

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/355712261>

SEASONAL PATTERNS OF PHYTOPLANKTON ASSEMBLAGE DENSITIES AND FUNCTIONAL TRAITS IN UTAH LAKE version 2.3

Technical Report · October 2021

CITATIONS

0

READS

126

1 author:



David Richards

OreoHelix Ecological

82 PUBLICATIONS 400 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Toxicity Studies [View project](#)



Freshwater mollusk surveys, status and metapopulation dynamics in Utah with a focus on native mussels [View project](#)

SEASONAL PATTERNS OF PHYTOPLANKTON ASSEMBLAGE DENSITIES AND FUNCTIONAL TRAITS IN UTAH LAKE

A FOODWEB MODEL PREREQUISITE



To
Wasatch Front Water Quality Council, Salt Lake City, UT

By
David C. Richards, Ph.D.



OreoHelix Ecological, Vineyard UT 84059
Phone: 406.580.7816
Email: oreohelix@icloud.com

October 28, 2021

SUMMARY

A comprehensive statistical evaluation of Utah Lake’s phytoplankton assemblages is necessary to understand ecosystem function, ecological interactions, water quality, and to develop relevant food web and watershed models. This technical report builds on our present knowledge of temporal patterns of phytoplankton assemblages in Utah Lake using data collected from 1995 to 2018. Phytoplankton division and genus/species level assemblage analyses were conducted. In addition, functional traits-based analysis that have never been conducted for Utah Lake phytoplankton assemblages, despite functional traits being suggested as the “Holy Grail” for understanding and predicting community processes, were conducted.

11,496 records of data from were evaluated from a UDWQ, USU, and WFWQ combined dataset of Utah Lake phytoplankton samples collected from 1995 to 2018 and processed by Rushforth Phycology. Cell volume (cells m L⁻¹) were the units evaluated. Several community multimetric analyses were used including Non-Metric Multidimensional Scaling, Multiple Response Permutation Procedure, and Indicator Species Analysis. Functional traits values for numerous trait categories were derived from the literature and provided by Rushforth Phycology. Traits were mostly analyzed using Community Weighted Means because there were numerous missing trait values for phytoplankton taxa from Utah Lake.

Results confirm that phytoplankton divisions differed seasonally in Utah Lake following a well understood successional pattern in temperate lakes, however fine detail of taxa responsible for these patterns was not discernable using algal divisions compared to evaluating phytoplankton temporal patterns using genus and species levels.

Species area curve showed that at least 70 samples annually are necessary to fully understand the contribution of phytoplankton assemblages to Utah Lake’s ecosystem functioning and to scientifically manage the lake. However, this level of sampling only occurred in 2016 and 2017. Low values of taxa richness and especially the effective number of taxa and diversity indices confirmed impaired conditions in the lake. Functional traits metric analyses, including colony type, motility type, buoyancy type, environmental distributions, functional trait richness and diversity, chemistry optima, trophic levels, morphological classification, and functional groups confirmed that functional traits can provide much more information than species level analysis alone, even given the limited availability of literature-based trait values for phytoplankton taxa in the lake.

Primary producers are the foundation of the food web. Without a solid understanding of phytoplankton assemblages, food web models will be highly generalized, less predictive, and far less representative of the ecosystem.

This report provides a wealth of useful information needed to best manage Utah Lake’s unique ecosystem including water quality. Continued sample collection and increased data analyses that focus on functional traits analyses is strongly recommended.

Table of Contents

INTRODUCTION	6
JUSTIFICATION.....	7
METHODS.....	7
PHYTOPLANKTON ASSEMBLAGE RELATIONSHIPS.....	8
<i>Phytoplankton Division Assemblages</i>	9
<i>Phytoplankton Taxa Assemblages</i>	9
FUNCTIONAL TRAITS BASED ANALYSIS	10
RESULTS	11
PHYTOPLANKTON DIVISION ASSEMBLAGES	11
ALGAL DIVISION ASSEMBLAGE TEMPORAL RELATIONSHIPS	14
PHYTOPLANKTON TAXA	15
<i>density and occurrences</i>	15
<i>richness and diversity</i>	23
PHYTOPLANKTON TAXA ASSEMBLAGES	27
<i>MRPP</i>	27
<i>Indicator Taxa</i>	28
FUNCTIONAL TRAITS	29
Colony Type	29
Motility Type.....	30
Buoyancy Type.....	31
Environmental Distribution	32
Functional Trait Richness and Diversity	34
Chemistry Optima.....	34
Trophic level functional traits.....	35
<i>Morphological Classification</i>	36
<i>Functional Group (Padisak 2009)</i>	37
DISCUSSION.....	41
FUNCTIONAL TRAITS	41
RELEVANCE TO FOODWEB	42
CONCLUSION	42
RECOMMENDATIONS	43
ACKNOWLEDGEMENTS	43
LITERATURE CITED	44
APPENDICES	48

List of Figures

Figure 1. Total Utah lake phytoplankton survey samples from 1995 to 2018 compiled from DWQ, USU, Ut. CO. Health, and wfwqc data.	7
Figure 2. relationship between algal cells ml ⁻¹ and cell volume (μ^3 /ml).....	8
Figure 3. mean abundances of Algal divisions by month in utah lake using cells/ml.....	12
Figure 4. Relative abundances of three algal divisions in utah lake by month.	13
Figure 5. Densities of three major phytoplankton divisions Bacillariophyta, chlorophyta, and cyanophyta by month. outliers were not plotted.....	14
Figure 6.NMS axis 1 and 2 showing relationships between and among algal divisions in utah lake by month.	15
Figure 7. Species area curve. Derived using relative sorenson distance and beals smoothing of taxa densities. this curve suggests that roughly 75 to 200 samples are required to adequately account for most phytoplankton taxa in utah lake.....	24
Figure 8. Phytplankton taxa richness and diversity indices by months. S: K-W $\chi^2 = 40.12$, 11 df, p = 0.0001; E: K-W $\chi^2 = 55.41$, 11 df, p = 0.0001; D: K-W $\chi^2 = 50.60$, 11 df, p = 0.0001; ENT: K-W $\chi^2 = 47.14$, 11 df, p = 0.0001.....	25
Figure 9. NMS axis 1 and 2 showing relationships between and among phytoplankton taxa in utah lake by month. axis 1 r2 = 0.94, axis 2 r2 = 0.04. several taxa ordinations are shown. for correlations between each taxon and each axis see Appendix 4.	27
Figure 10. Colony type functional traits for phytoplankton taxa in utah lake by month. scc = solitary, coenobial, or colonial.	30
Figure 11. motility type functional traits for phytoplankton in utah lake by month. Low = flagellum absent, moderate =gliding, oscilating, ETC., high = flagella PRESENT.	31
Figure 12. Buoyancy type functional traits for phytoplankton in utah lake by month.....	32
Figure 13. environmental distribution type functional traits for phytoplankton in utah lake by month.....	33
Figure 14. environmental DISTRIBUTION FUNCTIONAL traits for phytoplankton in utah lake by month without na’s.	33
Figure 15. functional trait taxa richness, effective number of taxa (ent), and shannon diversity by month.	34
Figure 16. Chemistry optima functional trait by month.	35
Figure 17. mixotrophic vs. autotrophic functional traits by month.....	36
Figure 18. morphological classification for phytoplankton in utah lake by month.....	37
Figure 19. functional groups of phytoplanton in utah lake by month. from padisak (2009).....	39
Figure 20. NMS ordination of pytoplankton assemblages using genus and species level taxonomy clearly showing seasonal patterns. from richards and miller 2017.....	41

List of Tables

Table 1. List of functional traits evaluated in this technical report.	11
Table 2. Mean cell densities (mg l ⁻¹) for algal divsions by month.	12
Table 3. Cell Densities and number of occurances. Minimum for all taxa = 0. See Appendix 1 for taxa names.	15

Table 4. Twenty most common taxa and their proportional occurrence. N = 778 samples analyzed.22

Table 5. Rare and Uncommon Taxa. n = 1 occurrence = Rare, n = 2 occurrences = uncommon.22

Table 6. Phytoplankton richness and diversity indices by month. median, 25th and 75th percentiles. s = taxa richness, e = evenness, h = shannon diversity, and ent = effective number of taxa (exp(h)).25

Table 7. significant Indicator phytoplankton taxa for months.....28

Table 8. Number of sampling units (SU) and taxa used and their percentages relative to total in the dataset for each functional trait metric. Bold percentages results should be used with caution.29

Table 9. morphological classification functional grouping modified from table 4 of kruk et al. (2010).....36

Table 10. *Trait-separated functional groups of phytoplankton in utah lake (updated from Reynolds, 1997 and padisak, 2009)*.....37

Table 11. Taxa List by Functional Groups (Padisak 2009). Functional groups are in Table 10. Taxa names are in Appendix 1.39

Table 12. Trait-separated functional groups of phytoplankton that were absent or at low densities in utah lake (updated from Reynolds, 1997 and padisak, 2009).....40

List of Appendices

Appendix 1. Utah Lake phytoplankton taxa list with taxon codes used in analyses and algal divisions.....48

Appendix 2. MRPP results for division assemblages.....54

Appendix 4. Correlations of phytoplankton taxa with nms axis 1 and axis 2.61

Appendix 5. List of taxa removed from multivariate phytoplankton taxa assemblage analyses. these taxa occurred in < 5% of the samples. for names of taxa see.....62

Appendix 6. MRPP for phytoplankton taxa by month63

Appendix 7. indicator taxa by month65

INTRODUCTION

A comprehensive statistical evaluation of Utah Lake’s phytoplankton assemblages is necessary to understand ecosystem function, ecological interactions, water quality, and to develop relevant food web and watershed models. Without such information, we will be unable to adequately manage the lake including determining nutrient loads as they relate to algal blooms. This technical report builds on our present knowledge of temporal patterns of phytoplankton assemblages in Utah Lake (Richards et al. 2019, Richards and Miller 2019a, b, Richards 2019a, b, Richards 2018, Richards and Miller 2017) using data collected from 1995 to 2018.

Division level taxonomy of phytoplankton (e.g., Bacillariophyta, Chlorophyta, Cyanophyta, etc.) is often used for some generalized water quality or food web models, but this low-level resolution usefulness has not been evaluated and compared to higher level taxonomy such as genus and species level in Utah Lake. Division and genus/species level assemblage analyses were conducted for this report.

Functional traits¹-based analyses have never been attempted for Utah Lake phytoplankton assemblages despite their recognized importance. Functional traits are increasingly recognized as equally important or superior to taxa-based analyses (Allen and Polimene 2011; Calow 1987; Tilman et al., 1997; Diaz and Cabido, 2001; Petchey et al., 2004; Hooper et al., 2005; Vogt et al., 2010, Hayden et al. 2019, Nock, Vogt, and Beisner 2016, Laliberté and Legendre 2010, Richards et al. 2020). Ecologists have recently suggested that species functional traits, rather than species identity, was a “Holy Grail” for understanding and predicting community processes and can ‘provide a path forward to a unified theory of community ecology’ (Lavorel and Garnier 2002, Wstob y and Wright 2006, McGill et al. 2006, Funk et al. 2016).

Martini et al. 2020 stated that:

“The underlying assumption is that functional grouping would make it easier to link community ecology to biogeochemical processes and biodiversity to ecosystem functioning (Naeem and Wright 2003). Through the study of functional diversity and functional traits, these approaches allow for the quantitative assessment of community or ecosystem resistance or resilience to changes through functional redundancy (Lavorel and Garnier 2002; McGill et al. 2006), which could potentially enhance generality and predictability in future projections of ecosystem function and service provision than the species-centered or taxonomic approaches (Levine 2016).”

Although there are very few reported functional trait values for Utah Lake phytoplankton taxa other than compiled and presented here, this is the first analysis of Utah Lake phytoplankton temporal patterns using functional traits. Taxa based and functional traits-based analyses are also compared in this report.

¹ Functional traits can be defined as different morphological, physiological, and phenological traits that influence the fitness of an individual by affecting its growth, reproduction, and survival (Violle et al., 2007) and role in ecosystem function.

Results from this technical report can be used for future reference, some of which will be used in ongoing Utah Lake food web models.

JUSTIFICATION

We are just beginning to understand the ecology of phytoplankton assemblages in Utah Lake and their role in ecosystem function including water quality and algal blooms. This knowledge is essential if we are to manage nutrient loads and other abiotic and biotic factors necessary to maintain and improve the ecological integrity of the lake.

METHODS

11,496 records of data from were evaluated from a UDWQ, USU, and WFWQ combined dataset of Utah Lake phytoplankton samples collected from 1995 to 2018. Sampling efforts increased substantially starting in 2016 by UDWQ and particularly with WFWQC and peaked in 2017 (Figure 1). Additional data from 2018 to present was not available.

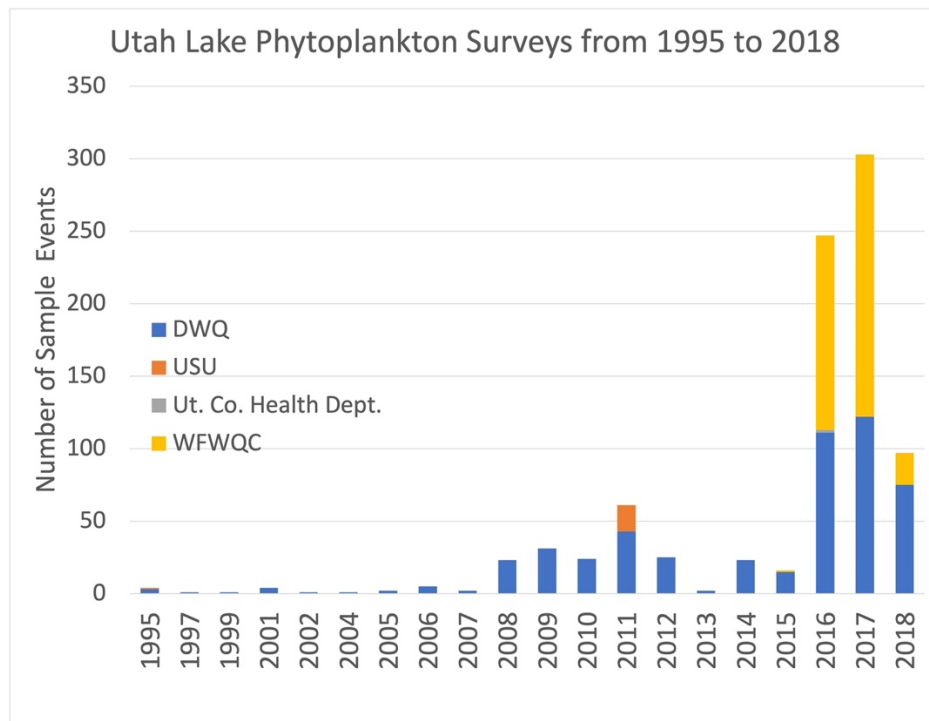


FIGURE 1. TOTAL UTAH LAKE PHYTOPLANKTON SURVEY SAMPLES FROM 1995 TO 2018 COMPILED FROM DWQ, USU, UT. CO. HEALTH, AND WFWQC DATA.

All phytoplankton and benthic algal taxonomy was performed by Rushforth Phycology, the leading algal taxonomy experts for Utah Lake and surrounding aquatic ecosystems. Taxa data were filtered and combined to the most recent taxonomic nomenclature and to genus or species OTUs. Four to five letter codes were made for each taxon, typically the first two letters of the genus name and the first two letters of the species name unless there were duplicates (see

Appendix 1). Seven to eight- digit location and sampling date codes were also developed for use in analyses. Month and year codes were also developed.

Rushforth Phycology reported results as number in stand, rank in stand, relative density, natural units per mL, cells per mL, and cell volume (μ^3/mL). The most commonly used values are cells per mL and cell volume. Linear regression analysis showed that both were highly significantly correlated ($R^2 = 0.97$), and therefore cells per mL were chosen for these analyses because cell volume was often $\gg 10^7$ and thus more difficult to visualize for the reader.

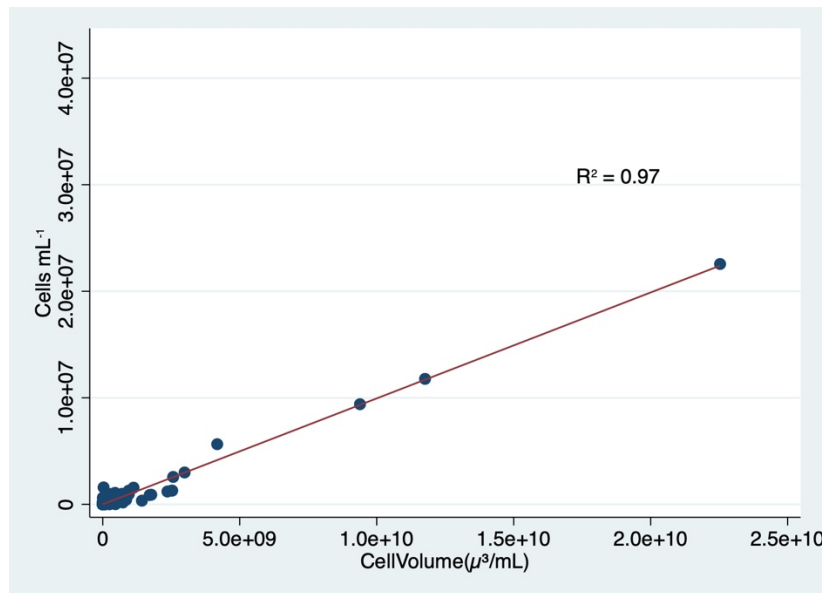


FIGURE 2. RELATIONSHIP BETWEEN ALGAL CELLS ML^{-1} AND CELL VOLUME (μ^3/ML).

Data were combined into month and years and statistical analyses were performed only on these temporal variables. Location (spatial) patterns were not examined at this time.

PHYTOPLANKTON ASSEMBLAGE RELATIONSHIPS

Non-metric multidimensional scaling (NMS) ordination was used to compare algal taxa and division relationships statistically and visually between months and years. 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 algal division assemblages 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).

PHYTOPLANKTON DIVISION ASSEMBLAGES

Cell density data were square root transformed and three less common algal divisions were removed to improve NMS models, Chrysophyta, Cryptophyta, and Proteobacteria. A Relative Sorensen 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 (McCune and Mefford 2018). The Relative Sørensen distance is the same as Sørensen distance except that it builds in a standardization by sample unit totals, each sample unit contributing equally to the distance measure (McCune and Mefford 2018). NMS ordinations were rotated using varimax rotation to maximize variation along the axes and extracted as univariate scores. Consequently, 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.

Multiple Response Permutation Procedure (MRPP), a non-parametric multivariate method was used to formally test the hypothesis of no differences in algal division assemblages between months and years. 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 Relative Sorensen (Bray-Curtis) distance measure was used on the square root transformed data 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 temporal groupings (McCune and Grace 2002).

PHYTOPLANKTON TAXA ASSEMBLAGES

Most of the taxa cell densities in the phytoplankton assemblage matrix were zero counts (94%), which is typical when sampling plankton but presents challenges for multivariate assemblage analysis (McCune 1994, De Cáceres and Legendre 2008). Consequently, we evaluated several transformation methods and decided that the most appropriate and useful transformation method was Beal’s Smoothing (McCune and Grace 2002, McCune 1994, De Cáceres and Legendre 2008). Beal’s smoothing is a multivariate transformation specially designed for species presence/absence community data containing noise and/or a lot of zeros. This transformation replaces the observed values of the target species by predictions of occurrence based on its co-occurrences with the remaining species (McCune and Grace 2002, McCune 1994, De Cáceres

and Legendre 2008). A well-known issue of multivariate analyses is the loss of sensitivity of resemblance measures as the environmental distance between sampling units increases. This occurs because abundance values for species are used as a surrogate measure for habitat suitability, and the information on suitability is lost whenever the species is absent (McCune 1994). Beals (1984) referred to this problem as the “zero truncation problem”, which is essentially similar to the well-known “double-zero problem” (Legendre and Legendre 1998). In order to lessen the zero-truncation problem, Beals (1984) introduced this data transformation (De Cáceres and Legendre 2008). See McCune and Grace 2002, and De Cáceres and Legendre 2008 for further discussion of Beal’s smoothing method.

MRPP analyses were also conducted to determine if assemblages differed monthly. See preceding section on MRPP.

Indicator Species Analysis was conducted using Dufrene’s and Legendre’s (1997) method. See McCune and Mefford (2018) for more details of indicator species analysis.

Descriptive statistics and graphs were also made on cell densities. Several richness and diversity indices were developed and compared between months including Taxa Richness, S ; Evenness, E ; Shannon Diversity, H Simpsons Diversity, D and Effective Number of Taxa ($\exp(H)$).

FUNCTIONAL TRAITS BASED ANALYSIS

Rushforth Phycology, under the direction of Sarah Rushforth, compiled available functional traits for Utah Lake phytoplankton from the following sources:

Academy of Natural Sciences, Philadelphia. Phycology Section, Patrick Center for Environmental Research.

Guiry, M.D. & Guiry, G.M. 2020. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org>.

John, David M., Whitton, Brian A., Brook, Alan J. 2011. The Freshwater Algal Flora of the British Isles. Cambridge, UK, Cambridge University Press.

Spaulding, S., Edlund, M., Potapova, M. et al. 2008. Diatoms of North America. diatoms.org/genera.

Prescott, G. W. 1951. Algae of the Western Great Lakes Area. Dubuque, Iowa, W.M. C Brown INC.

Prescott, G. W. 1970. How to Know the Freshwater Algae. Dubuque, Iowa. W.C. Brown Company.

Wehr, John D., Sheath, Robert G, Kociolek, Patrick J. 2015. Freshwater Algae of North America. London, Elsevier INC.

These sources were primarily from data collected from lotic not lentic sources. Subsequently, the data set was not complete for Utah Lake phytoplankton taxa.

Functional traits were categorized into two general groupings: morphological/environmental and chemistry optima and tolerances.

TABLE 1. LIST OF FUNCTIONAL TRAITS EVALUATED IN THIS TECHNICAL REPORT.

Morphological/Environmental	Chemistry optima/tolerances	
Division (categorical)	PO4opt	Orthophosphate dissolved (mg/L), optimum
Biovolume (quantitative)	PO4tol	Orthophosphate dissolved (mg/L), tolerance
Colony type (categorical)	TPopt	Total phosphorus (mg/L), optimum
Colony detail (categorical)	TPtol	Total phosphorus (mg/L), tolerance
Motility (categorical)	NH4opt	Ammonia dissolved (mg/L), optimum
Buoyancy (categorical)	NH4tol	Ammonia dissolved (mg/L), tolerance
Preferred Environment (categorical)	NO2+NO3opt	Nitrate + nitrite dissolved (mg/L), optimum
	NO2+NO3tol	Nitrate + nitrite dissolved (mg/L), tolerance
	TKNopt	Total organic plus ammonia nitrogen (mg/L), optimum
	TKNtol	Total organic plus ammonia nitrogen (mg/L), tolerance
	TNopt	Total nitrogen (mg/L), optimum
	TNtol	Total nitrogen (mg/L), tolerance
	CONDopt	Conductivity (mS/cm), optimum
	CONDtol	Conductivity (mS/cm), tolerance
	CHLORopt	Chloride dissolved (mg/L), optimum
	CHLORtol	Chloride dissolved (mg/L), tolerance

In addition to optimal and tolerance chemistry values, optima/tolerances, the ratio between tolerance and optimum was calculated. See Potapova (2005) for rational.

Additionally, Functional Groups as described by Padisak (2009), Morphological Classification (Kruk 2010), and trophic status mixotrophic vs. autotrophic functional traits values were calculated for each taxon. If no value was reported, then the next closest taxon values were used.

The simplest measure of community-level functional composition, the community-weighted mean (CWM) trait value was used for functional trait analysis in this first round. CWM uses the relative abundances of taxa and their trait values to calculate a community aggregated trait value (Violle et al. 2007, Funk et al. 2016). CWMs were calculated using PCORD 7.08 (Wild Blueberry Media 2018) by multiplying each taxon’s cell densities per each sampling unit (SU) X a trait value matrix for each trait by month as weighted averages without standardization. CWMs were calculated for all the functional traits listed in Table 1 and the three metrics described in the preceding paragraph. Basic statistics were then performed on these resulting values including non-parametric Kruskal Wallis tests of significance and graphical representations.

RESULTS

PHYTOPLANKTON DIVISION ASSEMBLAGES

Phytoplankton divisions varied by month and division with greater cell densities in summer and early autumn months, particularly Cyanophyta (Table 2).

TABLE 2. MEAN CELL DENSITIES (MG L⁻¹) FOR ALGAL DIVISIONS BY MONTH.

Month	Bacillariophyta	Chlorophyta	Chrysophyta	Cryptophyta	Cyanophyta	Dinophyta	Euglenophyta	Proteobacteria
Jan	500	10	0	0	0	0	3	0
Feb	3,169	358	0	0	97	8	1	0
March	8,271	2,357	0	0	2,284	0	35	0
April	2,846	7,610	0	22	1,176	1	77	0
May	2,662	5,648	1	12	18,691	2	14	0
June	2,003	21,050	137	57	129,271	7	24	0
July	2,880	20,526	2	61	1,423,187	21	56	3
Aug	9,698	56,757	23	721	682,640	13,668	84	1
Sept	6,626	22,923	1	261	159,147	4,592	332	6
Oct	2,651	29,313	6	112	99,263	15	356	0
Nov	2,452	75,979	2	96	10,965	25	67	0
Dec	1,062	177	0	0	729	0	0	0

Cyanobacteria clearly dominated during summer months (Figure 3 and Figure 4).

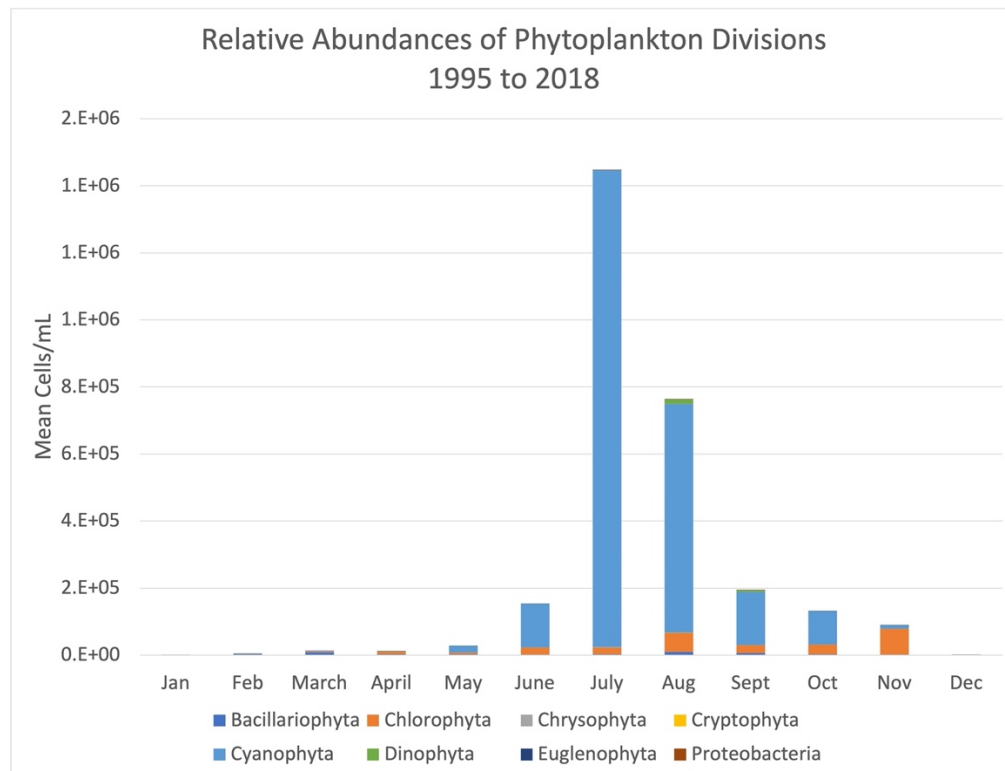


FIGURE 3. MEAN ABUNDANCES OF ALGAL DIVISIONS BY MONTH IN UTAH LAKE USING CELLS/ML.

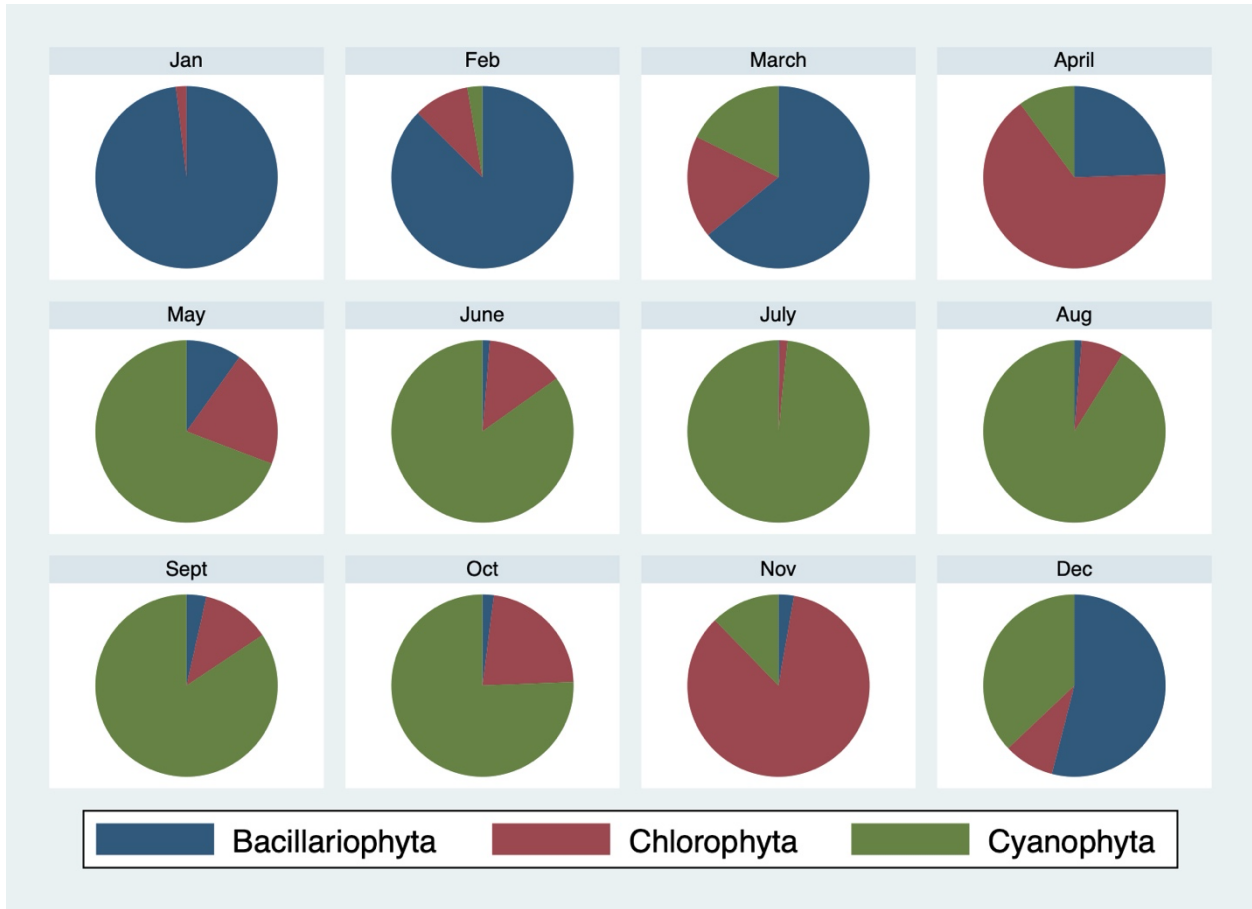
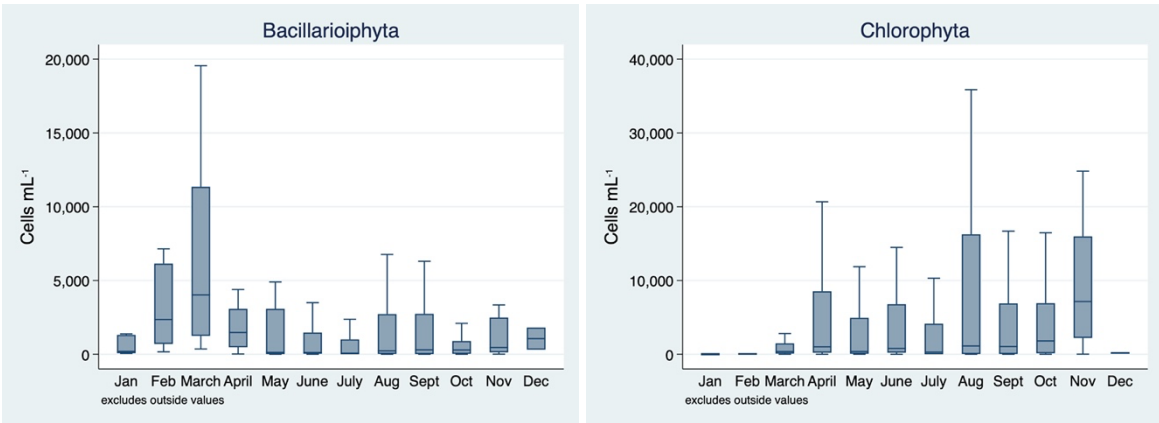


FIGURE 4. RELATIVE ABUNDANCES OF THREE ALGAL DIVISIONS IN UTAH LAKE BY MONTH.

Abundances (cells m L⁻¹) for the three major divisions differed by month but not as suggested in Figure 3 and Figure 4. Bacillariophyta were most abundant in February and March but similarly abundant in the other months (Figure 5). Their densities did not decrease in summer months, although their relative abundance to other divisions did. Likewise, Chlorophyta did not decrease in densities throughout the summer although their relative abundances to other divisions did (Figure 5).



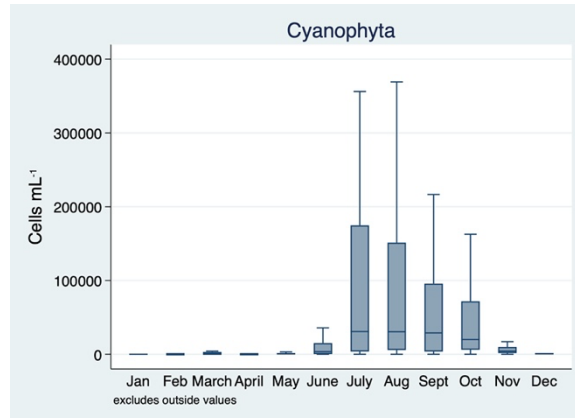


FIGURE 5. DENSITIES OF THREE MAJOR PHYTOPLANKTON DIVISIONS BACILLARIOPHYTA, CHLOROPHYTA, AND CYANOPHYTA BY MONTH. OUTLIERS WERE NOT PLOTTED.

ALGAL DIVISION ASSEMBLAGE TEMPORAL RELATIONSHIPS

The best fit NMS model had an extremely good final stress value = 6.90, final stability $\ll 0.001$, with number of iterations = 61. There is little error for misinterpretation of the NMS model given such low final stress. Post hoc analysis resulted in Axis 1 $R^2 = 0.83$ and Axis 2 $R^2 = 0.15$ for total $R^2 = 0.98$. These two axes explained virtually all the variability among algal divisions. Detailed NMS results available on request.

The NMS ordination in Figure 6 shows that phytoplankton assemblages at the division level taxonomy were clearly different seasonally with winter months from December through April much different than summer months of July through perhaps October but transitioning between winter and summer on both ends of the calendar year. This is typical and a well understood phenomenon with Bacillariophyta (diatoms) dominating at low densities in winter, transitioning from winter to spring and autumn to winter dominated by Cyanophyta (green algae) and very high abundances of dominant cyanophytes (blue-green algae) in summer.

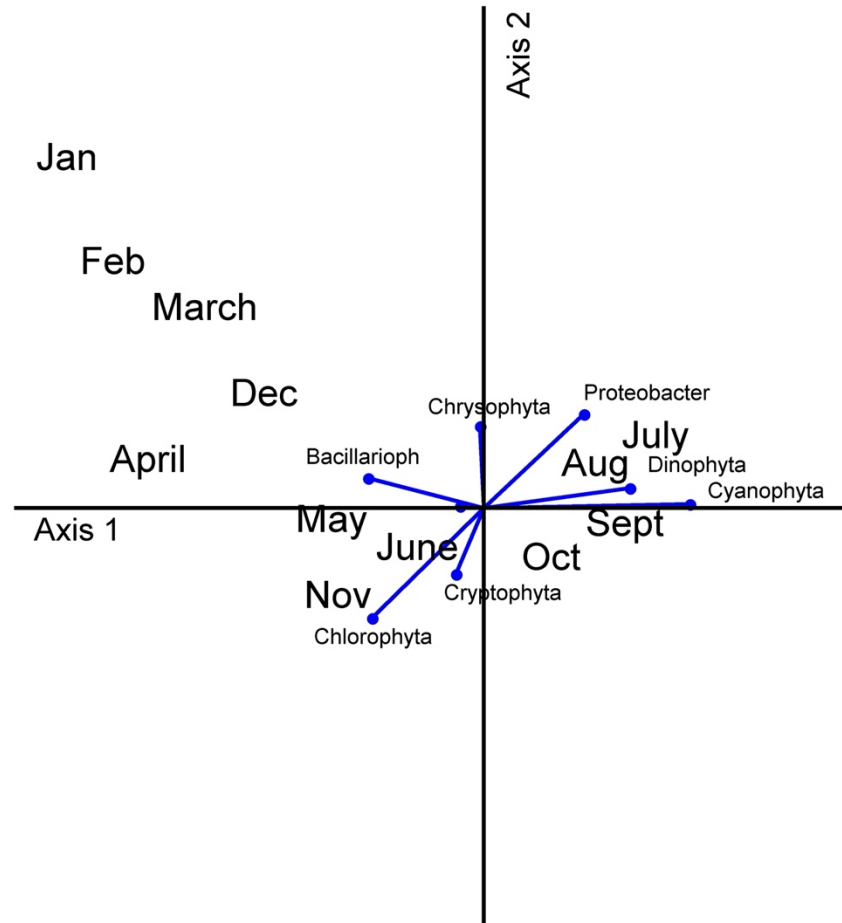


FIGURE 6. NMS AXIS 1 AND 2 SHOWING RELATIONSHIPS BETWEEN AND AMONG ALGAL DIVISIONS IN UTAH LAKE BY MONTH.

MRPP test statistic $A = 0.18$, $p < 0.001$ confirmed that indeed algal assemblages differed by month and post hoc analysis showed those months that assemblages significantly differed (Appendix 2).

PHYTOPLANKTON TAXA

DENSITY AND OCCURENCES

There was a wide range of densities (cell densities $mg L^{-1}$) of phytoplankton taxa in the dataset. Densities ranged from a mean = 235,200 cells $m L^{-1}$ to $< 1 mg L^{-1}$ (Table 3). $N = 778$ samples.

TABLE 3. CELL DENSITIES AND NUMBER OF OCCURANCES. MINIMUM FOR ALL TAXA = 0. SEE APPENDIX 1 FOR TAXA NAMES.

Taxon	Mean	Stand.Dev.	Maximum	Occurences
APFL	235,200	2,625,000	49,200,000	339
DOCR	103,100	1,129,000	22,560,000	109

PHRSP4	35,910	948,500	26,440,000	20
GESP	17,000	473,400	13,210,000	3
WIRE	13,580	85,000	951,000	284
PSSP	12,670	237,600	4,730,000	85
OSPR	11,960	333,100	9,292,000	17
MIAE	8,030	131,260	3,379,985	93
DOFL	5,632	50,544	790,632	82
PEAN	5,052	45,568	887,040	93
PHRSP	4,817	51,570	1,176,000	73
LEPTSP	4,208	34,732	631,277	154
RADA	4,160	62,217	1,589,991	16
APSP	3,674	22,704	537,852	220
OSAG	3,480	48,208	1,095,654	38
CEHI	3,475	78,651	2,157,386	175
MEGL	3,381	13,120	147,213	202
LISP	2,367	49,064	1,300,827	3
DOCI	2,168	13,096	206,984	124
PLXSP	2,135	36,642	1,003,408	46
PHRSP5	2,021	27,422	686,392	22
PEDI	2,003	20,109	525,588	594
PHRSP3	1,845	26,939	710,002	49
PHFO	1,445	21,110	512,447	26
PHRSP2	1,310	18,095	344,960	15
APGR	1,302	26,469	728,364	18
DECO	1,228	8,935	189,000	290
UNFICY	961	26,246	732,067	23
UNCOCYPI	877	21,036	584,696	13
DOLE	815	15,129	385,771	8
KILU	771	4,062	57,590	167
NIAC	697	7,198	147,398	133
CEDI2	677	4,414	104,384	364
MEGRA	583	4,317	94,245	278
CYPL	578	3,416	51,300	80
DOSI	448	6,738	144,561	13
CEDI	381	1,904	35,294	449
APPL	351	2,870	62,720	39
DOSP	297	1,959	28,426	85
APHS	249	2,487	38,011	23
UNSPCH2	218	1,888	40,326	158

SPSC	217	3,585	98,500	50
OOSP	211	666	11,100	337
OOBO	207	875	13,530	335
PEPE	203	2,161	57,344	125
CHRE	203	1,824	31,886	38
DEBI	186	1,404	27,500	172
PLAG	181	4,471	123,816	3
ANFA	170	2,558	55,600	196
MOAR	169	1,101	20,272	245
UNCOCH	165	1,823	45,203	99
FRVI	160	4,054	113,000	14
UNFICY3	159	3,947	109,810	5
APDE	158	3,047	60,480	3
MIIN	155	1,720	40,320	27
PEDU	151	867	13,440	106
CHGL	144	1,336	24,128	69
SNLA	143	1,515	30,029	24
SCDI	139	1,020	18,514	103
DEOP	136	1,163	27,040	89
BORA	125	1,091	17,920	26
PEDUC	117	1,433	24,000	24
PEBO	117	2,355	64,926	11
SCEL	116	1,086	27,664	99
SCOB	111	577	11,757	108
CHRS	109	1,142	24,640	21
CYDY	107	1,809	44,688	6
MISP	105	809	12,544	21
KISP	100	1,077	25,536	31
DEPR	97	631	10,035	58
UNCHLPIC	86	1,650	45,363	13
UNFICY2	81	865	14,560	14
UNSPCH	81	562	12,320	209
MEGR	77	1,729	48,160	51
DESP	75	1,162	25,830	35
COPL	71	857	21,504	25
KOSP2	67	605	8,893	62
OSAM	66	1,396	36,000	3
EUSP	66	498	11,781	207
GOAP	64	588	10,035	18

ACHA	62	529	9,520	46
CHSP	62	538	11,100	141
OSSP	61	566	11,107	25
LILI	61	629	16,128	46
DOPL	60	897	22,982	14
UNSPCH3	60	475	10,304	60
PESP	57	410	4,872	37
MESP	55	501	7,986	27
COES	51	935	25,500	29
UNCOCY	50	1,097	30,341	17
MOCO	50	355	7,168	169
UNFICY4	48	885	23,520	6
CRYP	47	417	9,769	74
CLLOT	46	759	16,700	54
EUSP2	43	1,015	27,800	10
ACGR	41	534	12,544	38
CRFE	41	282	4,480	57
CHMI	39	402	8,624	66
MODY	37	938	26,152	41
CRYP4	37	740	18,032	3
PTSP	32	281	3,987	83
CRSP	31	345	8,064	23
CHRO	30	429	11,424	47
SCQU	28	228	4,726	53
OOEL	25	239	6,048	48
GYSP	22	181	2,576	42
UNCOCY2	21	425	11,424	10
DIDI	18	453	12,600	6
CYLS	18	212	3,886	10
COMI	18	278	6,710	5
SPSP	18	482	13,440	2
CRQU	17	162	3,604	30
PHSP	16	205	4,396	68
UNELCHL	15	252	6,034	26
OOSP2	14	132	2,300	20
CHRO2	14	250	6,160	9
SPRSP	14	304	8,232	3
SNSP	14	276	7,280	3
CYCA	13	156	2,733	13

PLGE	13	178	3,584	8
CRSP2	13	268	7,168	4
SCQUQ	13	131	2,845	31
MEVA	13	127	2,464	41
SCBI	13	230	6,304	44
CRYP2	12	148	3,539	30
UNCRY2	12	109	1,792	33
PLSP	11	233	5,824	2
CASP	11	180	3,720	7
CHLS	11	259	7,168	7
NESP	11	93	1,792	22
CLLO	11	75	1,344	77
CHDI	11	156	4,032	11
SCSP	10	91	1,613	45
AUGR	10	79	1,254	21
OOGI	9	227	6,304	15
COEL	9	73	1,200	22
CRTE	9	237	6,608	4
QUSP	8	63	896	37
OOPA	8	89	1,434	11
SCSE	8	102	2,800	127
DIPA	8	101	1,792	10
AUSP1	8	154	4,082	7
MOCOV	8	55	806	49
TESP	8	78	1,770	34
BOSU	7	144	3,584	2
CHSP2	7	66	1,456	21
DEOPM	6	78	1,434	7
GLOSP	5	100	2,688	7
BILA	5	133	3,696	4
CRUS	5	100	2,688	4
CHPL	5	129	3,584	4
GOMSP	5	75	1,960	9
APHO	5	126	3,528	1
SCAR	4	43	717	14
UNCRY	4	33	448	30
LESP	4	43	1,075	33
TECA	4	40	672	18
CAGL	4	61	1,434	6

DISP	3	38	784	10
TEMI	3	33	672	24
ULSP	3	55	1,210	4
UNFICYPI	3	82	2,282	1
GLCYSP	3	77	2,150	2
NELI	3	56	1,434	3
TETR	3	29	448	9
FRCR	2	43	1,120	5
STNI	2	40	1,109	15
MOKO	2	13	182	30
DEOB	2	25	420	6
COSP3	2	20	448	15
BESP	2	27	605	5
MOMI	2	20	431	15
OOOB	2	33	882	3
PAMO	2	30	717	3
UNCOCH2	1	39	1,075	2
ASFO	1	16	235	8
OOSP3	1	20	403	7
MOSP	1	25	672	11
KOSP	1	13	224	12
CRYP3	1	18	448	5
CRCR	1	17	358	4
MICSP	1	23	538	2
SCJU	1	10	168	27
ACSP	1	19	515	5
SCQUM	1	16	336	6
MOIR	1	24	650	3
CHSP3	1	15	358	5
CLOS	1	24	661	6
UNSPCYPI	1	25	689	1
CRIR	1	9	90	9
UNFICH	1	15	403	4
DIAN	1	17	448	3
TRSP	1	11	224	18
UNSPCHR	1	13	336	4
ANSP	1	20	560	1
UNDINO	1	11	269	6
MOUSP	1	19	538	1

DEMA	1	11	224	4
STOP	1	17	462	1
GRLA	1	13	358	2
QUCH	1	16	448	1
GLEC	1	12	290	2
LYBI	1	14	396	1
ACOB	< 1	11	280	2
CONA	< 1	13	358	1
UNSPCY	< 1	7	196	7
COSP	< 1	3	34	27
CHTU	< 1	8	179	4
DEIN	< 1	10	280	1
GLVE	< 1	10	269	1
PETE	< 1	7	179	2
UNEUG	< 1	8	224	2
GLSP	< 1	5	112	7
DEMI	< 1	8	224	1
STSP3	< 1	8	224	1
PESP2	< 1	5	134	3
NEOB	< 1	6	168	2
SCRO	< 1	3	42	10
DESC	< 1	6	168	1
NIRE	< 1	5	140	1
STGR	< 1	2	56	13
OONA	< 1	5	134	1
MOGR	< 1	3	62	3
LESP2	< 1	2	45	3
UNSPCY2	< 1	4	112	1
CYSP	< 1	2	56	3
LEAC	< 1	3	90	1
LASP	< 1	3	84	2
CLSP	< 1	1	31	13
LACI	< 1	2	59	3
MOCV	< 1	2	45	3
MASP	< 1	2	42	3
COSP2	< 1	2	56	1
SESP	< 1	1	20	3
GOLSP	< 1	2	45	1
DINSP	< 1	1	34	1

ANFU	< 1	1	22	1
MISSP	< 1	1	22	1
PECI	< 1	1	22	1
UNCRY3	< 1	1	22	1
CLAC	< 1	1	14	1
UNSPCHPI	< 1	0	8	1
SPCH	< 1	0	3	2
TRSP2	< 1	0	2	1

Phytoplankton taxa occurrences also varied substantially. Occurrences ranged from 76% of samples to 0.13% of samples (Table 4 and Table 5). Twenty of the most common taxa and their proportional occurrences are in Table 4.

TABLE 4. TWENTY MOST COMMON TAXA AND THEIR PROPORTIONAL OCCURRENCE. N = 778 SAMPLES ANALYZED.

Taxon	Proportion Occurrence
PEDI	0.76
CEDI	0.58
CEDI2	0.47
APFL	0.44
OOSP	0.43
OOBO	0.43
DECO	0.37
WIRE	0.37
MEGRA	0.36
MOAR	0.31
APSP	0.28
UNSPCH	0.27
EUSP	0.27
MEGL	0.26
ANFA	0.25
CEHI	0.22
DEBI	0.22

Twenty-eight taxa had only one occurrence and fourteen taxa only had two occurrences out of the 778 samples and were considered rare and uncommon (Table 5).

TABLE 5. RARE AND UNCOMMON TAXA. N = 1 OCCURRENCE = RARE, N = 2 OCCURRENCES = UNCOMMON.

Occurrences	
Rare	Uncommon
APHO	SPSP

UNFICYPI	PLSP
UNSPCYPI	BOSU
ANSP	GLCYSP
MOUSP	UNCOCH2
STOP	MICSP
QUCH	GRLA
LYBI	GLEC
CONA	ACOB
DEIN	PETE
GLVE	UNEUG
DEMI	NEOB
STSP3	LASP
DESC	SPCH
NIRE	
OONA	
UNSPCY2	
LEAC	
COSP2	
GOLSP	
DINSP	
ANFU	
MISSP	
PECI	
UNCRY3	
CLAC	
UNSPCHPI	
TRSP2	

RICHNESS AND DIVERSITY

Estimated total number of phytoplankton taxa in Utah Lake ranged from 280 to 296 based on several estimators (i.e., first order and second order jackknife and Chao 2 classic and bias corrected). This is about a 15% to 21% increase from empirically estimated taxa richness. The species area curve (Figure 7) suggests that roughly 200 samples are required to fully account for most taxa and perhaps $\approx > 75$ samples are needed to account for the most abundant taxa. This level of sampling only occurred in 2016 and 2017, as of this writing.

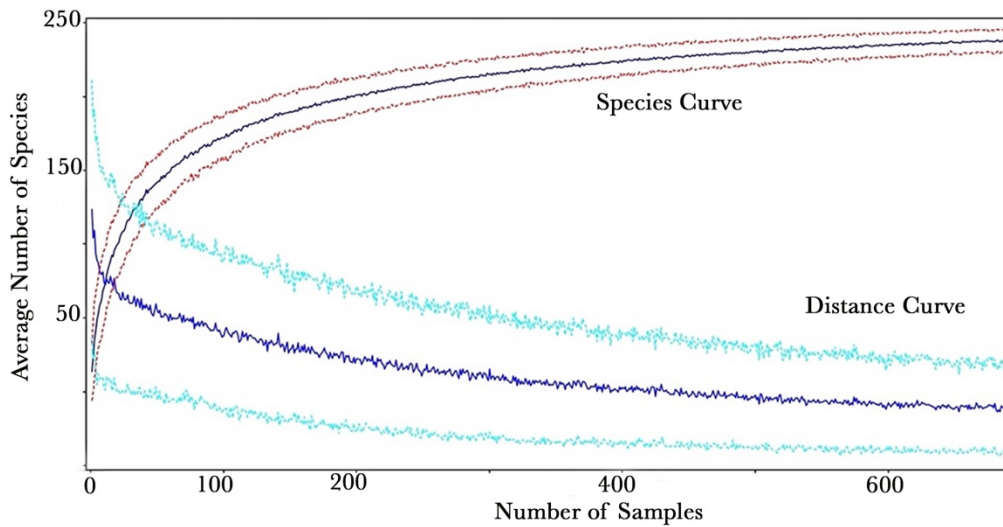
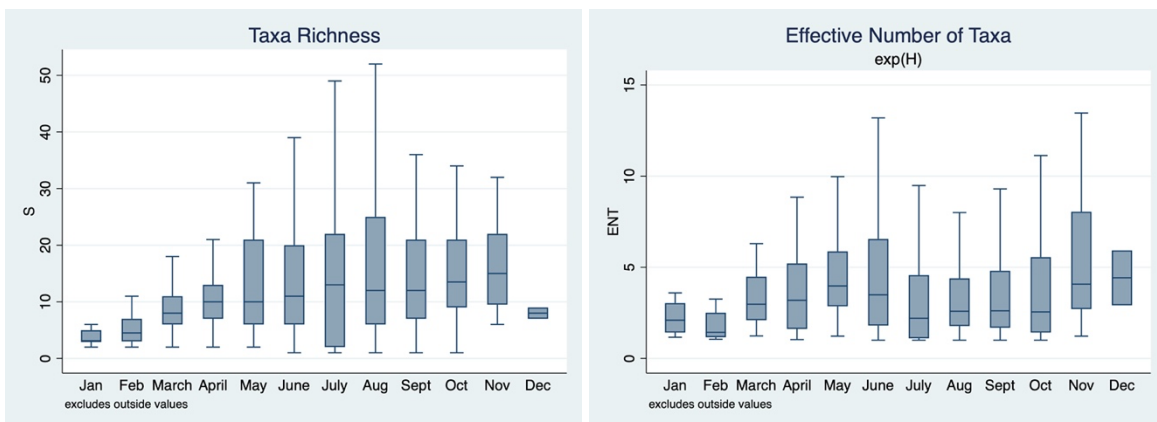


FIGURE 7. SPECIES AREA CURVE. DERIVED USING RELATIVE SORENSON DISTANCE AND BEALS SMOOTHING OF TAXA DENSITIES. THIS CURVE SUGGESTS THAT ROUGHLY 75 TO 200 SAMPLES ARE REQUIRED TO ADEQUATELY ACCOUNT FOR MOST PHYTOPLANKTON TAXA IN UTAH LAKE.

Richness and diversity varied between months and were mostly greatest in summer months and even considering the large variability, richness and diversity indices were significantly different between months (Figure 8). Taxa richness was greatest from late spring to a peak in November (median = 15 taxa) and lowest in winter months with the lowest in January (median = 3 taxa) (Figure 8 and Table 6). The effective number of taxa on the other had showed a slightly different trend with a decrease in summer months responding to the dominance of a few cyanobacteria taxa (Figure 8 and Table 6).



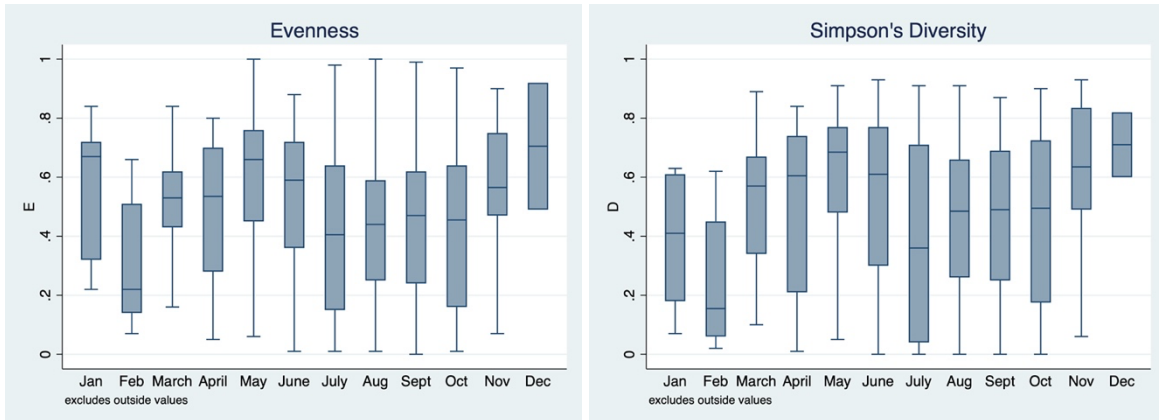


FIGURE 8. PHYTOPLANKTON TAXA RICHNESS AND DIVERSITY INDICES BY MONTHS. S: K-W $\chi^2 = 40.12$, 11 DF, P = 0.0001; E: K-W $\chi^2 = 55.41$, 11 DF, P = 0.0001; D: K-W $\chi^2 = 50.60$, 11 DF, P = 0.0001; ENT: K-W $\chi^2 = 47.14$, 11 DF, P = 0.0001.

Table 6 presents numerical summaries of richness and diversity indices to supplement Figure 8.

TABLE 6. PHYTOPLANKTON RICHNESS AND DIVERSITY INDICES BY MONTH. MEDIAN, 25TH AND 75TH PERCENTILES. S = TAXA RICHNESS, E = EVENNESS, H = SHANNON DIVERSITY, AND ENT = EFFECTIVE NUMBER OF TAXA (EXP(H)).

month	s	e	d	ENT
Jan				
Median	3	0.67	0.41	2.1
25th	3	0.32	0.18	1.4
75th	5	0.72	0.61	3.0
Feb				
Median	4.5	0.22	0.155	1.4
25th	3	0.14	0.06	1.2
75th	7	0.51	0.45	2.5
March				
Median	8	0.53	0.57	3.0
25th	6	0.43	0.34	2.1
75th	11	0.62	0.67	4.5
April				
Median	10	0.535	0.605	3.2
25th	7	0.28	0.21	1.6
75th	13	0.7	0.74	5.2

May				
Median	10	0.66	0.685	4.0
25th	6	0.45	0.48	2.9
75th	21	0.76	0.77	5.9
June				
Median	11	0.59	0.61	3.5
25th	6	0.36	0.3	1.8
75th	20	0.72	0.77	6.6
July				
Median	13	0.405	0.36	2.2
25th	2	0.15	0.04	1.1
75th	22	0.64	0.71	4.6
Aug				
Median	12	0.44	0.485	2.6
25th	6	0.25	0.26	1.8
75th	25	0.59	0.66	4.4
Sept				
Median	12	0.47	0.49	2.6
25th	7	0.24	0.25	1.7
75th	21	0.62	0.69	4.8
Oct				
Median	13.5	0.455	0.495	2.6
25th	9	0.16	0.175	1.4
75th	21	0.64	0.725	5.6
Nov				
Median	15	0.565	0.635	4.1
25th	9.5	0.47	0.49	2.7
75th	22	0.75	0.835	8.0
Dec				
Median	8	0.705	0.71	4.4
25th	7	0.49	0.6	2.9
75th	9	0.92	0.82	5.9

Total				
Median	11	0.495	0.53	2.9
25th	6	0.25	0.23	1.6
75th	21	0.66	0.72	5.1

PHYTOPLANKTON TAXA ASSEMBLAGES

The best fit NMS model had a good final stress value = 8.54, final stability << 0.001, with number of iterations = 82. This model is considered a good ordination with no real risk of drawing false inferences given its low final stress (McCune and Grace 2002). Post hoc analysis resulted in Axis 2 R² = 0.94 and Axis 1 R² = 0.04 for total R² = 0.98. These two axes and especially Axis 1 explained virtually all the variability among algal divisions. Detailed NMS results available on request.

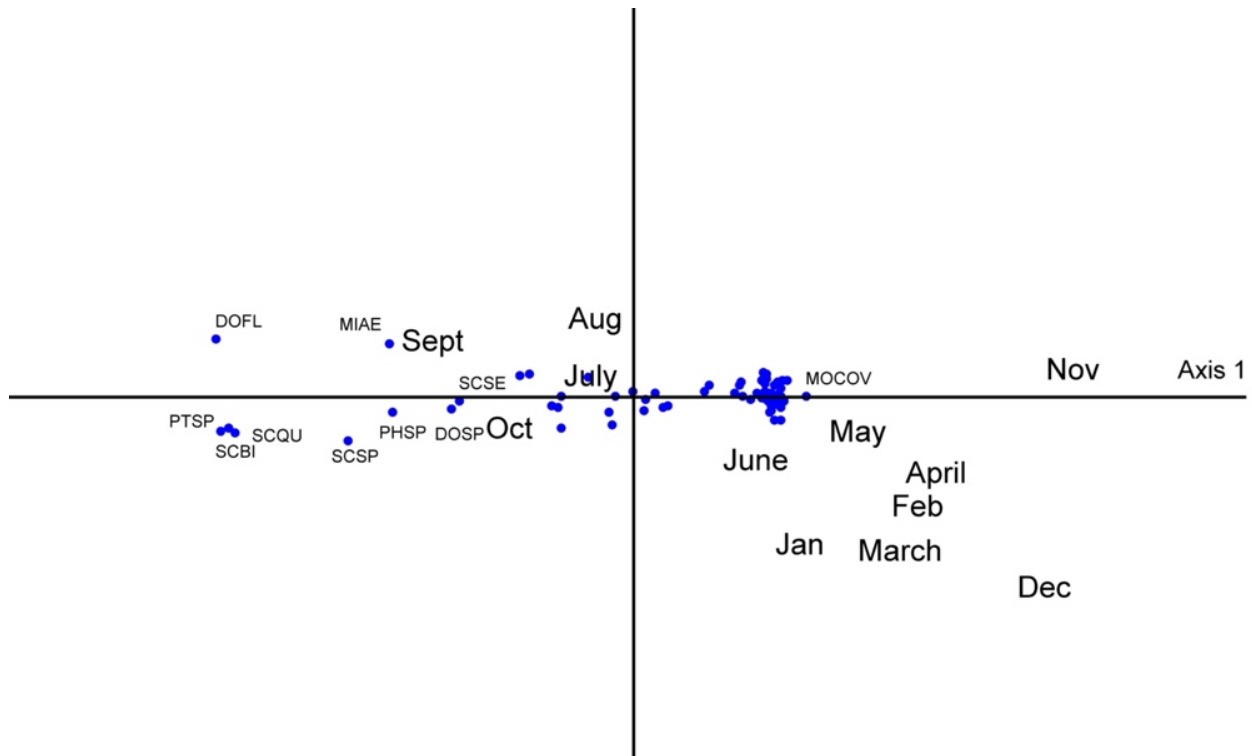


FIGURE 9. NMS AXIS 1 AND 2 SHOWING RELATIONSHIPS BETWEEN AND AMONG PHYTOPLANKTON TAXA IN UTAH LAKE BY MONTH. AXIS 1 R² = 0.94, AXIS 2 R² = 0.04. SEVERAL TAXA ORDINATIONS ARE SHOWN. FOR CORRELATIONS BETWEEN EACH TAXON AND EACH AXIS SEE APPENDIX 3.

MRPP

The multiple response permutation procedure, MRPP test statistic A = 0.07, p << 0.001 confirmed that indeed algal taxon assemblages differed among and between months. Post hoc

analysis showed that those months that separated in the NMS ordination significantly differed between the upper left and lower right quadrants but not within quadrants (Appendix 5).

INDICATOR TAXA

Indicator taxa analysis showed that several taxa were significant indicators of months, except for January, February, May, and June (Table 7). These taxa will be used in the Utah Lake food web model that is being developed.

TABLE 7. SIGNIFICANT INDICATOR PHYTOPLANKTON TAXA FOR MONTHS

Month	Taxon	Observed Indicator Value (IV)	IV from randomized groups		
			Mean	Std. dev.	p-value
March	<i>Nitzschia reversa</i>	4.3	1.5	2.82	0.05
March	<i>Lagerheimia</i> sp.	4.3	1.7	3.26	0.05
April	<i>Cryptomonas</i> sp. 3	8.5	2.5	4.83	0.05
July	<i>Aphanizomenon flosaquae</i>	56	20.2	9.44	0.01
July	<i>Dolichospermum crassum</i>	20.2	8.7	7.49	0.05
August	<i>Microcystis aeruginosa</i>	22.1	8.8	5.95	0.03
August	<i>Pseudanabaena</i> sp.	17.5	9	5.52	0.04
August	<i>Phormidium</i> sp.	17.5	6.5	6.73	0.05
August	<i>Chlamydomonas globosa</i>	15.7	6.2	7.06	0.05
August	<i>Chlamydomonas reinhardtii</i>	14.3	5	7.08	0.05
September	<i>Scenedesmus bijuga</i>	13.4	5.7	5.57	0.05
October	<i>Dolichospermum sigmoideum</i>	14.8	3.4	5.64	0.02
October	<i>Phacus</i> sp.	16.8	6.7	6.47	0.04
October	<i>Dolichospermum lemmermannii</i>	9.1	2.7	4.58	0.04
November	<i>Chlamydomonas</i> sp. 3	13.9	2.6	5.39	0.02
November	<i>Oocystis parva</i>	13.9	3.3	6.05	0.03
November	<i>Willea rectangularis</i>	35.6	13.7	9.41	0.03
November	<i>Komma</i> sp.	12.2	3.6	6.42	0.04
November	<i>Snowella</i> sp.	8.3	2.1	4.24	0.04
December	<i>Melosira varians</i>	43.2	5.1	6.61	0.01

FUNCTIONAL TRAITS

While functional trait-based ecology is a powerful approach used to explain and predict ecological interactions in Utah Lake, its utility is based on adequate and accurate trait classification. Most, but not all, functional traits analyzed in this report had an adequate number of traits assigned to each phytoplankton taxon. Taxa without reported trait values resulted in reduced percentages of sampling units and taxa that could be used in analyses (Table 8).

TABLE 8. NUMBER OF SAMPLING UNITS (SU) AND TAXA USED AND THEIR PERCENTAGES RELATIVE TO TOTAL IN THE DATASET FOR EACH FUNCTIONAL TRAIT METRIC. BOLD PERCENTAGES RESULTS SHOULD BE USED WITH CAUTION.

Functional Trait Metric	Sampling Units Used		Taxa Used	
	Count	Percent	Count	Percent
Colony type	778	1.00	244	1.00
Motility	778	1.00	244	1.00
Buoyancy	778	1.00	244	1.00
Environmental ²	778	1.00	171	0.70
TP	705	0.91	154	0.63
PO4	700	0.90	132	0.54
NH4 opt	690	0.89	103	0.42
NO2+NO3opt	681	0.88	116	0.48
TKN opt	703	0.90	152	0.62
TN opt	699	0.90	140	0.57
COND opt	na	na	142	0.58
CHLOR opt	na	na	142	0.58
pH opt	669	0.86	109	0.45
Mixotrophic/Autotrophic	778	1.00	244	1.00
Morphological Classification	778	1.00	197	0.81
Functional Group (Padisak 2009)	773	0.99	160	0.66

Some of the phytoplankton taxa without reported trait values were at high densities at different months. For example, chemistry optima/tolerance values for all six of the *Dolichospermum* taxa in the Utah Lake dataset were severely lacking. Subsequently, the following functional traits results, although highly informative, should be interpreted with some degree of caution.

COLONY TYPE

² Counts and percent taxa used also includes NAs for environmental functional traits.

The type of colonies³ that the phytoplankton taxa in Utah Lake can form varied from month to month (Figure 10). During winter months and into spring, taxa were mostly solitary cells, then starting in about May, phytoplankton colonies were mostly colonial or filamentous (Figure 10). Coenobial⁴ cell colonies occurred throughout seasons but varied in relative abundance (Figure 10).

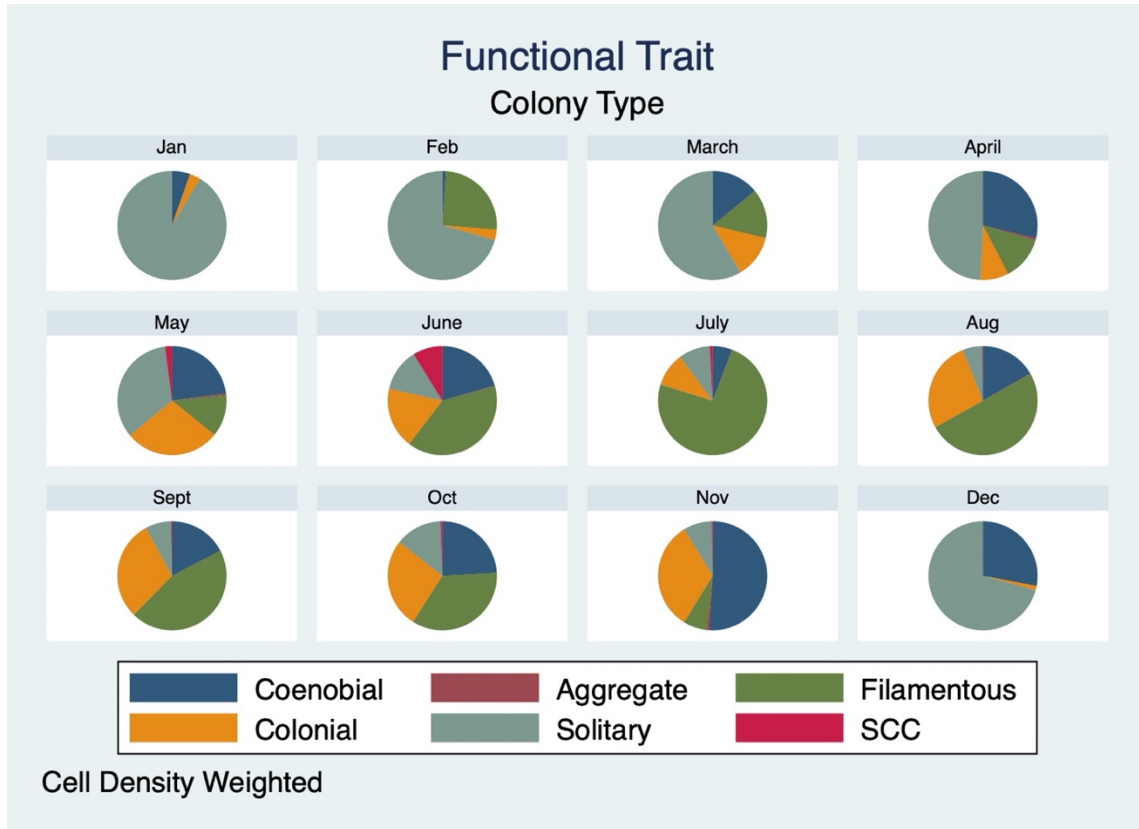


FIGURE 10. COLONY TYPE FUNCTIONAL TRAITS FOR PHYTOPLANKTON TAXA IN UTAH LAKE BY MONTH. SCC = SOLITARY, COENOBIAL, OR COLONIAL.

MOTILITY TYPE

Phytoplankton taxa were mostly without flagella throughout the seasons although flagellated taxa were abundant from mid-winter to spring (Figure 11). Moderate motility taxa (e.g., gliding, surface movement, etc.) occurred at low densities in all months except January (Figure 11).

³ Colony type is considered to have evolved in part due to predation,

⁴ Coenobial is a type of colony with a fixed number of interconnected cells embedded in a common matrix before release from the parental colony assumed to have evolved for defense from zooplankton predation.

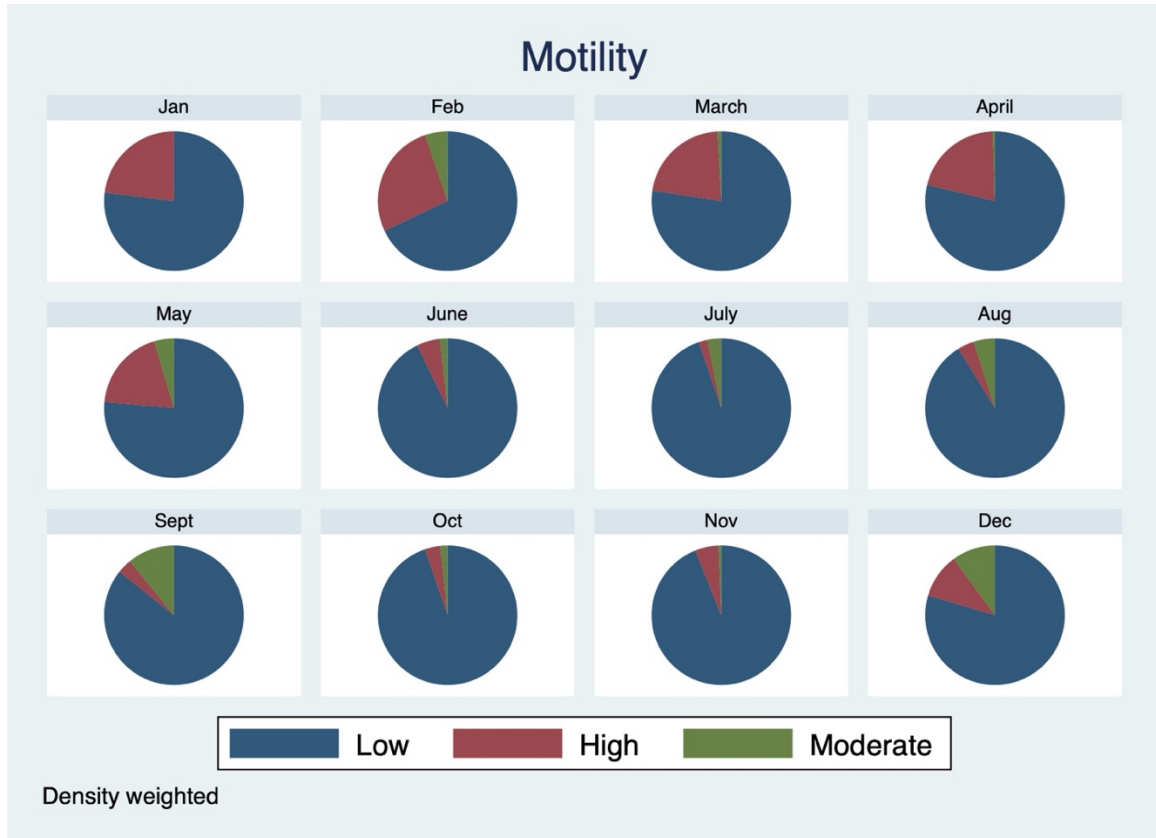


FIGURE 11. MOTILITY TYPE FUNCTIONAL TRAITS FOR PHYTOPLANKTON IN UTAH LAKE BY MONTH. LOW = FLAGELLUM ABSENT, MODERATE =GLIDING, OSCILATING, ETC., HIGH = FLAGELLA PRESENT.

BUOYANCY TYPE

Almost all the taxa from the months of October through June were free floating and were replaced by taxa that used gas vacuoles for buoyancy during summer months (e.g., many cyanobacteria taxa) (Figure 12).

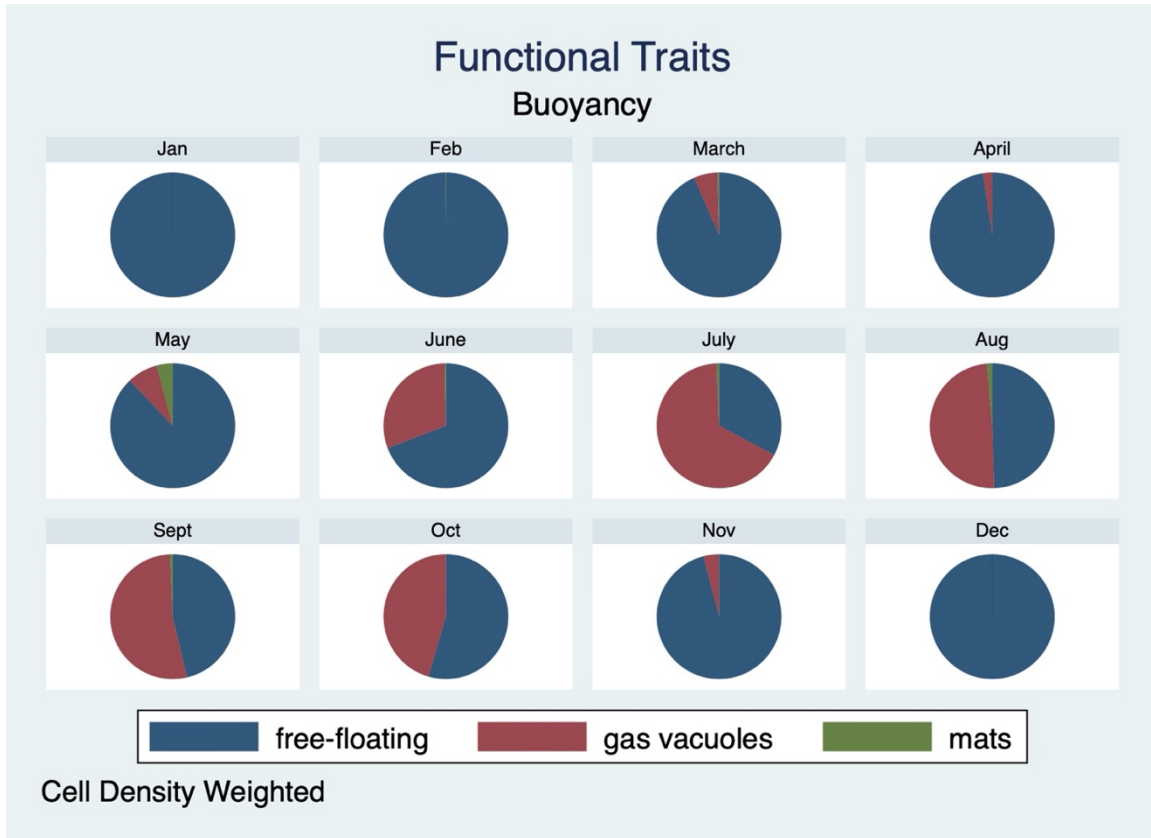


FIGURE 12. BUOYANCY TYPE FUNCTIONAL TRAITS FOR PHYTOPLANKTON IN UTAH LAKE BY MONTH.

ENVIRONMENTAL DISTRIBUTION

Most taxa in the functional trait databases that we examined did not have any reported environmental associations (however see section, Functional Group (Padisak 2009)) (Figure 13). When all the unreported (NAs) were removed for analysis, associated environmental distributions varied by month but were mostly associated with environments other than oligotrophic conditions, these included mesotrophic to eutrophic, fresh to brackish, widespread, and tolerant; all conditions that occur in Utah Lake (Figure 14).

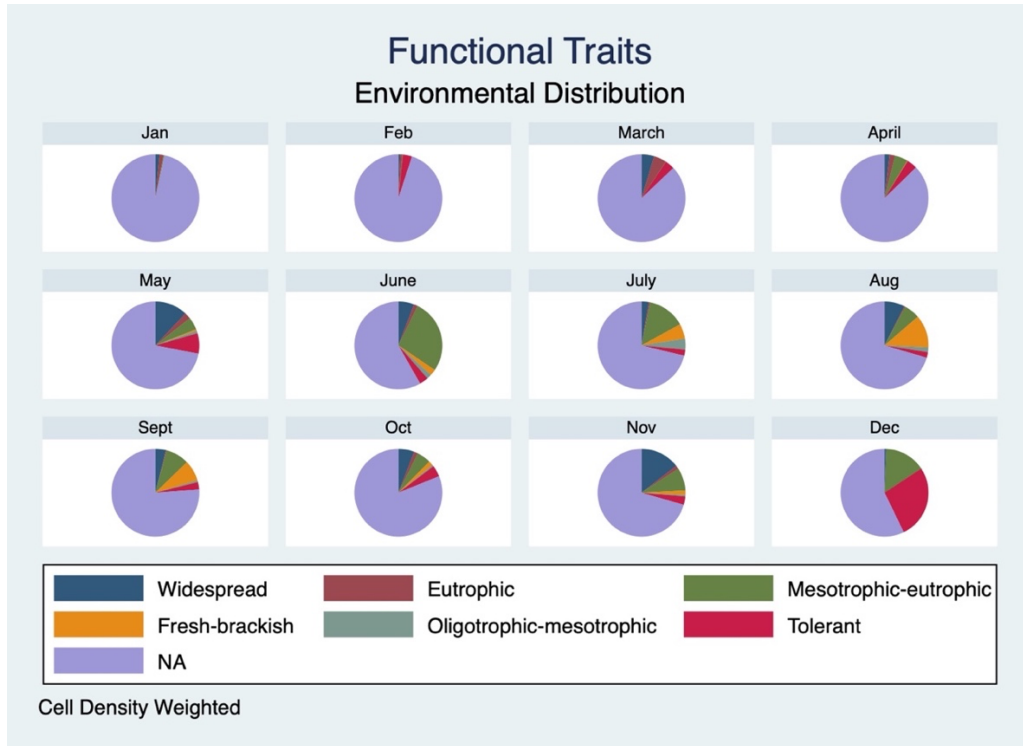


FIGURE 13. ENVIRONMENTAL DISTRIBUTION TYPE FUNCTIONAL TRAITS FOR PHYTOPLANKTON IN UTAH LAKE BY MONTH

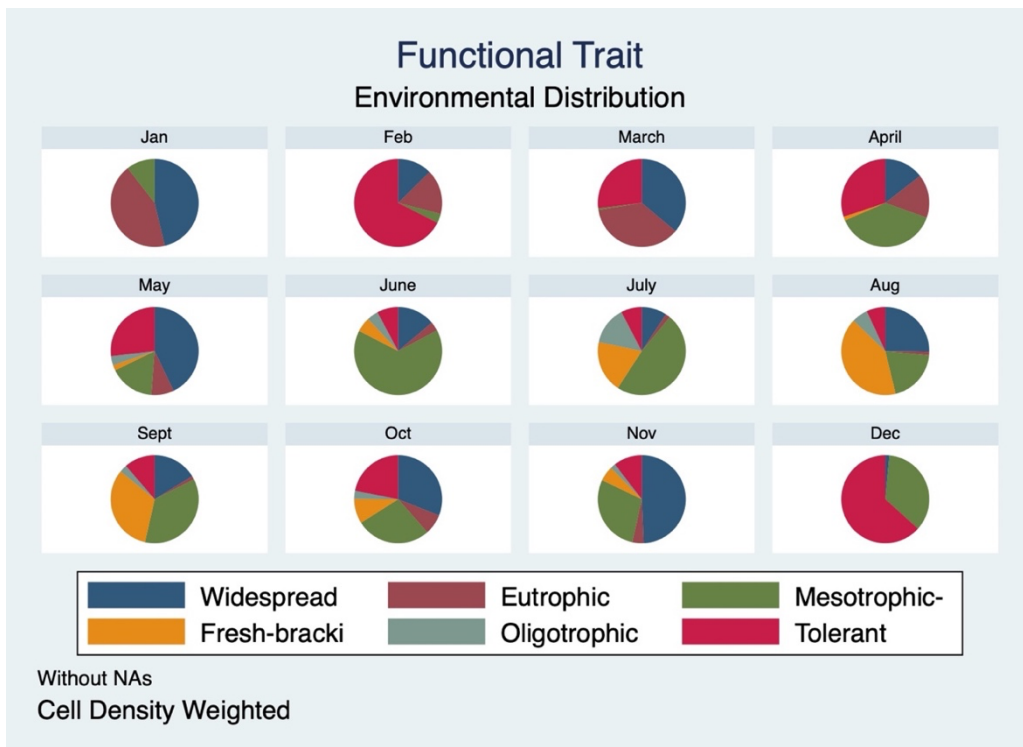


FIGURE 14. ENVIRONMENTAL DISTRIBUTION FUNCTIONAL TRAITS FOR PHYTOPLANKTON IN UTAH LAKE BY MONTH WITHOUT NA'S.

These results demonstrate the need for much more ecological functional traits work.

FUNCTIONAL TRAIT RICHNESS AND DIVERSITY

Richness and diversity indices based on environmental functional traits (see previous section) had similar patterns to indices using taxa-based indices ((Figure 8 and Table 6), including the relative differences in taxa richness vs. effective number of taxa (ENT) during summer months.

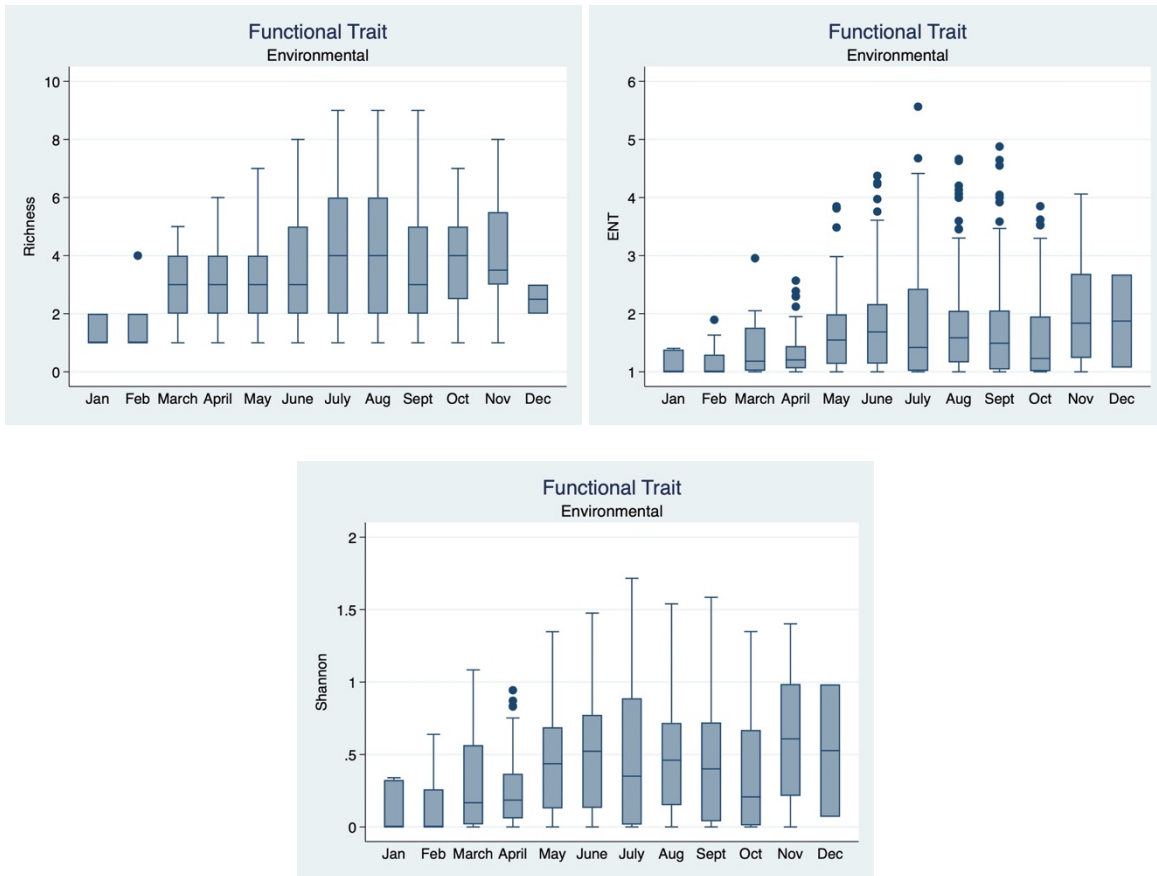


FIGURE 15. FUNCTIONAL TRAIT TAXA RICHNESS, EFFECTIVE NUMBER OF TAXA (ENT), AND SHANNON DIVERSITY BY MONTH.

CHEMISTRY OPTIMA

There was a noticeable decrease in nutrient optima for all chemistries evaluated, except $\text{NO}_2 + \text{NO}_3$, from winter through spring and summer (Figure 16). Reasons for the lower optima during summer months is speculative at this time.

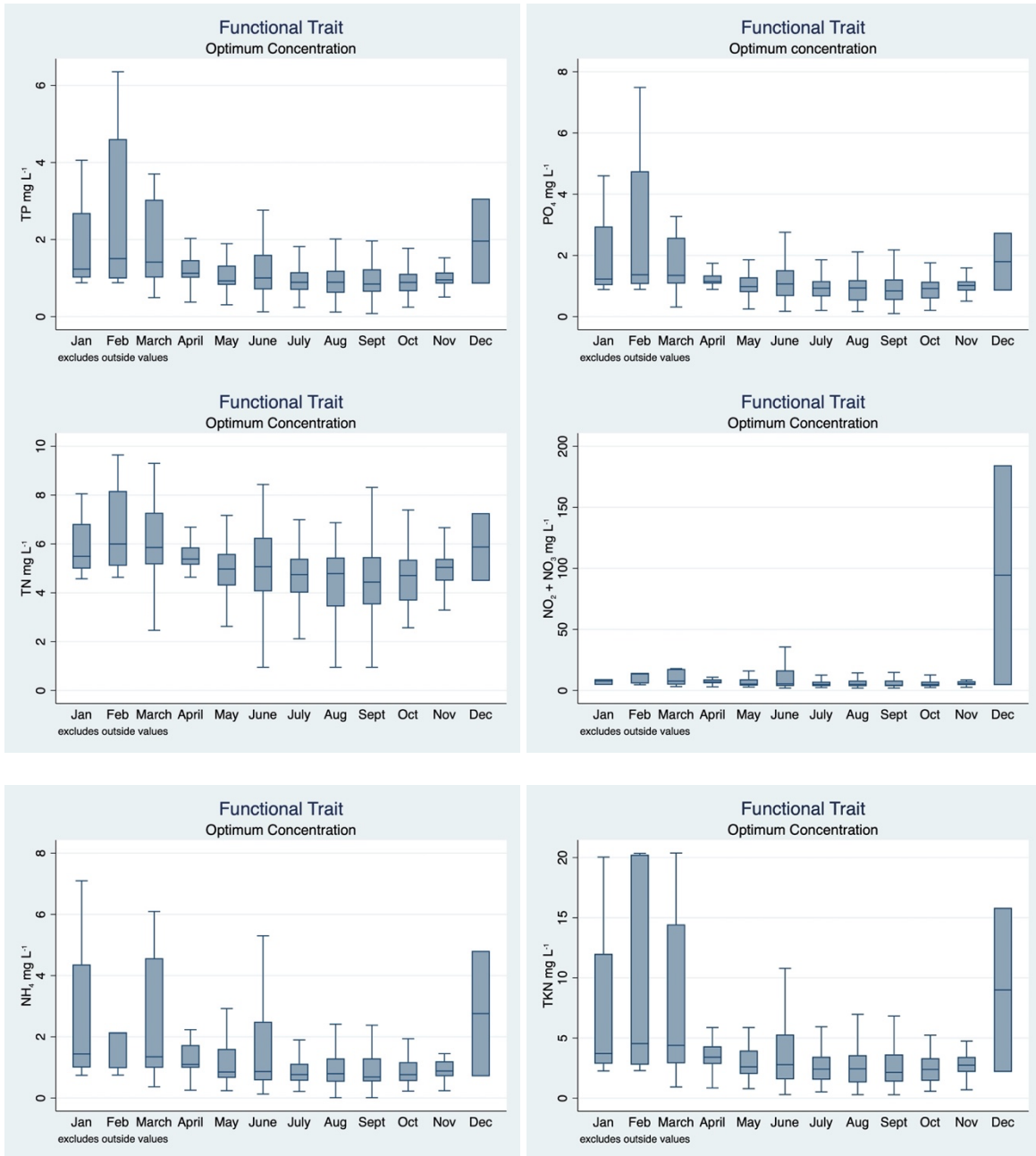


FIGURE 16. CHEMISTRY OPTIMA FUNCTIONAL TRAIT BY MONTH.

TROPHIC LEVEL FUNCTIONAL TRAITS

Virtually all the taxa were autotrophs not mixotrophs (Figure 17). Heterotrophs were absent from the dataset. This could have been due to inadequate classification and needs further literature review to verify trophic status of taxa in Utah Lake.

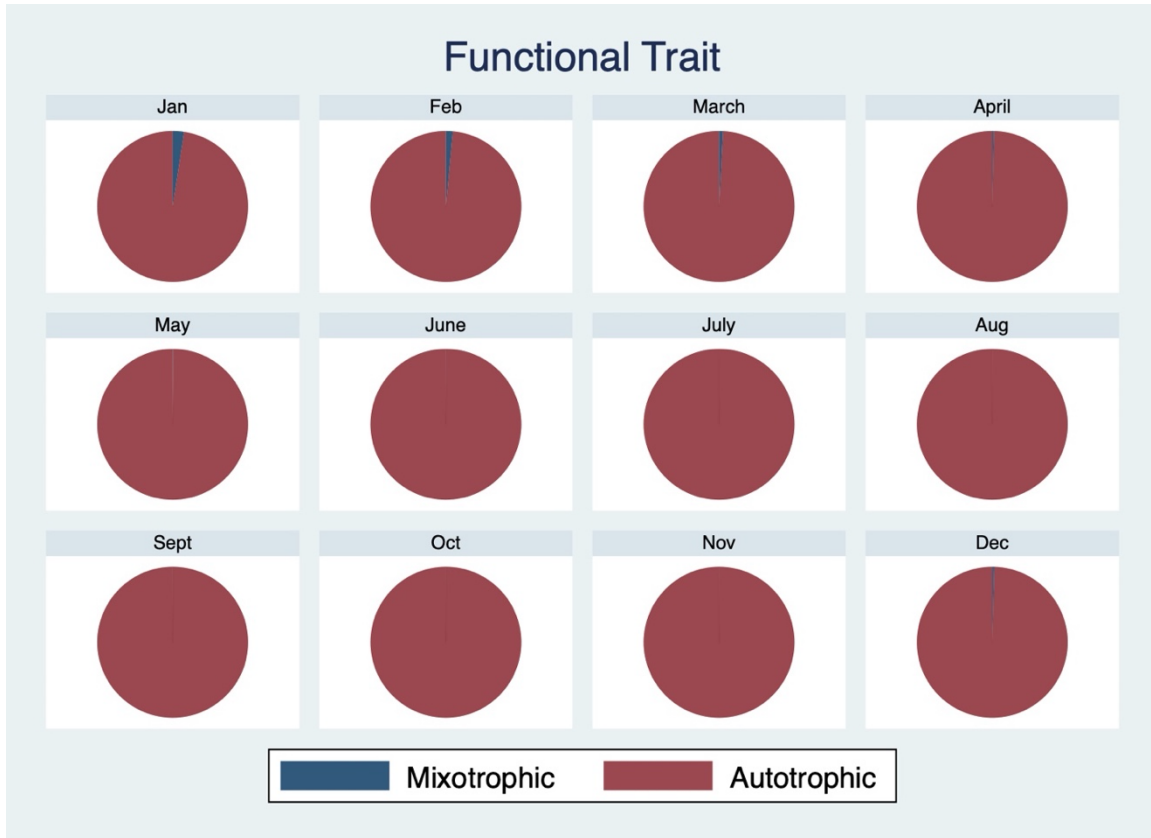


FIGURE 17. MIXOTROPHIC VS. AUTOTROPHIC FUNCTIONAL TRAITS BY MONTH.

MORPHOLOGICAL CLASSIFICATION

Results from the morphological classification functional groups based on Kruk et al. (2010) (Table 9) provide a wealth of information regarding phytoplankton assemblages in Utah Lake (Figure 18).

TABLE 9. MORPHOLOGICAL CLASSIFICATION FUNCTIONAL GROUPING MODIFIED FROM TABLE 4 OF KRUK ET AL. (2010).

Table 4 Description of the traits of the morphologically based functional groups (MBFG) and their potential ecological performance in terms of resources acquisition and avoidance of loss processes (consumption and sinking)

MBFG	Morphology	Traits			Potential ecological performance		
		Max growth rate (doublings day ⁻¹)	Sink velocity (md ⁻¹)	Population biomass (mm ³ L ⁻¹)	Resources gathering (Light, P, N, Si and C)	Vulnerability to consumption	Sinking losses
I	Small organisms with high S/V	2.08 (1.7–2.76)	0.03 (–0.01 to 0.04)	10.7 (9e–5–896)	Good gathering and low saturating concentration	High, good recovery	Low
II	Small flagellated organisms with siliceous exoskeletal structures	0.54 (0.30–0.74)	Potentially low	0.29 (3.1e–4–6.61)	Moderate, silicate requirements	High to moderate	Low to moderate
III	Large filaments with aerotopes	0.67 (0.40–0.98)	–0.09 (–0.10 to 0.10)	11.2 (2.82e–3–139)	Moderate saturating concentration, some fix atmospheric nitrogen	Low	None
IV	Organisms of medium size lacking specialized traits	1.49 (0.45–2.32)	0.14 (–0.01 to 0.39)	2.76 (4.5e–4–248)	Moderate	High loss	Low to moderate
V	Unicellular flagellates of medium to large size	0.89 (0.21–2.08)	0.192 (0.07–0.32)	0.42 (1.8e–4–12.7)	Moderate	High to moderate	Low to moderate
VI	Non-flagellated organisms with siliceous exoskeletons	0.93 (0.16–1.40)	0.68 (0.08–4.00)	3.50 (3.6e–4–130)	Moderate, silicate requirements	Moderate	High
VII	Large mucilaginous colonies	0.94 (0.48–1.39)	0.078 (0–0.52)	3.90 (1.2e–3–133)	High saturating concentration	Low	None or low

Means and ranges are shown for the physiological traits. The actual sizes for the groups are shown in Table 3. S/V, surface : volume ratio; Max, maximum; P, phosphorus; N, nitrogen; Si, silicate; C, carbon.

Phytoplankton morphological functional groups varied widely seasonally in the lake with Group VI a major component from December to about March, then from April through June having a more evenly distributed grouping mostly groups IV, VII, VI, transitioning to dominance by group III from July through October and then in November having very few group III but with mostly IV and VII (Figure 18).

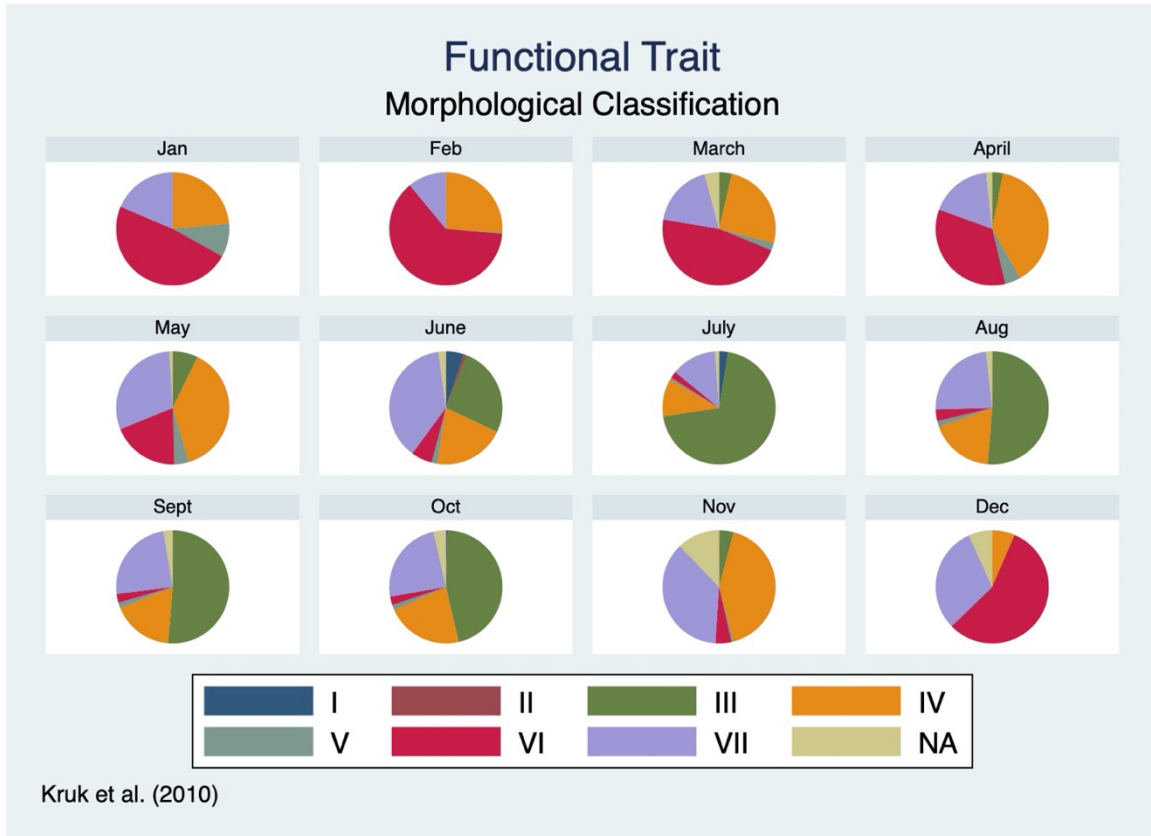


FIGURE 18. MORPHOLOGICAL CLASSIFICATION FOR PHYTOPLANKTON IN UTAH LAKE BY MONTH.

FUNCTIONAL GROUP (PADISAK 2009)

Eleven functional groups as defined by Reynolds et al. (1997) and refined by Padisak et al. (2009) occurred in Utah Lake (Table 10). As with the morphological functional traits results presented in the preceding section, there is a wealth of information to be gleaned from these results. See Padisak ET.AL. (2009) for more details.

TABLE 10. TRAIT-SEPARATED FUNCTIONAL GROUPS OF PHYTOPLANKTON IN UTAH LAKE (UPDATED FROM REYNOLDS, 1997 AND PADISAK, 2009). SEE PADISAK ET.AL. (2009) FOR MORE DETAILS.

Codon	Habitat	Tolerances	Sensitivities
B	mesotrophic, small- and medium-sized lakes to large shallow lakes with species sensitive to the onset of stratification.	light deficiency	pH rise, Si depletion stratification

S1	turbid mixed environments. This codon includes only shade-adapted cyanoprokaryotes	highly light deficient conditions	flushing (Reynolds et al., 2002)
X1	shallow mixed layers in enriched conditions, eutrophic-hypertrophic environments.	stratification	nutrient deficiency filter feeding
F	clear epilimnia, deeply mixed meso-eutrophic lakes.	low nutrients high turbidity	? CO ₂ deficiency
J	shallow, mixed, highly enriched systems (including many low-gradient rivers).		settling into low light
K	shallow, nutrient-rich water columns		deep mixing
H1	dinitrogen-fixing, Nostocales, eutrophic, both stratified and shallow lakes with low nitrogen content.	low nitrogen low carbon,	mixing, poor light, low phosphorus
L _o	summer epilimnia in mesotrophic lakes; deep and shallow, oligo to eutrophic, medium to large lakes.	segregated nutrients	prolonged or deep mixing
M	eutrophic to hypertrophic, small- to medium-sized water bodies.	high insolation	flushing, low total light
T _c	eutrophic standing waters, or slow flowing rivers with emergent macrophytes.	?	?
MP	frequently stirred up, inorganically turbid shallow lakes.	?	?

Functional groups varied seasonally in Utah Lake with group B dominating from January through April, more even distribution in May and June, dominance by group H1 from July through September, and more even distribution in October and November. December classifications in all analyses presented in the report are based on only two samples and not representative of general trends for that month.

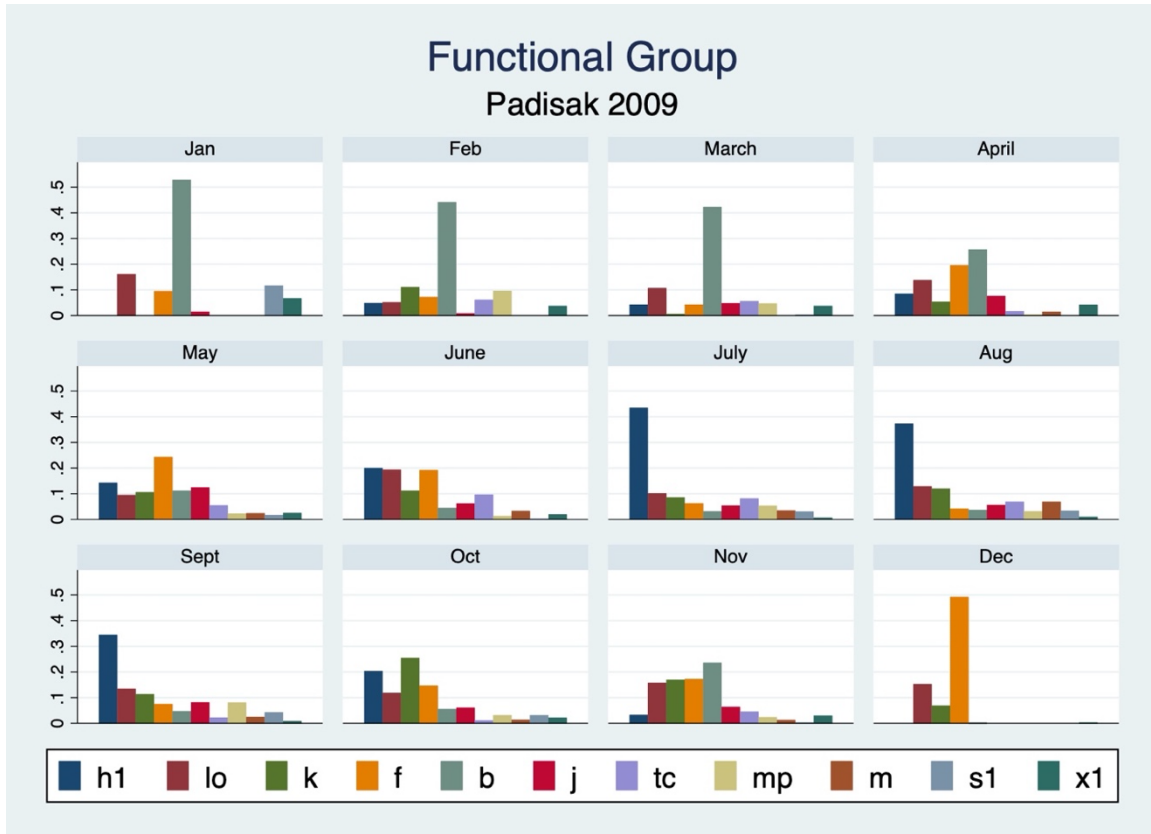


FIGURE 19. FUNCTIONAL GROUPS OF PHYTOPLANKTON IN UTAH LAKE BY MONTH. FROM PADISAK (2009). SEE PADISAK ET.AL. (2009) FOR MORE DETAILS.

Table 11 provides a list of taxa found in Utah Lake grouped by Padisak (2009) functional groups. The largest group was group J, representing shallow enriched lakes (Table 10) consistent with Utah Lake conditions.

TABLE 11. TAXA LIST BY FUNCTIONAL GROUPS (PADISAK 2009). FUNCTIONAL GROUPS ARE IN TABLE 10. TAXA NAMES ARE IN APPENDIX 1. SEE PADISAK ET.AL. (2009) FOR MORE DETAILS.

B	F	H1	J	K	Lo	M	MP	S1	Tc	X1
CEDI	BORA	APFL	ACGR	APDE	CEHI	MIAE	FRVI	GESP	LYBI	ANFA
CEDI2	GLCYSP		ACHA	APGR	CHDI	MIIN	OSAG	LISP	PHFO	ANFU
CYSP	GLVE		COES	APHO	CHRS	MISP	OSAM	PLAG	PHRSP	MOCO
	KILU		COMI	APHS	CHTU	MISSP	OSPR	PLSP	PHRSP2	MOCOV
	KISP		CRFE	APPL	COEL		OSSP	PLXSP	PHRSP3	MODY
	NELI		CRIR	APSP	CONA		SPSP	PSSP	PHRSP4	MOGR
	NEOB		CRQU	CYPL	GOAP		ULSP		PHRSP5	MOIR
	NESP		CRSP		MEGL					MOKO
	OBOB		CRSP2		MEGR					MOMI
	OOEL		CRTE		MEGRA					MOSP
	OOGI		GLOSP		MESP					SCJU
	OONA		GOLSP		PECI					

OOPA	PEAN	PESP
OOSP	PEBO	PESP2
OOSP2	PEDU	SNLA
OOSP3	PEDUC	
PLGE	PETE	
RADA	SCAR	
SPSC	SCBI	
	SCDI	
	SCEL	
	SCOB	
	SCQU	
	SCQUM	
	SCQUQ	
	SCSP	
	TECA	
	TEMI	
	TESP	
	TETR	

Some of the Padisak (2009) groups were absent or at very low densities including groups, C, P, G, N, T, and W2, also somewhat consistent with our knowledge of Utah Lake conditions. See following table for those groups missing or at very low densities (Table 12).

TABLE 12. TRAIT-SEPARATED FUNCTIONAL GROUPS OF PHYTOPLANKTON THAT WERE ABSENT OR AT LOW DENSITIES IN UTAH LAKE (UPDATED FROM REYNOLDS, 1997 AND PADISAK, 2009). *SEE PADISAK ET.AL. (2009) FOR MORE DETAILS.*

Codon	Habitat	Tolerances	Sensitivities
C	Mixed, eutrophic small-medium lakes	Light, C deficiencies	Si exhaustion stratification
N	mesotrophic epilimnia	Nutrient deficiency	stratification pH rise
P	eutrophic epilimnia	Mild light and C deficiency	stratification Si depletion
T	deep, well-mixed epilimnia	Light deficiency	Nutrient deficiency
G	Short, nutrient-rich water columns	high light	nutrient deficiency
W2	shallow mesotrophic lakes	?	?

DISCUSSION

Results presented in this technical report confirm that phytoplankton divisions differed seasonally in Utah Lake following a well understood successional pattern in temperate lakes, however fine detail of taxa responsible for these patterns was not discernable using algal divisions compared to evaluating phytoplankton temporal patterns using genus and species level taxonomy.

These results are very similar to what Richards and Miller 2017 found using phytoplankton genus and species level data to construct an NMS model that clearly showed seasonal patterns in algal assemblages using only 2016 data (Figure 20).

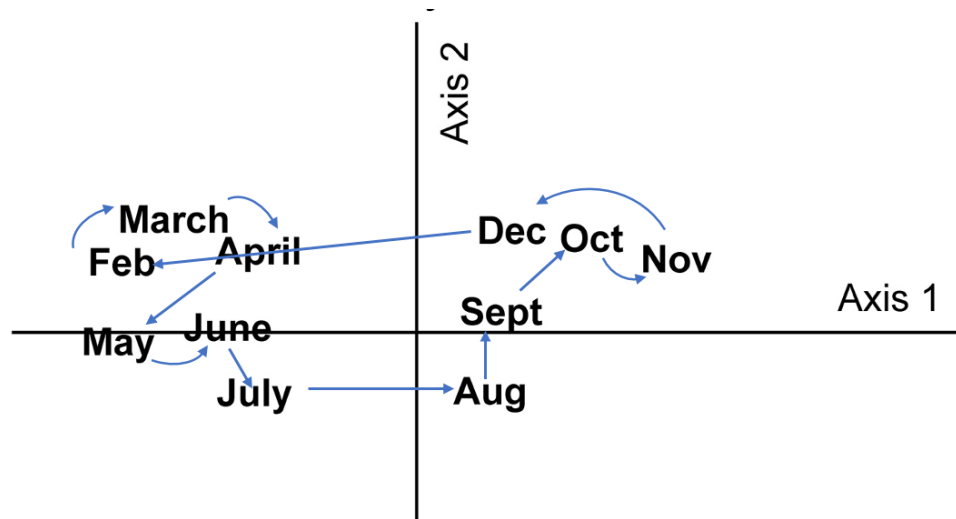


FIGURE 20. NMS ORDINATION OF PHYTOPLANKTON ASSEMBLAGES USING GENUS AND SPECIES LEVEL TAXONOMY CLEARLY SHOWING SEASONAL PATTERNS. FROM RICHARDS AND MILLER 2017.

Phytoplankton assemblage spatial patterns also exist in the lake (Richards and Miller 2017) and will require further analyses using the large dataset including any updated data.

The species area curve (Figure 7) demonstrates that many samples are required ($\cong 75$ to 200) if we are to fully understand and manage the contribution of phytoplankton assemblages to Utah Lake’s ecosystem functioning. This curve roughly translates into five or more locations sampled bimonthly at a minimum.

Low values of taxa richness and especially ENT and diversity indices confirms impaired conditions in the lake (see Richards et. al. citations in Literature Cited section).

FUNCTIONAL TRAITS

Ecologists have recently suggested that species functional traits, rather than species identity, was a “Holy Grail” for understanding and predicting community processes and can ‘provide a path forward to a unified theory of community ecology’ (Lavorel and Garnier 2002, Wstob y and Wright 2006, McGill et al. 2006, Funk et al. 2016). This was clearly the case presented in this report, given the limited availability of trait values based on a literature review.

As stated in the previous section, division level taxonomy is useless for functional traits analysis. Consequently, reliance on division level taxonomy for models of Utah Lake’s water quality or food web is not recommended.

Functional traits were literature based and may not be entirely relevant to Utah lake taxa. Literature based functional traits values although useful, can be used as hypothesis testing values when empirically based values become available.

The use of genetics to determine phytoplankton taxa relationships, particularly picoplankton in Utah Lake is in its infancy and needs to be encouraged. For example, see Li (2021).

Only simple functional trait analysis was conducted in this report (e.g., Community Weighted Means). This was mostly because of the limited percent of trait values available for phytoplankton taxa in the lake that precluded more complex functional trait analysis methods such as Rao Q, Functional Dispersion, Species Distances in Trait Space, Fourth Corner Analysis, etc. Once relevant functional trait values are available, these methods will be applied to the dataset.

RELEVANCE TO FOODWEB

Most primary production in Utah Lake occurs within the water column, roughly 20 to 30 cm light photic zone depth. Substrate conditions in much of the lake are unstable and make it difficult for benthic algal production to occur. Macrophyte primary production is limited to a small percentage of the lake. Subsequently, the food web of Utah Lake is almost entirely dependent on phytoplankton primary production (and to an unknown extent on heterotrophic bacteria in the benthos). The basic food web bottom-up transfer therefore is:

Nutrients in water column > phytoplankton uptake > zooplankton grazing > planktivory > piscivory (many of which have small gape sizes).

Primary producers are the foundation of the food web, without a solid understanding of phytoplankton assemblages, food web models will be highly generalized, less predictive, and far less representative of the ecosystem.

CONCLUSION

Algal division level analyses are not recommended for a detailed understanding of Utah Lake ecology, including water quality, algal blooms, and food web and watershed modeling, although some useful information can be gleaned from this low level taxonomy. Data collected prior to

2016 although useful, does not contain enough samples to evaluate seasonality (or spatial patterns) of phytoplankton assemblages. Continued extensive phytoplankton surveys and sampling intensity similar to that what conducted in 2016 and 2017 are required to fully understand the ecology of phytoplankton in Utah Lake and best manage it into the future. Additional analyses of phytoplankton assemblages using genus/species level taxonomy is presently being conducted and needs continued support. Results will then be used to determine the most appropriate taxa for inclusion in ongoing Utah Lake foodweb model development. Food web model development for Utah Lake is strongly encouraged by the DWQ Utah Lake Science Panel and fisheries managers at DNR to help manage the lake for this and future generations.

Functional traits analysis is fast becoming an important tool for understanding ecosystem function. However, verifiable functional trait values are somewhat lacking for phytoplankton assemblages in Utah Lake and are not empirically based on phytoplankton taxa residing in the lake. Despite this shortcoming, functional traits evaluation presented in this report provide a wealth of useful information urgently needed to best manage Utah Lake’s unique ecosystem.

RECOMMENDATIONS

We are on the cusp of understanding phytoplankton assemblage ecology and their contribution to ecosystem function, including water quality in Utah Lake. The following research items are highly recommended if we are to manage the lake properly:

- Review and revise phytoplankton taxonomy. Keeping updated with latest nomenclature and retrofitting past datasets.
- Continue to collect and increase the number of phytoplankton samples from various locations and seasons on the lake, similar to what was done in 2016 and 2017. Solicit additional phycology/taxonomy labs to augment Rushforth Phycology.
- Update and revise functional traits databases with Utah Lake centric values and most recent trait values from literature.
- Strengthen functional traits analyses using the most up to date and relevant statistical methods.
- Incorporate findings into Utah Lake food web model.

ACKNOWLEDGEMENTS

Much gratitude to the Wasatch Front Water Quality Council for continued financial support and understanding of the importance of this research. Rushforth Phycology, Sarah, Sam, and Aaron, continues to be the legacy taxonomy lab for phytoplankton in Utah Lake, without whom this research would not be possible.

LITERATURE CITED

- Allen, J. I. and L. Polimene. 2011. Linking physiology to ecology: towards a new generation of plankton models. *J. Plankton Res.* 33, 989–997.
- Beals, E. W. 1984. Bray-Curtis ordination: an effective strategy for analysis of multivariate ecological data. *Advances in Ecological Research* 14: 1-55.
- Botta-Dukát, Z. 2005. Rao's quadratic entropy as a measure of functional diversity based on multiple traits. *Journal of Vegetation Science* 16: 533-540.
- Calow, P. (1987) Towards a definition of functional ecology. *Funct. Ecol.* , 1, 57–61.
- Chao, A., C-H. Chiu, and L. Jost. 2010. Phylogenetic diversity measures based on Hill numbers. *Philosophical transactions of the Royal Society B.* <https://doi.org/10.1098/rstb.2010.0272>
- Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18:117-143.
- Diaz, S and M. Cabido. 2001. Vive la difference: plant functional diversity matters to ecosystem processes. *Trends in Ecology and Evolution* 16 (11): 646–655.
- Funk JL, Larson JE, Ames GM, Butterfield BJ, Cavender-Bares J, Firm J, Laughlin DC, Sutton-Grier AE, Williams L, Wright J. Revisiting the Holy Grail: using plant functional traits to understand ecological processes. *Biol Rev Camb Philos Soc.* 2017 May;92(2):1156-1173. doi: 10.1111/brv.12275. Epub 2016 Apr 22. PMID: 27103505.
- Gustafsson, C, Norkko, A. Quantifying the importance of functional traits for primary production in aquatic plant communities. *J Ecol.* 2019; 107: 154– 166. <https://doi.org/10.1111/1365-2745.13011>
- Hooper, D.U., Chapin, F.S., Ewel, J.J., et al. .2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs* 75: 3–35.
- Jost, L. 2006. Entropy and diversity. *Oikos* 113(2): 363-375.
- Kruskal, J. B. and M. Wish. 1978. *Multidimensional Scaling.* Sage Publications, Beverly Hills, California.

- Laliberté, E. and P. Legendre. 2010. A distance-based framework for measuring functional diversity from multiple traits. *Ecology*, 91: 299-305. <https://doi.org/10.1890/08-2244.1>
- Lavorel, S., Grigulis, K., McIntyre, S., Williams, N. S. G., Garden, D., Dorrough, J., Berman, S., Quétier, F., Thebault, A. & Bonis, A. 2008. Assessing functional diversity in the field – methodology matters! *Functional Ecology* 22:134-147.
- Legendre, P. and M. J. Anderson. 1999. Distance-based redundancy analysis: testing multispecies responses in multifactorial ecological experiments. *Ecological Monographs* 69:1-24.
- Levine, J. M. 2016. A trail map for trait-based studies. *Nature* 529: 163–164. doi:10.1038/nature16862
- Li, Hanyan. 2021. A molecular insight into harmful algal blooms of Utah Lake. Ph.D. dissertation. University of Utah, Salt Lake City, UT.
- Marshall, B. D. 2019. Laboratory Observations Regarding Identifications and likely Synonymies among Zooplankton from Utah Lake. Prepared for OreoHelix Consulting, and Wasatch Front Water Quality Council, Salt Lake City, UT 84114. River Continuum Concepts, Manhattan, MT.
- Martini, Séverine, Larras, Floriane, Boyé, Aurélien Faure, Emile Aberle, Nicole Archambault, Philippe Bacouillard, Lise Beisner, Beatrix Bittner, Lucie Danger, Michael Gauthier, Olivier Karp-Boss, Lee Fabien, Lombard Maps, Frederic Stemmann, Lars Thiébaud, Eric Usseglio-Polatera, Philippe Vogt, Meike Laviale, Martin Ayata, Sakina-Dorothee. (2020). Functional trait-based approaches as a common framework for aquatic ecologists. *Limnology and Oceanography*. 66. 10.1002/lno.11655.
- McCune, B. & J. B. Grace. 2002. *Analysis of Ecological Communities*. MjM Software, Glenden Beach, Oregon 97388, U.S.A. <http://www.pcord.com>
- McCune, B. 2015. The front door to the fourth corner: variations on the sample unit \times trait matrix in community ecology. *Community Ecology* 16:267-271.
- McCune, B. and M.J. Mefford 2018. PC-ORD. Multivariate analysis of ecological data. Version 7.08. Wild Blueberry Media, LLC.
- McGill, B. J., Enquist, B. J., Weiher, E. & Westoby, M. (2006a). Rebuilding community ecology from functional traits. *Trends in Ecology and Evolution* 21, 178–185.

Nock, C. A, Vogt, R. J and B. E. Beisner. 2016. Functional Traits. In: eLS. John Wiley & Sons, Ltd: Chichester. DOI: 10.1002/9780470015902.a0026282

Padisák, J., Crossetti, L.O. & Naselli-Flores, L. Use and misuse in the application of the phytoplankton functional classification: a critical review with updates. *Hydrobiologia* 621, 1–19 (2009). <https://doi.org/10.1007/s10750-008-9645-0>

Petchey, O.L., Hector, A. and K.J. Gaston. 2004. How do different measures of functional diversity perform? *Ecology* 85 (3): 847–857.

Potapova, M. 2005. Relationships of soft-bodied algae to water quality and habitat characteristics in U.S. rivers: Analysis of the National Water- Quality Assessment (NAWQA) Program data set. Report No. 05-08. The Academy of Natural Sciences. Patrick Center for Environmental Research – Phycology Section. 1900 Benjamin Franklin Parkway. Philadelphia, PA 19103-1195. <http://diatom.acnatsci.org/>, <http://www.acnatsci.org/>

Reynolds, C. S., V. Huszar, C. Kruk, L. Naselli-Flores & S. Melo, 2002. Towards a functional classification of the freshwater phytoplankton. *Journal of Plankton Research* 24: 417–428.

Richards, D.C. et al. 2019. Factors Effecting the Ecological Health and Integrity of Utah Lake with a Focus on the Relationships between Water Column Regulators, Benthic Ecosystem Engineers, and CyanoHABs. Progress Report 2020. Version 2.3. Report to Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Ecological, Vineyard, UT.

Richards, D. C. and T. Miller. 2019a. A Provisional Multi-Metric Index of Biological Integrity (MIBI) to Assess Water Quality in Utah Lake centered on Regulatory Directives. Draft Technical Report to Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Ecological, Vineyard, UT.

Richards, D. C. and T. Miller. 2019b. Utah Lake Research 2017-2018: Progress Report: Continued analysis of Utah Lake’s unique foodweb with a focus on the role of nutrients, phytoplankton, zooplankton, and benthic invertebrates on cyanoHABs. Chapter 1: Phytoplankton Assemblages. Submitted to Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Consulting, Vineyard, UT.

- Richards, D.C. 2019a. Zooplankton assemblages in highly regulated Utah Lake: 2015-2018. Progress Report to Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Consulting, Vineyard, UT.
- Richards, D.C. 2019b. Spatial and Temporal Variability of Zooplankton Body Lengths in Utah Lake. Technical Memo to Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Consulting, Vineyard, UT.
- Richards, D.C. 2019c. Spatial and Temporal Variability in Zooplankton Assemblages in Utah Lake 2015 to 2019. Progress Report to Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Consulting, Vineyard, UT.
- Richards, D. C. 2018. Relationships between Phytoplankton Richness and Diversity, Zooplankton Abundance, and cyanoHAB Dominance in Utah Lake, 2016. Draft Technical Report to Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Consulting. 67pp.
- Richards, D. C. and T. Miller. 2017. A preliminary analysis of Utah Lake’s unique foodweb with a focus on the role of nutrients, phytoplankton, zooplankton, and benthic invertebrates on HABs. Utah Lake Research 2016. Progress Report. Wasatch Front Water Quality Council, Salt Lake City, UT.
- Tilman D, Knops J, and D. Wedin, et al. 1997. The influence of functional diversity and composition on ecosystem processes. *Science* 277 (5330): 1300–1302.
- Violle, C., Navas, M.-L., Vile, D., Kazakou, E., Fortunel, C., Hummel, I. & Garnier, E. (2007). Let the concept of trait be functional!. *Oikos* 116, 882–892.
- Vogt, R.J., Beisner, B.E. and Y.T. Prairie. 2010. Functional diversity is positively associated with biomass for lake diatoms. *Freshwater Biology* 55 (8): 1636–1646.
- Westoby, M. & Wright, I. J. (2006). Land-plant ecology on the basis of functional traits. *Trends in Ecology and Evolution* 21, 261–268.

APPENDICES

APPENDIX 1. UTAH LAKE PHYTOPLANKTON TAXA LIST WITH TAXON CODES USED IN ANALYSES AND ALGAL DIVISIONS.

Algal Division	Taxon Code	Taxon
Chlorophyta	ACDI ¹	<i>Acutodesmus dimorphus</i> (= <i>Tetrademus dimorphus</i> (Turpin) Wynne)
Chlorophyta	ACGR	<i>Actinastrum gracillimum</i> Smith
Chlorophyta	ACHA	<i>Actinastrum hantzschii</i> Lagerheim
Chlorophyta	ACOB	<i>Acutodesmis obliquus</i>
Chlorophyta	ACSP	<i>Acutodesmus</i> sp.
Chlorophyta	ANFA	<i>Ankistrodesmus falcatus</i> (Corda) Ralfs
Chlorophyta	ANFU	<i>Ankistrodesmus fusiformis</i>
Cyanophyta	ANSP	<i>Anabaenopsis</i> sp.
Cyanophyta	APDE	<i>Aphanocapsa delicatissima</i> West & West
Cyanophyta	APFL	<i>Aphanizomenon flosaquae</i> Ralfs ex Bornet & Flahault
Cyanophyta	APGR	<i>Aphanocapsa grevillei</i> (Berkeley) Rabenhorst
Cyanophyta	APHO	<i>Aphanocapsa holsatica</i> (Lemmermann) G.Cronberg & Komárek
Cyanophyta	APHS	<i>Aphanothece</i> sp.
Cyanophyta	APPL	<i>Aphanocapsa planctonica</i> (G.M.Smith) Komárek & Anagnostidis
Cyanophyta	APSP	<i>Aphanocapsa</i> sp.
Bacillariophyta	ASFO	<i>Asterionella formosa</i>
Bacillariophyta	AUGR	<i>Aulacoseira granulata</i> (Ehrenberg) Simonsen (= <i>Melosira granulata</i> (Ehrenberg) Ralfs)
Bacillariophyta	AUSP1	<i>Aulacoseira</i> sp. 1
Proteobacteria	BESP	<i>Beggiatoa</i> sp.
Bacillariophyta	BILA	<i>Biddulphia laevis</i>
Chlorophyta	BORA	<i>Botryococcus braunii</i> Kützing
Chlorophyta	BOSU	<i>Botryosphaerella sudetica</i> (Lemmermann) Silva (= <i>Botryococcus sudeticus</i> Lemmermann)
Chlorophyta	CAGL	<i>Carteria globosa</i> Korsikov
Cyanophyta	CASP	<i>Calothrix</i> sp.
Bacillariophyta	CEDI	Centric diatoms species
Bacillariophyta	CEDI2	Centric diatoms species 2
Dinophyta	CEHI	<i>Ceratium hirundinella</i> (Müller) Dujardin
Cyanophyta	CHDI	<i>Chroococcus dispersus</i>
Chlorophyta	CHGL	<i>Chlamydomonas globosa</i> Snow
Chlorophyta	CHLS	<i>Chlorogonium</i> sp.
Chlorophyta	CHMI	<i>Chlorogonium minimum</i> Playfair

Chrysophyta	CHPL	<i>Chrysocapsa planktonica</i>
Chlorophyta	CHRE	<i>Chlamydomonas reinhardtii</i> Dangeard
Cryptophyta	CHRO	<i>Chroomonas</i> sp. 1
Cryptophyta	CHRO2	<i>Chroomonas</i> sp. 2
Cyanophyta	CHRS	<i>Chroococcus</i> sp.
Chlorophyta	CHSP	<i>Chlamydomonas</i> sp.
Chlorophyta	CHSP2	<i>Chlamydomonas</i> sp. 2
Chlorophyta	CHSP3	<i>Chlamydomonas</i> sp. 3
Cyanophyta	CHTU	<i>Chroococcus turgidus</i>
Chrysophyta	CLAC	<i>Closteriopsis acicularis</i>
Chlorophyta	CLLO	<i>Closteriopsis longissima</i> (Lemmermann) Lemmermann
Chlorophyta	CLLOT	<i>Closteriopsis longissima</i> var. <i>tropica</i> West & West
Chlorophyta	CLOS	<i>Closteriopsis</i> sp.
Chlorophyta	CLSP	<i>Closterum</i> sp.
Cyanophyta	COEL	<i>Coelosphaerium</i> sp.
Chlorophyta	COES	<i>Coelastrum</i> sp.
Chlorophyta	COMI	<i>Coelastrum microporum</i>
Cyanophyta	CONA	<i>Coelosphaerium naegelianum</i> Unger
Chlorophyta	COPL	<i>Coenococcus planktonicus</i> Korshikov
Chlorophyta	COSP	<i>Cosmarium</i> sp. 1
Chlorophyta	COSP2	<i>Cosmarium</i> sp. 2
Chlorophyta	COSP3	<i>Cosmarium</i> species 3
Chlorophyta	CRCR	<i>Crucigeniella crucifera</i> (Wolle) Komárek (= <i>Crucigenia cruciata</i> Schmidle, <i>Crucigenia crucifera</i> (Wolle) Collins)
Chlorophyta	CRFE	<i>Crucigenia fenestrata</i> (Schmidle) Schmidle
Chlorophyta	CRIR	<i>Crucigenia irregularis</i>
Chlorophyta	CRQU	<i>Crucigenia quadrata</i> Morren
Chlorophyta	CRSP	<i>Crucigenia</i> sp. 1
Chlorophyta	CRSP2	<i>Crucigenia</i> sp. 2
Chlorophyta	CRTE	<i>Crucigenia tetrapedia</i> (Kirchner) Kuntze
Chlorophyta	CRUS	<i>Crucigeniella</i> sp.
Cryptophyta	CRYP	<i>Cryptomonas</i> sp. 1
Cryptophyta	CRYP2	<i>Cryptomonas</i> sp. 2
Cryptophyta	CRYP3	<i>Cryptomonas</i> species 3
Cryptophyta	CRYP4	<i>Cryptomonas</i> sp. 4
Cyanophyta	CYCA	<i>Cyllindrospermopsis catemaco</i>
Cyanophyta	CYDY	<i>Cyanodictyon</i> sp.
Cyanophyta	CYLS	<i>Cylindrospermopsis</i> sp.

Cyanophyta	CYPL	<i>Cyanodictyon planctonicum</i> Mayer
Bacillariophyta	CYSP	<i>Cyclotella</i> sp.
Chlorophyta	DEBI	<i>Desmodesmus bicellularis</i> (Chodat) An, Friedl & Hegewald
Chlorophyta	DECO	<i>Desmodesmus communis</i> (Hegewald) Hegewald
Chlorophyta	DEIN	<i>Desmodesmus intermedius</i>
Chlorophyta	DEMA	<i>Desmodesmus magnus</i> (Meyen) Tsarenko
Chlorophyta	DEMI	<i>Desmodesmus microspina</i> (Chodat) Tsarenko
Chlorophyta	DEOB	<i>Desmodesmus obtusus</i>
Chlorophyta	DEOP	<i>Desmodesmus opoliensis</i> (Richter) Hegewald
Chlorophyta	DEOPM	<i>Desmodesmus opoliensis</i> var. <i>mononensis</i> (Chodat) Hegewald
Chlorophyta	DEPR	<i>Desmodesmus protuberans</i> (Fritsch & Rich) Hegewald
Chlorophyta	DESC	<i>Desmodesmus aculeolatus</i>
Chlorophyta	DESP	<i>Desmodesmus</i> sp.
Chlorophyta	DIAN	<i>Didymogenes anomala</i> (Smith) Hindák
Chrysophyta	DIDI	<i>Dinobryon divergens</i>
Chrysophyta	DINSP	<i>Dinobryon</i> sp.
Chlorophyta	DIPA	<i>Didymogenes palatina</i>
Chlorophyta	DISP	<i>Didymogenes</i> sp.
Cyanophyta	DOCI	<i>Anabaena circinalis</i> (= <i>Dolichospermum circinalis</i> (Nygaard) Wacklin, L.Hoffmann & Komárek)
Cyanophyta	DOCR	<i>Dolichospermum crassum</i>
Cyanophyta	DOFL	<i>Dolichospermum flosaquae</i>
Cyanophyta	DOLE	<i>Dolichospermum lemmermannii</i> (<i>Anabaena flos-aquae</i>)
Cyanophyta	DOPL	<i>Dolichospermum planktonicum</i> (Burn.) Wacklin et al.
Cyanophyta	DOSI	<i>Dolichospermum sigmoideum</i> (<i>Anabaena circinalis</i>)
Cyanophyta	DOSP	<i>Anabaena</i> sp.
Euglenophyta	EUSP	<i>Euglena</i> sp. 1
Euglenophyta	EUSP2	<i>Euglena</i> sp. 2
Bacillariophyta	FRCR	<i>Fragilaria crotonensis</i>
Bacillariophyta	FRVI	<i>Fragilaria virescens</i>
Cyanophyta	GESP	<i>Geitlerinema</i> sp.
Chlorophyta	GLCYSP	<i>Gloeocystis</i> sp.
Cyanophyta	GLEC	<i>Gloeotrichia echinulata</i>
Cyanophyta	GLOSP	<i>Gloeocapsa</i> sp.
Chrysophyta	GLSP	<i>Glenodinium</i> sp.
Chlorophyta	GLVE	<i>Gloeocystis vesiculosa</i> Nägeli
Cyanophyta	GOAP	<i>Gomphosphaeria aponina</i> Kützing
Chlorophyta	GOLSP	<i>Golenkinia</i> sp.
Cyanophyta	GOMSP	<i>Gomphosphaeria</i> sp.

Chlorophyta	GRLA	<i>Gregiochloris lacustris</i> (Chodat) Marvan, Komárek & Comas (= <i>Quadrigula lacustris</i> (Chodat) Smith)
Dinophyta	GYSP	<i>Gymnodinium</i> sp.
Chlorophyta	KILU	<i>Kirchneriella lunaris</i> (Kirchner) Möbius (= <i>Kirchneriella lunata</i>)
Chlorophyta	KISP	<i>Kirchneriella</i> sp.
Chlorophyta	KOSP	<i>Komma</i> sp. 1
Cryptophyta	KOSP2	<i>Komma</i> sp. 2
Chlorophyta	LACI	<i>Lagerheimia ciliata</i>
Chlorophyta	LASP	<i>Lagerheimia</i> species
Euglenophyta	LEAC	<i>Lepocinclis acus</i> (O.F.Müller) B.Marin & Melkonian in Marin
Cyanophyta	LEPTSP	<i>Leptolyngbya</i> sp.
Euglenophyta	LESP	<i>Lepocinclis</i> sp. 1
Euglenophyta	LESP2	<i>Lepocinclis</i> sp. 2
Cyanophyta	LILI	<i>Limnococcus limneticus</i> (Lemmermann) Komárková, Jezberová, Komárek & Zapomelová (= <i>Chroococcus limneticus</i> Lemmermann)
Cyanophyta	LISP	<i>Limnothrix</i> sp.
Cyanophyta	LYBI	<i>Lyngbya birgei</i>
Chrysophyta	MASP	<i>Mallomonas</i> sp.
Cyanophyta	MEGL	<i>Merismopedia glauca</i> (Ehrenberg) Kützing
Bacillariophyta	MEGR	<i>Melosira granulata</i>
Bacillariophyta	MEGRA	<i>Melosira granulata</i> var. <i>angustissima</i>
Cyanophyta	MESP	<i>Merismopedia</i> sp.
Bacillariophyta	MEVA	<i>Melosira varians</i>
Cyanophyta	MIAE	<i>Microcystis aeruginosa</i> (Kützing) Kützing
Chlorophyta	MICSP	<i>Microspora</i> sp.
Cyanophyta	MIIN	<i>Microcystis incerta</i>
Cyanophyta	MISP	<i>Microcystis</i> sp.
Chlorophyta	MISSP	<i>Micrasterias</i> sp.
Chlorophyta	MOAR	<i>Ankistrodesmus arcuatus</i> Korshikov (= <i>Monoraphidium arcuatum</i> (Korshikov) Hindák)
Chlorophyta	MOCO	<i>Monoraphidium contortum</i> (Thuret) Komárková-Legnerová
Chlorophyta	MOCOV	<i>Monoraphidium convolutum</i> (Corda) Komárková-Legnerová (= <i>Ankistrodesmus convolutus</i> Corda)
Chlorophyta	MOCV	<i>Ankistrodesmus convolutus</i>
Chlorophyta	MODY	<i>Monoraphidium dybowskii</i>
Chlorophyta	MOGR	<i>Monoraphidium griffithii</i> (Berkeley) Komarkova-Legnerova
Chlorophyta	MOIR	<i>Monoraphidium irregulare</i> (Smith) Komárková-Legnerová
Chlorophyta	MOKO	<i>Monoraphidium komarakovae</i>
Chlorophyta	MOMI	<i>Monoraphidium minutum</i> (Nägeli) Komárková-Legnerová
Chlorophyta	MOSP	<i>Monoraphidium</i> sp.
Chlorophyta	MOUSP	<i>Mougeotia</i> sp.

Chlorophyta	NELI	<i>Nephrocitium limneticum</i> (Smith) Smith
Chlorophyta	NEOB	<i>Nephrocitium obesum</i> (= <i>Oonephris obesa</i> (West & West) Fott)
Chlorophyta	NESP	<i>Nephrocitium</i> sp.
Bacillariophyta	NIAC	<i>Nitzschia acicularis</i>
Bacillariophyta	NIRE	<i>Nitzschia reversa</i>
Chlorophyta	OOBO	<i>Oocystis borgei</i> Snow
Chlorophyta	OOEL	<i>Oocystis ellipticus</i> West
Chlorophyta	OOGI	<i>Oocystis gigas</i>
Chlorophyta	OONA	<i>Oocystis natans</i> (Lemmermann) Lemmermann
Chlorophyta	OOOB	<i>Oonephris obesa</i> (West & West) Fott (= <i>Nephrocitium obesum</i> West & West)
Chlorophyta	OOPA	<i>Oocystis parva</i> West & West
Chlorophyta	OOSP	<i>Oocystis</i> sp. 1
Chlorophyta	OOSP2	<i>Oocystis</i> sp. 2
Chlorophyta	OOSP3	<i>Oocystis</i> sp. 3
Cyanophyta	OSAG	<i>Oscillatoria agardhii</i>
Cyanophyta	OSAM	<i>Oscillatoria amphibia</i>
Cyanophyta	OSPR	<i>Oscillatoria princeps</i>
Cyanophyta	OSSP	<i>Oscillatoria</i> sp.
Chlorophyta	PAMO	<i>Pandorina morum</i> (Müller) Bory
Chlorophyta	PEAN	<i>Pediastrum angulosum</i> Ehrenberg ex Meneghini
Chlorophyta	PEBO	<i>Pediastrum boryanum</i> (= <i>Pseudopediastrum boryanum</i> (Turpin) Hegewald)
Dinophyta	PECI	<i>Peridinium cinctum</i> (Müller) Ehrenberg
Bacillariophyta	PEDI	Pennate diatoms
Chlorophyta	PEDU	<i>Pediastrum duplex</i>
Chlorophyta	PEDUC	<i>Pediastrum duplex</i> Meyen (= <i>Pediastrum duplex</i> var. <i>clathratum</i> Meyen)
Chlorophyta	PEPE	<i>Pectinodesmus pectinatus</i> (Meyen) E.Hegewald, M.Wolf, Al.Keller, Friedl & Krienitz (= <i>Acutodesmus pectinatus</i> (Meyen) Tsarenko)
Chlorophyta	PESP	<i>Pediastrum</i> sp. 1
Dinophyta	PESP2	Peridinium species 2
Chlorophyta	PETE	<i>Pediastrum tetras</i> (= <i>Stauridium tetras</i> (Ehrenberg) Hegewald)
Cyanophyta	PHFO	<i>Phormidium formosum</i>
Cyanophyta	PHRSP	<i>Phormidium</i> sp. 1
Cyanophyta	PHRSP2	<i>Phormidium</i> sp. 2
Cyanophyta	PHRSP3	<i>Phormidium</i> sp. 3
Cyanophyta	PHRSP4	<i>Phormidium</i> sp. 4
Cyanophyta	PHRSP5	<i>Phormidium</i> sp. 5
Euglenophyta	PHSP	<i>Phacus</i> sp.
Cyanophyta	PLAG	<i>Planktothrix agardhii</i> (Gomont) Anagnostidis & Komárek

Chlorophyta	PLGE	<i>Planktosphaeria gelatinosa</i> Smith
Cyanophyta	PLSP	<i>Planktolynghya</i> sp.
Cyanophyta	PLXSP	<i>Planktothrix</i> sp.
Cyanophyta	PSSP	<i>Pseudanabaena</i> sp.
Chlorophyta	PTSP	<i>Pteromonas</i> sp.
Chlorophyta	QUCH	<i>Quadrigula chodatii</i> (Tanner-Füllemann) Smith
Chlorophyta	QUSP	<i>Quadrigula</i> sp.
Chlorophyta	RADA	<i>Raphidocelis danubiana</i> (Hindák) Marvan, Komárek & Comas (= <i>Kirchneriella contorta</i> (Schmidle) Bohlin)
Chlorophyta	SCAR	<i>Scenedesmus arcuatus</i> (Lemmermann) Lemmermann
Chlorophyta	SCBI	<i>Scenedesmus bijuga</i>
Chlorophyta	SCDI	<i>Tetradesmus lagerheimii</i> Wynne & Guiry (= <i>Acutodesmus acuminatus</i> (Lagerheim); <i>Scenedesmus dimorphus</i> (Turpin) Kützing)) Tsarenko)
Chlorophyta	SCEL	<i>Scenedesmus ellipticus</i> Corda
Chlorophyta	SCJU	<i>Ankyra judayi</i>
Chlorophyta	SCOB	<i>Scenedesmus obtusus</i> Meyen
Chlorophyta	SCQU	<i>Scenedesmus quadricauda</i>
Chlorophyta	SCQUM	<i>Scenedesmus quadricauda</i> var. <i>maximus</i>
Chlorophyta	SCQUQ	<i>Scenedesmus quadricauda</i> var. <i>quadrispina</i>
Chlorophyta	SCRO	<i>Schroederia robusta</i>
Chlorophyta	SCSE	<i>Schroederia setigera</i>
Chlorophyta	SCSP	<i>Scenedesmus</i> sp.
Chlorophyta	SESP	<i>Selenastrum</i> sp.
Cyanophyta	SNLA	<i>Snowella lacustris</i> (Chodat) Komárek & Hindák (= <i>Gomphosphaeria lacustris</i> Chodat)
Cyanophyta	SNSP	<i>Snowella</i> species
Chlorophyta	SPCH	Spherical chlorophyta
Cyanophyta	SPRSP	<i>Spirulina</i> sp.
Chlorophyta	SPSC	<i>Sphaerocystis schroeteri</i> Chodat
Chlorophyta	SPSP	<i>Spirogyra</i> sp.
Chlorophyta	STGR	<i>Staurastrum gracile</i>
Bacillariophyta	STNI	<i>Stephanodiscus niagarae</i>
Chlorophyta	STOP	<i>Stigeoclonium polymorphum</i>
Chlorophyta	STSP3	<i>Staurastrum</i> sp. 3
Chlorophyta	TECA	<i>Tetraëdron caudatum</i> (Corda) Hansgirg
Chlorophyta	TEMI	<i>Tetraëdron minimum</i> (Braun) Hansgirg
Chlorophyta	TESP	<i>Tetraëdron</i> sp.
Chlorophyta	TETR	<i>Tetraëdron trigonum</i> (Nägeli) Hansgirg
Euglenophyta	TRSP	<i>Trachellomonas</i> sp. 1
Euglenophyta	TRSP2	<i>Trachellomonas</i> sp. 2

Chlorophyta	ULSP	<i>Ulothrix</i> sp.
Chlorophyta	UNCHLPIC	Unknown chlorophyte picoplankter
Chlorophyta	UNCOCH	Unknown colonial chlorophyte
Chlorophyta	UNCOCH2	Unknown colonial chlorophyte species 2
Cyanophyta	UNCOCY	Unknown colonial cyanophyte
Cyanophyta	UNCOCY2	Unknown colonial cyanophyte species 2
Cyanophyta	UNCOCYPI	Unknown colonial cyanophyte picoplankter
Cryptophyta	UNCRY	Unknown cryptomonad
Cryptophyta	UNCRY2	Unknown cryptomonad 2
Cryptophyta	UNCRY3	Unknown cryptomonad 3
Dinophyta	UNDINO	Unknown dinoflagellate
Chlorophyta	UNELCHL	Unknown elongate chlorophyte
Euglenophyta	UNEUG	Unknown euglenoid
Chlorophyta	UNFICH	Unknown filamentous chlorophyta
Cyanophyta	UNFICY	Unknown filamentous cyanophyte
Cyanophyta	UNFICY2	Unknown filamentous Cyanophyta species 2
Cyanophyta	UNFICY3	Unknown filamentous Cyanophyta 3
Cyanophyta	UNFICY4	Unknown filamentous cyanophyte 4
Cyanophyta	UNFICYPI	Unknown filamentous cyanophyte picoplankter
Chlorophyta	UNSPCH	Unknown spherical chlorophyte
Chlorophyta	UNSPCH2	Unknown spherical chlorophyte 2
Chlorophyta	UNSPCH3	Unknown spherical chlorophyte 3
Chlorophyta	UNSPCHPI	Unknown spherical chlorophyte picoplanker
Chrysophyta	UNSPCHR	Unknown spherical chrysophyte
Cyanophyta	UNSPCY	Unknown spherical cyanophyta
Cyanophyta	UNSPCY2	Unknown spherical cyanophyte 2
Cyanophyta	UNSPCYPI	Unknown spherical cyanophyte picoplankter
Chlorophyta	WIRE	<i>Willea rectangularis</i> (Braun) John, Wynne & Tsarenko (= <i>Crucigenia rectangularis</i> (Nägeli) Gay (= <i>Crucigeniella rectangularis</i> (Nägeli) Komárek)

ACDI¹ Acutodesmus dimorphus (= Tetrademus dimorphus (Turpin) Wynne) = Scenedesmus dimorphus (= Tetrademus dimorphus) = SCDI in functional traits analysis.

APPENDIX 2. MRPP RESULTS FOR DIVISION ASSEMBLAGES

***** Multi-Response Permutation Procedures (MRPP) *****

PC-ORD, 7.08

7 Oct 2021, 11:47:23

Project file:

C:\Users\davidrichards\Desktop\UtahLakePhyto2016forAdditionalAnalyses\Phytoplankton Divisions all years\Utah Lake Phytoplankton DIVISIONS.7prj

OreoHelix Ecological “Dedicated to Evaluating and Protecting the World’s Ecological Health, Integrity, and Well Being, One Snail at a Time”

Main matrix: C:\Users\davidrichards\AppData\Roaming\MjM Software Design\PCORD 7\WORK.MJM
 Second matrix:
 C:\Users\davidrichards\Desktop\UtahLakePhyto2016forAdditionalAnalyses\Phytoplankton Divisions all years\PhytoplanktonDivisionsCODESforMultivariate.mjm

Grouping variable: Month from matrix 2

Groups were defined by values of: Month
 Input data has: 778 samples by 8 codes
 Weighting option: C(I) = n(I)/sum(n(I))
 Distance measure: Relative Sorensen

GROUP: 1
 Identifier: 8
 Size: 160 0.36293328 = Average distance

Members:

S17105	S17310AA	S17310AB	S17310AC	S17310AD	S17310AE	S17310U	
S17310V							
S17310W	S17310X	S17310Y	S17310Z	S17320D	S17320E	S17326E	
S17326F							
S17326G	S17326H	S17335AA	S17335AB	S17335AC	S17335AD	S17335AF	
S17335AG							
S17335AH	S17335AI	S17335Y	S17335Z	S17337B	S17365K	S17365L	
S17365M							
S17365N	S17365O	S17370AA	S17370AB	S17370R	S17370S	S17370T	
S17370U							
S17370V	S17370X	S17370Y	S17370Z	S17390AA	S17390AB	S17390AC	
S17390AD							
S17390AE	S17390AF	S17390AG	S17390AH	S17390AI	S17390AJ	S17390AK	
S17390AL							
S17390X	S17390Y	S17390Z	S17433E	S17439R	S17439S	S17439T	
S17444B							
S17450S	S17450T	S17450U	S17450V	S17450W	S17455N	S17455O	
S17455P							
S17455Q	S17455R	S17455S	S17455T	S17485B	S17485C	S17485D	
S17500P							
S17500Q	S17500R	S17500S	S17500T	S17505A	S17512C	S17520P	
S17520Q							
S17520R	S17520S	S17520T	S17520U	S17525N	S17532J	S17532K	
S17532L							
S17532M	S17535H	S17535I	S17535J	S17535K	S17537I	S17537J	
S17537K							
S17539G	S17539H	S17539I	S17539J	S17539K	S17539L	S17600O	
S17600P							
S17600Q	S17600R	S17600S	S17606C	S17608K	S17608L	S17608M	
S17608N							
S17608O	S17608P	S17608Q	S17608R	S17704F	S17706A	S17708J	
S17708K							
S17708L	S17708M	S17708N	S17709N	S17709O	S17709P	S17710F	
S17715M							
S17715N	S17715O	S17715P	S17715Q	S17728A	S17728B	S17728C	
S17768D							
S17770U	S17770V	S17770W	S17770X	S17772E	S17775D	S17778C	
S17778D							
S666	S777	S94790J	S94790K	S94790L	S94790M	S94790N	S9S58

GROUP: 2
 Identifier: 9
 Size: 115 0.38847638 = Average distance

Members:

S17300	S17310AF	S17310AG	S17310AH	S17310AI	S17310AJ	S17310AK
S17310AL						
S17310AM	S17310AN	S17310AO	S17310AP	S17310AQ	S17310AR	S17320F
S17320G						
S17335AJ	S17335AK	S17335AL	S17365P	S17365Q	S17365R	S17370AC
S17370AD						
S17370AE	S17370AG	S17370AH	S17370AI	S17370AJ	S17370AK	S17390AM
S17390AN						

OreoHelix Ecological “Dedicated to Evaluating and Protecting the World’s Ecological Health, Integrity, and Well Being, One Snail at a Time”

S17390AO	S17390AP	S17390AQ	S17390AR	S17390AS	S17390AT	S17390AU
S17390AV						
S17390AX	S17390AY	S1739AW	S17433F	S17439U	S17442C	S17442D
S17442E						
S17450AA	S17450X	S17450Y	S17450Z	S17455U	S17485E	S17500AA
S17500AB						
S17500U	S17500V	S17500W	S17500X	S17500Y	S17500Z	S17520AA
S17520AB						
S17520V	S17520W	S17520X	S17520Y	S17520Z	S17532O	S17535L
S17537L						
S17539M	S17539N	S17541X	S17600T	S17600U	S17600V	S17600W
S17600Y						
S17603H	S17603I	S17603J	S17608S	S17608T	S17608U	S17608V
S17704G						
S17704H	S17704I	S17706B	S17708O	S17708Q	S17709Q	S17709R
S17709S						
S17709T	S17710G	S17710H	S17715R	S17715S	S17715T	S17715U
S17715V						
S17715W	S17715X	S17768E	S17770AA	S17770AB	S17770AC	S17770Y
S17770Z						
S17775F	S17778E	S17778F				

GROUP: 3
 Identifier: 4
 Size: 38 0.42478395 = Average distance

Members:

S17310A	S17326A	S17326B	S17335G	S17335H	S17335I	S17439E
S17439F						
S17439G	S17439H	S17452B	S17452C	S17452D	S17455D	S17455E
S17455F						
S17460C	S17460D	S17460E	S17532C	S17532D	S17534	S17536C
S17537B						
S17603C	S17606A	S17608C	S17608D	S17613B	S17708A	S17709F
S17721A						
S17722	S17723	S17724	S17725	S17726	S17727	

GROUP: 4
 Identifier: 10
 Size: 88 0.37953439 = Average distance

Members:

S17310AS	S17310AT	S17310AU	S17310AV	S17310AW	S17310AX	S17320H
S17320I						
S17323C	S17335AM	S17335AN	S17335AO	S17335AP	S17335AQ	S17335AR
S17335AS						
S17365T	S17370AL	S17370AM	S17370AN	S17370AO	S17370AP	S17380
S17390AZ						
S17390BA	S17390BB	S17390BC	S17433G	S17433H	S17450AB	S17450AC
S17450AD						
S17450AE	S17450AF	S17450AG	S17455V	S17455W	S17455X	S17485F
S17500AC						
S17500AD	S17500AE	S17500AF	S17500AG	S17510B	S17520AC	S17520AD
S17520AE						
S17520AF	S17520AG	S17520AH	S17532P	S17532Q	S17535M	S17535N
S17535O						
S17537M	S17537N	S17537O	S17539O	S17539P	S17539Q	S17600AA
S17600AB						
S17600AC	S17600Z	S17603K	S17603L	S17608W	S17704J	S17704K
S17708R						
S17709U	S17709V	S17710I	S17710J	S17715Y	S17715Z	S17768F
S17770AD						
S17770AE	S17770AF	S17770AG	S17770AH	S91770	S94720	S94790O
S94790P						

GROUP: 5
 Identifier: 11
 Size: 36 0.36016150 = Average distance

Members:

S17310AY	S17310AZ	S17320J	S17335AT	S17335AU	S17365S	S17370AQ
S17370AR						
S17390BD	S17390BE	S17390BF	S17439V	S17450AH	S17455Y	S17500AH
S17500AI						

OreoHelix Ecological “Dedicated to Evaluating and Protecting the World’s Ecological Health, Integrity, and Well Being, One Snail at a Time”

S17520AI	S17520AJ	S17532R	S17535P	S17537P	S17539R	S17600AD
S17603M						
S17608X	S17704L	S17709W	S17709X	S17710K	S17710L	S17715AA
S17715AB						
S17768G	S17770AI	S17770AJ	S17778G			

GROUP: 6
 Identifier: 5
 Size: 46 0.43593793 = Average distance

Members:

S17310B	S17310C	S17310D	S17310E	S17320A	S17335J	S17335K
S17365A						
S17370A	S17370B	S17370C	S17388	S17390A	S17390B	S17439I
S17439J						
S17450A	S17450B	S17450C	S17455G	S17460F	S17460G	S17500A
S17500B						
S17520A	S17520B	S17520C	S17532E	S17535B	S17539A	S17600A
S17600B						
S17600C	S17608E	S17635A	S17709G	S17709H	S17710A	S17710B
S17715A						
S17715B	S17770A	S17770B	S17770C	S17775A	S94790B	

GROUP: 7
 Identifier: 6
 Size: 102 0.43909285 = Average distance

Members:

S17310F	S17310G	S17310H	S17310I	S17310J	S17320B	S17320C
S17335L						
S17335M	S17335N	S17335O	S17365B	S17365C	S17365D	S17365E
S17365F						
S17370D	S17370E	S17370F	S17370G	S17370H	S17390C	S17390D
S17390E						
S17390F	S17390G	S17390H	S17390I	S17390J	S17439K	S17439L
S17442B						
S17450D	S17450E	S17450F	S17450G	S17450H	S17450I	S17450J
S17450K						
S17450L	S17454H	S17455I	S17455J	S17458A	S17460H	S17500C
S17500D						
S17500E	S17500F	S17520D	S17520E	S17520F	S17520G	S17520H
S17532F						
S17532G	S17535C	S17535D	S17537D	S17537E	S17539B	S17539C
S17600D						
S17600E	S17600F	S17600G	S17600H	S17600I	S17603D	S17603E
S17603F						
S17608F	S17610B	S17613C	S17708B	S17709I	S17709J	S17710C
S17710D						
S17715C	S17715D	S17715E	S17715F	S17715G	S17721B	S17768B
S17770D						
S17770E	S17770F	S17770G	S17770H	S17770I	S17770J	S17770K
S17770L						
S17775B	S17778A	S94790C	S94790D	S96096	S97390	

GROUP: 8
 Identifier: 7
 Size: 151 0.32406408 = Average distance

Members:

S17310K	S17310L	S17310M	S17310N	S17310O	S17310P	S17310Q
S17310R						
S17310S	S17310T	S17326C	S17326D	S17335P	S17335Q	S17335R
S17335S						
S17335T	S17335U	S17335V	S17335W	S17335X	S17337A	S17365G
S17365H						
S17365I	S17365J	S17370I	S17370J	S17370K	S17370L	S17370M
S17370N						
S17370O	S17370P	S17370Q	S17390gc	S17390K	S17390L	S17390M
S17390N						
S17390O	S17390P	S17390Q	S17390R	S17390S	S17390T	S17390U
S17390V						
S17390W	S17410B	S17433A	S17433C	S17433D	S17439M	S17439N
S17439O						

OreoHelix Ecological “Dedicated to Evaluating and Protecting the World’s Ecological Health, Integrity, and Well Being, One Snail at a Time”

S17439P	S17439Q	S17450M	S17450N	S17450O	S17450P	S17450Q	
S17450R							
S17452E	S17455K	S17455L	S17455M	S17458B	S17460I	S17485A	
S17500G							
S17500H	S17500I	S17500J	S17500K	S17500L	S17500M	S17500N	
S17500O							
S17512A	S17512B	S17520I	S17520J	S17520K	S17520L	S17520M	
S17520N							
S17520O	S17532H	S17532I	S17535E	S17535F	S17535G	S17537F	
S17537G							
S17537H	S17539D	S17539E	S17539F	S17600J	S17600K	S17600L	
S17600M							
S17600N	S17603G	S17606B	S17608G	S17608H	S17608I	S17608J	
S17620B							
S17700A	S17702B	S17704D	S17704E	S17708C	S17708D	S17708E	
S17708F							
S17708G	S17708H	S17708I	S17709K	S17709L	S17709M	S17710E	
S17711H							
S17715I	S17715J	S17715K	S17715L	S17768C	S17770M	S17770N	
S17770O							
S17770P	S17770Q	S17770R	S17770S	S17770T	S17775C	S17778B	S888
S94790E	S94790F	S94790G	S94790H	S94790I	S95575B	S999	

GROUP: 9
Identifier: 2

Size: 10 0.36592549 = Average distance

Members:

S17323A	S17335B	S17335C	S17442A	S17444A	S17532A	S17603A
S17709B						
S17709C	S95575A					

GROUP: 10
Identifier: 3

Size: 23 0.33058302 = Average distance

Members:

S17323B	S17335D	S17335E	S17335F	S17439C	S17439D	S17452A
S17455B						
S17455C	S17460A	S17460B	S17532B	S17537A	S17603B	S17608A
S17608B						
S17613A	S17704B	S17704C	S17709D	S17709E	S17768A	S94790A

GROUP: 11
Identifier: 12

Size: 2 0.37003562 = Average distance

Members:

S17323D	S17709Y
---------	---------

GROUP: 12
Identifier: 1

Size: 7 0.23511029 = Average distance

Members:

S17335A	S17439A	S17439B	S17455A	S17610A	S17704A	S17709A
---------	---------	---------	---------	---------	---------	---------

Test statistic: T = -59.433621
Observed delta = 0.37618707
Expected delta = 0.45780082
Variance of delta = 0.18856551E-05
Skewness of delta = -0.57559997

Chance-corrected within-group agreement, A = 0.17827349
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.

OreoHelix Ecological “Dedicated to Evaluating and Protecting the World’s Ecological Health, Integrity, and Well Being, One Snail at a Time”

Groups (identifiers)		T	A	p
Compared				
8	vs. 9	0.37049105	-0.00084245	0.51908167
8	vs. 4	-58.80509720	0.19731169	0.00000000
8	vs. 10	-1.16887939	0.00303974	0.10996242
8	vs. 11	-21.25984191	0.07011616	0.00000000
8	vs. 5	-28.83723429	0.09105713	0.00000000
8	vs. 6	-27.83154943	0.06973265	0.00000000
8	vs. 7	-2.41618908	0.00524248	0.03451144
8	vs. 2	-27.35901053	0.10541074	0.00000000
8	vs. 3	-45.25499619	0.16394896	0.00000000
8	vs. 12	-2.26463827	0.01231405	0.02828084
8	vs. 1	-26.45648339	0.10687026	0.00000000
9	vs. 4	-46.50735361	0.20623619	0.00000000
9	vs. 10	-0.88722925	0.00286320	0.14461388
9	vs. 11	-17.46331932	0.07554374	0.00000004
9	vs. 5	-22.30834528	0.09155570	0.00000000
9	vs. 6	-20.28249950	0.06200369	0.00000000
9	vs. 7	-3.41177733	0.00873393	0.01395881
9	vs. 2	-23.10627500	0.12222897	0.00000000
9	vs. 3	-36.94470101	0.18108260	0.00000000
9	vs. 12	-1.92685434	0.01459493	0.04742311
9	vs. 1	-22.72543690	0.12688484	0.00000000
4	vs. 10	-40.58437341	0.22115420	0.00000000
4	vs. 11	-17.89946810	0.14806369	0.00000000
4	vs. 5	-8.56758801	0.06233812	0.00005230
4	vs. 6	-21.81490732	0.09495575	0.00000000
4	vs. 7	-61.87973819	0.24340115	0.00000000
4	vs. 2	-4.74644407	0.06647389	0.00300821
4	vs. 3	-4.82659471	0.04807835	0.00259185
4	vs. 12	-0.08563102	0.00180334	0.41107849
4	vs. 1	-5.48707985	0.08300060	0.00131849
10	vs. 11	-11.76814875	0.06676891	0.00000878
10	vs. 5	-17.22410511	0.08768222	0.00000006
10	vs. 6	-13.26250579	0.04765422	0.00000251
10	vs. 7	-4.52489451	0.01346260	0.00536249
10	vs. 2	-22.49703949	0.15649511	0.00000000
10	vs. 3	-34.85060546	0.21509879	0.00000000
10	vs. 12	-1.75774449	0.01898312	0.05393532
10	vs. 1	-21.97046586	0.16324528	0.00000000
11	vs. 5	-2.28335595	0.01729457	0.03761458
11	vs. 6	-1.20413719	0.00552776	0.10826789
11	vs. 7	-27.57224683	0.10845371	0.00000000
11	vs. 2	-16.74962762	0.23825742	0.00000000
11	vs. 3	-22.81722344	0.24825057	0.00000000
11	vs. 12	-1.09942212	0.02543476	0.13522752
11	vs. 1	-17.59972329	0.27031812	0.00000000
5	vs. 6	-1.32712564	0.00566279	0.09632243
5	vs. 7	-35.14627999	0.13059893	0.00000000
5	vs. 2	-10.15523037	0.12374975	0.00000909
5	vs. 3	-12.53855609	0.12054074	0.00000181
5	vs. 12	-0.15288867	0.00284447	0.40858924
5	vs. 1	-10.74338574	0.14472827	0.00000423
6	vs. 7	-36.49118222	0.10459284	0.00000000
6	vs. 2	-15.67645152	0.08982304	0.00000002
6	vs. 3	-23.63753151	0.11708871	0.00000000
6	vs. 12	-0.56404827	0.00484008	0.25772369
6	vs. 1	-16.03473184	0.09745924	0.00000001
7	vs. 2	-28.73273850	0.13147388	0.00000000
7	vs. 3	-47.02815588	0.20245515	0.00000000
7	vs. 12	-2.56308211	0.01731998	0.01630924
7	vs. 1	-27.25576689	0.13166504	0.00000000
2	vs. 3	-0.70610319	0.01439867	0.18473159
2	vs. 12	-0.58363225	0.04311815	0.25043784
2	vs. 1	0.42434991	-0.01633499	0.56101510
3	vs. 12	0.01850035	-0.00064576	0.44749413
3	vs. 1	-2.25227199	0.05251003	0.03750539
12	vs. 1	-1.60041669	0.16862979	0.06704956

***** MRPP finished *****

7 Oct 2021, 11:47:30

APPENDIX 3. CORRELATIONS OF PHYTOPLANKTON TAXA WITH NMS AXIS 1 AND AXIS 2.

Taxon Code	Axis 1	Axis 2
ACHA	0.777	-0.134
ANFA	0.285	0.17
APFL	-0.716	0.442
APSP	0.918	0.094
CEDI	0.159	-0.531
CEDI2	0.976	-0.02
CEHI	-0.704	0.371
CHGL	0.714	0.262
CHMI	-0.017	0.117
CHRO	0.702	0.214
CHSP	-0.19	0.061
CLLO	0.669	0.094
CLLOT	-0.372	0.032
CRFE	0.811	0.234
CRRE	0.883	0.054
CRYP	0.802	0.191
CYPL	0.759	-0.096
DEBI	0.916	0.091
DECO	0.954	-0.066
DEOP	0.771	-0.322
DEPR	0.791	-0.149
DOCI	0.789	0.301
DOCR	-0.125	0.153
DOFL	-0.795	0.3
DOSP	-0.711	-0.11
EUSP	0.361	-0.334
GYSB	0.752	0.083
KILU	0.886	0.16
KOSP2	0.696	0.363
LEPTSP	0.918	-0.003
LILI	0.71	0.27
MEGL	0.94	0.064
MEGR	-0.396	-0.095
MEGRA	-0.325	-0.515
MEVA	-0.112	-0.385
MIAE	-0.658	0.395

MOAR	0.948	0.097
MOCO	0.92	-0.052
MOCOV	0.763	0.016
MODY	0.737	-0.199
NIAC	0.762	-0.337
OOBO	0.173	-0.061
OOEL	0.743	0.241
OOSP	0.971	-0.008
PEAN	0.85	0.055
PEDI	0.606	-0.381
PEDU	-0.469	-0.513
PEPE	0.859	-0.221
PHRSP	0.665	0.208
PHRSP3	0.487	0.214
PHSP	-0.851	-0.137
PLXSP	0.686	0.331
PSSP	0.7	0.271
PTSP	-0.903	-0.202
SCBI	-0.881	-0.18
SCDI	0.082	-0.28
SCEL	0.882	0.037
SCOB	0.883	0.124
SCQU	-0.901	-0.217
SCSE	-0.866	-0.034
SCSP	-0.757	-0.304
SPSC	-0.376	-0.138
UNCOCH	0.874	-0.051
UNSPCH	0.909	-0.04
UNSPCH2	0.88	0.038
UNSPCH3	0.762	0.232
WIRE	0.657	0.169

APPENDIX 4. LIST OF TAXA REMOVED FROM MULTIVARIATE PHYTOPLANKTON TAXA ASSEMBLAGE ANALYSES. THESE TAXA OCCURRED IN < 5% OF THE SAMPLES. FOR NAMES OF TAXA SEE APPENDIX 1.

ACDI	ACGR	ACOB	ACSP	ANFU	ANSP	APDE	APGR	APHO
APHS	APPL	ASFO	AUGR	AUSP1	BESP	BILA	BORA	BOSU
CAGL	CASP	CHDI	CHLS	CHPL	CHRO2	CHRS	CHSP2	CHSP3
CHTU	CLAC	CLOS	CLSP	COEL	COES	COMI	CONA	COPL
COSP	COSP2	COSP3	CRCR	CRIR	CRQU	CRSP	CRSP2	CRTE
CRUS	CRYP2	CRYP3	CRYP4	CYCA	CYDY	CYLS	CYSP	DEIN
DEMA	DEMI	DEOB	DEOPM	DESC	DESP	DIAN	DIDI	DINSP
DIPA	DISP	DOLE	DOPL	DOSI	EUSP2	FRCR	FRVI	GESP
GLCYSP	GLEC	GLOSP	GLSP	GLVE	GOAP	GOLSP	GOMSP	GRLA
KISP	KOSP	LACI	LASP	LEAC	LESP	LESP2	LISP	LYBI
MASP	MESP	MICSP	MIIN	MISP	MISSP	MOCV	MOGR	MOIR
MOKO	MOMI	MOSP	MOUSP	NELI	NEOB	NESP	NIRE	OOGI
OONA	OOOB	OOPA	OOSP2	OOSP3	OSAG	OSAM	OSPR	OSSP
PAMO	PEBO	PECI	PEDUC	PESP	PESP2	PETE	PHFO	PHRSP2
PHRSP4	PHRSP5	PLAG	PLGE	PLSP	QUCH	QUSP	RADA	SCAR
SCJU	SCQUM	SCQUQ	SCRO	SESP	SNLA	SNSP	SPCH	SPRSP
SPSP	STGR	STNI	STOP	STSP3	TECA	TEMI	TESP	TETR
TRSP	TRSP2	ULSP	UNCHLPIC	UNCOCH2	UNCOCY	UNCOCY2	UNCOCYPI	UNCRY
UNCRY2	UNCRY3	UNDINO	UNELCHL	UNEUG	UNFICH	UNFICY	UNFICY2	UNFICY3
UNFICY4	UNFICYPI	UNSPCHPI	UNSPCHR	UNSPCY	UNSPCY2	UNSPCYPI		

APPENDIX 5. MRPP FOR PHYTOPLANKTON TAXA BY MONTH

Month	Compared	Month	T	A	p
Aug	vs.	Sept	-3.67	0.01	0.01
Aug	vs.	April	-19.12	0.06	0.00
Aug	vs.	Oct	-4.76	0.01	0.00
Aug	vs.	Nov	-20.01	0.06	0.00
Aug	vs.	May	-9.75	0.03	0.00
Aug	vs.	June	-9.58	0.02	0.00
Aug	vs.	July	-3.85	0.01	0.01
Aug	vs.	Feb	-5.61	0.02	0.00
Aug	vs.	March	-12.19	0.04	0.00
Aug	vs.	Dec	-1.17	0.01	0.12
Aug	vs.	Jan	-2.36	0.01	0.04
Sept	vs.	April	-20.33	0.09	0.00
Sept	vs.	Oct	-0.98	0.00	0.13
Sept	vs.	Nov	-22.02	0.10	0.00
Sept	vs.	May	-12.81	0.05	0.00
Sept	vs.	June	-13.88	0.04	0.00
Sept	vs.	July	-6.53	0.02	0.00
Sept	vs.	Feb	-6.09	0.03	0.00

Sept	vs.	March	-12.67	0.06	0.00
Sept	vs.	Dec	-1.21	0.01	0.02
Sept	vs.	Jan	-2.72	0.02	0.02
April	vs.	Oct	-15.34	0.09	0.00
April	vs.	Nov	-19.35	0.10	0.00
April	vs.	May	-5.64	0.02	0.00
April	vs.	June	-8.87	0.03	0.00
April	vs.	July	-20.13	0.07	0.00
April	vs.	Feb	-2.19	0.01	0.04
April	vs.	March	-2.88	0.02	0.02
April	vs.	Dec	-0.91	0.01	0.15
April	vs.	Jan	-2.01	0.02	0.05
Oct	vs.	Nov	-16.70	0.10	0.00
Oct	vs.	May	-8.58	0.05	0.00
Oct	vs.	June	-8.04	0.03	0.00
Oct	vs.	July	-6.19	0.02	0.00
Oct	vs.	Feb	-4.60	0.04	0.00
Oct	vs.	March	-9.28	0.06	0.00
Oct	vs.	Dec	-0.90	0.01	0.18
Oct	vs.	Jan	-1.92	0.02	0.05
Nov	vs.	May	-12.34	0.06	0.00
Nov	vs.	June	-15.69	0.06	0.00
Nov	vs.	July	-22.45	0.08	0.00
Nov	vs.	Feb	-9.96	0.09	0.00
Nov	vs.	March	-18.92	0.14	0.00
Nov	vs.	Dec	-1.28	0.02	0.11
Nov	vs.	Jan	-7.99	0.08	0.00
May	vs.	June	-1.67	0.01	0.07
May	vs.	July	-11.03	0.04	0.00
May	vs.	Feb	-3.17	0.02	0.02
May	vs.	March	-6.11	0.04	0.00
May	vs.	Dec	-0.78	0.01	0.15
May	vs.	Jan	-1.34	0.01	0.10
June	vs.	July	-9.40	0.02	0.00
June	vs.	Feb	-3.16	0.02	0.02
June	vs.	March	-5.77	0.02	0.00
June	vs.	Dec	-0.73	0.01	0.16
June	vs.	Jan	-1.00	0.01	0.13
July	vs.	Feb	-6.11	0.03	0.00
July	vs.	March	-12.63	0.05	0.00

July	vs.	Dec	-1.26	0.01	0.11
July	vs.	Jan	-2.66	0.01	0.03
Feb	vs.	March	-2.02	0.03	0.05
Feb	vs.	Dec	-0.73	0.03	0.22
Feb	vs.	Jan	-0.05	0.00	0.40
March	vs.	Dec	-0.53	0.01	0.26
March	vs.	Jan	-0.44	0.01	0.24
Dec	vs.	Jan	-0.47	0.05	0.20

APPENDIX 6. INDICATOR TAXA BY MONTH

Taxon Code	Month	Observed Indicator Value (IV)	IV from randomized groups		
			Mean	Std. dev.	p-value
ACAC	Aug	6.6	5.7	6.87	0.20
ACDI	Aug	0.7	1.6	2.79	0.75
ACGR	Jan	2.6	4.9	6.01	0.66
ACHA	July	4.3	5.6	7.27	0.34
ACOB	Oct	1.8	1.9	4.09	0.27
ACPE	Jan	8.2	8.6	6.6	0.34
ACSP	Aug	2.5	2.5	4.9	0.20
ANFA	Feb	11.1	15	7.42	0.67
ANFU	Jan	0.6	1.5	2.51	1.00
ANSP	July	1	1.5	2.54	0.45
APDE	Jan	1.2	2.1	3.95	0.52
APFL	Aug	56	20.2	9.29	0.01
APGR	Jan	4.9	3.7	5.2	0.14
APHO	Jan	0.6	1.6	3.44	1.00
APHS	April	9.9	3.9	6.03	0.06
APPL	April	4.8	5.1	6.91	0.26
APSP	Jan	10.2	10.3	7.03	0.32
ASFO	March	5.7	3.1	5.9	0.13
AUGR	Feb	3	4.3	7.12	0.37
AUSP1	Aug	0.8	2.6	4.93	0.84
BESP	Feb	1	2.5	5.01	0.64
BILA	Jan	1.8	2	3.61	0.35
BORA	May	3.3	4.6	6.85	0.34
BOSU	Feb	0.6	2	4.24	0.69
CAGL	Aug	4	2.6	5.06	0.11
CASP	Jan	0.8	2.8	5.1	0.81

CEDI	Oct	55.4	16.2	8.65	0.01
CEDI2	May	12.6	15.2	8.58	0.50
CEHI	Jan	23.3	19.1	6.69	0.17
CHDI	Jan	1.9	3.3	5.67	0.41
CHGL	Jan	15.7	6.1	6.31	0.06
CHLS	Jan	1.6	2.7	4.84	0.48
CHMI	Feb	4	6.3	6.51	0.55
CHPL	Jan	0.6	2.2	3.88	0.90
CHRE	Jan	14.3	4.8	6.48	0.05
CHRL	Jan	8.4	5.2	6.5	0.13
CHRO	Jan	3	5.7	5.91	0.71
CHRO2	Jan	4.3	2.8	4.47	0.13
CHRS	Jan	3.7	4.3	6.76	0.29
CHSP	April	13.5	9.1	7.36	0.13
CHSP2	May	5.3	4.1	6.56	0.16
CHSP3	May	13.9	2.5	4.74	0.01
CHTU	July	0.4	2.4	4.89	0.95
CLAC	July	1	1.6	3.37	0.46
CLLO	Jan	4.9	6.6	7.37	0.39
CLLOT	Feb	7.9	6.3	5.85	0.19
CLOS	Jan	1.1	2.3	3.47	0.68
CLSP	Feb	3.8	3.6	6.11	0.21
COEL	April	1.9	4.5	6.89	0.59
COES	May	2	4.6	5.24	0.84
COMI	June	5.9	2.6	5.29	0.10
CONA	Feb	0.9	1.6	3.28	0.61
COPL	Jan	3.5	4.2	5.75	0.32
COSP	Jan	1.4	4.6	6.82	0.83
COSP2	Aug	0.7	1.5	2.86	0.79
COSP3	Jan	2.3	3.8	6.45	0.41
CRCR	May	4.2	2.6	5.53	0.11
CRFE	May	5.1	5.8	6.71	0.30
CRIR	Jan	1.1	3.2	6.19	0.63
CRQU	April	6.5	4.4	5.89	0.15
CRRE	May	24.8	10.1	8.46	0.06
CRSP	Jan	2	4.2	6.35	0.59
CRSP2	Jan	1.8	2.2	4.02	0.34
CRTE	June	2.2	2	3.31	0.23
CRUS	Jan	0.4	2.2	4.09	0.98
CRYP	Jan	14.3	6.5	6.73	0.08

CRYP2	Jan	1.8	4.5	5.67	0.79
CRYP3	March	8.5	2.6	5.23	0.05
CRYP4	Jan	1.9	2.1	4.26	0.27
CYCA	Oct	9.5	3.5	6.14	0.06
CYDY	July	3.7	2.6	5.03	0.14
CYLS	Oct	5.2	3.1	5.67	0.13
CYPL	May	13.1	6.4	7.01	0.09
CYSP	Feb	0.5	2.1	4.42	0.91
DEBI	Jan	9.7	9.8	7.66	0.30
DECO	July	11.8	13.8	8.69	0.46
DEIN	July	1	1.6	3.37	0.46
DEMA	June	2.7	2.4	4.91	0.18
DEMI	Feb	0.9	1.5	2.97	0.60
DEOB	June	1.1	2.7	5.31	0.65
DEOP	May	4.2	7.1	7.08	0.63
DEOPM	Jan	1.9	3.1	6.09	0.34
DEPR	Jan	1.9	5.8	7.34	0.92
DESC	Jan	0.6	1.5	3.08	1.00
DESP	Jan	2.3	4.8	5.54	0.74
DIAN	Jan	0.4	2.1	4.52	0.95
DIDI	July	2.8	2.5	4.22	0.16
DINSP	Jan	0.6	1.5	3.09	1.00
DIPA	Jan	1.1	3.1	5.48	0.70
DISP	May	2.3	3.4	6.07	0.35
DOCI	Jan	12.8	7.8	7.52	0.12
DOCR	Aug	20.2	8.7	7.19	0.05
DOFL	Feb	11.9	6.9	7.16	0.10
DOLE	April	9.1	2.6	4.56	0.04
DOPL	July	4	3.7	6.36	0.19
DOSI	April	14.8	3.2	5.12	0.03
DOSP	April	8.2	6.7	7.1	0.19
ERGI	Jan	0.3	2.3	4.43	0.99
EUSP	April	11.3	10.8	7.51	0.28
EUSP2	Feb	1.4	2.9	4.63	0.72
FRCR	June	1.8	2.4	4.65	0.35
FRVI	Oct	2.4	3.3	4.06	0.48
GESP	Jan	1.9	1.8	2.55	0.29
GLCYSP	Jan	1.2	1.7	3.4	0.34
GLEC	Aug	0.4	2	4.29	0.97
GLOSP	Jan	1.6	2.8	5.16	0.48

GLSP	Aug	1	2.7	5.06	0.74
GLVE	Jan	0.6	1.6	2.91	1.00
GOAP	June	1.9	4	6.58	0.51
GOLA	June	1.6	4.1	6.18	0.72
GOLSP	June	2.2	1.5	2.75	0.20
GOMSP	July	2.3	3	5.36	0.30
GRLA	April	1	2	4.22	0.52
GYSP	Jan	8.8	5	6.49	0.11
KICO	July	3	3.4	5.53	0.30
KILU	May	17.7	8.7	7.1	0.08
KISP	May	8.2	4.6	6.31	0.10
KOSP	May	12.2	3.4	5.77	0.03
KOSP2	Jan	7	5.9	6.31	0.19
LACI	Aug	2	2	3.94	0.26
LASP	Oct	4.3	1.7	3.21	0.05
LEAC	Jan	0.6	1.6	3.02	1.00
LEPTSP	June	7.1	9.4	7.3	0.51
LESP	Jan	4.2	4.8	6.38	0.29
LESP2	April	1.4	2.2	4.74	0.42
LILI	May	3.8	2.9	5.62	0.16
LISP	Jan	1.9	2.1	4.05	0.28
LYBI	Aug	0.7	1.5	2.56	0.79
MASP	June	1.8	2	3.95	0.30
MEGL	Jan	13.2	9.5	7.9	0.16
MEGR	Jan	6.5	6.7	4.72	0.36
MEGRA	Feb	10.6	13.4	8.58	0.52
MESP	April	1.6	4.3	6.22	0.76
MEVA	Nov	43.2	5.1	6.68	0.01
MIAE	Jan	22.1	9	6.6	0.03
MICSP	May	2.3	2	4.2	0.17
MIIN	Jan	1.1	4.3	6.28	0.96
MISP	May	4.8	4.4	6.86	0.21
MISSP	April	1.1	1.5	2.83	0.32
MOAR	Jan	9.9	11.8	8.35	0.44
MOCO	Oct	16.7	9.6	8.16	0.10
MOCOV	May	6.8	5.4	7.1	0.17
MOCV	July	0.7	2.2	5.04	0.74
MODY	Aug	4.3	6	4.13	0.70
MOGR	March	0.9	2.1	4.34	0.59
MOIR	Sept	3.1	2.1	4.47	0.11

MOKO	Oct	3.3	4.7	6.89	0.37
MOMI	July	3.7	3.8	6.61	0.23
MOSP	May	1.5	3.2	5.16	0.62
MOUSP	July	1	1.5	2.7	0.45
NELI	Jan	1.9	2.2	4.49	0.27
NEOB	June	2.1	1.9	3.79	0.23
NESP	May	2.7	4.3	6.87	0.39
NIAC	Feb	4.1	9.5	7.39	0.96
NIRE	Oct	4.3	1.5	2.9	0.05
OOBO	July	17.6	12.2	7.61	0.13
OOEL	Jan	6.7	5.7	6.87	0.20
OOGI	Feb	2	3.4	4.12	0.66
OONA	June	2.2	1.6	3.35	0.21
OOOB	Jan	0.4	2.2	4.56	0.95
OOPA	May	13.9	3.3	5.72	0.03
OOSP	May	17.1	11.4	7.12	0.13
OOSP2	June	4	4.1	6.49	0.24
OOSP3	Oct	1.9	2.8	5.16	0.31
OSAG	Feb	10.7	5	5.99	0.08
OSAM	Feb	1.7	2	4.08	0.33
OSPR	Jan	4.4	3.5	2.77	0.18
OSSP	June	1.9	4.5	6.65	0.64
PAMO	Aug	1.3	2	3.87	0.47
PEAN	Jan	10.7	7.4	7.36	0.13
PEBO	Aug	1.6	3.3	5.5	0.61
PECI	Feb	0.9	1.5	3.02	0.61
PEDI	Jan	19.6	28.5	10.92	0.85
PEDU	July	5.6	7	6.85	0.40
PEDUC	Jan	1.3	4.1	5.69	0.89
PEPE	Jan	1.7	2.9	6.04	0.36
PESP	Oct	1.4	5	7.01	0.91
PESP2	July	1.9	2.2	4.49	0.26
PETE	Aug	1.3	2	4.4	0.44
PHFO	Jan	4.9	4.1	5.28	0.20
PHRSP	Jan	17.5	6.6	6.94	0.05
PHRSP2	Aug	2.7	3.6	5.77	0.33
PHRSP3	Aug	12.5	5.9	6.4	0.08
PHRSP4	Jan	7.5	3.9	3.45	0.07
PHRSP5	Aug	5.4	3.9	5.69	0.16
PHSP	April	16.8	6.4	5.88	0.04

PLAG	Feb	1.6	2	3.8	0.36
PLGE	April	1	3.1	5.85	0.70
PLSP	April	0.5	1.9	3.97	0.77
PLXSP	Jan	3.6	5.7	5.29	0.63
PSSP	Jan	17.5	9	5.58	0.04
PTSP	Feb	4.4	6.8	7.05	0.56
QUCH	Jan	0.6	1.5	2.91	1.00
QULA	April	1.4	3.7	6.28	0.69
QUSP	May	2.7	4.3	6.61	0.40
RADA	Aug	0.7	1.5	3.07	0.79
SCAR	Jan	1.4	3.7	6.31	0.60
SCBI	Feb	13.4	5.6	5.68	0.05
SCDI	Jan	3.5	5.4	6.63	0.46
SCEL	Jan	5.8	7.5	6.72	0.46
SCJU	July	1.3	4.4	6.26	0.89
SCOB	Jan	5.1	7.5	7.56	0.45
SCQU	July	4.5	5.5	6.64	0.34
SCQUM	Feb	1	2.7	5.27	0.71
SCQUQ	April	6.5	4.5	6.26	0.14
SCRO	July	5.2	3.2	5.78	0.12
SCSE	July	8.3	9.3	6.52	0.41
SCSP	April	3.7	5.1	6.01	0.41
SESP	Jan	1.9	2.2	4.44	0.27
SNLA	May	1.1	1.9	3.79	0.45
SNSP	May	8.3	2.1	3.92	0.05
SPCH	April	0.7	2	3.89	0.58
SPRSP	May	2.5	2.2	4.69	0.14
SPSC	Feb	5.1	5.9	5.48	0.38
SPSP	Jan	0.6	1.7	3.22	0.96
STGR	Aug	1.4	3.4	5.61	0.64
STNI	Jan	2.2	3.5	5.05	0.51
STOP	April	1.1	1.5	2.84	0.31
STSP3	April	1.1	1.5	3	0.33
TECA	Jan	1.7	4.1	6.82	0.60
TEDI	Feb	0.6	1.9	4.19	0.71
TEMI	Jan	1.2	4.2	6.27	0.87
TESP	Feb	5.6	4.8	6.66	0.20
TETR	June	0.8	3.2	5.97	0.86
TRSP	Feb	1.7	3.7	5.51	0.61
TRSP2	Feb	0.9	1.5	3.22	0.59

ULSP	July	1.7	2.4	5.03	0.35
UNCHLPIC	July	0.9	3.3	5.1	0.91
UNCOCH	March	7.7	7.9	6.78	0.30
UNCOCH2	Jan	0.6	1.9	3.95	0.90
UNCOCY	May	1.8	3.7	4.7	0.75
UNCOCY2	Aug	1.4	2.8	4.39	0.64
UNCOCYPI	Aug	3.3	3.1	4.06	0.23
UNCRY	May	3.2	4.7	6.83	0.37
UNCRY2	May	8.6	4.8	6.43	0.11
UNCRY3	July	1	1.5	3.06	0.44
UNDINO	Aug	2.3	2.7	5.34	0.25
UNELCHL	June	6.2	4.1	4.62	0.14
UNEUG	April	1	1.9	4.09	0.49
UNFICH	Oct	1.6	2.5	5.23	0.38
UNFICY	Jan	4.9	4.2	3.01	0.24
UNFICY2	Oct	3.7	3.6	6.41	0.21
UNFICY3	Jan	3.1	2.4	4.46	0.15
UNFICY4	Jan	0.6	2.6	5.06	0.91
UNFICYPI	April	1.1	1.5	2.38	0.32
UNSPCH	March	5.7	10.5	7.09	0.88
UNSPCH2	May	15.3	9.7	7.46	0.11
UNSPCH3	May	7.3	5.9	6.76	0.19
UNSPCHPI	July	1	1.6	3.14	0.46
UNSPCHR	May	1	2.4	4.86	0.56
UNSPCY	May	1	2.7	5.24	0.68
UNSPCY2	Jan	0.6	1.5	2.85	1.00
UNSPCYPI	April	1.1	1.5	2.38	0.32
WIRE	Aug	5.2	7.2	7.5	0.42