Macroinvertebrate Community Structure and Physicochemical Conditions of Three Southeastern Oklahoma Springs

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Abstract: Pontotoc Ridge Nature Preserve (PRNP) is located in southeastern Pontotoc County, Oklahoma. This area consists of 2,900 acres of assorted vegetation with several springs, all of which emerge from the Arbuckle-Simpson Aquifer. Three springs, two located within the Nature Preserve and one on adjacent property, were surveyed during this study. Aquatic macroinvertebrates and physicochemical data were collected on a seasonal basis, beginning January 2011 and ending January 2012. With the exception of 16 dissolved oxygen readings and six orthophosphate readings, the physicochemical data meet standards that support and allow for aquatic life. A total of 127,048 individuals, representing 114 taxa, were collected throughout the course of this study. Smith Spring was the most diverse with an average of 44.8 taxa, followed by Canyon Spring with an average of 32.4 taxa, and Cave Spring with an average of only 21 taxa. Canyon Spring was the most populated (84,339 individuals), followed by Smith Spring (38,837 individuals), and Cave Spring (3,873 individuals). The April 2011 collection contained both the largest number of individuals, 34,368, as well as the highest number of taxa, 74, found. Sorenson’s similarity indices for combined collections between springs were similar, with the average indices above 0.425. Similarity indices for comparisons between upper and lower collection sites were lower, with average indices no greater than 0.349. Shannon’s species diversity values were generally under 2.0, with a few exceptions in Cave Spring and Smith Spring, having averages no greater than 1.785. The results of this investigation indicate these springs are in nearly pristine condition and they play an important role in the Pontotoc Ridge ecosystem.

Introduction

Springs are described as naturally occurring sources of emerging groundwater that have unique properties unto themselves, such as discrete habitats with relatively constant conditions (van der Kamp 1995). Although they are limited in terms of their dimensions and do not have homogeneous environments (Cantonati et al. 2006), they have been described as having mosaic structures that have the potential to support numerous microhabitats (Springer and Stevens 2008). Due to this and the relative consistency of groundwater conditions, springs often support a very dense and diverse fauna (Lock and Williams 1981).

Although springs display unique and interesting ecosystems, studies of macroinvertebrate communities in these environments have been scarcely conducted in the United States and even fewer have taken place in Oklahoma. An investigation by Matthews et al. (1983) examined whether macroinvertebrate compositions could be useful indicators of groundwater quality, but this proved unsuccessful, as similarity values between the springs were very low. Varza and Covich (1995) concluded macroinvertebrate abundance varied in Buckhorn Spring, most likely due to limited food availability and predation by crayfish. Bass (2000) reported 39 taxa of macroinvertebrates from a one-time sampling effort in two springs of the Pontotoc Ridge Nature Preserve (PRNP) during 1995. Gaskin and Bass (2000) sampled seven springs across the state to establish any potentially occurring patterns and make inter-spring faunal comparisons. Their data suggested that an exclusive spring fauna was not present and the organisms were directly correlated to microhabitat availability. A macroinvertebrate community structure study conducted by Rudisill and Bass (2005) in Roman Nose State Park springs yielded 21,268 individuals, representing 64 taxa, with most individuals belonging to the order Diptera.

The PRNP is located in southeastern Pontotoc County, Oklahoma (Figure 1). It consists of 2,900 acres of assorted cross-timber and prairie vegetation, and limestone outcrops are quite common. Several springs and seeps are also located in and near the preserve, each draining from the Arbuckle-Simpson Aquifer (J. A. Tucker, pers. comm.). Because a number of years had passed since Bass (2000) initially investigated some of these springs, an extensive survey that included additional springs was requested by the PRNP to compare the macroinvertebrate community composition and determine the overall environmental condition of its springs.

This current investigation involves the two springs previously studied by Bass (2000) and a nearby spring located on a privately owned parcel of land adjacent to and immediately north of PRNP. Almost 16 years had passed since the initial survey was conducted in 1995 (Bass 2000), so a year-long study was done to gather additional information. Purposes of this investigation were to 1) determine the macroinvertebrate community composition of the springs, 2) compare macroinvertebrate community composition between the springs, 3) compare composition these communities to previously collected data on these and other springs, and 4) determine the water quality of the Pontotoc Ridge springs.

Methods

Aquatic macroinvertebrates were collected and physicochemical conditions were measured on a seasonal basis from January 2011 to January 2012 (January 2011, April 2011, July 2011, October 2011, and January 20112). The three study springs, Cave Spring, Smith Spring, and Canyon Spring, are all classified as rheocrene springs; flowing springs that emerge into one or more stream channels (Springer and Stevens 2008). Cave Spring is also classified as a true cave spring, which is a spring whose emergence comes from entirely

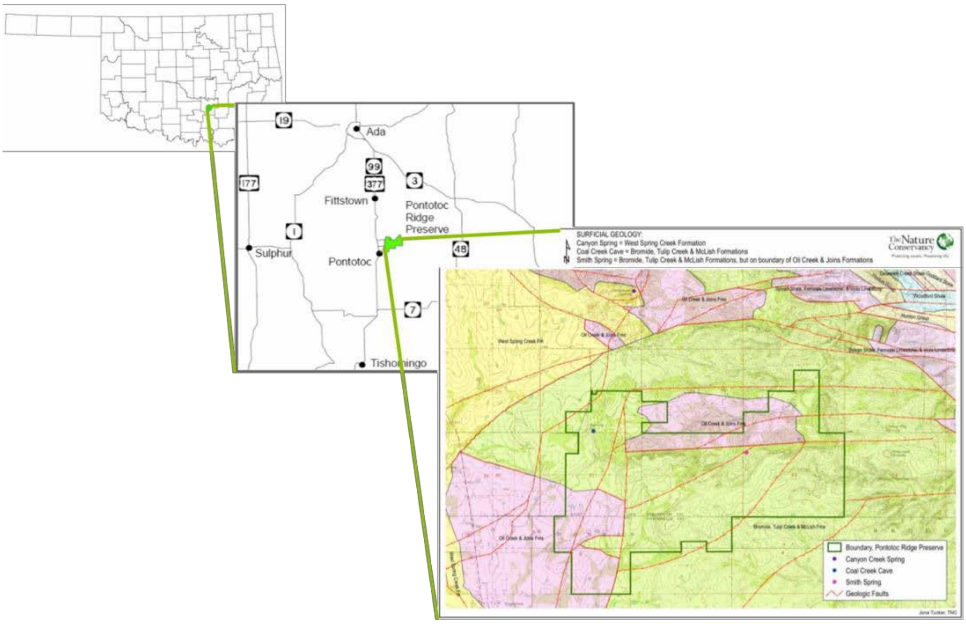

Figure 1. Pontotoc Ridge Nature Preserve, OK.

within a cave environment and is not directly connected to surface flow (Springer and Stevens 2008).

Two sampling sites (head and downstream) were established within each spring, where three Surber net samples were collected from each. Qualitative samples were also collected, using dip nets, to capture taxa potentially missed by the Surber net. All samples were washed through a number 60 (0.250mm) U.S. standard sieve bucket, and preserved with a 10% mixture of formalin and Rose Bengal dye. The preserved macroinvertebrates were returned to the laboratory to be sorted, identified, and counted. Identification of macroinvertebrates was determined using keys by Merritt et al. (2008), Pennak (1989), Epler (1995), and Wiederholm (1983).

Sorenson's index (Chao et al. 2006) of similarity was used to make comparisons between each collection period, combined collections for each spring, and comparisons made between the previous study conducted by Bass (2000) on Cave Spring and Smith Spring to the current study. Shannon's diversity index (Gotelli and Ellison 2004) was calculated for lower collection sites, upper collections sites, and combined collection sites for each spring for each collection period. Multi-Response Permutation Procedure (MRPP) was used to compare the species composition between the head and downstream areas and species composition between each spring. Calculations were conducted using the program 'R' (R Core Team 2013). Rarefaction curves were also generated to evaluate species richness between the head and downstream as well as richness seen between each spring (Gotelli & Entsminger 2000).

Physicochemical conditions such as temperature, dissolved oxygen, and pH were measured at both collecting sites within the spring, while alkalinity was measured only at the head. A water sample collected from the head of each spring was used to determine turbidity, conductivity, and concentrations of ammonia, nitrites, nitrates, and orthophosphates (Hach 2005) in the laboratory. Results from the analysis of physicochemical conditions in the water would indicate if its quality would be sufficient to support a diverse biota.

Results

Macroinvertebrates

A total of 127,048 individuals, representing 114 taxa, were collected over the course of the study (Table 1). Non-hexapods were the most abundant macroinvertebrate group collected with a total of 87,675 individuals, represented by 21 taxa (19.13%) and comprising 69% of macroinvertebrates collected. The amphipod, *Hyalella azteca* complex, was the most numerous non-hexapod with a total of 76,529 individuals, representing 60.24% of all individuals. Although non-hexapods represented 69% of all individuals, hexapods were represented by 93 taxa, which was 80.86% of taxa diversity.

The highest hexapod diversity was seen within the dipterans, comprised of 44 taxa (47.31% of hexapods) and having a total of 31,518 individuals, representing 80.05% of hexapods and 24.81% of all macroinvertebrates collected throughout the course of the study.

The highest number of individuals collected was from Canyon Spring, with a total of 84,399, representing 66.38% of all individuals collected, and a total of 38 taxa were identified. Canyon Spring was dominated by the amphipod *Hyalella azteca* complex with a total of 76,515 individuals collected over the entire study. Only 5,695 individuals were hexapods, the most abundant being trichopterans, with an individual count of 3,168, followed by dipterans, having a total of 2,178 individuals.

Smith Spring had a total of 38,837 individuals, representing 30.57% of all individuals collected throughout the course of the study. This spring was dominated by hexapods, with a total of 32,144 individuals, and was also the most species rich of the three springs with a total of 92 taxa collected. Dipterans were the most numerous group, with a total of 31,518 individuals and 37 taxa. The remaining hexapod groups comprised only 11.94% of individuals. Oligochaetes were the most numerous non-hexapod group collected with a total of 2,413 individuals, followed by nematodes and platyhelminths, each comprising around 20%

Table 1. Percent composition of total individuals for each taxon found in qualitative collections.

Taxon	Cave		Smith		Canyon		All	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Turbellaria								
Dugesia sp.	26	0.671	1432	3.687	1718	2.037	3176	2.500
Nematoda								
Unknown Nematoda	136	3.511	1387	3.571	45	0.053	1568	1.234
Oligochaeta								
Lumbriculus sp.	13	0.336	265	0.682	83	0.098	361	0.284
Limnodrilus sp.	179	4.622	2148	5.531	235	0.279	2562	2.017
Gastropoda								
Gyraulus sp.	0	0	0	0	0	0	0	0
Physa sp.	99	2.556	9	0.023	0	0.0000	108	0.085
Pelecypoda								
Unknown Pelecypoda	1	0.026	639	1.645	11	0.013	651	0.512
Sphaeriidae	0	0	25	0.064	4	0.005	29	0.023
Sphaerium sp.	0	0	114	0.294	20	0.024	134	0.105
Copepoda								
Cyclopoida	81	2.091	572	1.473	3	0.004	656	0.516
Ergasilus sp.	0	0	1	0.003	0	0	1	0.001
Harpacticoidia	1780	45.959	74	0.191	0	0	1854	1.459
Isopoda								
Unknown Isopoda	0	0	2	0.005	0	0.000	2	0.002
Caecidotea sp.	2	0.052	13	0.033	10	0.012	25	0.020
Amphipoda								
Hyallela azteca	5	0.129	9	0.023	76515	90.726	76529	60.236
Decopoda								
Unknown Decapoda	7	0.181	0	0	0	0	7	0
Astacidae	1	0.026	0	0	0	0	1	0
Cambaridae	0	0	1	0.003	0	0.000	1	0.001
Cambarinae	8	0.207	0	0	0	0	8	0
Acarina								
Sperchonpsis verrucosa	0	0	1	0.003	0	0.000	1	0.001
Collembola								
Corynothrix sp.	0	0	14	0.036	0	0.000	14	0.011
Isotomidae	0	0	2	0.005	0	0.000	2	0.002
Spinactalets sp.	0	0	8	0.021	0	0.000	8	0.006

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Ephemeroptera								
Unknown Ephemeroptera	1	0.026	277	0.713	2	0.002	280	0.220
Baetidae	0	0	0	0	3	0	3	0
Baetis sp.	8	0.207	272	0.700	30	0.036	310	0.244
Stenonema femoratum	0	0	0	0	1	0	1	0
Leptohyphidae	0	0	553	1.424	86	0.102	639	0.503
Tricorythodes sp.	0	0	10	0.026	28	0.033	38	0.030
Paraleptophlebia sp.	21	0.542	0	0	0	0	21	0
Odonata								
Unknown Odonata	0	0	90	0.232	13	0.015	103	0.081
Anisoptera	0	0	1	0.003	0	0.000	1	0.001
Aeshnidae								
Tricanthagyna sp.	0	0	0	0	0	0	0	0
Cordulegastridae								
Cordulegaster sp.	0	0	1	0.003	0	0.000	1	0.001
Neurocordulia sp.	0	0	0	0	2	0	2	0
Zygoptera	0	0	127	0.327	0	0.000	127	0.100
Calopteryx sp.	1	0.026	3	0.008	0	0.000	4	0.003
Hetaerina sp.	0	0	4	0.010	2	0.002	6	0.005
Coenagrionidae	0	0	2	0.005	0	0.000	2	0.002
Argia sp.	0	0	743	1.913	176	0.209	919	0.723
Archilestes sp.	0	0	1	0.003	0	0.000	1	0.001
Lestes sp.	0	0	6	0.015	0	0.000	6	0.005
Plecoptera								
Pteronarcella sp.	2	0.052	0	0	0	0	2	0
Pteronarcys sp.	1	0.026	0	0	0	0	1	0
Hemiptera								
Corixidae	0	0	1	0.003	0	0.000	1	0.001
Glaenocorisa sp.	0	0	1	0.003	0	0.000	1	0.001
Graptocorixa sp.	0	0	1	0.003	0	0.000	1	0.001
Trepobates sp.	0	0	3	0.008	0	0.000	3	0.002
Rhagovelia sp.	0	0	0	0	1	0	1	0
Tricoptera								
Helicopsyche sp.	2	0.052	701	1.805	3074	3.645	3777	2.973
Hydropsychidae	53	1.368	343	0.883	50	0.059	446	0.351
Hydroptila sp.	0	0	74	0.191	0	0	74	0.058
Ochrotrichia sp.	374	9.657	127	0.327	40	0.047	541	0.426
Nectopsyche sp.	0	0	0	0	3	0	3	0

Polycentropes sp.	1	0.026	4	0.010	0	0.000	5	0.004
Dolophilodes sp.	0	0	0	0	1	0	1	0
Coleoptera								
Dytiscidae	12	0.310	0	0	1	0	13	0
Agabates sp.	0	0	1	0.003	1	0.001	2	0.002
Agabus sp.	7	0.181	7	0.018	0	0.000	14	0.011
Hydrotrupes sp.	0	0	1	0.003	0	0.000	1	0.001
Hygrotus sp.	18	0.465	4	0.010	0	0.000	22	0.017
Laccophilinae	0	0	1	0.003	0	0.000	1	0.001
Helicus sp.	0	0	0	0	0	0	0	0
Ordobrevia sp.	0	0	438	1.128	3	0.004	441	0.347
Peltodytes sp.	0	0	14	0.036	0	0	14	0.011
Tropisternus sp.	0	0	3	0.008	0	0	3	0.002
Diptera								
Atherix sp.	0	0	15	0.039	3	0.004	18	0.014
Empidiae	0	0	6	0.015	0	0.000	6	0.005
Hemerodromia sp.	0	0	70	0.180	0	0.000	70	0.055
Caloparyphus sp.	0	0	3	0.008	18	0.021	21	0.017
Euparyphus sp.	0	0	0	0	9	0	9	0
Myxosargus sp.	0	0	2	0.005	0	0.000	2	0.002
Silvus sp.	0	0	0	0	1	0	1	0
Chrysops sp.	0	0	2	0.005	0	0.000	2	0.002
Tabanus sp.	0	0	0	0	2	0	2	0
Culicoides sp.	4	0.103	168	0.433	189	0.224	361	0.284
Probezzia sp.	17	0.439	272	0.700	4	0.005	293	0.231
Dasyhelea sp.	0	0	1	0.003	0	0.000	1	0.001
Eucorethra sp.	0	0	1	0.003	0	0.000	1	0.001
Ablabesmyia sp.	1	0.026	0	0	0	0	1	0
Cardiocladius sp.	0	0	0	0	1	0	1	0
Chironomus sp.	23	0.594	3	0.008	0	0.000	26	0.020
Corynoneura sp.	695	17.945	532	1.370	504	0.598	1731	1.362
Cricotopus sp.	2	0.052	3	0.008	0	0.000	5	0.004
Cryptochironomus sp.	0	0	46	0.118	19	0.023	65	0.051
Dicrotendipes sp.	74	1.911	11	0.028	30	0.036	115	0.091
Einfeldia sp.	4	0.103	4	0.010	0	0.000	8	0.006
Eukiefferiella sp.	0	0	3	0.008	95	0.113	98	0.077
Heleniella sp.	0	0	215	0.554	0	0.000	215	0.169
Larsia sp.	61	1.575	498	1.282	12	0.014	571	0.449

Microtendipes sp.	47	1.214	6	0.015	0	0	53	0.042
Orthocladius sp.	9	0.232	101	0.260	349	0.414	459	0.361
Parametriocnemus sp.	26	0.671	1335	3.437	76	0.09	1437	1.131
Paraspectra sp.	8	0.207	0	0	0	0	8	0
Paratanytarsus sp.	5	0.129	58	0.149	8	0.009	71	0.056
Paratendipes sp.	0	0	279	0.718	4	0.005	283	0.223
Paratrichocladius sp.	0	0	2	0.005	88	0.104	90	0.071
Phaenopsectra sp.	28	0.723	91	0.234	0	0.000	119	0.094
Polypedilum sp.	0	0	12	0.031	2	0.002	14	0.011
Procladius sp.	0	0	4	0.010	0	0.000	4	0.003
Rheotanytarsus sp.	0	0	5	0.013	28	0.033	33	0.026
Stenochironomus sp.	0	0	21	0.054	0	0.000	21	0.017
Sublettea sp.	0	0	0	0	1	0	1	0
Tanytarsus sp.	25	0.645	24496	63.074	21	0.025	24542	19.317
Thienemannimyia sp.	0	0	13	0.033	6	0.007	19	0.015
Tvetenia sp.	5	0.129	1	0.003	702	0.832	708	0.557
Dixa sp.	0	0	4	0.010	6	0.007	10	0.008
Pericoma sp.	0	0	7	0.018	0	0.000	7	0.006
Protoplasa fitchii	0	0	3	0.008	0	0.000	3	0.002
Tipula sp.	0	0	13	0.033	0	0.000	13	0.010
Totals	3873		38836		84339		127048	

of the non-hexapods collected within Smith Spring. Pelecypods and copepods together comprised 21.31% of individuals, the remaining groups (amphipods, decapods, gastropods, isopods, and acarinids) comprised <1% of individuals collected from Smith Spring.

Cave Spring had both the lowest number of individuals and the fewest taxa of the springs investigated, with only 3,873 individuals and 44 taxa. Non-hexapods were the most abundant group seen with a total of 2,338 individuals, but in terms of diversity, the hexapods were more prominent, having a total of 31 taxa collected. Copepods were the most abundant non-hexapod collected in this spring over the course of the study, with a total of 1,861 individuals, followed by the oligochaetes having a total of 192 individuals. Of the hexapod groups collected, the dipterans were the most diverse group with a total of 16 taxa, and 1,034 individuals, collected. Trichopterans were represented by four taxa and 430 individuals and coleopterans were represented by four taxa and 37 individuals. The remaining hexapod groups (Ephemeroptera, Odonata, and Plecoptera) constituted less than 3% of the remaining individuals collected from Cave Spring.

The April 2011 collection yielded the most individuals, 34,368, as well as the highest diversity. October 2011 was the next most abundant and species rich with a total of 28,299 individuals and 65 taxa, followed by July 2011 (27,509 individuals and 63 taxa), January 2012 (20,814 individuals and 62 taxa), and January 2011 (16,059 individuals and 33 taxa).Cave Spring had the lowest species richness seen throughout the study, while Smith Spring had the highest species richness. The species richness values seen in Cave and Smith Springs were higher, with two exceptions, in the upper collection sites; this is different than species richness recorded in Canyon Spring, which had higher values in the lower collection sites.

The highest species similarity observed (0.822) was in Canyon Spring between the months of April and July 2011 whereas the lowest species similarity value (0.125) was recorded in Cave Spring between the months of January and April 2011. The species similarity for Cave Spring between was highly impacted by drought during much of the year in 2011. Similarity indices between springs showed that Cave Spring and Canyon Spring had the lowest similarity (0.105), seen in the lower collection site, during January 2011. Smith Spring and Canyon Spring had the highest similarity (0.615), observed in the lower collection site, during July 2011.

Species diversity in each spring was calculated for the lower, upper, and combined collection sites. Diversity values ranged from a high of 2.671, in Cave Spring during April 2011, to a low of 0.101 in Canyon Spring during January 2011. Canyon Spring had the lowest overall means, never averaging above 1.00. Cave Spring had the highest overall means, averaging 1.785, while Smith Spring had overall means of 1.571.

A significant difference in community composition was observed between the head and downstream regions (mrpp, p=0.005) as well as between Cave Spring, Canyon Spring, and Smith Spring (mrpp, p=0.001).

Comparisons of taxa similarity were made between Cave Spring and Smith Spring from the 1995 (Bass 2000) survey to Cave Spring and Smith Spring from the current survey. Cave Spring had a similarity value of 0.286 and Smith Spring had a similarity value of 0.333 between the two investigations.

Physiochemical Conditions

The overall water quality of each spring system, with a few exceptions, falls well within the standards that support and allow for aquatic life (Table 2). Water temperatures were fairly constant for two of the three springs (Smith Spring and Canyon Spring) sampled in the study, ranging from 17.2C to 20.4C. Cave Spring's temperature measurements varied more, with readings from 13.5C to 19.5C.

The dissolved oxygen concentration ranged from a minimum of 1.4 mg/L (Canyon Spring in October 2011) to a maximum of 7.6 mg/L (Cave Spring in January 2012). D.O. concentrations were, with one exception, higher at the downstream sites. The percent dissolved oxygen saturation ranged from 26% at Cave Spring (upstream) during April 2011 to 75% at Cave Spring (downstream) during January 2012.

Free carbon dioxide values varied throughout the springs, ranging from 0.0 mg/L to 38mg/L (Table 2). The pH varied minimally throughout the collection period, with a range of 7.1 (Canyon Spring in April 2011) to 8.0 (Cave Spring in January 2012). Values were typically lower at the head and higher downstream, with three exceptions. Alkalinity values ranged from 248 mg/L (Smith Spring in January 2012) to 334 mg/L (Canyon Spring in July and October 2011).

Turbidity readings varied little. All 13 readings were <0.02 JTU, with four of the 13 readings recorded as zero JTU (Appendix 1G). The lowest readings were seen in Cave Spring, during January and April 2011, while Canyon Spring had readings almost always near 100%T, a turbidity value of zero. Conductivity readings varied greatly, ranging from 328 umhos/cm (Smith Spring in January 2012) to 906 umhos/cm (Canyon Spring in July 2011).

Nutrient values were generally low. Ammonia readings varied little, ranging from 0.093 mg/L (Canyon Spring in January 2011) to 0.177mg/L (Smith Spring in January 2012). Nitrate readings ranged from a low of 0.252mg/L (Cave Spring in January 2011) to a high of 0.779mg/L (Smith Spring in January 2012), with one sample being recorded as under measuring range. Orthophosphates varied greatly throughout the collection period. Of the thirteen readings, four were under measuring range and three were recorded as negative numbers. Of the remaining six values, Cave Spring had the lowest value at 0.109 mg/L during January 2011 and Smith Spring had the

Table 2. Physiochemical ranges of Cave Spring, Smith Spring, and Canyon Spring January 2011 - January 2012.

Site	Cave Spring		Smith Spring		Canyon Spring	
	Upper	Lower	Upper	Lower	Upper	Lower
Water Temperature (°C)	16.4-17.5	4.6-7.6	17.3-17.9	17.2-20.4	18.6-19.3	18.3-19.9
Dissolved Oxygen (DO) (mg/l)	2.6-6.5	47-75	2.7-6.0	3.8-6.3	1.4-1.6	4.5-4.9
Percent DO Saturation	26-67	7.3-8.0	28-62	41-64	14-17	45-57
pH	7.3-7.7		7.3-7.9	7.3-7.7	7.1-7.5	7.4-7.6
Free Carbon Dioxide (mg/l)	<10-37		<10-29		16-38	
Alkalinity (mg/l)	289-330		248-300		309-334	
Turbidity (JTU)	<0.02		<0.02		<0.02	
Conductivity (µmhos/cm)	400-539		328-455		568-906	
Ammonia (mg/l)	0.097-0.161		0.094-0.177		0.093-0.168	
Nitrites (mg/l)	UMR		UMR		UMR	
Nitrates (mg/l)	0.252-0.747		0.280-0.779		0.364-0.558	
Orthophosphates (mg/l)	<0.110		<0.205		<0.165	

highest value of 0.204 mg/L during October 2011.

Discussion

Throughout the course of the study, a total of 127,048 individuals, representing 114 taxa were collected (Table 1). One macroinvertebrate in particular was dominant throughout the study, the amphipod, *Hyalella azteca* complex. This taxon represented 60.24% of all individuals collected during the study. The non-hexapods were the most numerous macroinvertebrates found, comprising 69% of individuals collected, whereas the hexapods represented 31% of individuals collected. The hexapods were more numerous and diverse in terms of taxa, with a total of 93, most of which are represented by members of the order Diptera. Similar findings are seen in other studies that investigate spring macroinvertebrate community composition (Rudisill and Bass 2005; Ilmonen *et al.* 2009; Gaskin and Bass 2000; Bass 2000).

Cave Spring was the least species rich of the three springs, having an overall average of 21 taxa found throughout the study. This lower number is partly due to the drought that caused Cave Spring to cease flow and desiccate during much of the study period. In addition, the substrate of Cave Spring contained fewer microhabitats existing within the spring. Canyon Spring had the next highest species richness value with an overall average of 32.4 taxa, while Smith Spring had the highest overall species richness with an overall overage of 44.8 taxa. Although Smith Spring and Canyon Spring are fairly similar, the landscape immediately surrounding each spring, as well as the chemical composition of the water, may have contributed to the species richness values seen throughout the study.

Temperature, resource and microhabitat availability, low dissolved oxygen levels, and high phosphates levels influenced overall species richness, diversity, and various similarity values calculated. Temperature effects can be clearly seen in Cave Spring, which desiccated during the months of July and October 2011. Although a negative effect of temperature was seen in Cave Spring due to temperature, a positive relationship between temperature and vegetation was seen in Canyon Spring and

Smith Spring. This growth of surrounding terrestrial vegetation during the spring months allowed for more resources and microhabitats, and increased macroinvertebrate densities. There was also a slight rise in the number of individuals and taxa during October 2011; this is thought to be due to the introduction of decomposing vegetation, allowing for a variety of new, or different, microhabitats and food resources to exist within the springs. The success of *Hyalella azteca* complex may be in part due to their ability to survive in environments with such low dissolved oxygen levels (Nebeker et al. 1992), such as those recorded in Canyon Spring.

Comparisons between the survey conducted by Bass (2000) and the current survey indicate a fairly high similarity value, 0.419, between the lower collections sites of Smith Spring. This would suggest that even after such a long time span between collections, the spring habitat and surrounding area has undergone little change, allowing the macroinvertebrate communities to also remain somewhat stable over time. However, a much lower similarity value, 0.286, was found between the collections taken from Cave Spring. This spring was dry for several months, including two of the collection periods during the present investigation. According to J. Tucker (pers. comm.), this happens quite often throughout the year. This reoccurring desiccation of Cave Spring may influence the macroinvertebrate fauna community structure, and over a 16-year period this pattern may have had a large impact. The similarity index of 0.333 between Smith Spring surveys is only slightly higher. A 16-year period between surveys is a large amount of time to pass and other factors will have also had an influence on the macroinvertebrate compositions. Variations in similarity observed within and between each spring community throughout the current study may be primarily attributed to life cycle patterns as well as vegetation within and around each spring that provide various microhabitats and food resources.

Conclusions

The Pontotoc Ridge Nature Preserve is a very important ecosystem in southern Oklahoma. It serves both as a site for various types of research and as an educational resource to the public. The continual study of spring systems within Oklahoma is vital and the springs found within and around the Pontotoc Ridge Nature Preserve are considered as nearly pristine, based on the findings of this investigation. To keep the springs in this area and other areas throughout the state in this nearly pristine condition continued research is important. This research allows for identification and inventory of the macroinvertebrate community and water quality analysis indicating potential groundwater pollution.

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