208

1/4 Lindon Marina to Pelican Bay	6/14/16	Ankistrodesmus falcatus	70	70
1/4 Lindon Marina to Pelican Bay	6/14/16	centric diatoms	70	70
1/4 Lindon Marina to Pelican Bay	6/14/16	Crucigeniella rectangularis	294	4704
1/4 Lindon Marina to Pelican Bay	6/14/16	Desmodesmus communis	350	1280
1/4 Lindon Marina to Pelican Bay	6/14/16	Desmodesmus obtusus	84	420
1/4 Lindon Marina to Pelican Bay	6/14/16	Desmodesmus opoliensis	70	280
1/4 Lindon Marina to Pelican Bay	6/14/16	Euglena species	70	70
1/4 Lindon Marina to Pelican Bay	6/14/16	Leptolyngbya species 2	14	832
1/4 Lindon Marina to Pelican Bay	6/14/16	Merismopedia glauca	70	2380
1/4 Lindon Marina to Pelican Bay	6/14/16	Nitzschia acicularis	70	70
1/4 Lindon Marina to Pelican Bay	6/14/16	Oocystis borgei	210	840
1/4 Lindon Marina to Pelican Bay	6/14/16	Oocystis species	560	2100
1/4 Lindon Marina to Pelican Bay	6/14/16	pennate diatoms	840	840
1/4 Lindon Marina to Pelican Bay	6/14/16	Scenedesmus ellipticus	70	280
1/4 Lindon Marina to Pelican Bay	6/14/16	Sphaerocystis schroeteri	14	780
1/4 Lindon Marina to Pelican Bay	6/14/16	unknown spherical chlorophyta	14	14
1/4 Lindon Marina to Pelican Bay	6/14/16	unknown spherical chlorophyta 2	70	70
1/2 Lindon Marina to Pelican Bay Transect	6/14/16	centric diatoms	70	70
1/2 Lindon Marina to Pelican Bay Transect	6/14/16	Desmodesmus communis	140	840
1/2 Lindon Marina to Pelican Bay Transect	6/14/16	Euglena species	70	70
1/2 Lindon Marina to Pelican Bay Transect	6/14/16	Oocystis species	140	420
1/2 Lindon Marina to Pelican Bay Transect	6/14/16	Oscillatoria species	140	2800
1/2 Lindon Marina to Pelican Bay Transect	6/14/16	Pediastrum duplex	70	420
1/2 Lindon Marina to Pelican Bay Transect	6/14/16	pennate diatoms	70	70
1/2 Lindon Marina to Pelican Bay Transect	6/14/16	Unknown colonial chlorophyte	140	4800
3/4 Lindon Marina to Pelican Bay	6/14/16	Ankistrodesmus falcatus	84	84
3/4 Lindon Marina to Pelican Bay	6/14/16	centric diatoms	70	70
3/4 Lindon Marina to Pelican Bay	6/14/16	Desmodesmus communis	70	420
3/4 Lindon Marina to Pelican Bay	6/14/16	Melosira granulata var. angustissima	70	1400
3/4 Lindon Marina to Pelican Bay	6/14/16	Oocystis species	70	240
3/4 Lindon Marina to Pelican Bay	6/14/16	Pediastrum duplex var. clathratum	70	5600
3/4 Lindon Marina to Pelican Bay	6/14/16	unknown spherical chlorophyta	70	70
Pelican Bay	6/14/16	Acutidesmus pectinatus	28	480
Pelican Bay	6/14/16	Anabaenopsis species	14	560
Pelican Bay	6/14/16	Ankistrodesmus falcatus	14	14
Pelican Bay	6/14/16	Aphanocapsa species	14	280

Pelican Bay	6/14/16	centric diatoms	126	126
Pelican Bay	6/14/16	Crucigeniella rectangularis	131.6	2107
Pelican Bay	6/14/16	Desmodesmus communis	84	408
Pelican Bay	6/14/16	Dolichospermum crassa	14	280
Pelican Bay	6/14/16	Euglena species	3	3
Pelican Bay	6/14/16	Leptolyngbya species	14	560
Pelican Bay	6/14/16	Melosira granulata var. angustissima	28	560
Pelican Bay	6/14/16	Monoraphidium komarakovae	28	28
Pelican Bay	6/14/16	Nitzschia acicularis	14	14
Pelican Bay	6/14/16	Oocystis borgei	126	504
Pelican Bay	6/14/16	Oocystis species	126	480
Pelican Bay	6/14/16	pennate diatoms	322	322
Pelican Bay	6/14/16	Scenedesmus ellipticus	14	572
Pelican Bay	6/14/16	Unknown colonial chlorophyte	154	3280
Pelican Bay	6/14/16	unknown spherical chlorophyta	28	560
Utah Lake Outlet	6/14/16	centric diatoms	14	14
Utah Lake Outlet	6/14/16	Chlamydomonas species	14	14
Utah Lake Outlet	6/14/16	Coelastrum microporum	14	434
Utah Lake Outlet	6/14/16	Crucigeniella rectangularis	84	2690
Utah Lake Outlet	6/14/16	Desmodesmus communis	59	372
Utah Lake Outlet	6/14/16	Euglena species	28	28
Utah Lake Outlet	6/14/16	Leptolyngbya species	14	420
Utah Lake Outlet	6/14/16	Melosira granulata var. angustissima	14	240
Utah Lake Outlet	6/14/16	Monoraphidium contortum	14	14
Utah Lake Outlet	6/14/16	Monoraphidium komarakovae	182	182
Utah Lake Outlet	6/14/16	Monoraphidium species	14	14
Utah Lake Outlet	6/14/16	Oocystis borgei	182	1120
Utah Lake Outlet	6/14/16	Oocystis species	140	870
Utah Lake Outlet	6/14/16	Oscillatoria species	42	3360
Utah Lake Outlet	6/14/16	pennate diatoms	476	476
Utah Lake Outlet	6/14/16	Scenedesmus ellipticus	28	168
Utah Lake Outlet	6/14/16	Tetraedron minimum	14	14
Utah Lake Outlet	6/14/16	Ulothrix species	14	1210
Utah Lake Outlet	6/14/16	Unknown colonial chlorophyte	14	840
Utah Lake Outlet	6/14/16	unknown spherical chlorophyta	112	112
Goshen Bay, North Goose Point	6/16/16	centric diatoms	308	308
Goshen Bay, North Goose Point	6/16/16	Dolichospermum crassa	154	3080
Goshen Bay, North Goose Point	6/16/16	Melosira granulata var. angustissima	14	210
Goshen Bay, North Goose Point	6/16/16	Nitzschia acicularis	13876	13876

Goshen Bay, North Goose Point	6/16/16	Oocystis species	14	84
Goshen Bay, North Goose Point	6/16/16	pennate diatoms	1148	1148
Goshen Bay, North Goose Point	6/16/16	Scenedesmus ellipticus	56	448
Goshen Bay, North Goose Point	6/16/16	Stephanodiscus niagarae	28	28
Goshen Bay, North Goose Point	6/16/16	unknown spherical chlorophyta	14	14
Provo Bay Outlet	6/16/16	Actinastrum hantzschii	14	70
Provo Bay Outlet	6/16/16	Acutidesmus pectinatus	70	420
Provo Bay Outlet	6/16/16	centric diatoms	1554	1554
Provo Bay Outlet	6/16/16	Crucigeniella rectangularis	42	164
Provo Bay Outlet	6/16/16	Desmodesmus communis	406	1624
Provo Bay Outlet	6/16/16	Desmodesmus opoliensis	70	420
Provo Bay Outlet	6/16/16	Dolichospermum crassa	28	1120
Provo Bay Outlet	6/16/16	Euglena species	14	14
Provo Bay Outlet	6/16/16	Melosira granulata var. angustissima	28	460
Provo Bay Outlet	6/16/16	Monoraphidium arcuatum	14	14
Provo Bay Outlet	6/16/16	Nitzschia acicularis	395	395
Provo Bay Outlet	6/16/16	Oocystis borgei	14	56
Provo Bay Outlet	6/16/16	Oocystis species	101	312
Provo Bay Outlet	6/16/16	pennate diatoms	826	962
Provo Bay Outlet	6/16/16	Scenedesmus ellipticus	56	282
Provo Bay Outlet	6/16/16	Sphaerocystis schroeteri	42	182
Provo Bay Outlet	6/16/16	Unknown colonial chlorophyte	126	1260
Provo Bay West	6/16/15	Actinastrum hantzschii	1190	9520
Provo Bay West	6/16/15	Acutidesmus pectinatus	322	1288
Provo Bay West	6/16/15	centric diatoms	6482	6482
Provo Bay West	6/16/15	Closteriopsis acicularis	14	14
Provo Bay West	6/16/15	Crucigeniella rectangularis	28	360
Provo Bay West	6/16/15	Cylindrospermopsis species	14	2800
Provo Bay West	6/16/15	Cyllindarospermopsis catemaco	28	896
Provo Bay West	6/16/15	Desmodesmus communis	4718	189000
Provo Bay West	6/16/15	Desmodesmus intermedius	70	280
Provo Bay West	6/16/15	Desmodesmus opoliensis	350	1400
Provo Bay West	6/16/15	Euglena species	126	126
Provo Bay West	6/16/15	Melosira granulata	84	252
Provo Bay West	6/16/15	Melosira granulata var. angustissima	168	3360
Provo Bay West	6/16/15	Monoraphidium arcuatum	42	42
Provo Bay West	6/16/15	Monoraphidium komarakovae	14	42
Provo Bay West	6/16/15	Nitzschia acicularis	16086	16086
Provo Bay West	6/16/15	Pediastrum duplex	14	86

Provo Bay West	6/16/15	pennate diatoms	3542	3542
Provo Bay West	6/16/15	Phacus species	28	28
Provo Bay West	6/16/15	Psuedanabaena species	28	972
Provo Bay West	6/16/15	Schroederia setigera	70	2800
Provo Bay West	6/16/15	Trachellomonas species	14	14
Provo Bay West	6/16/15	Unknown colonial chlorophyte	126	126
Provo Bay West	6/16/15	unknown spherical chlorophyta 2	182	182
Provo Bay East	6/16/16	Actinastrum hantzschii	392	6300
Provo Bay East	6/16/16	Acutidesmus pectinatus	56	224
Provo Bay East	6/16/16	centric diatoms	658	658
Provo Bay East	6/16/16	Chlamydomonas species	112	112
Provo Bay East	6/16/16	Crucigeniella rectangularis	42	1344
Provo Bay East	6/16/16	Desmodesmus communis	1302	5200
Provo Bay East	6/16/16	Desmodesmus opoliensis	238	1950
Provo Bay East	6/16/16	Desmodesmus protrubans	728	2900
Provo Bay East	6/16/16	Euglena species	56	56
Provo Bay East	6/16/16	Leptolyngbya species	28	1230
Provo Bay East	6/16/16	Melosira granulata var. angustissima	11	165
Provo Bay East	6/16/16	Melosira varians	14	56
Provo Bay East	6/16/16	Merismopedia glauca	70	6600
Provo Bay East	6/16/16	Nitzschia acicularis	1778	1778
Provo Bay East	6/16/16	Oocystis borgei	14	42
Provo Bay East	6/16/16	Oocystis species	70	105
Provo Bay East	6/16/16	Pediastrum duplex	14	56
Provo Bay East	6/16/16	Pediastrum species	28	112
Provo Bay East	6/16/16	pennate diatoms	434	434
Provo Bay East	6/16/16	Psuedanabaena species	98	2200
Provo Bay East	6/16/16	Schroederia setigera	14	14
Provo Bay East	6/16/16	Sphaerocystis schroeteri	42	672
Provo Bay East	6/16/16	Unknown colonial chlorophyte	28	480
Provo Bay East	6/16/16	unknown spherical chlorophyta	140	
Mid-lake, Pelican Point	3/10/16	centric diatoms	18774	18744
Mid-lake, Pelican Point	3/10/16	Crucigeniella rectangularis	70	1160
Mid-lake, Pelican Point	3/10/16	Euglena species	140	140
Mid-lake, Pelican Point	3/10/16	Monoraphidium arcuatum	560	560
Mid-lake, Pelican Point	3/10/16	Monoraphidium contortum	154	154
Mid-lake, Pelican Point	3/10/16	Monoraphidium convolutus	364	364
Mid-lake, Pelican Point	3/10/16	Nitzschia acicularis	364	364
Mid-lake, Pelican Point	3/10/16	Oocystis borgei	70	220

Mid-lake, Pelican Point	3/10/16	pennate diatoms	9394	9394
Mid-lake, Pelican Point	3/10/16	unknown spherical chlorophyta	154	154
Utah Lake Outlet	3/9/16	Acutidesmus pectinatus	224	896
Utah Lake Outlet	3/9/16	centric diatoms	8064	8064
Utah Lake Outlet	3/9/16	Coelastrum species	84	5100
Utah Lake Outlet	3/9/16	Crucigenia rectangularis	140	2240
Utah Lake Outlet	3/9/16	Desmodesmus communis	140	560
Utah Lake Outlet	3/9/16	Euglena species	294	294
Utah Lake Outlet	3/9/16	Kirchniella lunata	70	840
Utah Lake Outlet	3/9/16	Lagerheimia species	84	84
Utah Lake Outlet	3/9/16	Monoraphidium arcuatum	2884	2884
Utah Lake Outlet	3/9/16	Monoraphidium contortum	1344	1334
Utah Lake Outlet	3/9/16	Monoraphidium komarakovae	140	140
Utah Lake Outlet	3/9/16	Nitzschia acicularis	714	714
Utah Lake Outlet	3/9/16	Nitzschia reversa	140	140
Utah Lake Outlet	3/9/16	Oocystis species	364	1274
Utah Lake Outlet	3/9/16	Oocystis species 2	140	560
Utah Lake Outlet	3/9/16	Oscillatoria species	84	5460
Utah Lake Outlet	3/9/16	Pediastrum species	84	4872
Utah Lake Outlet	3/9/16	pennate diatoms	9534	9534
Utah Lake Outlet	3/9/16	unknown filamentous Cyanophyta species 2	350	9800
Utah Lake Outlet	3/9/16	unknown spherical chlorophyta	490	490
Utah Lake Outlet	3/9/16	Unknown spherical chlorophyte 3	140	140
Mid-Provo Bay	3/10/16	centric diatoms	703	703
Mid-Provo Bay	3/10/16	Desmodesmus communis	157	628
Mid-Provo Bay	3/10/16	Melosira granulata	31	620
Mid-Provo Bay	3/10/16	Melosira granulata var. angustissima	14	340
Mid-Provo Bay	3/10/16	Nitzschia acicularis	28	28
Mid-Provo Bay	3/10/16	Oocystis borgei	17	68
Mid-Provo Bay	3/10/16	Pediastrum duplex	17	68
Mid-Provo Bay	3/10/16	pennate diatoms	3539	3539
Mid-Provo Bay	3/10/16	Phacus species	14	14
Mid-Provo Bay	3/10/16	Trachellomonas species	14	14
Pelican Bay Marina	3/9/16	centric diatoms	56	56
Pelican Bay Marina	3/9/16	Crucigenia rectangularis	14	280
Pelican Bay Marina	3/9/16	Melosira granulata var. angustissima	28	560
Pelican Bay Marina	3/9/16	Melosira varians	14	42
Pelican Bay Marina	3/9/16	Monoraphidium contortum	42	42
Pelican Bay Marina	3/9/16	Nitzschia acicularis	28	28

Pelican Bay Marina	3/9/16	pennate diatoms	5141	5141
Pelican Bay Marina	3/9/16	unknown filamentous Cyanophyta species 2	28	840
Pelican Bay Marina	3/9/16	unknown spherical chlorophyta	14	14
South End of Goshen Bay	3/10/16	Acutidesmus pectinatus	28	96
South End of Goshen Bay	3/10/16	centric diatoms	101	101
South End of Goshen Bay	3/10/16	Cylindrospermopsis species	48	1488
South End of Goshen Bay	3/10/16	Cyllindarospermopsis catemca	87	1740
South End of Goshen Bay	3/10/16	Euglena species	14	14
South End of Goshen Bay	3/10/16	Kirchniella lunata	14	168
South End of Goshen Bay	3/10/16	Monoraphidium arcuatum	171	171
South End of Goshen Bay	3/10/16	Monoraphidium contortum	59	59
South End of Goshen Bay	3/10/16	Monoraphidium convolutus	3	3
South End of Goshen Bay	3/10/16	Monoraphidium komarakovae	70	70
South End of Goshen Bay	3/10/16	Nitzschia acicularis	31	31
South End of Goshen Bay	3/10/16	Oocystis borgei	17	68
South End of Goshen Bay	3/10/16	Oocystis gigas	3	5
South End of Goshen Bay	3/10/16	Oocystis species 3	42	150
South End of Goshen Bay	3/10/16	pennate diatoms	227	227
South End of Goshen Bay	3/10/16	unknown spherical chlorophyta	56	56
Lindon Marina	3/9/16	centric diatoms	35294	35294
Lindon Marina	3/9/16	Crucigenia rectangularis	210	3360
Lindon Marina	3/9/16	Cryptomonas species	70	70
Lindon Marina	3/9/16	Cylindrospermopsis species	70	2240
Lindon Marina	3/9/16	Cyllindarospermopsis catemca	70	1350
Lindon Marina	3/9/16	Desmodesmus communis	140	560
Lindon Marina	3/9/16	Euglena species	84	84
Lindon Marina	3/9/16	Kirchniella lunata	84	2016
Lindon Marina	3/9/16	Leptolyngbya species	84	4700
Lindon Marina	3/9/16	Leptolyngbya species 2	70	4550
Lindon Marina	3/9/16	Melosira granulata var. angustissima	140	2650
Lindon Marina	3/9/16	Monoraphidium arcuatum	504	504
Lindon Marina	3/9/16	Monoraphidium contortum	784	784
Lindon Marina	3/9/16	Monoraphidium convolutus	140	140
Lindon Marina	3/9/16	Oocystis borgei	70	210
Lindon Marina	3/9/16	pennate diatoms	5964	5964
Lindon Marina	3/9/16	Unknown colonial chlorophyte	84	84
Lindon Marina	3/9/16	Unknown colonial cyanophyte species 2	84	84
Lindon Marina	3/9/16	unknown spherical chlorophyta	490	490
Mouth of Provo Bay	3/10/16	Acutidesmis obliquus	28	96

Mouth of Provo Bay	3/10/16	centric diatoms	7059	7059
Mouth of Provo Bay	3/10/16	Desmodesmus communis	143	644
Mouth of Provo Bay	3/10/16	Euglena species	31	31
Mouth of Provo Bay	3/10/16	Leptolyngbya species 2	14	280
Mouth of Provo Bay	3/10/16	Melosira granulata var. angustissima	31	600
Mouth of Provo Bay	3/10/16	Melosira varians	28	140
Mouth of Provo Bay	3/10/16	Monoraphidium arcuatum	168	168
Mouth of Provo Bay	3/10/16	Monoraphidium contortum	45	45
Mouth of Provo Bay	3/10/16	Nitzschia acicularis	17	17
Mouth of Provo Bay	3/10/16	pennate diatoms	3531	3531
Mouth of Provo Bay	3/10/16	Scenedesmus ellipticus	59	290
Mouth of Provo Bay	3/10/16	Scenedesmus obtusus	28	140
North End of Goshen Bay	3/10/16	Aphanothece species	14	910
North End of Goshen Bay	3/10/16	centric diatoms	45	45
North End of Goshen Bay	3/10/16	Cyllindarospermopsis catemca	14	280
North End of Goshen Bay	3/10/16	Desmodesmus communis	28	100
North End of Goshen Bay	3/10/16	Euglena species	14	14
North End of Goshen Bay	3/10/16	Kirchniella lunata	45	850
North End of Goshen Bay	3/10/16	Leptolyngbya species	14	490
North End of Goshen Bay	3/10/16	Leptolyngbya species 2	42	1500
North End of Goshen Bay	3/10/16	Monoraphidium arcuatum	185	185
North End of Goshen Bay	3/10/16	Monoraphidium contortum	283	283
North End of Goshen Bay	3/10/16	Nitzschia acicularis	14	14
North End of Goshen Bay	3/10/16	Oocystis borgei	17	68
North End of Goshen Bay	3/10/16	pennate diatoms	703	703
Northeast corner of Lindon Marina HAB	7/19/16	Aphanizomenon flos-aquae	179	4650
Northeast corner of Lindon Marina HAB	7/19/16	Dolichospermum crassa	6	196
Lindon Marina Outside Jetty HAB	12:00:00 AM	Aphanizomenon flos-aquae	2559	53840
HAB	7/19/16	Aphanizomenon flos-aquae	714	19990
Outlet HAB	7/19/16	Dolichospermum crassa	9	195
Lindon Marina 200m from Jetty HAB	7/19/16	Aphanizomenon flos-aquae	3	61
1000 meters outside of Provo Bay	7/28/16	Acutidesmus pectinatus	22	132
1000 meters outside of Provo Bay	7/28/16	Ankistrodesmus falcatus	6	6
1000 meters outside of Provo Bay	7/28/16	Aphanizomenon flos-aquae	6	128
1000 meters outside of Provo Bay	7/28/16	centric diatoms	358	358
1000 meters outside of Provo Bay	7/28/16	Desmodesmus communis	350	2100
1000 meters outside of Provo Bay	7/28/16	Desmodesmus opoliensis	39	215
1000 meters outside of Provo Bay	7/28/16	Desmodesmus species	11	66

1000 meters outside of Provo Bay	7/28/16	Euglena species	17	17
1000 meters outside of Provo Bay	7/28/16	Melosira granulata var. angustissima	17	335
1000 meters outside of Provo Bay	7/28/16	Merismopedia glauca	8	480
1000 meters outside of Provo Bay	7/28/16	Microcystis aeruginosa	22	2240
1000 meters outside of Provo Bay	7/28/16	Monoraphidium dybowskii	3	3
1000 meters outside of Provo Bay	7/28/16	Monoraphidium komarakovae	3	3
1000 meters outside of Provo Bay	7/28/16	Nitzschia acicularis	1646	1646
1000 meters outside of Provo Bay	7/28/16	Oocystis borgei	11	38
1000 meters outside of Provo Bay	7/28/16	Oocystis species	49	240
1000 meters outside of Provo Bay	7/28/16	Pediastrum duplex	6	24
1000 meters outside of Provo Bay	7/28/16	pennate diatoms	20	20
1000 meters outside of Provo Bay	7/28/16	Phormidium species	3	280
1000 meters outside of Provo Bay	7/28/16	Quadrigula species	3	18
1000 meters outside of Provo Bay	7/28/16	Scenedesmus ellipticus	42	225
1000 meters outside of Provo Bay	7/28/16	Sphaerocystis schroeteri	14	896
1000 meters outside of Provo Bay	7/28/16	unknown spherical chlorophyta	837	837
Utah Lake Spanish Fork	7/28/16	Actinastrum hantzschii	28	168
Utah Lake Spanish Fork	7/28/16	Ankistrodesmus falcatus	112	112
Utah Lake Spanish Fork	7/28/16	centric diatom species 2	56	56
Utah Lake Spanish Fork	7/28/16	centric diatoms	476	476
Utah Lake Spanish Fork	7/28/16	Crucigeniella rectangularis	28	448
Utah Lake Spanish Fork	7/28/16	Cyanodictyon planktonicum	84	12600
Utah Lake Spanish Fork	7/28/16	Desmodesmus communis	252	15000
Utah Lake Spanish Fork	7/28/16	Leptolyngbya species	252	8820
Utah Lake Spanish Fork	7/28/16	Monoraphidium arcuatum	56	56
Utah Lake Spanish Fork	7/28/16	Nitzschia acicularis	196	196
Utah Lake Spanish Fork	7/28/16	Oocystis species	84	320
Utah Lake Spanish Fork	7/28/16	pennate diatoms	3892	3892
Utah Lake Spanish Fork	7/28/16	Phormidium formosum	28	2800
Utah Lake Spanish Fork	7/28/16	Phormidium species	56	6608
Utah Lake Spanish Fork	7/28/16	unknown spherical chlorophyta	140	140
Mid Goshen Bay	7/28/16	Ankistrodesmus falcatus	56	56
Mid Goshen Bay	7/28/16	Aphanizomenon flos-aquae	28	672
Mid Goshen Bay	7/28/16	Aphanothece species	28	2900
Mid Goshen Bay	7/28/16	centric diatom species 2	168	168
Mid Goshen Bay	7/28/16	centric diatoms	812	812
Mid Goshen Bay	7/28/16	Crucigeniella rectangularis	28	896
Mid Goshen Bay	7/28/16	Dolichospermum flosaquae	84	2100
Mid Goshen Bay	7/28/16	Euglena species	28	28

Mid Goshen Bay	7/28/16	Gomphosphaeria aponina	28	2650
Mid Goshen Bay	7/28/16	Keratococcus species	28	236
Mid Goshen Bay	7/28/16	Leptolyngbya species	28	540
Mid Goshen Bay	7/28/16	Melosira granulata var. angustissima	28	560
Mid Goshen Bay	7/28/16	Merismopedia glauca	28	2800
Mid Goshen Bay	7/28/16	Microcystis aeruginosa	28	2240
Mid Goshen Bay	7/28/16	Monoraphidium contortum	28	28
Mid Goshen Bay	7/28/16	Nitzschia acicularis	140	140
Mid Goshen Bay	7/28/16	Oocystis species	168	588
Mid Goshen Bay	7/28/16	Pediastrum species	28	2800
Mid Goshen Bay	7/28/16	pennate diatoms	308	308
Mid Goshen Bay	7/28/16	Phormidium species	28	2800
Mid Goshen Bay	7/28/16	Phormidium species 3	196	284
Mid Goshen Bay	7/28/16	Scenedesmus ellipticus	28	140
Mid Goshen Bay	7/28/16	Sphaerocystis schroeteri	56	1790
Mid Goshen Bay	7/28/16	unknown spherical chlorophyta	56	56
Lincoln Beach, 300 feet from shore	7/28/16	Aphanizomenon flos-aquae	56	4590
Lincoln Beach, 300 feet from shore	7/28/16	centric diatom species 2	56	56
Lincoln Beach, 300 feet from shore	7/28/16	centric diatoms	28	28
Lincoln Beach, 300 feet from shore	7/28/16	Desodesmus bicellularis	28	56
Lincoln Beach, 300 feet from shore	7/28/16	Leptolyngbya species	224	6900
Lincoln Beach, 300 feet from shore	7/28/16	Merismopedia glauca	56	56200
Lincoln Beach, 300 feet from shore	7/28/16	Oocystis species	56	200
Lincoln Beach, 300 feet from shore	7/28/16	Pediastrum duplex	28	96
Lincoln Beach, 300 feet from shore	7/28/16	pennate diatoms	196	196
Lincoln Beach, 300 feet from shore	7/28/16	Phormidium species	56	13610
Lincoln Beach, 300 feet from shore	7/28/16	Phormidium species 3	56	18100
Lincoln Beach, 300 feet from shore	7/28/16	Scenedesmus ellipticus	28	168
Lincoln Beach, 300 feet from shore	7/28/16	Sphaerocystis schroeteri	28	448
Lincoln Beach, 300 feet from shore	7/28/16	Unknown colonial chlorophyte	28	940
Lincoln Beach, 300 feet from shore	7/28/16	unknown spherical chlorophyta	28	850
Lincoln Beach, 300 feet from shore	7/28/16	unknown spherical chlorophyta 2	196	2744
Mouth of Provo Bay	7/28/16	Acutidesmus pectinatus	28	180
Mouth of Provo Bay	7/28/16	centric diatom species 2	252	252
Mouth of Provo Bay	7/28/16	centric diatoms	168	168
Mouth of Provo Bay	7/28/16	Desmodesmus communis	644	3860
Mouth of Provo Bay	7/28/16	Desmodesmus opoliensis	112	560
Mouth of Provo Bay	7/28/16	Desmodesmus species	140	840
Mouth of Provo Bay	7/28/16	Desodesmus bicellularis	28	56

Mouth of Provo Bay	7/28/16	Fragilaria virescens	28	560
Mouth of Provo Bay	7/28/16	Leptolyngbya species	252	10300
Mouth of Provo Bay	7/28/16	Merismopedia glauca	28	2800
Mouth of Provo Bay	7/28/16	Monoraphidium contortum	28	28
Mouth of Provo Bay	7/28/16	Nitzschia acicularis	84	84
Mouth of Provo Bay	7/28/16	Pandorina morum	28	448
Mouth of Provo Bay	7/28/16	Pediastrum duplex	28	3080
Mouth of Provo Bay	7/28/16	pennate diatoms	11564	11564
Mouth of Provo Bay	7/28/16	Phormidium species	28	2800
Mouth of Provo Bay	7/28/16	Phormidium species 3	56	6160
Mouth of Provo Bay	7/28/16	Scenedesmus ellipticus	28	140
Mouth of Provo Bay	7/28/16	unknown spherical chlorophyta 2	28	28
Goshen Bay North	7/29/16	Ankistrodesmus falcatus	8	8
Goshen Bay North	7/29/16	Aphanizomenon flos-aquae	3	63
Goshen Bay North	7/29/16	Aphanothece species	3	330
Goshen Bay North	7/29/16	centric diatom species 2	3	3
Goshen Bay North	7/29/16	centric diatoms	3	3
Goshen Bay North	7/29/16	Crucigeniella rectangularis	3	72
Goshen Bay North	7/29/16	Desmodesmus species	3	18
Goshen Bay North	7/29/16	Desodesmus bicellularis	3	6
Goshen Bay North	7/29/16	Dolichospermum flosaquae	6	24
Goshen Bay North	7/29/16	Gomphosphaeria aponina	6	120
Goshen Bay North	7/29/16	Leptolyngbya species	20	2000
Goshen Bay North	7/29/16	Melosira granulata var. angustissima	3	63
Goshen Bay North	7/29/16	Monoraphidium arcuatum	6	6
Goshen Bay North	7/29/16	Monoraphidium species	3	3
Goshen Bay North	7/29/16	Oocystis species	3	12
Goshen Bay North	7/29/16	pennate diatoms	45	45
Goshen Bay North	7/29/16	Phormidium species 3	3	330
Goshen Bay North	7/29/16	Scenedesmus ellipticus	3	15
Goshen Bay North	7/29/16	Unknown colonial chlorophyte	6	64
Goshen Bay North	7/29/16	unknown spherical chlorophyta 2	8	48
Utah Lake State Park	7/29/16	Acutidesmus pectinatus	3	12
Utah Lake State Park	7/29/16	Ankistrodesmus falcatus	3	12
Utah Lake State Park	7/29/16	Aphanothece species	3	310
Utah Lake State Park	7/29/16	centric diatoms	31	31
Utah Lake State Park	7/29/16	Dolichospermum flosaquae	3	75
Utah Lake State Park	7/29/16	Leptolyngbya species	64	192
Utah Lake State Park	7/29/16	Monoraphidium arcuatum	3	3

Utah Lake State Park	7/29/16	pennate diatoms	361	361
Utah Lake State Park	7/29/16	unknown spherical chlorophyta	3	3
Utah Lake State Park	7/29/16	unknown spherical chlorophyta 2	11	11
Lindon Marina	7/29/16	Actinastrum hantzschii	3	24
Lindon Marina	7/29/16	Ankistrodesmus falcatus	11	11
Lindon Marina	7/29/16	Aphanothece species	6	660
Lindon Marina	7/29/16	centric diatoms	90	90
Lindon Marina	7/29/16	Coelosphaerum species	3	48
Lindon Marina	7/29/16	Desmodesmus communis	81	324
Lindon Marina	7/29/16	Desodesmus bicellularis	6	12
Lindon Marina	7/29/16	Leptolyngbya species	64	1280
Lindon Marina	7/29/16	Merismopedia glauca	8	840
Lindon Marina	7/29/16	Microcystis aeruginosa	17	340
Lindon Marina	7/29/16	Microcystis incerta	3	850
Lindon Marina	7/29/16	Monoraphidium arcuatum	6	6
Lindon Marina	7/29/16	Nitzschia acicularis	67	67
Lindon Marina	7/29/16	pennate diatoms	795	795
Lindon Marina	7/29/16	Phormidium formosum	6	630
Lindon Marina	7/29/16	Phormidium species	3	240
Lindon Marina	7/29/16	Scenedesmus ellipticus	3	15
Lindon Marina	7/29/16	unknown spherical chlorophyta	4	4
Sandy Beach	7/29/16	Acutidesmus pectinatus	28	112
Sandy Beach	7/29/16	centric diatom species 2	980	980
Sandy Beach	7/29/16	centric diatoms	28	28
Sandy Beach	7/29/16	Desmodesmus communis	84	332
Sandy Beach	7/29/16	Desmodesmus opoliensis	28	96
Sandy Beach	7/29/16	Leptolyngbya species	56	1736
Sandy Beach	7/29/16	Melosira granulata var. angustissima	84	1620
Sandy Beach	7/29/16	Merismopedia glauca	28	2800
Sandy Beach	7/29/16	Monoraphidium dybowskii	26152	26152
Sandy Beach	7/29/16	Nitzschia acicularis	252	252
Sandy Beach	7/29/16	Oocystis species	28	88
Sandy Beach	7/29/16	Pediastrum duplex	28	96
Sandy Beach	7/29/16	pennate diatoms	28	28
Sandy Beach	7/29/16	Pseudanabaena species	140	2800
Sandy Beach	7/29/16	Scenedesmus obtusus	224	1340
Sandy Beach	7/29/16	unknown spherical chlorophyta	1092	1092
Mouth of Provo Bay	8/4/16	Acutidesmus pectinatus	532	2020
Mouth of Provo Bay	8/4/16	centric diatom species 2	28	28

Mouth of Provo Bay	8/4/16	centric diatoms	252	252
Mouth of Provo Bay	8/4/16	Desmodesmus communis	84	332
Mouth of Provo Bay	8/4/16	Desmodesmus opoliensis	84	420
Mouth of Provo Bay	8/4/16	Desmodesmus species	4788	19152
Mouth of Provo Bay	8/4/16	Leptolyngbya species	84	2352
Mouth of Provo Bay	8/4/16	Merismopedia glauca	56	5600
Mouth of Provo Bay	8/4/16	Oocystis species	28	96
Mouth of Provo Bay	8/4/16	pennate diatoms	56	56
Mouth of Provo Bay	8/4/16	Phormidium species	28	3010
Mouth of Provo Bay	8/4/16	Pseudanabaena species	28	840
Mouth of Provo Bay	8/4/16	Ulothrix species	28	420
Mouth of Provo Bay	8/4/16	unknown spherical chlorophyta	28	28
1/2 Way Between Lindon and Saratoga	8/4/16	Aphanizomenon flos-aquae	28	588
1/2 Way Between Lindon and Saratoga	8/4/16	Closteriopsis longissima var. tropica	56	56
1/2 Way Between Lindon and Saratoga	8/4/16	Leptolyngbya species	56	1736
1/2 Way Between Lindon and Saratoga	8/4/16	Microcytis species	84	1680
1/2 Way Between Lindon and Saratoga	8/4/16	pennate diatoms	28	28
Provo Bay Mid-bay	8/4/16	Acutidesmus pectinatus	28	448
Provo Bay Mid-bay	8/4/16	Ankistrodesmus falcatus	896	896
Provo Bay Mid-bay	8/4/16	centric diatom species 2	476	476
Provo Bay Mid-bay	8/4/16	centric diatoms	28	28
Provo Bay Mid-bay	8/4/16	Desmodesmus aculeolatus	28	168
Provo Bay Mid-bay	8/4/16	Desmodesmus communis	168	672
Provo Bay Mid-bay	8/4/16	Desmodesmus opoliensis	28	140
Provo Bay Mid-bay	8/4/16	Desmodesmus species	6300	25830
Provo Bay Mid-bay	8/4/16	Leptolyngbya species	28	840
Provo Bay Mid-bay	8/4/16	Merismopedia glauca	14	1400
Provo Bay Mid-bay	8/4/16	Pediastrum duplex	3	12
Provo Bay Mid-bay	8/4/16	pennate diatoms	14	14
Provo Bay Mid-bay	8/4/16	unknown spherical chlorophyta	3	3
3/4 way on transect Bewteen Lindon and Saratoga	8/4/16	Aphanizomenon flos-aquae	14	294
3/4 way on transect Bewteen Lindon and Saratoga	8/4/16	Closteriopsis longissima var. tropica	3	3
3/4 way on transect Bewteen Lindon and Saratoga	8/4/16	Leptolyngbya species	6	168
3/4 way on transect Bewteen Lindon and Saratoga	8/4/16	Melosira granulata var. angustissima	6	110
3/4 way on transect Bewteen Lindon and Saratoga	8/4/16	pennate diatoms	3	3

3/4 way on transect Bewteen Lindon and Saratoga	8/4/16	Phormidium species	20	2400
Lindon Marina; 100m from Jetty	8/4/16	centric diatoms	3	3
Lindon Marina; 100m from Jetty	8/4/16	Desmodesmus communis	3	12
Lindon Marina; 100m from Jetty	8/4/16	Desodesmus bicellularis	3	6
Lindon Marina; 100m from Jetty	8/4/16	Leptolyngbya species	8	310
Lindon Marina; 100m from Jetty	8/4/16	Oocystis borgei	3	12
Lindon Marina; 100m from Jetty	8/4/16	Oocystis species	8	32
Lindon Marina; 100m from Jetty	8/4/16	Pediastrum duplex	3	12
Lindon Marina; 100m from Jetty	8/4/16	pennate diatoms	22	22
Lindon Marina; 100m from Jetty	8/4/16	Scenedesmus ellipticus	3	15
Lindon Marina; 100m from Jetty	8/4/16	Unknown colonial cyanophyte	3	90
1/4 distance from Lindon to Saratoga	8/4/16	Ankyra judayi	6	6
1/4 distance from Lindon to Saratoga	8/4/16	Aphanizomenon flos-aquae	8	225
1/4 distance from Lindon to Saratoga	8/4/16	Closteriopsis longissima	3	3
1/4 distance from Lindon to Saratoga	8/4/16	Melosira granulata	78	390
1/4 distance from Lindon to Saratoga	8/4/16	Melosira granulata var. angustissima	3	55
1/4 distance from Lindon to Saratoga	8/4/16	Oocystis species	56	224
1/4 distance from Lindon to Saratoga	8/4/16	Pediastrum duplex	28	168
1/4 distance from Lindon to Saratoga	8/4/16	pennate diatoms	84	84
1/4 distance from Lindon to Saratoga	8/4/16	unknown spherical chlorophyta	28	28
Saratoga Marina	8/4/16	Ankistrodesmus falcatus	84	84
Saratoga Marina	8/4/16	Aphanizomenon flos-aquae	56	1600
Saratoga Marina	8/4/16	Aphanocapsa species	28	3080
Saratoga Marina	8/4/16	Botryococcus braunii	28	1344
Saratoga Marina	8/4/16	centric diatoms	28	28
Saratoga Marina	8/4/16	Chrysocapsa planktonica	112	3584
Saratoga Marina	8/4/16	Closteriopsis longissima var. tropica	56	56
Saratoga Marina	8/4/16	Coelastrum species	672	25500
Saratoga Marina	8/4/16	Crucigeniella rectangularis	28	448
Saratoga Marina	8/4/16	Desmodesmus communis	28	168
Saratoga Marina	8/4/16	Desodesmus bicellularis	84	168
Saratoga Marina	8/4/16	Leptolyngbya species	2184	69900
Saratoga Marina	8/4/16	Melosira granulata var. angustissima	28	490
Saratoga Marina	8/4/16	Nitzschia acicularis	56	56
Saratoga Marina	8/4/16	Oocystis species	112	448
Saratoga Marina	8/4/16	pennate diatoms	56	56
Saratoga Marina	8/4/16	Phormidium formosum	56	7280
Saratoga Marina	8/4/16	Phormidium species	84	11340

Saratoga Marina	8/4/16	Scenedesmus arcuatus	17	68
Saratoga Marina	8/4/16	Scenedesmus obtusus	20	100
Saratoga Marina	8/4/16	Unknown colonial chlorophyte	8	240
Saratoga Marina	8/4/16	unknown spherical chlorophyta	6	6
Lindon Marina	8/11/16	Aphanocapsa species	28	3780
Lindon Marina	8/11/16	centric diatom species 2	3	3
Lindon Marina	8/11/16	centric diatoms	3	3
Lindon Marina	8/11/16	Crucigeniella rectangularis	3	48
Lindon Marina	8/11/16	Desmodesmus communis	11	66
Lindon Marina	8/11/16	Desmodesmus obtusus	22	120
Lindon Marina	8/11/16	Desmodesmus opoliensis	336	1680
Lindon Marina	8/11/16	Desodesmus bicellularis	3	6
Lindon Marina	8/11/16	Euglena species	232	232
Lindon Marina	8/11/16	Merismopedia glauca	3	330
Lindon Marina	8/11/16	Oocystis species	45	180
Lindon Marina	8/11/16	Pediastrum duplex	3	12
Lindon Marina	8/11/16	pennate diatoms	70	70
Lindon Marina	8/11/16	Phacus species	3	3
Lindon Marina	8/11/16	Scenedesmus ellipticus	3	12
Lindon Marina	8/11/16	Schroederia setigera	8	8
Lindon Marina	8/11/16	unknown spherical chlorophyta	3	3
1/2 way Lindon to Saratoga Transect	8/11/16	Acutidesmus pectinatus	3	12
1/2 way Lindon to Saratoga Transect	8/11/16	Ankistrodesmus falcatus	3	110
1/2 way Lindon to Saratoga Transect	8/11/16	centric diatoms	3	3
1/2 way Lindon to Saratoga Transect	8/11/16	Cyanodictyon planktonicum	20	1600
1/2 way Lindon to Saratoga Transect	8/11/16	Desmodesmus communis	34	205
1/2 way Lindon to Saratoga Transect	8/11/16	Melosira granulata var. angustissima	3	15
1/2 way Lindon to Saratoga Transect	8/11/16	Microcystis species	25	500
1/2 way Lindon to Saratoga Transect	8/11/16	Oocystis species	28	96
1/2 way Lindon to Saratoga Transect	8/11/16	pennate diatoms	84	84
1/2 way Lindon to Saratoga Transect	8/11/16	Scenedesmus ellipticus	112	448
1/2 way Lindon to Saratoga Transect	8/11/16	unknown spherical chlorophyta 2	28	28
Utah Lake Mid-Provo Bay	8/11/16	Ankistrodesmus falcatus	280	280
Utah Lake Mid-Provo Bay	8/11/16	Aphanocapsa species	196	29600
Utah Lake Mid-Provo Bay	8/11/16	centric diatom species 2	28	28
Utah Lake Mid-Provo Bay	8/11/16	centric diatoms	28	28
Utah Lake Mid-Provo Bay	8/11/16	Cyanodictyon planktonicum	112	15120
Utah Lake Mid-Provo Bay	8/11/16	Desmodesmus communis	56	224
Utah Lake Mid-Provo Bay	8/11/16	Desmodesmus opoliensis	4508	27040

Utah Lake Mid-Provo Bay	8/11/16	Euglena species	196	196
Utah Lake Mid-Provo Bay	8/11/16	Melosira granulata var. angustissima	112	2200
Utah Lake Mid-Provo Bay	8/11/16	Oocystis species	3	12
Utah Lake Mid-Provo Bay	8/11/16	pennate diatoms	3	3
Utah Lake Mid-Provo Bay	8/11/16	Phormidium species	3	360
Utah Lake Mid-Provo Bay	8/11/16	unknown spherical chlorophyta 2	14	400
3/4 Along Lindon to Saratoga Transect	8/11/16	Aphanocapsa species	25	2550
3/4 Along Lindon to Saratoga Transect	8/11/16	Melosira granulata var. angustissima	3	45
3/4 Along Lindon to Saratoga Transect	8/11/16	Microcystis aeruginosa	6	660
3/4 Along Lindon to Saratoga Transect	8/11/16	pennate diatoms	3	3
3/4 Along Lindon to Saratoga Transect	8/11/16	Unknown filamentous cyanophyte 4	6	540
1/4 way Between Lindon to Saratoga Transect	8/11/16	Aphanizomenon flos-aquae	3	110
1/4 way Between Lindon to Saratoga Transect	8/11/16	Aphanocapsa species	6	630
1/4 way Between Lindon to Saratoga Transect	8/11/16	centric diatoms	6	6
1/4 way Between Lindon to Saratoga Transect	8/11/16	Cyanodictyon planktonicum	3	540
1/4 way Between Lindon to Saratoga Transect	8/11/16	Melosira granulata var. angustissima	14	260
1/4 way Between Lindon to Saratoga Transect	8/11/16	Oocystis species	56	224
1/4 way Between Lindon to Saratoga Transect	8/11/16	pennate diatoms	56	56
1/4 way Between Lindon to Saratoga Transect	8/11/16	Sphaerocystis schroeteri	56	6160
1/4 way Between Lindon to Saratoga Transect	8/11/16	Unknown filamentous cyanophyte 4	56	5880
Goshen Bay	8/11/16	Acutidesmus pectinatus	84	332
Goshen Bay	8/11/16	Ankistrodesmus falcatus	168	168
Goshen Bay	8/11/16	Aphanizomenon flos-aquae	28	420
Goshen Bay	8/11/16	Aphanocapsa species	28	3010
Goshen Bay	8/11/16	centric diatom species 2	56	56
Goshen Bay	8/11/16	centric diatoms	28	28
Goshen Bay	8/11/16	Crucigenia species	56	224
Goshen Bay	8/11/16	Cyanodictyon planktonicum	56	8960
Goshen Bay	8/11/16	Desmodesmus communis	140	560
Goshen Bay	8/11/16	Desodesmus bicellularis	504	1008
Goshen Bay	8/11/16	Microcystis aeruginosa	28	2800
Goshen Bay	8/11/16	Nitzschia acicularis	56	56
Goshen Bay	8/11/16	Oocystis species	140	560
Goshen Bay	8/11/16	pennate diatoms	28	28

Goshen Bay	8/11/16	Phormidium formosum	140	16800
Goshen Bay	8/11/16	Scenedesmus ellipticus	28	120
Goshen Bay	8/11/16	Unknown filamentous cyanophyte 4	140	4340
Goshen Bay	8/11/16	unknown spherical chlorophyta	28	28
Goshen Bay	8/11/16	unknown spherical chlorophyta 2	28	28
Sandy Beach	8/15/16	Acutidesmus pectinatus	28	96
Sandy Beach	8/15/16	centric diatom species 2	28	28
Sandy Beach	8/15/16	Desmodesmus communis	1344	5376
Sandy Beach	8/15/16	Fragilaria virescens	56	1680
Sandy Beach	8/15/16	Melosira granulata var. angustissima	28	540
Sandy Beach	8/15/16	Merismopedia glauca	56	6048
Sandy Beach	8/15/16	pennate diatoms	28	28
American Fork	8/15/16	Acutidesmus pectinatus	84	344
American Fork	8/15/16	Ankistrodesmus falcatus	28	28
American Fork	8/15/16	Aphanocapsa species	84	8450
American Fork	8/15/16	centric diatom species 2	952	952
American Fork	8/15/16	Desmodesmus communis	140	560
American Fork	8/15/16	Euglena species	112	112
American Fork	8/15/16	Oocystis species	112	448
American Fork	8/15/16	pennate diatoms	28	28
American Fork	8/15/16	Scenedesmus ellipticus	56	280
American Fork	8/15/16	unknown spherical chlorophyta 2	28	28
Utah Lake @ State Park	8/15/16	centric diatoms	3892	3892
Utah Lake @ State Park	8/15/16	Crucigeniella rectangularis	28	448
Utah Lake @ State Park	8/15/16	Fragilaria virescens	28	840
Utah Lake @ State Park	8/15/16	Lepocinclis species	56	56
Utah Lake @ State Park	8/15/16	pennate diatoms	112	112
Lindon Marina	8/15/16	Ankistrodesmus falcatus	28	28
Lindon Marina	8/15/16	Aphanizomenon flos-aquae	28	504
Lindon Marina	8/15/16	centric diatom species 2	84	84
Lindon Marina	8/15/16	centric diatoms	28	28
Lindon Marina	8/15/16	Chroococcus dispersus	28	276
Lindon Marina	8/15/16	Crucigeniella rectangularis	84	1344
Lindon Marina	8/15/16	Desmodesmus communis	28	96
Lindon Marina	8/15/16	Dolichospermum flosaquae	1848	83160
Lindon Marina	8/15/16	Melosira granulata var. angustissima	28	510
Lindon Marina	8/15/16	Oocystis species	140	560
Lindon Marina	8/15/16	Oocystis species 3	28	92
Lindon Marina	8/15/16	pennate diatoms	28	28

Lindon Marina	8/15/16	Phormidium formosum	28	3360
Lindon Marina	8/15/16	Scenedesmus obtusus	28	140
Lindon Marina	8/15/16	unknown spherical chlorophyta	28	28
Lincoln Beach	8/15/16	Aphanocapsa species	28	2856
Lincoln Beach	8/15/16	centric diatom species 2	56	56
Lincoln Beach	8/15/16	Crucigeniella rectangularis	28	896
Lincoln Beach	8/15/16	Desodesmus bicellularis	84	168
Lincoln Beach	8/15/16	Dolichospermum flosaquae	28	1344
Lincoln Beach	8/15/16	Fragilaria virescens	28	840
Lincoln Beach	8/15/16	Melosira granulata	3444	48160
Lincoln Beach	8/15/16	Melosira granulata var. angustissima	168	3192
Lincoln Beach	8/15/16	Monoraphidium arcuatum	28	28
Lincoln Beach	8/15/16	Nitzschia acicularis	28	28
Lincoln Beach	8/15/16	pennate diatoms	84	84
Lincoln Beach	8/15/16	Phormidium formosum	28	4312
Goshen Bay	8/18/16	Actinastrum hantzschii	28	336
Goshen Bay	8/18/16	Acutidesmus pectinatus	56	224
Goshen Bay	8/18/16	centric diatoms	2856	2856
Goshen Bay	8/18/16	Closteriopsis longissima var. tropica	11872	11872
Goshen Bay	8/18/16	Desmodesmus communis	28	128
Goshen Bay	8/18/16	Melosira granulata var. angustissima	28	420
Goshen Bay	8/18/16	Nitzschia acicularis	112	112
Goshen Bay	8/18/16	pennate diatoms	112	112
Goshen Bay	8/18/16	Phormidium formosum	84	11340
Goshen Bay	8/18/16	Phormidium species	28	3900
Goshen Bay	8/18/16	Phormidium species 3	28	4200
Goshen Bay	8/18/16	Pseudanabaena species	28	1280
Goshen Bay	8/18/16	Scenedesmus obtusus	980	5096
Lindon Marina	8/18/16	Acutidesmus pectinatus	2548	10190
Lindon Marina	8/18/16	centric diatoms	28	28
Lindon Marina	8/18/16	Desmodesmus communis	28	208
Lindon Marina	8/18/16	Nitzschia acicularis	28	28
Lindon Marina	8/18/16	pennate diatoms	168	168
Lindon Marina	8/18/16	Scenedesmus obtusus	28	138
Lindon Marina	8/18/16	unknown spherical chlorophyta 2	1148	1148
1/4 Lindon to Saratoga	8/18/16	Desmodesmus communis	56	224
1/4 Lindon to Saratoga	8/18/16	Nitzschia acicularis	28	28
1/4 Lindon to Saratoga	8/18/16	Oocystis species	28	96
1/4 Lindon to Saratoga	8/18/16	pennate diatoms	28	28

1/2 Lindon to Saratoga	8/18/16	Aphanocapsa species	28	2856
1/2 Lindon to Saratoga	8/18/16	centric diatom species 2	56	56
1/2 Lindon to Saratoga	8/18/16	Chroococcus dispersus	28	108
1/2 Lindon to Saratoga	8/18/16	Fragilaria crotonensis	28	392
1/2 Lindon to Saratoga	8/18/16	Nitzschia acicularis	28	28
1/2 Lindon to Saratoga	8/18/16	pennate diatoms	56	56
3/4 Lindon to Saratoga	8/18/16	centric diatoms	28	28
3/4 Lindon to Saratoga	8/18/16	Melosira granulata	28	340
3/4 Lindon to Saratoga	8/18/16	Microcystis aeruginosa	308	31000
3/4 Lindon to Saratoga	8/18/16	pennate diatoms	112	112
Saratoga	8/18/16	Biddulphia laevis	924	3696
Saratoga	8/18/16	centric diatom species 2	28	28
Saratoga	8/18/16	centric diatoms	28	28
Saratoga	8/18/16	Fragilaria virescens	28	812
Saratoga	8/18/16	pennate diatoms	28	28
Saratoga	8/18/16	Scenedesmus ellipticus	5320	27664
Saratoga	8/18/16	unknown spherical chlorophyta	154	154
Center of Provo Bay	8/18/16	Aphanocapsa species	31	3190
Center of Provo Bay	8/18/16	Oocystis species	31	124
Center of Provo Bay	8/18/16	pennate diatoms	524	524
Lindon Marina	8/31/16	centric diatom species 2	31	31
Lindon Marina	8/31/16	Fragilaria virescens	31	850
Lindon Marina	8/31/16	Melosira varians	31	124
Lindon Marina	8/31/16	pennate diatoms	62	62
Lindon Marina	8/31/16	Phormidium formosum	62	8680
Lindon Marina	8/31/16	unknown spherical chlorophyta	62	186
1/2 Lindon to Saratoga	8/31/16	Oocystis species	31	124
1/2 Lindon to Saratoga	8/31/16	pennate diatoms	1057	1057
3/4 Lindon to Saratoga	8/31/16	Nitzschia acicularis	1	1
3/4 Lindon to Saratoga	8/31/16	pennate diatoms	31	31
3/4 Lindon to Saratoga	8/31/16	Stephanodiscus niagarae	1109	1109
Lincoln Harbor Shallow Skim	8/31/16	Microcystis aeruginosa	31	4030
Lincoln Harbor Shallow Skim	8/31/16	pennate diatoms	92	92
Provo Bay Center	8/31/16	Acutidesmus pectinatus	31	124
Provo Bay Center	8/31/16	centric diatom species 2	62	62
Provo Bay Center	8/31/16	Desmidium species	31	124
Provo Bay Center	8/31/16	Desmodesmus communis	31	124
Provo Bay Center	8/31/16	Melosira granulata var. angustissima	6283	94245
Provo Bay Center	8/31/16	Melosira varians	31	124

Provo Bay Center	8/31/16	Oocystis species	62	248
Provo Bay Center	8/31/16	Pediastrum duplex	1725	7073
Provo Bay Center	8/31/16	pennate diatoms	31	31
Pelican Bay	8/31/16	Biddulphia laevis	31	36
Pelican Bay	8/31/16	Melosira granulata var. angustissima	31	372
Pelican Bay	8/31/16	pennate diatoms	31	31
Pelican Bay	8/31/16	Stephanodiscus niagarae	31	31
Goshen Bay	8/31/16	Acutidesmus pectinatus	31	124
Goshen Bay	8/31/16	centric diatom species 2	31	31
Goshen Bay	8/31/16	centric diatoms	31	31
Goshen Bay	8/31/16	Closteriopsis longissima var. tropica	31	31
Goshen Bay	8/31/16	Crucigeniella rectangularis	31	992
Goshen Bay	8/31/16	Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	8316	16630
Goshen Bay	8/31/16	Melosira granulata	31	155
Goshen Bay	8/31/16	Melosira granulata var. angustissima	31	465
Goshen Bay	8/31/16	Oocystis species	31	124
Goshen Bay	8/31/16	pennate diatoms	31	31
Goshen Bay	8/31/16	Phormidium formosum	62	8122
Goshen Bay	8/31/16	Pseudanabaena species	31	6696
Goshen Bay	8/31/16	unknown spherical chlorophyta	31	31
Lincoln Harbor	8/31/16	Biddulphia laevis	31	124
Lincoln Harbor	8/31/16	centric diatom species 2	31	31
Lincoln Harbor	8/31/16	Fragilaria virescens	31	280
Lincoln Harbor	8/31/16	Melosira granulata var. angustissima	1140	17100
Lincoln Harbor	8/31/16	Melosira varians	31	910
Lincoln Harbor	8/31/16	Oocystis species	31	124
Lincoln Harbor	8/31/16	Pediastrum duplex var. clathratum	277	23545
Lincoln Harbor	8/31/16	pennate diatoms	154	154
Lincoln Harbor	8/31/16	Pseudoanabaena species	31	900
Lincoln Harbor	8/31/16	Stephanodiscus niagarae	154	154
Lindon Marina	9/16/16	Acutidesmus pectinatus	31	124
Lindon Marina	9/16/16	Aphanocapsa species	31	3190
Lindon Marina	9/16/16	Calothrix species	31	3720
Lindon Marina	9/16/16	centric diatom species 2	308	308
Lindon Marina	9/16/16	centric diatoms	62	62
Lindon Marina	9/16/16	Chroococcus dispersus	62	128
Lindon Marina	9/16/16	Closteriopsis longissima var. tropica	400	400
Lindon Marina	9/16/16	Crucigeniella rectangularis	31	496

Lindon Marina	9/16/16	Cyllindarospermopsis catemaco	92	2300
Lindon Marina	9/16/16	Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	13737	27500
Lindon Marina	9/16/16	Desmodesmus communis	31	124
Lindon Marina	9/16/16	Leptolyngbya species	678	24400
Lindon Marina	9/16/16	Melosira granulata var. angustissima	92	14720
Lindon Marina	9/16/16	Merismopedia glauca	62	8990
Lindon Marina	9/16/16	Monoraphidium contortum	4805	4805
Lindon Marina	9/16/16	Nitzschia acicularis	31	31
Lindon Marina	9/16/16	Oocystis species	31	124
Lindon Marina	9/16/16	Pediastrum duplex var. clathratum	370	24000
Lindon Marina	9/16/16	pennate diatoms	31	31
Lindon Marina	9/16/16	Scenedesmus obtusus	31	155
Lindon Marina	9/16/16	Sphaerocystis schroeteri	154	98500
Provo Airport	9/16/16	Aphanocapsa species	62	6600
Provo Airport	9/16/16	Aphanothece species	31	3100
Provo Airport	9/16/16	centric diatom species 2	31	31
Provo Airport	9/16/16	centric diatoms	31	31
Provo Airport	9/16/16	Chroococcus dispersus	31	600
Provo Airport	9/16/16	Closteriopsis longissima var. tropica	5390	5390
Provo Airport	9/16/16	Crucigeniella rectangularis	31	496
Provo Airport	9/16/16	Desmodesmus communis	123	775
Provo Airport	9/16/16	Leptolyngbya species	123	3813
Provo Airport	9/16/16	Merismopedia glauca	832	8320
Provo Airport	9/16/16	Monoraphidium contortum	31	31
Provo Airport	9/16/16	Nitzschia acicularis	31	31
Provo Airport	9/16/16	Oocystis species	123	492
Provo Airport	9/16/16	pennate diatoms	31	31
Provo Airport	9/16/16	Phormidium species 4	31	4309
Provo Airport	9/16/16	Scenedesmus obtusus	31	150
Provo Airport	9/16/16	unknown spherical chlorophyta 2	62	62
Lincoln Beach	9/16/16	Actinastrum hantzschii	31	558
Lincoln Beach	9/16/16	Acutidesmus pectinatus	185	1940
Lincoln Beach	9/16/16	Ankistrodesmus falcatus	62	62
Lincoln Beach	9/16/16	Aphanocapsa species	92	11960
Lincoln Beach	9/16/16	centric diatom species 2	31	31
Lincoln Beach	9/16/16	centric diatoms	123	123
Lincoln Beach	9/16/16	Closteriopsis longissima var. tropica	31	31
Lincoln Beach	9/16/16	Crucigeniella rectangularis	154	2320

Lincoln Beach	9/16/16	Cyanodictyon planktonicum	62	7750
Lincoln Beach	9/16/16	Desmodesmus communis	31	124
Lincoln Beach	9/16/16	Desodesmus bicellularis	31	62
Lincoln Beach	9/16/16	Euglena species	5051	5051
Lincoln Beach	9/16/16	Leptolyngbya species	31	1178
Lincoln Beach	9/16/16	Melosira granulata	62	620
Lincoln Beach	9/16/16	Melosira granulata var. angustissima	154	2156
Lincoln Beach	9/16/16	Merismopedia glauca	154	16500
Lincoln Beach	9/16/16	Microcystis aeruginosa	31	4200
Lincoln Beach	9/16/16	Monoraphidium contortum	1417	1417
Lincoln Beach	9/16/16	Nitzschia acicularis	216	216
Lincoln Beach	9/16/16	Oocystis species	123	812
Lincoln Beach	9/16/16	Pediastrum duplex	31	124
Lincoln Beach	9/16/16	pennate diatoms	31	31
Lincoln Beach	9/16/16	Phormidium species	31	4061
Lincoln Beach	9/16/16	Pseudanabaena species	31	1674
Goshen Bay	9/16/16	Aphanocapsa species	62	6200
Goshen Bay	9/16/16	centric diatom species 2	154	154
Goshen Bay	9/16/16	Crucigeniella rectangularis	62	1116
Goshen Bay	9/16/16	Desmodesmus communis	154	609
Goshen Bay	9/16/16	Melosira granulata var. angustissima	92	1288
Goshen Bay	9/16/16	Merismopedia glauca	246	24600
Goshen Bay	9/16/16	Microcystis aeruginosa	31	3720
Goshen Bay	9/16/16	Nitzschia acicularis	123	123
Goshen Bay	9/16/16	Oocystis species	123	510
Goshen Bay	9/16/16	pennate diatoms	154	154
Goshen Bay	9/16/16	Phormidium species	92	11300
Sandy Beach	9/16/16	Acutidesmus pectinatus	154	616
Sandy Beach	9/16/16	centric diatom species 2	62	62
Sandy Beach	9/16/16	centric diatoms	62	62
Sandy Beach	9/16/16	Crucigeniella rectangularis	2618	31400
Sandy Beach	9/16/16	Desmodesmus communis	31	124
Sandy Beach	9/16/16	Desmodesmus opoliensis	31	134
Sandy Beach	9/16/16	Desodesmus bicellularis	92	184
Sandy Beach	9/16/16	Merismopedia glauca	62	6260
Sandy Beach	9/16/16	Monoraphidium arcuatum	955	955
Sandy Beach	9/16/16	Monoraphidium contortum	1	1
Sandy Beach	9/16/16	Oocystis species	11	44
Sandy Beach	9/16/16	Pediastrum duplex	49	196

Sandy Beach	9/16/16	pennate diatoms	1	1
Sandy Beach Surface Skim	9/16/16	Aphanizomenon flos-aquae	3	86
Sandy Beach Surface Skim	9/16/16	Botryococcus braunii	6	1800
Sandy Beach Surface Skim	9/16/16	Microcystis aeruginosa	14	2100
Sandy Beach Surface Skim	9/16/16	Phormidium species 3	25	2600
1/4 Lindon to Pelican	9/8/16	Aphanocapsa species	3	340
1/4 Lindon to Pelican	9/8/16	Merismopedia glauca	62	6900
1/4 Lindon to Pelican	9/8/16	Oscillatoria species	31	4370
1/4 Lindon to Pelican	9/8/16	pennate diatoms	31	31
1/4 Lindon to Pelican	9/8/16	Scenedesmus obtusus	2556	11757
1/2 Lindon to Pelican	9/8/16	centric diatom species 2	31	31
1/2 Lindon to Pelican	9/8/16	Desmodesmus communis	92	368
1/2 Lindon to Pelican	9/8/16	Melosira granulata var. angustissima	2895	37640
1/2 Lindon to Pelican	9/8/16	Merismopedia glauca	31	3100
1/2 Lindon to Pelican	9/8/16	Monoraphidium arcuatum	31	31
1/2 Lindon to Pelican	9/8/16	Oocystis species	1355	5400
1/2 Lindon to Pelican	9/8/16	pennate diatoms	92	92
3/4 Lindon to Pelican Point	9/8/16	Coelosphaerum species	62	1200
3/4 Lindon to Pelican Point	9/8/16	Melosira granulata var. angustissima	2495	39900
3/4 Lindon to Pelican Point	9/8/16	Merismopedia glauca	31	3150
3/4 Lindon to Pelican Point	9/8/16	Nitzschia acicularis	31	31
3/4 Lindon to Pelican Point	9/8/16	Oocystis species	92	360
3/4 Lindon to Pelican Point	9/8/16	pennate diatoms	123	123
3/4 Lindon to Pelican Point	9/8/16	Scenedesmus obtusus	62	315
3/4 Lindon to Pelican Point	9/8/16	Sphaerocystis schroeteri	801	
Provo Bay Neck	9/8/16	centric diatom species 2	2803	2803
Provo Bay Neck	9/8/16	Desmodesmus communis	3	12
Provo Bay Neck	9/8/16	Desmodesmus opoliensis	3	13
Provo Bay Neck	9/8/16	Merismopedia glauca	14	1450
Provo Bay Neck	9/8/16	pennate diatoms	34	34
Goshen Bay North	9/8/16	Acutidesmus pectinatus	3	12
Goshen Bay North	9/8/16	Monoraphidium arcuatum	3	3
Goshen Bay North	9/8/16	Oocystis species	3	12
Goshen Bay North	9/8/16	pennate diatoms	3	3
Goshen Bay North	9/8/16	Scenedesmus obtusus	8	40
100m from Lindon Marina	9/8/16	Acutidesmus dimorphus	6	24
100m from Lindon Marina	9/8/16	Acutidesmus pectinatus	3	12
100m from Lindon Marina	9/8/16	Aphanocapsa species	6	660
100m from Lindon Marina	9/8/16	centric diatoms	6	6

100m from Lindon Marina	9/8/16	Crucigeniella rectangularis	25	400
100m from Lindon Marina	9/8/16	Desmodesmus communis	3	12
100m from Lindon Marina	9/8/16	Desmodesmus opoliensis	6	24
100m from Lindon Marina	9/8/16	Kirchniella lunata	36	648
100m from Lindon Marina	9/8/16	Leptolyngbya species	11	330
100m from Lindon Marina	9/8/16	Melosira granulata var. angustissima	196	2290
100m from Lindon Marina	9/8/16	Melosira varians	8	32
100m from Lindon Marina	9/8/16	Merismopedia glauca	3	330
100m from Lindon Marina	9/8/16	Oocystis species	59	236
100m from Lindon Marina	9/8/16	pennate diatoms	28	28
100m from Lindon Marina	9/8/16	unknown spherical chlorophyta 2	3	2
Provo Bay Mouth	9/8/16	Asterionella formosa	14	140
Provo Bay Mouth	9/8/16	centric diatom species 2	8	8
Provo Bay Mouth	9/8/16	centric diatoms	28	28
Provo Bay Mouth	9/8/16	Crucigeniella rectangularis	3	54
Provo Bay Mouth	9/8/16	Desmodesmus communis	6	24
Provo Bay Mouth	9/8/16	Desmodesmus opoliensis	3	12
Provo Bay Mouth	9/8/16	Leptolyngbya species	720	24500
Provo Bay Mouth	9/8/16	Melosira granulata var. angustissima	6	90
Provo Bay Mouth	9/8/16	Melosira varians	6	24
Provo Bay Mouth	9/8/16	Monoraphidium dybowskii	20	20
Provo Bay Mouth	9/8/16	pennate diatoms	92	92
Provo Bay Mouth	9/8/16	Pseudanabaena species	8	240
Provo Bay Mouth	9/8/16	unknown spherical chlorophyta 2	4525	4525
Provo Bay Center	9/8/16	centric diatom species 2	3	3
Provo Bay Center	9/8/16	Desmodesmus communis	6	24
Provo Bay Center	9/8/16	Desmodesmus opoliensis	8	34
Provo Bay Center	9/8/16	pennate diatoms	6	6
Lindon Marina	9/21/16	Acutidesmus pectinatus	3	48
Lindon Marina	9/21/16	Aphanocapsa species	3	360
Lindon Marina	9/21/16	centric diatom species 2	3	3
Lindon Marina	9/21/16	centric diatoms	3	3
Lindon Marina	9/21/16	Ceratium hirundinella	641	641
Lindon Marina	9/21/16	Desmodesmus opoliensis	3	12
Lindon Marina	9/21/16	Melosira granulata var. angustissima	661	10900
Lindon Marina	9/21/16	Melosira varians	3	12
Lindon Marina	9/21/16	Merismopedia glauca	6	660
Lindon Marina	9/21/16	Oocystis species	6	24
Lindon Marina	9/21/16	pennate diatoms	3	3

Lindon Marina	9/21/16	Scenedesmus obtusus	22	88
Lindon Marina	9/21/16	unknown spherical chlorophyta 2	8	8
Provo Airport	9/21/16	centric diatom species 2	3	3
Provo Airport	9/21/16	centric diatoms	3	3
Provo Airport	9/21/16	Desmodesmus communis	6	24
Provo Airport	9/21/16	Desmodesmus opoliensis	3	12
Provo Airport	9/21/16	Monoraphidium convolutus	347	347
Provo Airport	9/21/16	Monoraphidium dybowskii	3	3
Provo Airport	9/21/16	Oocystis species	8	24
Provo Airport	9/21/16	Pediastrum duplex	6	355
Provo Airport	9/21/16	pennate diatoms	6	6
Sandy Beach	9/21/16	Aphanocapsa species	8	840
Sandy Beach	9/21/16	centric diatom species 2	8	8
Sandy Beach	9/21/16	centric diatoms	45	45
Sandy Beach	9/21/16	Crucigeniella rectangularis	6	96
Sandy Beach	9/21/16	Desmodesmus communis	235	940
Sandy Beach	9/21/16	Desmodesmus opoliensis	3	12
Sandy Beach	9/21/16	Merismopedia glauca	20	2500
Sandy Beach	9/21/16	Oocystis species	6	24
Sandy Beach	9/21/16	pennate diatoms	3	3
Sandy Beach	9/21/16	Phormidium species 3	6	360
Lincoln Beach North	9/21/16	Acutidesmus pectinatus	6	24
Lincoln Beach North	9/21/16	centric diatom species 2	11	11
Lincoln Beach North	9/21/16	Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	356	712
Lincoln Beach North	9/21/16	Desmodesmus communis	8	32
Lincoln Beach North	9/21/16	Melosira granulata var. angustissima	3	40
Lincoln Beach North	9/21/16	Merismopedia glauca	3	325
Lincoln Beach North	9/21/16	pennate diatoms	11	11
Lincoln Beach North	9/21/16	Phormidium species 3	3	360
Goshen Bay North	9/21/16	Acutidesmus pectinatus	3	12
Goshen Bay North	9/21/16	Aphanocapsa species	36	4200
Goshen Bay North	9/21/16	centric diatom species 2	6	6
Goshen Bay North	9/21/16	Cyanodictyon planktonicum	193	26000
Goshen Bay North	9/21/16	Melosira granulata var. angustissima	3	44
Goshen Bay North	9/21/16	Merismopedia glauca	6	640
Goshen Bay North	9/21/16	Oocystis species	3	12
Goshen Bay North	9/21/16	pennate diatoms	14	14
Goshen Bay North	9/21/16	Quadrgigula lacustris	3	18

Provo Airport	9/26/16	Actinastrum hantzschii	3	54
Provo Airport	9/26/16	Acutidesmus pectinatus	8	32
Provo Airport	9/26/16	centric diatom species 2	20	20
Provo Airport	9/26/16	Crucigenia rectangularis	199	1592
Provo Airport	9/26/16	Cyanodictyon planktonicum	3	450
Provo Airport	9/26/16	Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	3	6
Provo Airport	9/26/16	Desmodesmus communis	3	12
Provo Airport	9/26/16	Merismopedia glauca	3	330
Provo Airport	9/26/16	Monoraphidium arcuatum	90	90
Provo Airport	9/26/16	Monoraphidium contortum	3	3
Provo Airport	9/26/16	Oocystis species	3	12
Provo Airport	9/26/16	Pediastrum duplex	3	180
Provo Airport	9/26/16	pennate diatoms	3	3
Provo Airport	9/26/16	Perionella species	28	28
Sandy Beach	9/26/16	Ankistrodesmus falcatus	3	3
Sandy Beach	9/26/16	Cyanodictyon planktonicum	11	1800
Sandy Beach	9/26/16	Desmodesmus opoliensis	3	12
Sandy Beach	9/26/16	pennate diatoms	11	11
Sandy Beach	9/26/16	Scenedesmus obtusus	3	12
Lincoln Beach	9/26/16	Aphanocapsa species	3	345
Lincoln Beach	9/26/16	centric diatom species 2	6	6
Lincoln Beach	9/26/16	centric diatoms	484	484
Lincoln Beach	9/26/16	Crucigeniella rectangularis	3	32
Lincoln Beach	9/26/16	Desmodesmus communis	34	128
Lincoln Beach	9/26/16	Melosira granulata var. angustissima	11	145
Lincoln Beach	9/26/16	Merismopedia glauca	3	345
Lincoln Beach	9/26/16	Microcystis aeruginosa	171	28200
Lincoln Beach	9/26/16	Nitzschia acicularis	3	3
Lincoln Beach	9/26/16	Oocystis species	3	12
Lincoln Beach	9/26/16	Oocystis species 3	115	345
Lincoln Beach	9/26/16	pennate diatoms	3	3
Goshen Bay North	9/26/16	Aphanocapsa species	11	1590
Goshen Bay North	9/26/16	Desodesmus bicellularis	3	6
Goshen Bay North	9/26/16	Merismopedia glauca	53	7420
Goshen Bay North	9/26/16	Nitzschia acicularis	3	3
Goshen Bay North	9/26/16	Oocystis species	6	24
Goshen Bay North	9/26/16	Pediastrum duplex	3	12
Goshen Bay North	9/26/16	pennate diatoms	3	3

Goshen Bay North	9/26/16	Scenedesmus obtusus	6	30
Sandy Beach	10/3/16	Acutidesmus pectinatus	3	12
Sandy Beach	10/3/16	Cyanodictyon planktonicum	3	150
Sandy Beach	10/3/16	Desmodesmus communis	283	1740
Sandy Beach	10/3/16	Desmodesmus obtusus	3	12
Sandy Beach	10/3/16	Desmodesmus opoliensis	3	12
Sandy Beach	10/3/16	Leptolyngbya species	70	2100
Sandy Beach	10/3/16	Merismopedia glauca	6	900
Sandy Beach	10/3/16	Monoraphidium arcuatum	3	3
Sandy Beach	10/3/16	Oocystis species	3	12
Sandy Beach	10/3/16	pennate diatoms	3	3
Lincoln Beach	10/3/16	Acutidesmus pectinatus	8	32
Lincoln Beach	10/3/16	centric diatom species 2	3	3
Lincoln Beach	10/3/16	centric diatoms	260	260
Lincoln Beach	10/3/16	Crucigeniella rectangularis	31	1900
Lincoln Beach	10/3/16	Cyanodictyon planktonicum	6	900
Lincoln Beach	10/3/16	Desmodesmus communis	3	12
Lincoln Beach	10/3/16	Merismopedia glauca	53	6625
Lincoln Beach	10/3/16	Nitzschia acicularis	3	3
Lincoln Beach	10/3/16	Oocystis species	6	24
Lincoln Beach	10/3/16	Pediastrum duplex var. clathratum	11	935
Lincoln Beach	10/3/16	pennate diatoms	6	6
Goshen Bay North	10/3/16	Acutidesmus pectinatus	3	12
Goshen Bay North	10/3/16	Aphanocapsa species	6	950
Goshen Bay North	10/3/16	centric diatom species 2	8	8
Goshen Bay North	10/3/16	centric diatoms	8	8
Goshen Bay North	10/3/16	Closteriopsis longissima var. tropica	3	3
Goshen Bay North	10/3/16	Crucigenia rectangularis	3	48
Goshen Bay North	10/3/16	Cyanodictyon planktonicum	3	450
Goshen Bay North	10/3/16	Desmodesmus communis	6	24
Goshen Bay North	10/3/16	Leptolyngbya species	868	25100
Goshen Bay North	10/3/16	Melosira granulata	3	45
Goshen Bay North	10/3/16	Melosira granulata var. angustissima	14	252
Goshen Bay North	10/3/16	Melosira varians	3	12
Goshen Bay North	10/3/16	Merismopedia glauca	17	2380
Goshen Bay North	10/3/16	Microcystis aeruginosa	260	35000
Goshen Bay North	10/3/16	Nitzschia acicularis	3	3
Goshen Bay North	10/3/16	Oocystis borgei	36	168
Goshen Bay North	10/3/16	Oocystis species	3	12

Goshen Bay North	10/3/16	pennate diatoms	3	3
Goshen Bay North	10/3/16	Phormidium formosum	6	810
Lindon Marina	10/6/16	centric diatom species 2	3	3
Lindon Marina	10/6/16	centric diatoms	6	6
Lindon Marina	10/6/16	Desmodesmus communis	6	24
Lindon Marina	10/6/16	Leptolyngbya species	274	11200
Lindon Marina	10/6/16	Melosira granulata var. angustissima	3	44
Lindon Marina	10/6/16	Melosira varians	3	12
Lindon Marina	10/6/16	Merismopedia glauca	6	800
Lindon Marina	10/6/16	pennate diatoms	988	988
1/4 Lindon to Pelican Point	10/6/16	Aphanocapsa species	3	450
1/4 Lindon to Pelican Point	10/6/16	centric diatoms	14	14
1/4 Lindon to Pelican Point	10/6/16	Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	11	22
1/4 Lindon to Pelican Point	10/6/16	Merismopedia glauca	8	1120
1/4 Lindon to Pelican Point	10/6/16	Monoraphidium arcuatum	104	104
1/4 Lindon to Pelican Point	10/6/16	Nitzschia acicularis	8	8
1/4 Lindon to Pelican Point	10/6/16	Oocystis species	6	24
1/4 Lindon to Pelican Point	10/6/16	Pediastrum duplex	3	12
1/4 Lindon to Pelican Point	10/6/16	pennate diatoms	260	260
1/2 Lindon to Pelican Point	10/6/16	Aphanocapsa species	6	810
1/2 Lindon to Pelican Point	10/6/16	centric diatom species 2	6	6
1/2 Lindon to Pelican Point	10/6/16	Desodesmus bicellularis	507	1014
1/2 Lindon to Pelican Point	10/6/16	Merismopedia glauca	3	375
1/2 Lindon to Pelican Point	10/6/16	Merismopedia species	3	240
1/2 Lindon to Pelican Point	10/6/16	Oocystis species	227	910
1/2 Lindon to Pelican Point	10/6/16	pennate diatoms	6	6
1/2 Lindon to Pelican Point	10/6/16	Phormidium formosum	6	750
3/4 Lindon to Pelican Point	10/6/16	Melosira granulata var. angustissima	255	3570
3/4 Lindon to Pelican Point	10/6/16	Merismopedia glauca	3	375
3/4 Lindon to Pelican Point	10/6/16	Nitzschia acicularis	8	8
3/4 Lindon to Pelican Point	10/6/16	Oocystis species	179	716
3/4 Lindon to Pelican Point	10/6/16	pennate diatoms	42	42
Provo Bay Mouth	10/6/16	Acutidesmus pectinatus	3	12
Provo Bay Mouth	10/6/16	Aphanocapsa species	3	440
Provo Bay Mouth	10/6/16	centric diatom species 2	42	42
Provo Bay Mouth	10/6/16	centric diatoms	25	25
Provo Bay Mouth	10/6/16	Cyanodictyon planktonicum	3	450
Provo Bay Mouth	10/6/16	Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	34	68

Provo Bay Mouth	10/6/16	Desmodesmus communis	11	44
Provo Bay Mouth	10/6/16	Desmodesmus opoliensis	417	1750
Provo Bay Mouth	10/6/16	Desmodesmus species	3	12
Provo Bay Mouth	10/6/16	Leptolyngbya species	8	254
Provo Bay Mouth	10/6/16	Melosira granulata var. angustissima	3	42
Provo Bay Mouth	10/6/16	pennate diatoms	3	3
Provo Bay Mouth	10/6/16	Sphaerocystis schroeteri	3	36
Provo Bay Mouth	10/6/16	unknown spherical chlorophyta 2	3	3
Provo Bay Center	10/6/16	Aphanocapsa species	8	880
Provo Bay Center	10/6/16	centric diatom species 2	17	17
Provo Bay Center	10/6/16	centric diatoms	3	3
Provo Bay Center	10/6/16	Cyanodictyon planktonicum	6	900
Provo Bay Center	10/6/16	Desmodesmus communis	3	12
Provo Bay Center	10/6/16	Desmodesmus opoliensis	3	12
Provo Bay Center	10/6/16	Leptolyngbya species	255	7900
Provo Bay Center	10/6/16	Merismopedia glauca	3	375
Provo Bay Center	10/6/16	Nitzschia acicularis	3	3
Provo Bay Center	10/6/16	Pediastrum species	3	240
Provo Bay Center	10/6/16	pennate diatoms	3	3
Pelican Bay	10/6/16	Cyanodictyon planktonicum	6	900
Pelican Bay	10/6/16	Desmodesmus obtusus	3	13
Pelican Bay	10/6/16	Desodesmus bicellularis	134	268
Pelican Bay	10/6/16	Fragilaria virescens	3	120
Pelican Bay	10/6/16	Leptolyngbya species	3	280
Pelican Bay	10/6/16	Melosira granulata var. angustissima	3	45
Pelican Bay	10/6/16	Merismopedia glauca	249	32000
Pelican Bay	10/6/16	Nitzschia acicularis	11	11
Pelican Bay	10/6/16	Oocystis species	6	24
Pelican Bay	10/6/16	Pediastrum species	3	12
Pelican Bay	10/6/16	pennate diatoms	3	3
Sandy Beach	10/7/16	centric diatom species 2	6	6
Sandy Beach	10/7/16	Crucigeniella rectangularis	3	18
Sandy Beach	10/7/16	Cyanodictyon planktonicum	342	51300
Sandy Beach	10/7/16	Desmodesmus communis	3	12
Sandy Beach	10/7/16	Desmodesmus opoliensis	3	12
Sandy Beach	10/7/16	Leptolyngbya species	11	330
Sandy Beach	10/7/16	Merismopedia glauca	3	375
Sandy Beach	10/7/16	Monoraphidium convolutus	160	160
Sandy Beach	10/7/16	Nitzschia acicularis	3	3

Sandy Beach	10/7/16	Oocystis species	3	12
Sandy Beach	10/7/16	Pediastrum duplex	3	240
Sandy Beach	10/7/16	pennate diatoms	3	3
Sandy Beach	10/7/16	Spherical chlorophyta	3	3
Goshen Bay North	10/7/16	Acutidesmus pectinatus	6	114
Goshen Bay North	10/7/16	Aphanocapsa species	3	375
Goshen Bay North	10/7/16	centric diatom species 2	1243	1243
Goshen Bay North	10/7/16	centric diatoms	3	3
Goshen Bay North	10/7/16	Crucigeniella rectangularis	11	352
Goshen Bay North	10/7/16	Desmodesmus communis	151	600
Goshen Bay North	10/7/16	Merismopedia glauca	6	800
Goshen Bay North	10/7/16	Monoraphidium arcuatum	3	3
Goshen Bay North	10/7/16	Oocystis species	3	12
Goshen Bay North	10/7/16	pennate diatoms	6	6
Lindon Marina	10/20/16	centric diatom species 2	3	3
Lindon Marina	10/20/16	centric diatoms	143	143
Lindon Marina	10/20/16	Desmodesmus opoliensis	3	12
Lindon Marina	10/20/16	Leptolyngbya species	3	99
Lindon Marina	10/20/16	Melosira granulata var. angustissima	8	120
Lindon Marina	10/20/16	pennate diatoms	3	3
1/4 distance Lindon to Pelican Bay	10/20/16	Acutidesmus pectinatus	3	12
1/4 distance Lindon to Pelican Bay	10/20/16	Botryococcus braunii	3	440
1/4 distance Lindon to Pelican Bay	10/20/16	centric diatom species 2	3	3
1/4 distance Lindon to Pelican Bay	10/20/16	Crucigeniella rectangularis	227	3600
1/4 distance Lindon to Pelican Bay	10/20/16	Cyanodictyon planktonicum	3	450
1/4 distance Lindon to Pelican Bay	10/20/16	Leptolyngbya species	11	330
1/4 distance Lindon to Pelican Bay	10/20/16	Melosira granulata var. angustissima	20	300
1/4 distance Lindon to Pelican Bay	10/20/16	Merismopedia glauca	3	375
1/4 distance Lindon to Pelican Bay	10/20/16	Monoraphidium arcuatum	1462	2462
1/4 distance Lindon to Pelican Bay	10/20/16	Oocystis species	6	24
1/4 distance Lindon to Pelican Bay	10/20/16	pennate diatoms	339	339
1/4 distance Lindon to Pelican Bay	10/20/16	Tetraedron minimum	8	32
1/2 distance Lindon to Pelican Point	10/20/16	Merismopedia glauca	3	375
1/2 distance Lindon to Pelican Point	10/20/16	Oocystis species	283	1100
1/2 distance Lindon to Pelican Point	10/20/16	pennate diatoms	8	8
3/4 Lindon to Pelican Bay	10/20/16	Aphanocapsa species	132	16500
3/4 Lindon to Pelican Bay	10/20/16	Crucigeniella rectangularis	6	96
3/4 Lindon to Pelican Bay	10/20/16	Merismopedia glauca	3	375
3/4 Lindon to Pelican Bay	10/20/16	Oocystis species	6	24

3/4 Lindon to Pelican Bay	10/20/16	pennate diatoms	512	510
3/4 Lindon to Pelican Bay	10/20/16	unknown spherical chlorophyta 2	3	3
Pelican Marina	10/20/16	Actinastrum hantzschii	137	1600
Pelican Marina	10/20/16	Cyanodictyon planktonicum	84	12200
Pelican Marina	10/20/16	Merismopedia glauca	22	2640
Pelican Marina	10/20/16	Oocystis species	6	24
Pelican Marina	10/20/16	pennate diatoms	3	3
Provo Bay Center	10/20/16	centric diatom species 2	3	3
Provo Bay Center	10/20/16	centric diatoms	8	8
Provo Bay Center	10/20/16	Desmodesmus communis	759	3036
Provo Bay Center	10/20/16	Desmodesmus opoliensis	3	12
Provo Bay Center	10/20/16	Fragilaria virescens	3	210
Provo Bay Center	10/20/16	Melosira granulata	6	90
Provo Bay Center	10/20/16	pennate diatoms	3	3
Provo Bay Center	10/20/16	Scenedesmus obtusus	6	24
Sandy Beach	11/4/16	centric diatom species 2	6	6
Sandy Beach	11/4/16	Cyanodictyon planktonicum	3	450
Sandy Beach	11/4/16	Desmodesmus communis	25	150
Sandy Beach	11/4/16	Melosira varians	3	12
Sandy Beach	11/4/16	Merismopedia glauca	6	900
Sandy Beach	11/4/16	Oocystis species	3	12
Sandy Beach	11/4/16	pennate diatoms	6	6
Lincoln Beach	11/4/16	Acutidesmus pectinatus	3	12
Lincoln Beach	11/4/16	Aphanocapsa species	17	2125
Lincoln Beach	11/4/16	Asterionella formosa	3	15
Lincoln Beach	11/4/16	centric diatom species 2	8	8
Lincoln Beach	11/4/16	centric diatoms	3	8
Lincoln Beach	11/4/16	Cyanodictyon planktonicum	3	450
Lincoln Beach	11/4/16	Desmidium species	14	140
Lincoln Beach	11/4/16	Desmodesmus communis	6	24
Lincoln Beach	11/4/16	Leptolyngbya species	59	1890
Lincoln Beach	11/4/16	Melosira varians	3	12
Lincoln Beach	11/4/16	Merismopedia glauca	17	2200
Lincoln Beach	11/4/16	Oocystis species	3	12
Lincoln Beach	11/4/16	pennate diatoms	3	3
Lincoln Beach	11/4/16	unknown spherical chlorophyta 2	11	11
Goshen Bay North	11/4/16	Aphanocapsa species	3	375
Goshen Bay North	11/4/16	Botryococcus braunii	20	600
Goshen Bay North	11/4/16	centric diatoms	3	3

Goshen Bay North	11/4/16	Cyanodictyon planktonicum	3	450
Goshen Bay North	11/4/16	Desmodesmus opoliensis	6	24
Goshen Bay North	11/4/16	Merismopedia glauca	28	3640
Goshen Bay North	11/4/16	Merismopedia species	3	375
Goshen Bay North	11/4/16	Monoraphidium arcuatum	76	76
Goshen Bay North	11/4/16	Oocystis species	134	536
Goshen Bay North	11/4/16	pennate diatoms	6	6
Goshen Bay North	11/4/16	unknown spherical chlorophyta 2	3	3
Lindon Marina	11/10/16	centric diatom species 2	3	3
Lindon Marina	11/10/16	centric diatoms	283	283
Lindon Marina	11/10/16	Cyanodictyon planktonicum	20	3000
Lindon Marina	11/10/16	Melosira granulata var. angustissima	25	350
Lindon Marina	11/10/16	Oocystis species	6	24
Lindon Marina	11/10/16	pennate diatoms	3	3
1/4 distance Lindon to Pelican Bay	11/10/16	Aphanocapsa species	6	810
1/4 distance Lindon to Pelican Bay	11/10/16	Cyanodictyon planktonicum	8	1160
1/4 distance Lindon to Pelican Bay	11/10/16	Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	3	6
1/4 distance Lindon to Pelican Bay	11/10/16	Desmodesmus communis	11	44
1/4 distance Lindon to Pelican Bay	11/10/16	Leptolyngbya species	22	704
1/4 distance Lindon to Pelican Bay	11/10/16	Merismopedia glauca	3	175
1/4 distance Lindon to Pelican Bay	11/10/16	Monoraphidium arcuatum	11	11
1/4 distance Lindon to Pelican Bay	11/10/16	Oocystis species	6	24
1/4 distance Lindon to Pelican Bay	11/10/16	pennate diatoms	6	6
1/4 distance Lindon to Pelican Bay	11/10/16	unknown spherical chlorophyta 2	31	31
1/2 Lindon to Pelican Bay	11/10/16	Aphanocapsa species	3	375
1/2 Lindon to Pelican Bay	11/10/16	centric diatom species 2	78	78
1/2 Lindon to Pelican Bay	11/10/16	centric diatoms	6	6
1/2 Lindon to Pelican Bay	11/10/16	Cyanodictyon planktonicum	22	3190
1/2 Lindon to Pelican Bay	11/10/16	Leptolyngbya species	14	434
1/2 Lindon to Pelican Bay	11/10/16	Merismopedia glauca	3	375
1/2 Lindon to Pelican Bay	11/10/16	Oocystis species	3	12
1/2 Lindon to Pelican Bay	11/10/16	pennate diatoms	62	62
3/4 Lindon to Pelican Marina	11/10/16	Aphanocapsa species	11	1430
3/4 Lindon to Pelican Marina	11/10/16	centric diatoms	62	62
3/4 Lindon to Pelican Marina	11/10/16	Crucigeniella rectangularis	11	55
3/4 Lindon to Pelican Marina	11/10/16	Cyanodictyon planktonicum	3	450
3/4 Lindon to Pelican Marina	11/10/16	Desmodesmus bicellularis (R. Chodat) S. An, T. Friedl & E. Hegewald	3	6
3/4 Lindon to Pelican Marina	11/10/16	Merismopedia glauca	3	335

3/4 Lindon to Pelican Marina	11/10/16	Oocystis species	3	12
3/4 Lindon to Pelican Marina	11/10/16	pennate diatoms	6	6
Pelican Marina	11/10/16	Biddulphia laevis	3	12
Pelican Marina	11/10/16	centric diatom species 2	8	8
Pelican Marina	11/10/16	Crucigeniella rectangularis	692	11000
Pelican Marina	11/10/16	Cyanodictyon planktonicum	3	450
Pelican Marina	11/10/16	Desmodesmus communis	384	1536
Pelican Marina	11/10/16	Desodesmus bicellularis	137	274
Pelican Marina	11/10/16	Merismopedia glauca	3	375
Pelican Marina	11/10/16	Oocystis species	28	96
Pelican Marina	11/10/16	pennate diatoms	14	14
Provo Bay Mouth	11/10/16	centric diatom species 2	8	8
Provo Bay Mouth	11/10/16	Cyanodictyon planktonicum	6	900
Provo Bay Mouth	11/10/16	Desmodesmus communis	3	12
Provo Bay Mouth	11/10/16	Desmodesmus opoliensis	448	1500
Provo Bay Mouth	11/10/16	Leptolyngbya species	3	93
Provo Bay Mouth	11/10/16	Melosira granulata	20	200
Provo Bay Mouth	11/10/16	Melosira granulata var. angustissima	3	45
Provo Bay Mouth	11/10/16	pennate diatoms	31	31
Provo Bay Center	11/10/16	Aphanocapsa species	11	1485
Provo Bay Center	11/10/16	centric diatom species 2	3	3
Provo Bay Center	11/10/16	Cyanodictyon planktonicum	3	450
Provo Bay Center	11/10/16	Desmodesmus communis	3	12
Provo Bay Center	11/10/16	Desmodesmus opoliensis	885	3540
Provo Bay Center	11/10/16	Leptolyngbya species	6	195
Provo Bay Center	11/10/16	Melosira granulata var. angustissima	6	90
Provo Bay Center	11/10/16	Melosira varians	3	12
Provo Bay Center	11/10/16	pennate diatoms	3	3
Lindon Marina South	12/4/16	centric diatom species 2	3	3
Lindon Marina South	12/4/16	centric diatoms	3	3
Lindon Marina South	12/4/16	Cyanodictyon planktonicum	3	450
Lindon Marina South	12/4/16	Desmodesmus communis	11	44
Lindon Marina South	12/4/16	Melosira varians	549	1800
Lindon Marina South	12/4/16	Merismopedia glauca	8	1000
Lindon Marina South	12/4/16	Monoraphidium dybowskii	14	14
Lindon Marina South	12/4/16	Nitzschia acicularis	3	3
Lindon Marina South	12/4/16	pennate diatoms	3	3
Sandy Beach	12/4/16	Aphanocapsa species	6	800
Sandy Beach	12/4/16	centric diatom species 2	3	3

Sandy Beach	12/4/16	Crucigeniella rectangularis	3	15
Sandy Beach	12/4/16	Cyanodictyon planktonicum	3	450
Sandy Beach	12/4/16	Desmodesmus communis	148	600
Sandy Beach	12/4/16	Desmodesmus opoliensis	6	26
Sandy Beach	12/4/16	Desodesmus bicellularis	8	16
Sandy Beach	12/4/16	Melosira granulata	8	80
Sandy Beach	12/4/16	pennate diatoms	6	6
Sandy Beach	12/4/16	unknown spherical chlorophyta 2	3	3
Lincoln Beach South	12/4/16	Aphanocapsa species	8	8
Lincoln Beach South	12/4/16	centric diatom species 2	126	126
Lincoln Beach South	12/4/16	Crucigeniella rectangularis	3	48
Lincoln Beach South	12/4/16	Nitzschia acicularis	123	123
Lincoln Beach South	12/4/16	Oocystis species	31	124
Lincoln Beach South	12/4/16	pennate diatoms	62	62
Lincoln Beach South	12/4/16	unknown spherical chlorophyta	123	123
Goshen Bay North	12/4/16	Aphanocapsa species	216	18300
Goshen Bay North	12/4/16	Merismopedia glauca	308	43000
Goshen Bay North	12/4/16	Nitzschia acicularis	62	62
Goshen Bay North	12/4/16	Oocystis species	246	984
Goshen Bay North	12/4/16	pennate diatoms	493	493
Utah Lake Provo Bay Center	9/8/16	centric diatoms	62	62
Utah Lake Provo Bay Center	9/8/16	Crucigeniella rectangularis	62	310
Utah Lake Provo Bay Center	9/8/16	Desmodesmus communis	154	616
Utah Lake Provo Bay Center	9/8/16	Desmodesmus opoliensis	62	222
Utah Lake Provo Bay Center	9/8/16	Desmodesmus species	62	222
Utah Lake Provo Bay Center	9/8/16	Fragilaria virescens	5667	113000
Utah Lake Provo Bay Center	9/8/16	Leptolyngbya species	31	930
Utah Lake Provo Bay Center	9/8/16	Melosira granulata	62	620
Utah Lake Provo Bay Center	9/8/16	Melosira granulata var. angustissima	2741	38400
Utah Lake Provo Bay Center	9/8/16	pennate diatoms	277	277
Utah Lake Pelican Marina	9/8/16	Monoraphidium komarakovae	123	123
Utah Lake Pelican Marina	9/8/16	Oocystis species	185	740
Utah Lake Pelican Marina	9/8/16	pennate diatoms	2741	2741
Utah Lake 1/4 Way Between Lindon and Saratoga	8/31/16	Merismopedia glauca	277	36000
Utah Lake 1/4 Way Between Lindon and Saratoga	8/31/16	Oocystis species	123	492
Utah Lake 1/4 Way Between Lindon and Saratoga	8/31/16	pennate diatoms	185	185

Chapter 1: Utah Lake Phytoplankton Assemblages 2016

Chapter 2

Spatial and Temporal Patterns of Zooplankton in Utah Lake

2016

Summary

Zooplankton are the primary top- down higher -trophic level controller of phytoplankton and HABs. We collected and analyzed zooplankton individual taxa and assemblages concurrently with phytoplankton and nutrient data. We identified eighteen zooplankton taxa from several diverse groups including; rotifers, cladocerans, copepods, ostracods, and amphipods. Assemblages significantly differed by locations and month. Provo Bay zooplankton assemblages were quite different than other areas of Utah Lake and will be analyzed separately in ongoing analyses. Zooplankton assemblages were also affected by depth with several taxa including Daphnia and Leptodiaptomus typically occurring at greater depths than other taxa. These preliminary results are shedding light onto zooplankton population dynamics and will guide us in our efforts to determine direct and indirect causes of HABs.

Introduction

Very little is known about the spatial and temporal patterns of zooplankton in Utah Lake despite the critical importance of relationships between: nutrient cycling, phytoplankton (including cyanobacteria blooms (HABs)) and other foodweb components in the lake. Zooplankton obviously have top down grazing effects on phytoplankton and cyanobacteria and in turn are affected by these (bottom up effects). Zooplankton also have different modes of feeding including grazers and predators, some of which prey upon other zooplankton. All of these complex interactions directly and indirectly influence nutrient cycling in the water column. Zooplankton excretion and respiration of nitrogen, phosphorus, and ammonia is immediately available and consumed by phytoplankton often within minutes. This phyto-zooplankton component of water column nutrient cycling has been well documented and known by limnologists and ecologists for several decades and is likely an important driver of cyanobacteria blooms in Utah Lake. A simplified diagram of Utah Lake water column nutrient cycling with zooplankton at its core is in Figure 1.

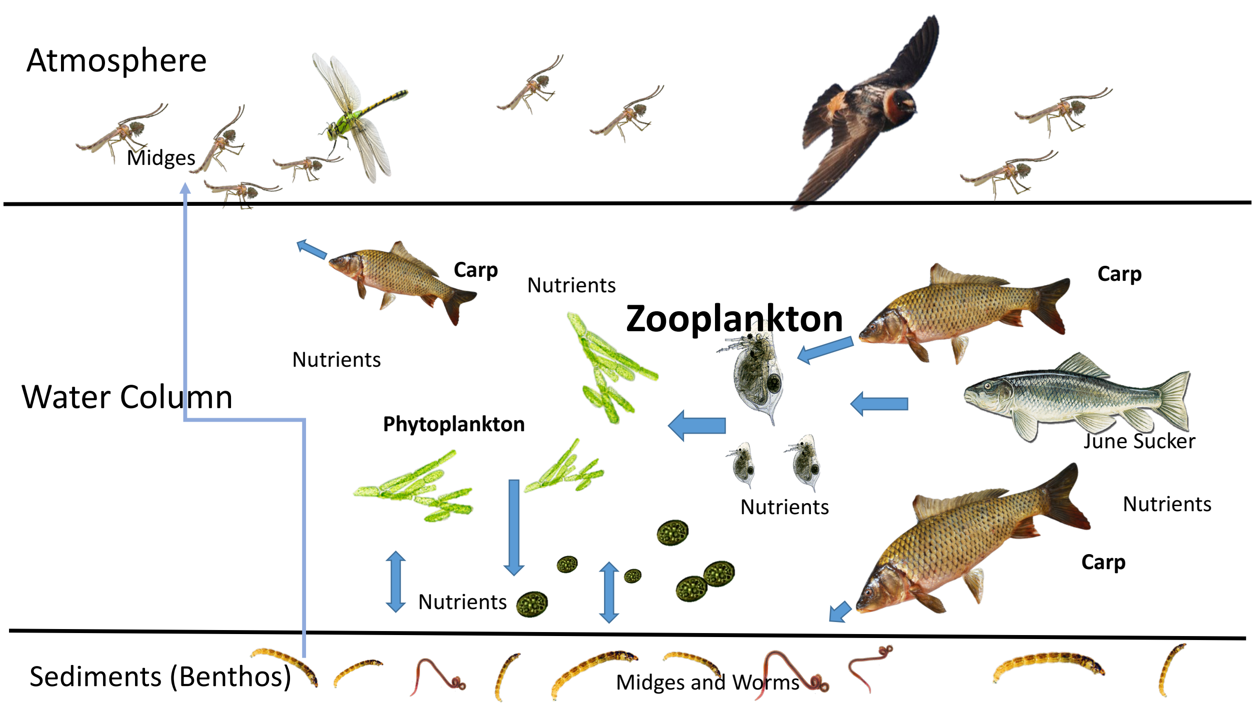


Figure 7. Simplified water column food web consisting of phytoplankton, zooplankton, carp, other zooplankton predators, and nutrients in Utah Lake. Zooplankton play the central role is this food web.

Many lake nutrient models fail to incorporate the water column foodweb component of phytoplankton, zooplankton, and fish or only use generalized attributes such as surrogate metrics (e.g. ChlA, or only include a handful of plankton taxa) and hence they have poor predictive power and provide little understanding of the intricacies of this component. By ignoring most of these zooplankton taxa or lumping them into superficial groups, critical information will likely be lost; information that could be used to alleviate cyanobacteria blooms in Utah Lake. There are likely dozens and dozens of phytoplankton- zooplankton interactions at the spatial and temporal scales that critically need to be explicitly incorporated into Utah Lake nutrient models.

Justification

We are conducting the most intensive and extensive zooplankton research on Utah Lake to date in an effort to understand their: spatial and temporal patterns, top down and bottom effects, and interactions and role in the food web. This research is specifically designed to better understand, predict, and control cyanobacteria blooms in the lake. The zooplankton research is concomitant with our nutrient and phytoplankton research and in collaboration with several other groups including; UDWQ, UDNR, USEPA, USU, BYU, UVU, and a consortium of several wastewater treatment facilities that discharge into Utah Lake including the City of Provo, Timpanogos, City of Orem, and others.

Methods

Sampling

We collected zooplankton samples for several locations in Utah Lake (Appendix 2 and Appendix 12) using a 200 µm mesh net with a 30-cm opening similar to the image in Figure 8. The net was lowered to the bottom of the water column just above the sediment surface, moved slightly to either side of where it was dropped and then pulled up either to the boat or researcher wading along shoreline (i.e. ‘vertical tow’). Depth of water column was recorded to adjust zooplankton density estimates. Contents were emptied into labeled plastic jar using a pipette and spray bottle washer and either isopropyl or ethanol was added to the contents to about 70% concentration. The airboat used in all of our sampling was provided by UDNR and piloted by Mr. Dick Buhler who is the leading expert of Utah Lake topography and Utah Lake’s most experience airboat captain.

Figure 8. Plankton net similar to the one used in our studies.

Lab

Zooplankton samples were then delivered to Dr. Larry Gray, at Utah Valley University for taxonomic identification and counting. Dr. Gray is a well-known expert of Utah Lake's zooplankton assemblages.

Statistics

Zooplankton counts for each location and date were adjusted for water column depths and estimates of densities L^{-1} were made. Zooplankton often differ is sizes (body lengths) which can reduce the usefulness of abundance based statistical analyses by biasing towards more abundant smaller taxa. We adjusted each zooplankton taxon abundance by body lengths reported from the literature to help compensate for this problem and to base our statistical analyses on more realistic values. All analyses reported in the following sections are based on zooplankton > 200µm, anything smaller was not analyzed.

Spatial and Temporal Patterns of Zooplankton Assemblages: *Multivariate Models*

Non-metric multidimensional scaling (NMS) ordination was used to visually compare zooplankton assemblage relationships between sites and months. Ordination techniques are often more informative than hypothesis-testing approaches for exploring relationships between multivariate ecological assemblages or communities (McCune and Grace 2002). In general, ordination is the ordering of objects along axes according to their (dis)similarities; the main objective of ordination is to reduce many-dimensional relationships into a small number of more easily interpretable dimensions (i.e., axes on a plot). The strongest correlation structure in the data is extracted and is then used to position objects in ordination space. Objects that are close in the ordination space are more similar than objects distant in ordination space (McCune and Mefford 2011).

NMS was used in these analyses because it has been shown to be robust and highly informative for understanding ecological relationships. NMS ordination is often more broadly applicable for ecological studies than other ordination techniques because it does not require relationships among variables to be linear (McCune and Mefford 2011; Peck 2010). NMS ordination permits the visualization of the multidimensional relationships of nutrients and other chemical variables into a more easily visualized, lower dimensional space. Dimensional reduction obviously creates some distortion in relationships between samples. The level of reduction in distortion is measured as 'stress'; where lower stress values equal less distortion. NMS plots with stress values lower than 15% (0.15) are typically considered to be a good representation of the data and stress values lower than 10% (0.10) are considered excellent representations (McCune and Mefford 2011; Peck 2010).

NMS analyses of Utah Lake zooplankton assemblage data was conducted using PC-ORD Version 6.0 (2011). A Sorensen (Bray-Curtis) distance measure was used in the NMS analysis and run for 250 iterations using the real data and 250 iterations in randomized Monte Carlo simulations. The Sorensen distance measure is based on pairwise comparisons between all sample pairs, therefore NMS ordinations were rotated using varimax rotation to maximize variation along the axes and extracted as univariate scores. Therefore, the final ordinations can be rotated either vertically or horizontally without effecting the results. The best model was chosen based on scree plots and final stress values. Centroid labels of sites were added to the ordinations to aid in the interpret the relationships. Post hoc proportion of variance represented by each axis was calculated based on the R^2 value between distance in the ordination space and distance in the original space. Individual nutrient and chemical variable correlations with NMS axes were also calculated.

MRPP (multi-response permutation procedure), a non-parametric multivariate method was used to formally test the hypothesis of no differences in assemblages between months and sites. MRPP has the advantage of not requiring distributional assumptions such as multivariate normality and homogeneity of variance and thus is often preferred over MANOVA for analyzing multivariate ecological data (McCune and Grace 2002). A Sorensen (Bray-Curtis) distance measure was used in this MRPP analysis. The chance-corrected within-group test statistic, *A* (and associated p-value) was used to evaluate the hypothesis of no difference in the spatial and temporal groupings (McCune and Grace 2002).

Individual Zooplankton Taxa Spatial and Temporal Patterns

Additional statistical analyses including taxon specific: time series graphs (using means), boxplots, ANOVAs, and probit and negative binomial regressions were made using Stata 14.2 (StatCorp 2015). Poisson probit and negative binomial regression methods were chosen because zooplankton density estimates are in actuality count data, truncated at zero, often with many zero counts and cannot be transformed to approximate normal Gaussian distributions.

Results

Dr. Larry Gray identified eighteen different zooplankton taxa from our 2016 collections (Table 11). These included cladocera, copepod, and rotifer taxa from several feeding groups with different life history and feeding strategies. We are presently compiling literature on life history, feeding strategies, and ecologies of these taxa to further refine our analyses and models.

Table 11. Zooplankton taxa list for Utah Lake study, 2016

Cladocera	**Family**	**Genus Species**
	Daphniidae	*Daphnia retrocurva*
	Daphniidae	*Daphnia pulex*
	Daphniidae	*Ceriodaphnia quadrangula*
	Bosminidae	*Bosmina longirostris*
	Chydoridae	*Chydorus sphaericus*
	Chydoridae	*Pleuroxus striatus*
	Chydoridae	*Leydigia leydigi*
	Leptodoridae	*Leptodora kindtii*
	Ilyocryptidae	*Ilyocryptus* sp.
	Sididae	*Diaphanosoma* sp.
Copepoda		
	Diaptomidae	*Leptodiaptomus sicilis*
	Cyclopidae	*Acanthocyclops robustus*
	Cyclopidae	*Eucyclops agilis*
	Canthocamptidae	*Attheyella* sp.
Rotifera		
	Brachionidae	*Brachionus* sp.
	Brachionidae	*Keratella* sp.
	Asplanchnidae	*Asplanchna* sp.
Ostracoda sp.		
Crustacea-Amphipoda	Hyalellidae	

Spatial and Temporal Patterns of Zooplankton Assemblages: *Multivariate Models*

Preliminary analyses using NMS and MRPP showed that zooplankton assemblages differed spatially and temporally with obvious monthly differences in zooplankton assemblages except between May and June samples (Appendix 3) and between Provo Bay and the rest of the lake. Therefore, additional analyses presented in this report excluded Provo Bay samples and focused on August and September samples. This subset of the data was also justified by our supposition that most of the important interactions regarding cyanobacteria blooms occur in the lake outside of Provo Bay and during the summer months (unfortunately very few samples were collected in July due to lake closure).

Provo Bay nutrient/plankton data will be analyzed separately in a forthcoming report. We have concluded that Provo Bay functions as a sheetflow wetland and ecologically is much different than the rest of Utah Lake based on our field observations and the preliminary analysis.

August Zooplankton Assemblages

Non metric multidimensional scaling (NMS) analysis produced a very good representative three-dimensional model of the zooplankton assemblages (log +1 transformed) based on August only samples (final stress = 0.08, at 70 iterations; final stability $< < 0.001$) with a cumulative R^2 of 0.95 (Axis 1 = 0.38, Axis 2 = 0.44, and Axis 3 = 0.13)(Figure 9, Figure 10, and Figure 11). With such a small final stress of 0.08 and large cumulative R^2 of 0.95 the NMS ordinations in Figures 3, 4, 5, there is a low likelihood of misinterpretation of the model and each individual sample (depicted by symbols) occurs in its spatial location with little error. MRPP results confirmed that overall, assemblages significantly differed between sites (Chance-corrected within-group agreement, $A = 0.22$; $P < 0.001$), which was also supported by significant pairwise comparisons (uncorrected for multiple comparisons) reported in Appendix 10.

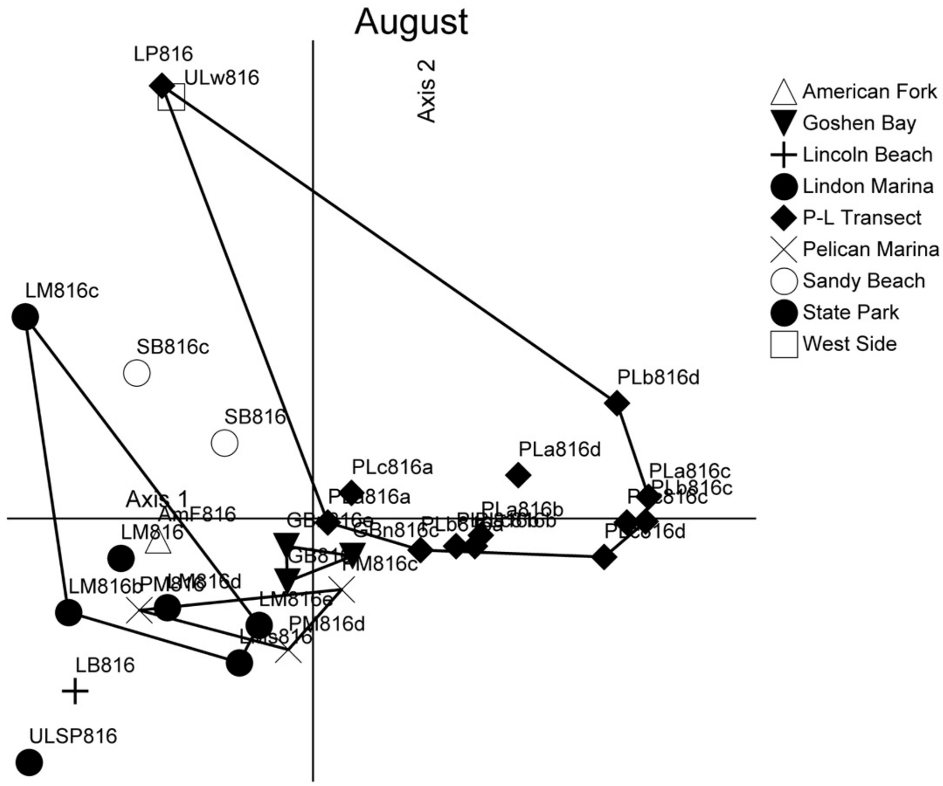


Figure 9. NMS axis 1 and axis 2 for August samples.

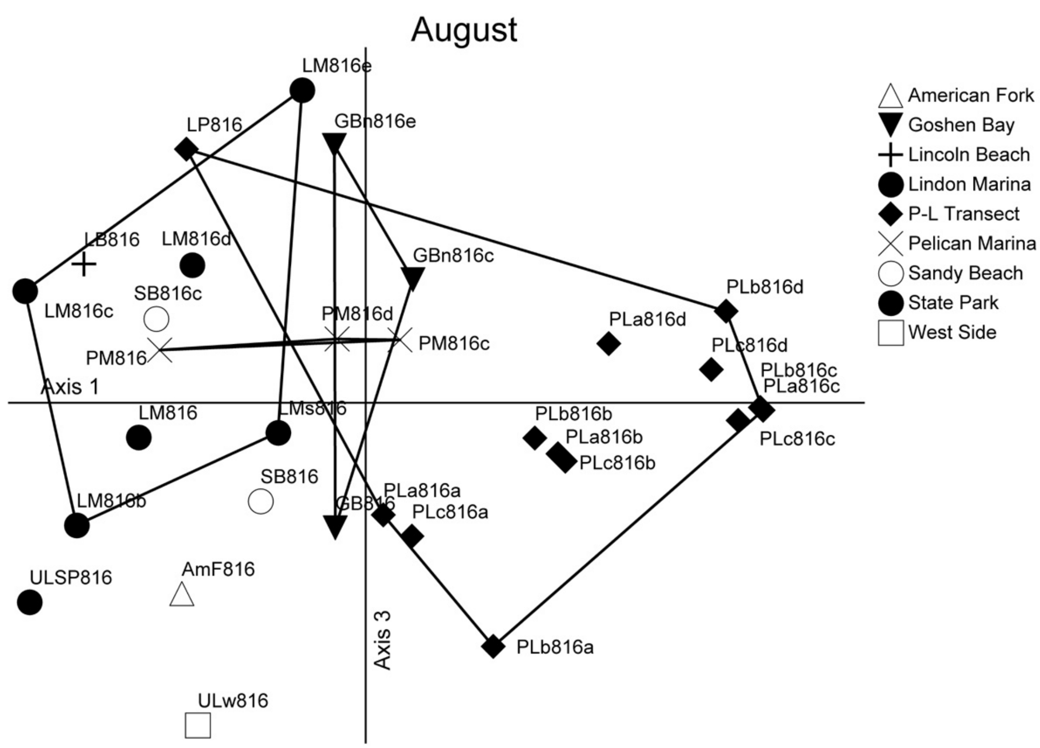


Figure 10. NMS axis 1 and axis 3 for August samples.

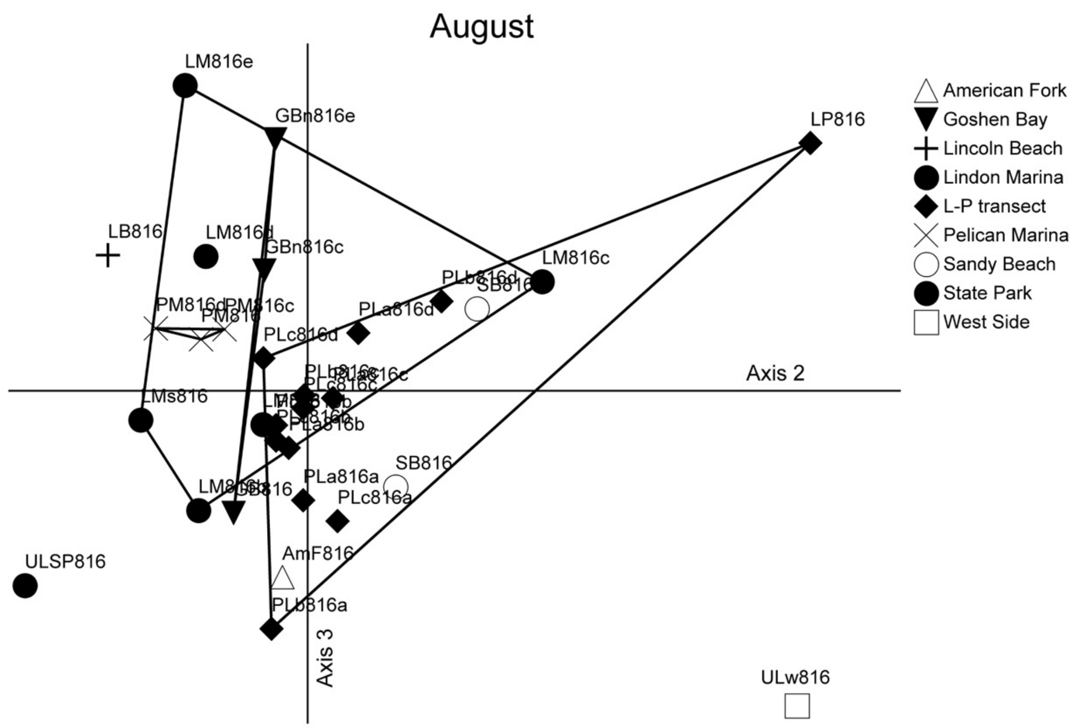


Figure 11. NMS axis 2 and axis 3 for August samples.

Several of the zooplankton taxa were strongly correlated with the three axes in either the negative or positive direction but most weren't (Table 12). Further interpretation and investigation is needed to determine the causes of these correlations.

Table 12.Taxa Correlations with NMS axes for August

Axis 1		Axis 2		Axis 3	
Taxon	**r**	**Taxon**	**r**	**Taxon**	**r**
Leptodora kindtii	0.849	Attheyel	0.251	Acanthoc	0.497
Daphnia retrocurva	0.721	Leptodor	0.039	D.retroc	0.354
Leptodiaptomus sicilis	0.697	Leptodia	-0.088	Bosmina	0.309
Daphnia pulex	0.608	Ilyocryp	-0.183	Ostracod	0.185
Acanthocyclops	0.168	D.retroc	-0.224	Brachion	0.108
Ceriodaphnia quadrangular	-0.23	Bosmina	-0.276	Leptodor	-0.022
Ostracoda	-0.337	Acanthoc	-0.392	D.pulex	-0.159
Ilyocryptus sp.	-0.444	Ostracod	-0.448	Ceriodap	-0.245
Attheyella sp.	-0.459	Diaphano	-0.475	Attheyel	-0.263
Diaphanosoma sp.	-0.595	Brachion	-0.483	Ilyocryp	-0.339

Brachionus sp.	-0.686	D.pulex	-0.646	Diaphano	-0.39
Bosmina longirostris	-0.723	Ceriodap	-0.727	Leptodia	-0.606

September Zooplankton Assemblages

Non metric multidimensional scaling (NMS) analysis produced a decent representative two-dimensional model of the zooplankton assemblages (log +1 transformed) based on September only samples (final stress = 0.11, at 74 iterations; final stability < < 0.001) with a cumulative R^2 of 0.92 (Axis 1 = 0.74, Axis 2 = 0.19). With a final stress of 0.11 and relatively large cumulative R^2 of 0.92 the NMS ordinations in Figure 12, there is a low likelihood of misinterpretation of the model however, each individual sample (depicted by symbols) may occur in its spatial location with some error. MRPP results confirmed that overall, assemblages significantly differed between sites (Chance-corrected within-group agreement, *A* = 0.29; P < 0.001)(Table 13), which was also supported by significant pairwise comparisons (uncorrected for multiple comparisons) reported in Appendix 6.

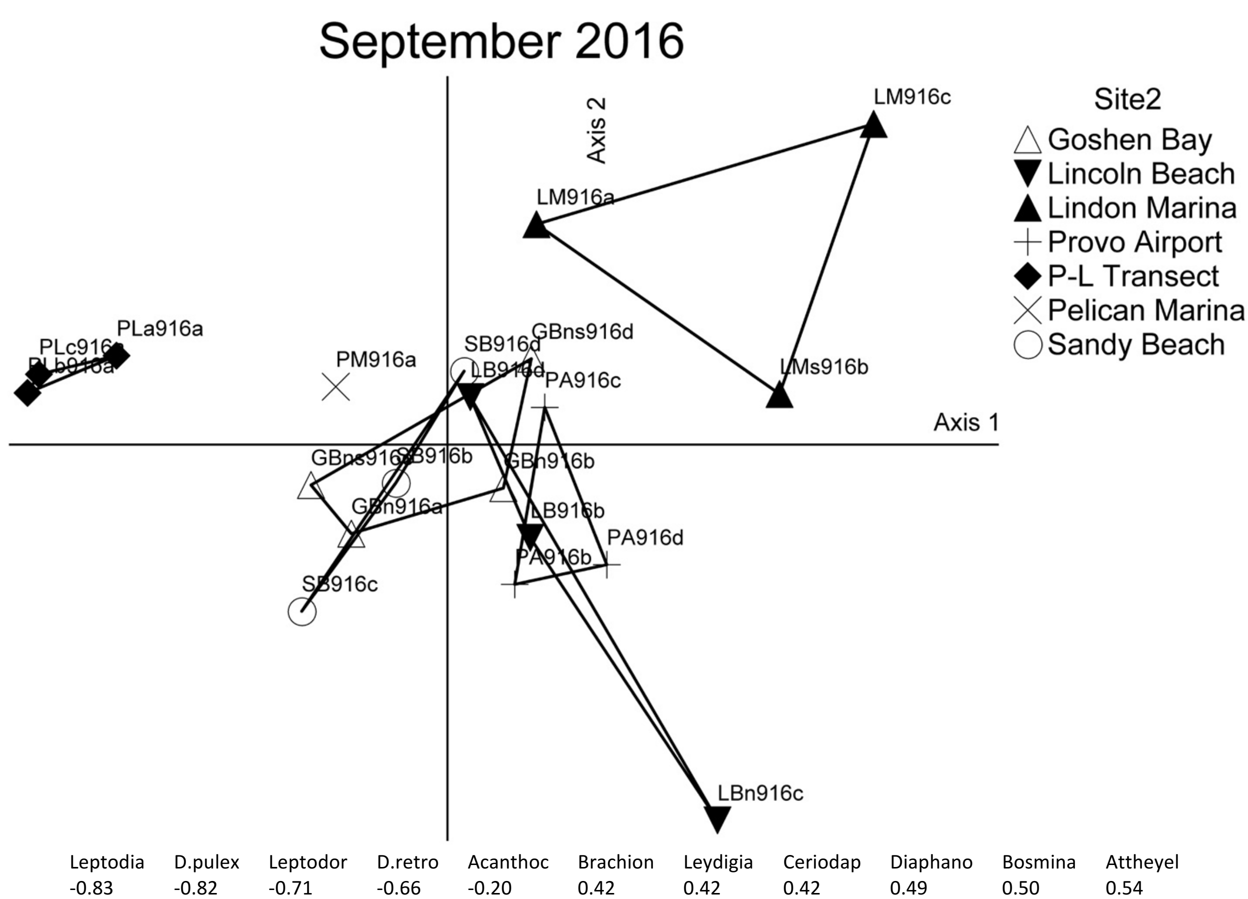


Figure 12.NMS axis 1 and axis 2 for September samples.

Table 13. NMS Axis 2 correlations for September

Attheyel	0.59
Leydigia	0.46
Acanthoc	0.40
Diaphano	0.36
Leptodor	0.20
Leptodia	0.14
D.retro	-0.16
D.pulex	-0.31
Ceriodap	-0.43
Bosmina	-0.56
Brachion	-0.60

Some of the differences in zooplankton assemblages in August and in September can be explained by the effects of depth (Figure 13 for September). NMS Axis 1 was significantly associated with depth in August (R^2 = 0.61) as was in September (R^2 = 0.67) (Figure 13). For more analyses of the relationships between depth and individual zooplankton see the following sections.

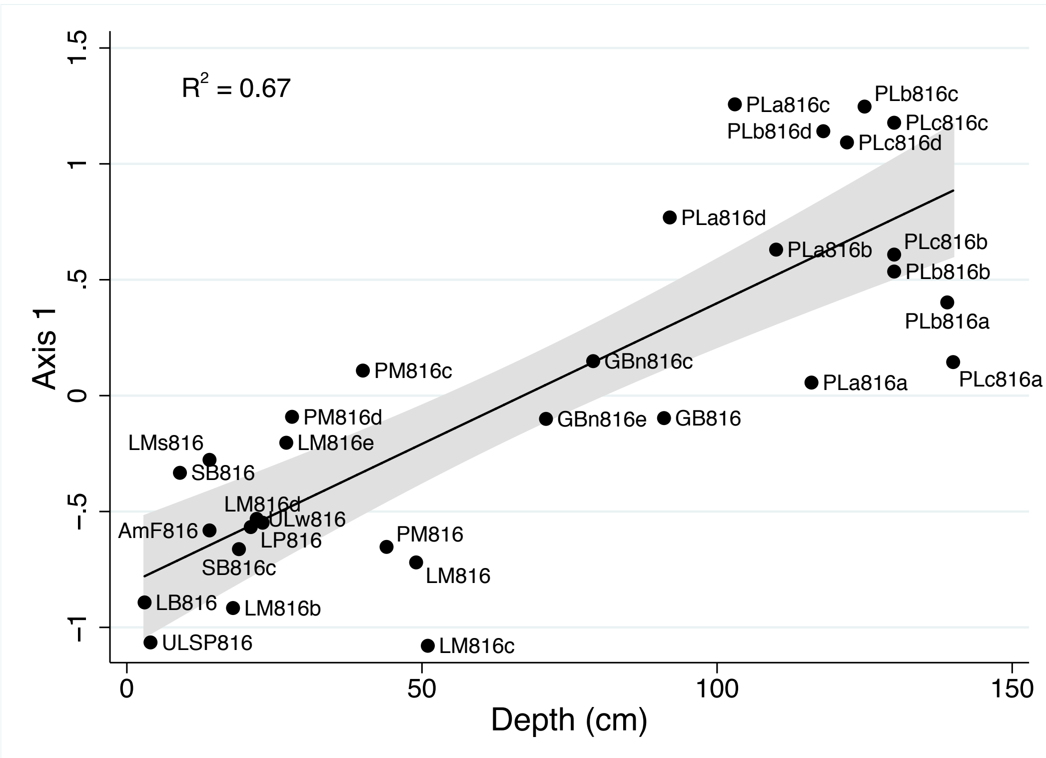


Figure 13. Relationship between depth and NMS axis 1 for September zooplankton samples.

Spatial and temporal patterns of individual zooplankton taxa

Spatial Patterns

The most common zooplankton taxa showed small to large differences in densities between sites (Figure 14). Some of the variability can be attributed to temporal effects and for two taxa the differences could be attributed to depth (see following section).

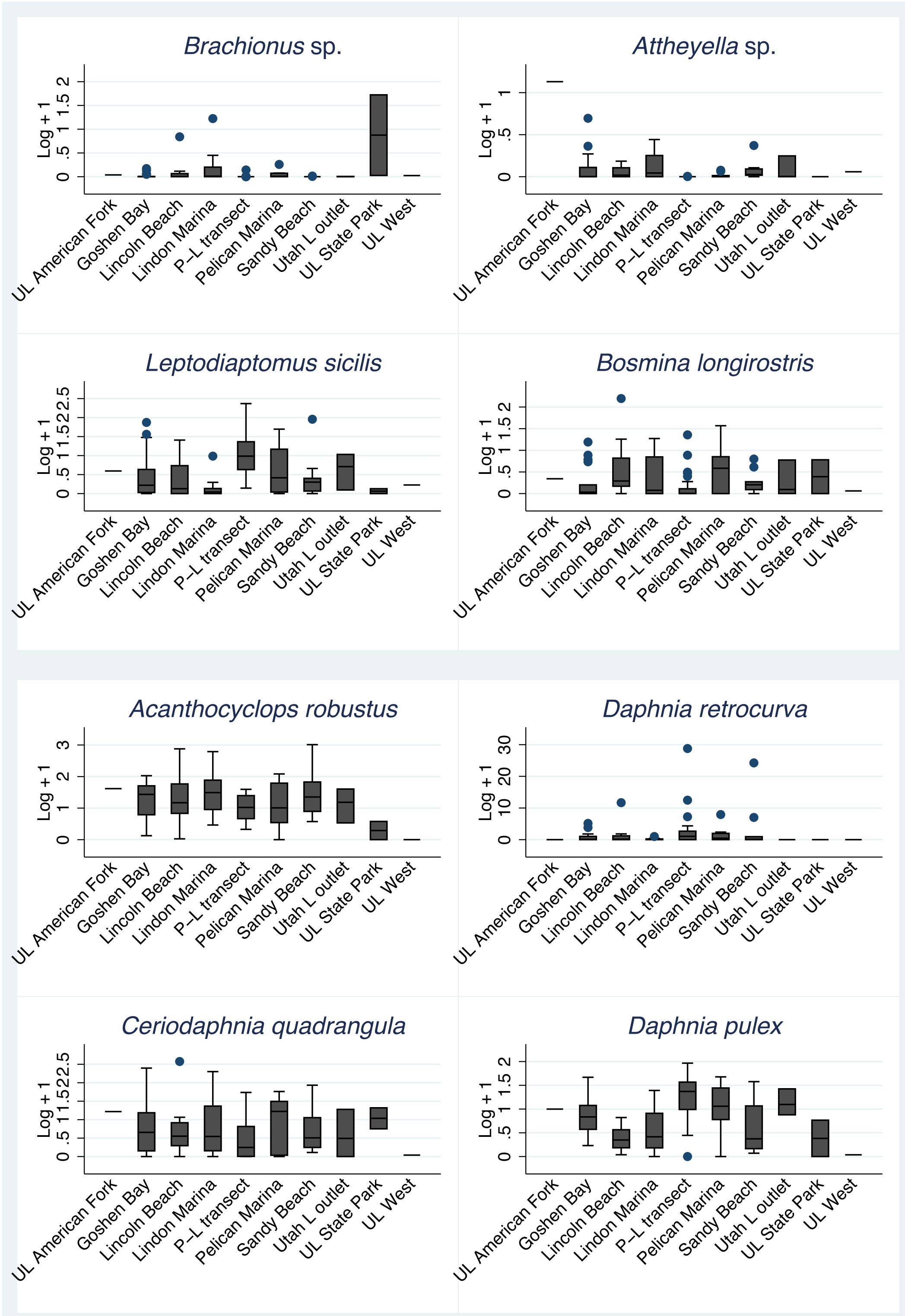
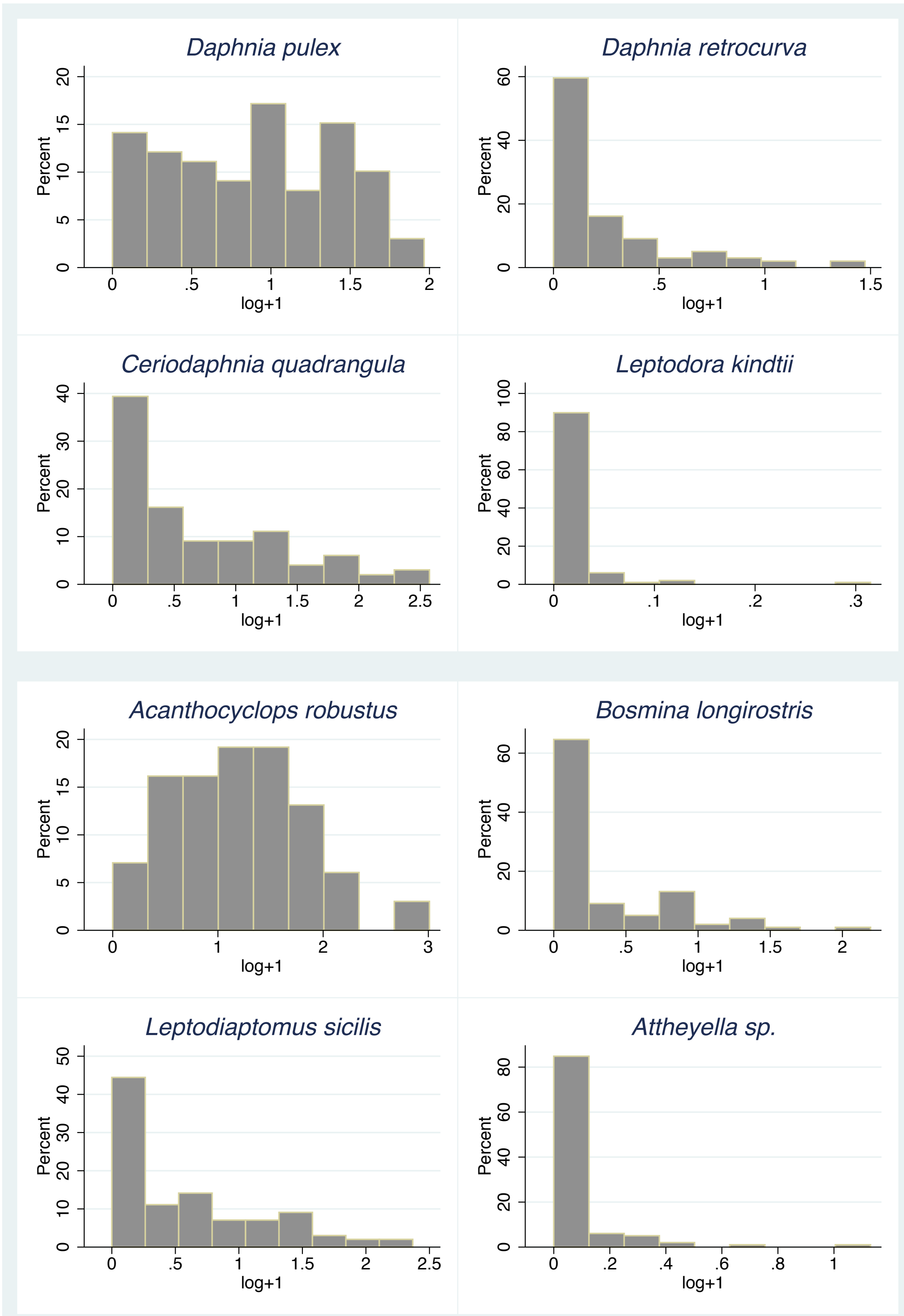


Figure 14. Zooplankton densities between sites.

Histograms of log+1 transformed taxa densities showed none to be normally distributed even after transformation, therefore regression analyses other than Gaussian (normal) based models were required and will be required in future analyses (Figure 15).



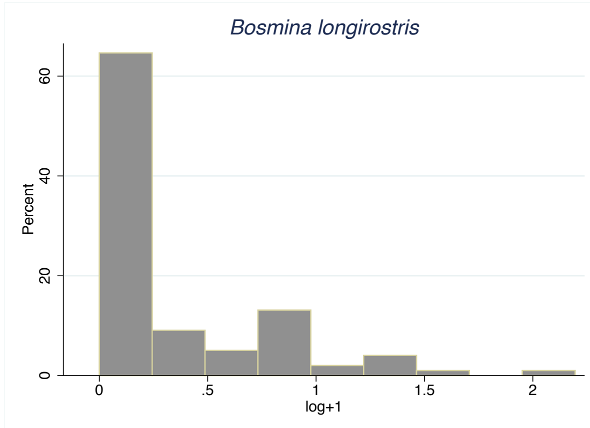


Figure 15. Histograms of log+1 transformed zooplankton densities showing that none were normally distributed and analyses other than Gaussian (normal) methods were required.

Zooplankton and Depth

Two taxa, *Daphnia pulex* and *Leptodiaptomus sicilis* were significantly positively correlated with depth (Figure 16). The other taxa did not show significant relationships with depth and could be considered depth generalists.

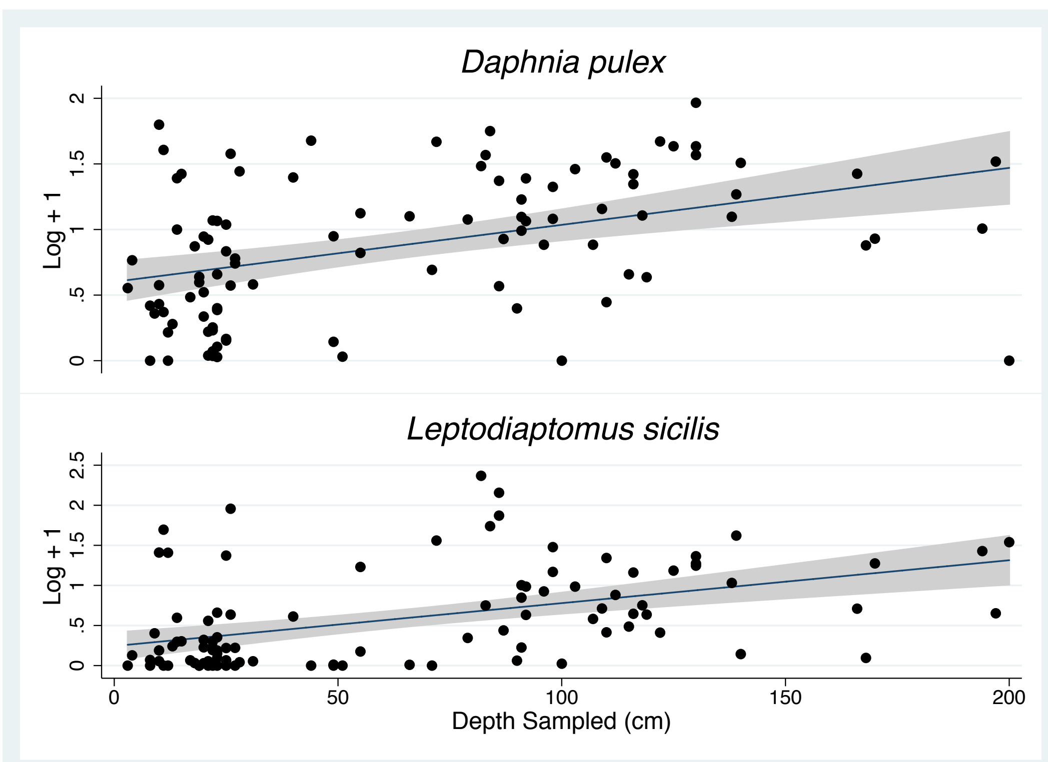


Figure 16. The only two taxa that were significantly positively related with depth.

Sample sites also varied with depth (Figure 17) and the relationship between *Daphnia pulex* and *Leptodiaptomus sicilis* and sample sites shown in Figure 14 can be explained mostly by the differences in depths at each site.

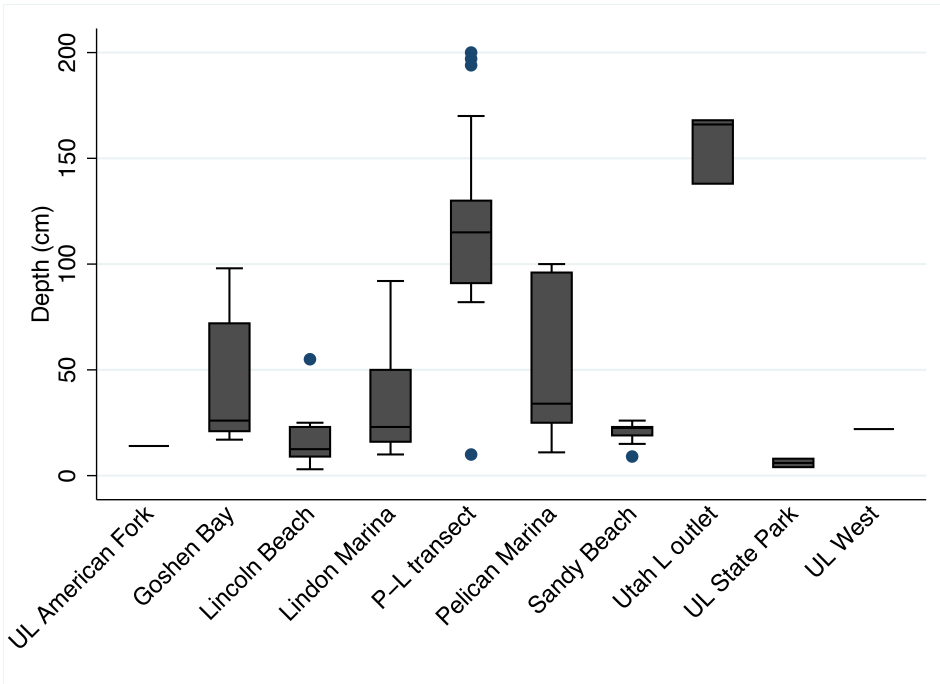


Figure 17. Relationship between sample sites and depth.

Daphnia pulex and *Leptodiaptomus sicilis* may very well be deeper water associated taxa and thus their ecologies may differ from the other taxa and may have to be modelled differently than the others in future analyses.

Temporal Patterns

Individual zooplankton densities L $^{-1}$ (size adjusted) changed throughout the 2016 sampling season often dramatically between sampling events (Figure 18 and Figure 19). Most often taxa followed synchronized fluctuations with each other, but not always. March to end of July time series densities shown in Figure 18 are not as informative as the other dates primarily because of much fewer samples collected during those times. Hence, caution in needed in interpretation in that time range.

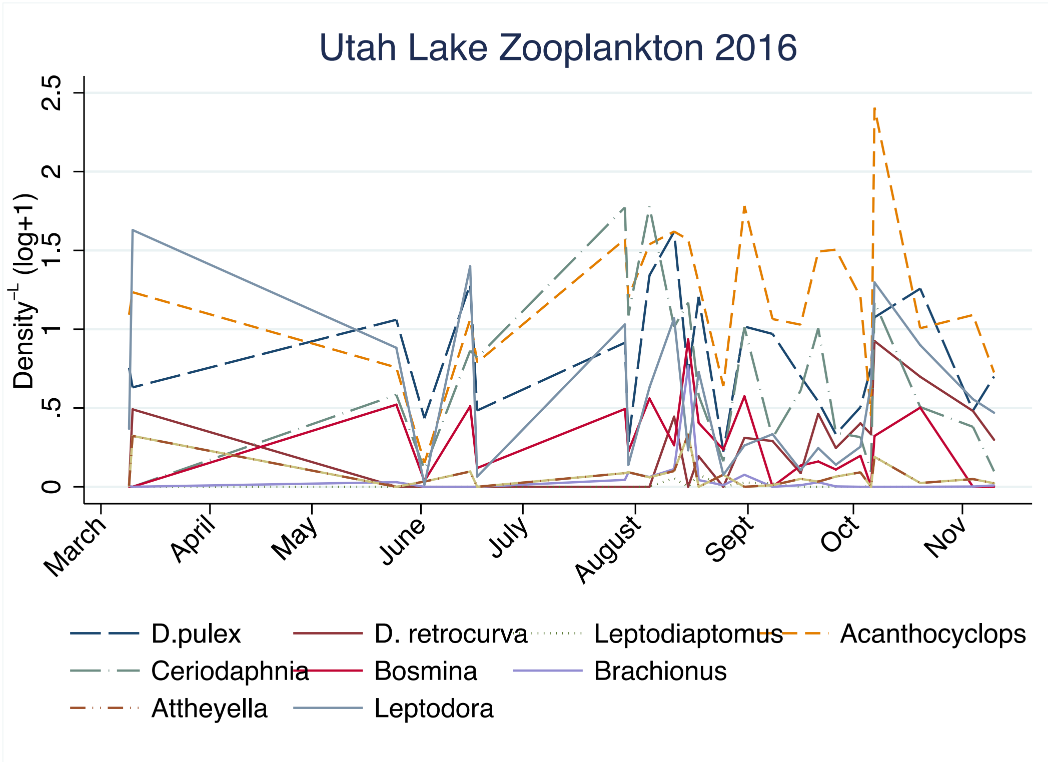


Figure 18. Time series graph of several of the more common zooplankton in Utah Lake from March to November, 2016. Based on mean values.

The narrow windowed time series graph from late July and early October (Figure 19) shows in more detail the often daily or weekly changes in zooplankton densities. Often zooplankton increased and decreased at the same rates with each other but there were notable exceptions. These difference can be attributed to competition and/or predation and further analyses will provide invaluable insights needed for future modeling. Most likely the synchronized changes of zooplankton densities will directly have been related to changes in phytoplankton taxa densities. Phytoplankton data results are forthcoming and will be analyzed in relation to zooplankton, nutrients, and environmental factors.

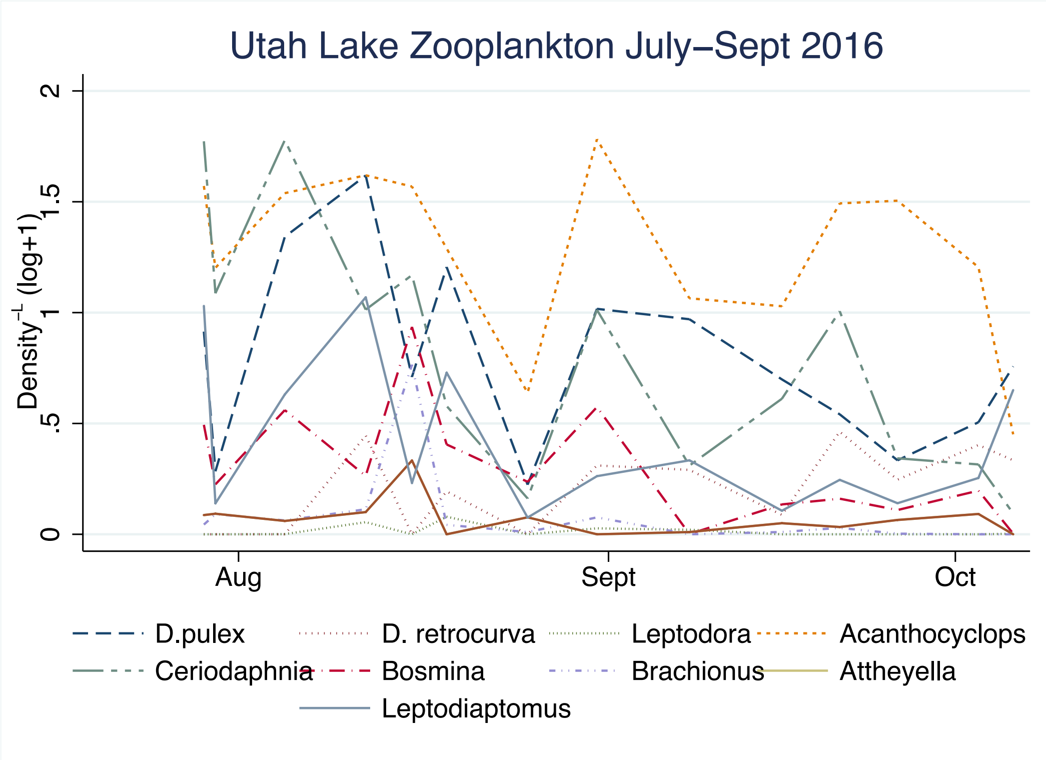


Figure 19. Time series graph of several of the more common zooplankton in Utah Lake from late July to beginning of October, 2016. Based on mean values.

Discussion and Conclusion

Although these are preliminary analyses focused entirely on our zooplankton data, some interesting and important trends were discovered. Even at these early stages of analysis they are the most comprehensive regarding zooplankton spatial and temporal patterns in Utah Lake, to date. This preliminary analysis and continued forth coming analyses are invaluable for understanding the complex nutrient cycle- food web interactions needed to understand and manage cyanobacteria blooms in the lake. Most importantly, these initial analyses will direct our 2017 sampling efforts and provide the baseline understanding of zooplankton patterns that will then be used in more detailed and intricate nutrient, phytoplankton, foodweb models developed by us and our colleagues. Nutrient-food web models will have very little predictive ability or usefulness in reducing HABs without this valuable analysis.

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StataCorp. 2015. Stata/IC 14.2 for Mac (64-bit Intel). Revision: 16 Nov 2016. College Station, TX.

Appendices

Appendix 2. Utah Lake Zooplankton Sample locations and dates, 2006

Utah Lake Zooplankton 2016

Sample	Date
South End Goshen Bay	10-Mar
North End Goshen Bay	10-Mar
Middle of Provo Bay	10-Mar
Mouth of Provo Bay	10-Mar
Mid-lake @ Pelican Point	10-Mar
Utah L. Outlet	9-Mar
Lindon Marina	9-Mar
Pelican Marina	9-Mar
Utah L. Outlet	24-May
Lindon Marina	24-May
Pelican Marina	24-May
Lindon-Pelican Transit 1/4	24-May
Lindon-Pelican Transit 2/4	24-May
Lindon-Pelican Transit 3/4	24-May
Goshen Bay 1/4 mi. N of Goose Point	1-Jun
Goshen Bay South End	1-Jun
Lindon Marina	14-Jun
Pelican Marina	14-Jun
Lindon-Pelican Transit 1/4	14-Jun
Lindon-Pelican Transit 2/4	14-Jun
Lindon-Pelican Transit 3/4	14-Jun

Utah L. Outlet	14-Jun
Provo Bay East	16-Jun
Provo Bay West	16-Jun
Provo Bay Outlet	16-Jun
Goshen Bay North Goose	16-Jun
Spanish Fork	28-Jul
Middle of Provo Bay	28-Jul
Mouth of Provo Bay	28-Jul
Provo Bay 1 km from shore	28-Jul
Lincoln Beach harbor 50m from shore	28-Jul
Mid Goshen Bay	28-Jul
Lindon Marina South	29-Jul
Sandy Beach	29-Jul
Utah Lake State Park	29-Jul
Goshen Bay North	29-Jul
Middle of Provo Bay	4-Aug
Mouth of Provo Bay	4-Aug
Goshen Bay	4-Aug
Lindon Marina	4-Aug
Lindon-Saratoga Transit 1/4	4-Aug
Lindon-Saratoga Transit 1/2	4-Aug
Lindon-Saratoga Transit 3/4	4-Aug
Saratoga Marina at Pelican Point	4-Aug
Lindon Marina South end	11-Aug
Lindon-Saratoga Transit 1/4	11-Aug
Lindon-Saratoga Transit 1/2	11-Aug
Lindon-Saratoga Transit 3/4	11-Aug
Middle of Provo Bay	11-Aug
Lindon Marina South end	15-Aug
Sandy Beach	15-Aug
Utah Lake State Park North	15-Aug
Lincoln Beach	15-Aug
Utah Lake-American Fork	15-Aug

Lindon Marina 100m	18-Aug
Lindon-Saratoga Transit 1/4	18-Aug
Lindon-Saratoga Transit 1/2	18-Aug
Lindon-Saratoga Transit 3/4	18-Aug
Lindon-Saratoga Transit 1/4 surface skim 1 m2	18-Aug
Saratoga	18-Aug
Goshen Bay North	18-Aug
Lindon-Saratoga Transit 1/4	31-Aug
Lindon-Saratoga Transit 1/2	31-Aug
Lindon-Saratoga Transit 3/4	31-Aug
Lindon Marina	31-Aug
Pelican Bay	31-Aug
Provo Bay Center	31-Aug
Lincoln Harbor	31-Aug
Goshen Bay North	31-Aug
Lindon Marina	8-Sep
Pelican Marina	8-Sep
Lindon-Pelican Transit 1/4	8-Sep
Lindon-Pelican Transit 2/4	8-Sep
Lindon-Pelican Transit 3/4	8-Sep
Goshen Bay North	8-Sep
Provo Bay Center	8-Sep
Provo Bay Mouth	8-Sep
Provo Bay Neck	8-Sep
Provo Airport	16-Sep
Lincoln Beach	16-Sep
Goshen Bay North	16-Sep
Lindon Marina South	16-Sep
Sandy Beach	16-Sep
Lincoln Point	25-Aug
West 1	25-Aug
Sandy Beach	25-Aug
Provo Airport	21-Sep

Lincoln Marina South	21-Sep
Goshen Bay North	21-Sep
Lincoln Beach North	21-Sep
Sandy Beach	21-Sep
Lincoln Beach	26-Sep
Goshen Bay North	26-Sep
Sandy Beach	26-Sep
Provo Airport	26-Sep
Goshen Bay North	3-Oct
Sandy Beach	3-Oct
Lincoln Beach	3-Oct
Lindon Marina	6-Oct
Pelican Marina	6-Oct
Lindon-Pelican Transit 1/4	6-Oct
Lindon-Pelican Transit 2/4	6-Oct
Lindon-Pelican Transit 3/4	6-Oct
Provo Bay Center	6-Oct
Provo Bay Mouth	6-Oct
Goshen Bay North	7-Oct
Sandy Beach	7-Oct
Lindon Marina	20-Oct
Pelican Marina	20-Oct
Lindon-Pelican Transit 1/4	20-Oct
Lindon-Pelican Transit 2/4	20-Oct
Lindon-Pelican Transit 3/4	20-Oct
Provo Bay Center	20-Oct
Goshen Bay North	4-Nov
Sandy Beach	4-Nov
Lincoln Beach	4-Nov
Lindon Marina	10-Nov
Pelican Marina	10-Nov
Lindon-Pelican Transit 1/4	10-Nov
Lindon-Pelican Transit 2/4	10-Nov
Lindon-Pelican Transit 3/4	10-Nov

Provo Bay Center	10-Nov
Provo Bay Mouth	10-Nov

Appendix 3. MRPP results for months all sites including Provo Bay

```
    Test statistic: T =   -17.536048
      Observed delta =   0.32715515
      Expected delta =   0.38336906
    Variance of delta =   0.10275999E-04
    Skewness of delta =   -0.44133476

    Chance-corrected within-group agreement, A =  0.14663130
     A = 1 - (observed delta/expected delta)
     Amax = 1 when all items are identical within groups (delta=0)
     A = 0 when heterogeneity within groups equals expectation by chance
     A < 0 with more heterogeneity within groups than expected by chance

    Probability of a smaller or equal delta, p =  0.00000000


------------------------------------------------------------------
PAIRWISE COMPARISONS
Note: p values not corrected for multiple comparisons.

   Groups (identifiers)
    Compared       T       A       p
    8 vs.   7   -2.40636685  0.02328024  0.02756941
    8 vs.   3   -9.32973976  0.09876150  0.00000323
    8 vs.   6   -8.99032501  0.08054399  0.00000655
    8 vs.   9   -9.92198758  0.07052245  0.00000245
    8 vs.   10  -10.40364865  0.08864661  0.00000339
    8 vs.   11  -10.60417201  0.11100574  0.00000173
    8 vs.   5   -4.61096297  0.05168567  0.00180226
    7 vs.   3   -6.03447375  0.13717054  0.00005509
    7 vs.   6   -2.29615019  0.04155410  0.02814518
    7 vs.   9   -6.92540760  0.07556700  0.00001582
    7 vs.   10   -8.08809284  0.12824503  0.00000828
    7 vs.   11   -7.33323251  0.15236839  0.00002461
    7 vs.   5   -2.86829494  0.08009229  0.01091799
    3 vs.   6   -3.96759560  0.07278636  0.00193438
    3 vs.   9   -7.76804818  0.10050022  0.00001325
    3 vs.   10   -6.57622602  0.09955871  0.00002950
    3 vs.   11   -3.25767322  0.07012614  0.00323123
    3 vs.   5   -5.02514170  0.15057808  0.00073768
    6 vs.   9   -8.69884340  0.08739506  0.00000140
    6 vs.   10   -6.57012098  0.08930621  0.00005927
    6 vs.   11   -5.92292777  0.10339731  0.00008319
    6 vs.   5   -0.90919582  0.02109611  0.16745335
    9 vs.   10   -3.69988468  0.03578609  0.00560069
    9 vs.   11   -4.29513353  0.04854834  0.00202464
    9 vs.   5   -7.96265232  0.10473167  0.00000681
```

```
   10 vs.   11   -2.73010619  0.03958470  0.01725314
   10 vs.   5   -6.22292122  0.10961025  0.00007645
   11 vs.   5   -7.58926677  0.21352531  0.00004808
------------------------------------------------------------------

***************************** MRPP finished *****************************
 6 Dec 2016, 15:43:57
```

Appendix 4. MRPP results for general locations by months July to September, Provo Bay removed.

No transformation or removal of <
July to September, Provo Bay removed
No significant differences between locations

```
  Test statistic: T =   0.15450217
      Observed delta =   0.69913611
      Expected delta =   0.69788042
    Variance of delta =   0.66053396E-04
    Skewness of delta =   -0.78971469

    Chance-corrected within-group agreement, A =  -0.00179929
     A = 1 - (observed delta/expected delta)
     Amax = 1 when all items are identical within groups (delta=0)
     A = 0 when heterogeneity within groups equals expectation by chance
     A < 0 with more heterogeneity within groups than expected by chance

    Probability of a smaller or equal delta, p =  0.50997872


------------------------------------------------------------------
PAIRWISE COMPARISONS
Note: p values not corrected for multiple comparisons.

   Groups (identifiers)
    Compared       T       A       p
    2 vs.   3   0.23103675  -0.00705155  0.50341715
    2 vs.   4   -0.74274028  0.00617234  0.19192027
    2 vs.   5   0.72401764  -0.02241858  0.74440679
    3 vs.   4   -0.30562346  0.00279100  0.30785163
    3 vs.   5   0.92760207  -0.02847187  0.82804042
    4 vs.   5   0.83744062  -0.00767141  0.80135846
------------------------------------------------------------------

  Groups were defined by values of: Site
    Input data has:   56 Sites  by   19 Taxa
    Weighting option: C(I) = n(I)/sum(n(I))
    Distance measure: Sorensen (Bray-Curtis)

   GROUP:   1
Identifier:   2
   Size:   9   0.61181257  = Average distance
Members:
 GB816  GBm716  GBn816c GBn816e GBn916a GBn916b GBNs716 GBns916c
 GBns916d
```

```
   GROUP:   2
Identifier:   3
   Size:   5   0.89168126  = Average distance
Members:
 LB816  LB916b  LB916d  LBa717  LBn916c

   GROUP:   3
Identifier:   4
   Size:  36   0.69112827  = Average distance
Members:
 LM716  LM816  LM816b  LM816c  LM816d  LM816e  LM916a  LM916c
 LMs816  LMs916b LP816  PA916b  PA916c  PA916d  PLa816a PLa816b
 PLa816c PLa816d PLa916a PLb816a PLb816b PLb816c PLb816d PLb916a
 PLc816a PLc816b PLc816c PLc816d PLc916a PM816  PM816c  PM816d
 PM916a  ULSP716 ULSP816 ULw816

   GROUP:   4
Identifier:   5
   Size:   6   0.71771415  = Average distance
Members:
 SB716  SB816  SB816c  SB916b  SB916c  SB916d
```

Appendix 5. MRPP results for sites from July to September, Provo Bay removed

JulyToSept, Provo Bay removed
Log+1 transformed
Site2 codes

Lots of significant differences

```
   Identifiers for excluded groups:
         1
         6

    Groups were defined by values of: Site2
    Input data has:   55 Sites  by   19 Taxa
    Weighting option: C(I) = n(I)/sum(n(I))
    Distance measure: Sorensen (Bray-Curtis)

   GROUP:   1
Identifier:   2
   Size:   9   0.29141319  = Average distance
Members:
 GB816  GBm716  GBn816c GBn816e GBn916a GBn916b GBNs716 GBns916c
 GBns916d

   GROUP:   2
Identifier:   3
   Size:   5   0.41657224  = Average distance
Members:
 LB816  LB916b  LB916d  LBa717  LBn916c

   GROUP:   3
```

```
Identifier:   4
   Size:   8   0.38859342  = Average distance
Members:
 LM716  LM816  LM816b  LM816c  LM816d  LM816e  LM916a  LM916c

   GROUP:   4
Identifier:   5
   Size:   2   0.35661298  = Average distance
Members:
 LMs816  LMs916b

   GROUP:   5
Identifier:   7
   Size:   3   0.18144536  = Average distance
Members:
 PA916b  PA916c  PA916d

   GROUP:   6
Identifier:   8
   Size:  15   0.20067340  = Average distance
Members:
 PLa816a PLa816b PLa816c PLa816d PLa916a PLb816a PLb816b PLb816c
 PLb816d PLb916a PLc816a PLc816b PLc816c PLc816d PLc916a

   GROUP:   7
Identifier:   9
   Size:   4   0.27437542  = Average distance
Members:
 PM816  PM816c  PM816d  PM916a

   GROUP:   8
Identifier:  10
   Size:   6   0.30990141  = Average distance
Members:
 SB716  SB816  SB816c  SB916b  SB916c  SB916d

   GROUP:   9
Identifier:  11
   Size:   3   0.70722693  = Average distance
Members:
 ULSP716 ULSP816 ULw816

    Test statistic: T =   -7.2615595
      Observed delta =   0.31201057
      Expected delta =   0.37150969
    Variance of delta =   0.67136894E-04
    Skewness of delta =   -0.37980285

    Chance-corrected within-group agreement, A =  0.16015496
     A = 1 - (observed delta/expected delta)
     Amax = 1 when all items are identical within groups (delta=0)
     A = 0 when heterogeneity within groups equals expectation by chance
     A < 0 with more heterogeneity within groups than expected by chance

    Probability of a smaller or equal delta, p =  0.00000004
```

```
------------------------------------------------------------------
PAIRWISE COMPARISONS
Note: p values not corrected for multiple comparisons.

   Groups (identifiers)
    Compared       T       A       p
    2 vs.   3   -0.30261563  0.00878513  0.31089463
    2 vs.   4   -2.69490352  0.05956967  0.01829672
    2 vs.   5   -0.48370623  0.02221160  0.30032029
    2 vs.   7   -1.63022537  0.06949862  0.07123597
    2 vs.   8   -6.30928186  0.12146071  0.00033168
    2 vs.   9   0.77712626  -0.02890911  0.77577655
    2 vs.   10   -0.36421707  0.00933002  0.29978429
    2 vs.   11   -1.46248492  0.04185002  0.08385205
    3 vs.   4   -0.75085775  0.01908319  0.20104513
    3 vs.   5   0.31963231  -0.01594425  0.63453456
    3 vs.   7   -2.26972097  0.10507421  0.02102780
    3 vs.   8   -6.76204131  0.17156054  0.00015568
    3 vs.   9   -0.05226762  0.00259022  0.38689276
    3 vs.   10   -0.89121931  0.02711241  0.17992028
    3 vs.   11   0.53615573  -0.02022969  0.68651655
    4 vs.   5   0.78406260  -0.03271747  0.77656505
    4 vs.   7   -2.79772059  0.11236186  0.01353840
    4 vs.   8  -10.60467958  0.24310289  0.00000832
    4 vs.   9   -0.83566219  0.02865734  0.18228336
    4 vs.   10   -1.87533162  0.04758098  0.05102831
    4 vs.   11   0.04866884  -0.00154813  0.46849846
    5 vs.   7   -1.73500159  0.16718595      NaN
    5 vs.   8   -2.98034475  0.11677689  0.00645819
    5 vs.   9   -0.04015080  0.00290801  0.48519613
    5 vs.   10   0.27461603  -0.01652053  0.59063907
    5 vs.   11   -0.19493714  0.01234509  0.00000000
    7 vs.   8   -5.86866251  0.18670471  0.00026656
    7 vs.   9   -1.85331184  0.17781781  0.05717720
    7 vs.   10   -1.32137370  0.05682133  0.09942951
    7 vs.   11   -1.72232407  0.11327284  0.05946732
    8 vs.   9   -3.38541813  0.10882015  0.01013520
    8 vs.   10   -6.33385767  0.15052962  0.00028624
    8 vs.   11   -5.51975748  0.14765932  0.00037474
    9 vs.   10   -1.17391758  0.05451500  0.12228954
    9 vs.   11   -1.05315854  0.05602241  0.14460708
   10 vs.   11   -0.63143715  0.02327143  0.25188724
------------------------------------------------------------------

****************************** MRPP finished ******************************
 6 Dec 2016, 17:09:09
```

Appendix 6. MRPP results for September data only, Provo Bay removed

September only

```
    Groups were defined by values of: Site2
    Input data has:   19 Sites  by   11 Taxa
    Weighting option: C(I) = n(I)/sum(n(I))
    Distance measure: Sorensen (Bray-Curtis)
```

```
   GROUP:   1
Identifier:   2
   Size:   4   0.20586673  = Average distance
Members:
 GBn916a GBn916b GBns916c GBns916d

   GROUP:   2
Identifier:   3
   Size:   3   0.24989908  = Average distance
Members:
 LB916b  LB916d  LBn916c

   GROUP:   3
Identifier:   4
   Size:   3   0.32274414  = Average distance
Members:
 LM916a  LM916c  LMs916b

   GROUP:   4
Identifier:   7
   Size:   3   0.18144536  = Average distance
Members:
 PA916b  PA916c  PA916d

   GROUP:   5
Identifier:   8
   Size:   3   0.10477195  = Average distance
Members:
 PLa916a PLb916a PLc916a

   GROUP:   6
Identifier:  10
   Size:   3   0.17076790  = Average distance
Members:
 SB916b  SB916c  SB916d

    Test statistic: T =   -5.3007576
      Observed delta =   0.20591328
      Expected delta =   0.29090061
    Variance of delta =   0.25705885E-03
    Skewness of delta =   -0.67412995

    Chance-corrected within-group agreement, A =  0.29215249
     A = 1 - (observed delta/expected delta)
     Amax = 1 when all items are identical within groups (delta=0)
     A = 0 when heterogeneity within groups equals expectation by chance
     A < 0 with more heterogeneity within groups than expected by chance

    Probability of a smaller or equal delta, p =  0.00008378


------------------------------------------------------------------
PAIRWISE COMPARISONS
Note: p values not corrected for multiple comparisons.

   Groups (identifiers)
```

```
    Compared       T       A       p
    2 vs.   3   -1.33186143  0.07563731  0.09942301
    2 vs.   4   -1.82972512  0.12387626  0.04864358
    2 vs.   7   0.06398128  -0.00356691  0.51618049
    2 vs.   8   -3.54148155  0.35193688  0.00941036
    2 vs.   10   -0.10336377  0.00645212  0.39544048
    3 vs.   4   -1.67676405  0.10974439  0.05655227
    3 vs.   7   -0.04445121  0.00256929  0.42966756
    3 vs.   8   -2.90314292  0.47810349  0.02210736
    3 vs.   10   -1.18719287  0.07945165  0.11601782
    4 vs.   7   -1.64861070  0.11599327  0.04871533
    4 vs.   8   -2.85137100  0.46002056  0.02242855
    4 vs.   10   -2.22132523  0.18778369  0.02916254
    7 vs.   8   -2.89499359  0.51013598  0.02215899
    7 vs.   10   -1.91474712  0.14608071  0.03794934
    8 vs.   10   -2.92082846  0.42119315  0.02204976
------------------------------------------------------------------

****************************** MRPP finished ******************************
 6 Dec 2016, 18:04:08
```

Appendix 7. Indicator Species Analysis for September only data, Provo Bay removed

```
MONTE CARLO test of significance of observed maximum
indicator value for Taxa
 4999 permutations.
Random number seed:    1900

-----------------------------------------------------
                  IV from
            Observed randomized
            Indicator  groups
  Column    Maxgrp Value (IV) Mean S.Dev  p *
-------------- -------- -------- ----- ------ -------
  1 Dpulex     8  22.7  20.4  1.21 0.0340
  2 Dretro     10  21.8  21.0  1.52 0.2935
  3 Ceriodap    10  23.5  21.9  1.63 0.1716
  4 Bosmina     3  28.2  24.1  2.45 0.0414
  5 Diaphano    4  61.2  26.8 14.77 0.0920
  6 Leydigia    4  14.0  23.6 15.87 0.5949
  7 Leptodia    8  32.7  25.8  3.95 0.0402
  8 Leptodor    8  100.0  24.3 15.11 0.0046
  9 Acanthoc    10  20.3  19.2  0.86 0.0950
  10 Attheyel    4  45.9  26.0  9.52 0.0250
  11 Brachion    3  56.0  28.3 11.23 0.0268
-----------------------------------------------------
   Averages     38.7455 23.76  7.10 0.1290
-----------------------------------------------------
```

Appendix 8. August NMS Axis coordinates by site location

```
AmF816   -0.58192  -0.08171  -0.60202
GB816    -0.09697  -0.23866  -0.39463
GBn816c   0.14889  -0.14039   0.38838
```

```
GBn816e   -0.10047  -0.10538   0.81300
LB816    -0.89218  -0.64701   0.43800
LM816    -0.72006  -0.14761  -0.10731
LM816b   -0.91632  -0.35261  -0.38689
LM816c   -1.07928   0.75767   0.35376
LM816d   -0.54858  -0.33136   0.43422
LM816e   -0.20301  -0.39897   0.98899
LMs816   -0.27691  -0.54100  -0.09444
LP816    -0.56730   1.62423   0.80034
PLa816a   0.05620  -0.01424  -0.35331
PLa816b   0.63027  -0.06198  -0.18276
PLa816c   1.25685   0.08325  -0.02394
PLa816d   0.76865   0.16293   0.18764
PLb816a   0.40234  -0.11817  -0.76760
PLb816b   0.53565  -0.10211  -0.11079
PLb816c   1.24747  -0.01067  -0.01475
PLb816d   1.14090   0.43151   0.28832
PLc816a   0.14498   0.09772  -0.42238
PLc816b   0.60850  -0.10270  -0.16037
PLc816c   1.17743  -0.01454  -0.05471
PLc816d   1.09274  -0.14448   0.10415
PM816    -0.65294  -0.34402   0.16761
PM816c    0.10838  -0.26768   0.19829
PM816d   -0.09137  -0.49077   0.20127
SB816    -0.33281   0.28408  -0.30863
SB816c   -0.66212   0.54657   0.26593
ULSP816   -1.06499  -0.91465  -0.62903
ULw816   -0.53198   1.58277  -1.01634
```

Appendix 9. August NMS Axis coordinates for taxa

```
D.pulex    0.09398  -0.07499  -0.01567
D.retroc    0.50075  -0.11706   0.15713
Ceriodap  -0.05642  -0.13393  -0.03843
Bosmina   -0.27574  -0.07918   0.07532
Diaphano  -0.34378  -0.20603  -0.14400
Ilyocryp  -0.86701  -0.26827  -0.42318
Leptodia   0.33111  -0.03149  -0.18405
Leptodor   0.91986   0.03151  -0.01532
Acanthoc   0.03468  -0.06093   0.06563
Attheyel  -0.58028   0.23843  -0.21298
Brachion  -0.53493  -0.28327   0.05368
Ostracod  -0.63713  -0.63684   0.22390
```

Appendix 10. MRPP August by site

Significant differences mostly due to depth

```
    Identifiers for excluded groups:
         1
         3
         9
        10

    Groups were defined by values of: SiteCode
```

```
    Input data has:   27 Sites  by   12 Taxa
    Weighting option: C(I) = n(I)/sum(n(I))
    Distance measure: Sorensen (Bray-Curtis)

   GROUP:   1
Identifier:   2
   Size:   3   0.22255261  = Average distance
Members:
 GB816  GBn816c GBn816e

   GROUP:   2
Identifier:   4
   Size:   6   0.27350715  = Average distance
Members:
 LM816  LM816b  LM816c  LM816d  LM816e  LMs816

   GROUP:   3
Identifier:   5
   Size:  13   0.24227572  = Average distance
Members:
 LP816  PLa816a PLa816b PLa816c PLa816d PLb816a PLb816b PLb816c
 PLb816d PLc816a PLc816b PLc816c PLc816d

   GROUP:   4
Identifier:   7
   Size:   3   0.15782794  = Average distance
Members:
 PM816  PM816c  PM816d

   GROUP:   5
Identifier:   8
   Size:   2   0.19857097  = Average distance
Members:
 SB816  SB816c

    Test statistic: T =   -5.1174402
      Observed delta =   0.23440411
      Expected delta =   0.30228645
    Variance of delta =   0.17595764E-03
    Skewness of delta =   -0.50243845

    Chance-corrected within-group agreement, A =  0.22456298
     A = 1 - (observed delta/expected delta)
     Amax = 1 when all items are identical within groups (delta=0)
     A = 0 when heterogeneity within groups equals expectation by chance
     A < 0 with more heterogeneity within groups than expected by chance

    Probability of a smaller or equal delta, p =  0.00004991


------------------------------------------------------------------
PAIRWISE COMPARISONS
Note: p values not corrected for multiple comparisons.

   Groups (identifiers)
    Compared       T       A       p
    2 vs.   4   -0.49862894  0.02624242  0.26097204
```

```
    2 vs.   5   -2.48406547  0.08444963  0.02272640
    2 vs.   7   0.46783825  -0.04197595  0.66583521
    2 vs.   8   -0.84497848  0.14047655      NaN
    4 vs.   5   -7.31227544  0.21151537  0.00015238
    4 vs.   7   -0.44197960  0.01776799  0.29074441
    4 vs.   8   -0.95134200  0.05802453  0.16737604
    5 vs.   7   -4.12967043  0.14613215  0.00239160
    5 vs.   8   -2.36286963  0.11859618  0.02418920
    7 vs.   8   -1.88924947  0.24153866      NaN
------------------------------------------------------------------

****************************** MRPP finished ******************************
 7 Dec 2016, 7:03:46
```

Appendix 11. Indicator species analysis for August by site

```
MONTE CARLO test of significance of observed maximum
indicator value for Taxa
 4999 permutations.
Random number seed:    1588

-----------------------------------------------------
                  IV from
            Observed randomized
            Indicator  groups
  Column    Maxgrp Value (IV) Mean S.Dev  p *
-------------- -------- -------- ----- ------ -------
  1 D.pulex     7  23.3  22.2  0.81 0.0802
  2 D.retroc    5  21.1  28.4  6.44 0.8210
  3 Ceriodap    7  23.3  23.9  1.53 0.6157
  4 Bosmina     7  25.9  26.5  2.79 0.5935
  5 Diaphano    4  25.1  28.5  6.64 0.7103
  6 Ilyocryp    4  33.3  22.7 12.63 0.1762
  7 Leptodia    5  32.6  27.8  3.81 0.0902
  8 Leptodor    5  76.9  26.9 11.79 0.0004
  9 Acanthoc    4  21.6  21.4  0.75 0.3319
  10 Attheyel    8  52.4  24.6 13.68 0.0556
  11 Brachion    4  38.0  28.3 10.38 0.2038
  12 Ostracod    7  19.8  23.1 12.19 0.5261
-----------------------------------------------------
   Averages     32.7813 25.36  6.95 0.3504
```

Appendix 12. Latitude and Longitude of sample sites.

Site		Latitude	Longitude
Beer Creek		40.14109109	-111.7933807
Goose Point North		40.09243094	-111.861129

Goshen Bay Center		40.08662632	-111.8900758
Goshen Bay South		40.03406289	-111.8897464
Hobble Creek At Confluence With Provo Bay		40.18723197	-111.6740778
Lincoln Marina		40.14248556	-111.8023818
Lincoln Marina Out		40.14410812	-111.7983279
Lindon /Saratoga one quarter		40.31873897	-111.793439
Lindon Marina		40.32697645	-111.7673372
Lindon Marina South		40.32556293	-111.7660461
Lindon Saratoga one half		40.31100465	-111.8188149
Lindon Saratoga three quarters		40.30307211	-111.8431384
MillRace Creek At Confluence With Provo Bay		40.19596855	-111.6794496
North End Of The Goshen Bay		40.12190582	-111.8787045
Outlet Provo Bay		40.18708019	-111.7299191
Pelican Marina		40.29059233	-111.8686682
Provo Bay Base Camp 1		40.18039378	-111.71728
Provo Bay Center		40.18649613	-111.6981764
Sandy Beach		40.1702659	-111.7479878
Utah Lake Outlet Jordan River		40.35949026	-111.8962022
Utah Lake State Park North		40.24164098	-111.7416926
American Fork		40.343223	-111.804166
Goshen Bay North		40.092776	-111.862278
Lincoln Beach		40.141755	-111.798205
Provo Airport		40.217297	-111.731953
S 4000 W		40.15300021	-111.7513355
Spanish Fork River confluence UL		40.168567	-111.751162

Chapter 2: Spatial and Temporal Patterns of Zooplankton in Utah Lake 2016

Chapter 3

Ecological Importance of Benthic Macroinvertebrates in Utah Lake

With a Focus on the Role of the Keystone Taxon Chironomidae on HABs

Summary

Nothing is known about how benthic invertebrates affect nutrients and HABs in Utah Lake although in other shallow lakes these ecosystem engineers, particularly chironomids are often critically linked to blooms. Utah Lake benthos is dominated by benthic invertebrates and there can easily be 6000 tons of chironomid midges in the sediments at any one time. Provo Bay benthic assemblages are much different than the rest of Utah Lake with Tanypodinae midges dominating. The importance of the benthic invertebrates to Utah Lake's ecology, nutrient cycling, foodweb and especially HABs should not be underestimated.

Introduction

Benthic macroinvertebrates are a critical component of the ecology and ecosystem functioning of Utah Lake. They are a major link between sediment chemistry, water column chemistry, nutrient cycling, benthic algae, phytoplankton, and Utah Lake's food web including carp, game fish, June suckers, waterfowl, shorebirds, etc. Benthic invertebrates provide underappreciated but invaluable ecosystem services and are keystone taxa instrumental for the functioning of Utah Lake' ecosystem. It has become clear that several dominant benthic taxa, primarily chironomids, play a key role in the timing and intensity of harmful algal blooms (HABs) in the lake. Very few studies have been conducted on the benthic invertebrate assemblages in Utah Lake (Barnes and Toole 1981, Spencer and Denton 2003, Shiozawa and Barnes 1977) and none were conducted at the level and intensity that is presently being accomplished by this group. No study has ever examined the role of benthic invertebrates on HABs in Utah Lake, this is the first. Our research is also an important element of sediment chemistry, nutrients, and food web models that are presently being conducted by us and others on Utah Lake. Preliminary results of our research are leading to valuable insights on the role of benthic macroinvertebrates in the ecology and ecosystem functioning of Utah Lake and will provide guidance on water quality issues, including HAB management.

Utah Lake Foodweb

Slightly- saline-eutrophic (i.e. productive)-turbid-shallow Utah Lake has a very simplified food web, despite its vast size (approximately 380km^2). Reasons for its simplified food web are varied but include; major impacts from introduced carp and to a lesser extent other introduced species, loss of native species including salmonids and mollusks, pollution, sedimentation, unstable substrates composed of fine sediments ('ooze'), and its high turbidity and shallow nature. Additional impacts maintaining the simplified food web but haven't been quantified likely occur during years with winter ice cover including: ice scouring the bottom substrate, hypoxic or anoxic conditions, freezing of benthic substrates, reduction in available underwater habitat, and harmful chemical interactions that could occur synergistically with low oxygen levels. Phytoplankton and zooplankton populations dynamics are also affected by ice cover conditions but vary due to ice thickness and transparency (Hampton et al. 2016). Winter ice also likely presets the ice free and summer dynamics of Utah Lake's food web and nutrient cycling, including HABs (Hampton et al. 2016).

Utah Lake's food web has undergone what is known as a 'catastrophic ecosystem shift' (Scheffer et al. 2001) and hysteresis[2] since the late 1800s (Carter 2003, Fuhriman et al. 1981, Janetski 1990). An abridged version of what was likely the food web in the Utah Lake prior to 1890s is presented in Figure 20.

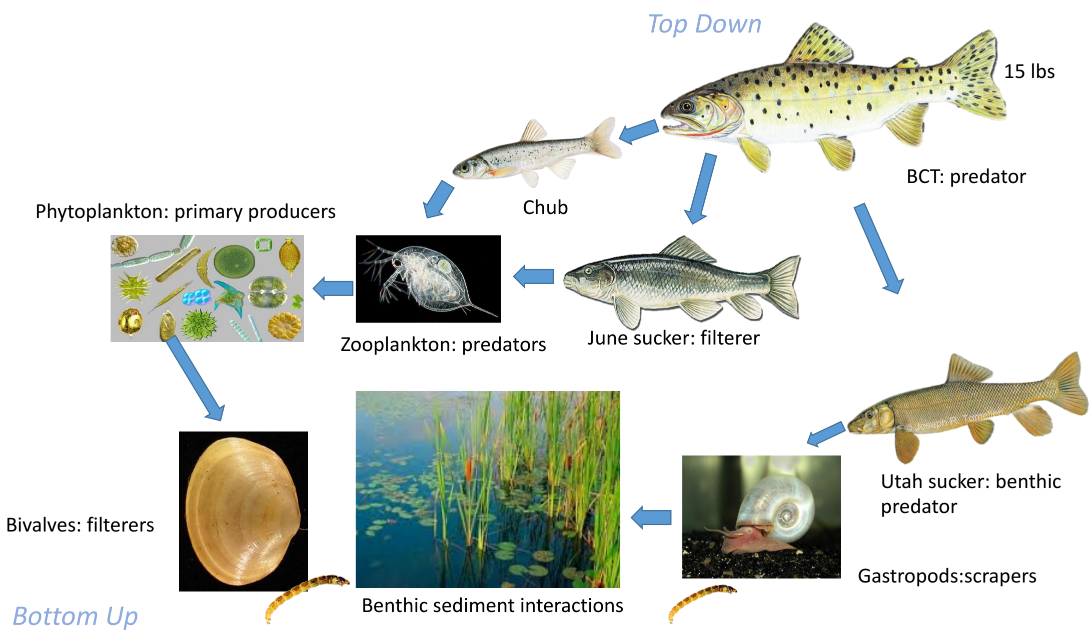

Figure 20. Abridged Utah Lake food web model as it likely occurred pre-1890.

Prior to settlement and shortly thereafter, Utah Lake's food web was dominated by the top down predator Bonneville cutthroat trout and twelve other fish species. Equally as important as the top down predators in the food web were Utah Lake's bottom up controllers, mollusks. There were an unprecedented seventeen mollusk taxa in Utah Lake prior to settlement, including at least two major water quality regulator mussel taxa. (Figure 20).

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[2] Hysteresis: Multiple states may persist under equal environmental conditions, ecological thresholds, in contrast to ecosystems which change smoothly and continuously along an environmental gradient.

Utah Lake's food web at present is much more simplified. An abridged current Utah lake food web is shown in Figure 21.

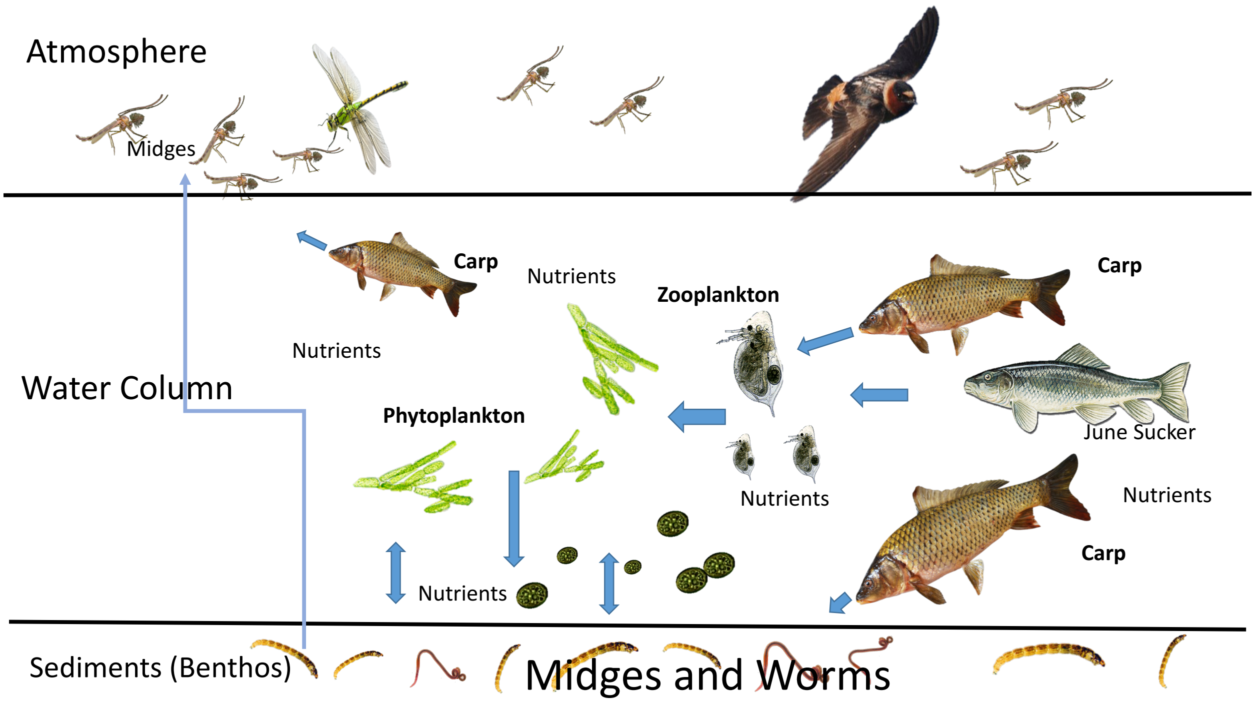

Figure 21. Abridged model of the simplified Utah Lake food web as of 2016 with a focus on midges and worms.

This current ecologically simplified food web consists of three interdependent 'spheres': hydrosphere(water), atmosphere(air) and the biosphere (living organisms). Utah Lake's food web past and present also is completely dependent on and interacts with the lithosphere (earth inorganic materials). The sediments (benthos) are composed of organic and inorganic materials/organisms.

The 2016 Progress Report by Richards "Spatial and temporal patterns of zooplankton in Utah Lake" discussed our initial findings on another water column key component of the food web, zooplankton. Data for another critical water column component, phytoplankton are presently being compiled. Of course, the importance/influence of introduced carp to the Utah Lake food web has been discussed at length. Carp are the most influential water column predator in the lake and effect all aspects of the food web including HABs via their perturbations of the sediments when feeding and spawning, and the incredible amount of nutrients released directly into the water column via respiration and excretion. The focus of this progress report however, is on our current findings and understanding of the benthic invertebrate contribution to the food web and ecosystem function.

Benthic Macroinvertebrates, 2016

Methods

We collected 93 benthic macroinvertebrate samples between June and November 2016. We used several sampling methods depending on locations and habitats in the lake including; Ekman dredge, kick net, and a modified bucket method developed by us specifically for use in shallow portions of the lake. Dr. Larry Gray, a leading expert on macroinvertebrates in Utah Lake at Utah Valley University, identified the taxa and estimated abundances and wet weight biomass. He also determined and grouped instar counts and biomass for two of the chironomid taxa, *Chironomus* sp. and *Tanypus* sp. We then adjusted all of Dr. Gray's results based on the sampling methods used. We then computed simple descriptive statistics and created graphical representations of our findings.

Results

A complete list of locations, dates, and adjusted biomass estimates of all benthic taxa are in Appendix 12 and Appendix 13. We focused our analyses on biomass instead of counts/abundances because benthic invertebrates occur in all sizes, thus biomass is more ecologically relevant.

Benthic Invertebrate Taxa

A list of all benthic macroinvertebrate taxa found in our 2016 study is in Table 14. Taxa were not uniformly distributed in Utah Lake. See following results and Appendix 1.

Table 14. List of Benthic Taxa collected in Utah Lake, 2016

INSECTS

Diptera

Chironomidae

Chironomus sp.

Tanypus sp.

Cladotanytarsus sp.

Orthocladiinae

Tipulidae

Tabanidae

Ceratopogonidae

Hemiptera

Corixidae

Corisella decolor

Corisella tarsalis

Coleoptera

Dytiscidae

Oreodytes sp.

CRUSTACEANS

Amphipoda

Hyalellidae

Hyalella sp.

Ostracoda sp.

Oligochaeta

various undetermined spp.

Hirudinea

Helobdella stagnalis

MOLLUSKS

Bivalvia

Corbicula fluminea

Gastropoda

Stagnicola sp.

Physa sp.

Standing crop biomass

Total benthic invertebrate biomass estimates in Utah Lake in 2016 was staggering. We estimate at any one time during the 2016 sampling season there were between 790 and 3210 tons (U.S. short tons) of wet weight benthic invertebrate standing crop biomass in the lake (Table 15). During peak growth in late summer there could easily have been 6000 tons (90^{th} centile)(Table 15).

Table 15. Estimated benthic macroinvertebrate standing crop biomass (wet weight) in 2016. (Corisella sp. removed)

		Entire Utah Lake		
Percentiles	g/m^2	kg	lb	U.S. short tons
1%	0.04	16,361	36,070	18
5%	0.47	180,120	397,096	199
10%	0.67	253,743	**559,406**	**280**
25%	1.89	719,890	1,587,084	794
50%	5.03	1,910,118	**4,211,084**	**2,106**
75%	7.66	2,912,284	6,420,478	3,210
90%	14.50	5,511,854	**12,151,544**	**6,076**
95%	18.85	7,163,000	15,791,693	7,896
99%	43.25	16,436,881	36,237,077	18,119

Standing crop biomass estimates are averages for the entire lake. Results that follow show that biomass was not uniform throughout the lake or during different time periods. Also, these were not estimates of secondary production, which is calculated on a per unit time typically biomass per day. In some of the following results we hint at production estimates and in future analyses we will make more formal estimates of production.

Provo Bay (center) and Lincoln Beach sampling sites had significantly greater benthic invertebrate biomass than the other locations (Figure 22). Our research on other aspects of Provo Bay including sediments, chemistry, flows and plankton and our field experience leads us to conclude that Provo Bay is a unique ecosystem (see section, Provo Bay: Unique Ecosystem). The other sites on Utah Lake had roughly similar amounts of benthic invertebrate biomass (Figure 22).

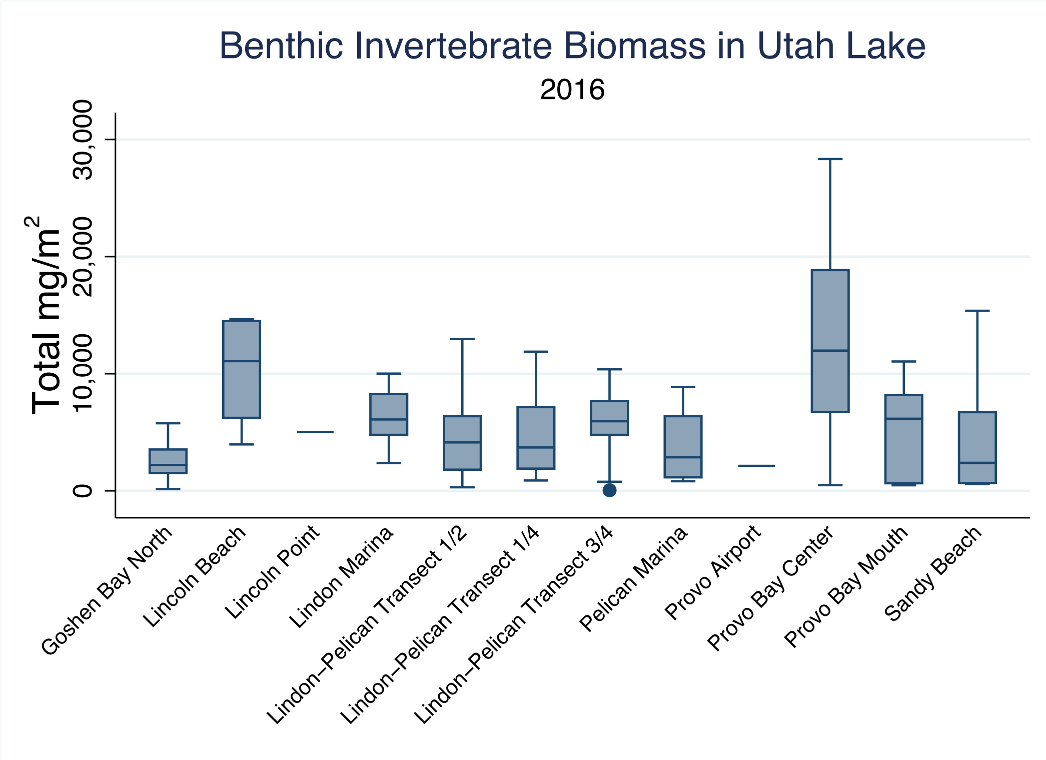

Figure 22. Benthic invertebrate biomass (mg/m^2) in Utah Lake at twelve sampling sites.

Benthic biomass for all of Utah Lake was dominated by three taxa; *Chironomus* sp. (midge), *Tanypus* sp.(midge), and Oligochaeta (segmented worms)(Figure 4). Other taxa made up only abut 1% of total biomass (Figure 4).

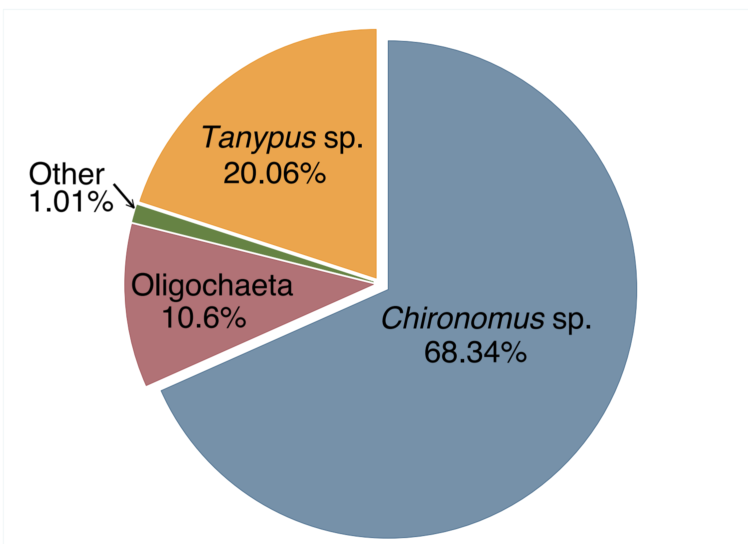

Figure 23. Percent benthic macroinvertebrate biomass at all site in Utah Lake. Other category includes: Corbicula, other Chironomidae, Hyalella, Helobdella, Oreodytes, Physa, Stagnicola , Tipulidae sp., Tabanidae sp. and Ostracoda

There was a major difference between percentage biomass of benthic invertebrates in Provo Bay and the rest of Utah Lake. Provo Bay was dominated by both *Chironomus* sp. and *Tanypus* sp. with *Tanypus* sp. being the most dominant, about 55% (Figure 24), whereas the rest of the lake was dominated by *Chironomus* sp. with almost 80% of the total biomass (Figure 25).

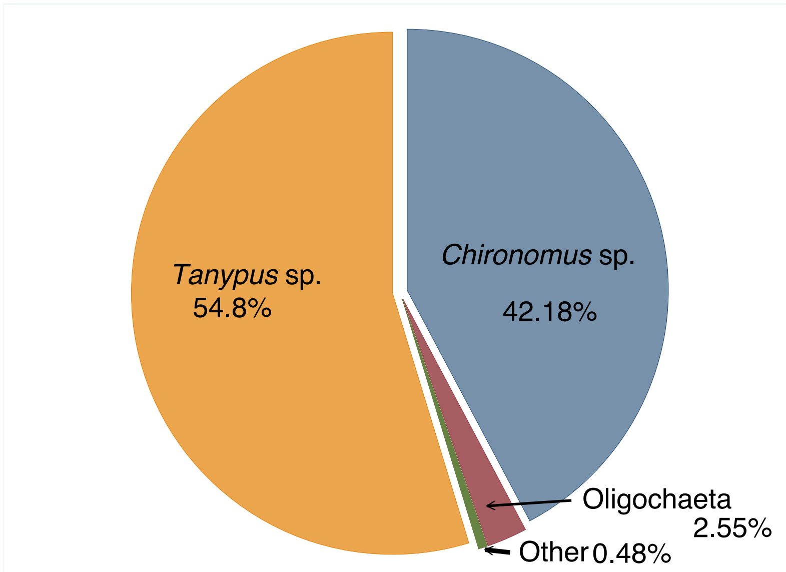

Figure 24. Percent benthic macroinvertebrate biomass in Provo Bay (center site).

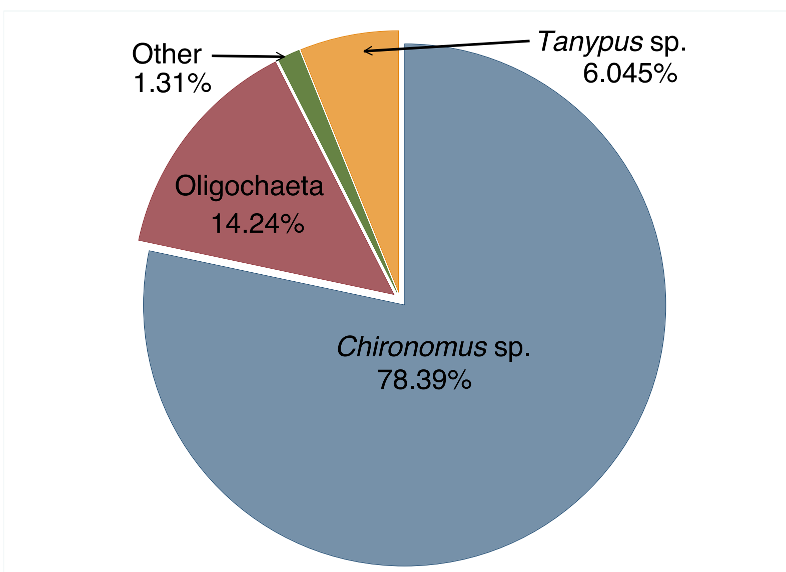

Figure 25. Percent benthic macroinvertebrate biomass in Utah Lake not including Provo Bay (center).

The Mighty Midge, Chironomus sp.

Chironomus sp. was by far the most dominant benthic invertebrate in Utah Lake, a close second in Provo Bay. This taxon had relatively similar biomass throughout the lake including Provo Bay however, its biomass was greatest at Lincoln Beach and lowest at Goshen Bay North and Sandy Beach (Figure 26). Lincoln Beach sediments have an abundance of organic material, whereas Goshen Bay North and Sandy Beach site sediments were mostly composed of inorganic materials, i.e. gravel and or sand. Midges, including *Chironomus* sp. often use organic material as a food source. Further analyses are required to determine preferred food items.

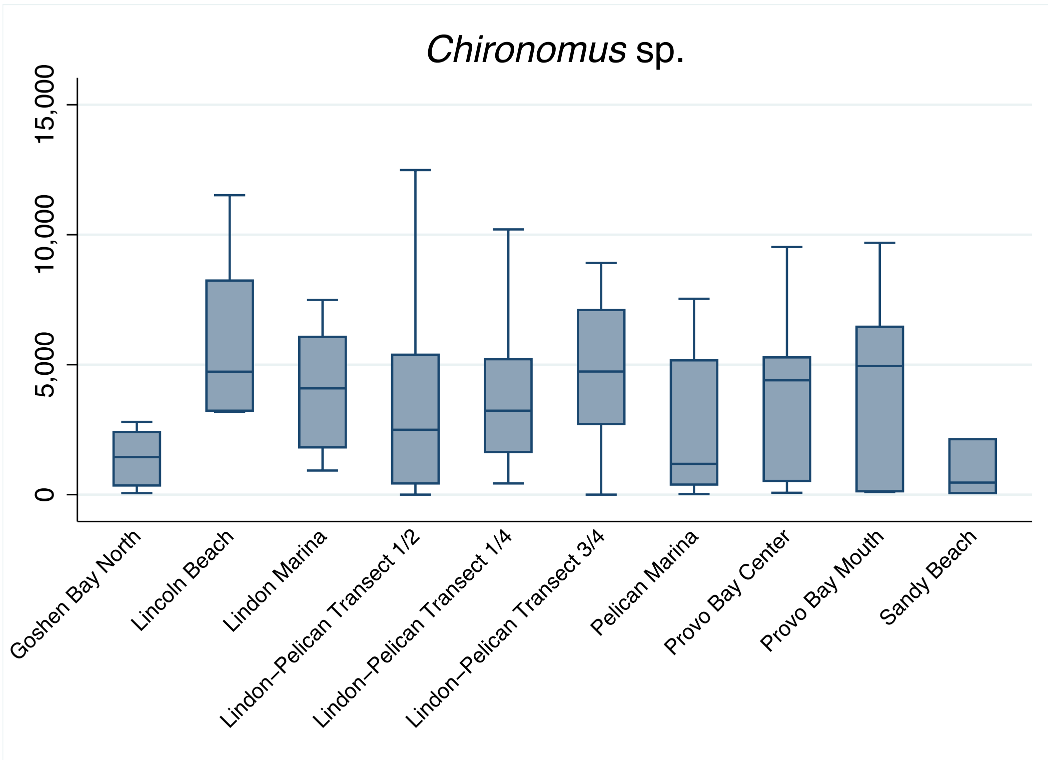

Figure 26. Chironomus sp. standing crop biomass (mg/m^2) in Utah Lake at each study site, 2016.

One of our working hypotheses was that midge biomass would be less in the middle of Utah Lake than locations closer to shorelines because more adult midges would drop eggs closer to shore due to flight distance restrictions. Although midges are relatively good flyers compared to mayflies they are not known as long distance dispersers and have a difficult time negotiating strong winds. Our preliminary results suggest that this is possibly the case although we did not find any significant differences in *Chironomus* sp. biomass in the middle of our transect site, L-P ½ compared with the other Lindon-Pelican transects closer to shore (Figure 27). Pelican Marina

(PM) had the lowest *Chironomus* sp. biomass of our lake transect sites but this was likely due to substrate mostly comprised of old broken mollusk shells, poor midge larvae habitat. If we exclude Pelican Marina there is more support for this hypothesis (Figure 27) but again, this is not conclusive.

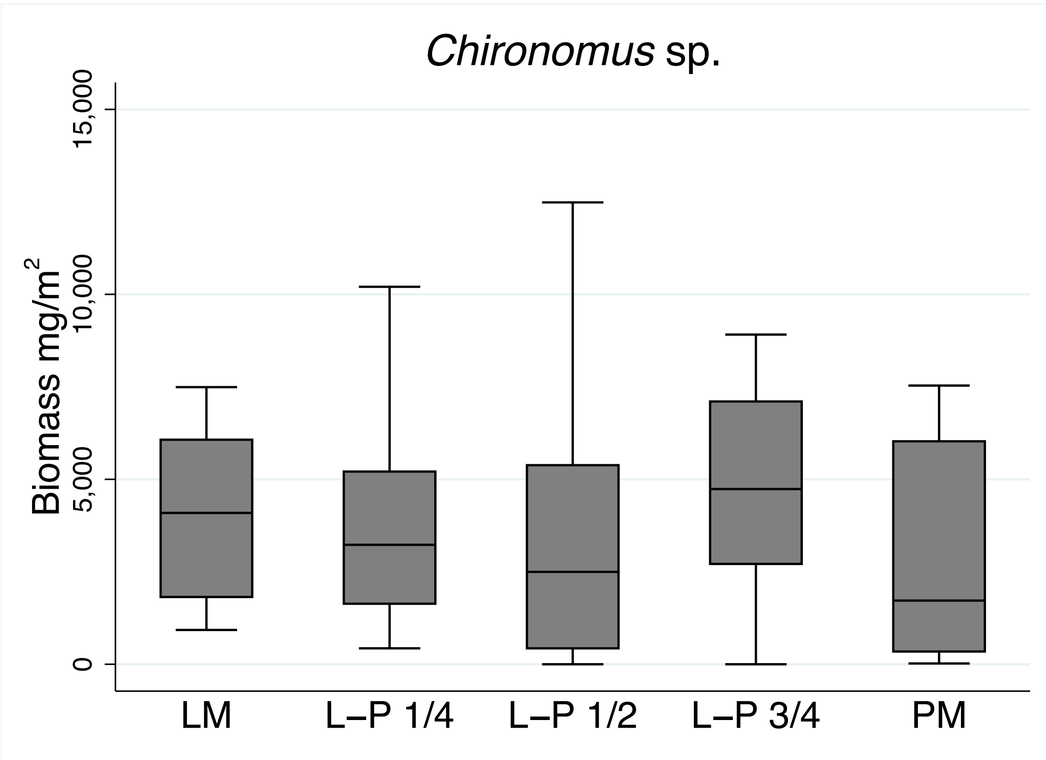

Figure 27. Comparison of Chironomus sp. biomass at our lake transect sites, Lindon-Pelican. LM = Lindon Marina, PM = Pelican Marina, L-P sites = distances from shore along the transect with L-P 1/2 being the middle of Utah Lake transect.

Chironomus sp. biomass varied from June through November with peak biomass occurring in late August early September, and the lowest biomass in early August and November (Figure 28). Understanding these fluctuations in biomass are critically important to their role in HABs (see section: Benthic Macroinvertebrates and HABs). Unfortunately, we were unable to collect benthic samples during most of July due to lake closure because of presumed HAB health hazards. This was very unfortunately because data collected during the algal blooms would have provided invaluable in our understanding of the relationships between *Chironomus* sp. and HABs.

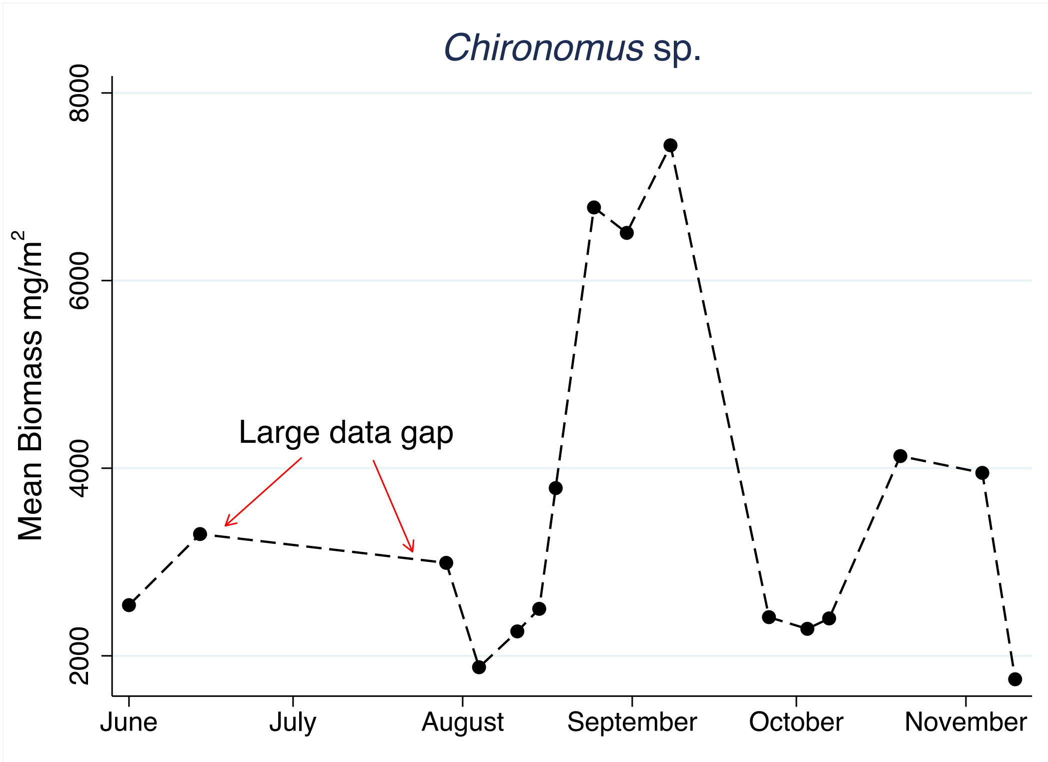

Figure 28. Lakewide mean biomass estimates of Chironomus sp. from June to November, 2016. A critical data gap occurred from late June through July due to lake closure.

Chironomus sp. Generation Times

It is also important to determine generation times of *Chironomus* sp. for understanding food web dynamics and their role in HABs. Our preliminary results suggest that *Chironomus* sp. larvae remain in the last, 4th instar much longer than the 1st and 2nd instars (Figure 29), which is typical. There was an observable generation cycle however there also appeared to be unsynchronized overlapping generation times at different locations in the lake (Figure 30and Appendix 14). We need to evaluate these results more carefully and after the 2017 field season, especially in relation to HABs. For example, *Chironomus* sp. biomass was lowest in early August, particularly on August 11 (Figure 28) and we did not find any early instars but mostly last (4th) instars and pupae on this date (Figure 30). This suggest that a major hatch occurred shortly before August 11 and that many larvae were about to pupate or pupating and a hatch was imminent or continuing. This could be a result of ample phytoplankton food resource availability coinciding with the HAB in July. There also seemed to be a cycle occurring as evidence by examining 1st and 2nd instars and/or examining 4th instars proportions shown in Figure 30. Further detailed examination is needed after collections in 2017.

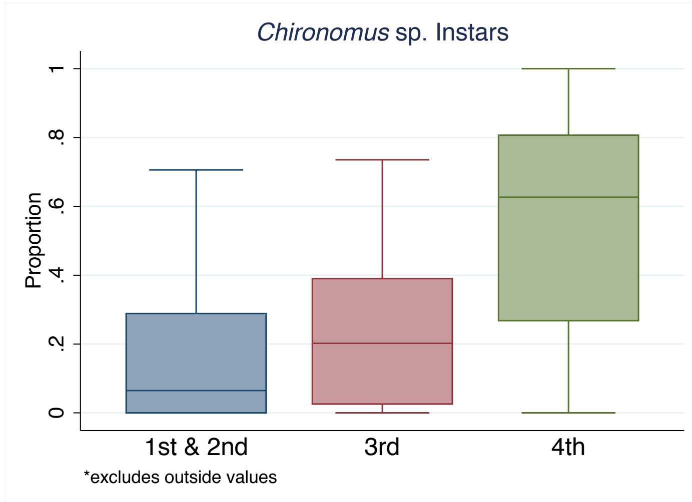

Figure 29. Proportion of Chironomus sp. larval instars in Utah Lake (excluding Provo Bay), for the entire sample season June through November 2016. Significantly more 4th instars were present compared to 1rst and 2nd instars. The ecological or sampling method bias cause for this difference is being examined

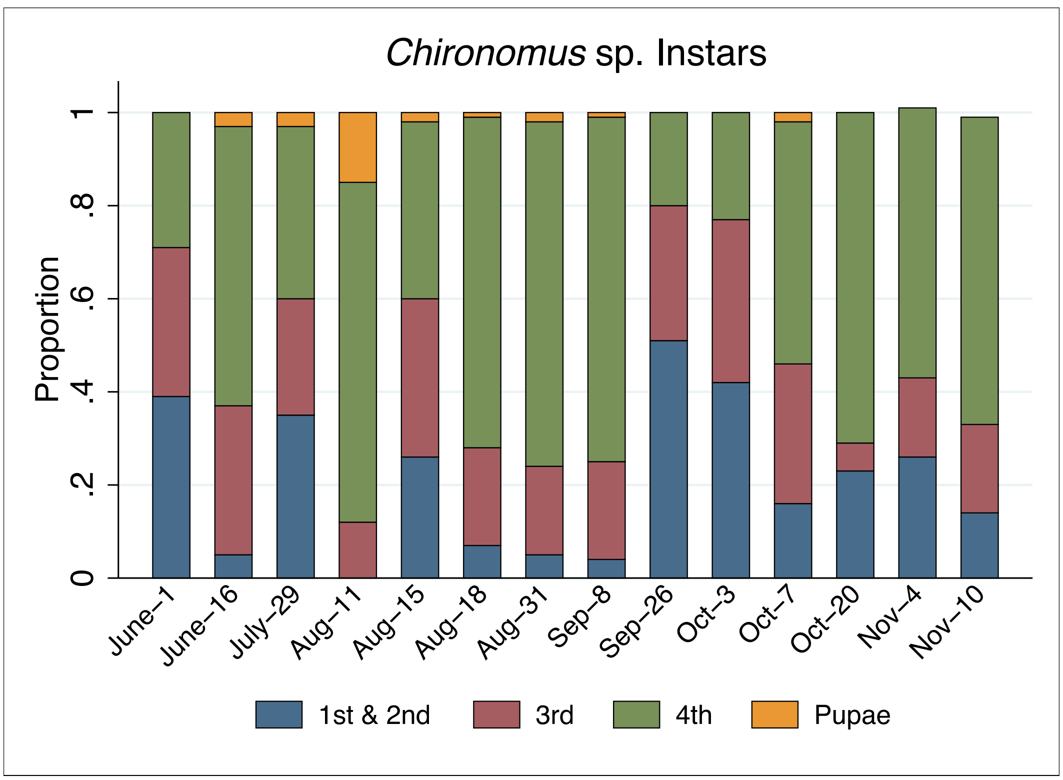

Figure 30.Proportion Chironomus sp. instars by dates in 2016 based on means, exclusive of Provo Bay center samples.

Generation times of a related species, *Chironomus riparius* was reported to be 28 days under lab culture by Postma and Davids 1994. This is probably similar to Utah Lake *Chironomus* sp. generation times during the main growing season (Figure 30). Also, tube dwelling *Chironomus* sp. are most likely the chironomid taxon filter-feeding on phytoplankton outside of Provo Bay where HABs predominantly occur. Likewise, its absence from tubes during adult and egg stages could have a noticeable effect on HABs (see section: Benthic Macroinvertebrates and HABs).

Note: We were surprised that there were significantly more 4th instar larvae than 1st and 2nd. This is not typically the case in population dynamics where there are often many more younger individuals than older due to higher mortality in the younger size/age classes. Our first thought was that many smaller larvae were getting caught in the 500-um mesh net when field washing sediments out of the net. Many individuals got caught in the mesh and we end up picking them with forceps but some were broken and were lost. Use of the Ekman dredge in the deeper water collected far fewer individuals than the kick net in Provo Bay, so the proportion of early instar loss may have been much greater using the Ekman. Provo Bay samples produced many more individuals and the proportion early instar loss due to field washing would have been much less because the large number of invertebrates in the sample 'balled up' into clumps making it easier to remove from the net. However, results of instar groupings were nearly the same from Utah Lake samples that excluded Provo Bay and samples collected only from Provo Bay suggesting that field sampling methods did not overly bias towards larger individuals. Another possibility for far fewer early instar *Chironomus* sp. being analyzed was lab sorting methods, particularly subsampling which can bias towards larger individuals. We will increase our field and lab quality controls in our 2017 season to examine this possiblity. If results are similar in 2017, we will continue to cautiously assume that indeed smaller sized early instar *Chironomus* sp. larvae are often less proportionally abundant due their rapid growth and transition into larger instars.

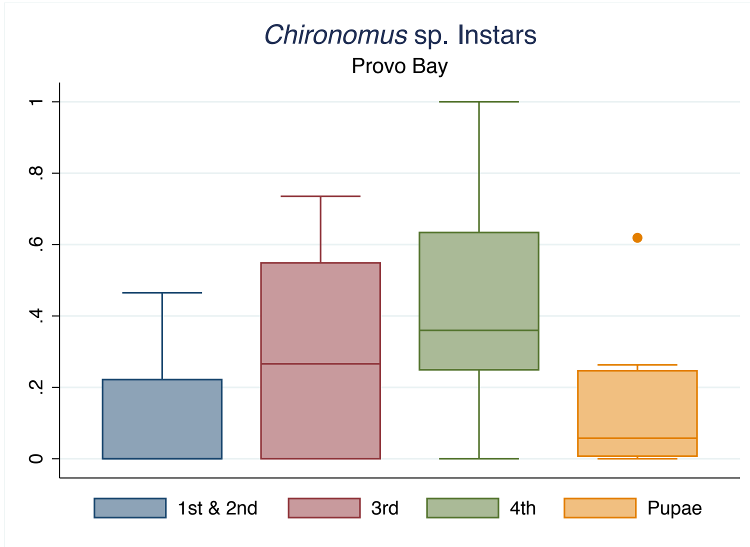

Figure 31. Proportion of Chironomus sp. larval instars in Provo Bay samples, for the entire sample season June through November 2016. Significantly more 4th instars were present compared to 1rst and 2nd instars. Significantly more 4th instars were present compared to 1rst and 2nd instars. The ecological or sampling method bias cause for this difference is being examined

Tanypus sp., second in command

Although *Chironomus* sp. was by far the most dominant benthic invertebrate taxon in most of Utah Lake (Figure 23), *Tanypus* sp. dominated Provo Bay benthos and had about 10% more biomass than *Chironomus* sp. in the bay (Figure 24 and Figure 32). This midge taxon has a different feeding strategy than *Chironomus* sp. and predominantly feeds on benthic algae and detritus. USEPA lists *Tanypus* sp. as either a predator or omnivore but our data from Great Salt Lake wetlands shows it primarily grazes on diatoms there (Figure 34 courtesy of Brett Marshall at River Continuum Concepts). USEPA functional feeding group designation was based on very limited anecdotal evidence and should be adjusted accordingly (Brett Marshall, River Continuum Concepts, personal communication). The dominance of *Tanypus* sp. in Provo Bay is a clear indicator of how the bay is ecologically unique compared with other portions of Utah Lake (Provo Bay: Unique Ecosystem).

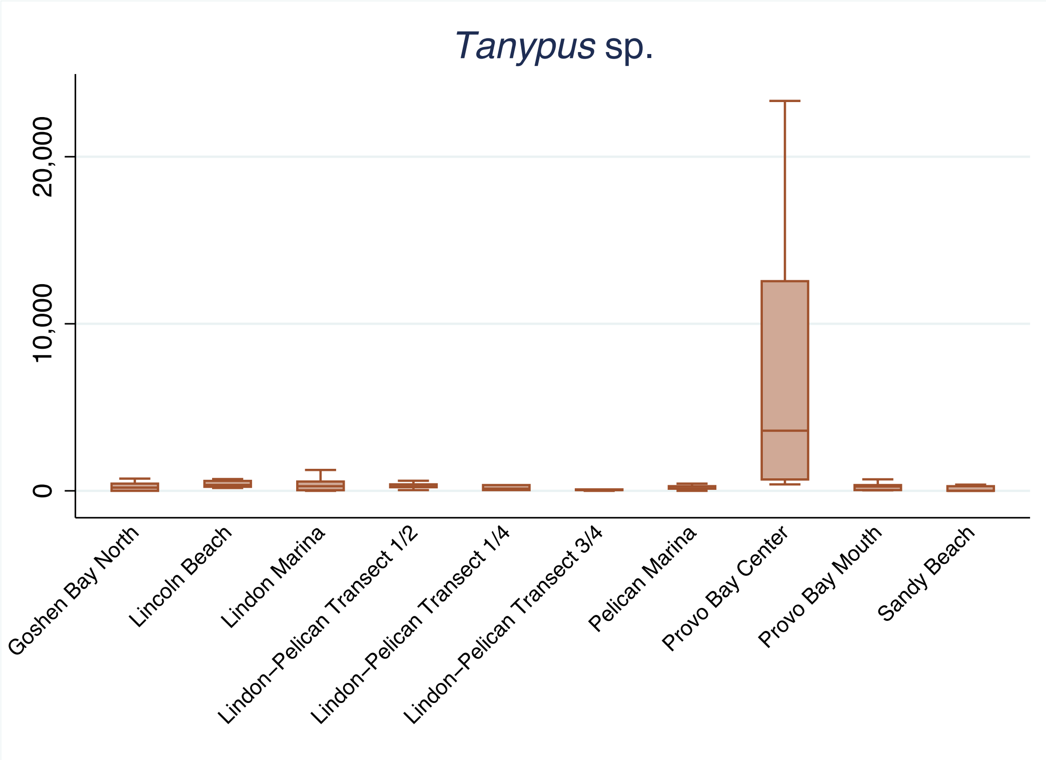

Figure 32. Tanypus sp. standing crop biomass (mg/m²) in Utah Lake at each study site, 2016.

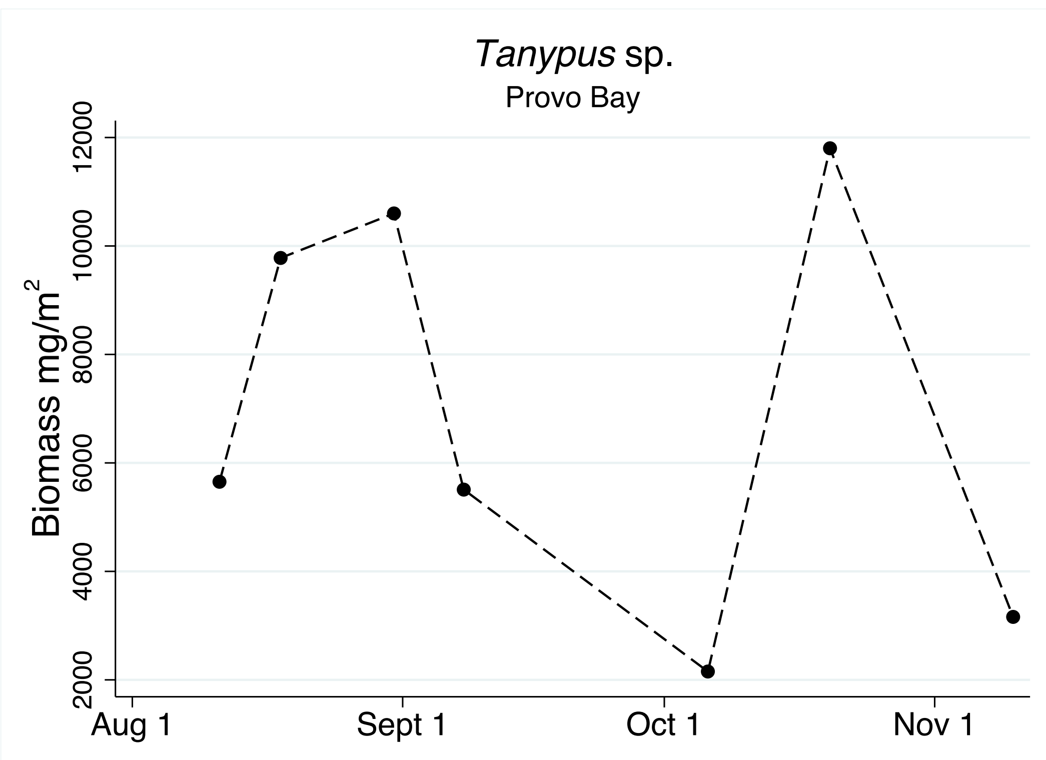

Figure 33. Biomass estimates of Tanypus sp. from August to November, 2016.

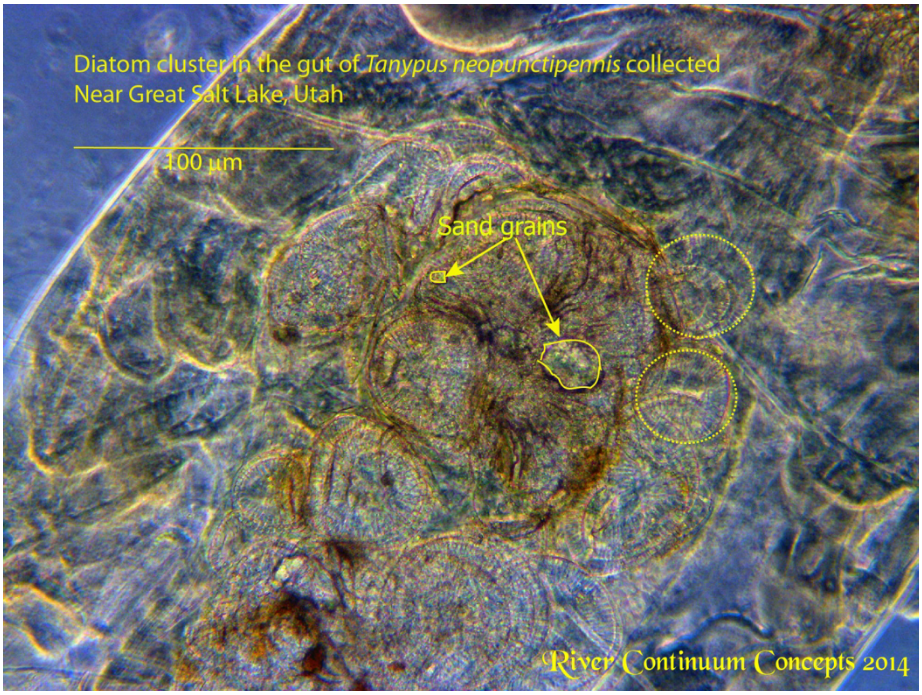

Figure 34. In this slide mounted Tanypus sp. midge, the individual diatom cells can be observed within the midges gut. Midge was collected from a Great Salt Lake wetland in 2014.

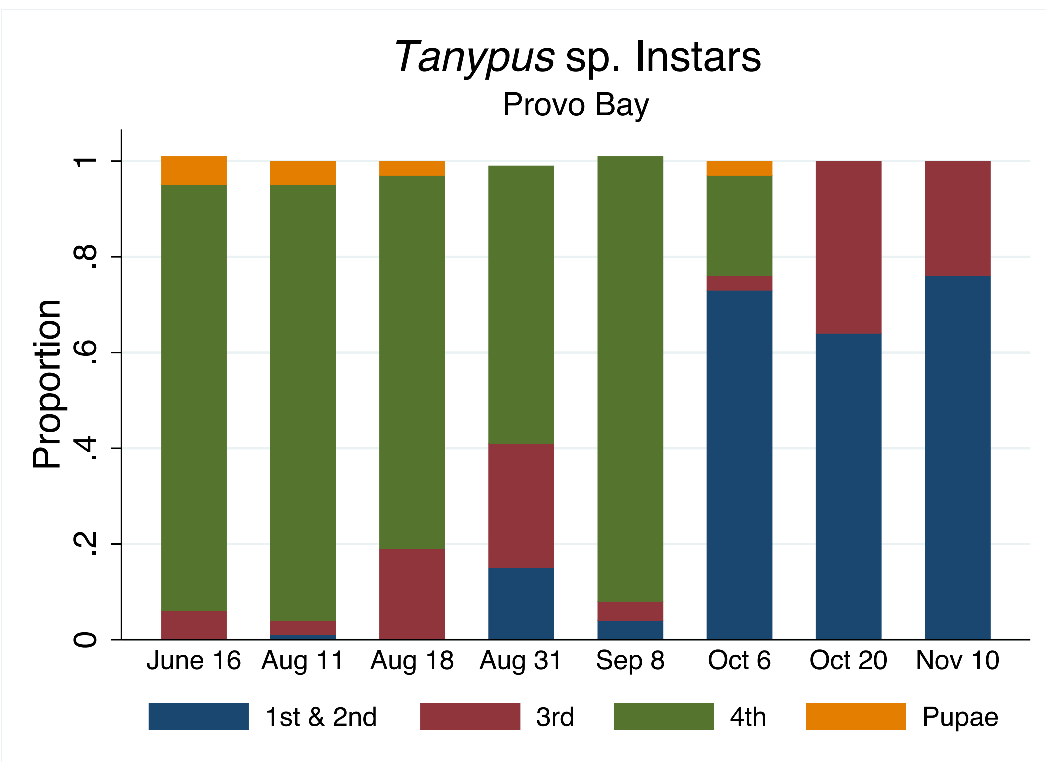

Figure 35. Proportion Tanypus sp. instars by dates in 2016

3rd place, Oligochaeta

Overall, the third most dominant taxon (wet weight biomass) in Utah Lake was the segmented worm, Oligochaeta (Figure 23). However, oligochaetes were the second most dominant in sections of Utah Lake outside of Provo Bay (Figure 24 and Figure 25). We did not identify oligochaetes beyond this taxonomic resolution however, others (Spencer and Denton 2003) have reported there to be 16 species of oligochaetes in the Family Naididae in the lake. The role of oligochaetes is critical for sediment nutrient cycling and respiration in the lake given their large biomass throughout the lake and should not be under estimated (Baranov et al. 2016).

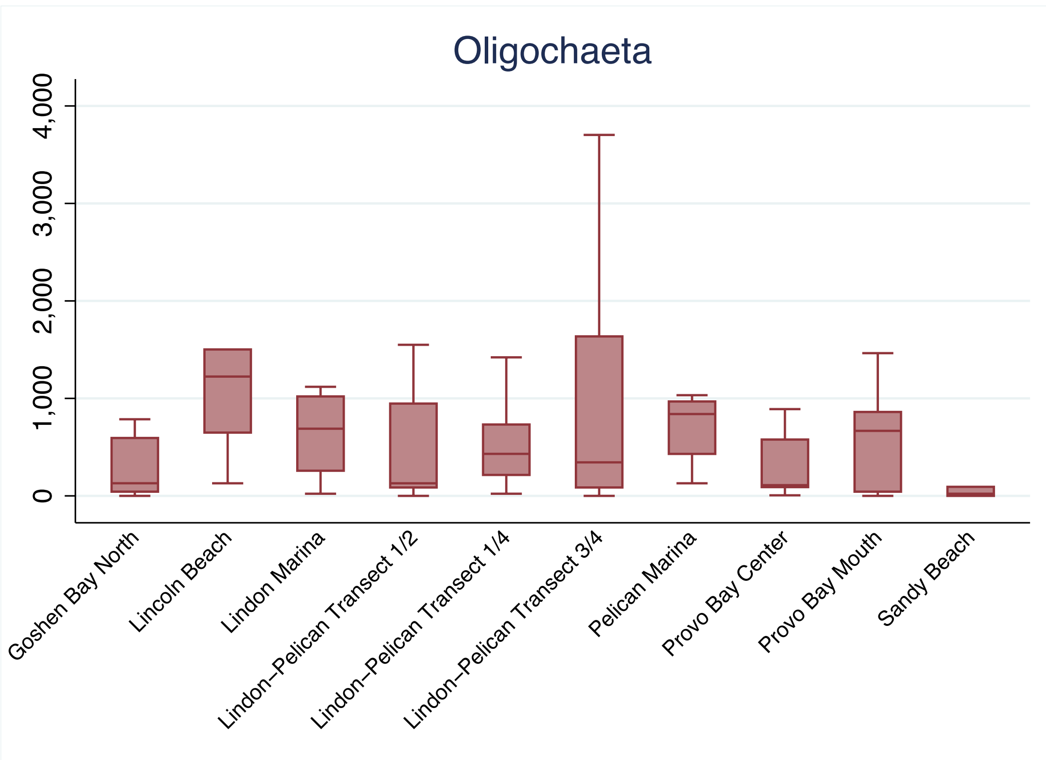

Figure 36. Oligochaeta standing crop biomass (mg/m^2) in Utah Lake at each study site, 2016.

Provo Bay: Unique Ecosystem

Provo Bay obviously produced greater benthic biomass than the other sites, except for Lincoln Beach (Figure 25), which also had a large amount of organic matter. However, as stated by us and other Utah Lake researchers numerous times; Provo Bay functions as a sheet flow wetland and is ecologically much different than other sections of Utah Lake. The midge, *Tanypus* sp. dominated the Provo Bay benthic assemblage and occurred at considerably and significantly greater biomass levels than any other sites in the lake (Figure 23, Figure 24, and Figure 25). In addition, Provo Bay was the only site where we collected live snails (Gastropods) including two taxa, *Stagnicola* sp. and *Physella* sp. although, we have found these taxa in the spring tributaries adjacent to the lake outside of Provo Bay. Individual snails and their trails were also clearly visible from our airboat when stopped for sample collection in the bay. These snails are scrapers and indicate an abundance of benthic algae growth and detritus based on benthic algae decay, which is uncommon in other parts of the lake.

Benthic Invertebrate Diversity vs. Biomass and Production

Utah Lake benthic invertebrate fauna is extremely depauperate. Three taxa [two midge (chironomid) taxa and one worm (oligochaete) taxon] accounted for almost 99% of total biomass. Dominance by only a few taxa, particularly midges and worms, is a classic indication of stress. Reasons for this low diversity are numerous and have been discussed by others (Carter 2003, Fuhriman et al. 1981, Janetski 1990) and include: shallow water with easily wind disturbed fine sediments that remain suspended for long periods of time and maintain high turbidity for most of the year except when ice covered. Other factors include mostly homogenous substrates, either fine 'ooze' in the main part of the lake (Barnes 1981) or hard packed, nearly impenetrable clay dominated sediments along wind swept shorelines. In addition, Utah Lake is slightly saline and eutrophic both of which can reduce or alter diversity. The lake has also historically been mismanaged and abused by residents.

Contrarily, under the present state, Utah Lake benthos are highly productive. What it lacks in diversity, it makes up for in productivity. Our standing crop estimates of approximately 2 to 15 mg/m^2 (Table 1) suggest very high secondary productivity. Our preliminary analyses suggest that the dominant midge, *Chironomus* sp. may have a generation time of < 1 month during warm water conditions that prevail from June through September (Figure 11). If this estimate of generation times is correct, then secondary production in Utah Lake can easily be between 800 and 6000 tons (wet weight)/month (Table 1). This high secondary production readily supports the more than 10 million pounds of carp reported to occur in the lake with a controlled harvest of more than 3 million in 2016 and the tens of thousands of resident and migratory birds that depend on this constant supply of nutritious food resource. Midges and worms are some of the most easily digestible and protein rich freshwater benthic invertebrates available to predators.

Midge larvae and worms are 50 to 60% protein and have no hard difficult to digest exoskeletons. Midges are also easily captured both as larvae and aerial adults. Thus, their food resource energy efficiency is vastly superior to other faster moving, thick chitinous shelled, benthic invertebrate taxa.

Benthic Macroinvertebrates and HABs

The relationship between benthic macroinvertebrates, particularly worms and midges, and harmful algal blooms has received very little attention. In this section, we discuss the latest science on just how important these interactions are to Utah Lake HABs.

For several decades it has been recognized that anoxia is a pre-condition for cyanobacteria blooms in eutrophic waters (Trimbee and Prepas 1988) and that warm temperatures and stable water columns promote anoxia (Paerl, 1988; Zhang & Prepas, 1996). However, the role of Fe in cyanobacteria blooms has been severely underappreciated and the role of midge (Chironomidae) larvae in regulating Fe availability has been even less so.

Anoxia and Fe

Molot et al. (2014) proposed that the role of anoxia and ferrous iron was critical for cyanobacteria bloom formation. Their model can be summarized as follows:

> "The model has several critical concepts: (i) P regulates biomass and productivity in fresh waters until excessive loading renders a system N-limited or light-limited, but it is the availability of ferrous ions (Fe^{2+}) that regulates the ability of cyanobacteria to compete with its eukaryotic competitors; (ii) Fe^{2+} diffusing from anoxic sediments is a major Fe source for cyanobacteria, which acquire it by migrating downwards into Fe^{2+}-rich anoxic waters from oxygenated waters; and (iii) subsequent cyanobacterial siderophore production provides a supply of Fe^{3+} for reduction at cyanobacteria cell membranes that leads to very low Fe^{3+} concentrations in the mixing zone.
>
> When light and temperature are physiologically suitable for cyanobacteria growth, bloom onset is regulated by the onset of internal Fe^{2+} loading which in turn is controlled by anoxia, reducible Fe content of surface sediments and sulphate reduction rate."

Figure 37 (taken from Molot et al. 2014) illustrates this concept.

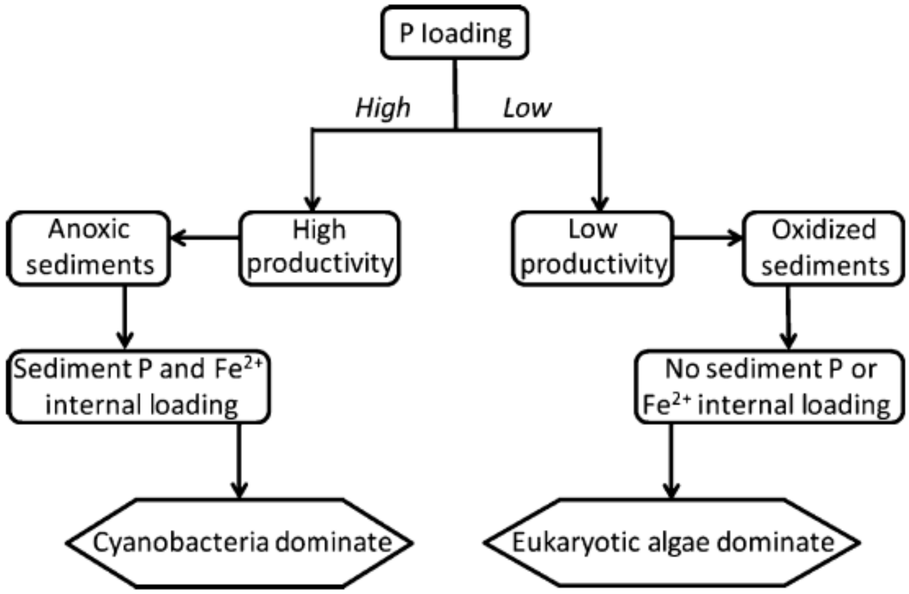

Figure 37. Simplified conceptual diagram of the modified phosphorus eutrophication model of cyanobacteria bloom formation for systems lacking naturally anoxic surficial sediments. The only factor controlling Fe^{2+} production shown here is anoxia at the sediment water interface.

Figure 38 (taken directly from Molot et al. 2014) illustrates the processes that promote Fe delivery to cyanobacteria and thereby promote cyanobacteria dominance in lakes.

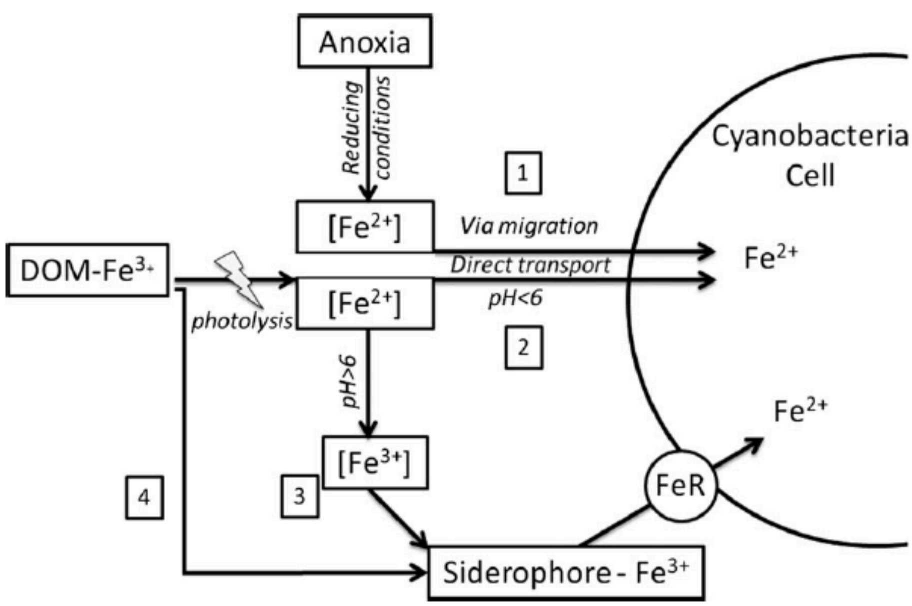

Figure 38. Anoxia: systems with anoxic sediments will experience Fe^{2+} flux into anoxic waters. Migrating cyanobacteria can acquire Fe^{2+} for direct transport into cells. (2) Photoreduction: DOM-Fe^{3+} can be photo-reduced, giving rise to Fe^{2+} that is available for direct Fe^{2+} transport into phytoplankton cells, but the transport rate is pH dependent. Acidity affects rates of abiotic oxidation by dissolved O_2 and at pH <6 Fe re-oxidation may be low enough to give rise to a pool of transportable Fe^{2+}. At higher pH, much of it is probably re-oxidised before transport. (3) and (4) Fe-scavenging (or acquisition) system: siderophores are produced by cyanobacteria that can (3) bind free soluble Fe^{3+} and (4) cleave Fe^{3+} from DOM complexes. Scavenged Fe^{3+} is then

delivered to the cell membrane, creating a pool of Fe only accessible by cyanobacteria. Fe^{3+} is reduced by the Fe reducing system (FeR) before transport across the inner membrane. The Fe^{2+} pool is shown as two separate pools – in anoxic waters (internal loading) and in the mixing layer (photo-reduction).

Midge larvae

Midge larvae can actively oxygenate the sediments near the sediment/water boundary, including converting Fe^{2+} to Fe^{3+} (Holker et al. 2015) (Figure 39). Midge larvae are extremely abundant in Utah Lake sediments (Figure 40) and can thus have a tremendous effect on Fe conversion. However, midge larvae pupate and then leave the lake as adults and are therefore not always present actively aerating the sediment. Subsequently, when larvae pupate and leave sediments as adults, larval tubes collapse and Fe^{3+} reduces to Fe^{2+} (Figure 39).

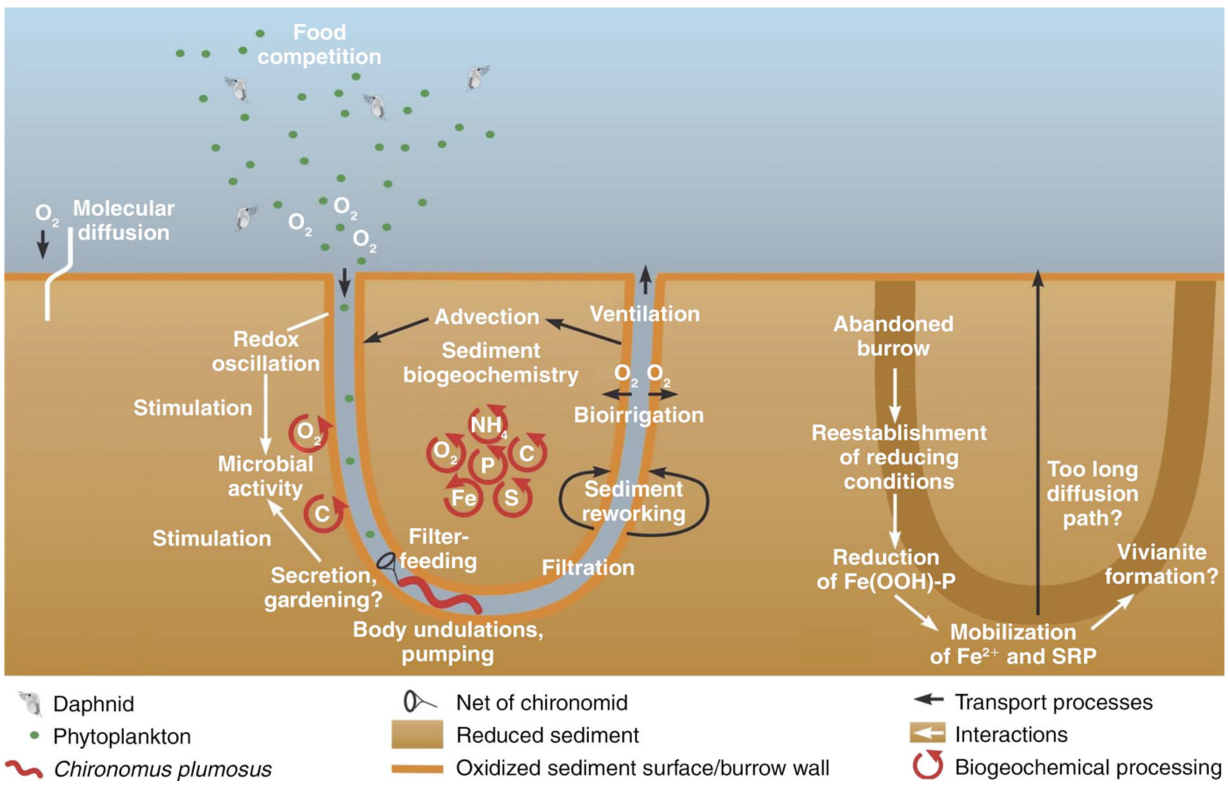

Figure 39. From: Holker et al. 2015. Tube-dwelling invertebrates: tiny ecosystem engineers have large effects in lake ecosystems

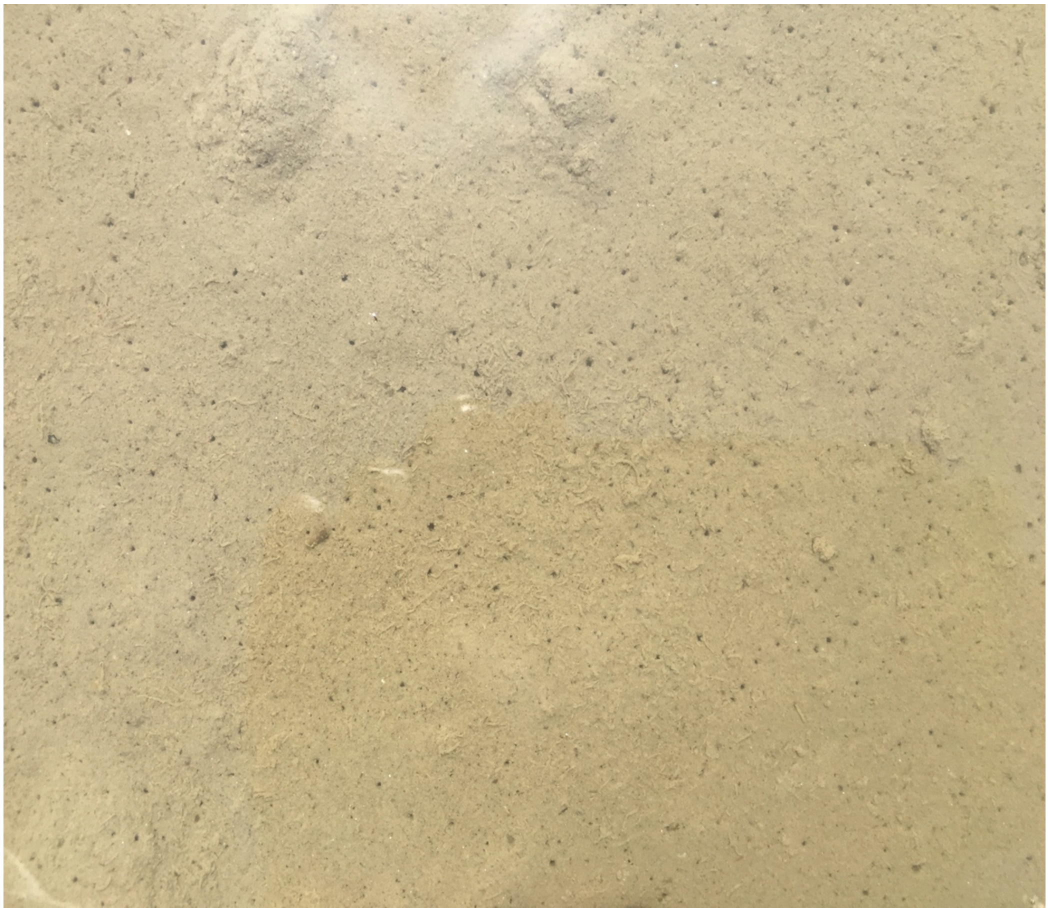

Figure 40. Thousands of midge larvae tubes with midges actively oxygenating the sediments including Fe near the sediment water boundary layer. Tubes are likely either Chironomus sp. or Tanypus sp. or both.

There are several midge taxa in Utah Lake predominately, *Chironomus* sp. and T*anypus* sp., with a few *Cladotanytarsus* sp., and Orthocladinae sp. Each of these midge taxa has different life histories, ecologies and adult emergence times, often with several generations per year and each taxon can affect Fe oxidation and reduction at different rates and times throughout the year.

The peaks and troughs of *Chironomus* sp. and *Tanypus* sp. biomass detailed in this report were larvae not adults. When HABs were most abundant it appeared *Chironomus* sp. had the lowest larvae biomass and was dominated by larger late instars and pupae preparing for emergence. Utah Lake was closed for most of July due to the largest HABs, which also appears to be when *Chironomus* sp. larvae had the least biomass. There is no doubt that there is a strong link between midges and HABs in Utah Lake. However, at this time we do not know if midge larvae activity regulates phytoplankton enough to prevent HABs from occurring when large numbers of larvae are present or if low abundance or absence of midge larvae allow for HABs to prevail. We also do not know what the complimentary and synergistic effects and relationships between midge larvae filtration and zooplankton predation are on HAB intensity.

Acknowledgements

We sincerely appreciate the hard work and dedication of the field crew members who assisted in sampling on the lake: Frank Fluckinger, W.D. Robinson, and others. We are also deeply indebted to our gnarly air boat captain and Utah Lake story teller, Dick Buhler for getting us to locations on the lake where no other pilot dared to venture and to UDNR for generously providing the use of their airboat and fetching Mr. Buhler out of retirement. We could not have completed this research without the taxonomic expertise and dedication of Dr. Larry Gary at Utah Valley University, Orem who spent countless hours processing and viewing our samples under the scope. We also sincerely appreciated Mr. Brett 'The Bug Guy' Marshall at River Continuum Concepts, Manhattan, MT for sage advice on all things midge- like. Finally, we are so very thankful for the funding provided by the wastewater treatment facilities on Utah Lake and other members of the WFWQC.

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Appendix 13. Biomass mg/m^2 (wet weight) of benthic taxa found in Utah Lake, 2016.

Site	Date	Chironomus	Tanypus	other Chironimid	Oligochaeta	Corisella	Hyalella	Ostracoda	Oreodytes	Helobdella	Corbicula	Stagnicola	Physa	Tipulidae	Tabanidae	Ceratopogo	Total mg/sample
Base Camp 1 Provo Bay	8/4/16	100	30	0	0	344	0	0	0	0	0	0	0	0	0	0	474
Goshen Bay	8/4/16	1464	129	0	43	0	0	0	0	0	0	0	0	0	0	0	1636
Goshen Bay 1/4 mi. N of Goose Point	6/1/16	4133	689	0	1550	0	0	0	0	0	0	0	0	0	0	0	6372
Goshen Bay North	7/29/16	742	278	0	0	19	464	22	0	0	0	0	0	0	0	0	1524
Goshen Bay North	8/18/16	1421	431	0	129	0	0	0	0	0	0	0	0	0	0	0	1981
Goshen Bay North	8/31/16	2411	732	0	86	0	0	0	0	0	0	0	0	0	0	0	3229
Goshen Bay North	9/8/16	2799	258	0	474	0	0	0	0	0	0	0	0	0	0	0	3531
Goshen Bay North	9/26/16	352	0	0	130	5194	0	0	0	93	0	0	0	0	0	0	5769
Goshen Bay North	10/3/16	1577	0	<1	594	260	0	0	0	0	0	0	0	0	0	0	2430
Goshen Bay North	10/7/16	56	0	0	37	56	0	0	0	0	0	0	0	0	0	0	148
Goshen Bay North	11/4/16	185	0	0	668	185	0	0	0	19	0	0	0	0	0	0	1057
Goshen Bay South End	6/1/16	947	2454	0	22	0	0	0	0	0	0	0	0	0	0	0	3423
Lincoln Beach	8/15/16	3190	705	0	649	9682	0	<1	278	0	0	0	0	0	0	0	14505
Lincoln Beach	9/26/16	8236	594	0	1502	742	0	0	0	0	0	0	0	0	0	0	11073
Lincoln Beach	10/3/16	4730	241	0	1224	37	0	0	0	0	0	0	0	0	0	0	6232
Lincoln Beach	11/4/16	11519	352	0	2801	0	0	0	0	0	0	0	0	0	0	0	14672
Lincoln Harbor	8/31/16	3229	172	0	129	431	0	0	0	0	0	0	0	0	0	0	3961
Lincoln Point	8/25/16	1391	19	445	74	2560	0	0	0	538	0	0	0	0	0	0	5027
Lindon Marina	6/14/16	4090	0	0	689	0	0	0	0	0	0	0	0	0	0	0	4779
Lindon Marina	8/31/16	5769	517	0	258	0	0	0	0	0	0	0	0	0	0	0	6544
Lindon Marina	10/6/16	7104	732	0	431	0	0	0	0	0	0	0	0	0	0	0	8267

Lindon Marina	10/20/16	7492	22	0	2497	0	0	0	0	0	0	0	0	0	0	0	10010
Lindon Marina	11/10/16	3272	43	0	861	0	0	0	0	0	0	0	0	0	0	0	4176
Lindon Marina 100m	8/4/16	5597	474	0	22	0	0	0	0	0	0	0	0	0	0	0	6092
Lindon Marina 100m	8/18/16	4081	556	0	371	0	0	0	0	0	0	0	0	0	0	0	5008
Lindon Marina 100m	9/8/16	6071	1249	0	1119	0	215	0	0	0	0	0	0	0	0	0	8654
Lindon Marina South	7/29/16	927	37	0	37	4266	0	0	0	0	0	0	0	0	0	0	5268
Lindon Marina South End	8/11/16	1292	172	0	904	0	0	0	0	0	0	0	0	0	0	0	2368
Lindon Marina South End	8/15/16	1818	278	0	1020	3190	37	0	0	0	0	0	0	0	0	0	6344
Lindon-Pelican Transit 1/2	9/8/16	8611	258	0	301	0	0	0	0	0	0	0	0	0	0	0	9171
Lindon-Pelican Transit 1/2	11/10/16	0	258	0	43	0	0	0	0	0	0	0	0	0	0	0	301
Lindon-Pelican Transit 1/4	9/8/16	10204	258	0	1421	0	0	0	0	0	0	0	0	0	0	0	11883
Lindon-Pelican Transit 1/4	10/6/16	3229	129	0	344	0	0	0	0	0	0	0	0	0	0	0	3703
Lindon-Pelican Transit 1/4	11/10/16	1636	43	0	215	0	0	0	0	0	0	0	0	0	0	0	1894
Lindon-Pelican Transit 2/4	10/6/16	1292	431	0	86	0	0	0	0	0	0	0	0	0	0	0	1808
Lindon-Pelican Transit 3/4	9/8/16	8697	43	0	1636	0	0	0	0	0	0	0	0	0	0	0	10376
Lindon-Pelican Transit 3/4	10/6/16	646	43	0	86	0	0	0	0	0	0	0	0	0	0	0	775
Lindon-Pelican Transit 3/4	11/10/16	0	0	0	43	0	0	0	0	0	0	0	0	0	0	0	43
Lindon-Saratoga Transit 1/2	8/4/16	0	603	0	0	0	0	0	0	0	0	0	0	0	0	0	603
Lindon-Saratoga Transit 1/2	8/11/16	431	172	0	3531	0	0	0	0	0	0	0	0	0	0	0	4133
Lindon-Saratoga Transit 1/2	8/18/16	5382	43	0	947	0	0	0	0	0	0	0	0	0	0	0	6372
Lindon-Saratoga Transit 1/2	8/31/16	12486	388	0	86	0	0	0	0	0	0	0	0	0	0	0	12960
Lindon-Saratoga Transit 1/2	10/20/16	3014	388	0	1550	0	0	0	0	0	0	0	0	0	0	0	4951
Lindon-Saratoga Transit 1/4	8/4/16	818	43	0	22	0	0	0	0	0	0	0	0	0	0	0	883
Lindon-Saratoga Transit 1/4	8/11/16	3444	344	0	431	0	0	0	0	0	0	0	0	0	0	0	4219
Lindon-Saratoga Transit 1/4	8/18/16	431	43	0	431	0	0	0	0	0	0	0	0	0	0	0	904
Lindon-Saratoga Transit 1/4	8/31/16	5210	947	0	990	0	0	0	0	0	0	0	0	0	0	0	7147

Lindon-Saratoga Transit 1/4	10/20/16	7406	344	0	732	0	0	0	0	0	0	0	0	0	0	0	8482
Lindon-Saratoga Transit 3/4	8/4/16	4736	43	0	0	0	0	0	0	0	0	0	0	0	0	0	4779
Lindon-Saratoga Transit 3/4	8/11/16	3875	86	0	3703	0	0	0	0	0	0	0	0	0	0	0	7664
Lindon-Saratoga Transit 3/4	8/18/16	7104	86	0	344	0	0	0	0	0	0	0	0	0	0	0	7535
Lindon-Saratoga Transit 3/4	8/31/16	8913	172	0	689	0	0	0	0	0	0	0	0	0	0	0	9774
Lindon-Saratoga Transit 3/4	10/20/16	2713	344	0	1722	0	0	0	0	0	0	0	0	0	0	0	4779
Middle of Provo Bay	8/11/16	7724	22026	0	100	150	0	0	0	0	0	0	0	0	0	0	30000
Middle of Provo Bay	8/4/16	72	386	0	6	20	0	0	0	0	0	0	0	0	0	0	484
Pelican Bay	8/31/16	7535	301	0	1033	0	0	0	0	0	0	0	0	0	0	0	8869
Pelican Bay	9/8/16	6028	258	0	818	0	0	0	0	0	0	0	0	0	0	0	7104
Pelican Marina	6/14/16	1722	0	0	129	0	0	0	0	0	0	0	0	0	0	0	1851
Pelican Marina	10/6/16	344	43	0	732	0	0	0	0	0	0	0	0	0	0	0	1119
Pelican Marina	10/20/16	22	215	0	904	0	0	0	0	0	0	0	0	0	0	43	1184
Pelican Marina	11/10/16	646	258	0	2971	0	0	0	0	0	0	0	0	0	0	0	3875
Pelican-Lindon Transit 1/4	6/14/16	2411	86	0	215	0	0	0	0	0	0	0	0	0	0	0	2713
Pelican-Lindon Transit 2/4	6/14/16	2497	215	0	129	0	0	0	0	0	0	0	0	0	0	0	2842
Pelican-Lindon Transit 3/4	6/14/16	5769	0	0	172	0	0	0	0	0	0	0	0	0	0	0	5942
Provo Airport	9/26/16	1002	56	0	148	927	0	0	0	0	0	0	0	0	0	0	2133
Provo Bay Center	8/31/16	4400	14400	0	50	0	0	0	0	0	0	0	0	0	0	0	18850
Provo Bay Center	9/8/16	528	10866	0	578	0	0	0	0	0	0	0	0	0	0	0	11972
Provo Bay Center (1-m2 net)	10/6/16	2850	1980	0	890	0	0	0	0	0	0	186	0	0	0	0	5906
Provo Bay Center 1-m2	10/20/16	24600	3600	0	110	20	0	0	0	0	0	0	0	0	0	0	28330
Provo Bay Center 1-m2	11/10/16	5280	680	0	480	0	0	0	0	0	0	0	291	0	0	0	6731
Provo Bay center half-way to millrace	8/11/16	2484	3074	0	80	0	0	0	0	0	0	0	0	0	0	0	5638
Provo Bay Center, 0.5 m2	8/18/16	192	23340	0	880	0	0	0	0	0	0	0	0	0	0	0	24412
Provo Bay East	6/16/16	17658	946	0	185	0	0	0	0	0	0	0	0	0	0	0	18790

Provo Bay Millrace	9/8/16	0	0	215	86	0	0	0	0	0	0	0	0	0	0	0	301
Provo Bay Mouth	9/8/16	3531	517	0	431	0	0	0	0	0	0	0	0	0	0	0	4478
Provo Bay Mouth	10/6/16	6458	258	0	1464	0	0	0	0	0	0	0	0	0	0	0	8181
Provo Bay Mouth	11/10/16	4951	344	0	861	0	0	0	0	0	0	0	0	0	0	0	6157
Provo Bay Neck	9/8/16	15844	861	0	904	0	0	0	0	0	0	0	0	0	0	0	17610
Provo Bay Outlet	6/16/16	129	43	0	43	431	0	0	0	0	0	0	0	0	0	0	646
Provo Bay West	6/16/16	1391	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1391
Sandy Beach	7/29/16	2133	0	19	22	4544	0	0	0	0	0	0	0	0	0	0	6718
Sandy Beach	8/15/16	464	371	0	22	5379	0	0	0	0	0	0	0	0	0	0	6235
Sandy Beach	8/25/16	12168	278	0	0	2838	0	0	93	0	0	0	0	0	0	0	15377
Sandy Beach	9/26/16	56	0	0	0	482	0	0	0	0	0	0	0	37	0	0	575
Sandy Beach	10/3/16	556	0	0	56	1762	0	0	0	0	0	0	0	0	19	0	2393
Sandy Beach	10/7/16	56	19	9	93	1484	0	0	0	0	0	0	0	0	19	9	1688
Sandy Beach	11/4/16	148	0	0	519	0	0	0	0	0	0	0	0	0	0	0	668
Saratoga	8/18/16	4306	431	22	861	22	0	0	0	0	0	0	0	0	0	0	5640
Saratoga Marina/Pelican Point	8/4/16	431	258	0	129	0	0	0	0	0	0	0	0	0	0	0	818
Utah Lake State Park	7/29/16	8161	1391	0	37	33665	0	0	0	0	0	0	0	0	0	0	43255
Utah Lake State Park North	8/15/16	3524	668	0	742	315	0	0	0	0	0	0	0	0	0	0	5249
Utah Lake West 1	8/25/16	0	0	19	185	2875	0	0	0	0	2226	0	0	0	0	0	5305
Utah Lake-American Fork	8/15/16	3506	185	0	742	1150	0	<1	0	0	0	0	0	0	0	0	5583

Appendix 14. Chironomus sp. instar counts in Utah Lake with sample site locations and dates. Results taken directly from report to JRFBWQC by Dr. Larry Gray.

Chironomus instar counts: Utah Lake

Date	Site	1st & 2nd	3rd	4th	Pupae
1-Jun-16	Goshen Bay 1/4 mi. N of Goose Point	17	13	21	0
1-Jun-16	Goshen Bay South End	8	7	3	0
14-Jun-16	Pelican-Lindon Transit 1/4	0	0	4	1
14-Jun-16	Pelican-Lindon Transit 2/4	0	0	3	0
14-Jun-16	Pelican-Lindon Transit 3/4	0	2	4	0
14-Jun-16	Pelican Marina	0	0	2	0
14-Jun-16	Lindon Marina	7	14	3	0
16-Jun-16	Provo Bay East	38	87	216	3
16-Jun-16	Provo Bay West	184	12	0	0
16-Jun-16	Provo Bay Outlet	0	3	0	0
29-Jul-16	Goshen Bay North	13	5	5	0
29-Jul-16	Lindon Marina South	41	7	8	0
29-Jul-16	Utah Lake State Park	0	5	34	5
29-Jul-16	Sandy Beach	9	45	31	0
11-Aug-16	Lindon-Saratoga Transit 1/4	0	3	5	0
11-Aug-16	Lindon-Saratoga Transit 1/2	0	0	1	0
11-Aug-16	Lindon-Saratoga Transit 3/4	0	1	7	1
11-Aug-16	Lindon Marina South End	0	0	1	1

11-Aug-16	Middle of Provo Bay	0	152	316	167
11-Aug-16	Provo Bay center half-way to millrace	0	0	201	60

15-Aug-16	Utah Lake State Park North	7	30	30	0
15-Aug-16	Lincoln Beach	0	32	24	3
15-Aug-16	Sandy Beach	10	9	4	0
15-Aug-16	Lindon Marina South End	22	14	10	0
15-Aug-16	Utah Lake-American Fork	8	0	19	1

18-Aug-16	Lindon-Saratoga Transit 1/4	0	0	1	0
18-Aug-16	Lindon-Saratoga Transit 1/2	0	2	12	0
18-Aug-16	Lindon-Saratoga Transit 3/4	0	4	14	0
18-Aug-16	Lindon Marina 100m	3	7	31	2
18-Aug-16	Saratoga	8	4	12	0
18-Aug-16	Provo Bay Center, 0.5 m^2	0	0	8	13
18-Aug-16	Goshen Bay North	0	4	3	0

31-Aug-16	Lindon-Saratoga Transit 1/4	0	3	7	0
31-Aug-16	Lindon-Saratoga Transit 1/2	4	2	18	0
31-Aug-16	Lindon-Saratoga Transit 3/4	0	1	16	0
31-Aug-16	Lindon Marina	0	0	20	1
31-Aug-16	Pelican Bay	2	6	22	0
31-Aug-16	Provo Bay Center	0	0	200	0
31-Aug-16	Lincoln Harbor	0	4	11	0
31-Aug-16	Goshen Bay North	1	5	4	1

8-Sep-16	Lindon-Pelican Transit 1/4	1	9	10	0
8-Sep-16	Lindon-Pelican Transit 1/2	0	0	17	0
8-Sep-16	Lindon-Pelican Transit 3/4	0	2	15	0
8-Sep-16	Lindon Marina 100m	0	5	14	0
8-Sep-16	Pelican Bay	1	1	17	0
8-Sep-16	Goshen Bay North	0	0	8	1
8-Sep-16	Provo Bay Center	0	50	17	1
8-Sep-16	Provo Bay Mouth	2	13	6	0
8-Sep-16	Provo Bay Neck	4	6	28	0

26-Sep-16	Goshen Bay North	9	7	1	0
26-Sep-16	Provo Airport	45	8	6	0
26-Sep-16	Sandy Beach	2	1	0	0
26-Sep-16	Lincoln Beach	8	37	81	1

3-Oct-16	Goshen Bay North	12	4	1	0
3-Oct-16	Sandy Beach	2	3	1	0
3-Oct-16	Lincoln Beach	32	44	63	1
6-Oct-16	Provo Bay Center (1-m^2 net)	80	501	221	89
6-Oct-16	Provo Bay Mouth	11	66	38	0
6-Oct-16	Lindon-Pelican Transit 1/4	0	1	14	0
6-Oct-16	Lindon-Pelican Transit 2/4	0	0	6	0
6-Oct-16	Lindon-Pelican Transit 3/4	0	0	3	0
6-Oct-16	Lindon Marina	7	7	17	2
6-Oct-16	Pelican Marina	0	1	0	0

7-Oct-16	Goshen Bay North	58	10	5	0
7-Oct-16	Sandy Beach	2	4	3	1

20-Oct-16	Lindon-Saratoga Transit 1/4	0	2	19	0
20-Oct-16	Lindon-Saratoga Transit 1/2	0	0	8	0
20-Oct-16	Lindon-Saratoga Transit 3/4	0	1	6	0
20-Oct-16	Lindon Marina	6	2	31	0
20-Oct-16	Pelican Marina	1	0	0	0
20-Oct-16	Provo Bay Center 1-m^2	4600	3800	4400	200

4-Nov	Goshen Bay North	1	2	1	0
4-Nov	Sandy Beach	1	0	2	0
4-Nov	Lincoln Beach	25	0	109	0

10-Nov	Provo Bay Mouth	3	10	36	0
10-Nov	Provo Bay Center 1-m^2	2120	2440	0	0
10-Nov	Lindon Marina	12	25	20	1
10-Nov	Lindon-Pelican Transit 1/4	0	1	6	0
10-Nov	Pelican Marina	2	0	5	0

Appendix 15. Tanypus sp. instar counts in Utah Lake with sample site locations and dates. Results taken directly from report to JRFBWQC by Dr. Larry Gray.

Tanypus instar counts: Utah Lake

Date	Site	1st & 2nd	3rd	4th	Pupae
1-Jun-16	Goshen Bay 1/4 mi. N of Goose Point	0	0	5	0
1-Jun-16	Goshen Bay South End	56	29	22	2
14-Jun-16	Pelican-Lindon Transit 1/4	0	1	0	0
14-Jun-16	Pelican-Lindon Transit 2/4	0	0	0	1
16-Jun-16	Provo Bay East	0	1	16	1
16-Jun-16	Provo Bay Outlet	0	1	0	0
29-Jul-16	Goshen Bay North	0	1	1	1
29-Jul-16	Lindon Marina South	0	3	2	0
29-Jul-16	Utah Lake State Park	10	4	17	4
11-Aug-16	Lindon-Saratoga Transit 1/4	0	1	3	0
11-Aug-16	Lindon-Saratoga Transit 1/2	0	1	1	0
11-Aug-16	Lindon-Saratoga Transit 3/4	0	0	1	0
11-Aug-16	Lindon Marina South End	0	0	1	1
11-Aug-16	Middle of Provo Bay	100	180	8220	504
11-Aug-16	Provo Bay center half-way to millrace	20	102	1009	20
15-Aug-16	Utah Lake State Park North	5	4	16	3
15-Aug-16	Lincoln Beach	2	4	28	1

15-Aug-16	Sandy Beach	11	6	2	1
15-Aug-16	Lindon Marina South End	18	1	10	0
15-Aug-16	Utah Lake-American Fork	7	5	6	1

18-Aug-16	Lindon-Saratoga Transit 1/4	3	0	0	0
18-Aug-16	Lindon-Saratoga Transit 1/2	0	2	0	0
18-Aug-16	Lindon-Saratoga Transit 3/4	0	0	2	0
18-Aug-16	Lindon Marina 100m	5	11	10	1
18-Aug-16	Saratoga	2	3	10	0
18-Aug-16	Provo Bay Center, 0.5 m^2	40	1883	7603	252
18-Aug-16	Goshen Bay North	2	1	7	0

31-Aug-16	Lindon-Saratoga Transit 1/4	1	2	9	0
31-Aug-16	Lindon-Saratoga Transit 1/2	0	0	5	0
31-Aug-16	Lindon-Saratoga Transit 3/4	0	0	2	0
31-Aug-16	Lindon Marina	0	3	8	0
31-Aug-16	Pelican Bay	0	0	7	0
31-Aug-16	Provo Bay Center	1600	2800	6200	0
31-Aug-16	Lincoln Harbor	1	0	3	0
31-Aug-16	Goshen Bay North	0	2	10	3

8-Sep-16	Lindon-Pelican Transit 1/4	0	0	4	0
8-Sep-16	Lindon-Pelican Transit 1/2	0	0	4	0
8-Sep-16	Lindon-Pelican Transit 3/4	0	0	1	0
8-Sep-16	Lindon Marina 100m	0	2	20	0
8-Sep-16	Pelican Bay	0	0	5	0

8-Sep-16	Goshen Bay North	0	0	5	0
8-Sep-16	Provo Bay Center	200	201	5107	1
8-Sep-16	Provo Bay Mouth	0	1	11	0
8-Sep-16	Provo Bay Neck	0	2	18	1
26-Sep-16	Provo Airport	2	0	0	0
26-Sep-16	Lincoln Beach	1	3	15	1
3-Oct-16	Goshen Bay North	1	0	0	0
3-Oct-16	Lincoln Beach	15	0	33	1
6-Oct-16	Provo Bay Center (1-m^2 net)	1571	61	461	60
6-Oct-16	Provo Bay Mouth	1	0	3	0
6-Oct-16	Lindon-Pelican Transit 1/4	0	2	0	0
6-Oct-16	Lindon-Pelican Transit 2/4	0	0	6	0
6-Oct-16	Lindon-Pelican Transit 3/4	0	1	0	0
6-Oct-16	Lindon Marina	0	1	7	2
6-Oct-16	Pelican Marina	0	0	1	0
7-Oct-16	Sandy Beach	0	0	2	0
20-Oct-16	Lindon-Saratoga Transit 1/4	0	0	5	0
20-Oct-16	Lindon-Saratoga Transit 1/2	0	0	7	0
20-Oct-16	Lindon-Saratoga Transit 3/4	0	0	5	0
20-Oct-16	Lindon Marina	2	0	0	0
20-Oct-16	Pelican Marina	0	7	0	0

20-Oct-16	Provo Bay Center 1-m^2	7600	4200	0	0
4-Nov	Lincoln Beach	15	4	15	0
10-Nov	Provo Bay Mouth	0	1	3	0
10-Nov	Provo Bay Center 1-m^2	2400	760	0	0
10-Nov	Lindon Marina	0	1	0	0
10-Nov	Lindon-Pelican Transit 1/4	0	1	1	0
10-Nov	Lindon-Pelican Transit 1/2	0	3	0	0
10-Nov	Pelican Marina	0	0	3	0