UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

July 2009

AWRC

Heterosternuta sulphuria (Coleoptera: Dytiscidae) Occurrence in the Sulphur Springs Headwater System and in Buffalo National River Tributaries (Arkansas, USA): Current Distribution, Habitat Conditions, and Biomonitoring Framework

Funded by Arkansas Game and Fish Commission
MSC Publication 351 | Arkansas Water Resources Center

Heterosternuta sulphuria (Coleoptera: Dytiscidae) Occurrence in the Sulphur Springs Headwater System and in Buffalo National River Tributaries (Arkansas, USA): Current Distribution, Habitat Conditions, and Biomonitoring Framework

S.D. Longing[1] and B.E. Haggard[2]

[1]Former Research Associate, Biological and Agricultural Engineering Department, UA Division of Agriculture
[2]Director and Associate Professor, Arkansas Water Resources Center, UA Division of Agriculture, 203 Engineering Hall Fayetteville, AR 72701. Corresponding author: haggard@uark.edu

Heterosternuta sulphuria is an endemic aquatic species of concern in Arkansas, with a priority score of 80 out of 100 and a conservation rank of S1and G1. A need of the Arkansas Wildlife Action Plan (AWAP) was to obtain baseline information on distribution and population status of *H. sulphuria.* Here, we report new *H. sulphuria* records for 39 sites across 10 counties in the Ozark Highlands and Boston Mountain ecoregions and a determined habitat type of shallow margins and small bedrock pools of perennial streams and spring seeps. Few habitat patches were observed per site because detection was typically rapid and (unconfirmed) field identifications were possible because of the unique coloration of the pronotum, therefore only a small portion of the total available habitat was surveyed. We conclude that from our surveys and information gathered from other sources that in Arkansas *H. sulphuria* is probably ubiquitous among permanently wet aquatic habitats (primarily in upland headwater systems) throughout the Ozark Highlands and Boston Mountain ecoregions. Based on the number of occurrences, we recommend a downgrade of conservation status to S3 or S4. While some locations provide protection for current *H. sulphuria* populations (e.g., Buffalo National River, Hobbs State Park – Conservation Area, Sherfield Cave effluent stream, and USFS Richland Creek Wilderness), populations on unprotected lands in urban and agricultural settings probably have a much greater risk of population decline. A final determination of conservation status should consider several factors including dispersal capacity, population sizes, and genetic differentiation among populations. Furthermore, determining if existing *H. sulphuria* populations are isolated subpopulations or an interacting metapopulation and the habitat area required for population persistence are key for developing effective conservation actions. Monitoring existing populations should involve revisiting current *H. sulphuria* sites, and this is especially important for potentially fragmented populations in unprotected streams. Bioassessment programs could benefit from monitoring these easily observed populations that might positively relate to the overall physical and biological integrity of permanent Ozark streams and riparian corridors.

KEY FINDINGS

- A new record for *H. sulphuria* from the type locality, Sulphur Springs, Arkansas, where it had not been collected since 1955.
- *Heterosternuta sulphuria* populations are apparently secure on protected lands; on unprotected lands these populations may be vulnerable to population decline. Conservation of the latter is especially important for potentially isolated, yet protected populations within agricultural watersheds vulnerable to urban development (Figure 1).
- Dispersal capacity, population sizes and habitat areas, genetic differentiation, and metapopulation structure are key factors for determining a final conservation rank.
- The previously unknown larva was reared during this study and is currently being described.
- New element occurrences and habitat information for the associated SGCN *Heterosternuta phoebeae* will support a re-evaluation of its AWAP priority score and overall conservation rank.
- Spring-specialists co-occurring with *H. sulphuria* in the most upland habitats included a potential new species (*Sanfilippodytes* sp.) and the recently described *Hydrocolus oblitoides* Roughley and Larson.

Figure 1. Sneeds Creek tributary of the Buffalo National River, and *H. sulphuria.*

SPECIES INFORMATION AND BACKGROUND

Name and Classification

Kingdom Animalia: Animal, animals, animaux
Phylum: arthropods, arthropods, Artrópode
Subphylum: Hexapoda - hexapods
Class: Insecta – hexapoda, insects, insects, inseto
Subclass: Pterygota – insect ailés, winged insects
Infraclass: Neoptera – modern, wing-folding insects
Order: Coleoptera Linnaeus, 1758 – beetles, besouro, coléoptères
Suborder: Adephaga, Shellenberg 1806
Family: Dytiscidae, Latreille 1802 – dytiscids, predaceous diving beetle
Subfamily: Hydroporinae, Aubé 1836
Tribe: Hydroporini, Aubé 1836
Genus: *Heterosternuta* Strand 1935
Species: *H. sulphuria*, Matta and Wolfe 1979 – Sulphur Springs Diving Beetle

Wolfe (2000) elevated the subgenus *Heterosternuta* of genus *Hydroporus* to the generic level. This resulted in *Hydroporus* (*Heterosternuta*) *sulphurius* henceforth being referred to as *Heterosternuta sulphurius* (Figure 2). Additionally, *sulphurius* was changed to *sulphuria* for gender agreement between genus and species names (Nilsson 2007). Regarding two other Arkansas species of concern within this genus, *Heterosternuta ouachita* was changed to *H. ouachita*, while *H. phoebeae* was left unchanged (Nilsson 2007).

Members of the Dytiscidae are commonly known as predaceous diving beetles, although some are considered scavengers. There are over 400 described species in North America. The subfamily Hydroporinae (including *Heterosternuta*) contain the smallest dytiscids, ranging in size from 1–7.2 mm. Dytiscids are atmospheric air breathers, requiring contact with the water surface to replenish air supplies. While larger dytiscids typically can move freely in deeper waters, the small Hydroporinae are intimately associated with shallow waters and stream margins (Larson, Alarie, and Roughley 2000). Furthermore, dytiscids pupate terrestrially at the water-land interface, and physical stability during this time is probably vital for adult emergence.

The Dytiscidae are one of the most highly specialized coleopteran families in aquatic systems, and their populations are typically comprised of hig h densities of individuals among defined environmental settings (Larson 1985, Eyre 2006). These aquatic beetles differ in their preference for particular habitats, ranging in type from small ponds and lake margins to small shaded streams. The diversity of the dytiscid fauna of Arkansas is influenced by our natural regions and the variety of habitats provided. Several studies have developed species lists for the Dytiscidae occurring in Arkansas (e.g. Pippenger and Harp 1985, Mitchell 1989, Holt and Harp 1995, Wolfe and Harp 2003). The dytiscid fauna of extreme upland headwaters in the mountainous regions have been studied less, with the Ozark and Ouachita Mountains home to Arkansas's three endemic *Heterosternuta*.

Need for Re-evaluation of Conservation Status

Heterosternuta sulphuria was originally collected from Sulphur Springs, Arkansas, in 1955 by Paul Spangler and later described (Matta and Wolfe 1979; Nilsson 2007). Fourteen species currently are described in this genus (Wolfe 2000), with three of these found only in Arkansas (*H. sulphuria, H. ouachita*; Matta and Wolfe 1979, and *H. phoebeae*; Wolfe and Harp 2003). *Heterosternuta sulphuria* was not collected on subsequent trips to the type locality (Matta and Wolfe 1979), and few *H. sulphuria* have been collected since the type series of 33 specimens. Only two historical surveys of various water beetle species, which produced a total of 1,161 organisms, provided evidence for *H. sulphuria*: one suspect female specimen collected in a 1988 survey (G. L. Harp, in litt.) and three female specimens (two positively identified and one suspect) collected in a 1992 survey (Wolfe and Harp 2003). All four specimens were collected from four separate streams in the watershed of Buffalo National River. *Heterosternuta sulphuria* has been listed as a species of greatest conservation need in Arkansas with a priority score of 80 out of 100 (Anderson 2006). Accordingly, developing baseline information on distribution and population status of *H. sulphuria* is needed for the AWAP (Anderson 2006).

Figure 2. *Heterosternuta sulphuria*

OBJECTIVES

- Determine occurrence of *H. sulphuria* populations near historic locations.
- Compare the performance of sampling devices and sampling methods using performance measures.
- Determine environmental descriptors and habitat information for *H. sulphuria*.
- Develop a conservation-monitoring framework for detecting long-term trends in *H. sulphuria* populations and for protecting existing populations.

METHODS

Pilot surveys were conducted in fall 2007 in tributaries of the Buffalo National River. A variety of sampling techniques were considered for sampling the potentially rare *H. sulphuria* including bottle traps and hand nets, with efficacy of these different sampling strategies determined with performance measures (modified from Barbour et al. 1999). The performance measures (Per1–Per4) were as follows:

Performance Measure 1 (Per1): Aquatic invertebrate abundance and coefficients of variation of abundances across invertebrate samples for each sampling device and sampling method.

Performance Measure 2 (Per2): Dytiscidae abundance and coefficients of variation of abundances across invertebrate samples for each sampling device and sampling method.

Performance Measure 3 (Per3): *H. sulphuria* abundance and coefficients of variation of abundances across invertebrate samples for each sampling device and sampling method.

Performance Measure 4 (Per4): Number of influential environmental descriptors for *H. sulphuria* and an associated assemblage. High performance will be indicated by an environment that is explained with the strongest and fewest environmental descriptors, and yields consistent high performance with Per2 and Per3.

Field Measurements

Due to the increase in total number of sites visited (83) compared to that proposed (12–15, see below in Results), we only collected water quality samples and *in situ* measurements of DO, temperature, pH, and conductivity at a subset of visited sites (n=36 for physio-chemical measurements and n=17 for water chemistry). In addition, at each site we recorded GPS coordinates, photographed beetle habitats, and recorded dominant benthic substrate. When the GPS device could not acquire satellites, specific locations were marked on maps and GPS coordinates were acquired using Delorme TOPO USA (version 3.0, Southeast Regional Addition).

Collecting H. sulphuria *and co-occurring dytiscids*

At each selected site, we first assessed the physical streambanks for the occurrence of potential hydroporine and *H. sulphuria* habitat. Some sites were discarded following initial assessment, because of failure to locate potential habitat, but these were very few. When potential habitats were noted at select sites, individual habitat patches (0.25–1 m distance along either bank or entire small bedrock pools) were observed for crawling/swimming beetles. If no beetles were observed during the initial check of the habitat, the substrate was disturbed for a brief period (5 s) and the benthos and water column were observed again for beetle activity. Observations within an individual habitat patch were terminated at 5–10 minutes if no beetles were found. Collecting apparatus included small green aquarium nets, plastic bulb pipettes (with 0.5 cm cut from the tip), D-frame nets, and by hand.

Data Compilation and Analysis

We developed a species information spreadsheet containing site name, GPS coordinates, county, habitat, temperature, pH, dissolved oxygen, conductivity, nitrate-nitrogen concentrations (NO_3-N), total number of *H. sulphuria* collected, and co-occurring species abundances. ANOVA was used to determine differences in physio-chemical measurements and NO_3-N concentrations among site groups based on presence/absence of *H. sulphuria*.

A re-evaluation of conservation status for *H. sulphuria* was supported using the conservation rankings of NatureServ (Tables 1 and 2, http://www.natureserve.org/explorer/ranking.htm#globalstatus) and based on numbers of observed populations.

Table 1. Global (G) Conservation Status Ranks

Rank	Definition
GX	Presumed Extinct (species) – Not located despite intensive searches and virtually no likelihood of re-discovery. Eliminated (ecological communities) – Eliminated throughout its range, with no restoration potential due to extinction of dominant or characteristic taxa and/or elimination of the sites and disturbance factors on which the type depends.
GH	Possibly Extinct (species) Eliminated (ecological communities and systems) – Known only from historical occurrences but still some hope of rediscovery. There is evidence that the species may be extinct or the ecosystem may be eliminated throughout its range, but not enough to state this with certainty. Examples of such evidence include (1) that a species has not been documented in approximately 20–40 years despite some searching or some evidence of significant habitat loss or degradation; (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is extinct or eliminated throughout its range.
G1	Critically Imperiled – At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors.
G2	Imperiled – At high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors
G3	Vulnerable – At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors.
G4	Apparently Secure – Uncommon but not rare; some cause for long-term concern due to declines or other factors.
G5	Secure – Common; widespread and abundant

Table 2. National (N) and Subnational (S) Conservation Status Ranks

Rank	Definition
NX SX	Presumed Extirpated – Species or ecosystem is believed to be extirpated from the jurisdiction (i.e., nation or state/province). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
NH SH	Possibly Extirpated – Known from only historical records but still some hope of rediscovery. There is evidence that the species or ecosystem may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include (1) that the species has not been documented in approximately 20–40 years despite some searching or some evidence of significant habitat loss or degradation; (2) that a species or ecosystem has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.
S1	Critically Imperiled – Critically imperiled in the jurisdiction because of extreme rarity or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the jurisdiction.
S2	Imperiled – Imperiled in the jurisdiction because of rarity due to very restricted range, very few populations, steep declines, or other factors making it very vulnerable to extirpation from jurisdiction.
S3	Vulnerable – Vulnerable in the jurisdiction due to a restricted range, relatively few populations, recent and widespread declines, or other factors making it vulnerable to extirpation.
S4	Apparently Secure – Uncommon but not rare; some cause for long-term concern due to declines or other factors.
S5	Secure – Common; widespread and abundant in the jurisdiction.

Species Identification

Wolfe (2000) provides a key to species of *Heterosternuta.* A positive identification is primarily based on unique morphology of the adeagus, with the *Heterosternuta* having a characteristic bifid adeagus (exception *H. phoebeae*). The presence of short, stout setae on the ventral surface of the median lobe of the adeagus (Figure 3, arrow) is characteristic of *H. sulphuria*. Unconfirmed field identification is aided by the color of the pronotum, where *H. sulphuria* and *H. laetus* are the only members of the *Heterosternuta* to have completely red pronotums. The latter occurs primarily in the eastern U.S. through Tennessee and Kentucky (Larson, Alarie, and Roughley 2000) and was not collected during our surveys. The coloration of the head showed some variation across locations; some were entirely red, but the majority had a transverse red band connecting the posterior margin of the eyes, with the anterior vertex and frons entirely yellow (Figure 3). Furthermore, the markings on the elytra were observed to vary across most sites regarding proportional areas of black/yellow and in overall brightness. It is possible that morphological variations exist across locations.

Figure 3. *Heterosternuta sulphuria* group (top) and male genitalia used for identification. Dorsal view (bottom left) of the bifid adeagus and lateral view (bottom right) of the aedeagus showing the characteristic setae of the median lobe (arrow) and the parameres above. The broken base of the adeagus is attached to the parameres.

RESULTS

Sampling Performance

During initial beetle surveys in fall 2007, several drying pools in Shop Creek and Bear Creek had very high observed densities of dytiscids and haliplid water beetles (dominated by *H. phoebeae,* Appendix 1). While traveling from Snowball to Mt. Judea, AR, during these initial surveys we located a small headwater seep (i.e., Richland Creek tributary) where we first collected *H. sulphuria* and determined a potential habitat of shallow, slow-water margins and shallow bedrock pools in small headwater perennial streams. As a result, our most conservative, proposed sampling performance measures (collecting dytiscids and *H. sulphuria* within a sample and describing environment based on the fewest descriptors, Per3 and Per4, respectively) were subsequently high and therefore further surveys included selecting potential habitats from perennial headwater systems only. This completely removed the necessity to evaluate our sampling based on the performance measures 1 and 2 detailed in the proposal and to test different collecting methods, as long as we were successful in collecting *H. sulphuria* throughout the surveys. Furthermore, bottle traps deployed at three different locations performed poorly, and these were not used throughout the remainder of the study.

Following initial surveys in fall 2007 and after determining the potential habitat of *H. sulphuria*, we acquired data from Buffalo National River (BNR) that contained spring locations and descriptions including perennial or intermittent. From this information we selected Sneeds Creek and Indian Creek in the Ponca Wilderness at BNR because of the dominance of groundwater-influenced headwater streams. Additional sites throughout the remainder of surveys were selected from both *a priori* knowledge of the flow regime of particular watersheds, expert opinion, and in peri-meter counties we simply located potential permanent streams and made site visits consecutively. As a result of adapting the sampling strategy to potentially gain more element occurrence data, the proposed number of sites increased from the proposed 12–15 to 78. This resulted in considerably more element occurrence data for *H. sulphuria* and therefore a more accurate assessment of its distribution.

Element Occurrences, Habitat, and Co-Occurring Species

Heterosternuta sulphuria was collected from 39 of 78 surveyed sites across 10 counties in Arkansas (Table 3, Figures 4 and 5). A total of 210 specimens were collected over the two-year period, with an average of 4.6 beetles collected per site (1–24 per site). *H. sulphuria* was collected on more than one date from 5 sites (Table 3). At a site surveyed only once, Beech Creek (Newton County), eight (suspect) individuals were observed but not collected; these were not included in the total number of individuals reported above. Additionally, Mud Creek Trib 3 (Washington Co.) was surveyed multiple times but during the later survey dates beetles were only observed and not collected; these were

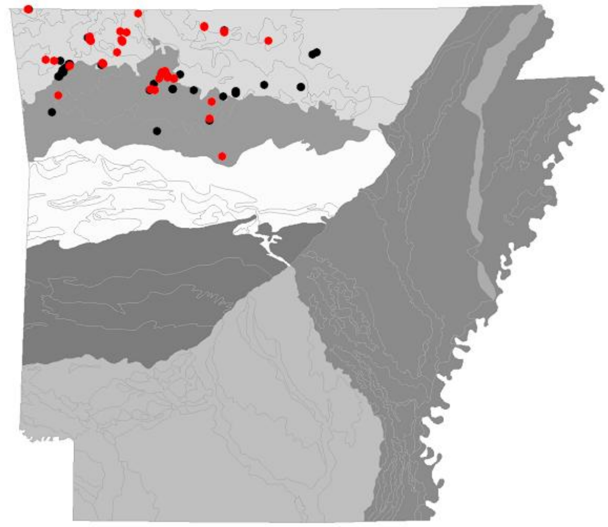

Figure 4. Element occurrences of *H. sulphurius* across surveyed locations from 2007 – 2009. Red dots indicate presence and black dots indicate absence of *H. sulphurius*. Symbols overlap considerably.

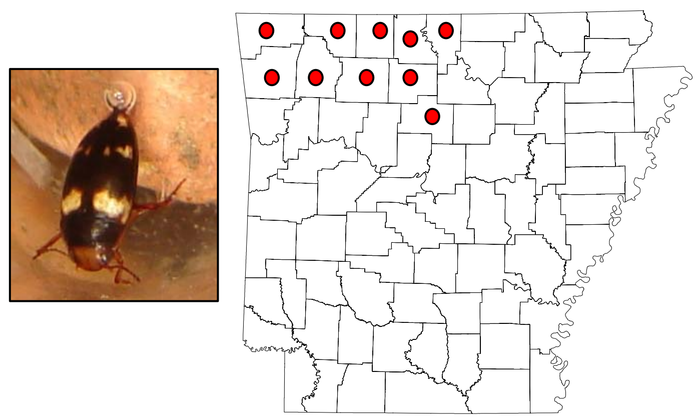

Figure 5. Arkansas' counties where *H. sulphuria* was collected during 2007 – 2009 surveys.

Table 3. Locations where *H. sulphuria* was collected in northwest Arkansas during 2007 – 2009 surveys.

Site	Date	County	Easting	Northing	Number of *H. sulphuria* collected	Dominant substrate/ habitat
Richland Trib 1	9/30/2007	Searcy	507508	3969294	10	crevices and pools in bedrock
Richland Trib 1	10/25/2007	Searcy	507508	3969294	3	crevices and pools in bedrock
Richland Trib 1	2/16/2008	Searcy	507508	3969294	2	crevices and pools in bedrock
Sherfield Cave Stream	10/25/2007	Newton	464392	3977996	10	cobble margins
Leatherwood Creek	2/15/2008	Newton	468073	3986391	5	gravel margins
Hobbs Spring 1	3/14/2008	Benton	416797	4015340	7	small gravel / seep
Hobbs Spring 2	3/14/2008	Benton	416469	4015170	1	small gravel / seep
Hobbs Spring 3	3/25/2008	Benton	415448	4015721	1	small gravel / seep
Little Wildcat Creek	10/21/2006	Washington	388965	4000306	1	gravel margin
Little Wildcat Creek	10/6/2007	Washington	388965	4000306	1	gravel margin
Wildcat Creek Trib	4/21/2008	Washington	382552	4000643	1	gravel margin
Wildcat creek Trib	10/21/2007	Washington	382552	4000643	1	gravel margin
Sulphur Springs Stream	4/15/2008	Benton	369420	4038603	3	gravel margin
Spence's Stream	3/12/2008	Washington	391878	3973853	1	gravel/clay margin
Mud Creek Trib 3	10/12/2007	Washington	400978	3996179	2	cobble margin
Mud Creek Trib 3	4/8/2008	Washington	400978	3996179	7	cobble margin
Mud Creek Trib 3	8/14/2008	Washington	400978	3996179	3 (obs.)	depositional margin, fines
Mud Creek Trib 3	6/2/2009	Washington	400978	3996179	5 (obs.)	cobble margin
Indian Creek	3/29/2008	Newton	474349	3988901	1	cobble margin
Indian Creek Tributary	3/29/2008	Newton	474207	3987685	5	bedrock margin
Boulder Branch Trib 1	2/15/2008	Newton	479171	3986321	2	bedrock margin
Boulder Branch Trib 2	2/15/2008	Newton	479006	3986488	1	bedrock margin
Sneeds Creek Site 1	3/15/2008	Newton	470061	3991545	24	bedrock crevices and margin
Sneeds Creek Site 2	3/15/2008	Newton	470057	3991659	7	gravel margin
Sneeds Creek Site 3	3/15/2008	Newton	469990	3991659	17	plunge pool depositional
Hemmed in Hollow Site 1	3/16/2008	Newton	472184	3991777	5	gravel margin in plunge pool
Hemmed in Hollow Site 2	3/16/2008	Newton	472213	3991764	2	gravel margin
Hemmed in Hollow Site 3	3/16/2008	Newton	472309	3991952	4	cobble margin of plunge pool
Hobbs SP-CA Pigeon Roost	1/6/2008	Benton	415821	4017907	5	small gravel on bedrock
Hobbs SP-CA Pigeon Roost	12/31/2007	Benton	415821	4017907	3	small gravel on bedrock
Beach Creek	4/16/2008	Newton	461509	3979134	8 (obs.)	gravel margin of pool
Glade Creek @ Hwy 45	10/13/2008	Madison	425498	3998158	2	depositional margin at bluff
Glade Creek Site 3	10/13/2008	Madison	425611	3997778	4	shallow bedrock pools
Baxter Co. Stream 1	10/14/2008	Baxter	549696	4015245	6	gravel margin
Markle Spring Stream	10/14/2008	Marion	517071	4021825	8	gravel margin
Markle Stream	10/14/2008	Marion	517099	4022031	2	gravel margin
Willis Spring	10/14/2008	Boone	501583	4025885	5	bedrock crevices
Belden Spring	10/14/2008	Boone	501839	4025767	2	gravel margins
Indian Creek Trib (Urbanette)	10/13/2008	Carroll	451909	4035863	2	gravel margins
Carrol Co. Stream 2	10/13/2008	Carroll	443391	4021198	8	gravel/cobble margins
Winona Spring	10/13/2008	Carroll	438280	4022372	2	bedrock margins
Rockhouse Stream	10/12/2008	Madison	439355	4015616	4	gravel margins
Rockhouse Pool	10/12/2008	Madison	440441	4015205	3	gravel/sand pool margin
Madison Co. Stream 1	10/12/2008	Madison	440011	4014214	8	gravel margins
Madison Co. Seep	10/12/2008	Madison	436115	4006571	6	gravel margins
Falling Water @ LW Bridge	5/28/2009	Searcy	505560	3956536	4	gravel/sand depositional pool
Dragonfly Site	5/29/2009	Van Buren	514980	3928007	4	gravel/bedrock margins

A larger relative number of beetles were collected from the headwaters of Sneeds Creek (BNR, Newton County), yet this was probably a result of increased overall sampling effort due to multiple collectors. However, we suggest that Sneeds Creek could have the largest population of *H. sulphuria* of all sites visited, supported by high quality habitat within a protected watershed (Figure 1). However, comparisons of total numbers of *H. sulphuria* collected cannot be made because of different sampling efforts across sites (directed by a primary concern of *H. sulphuria* occurrence only). We generally observed either many beetles within a site-specific habitat or very few and this could be attributed to a range of stream and riparian conditions. Several streams where we collected *H. sulphuria* were located within protected areas, including Buffalo National River, Hobbs State Park - Conservation Area, Sherfield Cave, Richland Creek Wilderness and various other USFS locations (Figure 6 and 7), and these locations should provide adequate protection to sustain *H. sulphuria* populations (Longing and Haggard 2009). *Heterosternuta sulphuria* should be added to species lists of these protected areas to further highlight regional biodiversity and endemism.

Based on the number of sites visited at these locations, we cannot conclude that this is the range extent for *H. sulphuria* in Arkansas as well as in the two ecoregions. Protected sites at the southern and eastern perimeters of the current distribution should be surveyed to more accurately define the distribution of *H. sulphuria* in Arkansas (e.g. Gulf Mountain WMA, Cherokee WMA, Piney WMA, White Rock WMA, etc.). Furthermore, documenting populations on protected lands in southern Missouri and eastern Oklahoma will fill an important data gap regarding the full distribution range and level of endemism for *H. sulphuria.*

From the limited environmental data collected across sites, we found no significant differences of temperature (P=0.354), dissolved oxygen (P=0.702), conductivity (P=0.517), pH (P=0.627), or NO_3-N concentrations (P=0.614) among site groups with and without *H. sulphuria. Heterosternuta sulphuria* individuals were generally collected from the first 2 – 3 patches within an area of 20 m, and first sightings typically occurred within 15 minutes. All *H. sulphuria* and other *Heterosternuta* were collected from shallow waters ≈ 1 – 20 cm in depth, either at margins or in shallow depressions and crevices in bedrock. Beetles were found in a variety of substrate, ranging from loamy sand and silt to bedrock. Because of this range of substrate, it is likely that the geomorphology of these shallow habitats at the air-water interface is less important than major environmental factors such as water permanence and overall physical habitat integrity (e.g., lack of streambank disturbances). At one site, seven Hydroporinae species were collected from a single pool within a dry stream ("Rockhouse pool", Figure 7); this pool probably maintains water throughout the year due to the observed spring sources and the diverse hydroporine fauna including *H. sulphuria*. Furthermore, this pool is likely critical refugia in this intermittent stream for two endemic species, *H. sulphuria* and *H. phoebeae,* and others.

Heterosternuta sulphuria was not found in 11 perennial streams located within the Fayetteville city limits of northwest Arkansas. However, it was collected from three perennial streams draining agricultural and forested lands adjacent to and surrounding this urban area. It is possible that historical populations (if existed) within these urban areas could have experienced population decline from typical disturbances associated with urbanization including flashy flows and persistent channel degradation (Meyer and Paul 2001, Walsh et al. 2005), while some streams on adjacent agricultural lands (i.e., Little Wildcat Creek, Figure 7) provided at least some protected habitat for *H. sulphuria* populations. Individuals collected from protected habitats within agricultural sites were in areas fenced off from cattle, while no *H. sulphuria* were found from surveyed habitats where cattle had access. This has very important implications along two fronts. First, populations in the same watersheds as livestock pastures may rely on isolated, protected habitats for persistence. Second, continued pressure from urban sprawl and the conversion of agricultural lands (that contain at least some protected habitat) to urban/suburban land-use might contribute to *H. sulphuria* population decline in the future. This is highlighted by the fact that urban land use in the Illinois River watershed in northwest Arkansas has increased from 6.91 (1999) to 13.11 percent (2006) (CAST, http://watersheds.cast.uark.edu/viewhuc.php?hucid=11110103).

The total habitat area needed to sustain *H. sulphuria* populations, and to avoid population isolation and potential decline, is unknown. Overall questions to address for the conservation of vulnerable *H. sulphuria* populations on unprotected lands include: Are current populations in affected watersheds transient and prone to localized extirpation compared to those at protected sites? What habitat conditions and population sizes are required to sustain populations through time in affected watersheds? The water beetles could provide important information for elucidating the effects of anthropogenically-derived habitat fragmentation on regional biodiversity.

Heterosternuta sulphuria co-occurred with several species of *Heterosternuta* as well as *Sanfilippodytes* sp. and *Hydrocolus oblitoides.* These species, along with *H. sulphuria*, occupied similar habitats in the most upland systems, while other *Heterosternuta* from current and historical surveys have also been collected from upland habitats but are primarily collected from mid-order or higher streams (Harp, in litt, Wolfe and Harp 2003). Furthermore, *Hydrocolus* occupies a basal position within the phylogeny of the Hydroporinae (Miller et al. 2006), and *Sanfilippodytes* was originally described from a cave in Mexico (Larson, Alarie, and Roughley 2000), with a large group of other stygobiont Hydroporinae showing affinity for groundwater habitats in Texas (Miller et al. 2009). Furthermore, Robison and Allen (1995) suggest (based on preliminary data) that "the Interior Highlands, including north and west Arkansas, provided a safe haven for many forms during geological epochs when most of the rest of the continent was not available for habitation." This, and the potentially limited dispersal capacity of this group, suggests a long and closely-related evolutionary history of these water beetles co-occurring in permanent Ozark streams.

Conservation Status Recommendation and Monitoring

We conclude from our survey and information gathered from other sources that, in Arkansas, *H. sulphuria* is primarily found in permanently wet aquatic habitats (small permanent stream margins and spring seeps), in headwater systems throughout the Ozark Highlands and Boston Mountain ecoregions. Furthermore, detection was rapid at sites, with few habitat patches visited (with the exception of Sneeds Creek and Indian Creek, BNR where sampling effort was increased), and a potentially small portion of the total area of suitable margin-habitat patches were sampled among these two ecoregions. Given the number of populations recorded, we recommend a downgrade of conservation status for *H. sulphuria* from S1? to S3/S4 and G1 to G3/G4. The split is because some locations provide protection for current *H. sulphuria* populations (e.g., Buffalo National River, Hobbs State Park – Conservation Area, Sherfield Cave, and USFS Richland Creek Wilderness), yet on unprotected lands in urban and agricultural settings probably have a much greater risk of population decline. A final determination of conservation rank should consider several factors including dispersal capacity, population size, and genetic differentiation among populations.

Agriculturally dominated, perennial streams provide an unknown mosaic of protected habitat patches, and sustaining at least the current physical habitat integrity in these systems could be necessary for sustaining *H. sulphuria* populations affected by urbanization. Furthermore, determining if existing *H. sulphuria* populations are isolated subpopulations or interacting metapopulations and the habitat area required for population persistence, are key for developing effective conservation actions.

Populations from both protected and unprotected sites should be monitored routinely (e.g., at least every 3 years, an estimated every other generation). GPS coordinates provided for specific locations should support future monitoring of existing *H. sulphuria* populations (Table 3) and co-occurring species including the SGCN *H. phoebeae* (Appendix 1). Protected sites could support long-term monitoring on the effects of potentially changing surface and ground-water regimes on *H. sulphuria* and associated species, while providing key information on "natural" habitat areas and population sizes in groundwater influenced systems. Furthermore, protected sites would provide reference information for developing conservation actions and monitoring of populations vulnerable to urbanization (e.g., habitat areas required to sustain the mean population size determined from protected headwater catchments). In contrast, *H. sulphuria* population characteristics and habitat quality in affected watersheds would improve our understanding of the overall risk to it and other potentially isolated populations.

Finally, besides monitoring *H sulphuria* populations and implementing conservation actions for species conservation, additional, potential benefits of these activities are presented. For example, conditions related to *H. sulphuria* populations (e.g., presence-absence, population size and habitat occupancy) might provide an overall indicator of streambank stability, riparian corridor integrity, watershed land-use and management, and in-stream physical habitat integrity. This would support both local and other conservation goals in connected aquatic systems (e.g. ground-waters and downstream rivers and reservoirs). Further, because populations are widely distributed in the region and individuals are relatively easy to collected and observe in the field (e.g., in comparison to riffle assemblages that require netting), bioassessment programs that include monitoring these populations may benefit if *H. sulphuria* populations sustained over time are determined to be positively related to other assemblages and the overall biological and physical habitat integrity of permanent Ozark streams. In addition to *H. sulphuria*, determining the efficacy of using other aquatic species of concern with beneficial traits (and non-rare occurrences) to supplement watershed conservation and biomonitoring should be the subject of future research.

POTENTIAL CONCERNS

- Land development and unlimited livestock grazing along perennial headwater streams.
- Potential habitat and population fragmentation due to physical disturbances.
- Changes to natural hydrology including groundwater regime that could affect water permanence or habitat areas.

Figure 6. Habitat of *H. sulphuria*, clockwise from top left. Live *H. sulphuria* on bedrock in Indian Creek (Buffalo National River tributary), collecting *H. sulphuria* from bedrock depressions in a headwater seep in Searcy County; small seep (Richland Creek Trib.), bedrock pool at Indian Creek, low gradient section of Indian Creek tributary, and Sherfield Cave system.

Figure 7. Habitat of *H. sulphuria* (clockwise from top left): Clean gravel margin of "Rockhouse Stream" in Madison County, permanent spring seep at Hobbs State Park – Conservation Area (Hobbs Spring 1), Little Wildcat Creek, an agriculturally dominated stream in Washington County, spring fed pool (Rockhouse pool) that contained seven dytiscid genera, and a spring seep in Baxter County.

Monitoring Populations Associated With a Natural Disturbance – 2009 Ice Storm at HOBBS

Four springs at Hobbs State Park Conservation Area were surveyed in spring 2008 for *H. sulphuria* and *Sanfilippodytes*. All four springs contained at least one of these species, although populations were primarily separated among spring seeps (Appendix 1). During the 2008 surveys, the springs were heavily shaded and the substrate, although affected by some sedimentation, showed no evidence of benthic algae accumulations. A revisit to Spring 3 following the 2009 ice storm revealed a dramatically different spring seep, with evident heavy accumulations of filamentous green algae. A subsequent beetle survey revealed only 9 water beetles of the genus *Sanfilippodytes,* which is being determined and is currently considered a potential new species (Dr. Rob Roughley, personal communication). The surveys the previous spring and before the ice storm resulted in 29 *Sanfilippodytes* collected and 63 observed for this small, permanently wet seep. The nine individuals observed following the ice storm were located on the streambed in areas shaded by fallen or standing trees, while no beetles were observed in bedrock depressions because of the presence of filament-tous algae (Figure 8). Tracking these popula-tions over time might pro-vide an effective monitoring tool for tracking system disturbance and recovery.

Figure 8. Beetle habitat at Hobbs State Park – Conservation Area showing algae covering bedrock. This specific spring/seep (Hobbs Spring 3) is where the largest population of *Sanfilippodytes spp.* was observed.

ACKNOWLEDGEMENTS

We thank many beetle experts including Dr. George Harp, Dr. Bill Wolfe, Dr. Rob Roughley, Dr. Yves Alarie, and Dr. Eric Chapman. We are grateful to Andres Bacon, Faron Usrey, Mark Depoy, Terrel Spencer, Phil Penny, Ram Pandy, Kerri McCabe, Richard Walker, Julie Day, Justin Wright, Cameron Cheri, Kevin Cheri, and Laura Timby for assistance with beetle surveys. Thanks to Faron Usrey, Chuck Bitting, and Mark Depoy (BNR), Mark Clippinger and Steve Churchyll (Hobbs State Park – Conservation

Area), and Jane Anderson (Sherfield Cave) for providing resources and access to sites. Very special thanks to Dr. George Harp for insightful suggestions and resources on the aquatic Coleoptera of Arkansas. Dr. Jeff Barne's assistance in photographing beetle specimens was instrumental in SWG reporting and in developing a photo log for *H. sulphuria* adults and larvae. Special thanks to Andrea Romi for taking the best photograph of *H. sulphuria* (Figure 1 inset and Figure 4).

Aquatic insects were collected under the following permits: 061020072 and 012220071 (AGFC), SO-FW-FY08-02 (USFS), and BUFF-2007-SCI-0001 (National Park Service - BNR). Three *H. sulphuria* specimens from Sherfield Cave Stream were donated to Rob Roughley (J. B. Wallis Museum, University of Manitoba). Two *H. sulphuria* specimens from the unnamed tributary to Richland Creek were donated to Eric Chapman (University of Kentucky). All other specimens were deposited in the University of Arkansas Arthropod Museum in the Dale Bumpers College of Agriculture and Life Sciences.

LITERTURE CITED

Anderson, J. E., editor. 2006. Arkansas wildlife action plan. Arkansas Game and Fish Commission, Little Rock.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA 841-B-99-002. US Environmental Protection Agency, Office of Water. Washington, D.C.

Eyre, M. D. 2006. A strategic interpretation of beetle (Coleoptera) assemblages, biotopes, habitats and distribution, and the conservation implications. Journal of Insect Conservation 10: 151-160.

Holt, A., and G. L Harp. 1995. Dytiscidae (Coleoptera) of Jackson County, Arkansas. Proceedings of the Arkansas Academy of Science 49: 71-74.

Larson, D. J. 1985. Structure in temperate predaceous diving beetle communities (Coleoptera: Dytiscidae). Holartctic Ecology 8:18-32.

Larson, D. J., Y. Alarie, and R. E. Roughley. 2000. Predaceous diving beetles (Coleoptera: Dytiscidae of the Nearctic region, with emphasis on the fauna of Canada and Alaska (D. J. Larson, Y. Alarie, and R. E. Roughley, eds.). National Research Council of Canada Research Press, Ottawa, Ontario, Canada.

Longing, S. D. and B. E. Haggard. 2009. *In press*. New Distribution Records of an endemic diving beetle, *Heterosternuta sulphuria* (Coleoptera: Dytiscidae: Hydroporinae), in Arkansas with comments on habitat and conservation. Southwestern Naturalist. 54(7):tbd.

Marks, M. K. 1989. A synopsis of the Laccophilinae (Coleoptera: Dytiscidae) of Arkansas. Proceedings of the Arkansas Academy of Science 43: 118-119.

Matta, J. F., and G. W. Wolfe. 1979. New species of Nearctic *Hydroporus* (Coleoptera: Dytiscidae). Proceedings of the Biological Society of Washington 92:287-293.\

Miller, K. B., G. W. Wolfe, and O. Biström. 2006. The phylogeny of the Hydroporinae and classification of the genus *Peschetius* Guignot, 1942 (Coleoptera: Dytiscidae). Insect Systematics and Evolution 37:257 – 279.

Miller, K. B., J. R. Gibson, and Y. Alarie. 2009. North American stygobiontic diving beetles (Coleoptera: Dytiscidae: Hydroporinae) with description of *Ereboporus naturaconservatus* Miller, Gibson and Alarie, new genus and species from Texas, U.S.A. The Coleopterists Bulletin 63: 191 – 202.

Nilsson, A. N. 2007. Some necessary corrections of the spelling of species-group names within the family Dytiscidae. Zootaxa 1615:49-54.

Paul, M. J. and J. L. Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32:333 – 365.

Pippenger, M. A. and G. L. Harp. 1985. Dytiscidae from Randolph County, Arkansas. Proceedings of the Arkansas Academy of Science 39: 146 – 147.

Walsh, C. J., A. H. Roy, J. W. Feminella, P. D. Cottingham, P. M. Groffman, and R. P. Morgan II. 2005. The urban stream syndrome: current knowledge and search for a cure. Journal of the North American Benthological Society 24:706 – 723.

Wolfe, G. W. 2000. Key to species of Heterosternuta of Canada and the United States. Pages 230-232 in Predaceous diving beetles (Coleoptera: Dytiscidae) of the Nearctic region, with emphasis on the fauna of Canada and Alaska. D. J. Larson, Y. Alarie, and R. E. Roughley, eds. National Research Council of Canada Research Press, Ottawa, Ontario, Canada.

Wolfe, G. W., and G. L. Harp. 2003. A new species of predacious diving beetle, *Heterosternuta phoebeae* (Coleoptera: Dytiscidae), from the Ozark Mountains of Arkansas. Coleopterists Bulletin 57:117-121.

Appendix 1. *Heterosternuta sulphuria* and co-occuring Hydroporinae in Arkansas's mountain streams.

Site	*H. sulphuria*	*H. phoebeae*	*H. pulchra*	*H. wickhami*	*H. ouachita*	*Hydrocolus oblitoides*	*Sanfilippodytes* sp.
Shop Creek - Pool 1		4					
Shop Creek - Pool 2		11					
Shop Creek - Pool 3		29					
Big Creek							
Bear Creek - Pool 1		31		11			
Bear Creek - Pool 2		13	2				
Bear Creek - Pool 3 - varsia		4					
Bear Creek				1			
Left Fork Big Creek		3					
Richland Trib 1	10					1	
Richland Trib 1	3						
Richland Trib 1	2						
Sherfield Cave Stream	10						
Calf Creek Pool		38		8			
Boxley Spring 1							
Whitley Branch		5	4		1		2
Steel Creek							
Henry Koen Forest Stream							
Leatherwood Creek	5						1
Hobbs Spring 1	7						
Hobbs Spring 2	1						1
Hobbs Spring 3	1						1
Hobbs Spring 4							1
Little Wildcat Creek	1						
Little Wildcat Creek	1						
Wildcat Creek Trib	1						
Wildcat Creek Trib	1						
Sulphur Springs Impoundment							
Sulphur Springs Stream	3						
Spence's Stream	1						
Mud Creek Trib 3	2						
Mud Creek Trib 3	7						
Mud Creek Trib 3	3 (obs.)						
Mud Creek Trib 3	5 (obs.)						
Indian Creek	1	1					
Indian Creek Tributary	5			3			
Boulder Branch Trib 1	2						1
Boulder Branch Trib 2	1		1				
Sneeds Creek Site 1	24						
Sneeds Creek Site 2	7			1			
Sneeds Creek Site 3	17						
Sneeds Creek Site 4							
Sneeds Creek Spring							
Sneeds Creek Site 5			3				1
Sneeds Creek Site 6							
Sneeds Creek Site 7							
Sneeds Creek Site 8				2			2
Center Point Tributary							3
Hemmed in Hollow Site 1	5						2
Hemmed in Hollow Site 2	2						
Hemmed in Hollow Site 3	4						
Devils Den - Lee Creek Spring			1	1			

Appendix 1 cont.							
Site	*H. sulphuria*	*H. phoebeae*	*H. pulchra*	*H. wickhami*	*H. ouachita*	*Hydrocolus oblitoides*	*Sanfilippodytes* sp.
Little Clifty Spring							
Hobbs SP-CA Pigeon Roost	5						9
Hobbs SP-CA Pigeon Roost	3						1
Beach Creek	8 (obs.)						
Cato Springs					1		
Cato Springs Trib							
Mullins Creek							
Skull Creek							
Clear Creak Trib 1							
Mission Rd. Stream							
Gully Park Stream							
Spout Spring Stream							
Mud Creek Trib 1							
Mud Creek Trib 2							
Skillern Spring Seep							
Glade Creek @ Hwy 45	2	2	2				
Glade Creek Site 2		3					
Glade Creek Site 3	4						
Little Creek		1	5				1
Brushy Creek				2			
Baxter Co. Stream 1	6		1				
Markle Spring Trib	8	1		5			
Markle Stream	2			2			
Haliplid Site							
Willis Spring	5						10
Belden Spring	2						
Indian Creek Trib (Urbanette)	2	1	1	3			
Carrol Co. Stream 2	8						
Winona Spring	2						1
Rockhouse Stream	4		2			1	1
Blanchard Springs							
Spring at catwalk - Blanchard						2	7
Rockhouse Pool	3	12	1	2		1	
Madison Co. Stream 1	8	3	2	1			
Madison Co. Seep	6						2
Falling Water Falls							
Falling Water @ LW Bridge	4					1	
Dragonfly Site	4		1				
Little Piney Creek						1	