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Zooplankton sensitivity to climate-driven conditions in high-elevation lakes in Maine

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Introduction

- High-elevation lakes provide a unique opportunity to evaluate ecosystem response to climate change due to their remoteness, environmental gradients, and response to environmental stressors (Moser et al, 2019).
- Northeast lakes are experiencing changes in water chemistry such as decreased sulfate concentrations, and increased DOC (Dykema et al, 2023).
- Zooplankton (small aquatic invertebrates) play a crucial role in lake ecosystems and are strong indicators of climate change because they are highly responsive to changing water temperatures and shifting water chemistry and nutrient concentrations.
- Since 2018, zooplankton have been sampled from nine high-elevation ponds in Maine as part of the Maine Mountain Ponds project, an extension of the High Elevation Lakes Monitoring Program. This long term project has focused on collecting water chemistry records since 1970, and now includes data on thermal environment and primary and secondary production, including zooplankton community composition.

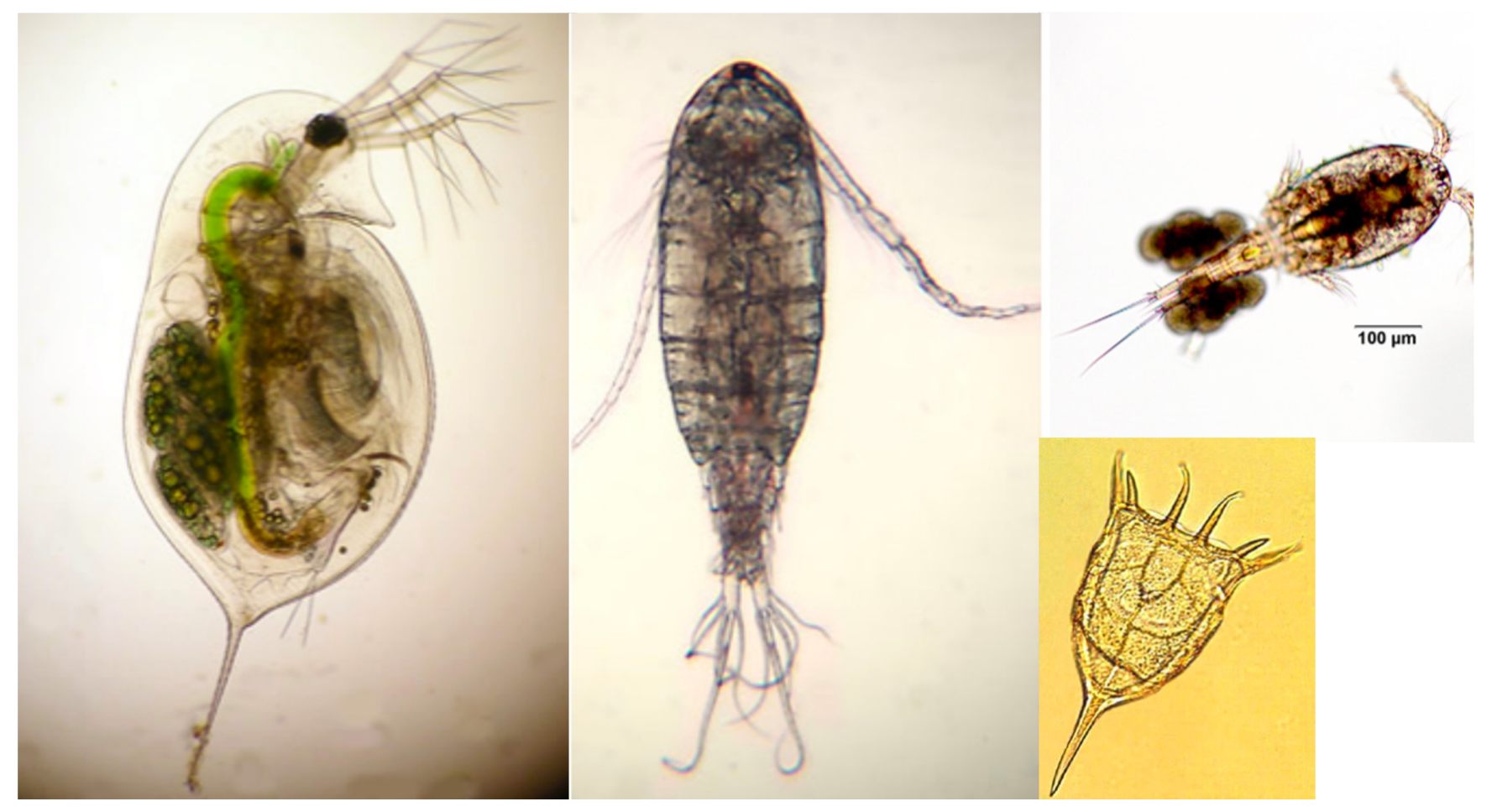

Figure 1. Common zooplankton genera found in high elevation ponds in Maine.
A: *Daphnia* spp. (Cladocera)
B: *Osphranticum* spp. (Calanoida)
C: *Microcyclops* spp. (Cyclopoida)
D: *Keratella* spp. (Ploima)
Image source: UNH

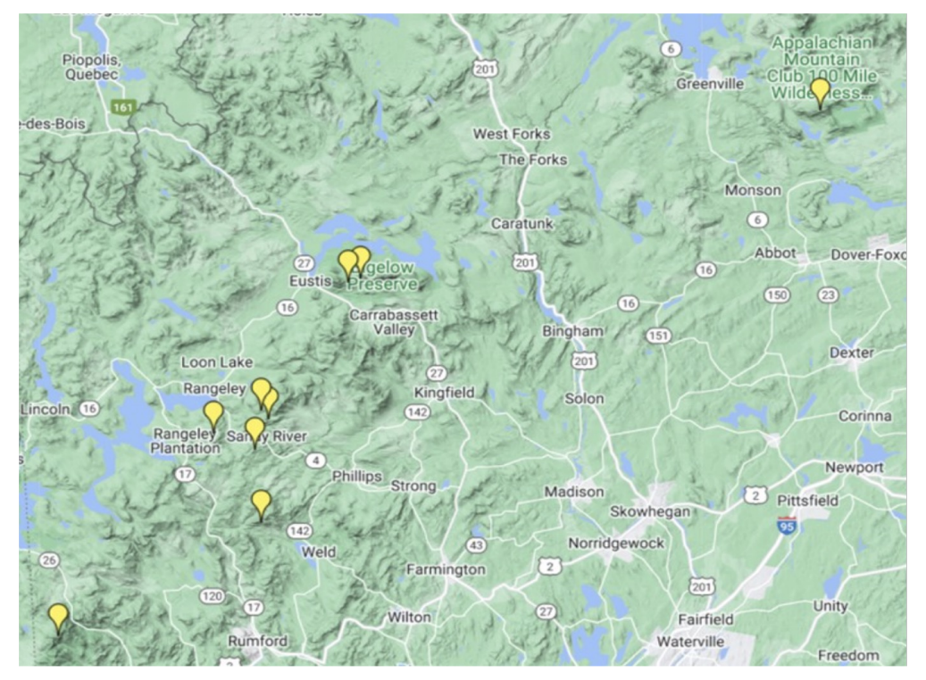

Figure 2. Locations of the nine lakes in this study. From north to south: Cloud Pond, Horns Pond, Cranberry Pond, Midway Pond, Eddy Pond, Mountain Pond, South Pond, Tumbledown Pond, and Speck Pond.

Objectives

- Determine if shifts in abundance of different taxonomic groups is associated with climate-related lake conditions. Given differences in physiology, life history, and relative abundance, we expect that specific orders and families will react differently to changes in ice-out dates, average summer temperatures, secchi depths, dissolved oxygen, and chlorophyll.
- Understanding which taxonomic groups are more sensitive to changing conditions could help us develop a better understanding of how food webs respond to changing lakes.

Methods

Sample collection:

At each lake, a buoy with 3 temperature loggers (surface, 2m, and bottom) collected yearly temperatures. Zooplankton were captured with a 63 µm mesh Wisconsin zooplankton net, *in situ* DO and chlorophyll were collected using a YSI sonde vertical profile, and a secchi disk was used to determine water clarity.

Zooplankton identification:

Zooplankton were preserved in ethanol and enumerated and identified to family or genus using standard methods.

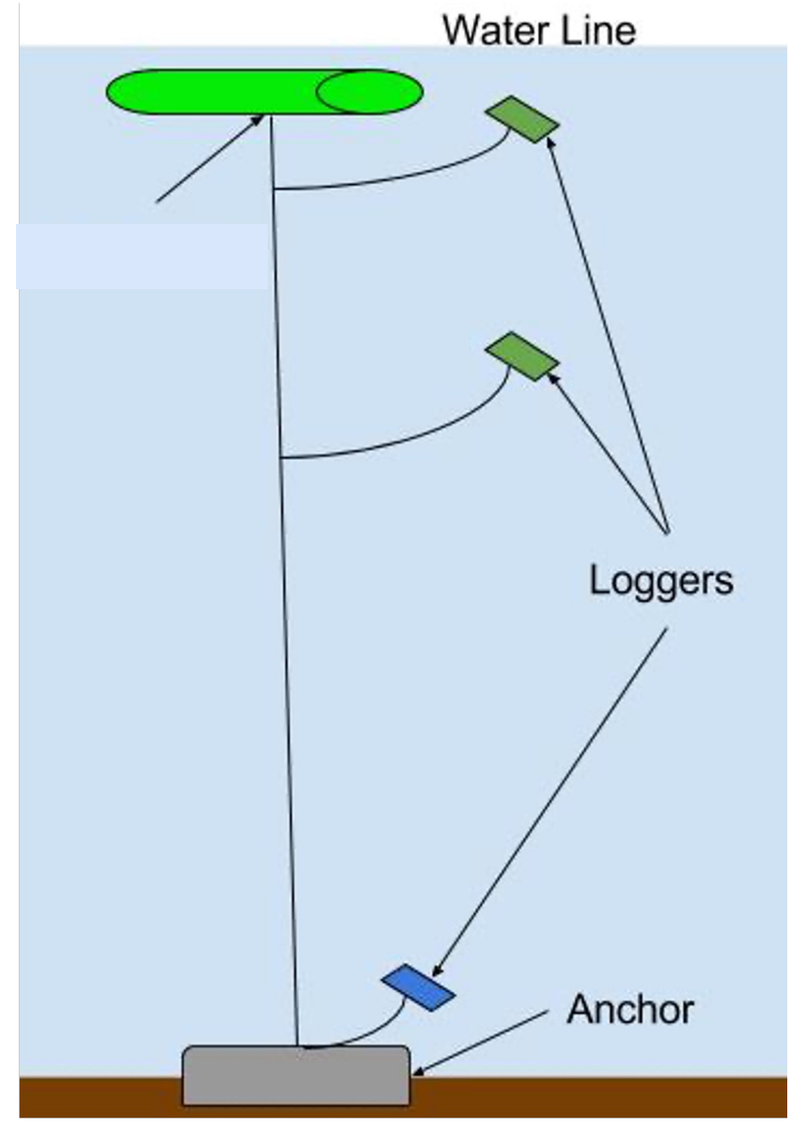

Figure 3. Set-up of data loggers, anchor, and buoy in each pond.

Figure 4. Zooplankton net used to collect samples of zooplankton.

Data analysis:

All available data from 2018-2023 were used. Ice-out dates were estimated by determining the day when surface temperatures exceeded bottom temperatures in the spring. The average July bottom temperature was used to estimate summer average summer temperatures. All data was analyzed using Program R to create linear regression models or multivariate analysis.

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Results

Linear models

Linear models revealed multiple significant relationships between the density (ind/L) of different taxonomic orders and lake conditions. Positive relationships were identified between: Ploima and average July temperature, Cladocera and secchi disk depth, Calanoida and surface/bottom DO and bottom/maximum chlorophyll, and Floscularifaceae and bottom DO. Cyclopoida and bottom DO had a negative relationship.

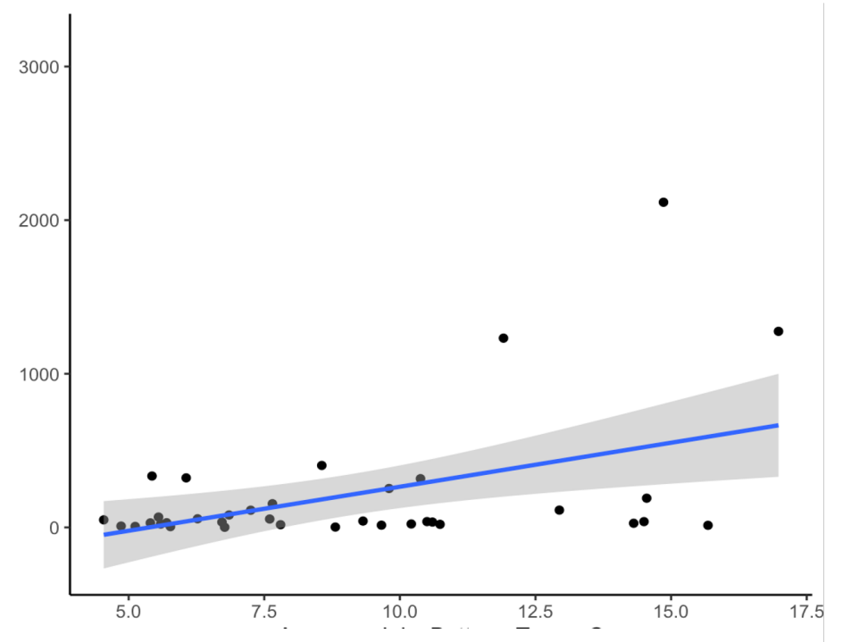

Figure 5: Positive relationship between Ploima and the average July bottom temp ($p<0.001$)

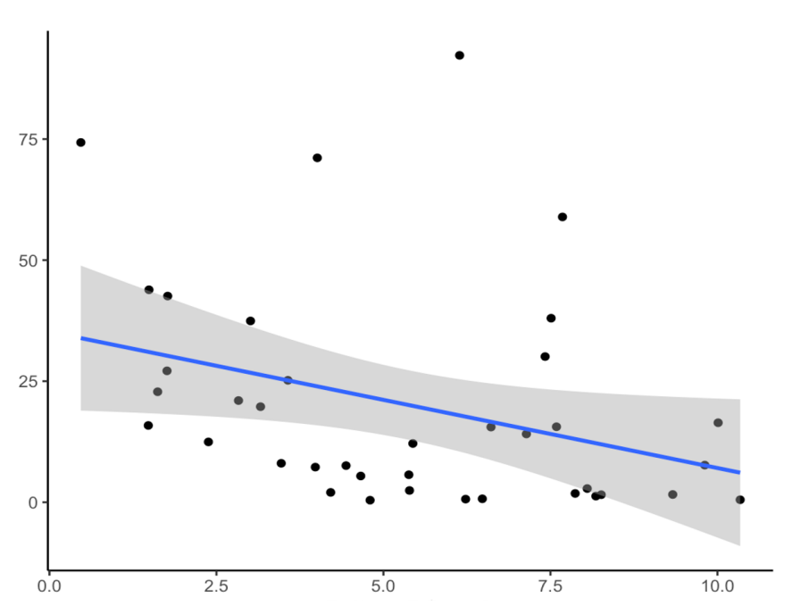

Figure 6: Negative relationship between Cyclopoida and bottom DO ($p=0.04$)

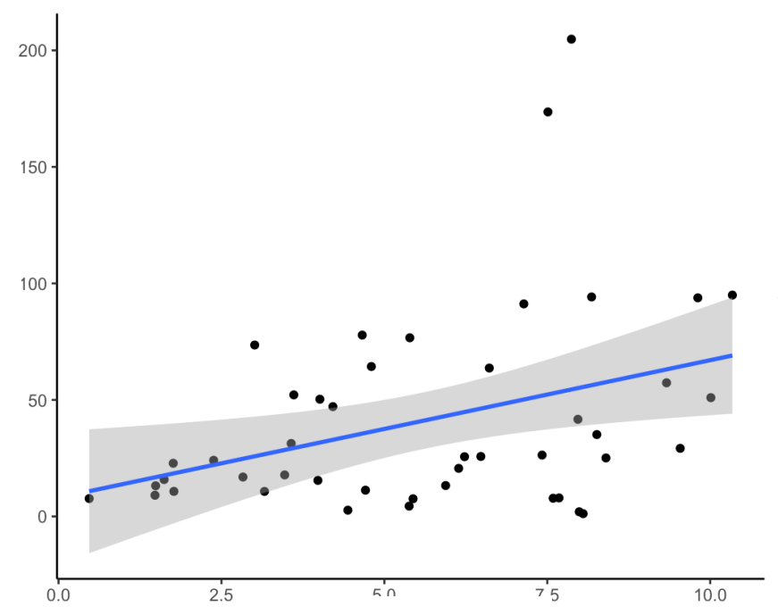

Figure 7: Positive relationship between Calanoida and bottom DO ($p=0.01$)

We further evaluated relationships between select families and lake conditions. Positive significant relationships were found between Bosminidae and secchi, Daphniidae and surface chlorophyll. A negative significant relationship was found between Diaptomidae and maximum water column chlorophyll.

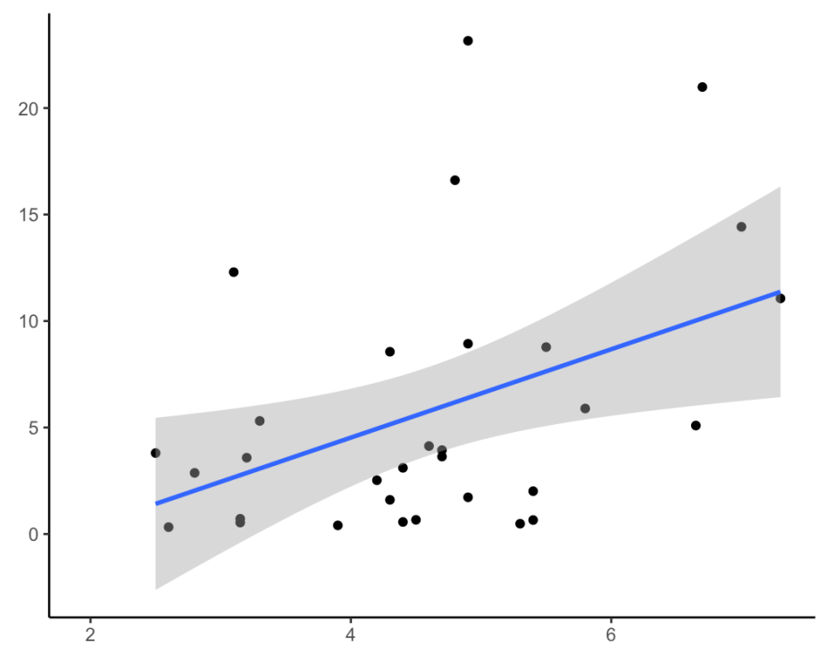

Figure 8: Positive relationship between Bosminidae and secchi depth ($p=0.01$)

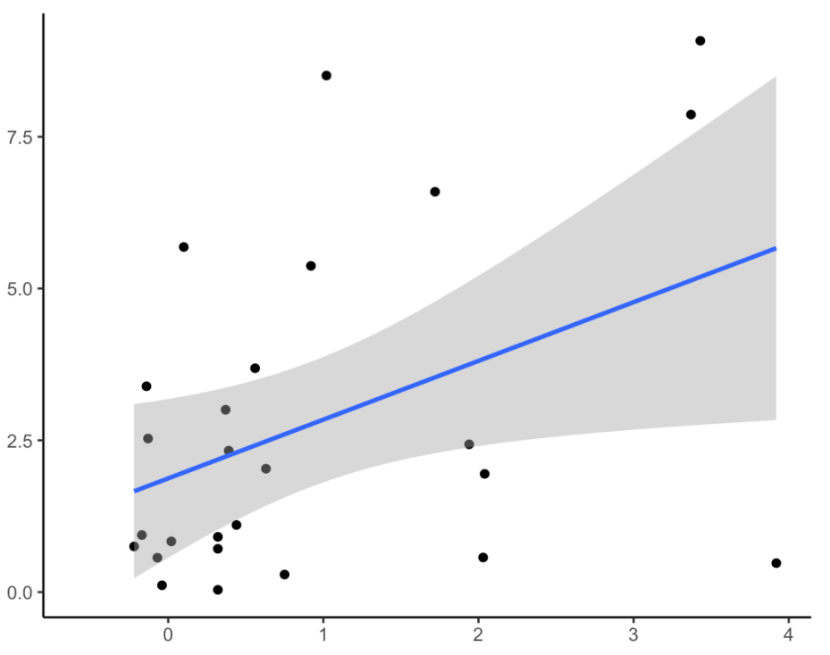

Figure 9: Positive relationship between Daphniidae and surface chlorophyll ($p=0.03$)

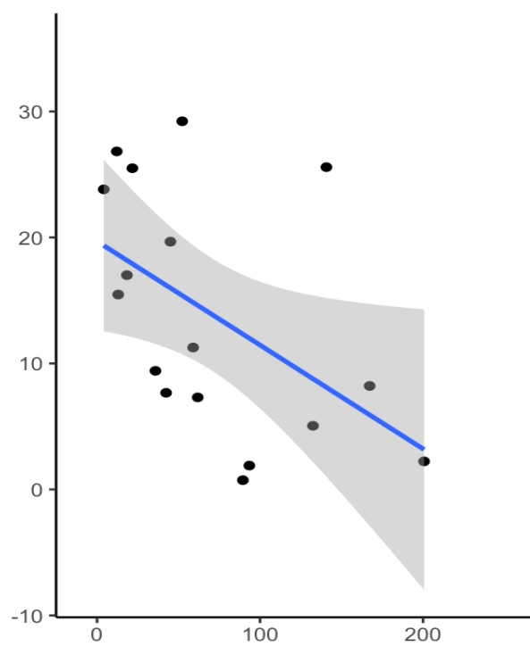

Figure 10: Negative relationship between Diaptomidae and max chlorophyll ($p=0.03$)

Multivariate analysis

Multivariate analysis revealed a directional shift in community composition from 2018-2023. This shift corresponded with increasing chlorophyll concentration.

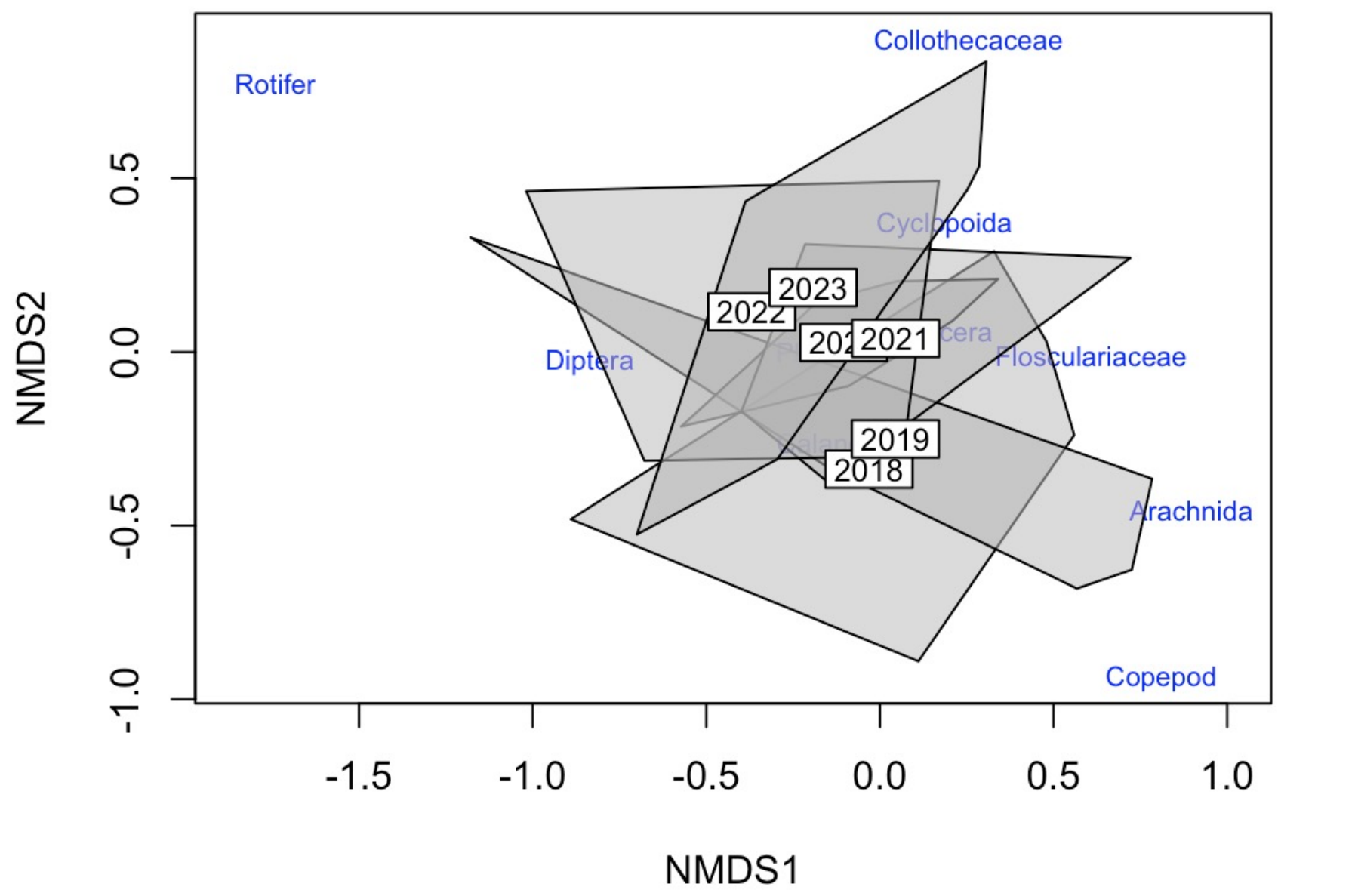

Figure 11: Multidimensional plot of zooplankton community composition by site and year. Hulls connect sample years.

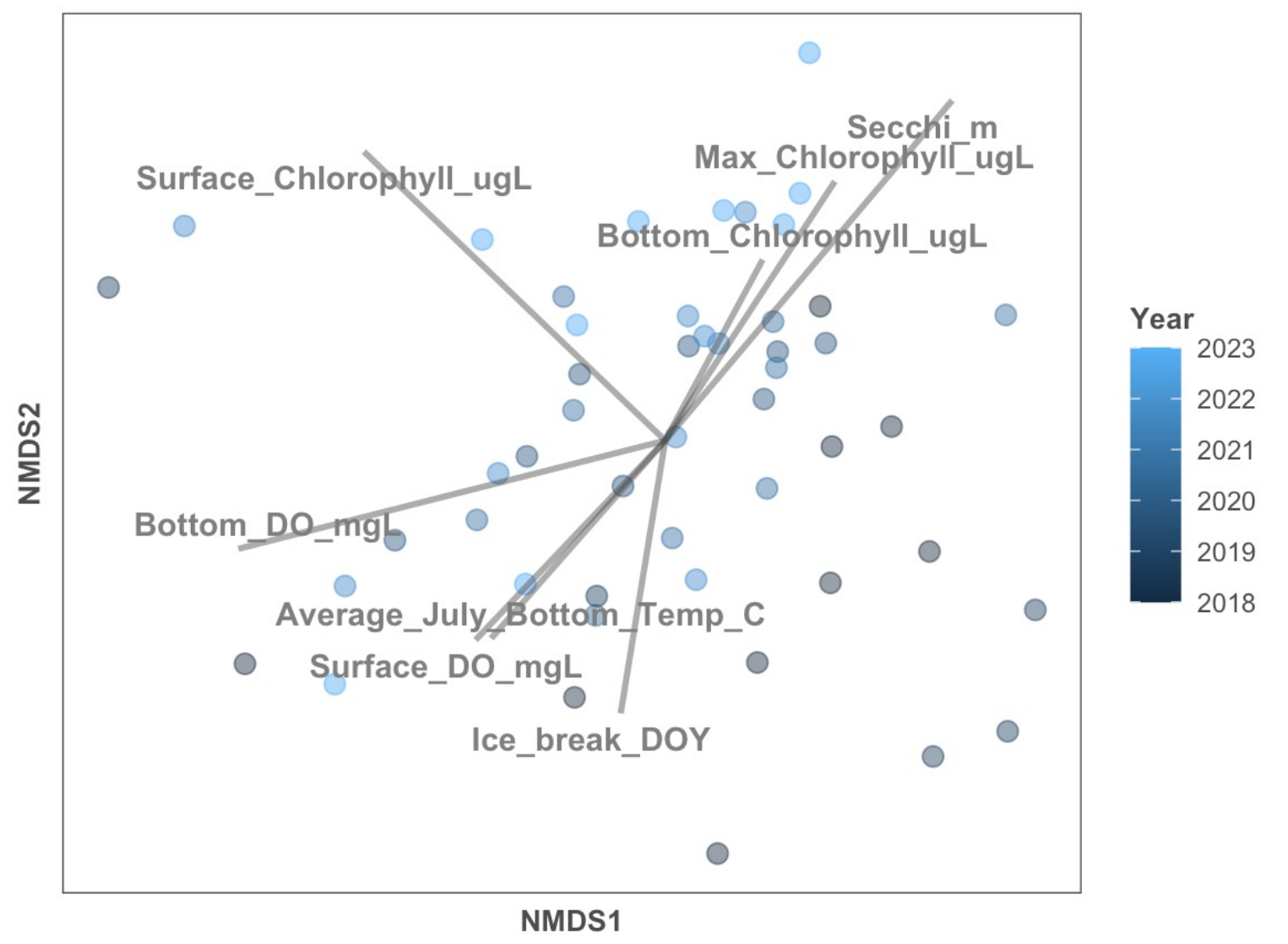

Figure 12: Each point represents zooplankton community composition for a given site and year. Lines represent the lake condition covariates.

Discussion

Dissolved oxygen, chlorophyll, and temperature influence the density of different zooplankton orders or families. Similar to our results, other studies have found increased Calanoid abundance with increase in DO (Sun et al, 2020). DO levels have not fluctuated drastically in our lakes; however rising temperatures and changing stratification can cause DO to decline (Blumberg and Toro, 2011). This can lead to decline in the orders of zooplankton that are positively correlated with DO, such as Calanoida and Flosculariaceae.

Our multivariate analysis revealed that there has been a shift in community composition since the beginning of our study. This could be related to shifts in chlorophyll, which was also a significant driver in linear models. Increased chlorophyll can indicate increases in zooplankton food sources (Azis et al, 2003). While more research is needed, our results indicate links between zooplankton abundance and community composition and important lake conditions that are sensitive to climate change.

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