Journal of the Arkansas Academy of Science

Volume 71 Article 32

2017

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Recommended Citation

Longing, Scott; Mack, L. A.; and Haggard, Brian E. (2017) "Bioassessment of Four Karst Springs at Hobbs State Park – Conservation Area with a Focus on Diving Beetle (Dytiscidae: Hydroporinae) Species of Concern," *Journal of the Arkansas Academy of Science*: Vol. 71, Article 32.
https://doi.org/10.54119/jaas.2017.7130
Available at: https://scholarworks.uark.edu/jaas/vol71/iss1/32

Bioassessment of Four Karst Springs at Hobbs State Park – Conservation Area with a Focus on Diving Beetle (Dytiscidae: Hydroporinae) Species of Concern

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Running Title: Bioassessment of Springs at Hobbs State Park Conservation Area

Abstract

Four springs were surveyed at Hobbs State Park-Conservation Area to provide an initial bioassessment and to determine occurrences of two endemic predaceous diving beetles of concern, *Heterosternuta sulphuria* and *Sanfilippodytes* sp. Habitat in the four spring runs were dominated by bedrock and gravel substrate with heavy accumulations of leaf litter. Thirty-three taxa representing 11 orders were collected from the four springs. Non-insect taxa included Oligochaeta, Physidae, and Isopoda, and predominant insect orders included Ephemeroptera, Coleoptera, Diptera, and Trichoptera. The total number of taxa across springs ranged from seven to 19, with total abundances ranging from 39 to 86 individuals. No individual taxon occurred across all four springs. Percent tolerant organisms and the Hilsenhoff Biotic Index showed that spring communities were dominated by taxa tolerant to organic pollution, likely because of low flows and heavy accumulations of leaves. Predators were the dominant functional group followed by shredders. The endemic, predaceous diving beetle *Heterosternuta sulphuria* was collected from two springs and *Sanfilippodytes* sp. was collected from three springs. One spring contained the largest number of *Sanfilippodytes* sp. individuals recorded among all other aquatic habitats surveyed to date. Findings highlight the importance of spring systems at Hobbs State Park Conservation Area for endemic-species conservation, while information on the invertebrate community provides a baseline for future monitoring and comparison.

Introduction

The karst geology of the Ozark Mountains of the U.S. Interior Highlands is the foundation of a landscape thriving with surface and subsurface aquatic habitats. Allen (1990) noted that the Ozarks likely have been a permanent fixture on the landscape for over 300 million years, providing island refugia for organisms when the region was surrounded by ancient seas. Numerous endemic organisms occur in the region and many of these are aquatic species occurring in surface and subterranean aquatic habitats (Robison *et al*. 2008). Perennial aquatic habitats such as freshwater springs are important components of these systems, providing both hydrologic connectivity and flow permanence to support populations when other water sources become unavailable as a result of stream drying (Roughley and Larson 1991; Erman and Erman 1995; Williams and Williams 1998; Smith and Wood 2002). Understanding habitat conditions and biota of these systems is essential for conservation and long-term monitoring.

Aquatic invertebrates contribute to the natural processes of freshwater systems, including nutrient cycling, decomposition, regulation of primary production rates and water clarity (Wallace and Webster 1996). However, aquatic invertebrate communities are exposed to major environmental stressors that threaten biodiversity and these natural processes (Strayer 2006). Some groups of aquatic insects that depend on high-quality habitats in upland streams, such as numerous stoneflies, are considered highly imperiled in the U.S. (DeWalt *et al.* 2005).

Freshwater bioassessment provides a means to summarize the conditions and evaluate the health of aquatic communities in relation to reference (i.e. least-affected) conditions or known responses to environmental stressors (Resh and Jackson 1993). Typically, *metrics* are calculated that summarize benthic macroinvertebrate communities (e.g. species richness or percent predators). Assemblage metrics can be used to both document initial conditions and to monitor potential changes in conditions over time. In mountainous regions where small, wadeable streams

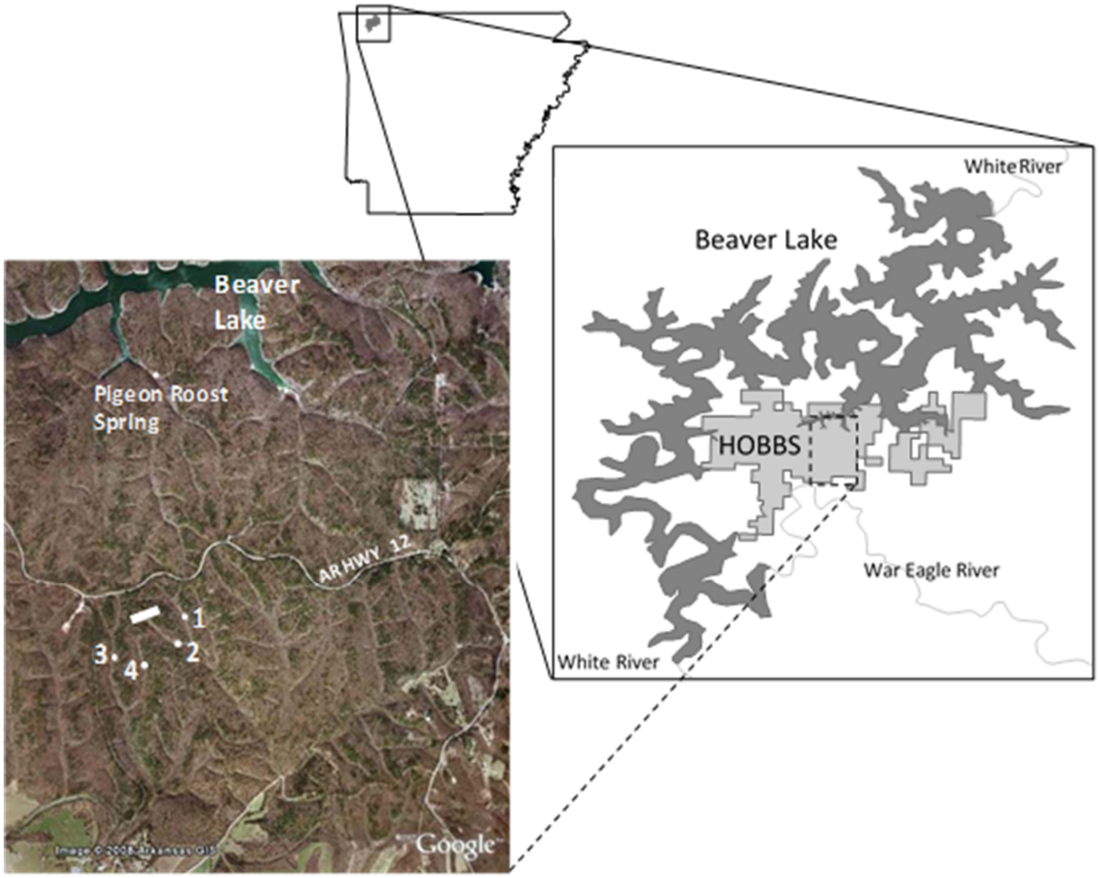

Figure 1. Hobbs State Park-Conservation Area in northwest Arkansas showing the location of the four springs where bioassessments were conducted (springs 1 - 4) and the spring where *H. sulphuria* was first collected at HOBBS, at the terminus of Pigeon Roost trail. Location of the visitors center is shown as a white rectangle.

dominate as a result of the dendritic pattern of stream networks, bioassessment is an effective tool for concurrently surveying multiple streams by both researchers and volunteer-monitoring groups (Engel and Voshell 2002).

Hobbs State Park Conservation Area (HOBBS) comprises 4,874 ha within the Springfield Plateau, a subdivision of the Ozark Highlands Ecoregion (Arkansas Department of Parks and Tourism 2008, Woods *et al*. 2004) (Fig. 1). The region is underlain with cherty limestone from the Mississippian Boone formation. The limestone is highly soluble and has eroded over time, forming many karst features including underground drainage, caves, springs, springbrooks, seeps, disappearing streams, and sinkholes. The moderate topographic relief consists primarily of limestone glades and narrow ridges divided by steep hollows that are vegetated by an upland forest of pine, oak and hickory (Woods *et al*. 2004). One-third of the HOBBS perimeter is in contact with Beaver Lake, the region's 11,480-ha primary source of drinking water. In 1979 land was acquired and legislation enacted to create HOBBS with the mission "to provide enriching educational and recreational experiences in harmony with resource stewardship" (Friends of Hobbs State Park-Conservation Area 2004). HOBBS is jointly managed by the Arkansas Game and Fish Commission, Arkansas State Parks, and the Arkansas Natural Heritage Commission.

During a previous survey of a single spring at HOBBS, we documented the occurrence of two diving beetles, the Ozark-endemic *Heterosternuta sulphuria* Matta and Wolfe and another diving beetle in the genus *Sanfilippodytes* Franciscolo (Longing and Haggard 2009). *Heterosternuta sulphuria* is a species of concern in the Arkansas Wildlife Action Plan (Anderson 2006). Additional occurrences of these species have been further documented from regional streams and springs in the region (Longing *et al*. 2013). Following this initial survey, we selected four additional springs to both document additional occurrences of these diving beetle species of concern and to provide a baseline for further

https://scholarworks.uark.edu/jaas/vol71/iss1/32
DOI: 10.54119/jaas.2017.7130

monitoring. Here, we report those findings to support strategies for conservation aimed at protecting these unique aquatic habitats.

Materials and Methods

Information on springs of HOBBS was reviewed in order to select perennial springs, or springs known to maintain at least some surface water over time. Using historical maps provided by HOBBS superintendent M. Clippinger showing the occurrences of perennial springs, we selected four springs located on opposite sides of 3 adjacent ridges and separated by approximately 500 m (Figure 1, springs 1 - 4). Springs emerged in small, narrow valleys and emptied into spring runs of short lengths (25-100 m) that flowed over limestone bedrock and gravel in narrow channels. The valley slopes were heavily wooded, providing mature canopies that shaded springs. All springs were located in proximity to and immediately south of the HOBBS Visitors Center.

Bioassessments of the four springs were conducted in March 2008. At each spring, the sampling reach was marked by measuring 50 m along the bank with a tape, with the upstream end of the reach located within 5-10 m below the observed spring source or the point of water accumulation. At spring four, the length of the reach did not extend to 50 m, therefore only 25 m was surveyed. Along each reach, wetted widths and water depths were recorded at transects spaced 5 m apart and perpendicular to the channel. From a limited number of locations (i.e. where flows and depths were sufficient for flow-meter measurements) we measured flow velocity and estimated discharge (m^3s^{-1}). At the midpoint of each reach, water temperature (°C), pH, electrical conductivity (EC, $\mu S \cdot cm^{-1}$), and dissolved oxygen (DO, $mg \cdot L^{-1}$) were recorded using a portable YSI 85 meter. Reaches were further characterized by recording dominant and sub-dominate substrate along each transect.

Invertebrate sampling was standardized by collecting invertebrates for 1 hr. from all available habitat types within reaches. D-frame nets (350µm) were used to collect invertebrates by either kicking upstream of the net and letting debris flow through the net or by jabbing the net in habitats where flow velocities were low. We collected from up to approximately 50 percent of the total habitat areas within reaches to avoid over-collecting. Invertebrates were picked from the nets in the field and preserved in 70 percent ethanol in glass vials. Invertebrates were identified to the lowest practical taxonomic level, usually genus (Merritt *et al*. 2007), while predaceous diving beetles were identified to the level of genus or species (Larson *et al*. 2000).

Total number of taxa and total number of individuals for each spring were calculated, in addition to assemblage metrics describing the taxonomic, functional feeding group, habit group and pollution-tolerance of the invertebrate assemblage (Resh and Jackson 1993) (Table 3). Tolerance values were assigned to each taxon using values from Merritt *et al*. (2007). We additionally calculated the Hilsenhoff Biotic Index, a metric that summarizes the tolerance of the invertebrate assemblage to organic pollution weighed by the relative abundance of each taxon, using the following formula (Hilsenhoff 1987):

$$\text{HBI} = \frac{\sum n_i \text{ x } a_i}{\text{N}}$$

Where n = number of specimens in taxon *i*, a = tolerance value of taxon *i* and N = total number of specimens in the sample. A higher HBI represents greater tolerance of the assemblage to organic pollution.

Results

Physico-chemical properties varied across the four adjacent springs (Table 1). Mean depth ranged from 2.9 cm at spring 3 to 5.1 cm at spring 2. Discharge rates were very low; for springs 1, 2, and 4 discharge was estimated to be < 0.02 $m^3 \cdot s^{-1}$ (< 0.5 cfs) while spring 3 had a rate > 0.02 $m^3 \cdot s^{-1}$. Habitat substrate was dominated by bedrock, leaf packs, large and small gravel, and with some bryophytes covering bedrock at channel margins. Conductivity for springs 1 and 2 was 71.2 and 58.2$\mu S \cdot cm^{-1}$, respectively. Conductivity was considerably higher for springs 3 and 4 at 140.6 and 152.4$\mu S \cdot cm^{-1}$, respectively. Dissolved oxygen ranged from 5.36$mg \cdot L^{-1}$ at spring 1 to 9.85$mg \cdot L^{-1}$ at spring 3.

Thirty-three taxa representing 11 orders were collected from the 4 springs (Table 2). Three non-insect taxa collected from the springs were Oligochaeta Physidae, and Isopoda. Insect orders collected included Ephemeroptera, Coleoptera, Diptera, Hemiptera, Megaloptera, Odonata, and Plecoptera. Coleoptera and Diptera were the most diverse insect orders with 7 taxa each. Other insect orders containing multiple taxa included Ephemeroptera (3 taxa), Trichoptera (5 taxa), and Megaloptera (2 taxa). Across the 4 springs, insect orders containing only 1 taxon included Plecoptera, Hemiptera, and Odonata.

Table 1. Physico-chemical properties of four springs at Hobbs State Park-Conservation Area.

Variable	Spring 1	Spring 2	Spring 3	Spring 4
GPS coordinates	N 36°17'05.5" W 93°56'06.6"	N 36°16'58.7" W 93°56'10.1"	N 36°16'57.9" W 93°56'29.4"	N 36°16'55.3" W 93°56'21.5"
Dominant substrate	bedrock	large gravel, leaf packs at margins	bedrock and cobble	bedrock
Sub-dominant substrate	leaf packs on margin	bedrock	large gravel and leaf packs	leaf packs and small gravel
Spring-run length (m)	50	50	50	25
Mean depth (cm)	3.2 (± 3.3)	5.1 (± 2.5)	2.9 (± 3.3)	4.3 (± 3.0)
Bank width (m)	0.5	1.2	2.5	0.5
Discharge (m^3s^{-1})	<0 .02	< 0.02	>0 .02	<0 .02
pH	8.45	7.6	8.23	7.9
Temperature (°C)	12.3	12.2	12.5	11.4
Conductivity ($\mu S\ cm^{-1}$)	71.2	58.2	140.6	152.4
DO ($mg\ L^{-1}$)	5.36	8.12	9.85	7.59

Spring 2 was the most biologically diverse with 19 taxa and spring 4 was the least diverse with 7 taxa. The total number of individuals among springs ranged from 39 (spring 1) to 86 (spring 3). No individual taxa occurred at all 4 springs. Oligochaeta, Physidae, *Zealeuctra, Argia, Sanfilippodytes, Prionocyphon,* and *Tipula* were collected at three of the four springs. Planorbidae, *Caecidotea,* Odontoceridae, *Helicopsyche, Microvelia*, *Chauliodes*, *Heterosternuta sulphuria*, Sphaeridiinae, Tanypodinae, and *Hexatoma* were collected from two springs. *Lirceus*, Baetidae, Leptophlebiidae, *Ameletus*, *Polycentropus, Pycnopsyche, Pseudostenophylax, Sialis, Agabus, Copelatus*, *Optioservus, Ectopria, Ptycoptera,* Tabanidae, *Myxosaurgus*, and Limoniinae were collected from only one spring. Taxa represented by singletons (i.e. only one individual collected) included *Lirceus*, *Polycentropus*, *Pycnopsyche*, *Sialis*, *Copelatus*, *Ptycoptera*, and Limoniinae.

The metric percent EPT (i.e. percent Ephemeroptera, Plecoptera, and Trichoptera) ranged widely among the streams from 5.13 percent at spring 1 to 37.2 percent at spring 3. Taxon dominance in the springs is shown by the metric *percent 2 dominant*, which ranged from 44.1 percent to 67.5 percent. Spring 3 had the lowest percent tolerant organisms (55.8) and the greatest number of intolerant taxa (9). In contrast, springs 1, 2 and 4 had percent tolerant organisms > 80. Spring 3 showed the lowest HBI score (4.78, Good ranking), compared to spring 1 (6.79, Fairly Poor), spring 2 (6.70, Fairly Poor), and spring 4 (6.16, Fair) (Hilsenhoff 1987). The relatively high HBI scores at springs 1, 2, and 4 reflect moderate levels of organic pollution. Based on functional feeding group metrics, the springs were comprised primarily of predators, shredders and collector gatherers, likely attributed to low flows and heavy accumulations of leaf material. The metric *percent scrapers* was relatively high at spring 3 because of the occurrence of the mayfly genus *Ameletus.* This spring also had the greatest depths and highest flow velocities, which likely provided *Ameletus* the substrate and flows necessary for filtering organic matter from the water.

Ten individuals of the endemic predaceous diving beetle *Heterosternuta sulphuria* were collected from springs 1 and 2, while *Sanfilippodytes* sp. was represented by 46 individuals collected from springs 2, 3 and 4, with Spring 3 having the largest number of *Sanfilippodytes* sp. (28 individuals).

DOI: 10.54119/jaas.2017.7130

Table 2. Macroinvertebrates collected with associated functional group, habit group, and tolerance values.

Taxon	Order	Functional group	Tolerance values	Habit	Spring 1	Spring 2	Spring 3	Spring 4
Oligochaeta	Oligochaeta	CG	8	BU	3	2	4	
Physidae	Gastropoda	CG	8	SP	3	2	4	
Planorbidae	Gastropoda	CG	7	SP		1	1	
Caecidotea	Isopoda	CG	8	SP	3			8
Lirceus	Isopoda	CG	8	SP	1			
Baetidae	Ephemeroptera	CG	5	CG			8	
Leptophlebiidae	Ephemeroptera	CG	2	CR		3		
Ameletus	Ephemeroptera	SC	1	CG			8	
Polycentropus	Trichoptera	PR	4	CG			1	
Odontoceridae	Trichoptera	SC	0	CG		1	3	
Helicopsychidae	Trichoptera	SC	5	CR	1	1		
Pycnopsyche	Trichoptera	SH	4	CR	1			
Pseudostenophylax	Trichoptera	SH	4	CG			2	
Zealeuctra	Plecoptera	SH	0	CR		2	10	3
Microvelia	Hemiptera	PR	8	CL	1	17		
Argia	Odonata	PR	8	CR	1	4	1	
Chauliodes	Megaloptera	PR	9	SP	1	1		
Sialis	Megaloptera	PR	7	SP		1		
Agabus	Coleoptera	PR	8	GN			9	
Copelatus	Coleoptera	PR	6	GN			1	
Heterosternuta sulphuria	Coleoptera	PR	6	GN	7	3		
Sanfilippodytes	Coleoptera	PR	6	GN		1	28	17
Optioservus	Coleoptera	SC	5	CG			3	
Sphaeridiinae	Coleoptera	PR	8	GN		1		4
Prionocyphon	Coleoptera	SH	6	CL	11	1		3
Ectopria	Coleoptera	SC	4	CG	1			
Tanypodinae	Diptera	PR	9	SP	3			1
Ptycoptera	Diptera	CG	7	BU	1			
Tabanidae	Diptera	PR	7	BU		2		
Myxosaurgus	Diptera	CG	9	BU		2		
Limoniinae	Diptera	SH	6	BU		1		
Hexatoma	Diptera	PR	3	CR			2	1
Tipula	Diptera	SH	5	BU	1	1	1	

Discussion

Several historical surveys focusing on springs of the Ozark region have been conducted (Hargis 1995; Mathis 1994; Webb *et al*. 1998). Hargis (1995) compared the flora, fauna, and water quality of 65 springs within the Main, Lee Creek, and Wedington Units of the Ozark National Forest (ONF) in the Boston Mountain ecoregion. In springs at HOBBS, pH, temperature, and EC were within reported ranges of those reported by Hargis (1995), and all but one DO measurement from our study was within the reported range (0.8 to 8.5 mg·L^{-1}).

Table 3. Metrics calculated for aquatic macroinvertebrate surveys of springs at four springs at Hobbs State Park-Conservation Area. EPT = Ephemeroptera, Plecoptera and Trichoptera, CG = collector-gatherers, CF = collector-filterers, SC = scrapers, SH = shredders, PR = predators.

METRIC	Spring 1	Spring 2	Spring 3	Spring 4
Total Number of Individuals (N)	39	47	86	37
Number of Taxa	15	19	16	7
Number of EPT Taxa (EPT Taxa)	2	4	6	1
Percent EPT (%EPT)	5.13	14.89	37.21	8.11
Percent 1 Dominant Taxon	28.21	36.17	32.56	45.95
Percent 2 Dominant Taxa	46.15	44.68	44.19	67.57
Percent Tolerant Organisms	89.74	82.98	55.81	89.19
# intolerant Taxa	4.00	5.00	9.00	2.00
Percent non-insect	25.64	10.64	10.47	21.62
per CG	28.21	21.28	19.77	21.62
per CF	0.00	0.00	0.00	0.00
per SC	5.13	4.26	16.28	0.00
per SH	33.33	10.64	15.12	16.22
per PR	33.33	63.83	48.84	62.16
Hilsenhoff Biotic Index	6.79	6.70	4.78	6.16

The DO measurement at HOBBS that fell outside that range was spring 3, where relatively higher discharge occurred and water was relatively turbulent, flowing over bedrock slides. Similar to the springs at HOBBS, Hargis (1995) reported that springs in the ONF had little surface flow and only a few springs had discharge rates that exceeded 0.03 $m^3 \cdot s^{-1}$.

It should be noted that because the springs we sampled were not randomly selected among all springs at HOBBS or across a larger area of interest, our range of inference is limited to only the four springs surveyed in this study. Moreover, other springs at HOBBS could fall within or outside the range of characteristics reported for these four spring systems. For general comparison, the biodiversity of springs at HOBBS was similar to that found in other springs in the ONF, with some differences. The non-insect taxa that we collected were among those previously reported from regional, low flow springs in the region. However, some non-insect taxa reported in historical surveys of Ozark springs that were not collected during our surveys were Nematomorpha, Amphipoda and Decapoda. Insect orders dominating the insect communities of springs in Hargis (1995) were Coleoptera (15 taxa), Trichoptera (13), and Diptera (11), and while the dominant orders in our study were similar, we observed lower taxonomic richness within these dominant orders (i.e. Coleoptera; 7 taxa, Diptera; 7, and Trichoptera 5).

Mathis (1994) surveyed the macroinvertebrate fauna of 3 springs in the Buffalo National River (BNR) in September and December 1993 and March 1994. Unlike the Hargis survey (Hargis 1995) and our current surveys of springs at HOBBS, the highest species richness among insect orders in springs in the BNR were Trichoptera (16 taxa), Ephemeroptera (7), and Coleoptera (7). Mathis (1994) reported the following taxa from the survey of BNR springs as invertebrates that typically occur in crenal (spring) habitats according to Hynes (1970): *Lepidostoma* sp., *Ironoquia punctatissima*, *Pycnopsyche rossi*, and *Hyallela azteca*. Of these, we collected only *Pycnopsyche* and Hargis (1995) collected *Lepidostoma* sp. and *Pycnopsyche* sp. from ONF. The 3 most abundant taxa collected during our surveys were *Sanfilippodytes* (48), *Microvelia* (18), and *Caecidotea* (12). In comparison, the 3 most abundant species collected at the 3 springs in the BNR were the caddisfly *Agapetus allini* (273 individuals) and the isopods *Lirceus hoppinae* (193) and *L. garmani* (152) (Mathis 1994). Differences in macroinvertebrate communities across BNR, ONF (i.e. Hargis 1995) and HOBBS could be attributed to higher discharge and flow velocities in BNR springs.

Webb *et al*. (1998) sampled 10 karst spring in southwestern Illinois, where a relatively small portion

https://scholarworks.uark.edu/jaas/vol71/iss1/32
DOI: 10.54119/jaas.2017.7130

of the Ozark Highlands extends east of the Mississipi River. In contrast to our study at HOBBS and the studies at the ONF and BNR where aquatic insects dominated the community, Webb *et al*. (1998) found the non-insect taxa oligochaetes, amphipods, isopods, and turbellarians exceeded all aquatic insects in abundances.

The predaceous diving beetles *Heterosternuta sulphuria* or *Sanfillipodytes* were collected across all four springs surveyed at HOBBS, with overlap in occurrences only in Spring 2. The former species recently has been documented to occur throughout small Ozark streams in northern Arkansas (Longing *et al.* 2013) and its distribution likely extends further into southern Missouri and eastern Oklahoma, while the latter has been found to frequently co-occur with *H. sulphuria*. The springs surveyed at HOBBS in this study produced the largest number of *Sanfilippodytes* sp. individuals collected to date, which is significant considering *Sanfilippodytes* was observed to be an undescribed species (R. Roughley, deceased, *pers. comm.*).

Our assessment of these four springs at HOBBS occurred in 2008, a year preceeding a major ice storm that removed much of the canopy that provided shade to these stream channels. It would be worthwhile to re-survey these systems to determine if the communities and especially the species of concern persisted following that disturbance, and to further compare the habitat and physico-chemical conditions across time.

Information developed from these surveys emphasizes the need for the continued protection of perennial spring systens at HOBBS. The occurrences of two diving beetles, *Heterosternuta sulphuria* and *Sanfilippodytes sp*., highlights the need for monitoring and conservation strategies for these species, while additional surveys of spring systems at HOBBS would provide a better understanding of how these habitats are influencing populations. Furthermore, these easily collected diving beetles could serve as biological targets to integrate with regional watershed management and conservation program initiatives. The bioassessment and documentation of species of concern from these four springs provides an initial framework for monitoring and further highlights HOBBS as an important conservation area for the preservation of the region’s unique biodiversity.

Acknowledgements

We thank Hobbs State Park Conservation Area Superintendent Mark Clippinger and Steve Churchyll for providing detailed information on spring locations throughout the park.

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