Filename: Spatial and Temporal Variability in Zooplankton Assemblages in Utah Lake 2015 to 2019

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Spatial and Temporal Variability in Zooplankton Assemblages in Utah Lake 2015 to 2019

2019 Progress Report To:

Wasatch Front Water Quality Council

Salt Lake City, UT

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Summary

Zooplankton play a critical role in the ecological functioning of Utah Lake, including their role in regulating cyanoHABs. We have been collecting and analyzing Utah Lake's zooplankton data since 2015 and have amassed the most thorough database to date, with over 400 samples collected and analyzed so far. These analyses have generated several reports, including this progress report. These data have also allowed us and our taxonomist to update and revise taxonomic errors and document new or misidentified taxa in Utah Lake. This taxonomic revision is crucial for any valid analyses of zooplankton ecology, their interactions in the food web, and their effects on water quality.

Results presented in this progress report showed that zooplankton assemblages in the Utah Lake varied spatially and temporally. Assemblages and individual taxa followed a seasonal pattern that is typical of most temperate lakes. Zooplankton assemblages and individual taxa densities 1) differed between shallow and open water habitats, 2) were somewhat different from north to south ends of the lake and 3) were substantially different in Provo Bay from other sections. Zooplankton densities were highest in summer and lowest in winter, as was expected, and there appeared to be an increase in densities from 2016 to 2019. Results of this and our other analyses will allow us to populate zooplankton metrics into the Utah Lake Multimetric Index of Biological Integrity, a valuable tool for managers and those wanting to monitor Utah Lake's health. Continued zooplankton data collection and analyses are required to fully understand their role in the ecosystem, including their relationships with cyanoHABs.

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Introduction

Zooplankton grazers are the number one water column regulator of phytoplankton, including cyanoHABs worldwide (Iglesias et al. 2007, Scheffer 1998, Karlson et al. 2015) and in Utah Lake (Richards and Miller 2019, Richards and Miller 2017, Richards et al. 2019, Richards 2016, Richards 2018, Richards 2019). They are also the number one transferrer of energy to higher tropic levels in the water column primarily via planktivores. Zooplankton have top down grazing effects on phytoplankton and cyanobacteria and in turn are affected by these (e.g. bottom up effects) (Iglesias et al. 2007). Zooplankton assemblages are also strongly affected by native and introduced planktivorous fish, as well as other types of pollutants in Utah Lake (Richards and Miller 2019, Richards and Miller 2017, Richards et al. 2019, Richards 2016, Richards 2018, Richards 2019). Despite their keystone importance and precarious existence in isolated and highly regulated Utah Lake, very little research has been conducted on zooplankton taxonomy, life history, population dynamics, and ecological relationships within the lake (Richards and Miller 2019, Richards and Miller 2017, Richards et al. 2019, Richards 2016, Richards 2018, Richards 2019). This progress report is a continuation of our previous analyses and is intended to fill some of the gaps in our knowledge of zooplankton assemblages in Utah Lake. It also complements our most recent evaluation of Utah Lake's ecosystem, i.e. Richards et al. (2019).

Methods

Sample Collection

Four hundred and twenty-three zooplankton samples were collected from various locations in Utah Lake between 2015 and 2019 by OreoHelix Consulting and Wasatch Front Water Quality Council (Figure 1). Most of the zooplankton samples were collected in the same locations and on the same dates as phytoplankton samples and many were collected concomitantly with nutrient and water chemistry data. Every attempt was made to collect zooplankton samples from the same locations where we sampled previously (e.g. Richards and Miller 2017) but this was not always the case.

Samples were collected using a 200 µm mesh net with a 30 cm diameter opening similar to the image in Figure 1. The net was dropped to the bottom of the water column, moved slightly to either side of where it was dropped and then pulled up either to the boat or researcher wading along shoreline (i.e. 'vertical tow'). Depth of water column was recorded to adjust zooplankton density estimates. Contents were emptied into labeled plastic jar using a pipette and spray bottle washer and either isopropyl or ethanol was added to the contents for a final 70% concentration.

Figure 1. Map of zooplankton sample locations. Location names are in Table 4.

Figure 2. Plankton net similar to the one used in our studies.

Taxonomy

Valid taxonomic identification of microscopic zooplankton based on morphology is critical but can be challenging and requires qualified taxonomists. Published DNA barcodes are dependent on proper taxonomic identification and if taxonomic identifications are inaccurate, so will be DNA barcodes. We commissioned four zooplankton taxonomic labs throughout the duration of this study. Our primary taxonomist, Dr. Larry Gray at Utah Valley University, passed away in 2017, subsequently we then contracted three other taxonomic labs, including a genetics lab and River Continuum Concepts Inc., Manhattan, MT, which is now our primary taxonomy lab. Results from all four labs showed some potentially misidentifications and taxonomic discrepancies, which could have resulted in major errors in our ecological interpretations and analyses. We then had Brett Marshall, director of River Continuum Concepts, Inc. conduct a preliminary evaluation of taxonomic identifications and synonymies of the zooplankton from the four labs to help reconcile this dilemma. Results of his evaluation are presented in Laboratory Observations Regarding Identifications and likely Synonymies among Zooplankton from Utah Lake (Marshall 2019) and is invaluable in our research.

The majority of the analysis conducted in this report uses zooplankton data that have been 'rolled up' to higher than species level based on recommendations by Marshall (2019) and our professional experience statistically analyzing ecological data consisting of taxa of questionable or differing levels of taxonomic effort (OTUs) and resolution. Unfortunately, much valuable ecological information is lost when working at levels higher than species level or even genus level, but this decision was our most judicious in light of the problems with Utah Lake zooplankton taxonomy. However, in situations where we could use species or genus level in our analysis, we did so.

The following table, Table 1 contains the list of zooplankton taxa encountered in our sampling of Utah Lake between 2015 and 2019. Taxonomic revisions are ongoing, and some taxa listed may not be valid, misidentified, or duplicated.

Table 1. List of potential zooplankton taxa found in Utah Lake from our 2015 to 2019 sampling efforts. See Marshall (2019) for an evaluation of Utah Lake zooplankton taxonomic revisions.

Phylum	Subphylum	Class	Subclass	Order	Suborder	Family	Genus	Species
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Bosminidae	Bosmina	*Bosmina liederi*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Bosminidae	Bosmina	*Bosmina longirostris*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Bosminidae	Bosmina	*Bosmina* sp.
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	*Alona*	*Alona setulosa*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	*Chydorus*	*Chydorus brevilabrus*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	*Chydorus*	*Chydorus sphaericus*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	Leydigia	*Kurzia media*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	Leydigia	*Leberis c.f. davidi*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	Leydigia	*Leydigia leydigi*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	Leydigia	*Leydigia lousi*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	*Pleuroxus*	*Pleuroxus aduncus*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	*Pleuroxus*	*Pleuroxus denticulatus*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Chydoridae	*Pleuroxus*	*Pleuroxus striatus*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Ceriodaphnia	*Ceriodaphnia cf. acanthina*

Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Ceriodaphnia	*Ceriodaphnia dubia*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Ceriodaphnia	*Ceriodaphnia quadrangula*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Ceriodaphnia	*Ceriodaphnia* sp.
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Daphnia ambigua*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Daphnia exilis*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Daphnia galeata*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Daphnia magna*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Daphnia mendotae*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Daphnia pulex*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Daphnia retrocurva*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Daphnia* sp.
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	Daphnia	*Scapholeberis mucronata*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	*Simocephalus*	*Simocephalus vetulus*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	*Simocephalus*	*Simocephalus mixtus*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Daphniidae	*Simocephalus*	*Simocephalus c.f. punctatus*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Leptodoridae	Leptodora	*Leptodora kindtii*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Macrothricidae	Macrothrix	*Macrothrix* sp.
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Moinidae	Moina	*Moina cf. micrura*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Moinidae	Moina	*Moina macrocopa*

Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Moinidae	Moina	*Moina* sp.
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Ilyocryptidae	*Ilyocryptus*	*Ilyocryptus* sp.
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Sididae	Diaphanosoma	*Diaphanosoma brachyurum*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Sididae	Diaphanosoma	*Diaphanosoma cf. Heberti*
Arthropoda	Crustacea	Branchiopoda	Phyllopoda	Diplostraca	Cladocera	Sididae	Diaphanosoma	*Diaphanosoma* sp.
Arthropoda	Crustacea	Maxillopoda	Copepoda	Calanoida		Diaptomidae	Leptodiaptomus	*Leptodiaptomus sicilis*
Arthropoda	Crustacea	Maxillopoda	Copepoda	Cyclopoida		Cyclopidae	Acanthocyclops	*Acanthocyclops americanus*
Arthropoda	Crustacea	Maxillopoda	Copepoda	Cyclopoida		Cyclopidae	Acanthocyclops	*Acanthocyclops robustus*
Arthropoda	Crustacea	Maxillopoda	Copepoda	Cyclopoida		Cyclopidae	*Eucyclops*	*Eucyclops agilis*
Arthropoda	Crustacea	Maxillopoda	Copepoda	Cyclopoida		Cyclopidae	*Microcyclops*	*Microcyclops rubellus*
Arthropoda	Crustacea	Maxillopoda	Copepoda	Harpacticoida		Canthocamptidae	*Attheyella*	*Attheyella* sp.
Arthropoda	Crustacea	Maxillopoda	Copepoda	Harpacticoida		Canthocamptidae	*Cletocamptus*	*Cletocamptus sp.*
Arthropoda	Crustacea	Maxillopoda	Copepoda	Harpacticoida		Laophontidae	*Onychocamptus*	*Onychocamptus mohammed*
Arthropoda	Crustacea	Ostracoda	Podocopa	Podocopida		Cyprididae	Cypridopsis	*Cypridopsis vidua*
Arthropoda	Crustacea	Ostracoda	Podocopa	Podocopida		None	Podocopida	*Podocopida* sp.
Arthropoda	Crustacea	Ostracoda						*Ostracoda* sp.
Arthropoda	Chelicerata	Arachnida	Acari	Philodinida		Philodinidae	Dissotrocha	*Dissotrocha aculeata*
Rotifera		Eurotatoria		Flosculariaceae		Testudinellidae	*Filinia*	*Filinia* sp.
Rotifera		Monogononta		Ploima		Asplanchnidae	Asplanchna	*Asplanchna silvestrii*

Rotifera		Monogononta	Ploima		Asplanchnidae	Asplanchna	*Asplanchna* sp.
Rotifera		Monogononta	Ploima		Brachionidae	Brachionus	*Brachionus calyciflorus*
Rotifera		Monogononta	Ploima		Brachionidae	Brachionus	*Brachionus plicatilis*
Rotifera		Monogononta	Ploima		Brachionidae	Brachionus	*Brachionus quadridentatus*
Rotifera		Monogononta	Ploima		Brachionidae	Brachionus	*Brachionus variabilis*
Rotifera		Monogononta	Ploima		Brachionidae	Brachionus	*Brachionus sp. Almenara*
Rotifera		Monogononta	Ploima		Brachionidae	Keratella	*Keratella cochlearis*
Rotifera		Monogononta	Ploima		Brachionidae	Keratella	*Keratella* sp.
Rotifera		Monogononta	Ploima		Brachionidae	Keratella	*Platyias quadricornis*
Rotifera		Monogononta	Ploima		Synchaetidae	Polyarthra	*Polyarthra dolichoptera*
Rotifera		Monogononta	Ploima		Synchaetidae	Polyarthra	*Polyarthra* sp.
Rotifera		Monogononta	Ploima		Synchaetidae	Polyarthra	*Polyarthra vulgaris*

As a result of zooplankton taxonomic discrepancies and ongoing revisions we were forced to 'roll up' our taxa groups for analyses based on Marshall (2019). Unfortunately, this resulted in a large loss of valuable data but was unavoidable. This resulted in eighteen taxa groups (Table 2).

Table 2. Taxa and site codes used in our analyses for this progress report.

Taxon Code	Taxon Name		Site Code	Site Name
ACAM	*Acanthocyclops americanus*		BI	Bird Island
ATSP	*Attheyella* sp.		GB	Goshen Bay
BOLO	*Bosmina longirostris*		LB	Lincoln Beach
CESP	*Ceriodaphnia* sp.		LBM	Lincoln Beach Marina
CHYDORIDAE	Chydoridae		LM	Lindon Marina
CLSP	*Cletocamptus* sp.		LMS	Lindon Marina South
DAMAAM	*Daphnia magna/ambigua*		LMO	Lindon Marina outside
DIHE	*Diaphanosoma cf. heberti*		LP	Lindon-Pelican Transect
ROTIFERA	Rotifera		Out	Near outlet Utah Lake
ILSP	*Ilyocryptus* sp.		PA	Near Provo Airport
KESP	*Keratella* sp.		PBC	Provo Bay Center
LEKI	*Leptodora kindtii*		PBM	Provo Bay Mouth
LESP	*Leydigia* sp.		PBS	Provo Bay Swede Access
LEPSP	*Leptodiaptomus* sp.		PM	Pelican Marina
MIRU	*Microcyclops rubellus*		SB	Sandy Beach
MOSP	*Moina* sp.		SP	Utah Lake State Park Marina
ONMO	*Onychocamptus mohammed*			
OSSP	*Ostracoda* sp.			

Zooplankton Relativization by Body Lengths

Biomass of individual zooplankton within each taxon can vary substantially spatially and temporally, between sexes, and is dependent on their physical condition (Culver et al. 1985; Rosen 1981; Havens and Beaver 2011). However, individual length or biomass estimates, or consistent sex identifications were not made during taxonomic processing of our samples. Several researchers have derived length-weight regression estimates for many zooplankton taxa, particularly cladocerans and copepods, including for several species and genera found in Utah Lake (Culver et al. 1985; Rosen 1981). Biomass is the preferred measure of analyzing ecologic function of zooplankton in aquatic systems, including our preference, however incorporating biomass estimates from length regressions can add considerable error, especially when individual lengths are unknown. For example, we calculated dry weights of *Daphnia retrocurva*, a common taxon in Utah Lake, based on length ranges (mean ± std. dev.) available from the literature and the ranges of length-weight regression coefficients (a, b) derived for the Culver et al. (1985) equation: weight (ug) = a*length (mm)^b. Our derived minimum estimate of individual *D. retrocurva* biomass was 0.99 µg and the maximum was 437.89 µg. Extrapolating such wide ranges of biomass estimates from count data would therefore not be appropriate given the limitations of our data set and the goals of our analyzes presented in this report. However, given that count data fails to address important ecosystem effects of zooplankton size differences; we concluded that the most prudent solution was to relativize counts by a much less variable measure, body length derived from the literature with our full knowledge that body lengths don't completely correlate with biomass measures. Zooplankton estimated length values are presented in Table 3. Our count data was relativized by these lengths for all analyses presented in this report. If further reanalysis of results presented in this report using biomass estimates are desired it is simply a matter of readjusting our relativized counts and then selecting the most appropriate weight-length regressions available. However, we suggest that future analyses attempting to use length-weight regressions based on count only data when body lengths are determined should do so with caution. Taxa were length relativized before 'rolling-up' into groups listed in Table 2.

Table 3. Length estimates of zooplankton found in our study based on values from literature. Count data analyzed for this report were relativized by these estimated length values. Length estimate sources: Central Michigan University website (accessed March 12, 2019), Culver et al. (1985), and NOAA Great Lakes Environmental Research Laboratory website (accessed March 12, 2019), Center for Freshwater Biology (accessed March 20, 2019). USGS (accessed March 20, 2019). Taxa not listed were matched to the closest taxon.

Taxon	mean length (mm)
Acanthocyclops americanus	1.13
Alona setulosa	0.71
Asplanchna sp.	0.80
Attheyella sp.	0.75
Bosmina longirostris complex	0.41
Brachionus calyciflorus	0.38
Brachionus sp. Almenara	0.18
Brachionus variabilis	0.28
Ceriodaphnia dubia	0.85

Ceriodaphnia sp.	0.75
Chydoridae sp.	0.48
Daphnia ambigua	0.80
Daphnia magna	4.00
Daphnia mendotae	2.15
Daphnia retrocurva	1.14
Daphnia sp.	1.50
Diaphanosoma cf. Heberti	0.56
Ilyocryptus sp.	0.73
Leptodiaptomus sicilis female	1.25
Leptodiaptomus sicilis male	1.25
Leptodora kindti	1.00
Leydigia louisi	0.56
Macrothrix sp.	0.71
Microcyclops rubellus	0.64
Moina micrura	0.50
Onychocamptus mohammed	0.55
Ostracoda	0.70
Platyias quadricornis	0.23
Scapholeberis mucronata	0.70
Simocephalus sp.	3.50

Statistical Analyses

Spatial and Temporal Patterns of Zooplankton Assemblages: Multivariate Models

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

NMS was used in these analyses because it has been shown to be robust and highly informative for understanding ecological relationships. NMS ordination is often more broadly applicable for ecological studies than other ordination techniques because it does not require relationships among variables to be linear (McCune and Mefford 2011; Peck 2010). NMS ordination permits the visualization of the multidimensional relationships of zooplankton 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).

A Relative Sorenson 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 ("relativized Manhattan" in Faith et al. 1987) 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). Twelve Relative Sørensen distance outlier samples were removed that had multivariate standard deviations > 2.0. 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.

The majority of the taxa densities in the zooplankton assemblage matrix were zero counts, which is typical when sampling zooplankton 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 on the basis of 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.

Multiple Response Permutation Procedure (MRPP) is a non-parametric multivariate method and used to formally test the hypothesis of no differences in zooplankton assemblages between months and sites. MRPP has the advantage of not requiring distributional assumptions such as multivariate normality and homogeneity of variance and thus is often preferred over MANOVA for analyzing multivariate ecological data (McCune and Grace 2002). A Relative Sorensen (Bray-Curtis) distance measure was used on raw 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 spatial and temporal groupings (McCune and Grace 2002). We also conducted Indicator Species Analysis using Dufrene's and Legendre's (1997) method. See McCune and Mefford 2018 for more details of indicator species analysis. All multivariate analyses of Utah Lake zooplankton assemblage data were conducted using PC-ORD Version 7.07 (McCune and Mefford 2018).

Individual Zooplankton Taxa Spatial and Temporal Pattern Statistical Methods

Additional statistical analyses included marginal predicted means and 95% CI estimates based on negative binomial regressions using Stata 16.0 for Mac (64-bit Intel) (StatCorp 2019). Negative binomial regression methods were chosen because individual zooplankton taxa density estimates were count data truncated at zero, contained mostly zero counts, and were non-normally distributed (Figure 3). Typically, these types of data cannot be reasonably transformed to approximate normal Gaussian distributions using any transformation method, therefore linear models were not considered appropriate.

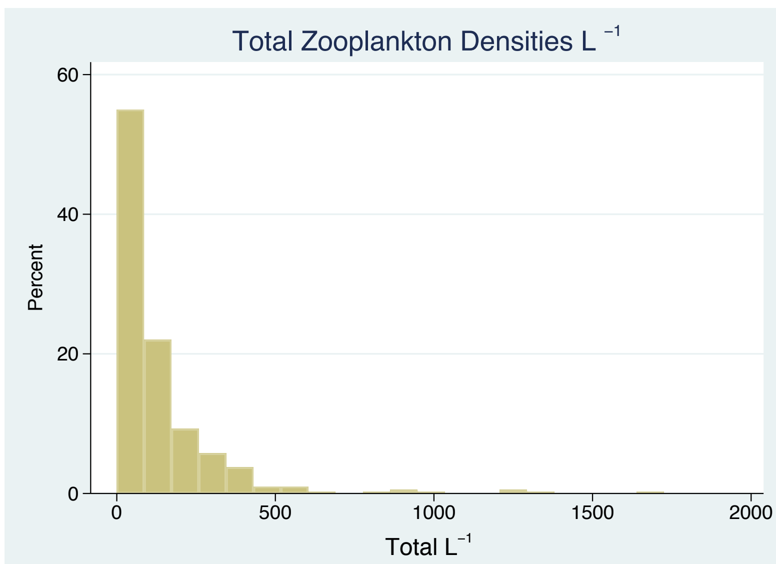


Figure 3. Distribution of zooplankton densities (L^{-1}) for Utah Lake 2015-2019 from 423 samples. This distribution is a typical truncated negative binomial distribution of count data that cannot reasonably be transformed for use in standard linear models. All of the individual taxa density distributions were also truncated negative binomials.

Results

The best NMS model had a final stress = 6.33; < 0.0001 final stability; at 85 iterations. A final stress value of 6.33 is extremely accurate and there should be no misinterpretation of individual sample relationships (Appendix 1). Post-hoc analysis resulted in an Axis 1 R^2 = 0.700; Axis 2 R^2 = 0.215; Axis 3 R^2 = 0.063. Because Axis 3 R^2 was small, we don't include it in our model results. Figure 4 shows the taxa relationships of Axis 1 and Axis 2.

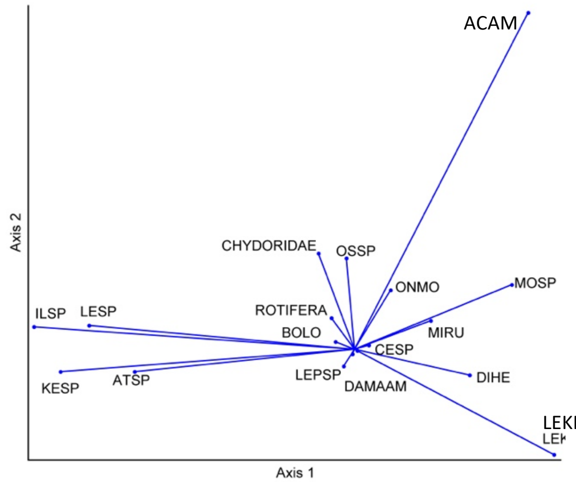


Figure 4. Taxa ordination on NMS axis 1 and axis 2.

Several taxa were strongly dissimilar to other taxa particularly *Acanthocyclops americanus* (ACAM), *Leptodora kindtii* (LEKI), *Ilyocryptus* sp. (ILSP), *Keratella* sp. (KESP), *Leydigia* sp. (LESP), and *Attheyella* sp. (ATSP). Other taxa were more ubiquitous within the lake including *Bosmina longirostris* (BOLO), *Ceriodaphnia* sp. (CESP), *Daphnia magna/ambigua* (DAMAAM) group, rotifers, etc., however 'rolling-up' of taxa may have masked some of these differences.

Assemblage Level Spatial Patterns

Zooplankton assemblages were a mixture of homogenous site similarities and significantly dissimilar sites (Figure 5). Only the NMS centroids are shown to allow a clearer understanding of spatial patterns.

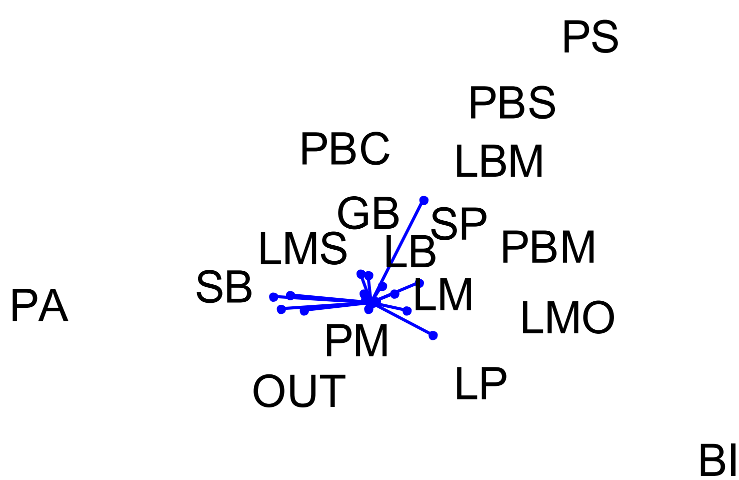


Figure 5. NMS centroids Site Codes Axis 1 and Axis 2. Blue lines and dots are taxa ordinations.

Our interpretation of the zooplankton assemblages based on NMS site ordination and MRPP is that assemblages significantly differed between locations (MRPP *A* = 0.09; P < 0.0001). Further detailed interpretation is as follows:

- Bird Island (BI) and 100 meters outside of Powell Slough (PS) sites each had only one sample collected; their ordination should be carefully interpreted or ignored.
- Zooplankton assemblages collected from more open water areas north of Goshen Bay (GB) including; Bird Island (BI), Lindon-Pelican transect (LP), near the outlet of the lake (OUT), near Provo Airport (PA), just outside Pelican Marina (PM), just outside of Lindon Marina (LMO), and to a lesser extent, Sandy Beach area (SB) grouped in the lower to lower left and lower right of the ordination. Lindon-Pelican transect samples and samples collected just outside of Lindon Marina (LMO) ordinated away from Sandy Beach (SB) assemblages along the left to right axes (axis 1). Samples collected about 50 m outside of Lindon Marina (LMO) were collected at one of the same locations as the Lindon-Pelican transect (LP) samples and could have been combined with LP but LMO samples were not collected on the same dates as LP samples. LMO did however, ordinate closely to LP. This suggests that assemblages in open water areas differ from near shore sites, e.g. Goshen Bay (GB), and Provo Bay (PB).
- Somewhat unexpectedly, Provo Bay zooplankton assemblages clearly differed between locations within the bay (PBS, PBC, and PBM) but were more similar to each other than with the main part of the lake north of Goshen Bay. This suggests that, as we reported in several reports, the Provo Bay ecosystem is measurably different than other locations in the lake and should be managed separately. These results and our experience also suggest that Provo Bay is much more ecologically diverse, productive, and dynamic than the open waters of the lake and is in more immediate need of protection. Also, samples collected at the Provo Bay site near Swede access (PBS) were all from shallow, shoreline locations and subsequently influenced.
- Lincoln Beach Marina (LBM) assemblages were very similar to Provo Bay assemblages primarily because both locations had greater than average densities of *Microcylops rubellus* and average or greater than average densities of rotifers in March. However, all three of the Provo Bay sites had greater than average total zooplankton densities whereas, LBM had average densities. See the following individual taxa estimated densities by month and site location (Figure 7) for more similarities and dissimilarities (Appendix 2).
- We only showed NMS centroids in Figure 5 to provide an overview of zooplankton assemblage dis(similarities) between sites. There was, however, a large amount of variability between samples within most of the sites that was not shown in Figure 5 but their NMS axis coordinates are presented in Appendix 1 and can be easily graphed by those wishing to explore relationships further. Appendix 2 provides MRPP results comparing significance between sites. About half the sites significantly (P < 0.05) differed from each other, while about half the sites did not.
- More detailed interpretation of our multivariate analyses can be conducted, although the general interpretation of zooplankton assemblage variability is very clear.

Assemblage Level Temporal Patterns

Zooplankton assemblages clearly differed between most months with expected seasonal transitions (Figure 6). Only the NMS centroids are shown to allow a clearer understanding of spatial patterns. Individual sample NMS ordination coordinates are in Appendix 1.

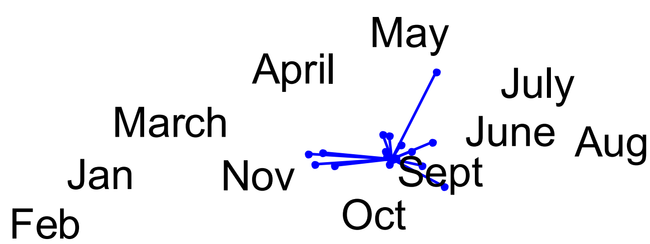


Figure 6. NMS centroids by Month Axis 1 and Axis 2. Blue lines and dots are taxa ordinations (Figure 4). Note the clear almost circular seasonal trend with November assemblages more closely related to the winter months.

As was the case with NMS and MRPP results based on site locations, temporal sample variability was large for many months (convex hulls not shown). MRPP results suggested that zooplankton assemblages varied significantly (P < 0.05) for almost all of months (MRPP *A* = 0.12; P < 0.0001), except for January vs. April; June vs. May; January vs. November; October vs. November, and March vs. November (Appendix 3).

Indicator Taxa by Month

Several taxa were significant indicators of months using Indicator Species Analysis (Table 4).

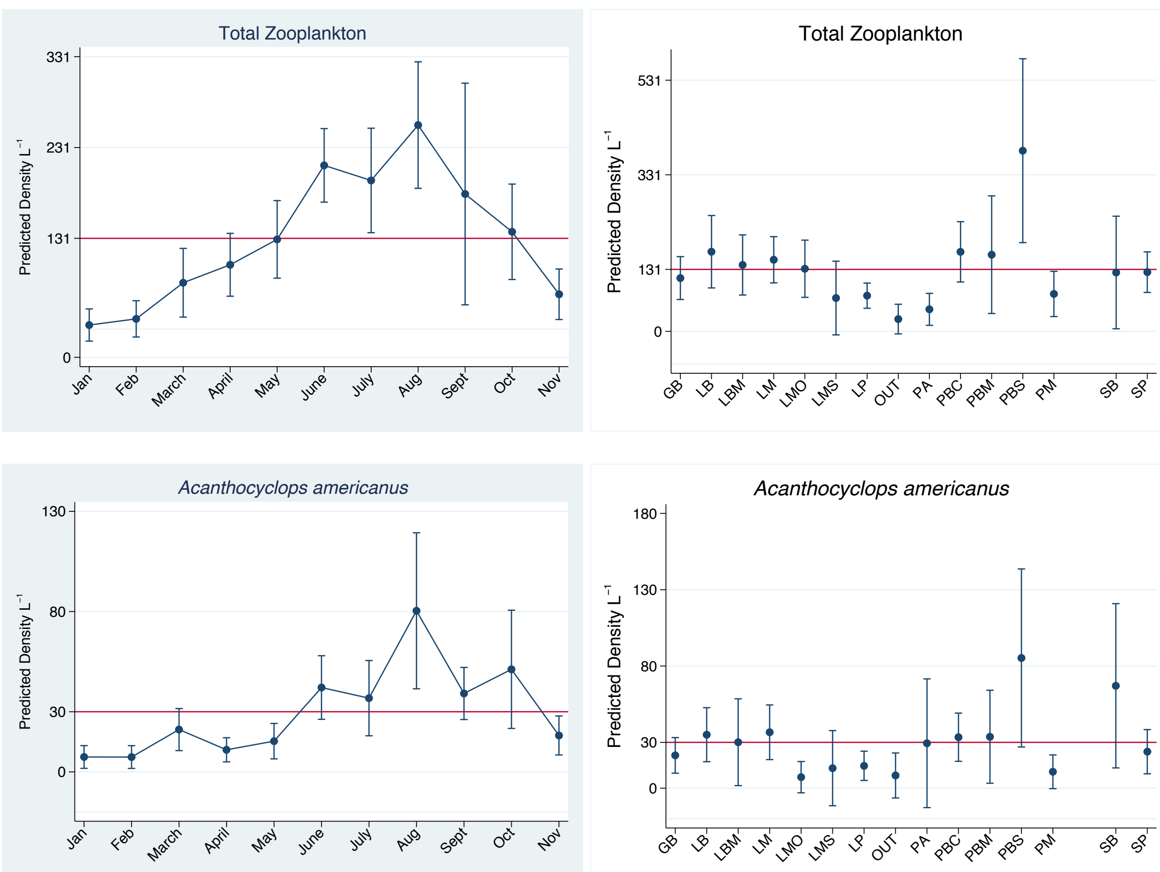
Table 4. Significant Indicator Taxa by Month. Liberal P value < 0.08.

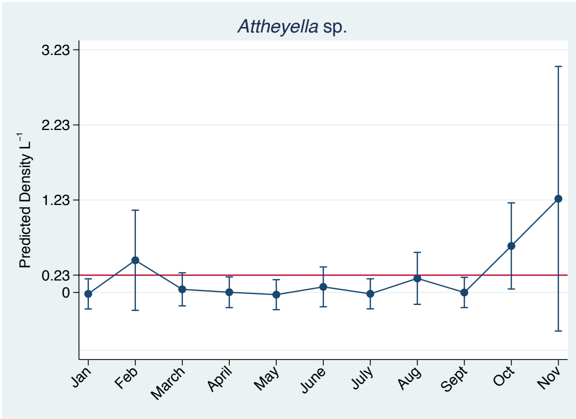
			IV from Randomized Groups		
Taxon	Month	Observed Indicator Value (IV)	Mean	Std. Dev.	P-value
Leptodiaptomus sp.	April	30.5	14.3	3.99	0.008
Rotifera	April	30	11.3	4.61	0.009
Moina sp.	August	16.3	7.9	4.77	0.045

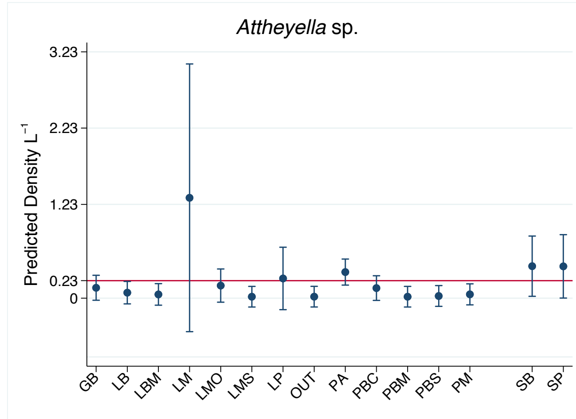
Acanthocyclops americanus	August	27.4	18	5.71	0.067
Leptodora kindtii	August	12.7	6.7	4.33	0.079
Microcyclops rubellus	July	20.5	12.4	4.58	0.056
Bosmina longirostris	June	32.8	15.2	5.86	0.021
Diaphanosoma cf. heberti	June	21	10.5	5.22	0.046
CHYDORIDAE	May	20	8	5.02	0.032
Ostracoda	May	14.5	7.5	4.25	0.069
Attheyella sp.	November	31.1	9.2	5.4	0.011

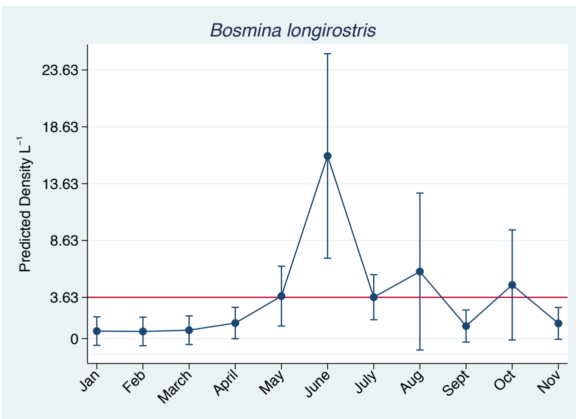
Taxa Based Spatial and Temporal Patterns

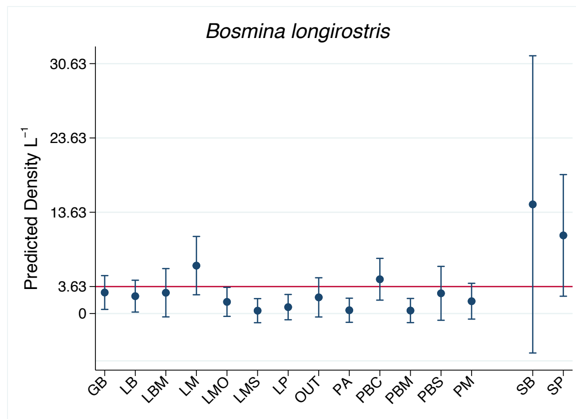
Total zooplankton length-adjusted densities (L^{-1}) were highest from June through September and lowest in the winter months and highest in Provo Bay and Lincoln Beach area and lowest in the open water areas of the lake (Figure 7). Individual taxa varied both spatially and temporally (Figure 7).

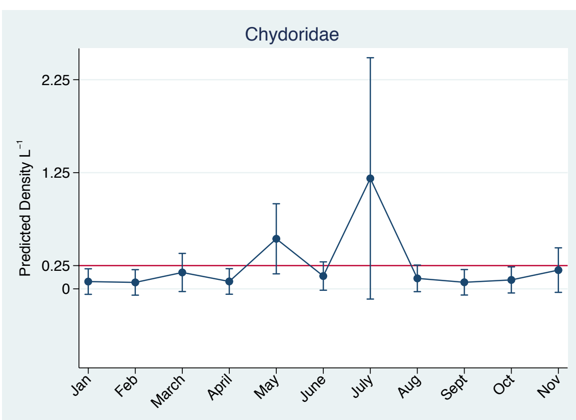


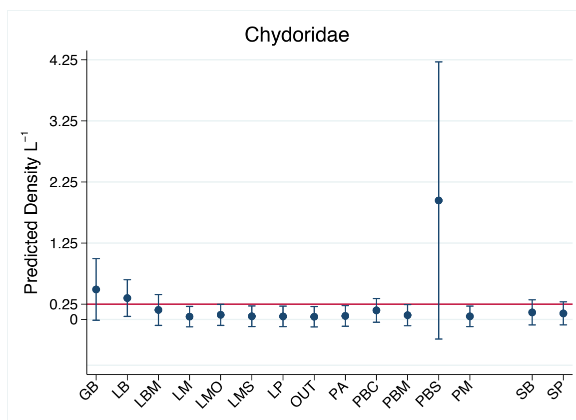

Attheyella sp.
Predicted Density L⁻¹
3.23
2.23
1.23
0.23
0
Jan
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov


Attheyella sp.
Predicted Density L⁻¹
3.23
2.23
1.23
0.23
0
GB
LB
LBM
LM
LMO
LMS
LP
OUT
PA
PBC
PBM
PBS
PM
SB
SP


Bosmina longirostris
Predicted Density L⁻¹
23.63
18.63
13.63
8.63
3.63
0
Jan
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov


Bosmina longirostris
Predicted Density L⁻¹
30.63
23.63
13.63
3.63
0
GB
LB
LBM
LM
LMO
LMS
LP
OUT
PA
PBC
PBM
PBS
PM
SB
SP


Chydoridae
Predicted Density L⁻¹
2.25
1.25
0.25
0
Jan
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov


Chydoridae
Predicted Density L⁻¹
4.25
3.25
2.25
1.25
0.25
0
GB
LB
LBM
LM
LMO
LMS
LP
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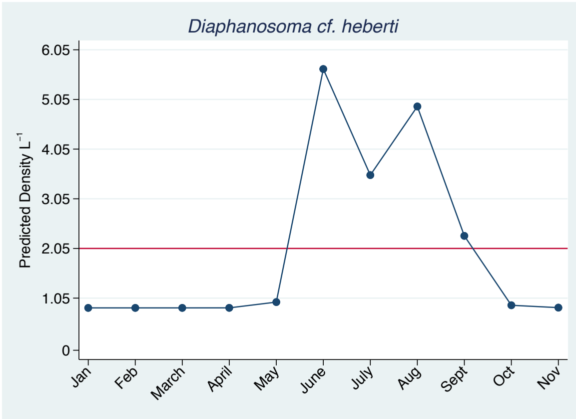
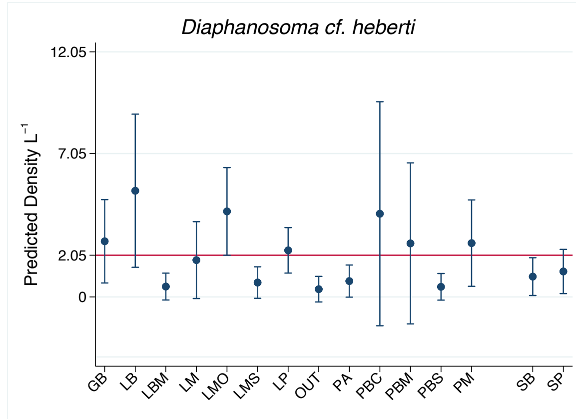
PA
PBC
PBM
PBS
PM
SB
SP


Diaphanosoma cf. heberti
Predicted Density L⁻¹
6.05
5.05
4.05
3.05
2.05
1.05
0
Jan
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov


Diaphanosoma cf. heberti
Predicted Density L⁻¹
12.05
7.05
2.05
0
GB
LB
LBM
LM
LMO
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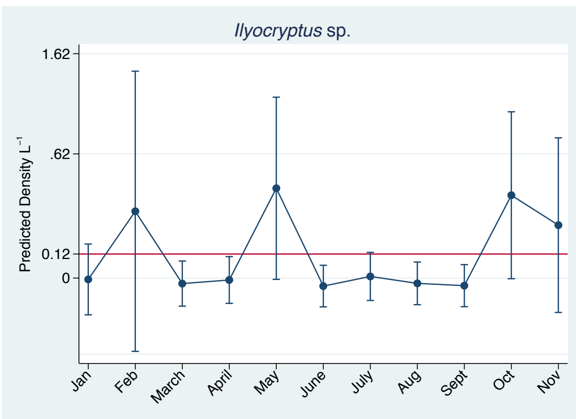
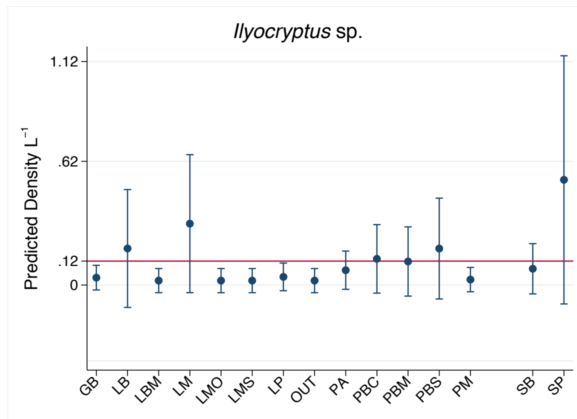
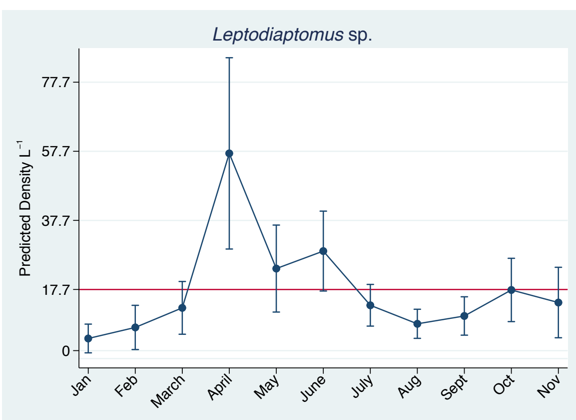
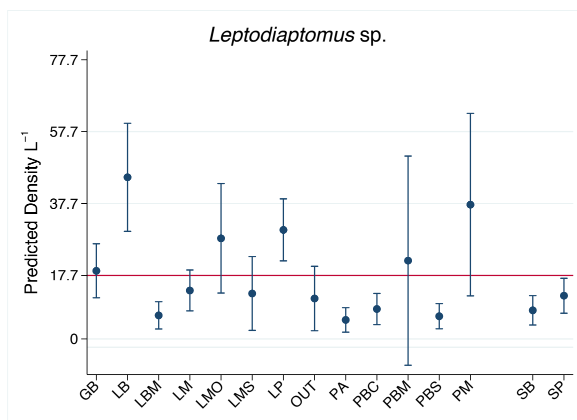
PBM
PBS
PM
SB
SP


Ilyocryptus sp.
Predicted Density L⁻¹
1.62
.62
0.12
0
Jan
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov


Ilyocryptus sp.
Predicted Density L⁻¹
1.12
.62
.12
0
GB
LB
LBM
LM
LMO
LMS
LP
OUT
PA
PBC
PBM
PBS
PM
SB
SP


Leptodiaptomus sp.
Predicted Density L⁻¹
77.7
57.7
37.7
17.7
0
Jan
Feb
March
April
May
June
July
Aug
Sept
Oct
Nov


Leptodiaptomus sp.
Predicted Density L⁻¹
77.7
57.7
37.7
17.7
0
GB
LB
LBM
LM
LMO
LMS
LP
OUT
PA
PBC
PBM
PBS
PM
SB
SP

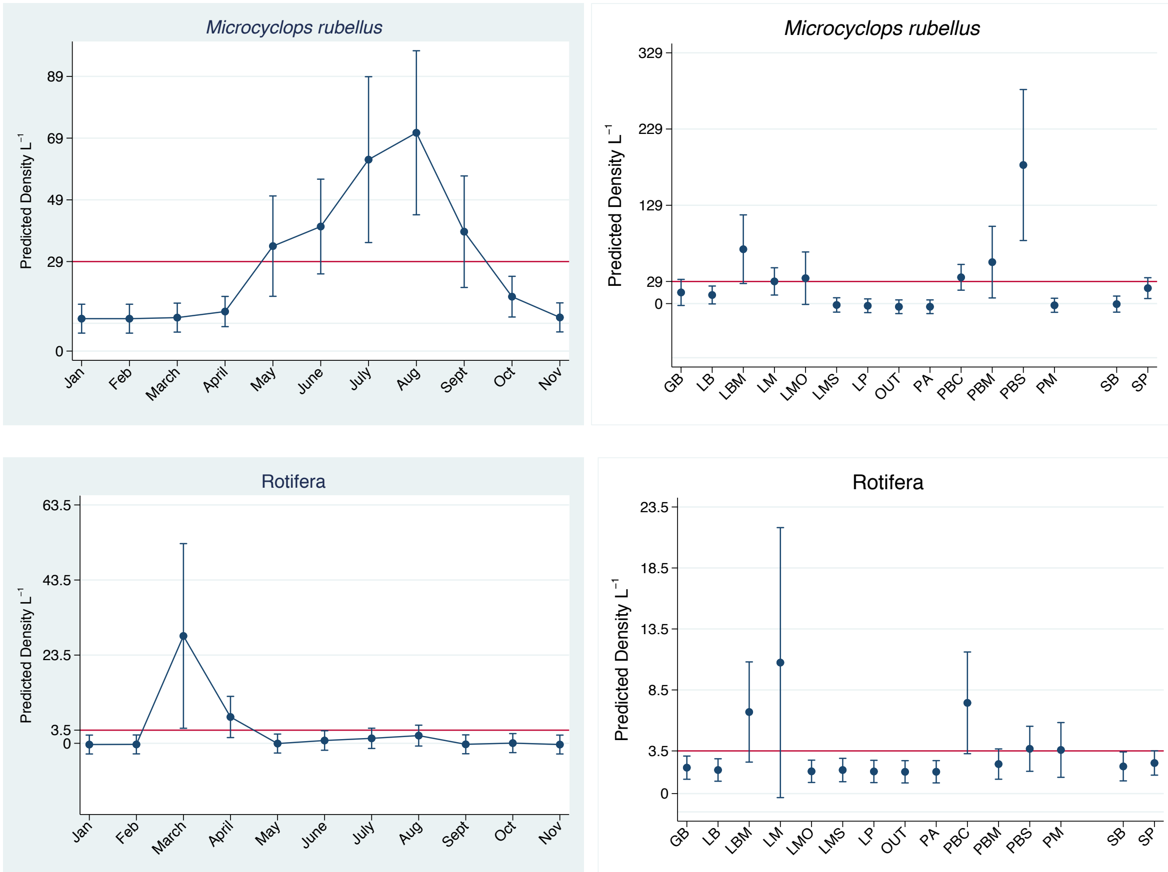


Figure 7. Predicted mean and 95% Cis of total zooplankton densities (L^{-1}) and individual taxa group densities by month and site.

Relative abundances of taxa also varied seasonally (Figure 8).

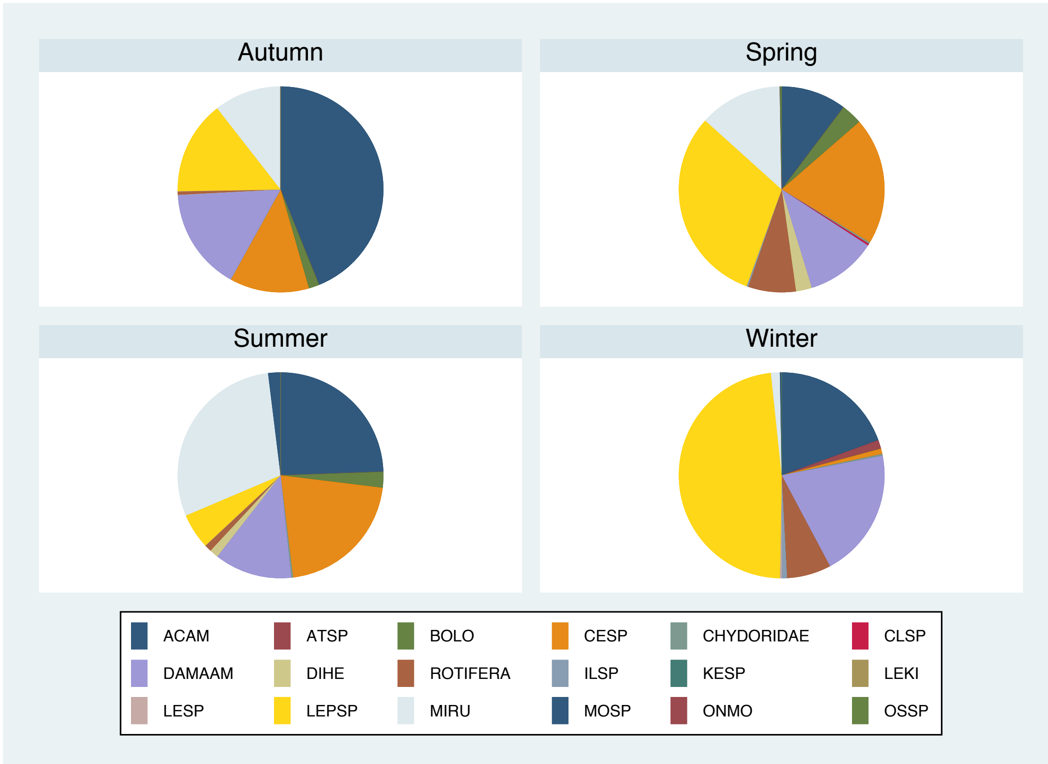


Figure 8. Seasonal differences in zooplankton taxa densities in Utah Lake. Taxa code names are in Table 2.

Total zooplankton densities varied seasonally and annually with highest densities in summer, lowest in winter and an increasing trend from 2016 to 2019 (Figure 9). Seasonal trends in zooplankton densities were expected. The reason for higher densities in 2019 compared to 2016 are not fully understood but 2016 was a very low water year with low lake levels and 2019 was a high-water year with high lake levels which could partially explain this trend but will require further investigation.

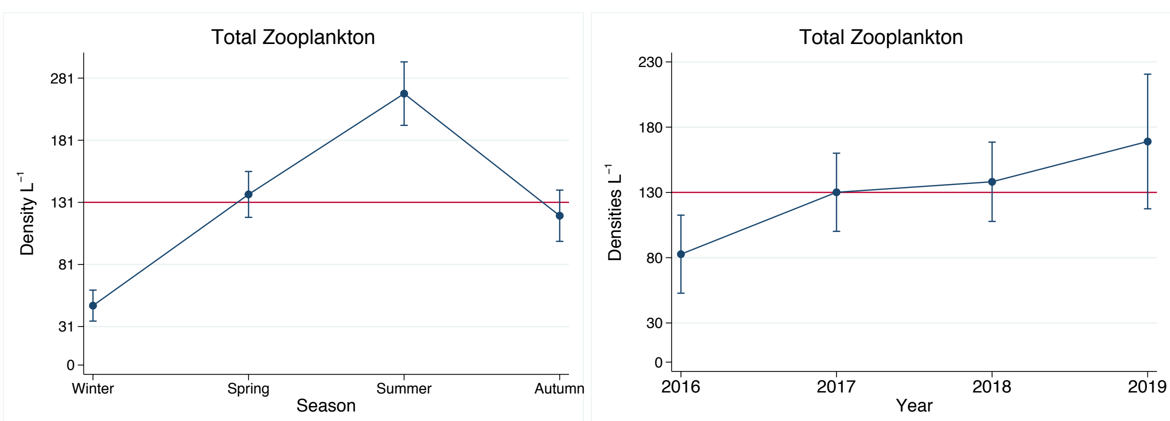


Figure 9. Seasonal and annual trends in zooplankton densities in Utah Lake.

Incorporation of Results into MIBI

Results from these analyses will be used to populate zooplankton metrics that are in the Multimetric Index of Biological Integrity (MIBI) that we are developing for Utah Lake (Richards and Miller 2019). For example, total zooplankton mean and 95% CI densities by season is one of our metrics and those values are presented in Table 5 and will be used to update our MIBI.

Table 5. Descriptive statistics of Total Zooplankton densities (L^{-1}) by season to be used in our Utah Lake MIBI.

Season	Mean	Std. Error	LCL	UCL
Winter	48	137	35	60
Spring	137	140	119	156
Summer	219	144	193	244
Autumn	120	142	100	141

Phytoplankton/Zooplankton Relationships

Understanding the relationship between zooplankton assemblages and phytoplankton assemblages is important for managing Utah Lake. There were clear spatial and temporal trends in zooplankton assemblages in the lake documented in this progress report and our past reports (Richards and Miller 2019, Richards and Miller 2017, Richards et al. 2019, Richards 2016, Richards 2018, Richards 2019). There were also clear spatial and temporal trends in phytoplankton assemblages in the lake documented by us in past reports (Richards and Miller 2019, Richards and Miller 2017, Richards et al. 2019, Richards 2016, Richards 2018, Richards 2019). We also documented preliminary relationships between the two (Richards 2018). However, phytoplankton densities can significantly vary weekly whereas, zooplankton abundances lag behind phytoplankton abundances often up to several weeks behind. Detailed cause and effect relationships, therefore, cannot be fully understood from our sampling efforts because we rarely sampled more than once per month. However, the literature is ripe with documentation of these relationships and we have no reason to assume that the relationships between zooplankton and phytoplankton in Utah Lake would behave much differently than reported in the literature. At this time, we do not anticipate any increase in our plankton sampling intensity.

Recommendations

Individual zooplankton taxa and zooplankton assemblages play crucial roles in the ecology of Utah Lake, including their ability to regulate cyanoHABs. However, correct taxonomic identification of zooplankton in Utah Lake is a critical prerequisite for any statistical and ecological analyses and needs to be documented and available to all researchers and managers.

We have only been collecting zooplankton samples on a semiregular basis. Subsequently direct empirical evidence of the relationships between zooplankton assemblages and cyanoHABs in the lake is not fully achievable, nor is a complete understanding of zooplankton ecology or environmental factors that reduce their ability to fully function as healthy members of Utah Lake's ecosystem. We, therefore, recommend the following:

1. Continue collecting zooplankton samples and associated environmental data
2. Continue refining zooplankton taxonomy and make available to others.
3. Increase zooplankton sampling efforts in Provo Bay on a biweekly basis.
4. Continue analyzing zooplankton data to better understand their ecology and ecosystem functions.
5. Continue to incorporate zooplankton metrics in the Utah Lake Multimetric Index of Biological Integrity.

Acknowledgements

We thank all the members of the Wasatch Front Water Quality Council field crews past and present. We also thank Brett Marshall at River Continuum Concepts, Manhatten, MT for undertaking the challenging task of updating Utah Lake zooplankton taxonomy. Special thanks to the WFWQC for funding this and future zooplankton studies in the Utah Lake/Jordan River drainage. Finally, we pay homage to the late Dr. Larry Gray for his love of zooplankton and all things invertebrate in Utah Lake.

Literature Cited

Beals, E.W. 1984. Bray–Curtis ordination: an effective strategy for analysis of multivariate ecological data. Adv Ecol Res 14:1–55

De Cáceres, M. and P. Legendre. 2008. Beals smoothing revisited. Oecologia. 156: 657-669.

Culver, D. A., M. M. Boucherle, D. J. Bean, and J. W. Fletcher. 1985. Biomass of freshwater crustacean zooplankton from length-weight regressions. Canadian Journal of Fisheries and Aquatic Sciences 42:1380-1390.

Dufrêne, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs. Vol. 67. No. 3. 345-366.

Havens, K.D. and J. R. Beaver. 2011.Composition, size, and biomass of zooplankton in large productive Florida lakes. Hydrobiologia 668:49–60. DOI 10.1007/s10750-010-0386-5

Iglesias, C., Guillermo Goyenola, Nestor Mazzeo, Mariana Meerhoff, Elena Rodo´,and Erik Jeppesen. 2007. Horizontal dynamics of zooplankton in subtropical Lake Blanca (Uruguay) hosting multiple zooplankton predators and aquatic plant refuges. Hydrobiologia (2007) 584:179–189 DOI 10.1007/s10750-007-0599-4.

Karlson, A.M.L., Jon Duberg, Nisha H. Motwani, Hedvig Hogfors, Isabell Klawonn, Helle Ploug, Jennie Barthel Svede´n, Andrius Garbaras, Brita Sundelin, Susanna Hajdu, Ulf Larsson, Ragnar Elmgren, Elena Gorokhova. 2015. Nitrogen fixation by cyanobacteria stimulates production in Baltic food webs. Journal of the Human Environment. AMBIO 2015, 44(Suppl. 3): S413–S426. DOI 10.1007/s13280-015-0660-x.

Legendre P, and L. Legendre .1998. Numerical ecology, 2nd English edition. Elsevier, Amsterdam

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.

McCune, B. 1994. Improving community analysis with the Beals smoothing function. Ecoscience 1:82–86.

McCune, B. and J.B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, Oregon.

McCune, B. and M. J. Mefford. 2011. PC-ORD. Multivariate analysis of ecological data. Version 6.22. MjM Software, Gleneden Beach, Oregon. USA.

McCune, B. and M. J. Mefford. 2018. PC-ORD. Multivariate analysis of ecological data. Version 7.07. MjM Software, Gleneden Beach, Oregon. USA.

Peck, J.E. 2010. Multivariate analysis for community ecologists. MJM Software Design. Gleneden Beach, OR. 162 pp.

Richards, D.C. 2016. Spatial and Temporal Patterns of Zooplankton in Utah Lake 2016. 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. Technical Report. To Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Consulting, Vineyard, UT.

Richards, D.C. 2019. 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. 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.

Richards, D. C. and T. Miller. 2019c. 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., Miller, T., Holcomb, J., Finley, H., Robinson, W.D., and F. Fluckiger. 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 to Wasatch Front Water Quality Council, Salt Lake City, UT. OreoHelix Ecological, Vineyard, UT.

Rosen, R. 1981. Length-dry weight relationships of some freshwater zooplankton. Journal of Freshwater Ecology. 1(2):225-229. DOI: 10.1080/02705060.1981.9664034.

Scheffer, M. 1998. Ecology of Shallow Lakes. Kluwer Academics Publishers.

StataCorp. 2015. Stata/IC 16.0 for Mac (64-bit Intel). Revision: 14 Nov 2019. College Station, TX.

Acknowledgements

We thank all the members of our field crew at the Wasatch Front Water Quality Council that helped collect zooplankton and environmental data. We also thank WFWQC for funding this important research

Appendices

Appendix 1. Nonmetric multidimensional scaling results.

NMS Results

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)

	Stress in real data 250 run(s)			Stress in randomized data Monte Carlo test, 249 runs				
Axes	Minimum	Mean	Maximum	Minimum	Mean	Maximum	p	n
3	6.323	6.386	6.491	20.702	21.681	22.892	0.0040	0

p = proportion of randomized runs with stress < or = observed stress

i.e., p = (1 + n)/(1 + N)

n = no. permutations <= observed

N = no. permutations

Conclusion: a 3-dimensional solution is recommended.

Selected file CONFIG3.GPH for the starting configuration for the final run.

Ordination of Sites in Taxa space. 405 Sites 18 Taxa

The following options were selected:

ANALYSIS OPTIONS

1. REL.SOREN. = Distance measure

2. 3 = Number of axes (max. = 6)

3. 500 = Maximum number of iterations

4. FROM FILE = Starting coordinates (random or from file)

5. 3 = Reduction in dimensionality at each cycle

6. NO PENALTY = Tie handling (Strategy 1 does not penalize
   ties with unequal ordination distance,
   while strategy 2 does penalize.)

7. 0.20 = Step length (rate of movement toward minimum stress)

8. USER-SUPPL = Random number seeds (use time vs. user-supplied)

9. 1 = Number of runs with real data

10. 0 = Number of runs with randomized data

11. NO = Autopilot

12. 0.000001 = Stability criterion, standard deviations in stress
    over last 10 iterations.

OUTPUT OPTIONS

14. NO = Write distance matrix?

15. NO = Write starting coordinates?

16. NO = List stress, etc. for each iteration?

17. YES = Plot stress vs. iteration?

18. NO = Plot distance vs. dissimilarity?

19. YES = Write final configuration?

20. PRINC.AXES = Write varimax-rotated, principal axes, or unrotated scores for graph?

21. NO = Write run log?

22. YES = Write weighted-average scores for Taxa?

File containing starting coordinates:

CONFIG3.GPH

6.32525 = final stress for 3-dimensional solution

0.00000 = final instability

85 = number of iterations

MEASURES OF FIT

R^2n (nonmetric fit) = 0.9960 Intrinsic measure for NMS. Null: all points co-located.

R^2l (linear fit) = 0.9806 Null: all ordination distances equal.

R^2m (metric fit) = 0.9778 Null: no linear relationship with observed dissimilarities.

CHANCE-CORRECTED EVALUATIONS

Improvement: I = 0.8205

Null model: final configuration no better than initial random configuration.

Interpretation: 0 = random expectation, 1 = perfect fit, <0 = worse than random expectation

Basis: 3 dimensions

250 = number of random initial configurations used

35.2472 = average initial stress

6.3252 = final stress

Association: A = 0.5488

Null model: relationships among columns no stronger than expected chance, based on shuffling within columns.

Interpretation: 0 = random expectation, 1 = perfect fit, <0 = worse than random expectation

Basis: 3 dimensions

499 = number of randomizations used

14.0180 = average final stress from randomizations

6.3252 = final stress

NMS axes coordinates

Sample Name	Axis 1	Axis 2	Axis 3
BIsept19	1.10362	-0.67148	0.32317
GBSep15	-0.12574	-0.29585	-0.40226
GBOct15	-0.20916	0.00724	-0.62927
GB2Mar16	-2.37344	-0.44495	0.54492
GB2Jun16	-2.35244	-0.57724	0.15864
GB1Jun16	-0.17587	-0.41003	-0.24523
GB3Jun16	-0.7907	-0.53057	-0.12119
GB1Jul16	0.22061	-0.45848	0.0956
GB2Jul16	0.43163	-0.16528	-0.26559
GB1Aug16	0.40128	0.19833	0.31475
GB2Aug16	0.11563	-0.22458	-0.10877
GB3Aug16	-0.20342	0.57707	-0.43929
GB1Sep16	-0.06224	-0.51045	-0.21429
GB2Sep16	0.03298	0.04449	-0.26707
GB3Sep16	0.08564	0.63005	-0.24283
GB4Sep16	-0.7596	0.28896	-0.15032
GB1Oct16	-0.12574	-0.29585	-0.40226

GB2Oct16	-0.17587	-0.41003	-0.24523
GBJan17	-0.20643	-0.80922	0.08293
GB1Feb17	-1.95038	-0.71025	0.13291
GB2Feb17	-0.33307	-0.5943	-0.08521
GB1Mar17	-0.9388	0.05029	-0.35578
GB2Mar17	-1.41357	-0.38998	0.02313
GB1Apr17	-0.77459	-0.23881	-0.34309
GB3Apr17	-0.83267	-0.67615	-0.05699
GB2Apr17	-0.7596	0.28895	-0.15029
GB6Apr17	-2.11558	0.01257	-0.12609
GB4Apr17	-0.81689	-0.32434	-0.38129
GBMay17	-0.0496	0.91714	0.12159
GB2May17	0.1493	-0.10041	0.00418
GB1Jun17	0.15345	0.99314	0.83874
GBJun17	0.50503	-0.20267	0.24979
GB2Jun17	1.30918	-0.74729	0.46513
GBJul17	0.31299	0.54107	0.50758
GB2Jul17	0.99698	-0.14551	0.54864
GB1Aug17	1.10362	-0.67148	0.32317
GB4Aug17	0.74654	0.44515	0.20142
GB2Aug17	0.99698	-0.14551	0.54864
GB5Aug17	0.55478	1.00323	-0.39783
GB3Aug17	0.24031	0.73956	-0.27526
GBNov17	-0.52579	0.2855	0.3329

GBMar18	-0.35459	0.54035	0.03797
GBJun18	0.40128	0.19833	0.31475
GB1Jun18	0.3846	0.27773	0.58614
GBJul18	0.31299	0.54107	0.50758
GBjuly18	0.44723	-0.03007	0.53017
GBaug18	0.99698	-0.14551	0.54864
GBapr19	-0.95191	0.4634	0.03218
GBmay19	-0.30506	0.86216	1.1584
GBmay19b	-0.41335	0.97691	1.05859
GBmay19c	0.15342	0.9924	0.83958
GBmay19d	-1.0519	0.97536	0.49162
GBjuly19	0.11229	0.96493	0.28717
GBaug19	0.28483	0.31488	0.11328
GBaut19b	0.80225	0.3177	-0.21023
GBsept19	0.67354	0.26427	0.52697
GBoct19	0.62942	-0.2803	0.1705
GBoct19b	0.77395	-0.27944	0.31569
LBJul16	-0.7596	0.28895	-0.15029
LB1Aug16	0.86358	-0.43863	0.14913
LB2Aug16	-0.24131	-0.13454	-0.44546
LB3Aug16	-0.46361	-0.05143	-0.18546
LB1Sep16	-0.20916	0.00724	-0.62927
LB3Sep16	-1.24756	-0.10035	-0.10851
LB2Sep16	-0.77459	-0.23881	-0.34309

LB4Sep16	-0.17587	-0.41003	-0.24523
LBOct16	-0.79465	0.06275	0.17406
LBNov16	-0.06224	-0.51045	-0.21429
LBJan17	-0.20705	-0.80793	0.08748
LB1Feb17	-0.34048	-0.28094	-0.64538
LB2Feb17	-1.64798	-0.49988	0.87239
LB1Mar17	-0.17587	-0.41003	-0.24523
LB2Mar17	-0.86918	0.56196	0.08669
LB1Apr17	-0.24131	-0.13454	-0.44546
LB2Apr17	-0.10938	0.23032	0.14376
LB3Apr17	-0.24052	0.37082	-0.26667
LB4Apr17	-1.70839	0.53877	0.1345
LB5Apr17	-0.15029	-0.1954	-0.49701
LB6Apr17	-0.93879	0.05029	-0.35579
LB7Apr17	-0.24131	-0.13454	-0.44546
LB8Apr17	-0.17587	-0.41003	-0.24523
LB10Apr17	-0.24131	-0.13454	-0.44546
LB9Apr17	-0.15029	-0.1954	-0.49701
LBMay17	0.37534	0.6488	0.61641
LB1May17	0.87122	2.03199	0.53087
LBJun17	0.47958	0.7965	0.72061
LB1Jun17	0.42386	-0.21185	0.14775
LB5Jun17	0.42386	-0.21185	0.14775
LB2Jun17	0.42386	-0.21185	0.14775

LBMJul17	0.10797	0.19156	-0.40732
LBM2Jul17	0.79233	1.06574	0.1766
LBMAug17	1.13747	0.8602	-0.95216
LBB1Aug17	0.66443	0.88096	0.22013
LBM2Aug17	0.55478	1.00323	-0.39782
LBB2Aug17	1.10363	-0.67148	0.32317
LB2Aug17	1.42985	-0.30813	0.26446
LBAug17	0.84692	-0.15121	0.13379
LBSep17	0.70613	0.77772	0.50126
LBMay18	0.09952	0.33352	0.09443
LBMJul18	0.23851	0.03402	-0.17402
LBjuly18	1.01274	-0.0913	1.30364
LBjuly18	0.38606	0.37072	-0.58915
LBaug18	0.9015	-0.66587	0.11893
LBNov18	-0.54534	-0.20613	0.17529
LBapril19	-0.43677	-0.2523	0.00883
LBmay19	-1.08631	1.00166	0.65083
LBjuly19	0.20915	0.61592	0.29519
LBjuly19b	0.21509	0.33006	0.23461
LBaug19	0.68389	0.47611	0.33189
LBaug19b	1.10363	-0.67148	0.32316
LBaug19c	0.41144	0.89681	-0.20023
LBsept19	1.21892	0.44435	0.80738
LBoct19	0.28957	-0.19255	-0.07492

LBoct19c	0.28957	-0.19255	-0.07492
LBoct19b	0.28957	-0.19255	-0.07492
LBoct19d	0.28957	-0.19255	-0.07492
LMJun18	0.42386	-0.21185	0.14775
LMSep15	0.04833	-0.33411	-0.38828
LM1Oct15	-0.12574	-0.29585	-0.40226
LM2Oct15	-1.80248	-0.22438	0.27799
LMNov15	-1.67193	0.29368	0.44974
LMMar16	-0.95713	-0.2939	-0.38004
LMMay16	-0.24131	-0.13454	-0.44546
LMJun16	-1.3105	-0.37148	0.19128
LMJul16	-0.37343	-0.4005	0.11823
LM1Aug16	0.22819	-0.10251	-0.26419
LM2Aug16	0.70178	-0.80047	0.27216
LM4Aug16	0.71557	-1.06652	0.06142
LM5Aug16	0.71594	-1.06641	0.06004
LM1Sep16	0.99191	-0.98975	0.30939
LM2Sep16	-0.4712	-0.04914	0.24715
LM3Oct16	-0.4503	0.45131	0.37876
LM4Oct16	-0.17587	-0.41003	-0.24523
LMNov16	-0.15029	-0.1954	-0.49701
LMJan17	-0.78849	0.64506	0.69893
LM1Feb17	-0.2504	-0.28226	-0.58216
LM2Feb17	-1.94676	-0.7109	0.14953

LM1Mar17	-0.24131	-0.13454	-0.44546
LM2Mar17	-0.30806	0.64109	-0.29722
LM1Apr17	-1.24756	-0.10035	-0.10851
LM2Apr17	-0.24131	-0.13454	-0.44546
LM3Apr17	-1.89247	0.16259	-0.07474
LM4Apr17	-0.15029	-0.1954	-0.49701
LM5Apr17	-0.24131	-0.13454	-0.44546
LMMay17	0.03298	0.04449	-0.26707
LMJun17	0.14817	0.47844	0.12439
LM1Jun17	0.23851	0.03402	-0.17402
LM2Jun17	0.42386	-0.21185	0.14775
LM4Jun17	0.40128	0.19833	0.31475
LM5Jun17	0.52182	0.02025	0.45269
LM3Jun17	1.14416	0.01346	0.02107
LMJul17	0.80155	0.08422	0.0523
LM2Jul17	1.1036	-0.67147	0.32326
LM1Aug17	0.41679	0.29331	-0.36991
LM2Aug17	0.42923	0.08223	-0.09293
LM3Aug17	0.66034	0.20279	-0.11531
LM4Aug17	0.41679	0.29331	-0.36991
LM5Aug17	0.83296	-0.53387	0.2953
LM6Aug17	0.84174	-0.02326	-0.15651
LM7Aug17	0.76862	0.47984	-0.63755
LM10Aug17	0.76862	0.47985	-0.63755

LM8Aug17	0.52685	0.44175	-0.52368
LM11Aug17	0.41679	0.29331	-0.36991
LM12Aug17	0.10797	0.19156	-0.40732
LM9Aug17	0.41679	0.29331	-0.36991
LMSep17	0.42386	-0.21185	0.14775
LMOct17	-0.59277	0.19017	-0.21474
LMNov17	0.80155	0.08422	0.0523
LMMar18	-0.54967	1.00183	0.29296
LMMay18	0.11743	-0.13703	-0.0769
LM1May18	0.16095	0.02496	-0.31155
LM1Jun18	0.32144	-0.41148	1.05732
LM2Jun18	0.57154	-0.10025	0.12946
LM3Jun18	0.83295	-0.53386	0.29532
LM4Jun18	0.42386	-0.21185	0.14775
LMJul18	0.42386	-0.21185	0.14775
LM1Jul18	0.32144	-0.41148	1.05732
LMmay19	0.06447	0.7164	0.08127
LMjuly19	0.76862	0.47984	-0.63755
LCSep15	0.28523	-0.56547	-0.17643
LP1Sep15	-0.15029	-0.1954	-0.49701
LP2Sep15	-0.24131	-0.13454	-0.44546
LP3Sep15	-0.8519	0.05314	-0.26336
LCOct15	-0.24131	-0.13454	-0.44546
LCMar16	0.01025	0.137	-0.24025

LP1May16	-1.1248	-0.89001	-0.01138
LP2May16	-0.26131	-0.50041	-0.22011
LP3May16	-0.17587	-0.41003	-0.24523
LP1Jun16	-0.7907	-0.53057	-0.12118
LP2Jun16	-0.17587	-0.41003	-0.24523
LP3Jun16	-0.06224	-0.51045	-0.2143
LP1aAug16	-0.89239	-0.46128	-0.21153
LP2aAug16	0.22061	-0.45848	0.0956
LP3aAug16	0.40833	-0.56023	0.14261
LP1bAug16	0.22061	-0.45848	0.0956
LP2bAug16	0.7018	-0.80049	0.27208
LP3bAug16	0.52023	-0.56987	0.10672
LP1cAug16	-0.92815	-0.15813	0.05631
LP2cAug16	0.71592	-1.06641	0.06011
LP3cAug16	0.71602	-1.06638	0.05972
LP1dAug16	-0.42863	-0.16958	-0.02719
LP2dAug16	0.4169	-0.84006	0.04816
LP3dAug16	0.46459	-0.98879	0.12266
LP1Sep16	0.10797	0.19156	-0.40732
LP2Sep16	0.41686	-0.84006	0.04833
LP3Sep16	0.8516	-1.33795	0.1967
LP1aOct16	-0.17587	-0.41003	-0.24523
LP2aOct16	0.41691	-0.84006	0.04815
LP3aOct16	0.85228	-1.33805	0.19357

LP1bOct16	-0.06758	-0.54698	-0.11298
LP2bOct16	-0.24131	-0.13454	-0.44546
LP3bOct16	-0.17587	-0.41003	-0.24523
LP1Nov16	-0.90372	0.05232	0.4483
LP2Nov16	-0.81689	-0.32434	-0.38129
LP3Nov16	-0.15029	-0.1954	-0.49701
LP1Jun17	-0.10762	0.28304	0.57392
LP3Jun17	0.42386	-0.21185	0.14775
LP2Jun17	0.91457	-0.36284	0.56429
LP2aJul17	1.42986	-0.30815	0.26436
LP1bJul17	0.15722	0.38575	0.34947
LP1Jul17	0.33095	-0.23445	-0.02251
LP3Jul17	1.10365	-0.67149	0.32308
LP2july17	0.86367	0.20051	-0.14753
LP1aJul17	1.16095	-0.20896	0.23639
LP2Aug17	1.10363	-0.67148	0.32315
LP1Aug17	0.5623	0.55432	0.12909
LP3Aug17	1.62708	-0.37243	0.36794
LP1aAug17	1.1036	-0.67147	0.32326
LP3Sep17	0.72888	-0.33597	0.28988
LP2Oct17	0.45601	-0.71035	0.30074
LP1May18	0.60452	-0.82672	0.63021
LP2Jun18	1.30931	-0.7474	0.46465
LP1Jun18	0.91457	-0.36284	0.56429

LP3Jun18	0.60452	-0.82676	0.63016
LP1aJun18	0.96649	-0.58163	0.3987
LP3aJun18	0.45749	-0.2375	0.22548
LP2Jul18	0.72888	-0.33597	0.28989
LP1Jul18	0.21932	0.63854	0.73333
LP3Jul18	0.60454	-0.8269	0.62997
LP2may19	0.28957	-0.19255	-0.07492
OUTSep15	-0.03048	-0.46079	-0.40862
OUTMar16	-1.05841	-0.42298	-0.44323
OUTMay16	-0.24131	-0.13454	-0.44546
OUTJun16	-0.17587	-0.41003	-0.24523
PA1Sep16	-0.49623	0.34396	0.22913
PA2Sep16	-1.456	-0.10109	0.48219
PA3Sep16	-0.7907	-0.53057	-0.12119
PA1Feb17	-1.71589	0.02865	-0.45599
PA2Feb17	-1.6479	-0.50091	0.87199
PB1Mar16	-1.77256	-0.61457	0.44562
PB2Mar16	-0.14056	-0.67541	-0.15264
PB1Jun16	-0.95989	-0.58748	-0.60765
PB3Jun16	-0.89034	-0.38094	0.33959
PB2Jun16	-0.06224	-0.51045	-0.2143
PB3Jul16	-0.7907	-0.53057	-0.12119
PB1Jul16	-0.7907	-0.53057	-0.12119
PB2Jul16	0.35951	0.34398	-0.49995

PB1Aug16	-0.84251	-0.17204	0.18301
PB3Aug16	-0.1706	-0.12439	0.0811
PB4Aug16	0.08318	0.24362	0.08373
PB1Sep16	-0.17587	-0.41003	-0.24523
PB3Sep16	-0.50443	0.13921	0.28519
PB1Oct16	-1.41355	-0.39001	0.02331
PB3Oct16	-0.7907	-0.53057	-0.12119
PB1Nov16	-1.05841	-0.42299	-0.4432
PB2Nov16	-1.54561	0.44968	0.81516
PBJan17	-2.84925	-0.50228	0.83616
PB1Mar17	-0.19559	-0.02429	-0.84482
PB2Mar17	0.04833	-0.33411	-0.38828
PB3Mar17	-0.48986	0.8607	0.2535
PB4Mar17	-0.45446	0.36227	-0.05415
PB5Mar17	-0.50695	0.18191	-0.093
PB1Apr17	-1.41583	0.18158	-0.07778
PB2Apr17	0.03298	0.04449	-0.26707
PB3Apr17	-0.15029	-0.1954	-0.49701
PB4Apr17	-1.47412	0.07061	-0.28126
PB5Apr17	-0.61792	0.2476	-0.29632
PB6Apr17	-0.69176	0.29675	-0.21356
PB7Apr17	-0.53834	0.37332	0.05745
PB8Apr17	0.03298	0.04449	-0.26707
PBSMay17	0.66983	0.29451	-0.17989

PB2May17	0.24031	0.73956	-0.27526
PB1May17	-0.62363	1.27248	0.50279
PB3May17	-0.58724	0.8778	0.16288
PB2Jun17	0.20025	1.3995	0.01054
PBS1Jun17	0.23851	0.03402	-0.17402
PB9Jun17	0.59491	0.211	0.39395
PB1Jun17	0.24031	0.73956	-0.27526
PBNJun17	0.61173	0.52046	0.02599
PBS2Jun17	0.43434	0.69698	0.03402
PBSJul17	-0.62275	0.38549	-0.34132
PBJul17	0.00478	0.67649	-0.10755
PB2Jul17	0.24031	0.73957	-0.27526
PB1Aug17	0.76862	0.47985	-0.63755
PBNAug17	0.76862	0.47985	-0.63755
PB3Aug17	0.41679	0.29331	-0.36991
PB4Aug17	0.76862	0.47985	-0.63755
PBSAug17	0.93351	0.93585	-0.17479
PBS1Aug17	0.66034	0.20279	-0.11531
PB2Aug17	0.4771	0.82652	-0.3247
PBSNov17	-0.28949	0.46884	0.53192
PBApr18	-0.23316	0.41461	0.43726
PBSmay18	-1.11047	0.72167	0.72776
PBMay18	0.32108	0.14505	-0.09479
PB11Jun18	-0.1702	0.27487	0.68243

PB12Jun18	0.12874	0.81003	-0.31072
PB1Jun18	0.15966	0.31808	-0.49752
PB13Jun18	0.10797	0.19156	-0.40732
PB2Jun18	0.42386	-0.21185	0.14775
PBSjun18b	0.64936	0.11504	-0.1192
PB5Jun18	0.31173	-0.03358	-0.01182
PB6Jun18	0.23851	0.03402	-0.17402
PBSJun18	0.2069	0.57685	0.01271
PBJul18	0.11743	-0.13703	-0.0769
PBSjuly18	0.67621	0.94723	-0.39174
PBaug18	0.01241	0.98228	0.0287
PBaug18b	1.32751	0.56579	-0.59364
PBapril19	0.52472	1.29818	-0.08377
PBapril19b	0.22761	1.41127	-0.14433
PBmay19	-0.55667	0.56056	0.42371
PBSmay19	0.10797	0.19156	-0.40732
PBmay19b	0.47723	-0.00122	-0.2275
PBSjune19	-0.54052	0.68294	0.23731
PBjune19b	0.03298	0.04449	-0.26707
PBjune19	0.10797	0.19156	-0.40732
PBSaug19d	0.13898	1.13111	0.03701
PBSjuly19	0.28403	1.13143	0.35828
PBSaug19	1.04427	0.36508	-0.48259
PBaug19	0.72859	0.34849	-0.38093

PBSaug19c	0.60302	0.30979	-0.45011
PBSaug19b	0.72859	0.34849	-0.38093
PBsept19	1.3146	0.19906	-0.04688
PBsept19b	1.10362	-0.67148	0.3232
PBSsept19	1.04428	0.36511	-0.48255
PBSoct19	0.62298	0.90245	-0.24171
PBSoct19b	0.36298	0.37307	0.29498
PMMar16	-1.05841	-0.42298	-0.44322
PMMay16	-0.24131	-0.13454	-0.44546
PMJun16	-0.1406	-0.67541	-0.15243
PM1Aug16	0.70177	-0.80047	0.27216
PM2Aug16	-0.58411	0.14951	-0.12134
PM3Aug16	0.22819	-0.10251	-0.26419
PMSep16	-1.55639	-0.55775	0.1012
PM1Oct16	-0.14052	-0.67542	-0.15285
PM2Oct16	-0.83267	-0.67615	-0.05698
PMNov16	-0.54001	0.42968	0.10834
PM1Apr17	-0.91151	0.25988	-0.93888
PM2Apr17	0.13428	0.49992	-0.13723
PM3Apr17	0.13428	0.49992	-0.13723
PMJun17	0.31738	0.20691	0.44836
PMJul17	0.83296	-0.53387	0.2953
PMAug17	0.33095	-0.23445	-0.02251
PMJun18	1.1036	-0.67146	0.32327

PSaug17	0.64096	0.75516	0.30325
SB1Jul16	-0.89034	-0.38094	0.3396
SB2Jul16	-0.08589	0.13856	-0.88496
SB1Aug16	0.17136	0.43653	0.00739
SB2Aug16	-0.89776	-0.23658	-0.34728
SB1Sep16	-0.24131	-0.13454	-0.44546
SB2Sep16	-0.17587	-0.41003	-0.24523
SB3Sep16	-1.31052	-0.37147	0.19117
SB1Oct16	-0.7907	-0.53057	-0.12119
SB2Oct16	-0.86817	0.08095	0.30967
SBNov16	-0.81689	-0.32434	-0.38129
SBFeb17	-2.92943	0.51277	1.34769
SB1Mar17	-0.29358	0.20784	0.2216
SB2Mar17	-0.06224	-0.51045	-0.21429
SBJun18	-0.17339	0.44261	0.59379
SBJul18	0.42386	-0.21185	0.14775
SP1Oct15	-1.56896	0.45315	0.17506
SP2Oct15	-1.84203	0.50065	0.4794
SPNov15	-0.7907	-0.53057	-0.12119
SPJul16	-0.24052	0.37082	-0.26667
SPAug16	-0.90767	-0.72049	0.38292
SP1Jan17	-1.86126	0.49466	0.27606
SP1Mar17	-0.29358	0.20784	0.2216
SP2Mar17	-1.4173	0.64449	-0.14551

SP1Apr17	-0.24131	-0.13454	-0.44546
SP2Apr17	-0.24131	-0.13454	-0.44546
SP3Apr17	-0.86701	0.54437	-0.15727
SP4Apr17	-0.86816	0.08095	0.30968
SP5Apr17	-0.24131	-0.13454	-0.44546
SP6Apr17	-0.24131	-0.13454	-0.44546
SPMay17	0.1493	-0.10041	0.00418
SP2May17	0.40128	0.19833	0.31475
SPJun17	0.11743	-0.13703	-0.0769
SP1Jun17	0.42386	-0.21185	0.14775
SP2Jun17	0.31173	-0.03358	-0.01182
SP4Jul17	0.31173	-0.03358	-0.01182
SP2Jul17	1.42984	-0.30811	0.26454
SP3Jul17	1.27232	0.48004	-0.52248
SP1Aug17	0.41679	0.29331	-0.36991
SP2Aug17	0.41679	0.29331	-0.36991
SPNov17	-0.52534	0.43381	0.50654
SPJun18	0.51641	-0.17163	0.1975
SPJul18	0.42386	-0.21185	0.14775
ULSPjul18	1.32715	0.56459	-0.59559
ULSPaug18	1.20555	-0.11988	0.08242
ULSPjun19	0.15909	0.81701	0.33541
ULSPaug19	0.66034	0.20279	-0.11531
ULSPaug19b	1.00054	-0.45708	0.26181

ULSPsep19	1.16094	-0.20895	0.23641
ULSPsep19b	1.10362	-0.67148	0.32319
ULSPoct19	0.16095	0.02496	-0.31155
ULSPoct19b	0.16095	0.02496	-0.31155

ACAM	0.00263	-0.00155	-0.00455
ATSP	-0.23025	-0.02385	0.01964
BOLO	-0.02118	0.00786	-0.00262
CESP	0.01453	0.00434	-0.00251
CHYDORIDAE	-0.03474	0.10057	0.04086
CLSP	0.17826	0.34816	0.06188
DAMAAM	-0.00269	-0.00538	0.00047
DIHE	0.12006	-0.02649	0.03055
ROTIFERA	-0.02438	0.03369	-0.0315
ILSP	-0.33422	0.02247	0.03265
KESP	-0.30722	-0.02298	-0.03865
LEKI	0.20698	-0.11117	0.04538
LESP	-0.27624	0.02397	0.05325
LEPSP	-0.01138	-0.01852	0.00836
MIRU	0.07972	0.0294	0.00616

MOSP	0.16217	0.06771	-0.024
ONMO	0.0355	0.05877	0.10488
OSSP	-0.00925	0.09467	0.02182

Appendix 2. Multiple response permutation procedure (MRPP) results by Sites.

MRPP by Site Code

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

PC-ORD, 7.07

5 Dec 2019, 12:26:45

Project file: \\Mac\Home\Documents\PCORD\State Canal Electrofishing Summer 2019 Up Down East West.7prj

Main matrix: C:\Users\davidrichards\AppData\Roaming\MjM Software Design\PCORD 7\WORK.MJM

Second matrix: C:\Users\davidrichards\AppData\Roaming\MjM Software Design\PCORD 7\WORK2.MJM

Grouping variable: SiteCode from matrix 2

Groups were defined by values of: SiteCode

Input data has: 403 Sites by 18 taxa

Weighting option: C(I) = n(I)/sum(n(I))

Distance measure: Relative Sorensen

GROUP: 1

Identifier: GB

Size: 57 0.67183581 = Average distance

Members:

GBSep15 GBOct15 GB2Mar16 GB2Jun16 GB1Jun16 GB3Jun16 GB1Jul16 GB2Jul16
GB1Aug16 GB2Aug16 GB3Aug16 GB1Sep16 GB2Sep16 GB3Sep16 GB4Sep16 GB1Oct16
GB2Oct16 GBJan17 GB1Feb17 GB2Feb17 GB1Mar17 GB2Mar17 GB1Apr17 GB3Apr17
GB2Apr17 GB6Apr17 GB4Apr17 GBMay17 GB2May17 GB1Jun17 GBJun17 GB2Jun17
GBJul17 GB2Jul17 GB1Aug17 GB4Aug17 GB2Aug17 GB5Aug17 GB3Aug17 GBNov17
GBMar18 GBJun18 GB1Jun18 GBJul18 GBjuly18 GBaug18 GBapr19 GBmay19
GBmay19b GBmay19c GBmay19d GBjuly19 GBaug19 GBaut19b GBsept19 GBoct19
GBoct19b

GROUP: 2

Identifier: LB

Size: 48 0.61966208 = Average distance

Members:

LBJul16 LB1Aug16 LB2Aug16 LB1Sep16 LB3Sep16 LB4Sep16 LBOct16 LBNov16
LBJan17 LB1Feb17 LB2Feb17 LB1Mar17 LB2Mar17 LB1Apr17 LB2Apr17 LB3Apr17
LB4Apr17 LB5Apr17 LB6Apr17 LB7Apr17 LB8Apr17 LB10Apr17 LB9Apr17 LBMay17
LB1May17 LBJun17 LB1Jun17 LB5Jun17 LBB1Aug17 LBB2Aug17 LB2Aug17 LBAug17
LBSep17 LBMay18 LBjuly18 LBaug18 LBNov18 LBapril19 LBmay19 LBjuly19
LBjuly19b LBaug19 LBaug19b LBsept19 LBoct19 LBoct19c LBoct19b LMJun18

GROUP: 3

Identifier: LBM

Size: 11 0.52807424 = Average distance

Members:

LB3Aug16 LB2Sep16 LB2Jun17 LBMJul17 LBM2Jul17 LBMAug17 LBM2Aug17 LBMJul18

LBjuly18a LBaug19c LBoct19d

GROUP: 4

Identifier: LM

Size: 49 0.59599997 = Average distance

Members:

LMSep15 LM1Oct15 LM2Oct15 LMNov15 LMMar16 LMMay16 LMJun16 LMJul16

LM1Aug16 LM4Aug16 LM5Aug16 LM1Sep16 LM3Oct16 LM4Oct16 LMNov16 LMJan17

LM1Feb17 LM2Feb17 LM1Mar17 LM2Mar17 LM1Apr17 LM2Apr17 LM3Apr17
LM4Apr17

LM5Apr17 LMMay17 LMJun17 LM1Jun17 LM2Jun17 LM4Jun17 LM3Jun17 LMJul17

LM1Aug17 LM3Aug17 LM4Aug17 LM6Aug17 LM7Aug17 LM10Aug17 LM8Aug17
LM11Aug17

LM12Aug17 LM9Aug17 LMOct17 LMNov17 LMMay18 LM2Jun18 LM4Jun18 LMJul18

LMjuly19

GROUP: 5

Identifier: LMS

Size: 3 0.77089079 = Average distance

Members:

LM2Aug16 LM2Sep16 LMMar18

GROUP: 6

Identifier: LMO

Size: 10 0.48423846 = Average distance

Members:

LM5Jun17 LM2Jul17 LM2Aug17 LM5Aug17 LMSep17 LM1May18 LM1Jun18 LM3Jun18

LM1Jul18 LMmay19

GROUP: 7

Identifier: LP

Size: 61 0.53723556 = Average distance

Members:

LCSep15 LP1Sep15 LP2Sep15 LP3Sep15 LCOct15 LCMar16 LP1May16 LP2May16

LP3May16 LP1Jun16 LP2Jun16 LP3Jun16 LP1aAug16 LP2aAug16 LP3aAug16 LP1bAug16

LP2bAug16 LP3bAug16 LP1cAug16 LP2cAug16 LP3cAug16 LP1dAug16 LP2dAug16
LP3dAug16

LP1Sep16 LP2Sep16 LP3Sep16 LP1aOct16 LP2aOct16 LP3aOct16 LP1bOct16 LP2bOct16

LP3bOct16 LP1Nov16 LP2Nov16 LP3Nov16 LP1Jun17 LP3Jun17 LP2Jun17 LP2aJul17

LP1bJul17 LP1Jul17 LP3Jul17 LP2july17 LP1aJul17 LP2Aug17 LP1Aug17 LP3Aug17

LP1aAug17 LP3Sep17 LP2Oct17 LP1May18 LP2Jun18 LP1Jun18 LP3Jun18 LP1aJun18

LP3aJun18 LP2Jul18 LP1Jul18 LP3Jul18 LP2may19

GROUP: 8

Identifier: OUT

Size: 4 0.60764809 = Average distance

Members:

OUTSep15 OUTMar16 OUTMay16 OUTJun16

GROUP: 9

Identifier: PA

Size: 5 0.63416210 = Average distance

Members:

PA1Sep16 PA2Sep16 PA3Sep16 PA1Feb17 PA2Feb17

GROUP: 10

Identifier: PBC

Size: 56 0.58612335 = Average distance

Members:

PB1Mar16 PB1Jun16 PB2Jun16 PB3Jul16 PB1Jul16 PB1Aug16 PB3Aug16 PB4Aug16

PB1Sep16 PB1Oct16 PB3Oct16 PB1Nov16 PBJan17 PB1Mar17 PB2Mar17 PB3Mar17

PB4Mar17 PB5Mar17 PB1Apr17 PB2Apr17 PB3Apr17 PB4Apr17 PB5Apr17 PB6Apr17

PB7Apr17 PB8Apr17 PB2May17 PB1May17 PB3May17 PB2Jun17 PB9Jun17 PB1Jun17

PBJul17 PB2Jul17 PB1Aug17 PB4Aug17 PB2Aug17 PBApr18 PBMay18 PB11Jun18

PB12Jun18 PB1Jun18 PB13Jun18 PB2Jun18 PB5Jun18 PB6Jun18 PBJul18 PBaug18

PBapril19 PBapril19b PBmay19 PBmay19b PBjune19b PBjune19 PBaug19 PBsept19

GROUP: 11

Identifier: PBM

Size: 10 0.57125105 = Average distance

Members:

PB2Mar16 PB3Jun16 PB2Jul16 PB3Sep16 PB2Nov16 PBNJun17 PBNAug17 PB3Aug17

PBaug18b PBsept19b

GROUP: 12

Identifier: PBS

Size: 21 0.48030223 = Average distance

Members:

PBSMay17 PBS1Jun17 PBS2Jun17 PBSJul17 PBSAug17 PBS1Aug17 PBSNov17 PBSmay18

PBSjun18b PBSJun18 PBSjuly18 PBSmay19 PBSjune19 PBSaug19d PBSjuly19 PBSaug19

PBSaug19c PBSaug19b PBSsept19 PBSoct19 PBSoct19b

GROUP: 13

Identifier: PM

Size: 17 0.63346616 = Average distance

Members:

PMMar16 PMMay16 PMJun16 PM1Aug16 PM2Aug16 PM3Aug16 PMSep16
PM1Oct16

PM2Oct16 PMNov16 PM1Apr17 PM2Apr17 PM3Apr17 PMJun17 PMJul17 PMAug17

PMJun18

GROUP: 14

Identifier: SB

Size: 15 0.61653568 = Average distance

Members:

SB1Jul16 SB2Jul16 SB1Aug16 SB2Aug16 SB1Sep16 SB2Sep16 SB3Sep16 SB1Oct16

SB2Oct16 SBNov16 SBFeb17 SB1Mar17 SB2Mar17 SBJun18 SBJul18

GROUP: 15

Identifier: SP

Size: 36 0.60356301 = Average distance

Members:

SP1Oct15 SP2Oct15 SPNov15 SPJul16 SPAug16 SP1Jan17 SP1Mar17 SP2Mar17

SP1Apr17 SP2Apr17 SP3Apr17 SP4Apr17 SP5Apr17 SP6Apr17 SPMay17 SP2May17

SPJun17 SP1Jun17 SP2Jun17 SP4Jul17 SP2Jul17 SP3Jul17 SP1Aug17 SP2Aug17

SPNov17 SPJun18 SPJul18 ULSPjul18 ULSPaug18 ULSPjun19 ULSPaug19 ULSPaug19b

ULSPsep19 ULSPsep19b ULSPoct19 ULSPoct19b

Test statistic: T = -19.009013

Observed delta = 0.59291826

Expected delta = 0.64904185

Variance of delta = 0.87170936E-05

Skewness of delta = -0.40081426

Chance-corrected within-group agreement, A = 0.08647145

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.

Site Comparisons			T	A	P
LB	vs.	PBC	-15.83	0.07	0.000
LP	vs.	PBC	-27.45	0.11	0.000
LP	vs.	PBS	-25.21	0.16	0.000
LP	vs.	SP	-16.77	0.09	0.000
GB	vs.	PBS	-14.10	0.08	0.000
LB	vs.	PBS	-16.37	0.12	0.000
LM	vs.	LP	-15.95	0.07	0.000
LBM	vs.	LP	-13.18	0.10	0.000
PBS	vs.	SB	-11.57	0.15	0.000
GB	vs.	PBC	-10.14	0.04	0.000
PBS	vs.	PM	-11.16	0.15	0.000
LMO	vs.	PBC	-8.68	0.06	0.000
LB	vs.	LBM	-8.44	0.07	0.000
PBC	vs.	PBS	-7.90	0.05	0.000
PBS	vs.	SP	-7.76	0.06	0.000
PBC	vs.	PM	-7.34	0.05	0.000
LB	vs.	LM	-8.06	0.04	0.000
LMO	vs.	PBS	-8.43	0.15	0.000

PA	vs.	PBS	-7.02	0.14	0.000
LP	vs.	PBM	-7.69	0.06	0.000
LM	vs.	PBS	-7.23	0.05	0.000
GB	vs.	LBM	-6.43	0.04	0.000
LMO	vs.	SB	-6.57	0.14	0.000
LBM	vs.	PM	-6.18	0.11	0.000
LB	vs.	SP	-6.47	0.04	0.000
LBM	vs.	SB	-5.42	0.10	0.001
OUT	vs.	PBS	-5.16	0.10	0.001
LM	vs.	LMO	-5.56	0.05	0.001
GB	vs.	LP	-5.88	0.02	0.001
SB	vs.	SP	-5.12	0.05	0.001
LB	vs.	PBM	-5.34	0.05	0.001
LBM	vs.	LMO	-5.50	0.14	0.001
PBC	vs.	SB	-4.91	0.03	0.001
LP	vs.	SB	-5.48	0.04	0.001
GB	vs.	LM	-4.73	0.02	0.002
PA	vs.	PBC	-4.47	0.03	0.002
PM	vs.	SP	-4.80	0.04	0.002
LMO	vs.	PA	-4.19	0.17	0.002
PA	vs.	SP	-4.42	0.05	0.002
LMO	vs.	SP	-4.48	0.05	0.003
LBM	vs.	PA	-3.98	0.15	0.003
GB	vs.	PBM	-3.91	0.03	0.004

LB	vs.	SB	-4.20	0.04	0.004
PBM	vs.	SB	-3.73	0.07	0.005
PBM	vs.	PM	-3.47	0.07	0.009
GB	vs.	SP	-3.33	0.02	0.010
LM	vs.	PM	-3.33	0.03	0.010
LMO	vs.	PBM	-3.48	0.10	0.011
PBC	vs.	SP	-3.16	0.01	0.012
PBM	vs.	SP	-3.05	0.03	0.013
LM	vs.	PA	-2.84	0.03	0.017
LMO	vs.	PM	-2.79	0.05	0.018
LBM	vs.	SP	-2.76	0.03	0.019
LM	vs.	SB	-2.73	0.02	0.020
GB	vs.	SB	-2.76	0.02	0.020
LB	vs.	LP	-2.86	0.01	0.020
LMO	vs.	LP	-2.69	0.02	0.023
PA	vs.	PBM	-2.44	0.10	0.026
LBM	vs.	OUT	-2.28	0.09	0.031
GB	vs.	LMO	-2.16	0.02	0.038
LMO	vs.	OUT	-2.11	0.07	0.039
LBM	vs.	PBC	-2.12	0.01	0.040
LP	vs.	PA	-2.03	0.02	0.047
LBM	vs.	LM	-1.91	0.02	0.052
GB	vs.	PA	-1.86	0.02	0.055
LB	vs.	PA	-1.80	0.02	0.059

PBC	vs.	PBM	-1.78	0.01	0.060
LB	vs.	LMO	-1.76	0.02	0.063
LM	vs.	SP	-1.62	0.01	0.073
OUT	vs.	PBM	-1.14	0.04	0.126
PM	vs.	SB	-1.04	0.02	0.132
OUT	vs.	PBC	-0.82	0.01	0.181
OUT	vs.	SP	-0.81	0.01	0.182
LM	vs.	PBM	-0.74	0.01	0.190
LM	vs.	PBC	-0.62	0.00	0.216
LMS	vs.	PBS	-0.60	0.01	0.225
PA	vs.	PM	-0.49	0.01	0.231
LB	vs.	OUT	-0.45	0.00	0.263
GB	vs.	PM	-0.31	0.00	0.294
PBM	vs.	PBS	-0.18	0.00	0.350
LP	vs.	OUT	-0.13	0.00	0.354
OUT	vs.	PA	-0.06	0.01	0.360
GB	vs.	LB	-0.02	0.00	0.382
LMS	vs.	PA	0.00	0.00	0.391
LM	vs.	OUT	-0.01	0.00	0.408
GB	vs.	OUT	0.00	0.00	0.413
LB	vs.	PM	0.12	0.00	0.425
LP	vs.	PM	0.26	0.00	0.481
LBM	vs.	LMS	0.21	-0.01	0.514
PA	vs.	SB	0.38	-0.01	0.548

OUT	vs.	PM	0.46	-0.01	0.606
LBM	vs.	PBM	0.53	-0.01	0.647
LBM	vs.	PBS	0.68	-0.01	0.721
LMS	vs.	SB	0.69	-0.02	0.727
LMS	vs.	LMO	0.72	-0.03	0.745
LMS	vs.	LP	0.74	-0.01	0.752
OUT	vs.	SB	0.84	-0.03	0.804
LMS	vs.	PBM	0.89	-0.04	0.812
LMS	vs.	SP	0.92	-0.01	0.838
LMS	vs.	OUT	0.96	-0.08	0.848
LMS	vs.	PM	0.96	-0.03	0.854
LB	vs.	LMS	0.97	-0.01	0.855
LMS	vs.	PBC	1.09	-0.01	0.894
GB	vs.	LMS	1.27	-0.01	0.963
LM	vs.	LMS	1.34	-0.01	0.978

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

5 Dec 2019, 12:26:47

Appendix 3. Multiple response permutation procedure (MRPP) results by Month.

MRPP by Month

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

PC-ORD, 7.07

5 Dec 2019, 12:28:39

Project file: \\Mac\Home\Documents\PCORD\State Canal Electrofishing Summer 2019 Up Down East West.7prj

Main matrix: C:\Users\davidrichards\AppData\Roaming\MjM Software Design\PCORD 7\WORK.MJM

Second matrix: C:\Users\davidrichards\AppData\Roaming\MjM Software Design\PCORD 7\WORK2.MJM

Grouping variable: Month from matrix 2

Groups were defined by values of: Month

Input data has: 403 Sites by 18 taxa

Weighting option: C(I) = n(I)/sum(n(I))

Distance measure: Relative Sorensen

GROUP: 1

Identifier: 9

Size: 38 0.51030492 = Average distance

Members:

GBSep15 GB1Sep16 GB2Sep16 GB3Sep16 GB4Sep16 GBsept19 LB1Sep16 LB3Sep16

LB2Sep16 LB4Sep16 LBSep17 LBsept19 LMSep15 LM1Sep16 LM2Sep16 LMSep17

LCSep15 LP1Sep15 LP2Sep15 LP3Sep15 LP1Sep16 LP2Sep16 LP3Sep16 OUTSep15

PA1Sep16 PA2Sep16 PA3Sep16 PB1Sep16 PB3Sep16 PBsept19 PBsept19b PBSsept19

PMSep16 SB1Sep16 SB2Sep16 SB3Sep16 ULSPsep19 ULSPsep19b

GROUP: 2

Identifier: 10

Size: 36 0.58911387 = Average distance

Members:

GBOct15 GB1Oct16 GB2Oct16 GBoct19 GBoct19b LBOct16 LBoct19 LBoct19c

LBoct19b LBoct19d LM1Oct15 LM2Oct15 LM3Oct16 LM4Oct16 LMOct17 LCOct15

LP1aOct16 LP2aOct16 LP3aOct16 LP1bOct16 LP2bOct16 LP3bOct16 LP3Sep17 LP2Oct17

PB1Oct16 PB3Oct16 PBSoct19 PBSoct19b PM1Oct16 PM2Oct16 SB1Oct16 SB2Oct16

SP1Oct15 SP2Oct15 ULSPoct19 ULSPoct19b

GROUP: 3

Identifier: 3

Size: 24 0.53792549 = Average distance

Members:

GB2Mar16 GB1Mar17 GB2Mar17 GBMar18 LB1Mar17 LB2Mar17 LMMar16 LM1Mar17

LM2Mar17 LMMar18 LCMar16 OUTMar16 PB1Mar16 PB2Mar16 PB1Mar17 PB2Mar17

PB3Mar17 PB4Mar17 PB5Mar17 PMMar16 SB1Mar17 SB2Mar17 SP1Mar17 SP2Mar17

GROUP: 4

Identifier: 6

Size: 64 0.63059524 = Average distance

Members:

GB2Jun16 GB1Jun16 GB3Jun16 GB1Jun17 GBJun17 GB2Jun17 GBJun18 GB1Jun18

LBJun17 LB1Jun17 LB5Jun17 LB2Jun17 LMJun18 LMJun16 LMJun17 LM1Jun17

LM2Jun17 LM4Jun17 LM5Jun17 LM3Jun17 LM1Jun18 LM2Jun18 LM3Jun18 LM4Jun18

LP1Jun16 LP2Jun16 LP3Jun16 LP1Jun17 LP3Jun17 LP2Jun17 LP2Jun18 LP1Jun18

LP3Jun18 LP1aJun18 LP3aJun18 OUTJun16 PB1Jun16 PB3Jun16 PB2Jun16 PB2Jun17

PBS1Jun17 PB9Jun17 PB1Jun17 PBNJun17 PBS2Jun17 PB11Jun18 PB12Jun18 PB1Jun18

PB13Jun18 PB2Jun18 PBSjun18b PB5Jun18 PB6Jun18 PBSJun18 PBjune19b PBjune19

PMJun16 PMJun17 PMJun18 SBJun18 SPJun17 SP1Jun17 SP2Jun17 SPJun18

GROUP: 5

Identifier: 7

Size: 57 0.59728636 = Average distance

Members:

GB1Jul16 GB2Jul16 GBJul17 GB2Jul17 GBJul18 GBjuly18 GBjuly19 GBaug19

LBJul16 LBMJul17 LBM2Jul17 LBMAug17 LBMJul18 LBjuly18 LBjuly18a LBjuly19

LBjuly19b LBaug19 LMJul16 LMJul17 LM2Jul17 LMJul18 LM1Jul18 LMjuly19

LP2aJul17 LP1bJul17 LP1Jul17 LP3Jul17 LP2july17 LP1aJul17 LP2Jul18 LP1Jul18

LP3Jul18 PB3Jul16 PB1Jul16 PB2Jul16 PBSJul17 PBJul17 PB2Jul17 PB1Aug17

PBNAug17 PBJul18 PBSjuly18 PBSaug19d PBSjuly19 PBSaug19 PMJul17 SB1Jul16

SB2Jul16 SBJul18 SPJul16 SP4Jul17 SP2Jul17 SP3Jul17 SPJul18 ULSPjul18

ULSPaug19

GROUP: 6

Identifier: 8

Size: 77 0.58553404 = Average distance

Members:

GB1Aug16 GB2Aug16 GB3Aug16 GB1Aug17 GB4Aug17 GB2Aug17 GB5Aug17 GB3Aug17

GBaug18 GBaut19b LB1Aug16 LB2Aug16 LB3Aug16 LBB1Aug17 LBM2Aug17 LBB2Aug17

LB2Aug17 LBAug17 LBaug18 LBaug19b LBaug19c LM1Aug16 LM2Aug16 LM4Aug16

LM5Aug16 LM1Aug17 LM2Aug17 LM3Aug17 LM4Aug17 LM5Aug17 LM6Aug17
LM7Aug17

LM10Aug17 LM8Aug17 LM11Aug17 LM12Aug17 LM9Aug17 LP1aAug16 LP2aAug16
LP3aAug16

LP1bAug16 LP2bAug16 LP3bAug16 LP1cAug16 LP2cAug16 LP3cAug16 LP1dAug16
LP2dAug16

LP3dAug16 LP2Aug17 LP1Aug17 LP3Aug17 LP1aAug17 PB1Aug16 PB3Aug16 PB4Aug16

PB3Aug17 PB4Aug17 PBSAug17 PBS1Aug17 PB2Aug17 PBaug18 PBaug18b PBaug19

PBSaug19c PBSaug19b PM1Aug16 PM2Aug16 PM3Aug16 PMAug17 SB1Aug16 SB2Aug16

SPAug16 SP1Aug17 SP2Aug17 ULSPaug18 ULSPaug19b

GROUP: 7

Identifier: 1

Size: 5 0.49182669 = Average distance

Members:

GBJan17 LBJan17 LMJan17 PBJan17 SP1Jan17

GROUP: 8

Identifier: 2

Size: 9 0.20665735 = Average distance

Members:

GB1Feb17 GB2Feb17 LB1Feb17 LB2Feb17 LM1Feb17 LM2Feb17 PA1Feb17 PA2Feb17

SBFeb17

GROUP: 9

Identifier: 4

Size: 42 0.51831925 = Average distance

Members:

GB1Apr17 GB3Apr17 GB2Apr17 GB6Apr17 GB4Apr17 GBapr19 LB1Apr17 LB2Apr17

LB3Apr17 LB4Apr17 LB5Apr17 LB6Apr17 LB7Apr17 LB8Apr17 LB10Apr17 LB9Apr17

LBapril19 LM1Apr17 LM2Apr17 LM3Apr17 LM4Apr17 LM5Apr17 PB1Apr17 PB2Apr17

PB3Apr17 PB4Apr17 PB5Apr17 PB6Apr17 PB7Apr17 PB8Apr17 PBApr18 PBapril19

PBapril19b PM1Apr17 PM2Apr17 PM3Apr17 SP1Apr17 SP2Apr17 SP3Apr17 SP4Apr17

SP5Apr17 SP6Apr17

GROUP: 10

Identifier: 5

Size: 35 0.62059087 = Average distance

Members:

GBMay17 GB2May17 GBmay19 GBmay19b GBmay19c GBmay19d LBMay17 LB1May17

LBMay18 LBmay19 LMMay16 LMMay17 LMMay18 LM1May18 LMmay19 LP1May16

LP2May16 LP3May16 LP1May18 LP2may19 OUTMay16 PBSMay17 PB2May17
PB1May17

PB3May17 PBSmay18 PBMay18 PBmay19 PBSmay19 PBmay19b PBSjune19 PMMay16

SPMay17 SP2May17 ULSPjun19

GROUP: 11

Identifier: 11

Size: 16 0.60604623 = Average distance

Members:

GBNov17 LBNov16 LBNov18 LMNov15 LMNov16 LMNov17 LP1Nov16 LP2Nov16

LP3Nov16 PB1Nov16 PB2Nov16 PBSNov17 PMNov16 SBNov16 SPNov15 SPNov17

Test statistic: T = -31.720086

Observed delta = 0.57197349

Expected delta = 0.64904185

Variance of delta = 0.59031460E-05

Skewness of delta = -0.49337871

Chance-corrected within-group agreement, A = 0.11874174

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.

	T	A	P
Aug vs. April	-31.83	0.12	0.000
Aug vs. Feb	-23.94	0.14	0.000

July	vs. Feb	-16.78	0.15	0.000
July	vs. April	-21.87	0.11	0.000
Mar	vs. July	-17.28	0.10	0.000
Sept	vs. July	-18.31	0.09	0.000
Sept	vs. April	-26.05	0.17	0.000
Sept	vs. Feb	-20.23	0.26	0.000
Sept	vs. June	-16.50	0.08	0.000
Sept	vs. May	-15.30	0.11	0.000
Oct	vs. Feb	-13.60	0.17	0.000
Mar	vs. May	-12.20	0.10	0.000
June	vs. Aug	-11.93	0.04	0.000
Oct	vs. April	-12.88	0.08	0.000
Mar	vs. June	-12.20	0.07	0.000
Mar	vs. Aug	-10.90	0.05	0.000
April	vs. May	-11.67	0.07	0.000
Feb	vs. May	-11.63	0.15	0.000
June	vs. April	-12.40	0.06	0.000
Aug	vs. May	-9.62	0.04	0.000
June	vs. Feb	-11.21	0.10	0.000
Mar	vs. Feb	-10.99	0.22	0.000
Oct	vs. July	-8.94	0.05	0.000
July	vs. Nov	-8.79	0.06	0.000
Mar	vs. April	-9.86	0.08	0.000
Aug	vs. Jan	-7.76	0.05	0.000

Sept vs. Jan	-8.00	0.11	0.000
Aug vs. Nov	-7.26	0.04	0.000
Sept vs. Aug	-7.35	0.03	0.000
July vs. Jan	-6.50	0.06	0.000
July vs. Aug	-5.43	0.02	0.001
Sept vs. Nov	-5.47	0.05	0.001
Oct vs. June	-5.46	0.03	0.001
Feb vs. Nov	-5.86	0.16	0.001
Sept vs. Mar	-4.86	0.04	0.002
Oct vs. May	-4.75	0.03	0.002
May vs. Nov	-4.61	0.04	0.002
Oct vs. Aug	-4.23	0.02	0.004
June vs. Nov	-4.46	0.03	0.004
Feb vs. April	-4.52	0.05	0.004
Oct vs. Jan	-3.73	0.05	0.006
Mar vs. Jan	-3.71	0.07	0.006
June vs. July	-3.82	0.02	0.007
June vs. Jan	-3.63	0.03	0.008
Jan vs. May	-3.33	0.05	0.011
Sept vs. Oct	-3.16	0.02	0.014
July vs. May	-3.08	0.02	0.015
April vs. Nov	-2.91	0.03	0.020
Oct vs. Mar	-2.21	0.02	0.037
Jan vs. Feb	-1.84	0.09	0.056

Jan vs. April	-1.57	0.02	0.077
June vs. May	-1.40	0.01	0.090
Jan vs. Nov	-0.97	0.03	0.146
Oct vs. Nov	-0.62	0.01	0.213
Mar vs. Nov	-0.46	0.01	0.245

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

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