AQUATIC INVERTEBRATE POPULATIONS IN ROADSIDE WETLANDS IN RELATION TO WATER CHARACTERISTICS

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***Abstract*—The continual habitat destruction and draining of wetland systems makes the need to understand the ecology of roadside wetlands all the more necessary. Roadside wetlands provide valuable habitat to countless aquatic invertebrates, which can provide insight into the health of the wetland system due to their diversity. The objective of this study was to analyze the populations of aquatic invertebrates in roadside wetlands in relation to water characteristics such as pH, salinity, conductivity, water depth and temperature, and dissolved oxygen. This was done by collecting samples of invertebrate populations from roadside wetlands, in addition to data on water quality characteristics using an aquatic D-frame dip net, YSI multi-parameter water quality meter , and a handheld water quality testing meter The results as shown by the NMDS graph are that the water quality characteristics that are significantly related to invertebrate community structure are dissolved oxygen (P = 0.017) and pH (P = 0.028). On average, sample locations had low dissolved oxygen and low pH. These samples contained communities that were made up of Planorbidae, Chironomidae, *Hylella*, and other groups that are known to live in low water quality conditions. In addition, invertebrate groups were found to fulfil a range of ecological niches such as Sphaeriidae, Coenagrionidae, Ptychopteridae, and Libellulidae. Roadside wetlands are a valuable habitat for aquatic invertebrates, and the results of this study can be used to intentionally manage roadside wetlands for aquatic invertebrates.**

I. INTRODUCTION

As climate change continues to alter valuable ecosystems, it becomes more important to understand the role that people play in the creation and alteration of our habitats and ecosystems (Davidson 2014; Tatariw et al. 2021). An estimated 87% of wetlands have been lost due to human activity since the 18th century, with inland wetland reduction being more severe than that of coastal wetlands (Davidson 2014). An estimated 33% of global wetlands have been lost since 2009 (Hu et al. 2017). It is well known that wetland ecosystems provide numerous services both ecologically and economically. A wetland system will reduce the risk of floods, provide habitat for wildlife of all levels, capture and transform chemicals such as nitrogen and phosphorus, recharge groundwater, and provide various recreation opportunities (Kent 2000). As wetlands continue to be altered, man-made systems have been created to make up for the lost ecological and hydrological services, including stormwater systems such as constructed wetlands and roadside ditches (Gold et al. 2019; Tatariw et al. 2021). While the intended purpose of roadside ditches is to manage stormwater runoff and retain pollutants, they have proven to be capable of a level of nitrogen removal approximate to that of natural wetlands (Tatariw et al. 2021).

In addition to being capable of nitrogen removal, for a roadside ditch to truly mimic the function of a natural wetland, the roadside ditch must also be able to provide habitat. While roadside wetlands and other wetland systems that exist in urban settings are often overlooked, they still act as valuable habitat and provide habitat for a wide range of creatures, including invertebrates (Palta et al. 2017). Invertebrates are known to be good indicators of ecosystem diversity and health, due to their size, group diversity, and sensitivity (Weaver 1995). With respect to the health of the ecosystem, the invertebrate population can also be an early indicator of environmental stressors (Weaver 1995; Borges et al. 2021). Within a wetland, invertebrates act as a trophic link between vegetation and animal life, and are an important food source for fish and waterfowl (Gleason et al. 2018; Wrubleski and Ross 2011). A healthy invertebrate population generally reflects a healthy wetland (Wrubleski and Ross 2011; Luell 2020).

Because of the diversity among invertebrates, to get a complete picture of a wetland's health it is necessary to understand which invertebrates are present and why. When it comes to habitat preference, freshwater invertebrates can generally be sorted into multiple broad categories (Bouchard 2004). Some are more likely to be found in areas with heightened water flow, such as order Ephemeroptera and order Trichoptera, while other orders prefer slow water flow, such as order Diptera (Quesada-Alvarado et al. 2020).

An additional method of categorizing freshwater invertebrates is based upon water pollution tolerance -

species that cannot tolerate pollution, species that can somewhat tolerate pollution, and species that can tolerate pollution (Luell 2020; Bouchard 2004). Invertebrates can also be categorized according to functional feeding groups, which are based on how an organism acquires food (Luell 2020). For example, order Ephemeroptera belongs to the group that cannot tolerate pollution, and this information in conjunction with Ephemeroptera being found in areas of high water flow indicates that if Ephemeroptera is found in a wetland or stream, that location most likely has high oxygen and low pollution (Bouchard 2004; Luell 2020). This logic can be applied to all aquatic invertebrates found in wetlands. By collecting a sample of the aquatic invertebrate population within a wetland and identifying specimens down to the family level, valuable information can be inferred about the health and quality of that wetland.

The objectives of this study are to provide an overview and analysis of aquatic invertebrate populations in roadside wetlands located off the major roads in Bemidji, as well as test for a correlation among invetebrate commuity sturcture and water quality characteristics such as pH, conductivity, salinity, total dissolved solids, and water temperature.

II. Methods

The data for this study was collected from September to mid-October 2024. A total of 16 samples of invertebrates and water quality measurements were taken from roadside wetlands along major roads in and around Bemidji, MN (Figure 1). For the purposes of this study, a roadside wetland was defined as any location that had wetland vegetation, at least 2.54 cm of standing water, and was no more than 9 m away from a paved road. Once a location that fit these criteria was selected, the area that had water and vegetation closest to the road was selected for sampling. If there were multiple potential sampling sites that fit these criteria, the site that was the easiest to get to on foot was chosen.

The same process for taking samples was used at each site. To avoid disturbing the sediment, water quality readings were taken first using a YSI multi-parameter to measure temperature and dissolved oxygen and a handheld water quality testing meter to measure pH, conductivity, salinity, and total dissolved solids. Then an aquatic D-frame dip net was used to collect invertebrate samples in the same location the water quality samples were taken. A D-net was used for its ability to be used in habitats of varying sediment types. Using tweezers and buckets, invertebrates were removed from the vegetation and sediment brought up by the D-net and placed into labeled containers containing 70% ethanol. To take water depth measurements, the handle of the D-net was vertically dropped into the water and sediment. The measure recorded was the length to which the handle entered the water with no additional force beyond the drop.

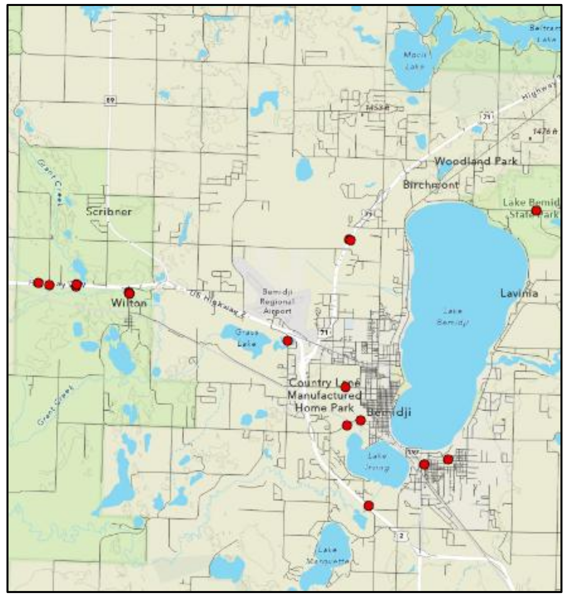

Fig. 1. Map of all 16 locations that were sampled for this study. Samples were taken in September-October 2024. Map created using ArcGIS pro, basemap provided by ArcGIS.

Various taxonomic keys were used to identify invertebrates down to the appropriate taxonomic level i.e., order, family, or genus (Bouchard 2004; Morse et al. 2020; MNDNR 2007; MNWHEP 2021). The identifications were recorded on a data sheet along with the water quality measurements.

Once the data was entered into an excel spreadsheet, R was used to create a nonmetric multidimensional scaling graph and determine significance of water quality measurements. Envfit was used to identify the water quality characteristics that were correlated to aquatic invertebrate community structure. The average values of water quality characteristics were calculated, as well as the most to least abundant invertebrate groups identified in the samples. Using coordinates taken at each site, ArcGIS was used to create a map of sampling locations.

III. Results

In total, 1,608 aquatic invertebrates were collected and identified (Figure 2). The largest number of invertebrates in one sample was 526 at site 16, and the lowest amount was 9 at site 2. The most abundant family was Chironomidae, present in 9 samples. Sample 16 had 506 chironomids, making up the bulk of invertebrates in the sample. The most common family was Planorbidae, which was present in all samples except sample 2. Trichoptera and Ephemeroptera were only present in samples 8 and 14 with dissolved oxygen values of 7.24 - 9.11 mg/L, in addition to sample 13 which contained one Trichoptera and had a dissolved oxygen of 1.54 mg/L.

Samples 8 and 14 also contained the greatest number of different families, with sample 14 containing 15 different families and sample 8 containing 21. These samples were the highest in dissolved oxygen overall. In total, there were 36 different groups collected, most being identified down to the family level. Most samples had 5-7 different families present.

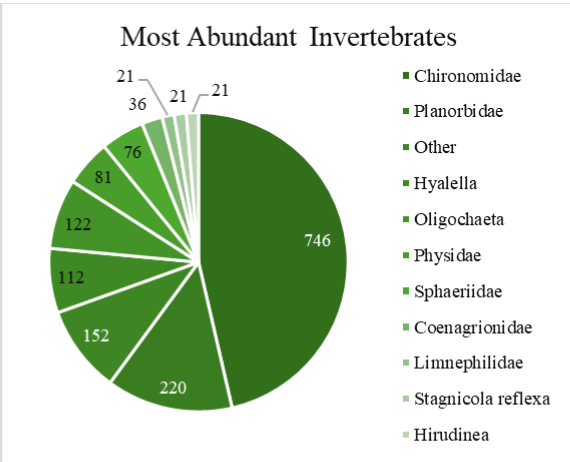

Fig. 2. Most abundant invertebrates found overall, other consisting of groups that were 20 individuals or less. Invertebrates were collected from wetlands along paved roads in the Bemidji area in September to late October 2024.

Dissolved oxygen (*P* = 0.017) and pH (*P* = 0.028) were found to be significantly related to invertebrate community structure (Figure 3). The impact of salinity (*P* = 0.046), conductivity (*P* = 0.046), and total dissolved solids (*P*=0.041) on the invertebrate community are nearly identical and not significant to community structure. Water temperature (*P* = 0.51) and water depth (*P* = 0.29) were also not significantly related to community structure. Most samples had low dissolved oxygen, low pH, and elevated salinity, conductivity, and total dissolved solids (Table 1). The average values of the water quality characteristics indicate that sampling locations were slightly acidic and had low dissolved oxygen.

Even though salinity, conductivity, and total dissolved solids were not significant overall, samples 3, 4, 10, and 13 had the highest values of salinity, conductivity, and total dissolved solids. The invertebrate communities in these samples were made up of groups that have been discussed as living in low water quality conditions. Samples 3 and 4 contain the only Ptychopteridae found during this study, and Ptychopteridae have a very high tolerance level (Bouchard 2004; Morse et al. 2020). Increased salinity is known to cause a decrease in dissolved oxygen, as is the same for conductivity and total dissolved solids. Sample 10 contains the highest number of Planorbidae, and sample 13 contains the highest number of Oligochaeta and Hirudinea. As salinity, conductivity, and total dissolved solids increase, the invertebrate community composition becomes more focused on species that can tolerate low quality water.

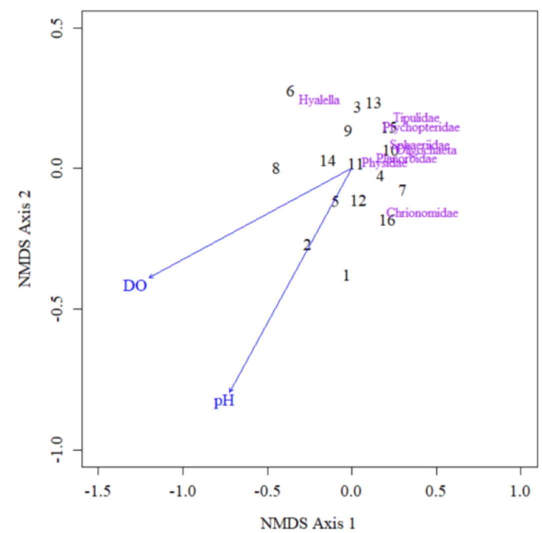

Fig. 3. Nonmetric multidimensional scaling graph showing similarity of samples. Numbers represent the sample identification number. Vectors represent the value of water quality samples of dissolved oxygen (DO) and pH. Samples were collected from wetlands along paved roads in the Bemidji area in September to late October 2024.

TABLE 1. AVERAGE VALUES OF WATER QUALITY CHARACTERISTICS, MEASUREMENTS TAKEN FROM WETLANDS ALONG PAVED ROADS IN THE BEMIDJI AREA IN SEPTEMBER TO LATE OCTOBER 2024.

Water Quality Characteristics	Average	Standard Deviation
pH	6.35	0.28689
DO (mg/L)	5.27	2.54723
Water Temperature (°C)	11.85	5.32152
Conductivity (mS/m)	568.16	267.807
TDS (mg/L)	404.81	199.248
Salinity (mg/L)	312.13	165.291
Water Depth (cm)	42.672	6.03733

IV. Discussion

The objective of this study was to examine roadside wetlands and determine if there was a relationship between invertebrates found and water quality characteristics. It was determined there was a correlation between water quality and number type of invertebrate found. The most common families found in the samples, Planorbidae and Physidae, are known to tolerate a wide range of habitat types and oxygen levels. They are lunged snails, and as such can handle low oxygen conditions well (Bouchard 2004). Similarly, the most abundant family in the gathered samples Chironomidae is known to inhabit any water body of any quality (Bouchard 2004). When living in low-oxygen environments, Chironomidae will present a red color due to hemoglobin for oxygen storage, and many red Chironomidae were found during this study. The sample locations can be considered low oxygen, which is supported by the presence of Planorbidae and Chironomidae. Another group present in most samples is Oligochaeta, and like Chironomidae, Oligochaeta are known to be able to live in a large habitat range, especially polluted waters and low oxygen areas (Bouchard 2004).

The third most abundant invertebrate group collected in the samples was *Hyalella* (Fig. 3), though 59 of the 112 individuals collected were from sample 14. *Hyalella* are known to be very tolerant of low water quality (Bouchard 2004), though sample 14 had high dissolved oxygen and a pH of 6.3. While various Trichoptera and Ephemeroptera were found, majority of collected invertebrates belong to groups that tolerate low water quality.

As an example, Chironomidae, Tipulidae, Corixidae, Planorbidae, Sphaeriidae, Coenagrionidae, Ptychopteridae, and Libellulidae are only a few of the families identified in the samples that tolerate low water quality. The above families represent a range of functional feeding types, from grazers, predators, filterers, and gatherers (Luell 2020, Bouchard 2004). This study collected a range of invertebrates from different orders that occupy different ecological niches.

The water quality measurements taken showed that most sample locations were low in oxygen. Natural wetlands are low in oxygen due to factors such as soil and vegetation composition (Wrubleski and Ross 2011), so these sample sites having low oxygen and low oxygen tolerant invertebrates make them analogous to natural, larger wetlands. The only sample locations that had invertebrates that required high oxygen and are not tolerant to low water quality were the locations that had flowing water, samples 14 and 8. All other locations were stagnant, and majority had biofilm and large amounts of loose organic sediment. All locations had wetland vegetation as that was a selection criterion, though wetland size was highly variable.

The results of this study show that roadside wetlands provide habitat to a diverse range of aquatic invertebrates. Despite commonly being overlooked, roadside wetlands are valuable ecosystems, though often created as a byproduct of construction (Palta et al. 2017). The water is slightly acidic and low in oxygen, and the invertebrates found reflect that. Though the water may be low quality, and the insects found within mostly flies and snails, roadside wetlands are still valuable ecosystems.

Intentionally managing the upkeep of roadside wetlands may benefit areas that have experienced extreme wetland loss, such as urban areas. Knowing that roadside wetlands can host a wide range of invertebrates while having low water quality can be beneficial for future work in wetland restoration.

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