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FINAL PERFORMANCE REPORT

FEDERAL AID GRANT NO. T-16-P-1

FAUNAL SURVEY OF OKLAHOMA CAVE AND SPRINGS

OKLAHOMA DEPARTMENT OF WILDLIFE CONSERVATION

June 1, 2004 through May 31, 2008

FINAL REPORT

State: Oklahoma **Grant Number:** T-16-P-1

Grant Program: State Wildlife Grant

Grant Name: Faunal Survey of Oklahoma Caves and Springs

Grant Period: June 1, 2004 – May 31, 2008

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A. Abstract:

General biological inventories of caves, springs, and other subterranean habitats were performed in at least 101 sites throughout Oklahoma from 2004 to 2008. Additionally, 50 springs throughout Oklahoma were intensively studied and their biological and physio-chemical properties analyzed from 2003 to 2008. The objectives of these studies were: to describe the biodiversity of animal life in subterranean habitats of Oklahoma; to determine the status and distribution of rare and endangered animals in these habitats; to examine habitat variables to determine zoogeographic patterns in subterranean diversity and to rank the inventoried sites in order of biological importance; to provide this information to ODWC to facilitate conservation planning.

Very few cave habitats had a species richness greater than 20 taxa. The most species-rich cave habitats were the cave AD-14 with 80 taxa, and GR-011and DL-39, both with 63 taxa. Species richness in springs was significantly greater because of their connectivity with surface ecosystems. Numerous rare and endangered species utilize subterranean habitats in Oklahoma. There are at least 40 species that are known to be limited to, or adapted to, groundwater habitats (stygobites) or caves (troglobites), including 8 new species that await taxonomic description. The most common subterranean-obligate was grotto salamander (*Eurycea spelaea*) and the second was cave isopod (*Caecidotea* sp.). Overall, arthropods dominated the cave habitats, especially crickets, mosquitoes, spiders, and springtails. The most common invertebrate taxon was cave crickets of the genus *Ceuthophilus*. The most common vertebrates were eastern pipistrelle bat (*Periomyotis subflavus*) and cave salamander (*Eurycea lucifuga*). An accumulation curve was generated, which indicated that sampling effort to date has detected the majority of total species that can be found in cave habitats of Oklahoma, and that future bioinventories will add more species to this cumulative list, but probably at an exponentially slower rate.

Habitat variables data were collected during the fieldwork at each site; these data were compared to each cave site's total species richness and obligate richness to discern any biodiversity patterns. Richness of a cave was directly proportional to its passage length; the longest caves are the most-biologically rich. This constitutes a significant management challenge, as the longest caves are usually the most attractive for recreational caving. Richness was also higher in cave sites with organics present

(especially bat guano), when subterranean streams were present, and when sites had regulated access (especially by gating). However, frequent public use or the presence of vandalism did not correlate to lower richness measurements. Caves were ranked in biological importance using 3 variables: site length, total species richness, and obligate richness. Cave AD-14 ranked highest in Oklahoma, and cave DL-39 was second.

The intensive surveying of 50 springs revealed that Oklahoman springs have a diverse biota, especially with respect to invertebrates (primarily insects); over 200 taxa were found. Spring faunas consist of a combination of generalists species, which are commonly found in area ponds and/or streams, spring specialists (including endemics), and occasional subterranean-obligate crustaceans. Aquatic worms, fly larvae (chironomids and ceratopogonids), water striders, fingernail clams, and pond snails are all common in ponds and streams – as well as in springs. Although Arbuckle and Ozark springs are both limestone-based, their invertebrate faunas are different. In contrast, the invertebrate faunas of Arbuckle and High Plains springs are similar although the High Plains springs are mostly sand-based rather than limestone-based. These results highlight the distinctiveness of the Ozark and Arbuckle faunas.

B. Need:

The study of cave and spring faunas is important because of their connection with groundwater and mineral resources, their interest to science, and their rarity. Groundwater supplies 62% of the overall water demands of the United States (Job and Simons, 1994). In Oklahoma, groundwater is withdrawn at an estimated rate of 960 million gallons per day and accounts for over half of the total freshwater withdrawal (Tortorelli, 2002). Despite this high use of groundwater, little is known about groundwater ecosystems (Job and Simons, 1994). In addition to the extensive use of groundwater by humans, groundwater provides crucial ecological services, such as providing a reliable water source for springs and rivers, and altering the mineral and organic content of waters.

Groundwater habitats tend to have highly endemic faunal communities, with many species found only in a single cave or groundwater system. Approximately 90% of cave/groundwater communities have not been surveyed (Culver and Hobbs III, 2000). Cave-limited fauna (troglobites) and ground-water limited fauna (stygobites) represent more than half of the imperiled (G1-G2) animal species listed in the Natural Heritage Program, and include several species in the ODWC Species of Greatest Conservation Need yet, nationally, less than 4% of these species have federal protection status (Culver *et al.* 2000, NatureServe 2002).

Groundwaters produce springs where they reach the surface. Springs contain a combination of spring-adapted, stream-generalist, and groundwater-adapted species and, as a consequence, several spring-dwelling species are included in the ODWC Species of Greatest Conservation Need.

Groundwater, cave, and spring faunas generally share the same threats. Foremost among these is groundwater withdrawal, which destroys these habitats through direct

dewatering. Nutrient and toxic pollutants are localized problems which especially affect groundwaters in limestone regions, such as the Ozark Plateau and Arbuckle Range in Oklahoma, because of direct input of chemicals through sinkholes and disappearing streams. Human disturbances, such as trampling and modification of springs, also impact these habitats and their faunas.

In order to conserve springs, caves, and groundwater habitats and their associated fauna, there is a clear need of additional information on the distribution, ecology, and taxonomy of the fauna of these habitats. This proposed project addresses this need by investigating key subterranean and spring habitats; these habitats will be surveyed through species censuses; and the status, distribution, and taxonomy of rare species will be updated.

Among the target species of this bioinventory are several crustaceans, including cave and spring/stream dwelling crayfishes, and cave amphipods and isopods. Cave crayfish in the Ozarks of particular interest because both *Cambarus tartarus* and *C. subterraneus* have very limited known distributions; yet the identification of the crayfish in some Oklahoma caves is unresolved and additional surveys may allow identification of these undetermined crayfish. Also of interest is the federally endangered Benton Cave Crayfish (*Cambarus aculabrum*), which occurs on the Oklahoma/Arkansas border in the Illinois River watershed, but has not been documented in Oklahoma. Investigation of caves in the Oklahoma portion of this watershed should indicate whether *C. aculabrum* occurs in the state. Vertebrates on the target list include the Ozark cavefish and spring dwelling darters, and salamanders found in caves and springs. While the populations of federally threatened Ozark cavefish (*Amblyopsis rosae*) have been surveyed regularly in Arkansas and Missouri, censuses of most cavefish habitats in Oklahoma are a decade old. This study will help bring the Oklahoma censuses up to date, which will contribute to recovery efforts of this species. Most other species encountered will also be inventoried, and this data will provide information on associates of rare species and information on the distribution of cave- and spring- inhabiting species in the state.

C. Objectives:

The objectives of this project are:

- conduct field surveys of caves and springs, especially in the Ozark and Arbuckle regions of Oklahoma,
- update the status, distribution, and taxonomy of rare cave and spring species in Oklahoma,
- provide information needed for conservation planning for several current and potential Species of Greatest Conservation Need.

D. Approach:

Cave Bioinventories

In each cave surveyed, fauna were inventoried using the most unobtrusive methods possible and at times when bats were not hibernating or birthing. Vertebrates and macroscopic invertebrates were counted visually with helmet-mounted lights, using snorkeling gear and dive lights for deep pools. Collections were limited to those fauna

that were impossible to identify on site, and where permitted. Voucher specimens were collected by hand, aspirator, or net, and brought back to the Oklahoma Biological Survey for preservation, cataloging, and identification or shipment to taxonomists. The cobble substrate of streams derived from spring sources was examined through "cobble sifting", in which rocks are placed into mesh sieves and moved around and examined for organisms. The mouths of some springs were fitted with temporary drift nets to capture subterranean fauna expelled by the flow of the spring (a method whose efficacy was shown in surveys of groundwater invertebrates of the Edwards Plateau in Texas). Drift nets were set and checked every two to three hours.

At each site, the following habitat parameters were determined and recorded:

- Site category – "Bluff Shelter", "Cave", "Crevice/Talus", "Hyporheos", "Mine", "Pit", "Sinkhole", "Spring", "Well", or "Unknown";
- Degree of use by the public (primarily recreational caving) – "None", "Light", "Moderate", "Heavy", or "Unknown";
- Presence or absence of vandalism: "No" (including "Unknown") or "Yes" (defined as evidence of looting, presence of trash litter, campfire smoke residue, graffiti, animal injury, or damage to speleothems);
- Presence or absence of organics: "No" (including "Unknown") or "Yes" (defined as presence of bat guano or other feces, leaf litter, woody debris, etc.)
- Presence or absence of bat guano: "No" (including "Unknown") or "Yes" (defined as a significant accumulation, such as evidenced by a "guano pile", strong smell of urine/ammonia, or majority of surfaces covered)
- Subterranean water resource category that was dominant at the site – "Dry", "Drip Pool", "Intermittent Stream", "Perennial Stream", or "Unknown"; entrance to site gated (including fenced) – "yes" or "no"
- Degree of public access: "Unrestricted" (access uncontrolled; visitation not necessarily sanctioned by landowner); "By Permit Only" (permission by landowner must be obtained before entry); "Scientific Study Only"; "Closed or Sealed" (entrance sealed shut)
- Site landowner category: "Federal"; "State" (included counties and municipalities), "NGO" non-governmental organization (e.g., church, not-for-profit entity, land trust)", "Commercial" (owned by a business / fee charged to enter cave), "Private", or "Unknown"
- Site geologic unit (surficial geologic unit was determined using geographical information system software and digital USGS geologic maps).
- Site length (in meters): total mapped cave horizontal passage length; default length for wells and springs having no humanly-accessible horizontal extent was 1 m (this data was obtained primarily from unpublished data of members of the National Speleological Society).

Cavefish and Cave Crayfish Censuses

In caves with cavefish or cave crayfish, faunal censuses were performed using established methods (Graening and Brown, 2000). Surveyors moved slowly upstream and counted individuals as they were sighted, using helmet lights and powerful SCUBA lights. This method is understood to produce fairly reliable quantitative population information with minimal impact on the cave habitats and their inhabitants.

Spring Inventories

Methods used to sample springs followed those used by Bergey (2002) and included the following components:

- Site description, including TRS coordinates, GPS readings, a site sketch, photos, local land use, modifications of the spring, and directions for re-finding the site.

- Discharge information (flow width, depths, and mean velocities). Velocity was measured with a Marsh-McBirney electromagnetic flowmeter.
- An owner questionnaire, used to get information on land use changes, changes in discharge, and historical use of springs (when possible).
- Fish sampling, using seines or dipnets. Only one or two fish of each species were collected. Dr. William Matthews (Department of Zoology, University of Oklahoma) verified identifications and specimens will be deposited at the Sam Noble Oklahoma Museum of Natural History at OU.
- Invertebrates sampling, using hand nets for qualitative sampling and a small corer for quantitative sampling. Samples were preserved in the field and returned to the Bergey laboratory for sample sorting and invertebrate identification.

Taxonomy

Collected specimens were identified at the University of Oklahoma by the authors, or sent to taxonomic specialists, including: Dr. Jeffrey Barnes (UAF Dept. of Entomology) for dipterans and other Insecta, Dr. Kenneth Christiansen (Grinnell College) and Dr. Jeffrey Battigelli (Earthworks Research Group) for collembolans; Dr. Horton Hobbs III (Wittenburg University) for decapods; Dr. John Holsinger (Old Dominion University) for amphipods; Dr. Jerry Lewis (Lewis Consulting) for isopods and diplopods; Dr. Jeffrey Battigelli for acari; Dr. William Muchmore (University of Rochester) for pseudoscorpions; Dr. Henry Robison (Southern Arkansas University) or Dr William Matthews and staff at the Oklahoma Museum of Natural History (University of Oklahoma) for fishes; Dr. Stewart Peck (Carleton University) or Dr. John Epler (Independent consultant) for coleopterans; Dr. James Cokendolpher (Museum of Texas Tech University) and Dr. Darrell Ubick (California Academy of Sciences) for opilionids; Dr. Lynn Ferguson (Longwood College) and Mark Muegge (Texas Cooperative Extension) for diplurans; Dr. Gerald Walsh for gastropods; and Dr. Theodore Cohn (University of Michigan) for orthopterans, Dr. Peter Adler (Clemson University) for dipterans, Dr. Donald Klemm (USEPA-Cincinnati) for leeches. Adult aquatic insects were sent to Dr. Boris Kondratieff (Colorado State University) for mayflies and stoneflies and Dave Ruiter (EPA, Colorado) for caddisflies. Collected specimens will be curated in the US National Museum, the Oklahoma Biological Survey, or the Sam Noble Oklahoma Museum of Natural History, or they reside in the personal collections of taxonomists.

Permits held by Dr. Graening:

- Oklahoma Department of Wildlife Conservation Scientific Collector's Permit 3982;
- USFWS Special Use Permit 43590 – HLB-1-01; and
- USFWS Recovery Permits RT-834518, TE834518-1, TE834518-2, and TE834518-3.

Permits held by Dr. Bergey

- Oklahoma Department of Wildlife Conservation Scientific Collector's Permit 3571;
- University of Oklahoma, project-specific approved AUS protocols; file number R04-010 (for working with cave/spring fishes and salamanders)

Location

This project focused primarily on the limestone (karst) areas of Oklahoma, which are the Ozark Plateau (e.g., Adair, Delaware and Ottawa Counties) and the Arbuckle Range (e.g., Murray County and Pontotoc County), with their relatively high densities of caves and springs. Previous spring and cave surveys have concentrated primarily on the Ozarks and relatively little work has been done in the Arbuckles. Other appropriate areas in the state that include suitable habitat for cave and spring -associated species (e.g., the Ouachita Mountains) were included as time and site access permitted.

E. Results and Discussion:

Because of the differences in methods and types of data collected, the two subsections – Part 1 Cave Survey and Part 2 Spring Survey - are presented separately.

Part 1. Cave Survey.

Bioinventory Effort

For this grant period (6/2004 to 6/2008), 219 inventory events (including some repeated trips) were been performed in 101 subterranean sites in Oklahoma. This does not include 41 springs that were intensively studied by Dr. Bergey. The locations of these 101 subterranean habitats are shown graphically in Figure 1 (gray squares). Appendix 1 summarizes the faunal inventory checklists generated during this grant period.

This ODWC-funded study is part of a larger biodiversity study – the Subterranean Biodiversity Project, which started in 1999. Data generated from this study was pooled with other data from the Subterranean Biodiversity Project and previous studies from other authors. This combined data set produced the following: 5,122 total faunal occurrence records in subterranean sites in Oklahoma, with dates spanning from 1924 to 2007; 289 inventory events performed in 458 sites (including some repeated inventories); and a faunal checklist of approximately 750 unique taxa, including morphospecies not defined to the generic or specific level.

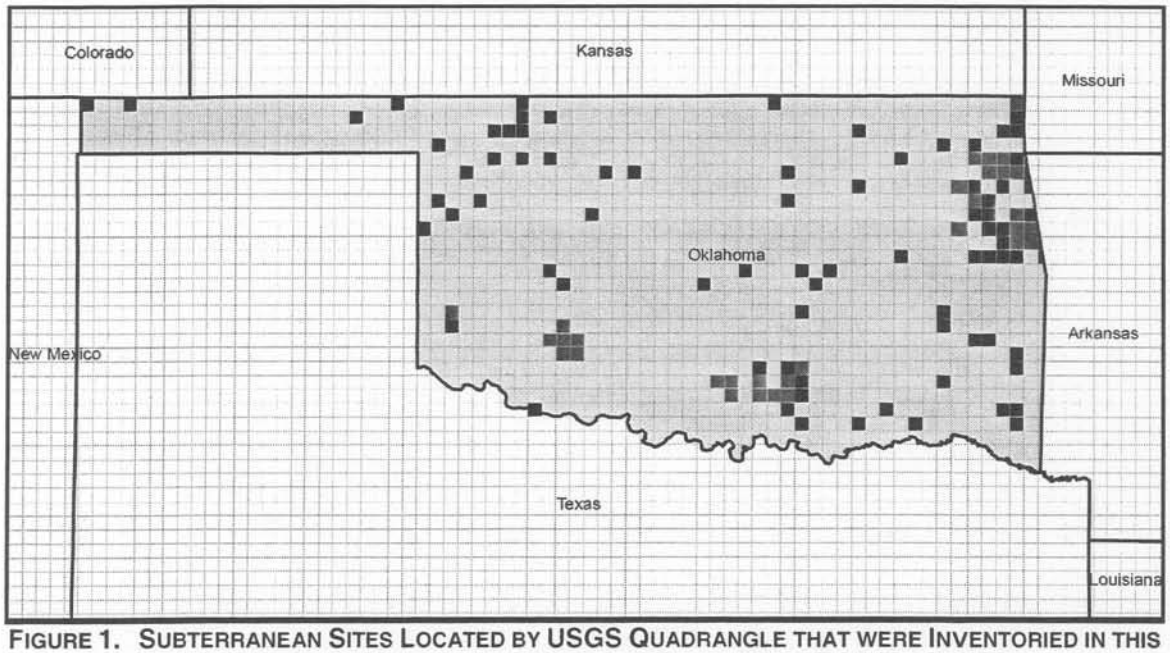

FIGURE 1. SUBTERRANEAN SITES LOCATED BY USGS QUADRANGLE THAT WERE INVENTORIED IN THIS ODWC STUDY (GRAY SQUARES) AND OTHER STUDIES (BLACK)

Site-specific Biodiversity Estimates

Very few caves site had a species richness greater than 20 taxa; the number of sites decreases exponentially as the richness increases (Figure 2).

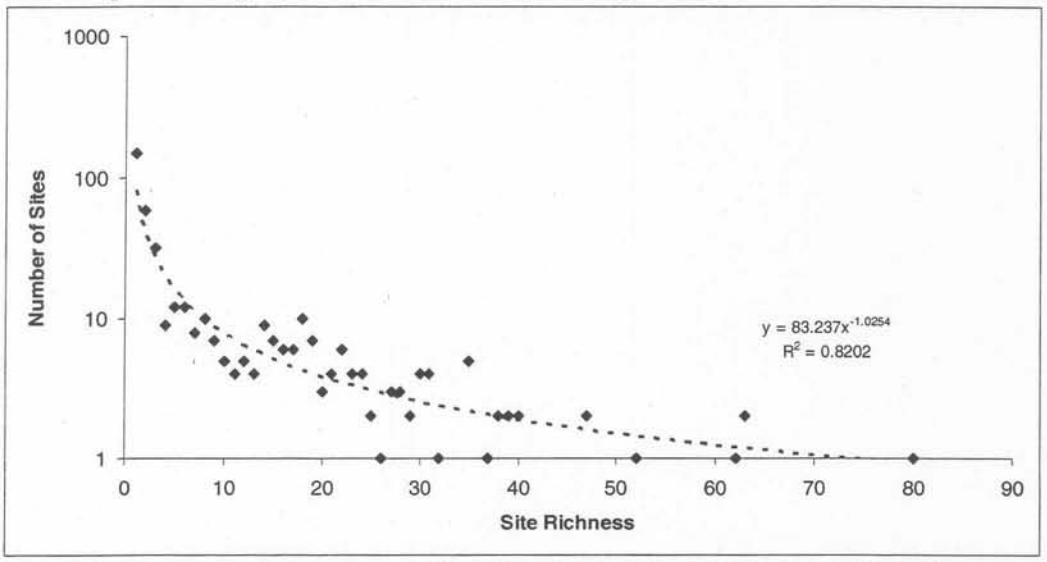

FIGURE 2. EXPONENTIAL RELATIONSHIP BETWEEN RICHNESS AND NUMBER OF SITES HAVING THAT RICHNESS

All of the subterranean sites were ranked by species richness; springs were excluded because their connectivity with surface habitats inflates their site richness with species that are not strongly associated with subterranean ecosystems. Table 1 lists the top 40 most species-rich subterranean sites (primarily caves) in Oklahoma. The most species-rich cave currently is AD-14 with 76 taxa, with Jester Cave and the J. Selman Cave System very close behind (75 and 69 taxa, respectively).

TABLE 1. TOP 40 MOST SPECIES-RICH CAVES IN OKLAHOMA

Richness	Site Name (or Code)	County
76	AD-14	Adair
75	Jester Cave	Greer
69	J. Selman Cave System	Woodward
63	DL-39	Delaware
63	CZ-9	Cherokee
47	MU-2	Murray
47	DL-91	Delaware
39	AD-19	Adair
38	AD-7	Adair
37	DL-3	Delaware
35	DL-8	Delaware
35	DL-41	Delaware
34	AD-8	Adair
33	Nescatunga Cave	Major
32	AD-137	Adair
31	AD-9	Adair
31	DL-32	Delaware
31	Coal Creek Cave	Pontotoc
30	DL-102	Delaware
30	DL-148	Delaware
30	AD-15	Adair
28	DL-59	Delaware
27	SQ-1	Sequoyah
25	WA-012	Washita
25	AD-29	Adair
25	CZ-18	Cherokee
24	DL-38	Delaware
23	OT-4	Ottawa
23	CZ-11	Cherokee
22	DL-79	Delaware
22	CZ-12	Cherokee
22	Doolin Cave	Seminole
21	Washita Bat Caves	Washita
21	DL-51	Delaware
21	Lost Turtle Cave	Adair
20	AD-13	Adair
20	CZ-19	Cherokee
19	Little Crystal Cave	Murray
19	DL-1	Delaware
19	AD-17	Adair
19	AD-220	Adair

Rare Species

Numerous rare and endangered species utilize subterranean habitats in Oklahoma. Table 2 lists these species (taxa awaiting species description are not listed), where "rare" is defined as a species having a Natural Heritage / NatureServe ranking of G1, G2, S1, or S2 (see http://www.natureserve.org/explorer for an explanation of the ranking system and further data). There are at least 40 known subterranean-obligates in Oklahoma (Table 3), including 8 new species that await taxonomic description. Culver et al. (2000) reported 27 subterranean-obligates from Oklahoma – we expanded the list to 40. In Oklahoma, the most common troglobite was grotto salamander (*Eurycea spelaea*) with at least 74 occurrences in 43 sites (second most common were cave isopods [*Caecidotea* sp.]). In the USA, the most common obligate reported was a cave dung fly (*Spelobia tenebrarum*) found in at least 50 counties and 12 States (Culver et al. 2000).

TABLE 2. RARE AND ENDANGERED SPECIES REPORTED IN SUB. HABITATS OF OKLAHOMA

Scientific Name	Common Name	ESA Status	Global Rank	State Rank
*Allocrangonyx pellucidus**	Oklahoma Cave Amphipod	Not Listed	G2G3	S1?
*Amblyopsis rosae**	Ozark Cavefish	Threatened	G2G3	S1
*Arrhopalites jay**	Cave Globular Springtail	Not Listed	G2G3	SNR
*Bactrurus hubrichti**	Kansas Well Amphipod	Not Listed	G4	S2?
*Caecidotea acuticarpa**	Cave Isopod	Not Listed	G2G3	SNR
*Caecidotea adenta**	Cave Isopod	Not Listed	G1G2	SNR
*Caecidotea macropropoda**	Bat Cave Isopod	Not Listed	G2G3	SNR
Caecidotea oculata	Water Slater	Not Listed	G2G3	SNR
*Caecidotea simulator**	Springfield Plain Groundwater Isopod	Not Listed	G2G3	SNR
*Cambarus subterraneus**	Delaware County Cave Crayfish	Not Listed	G1G2	S1
*Cambarus tartarus**	Oklahoma Cave Crayfish	Not Listed	G1G2	S1
Coragyps atratus	Black Vulture	Not Listed	G5	S2B
Corynorhinus townsendii ingens	Ozark Big-eared Bat	Endangered	G4T1	S1
Etheostoma craginii	Arkansas Darter	Candidate	G3	S2
Eurycea lucifuga	Cave Salamander	Not Listed	G5	S2S3
*Miktoniscus racovitzai**	Racovitza's Cave Isopod	Not Listed	G3G4T1T2	SNR
Myotis grisescens	Gray Bat	Endangered	G3	S2
Myotis leibii	Eastern Small-footed Bat	Not Listed	G3	S1
Myotis lucifugus	Little Brown Bat	Not Listed	G5	S1
Myotis septentrionalis	Northern Long-eared Bat	Not Listed	G4	S2
Myotis sodalis	Indiana Bat	Endangered	G2	S1
Myotis yumamensis	Yuma Myotis (Bat)	Not Listed	G5	S1
Orconectes meeki	Meek's Crayfish	Not Listed	G4	S2S3
Plethodon angusticlavius	Ozark Zigzag Salamander	Not Listed	G4	S2
Plethodon ouachitae	Ouachita Salamander	Not Listed	G2G3	S2
*Pseudosinella dubia**	Cave Springtail	Not Listed	G1G2	SNR
Rana palustris	Pickerel frog	Not Listed	G5	S2S3
Spilogale putorius	Eastern Spotted Skunk	Not Listed	G5	S2
*Stygobromus bowmani**	Bowman's Cave Amphipod	Not Listed	G1G2	S1?
*Stygobromus ozarkensis**	Ozark Cave Amphipod	Not Listed	G3G4	S1
*Stygobromus onondagaensis**	Onondaga Cave Amphipod	Not Listed	G1	SNR
Vulpes velox	Kit Fox	Not Listed	G3	S1

Note: Asterisk (*) indicates that the species is adapted or restricted to subterranean habitats.

TABLE 3. SUBTERRANEAN-OBLIGATE ANIMALS OF OKLAHOMA. AT LEAST 40 SPECIES ARE KNOWN TO BE LIMITED TO, OR ADAPTED TO, GROUNDWATER HABITATS (STYGOBITES) OR CAVES (TROGLOBITES) OF OKLAHOMA.

Scientific Name	Common Name	Global Rank	State Rank	# of Sites
Allocrangonyx pellucidus	Oklahoma Cave Amphipod	G2G3	S1?	18
Amblyopsis rosae	Ozark Cavefish	G2G3	S1	13
Amerigoniscus centralis	Cave Isopod	GNR	SNR	1
Arrhopalites jay	Cave Globular Springtail	G2G3	SNR	2
Arrhopalites sp. nov.	New Species of Globular Springtail	GU	SU	1
Bactrurus hubrichti	Kansas Well Amphipod	G4	S2?	2
Caecidotea acuticarpa	Cave Isopod	G2G3	SNR	20
Caecidotea adenta	Cave Isopod	G1G2	SNR	1
Caecidotea ancyla	Cave Isopod	G3G4	SNR	9
Caecidotea antricola	Cave Isopod	G5	SNR	2
Caecidotea mackini	Long's Cave Isopod	GNR	SNR	1
Caecidotea macropropoda	Bat Cave Isopod	G2G3	SNR	6
Caecidotea simulator	Springfield Plain Groundwater Isopod	G2G3	SNR	6
Caecidotea steevesi	Steeves' Cave Isopod	G3G4	SNR	3
Caecidotea stiladactyla	Cave Isopod	G3G4	SNR	9
Cambarus subterraneus	Delaware County Cave Crayfish	G1G2	S1	4
Cambarus tartarus	Oklahoma Cave Crayfish	G1G2	S1	3
Causeyella sp.	Cave Millipede	GU	SU	2
Chaetaspis sp.	Cave Millipede	GU	SU	1
Chaetaspis sp. nov. # 2	New Species of Cave Millipede	GU	SU	1
Crosbyella sp.	Cave Harvestman	GU	SU	7
Eurycea spelaea	Grotto Salamander	G4	S3	43
Hesperochernes occidentalis	Cave False Scorpion	G4G5	SNR	2
Islandiana unicornis	Cave Spider	G3G4	SNR	1
Japygidae	Two-pronged Bristletail	GU	SU	3
Litocampa sp.	Cave Two-pronged Bristletail	GU	SU	5
Litocampa sp. nov.	New Species of Cave Two-pronged Bristletail	GU	SU	1
Miktoniscus racovitzai	Racovitza's Cave Isopod	G3G4T1T2	SNR	1
Nesticus pallidus	Cave Spider	GNR	SNR	3
Nicoletia sp.	Cave Silverfish	GU	SU	2
Porrhomma cavernicola	Appalachian Cave Spider	G4G5	SNR	1
Pseudosinella dubia	Cave Springtail	G1G2	SNR	1
Pseudosinella sp. nov. # AB	New Species of Cave Springtail	GU	SU	1
Spelobia tenebrarum	Cave Dung Fly	GNR	SNR	2
Stygobromus alabamensis	Alabama Cave Amphipod	G4G5	SNR	24
Stygobromus bowmani	Bowman's Cave Amphipod	G1G2	S1?	1
Stygobromus onondagaensis	Onondaga Cave Amphipod	G1	SNR	9
Stygobromus ozarkensis	Ozark Cave Amphipod	G3G4	S1	13
Stygobromus sp. nov.	Arbuckle Mountains Cave Amphipod	GU	SU	1
Trigenotyla blacki	Black's Cave Millipede	GNR	SNR	5

Based upon the findings of this study, we suggest changes to Natural Heritage / NatureServe global and subnational (or "state") ranks as summarized in Table 4.

TABLE 4. CURRENT (OLD) GLOBAL (G) RANKS ANS STATE (S) RANKS AND SUGGESTED CHANGES (NEW) TO OLD RANKS

Taxon	Common Name	Old G rank	New G rank	Old S rank	New S rank	Comment
Achaeranea tepidariorum	Common House Spider	GNR	G5	SNR	S5	Common in USA
Acris crepitans blanchardi	Blanchard's Cricket Frog	G5T5		SNR	S5	Common in OK
Allocrangonyx pellucidus	Oklahoma Cave Amphipod	G2G3	G2	S1?	S2	Known from less than 200 individuals & 18 sites
Amblyopsis rosae	Ozark Cavefish	G2G3	G2	S1		Known from less than 300 individuals
Ameiurus melas	Black Bullhead Catfish	GNR	G5	SNR	S5	Common in OK
Ameiurus natalis natalis	Yellow Bullhead Catfish	GNR	G5	SNR	S5	Common in OK
Amerigoniscus centralis	Cave Isopod	GNR	G1	SNR	S1	Single-site endemic
Argiope aurantia	Yellow Garden Spider	GNR	G5	SNR	S5	Common in OK
Arrhopalites jay	Cave Globular Springtail	G2G3	G1	SNR	S1	Found in only 2 sites in the world
Bactrurus hubrichti	Kansas Well Amphipod	G4		S2?	S1	Found in only 2 sites in OK
Caecidotea acuticarpa	Cave Isopod	G2G3	G1	SNR	S1	Known from less than 100 individuals
Caecidotea adenta	Cave Isopod	G1G2	G1	SNR	S1	Found in only 2 sites in the world
Caecidotea ancyla	Cave Isopod	G3G4	G3	SNR	S2	Endemic to Ozarks, rare in OK
Caecidotea antricola	Cave Isopod	G5	G3	SNR	S1	Endemic to Ozarks, rare in OK
Caecidotea communis	Water Slater	GNR	G4	SNR	S1	See Graening et al. 2008
Caecidotea mackini	Long's Cave Isopod	GNR	G1	SNR	S1	Single-site endemic
Caecidotea macropoda	(delete this element - it is a misspelling of C. macropropoda - J. Lewis, pers. comm.)					See Graening et al. 2008
Caecidotea macropropoda	Bat Cave Isopod	G2G3	G2	SNR	S1	See Graening et al. 2008
Caecidotea oculata	Water Slater	G2G3	G1	SNR	S1	See Graening et al. 2008
Caecidotea simulator	Springfield Plain Groundwater Isopod	G2G3	G3	SNR	S2	See Graening et al. 2008
Caecidotea steevesi	Steeves' Cave Isopod	G3G4	G3	SNR	S1	See Graening et al. 2008
Caecidotea stiladactyla	Cave Isopod	G3G4	G3	SNR	S2	See Graening et al. 2008
Cambarus subterraneus	Delaware County Cave Crayfish	G1G2	G1	S1		Found in only 4 sites in the world
Cambarus tartarus	Oklahoma Cave Crayfish	G1G2	G1	S1		Found in only 3 sites in the world
Ceuthophilus gracilipes	Cave Cricket	GNR	G5	SNR	S5	Common in eastern USA
Crangonyx forbesi	Amphipod	GNR	G3	SNR	S2	See Graening et al. 2006
Crangonyx pseudogracilis	Sideswimmer	GNR	G5	SNR	S2	See Graening et al. 2006
Crosbyella spinturnix	Harvestman	GNR		SNR	S1	Found in 3 caves in OK
Cylisticus convexus	Sow Bug	GNR	G5	SNR	SNA	exotic species

Taxon	Common Name	Old G rank	New G rank	Old S rank	New S rank	Comment
Dendrocoelopsis americana	Cave Flatworm	G3G4		SNR	S2	Found in 6 caves in OK
Dugesia dorotocephala	Flatworm	GNR	G5	SNR	S5	Common in eastern USA
Elaphe guttata emoryi	Great Plains Rat Snake	G5T5		SNR	S5	
Eurycea longicauda melanopleura	Dark-sided Salamander	G5T4		SNR	S3	Known from 24 caves in OK
Eurycea lucifuga	Cave Salamander	G5		S2S3	S3	Known from 59 caves in OK
Folsomia candida	White Springtail	GNR	G5	SNR	S5	Common in eastern USA
Gammarus lacustris	Sideswimmer	GNR	G4	SNR	S1	See Graening et al. 2006
Gammarus minus	Sideswimmer	GNR	G4	SNR	S4	See Graening et al. 2006
Gammarus pseudolimnaeus	Northern Spring Amphipod	G5	G4	SNR	S1	See Graening et al. 2006
Gerris remigis	Water Strider	GNR	G5	SNR	S5	Common in eastern USA
Hesperochernes occidentalis	Cave False Scorpion	G4G5		SNR	S1	Found in only 2 sites in OK
Hyalella azteca	Sideswimmer	G5		SNR	S4	See Graening et al. 2006
Islandiana unicornis	Cave Spider	G3G4		SNR	S1	Found in only 1 site in OK
Lirceus garmani	Water Slater	GNR	G4	SNR	S4	See Graening et al. 2008
Lirceus hoppinae	Water Slater	GNR	G4Q	SNR	S1Q	See Graening et al. 2008
Lirceus ouachitaensis	Water Slater	GNR	G2Q	SNR	S2Q	See Graening et al. 2008
Lirceus trilobus	Water Slater	GNR	G1Q	SNR	S1Q	See Graening et al. 2008
Loxosceles reclusa	Brown Recluse Spider	GNR	G5	SNR	S5	Common in eastern USA
Macrocera nobilis	Fungus Gnat	GNR	G5	SNR	S4	Abundant in caves in OK
Meta americana	Cave Orb Weaver	GNR	G5	SNR	S4	Abundant in caves in OK
Miktoniscus racovitzai	Racovitza's Cave Isopod	G3G4-T1T2	G3-T1	SNR	S1	Single-site endemic subspecies
Musca domestica	Common Housefly	GNR		SNR	SNA	Common in USA; not a conservation target
Narceus americanus	Millipede	G5		SNR	S4	Common in OK
Orconectes neglectus neglectus	Ringed Crayfish	G5-T4T5		SNR	S4	Common in OK
Oxidus gracilis	Greenhouse Millipede	G5		SNR	SNA	exotic species
Plethodon albagula	Slimy Salamander	G5		SNR	S4	Abundant in caves in OK
Porrhomma cavernicola	Appalachian Cave Spider	G4G5		SNR	S1	Found in only 1 site in OK
Pseudosinella dubia	Cave Springtail	G1G2		SNR	S1	Found in only 1 site in OK
Ptomaphagus cavernicola	Round Fungus Beetle	GNR		SNR	S1	Found in only 4 sites in OK
Scoliopterix libratix	Pink Cave Moth	GNR	G5	SNR	S3	
Spelobia tenebrarum	Cave Dung Fly	GNR		SNR	S1	Found in only 2 sites in OK
Stygobromus alabamensis	Alabama Cave Amphipod	G5	G4	SNR	S3	See Graening et al. 2006
Stygobromus bowmani	Bowman's Cave Amphipod	G1G2	G1	S1?	S1	See Graening et al. 2006
Stygobromus onondagaensis	Onondaga Cave Amphipod	G5	G3	SNR	S2	See Graening et al. 2006
Stygobromus ozarkensis	Ozark Cave Amphipod	G4		S1	S3	See Graening et al. 2006
Trigenotyla blacki	Black's Cave Millipede	GNR	G1	SNR	S1	Extremely endemic (Shear 2003)

Taxon	Common Name	Old G rank	New G rank	Old S rank	New S rank	Comment
Trigenotyla seminole	Millipede	GNR	G1	SNR	S1	Extremely endemic (Shear 2003)
Trigenotyla vaga	Millipede	GNR	G1	SNR	S1	Extremely endemic (Shear 2003)

The relationship between total species richness of a site and the richness of subterranean-obligates at the site is significant (Figure 3), indicating that general species richness is an estimator for subterranean obligate diversity (which is the generally-accepted metric of subterranean biodiversity worldwide). The relationship between a site's richness and the number of obligates in the site is directly proportional, with roughly one obligate for every 10 total species. The equation of linear fit is: # of obligates = 1.065 + 0.082 x richness ($r^2 = 0.546$, $p < 0.001$).

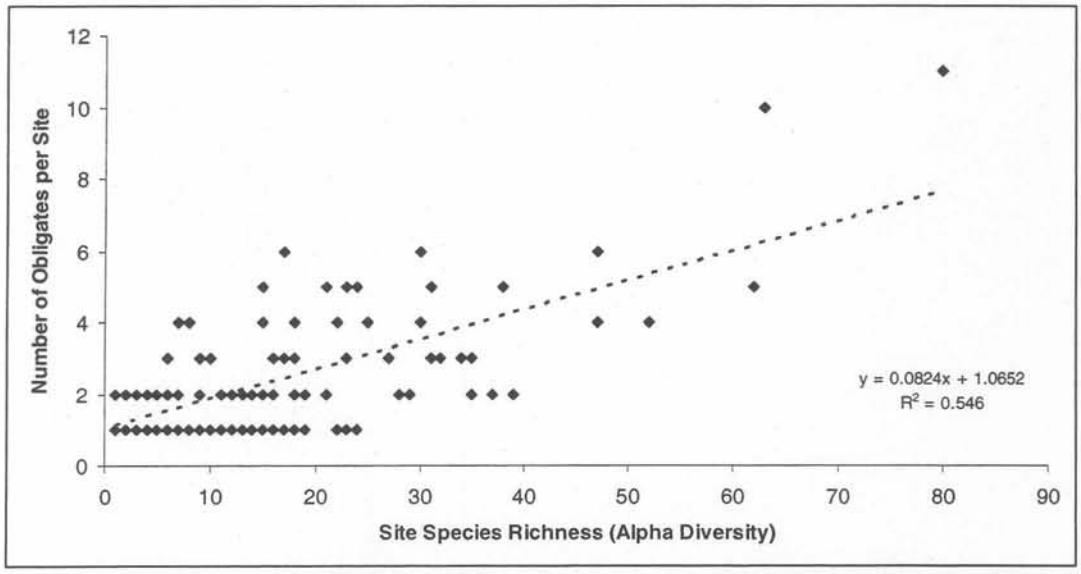

FIGURE 3. RELATIONSHIP BETWEEN TOTAL RICHNESS AND OBLIGATE RICHNESS IN OKLAHOMA

Most Common Species

Overall, arthropods dominated the subterranean habitats, especially crickets, mosquitoes, spiders, and springtails. The most common invertebrate taxon was cave crickets of the genus *Ceuthophilus*. The most common vertebrates were eastern pipistrelle bat (*Periomyotis subflavus*) and cave salamander (*Eurycea lucifuga*). In aquatic habitats, crustaceans dominated (with the majority of occurrences represented by cave isopods (*Caecidotea*). Table 4 lists the most commonly occurring animal Families in subterranean habitats of Oklahoma and the number of sites in which they were found.

TABLE 5. TOP 40 MOST COMMON FAMILIES IN SUBTERRANEAN HABITATS OF OKLAHOMA

Scientific Name	Common Family Name	Number of Sites
Vespertilionidae	Bats	170
Plethodontidae	Lungless Salamanders	81
Raphidophoridae	Camel Crickets	79
Asellidae	Water Slaters & Sowbugs	117
Crangonyctidae	Sideswimmers	92
Muridae	Mice	37
Heleomyzidae	Flies	34
Cambaridae	Crayfishes	81
Culicidae	Mosquitoes	50
Mycetophilidae	Fungus Gnats	37
Staphylinidae	Rove Beetles	33
Entomobryidae	Springtails	20
Chironomidae	Midges	61
Araneidae	Orb-weaver Spiders	29
Tipulidae	Crane Flies	32
Tyrannidae	Flycatchers	35
Leiodidae	Round Fungus Beetles	20
Ranidae	Frogs	34
Carabidae	Ground Beetles	37
Trichopetalidae	Millipedes	13
Gerridae	Water Striders	51
Polygyridae	Land Snails	14
Campodeidae	Two-pronged Bristletails	10
Lumbricidae	Earthworms	29
Veliidae	Broad-shouldered Water Striders	37
Physidae	Aquatic Snails	57
Sminthuridae	Globular Springtails	13
Procyonidae	Raccoons, Skunks, etc.	26
Dytiscidae	Predaceous Diving Beetles	38
Sphaeroceridae	Dung Flies	23
Gammaridae	Sideswimmers	25
Hyallelidae	Side Swimmers	52
Phalangodidae	Harvestmen	12
Hydrophilidae	Water Scavenger Beetles	37
Paradoxosomatidae	Millipedes	28
Phoridae	Humpbacked Flies	5
Pisidiidae	Peaclams	18
Rhagidiidae	Mites	9
Planaridae	Flatworms	33
Sciaridae	Fungus Gnats	12

Regional Richness Estimates

The bioinventory effort to date may be noteworthy, but it is far from complete. One statistical method for estimating this effort is an accumulation curve, where each new species found during consecutive collecting trips is added to the total number of species found and plotted against total number of collecting trips. This plotted curve usually is steep in the beginning, where early sampling efforts produce many new species, and the curve flattens later, when later sampling efforts produce few, if any, species not previously collected. The collector's curve approaches a theoretical maximum (asymptote), which represents the grand total number of species in that sampled habitat, a value that is sometimes interpreted as the carrying capacity of that ecosystem. A collector's curve for this study was generated (Figure 4), which compared sampling effort (cumulative number of bioinventories) to the growing species list (cumulative number of species), defined as total number of species or total number of obligate species. The flattening trend of the curve suggests that sampling effort to date has detected the majority of total species that can be found in subterranean habitats of Oklahoma, and that future bioinventories will add more species to this cumulative list, but probably at an exponentially slower rate.

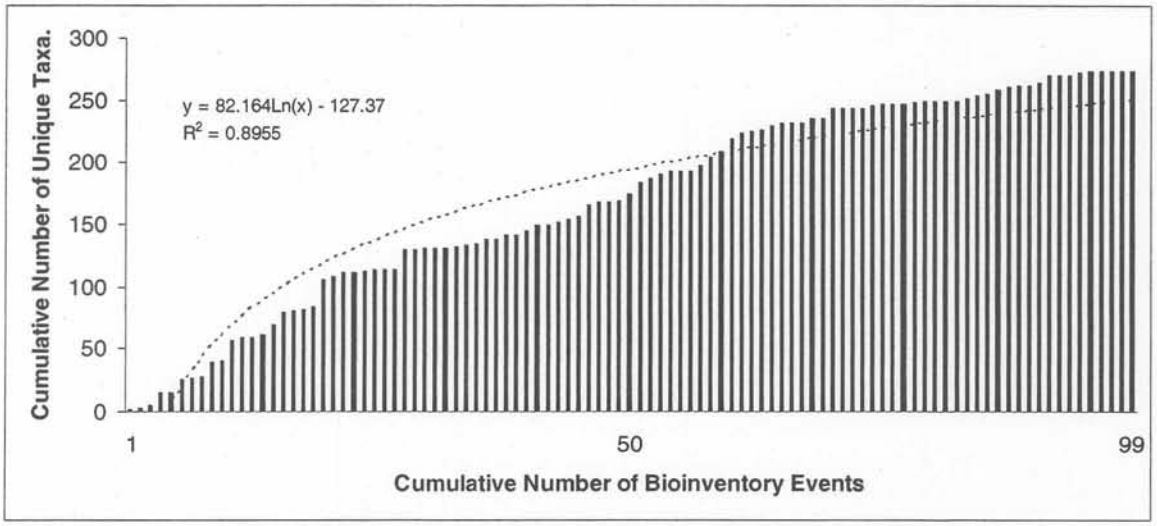

FIGURE 4. STUDY EFFORT AND RESULTING RICHNESS IN OKLAHOMA

Habitat Correlates Compared to Richness

Habitat variables data were collected during the fieldwork at each site; these data were compared to the site's total species richness and obligate richness to discern any biodiversity patterns. Species richness of a site was directly proportional to its passage length (m)(Figure 5). Linear regression indicates that the relationship is directly proportional, but a poor fit, where roughly one additional species is added for every 200 m of passage added ($r^2 = 0.466$, $p < 0.001$).

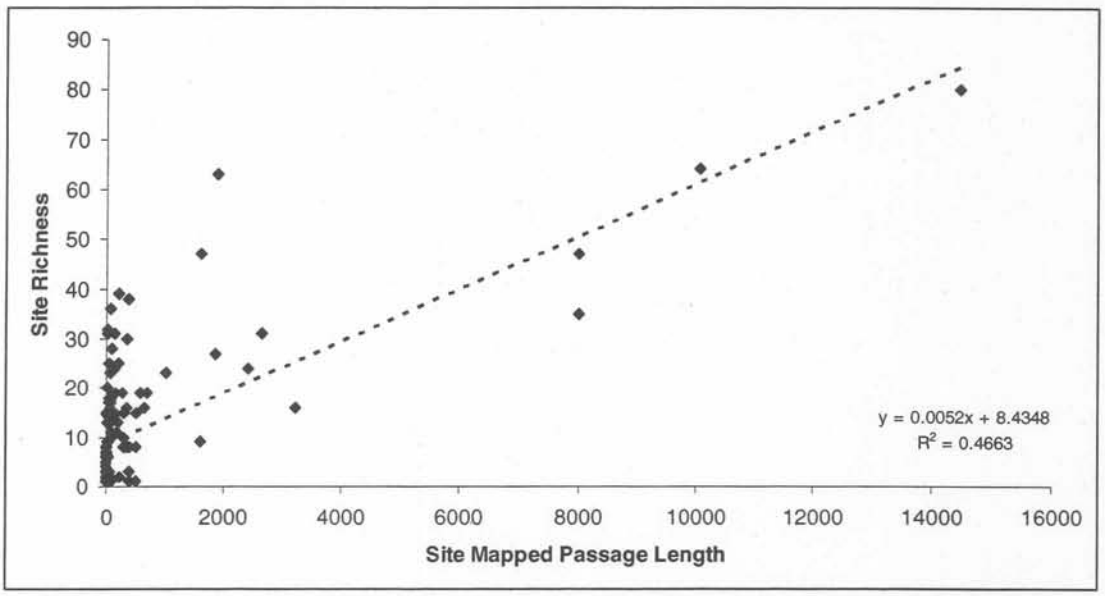

FIGURE 5. SPECIES RICHNESS OF A SITE WAS DIRECTLY PROPORTIONAL TO ITS PASSAGE LENGTH (METERS)

Other habitat characteristics were compared to site richness. Most caves did not have appreciable organics and most did not have bat guano, but species richness was significantly greater when organics and/or guano were present (*t*-test on organics, t = -18.157, $p < 0.001$)(*t*-test on guano; t = -14.522, $p < 0.001$). Similarly, richness of obligates was greater with organics present and when guano was present.

Species richness did significantly differ between category of water resource; ANOVA and Tukey-Kramer Honestly Significantly Different (HSD) statistics determined that sites with perennial streams were significantly richer than all other types of sites, and conversely, dry sites were the lowest in richness (ANOVA, n = 664, F= 58.178, $p <$ 0.001). Obligate richness followed a similar pattern.

Species richness was significantly different between habitat types (F = 3.882, p = 0.001); but comparison of means by Tukey-Kramer HSD determined that habitat types were not significantly different. When habitat types were collapsed into more general categories (caves and mines combined; springs and wells combined; hyporheos sites removed; bluff shelter, sinkhole, pit, and crevice/talus combined into "other"), caves (and springs were found to be richer than "other" types of sites (F = 9.924, $p < 0.001$).

For sites having degree of public (recreational) use, most sites ranked "light". Site richness was significantly different between degree of use categories (ANOVA, F = 9.505, $p < 0.001$); comparison of pairs using Tukey-Kramer HSD revealed that sites with moderate and heavy use were significantly more rich than sites with light use or no use. Given the correlation between richness and passage length, this result was not totally unexpected as degree of public use was significantly related to passage length (ANOVA, F= 3.019 p = 0.030). Richness of obligates followed a similar pattern.

Species richness was significantly greater when the site was gated versus ungated caves (including "unknown") (*t*-test, $t = -12.452$, $p < 0.001$). Richness of obligates followed a similar pattern (*t*-test, $t = -11.274$, $p < 0.001$). However, this may be another nested effect because almost all long caves are gated, and we demonstrated earlier that longer caves have greater richness.

Species richness was significantly different between site access types ($F = 27.546$, $p < 0.001$); comparison of pairs using Tukey-Kramer HSD revealed that the category "Scientific Study Only" was the highest in richness and "Unrestricted access" and "closed/sealed" were the lowest in richness.

Most sites were not vandalized; however, those that were vandalized had greater richness (*t*-test, $t = -13.716$, $p < 0.001$). Richness of obligates followed a similar pattern ($F = 159.457$, $p < 0.001$). Again, due to the correlation between richness and length, this result was not totally unexpected. Vandalized caves were significantly longer than caves not vandalized (*t*-test, $t = -5.391$, $p < 0.001$). Contingency analysis of vandalism by degree of public use revealed a significant relationship (Pearson $X^2 = 136.790$, $p < 0.001$). Most sites having light use or no use had no vandalism but those sites rated "moderate" and "heavy use" (18 and 19 respectively) were more often vandalized.

Owner class was compared to richness and found to be significantly different by class ($F = 4.525$; $p = 0.001$). This was a confusing result, as the "federal" and "state" classes were lower in richness than "commercial" and "private" classes.

Ranking of Cave Sites in Terms of Biological Importance

Sites were ranked in biological importance using 3 variables: site length, total species richness, and obligate richness. Caves have often been likened to islands due to their insular features, especially their hydrologic and geologic barriers (e.g. Culver, 1970). As a general pattern, larger islands carry more species than smaller ones, and this species-area relationship is well documented in diversity studies (e.g. MacArthur and Wilson, 1967). Similarly, the largest caves (measured as passage length) are often the most diverse - the world's longest cave, Mammoth Cave, at over 571 km of passage, has the greatest known number of stygobites and troglobites (Culver and Sket, 2000). Longer caves imply more habitat types and trophic resources, which may increase the few niches available, and increase carrying capacity (Culver and Sket, 2000). Cave length was significantly correlated to richness in this study; for this reason, length was used as primary criterion for biological significance ranking. The richness of obligate species is often used to rank the importance of the world's caves (e.g. Culver and Sket, 2000), and this criterion was also used in this study. The third criterion was total species richness, which is a common measure of biological significance, and in this study, significantly fewer caves had high species counts. Sites that had been bioinventoried adequately were ranked according to these three criteria, with a minimum of at least 1 obligate species to pass; Table 5 shows the top 40 ranking caves according to their score, where Score = total richness + (10 x obligate richness) + square root of length (m).

TABLE 6. TOP 40 HIGHEST RANKING CAVE SITES IN OKLAHOMA

Site Name (or Code)	Total Richness	No. of Obligates	Mapped Length	Score	Rank
AD-14	76	11	14494	306	1st
DL-39	63	10	1891	206	2nd
J. Selman Cave System	69	1	8000	134	3rd
MU-2	47	3	8000	166	4th
DL-91	47	6	1600	147	5th
CZ-9	62	5	604	138	6th
AD-9	32	5	2641	133	7th
DL-148	30	6	352	109	8th
AD-7	38	5	370	107	9th
Mystic Cave	16	3	3220	103	10th
SQ-1	27	3	1854	100	11th
DL-32	31	5	137	93	12th
Nescatunga Cave	33	1	2400	92	13th
DL-21	17	6	100	87	14th
DL-38	24	5	130	85	15th
OT-4	23	3	1000	85	16th
DL-74	15	5	300	82	17th
CZ-11	23	5	75	82	18th
CZ-18	25	4	200	79	19th
OT-19	9	3	1600	79	20th
AD-8	34	3	214	79	21st
DL-119	18	5	100	78	22nd
DL-8	35	3	107	75	23rd
AD-19	39	2	200	73	24th
DL-51	21	5		71	25th
DL-102	30	4		70	26th
AD-137	32	3	30	67	27th
Coal Creek Cave	31	3	30	66	28th
DL-41	35	3		65	29th
DL-3	36	2	80	66	30th
DL-1	19	2	567	63	31st
DL-79	22	4		62	32nd
DL-59	28	2	100	58	33rd
DL-104	15	2	500	57	34th
DL-47	10	3	300	57	35th
AD-54	17	3	100	57	36th
AD-220	19	2	281	56	37th
DL-64	18	3	50	55	38th
MY-12	15	4		55	39th
DL-19	17	3	50	54	40th

Note: Score = total richness + (10 x obligate richness) + square root of length (m)

Other Findings and Resulting Publications

This grant project produced many other findings, which have been presented separately in various journal articles listed below (with the State Wildlife Grant Program acknowledged). Likewise, results of individual status surveys of some rare and endangered fauna of Oklahoma caves were published in the following articles:

- Bergey, E., W. Matthews, and FJ. Fry. In press. Springs in time: fish fauna and habitat changes in springs over a 20-year interval. Aquatic Conservation: Marine and Freshwater Ecosystems

- Graening, G., M. Slay, D. Fenolio, and H. Robison. 2008. Annotated checklist of the Isopoda (Subphylum Crustacea: Class Malacostraca) of Arkansas and Oklahoma, with emphasis upon subterranean habitats. Proceedings of the Oklahoma Academy of Science.

- Graening, G., J. Holsinger, D. Fenolio, E. Bergey, and C. Vaughn. 2006. Annotated checklist of the amphipod crustaceans of Oklahoma, with emphasis on groundwater habitats. Proceedings of the Oklahoma Academy of Science 86:65-74.

- Lewis, J., G. Graening, D. Fenolio, and E. Bergey. 2006. Caecidotea mackini, new species, with a synopsis of the subterranean asellids of Oklahoma (Crustacea: Isopoda: Asellidae). Proceedings of the Biological Society of Washington 119(4):563-575.

- Graening, G., H. Hobbs III, M. Slay, W. Elliott, and A. Brown. 2006. Status update for bristly cave crayfish, Cambarus setosus (Decapoda: Cambaridae) and range extension into Arkansas. Southwestern Naturalist 51(3):382-391.

- Fenolio, D., G. Graening, and J. Stout. 2006. Coprophagy in a cave-adapted salamander. Proceedings of the Royal Society of London, B, 273(1585):439-444.

- Graening, G., and D. Fenolio. 2005. Status update of the Delaware County crayfish, Cambarus subterraneus (Decapoda: Cambaridae). Proceedings of the Oklahoma Academy of Science 85:85-89.

- Fenolio, D., G. Graening, and J. Stout. 2005. Seasonal movement pattern of pickerel frogs (Rana palustris) through an Ozark Cave and ecological implications supported by stable isotope evidence. Southwestern Naturalist 50(3):385-389.

Other publications related to the authors or this project can be found at:
http://research.naturalinvestigations.com/Cave_Pubs.htm

Part 2. Spring Survey.

Habitat characterization. Forty-one springs were sampled. Additionally, samples from 9 springs sampled previously were also processed. The survey included springs in 17 counties, and 6 named and 2 alluvial aquifers (Fig. A). Chemically, most of the sampled springs had circum-neutral pH (Table A). The four gypsum springs (springs SPR06-01 through -04) tended to have higher pH. These four springs also had elevated conductivity (over 2000 µS/cm). One sulphur spring (SPR04-7), which had very high conductivity, was included in the survey.

Discharge, or the amount of water flowing from the spring, is an important determinant of the spring's biota. The higher discharge springs (> 10 l/s) were primarily associated with aquifers in limestone areas – the Arbuckle-Simpson and Ozark Plateau. These aquifers included springs with both high and low discharge; for example the discharge range among the 13 Arbuckle springs was 0.08 to 90.6 l/s. One high discharge spring, McCorkle Spring (SPR05-08), was found in western Oklahoma. This spring has diffuse outlets and supports a large wetland with a diverse assemblage of vascular plants; the other sampled springs associated with the High Plains Aquifer were either linear springs along streams, hillslope seeps, or a seep are supporting a cattail marsh.

The water temperature of springs is almost constant and often reflects the average annual temperature of the region. The temperature of most of the sampled springs was in the 15 to 20 °C range. Higher temperatures were found in the High Plains Aquifer springs (Table A), which ranged from 20 to 28 °C. Springs with deep water sources may have somewhat higher temperatures than shallow-source springs (Förster et al., 1994); alternatively, higher temperatures may result from surface heating when temperatures are taken in the springbrook downstream of the source, especially where and discharge is low or the water is pooled and thus retained. Both of these factors may contribute to the higher temperatures in the High Plains Aquifer springs, which originate low in the aquifer (Pete Thurmond, personal communication) and often occur as seeps that have shallow water that can be quickly warmed.

Rare fish, crayfish and invertebrates. Although rare fish (e.g., *Etheostoma cragini*) and crayfish have been found in similar surveys of different springs (Bergey, unpublished data), no rare species of fish or crayfish were found in this survey of 41 springs (Table B). An as-yet-unidentified cave amphipod was collected in an Okfuskee County spring.

The most exciting find was a single specimen of a freshwater polychaete, which has been provisionally identified as *Manayunkia speciosa*, based on its known distribution and resemblance to illustrations. Polychaetes are segmented worms and are in the same phylum (the Annelida) as oligochaetes, the common freshwater worms, and leeches. Nearly all polychaetes are marine. In the USA, freshwater polychaetes are found almost entirely in habitats along the East and West coasts. (Pennak, 1989). *Manayunkia speciosa* is found in the Great Lakes, and in states bordering both coasts and the Gulf of Mexico. It's occurrence in NE Oklahoma, if substantiated, is a significant range extension.

Invertebrate biodiversity. Despite their patchy distribution, relative isolation and cool summer temperatures, Oklahoma springs have a diverse biota, especially with respect to invertebrates. Over 200 taxa were found among the 41 springs (Appendix 2). Insects were especially diverse, with over 30 taxa of aquatic beetles (Coleoptera) and flies (Diptera), and over 20 taxa of true bugs (Hemiptera). Rudisill and Bass (2005) likewise found diverse and abundant insect populations in springs. Common non-insects included crustaceans such as amphipods and crayfish, and various snails and worms.

Richness, or the number of species present, ranged from a low of 10 taxa to a high of 51 taxa (Appendix 2). These counts are conservative because they do not include microcrustaceans (ostracods, copepods, and cladocerans), and several groups were not identified to genus (e.g., naidid and tubificid worms, water mites, and chironomid midges). The highest richness was found in Lowrance Spring (SPR04-01), which is made up of several 'boils' in a spring pond with vegetated edges and an extensive, well-vegetated springbrook. Lowrance Spring also had the highest flow (90.6 l/s) among the 41 sampled springs, which suggests a relationship between discharge and richness. Regression analysis showed a relationship ($F = 9.62$, $p = 0.004$); however the relationship is weak, accounting for only 22% of the variability of the data ($R^2 = 0.216$). The wide range in the number of taxa present in low-discharge springs weakened the relationship and occurred, in part, because the microhabitat structure of springs affects richness (Rudisill and Bass 2005).

One of the low-richness springs was a sulphur spring (SPR04-07) where the harsh chemical conditions supported 13 species. Several of the other springs with few taxa were found in the Ozarks; where some of the sampled streams were quite small. Drought conditions undoubtedly reduced habitat space and variation within some of these springs and affected the number of taxa.

A comparison of the invertebrate composition among springs using non-metric multidimensional scaling (NMDS) is shown graphically in Figure B. Springs from each aquifer-association grouped together, indicating similar taxonomic composition. Although clusters of many of the aquifer-groups have considerable overlap, some pairs of aquifer groups differ. Differing pairs of aquifer-springs were identified using ANOSIM (Analysis of similarity; PRIMER). Included among the differing pairs were the Arbuckle-Simpson and Ozark springs ($R = 0.566$, $p < 0.001$) and the High Plains and Ozark springs ($R = 0.729$, $p < 0.001$). Significant differences in 5 other spring-group pairs were found (using the aquifer-group abbreviations from Fig. B: C-H, H-a, H-T, a-O, H-R), but the number of springs in each set were considered too small for accurate analysis.

This NMDS pattern is caused by a combination of taxa that are present in most springs (= characteristic taxa, occurring in 50% or more of the springs) and groups of taxa that are characteristic of specific aquifer-groups of springs. Characteristic taxa for all springs and for springs associated with the Arbuckle-Simpson, Ozark, and High Plains aquifers are shown in Table C.

Spring faunas consist of a combination of generalists species, which are commonly found in area ponds and/or streams, spring specialists (including endemics), and occasional subterranean crustaceans. Most of the characteristic taxa in the surveyed springs are generalists, a pattern that has been noted in other surveys of Oklahoma springs (Gaskin and Bass 2000, Rudisill and Bass 2005). Aquatic worms, fly larvae (chironomids and ceratopogonids), water striders, fingernail clams, and pond snails are all common in ponds and streams – as well as in springs. Three of the characteristic taxa are apparently specialized for springs: planarians, the damselfly genus *Argia* and the scud *Hyalella azteca*. Planarians included the large black *Dugesia dorotocephala* and also smaller species; all were typically found in large numbers. The possibility of *Argia* as a spring indicator-species has been noted by David Bass (personal communication). *Hyalella azteca* is a species complex and molecular studies have indicated that more than one species occurs in springs. Although *Hyalella* can be found in a variety of other aquatic habitats, densities in springs are often very high.

Ozark springs were uniquely characterized by three crustaceans: the amphipod *Gammarus*, the isopod *Lirceus* and the ringed crayfish *Orconectes neglectus*. In Ozark springs, *Gammarus* replaced *Hyalella azteca*, which was the common amphipod in all the other groups of springs. Isopods were common only in the Ozark springs, where they were often abundant. Although the distribution of the ringed crayfish in Oklahoma is primarily in the Ozark Plateau, hence it's presence in Ozark springs, the species also occurs as a disjunct population in the Blue River, within the Arbuckle-Simpson area. However no ringed crayfish were found in the sampled Arbuckle springs, indicating that the species is restricted within the Arbuckles.

Although Arbuckle and Ozark springs are both limestone-based, their invertebrate faunas are different (Fig. B and Table C). In contrast, the invertebrate faunas of Arbuckle and High Plains springs are similar although the High Plains springs are mostly sand-based rather than limestone-based. These results highlight the distinctiveness of the Ozark and Arbuckle faunas.

Figure A. Maps showing the locations of sampled springs by sampling year. Circled springs sampled in 2003, 2004, 2005 are associated with the Arbuckle-Simpson aquifer; circled springs sampled in 2006 are Ozark-associated springs.

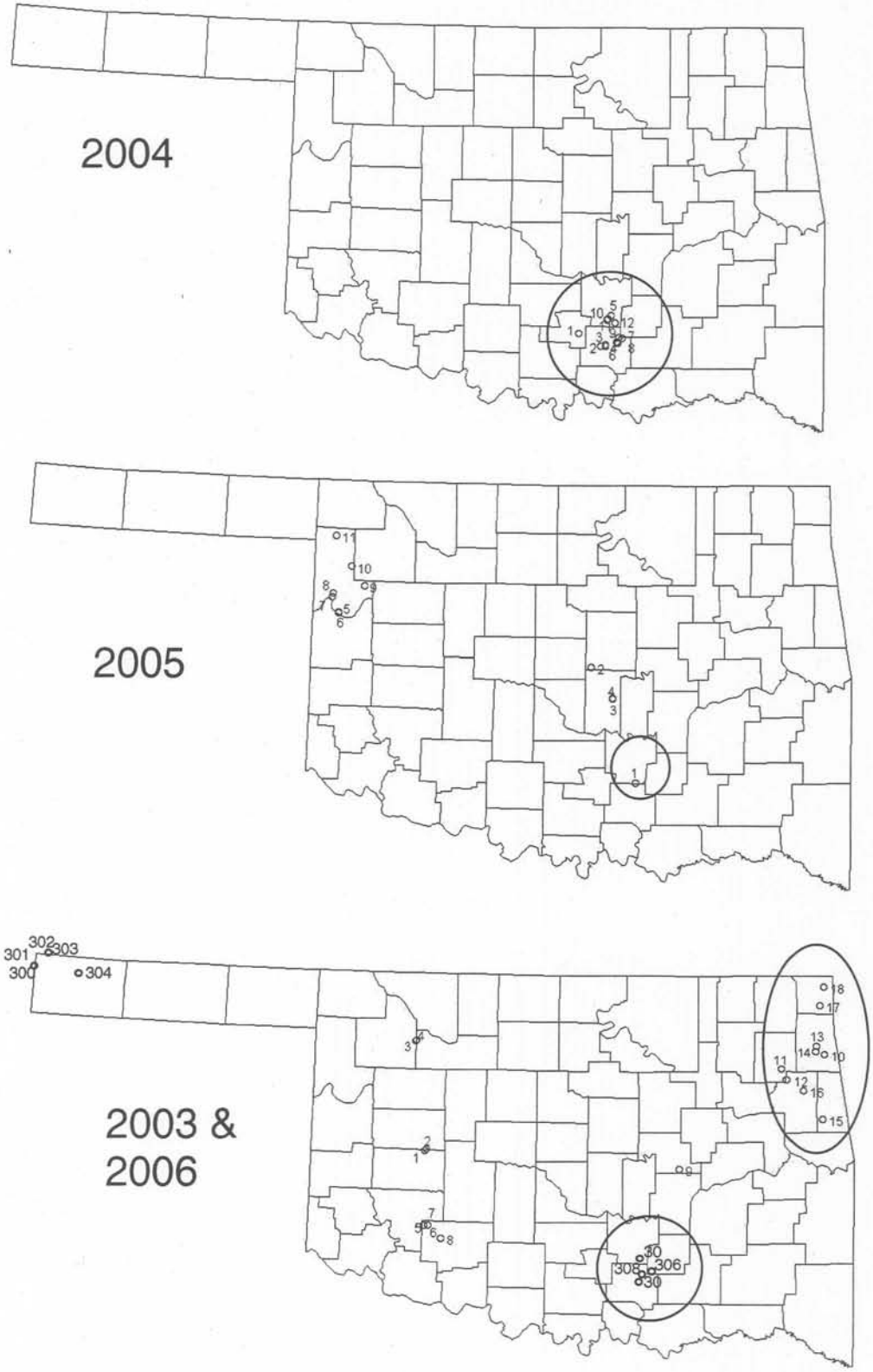

Table A. Springs surveyed in 2004-2006, including locations and water quality characteristics.

Code (#)	Site name	County	Aquifer	Sampling date	Discharge (l/s)	Temp. (°C)	pH	Conduct. (µS/cm)
SPR04-01 (1)	Lowrance Spring	Murray	Arbuckle-Simpson	17-Jun-04	90.62	18.3	7.2	187
SPR04-02 (2)	unnamed	Johnston	Arbuckle-Simpson	17-Jun-04	2.34	20.6	7.2	594
SPR04-03 (3)	Three Springs	Johnston	Arbuckle-Simpson	22-Jul-04	7.08	18.0	7.2	591
SPR04-04 (4)	Wolf Spring	Johnston	Arbuckle-Simpson	22-Jul-04	3.17	18.1	7.3	559
SPR04-05 (5)	unnamed spring	Pontotoc	Arbuckle-Simpson	23-Jul-04	0.67	18.1	7.2	696
SPR04-06 (6)	Rutherford Spring	Johnston	Arbuckle-Simpson	24-Jul-04	15.53	18.3	6.9	758
SPR04-07 (7)	Rotten Egg Spring	Coal	Arbuckle-Simpson	24-Jul-04	0.52	20.5	6.9	12.4 mS
SPR04-08 (8)	Viola Spring	Johnston	Arbuckle-Simpson	25-Jul-04	11.38	NA	7.1	1795
SPR04-09 (9)	Houghtubby Spring	Coal	Arbuckle-Simpson	25-Jul-04	0.08	18.5	7.1	708
SPR04-10 (10)	Sheep Creek Spring	Pontotoc	Arbuckle-Simpson	25-Jul-04	44.04	17.1	7.2	605
SPR04-11 (11)	unnamed spring	Pontotoc	Arbuckle-Simpson	26-Jul-04	2.33	17.0	7.2	616
SPR04-12 (12)	Wildcat Spring	Pontotoc	Arbuckle-Simpson	02-Aug-04	1.82	19.4	6.9	557
SPR05-01 (13)	Coal Cave Spring	Pontotoc	Arbuckle-Simpson	17-May-05	0.19	16.8	7.1	684
SPR05-02 (14)	Doddehl Spring	Lincoln	Central Oklahoma	18-May-05	0.5	14.8	6.6	257
SPR05-03 (15)	Trevor Spring	Pottawat.	Central Oklahoma	19-May-05	0.08	16.2	6.0	121
SPR05-04 (16)	unnamed spring	Pottawat.	Central Oklahoma	19-May-05	0.15	16.6	7.3	872
SPR05-05 (17)	unnamed seeps	Ellis	High Plains	07-Jun-05	NA	24.4	8.1	646
SPR05-06 (18)	unnamed seep	Ellis	High Plains	07-Jun-05	0.13	27.9	7.6	895
SPR05-07 (19)	Word Spring	Ellis	High Plains	08-Jun-05	3.50	20.6	7.8	792
SPR05-08 (20)	McCorkle Spring	Ellis	High Plains	08-Jun-05	13.12	22.1	7.7	413
SPR05-09 (21)	Bowman Spring	Ellis	High Plains	08-Jun-05	5.00	25.9	7.8	692
SPR05-10 (22)	Reininger Spring	Ellis	High Plains	09-Jun-05	1.18	20.6	7.4	630
SPR05-11 (23)	Dugger Spring	Ellis	High Plains	09-Jun-05	NA	25.0	8.1	694

Code (#)	Site name	County	Aquifer	Sampling date	Discharge (l/s)	Temp. (°C)	pH	Conduct. (µS/cm)
SPR06-01 (24)	Gyp Crk springs	Washita	Rush Spring	15-May-06	NA	16.5	8.1	2810
SPR06-02 (25)	Gyp Crk springs	Custer	Rush Spring	15-May-06	NA	17.6	8.0	2900
SPR06-03 (26)	Inman Spring	Major	Cimmaron River*	16-May-06	0.06	15.1	8.0	3075
SPR06-04 (27)	Bat Cave Springs	Major	Cimmaron River*	16-May-06	0.05	13.6	7.4	2800
SPR06-05 (28)	Time-of-Day	Comanche	Arbuckle-Timbered Hills**	17-May-06	1.72	17.0	7.5	630
SPR06-06 (29)	Baker Peak Spr	Comanche	Arbuckle-Timbered Hills**	17-May-06	0.24	16.6	7.0	346
SPR06-07 (30)	Sugar Creek Spr	Comanche	Arbuckle-Timbered Hills**	17-May-06	0.06	18.4	8.3	399
SPR06-08 (31)	White Sulphur Spr	Comanche	Arbuckle-Timbered Hills**	18-May-06	0.01	17.7	8.0	287
SPR06-09 (32)	Burden Spring	Okfuskee	N. Canadian R.*	19-Jun-06	0.12	17.8	6.1	137
SPR06-10 (33)	January-Stansbury Spr	Delaware	Ozark Plateau	19-Jun-06	18.36	14.5	7.0	223
SPR06-11 (34)	Roadside Park Spr	Mayes	Ozark Plateau	20-Jun-06	1.15	15.5	7.2	359
SPR06-12 (35)	Cave Spring	Cherokee	Ozark Plateau	20-Jun-06	5.84	15.4	6.8	183
SPR06-13 (36)	Everitt Spring	Delaware	Ozark Plateau	20-Jun-06	64.54	15.3	6.9	235
SPR06-14 (37)	Krause Spring	Delaware	Ozark Plateau	20-Jun-06	0.60	18.5	7.4	195
SPR06-15 (38)	Cave Spring	Adair	Ozark Plateau	21-Jun-06	0.19	15.6	7.7	341
SPR06-16 (39)	PumSpkin Spring	Cherokee	Ozark Plateau	21-Jun-06	negligible	21.1	7.7	220
SPR06-17 (40)	Cave Spring	Ottawa	Ozark Plateau	22-Jun-06	negligible	16.5	7.8	405
SPR06-18 (41)	Cave Spring	Ottawa	Ozark Plateau	07-Jul-06	0.82	15.4	7.0	333
SPR03-300	unnamed	Union, NM	High Plains	19-May-03	negligible	16.8	7.8	1083
SPR03-301	Chet Springs	Union, NM	High Plains	19-May-03	negligible	17.9	7.6	593
SPR03-302	unnamed	Baca, CO	High Plains	20-May-03	0.04	17.1	7.9	963
SPR03-303	unnamed	Baca, CO	High Plains	20-May-03	negligible	26.6	8.1	246
SPR03-304	Flagg Springs	Cimarron	High Plains	21-May-03	0.04	15.0	9.0	321
SPR03-305	Desperado Spring	Johnston	Arbuckle-Simpson	24-Jul-03	0.09	18.0	6.9	668

SPR03-306	Pot Spring	Pontotoc	Arbuckle-Simpson	25-Jul-03	1.94	17.7	7.3	459
SPR03-307	Wide Spring	Coal	Arbuckle-Simpson	25-Jul-03	unknown	17.5	7.2	535
SPR03-308	Deadman Spring	Johnston	Arbuckle-Simpson	26-Jul-03	1.10	17.8	7.1	678

* alluvial springs along major rivers

** closest named aquifer to the springs in the Wichita Mountains National Wildlife Refuge

Notes:

1. High Plains Aquifer is also the Ogallala Aquifer and the Ozark Plateau Aquifer is also called the Ozark Aquifer or the Roubidoux Aquifer.
2. NA = data missing or not available (e.g., discharge of small linear springs along streams)

Table B. Occurrence records of crayfish and fish in the 2003-2008 survey of 41 Oklahoma springs.

Code (#)	Site name	Aquifer	Crayfish	Fish
SPR04-01 (1)	Lowrance Spring	Arbuckle	*O. virilis*	*G. affinis, E. radiosum, E. gracile, Etheostoma sp.*
SPR04-02 (2)	unnamed	Arbuckle	*O. virilis*	*G. affinis, Campostoma anomalum, E. spectabile, Lepomis macrochirus*
SPR04-03 (3)	Three Springs	Arbuckle	*P. simulans*	*E. spectabile*
SPR04-04 (4)	Wolf Spring	Arbuckle	*O. nais*	*G. affinis, E. spectabile, Micropterus salmoides*
SPR04-05 (5)	unnamed spring	Arbuckle	unidentified juv.	
SPR04-06 (6)	Rutherford Spring	Arbuckle		*G. affinis*
SPR04-07 (7)	Rotten Egg Spring	Arbuckle		
SPR04-08 (8)	Viola Spring	Arbuckle	*O. palmeri longimanus*	
SPR04-09 (9)	Houghtubby Spring	Arbuckle		
SPR04-10 (10)	Sheep Creek Spring	Arbuckle	*O. palmeri longimanus*	*C. anomalum, E. radiosum, Etheostoma sp.*
SPR04-11 (11)	unnamed spring	Arbuckle	unidentified juv.	
SPR04-12 (12)	Wildcat Spring	Arbuckle		*G. affinis*
SPR05-01 (13)	Coal Cave Spring	Arbuckle	*O. palmeri longimanus, P. simulans*	*E. radiosum*
SPR05-02 (14)	Doddehl Spring	Central OK		
SPR05-03 (15)	Trevor Spring	Central OK	*P. simulans*	
SPR05-04 (16)	unnamed spring	Central OK	*P. simulans*	
SPR05-05 (17)	unnamed seeps	High Plains	unidentified juv.	
SPR05-06 (18)	unnamed seep	High Plains		*Gambusia affinis*
SPR05-07 (19)	Word Spring	High Plains		
SPR05-08 (20)	McCorkle Spring	High Plains		*Gambusia affinis*
SPR05-09 (21)	Bowman Spring	High Plains		
SPR05-10 (22)	Reininger Spring	High Plains		*Gambusia affinis*
SPR05-11 (23)	Dugger Spring	High Plains	unidentified juv.	
SPR06-01 (24)	Gyp Crk springs	Rush Spr.	*Orconectes* sp. (juveniles)	
SPR06-02 (25)	Gyp Crk springs	Rush Spr.	*Procambarus* sp. (juveniles)	
SPR06-03 (26)	Inman Spring	Cimmar. R.		
SPR06-04 (27)	Bat Cave Springs	Cimmar. R.	*Procambarus* sp. (juveniles)	*Pimephales promelas, Lepomis macrochirus*
SPR06-05 (28)	Time-of-Day	Timbered Hills		*Lepomis cyanellus*
SPR06-06 (29)	Baker Peak Spr	Timbered Hills	*Procambarus simulans*	
SPR06-07 (30)	Sugar Creek Spr	Timbered Hills	*Orconectes* sp. (juveniles)	

Code (#)	Site name	Aquifer	Crayfish	Fish
SPR06-08 (31)	White Sulphur Spr	Timbered Hills		*Gambusia affinis*
SPR06-09 (32)	Burden Spring	N. Can. R.		
SPR06-10 (33)	January-Stans. Spr	Ozark Plat.	*Orconectes neglectus*	
SPR06-11 (34)	Roadside Park Spr	Ozark Plat.		
SPR06-12 (35)	Cave Spring	Ozark Plat.	*Orconectes* sp. (juveniles)	*Pimephales promelas, Lepomis macrochirus*
SPR06-13 (36)	Everitt Spring	Ozark Plat.	*O. neglectus*	*Cottus carolinae*
SPR06-14 (37)	Krause Spring	Ozark Plat.	*O. neglectus*	
SPR06-15 (38)	Cave Spring	Ozark Plat.	*O. neglectus*	*Cottus carolinae*
SPR06-16 (39)	Pumpkin Spring	Ozark Plat.	*O. neglectus*	
SPR06-17 (40)	Cave Spring	Ozark Plat.		
SPR06-18 (41)	Cave Spring	Ozark Plat.		
SPR03-300	unnamed	High Plains		
SPR03-301	Chet Springs	High Plains		
SPR03-302	unnamed	High Plains		
SPR03-303	unnamed	High Plains		
SPR03-304	Flagg Springs	High Plains	*Orconectes* sp. (juveniles)	unidentified catfish
SPR03-305	Desperado Spring	Arbuckle	*Orconectes* sp. (juveniles)	seen downstream
SPR03-306	Pot Spring	Arbuckle	*Orconectes* sp. (juveniles)	
SPR03-307	Wide Spring	Arbuckle	*Orconectes* sp. (juveniles)	
SPR03-308	Deadman Spring	Arbuckle		

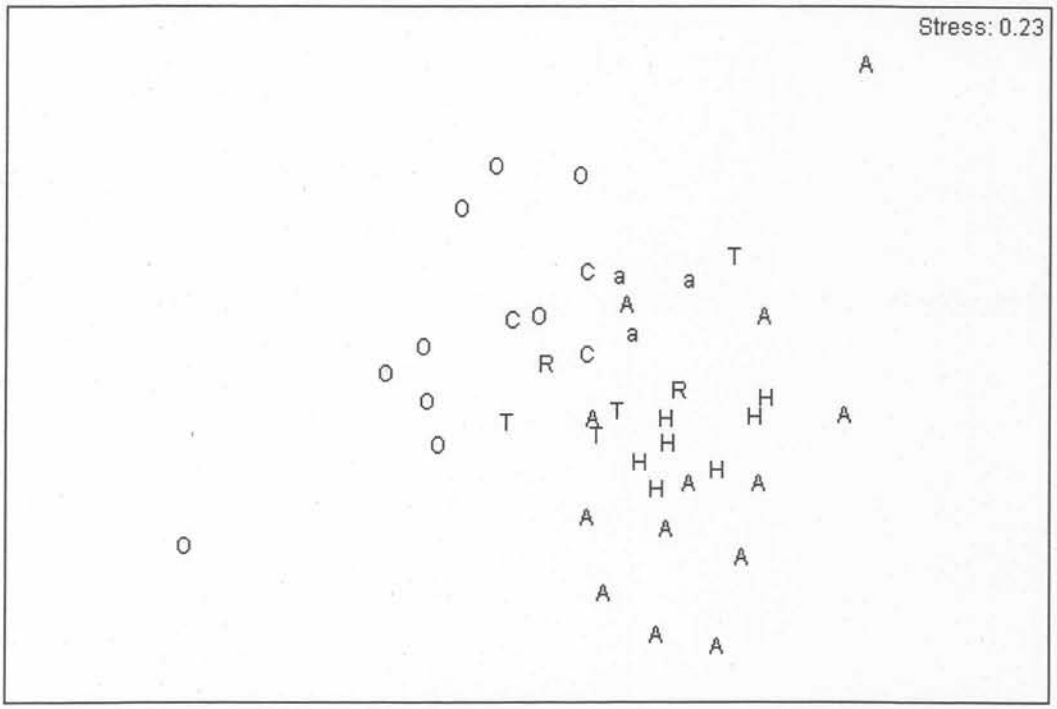

Figure B. Relative similarity of the invertebrate faunas of 41 springs surveyed in 2004-2006 as depicted using non-metric multi-dimensional scaling (PRIMER, Version 5; Primer-E Ltd, Plymouth Marine Laboratory, U.K.). Springs are by aquifer: A = Arbuckle-Simpson, O = Ozark, H = High Plains, C = Central Oklahoma, R = Rush Springs, T = Timbered Hills, a = alluvial springs.

Table C. Characteristic taxa of invertebrates in all 41 surveyed springs and in the springs associated with three aquifers (other aquifers had few sampled springs). Characteristic taxa occur in at least half of the springs.

Common name	All springs (N = 41)	Arbuckle (N = 13)	Ozark (N = 9)	High Plains (N = 7)
flatworms	planarians	▲	▲	▲
aquatic worms	Naididae			▲
aquatic worms	Tubificidae	▲	▲	▲
a no-see-um larva	Ceratopogonidae	▲		▲
midge larvae	Chironomidae	▲	▲	▲
a water strider	*Aquarius*	▲		
broad-shouldered water strider	*Microvelia*	▲	▲	▲
damselfly nymph	*Argia*	▲		▲

scud	*Hyalella*	▲		▲
a fingernail clam	Sphaeriidae	▲		▲
pond snail	*Physa*	▲	▲	▲
a water scavenger beetle		*Tropisternus* III		
a marsh beetle		*Limnichus*		▲
a mosquito larva		*Anopheles*		
a mayfly nymph		*Callibaetis*		▲
a water strider		*Trepobates*		
ringed crayfish			*O. neglectus*	
an isopod			*Lirceus*	
a scud			*Gammarus*	
hydra				*Hydra*
aquatic roundworms				nematodes
a predaceous diving beetle				*Hydroporus* II
a crawling water beetle				*Peltodytes*
a water scavenger beetle				*Berosus*
a water scavenger beetle				*Enochrus*
a dixid midge				*Dixella*
giant water bug				*Belostoma/Abedus*
a dragonfly nymph				*Aeschna*
a net-spinning caddisfly				*Cheumatopsyche*

F. Significant deviations:

- Springs surveys were conducted in under-surveyed portions of Oklahoma, in addition to surveys in the limestone areas. These included gypsum areas and the High Plains aquifer springs. Because we found only one flowing spring in Cimarron County, we sampled four springs located within a few miles of Oklahoma (other Cimarron County springs were dry or tapped and stored for stock tanks (with no release).

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I. Appendices

Appendix 1: Checklist of Taxa Inventoried in Caves During This Study

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Adair County

AD-12: Araneae, Caecidotea sp., Caudata (larval), Corynorhinus townsendii ingens, Eurycea lucifuga, Gordiidae, Litocampa sp., Periomyotis subflavus, Plethodon albagula

AD-13: Araneae sp. no. 2, Ceuthophilus sp., Coleoptera, Collembola, Corynorhinus townsendii ingens, Diptera, Eurycea lucifuga, Gastropoda (terrestrial snail), Hemiptera, Hesperochernes sp., Ixodes sp., Lepidoptera, Macrocera nobilis, Meta americana, Neotoma floridana, Periomyotis subflavus, Porcellionides pruinosis, Scolopendromorpha, Siphonaptera, Trombidiidae

AD-137: Caecidotea ancyla, Caecidotea sp., Ceuthophilus gracilipes, Collembola, Collembola sp. no. 2, Cottus carolinae, Culicidae, Cylisticus convexus, Didelphis virginiana, Diplopoda sp. no. 2, Diplopoda sp. no. 3, Diptera, Dolomedes sp., Eurycea lucifuga, Gastropoda (slug), Heleomyzidae, Hymenoptera, Inflectarius inflectus, Isopoda (terrestrial), Mycetophilidae, Orconectes sp., Oxidus gracilis, Oxidus gracilis, Platynus sp., Plecoptera, Procyon lotor, Stygobromus ozarkensis, Trichoptera

AD-14: Acarina, Araneae, Araneae sp. no. 4, Archaeognatha, Caecidotea stiladactyla, Caudata (larval), Ceuthophilus gracilipes, Collembola, Collembola sp. no. 2, Corynorhinus townsendii ingens, Crosbyella sp., Culicidae, Diplopoda, Entomobryidae, Eurycea multiplicata griseogaster, Eurycea spelaea, Heleomyzidae, Hemiptera, Hyla sp., Inflectarius inflectus, Japygidae, Leiodidae, Linyphiidae, Lumbricidae, Lycosidae, Macrocera nobilis, Meta americana, Mycetophilidae, Myotis grisescens, Myotis septentrionalis, Neotoma floridana, Opiliones, Periomyotis subflavus, Plethodon albagula, Procyon lotor, Pseudosinella sp., Psocoptera, Ptomaphagus sp., Sayornis phoebe, Sayornis phoebe, Sciaridae, Scolopendromorpha, Stygobromus alabamensis, Thysanura, Tipulidae, Tomocerus sp.

AD-161: Periomyotis subflavus

AD-17: Araneae sp. no. 2, Araneae sp. no. 3, Ceuthophilus gracilipes, Collembola, Collembola sp. no. 2, Corynorhinus townsendii ingens, Culicidae, Eurycea lucifuga, Heleomyzidae, Isopoda (terrestrial), Leiodidae, Lepidoptera, Macrocera nobilis, Meta americana, Mycetophilidae, Myotis septentrionalis, Neotoma floridana, Oxidus gracilis, Periomyotis subflavus

AD-18: Araneae sp. no. 3, Araneae sp. no. 4, Carabidae, Ceuthophilus gracilipes, Corynorhinus townsendii ingens, Dolomedes sp., Eptesicus fuscus, Heleomyzidae, Meta americana, Mycetophilidae, Neotoma floridana, Periomyotis subflavus, Staphylinidae

AD-19: Acarina, Amphipoda (stygobitic), Araneae sp. no. 2, Araneae sp. no. 3, Caecidotea steevesi, Ceuthophilus gracilipes, Coleoptera, Collembola, Collembola sp. no. 2, Corynorhinus townsendii ingens, Didelphis virginiana, Diptera, Diptera sp. no. 2, Diptera sp. no. 3, Discus patulus, Heleomyzidae, Inflectarius inflectus, Leiodidae, Lepidoptera, Lumbricidae, Macrocera nobilis, Mesodon thyroidus, Meta americana, Myrmeleontidae, Neotoma floridana, Periomyotis subflavus, Plethodon albagula, Procyon lotor, Pseudoscorpiones, Psychodidae, Sayornis phoebe, Siphonaptera, Sphecidae, Staphylinidae, Thryothorus ludovicianus, Tipulidae, Zonitoides arboreus

AD-220: Amphipoda (stygobitic), Carabidae, Caudata (larval), Ceuthophilus sp., Collembola, Eurycea spelaea, Heleomyzidae, Leiodidae, Lirceus sp., Mycetophilidae, Myotis grisescens, Opiliones, Oxidus gracilis, Periomyotis subflavus, Plethodon albagula, Plethodon angusticlavius, Sayornis phoebe, Staphylinidae, Tipulidae

AD-24: Araneae sp. no. 2, Corynorhinus townsendii ingens, Gastropoda (terrestrial snail), Gastropoda (terrestrial snail) no. 2, Leiodidae, Macrocera nobilis, Meta americana, Oxidus gracilis, Periomyotis subflavus, Staphylinidae, Stygobromus onondagaensis

AD-25: Corynorhinus townsendii ingens, Meta americana, Periomyotis subflavus

AD-29: Acarina, Araneae sp. no. 2, Araneae sp. no. 3, Araneae sp. no. 4, Ceuthophilus gracilipes, Collembola, Collembola sp. no. 2, Corynorhinus townsendii ingens, Culicidae, Diptera sp. no. 2, Eurycea lucifuga, Formicidae, Isopoda (terrestrial), Leiodidae, Lumbricidae, Macrocera nobilis, Mesodon thyroidus, Mesomphix sp., Meta americana, Neotoma floridana, Oxidus gracilis, Periomyotis subflavus, Procyon lotor, Sayornis phoebe, Scolopendromorpha

AD-41: Corynorhinus townsendii ingens, Periomyotis subflavus

AD-54: Caecidotea simulator, Carabidae, Ceuthophilus gracilipes, Collembola, Collembola sp. no. 2, Corynorhinus townsendii ingens, Crosbyella sp., Isopoda (terrestrial), Macrocera nobilis, Meta americana,

Mus musculus, Neotoma floridana, Opiliones, Patera perigrapta, Periomyotis subflavus, Procyon lotor, Stygobromus alabamensis
AD-6: Acarina, Araneae sp. no. 2, Cicurina sp., Collembola, Corynorhinus townsendii ingens, Hesperochernes sp., Leiodidae, Lepidoptera, Meta americana, Neotoma floridana, Oxidus gracilis, Psocoptera, Stygobromus sp.
AD-7: Acarina, Araneae sp. no. 2, Araneae sp. no. 3, Araneae sp. no. 4, Caudata (larval), Ceuthophilus sp., Cicurina sp., Collembola (troglobitic), Corynorhinus townsendii ingens, Crosbyella sp., Culicidae, Diplopoda (troglobitic), Diptera, Entomobryidae, Eptesicus fuscus, Eurycea longicauda melanopleura, Eurycea lucifuga, Heleomyzidae, Hesperochernes sp., Isopoda (terrestrial), Lirceus sp., Macrocera nobilis, Meta americana, Myotis grisescens, Narceus americanus, Oxidus gracilis, Periomyotis subflavus, Psychodidae, Rhagidiidae, Sciaridae, Staphylinidae, Staphylinidae sp. no. 2, Stygobromus alabamensis
AD-85: Ceuthophilus gracilipes, Collembola, Culicidae, Leiodidae, Meta americana, Periomyotis subflavus, Procyon lotor, Staphylinidae
AD-86: Araneae sp. no. 2, Araneae sp. no. 2, Cambala minor, Cathartes aura, Ceuthophilus gracilipes, Culicidae, Lepidoptera, Meta americana, Neotoma floridana, Oxidus gracilis, Patera perigrapta, Periomyotis subflavus, Platynus sp., Procyon lotor, Sayornis phoebe, Scolopendromorpha
AD-87: Cambala minor, Culicidae, Gastropoda (terrestrial snail) no. 2, Meta americana, Mus musculus, Neotoma floridana, Noctuidae, Patera perigrapta, Sphecidae
Lost Turtle Cave: Araneae sp. no. 3, Cambaridae, Carabidae, Ceuthophilus gracilipes, Chilopoda, Collembola, Diptera, Gastropoda (terrestrial snail), Lepidoptera, Linyphiidae, Lumbricidae, Macrocera nobilis, Meta americana, Neotoma floridana, Oxidus gracilis, Periomyotis subflavus, Procyon lotor, Procyon lotor, Pseudosinella sp., Sminthuridae, Staphylinidae, Testudines

Cherokee County

Cave Spring: Caecidotea sp., Caudata (larval), Cottus carolinae, Crangonyx forbesi, Culicidae, Eurycea longicauda melanopleura, Eurycea lucifuga, Heleomyzidae, Micropterus dolomieu, Orconectes neglectus neglectus, Oxidus gracilis, Periomyotis subflavus, Rana palustris
CZ-10: Achaeranea tepidariorum, Araneae, Ceuthophilus gracilipes, Coccinellidae, Collembola, Eurycea lucifuga, Heleomyzidae, Litocampa sp., Psocoptera, Scutigera sp., Sphaeroceridae, Staphylinidae
CZ-11: Araneae sp. no. 2, Caecidotea simulator, Ceuthophilus sp., Coleoptera, Crosbyella sp., Eurycea lucifuga, Heleomyzidae, Isopoda (terrestrial), Leiodidae, Lepidoptera, Litocampa sp., Meta americana, Nicoletiidae gen. nov. sp. nov., Oxidus gracilis, Polydesmida, Psocoptera, Sphaeroceridae, Staphylinidae, Stygobromus sp., Trichoniscidae
CZ-12: Achaeranea tepidariorum, Ceuthophilus gracilipes, Cicurina sp., Coleoptera, Collembola, Crosbyella sp., Culicidae, Eurycea lucifuga, Formicidae, Isopoda (terrestrial), Leiobunum sp., Meta americana, Noctuidae, Oxidus gracilis, Pseudacris crucifer crucifer, Psocoptera, Sphaeroceridae, Staphylinidae, Tabanidae, Tomocerus sp., Trichoniscidae
CZ-18: Corynorhinus townsendii ingens, Periomyotis subflavus
CZ-19: Corynorhinus townsendii ingens, Periomyotis subflavus
CZ-9: Acarina sp. no. 2, Achaeranea tepidariorum, Araneae sp. no. 4, Caecidotea ancyla, Ceuthophilus gracilipes, Ceuthophilus sp., Coleoptera sp. no. 2, Corydalidae (larva), Dasypus novemcinctus, Dolomedes sp., Eurycea longicauda melanopleura, Eurycea lucifuga, Eurycea multiplicata griseogaster, Heleomyzidae, Isopoda (terrestrial), Leiobunum sp., Leiodidae, Lithobiidae, Lycosidae, Macrocera nobilis, Megapallifera ragsdalei, Muridae, Neotoma floridana, Onychiuridae, Platynus sp., Plethodon albagula, Polydesmida, Pseudoscorpiones, Rhagidiidae, Sphaeroceridae, Staphylinidae sp. no. 2, Stygobromus sp., Thysanura, Tipulidae, Tomocerus sp.
Luck Spring: Caecidotea sp., Crangonyx forbesi, Eurycea spelaea

Comanche County

Baker's Peak Cave: Ceuthophilus sp.
Baker's Spring: Odonata (naiad), Procambarus simulans, Stygobromus alabamensis
Black Bear Spring: Culicidae, Elimia sp., Ephemeroptera (larva), Odonata (naiad), Orconectes sp.
Bluff Shelter on Bat Cave Mountain: Ceuthophilus sp., Pipistrellus hesperus
Bonanza Mine: Culicidae, Rana catesbeiana
Panther Creek CCC Well: Caecidotea sp., Ceuthophilus sp., Muridae, Stygobromus alabamensis
Pennington Mine: Ceuthophilus sp., Chilopoda, Coleoptera, Corynorhinus townsendii pallescens, Elimia sp., Gastropoda (terrestrial snail), Lumbricidae, Periomyotis subflavus, Staphylinidae

Sugar Creek Spring: Acris crepitans, Cambaridae, Elimia sp., Hyalella azteca, Odonata (naiad), Ostracoda
Tarbone Spring: Culicidae, Elimia sp., Odonata (naiad), Plecoptera, Rana catesbeiana
Time O'Day Spring: Hyalella azteca, Lepomis cyanellus, Odonata (naiad), Orconectes sp., Ostracoda
Turtle Springs: Culicidae, Gyrinidae, Orconectes sp., Plecoptera
Unnamed spring on Wichita Mountains NWR: Odonata (naiad), Ostracoda

Delaware County

Carroll's Grotto: Caecidotea simulator, Cambarus subterraneus, Cottus carolinae, Culicidae, Inflectarius inflectus
Cave near Brush Creek Bridge: Amphipoda (stygobitic), Caecidotea stiladactyla, Ceuthophilus gracilipes, Culicidae, Eurycea spelaea, Lirceus sp., Rana palustris, Tricladida (stygobitic)
DL-1: Caecidotea stiladactyla, Caudata (larval), Culicidae, Eurycea spelaea, Heleomyzidae, Leiodidae, Macrocera nobilis, Meta americana, Mycetophilidae, Myotis grisescens, Periomyotis subflavus, Platynus sp., Procyon lotor, Rana palustris, Scoliopterix sp.
DL-102: Araneae sp. no. 2, Caecidotea sp., Campodeidae, Ceuthophilus sp., Ceuthophilus utahensis, Chironomidae, Cicurina sp., Diplopoda sp. no. 2, Dolomedes sp., Eurycea lucifuga, Eurycea spelaea, Formicidae, Gordiidae, Heleomyzidae, Leiobunum sp., Lepidoptera, Megapallifera ragsdalei, Mycetophilidae, Nicoletiidae gen. nov. sp. nov., Oxidus gracilis, Periomyotis subflavus, Plethodon albagula, Psocoptera, Staphylinidae, Tipulidae, Tomocerus sp.
DL-104: Caecidotea sp., Collembola, Dolomedes sp., Eurycea lucifuga, Eurycea spelaea, Leiodidae, Lumbricidae, Meta americana, Oxidus gracilis, Periomyotis subflavus, Platynus sp., Plethodon albagula, Procyon lotor, Turbellaria
DL-105: Collembola sp. no. 2, Eurycea lucifuga, Eurycea spelaea, Lycosidae, Myotis grisescens, Oxidus gracilis, Plethodon albagula, Rana catesbeiana, Rana palustris, Sayornis phoebe, Sciaridae, Sphaeroceridae, Staphylinidae, Tomocerus sp.
DL-119: Amblyopsis rosae, Cambarus tartarus
DL-148: Amblyopsis rosae, Caecidotea ancyla, Caecidotea mackini, Cambarus tartarus, Cambarus tartarus, Castor canadensis, Dolomedes sp., Dugesia sp., Eurycea lucifuga, Gerridae, Mycetophilidae, Oxidus gracilis, Rana palustris, Semotilus atromaculatus, Sphaeroceridae, Stygobromus sp., Tipula sp., Tipulidae
DL-16: Caecidotea sp., Cottus carolinae, Culicidae, Gastropoda (terrestrial snail), Periomyotis subflavus, Sayornis phoebe
DL-19: Caecidotea ancyla, Culicidae, Didelphis virginiana, Dolomedes sp., Eurycea longicauda melanopleura, Eurycea spelaea, Eurycea spelaea, Gastropoda (terrestrial snail), Lycosidae, Mycetophilidae, Nocomis biguttatus, Oxidus gracilis, Plethodon albagula, Rana catesbeiana, Rana palustris, Sphaeroceridae, Tipulidae
DL-2: Ceuthophilus gracilipes, Cicurina sp., Culicidae, Cyprinidae, Diplopoda (troglobitic), Diplopoda sp. no. 2, Dolomedes sp., Dytiscidae, Eurycea lucifuga, Ictaluridae, Neotoma floridana, Periomyotis subflavus, Platynus sp., Rana catesbeiana, Rana sphenocephala, Sciaridae, Staphylinidae
DL-21: Amblyopsis rosae, Ceuthophilus sp., Corynorhinus townsendii ingens, Cottus carolinae, Japygidae, Lepomis sp., Myotis grisescens, Orconectes sp., Orconectes sp., Periomyotis subflavus
DL-22: Ambloplites constellatus, Ceuthophilus sp., Cottus carolinae, Cyprinidae, Eurycea lucifuga, Orconectes neglectus neglectus
DL-3: Araneae sp. no. 3, Arrhopalites sp., Carabidae, Ceuthophilus gracilipes, Cicurina sp., Collembola sp. no. 2, Dolomedes sp., Formicidae, Gastropoda (terrestrial snail), Isopoda (terrestrial), Lepidoptera, Macrocera nobilis, Megapallifera ragsdalei, Meta americana, Periomyotis subflavus, Plethodon albagula, Procyon lotor, Pseudoscorpiones, Psocoptera, Salticidae, Sayornis phoebe, Scarabaeidae, Sphaeroceridae, Staphylinidae, Stygobromus sp., Tomocerus sp.
DL-32: Araneae sp. no. 2, Caecidotea sp., Cathartes aura, Ceuthophilus sp., Dolomedes sp., Heleomyzidae, Ixodidae, Litocampa sp., Megapallifera ragsdalei, Mycetophilidae, Neotoma floridana, Oxidus gracilis, Periomyotis subflavus, Plethodon albagula, Pseudacris crucifer crucifer, Rana catesbeiana, Rana palustris, Rhagidiidae, Sminthuridae, Sphaeroceridae, Staphylinidae, Stygobromus sp., Tipulidae, Tomocerus sp.
DL-38: Amblyopsis rosae, Cambarus subterraneus, Eptesicus fuscus, Eurycea spelaea, Heleomyzidae, Neotoma floridana, Periomyotis subflavus
DL-39: Culicidae, Eurycea lucifuga, Eurycea spelaea, Heleomyzidae, Macrocera nobilis, Mycetophilidae, Myotis grisescens, Myotis septentrionalis, Orconectes neglectus neglectus, Periomyotis subflavus, Procyon lotor, Rana palustris

DL-41: Araneae, Araneae sp. no. 2, Arrhopalites sp., Ceuthophilus gracilipes, Cicurina sp., Collembola sp. no. 2, Culicidae, Diptera sp. no. 3, Eurycea lucifuga, Formicidae, Gastropoda (terrestrial snail), Hesperochernes sp., Isopoda (terrestrial), Leiobunum sp., Lepidoptera, Lumbricidae, Megapallifera ragsdalei, Neotoma floridana, Oribatida, Oxidus gracilis, Periomyotis subflavus, Plethodon albagula, Procyon lotor, Psocoptera, Rhagidiidae, Sminthuridae, Staphylinidae, Staphylinidae sp. no. 2, Stygobromus sp., Tipulidae, Tomocerus sp., Trichoniscidae
DL-51: Arrhopalites sp., Caecidotea ancyla, Caecidotea stiladactyla, Eurycea longicauda melanopleura, Eurycea lucifuga, Heleomyzidae, Megapallifera ragsdalei, Oxidus gracilis, Plethodon albagula, Sphaeroceridae, Staphylinidae, Stygobromus sp., Tipulidae
DL-59: Acarina, Araneae sp. no. 2, Caecidotea stiladactyla, Caudata (larval), Ceuthophilus sp., Cicurina sp., Culicidae, Eurycea lucifuga, Eurycea spelaea, Gastropoda (terrestrial snail), Heleomyzidae, Isopoda (terrestrial), Leiobunum sp., Lepidoptera, Mycetophilidae, Onychiuridae, Oxidus gracilis, Periomyotis subflavus, Phoridae, Plethodon albagula, Psychodidae, Rana palustris, Sminthuridae, Sphaeroceridae, Staphylinidae, Staphylinidae sp. no. 2
DL-64: Cambarus sp. (stygobitic), Ceuthophilus sp., Cicurina sp., Culicidae, Dolomedes sp., Eurycea spelaea, Heleomyzidae, Inflectarius inflectus, Macrocera nobilis, Nematoda, Orconectes neglectus neglectus, Oxidus gracilis, Periomyotis subflavus, Platynus sp., Sayornis phoebe
DL-74: Amblyopsis rosae, Caecidotea antricola, Cambarus subterraneus, Culicidae, Eurycea lucifuga, Eurycea spelaea, Macrocera nobilis, Procyon lotor, Rana palustris, Rana sp., Sayornis phoebe, Stygobromus sp., Trichoceridae
DL-79: Araneae, Arrhopalites sp., Caecidotea stiladactyla, Cathartes aura, Cicurina sp., Collembola sp. no. 2, Eurycea lucifuga, Formicidae, Gastropoda (terrestrial snail), Heleomyzidae, Lumbricidae, Megapallifera ragsdalei, Meta americana, Mycetophilidae, Oribatida, Plethodon albagula, Pseudoscorpiones, Staphylinidae, Stygobromus sp., Tipulidae, Tricladida (stygobitic)
DL-8: Araneae, Caecidotea stiladactyla, Ceuthophilus gracilipes, Cicurina sp., Eptesicus fuscus, Gastropoda (terrestrial snail), Heleomyzidae, Isopoda (terrestrial), Leiobunum sp., Lithobiidae, Myotis grisescens, Noctuidae, Onychiuridae, Oxidus gracilis, Periomyotis subflavus, Plethodon albagula, Pseudoscorpiones, Psocoptera, Rhagidiidae, Sayornis phoebe, Sciaridae, Sminthuridae, Staphylinidae, Stygobromus onondagaensis, Tipulidae, Tomocerus sp., Trichoniscidae
DL-91: Cambarus subterraneus
DL-92: Acarina, Caecidotea stiladactyla, Collembola, Culicidae, Gambusia affinis, Macrocera nobilis, Mycetophilidae, Oxidus gracilis, Platynus sp., Stygobromus ozarkensis, Tipulidae
DL-97: Caecidotea ancyla, Diplopoda (troglobitic), Diptera, Heleomyzidae, Lumbricidae, Macrocera nobilis, Orthoptera, Oxidus gracilis, Periomyotis subflavus, Stygobromus sp.
Krause Spring: Dugesia sp., Eurycea spelaea
Matthews et al. (1983) Spring # 12: Gammarus minus
Pitfall Cave: Araneae, Caudata (larval), Eurycea lucifuga, Eurycea spelaea, Heleomyzidae, Litocampa sp., Neotoma floridana, Periomyotis subflavus, Platynus sp., Rana catesbeiana, Rana palustris, Rhagidiidae
Spring on Bob Kelley's Land: Amphipoda, Dugesia sp., Gambusia affinis, Lirceus sp.
Unnamed cave on Dry Creek: Cambaridae, Castor canadensis, Cottus carolinae, Culicidae, Eurycea longicauda melanopleura, Lepomis macrochirus, Oxidus gracilis, Platynus sp., Polydesmida, Rana clamitans melanota, Semotilus atromaculatus

Ellis County

Bowman Spring 1: Hyalella azteca
Dugger Spring 1: Cambaridae, Hyalella azteca
McCorkle Springs: Gambusia affinis, Hyalella azteca
OBS Spring # SPR05-05: Cambaridae, Hyalella azteca
OBS Spring # SPR05-06: Gambusia affinis, Hyalella azteca
Reininger Spring: Gambusia affinis, Hyalella azteca
Word Springs: Hyalella azteca

Greer County

Jester Cave: Ameiurus melas, Anthicidae, Araneae, Araneae sp. no. 2, Araneae sp. no. 3, Armadillidae, Cambaridae, Carabidae, Castor canadensis, Ceuthophilus sp., Chilopoda, Coleoptera, Coleoptera sp. no. 2, Collembola sp. no. 2, Corydalidae (larva), Corynorhinus townsendii pallescens, Culicidae, Deroceras laeve, Diplopoda, Diptera sp. no. 2, Dolomedes sp., Dytiscidae, Gerridae, Gerridae, Hirudinea, Isopoda

(terrestrial), Leiodidae, Lepidoptera, Lumbricidae, Myotis velifer, Orconectes sp., Periomyotis subflavus, Phoridae, Physa virgata, Rana blairi, Rhagidiidae, Sayornis phoebe, Scaphinotus sp., Sphaeroceridae, Staphylinidae, Staphylinidae sp. no. 2, Tomocerus sp.

Johnston County

Big Spring: Gammarus lacustris
Deadman Spring: Caecidotea sp.
Inslee Spring: Gammarus lacustris
Martin Spring: Allocrangonyx pellucidus, Caecidotea acuticarpa, Hyalella azteca
Nelson Spring: Amphipoda (stygobitic), Caecidotea sp., Gammarus lacustris, Gastropoda (aquatic snail), Hirudinea, Orconectes sp., Plecoptera, Turbellaria
Rutherford Spring: Caecidotea sp.
Second spring upstream of Tishomingo National Fish Hatchery: Allocrangonyx pellucidus, Amphipoda, Caecidotea acuticarpa, Orconectes sp.
Spring # 2 on Bruno's Land: Amphipoda, Caecidotea acuticarpa, Lirceus sp.
Spring on Easterling's Land: Amphipoda, Dugesia sp., Gambusia affinis, Gastropoda (aquatic snail), Percidae, Rana sphenocephala
Springbox upstream of Tishomingo National Fish Hatchery: Allocrangonyx pellucidus, Araneae sp. no. 2, Caecidotea acuticarpa, Loxosceles reclusa, Orconectes sp.
Twin Vulture Cave: Amphipoda, Caecidotea acuticarpa, Ceuthophilus sp., Coragyps atratus, Culicidae, Neotoma floridana
Unnamed cave on Oliver Ranch: Araneae, Araneae sp. no. 2, Araneae sp. no. 3, Carabidae, Ceuthophilus sp., Culicidae, Gastropoda (terrestrial snail), Neotoma floridana, Sphaeroceridae, Staphylinidae, Tomocerus sp.
Washington Spring: Amphipoda, Caecidotea sp., Gammarus sp., Plecoptera, Turbellaria

Kiowa County County

Dietrich's Spring: Cambaridae, Coleoptera, Gastropoda (terrestrial snail), Hyalella azteca, Physidae, Trichoptera
Turtle Spring: Acarina, Cordulegaster sp., Cyprinidae, Gastropoda (aquatic snail), Hirudinea, Lepomis sp., Percidae

Major County County

Nescatunga Cave: Ambystoma tigrinum, Corynorhinus townsendii pallescens, Stygobromus alabamensis
Vickery Cave: Tadarida brasiliensis

Mayes County County

MY-12: Caecidotea sp., Caudata (larval), Causeyella sp., Ceuthophilus gracilipes, Dolomedes sp., Eurycea lucifuga, Eurycea spelaea, Heleomyzidae, Japygidae, Leiobunum sp., Onychiuridae, Plethodon albagula, Scarabaeidae, Sminthuridae, Sphaeroceridae
Roadside Park Spring: Crangonyx forbesi, Lirceus garmani

Murray County County

Blue Hole Spring: Cyprinidae, Dytiscidae
Crystal Cave: Achaeranea tepidariorum, Araneae sp. no. 2, Ceuthophilus sp., Coccinellidae, Diplopoda (troglobitic), Isopoda (terrestrial), Lumbricidae, Trichoniscidae
Cueva Cascavel: Araneae, Ceuthophilus sp., Coleoptera, Collembola, Crotalus sp., Gastropoda (terrestrial snail), Lumbricidae
Cueva Escorpion: Centruroides vittatus
Little Crystal Cave: Achaeranea tepidariorum, Araneae, Araneae sp. no. 2, Ceuthophilus sp., Crosbyella sp., Gastropoda (terrestrial snail), Heleomyzidae, Leiobunum sp., Lumbricidae, Neotoma floridana, Rana sp., Scolopendromorpha, Squamata (Snake), Tomocerus sp., Trichoniscidae
MU-2: Allocrangonyx pellucidus, Araneae, Argiope aurantia, Caecidotea acuticarpa, Ceuthophilus sp., Collembola sp. no. 2, Collembola sp. no. 3, Leiobunum sp., Oxidus gracilis, Periomyotis subflavus, Platynus sp., Rhagidiidae, Scolopendromorpha, Tomocerus sp., Trigenotyla vaga
Mystic Cave: Allocrangonyx pellucidus, Caecidotea acuticarpa, Caecidotea acuticarpa, Cambaridae, Collembola, Diplopoda (troglobitic), Diptera, Gastropoda (terrestrial snail), Ictaluridae, Lepomis sp., Periomyotis subflavus, Platynus sp., Platynus sp., Procambarus simulans, Trichoniscidae
Outlaw Cave: Achaeranea tepidariorum, Araneae sp. no. 2, Crosbyella sp., Culicidae, Eptesicus fuscus, Isoptera, Opiliones

Spring # 1 on Hickory Creek: Allocrangonyx pellucidus, Caecidotea acuticarpa, Gastropoda (aquatic snail)
Spring # 2 on Hickory Creek: Allocrangonyx pellucidus, Caecidotea sp., Cambaridae
Spring # 3 on Hickory Creek: Allocrangonyx pellucidus, Caecidotea sp.
Spring # 4 on Hickory Creek: Allocrangonyx pellucidus, Caecidotea sp.
Spring # 5 on Hickory Creek: Allocrangonyx pellucidus, Caecidotea sp.
Spring # 6 on Hickory Creek: Allocrangonyx pellucidus, Caecidotea sp.
Squeeze Box: Araneae, Araneae sp. no. 2, Armadillidium sp., Ceuthophilus sp., Collembola, Gastropoda (terrestrial snail), Gastropoda (terrestrial snail) no. 2, Trombidiidae
Wagon Wheel Cave: Culicidae, Opiliones

Ottawa County County

OT-19: Amblyopsis rosae, Amphipoda, Caecidotea sp., Chironomidae, Lirceus sp.
Unnamed Cave: Araneae, Araneae sp. no. 2, Caecidotea simulator, Ceuthophilus sp., Culicidae, Diplopoda (troglobitic), Isopoda (terrestrial), Macrocera nobilis, Neotoma floridana, Oxidus gracilis, Periomyotis subflavus, Sciaridae

Pontotoc County

Byrds Mill Spring: Caecidotea acuticarpa
Coal Creek Cave: Allocrangonyx pellucidus, Caecidotea acuticarpa, Ceuthophilus sp., Culicidae, Diplopoda (troglobitic), Gastropoda (terrestrial snail), Gerridae, Lumbricidae, Orconectes sp., Sayornis phoebe
Coffee Pot Spring: Bezzia sp., Cambaridae, Cricotopus sp., Dixa sp., Larsia sp., Odontomyia sp., Pseudochironomus sp., Rheotanytarsus sp., Stenochironomus sp.
Deadman's Spring: Amphipoda (stygobitic), Caecidotea acuticarpa, Hyalella azteca

Sequoyah County

SQ-1: Corynorhinus townsendii ingens

Washita County

Lady's Cave: Ceuthophilus sp., Dolomedes sp., Isopoda (terrestrial), Platynus sp., Staphylinidae
WA012: Araneae, Carabidae, Ceuthophilus sp., Coleoptera, Culicidae, Diplopoda, Diptera sp. no. 2, Diptera sp. no. 3, Gerridae, Gryllidae, Insecta, Isopoda (terrestrial), Lumbricidae, Oxidus gracilis, Phoridae, Staphylinidae

Woodward County

J. Selman Cave System: Acarina, Annelida, Araneae, Araneae sp. no. 2, Araneae sp. no. 3, Araneae sp. no. 4, Carabidae, Ceuthophilus sp., Coleoptera, Coleoptera sp. no. 2, Collembola, Deroceras laeve, Diplopoda, Diptera, Diptera sp. no. 2, Diptera sp. no. 3, Elimia sp., Hymenoptera, Insecta, Isopoda (terrestrial), Leiodidae, Lepidoptera, Oxidus gracilis, Phoridae, Physa sp., Platynus sp., Psephenidae, Staphylinidae, Staphylinidae sp. no. 2

Appendix 2: Taxonomic Composition of 50 Surveyed Springs

Appendix 2. Taxonomic composition of 50 surveyed springs. 'x' = present. Site numbers are given in Table A. Summary statistics are the total number of sites where a taxon occurs ('sites') and the total number of taxa present at a site ('richness'). Modified richness excludes microcrustaceans and double counts of both larvae and pupae for a single taxon.

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Cnidaria	Hydroida	Hydridae	*Hydra*	x														x	x	x		x	x		
Turbellaria	Tricladida	Dugesiidae	planarians	x			x	x	x		x		x	x						x	x	x	x	x	x
Annelida	Hirudinea	Glossiphoniidae	*Batracobdella phalera*				x																		
			Deserobdella picta		x																				
			Helobdella fusca																			x			
			Helobdella stagnalis																				x		
			Helobdella triserialis				x																		
			Placobdella ornata	x																					
			Placobdella papillifera																				x		
		Eprobdellidae	*Erpobdella* nr. *punctata*																						
			Mooreobdella fervida																			x			
			unidentified																	x					
	Oligochaeta	Naididae	unidentified	x	x		x							x		x	x		x	x		x	x		x
		Tubificidae	*Brachiura sowerbyi*		x																				
			unidentified		x		x	x		x		x	x	x		x	x	x	x	x		x	x		x
		Lumbriculidae	unidentified																						
	Polychaeta	Sabellidae	*Manayunkia speciosa*?																						
Nematoda		unidentified	unidentified				x							x		x	x	x	x	x		x	x		
Entognatha	Collembola	Isotomidae	unidentified	x				x						x			x			x					
Entognatha		Poduridae	*Podura*	x												x									
		Sminthuridae	unidentified																	x	x		x		
Insecta	Coleoptera	Dytiscidae	*Agabus*									x				x	x	x				x		x	
			Coptotomus																	x					
			Hydaticus														x								
			Hydrobius													x									
			Hydroporus I				x		x			x	x												x
			Hydroporus II			x	x					x				x					x	x		x	x
			Hydroporus III				x	x								x									
			Hydroporus larvae															x							
			Hydrovatus																			x		x	x

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			Ilybius																	x	x				
			Laccophilus			x	x				x		x												
			Liodessus	x									x							x			x	x	
			Liodessus II																			x			
			Neoporus																						
			Oreodytes													x		x							
			Uvarus													x	x								
			unid dytiscid																						
		Elmidae	*Dubiraphia vittata*		x																				
			Microcylloepus pusillus																			x			
			Optioservus																						
			Stenelmis		x															x					
			unid (too small)																						
		Gyrinidae	*Dineutis*		x																				
		Haliplidae	*Haliplus*												x								x		
			Peltodytes	x	x	x	x		x											x		x		x	x
		Helophoridae	*Helophorus*									x	x												
		Heteroceridae	unidentified																						
		Hydrochidae	*Hydrochus*	x																					
		Hydrophilidae	*Berosus*				x													x	x	x	x		
			Crenitulus	x			x	x				x	x		x										
			Cymbiodyta									x													
			Enochrus	x								x	x							x		x		x	x
			Hydrochara	x																					
			Laccobius									x													
			Paracymus	x			x					x										x			x
			nr *Paracymus*																						
			Phaenonotum				x	x																	
			Tropisternus II																		x		x		x
			Tropisternus III	x	x	x	x		x		x		x						x				x		x
			Tropisternus (larvae)					x										x							
		Limnichidae	*Limnichus*			x	x	x	x		x	x		x	x				x	x	x	x			
		Noteridae	*Suphisellus*								x														
		Psephenidae	*Ectopria nervosa*																						
		Scirtidae	*Microcara*																						
		unidentified	immature larvae																						

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	Diptera	Ceratopogonidae	*Bezzia/Palpomyia*	x				x				x			x	x		x				x	x	x	
			Dasyhelea																x				x		
			others	x	x	x	x		x	x	x				x	x	x			x	x	x	x	x	
		Chironomidae	Orthocladinae	x			x	x			x	x	x	x	x	x	x	x	x	x	x		x	x	
			Tanypodinae	x	x	x	x					x	x	x	x	x	x	x	x	x	x		x	x	x
			Chironominae	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x		x	x	x
			unid. small larvae	x		x					x		x		x										
			pupae				x										x	x							x
		Culicidae	*Anopheles*		x	x		x	x		x		x	x		x		x	x				x		x
			Culex															x	x						
			Culiseta																						
			pupae															x	x	x					
		Dixidae	*Dixa*								x														
			Dixella	x				x					x	x		x				x			x	x	x
			pupae															x		x	x		x		
		Empididae	*Chelifera*										x												
			Hemerodromia	x			x																		
		Ephydridae	*Lemnaphila*																						x
			Parydra																						
			Pelina																						
			Scatella																						
			unidentified					x		x															
		Muscidae	unidentified																						
		Psychodidae	*Pericoma/Telmatoscopus*																						
			Psychoda	x						x									x				x	x	
			pupa														x								
		Ptychopteridae	*Ptychoptera*																					x	
		Sciomyzidae	*Sepedon/Sepedomenerus*																						
		Simuliidae	*Simulium*	x													x			x			x	x	
		Stratiomyidae	*Caloparyphus*							x		x													
			Euparyphus							x															
			Myxosargus				x	x	x		x			x											
			Nemotelus																						
			Odontomyia (Catatasina)							x															
			Odontomyia/Hedriodiscus	x															x				x		x
			Stratiomys				x			x														x	

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			unid																						
		Tabanidae	*Chrysops*			x	x													x	x				
		Tipulidae	*Gonomyia*							x															
			Holorusia										x												
			Limonia																x						
			Pseudolimnophila					x																	
			Tipula	x	x				x		x	x				x		x	x						
			Ulomorpha																						x
			pupae/unidentified														x				x				
		unidentified																							
	Ephemeroptera	Baetidae	*Baetis*										x										x		
			Callibaetis			x	x	x				x	x	x	x	x			x	x	x		x		x
		Caenidae	*Caenis*												x										
		Ephemerellidae	*Hexagenia*	x																					
		Heptageniidae	*Leucrocuta*																						
			Stenacron																						
		Leptophlebiidae	*Paraleptophlebia*													x									
	Hemiptera	Belostomatidae	*Belostoma /Abedus*	x																	x		x	x	
		Corixidae	*Hesperocorixa*			x																			
			Sigara	x					x		x	x	x												
			Trichocorixa				x	x																	
			unidentified															x							
		Gelastocoridae	*Gelastocoris*																						
		Gerridae	*Aquarius*	x	x	x	x	x	x		x		x	x				x	x		x		x		
			Gerris		x						x				x	x		x			x				
			Limnoporus													x	x								
			Trepobates		x	x	x	x	x		x		x	x	x										
			Rheumatobates																						
			Trepobates													x							x		
		Hebridae	*Hebrus*							x		x													
			Merragata	x											x								x		
		Hydrometridae	*Hydrometra*																				x		
		Mesoveliidae	*Mesovelia*	x						x					x								x		
		Notonectidae	*Notonecta*			x					x														
		Pleidae	*Paraplea*												x										x
		Veliidae	*Microvelia*	x		x	x	x	x		x	x	x	x		x	x	x	x	x	x	x	x	x	x

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			Platyvelia	x	x		x																	x	
			Rhagovelia		x				x		x									x					
	Lepidoptera	Pyralidae	*Paraponyx*	x																					
			Mun./Syn./Neocat.																						
			unidentified	x																				x	
	Megaloptera	Sialidae	*Sialis*												x										
	Odonata	Aeshnidae	*Aeshna*				x	x						x				x		x		x	x		x
			Anax																						
			Boyeria																						
			unidentified																						
		Calopterygidae	*Calopteryx*				x													x					
			Hetaerina	x																x		x			
		Coenagrionidae	*Argia*	x	x		x	x		x	x	x	x	x			x	x	x	x	x	x	x	x	x
			Coenagrion/Enallagma																						
			Enallagma			x									x										
			Enallagma/Ishnura	x		x																			
			unidentified					x																	
		Corduliidae	*Epitheca (Epicordulia)*												x										
			Didymops transversa												x										
			Somatochlora				x																		
		Gomphidae	*Erpetogomphus*																						
			Gomphus																						
			Progomphus																	x					
		Lestidae	*Archilestes*			x					x	x	x									x			
		Libellulidae	*Dythemis*		x																				
			Erythemis	x							x				x						x		x		
			Erythrodiplex																					x	
			Libellula															x							
			Perithemis																						
			Plathemis																			x			
			Sympetrum																						
			unidentified												x										
	Orthoptera	Tetrigidae	unidentified									x													
	Trichoptera	Helicopsychidae	*Helicopsyche*	x			x						x												
		Hydropsychidae	*Cheumatopsyche*														x			x		x	x		
			Diplectrona																						

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			unidentified juveniles																						
		Hydroptilidae	*Hydroptila*	x			x					x											x		
			Ochrotrichia																x	x			x		
			Oxyethira	x																			x		
			pupa																						
		Lepidostomatidae	*Lepidostoma*																						
		Leptoceridae	*Nectopsyche*				x													x					
		Limnephidae	*Pycnopsyche*		x																				
		Molannidae	*Molanna*																						
		Philopotamidae	*Chimarra*															x							
			Wormaldia															x							
		Polycentropidae	*Polycentropus*																						
		Psychomyidae	*Psychomyia*																						
		unidentified	pupae																						
Crustacea	Amphipoda		cave amphipod																						
		Crangonyctidae	Crangonyx forbesi																						
		Gammaridae	*Gammarus*																						
		Talitridae	*Hyalella azteca*	x	x	x	x	x	x		x		x		x					x	x	x	x	x	x
	Isopoda	Asellidae	*Lirceus hoppinae*															x	x						
			Caecidotea						x																
			Caecidotea acuticarpa																						
	Ostracoda		type A																	x	x	x	x	x	x
			type B					x							x			x					x		
			type C											x		x				x				x	
			type D																			x	x		
			type E																					x	x
			type F							x									x	x	x	x		x	
			type G																						
			type H																						
			type I																						
			type J																						
			type K							x															
			type L																						
			type M																						
	Decapoda		*Orconectes nais*				x																		
			Orconectes neglectus																						

				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
			O. palmeri longimanus								x		x			x									
			Orconectes virilis	x	x																				
			Orconectes sp.					x						x											
			Procambarus simulans			x										x		x	x	x					
	Copepoda	Cyclopoida	copepod	x		x	x	x					x	x	x	x		x		x		x	x		
		Harpacticoida	copepod	x		x		x	x		x	x	x			x	x		x	x	x	x	x		
	Cladocera		unidentified															x							
	Acari		misc. mites			x	x	x		x		x	x			x		x				x	x		x
Bivalvia		Sphaeriidae	unidentified	x		x	x		x		x			x	x					x	x	x	x	x	x
Gastropoda		Ancylidae	*Ferrissia*	x		x																			
		Hydrobiidae	unidentified		x																				
		Lymnaeidae	*Fossaria*	x	x	x			x											x	x			x	
		Physidae	*Physa*	x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Planorbidae	*Gyraulus*				x											x							
			Helisoma	x		x														x	x				x
			Menetus	x																					
			Planorbula				x	x																	
			Promenetus																x						
		Pleuroceridae	*Elimia*																						
		Pomatiopsidae	*Pomatiopsis*																						
			richness	53	27	30	47	31	20	16	26	28	32	23	27	31	21	34	28	47	29	35	50	31	31
			richness (modified)	51	27	27	45	28	19	13	25	26	29	21	24	27	20	30	26	42	26	29	44	27	28

Appendix 2. Taxonomic composition of 50 surveyed springs. 'x' = present. Site numbers are given in Table A. Summary statistics are the total number of sites where a taxon occurs ('sites') and the total number of taxa present at a site ('richness'). Modified richness excludes microcrustaceans and double counts of both larvae and pupae for a single taxon.

				23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	300	301
Cnidaria	Hydroida	Hydridae	*Hydra*	x		x	x	x	x		x					x		x		x				x
Turbellaria	Tricladida	Dugesiidae	planarians	x					x	x	x			x	x	x	x	x		x		x		
Annelida	Hirudinea	Glossiphoniidae	*Batracobdella phalera*																					
			Deserobdella picta																					
			Helobdella fusca																					
			Helobdella stagnalis																					
			Helobdella triserialis																					
			Placobdella ornata																					
			Placobdella papillifera																					
		Eprobdellidae	*Erpobdella* nr. *punctata*												x						x			
			Mooreobdella fervida	x											x									
			unidentified																					
	Oligochaeta	Naididae	unidentified		x	x	x	x	x		x	x	x			x	x			x	x			
		Tubificidae	*Brachiura sowerbyi*																					
			unidentified	x	x	x	x	x		x	x	x	x		x		x	x	x	x	x	x		
		Lumbriculidae	unidentified												x									
	Polychaeta	Sabellidae	*Manayunkia speciosa*?															x						
Nematoda		unidentified	unidentified	x			x			x			x					x	x		x			
Entognatha	Collembola	Isotomidae	unidentified	x		x	x		x			x				x	x			x				
Entognatha		Poduridae	*Podura*					x	x								x		x					
		Sminthuridae	unidentified																					
Insecta	Coleoptera	Dytiscidae	*Agabus*	x	x	x																	x	
			Coptotomus																					
			Hydaticus																					
			Hydrobius																					
			Hydroporus I																					
			Hydroporus II																					
			Hydroporus III		x	x				x														
			Hydroporus larvae																					
			Hydrovatus																					

				23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	300	301
			Ilybius																					x
			Laccophilus	x								x												
			Liodessus																					
			Liodessus II																					
			Neoporus						x															
			Oreodytes			x		x	x	x								x						
			Uvarus																					
			unid dytiscid					x												x				
		Elmidae	*Dubiraphia vittata*	x	x	x																		
			Microcylloepus pusillus			x			x							x								
			Optioservus													x								
			Stenelmis			x			x							x								
			unid (too small)		x											x								
		Gyrinidae	*Dineutis*																					
		Haliplidae	*Haliplus*																					
			Peltodytes	x	x			x		x	x	x												
		Helophoridae	*Helophorus*																					
		Heteroceridae	unidentified																					
		Hydrochidae	*Hydrochus*																					
		Hydrophilidae	*Berosus*	x	x			x																
			Crenitulus												x									
			Cymbiodyta				x	x																
			Enochrus																					
			Hydrochara														x							
			Laccobius																					
			Paracymus					x																
			nr *Paracymus*																					
			Phaenonotum																					
			Tropisternus II									x												
			Tropisternus III	x			x																x	x
			Tropisternus (larvae)					x	x						x								x	x
		Limnichidae	*Limnichus*	x					x															
		Noteridae	*Suphisellus*																					
		Psephenidae	*Ectopria nervosa*															x						
		Scirtidae	*Microcara*																					
		unidentified	immature larvae														x							

				23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	300	301
	Diptera	Ceratopogonidae	*Bezzia/Palpomyia*		x	x	x	x	x			x	x					x	x					
			Dasyhelea						x				x											
			others	x	x	x	x		x		x	x	x		x	x								
		Chironomidae	Orthocladinae	x	x	x	x	x	x		x	x	x		x	x	x		x	x	x		x	x
			Tanypodinae	x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x		x
			Chironominae	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
			unid. small larvae		x											x	x					x		
			pupae	x	x	x	x	x	x	x	x	x	x			x	x		x		x	x		x
		Culicidae	*Anopheles*																	x				
			Culex					x				x												
			Culiseta																				x	x
			pupae										x											
		Dixidae	*Dixa*																	x		x		
			Dixella						x															
			pupae																					
		Empididae	*Chelifera*													x	x	x				x		
			Hemerodromia												x	x				x				
		Ephydridae	*Lemnaphila*																					
			Parydra														x							
			Pelina									x												
			Scatella												x									
			unidentified																					
		Muscidae	unidentified										x		x									
		Psychodidae	*Pericoma/Telmatoscopus*				x						x				x							
			Psychoda										x							x				
			pupa						x				x											
		Ptychopteridae	*Ptychoptera*																					
		Sciomyzidae	*Sepedon/Sepedomenerus*	x		x						x												
		Simuliidae	*Simulium*		x				x							x							x	
		Stratiomyidae	*Caloparyphus*																					
			Euparyphus						x											x				
			Myxosargus																					
			Nemotelus									x	x											
			Odontomyia (Catatasina)																					
			Odontomyia/Hedriodiscus																					
			Stratiomys								x	x												

				23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	300	301
			unid															x						
		Tabanidae	*Chrysops*	x									x											
		Tipulidae	*Gonomyia*																					
			Holorusia										x											
			Limonia																	x				
			Pseudolimnophila								x	x	x											
			Tipula			x							x											
			Ulomorpha	x																				
			pupae/unidentified	x									x						x			x		
		unidentified											x											
	Ephemeroptera	Baetidae	*Baetis*		x	x			x					x		x	x	x						
			Callibaetis	x	x		x	x	x	x		x											x	x
		Caenidae	*Caenis*		x	x																		
		Ephemerellidae	*Hexagenia*																					
		Heptageniidae	*Leucrocuta*														x							
			Stenacron								x			x		x								
		Leptophlebiidae	*Paraleptophlebia*																					
	Hemiptera	Belostomatidae	*Belostoma / Abedus*	x								x												
		Corixidae	*Hesperocorixa*																					
			Sigara						x								x					x		
			Trichocorixa	x																				
			unidentified																				x	
		Gelastocoridae	*Gelastocoris*									x												
		Gerridae	*Aquarius*	x	x		x		x		x		x	x			x							x
			Gerris	x		x	x			x				x			x	x				x		
			Limnoporus					x								x								
			Trepobates		x																			
			Rheumatobates	x		x																		
			Trepobates	x																				
		Hebridae	*Hebrus*																					
			Merragata																					
		Hydrometridae	*Hydrometra*																					
		Mesoveliidae	*Mesovelia*																					
		Notonectidae	*Notonecta*																				x	x
		Pleidae	*Paraplea*																					
		Veliidae	*Microvelia*	x		x			x	x	x		x		x	x	x	x		x	x	x		

				23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	300	301
			Platyvelia																					
			Rhagovelia		x																			
	Lepidoptera	Pyralidae	*Paraponyx*																					
			Mun./Syn./Neocat.									x												
			unidentified	x																				
	Megaloptera	Sialidae	*Sialis*	x	x	x												x						
	Odonata	Aeshnidae	*Aeshna*	x						x						x								
			Anax																					x
			Boyeria																					
			unidentified																					
		Calopterygidae	*Calopteryx*	x	x	x	x																	
			Hetaerina	x																				
		Coenagrionidae	*Argia*	x	x	x	x	x	x	x	x					x		x		x				x
			Coenagrion/Enallagma						x															x
			Enallagma																					
			Enallagma/Ishnura																					
			unidentified							x														
		Corduliidae	*Epitheca (Epicordulia)*																					
			Didymops transversa																					
			Somatochlora								x													
		Gomphidae	*Erpetogomphus*	x																				
			Gomphus	x																				
			Progomphus																					
		Lestidae	*Archilestes*			x	x			x	x													
		Libellulidae	*Dythemis*																					
			Erythemis																					
			Erythrodiplex																					
			Libellula																					x
			Perithemis						x															
			Plathemis	x																				
			Sympetrum									x												
			unidentified																					
	Orthoptera	Tetrigidae	unidentified					x																
	Trichoptera	Helicopsychidae	*Helicopsyche*													x	x							
		Hydropsychidae	*Cheumatopsyche*	x	x	x											x							
			Diplectrona											x		x		x						

				23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	300	301
			unidentified juveniles			x			x							x								
		Hydroptilidae	*Hydroptila*	x	x						x	x					x					x		
			Ochrotrichia		x	x										x								
			Oxyethira													x	x							
			pupa	x							x													
		Lepidostomatidae	*Lepidostoma*															x						
		Leptoceridae	*Nectopsyche*																					
		Limnephidae	*Pycnopsyche*																					
		Molannidae	*Molanna*															x						
		Philopotamidae	*Chimarra*																					
			Wormaldia																					
		Polycentropidae	*Polycentropus*							x				x		x						x		
		Psychomyidae	*Psychomyia*														x							
		unidentified	pupae													x	x							
Crustacea	Amphipoda		cave amphipod										x											
		Crangonyctidae	Crangonyx forbesi												x									
		Gammaridae	*Gammarus*			x								x		x	x				x	x		
		Talitridae	*Hyalella azteca*	x	x			x	x		x		x											
	Isopoda	Asellidae	*Lirceus hoppinae*										x		x	x	x		x	x	x	x		
			Caecidotea																					
			Caecidotea acuticarpa																					
	Ostracoda		type A	x					x														x	x
			type B																					
			type C																					
			type D																					
			type E							x							x							
			type F	x			x	x		x	x					x			x				x	
			type G				x	x																x
			type H										x			x								
			type I				x		x							x				x				
			type J					x								x	x					x		
			type K																					
			type L																				x	
			type M																					
	Decapoda		*Orconectes nais*																					
			Orconectes neglectus											x			x	x	x	x				

				23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	300	301
			O. palmeri longimanus																					
			Orconectes virilis																					
			Orconectes sp.	x	x						x					x	x	x						
			Procambarus simulans			x		x		x														
	Copepoda	Cyclopoida	copepod	x	x	x	x	x	x	x	x	x	x		x					x		x	x	x
		Harpacticoida	copepod	x		x	x		x		x		x		x	x	x		x	x		x		
	Cladocera		unidentified				x			x	x	x									x		x	x
	Acari		misc. mites	x	x		x	x	x	x	x		x		x	x	x	x	x	x		x	x	x
Bivalvia		Sphaeriidae	unidentified	x		x			x		x	x	x		x			x	x	x				
Gastropoda		Ancylidae	*Ferrissia*							x											x			
		Hydrobiidae	unidentified																					
		Lymnaeidae	*Fossaria*																					
		Physidae	*Physa*	x	x	x	x	x	x	x	x	x	x		x	x	x			x		x	x	x
		Planorbidae	*Gyraulus*																	x				
			Helisoma								x													
			Menetus																				x	
			Planorbula																					
			Promenetus																					
		Pleuroceridae	*Elimia*													x								
		Pomatiopsidae	*Pomatiopsis*																					
			richness	51	33	36	27	29	39	25	30	28	33	10	21	41	36	24	15	26	13	21	18	22
			richness (modified)	46	31	34	20	24	34	20	25	26	29	10	18	34	31	23	12	22	12	17	12	16

Appendix 2. Taxonomic composition of 50 surveyed springs. 'x' = present. Site numbers are given in Table A. Summary statistics are the total number of sites where a taxon occurs ('sites') and the total number of taxa present at a site ('richness'). Modified richness excludes microcrustaceans and double counts of both larvae and pupae for a single taxon.

				302	303	304	305	306	307	308	sites
Cnidaria	Hydroida	Hydridae	*Hydra*								16
Turbellaria	Tricladida	Dugesiidae	planarians	x		x		x	x	x	29
Annelida	Hirudinea	Glossiphoniidae	*Batracobdella phalera*								1
			Deserobdella picta								1
			Helobdella fusca								1
			Helobdella stagnalis								1
			Helobdella triserialis								1
			Placobdella ornata								1
			Placobdella papillifera								1
		Eprobdellidae	*Erpobdella* nr. *punctata*								2
			Mooreobdella fervida								3
			unidentified								1
	Oligochaeta	Naididae	unidentified		x	x			x		26
		Tubificidae	*Brachiura sowerbyi*								1
			unidentified								31
		Lumbriculidae	unidentified				x				2
	Polychaeta	Sabellidae	*Manayunkia speciosa*?								1
Nematoda		unidentified	unidentified	x							17
Entognatha	Collembola	Isotomidae	unidentified				x		x		15
Entognatha		Poduridae	*Podura*								6
		Sminthuridae	unidentified								3
Insecta	Coleoptera	Dytiscidae	*Agabus*	x		x					12
			Coptotomus								1
			Hydaticus								1
			Hydrobius							x	2
			Hydroporus I								5
			Hydroporus II								8
			Hydroporus III								6
			Hydroporus larvae					x			2
			Hydrovatus								3

				302	303	304	305	306	307	308	sites
			Ilybius								3
			Laccophilus	x							7
			Liodessus								5
			Liodessus II								1
			Neoporus			x					2
			Oreodytes								7
			Uvarus								2
			unid dytiscid					x			3
		Elmidae	*Dubiraphia vittata*					x			5
			Microcylloepus pusillus								4
			Optioservus								1
			Stenelmis								5
			unid (too small)								2
		Gyrinidae	*Dineutis*								1
		Haliplidae	*Haliplus*			x					3
			Peltodytes					x	x		17
		Helophoridae	*Helophorus*								2
		Heteroceridae	unidentified			x					1
		Hydrochidae	*Hydrochus*			x					2
		Hydrophilidae	*Berosus*			x					9
			Crenitulus					x			8
			Cymbiodyta								3
			Enochrus								7
			Hydrochara								2
			Laccobius								1
			Paracymus								6
			nr *Paracymus*					x			1
			Phaenonotum								2
			Tropisternus II		x	x					5
			Tropisternus III	x				x			16
			Tropisternus (larvae)	x		x		x	x		11
		Limnichidae	*Limnichus*					x	x		16
		Noteridae	*Suphisellus*								1
		Psephenidae	*Ectopria nervosa*								1
		Scirtidae	*Microcara*						x	x	2
		unidentified	immature larvae								1

				302	303	304	305	306	307	308	sites
	Diptera	Ceratopogonidae	*Bezzia/Palpomyia*	x							19
			Dasyhelea								4
			others		x						26
		Chironomidae	Orthocladinae			x	x	x			36
			Tanypodinae	x			x	x			38
			Chironominae	x	x	x	x	x	x		46
			unid. small larvae								9
			pupae								20
		Culicidae	*Anopheles*					x	x		15
			Culex							x	5
			Culiseta	x							3
			pupae	x							5
		Dixidae	*Dixa*				x				4
			Dixella	x					x		12
			pupae								4
		Empididae	*Chelifera*								5
			Hemerodromia								5
		Ephydridae	*Lemnaphila*								1
			Parydra								1
			Pelina								1
			Scatella								1
			unidentified								2
		Muscidae	unidentified								2
		Psychodidae	*Pericoma/Telmatoscopus*								3
			Psychoda								7
			pupa								3
		Ptychopteridae	*Ptychoptera*								1
		Sciomyzidae	*Sepedon/Sepedomenerus*								3
		Simuliidae	*Simulium*								9
		Stratiomyidae	*Caloparyphus*								2
			Euparyphus								3
			Myxosargus								5
			Nemotelus								2
			Odontomyia (Catatasina)								1
			Odontomyia/Hedriodiscus								4
			Stratiomys	x							6

				302	303	304	305	306	307	308	sites
			unid								1
		Tabanidae	*Chrysops*								6
		Tipulidae	*Gonomyia*								1
			Holorusia	x				x			4
			Limonia								2
			Pseudolimnophila								4
			Tipula								10
			Ulomorpha								2
			pupae/unidentified								6
		unidentified									1
	Ephemeroptera	Baetidae	*Baetis*								9
			Callibaetis	x		x				x	25
		Caenidae	*Caenis*	x						x	5
		Ephemerellidae	*Hexagenia*								1
		Heptageniidae	*Leucrocuta*								1
			Stenacron								3
		Leptophlebiidae	*Paraleptophlebia*								1
	Hemiptera	Belostomatidae	*Belostoma /Abedus*								6
		Corixidae	*Hesperocorixa*								1
			Sigara			x	x	x			11
			Trichocorixa								3
			unidentified								2
		Gelastocoridae	*Gelastocoris*								1
		Gerridae	*Aquarius*	x			x	x	x		26
			Gerris			x					15
			Limnoporus								4
			Trepobates								10
			Rheumatobates							x	2
			Trepobates							x	4
		Hebridae	*Hebrus*								2
			Merragata								3
		Hydrometridae	*Hydrometra*								1
		Mesoveliidae	*Mesovelia*							x	5
		Notonectidae	*Notonecta*	x	x	x	x	x			8
		Pleidae	*Paraplea*								2
		Veliidae	*Microvelia*		x	x			x		35

				302	303	304	305	306	307	308	sites
			Platyvelia								4
			Rhagovelia								5
	Lepidoptera	Pyralidae	*Paraponyx*								1
			Mun./Syn./Neocat.								1
			unidentified								3
	Megaloptera	Sialidae	*Sialis*								5
	Odonata	Aeshnidae	*Aeshna*								11
			Anax								1
			Boyeria						x		1
			unidentified			x					1
		Calopterygidae	*Calopteryx*								6
			Hetaerina								4
		Coenagrionidae	*Argia*				x	x		x	33
			Coenagrion/Enallagma							x	3
			Enallagma			x					3
			Enallagma/Ishnura								2
			unidentified								2
		Corduliidae	*Epitheca (Epicordulia)*								1
			Didymops transversa								1
			Somatochlora								2
		Gomphidae	*Erpetogomphus*								1
			Gomphus								1
			Progomphus								1
		Lestidae	*Archilestes*					x			10
		Libellulidae	*Dythemis*								1
			Erythemis							x	6
			Erythrodiplex								1
			Libellula	x	x						4
			Perithemis							x	2
			Plathemis								2
			Sympetrum								1
			unidentified								1
	Orthoptera	Tetrigidae	unidentified					x			3
	Trichoptera	Helicopsychidae	*Helicopsyche*					x			6
		Hydropsychidae	*Cheumatopsyche*								8
			Diplectrona								3

				302	303	304	305	306	307	308	sites
			unidentified juveniles								3
		Hydroptilidae	*Hydroptila*						x		11
			Ochrotrichia								6
			Oxyethira								4
			pupa								2
		Lepidostomatidae	*Lepidostoma*								1
		Leptoceridae	*Nectopsyche*								2
		Limnephidae	*Pycnopsyche*								1
		Molannidae	*Molanna*								1
		Philopotamidae	*Chimarra*								1
			Wormaldia								1
		Polycentropidae	*Polycentropus*								4
		Psychomyidae	*Psychomyia*								1
		unidentified	pupae								2
Crustacea	Amphipoda		cave amphipod								1
		Crangonyctidae	Crangonyx forbesi								1
		Gammaridae	*Gammarus*								6
		Talitridae	*Hyalella azteca*				x		x	x	24
	Isopoda	Asellidae	*Lirceus hoppinae*								10
			Caecidotea								1
			Caecidotea acuticarpa							x	1
	Ostracoda		type A						x		11
			type B				x				5
			type C	x							5
			type D	x							3
			type E								4
			type F	x	x	x		x	x		19
			type G								3
			type H								2
			type I				x				5
			type J							x	5
			type K								1
			type L								1
			type M	x							1
	Decapoda		*Orconectes nais*								1
			Orconectes neglectus								5

				302	303	304	305	306	307	308	sites
			O. palmeri longimanus								3
			Orconectes virilis								2
			Orconectes sp.				x	x	x		11
			Procambarus simulans								8
	Copepoda	Cyclopoida	copepod		x	x	x		x	x	32
		Harpacticoida	copepod	x					x		28
	Cladocera		unidentified	x		x				x	11
	Acari		misc. mites						x	x	30
Bivalvia		Sphaeriidae	unidentified		x			x	x		26
Gastropoda		Ancylidae	*Ferrissia*								4
		Hydrobiidae	unidentified								1
		Lymnaeidae	*Fossaria*								7
		Physidae	*Physa*	x	x	x		x	x	x	41
		Planorbidae	*Gyraulus*								3
			Helisoma						x		7
			Menetus								2
			Planorbula			x					3
			Promenetus								1
		Pleuroceridae	*Elimia*								1
		Pomatiopsidae	*Pomatiopsis*				x				
			richness	26	11	24	16	26	24	20	
			richness (modified)	19	9	21	13	25	19	16	

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