Characterization of Vernal Pools at Grape Vine Point, Douglas Lake, Cheboygan Co. MI

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EEB 320 Rivers, Lakes and Wetlands
August 19, 2010
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Abstract

Vernal pools are ephemeral pools with seasonal changes of water levels that are distributed widely around the world. Vernal pools are mostly fed by rainwater and a limited watershed makes vernal pools nutrients poor. However, vernal pools serve as important wetland habitat for macroinvertebrates and amphibians. The purpose of the study was to conduct a comprehensive survey of biotic and abiotic features of vernal pools at Grapevine Point of Douglas Lake, Cheboygan Co. MI. There is less study done on the vernal pools at Grapevine Point and our study served as preliminary characterization of the vernal pools.

Biotic features including macroinvertebrates in pool and amphibians surrounding the pool were sampled. Abiotic features included in this study comprise physical measurements of the pool, dissolved oxygen, pH, conductivity, alkalinity, pool surface irradiance, chlorophyll-a, and nutrients. Our survey found that both biotic and abiotic characteristics of the pools were similar with other vernal pools that have been studied in the region.

Introduction

Vernal pools, also known as forest ephemeral pools, are unique aquatic habitats defined as confined basin depressions with fluctuating water levels during the cooler part of the year but with extended dry periods in summer months (Zedler 2003) These ephemeral pools are distributed globally especially in Mediterranean climates (Keeley and Zedler 1998.) In the United States, vernal pools are most common in California, the Pacific Coast and in the glaciated landscapes of the north and northeast (Zedler 2003).

Even though vernal pools are not permanent, they are ideal habitats for diverse organisms. A wide diversity of macroinvertebrates is found in vernal pools in North America (Wiggins 1980). In addition, many endemic and rare species of Crustaceans are found in California vernal pools (King et al. 1996). Vernal pools also serve as ideal breeding habitats for amphibians; frogs and salamanders rely on vernal pools for larvae development and metamorphosis into adulthood (Brooks 2004; Homan et al. 2004).

The abundance and breeding of vernal pool organism could be greatly affected by the physicochemical characteristics and nutrients levels of the pools. Many studies have been done to study the physical and chemical properties of vernal pools (Bonner et al. 1997; Carrino-Kyker and Swanson 2007; Boeckman and Bodwell, 2007. However, many of these studies lack explanations of abiotic characteristics in relation to vernal pool organisms.

The vernal pools at Grapevine Point are located adjacent to the shoreline of Douglas Lake. The pools are less studied and they are in close proximity to the lake; these make them ideal sites for comprehensive community study. We chose three vernal pools site for preliminary surveys on physical and chemical properties, macroinvertebrate community and amphibian community. We would like to investigate the relationship between the biotic and abiotic features of vernal pools.

Furthermore, vernal pools are important breeding grounds for amphibians. However, human developments and subsequent habitat lost have resulted in extinctions and decline of amphibian populations (Homan et al. 2004). Climate change is also increasingly threatening the populations of amphibians (Carey and Alexander, 2003). Therefore, it would be crucial for us to have comprehensive study of vernal pools and to have a record for future studies pertinence to the challenges faced by the vernal pool communities.

Methods

The study was carried out at three vernal pool sites at Grapevine Point of Douglas Lake in Cheboygan County, Michigan. The vernal pools (VP1, VP2, and VP3) were located close to the Douglas Lake shoreline (Map 1). Of the three vernal pools we sampled, VP2 was located within a vernal pool complex. The study was carried out over a span of 2 weeks from July 22 to Aug 6, 2010.

Physical characteristics were measured on July 22, 2010. At each site, the perimeter, maximum length, maximum width and depth of each vernal pool were measured using a measuring tape. Ten measurements of depth were taken across the width of the pool and were averaged into average depth reading. At VP2, the total length of the vernal pool complex was also measured. Pool surface area was estimated by deriving radius from perimeter reading. On July 26, 2010, depth of each pool was measured at the deepest part of the pool.

Dissolved oxygen (DO), pH and conductivity were measured on August 2, 2010. DO was measured using a digital DO meter; pH was measured using a calibrated Fisher Scientific Accumet portable pH meter and conductivity was measured using a YSI 30 handheld conductivity meter. All measurements were taken with minimum stirring of the pool benthos. For alkalinity and nutrient contents, pool water was collected in acid washed bottles for analysis at chemistry lab at University of Michigan Biological Station. The sampling was conducted on July 27, 2010.

In order to determine benthic algal abundance, a 17.5cm^2 tile was placed on each pool benthos for two weeks. On Aug 5, 2010, the tiles were scraped and washed into syringe with filter paper attached for filtration. The filter papers were secured in aluminum foils and chlorophyll-a determination was done in the chemistry lab to determine the benthic algae abundance. The tiles were washed with pool water so subsequent determination of pool water chlorophyll-a was carried out to get a corrected value for benthic algae. Surface irradiance at each pool was measured with a digital photometer at 9am, 1pm and 5pm on Aug 6, 2010.

We also surveyed amphibians and macroinvertebrates. The amphibian survey was conducted on a 5m distance from the pool along the perimeter. Amphibians were identified into species on sight. Macroinvertebrate surveys were done on July 22, 2010 and July 26, 2010. Catch per unit effort (CPUE) was two dip net samples across 1m. One unit effort was conducted in one site on each survey day; Each CPUE consisted of one sampling at the middle of pool and one at the edge of the pool. Shannon diversity index for macroinvertebrates was calculated with Microsoft Excel template provided by Amy Schrank, instructor of Rivers, Lakes and Wetlands at UMBS.

Results

VP1 was the biggest pool in term of perimeter and estimated surface area (Table 1). VP1 also had the deepest water. VP3 was smallest in estimated surface area but deeper than VP2. Maximum depth on second visit was 38m for VP1, 13.5m for VP2 and 28m for VP3.

Site	Maximum length (m)	Maximum width (m)	Perimeter (m)	Estimated area (m^2)	Maximum depth (cm)	Average depth (cm)
VP1	21.05	8.80	57.20	260.36	40.00	34.20
VP2	7.30	6.00	23.60	44.32	14.00	8.10
VP3	7.20	5.90	22.40	39.93	36.00	27.00

Table 1. VP1 was the biggest vernal pool among the sites base on the physical measurements of perimeter and surface area.

Dissolved oxygen ranged from 0.80mg/l to 4.03mg/l and was lowest in VP2 (Fig. 1). All three sites had pH values close to neutral (Fig. 2). Conductivity values were likewise similar though VP1 (285.9µs) was higher than VP2 and VP3 (Fig. 3). Alkalinity at all three sites was similar, which ranged from 160.5mg $CaCO_3$/L to 167.5mg $CaCO_3$/L (Fig. 4).

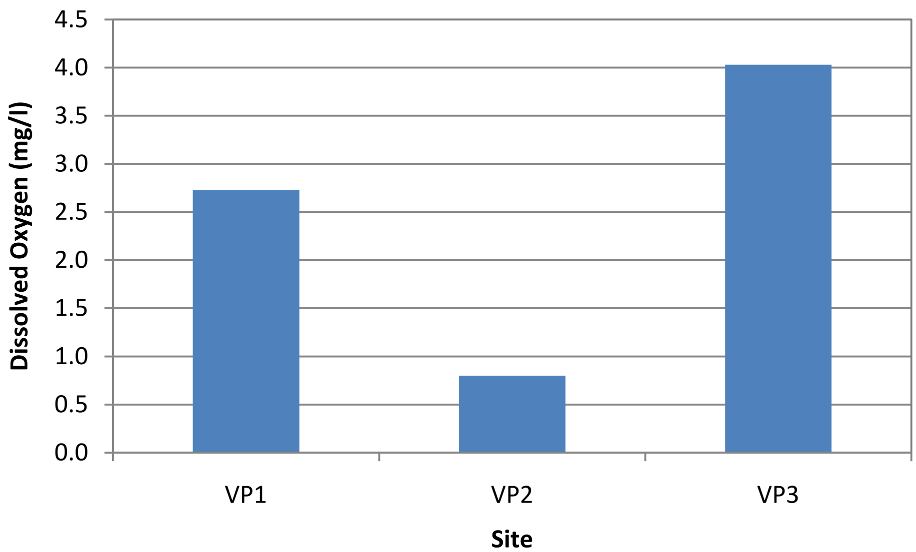

Figure 1. Dissolved oxygen was highest at VP3, followed by VP1 and VP2.

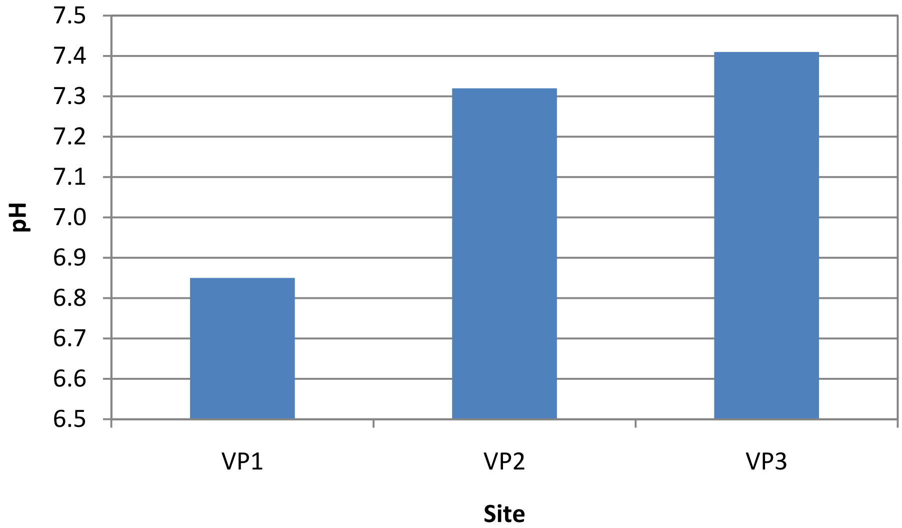

Figure 2. pH value varied across the sites. All sites have pH vales close to neutral.

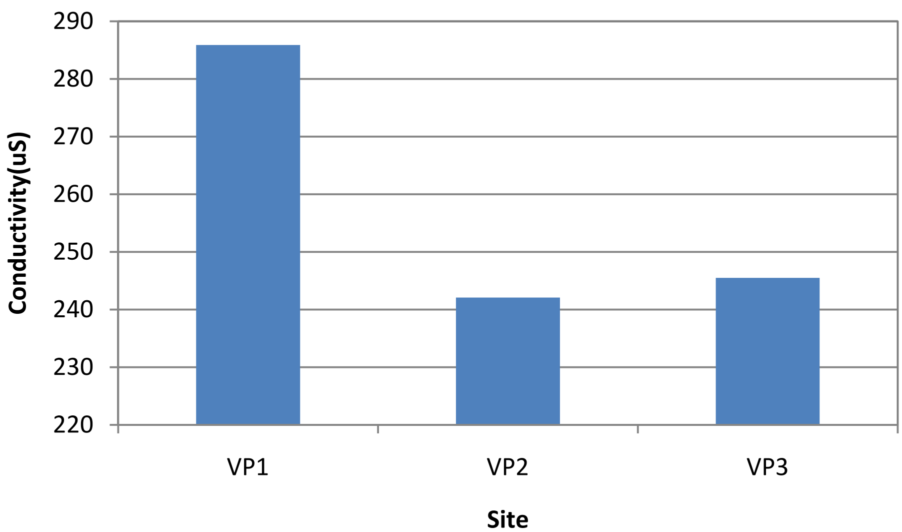

Figure 3. VP1 had relatively higher conductivity than both VP2 and VP3.

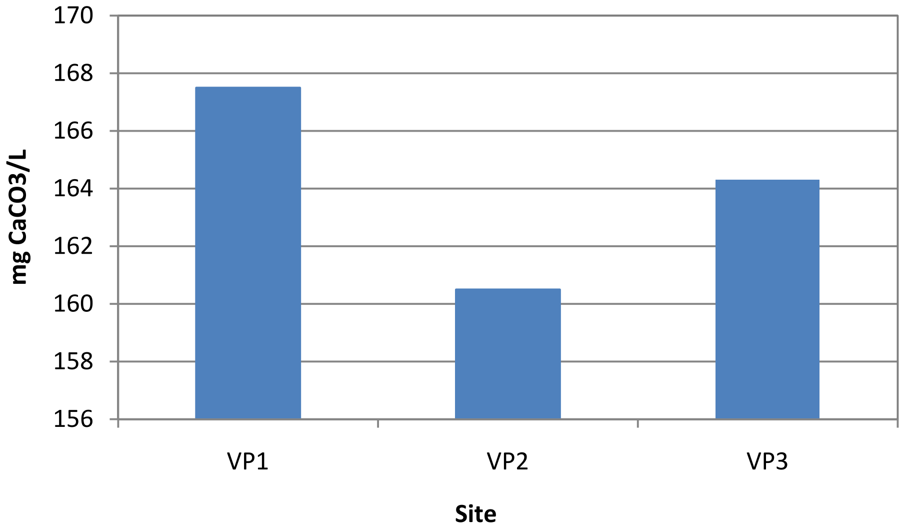

Figure 4. Alkalinity level was similar among the vernal pools. VP1 had relatively higher alkalinity than VP3 and VP2.

Total phosphorous (TP) was similar across the sites with VP3 had relatively higher TP than VP1 and VP2 (Fig. 5; Table 2). Phosphate (PO_4^{3-}) level varied across the sites in which VP1 was comparatively lower than VP2 and VP3. Nitrogen levels patterns were distinguishable in the sampled sites (Figure 6; Figure 7; Table 2). VP1 and VP3 had high total nitrogen (TN), ammonium (NH_4) and nitrate (NO_3^-). VP2 had the lowest nitrogen levels among the sites.

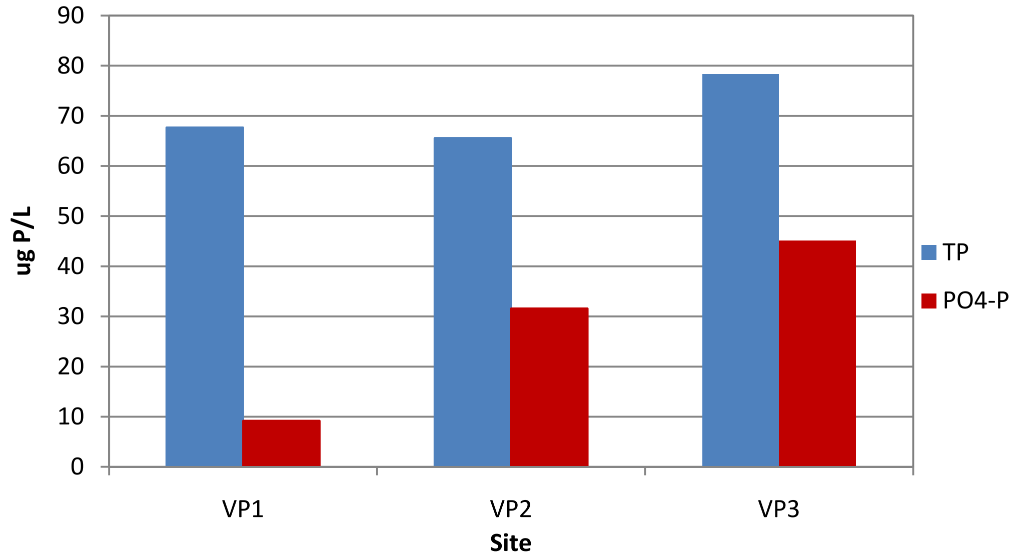

Figure 5. Total phosphorous level was similar at all sites but phosphate level was lowest in site 1 and highest in site 3.

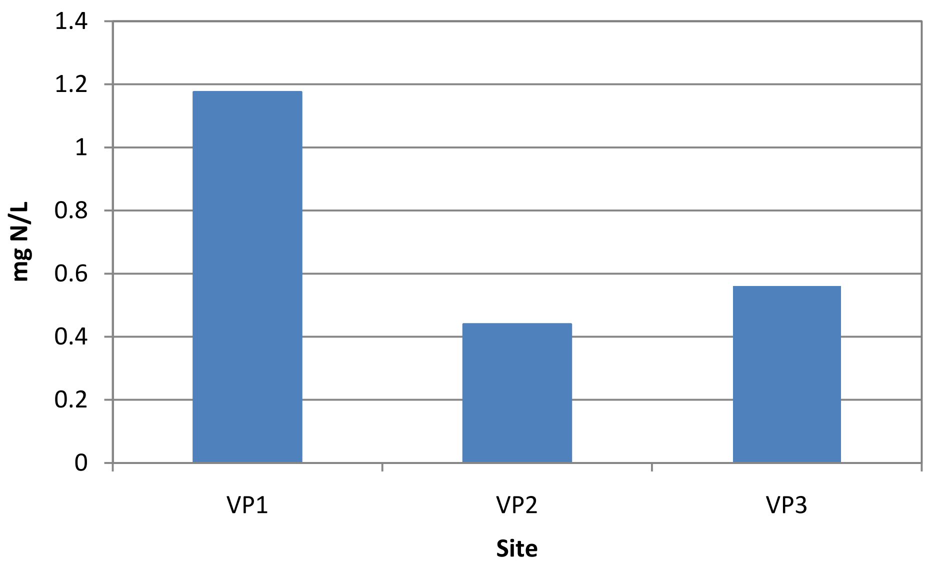

Figure 6. VP1 had the highest total nitrogen followed by VP3 and VP2.

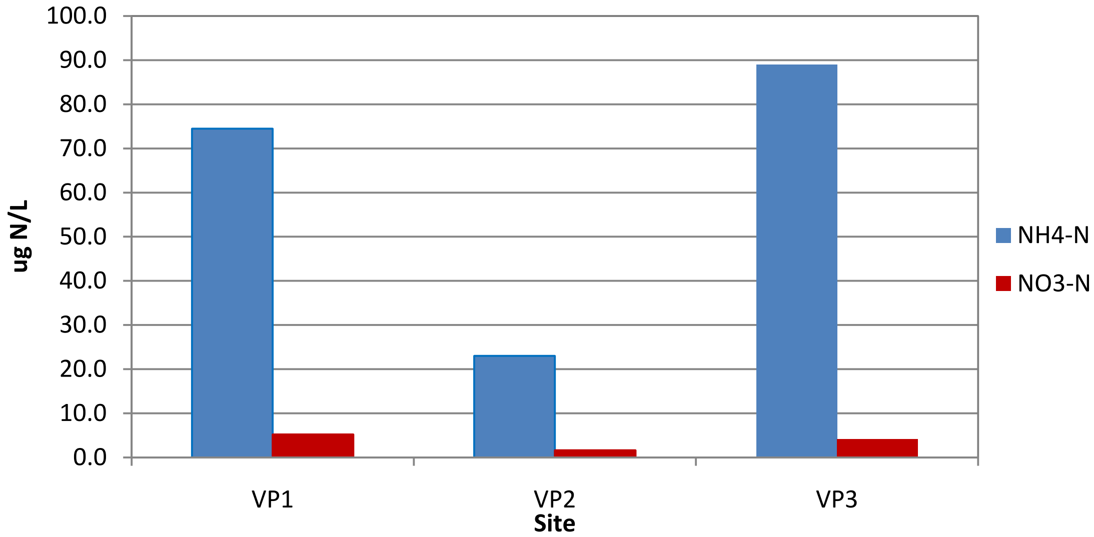

Figure 7. Ammonium level was similar in VP1 and VP3 and comparatively lower in VP2. Nitrate was highest in VP1, followed by VP3 and VP2.

VP1 had the highest chlorophyll-a level in the water but the lowest benthic chlorophyll-a concentration (Table 2). Benthic chlorophyll-a concentration at VP3 was not able to be calculated. Average surface Irradiance was highest at VP1, followed by VP2 and VP3 (Fig. 8). At all sites, surface irradiance at 5pm was relatively higher than other at 9am and 1pm.

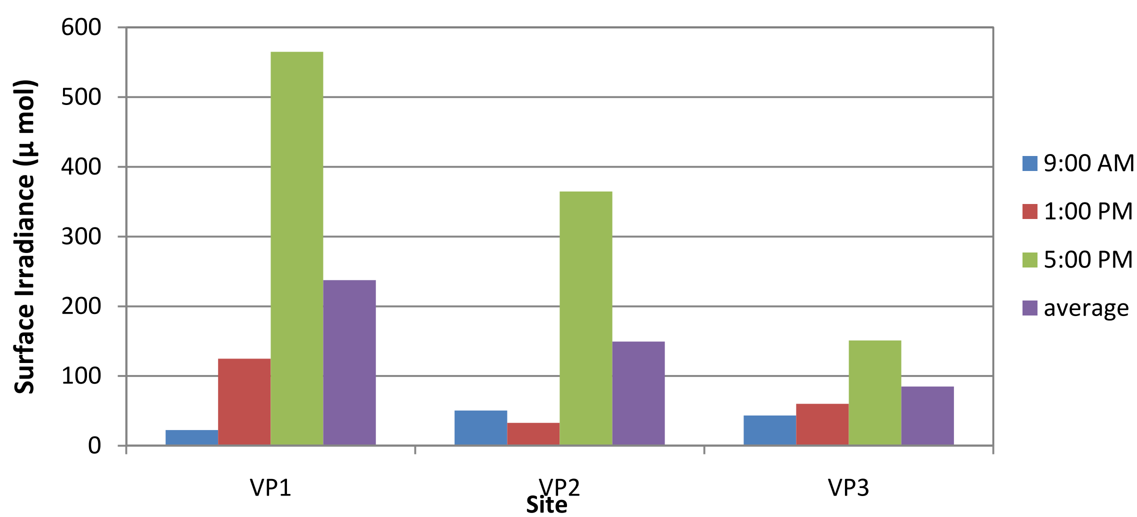

Figure 8. Average surface irradiance was highest at VP1, followed by VP2 and VP3. Surface irradiance was highest at 5pm at all sites.

Site	Total Phosphorous	Phosphate	Total nitrogen	Nitrate	Ammonium	Alkalinity	Water chlorophyll a	Benthic chlorophyll a
	µg P/L	µg P/L	mg N/L	µg N/L	µg N/L	mg CaCO3/L	µg/ L	µg/cm^2
VP1	67.700	9.200	1.176	5.200	74.500	167.500	172.3	0.017
VP2	65.600	31.600	0.440	1.600	23.000	160.500	23.7	0.065
VP3	78.400	45.100	0.560	4.100	89.000	164.300	79.4	*

Table 2. Total phosphorous and alkalinity were similar in all sites. Total nitrogen, nitrate and and ammonium levels were highest at VP1. Phosphate level was highest at VP3. VP1 had the highest chlorophyll-a content in water but lowest benthic chlorophyll-a density. * denotes unavailable calculation for benthic chlorophyll-a density at VP3.

The identified macroinvertebrate families in our dip net samplings include Corydalidae, Lymnaidae, Sphaeriidae, Chironomidae, Hydrophilidae, Limnephilidae and Hydrachnidia (Table 3). There was one unidentified adult aquatic Coleoptera found in site 1 on July 22. The most abundance macroinvertebrates were from the family Lymnaidae, followed by Chironomidae, Sphaeriidae, Hydrophilidae and Limnephilidae. Members from Corydalidae and Hydrachnidia were the lowest with only one individual from each family.

Macroinvertebrate Families	VP1		VP2		VP3	
	Average	Standard error	Average	Standard error	Average	Standard error
Megaloptera - Corydalidae	0.5	0.5	0.0	0.0	0.0	0.0
Gastropoda - Lymnaidae	5.5	0.5	21.5	15.5	10.5	4.5
Sphaeriidae	7.5	2.5	15.5	3.5	0.0	0.0
Diptera - Chironomidae	2.5	1.5	23.5	23.5	4.0	2.0
Coleoptera - hydrophilidae	1.0	1.0	1.0	1.0	0.0	0.0
Coleoptera - Unidentified	0.5	0.5	0.0	0.0	0.0	0.0
Trichoptera - Limnephilidae	0.0	0.0	0.5	0.5	0.5	0.5
Acari – Hydrachnidia	0.0	0.0	0.0	0.0	0.5	0.5

Table 3. The family of macroinvertebrates found in vernal pools using dip net. Average number of family members is also indicating CPUE.

VP1 had the highest macroinvertebrate family richness with average richness of 4.5 families (N=2) (Fig. 9). However, VP2 and VP3 were also close with average richness of 3.5 families (N=2) and 3 families (N=2) respectively. Shannon diversity index varied from 0.83 to 1.37 with VP1 being the most diverse pool (Fig. 10).

Total CPUE was highest at VP2 with 62 macroinvertebrate per two dip nets (Fig. 11). VP1 and VP3 were relatively low in total CPUE compared to VP2. When comparing CPUE of macroinvertebrate families across the site, Lymnaidae, Sphaeriidae and Chironomidae had relatively high CPUE than other families with the exception of Sphaeriidae at VP3 (Fig. 12).

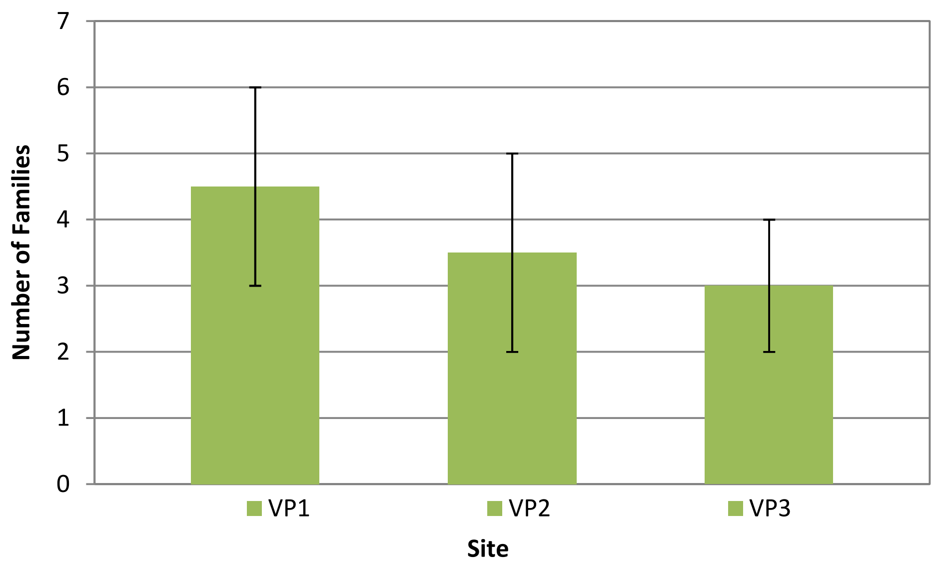

Figure 9. VP1 had the highest family richness, followed by VP 2 and VP3. Values shown are the averages (± 1 SE).

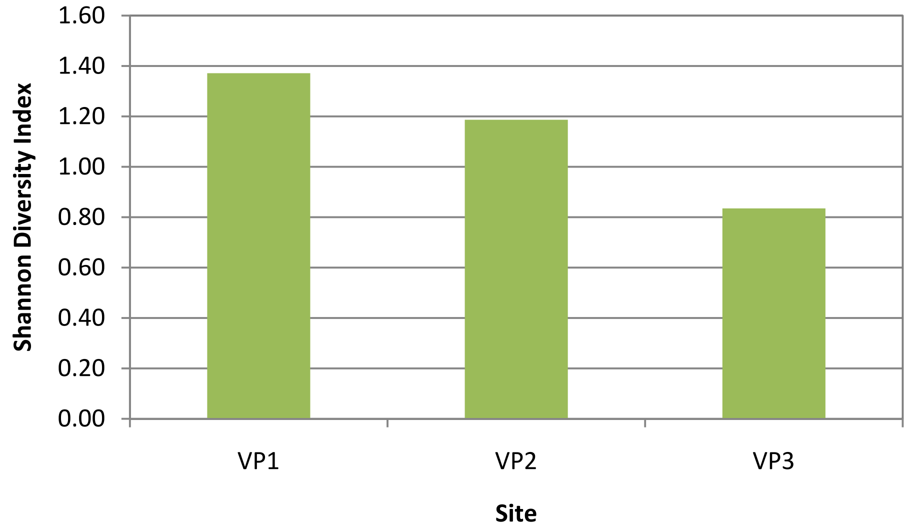

Figure 10. VP1 had the highest diversity index, followed by VP2 and VP3.

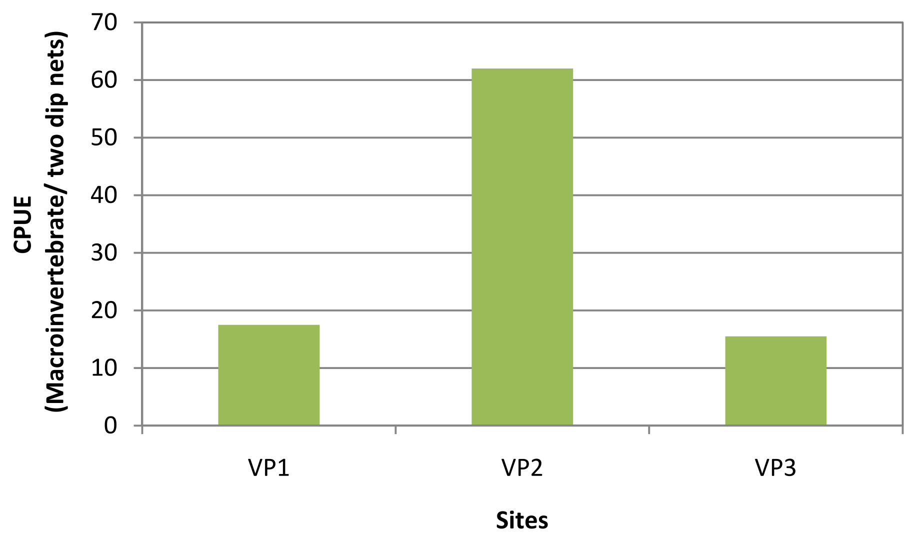

Figure 11. VP2 had the highest CPUE followed by site 1 and site 3.

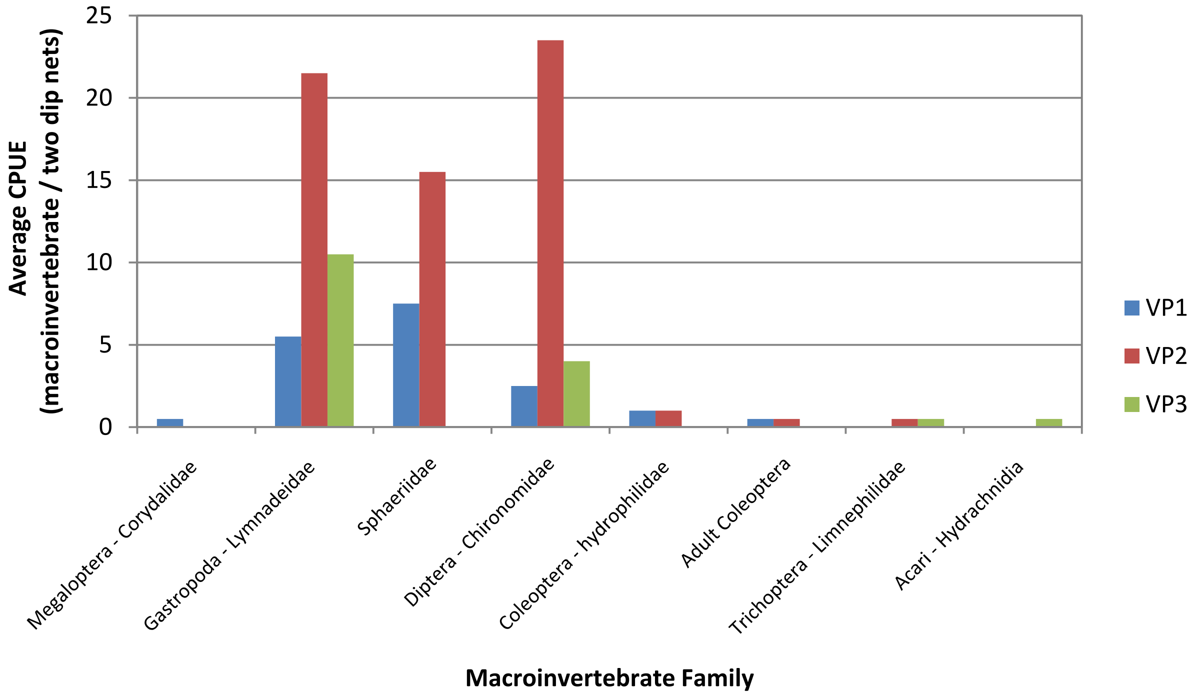

Figure 12. Lymnadeidae, Sphaeriidae and Chironomidae had obvious high CPUE compared to other families. However, Sphaeriidae was not found on VP3.

Wood frog (*Rana sylvatica*) was the most abundant amphibian found around the vernal pools. At VP1, there were two wood frogs, one redback salamander (*Plethodon cinereus)*. At VP2, there were nine wood frogs, two unidentified frogs. No salamander was spotted. At VP3, six wood frogs were found. Additionally, when we were sampling macroinvertebrates with dip net, two unidentified salamander and two tadpoles were found at VP1; two tadpoles were also found at VP2.

Discussion

The vernal pools at Grapevine Point were less than $300m^2$ and thus can be considered as very small in size (Bonner et al. 1997). Vernal pools of smaller sizes were most likely to dry up during drier months in summer. Our observations also indicated the drying of the pools. The deepest depths of all pools have declined on our second visit.

The abiotic features such as DO, conductivity, pH at the vernal pools corresponded to other vernal pools in Ohio, Mississippi and Oklahoma in summer (Carrino-Kyker and Swanson, 2007; Bonner et al. 1997; Boeckman and Bidwell, 2007). On warm summer, dissolved oxygen level is lower due to higher water temperature. In Northern Ohio vernal pools, average DO decreased from 9.05 mg/L in January to 2.19 mg/ L in June (Carrino-Kyker and Swanson, 2007). Our Dissolved oxygen level on site 2 was the lowest and this could be explained by the abundance of macroinvertebrates in the pool. Higher biota abundance requires more oxygen for respiration and thus reduces the pool dissolved oxygen level.

The average conductivity in Northern Ohio vernal pools was 258µs in June (Carrino-Kyker and Swanson, 2007). Although the conductivity range of the pools were on par with the mean conductivity of vernal pools in Ohio, the variation of the conductivity among the pools in grape Vine Points cannot be satisfactory explained. Higher conductivity indicates concentrations of major ions (Wetzel, 1975). At VP2 which had lowest depth, we would expect higher conductivity as the pool dries and concentrate more ions. Higher nutrient waters have higher conductivity (Dodds, 2002); thus at VP1 and VP3 which have higher nitrogen nutrients, conductivity was higher than at VP2 which had lower nitrogen nutrients.

The pH of the pools was close to neutral value. Vernal pools are recharged by acidic rainwater and the pools solely recharged by rainwater would be more acidic (Colburn, 2004); however, primary producers in the pool can reduce carbon dioxide concentrations through photosynthesis and reduce carbonic acid levels thus eventually increases pH (Boeckman and Bidwell, 2007). The pH range of

Grapevine Point vernal pools was also similar to those of Northern Ohio (Carrino-Kyker and Swanson, 2007).

The alkalinity in Oklahoma vernal pools peak at 122mg/L $CaCo_3$ thus alkalinity in Grapevine Point vernal pools was relatively high; this can be attributed to evaporation in summer (Boeckman and Bidwell, 2007). The high alkalinity was the result of accumulation of bicarbonate from the reduction of iron, sulfate, manganese and calcium at the sediments (Scholnick, 1994).

Vernal pools tend to have low nutrient levels that resemble oligotrophic lakes at high elevations and latitudes (Keeley and Zedler, 1998). Nutrients levels and productivity affect species richness in vernal pool habitats (King et al. 1995). Higher nutrients in vernal pool provide abundant resource for the organisms and thus result in less competition among different species, and consequently allow higher species richness. VP1 had the highest TN and NO_3^- levels and high TP and NH_4 levels and thus correlated to higher macroinvertebrate family richness found in our study. Although VP1had the lowest PO_4^{3-}, this could be due to high intake of PO_4^{3-} by phytoplanktons at VP1. VP1 had the highest pool water chlorophyll-a concentration among the three pools and this implied high abundance of phytoplankton at VP1. VP2 had much lower NO_3^- than VP1 and VP3; the fact that VP2 had the lowest DO suggests the denitrification process at VP2 converting more NO_3^- to N_2 that released into the atmosphere.

VP1 had the highest average surface irradiance and this could be due to the fact that VP1 was less shaded. Surface area of VP1 was biggest and thus had more opening area available for sunlight to shine through canopy level. VP2 and VP3 were smaller in surface area and were surrounded by tall trees such as sugar maples and beeches thus less sunlight was able to reach the pool surface.

Moore (1970) found that heavily shaded pools were more likely heterotrophic, supporting little phytoplankton; but exposed pools were autotrophic and rich in phytoplankton. VP1 had highest average surface irradiance and thus had more phytoplankton in the pool. This relationship also can be explained by the relatively high pool water chlorophyll-a level at VP1, which is the indicator for autotrophic algae. The density of benthic algae (Inferred by benthic chlorophyll-a content) was highest at VP2. VP2 had shallowest water among the three pools thus less light attenuation at the bottom; this allows more benthic algae to grow in VP2. We couldn't obtain a positive value for benthic chlorophyll-a content for VP3. This could be due to inaccurate lab determination of chlorophyll-a content as well as due to high fluctuation of algae abundance in the pool water during our sampling days.

All the macroinvertebrates found are common in vernal pools in North America except Corydalidae from the order Megaloptera (Wiggins et al 1980). The existence of Corydalidae can be due to the proximity of the pool to Douglas Lake. Wiggins et al. (1980) described Lymnaeidae and Sphaeriidae as overwintering residents of vernal pools. These families survive dry summer and winter in the pool as drought resistant cysts and eggs. They are able to endure extreme drought and cold conditions, thus explaining their abundance in the pools. Chironomidae and Hydrophilidae are grouped as overwintering spring recruits. Their oviposition requires water on the pool during spring; they survive dry summer and winter mainly as egg or larvae. Limnephilidae's oviposition also requires water and they are able to enter pool basin after surface water disappears; they also overwinter in the dry pool. Hydrachnidia is not an overwintering family and the family enters a vernal pool by migration.

Wood frogs and salamanders are common amphibians in vernal pools. Vernal pools are considered as preferred breeding habitats for salamanders and wood frogs (Brooks, 2004). The lack of predators in vernal pools also makes it a safe habitat for amphibians (Kagan, 2005). In the survey, we had two unidentified frogs; we would predict them to be wood frogs as they were the most common frogs in vernal pools and there was no other frog species identified in this study. The presence of both salamanders and frogs indicate the pools are good habitat for the amphibians.

In short, our surveys of Grapevine Point vernal pools indicate the pools are similar in characteristics with other pools in United States. This study may however best serve as preliminary characterization of Grapevine Point vernal pools. Long term study on the pools should be carried out to explain the trends in physical changes, nutrient contents and other abiotic measurements. Longer study periods also enable us to observe the effects of climate change imposed on vernal pools. Vernal pools also reported to have significant diurnal fluctuations in physicochemical properties (Bonner et al. 1997); thus characterization of vernal pools should also consider the specific time of the day.

References

Boeckman, C. J., & Bidwell, J. R. (2007). Spatial and seasonal variability in the water quality characteristics of an ephemeral wetland. *Proceedings of the Oklahoma Academy of Science, 87*, 45-54.

Bonner, L. A., Diehl, W. J., & Altig, R. (1997). Physical, chemical and biological dynamics of five temporary dystrophic forest pools in central Mississippi. *Hydrobiologia, 353*, 77-89.

Brooks, R. T. (2000). Annual and seasonal variation and the effects of hydroperiod on benthic macroinvertebrates of seasonal forest ("vernal") ponds in central massachusetts, USA. *Wetlands, 20*(4), 707-715.

Brooks, R. T. (2004). Weather-related effects on woodland vernal pool hydrology and hydroperiod. *Wetlands, 24*(1), 104-114.

Carey, C and M. A. Alexander (2003). Climate change and amphibian decline: is there a link? *Diversity and Distributions, 9*, 111-121.

Carrino-Kyker, S. R., & Swanson, A. K. (2007). Seasonal physicochemical characteristics of thirty northern ohio temporary pools along gradients of GIS-delineated human land-use. *Wetlands, 27*(3), 749-760.

Colburn, E. A. 2004. Vernal Pools. Natural History and Conservation. The McDonald and Woodward Publishing Company, Blacksburg, VA, USA.

Dodds, W. K. (2002). *Freshwater ecology: Concepts and environmental applications*. San Diego: Academic Press.

Homan, R. N., Windmiller, B. S., & Reed, J. M. (2004). Critical thresholds associated with habitat loss for two vernal pool-breeding amphibians. *Ecological Applications, 14*(5), 1547-1553.

Keeley, J. E., and P. H. Zedler (1998). Characterization and global distribution of vernal pools. p. 1–14. In Carol C. Witham (ed.) Vernal Pool Ecosystems. California Native Plant Society, Sacramento, CA, USA.

Kangas, M. (2005). Review: Vernal pools: A little known but critical habitat. *Frontiers in Ecology and the Environment, 3*(5), 286.

King, J. L., Simovich, M. A., & Brusca, R. C. (1996). Species richness, endemism and ecology of crustacean assemblages in northern california vernal pools. *Hydrobiologia, 328*(2), 85-116.

Moore, W.G. (1970). Limnological studies of temporary ponds in southeastern Louisiana. *Southwestern Naturalist, 15*(1)*,* 83-110.

Scholnick, D. A. (1994). Seasonal variation and diurnal fluctuations in ephemeral desert pools. *Hydrobiologia, 294*(2), 111-116.

Wetzel, R.G. 1975. Limnology. W.B. Saunders Company, Philadelphia,PA, USA.

Wiggins, G. B., Mackay, R. J., & Smith, I. M. (1980). Evolutionary and ecological strategies of animals in annual temporary pools. *Archiv Fuer Hydrobiologie Supplement, 58*(1-2), 97-206.

Zedler, P. H. (2003). Vernal pools and the concept of "isolated wetlands". *Wetlands, 23*(3), 597-607.

Map 1. Location of Grapevine Point vernal pools.