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Local Ecology Research Papers

Factors affecting zooplankton diversity and community composition in two suburban lakes

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Factors affecting zooplankton diversity and community composition in two suburban lakes

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Abstract

Zooplankton are a vital part of aquatic food webs. Zooplankton communities are affected by a number of factors including lake size, permanence, temperature, dissolved oxygen, and nutrient availability. This study examines the effects of biotic and abiotic variables on zooplankton community composition and diversity in two suburban lakes in Minnesota. Arrowhead Lake (44.8863, -93.3955) is an 8.9ha lake, is located in a heavily residential area, and is aerated year-round. Fireman's Clayhole (44.7911, -93.6033) is a 3.64ha lake located at the intersection of two major roads. Both lakes contain fish and have been reported to contain *Craspedacusta sowerbyi*, a freshwater jellyfish. *C. sowerbyi* was not found at time of sampling. We found 7 families of zooplankton in Arrowhead Lake and 6 families of zooplankton in Fireman's Clayhole. Data show that increased dissolved oxygen was associated with increased diversity in Arrowhead Lake and that species richness was positively impacted by nutrients, colored dissolved organic matter (CDOM), turbidity, conductivity and nitrates. These results suggest that zooplankton diversity and community composition may be dependent upon multiple factors in these lakes, but that additional data are required to confirm our findings.

Keywords: zooplankton, community composition, diversity, species richness

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Introduction

The resilience of aquatic ecosystems greatly depends on the biodiversity and health of the organisms within the ecosystem. Zooplankton communities are a vital part of the aquatic food web and are a major food source for invertebrate predators as well as fish. Zooplankton community composition and diversity can be affected by a number of factors, including predator type and spatial distribution (Detmer 2019) as well as natural lake water chemistry and anthropogenic factors (Dodson et al. 2009). Some anthropogenic factors such as chlorides from runoff can greatly affect aquatic organisms and can decrease zooplankton density (Van Meter & Swan 2014).

Residential areas and developments can have negative impacts on aquatic environments and often lead to increased nutrients and salt concentrations (Arnott et al. 2020). The effects of urbanization have detrimental effects on all parts of aquatic ecosystems, including zooplankton (Sun et al. 2018). Zooplankton community composition and diversity provide a way to understand the resilience of a lake ecosystem to environmental influences and to identify environmental variables which contribute to increases or decreases in zooplankton species diversity. A better understanding of community structure and changes allows for improved predictions of future zooplankton diversity and community composition (Celik, Bozkurt & Sevindik 2018).

In this study, I investigated the differences in two lakes near the Twin Cities in Minnesota: Arrowhead Lake and Firemen's Clayhole. The lakes differ in size and trophic status, two factors which could affect zooplankton richness, evenness, diversity, and community composition. A comparison of these two lakes will allow for insight into zooplankton diversity and community structure in an urban environment. Because Arrowhead Lake is located in a highly residential area whereas Firemen's Clayhole is located nearer to two major roads, I expect to see differences in nutrient availability and conductivity levels from increased runoff in these suburban areas.

I hypothesized that zooplankton community composition will shift to more cold tolerant species as fall progresses and temperatures fall, and that zooplankton densities will decline later in the season.

The objectives for this study were to:

1. Determine the types of zooplankton present in both lakes.
2. Analyze the differences between zooplankton communities between and within lakes across three sampling periods.
3. Determine what, if any, effects on the zooplankton community can be attributed to water chemistry differences between lakes.

Methods

Study Sites

I selected two lakes in the Twin Cities suburbs of Minnesota, Arrowhead Lake (44.8863, -93.3955) in Edina, and Firemen's Clayhole (44.7911, -93.6033) in Chaska. Arrowhead Lake is a 8.9ha lake, with a maximum depth of 2.4m, and is located in a heavily residential area. It is surrounded by houses on all sides, and lawns reach the water's edge. Arrowhead Lake supports a variety of fish species, and is aerated year-round. Arrowhead Lake has higher conductivity and nutrients than Firemen's Clayhole (Table 2).

Firemen's Clayhole is a 3.64ha lake with a maximum depth of 4.5m. It has a swimming beach and is located at the intersection of two major roads. One side of the lake has the beach and a grassy park, and the other side has a boardwalk and is forested. Firemen's Clayhole also contains fish and has a sandy substrate.

Both of these lakes were initially selected because they were reported to contain *Craspedacusta sowerbyi*, a non-native species of freshwater jellyfish, which could impact zooplankton communities (Spadinger & Maier 1999). We did not see or collect *C. sowerbyi* at either of the two lakes.

Zooplankton Sampling and Identification

Zooplankton were sampled in both lakes on September 5, 12, and October 13, 2020. Zooplankton were collected by vertical tows of a zooplankton mesh at the deepest point near the middle of each lake. The tow was lowered to the bottom of the lake and pulled up vertically. Alka-seltzer was added to the samples to prevent zooplankton from dropping their eggs and to aid identification. Zooplankton samples were euthanized using 15% ethanol in the field and transferred to 70% ethanol in the lab for preservation and identification. In the weeks following collection, 1ml samples of each zooplankton tow were counted and identified to family or genus level using a Bogorov counting chamber and An Image-Based Key To The Zooplankton Of North America (Aliberti 2013) to analyze zooplankton. Zooplankton were identified to genus and species when possible but were ultimately analyzed at the family level. Numbers of zooplankton individuals and individuals with eggs were tallied and totaled in Excel.

Environmental Sampling

Water chemistry measurements were taken using a Eureka Manta+ water probe. I collected temperature, pH, conductivity, dissolved oxygen, turbidity (NTU), colored dissolved organic matter, chlorophyll a, NO_3, and NH_4 in both sites on all three sampling dates. Photosynthetically active radiation data was also collected but was not used in our analysis as only surface values were used to determine site differences and zooplankton responses.

Statistical Analysis

To determine species composition and diversity, species richness and species evenness were calculated. I analyzed differences in zooplankton densities between sites and across sampling dates. Although most zooplankton were identified to the genus level, not all genera of zooplankton were identified, so I analyzed zooplankton at the family level to avoid giving extra weight to zooplankton families that were identified to genus. The Shannon-Simpson index was used to calculate family diversity in both lakes. To evaluate the effects of environmental variables on family diversity and zooplankton community composition, I used surface water measurements from each of the lakes on each sampling date. I evaluated the relationship between environmental variables, zooplankton density, and zooplankton diversity through linear regressions. All figures and analyses were created and performed in R version 1.3.1073 or Excel.

Results

Family Composition

Arrowhead Lake had a total of seven families of zooplankton; 4 cladoceran families (Bosminidae, Chydoridae, Sididae, Daphniidae) and 3 copepod families (Diaptomidae, Cyclopidae, Temoridae) (Table 1). Cladocerans were the dominant zooplankton type in September in Arrowhead Lake and Firemen's Clayhole (Fig. 1). Bosminidae had the densest population in Arrowhead Lake on September 5th and 13th, and in Firemen's Clayhole on September 13th and October 10th (Fig. 2). In Firemen's Clayhole on September 5th Sididae were the most dominant family (Fig. 2, Fig. 3).

Total zooplankton density was highest on September 13th in both lakes, with Arrowhead Lake's maximum zooplankton density reaching 7611 zooplankton individuals/L (Fig. 4) and Firemen's Clayhole reaching 3056 zooplankton individuals/L (Fig. 3). Zooplankton density dropped drastically in October, with zooplankton densities at their lowest point within the three sampling dates. Cladoceran densities decreased most abruptly and cladoceran:copepod densities became more even. In Arrowhead Lake, there were more copepods than cladocerans (Fig. 1).

Family Diversity

We found 7 families of zooplankton in Arrowhead Lake, and 6 families of zooplankton in Firemen's Clayhole (Table 3). Zooplankton family richness increased significantly with increases in colored dissolved organic matter (Fig. 5, p=0.023) and conductivity (Fig. 5, p=0.017). Zooplankton family richness also increased with increases in turbidity (Fig. 5, p=0.052) and nitrates (Fig. 5, p=0.07).

Zooplankton family evenness changed across sampling dates as the densities of zooplankton families changed, however the day of year did not significantly relate to family evenness (p>0.05). With the exception of the first sampling date, Arrowhead Lake was more even than Firemen's Clayhole (Table 3).

Zooplankton family diversity was highest in Arrowhead Lake (Table 3). Zooplankton family diversity trended upward with increasing dissolved oxygen concentrations but was not significantly related to any environmental variables (Fig. 6).

Discussion

Family Composition

There was a shift in community composition in both lakes. Both lakes were initially dominated by cladocerans, but in October, the proportion of Cladocera to Copepoda was closer to one. This is contrary to what Ayub et al. (2018) found in their study of Chashma Lake in Pakistan. They found that copepods dominated the zooplankton community in the fall and rotifers dominated the community in the winter. Additional studies found that copepod nauplii had extremely high densities in lakes with fish, possibly because of differences in feeding habits and size factors (Hu et al. 2019). These differences may be primarily because we did not include copepod nauplii in the analysis of zooplankton diversity or community composition.

There were also drastic declines in zooplankton density in October when compared to September sampling dates. This is in line with findings that zooplankton abundances decrease in the winter (Hu et al. 2019). In the beginning of October, there were several days with cooler than average temperatures as well as some days with warmer than average temperatures. These temperature fluctuations may also have contributed to the decline in zooplankton density on October 13th.

One difference between the two lakes that was not analyzed in the analysis of family diversity and community composition was that Arrowhead Lake had *Daphnia spp.* And Firemen's Clayhole had *Ceriodaphnia spp.* Both of these genera belong to the family Daphniidae, so the difference between the two lakes was not explored in our analysis. However, *Ceriodphnia* are found in a range of water bodies worldwide (Merrix-Jones et al. 2013), so further analysis could explore the differences between the two lakes to determine why *Ceriodaphnia* only appeared in Firemen's Clayhole.

Family Evenness and Diversity

Arrowhead Lake and Firemen's Clayhole were very similar in the total number of families and types of zooplankton, but Arrowhead Lake did have one additional Daphnia family. This difference may very well be due to the larger size of Arrowhead Lake. Arrowhead is more than twice the size of Firemen's Clayhole. Many studies have found that size is a deciding factor in determining species richness across all still water body types (Dodson et al. 2000; Merrix-Jones et al. 2013). Larger lakes provide a greater number of habitats for zooplankton and may offer more refuge from fish predation. However, Arrowhead Lake is much shallower than Firemen's Clayhole. Depth is often an important factor in allowing zooplankton to escape fish predation, as many zooplankton species will migrate to the bottom of the lake during the day to avoid fish predation.

Arrowhead Lake also appears to be driving all of the linear regressions for family richness. This is unsurprising, as Arrowhead Lake has a family richness of 7, and Firemen's

Clayhole has a family richness between 5 and 6. It is likely that this study differs from others because of the weight given to Arrowhead Lake in this analysis.

None of the environmental variables significantly affected the Shannon diversity index but increases in dissolved oxygen concentrations did appear to increase diversity. This could be due to a number of factors and may be related to the amount of nutrients within the lake that ultimately support photosynthesis. In addition, Arrowhead Lake had higher dissolved oxygen concentrations, and is aerated year-round. The aeration could also account for the higher dissolved oxygen concentrations.

Future Research Directions

Ultimately, we will need additional sites to determine the impact that lake size and lake depth have on zooplankton community composition. We will also need to identify zooplankton as near to species as possible to gain a better understanding of community composition within both Arrowhead Lake and Firemen's Clayhole as well as any additional lakes in the study as analysis at the family level did not show major differences between lakes. A closer analysis of zooplankton community composition could reveal significant differences between the lakes.

Additionally, some zooplankton exhibit phenotypic responses to fish predation, and fish predation is known to induce selective pressures on zooplankton size (Welborn, Skelly & Werner 1996). Examining the impacts of fish predation on zooplankton communities would deepen the understanding of each lake's structure.

Conclusion

Overall, I found that there were drastic declines in zooplankton density in October, shifts in zooplankton community composition, and environmental variables that were correlated with zooplankton family diversity and richness. Further and more extensive research is needed to address community composition shifts over time. A higher sampling resolution as well as a larger time frame will better capture shifts in community composition and changes in diversity, and additional sites would increase the power of statistical analysis for environmental variables.

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Table 1. All families found in Arrowhead Lake and Firemen's Clayhole and densities (individuals/L).

Taxa	Family	Arrowhead 9/5	Firemen's Clayhole 9/5	Arrowhead 9/13	Firemen's Clayhole 9/13	Arrowhead 10/10	Firemen's Clayhole 10/10
Cladocera	Bosminidae	1450.00	199.38	1894.44	1225.35	111.11	176.06
Cladocera	Chydoridae	30.56	11.00	88.89	0.00	5.56	23.47
Cladocera	Sididae	102.78	154.05	166.67	142.61	5.56	7.04
Cladocera	Daphniidae	194.44	36.09	838.89	19.37	66.67	32.86
Copepoda	Diaptomidae	91.67	79.67	255.56	111.80	66.67	124.41
Copepoda	Cyclopidae	86.11	9.68	461.11	19.37	166.67	16.43
Copepoda	Temoridae	108.33	0.00	100.00	0.00	55.56	0.00
Cladocera	Total Cladocera	1777.78	400.53	2988.89	1387.32	188.89	239.44
Copepoda	Total Copepoda	286.11	89.35	816.67	150.53	288.89	140.85
Total		4127.78	979.75	7611.11	3056.34	955.56	760.56

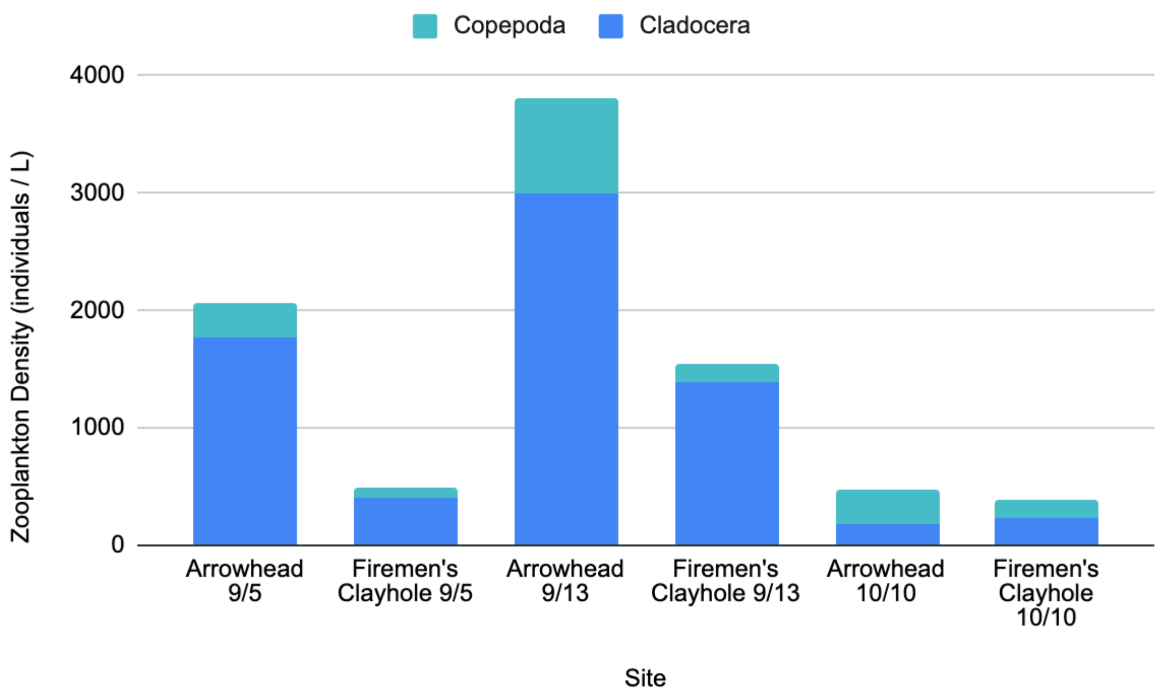

Figure 1. Zooplankton densities (individuals / L) in Arrowhead Lake and Firemen's Clayhole by taxa (Cladocera/Copepoda) on September 5 and 13 and October 10.

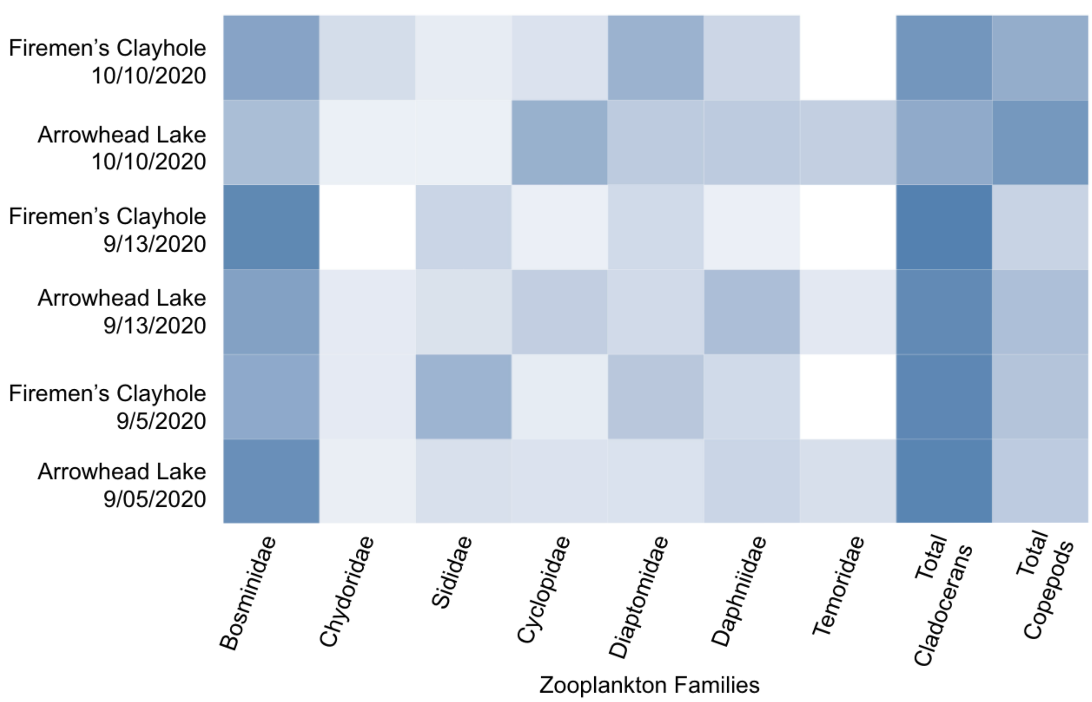

Figure 2. Abundances of zooplankton in each family found at Arrowhead Lake and Firemen's Clayhole on September 5 and 13 and October 10. Darker colors represent higher densities.

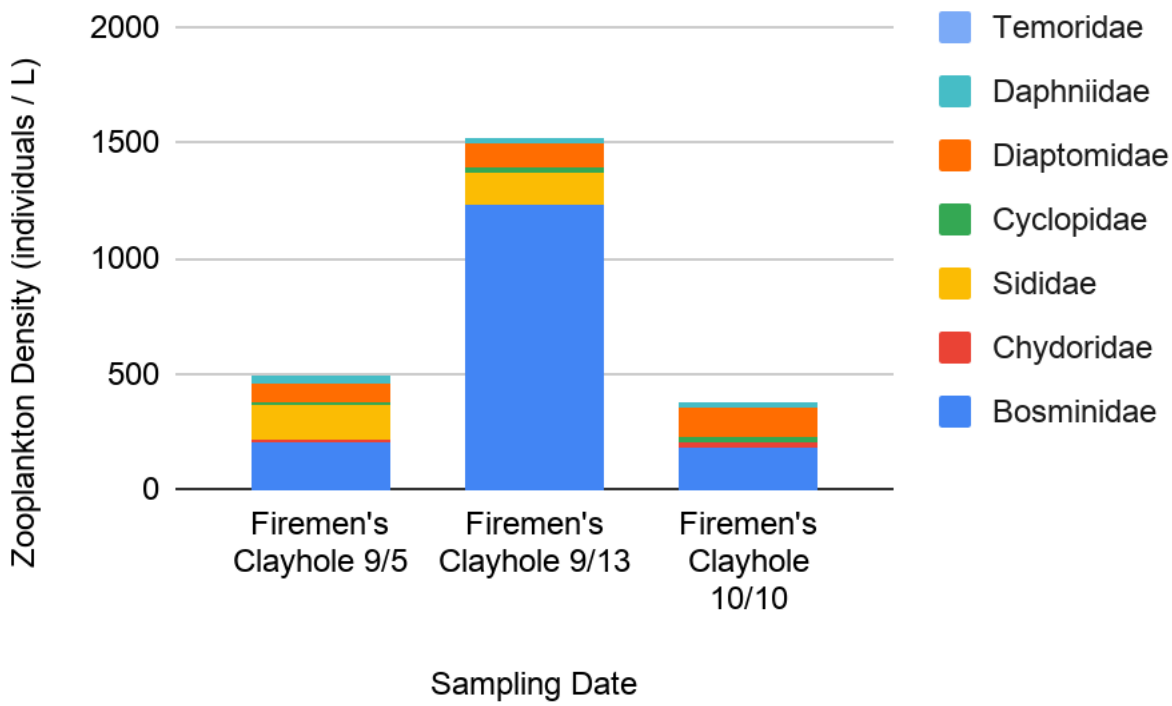

Figure 3. Zooplankton densities (individuals / L) in Firemen's Clayhole for each family on September 5 and 13 and October 10.

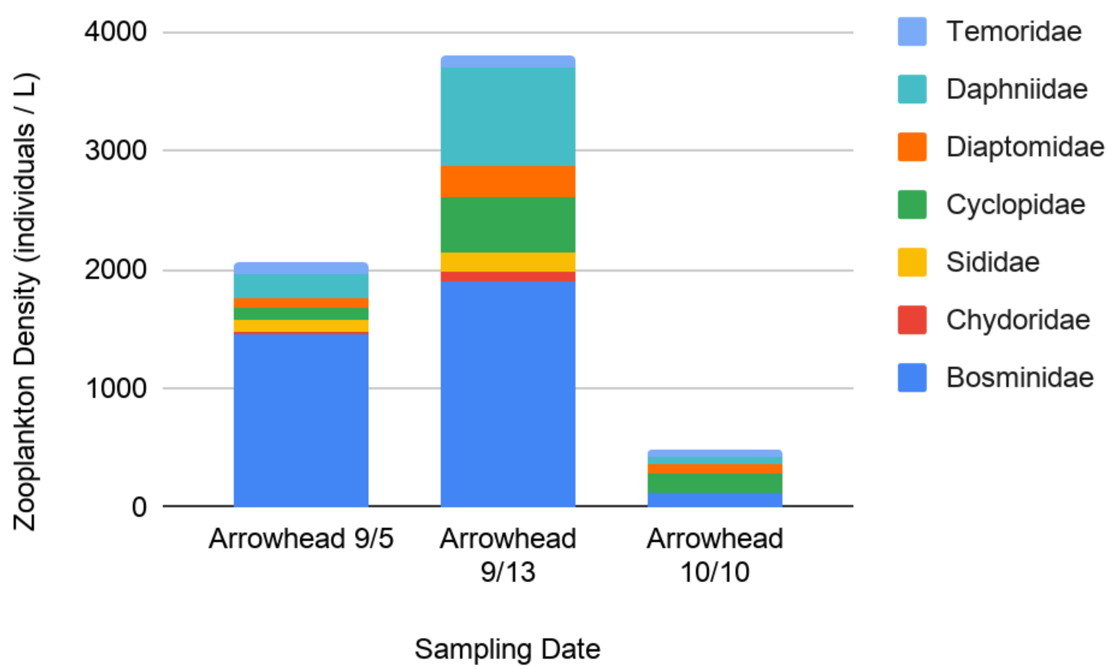

Figure 4. Zooplankton densities (individuals / L) in Arrowhead Lake for each family on September 5 and 13 and October 10.

Table 2. Physical and chemical conditions observed in Arrowhead Lake and Firemen's Clayhole on each zooplankton sampling date.

Site	**Date**	**Temperature (°C)**	**pH**	**cond (uS/cm)**	**Dissolved Oxygen (% saturation)**	**Turbidity (NTU)**
Arrowhead Lake	9/5/2020	21.45	7.8	524.4	89.2	5.99
Firemen's Clayhole	9/5/2020	24.51	9.08	384.9	97.3	1.96
Arrowhead Lake	9/13/2020	15.99	7.76	519.1	93.7	4.51
Firemen's Clayhole	9/13/2020	18.79	8.21	399.6	85.7	1.19
Arrowhead Lake	10/10/2020	14.22	8.05	530.2	102.5	3.27
Firemen's Clayhole	10/10/2020	15.77	8.35	424.9	107.5	0.79
		Colored Dissolved Organic Matter	***chlorophyll* a (ug/L)**	**NO_3 (mg/L)**	**NH_4 (mg/L)**	**PAR**
Arrowhead Lake	9/5/2020	29.81	20.92	0.3	0.3	NA
Firemen's Clayhole	9/5/2020	11.92	1.89	0	0.1	NA
Arrowhead Lake	9/13/2020	32.16	13.89	0.1	0.4	NA
Firemen's Clayhole	9/13/2020	13.42	1.55	0	0.1	NA
Arrowhead Lake	10/10/2020	30.92	14.38	0.2	0.2	3812.9
Firemen's Clayhole	10/10/2020	12.63	2.23	0	0.1	3967.2

Table 3. Family richness, evenness, and diversity scores for Arrowhead Lake and Firemen's Clayhole on all three sampling dates.

Site	Sampling Date	Shannon Diversity	Family Richness	Family Evenness
Arrowhead Lake	9/5/2020	1.108	7	0.569
Firemen's Clayhole	9/5/2020	1.380	6	0.770
Arrowhead Lake	9/13/2020	1.438	7	0.739
Firemen's Clayhole	9/13/2020	0.699	5	0.434
Arrowhead Lake	10/10/2020	1.610	7	0.827
Firemen's Clayhole	10/10/2020	1.315	6	0.734

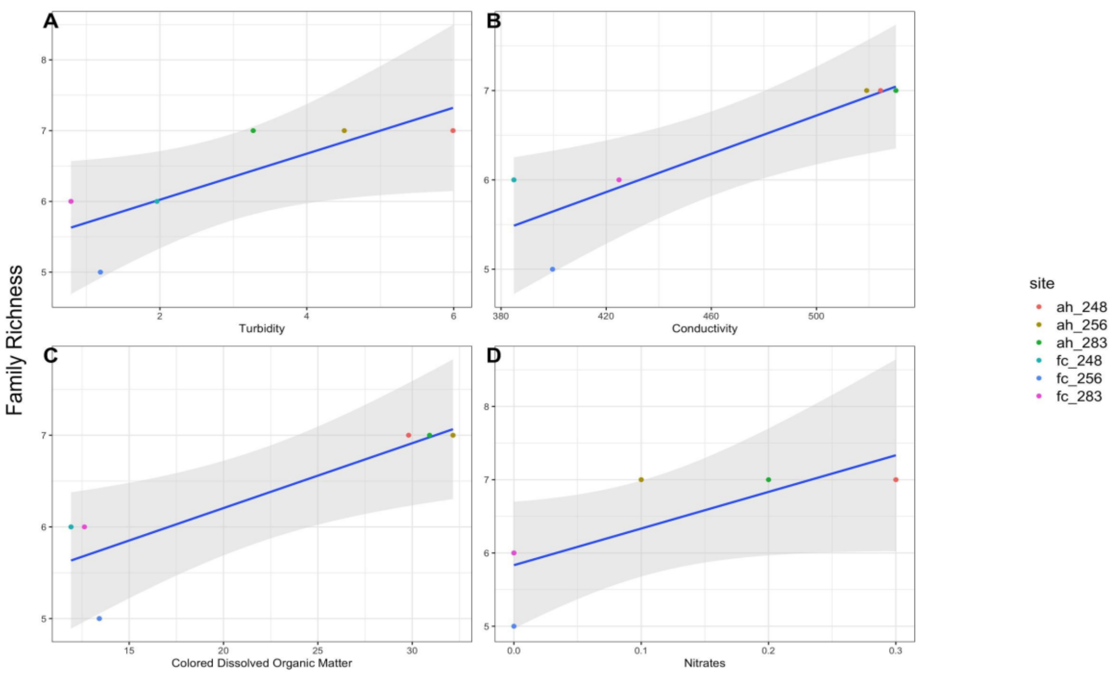

Figure 5. Environmental and chemical factors compared to specific zooplankton family richness for each study date and lake. A. Zooplankton family richness positively associated with increasing turbidity (p=0.052, R^2=0.56). B. Zooplankton family richness positively associated with increasing conductivity (p=0.017, R^2=0.74). C. Zooplankton family richness positively associated with increasing colored dissolved organic matter (p=0.023, R^2=0.70). D. Zooplankton family richness positively associated with increasing nitrate concentration (p=0.07, R^2=0.5).

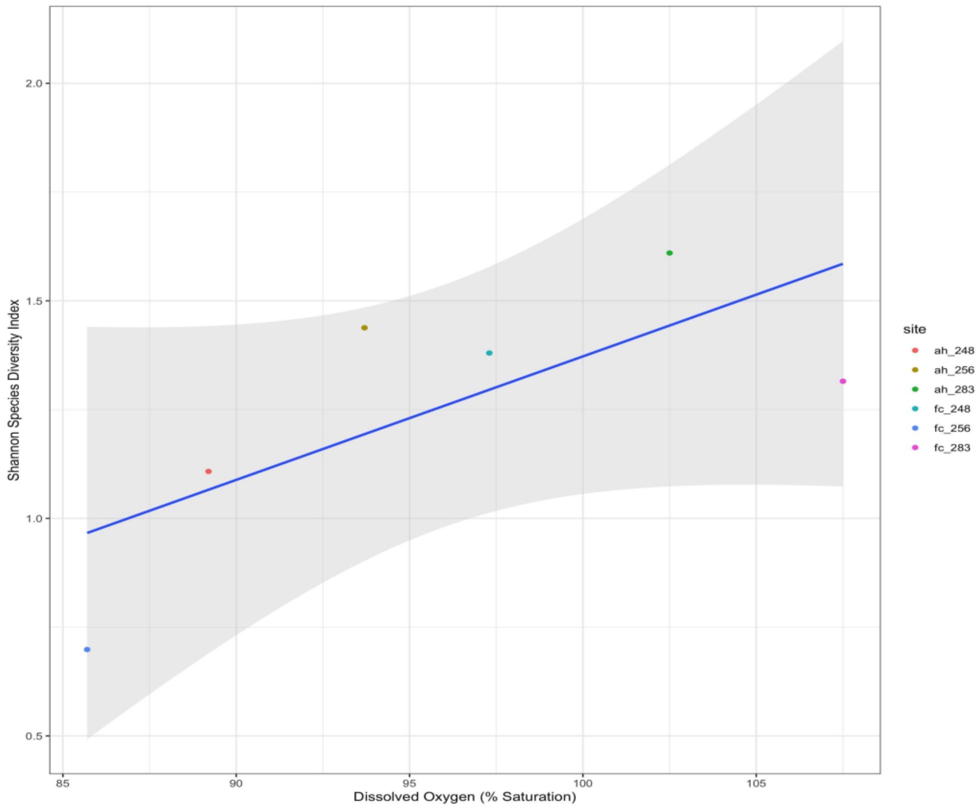

Figure 6. Increasing Shannon Diversity Index with increasing dissolved oxygen concentrations ($p=0.1023$, $R^2=0.409$).