Water chemistry, aquatic macroinvertebrate communities, and bird communities in managed Waterfowl Production potholes and natural potholes in the National Bison Range

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Abstract

Throughout the mid-west and western United States lays the prairie pothole ecosystem. Small ponds, referred to as potholes, collect water and are a lifeline for many organisms. Macroinvertebrate communities can thrive in small potholes and birds annually use potholes to breed and nest. Other land animals also use these potholes as watering holes. This study looked at 12 potholes spread out in Northwestern Montana in the National Bison Range and two Waterfowl Production Areas (Duck Haven and Sandsmark). The objective of this study was to determine if natural and managed potholes supported significantly different macroinvertebrate and bird communities, as well as measure any differences in water chemistry. This study found no significant differences in the water chemistry, aquatic invertebrates, and bird communities of the two types of potholes.

Introduction

In the North Western United States and Southwest Canada, lays an ecosystem called the Prairie Pothole Region (PPR) (Goldhaber 2014). The PPR is so extensive that it makes up one of the largest wetland ecosystems and covers approximately 750,000 km^2 (Goldhaber 2014; Mushet 2016). During the Wisconsin glaciation, indentations in the ground caused by glaciers created the potholes on the ground seen today (Mekonnen 2014). These glacial potholes create a wetland ecosystem and they are refilled with water through snowmelt and rain (Montana DEQ). Specifically in Montana, prairie potholes can be found and about 145 square kilometers are considered part of the Great Plains Prairie Pothole in Montana as of 2017 (Montana DEQ;

Montana Natural Heritage Program). These potholes can have a wide range of water characteristics that vary annually and seasonally (Montana Natural Heritage Program). Water in these potholes can range from fresh to very saline, depending on the dissolved solids in the water (Montana Natural Heritage Program). Water in these potholes also tends to be alkaline, with a pH over 7.4 (Montana Natural Heritage Program). During the summer months, evapotranspiration is often greater than precipitation, resulting in potholes drying up (Natural Heritage Program). In general, the land that surrounds the prairie potholes is used for agriculture (Montana Natural Heritage Program). Historically the PPR is a grassland ecosystem and in the 1990's it was found that only 30 % and less of the mixed grass and 1 % of the tall grass landscape remained (Dahl 2014**).** The PPR has been subjected to many land use changes, predominantly agricultural, which often involves draining of the potholes (Dahl 2014; Delphey et al 1993). Invasive species, habitat fragmentation, and reduced biodiversity are other problems prairie pothole ecosystems face (Dahl 2014). Although Prairie potholes have been and are converted over for agriculture, they provide many beneficially environmental services such as reducing the effect of floodwaters, recharge ground water, provide water and habitat for organisms, and support biodiversity (Dahl 2014).

The importance of potholes has been rediscovered and steps have been taken to restore prairie potholes on federal and state levels. One of those ways is through the creation of Waterfowl Production Areas (WPA). WPAs are managed through the U.S. fish and Wildlife Service and then further managed by Wetland Management Districts (Systems n.d.) . There are over 36,000 WPAs throughout the PPR (Systems n.d.). The main goal of WPAs is to conserve the prairie pothole ecosystem for waterfowl and other animals and maintain bird populations to support recreational hunting (Systems n.d.; and Northwest Montana Waterfowl Production Areas

Lake County). The National Bison Range also contains potholes. The National Bison Range encompasses a variety of habitats including grasslands, forests, and wetlands (The National Bison Range, n.d.). Although the maintenance of prairie potholes is not the primary management focus of the National Bison Range, they make up about three percent of the area within the range (National Bison Range, n.d).

Birds are one of the main organisms that utilize the prairie pothole habitat. The pothole wetland ecosystem is an important stopping place for migratory shorebirds (Steen et al 2018). In the PPR, over 7.5 million shore birds utilize the pothole wetlands to nest during the springtime (Steen et al 2018). Additionally, prairie potholes are estimated to be a very important breeding ground for waterfowl, with 50 to 80 % of the main species being produced there (Montana Natural Heritage Program). Ducks are highly dependent on the wetland ecosystem to breed and nest (Klett et al 1988). When looking at WPAs and National wildlife refuges, they produce 23 % of the area's waterfowl populations even though they only make up 2 % of the environment within the PPR states (Systems n.d.). In 1988, a study found that four duck species (mallard, gallawad, blue-winged teal, northern shoveler) in the PPR all had nest success rates that were unsuccessful to maintain population levels (Klett et al 1988).

As potholes are filled in for agricultural purposes valuable bird nesting sites are lost (Delphey et al 1993). However, efforts to restore prairie potholes has the potential to support high population densities of breeding birds (Delphey et al 1993). However, restored potholes can have problems and some get designed improperly, and certain abiotic characteristics such as depth may not make them suitable for bird use (Dephley et al 1993; Galatowitsch 1996).

Prairie potholes can also support diverse aquatic macroinvertebrate communities. Macroinvertebrates have important roles as food for other animals such as fish, amphibians, and water birds (Voshell 2003). Aquatic macroinvertebrates also play a role in various ecological processes such as decomposition of organic matter and nutrients (Voshell 2003). The potholes offer a unique ecosystem because it is common for the potholes to dry up, which can result in fluctuations in macroinvertebrate community composition (Silver 2010). It is likely that temporary and permanent potholes support different communities and abundances of macroinvertebrates, which is important to consider since many waterfowl rely on these organisms as primary food sources (Silvers 2010).

Much of the research on prairie potholes was conducted several decades ago, which leaves a staggering gap of knowledge into the role of restored potholes in supporting bird populations. Motivated by the need to address how restored potholes compare to naturally occurring potholes in terms of water chemistry, macroinvertebrate, and bird communities, I conducted a field study in North West Montana.

Objectives

- To determine if differences in water chemistry exist between natural potholes (NBR) and modified potholes (Duck haven and Sandsmark WPA).
- To determine if the aquatic macroinvertebrate communities and diversity differ between natural (NBR) and modified natural potholes (Duck Haven and Sandsmark WPA).
- To determine if the bird communities and diversity differ between natural (NBR) and modified potholes (Duck Haven and Sandsmark WPA).
- To evaluate relationships between water chemistry, aquatic macroinvertebrate communities, and bird communities between natural potholes (NBR) and modified natural potholes (Duck Haven and Sandsmark WPA).

Hypotheses

1. Modified and natural potholes will have differences in water chemistry because restored potholes often take a long time to achieve conditions seen in natural potholes.
2. The aquatic macroinvertebrate community will differ between natural and modified natural potholes because some of the modified potholes do not have standing water throughout the growing season.
3. A higher diversity of birds will be observed in the WPA (modified potholes), since it is managed specifically for birds compared to the NBR (natural potholes).

Methods

Sites

Potholes located within three distinct management areas of Charlo, MT, were selected for study. Two WPAs, Duck Haven and Sandsmark, contain both created and natural potholes, and are primarily managed to support waterfowl production. The third pothole ecosystem was situated on the National Bison Range and consisted of naturally-occurring, and unmanaged potholes. Figures 1 -3 provide detailed maps of the study sites. Within each area, four ponds were surveyed for water chemistry, invertebrates, and birds.

Water Chemistry Tests

To assess the pothole water quality, five parameters were used: dissolved oxygen (%), pH, temperature (°C), conductivity (µS), and total dissolved solids (ppm). Pothole depth (cm) and perimeter size (m) were also taken as physical characteristics of the potholes. Pothole perimeter was no larger than 190 m. Dissolved oxygen, pH, water temperature, conductivity, total dissolved solids, and depth were taken in each cardinal direction. The Oakton DO 6+ meter was used to find the dissolved oxygen. Apera pH probe was used to determine the pH and temperature and a Sper Scientific multi-parameter probe was used to determine conductivity and total dissolved solids. A PVC pole with markings every five centimeters was used to determine the depth. Google Earth was used to find each pothole's perimeter. Average values for each of the water parameters were calculated.

Surveying Macroinvertebrates

Three to four aquatic macroinvertebrates samples were taken from each pond. A 500-600 micron – D net frame was swept for one meter approximately two meters away from the edge of the pond (Protocols for Sampling Aquatic Macroinvertebrates, n.d.). Contents of the net were placed into a glass jar with 70 % ethanol. In the lab, the organisms were identified to the Family level with a dissecting scope and then preserved in 70 % ethanol in small glass vials. Organisms were counted only if the head was attached, and adult insects were excluded. Macroinvertebrate counts were used to determine Shannon Weiner diversity.

Bird Surveys

A point count survey was performed at each pothole. Each survey consisted of visual and auditory counts of birds within a 20-meter radius surrounding each pond (Hostetler & Main 2001). Each point survey was conducted between 6 am and 11 am, and lasted 5 minutes. Flushed birds were also recorded as part of the study. Two surveys were performed at each pond. Total abundance, Shannon-Weiner diversity, and species richness were computed for each site.

Statistics

All data was checked for normality and if assumptions were not met then data was transformed or non-parametric tests were used. Past 3 statistical program (Hammer 2001) and R (R core team 2013) were used to analyze data.

Water chemistry

The water chemistry data from each pond was averaged so that one number for each water chemistry test was obtained per pothole; these averages were used in multiple linear regression. A non-parametric one way ANOSIM was ran and a Bonferroni with corrected p-values was used for a post hoc test.

Macroinvertebrates

The Shannon-Wiener diversity index was found for each cardinal direction for each pothole. The Shapiro- Wilk normality test showed that the data were normal, and macroinvertebrate diversity was analyzed with a one-way ANOVA, followed by Tukey's HSD post-hoc test. In Past 3 (Hammer 2001) a multiple linear regression was used to determine if macroinvertebrate diversity was related to water chemistry.

Birds

Shannon-Wiener diversity indices were created for each point count sample. The Shapiro- Wilk normality test showed that the data were not normally distributed, and so the Kruskal Wallis test was used, followed by the Dunn's post hoc test. Finally, multiple linear regression using the various water chemistry parameters and macroinvertebrate diversity as predictor variables was used to assess relationships between pothole characteristics and bird communities.

Results

Water chemistry

The main objectives for analyzing water chemistry was to determine if there were any differences found between the three sites. The National Bison Range potholes and the Duck Haven potholes were significantly different for all seven parameters (Table 1). Except for water temperature, the National Bison range potholes and the Sandsmark WPA potholes were not significantly different (Table 1). The Sandsmark WPA potholes and the Duck Haven WPA potholes were significantly different for all the water chemistry parameters except dissolved oxygen (Table 1). There was no statistical significant difference in pothole depth and perimeter sized between the National Bison Range, Duck Haven WPA, and Sandsmark WPA potholes.

Macroinvertebrates

The main objective for the aquatic macroinvertebrate community was to determine if there were any differences in diversity among the National Bison Range, Duck Haven WPA, and Sandsmark WPA. The abundant aquatic macroinvertebrate taxa found were lymnaeid and physidae snails, mayflies (family Baetidae), and chironomid larvae. Backswimmers (Notonectidae)and predaceous diving beetles (Dytiscidae) were other notable families. In total, 33 families were found. No statistical significance was found for Shannon – weiner diversity indices between the National Bison Range, Duck Haven WPA, and Sandsmark WPA (Table 2). Of all the taxa found, only two were found to have statistical significance when comparing the National Bison Range, Duck Haven, and Sandsmark: Mayflies (Baeitdae) and Snails (Physidae). Mayflies, family Baetidae, were found to be significantly different in the National Bison Range potholes compared to the Sandsmark and Duck Haven potholes (p – value 0.01). The snails:

Physidae were found in significantly different abundances (p-value 0.01) in the Sandsmark WPA compared to the Duck Haven WPA and the National Bison Range potholes.

Birds

Bird diversity was calculated to determine whether there was a difference between the National bison range, Duck Haven WPA, and Sandsmark WPA potholes. Thirteen bird species were recorded during the study period. Across the three sites Western Meadow larks, Yellow-headed Black Birds, and American Coots were some of the more common birds. Red winged Black Birds were spotted in abundance but only on the National Bison Range. Other birds spotted in lower abundance were the Grasshopper sparrow, Blue-winged Teal, Barn Swallow, Cliff Swallow, Killdeer, Mourning dove, and Magpie. At the National Bison Range the diversity ranged from 0.5004 to 1.561. The Duck Haven WPA diversity ranged from 0.6931 to 1.609 while the Sandsmark WPA ranged from 0.6931 to 1.332. However, no significant statistical difference was found between the Shannon – wiener diversity indices for the National Bison Range, Duck Haven WPA, and Sandsmark WPA (Table 3). A multiple linear regression analysis showed no relationship between diversity of birds and macroinvertebrates (p-value 0.8836, $r^2 = 0.002278$) along with no relationship between birds and water chemistry (p-value >0.05, $r^2 < 0.27$).

Discussion

Initially this study aimed to evaluate community differences in manmade versus natural potholes in Montana. However, upon looking at historical pictures of the study sites dating back to 1958, the manmade or natural categories were not straightforward. One of the reasons for this was poor historic aerial photo chemistry of the study sites, which limited ability to definitively assign natural and manmade labels to the potholes. Also, potholes located within WPA's have historically been drained. Water has potentially been added back but information is not available on which potholes have been modified or restored. The National Bison Range does not manage the Ravalli Wetlands and these potholes receive little to no management. The main objectives of the present study were to determine if there were any differences in terms of water chemistry, macroinvertebrate diversity, and bird diversity between the potholes of the NBR and the WPAs.

Water chemistry analysis included 5 parameters: dissolved oxygen, pH, water temperature, conductivity, total dissolved solids and 2 pothole characteristics: depth and perimeter. No significance was found between the three sites for depth or perimeter. This indicates that the sampled potholes were similar in size and depth. This makes sense because perimeter size was controlled for and depth would most likely increase with size. In addition, depth was measured closer to the edge rather than in the middle of the pond. For all the water chemistry parameters, the NBR and Duck Haven were found to be significantly different from each other while the NBR and Sandsmark were not found to be significantly different (Table 1). In general, Sandsmark WPA and Duck Haven WPA are significantly different from each other, except for dissolved oxygen (Table 1). These groupings could have occurred for a variety of reasons. One study found that there was a difference in water chemistry if the potholes were temporary, semi-permanent, and permanent (Driver 1977). Water duration in potholes was not controlled for in this study but visually the potholes seemed to be temporary and a few semi-permanent. Therefore, the water chemistry may not have varied significantly if they were in the same water duration category.

The Shannon – Wiener diversity index for aquatic invertebrates was not significantly differenent between the three sites. There was no significant difference in aquatic invertebrate taxa found based on abundance data except for two families, Mayflies (Baetidae) and Snails (Physidae). This finding is consistent with another study that found no difference in aquatic macroinvertebrate taxa between natural and restored wetlands (Zimmer 2000). One explanation for this could be that most of the potholes in this study had standing water for only part of the summer. This study did not specifically control for only temporary potholes but it could be that the ones chosen happened to be temporary potholes. Therefore, similar types of aquatic invertebrates occupied those potholes, those that could handle drying water conditions and therefore had a terrestrial portion of their life to accommodate. This is consistent with a study that found less taxa of aquatic macroinvertebrates in temporary ponds than in permeant ponds (Silver 2010).The study also found that in temporary potholes, most invertebrates had terrestrial life stages to accommodate drying (Silver 2010). However, some invertebrates were found to be purely aquatic. This could be explained by dispersal from birds (Green 2005, Silver 2010). A multilinear regression found no relationship between macroinvertebrates and water chemistry. This could be because the aquatic invertebrates are adapted for a lifestyle with drastically changing water chemistry as the potholes dry up (Silver 2010).

The Shannon – Wiener index for the bird point counts found no significant difference between the potholes of the three sites. This could be due to the vegetation found at the potholes. Although vegetation was not sampled, it has been found that vegetation does affect the type of marsh birds that can be found around wetlands (Weller 1965). If the three sites had similar vegetation, they could potentially support similar bird diversities. A multiple linear regression was ran to determine if there was a relationship between water chemistry, macroinvertebrate diversity, and bird diversity but nothing was significant. The current research on the relationship between birds and aquatic macroinvertebrates has mixed results, with some studies finding a relation and others not (Murkin 1986, Voigts 1969). Macroinvertebrates and birds may not have a relationship in this study because of bird food preferences. Birds may not care what insects they eat as long as there are some to eat or birds may prefer vegetation. Of the two water birds found, American coots are herbivores and Blue-winged teals are omnivores (American Coot n.d.,Blue-winged Teal Life History n.d.). A study also found American coots did not have a relationship with aquatic macroinvertebrates (Murkins 1969). So based off the birds found in this study, birds may not depend on the aquatic macroinvertebrate community. In regards to the relationship between water chemistry and birds, birds may be a better indicator of pollution rather than basic water chemistry, which could be why no relationship was found (Ormerod 1963).

To improve this study, taking into consideration for temporary, semi-permanent, and permanent potholes may help to differentiate if this is where differences in water quality, and invertebrate and bird communities lay. Also, the potholes dried sooner than expected, so having multiple measurements at the same time of day throughout the summer to measure water chemistry could show how the water chemistry parameters change as the potholes dry up. This is important because time of day was not controlled for with water chemistry.

Overall, this study found that there was no relationship between water chemistry, macroinvertebrates, and birds. This could be because of a degree of “naturalization” has occurred. Wetlands may have been modified but by now, they may be mostly “natural” or have at least had to become less manmade. Although the results were not statistically significant it is still important to note that more birds were counted more on average in the NBR than at Duck

Haven WPA and Sandsmark WPA. This is important to note because WPAs are managed specifically for birds and it is expected that there would be more birds at a place where management is directed at them.

In the future studies could look at temporary and permanent potholes to see if there is a difference in water chemistry, aquatic macroinvertebrate communities, and bird usages at potholes. In WPAs, studies could also focus on current management, to see if current management practices yield higher bird communities or healthier wetland ecosystems.

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Appendix

Fig 1. Overhead map of the four sampled potholes at the Duck Haven WPA from Google Earth.

Fig 2. Overhead map of the four sampled potholes at the Sandsmark WPA from Google Earth.

Fig 3. Overhead map of the four sampled potholes at the National Bison Range from Google Earth.

Table 1. P- values from the water chemistry parameter.

Dissolved oxygen

NBR	DH	SM
NBR	0.01517	0.11
DH		0.746

Total dissolved solids

NBR	DH	SM
NBR	0.04064	0.9662
DH		0.02005

pH

NBR	DH	SM
NBR	2.73E-05	0.9766
DH		4.12E-05

Depth

NBR	DH	SM
NBR	0.05998	1
DH		0.2278

Water temperature

NBR	DH	SM
NBR	0.000739	0.04163
DH		2.12E-07

Perimeter

NBR	DH	SM
NBR	0.02109	0.5935
DH		0.07037

Conductivity

NBR	DH	SM
DH	0.007072	0.01547
NBR		0.7525

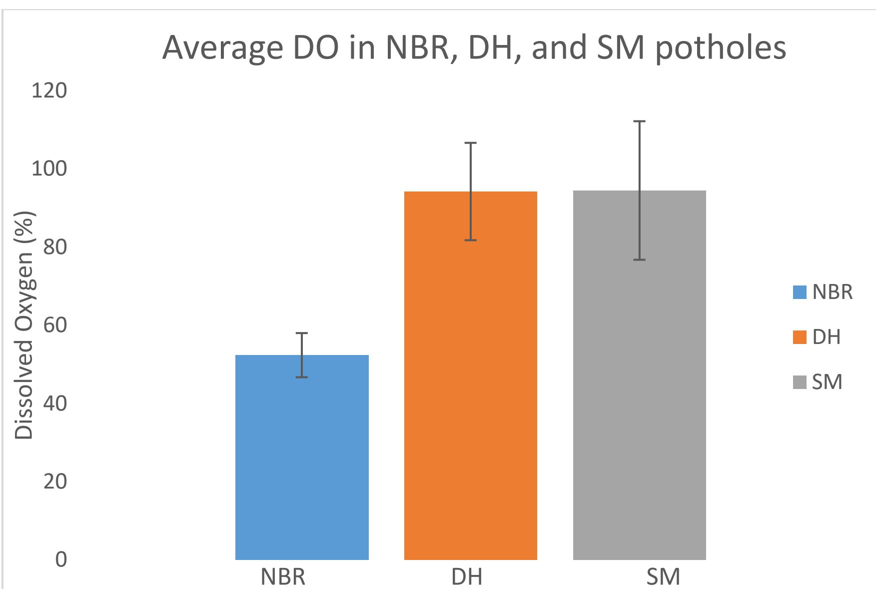

Fig 4. The average dissolved oxygen content at the National Bison Range, Duck Haven WPA, and Sandsmark WPA with standard error bars.

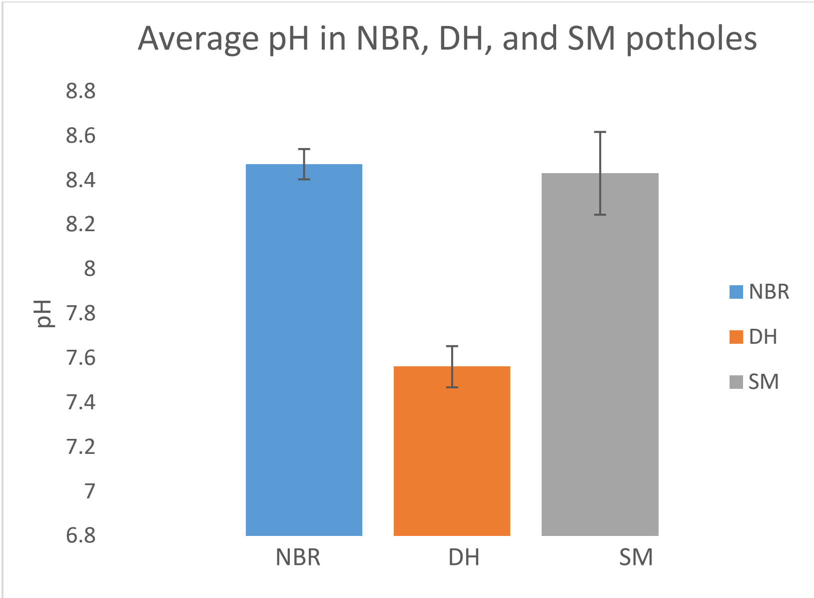

Fig 5. The average pH at the National Bison Range, Duck Haven WPA, and Sandsmark WPA with standard error bars.

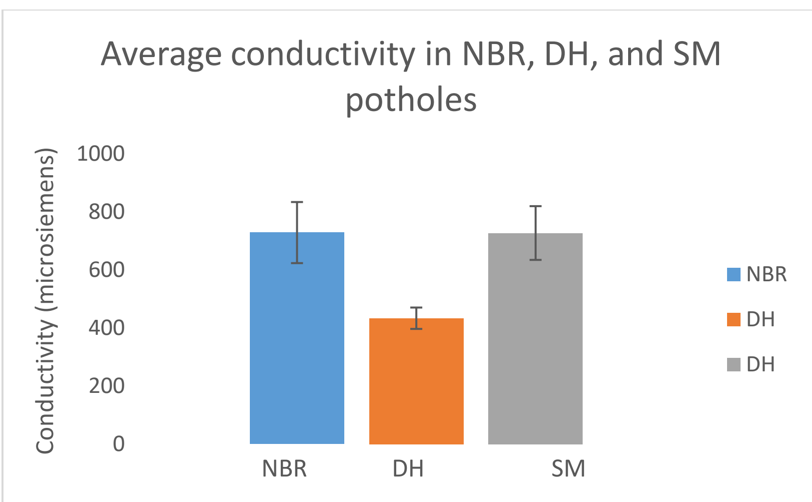

Fig 6. The average conductivity at the National Bison Range, Duck Haven WPA, and Sandsmark WPA with standard error bars.

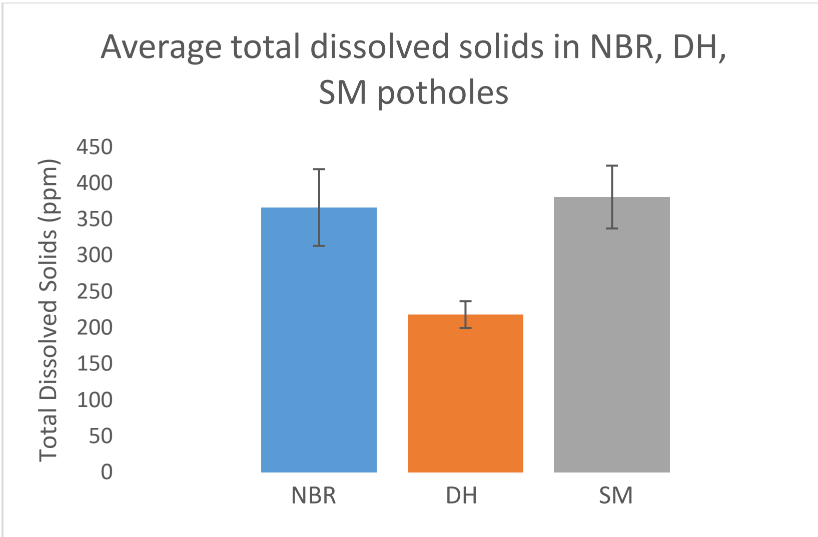

Fig 7. The average total dissolved solids at the National Bison Range, Duck Haven WPA, and Sandsmark WPA with standard error bars.

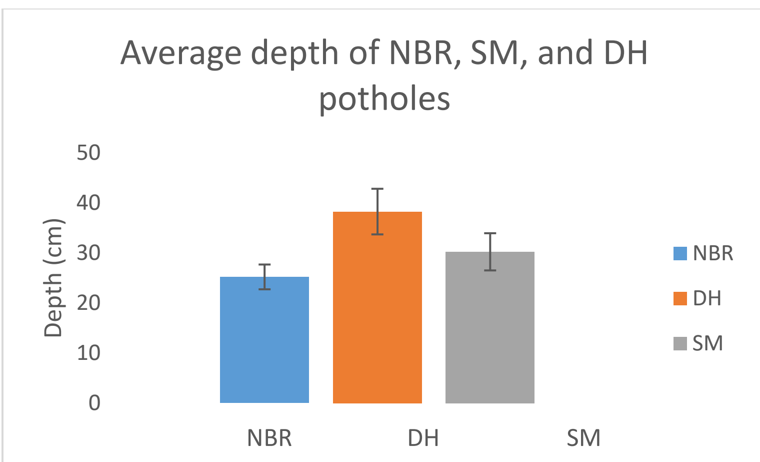

Fig 8. The average depth at the National Bison Range, Duck Haven WPA, and Sandsmark WPA with standard error bars.

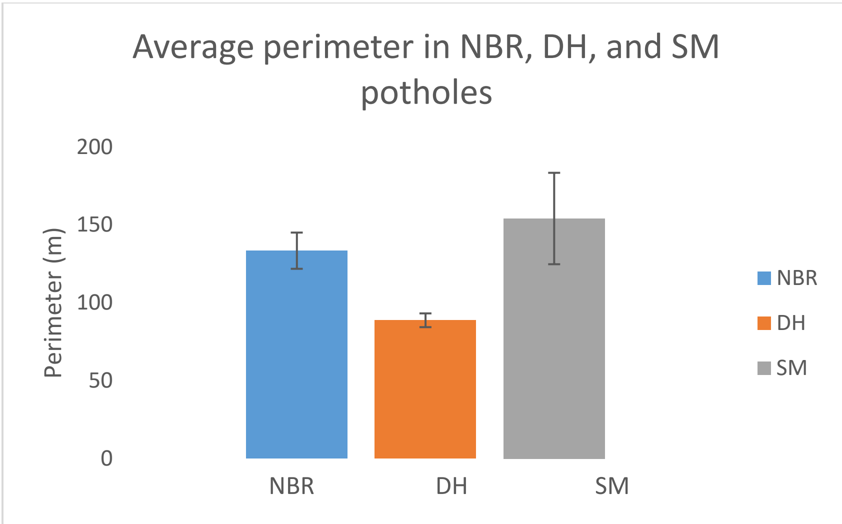

Fig 9. The average perimeter at the National Bison Range, Duck Haven WPA, and Sandsmark WPA with standard error bars.

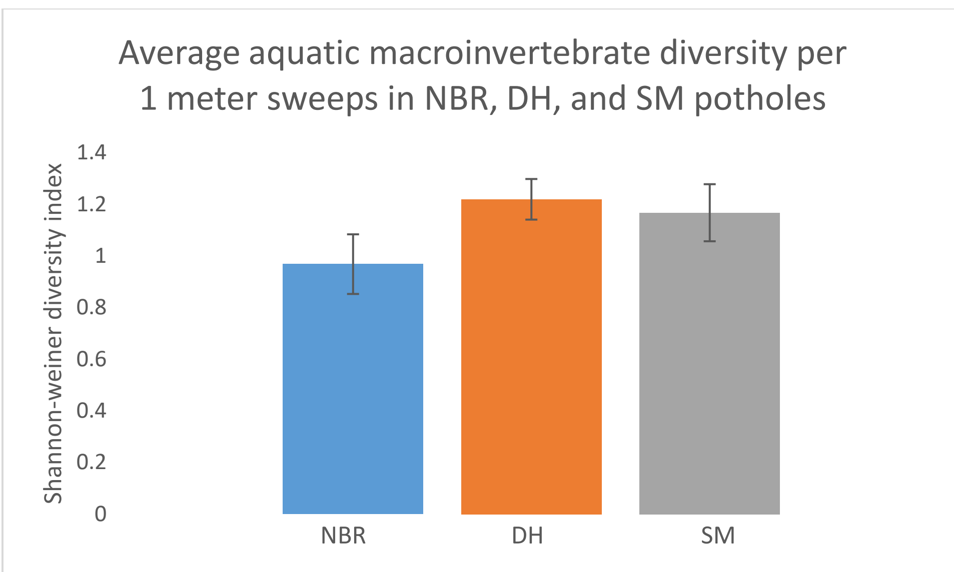

Fig 11. The average aquatic macroinvertebrate diversity per 1-meter sweep in the National Bison Range, Duck Haven WPA, and Sandsmark WPA.

Table 2. P – value table from aquatic macroinvertebrate Shannon – wiener diversity values between the National Bison Range, Duck Haven WPA, and Sandsmark WPA.

Aquatic macro invertebrate Shannon – wiener diversity index p-values

	NBR	SM	DH
NBR		0.6236	0.4261
SM			0.933

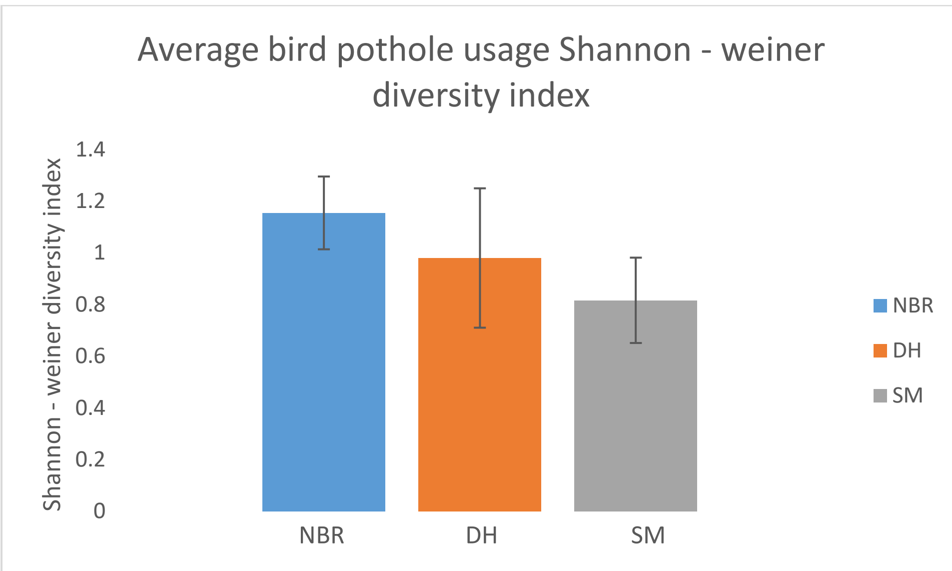

Fig 12. Bar graph of the Shannon – wiener diversity index from the bird usage of potholes at the National Bison Range, Duck Haven WPA, and Sandsmark WPA.

Table 3. The p –value table for the Shannon – wiener diversity indices from the bird usage of potholes from the National Bison Range, Duck Haven, and Sandsmark WPA.

Bird Shannon – wiener diversity Indices p-values

	DH	SM	NBR
DH		0.716	1
SM			1