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Status Survey of Aquatic Cave Fauna in Arkansas

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Cover design by Jason Gunter. Cover photograph is of Blowing Springs Cave, Benton County, Arkansas.

INTRODUCTION

The Need for Subterranean Bioinventories

Ground water supplies 62% of the overall water demands of the United States, yet little is known about ground water ecosystems (Job and Simons, 1994). Phreatic habitats provide crucial ecological services and sustain rich endemic communities, an estimated 90% of which remain undescribed (Karst Waters Institute, 1999). Despite the importance of subterranean habitats, they have received very little study by the scientific community (Cullimore, 1993). Little is known about the distribution of species and their limiting factors (Strayer, 1994), very few food webs have been described (Culver, 1994), and the nutrient dynamics are poorly understood (Gibert *et al.*, 1994). Knowledge of subterranean ecosystem dynamics is needed not only for the protection of the groundwater resource, but because its denizens are among the world's most rare and endangered freshwater fauna, and are under-protected in the existing network of preserves (IUCN, 1996).

Arkansas lacks a comprehensive inventory of subterranean biodiversity, which is needed for many reasons. The cave fauna of Arkansas is poorly documented, and little is known about their status or distribution. Subterranean fauna are important ground water quality indicators (Job and Simons, 1994; Notenboom *et al*., 1994; Malard *et al*., 1996), and ground water is a major water resource for communities, agriculture, and industry (Smith and Steele, 1990). Freshwater fishes, amphipods, and crayfishes are among the world's most endangered animals (IUCN, 1996), and caves in the Ozarks harbor a rich diversity of these animals. The International Union for the Conservation of Nature (IUCN, 1994) emphasizes this need for bioinventories:

> "*The need for a stronger focus on invertebrate conservation has long been recognized, but information on the status and distribution of the majority of invertebrates simply does not exist*."

Yet, the Ozarks, specifically the Boston Mountains and Ozark Highlands ecoregions, are experiencing rapid land use changes and deteriorating water quality (Steele, 1985). Some of these cave animals are unique to Arkansas, and are an important part of the natural heritage of the State. Another reason to perform these cave faunal inventories is that they are mandated by the listed species' Recovery Plans under the Endangered Species Act. Furthermore, cave inventories provide the information base from which effective cave management plans can be designed (Hummel, 1983). In general, a basic requirement for the conservation and management of biological resources is the ability to list and describe the biota (Gall and Christian, 1984).

Status of Subterranean Biodiversity in North America and in the Ozarks

There are an estimated 60,000 species of obligate cave-dwelling animals in North America, and up to 100,000 species worldwide (Culver and Holsinger, 1992). In North America, the number of known troglobites (cave-limited, terrestrial organisms) and stygobites (groundwater-limited organisms) has increased exponentially since the late 1800's, as is shown in Figure 1. In the most recent summary of the obligate cave fauna of the U.S., 927 species have been described, with 54% of these species known from only a single county (Culver *et al*., 2000). An estimated 1000 troglobites and stygobites occur in the Ozark Plateaus (Culver and Holsinger, 1992), yet less than 100 cave-adapted species have been described from this ecoregion (Karst Waters Institute, 1999). In fact, as of 1998, there have only been 40 species of obligate, subterranean fauna species reported in the Ozarks (Peck, 1998).

Laing *et al*. (1976) suggest that more species may be discovered within known populations by comparing their genomes. An electrophoretic comparison of two demes of a blind Kentucky cave millipede (*Scoterpes copei*) revealed little genetic similarity between the two populations, with more than enough divergence to assign to different species (Laing *et al*., 1976). Since each deme had little variability among the members, Laing *et al*. concluded that genetic drift due to geographical isolation was the divergence mechanism, and they hypothesized that sibling species may be common among troglobites, many of whom experience extreme geographic isolation. Furthermore, the rich interstitial faunal diversity of Europe suggests that similar North American habitats could have rich faunal diversity, but hyporheic and phreatic environments in the United States have scarcely been explored (Holsinger, 1972; Juberthie *et al*., 1980; Belles, 1987; Camacho, 1992). Thus, subterranean diversity could be much richer than current estimates.

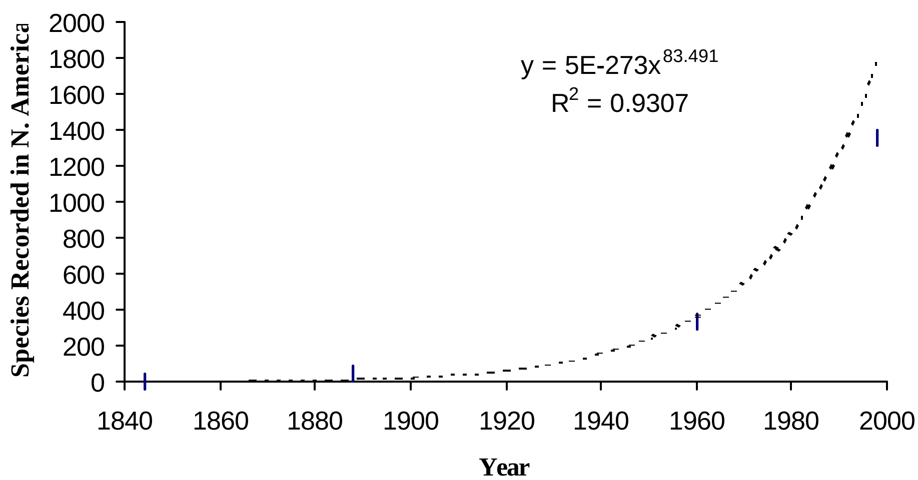

Figure 1. Trend of historic inventories of obligate, cave-dwelling species (troglobitic and stygobitic) in North America (DeKay, 1842; Nicholas, 1960; Packard, 1888; Peck, 1998) and a power function trend line fitted to the data.

Cave amphipods, cave crayfishes, and cavefishes are among the most endangered of animals globally. In the United States, troglobites and stygobites represent more than 50% of the imperiled (G1-G2) fauna listed in the Natural Heritage Program, yet less than 4% have federal status (Culver *et al.*, 2000). The International Union for the Conservation of Nature (1996) summarizes:

> "*The number of threatened inland freshwater crustaceans strongly supports the notion that species in freshwater habitats are particularly at risk. The two orders with the greatest number of threatened species are the Decapoda (crayfishes) and the Amphipoda (amphipods) with 168 and 67 threatened species respectively. The crayfishes at risk are virtually all threatened by habitat loss. Most of the threatened amphipods live in extremely restricted and vulnerable environments (caves).*"

There are at least 8 isopods, 34 *Cambarid* crayfishes, and 40 Stygobromid amphipods on the International Red List, an international database that ranks rare species by their vulnerability of extinction (IUCN, 1996; World Conservation Monitoring Center, 1999). Ozark cave fauna on the Red List include all of the described cave crayfish species - *Cambarus aculabrum* (endangered), *C. subterraneus* (endangered), *C. tartarus* (critically endangered), *C. zophonastes* (critically endangered), and two of the cavefishes - *A. rosae* (vulnerable) and *Typhlichthys subterraneus* (vulnerable) (World Conservation Monitoring Center, 1999). Ozark cave species on the US Fish and Wildlife Service list of endangered species (Endangered Species Act) are: *A. rosae* (threatened), *C. aculabrum* (endangered), *C. zophonastes* (endangered); and three bat species - *Corynorhinus townsendii ingens* (Threatened), *Myotis grisescens* (endangered), and *Myotis sodalis* (endangered). Arkansas cave species with the designation "State Species of Concern" include: the snail *Amnicola cora* (G1, S1); *A. rosae* (G2, S1); the cave isopods *Caecidotea ancyla* (G1?, S1?), *C. stiladactyla* (G1?, S1?), and *C. steevesi* (G1?, S1?); *C. aculabrum* (G1, S?); *C. zophonastes* (G1, S1); *Corynorhinus rafinesquii* (G3G4, S2); *C. townsendii ingens* (G4T1, S1); *M. grisescens* (G3, S2); *M. sodalis* (G2, S2); the cave amphipods *Stygobromus montanus* (G1, S1) and *S. ozarkensis* (G?, S1); and *T. subterraneus* (G3, S1) (Natural Diversity Database, ANHC, 1999). A description of the global and state ranks can be found in Appendix I.

Other obligate cave-inhabitants of Arkansas include: amphipods of the genus *Bactrurus*; the Grotto salamander (*Typhlotriton spelaeus*); the spider *Porhomma cavernicolum*; pseudoscorpions in the genera *Apochthonius* and *Hesperochernes*; harvestmen in the genus *Crosbyella*, springtails in the genus *Arrhopalites*, bristletails in the genus *Litocampa*, and the dung fly *Spelobia tenebrarum* (Peck, 1998; Karst Waters Institute, 1999).

Factors in the Abundance and Rarity of Cave-adapted Organisms

The zonal variation in physical, chemical, and biological properties of caves influences the distribution of fauna inhabiting these zones (Barr, 1963, 1968). There is more diversity but more environmental variability in cave entrances and there is more endemism and more environmental constancy in the dark zone. Organisms that are associated with sediments (benthos) have a greater tendency toward endemism than free-swimming species (Lampert and Sommer, 1997).

Lake Baikal (Siberia), which has the highest degree of endemism of any lake (58% of the 1219 species), is a classic example (Kozhov, 1963): among the free-swimming protists, microinvertebrates, and fish species, few or no endemic species are present, while most benthic invertebrate and fish species are endemic in Lake Baikal. Caves with mild hydrologic regimes contain more species than caves which experience severe flooding (Culver, 1982). Yet, storm flows import most of the organic matter in cave streams, and in some caves, flood/drought cycles regulate the life cycles of the cave biota (Hawes, 1939). In some caves, spring floods stimulate reproductive activity and molting (Poulson, 1963; Jegla, 1969). Yet many cave animals are sensitive to current flow, especially spring floods that can cause heavy mortality (Culver, 1982).

The distribution of troglobites in caves is patchy and non-random, and, like their epigean counterparts, they appear to congregate where fungi, bacteria, and organics are most concentrated (see review by Dickson, 1975). Poulson (1976) hypothesized that cave biodiversity depends largely upon food resource availability and variety. Dickson (1975) found that the distribution of troglobitic invertebrates was correlated to fungal densities (and organic matter content) in Virginia caves. Caves with significant guano resources add complexity and diversity to cave food webs and add environmental variability to caves by changing their thermal and humidity regimes and their gas composition (Harris, 1970). Bat guano can supply sufficient food to cave ecosystems to relax the selective pressure of oligotrophy, with resulting changes in community structure, including the presence of species without troglomorphic characteristics (Culver, 1982). Moreover, the quality and frequency of feces (bat guano, mammalian scat, and insect frass) varies enough among invertebrates and mammals that distinct copraphagic communities can associate with each fecal type (Poulson, 1978). Aquatic cave communities are thought to be less diverse because of the preponderance of feeding generalists and the lack of specialization on food type (Poulson, 1976).

The assessment of cave faunal abundance is exacerbated by the fact that man-sized conduits (caves) represent only a fraction of the entire active karst drainage systems (White, 1993), and only about one-tenth of cave complexes have openings to the surface (Curl, 1958). Furthermore, most cave animals display cryptic behavior and photophobia, making accurate population estimates difficult. Most published cave inventories report small population sizes, yet Culver *et al*. (2000) believe that population sizes of less than 500 are uncommon for troglobite and stygobite populations, and that small populations are the exception, not the rule (Culver, 1982; Knapp and Fong, 1999). Only a handful of Salem crayfish (*Cambarus hubrichti*) were known from Meramec Cave until an ammonia spill forced the evacuation of thousands from the cave; this exodus also produced the first sighting of *T. subterraneus* from this site (Crunkilton, 1982). Cave population sizes have important conservation and evolutionary implications. Franklin (1980) calculated that a minimum of 50 individuals were needed in an animal population to maintain short-term genetic fitness, and that at least 500 individuals were needed to maintain sufficient genetic variation for adaptation to changing environments. Estimates of biodiversity are also confounded by sampling bias and the general habitat heterogeneity of caves. Species richness increases exponentially with increases in the number of individuals collected (Kuusela, 1979), increases in sample size (Allen, 1995), and increases in habitat size (MacArthur and Wilson, 1967).

Perhaps the most alarming factor in the rarity and abundance of cave-adapted organisms is habitat alteration and degradation. Elliot (2000) posits that at least 10 troglobites and stygobites are extinct because of anthropogenic disturbance in the U.S. Furthermore, cave-adapted organisms are more vulnerable to pollution because of their longevity and low reproduction potential. Poulson (1964) found that troglobites were more sensitive to changes in temperature and dissolved oxygen than their surface counterparts, and concluded that troglobites were more susceptible to anthropogenic disturbance. In general, stygophilic species, with their shorter lifespans and faster metabolic rates, are more susceptible to acute toxin exposure and stygobitic species, with their long lifespans and slower metabolic rates are more susceptible to chronic, low-level toxin exposure (Poulson, 1990).

OBJECTIVES AND METHODS

The objectives of this study were to:

1) Update the status and distribution of several federally listed, aquatic cave species (*Cambarus aculabrum*, *C. zophonastes*, and *Amblyopsis rosae*).
2) Census other aquatic life in as many caves as possible.
3) Determine the environmental quality in selected caves.
4) Summarize these findings into a database linked to a geographical information system.

This study was performed under the following permits: Federal Fish and Wildlife Permit #TE834518-2 and #TE834518-1; ANHC Permit # S-NHCC-99-005; and AGFC Educational Collecting Permit #1082.

Environmental Quality

Selected caves, including every cave habitat found to contain cavefishes or cave crayfishes, were assessed for environmental quality. Records were kept of all biota encountered (including troglophilic and epigean species which may compete with or predate upon the endangered species), level of human visitation and disturbance, and type of organic matter input. The following physical parameters were measured, when possible: water temperature ($^{+}/-$ 0.1 ^{o}C), dissolved oxygen ($^{+}/-$ 0.1 mg/l), conductivity ($^{+}/-$ 5 µSiemens/cm), turbidity ($^{+}/-$ 0.5 NTU), and pH ($^{+}/-$ 0.2 unit). Thirty-eight caves were measured for the following water quality parameters: total hardness, nitrate-nitrogen, total organic carbon, total viable, total coliform and *Escherichia coli* densities, chloride, and sulfate, fluoride, total kjeldahl nitrogen, total phosphorous, ortho-phosphate, and dissolved metals (arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, sodium, vanadium, zinc). A SPECTRO ™ Flame Modula E inductively coupled plasma optical emission spectrometer was used to measure metal concentration. Solid samples were prepared by weighing, ashing, digestion with HCl, and centrifugation. Detection limits (ug/l) are: Al = 0.25; As = 3.9; Sb = 3.9; Ba = 0.1; B = 0.5; Be = 0.05; Cd = 0.25; Ca = 0.075; Cr = 0.5; Co = 0.5; Cu =0.9; Fe = 0.4; K = 3.5; Pb = 3.5; Mg = 0.03; Mn = 0.05; Mo = 0.6; Hg = 1; Ni = 0.75; P = 5; Se = 3.9; Si = 1.5; Na = 2.5; Va = 0.25; and Zn = 0.4. The samples for mercury were held for 8 weeks at 3 ^{o}C before analyzing, and thus may not have detected methyl-mercury lost from volatilization. For flowing cave streams, all water samples were collected manually where discharge is greatest for the stream cross-section, and for still water, the samples were collected in the largest accessible pool. Care was taken to avoid disturbing bottom sediments. Water samples were collected upstream of the person collecting the sample in order to avoid contamination from the collector. Sampling techniques and analytical procedures followed approved U.S. Environmental Protection Agency methods, and appropriate quality assurance and quality control measures will be taken. Many of the water quality analyses were performed by the Arkansas Department of Environmental Quality (Environmental Chemistry Laboratory) as a project participant, some were performed under sub-contract by Arkansas Water Resources Center (Water Quality Laboratory), and others were performed by the authors at the Department of Biological Sciences, UAF.

Total viable cell density was estimated using direct counts of microbial cells by epifluorescence microscopy (Hoff, 1993). Water samples were collected in sterile, 120-ml specimen containers and immediately preserved with Formalin (final concentration of 3.7% formaldehyde). The samples were transported on ice, held at 4 ^{o}C at the lab, and processed within 48 hours. Subsamples, ranging from 0.001 to 30 mL depending upon microbial density, were diluted or directly pipetted into the funnel tower and stained with 1 ml of DAPI (1 mg/ml stock solution), then filtered through a 0.2-μm black, polycarbonate filter membrane (Nuclepore ™), backed by a polypropylene support filter, under low vacuum (Hoff, 1993). The polycarbonate filter was then mounted on a glass slide with a drop of immersion oil and covered with a cover slip. A Nikon Standard microscope, outfitted with an ultra-violet light source (365 nm) was used. Quality control was assured by performing cell counts on lab blanks of distilled water. For each subsample, at least 10 microscope fields (reticules) were counted with roughly 30 cells/reticule (Kirchman, 1993) at 1000X. The cell counts were converted to cell density by the following equation, where the effective filter area = 201.06 mm^2, the reticule area = 0.0113 mm^2 at 1000X:

$$\frac{\text{\# of cells}}{\text{reticule area (mm)}} \times \frac{\text{filter area (mm)}}{\text{sample volume (mL)}} \times \text{dilution factor} = \frac{\text{cells}}{\text{mL}}$$

Cave Bioinventories

Bioinventories were performed in the Ozark Plateaus of Arkansas with special emphasis upon caves known or suspected to contain the Ozark cavefish (*A. rosae*) or cave crayfishes (*C. aculabrum* or *C. zophonastes*), or which were near the published range of these species and had suitable habitat (*i.e*., having perennial streams or significant organic matter resources). Caves were georeferenced in latitude/longitude coordinates with a global positioning system handheld unit (Garmin III Plus), and the estimated position error noted (range of 1 to 30 m). In each cave surveyed, fauna were inventoried using the most unobtrusive methods possible. Plankton nets, kick nets and/or vacuum samplers were used where possible for sampling of invertebrates. Vertebrates and macroscopic invertebrates were counted visually, using snorkeling and/or SCUBA diving gear when necessary. When possible and permitted, specimens that were difficult to identify were collected and brought back to the laboratory (UAF). If they could not be identified, the specimens were sent to systematics experts appropriate for each taxon. The identification process was quite time-consuming, and not all organisms have been identified to species yet. Collected specimens will be curated in suitable museum collections (e.g. Smithsonian, UAF, etc.). Searches were discontinued any time endangered bats of any species are encountered. Note that US Fish and Wildlife Permit #TE834518-3 allows the lethal take of *A. rosae, C. aculabrum*, and *C. zophonastes* as voucher specimens to document new populations outside of their published ranges. Taxonomic keys used for identification include: Hubricht, 1941; Hubricht and Macklin, 1949; Holsinger, 1967; Holsinger, 1972; Schram, 1980; Raper, 1984; Bold and Wyne, 1985; Pennak, 1989; Robison and Buchanan, 1992; Patterson, 1992; Moulton II and Stewart, 1996; Merrit and Cummins, 1996).

Cavefish and Cave Crayfish Censuses

The visual surveys were performed by the same method as previous surveys and included at least two of the people used in a previous survey (Willis and Brown, 1985; Brown and Todd, 1987; Hobbs Jr. and Brown, 1987). Using helmet lights as well as powerful diving lights underwater, surveyors moved slowly upstream and counted individuals as they were sighted. This method can produce fairly reliable quantitative population information with minimal impact on the cave habitats and their inhabitants, endangered or otherwise. Pearson *et al*. (1995) reported that the use of powerful dive lights underwater increased significantly the number of fishes observed over typical dry caving lights. Stan Todd and Brian Wagner, both of the AGFC, assisted with some of the surveys.

Zoogeographical Analyses, Computer Modeling, and Statistics

The environmental quality data and species' occurrence data were entered into the Arkansas Cave Database (Access 2000, Microsoft, Inc.), and combined with all other possible data sources, including data from previous surveys, the Natural Heritage database (ANHC), data from the US Forest Service (Ozark/St. Francis National Forests), and literature reviews. A geographical information system (ArcView 3.2) was designed, and will be dynamically linked to the Arkansas Cave Database. The extensive resources of HSI-Geotrans, Inc., Arête Systems and the UA Center for Advanced Spatial Technologies were used for the geographic information system (GIS) analyses. Range maps of each cave species were generated using the following: latitude/longitude point data from field global positioning system (GPS) locations (Garman III-Plus ™, Garman, Inc.); a database query of current, historic, and rumored occurrences, and a background layer of the county boundaries of Arkansas.

Excel 2000 ™ (Microsoft Co.), SAS 8 for Windows ™ and JMP ™ (S.A.S., Inc.) were used for statistical analyses. All water quality parameters that were below detection limits were set to one-half the detection limit for statistical analyses. For bacteriological data, any value that was reported greater than a value was set to that value. Pairwise correlations were used to explore relationships between water quality parameters with a significance level (α) set to at least 0.05. One-way analysis of variance (ANOVA) was used to compare the presence/absence of an animal by a single water quality parameter. For the presence/absence of selected animal types, "isopod" denoted only occurrences of the genus *Caecidotea*, for "amphipod" only the genus *Stygobromus*, and for “salamander,” “bat,” and “crayfish,” all genera and species were used. For the category “bat,” only caves with populations (all bat species) greater than 100 individuals were ranked with “yes”. Table 5 shows a summary of these presence/absence data. To compare multiple water quality variables to the presence/absence of cave fauna, logistic regression models were first used, but backwards and stepwise selection revealed no significant predictors and data separation occurred. Linear discriminant analysis was used as an alternative (Agresti, 1996). Backwards elimination was used to determine which variables best discriminated between presence/absence of cave fauna, and these variables were then used to generate canonical variables and linear classification functions.

RESULTS

Water Quality Results

The base-flow water quality analysis results of grab samples of 37 Ozark caves are summarized in Tables 1 through 5. Table 6 provides descriptive statistics of these water quality parameters. Every cave sampled was found to contain some coliform bacteria (mean coliform density of 1080 MPN/100ml), which indicates contamination by mammalian feces. Significant bat populations (greater than 100 individuals) were present in less than 30% of the caves sampled, and one-way analysis of variance of microbiological parameters by bat (presence/absence) failed to reveal any significant relationship. These results indicate that bat guano cannot explain this fecal contamination entirely. One-quarter of the sites had nitrate concentrations greater than 3 mg/l, which is regarded as the threshold concentration that indicates human sources rather than natural sources (Madison and Burnett, 1984; Spalding and Exner, 1993). The National Water Quality Assessment Program reported a median nitrate concentration of 2.6 mg/l for Springfield Plateau aquifer springs and wells (Petersen *et al*., 1998). The median concentration of nitrate for the 37 caves sampled in this study was 2.3 mg/l. Pair-wise correlations revealed some relationships between water quality variables, and the significant correlations are listed in Table 7. Most nutrient variables (nitrate, total phosphorous, ortho-phosphate) were correlated to bacteriological variables (total coliforms, *E. coli*, and total viable cell densities). Total viable bacterial cell densities were highly correlated to total coliforms densities.

The presence/absence of amphipods, isopods, and their combination were related to the water quality variables using linear discriminant analysis. For isopod presence/absence, the variables with the largest correlations were hardness, calcium, and copper. Linear classification was very accurate, with a misclassification of only two caves (Logan and Rowland). This statistic indicates that isopods are present in caves when hardness, calcium, and copper values are high, and absent when these values are low. Note that this function predicts that isopods will not be found in Logan Cave based upon its water quality, and that although Logan Cave is known to contain isopods (Schram, 1980) and was classified as such, recent bioinventories have failed to find any cave isopods. For amphipod presence/absence, the variables with the largest correlations were total viable cells and zinc. Linear classification was again quite accurate, misclassifying only 3 caves (Bella Vista Trout Farm, Johnson’s, and Pine Creek Cave). This statistic indicates that amphipods are usually present in caves with low total viable bacterial densities and high zinc concentrations.

Table 1. Summary of physical parameters in base-flow water samples of 37 Ozark caves.

	Date	**Time**	**Temp.**	**pH**	**Turbidity**	**Conduct.**	**Hardness**
		24 hr	Celsius	pH unit	NTU	µSiemen/cm	mgl
Bald Scrappy	2/20/00	10:00	---	---	1.5	70	26
Bear Hollow Cave	2/20/00	11:30	---	6.5	4.0	240	105
Bella Vista Trout Farm	2/20/00	10:30	---	6.5	5.0	230	90
Biology Cave	2/20/00	12:00	---	6.8	7.0	180	79
Blanchard Springs	2/19/00	19:00	---	6.8	2.0	290	132
Blowing Spring Cave	2/20/00	11:00	---	6.6	2.0	230	90
Cave Springs Cave	2/20/00	11:20	14.3	< 6.5	2.0	350	146
Civil War Cave	2/20/00	10:00	---	6.7	1.5	440	176
Clark Spring	2/19/00	16:00	---	---	3.5	305	131
Copperhead Cave	2/20/00	15:50	11.7	6.5	6.0	150	57
Cosmic Cavern	2/20/00	11:25	---	7.4	2.0	560	283
Dickerson Cave	2/20/00	16:40	---	< 6.5	2.0	340	128
Eagle Hollow Cave	2/20/00	6:05	11.0	< 6.5	1.0	235	92
Fish Pond Cave	2/20/00	14:40	13.6	< 6.5	3.0	260	76
Hannah’s Cave	2/20/00	11:05	---	6.5	6.0	75	26
Hell Creek Cave	2/20/00	16:00	---	6.7	2.0	290	128
Hurricane River Cave	2/20/00	13:05	---	6.8	4.0	360	168
Indian Rockhouse	2/19/00	14:20	13.3	---	1.5	295	113
James Ditto Cave	2/20/00	14:00	---	< 6.5	50.0	220	84
John Eddings Cave	2/20/00	9:51	11.9	6.5	8.0	310	135
Johnson’s Cave	2/20/00	10:30	14.8	< 6.5	3.0	345	135
Logan Cave	2/20/00	12:20	13.7	7.1	2.0	290	119
Mystic Cavern	2/20/00	13:53	---	7.1	2.0	440	191
Nesbitt Springs Cave	2/20/00	16:00	---	6.8	1.5	290	116
Onyx Cave	2/20/00	10:05	---	6.5	10.5	145	50
Pigeon Roost Cave	2/20/00	17:05	12.0	6.5	2.0	270	120
Pine Creek Cave	2/20/00	16:20	---	6.5	8.0	120	53
Pretty Clean Cave	2/19/00	17:13	12.2	6.5	4.0	205	92
Rainy Day Cave	2/20/00	15:35	11.0	7.2	4.0	180	76
Rootville Cave	2/20/00	16:00	---	< 6.5	3.0	270	115
Rory Cave	2/19/00	14:00	---	---	3.0	340	147
Rowland Cave	2/19/00	17:00	---	---	1.5	290	128
Van Dyke Spring	2/20/00	19:25	10.6	6.5	5.5	210	89
War Eagle Creek Cave	2/20/00	15:22	---	6.5	7.0	215	78
War Eagle Cavern	2/20/00	14:35	9.5	6.5	2.5	225	89
Withrow Springs Cave	2/20/00	15:45	---	6.5	7.5	200	77
Wolf Creek Cave	2/20/00	13:08	8.3	6.5	7.0	75	27

Table 2. Summary of nutrient parameters in base-flow water samples of 37 Ozark caves.

	Sulfate mg/l	**Ortho-P.** mg/l	**Total Phosph.** mg/l	**Nitrate** mg/l	**TKN** mg/l	**TOC** mg/l
Bald Scrappy	5.114	0.084	0.111	1.644	< 0.050	1.89
Bear Hollow Cave	4.842	0.009	0.067	0.766	< 0.050	2.29
Bella Vista Trout Farm	4.647	0.017	0.082	1.845	< 0.050	1.45
Biology Cave	3.886	0.007	0.063	0.068	0.079	1.27
Blanchard Springs	2.702	0.017	0.056	0.615	< 0.050	< 1.00
Blowing Spring Cave	3.999	0.020	0.074	2.076	< 0.050	< 1.00
Cave Springs Cave	3.098	0.019	0.075	5.000	< 0.050	< 1.00
Civil War Cave	3.334	0.029	0.075	8.354	< 0.050	< 1.00
Clark Spring	7.442	0.022	0.076	1.237	< 0.050	1.11
Copperhead Cave	13.435	0.005	0.067	0.243	0.119	1.74
Cosmic Cavern	13.917	0.004	0.057	2.132	< 0.050	1.28
Dickerson Cave	10.393	0.229	0.305	11.527	< 0.050	1.58
Eagle Hollow Cave	7.093	0.157	0.158	5.506	< 0.050	1.42
Fish Pond Cave	8.248	0.215	0.230	13.58	< 0.050	2.60
Hannah’s Cave	3.428	0.011	0.061	0.176	0.107	1.24
Hell Creek Cave	2.902	0.025	0.076	0.669	< 0.050	< 1.00
Hurricane River Cave	1.613	0.014	0.066	0.378	< 0.050	< 1.00
Indian Rockhouse	4.476	0.014	0.069	0.575	< 0.050	1.13
James Ditto Cave	4.735	0.012	0.092	2.594	0.103	< 1.00
John Eddings Cave	4.506	0.023	0.079	0.803	< 0.050	< 1.00
Johnson’s Cave	6.733	0.028	0.076	2.667	< 0.050	< 1.00
Logan Cave	2.598	0.02	0.055	3.638	< 0.050	< 1.00
Mystic Cavern	13.017	0.019	0.074	1.399	0.117	1.21
Nesbitt Springs Cave	7.368	0.029	0.091	0.624	< 0.050	< 1.00
Onyx Cave	4.512	0.033	0.103	3.738	1.458	1.86
Pigeon Roost Cave	2.823	0.013	0.076	0.174	< 0.050	< 1.00
Pine Creek Cave	3.818	0.005	0.077	0.262	0.078	1.33
Pretty Clean Cave	4.167	0.016	0.084	0.159	0.109	1.1
Rainy Day Cave	3.290	0.012	0.087	0.27	0.060	1.52
Rootville Cave	7.902	0.015	0.083	0.925	0.050	2.18
Rory Cave	5.046	0.015	0.121	1.413	< 0.050	1.25
Rowland Cave	2.449	0.017	0.069	0.617	< 0.050	< 1.00
Van Dyke Spring	9.625	0.001	0.064	0.122	0.108	1.32
War Eagle Creek Cave	2.776	0.014	0.068	0.503	< 0.050	1.30
War Eagle Cavern	3.944	0.009	0.069	3.179	< 0.050	1.53
Withrow Springs Cave	4.083	0.011	0.076	3.528	< 0.050	1.68
Wolf Creek Cave	3.867	0.003	0.053	0.125	0.176	< 1.00

Table 3. Summary of bacteriological parameters in base-flow water samples of 37 caves.

	Total Coliform MPN/100ml	***E. coli*** MPN/100ml	**Total Viable** cells/ml
Bald Scrappy	200	< 10	1152
Bear Hollow Cave	200	10	32474
Bella Vista Trout Farm	1640	31	12676
Biology Cave	75	< 10	241985
Blanchard Springs	100	< 10	2305
Blowing Spring Cave	1640	42	11601
Cave Springs Cave	200	20	11055
Civil War Cave	100	< 10	8066
Clark Spring	200	< 10	18554
Copperhead Cave	200	10	4155
Cosmic Cavern	100	< 10	---
Dickerson Cave	> 20050	> 20050	101093
Eagle Hollow Cave	10910	< 10	109993
Fish Pond Cave	3640	1370	310809
Hannah’s Cave	310	< 10	69338
Hell Creek Cave	310	100	2305
Hurricane River Cave	200	200	1209
Indian Rockhouse	100	< 10	33630
James Ditto Cave	> 20050	87	472447
John Eddings Cave	870	< 10	20526
Johnson’s Cave	6240	200	148648
Logan Cave	640	< 10	5228
Mystic Cavern	420	100	39888
Nesbitt Springs Cave	200	< 10	1048
Onyx Cave	530	< 10	22076
Pigeon Roost Cave	100	< 10	3465
Pine Creek Cave	420	31	15556
Pretty Clean Cave	1370	< 10	3310
Rainy Day Cave	100	< 10	10470
Rootville Cave	990	< 10	225348
Rory Cave	344	< 10	5066
Rowland Cave	20	< 10	3457
Van Dyke Spring	200	< 10	3475
War Eagle Creek Cave	640	42	5781
War Eagle Cavern	420	< 10	17451
Whippoorwill Cave	3060	100	23046
Withrow Springs Cave	1920	530	7313
Wolf Creek Cave	288	< 10	5506

Table 4. Summary of dissolved metals in base-flow water samples of 37 Ozark caves.

	As µg/l	Ba µg/l	Be µg/l	Cd µg/l	Ca mg/l	Cl mg/l	Cr µg/l	Co µg/l	Cu µg/l	Fl mg/l
Bald Scrappy	< 1	9.1	0.2	< 0.14	6.4	1.466	< 0.40	< 0.50	1.08	0.076
Bear Hollow Cave	< 1	23.3	< 0.11	0.42	37.4	5.064	< 0.40	< 0.50	1.45	0.078
Bella Vista Trout Farm	< 1	23.1	< 0.11	< 0.14	34.4	5.748	< 0.40	< 0.50	2.06	0.046
Biology Cave	< 1	< 8.8	< 0.11	< 0.14	28.7	3.437	< 0.40	< 0.50	3.03	0.048
Blanchard Springs	< 1	15.8	< 0.11	< 0.14	50.9	4.879	< 0.40	< 0.50	0.72	0.060
Blowing Spring Cave	< 1	31.0	< 0.11	< 0.14	33.7	5.645	< 0.40	< 0.50	3.08	0.058
Cave Springs Cave	< 1	39.7	< 0.11	< 0.14	56.1	7.433	< 0.40	< 0.50	2.52	0.085
Civil War Cave	< 1	38.9	< 0.11	< 0.14	66.7	9.572	1.02	< 0.50	1.59	0.061
Clark Spring	< 1	19.3	< 0.11	< 0.14	50.2	6.087	0.43	< 0.50	2.26	0.066
Copperhead Cave	< 1	9.0	< 0.11	0.27	20.5	2.952	< 0.40	< 0.50	9.60	0.092
Cosmic Cavern	< 1	41.8	< 0.11	< 0.14	54.7	6.156	0.69	< 0.50	1.14	0.097
Dickerson Cave	< 1	42.2	< 0.11	< 0.14	46.6	9.746	< 0.40	< 0.50	1.42	0.066
Eagle Hollow Cave	< 1	19.5	< 0.11	< 0.14	33.2	1.145	< 0.40	< 0.50	5.23	0.051
Fish Pond Cave	< 1	107.3	< 0.11	< 0.14	24.4	9.135	< 0.40	< 0.50	12.24	0.125
Hannah’s Cave	< 1	< 8.8	< 0.11	< 0.14	9.8	0.933	< 0.40	< 0.50	1.80	0.045
Hell Creek Cave	< 1	16.9	< 0.11	< 0.14	49.4	4.636	0.51	< 0.50	1.11	0.058
Hurricane River Cave	< 1	15.4	< 0.11	< 0.14	66.2	2.796	1.47	< 0.50	8.50	0.064
Indian Rockhouse	< 1	26.9	< 0.11	< 0.14	39.3	8.554	0.63	< 0.50	2.46	0.067
James Ditto Cave	< 1	15.1	< 0.11	< 0.14	32.0	4.244	< 0.40	< 0.50	1.64	0.070
John Eddings Cave	< 1	16.0	< 0.11	< 0.14	52.8	3.628	< 0.40	< 0.50	10.02	0.090
Johnson’s Cave	< 1	45.8	< 0.11	< 0.14	50.8	8.705	1.26	< 0.50	3.18	0.063
Logan Cave	< 1	27.3	< 0.11	< 0.14	45.6	6.958	< 0.40	< 0.50	1.58	0.049
Mystic Cavern	< 1	28.1	< 0.11	< 0.14	73.3	8.903	0.89	< 0.50	1.27	0.051
Nesbitt Springs Cave	< 1	13.9	< 0.11	< 0.14	44.2	5.037	0.7	< 0.50	3.52	0.082
Onyx Cave	< 1	15.5	< 0.11	< 0.14	16.7	2.674	< 0.40	< 0.50	3.47	0.044
Pigeon Roost Cave	< 1	18.6	< 0.11	< 0.14	46.0	3.758	1.63	< 0.50	8.22	0.099
Pine Creek Cave	< 1	< 8.8	< 0.11	< 0.14	20.3	1.211	< 0.40	< 0.50	1.95	0.036
Pretty Clean Cave	< 1	9.4	< 0.11	< 0.14	35.5	1.152	0.85	< 0.50	4.71	0.080
Rainy Day Cave	< 1	16.0	< 0.11	< 0.14	27.6	2.011	< 0.40	< 0.50	3.12	0.106
Rootville Cave	< 1	21.6	< 0.11	< 0.14	44.7	3.22	0.62	< 0.50	1.19	0.078
Rory Cave	< 1	14.8	< 0.11	< 0.14	57.4	12.613	0.46	< 0.50	1.25	0.048
Rowland Cave	< 1	14.4	< 0.11	< 0.14	49.3	4.836	0.85	< 0.50	2.30	0.057
Van Dyke Spring	< 1	10.6	< 0.11	< 0.14	33.2	3.824	< 0.40	< 0.50	1.80	0.053
War Eagle Creek Cave	< 1	20.3	< 0.11	< 0.14	29.7	3.841	< 0.40	< 0.50	3.57	0.065
War Eagle Cavern	< 1	19.9	< 0.11	< 0.14	32.0	7.435	0.79	< 0.50	1.96	0.035
Withrow Springs Cave	< 1	21.5	< 0.11	< 0.14	29.2	7.327	< 0.40	< 0.50	0.98	0.052
Wolf Creek Cave	< 1	< 8.8	< 0.11	0.19	9.3	1.588	< 0.40	< 0.50	21.60	0.127

Table 4, cont. Summary of dissolved metals in base-flow water samples of 37 caves.

	Fe µg/l	**Pb** µg/l	**Mg** mg/l	**Mn** µg/l	**Hg** µg/l	**Ni** µg/l	**K** mg/l	**Se** µg/l	**Na** mg/l	**V** µg/l	**Zn** µg/l
Bald Scrappy	< 15	< 0.30	2.3	1	< 1	< 2.0	0.50	< 3	2.2	< 1.0	3.8
Bear Hollow Cave	< 15	< 0.30	2.9	1	< 1	< 2.0	0.60	< 3	3.6	< 1.0	12.3
Bella Vista Trout Farm	< 15	< 0.30	1.1	< 0.5	< 1	< 2.0	0.90	< 3	4.2	< 1.0	7.7
Biology Cave	< 15	< 0.30	1.8	0.6	< 1	2.16	0.60	< 3	3.3	< 1.0	6.2
Blanchard Springs	< 15	< 0.30	1.3	< 0.5	< 1	< 2.0	0.90	< 3	3.2	< 1.0	3.3
Blowing Spring Cave	< 15	< 0.30	1.3	0.5	< 1	< 2.0	1.40	< 3	4.7	< 1.0	8.1
Cave Springs Cave	< 15	< 0.30	1.4	< 0.5	< 1	< 2.0	0.60	< 3	5.4	< 1.0	11.6
Civil War Cave	< 15	< 0.30	2.3	0.6	< 1	< 2.0	1.20	< 3	7.3	< 1.0	9.6
Clark Spring	< 15	< 0.30	1.4	2.8	< 1	< 2.0	0.50	< 3	3.2	< 1.0	5.4
Copperhead Cave	< 15	0.68	1.5	0.9	< 1	3.12	0.70	< 3	3.8	< 1.0	45.6
Cosmic Cavern	< 15	< 0.30	35.6	< 0.5	< 1	< 2.0	< 0.46	< 3	5.7	1.09	6.3
Dickerson Cave	< 15	< 0.30	2.9	0.5	< 1	< 2.0	3.50	< 3	6.9	< 1.0	5.1
Eagle Hollow Cave	< 15	0.32	2.2	< 0.5	< 1	< 2.0	0.70	< 3	3.1	< 1.0	9.3
Fish Pond Cave	< 15	< 0.30	3.7	1.5	< 1	3.87	4.70	< 3	8.4	< 1.0	12.0
Hannah's Cave	< 15	< 0.30	0.4	< 0.5	< 1	< 2.0	< 0.46	< 3	1.8	< 1.0	7.6
Hell Creek Cave	< 15	< 0.30	1.3	< 0.5	< 1	< 2.0	< 0.46	< 3	3.6	< 1.0	4.9
Hurricane River Cave	< 15	0.52	0.6	0.6	< 1	3.11	< 0.46	< 3	2.1	1.28	16.6
Indian Rockhouse	< 15	0.45	3.6	0.7	< 1	< 2.0	0.50	< 3	6.4	< 1.0	13.4
James Ditto Cave	< 15	< 0.30	1.0	0.6	< 1	< 2.0	< 0.46	< 3	3.6	< 1.0	10.6
John Eddings Cave	< 15	1.03	0.8	1.2	< 1	4.08	< 0.46	< 3	3.2	< 1.0	34.5
Johnson's Cave	< 15	< 0.30	2.0	0.5	< 1	< 2.0	2.10	< 3	7.6	1.03	18.8
Logan Cave	< 15	< 0.30	1.1	< 0.5	< 1	< 2.0	1.30	< 3	5.2	< 1.0	6.4
Mystic Cavern	< 15	< 0.30	2.1	5.1	< 1	< 2.0	0.50	< 3	5.4	< 1.0	5.0
Nesbitt Springs Cave	< 15	< 0.30	1.4	< 0.5	< 1	2.1	< 0.46	< 3	4.1	< 1.0	11.6
Onyx Cave	< 15	< 0.30	1.9	0.8	< 1	< 2.0	1.50	< 3	2.6	< 1.0	18.2
Pigeon Roost Cave	< 15	0.35	1.3	0.7	< 1	3.49	< 0.46	< 3	3.5	1.0	17.0
Pine Creek Cave	< 15	< 0.30	0.5	0.6	< 1	< 2.0	< 0.46	< 3	1.9	< 1.0	12.8
Pretty Clean Cave	< 15	< 0.30	0.9	0.6	< 1	< 2.0	< 0.46	< 3	1.8	< 1.0	14.8
Rainy Day Cave	< 15	< 0.30	1.6	< 0.5	< 1	< 2.0	< 0.46	< 3	2.1	< 1.0	9.0
Rootville Cave	< 15	< 0.30	0.8	< 0.5	< 1	< 2.0	< 0.46	< 3	2.2	< 1.0	5.1
Rory Cave	< 15	< 0.30	1.0	< 0.5	< 1	< 2.0	< 0.46	< 3	4.5	< 1.0	3.7
Rowland Cave	< 15	< 0.30	1.2	< 0.5	< 1	< 2.0	0.60	< 3	3.0	< 1.0	6.7
Van Dyke Spring	< 15	< 0.30	1.5	0.9	< 1	< 2.0	0.70	< 3	2.8	< 1.0	5.5
War Eagle Creek Cave	< 15	< 0.30	1.0	< 0.5	< 1	< 2.0	0.80	< 3	4.3	< 1.0	12.6
War Eagle Cavern	< 15	< 0.30	2.2	1.1	< 1	< 2.0	< 0.46	< 3	3.4	< 1.0	6.2
Withrow Springs Cave	< 15	< 0.30	0.9	< 0.5	< 1	< 2.0	1.40	< 3	4.1	< 1.0	6.8
Wolf Creek Cave	44.5	3.19	1.0	7.5	< 1	7.36	< 0.46	< 3	1.5	< 1.0	62.9

Table 5. Summary of presence/absence data of selected cave animals (Stygobromid amphipods, Caecidotid isopods, and combined species of bats, crayfish, or salamanders) in the same 37 Ozark caves tested for base-flow water quality.

	Amphipod	Bat	Crayfish	Isopod	Salamander
Bald Scrappy	?	yes	no	?	?
Bear Hollow Cave	yes	no	yes	yes	yes
Bella Vista Trout Farm	no	no	no	yes	no
Biology Cave	?	no	?	?	?
Blanchard Springs	yes	yes	?	?	yes
Blowing Spring Cave	no	no	no	no	yes
Cave Springs Cave	yes	yes	yes	yes	yes
Civil War Cave	yes	no	no	yes	yes
Clark Spring	?	no	?	?	?
Copperhead Cave	yes	no	no	yes	yes
Cosmic Cavern	?	no	no	yes	?
Dickerson Cave	yes	no	yes	yes	yes
Eagle Hollow Cave	?	no	no	no	yes
Fish Pond Cave	no	no	no	yes	yes
Hannah’s Cave	no	no	no	no	yes
Hell Creek Cave	no	yes	yes	yes	no
Hurricane River Cave	?	?	?	yes	?
Indian Rockhouse	no	?	no	no	yes
James Ditto Cave	no	no	yes	no	yes
John Eddings Cave	?	no	yes	yes	yes
Johnson's Cave	no	no	no	no	no
Logan Cave	yes	yes	yes	yes	yes
Mystic Cavern	?	no	?	?	?
Nesbitt Springs Cave	no	no	yes	yes	no
Onyx Cave	?	no	no	?	?
Pigeon Roost Cave	?	yes	no	?	?
Pine Creek Cave	yes	yes	no	no	yes
Pretty Clean Cave	?	no	?	?	?
Rainy Day Cave	no	no	no	no	?
Rootville Cave	no	no	yes	yes	yes
Rory Cave	no	yes	no	no	yes
Rowland Cave	?	yes	?	yes	yes
Van Dyke Spring	no	no	yes	yes	yes
War Eagle Creek Cave	yes	no	no	yes	yes
War Eagle Cavern	no	yes	yes	yes	yes
Withrow Springs Cave	yes	no	yes	yes	yes
Wolf Creek Cave	yes	?	?	yes	?

Table 6. Descriptive statistics of water quality parameters in base-flow water samples of 37 Ozark caves

	Conductivity µSiemens/cm	Chloride mg/l	Sulfate mg/l	Hardness mgl	Ortho-phosp. mg/l	Total Phosph. mg/l
Minimum	70	0.933	1.613	26	0.001	0.053
Mean	256	5.054	5.411	106	0.031	0.088
Maximum	560	12.613	13.917	283	0.229	0.305

	Nitrate mg/l	TKN mg/l	TOC mg/l	Coliform MPN/100ml	*E. coli* MPN/100ml	Viable cells/ml
Minimum	0.068	0.05	1.1	20	< 10	1048
Mean	2.269	0.21	1.5	1080	191	54365
Maximum	13.580	1.46	2.6	> 20050	> 20050	472447

Table 7. Summary of significant ($\alpha < 0.05$) correlations between water quality parameters for the 37 Ozark Caves sampled.

Variable	By Variable	Correlation	Count	Probability
Escherichia coli	Total Phosphorous	0.7854	37	< 0.0001
Escherichia coli	Total Coliforms	0.6371	37	< 0.0001
Nitrate	Chloride	0.0013	37	0.0013
Nitrate	Ortho-phosphate	0.8176	37	< 0.0001
Total Coliforms	Nitrate	0.4939	37	0.0016
Total Coliforms	Ortho-phosphate	0.5723	37	0.0002
Total Coliforms	Total Phosphorous	0.6640	37	< 0.0001
Total Organic Carbon	Ortho-phosphate	0.3665	37	0.0236
Total Organic Carbon	Sulfate	0.3809	37	0.0183
Total Organic Carbon	Total Phosphorous	0.3916	37	0.0150
Total Phosphorous	Nitrate	0.7812	37	< 0.0001
Total Phosphorous	Ortho-phosphate	0.9424	37	< 0.0001
Total Viable Cells	Nitrate	0.3398	37	0.0396
Total Viable Cells	Total Phosphorous	0.3347	37	0.0429
Total Viable Cells	Total Coliforms	0.6195	36	< 0.0001

Bioinventories

A Microsoft 2000 Access ™ database was designed that summarizes species occurrence data and habitat characteristics of Arkansas caves from a review of the literature, the union of several other databases, and current cave inventories. To date, 417 karst features (95% of which are caves), 1190 faunal occurrences, and 151 species have been entered into the database. During this study, biological reconnaissance of 78 caves were performed, with all but 18 representing thorough inventories. It should be understood however, that bioinventories should never be considered complete due to the inaccessibility of much of the cave habitat and the cryptic nature of cave fauna. Over 73 species have been identified, with many new occurrence records at the county and state levels, and several new species have been discovered that are awaiting description and publication. Appendix II contains a full list of the caves and species studied, but location data other than county have been withheld. Of special note is the discovery of one new population of *A. rosae* and six new populations of cave crayfishes, which are either new species of *Cambarus*, or range extensions of *C. aculabrum*, *C. zophonastes*, or *C. setosus*.

Status of the Ozark Cavefish

All known Ozark cavefish sites in Arkansas were surveyed for cavefish populations (Woods and Inger, 1957; Page, Tumlinson, and McDaniel, 1981; Brown and Todd, 1987; ANHC, 1999), and Table 8 summarizes these latest population censuses. Figure 2 illustrates the occurrences of this species and *Typhlichthys subterraneus* by county. One new population of cavefish was found in an unnamed cave (designated Tom Allen Cave #2) near Tom Allen Cave. The AGFC Nursery Pond sinkhole appears to no longer be a suitable habitat for cavefish because of soil subsidence that has filled the karst window. The sinkhole at Monte Ne was been bulldozed shut by the landowner (Brown and Willis, 1984). Eight caves rumored to contain cavefish were surveyed, but no cavefish were found. Cloutman and Olmsted (1976) reported the only known *A. rosae* occurrence in Washington County. We were unable to find this location or confirm this sighting, but the location appears to be somewhere on Brush Creek. An amblyopsid scale was reported from Bear Hollow (Willis and Brown, 1985), but no cavefish have ever been seen in this habitat.

Table 8. Summary of censuses of cavefish populations in Arkansas during 1999-2000, including rumored sites. Censuses not yet performed are indicated by "?", and rumored sighting that could not be confirmed are indicated by "no." Owner class "NGO" indicates a non-governmental organization, such as *The Nature Conservancy*, and "Commercial" indicates a commercial cave operation. Location data taken from Woods and Inger (1957), Page *et al*., (1981), Brown and Todd (1987), Natural Heritage Database (1999), and this study.

Habitat Name	**County**	**1999-2000 Census**	**Sighting Confirmed?**	**Public Use**	**Owner Class**
Amblyopsis rosae					
Bear Hollow Cave	Benton	0	no	Moderate	NGO
Brush Creek	Washington	0	no	?	?
Cave Spring	Washington	1	no	Unknown	Private
Cave Springs Cave	Benton	102	yes	Light	State
Civil War Cave	Benton	5	yes	Heavy	Private
Cosmic Cavern	Carroll	0	no	Heavy	Commercial
Fitton Cave	Newton	0	no	Moderate	Federal
Hewlitt's Spring Hole	Benton	?	yes	?	?
James Ditto	Benton	3	yes	Light	State
Johnson's Cave	Washington	0	no	None	Private
Logan Cave	Benton	31	yes	Moderate	Federal
Monte Ne Sinkhole	Benton	?	yes	None	State
Mule Hole Sink	Benton	?	yes	None	Private
Nursery Pond	Benton	0	yes	None	Federal
Prairie Creek Cave	Benton	0	no	Light	Federal
Rootville Cave	Benton	1	yes	Light	Private
Savoy Cave	Benton	0	no	Light	Private
Tom Allen Cave	Benton	2	yes	Light	Private
Tom Allen Cave #2	Benton	7	yes	Light	Private
War Eagle Cavern	Benton	0	no	Heavy	Commercial
Typhlichthys subterraneus					
Cave River Cave	Stone	?	no	?	Private
Clark Spring	Stone	?	yes	?	Federal
Richardson Cave	Fulton	?	yes	?	?
Un-named well	Fulton	?	yes	?	?

Status of the Cave Crayfishes (*Cambarus* spp.)

All known *C. aculabrum* sites and one *C. zophonastes* site were surveyed for crayfish populations, and Table 9 summarizes these latest population censuses. Figure 3 illustrates the occurrences of these species by county. Note that six new cave crayfish populations were discovered (one by Stan Todd, AGFC, and one by Dawn Cannon, Dept. of Geosciences, UAF). The names of these caves have been withheld until identification and protection measures are complete. There are at least 7 rumored sightings of cave crayfish, and inventories of two of these habitats failed to find any cave-adapted crayfish.

Table 9. Summary of censuses of crayfish populations in Arkansas during 1999-2000, including rumored sites. Incomplete censuses are indicated by "*", and censuses not yet performed indicated by "?" Rumored sightings that could not be confirmed are indicated by "no." Owner class "NGO" indicates a non-governmental organization, such as *The Nature Conservancy*, and "Commercial" indicates a commercial cave operation.

Habitat Name	**County**	**1999-2000 Census**	**Sighting Confirmed?**	**Public Use**	**Owner Class**
Cambarus aculabrum					
Bear Hollow Cave	Benton	9	yes	Moderate	NGO
Logan Cave	Benton	24	yes	Moderate	Federal
Cambarus zophonastes					
Cave River Cave	Stone	?	yes	Light	Private
Hell Creek Cave *	Stone	2	yes	Light	State
Nesbitt Springs Cave *	Stone	0	yes	Light	Private
Cambarus sp.					
Beckham Creek Cave *	Newton	1	yes	Light	Private
Big Spring	Benton	0	no	Heavy	Private
Blanchard Springs Cavern	Stone	?	no	Heavy	Federal
Crystal Dome Cave	Newton	?	no	Heavy	Commercial
Dozen Den Cave	Independence	?	no	?	Private
Martin Hollow Cave	Stone	?	no	?	Private
Un-named cave	Benton	1	yes	Light	Private
Un-named cave	Benton	1	yes	Light	Private
Rory Cave	Stone	0	no	Light	Private
Un-named cave	Benton	2	yes	Light	Private
Un-named cave	Benton	5	yes	Light	Private
Un-named cistern *	Benton	11	yes	None	Private
War Eagle Cavern	Benton	0	no	Heavy	Commercial

Status of State Species of Concern

Tables 10 and 11 summarize the 1999-2000 censuses of the cave isopods and amphipods in Arkansas, respectively, all of which are designated "Species of Concern." Figures 3 and 4 illustrate the occurrences of these species by county. Cave isopods of the genus *Caecidotea* were found to be much more abundant than previously thought (Schram, 1980, Natural Heritage Database, 1999). Several new sites were found for cave amphipods (*Stygobromus* spp.), but at several historic sites, none could be found.

Table 10. Summary of censuses of cave-adapted isopod populations in Arkansas during 1999-2000. Censuses not yet performed are indicated by "?" Owner class "NGO" indicates a non-governmental organization, and "Commercial" indicates a commercial cave operation. Some locations are from Schram, 1980.

Habitat Name	County	1999-2000 Census	Public Use	Owner Class
Caecidotea ancyla				
Bear Hollow Cave	Benton	2	Moderate	NGO
Ivy Springs Cave	Madison	2	?	?
Marshall Caves	Benton	60	Light	Private
Old Pendergrass Cave	Benton	8	Light	Private
Rootville Cave	Benton	15	Light	Private
War Eagle Creek Cave	Madison	0	Heavy	State
Withrow Springs Cave	Benton	0	None	State
Caecidotea antricola				
Civil War Cave	Benton	1000	Heavy	Private
Logan Cave	Benton	0	Moderate	Federal
Wonderland Cave	Benton	7	Heavy	Private
Caecidotea steevesi				
War Eagle Creek Cave	Madison	3	Heavy	State
Caecidotea stiladactyla				
3 Be 532	Benton	100	Light	Private
Big Mouth Cave	Benton	10	Heavy	Private
Big Spring	Benton	5	Heavy	Private
Cave Springs Cave	Benton	600	Light	State
Dickerson Cave	Benton	15	Light	Private
Spring on Butler Creek Road	Benton	3		Private
War Eagle Cavern	Benton	0	Heavy	Commercial
Withrow Springs Cave	Benton	0	None	State

Table 10, continued. Summary of censuses of cave-adapted isopods populations in Arkansas during 1999-2000. Censuses not yet performed are indicated by "?" Owner class "NGO" indicates a non-governmental organization, such as *The Nature Conservancy*, and "Commercial" indicates a commercial cave operation. Some locations are from Schram, 1980.

Habitat Name	**County**	**1999-2000 Census**	**Public Use**	**Owner Class**
Caecidotea sp.				
Bella Vista Trout Farm Cave	Benton	2	Light	Private
Brock Spring	Washington	200		Private
Cave Spring	Washington	3	Unknown	Private
Cold Cave	Benton	1	Heavy	Private
Copperhead Cave	Newton	6	Heavy	Federal
Fish Pond Cave	Benton	20	Light	Private
Fitton Cave	Newton	10	Moderate	Federal
Granny Parker's Cave	Washington	60	Light	Private
Hell Creek Cave	Stone	1	Unknown	State
John Eddings Cave	Newton	10	Heavy	Federal
Little Devil's Den Cave	Newton	5	Light	Federal
Little Mouth Cave	Benton	5	Heavy	Private
Martin Hollow Cave	Stone	3		Private
Mineral Springs Road Cave	Washington	1	Light	Private
Nesbitt Springs Cave	Stone	1		Private
No name #02	Madison	1	Heavy	Private
No name #17	Benton	4	Moderate	Private
Nursery Pond	Benton	15	None	Federal
Seep at Weddington	Washington	100		Federal
Sherfield Cave	Newton	50	Light	Private
Spring at Hulet Cave	Washington	50		Private
Tanyard Creek Nature Trail Cave	Benton	2	Moderate	Private
Tom Allen Cave #2	Benton	10	Light	Private
Van Dyke Spring Cave	Newton	2	Moderate	Federal
Wildcat Hollow Cave	Marion	10	Light	Private
Wolf Creek Cave	Newton	100	Light	Federal

Table 11. Summary of censuses of cave-adapted amphipods populations in Arkansas during 1999-2000. Censuses not yet performed are indicated by "?" Owner class "NGO" indicates a non-governmental organization, such as *The Nature Conservancy*, and "Commercial" indicates a commercial cave operation.

Habitat Name	County	1999-2000 Census	Public Use	Owner Class
Stygobromus alabamensis				
Bald Scrappy Cave	Stone	?	Light	?
Bergren Cave	Izard	?	?	Private
Blanchard Springs Cavern	Stone	?	Heavy	Federal
Stygobromus ozarkensis				
Bear Hollow Cave	Benton	1	Moderate	NGO
Cave Springs Cave	Benton	0	Light	State
Civil War Cave	Benton	100	Heavy	Private
Danford Cave	Benton	?	?	?
Dickerson Cave	Benton	1	Light	Private
Logan Cave	Benton	0	Moderate	Federal
Old Pendergrass Cave	Benton	2	Light	Private
War Eagle Creek Cave	Madison	0	Heavy	State
Withrow Springs Cave	Benton	0	None	State
Stygobromus sp.				
3 Be 532	Benton	1	Light	Private
Big Spring	Benton	5	Heavy	Private
Civil War Cave	Benton	100	Heavy	Private
Cold Cave	Benton	50	Heavy	Private
Copperhead Cave	Newton	1	Heavy	Federal
Fitton Cave	Newton	1	Moderate	Federal
Friday the 13th Cave		10	Heavy	Federal
Logan Cave	Benton	1	Moderate	Federal
No name #02	Madison	100	Heavy	Private
Old Pendergrass Cave	Benton	1	Light	Private
Pine Creek Cave	Madison	1	Heavy	State
Sherfield Cave	Newton	2	Light	Private
Spring at Hulet Cave	Washington	30	?	Private
Wolf Creek Cave	Newton	1	Light	Federal

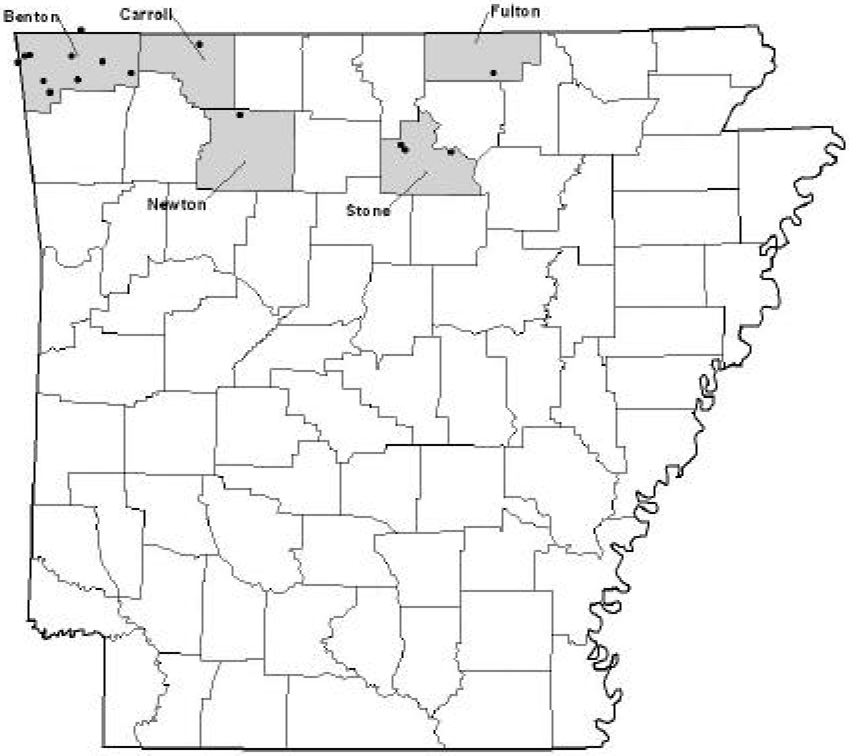

Figure 2. Range map of the distribution of known cavefish (*Amblyopsis rosae* and *Typhlichthys subterraneus*) habitats in Arkansas by location and by county.

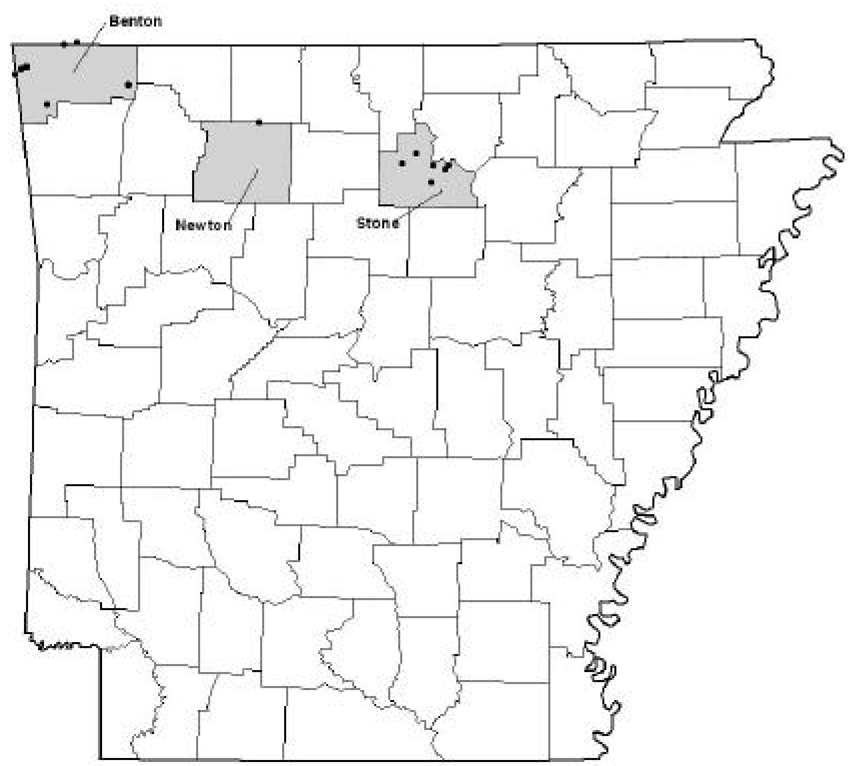

Figure 3. Range map of the distribution of known cave crayfish (*Cambarus aculabrum* and *C. zophonastes*) habitats in Arkansas by location and by county.

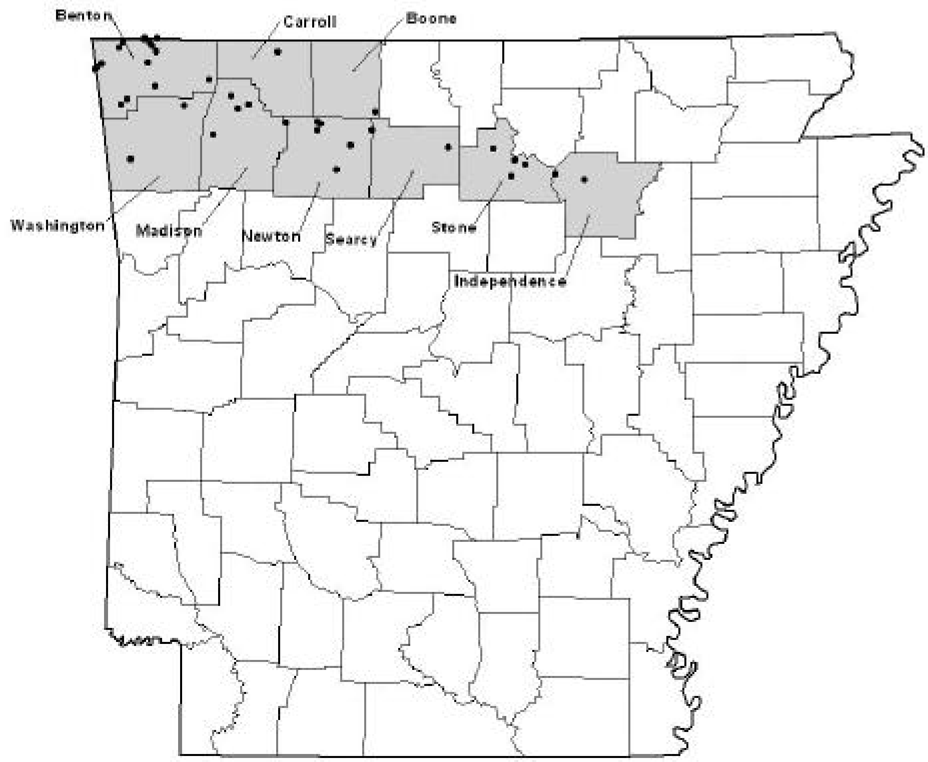

Figure 4. Range map of the distribution of known cave isopod (*Caecidotea spp.*) habitats in Arkansas by location and by county.

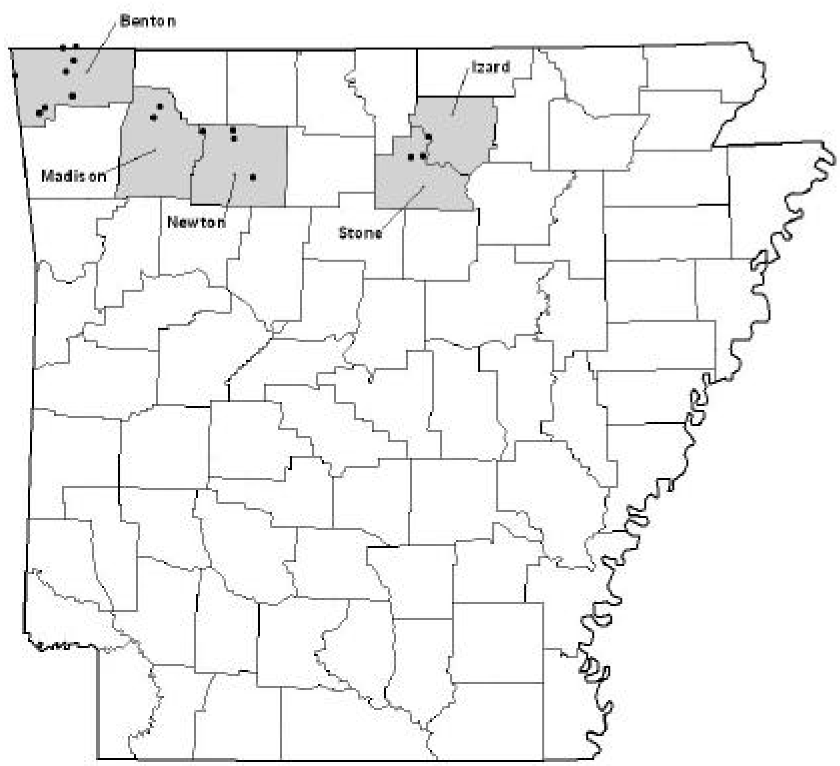

Figure 5. Range map of the distribution of known cave amphipod (*Stygobromus spp.*) habitats in Arkansas by location and by county.

DISCUSSION

Habitat Quality in Ozark Caves

Results of this study indicate some degree of fecal contamination in all 37 caves sampled, and some of these caves have nutrient concentrations well above regional averages. The presence of bats and their guano is not the only source of these high bacterial and nutrient concentrations. Septic system leachate, grazing livestock, and the land-application of confined animal feeding operation waste are probable sources. Concentrations of dissolved metals appear to be below toxic levels, even for regions known to be lead-zinc mining districts. Some of the water quality variables are correlated to the presence or absence of stygobitic isopods and amphipods. Water hardness was the most important factor explaining the presence of isopods, and calcium is the major factor in water hardness variation. Calcium is a critical element in arthropod exoskeletons, and the abundance of dissolved calcium may be a factor in the success of isopod populations in cave streams. Low bacterial density (total viable cells) was the most important factor explaining the presence of cave amphipods. Several case studies document the extirpation of cave amphipods from caves polluted with excess nutrients and bacteria (Holsinger, 1966; Sinton, 1984; Simon and Buikema Jr., 1997; Graening and Brown, 2000).

Dominant Cave Species

In the United States, arachnids, crustaceans and insects dominate species diversity of cave fauna (Culver *et al*., 2000). In a survey of cave streams of the Springfield plateau, Willis and Brown (1985) found that isopods *(Caecidotea* spp.) were the most common benthic invertebrates and chironomids, second. This study also found isopods to be the most abundant benthic invertebrate, with *Caecidotea* spp. found at 60 sites and other Asellidae at 18 sites. Crayfish were second most abundant with *Orconectes* spp. found at 22 sites, cave-adapted *Cambarus* spp. at 11 sites, and other species at 7 sites. Amphipods were third most abundant, with *Stygobromus* spp. at 27 sites and *Gammarus* spp. at 11 sites. Springtails (Collembola) were the most abundant terrestrial invertebrate, with *Arrhopalites* spp. fount at 28 sites, *Pseudosinella* spp. at 26 sites, and other species at 40 sites (Christiansen, 2000; this study). Bats were the most abundant vertebrate, with *Pipistrellus subflavus* found at 50 sites, *Corynorhinus* spp. at 18 sites, *Myotis grisescens* at 53 sites, *M. sodalis* at 20 sites, and other species at 4 sites. Salamanders were the second most abundant vertebrate, with *Eurycea lucifuga* found at 46 sites, *E. longicauda* at 28 sites, other *Eurycea* spp. at 3 sites, *Plethodon* spp. at 20 sites, *Typhlotriton spelaeus* at 38 sites, and unidentifiable larvae at 30 sites. This summary of abundant species does not fully represent the biodiversity of these cave communities, however. Overall, population sizes were small and species richness was low in these cave habitats.

Status of the Ozark Cavefish

In the primary recovery caves (designated in the Recovery Plan, US Fish and Wildlife Service, 1989), Ozark Cavefish are near maximum historic abundance, and thus appear to be recovering (Table 8, Figures 6 and 7). However, Cave Springs Cave, which contains over 50% of all censused Ozark cavefish, is experiencing significant habitat degradation.
Studies by Brown *et al*. (1998) and Graening and Brown (1999, 2000) report excessive bacterial and nutrient concentrations, the presence of toxic metals in the cave sediments and food web, and the possible extirpation of the Ozark Cave amphipod. Degraded water quality is not the only threat to Ozark Cavefish. Some *A. rosae* caves have been intentionally shut by landowners (e.g. Mill's Cave, Jolly Mill Cave, Moore's Spring Cave and Monte Ne sinkhole) and some cavefish habitats are now inundated by reservoirs (Hickory Creek, Prairie Creek, Pigeon Roost, and Hole in the Wall Caves) (Brown and Willis, 1984). Swan and Gentry Caves (*A. rosae* sites in Missouri) are now dry from lowered water tables (Brown and Willis, 1984). Caving, whether recreational or scientific, is a threat to cavefish because these fish forage and hide in the cobble substrate. Inadvertent trampling is documented in at least one case (Graening and Brown, 2000). Another mortality factor in cavefish population dynamics is flooding. Poulson (1961) believes that floods washing cavefish out of caves is a major mortality factor. No stygobitic amblyopsids have ever been collected outside of a groundwater ecosystem (Burr, 1992) except after extreme flooding (Smith, 1980). Three live Ozark Cavefish have been observed in pools downstream of Cave Springs Cave after major storm events (Graening and Brown, 1999). Graening found a live *A. rosae* in the pool below the spring at Logan Cave, as well.

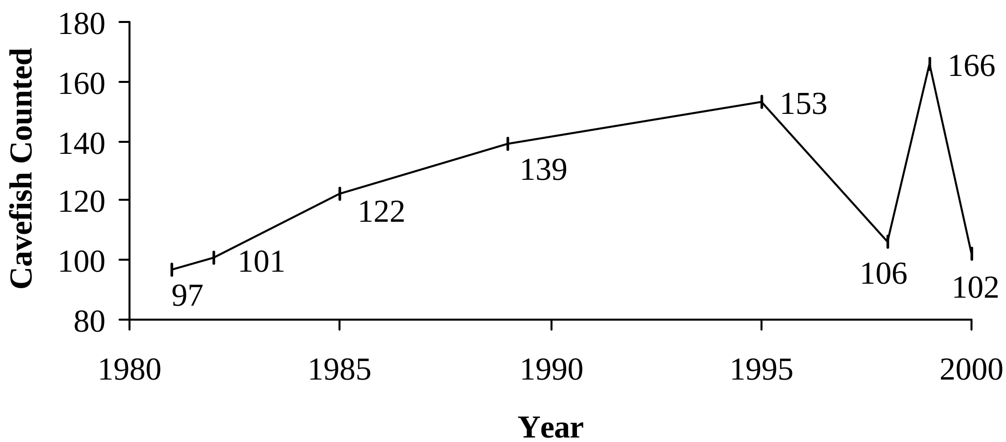

Figure 6. Summary of all known population censuses of *Amblyopsis rosae* in Cave Springs Cave (Brown *et al*., 1998; Graening and Brown, 1999, 2000).

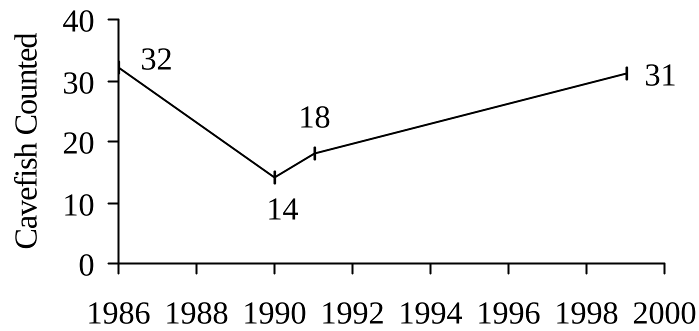

Figure 7. Summary of all known population censuses of *Amblyopsis rosae* in Logan Cave (Brown and Willis, 1984; Brown and Todd, 1987; Means, 1993; Means *et al*., 1995; Brown, 1996; this study). Note that this summary includes only data of actual cavefish sighted and does not include population estimates from mark/recapture studies (*e.g.* Means, 1993; Means *et al*., 1995).

Status of the Cave Crayfishes

The status of *Cambarus zophonastes* is still uncertain because complete censuses of the three known cave habitats have never been performed (Hobbs, Jr., and Brown, 1987; US Fish and Wildlife Service, 1988). All three habitats have extensive submerged passage, and require SCUBA gear to perform the censuses. Funding from the AGFC and the ANHC should facilitate these censuses in the next year. The known partial surveys of Hell Creek Cave are shown in Figure 8.

In the primary recovery caves, which are designated in the Recovery Plan (US Fish and Wildlife Service, 1988), *Cambarus aculabrum* is at or above maximum historic abundance, and thus appear to be recovering, as shown in Figures 9 and 10. Furthermore, six new cave crayfish populations have been found, indicating that these Cambarid crayfish are more widely distributed than previously thought. Population numbers are still extremely low and environmental quality data gathered during this study indicates habitat degradation, which supports the continued listing of these crayfishes as "endangered." Threats to these cave crayfishes are similar to those for cavefishes. In-stream walking is a direct threat to *C. aculabrum* in Bear Hollow Cave (US Fish and Wildlife Service, 1996) and in Logan Cave. Flooding is an important mortality factor. The neighbor downstream of Bear Hollow Cave reports seeing cave crayfish being washed out of the cave after a record flood event and surfacing upon springs on his land (Scott Green, *pers. comm*., 1999). Cave crayfish at War Eagle Cavern have also been reportedly washed out by flooding (Hank Law, manager of War Eagle Cave, *pers. comm*., 1999), but the crayfish's presence has not been confirmed. Other threats to *C. aculabrum* include predation (by other fish and crayfish) (US Fish and Wildlife Service, 1996). *C. aculabrum* has been found in the guts of sculpin on several occasions (Brown *et al*., 1994; Means and Johnson, 1995).

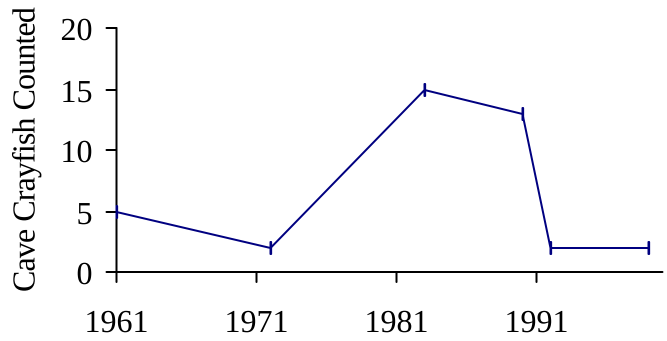

Figure 8. Summary of all known population censuses of *Cambarus zophonastes* in Hell Creek Cave (Bedinger and Hobbs, 1965; Smith, 1984, US Fish and Wildlife Service, 1988; this study). Note that these censuses do not include inventory of submerged passages.

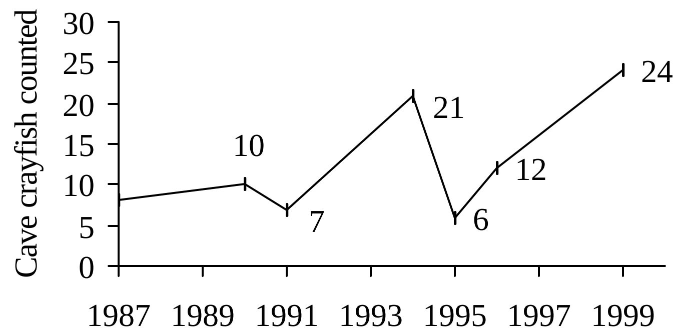

Figure 9. Summary of all known population censuses of *Cambarus aculabrum* in Logan Cave. (Hobbs Jr. and Brown, 1987; Brown, 1996; US Fish and Wildlife Service, 1996; this study).

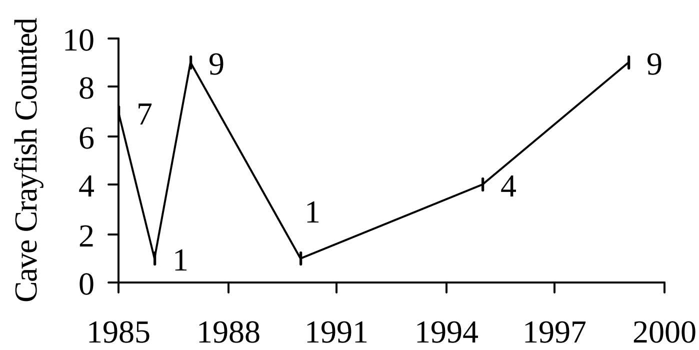

Figure 10. Summary of all known population censuses of *Cambarus aculabrum* in Bear Hollow (Hobbs Jr. and Brown, 1987; US Fish and Wildlife Service, 1996; this study).

Protection

Arkansas is one of 22 states with cave protection laws (Hupert, 1995). The Arkansas Cave Resources Protection Act (State of Arkansas, 1989) affords limited protection to caves. It is a Class A misdemeanor to vandalize any cave, which includes marking upon surfaces, tampering with gates or signs, removing or disturbing archaeologically valuable material (Section 3, Act 523). It is also a Class A misdemeanor to pollute any cave or sinkhole, which includes the storage, dumping, littering, or placing of refuse, garbage, sewage, or toxic substances harmful to cave live or humans (Section 4, Act 523). Yet the Act states that no agricultural or silvicultural practice whatsoever shall be prohibited or regulated (Section 4, Act 523). All troglobitic and stygobitic species are protected by Arkansas Game and Fish Commission Regulation #1817 – "Wildlife Pet Restrictions" – which prohibits their possession or sale. The Federal Endangered Species Act protects listed species from harassment, taking, killing, or habitat destruction with a fine of up to $50,000 or one year imprisonment. Federal Cave Resources Protection Act protects caves designated as "significant" on federal lands by allowing federal land managers to keep cave locations and names confidential and assign a penalty of up to $10,000 for abuses. Other legislation that could protect caves includes the Wilderness Act of 1964.
The Department of the Interior has accepted the legality of the underground wilderness concept (Stitt, 1976), although no cave complexes have been given Wilderness Area designation. However, some Wilderness Areas include cave systems, such as the lava tubes at Craters of the Moon and Lava Beds National Monuments (Tousley, 1976). Protection for Arkansas caves also necessitates the enforcement of state and federal water quality standards.

LITERATURE CITED

Agresti, A. 1996. An introduction to categorical data analysis. Wiley-Interscience Publication, John Wiley and Sons, Inc. New York, New York. 290 pp.

Allen, J. 1995. Stream Ecology: structure and function of flowing waters. Chapman and Hall, London, United Kingdom.

Barr, T. 1963. Ecological classification of cavernicoles. Cave Notes 5: 9-16.

- 1968. Cave ecology and the evolution of troglobites. Evolutionary Biology 2: 35-102.

Bedinger, M., and H. Hobbs, Jr. 1965. Observations of a new troglobitic crayfish (with notes on the distribution of troglobitic crayfishes of the Ozark region). Bulletin of the National Speleological Society 27(3): 93-96.

Belles, X. 1987. Fauna cavernicola i intersticial de la peninsula Iberica i les Illes Balears. Consell Superior d'Investigacions Cientifiques. Mallorca, Spain.

Bold, H., and M. Wyne. 1985. Introduction to the Algae: structure and reproduction, 2nd edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 720 pp.

Brown, A., G. Graening, and P. Vendrell. 1998. Monitoring cavefish populations and environmental quality in Cave Springs Cave, Arkansas. Miscellaneous publication no. 214. Arkansas Water Resources Center, University of Arkansas, Fayetteville, Arkansas.

Brown, A., W. Pierson, and K. Brown. 1994. Endangered species conservation through cave ecosystem management. A final report to the Arkansas Game and Fish Commission.

Brown, A. and C. Todd. 1987. Status review of the threatened Ozark cavefish (Amblyopsis rosae). Proceedings of the Arkansas Academy of Science 41:99-100.

Brown, A., and L. Willis. 1984. Cavefish (Amblyopsis rosae) in Arkansas: populations, incidence, habitat requirements, and mortality factors. Final report to the Arkansas Game and Fish Commission.

Brown, Z. 1996. Population dynamics and growth of Ozark cavefish in Logan Cave, Benton County, Arkansas. Thesis, University of Arkansas, Fayetteville, Arkansas.

Burr, B. 1992. Phylogenetics of North American freshwater fishes. Pages 18-75 in R. Mayden, editor. Systematics, historical ecology, and North American freshwater fishes. Stanford University Press, Stanford, California.

Camacho, A. 1992. A classification of the aquatic and terrestrial subterranean environments and their associated fauna. Pages 57-103 in A. Camacho, editor. The natural history of biospeleology. Museo Nacional de Ciencias Naturales. Madrid, Spain.

Christiansen, K. 2000. Unpublished data, personal communication with authors. Department of Biology, Grinnell College, IA.

Cloutman, D., and L. Olmsted. 1976. The fishes of Washington County, Arkansas. Publication No. 39, Arkansas Water Resources Center, University of Arkansas, Fayetteville, Arkansas. 109 pp.

Crunkilton, R. 1982. Bitter Harvest. Missouri Conservationist, November 1982: 4-7.

Cullimore, D. 1993. Practical Manual of Groundwater Microbiology. Lewis Publishers, Chelsea, Michigan. 412 pp.

Culver, D. 1994. Species interactions. Pages 271-286 in J. Gibert, D. Danielopol, and J. Stanford, editors. Groundwater Ecology. Academic Press, San Diego, California. 571 pp.

- 1982. Cave Life: Evolution and Ecology. Harvard University Press, Cambridge, Massachusetts. 189 pp.

Culver, D. and J. Holsinger. 1992. How many species of troglobites are there? National Speleological Society Bulletin 54: 79-80.

Culver, D., L. Master, M. Christman, and Hobbs III, H. 2000. The obligate cave fauna of the 48 contiguous United States. Conservation Biology 14(2): 386-401.

Curl, R. L. 1958. A statistical theory of cave entrance evolution. Bulletin of the National Speleological Society 20:9-22.

DeKay, J. 1842. Footnote, p. 187 in Zoology of New York of the New-York fauna. Part IV. Fishes. W. & A. White and J. Visscher, Albany, NY.

Dickson, 1975. A preliminary study of heterotrophic microorganisms as factors in substrate selection of troglobitic invertebrates. National Speleological Society Bulletin 37(4): 89-93.

Elliot, W. 2000. Conservation of the North American cave and karst biota. Pages 671-695 in H. Wilkens, D. Culver, and W. Humphreys, editors. Subterranean ecosystems. Elsevier, Oxford, United Kingdom.

Franklin, I. 1980. Evolutionary change in small populations. Pages 135 to 150 in Conservation Biology: an evolutionary – ecology perspective. M. Soule and B. Wilcox, editors. Sinauer, Sunderland.

Gall, B. and K. Christian. 1984. A program of wildlife inventory. Journal of Environmental Management 19: 277-289.

Gibert, J., J. Stanford, M. Dole-Olivier. 1994. Basic attributes of groundwater ecosystems and prospects for research. Pages 8-37 in J. Gibert, D. Danielopol, and J. Stanford, editors. Groundwater Ecology. Academic Press, San Diego, California. 571 pp.

Graening, G. and A. Brown. 1999. Cavefish Population Status and Environmental Quality in Cave Springs Cave, Arkansas. A report submitted to the Arkansas Natural Heritage Commission. Publication No. 276, Arkansas Water Resources Center, University of Arkansas, Fayetteville, Arkansas.

Graening, G., and A. Brown. 2000. Trophic dynamics and pollution effects in Cave Springs Cave, Arkansas. A report submitted to the Arkansas Natural Heritage Commission. Publication No. MSC-285. Arkansas Water Resources Center, University of Arkansas, Fayetteville, Arkansas.

Harris, J. 1970. Bat-guano cave environment. Science 169: 1342-1243.

Hawes, R. 1939. The flood factor in the ecology of caves. Journal of Animal Ecology 8:1-5.

Hobbs Jr., H., and A. Brown. 1987. A new troglobitic crayfish from northwestern Arkansas (Decapoda: Cambaridae). Proc. Biol. Soc. Wash. 100(4):1040-1048.

Hoff, K. 1993. Total and specific bacterial counts by simultaneous staining with DAPI and fluorochrome-labeled antibodies. Pages 149-154, Kemp, P., B. Sherr, E. Sherr, and J. Cole, editors. Handbook of Methods in Aquatic Microbial Ecology. Lewis Publishers, Boca Raton, Florida.

Holsinger, J. 1967. Systematics, speciation, and distribution of the subterranean amphipod genus *Stygonectes* (Gammaridae). United States National Museum Bulletin 259: 1-176. Smithsonian Institution Press, Washington, DC.

- 1972. The freshwater amphipod crustaceans (Gammaridae) of North America. Biota of Freshwater Ecosystems: Identification Manual #5. U. S. Environmental Protection Agency, Washington, D.C. 89 pp.

Hubricht, L. 1941. The cave Mollusca of the Ozark region. Nautilus 54(4): 111-112.

Hubricht, L., and J. Macklin. 1949. The freshwater isopods of the genus *Lirceus* (Asellota, Asellidae). The American Midland Naturalist 42(2): 334-349.

Hummel, J. 1983. Cave inventories as a pre-requisite to formulation of cave management plans. National Speleological Society Bulletin 45: 1-8.

Hupert, G. 1995. Legal protection for caves in the United States. Environmental Geology 26(2): 121-123.

International Union for the Conservation of Nature. 1994. 1994 IUCN Red List of Threatened Animals. B. Groombridge, editor. Gland, Switzerland. 286 pp.

International Union for the Conservation of Nature. 1996 IUCN Red List of Threatened Animals. J. Baillie, and B. Groombridge, editors. Gland, Switzerland. 448 pp.

Jegla, T. 1969. Reproductive and molting cycles in cave crayfish. Biological Bulletin 130: 345-358.

Job, C. and J. Simons. 1994. Ecological basis for management of groundwater in the United States: Statutes, regulations and a strategic plan. Pages 524-541, J. Gibert, D. Danielopol, and J. Stanford, editors. Groundwater Ecology. Academic Press, San Diego, California.

Juberthie, C., B. Delay, and M. Bouillon, 1980. Extension du milieu souterrain en zone non-volcanic: description d'un nouveau milieu et son peuplement par les Coleopteres troglobies. Memoires de Biospeologie 7:19-52.

Karst Waters Institute, 1999. Internet site http://www.karstwaters.org/kwidata.htm. D. Culver and H. Hobbs, III, editors. US troglobites and stygobites.

Kirchman, D. 1993. Statistical analysis of direct counts of microbial abundance. Pages 117-120, Kemp, P., B. Sherr, E. Sherr, and J. Cole, editors. Handbook of Methods in Aquatic Microbial Ecology. Lewis Publishers, Boca Raton, Florida.

Knapp, S. and D. Fong. 1999. Estimates of population size of *Stygobromus emarginatus* (Amphipoda: Crangonyctidae) in a headwater stream in Organ Cave, West Virginia. Journal of Cave and Karst Studies 61(1): 3-6.

Kozhov, M. 1963. Lake Baikal and its life. Junk Pub., Den Haag.

Kuusela, K. 1979. Early summer ecology and community structure of the macrozoobenthos on stones in the Javajankoski Rapids on the River Lestijoki, Finland. Acta Univ. Ouluensis Ser. A, No. 87.

Laing, C., G. Carmody, and S. Peck. 1976. How common are sibling species in cave inhabiting invertebrates? American Naturalist 110: 184-189.

Lampert, W., and U. Sommer. 1997. Limnoecology: the ecology of lakes and streams. Oxford University Press, New York, NY. 382 pp.

MacArthur, R., and E. Wilson. 1967. The theory of Island Biogeography. Princeton University Press. Princeton, New Jersey.

Madison, R. J., and J. O. Burnett. 1984. Water-quality issues. Pages 93-105 in National Water Summary 1984. U S Geological Survey, Denver, Colorado.

Malard, F., S. Plenet, and J. Gibert. 1996. The use of invertebrates in groundwater monitoring: a rising research field. Groundwater Monitoring and Remediation 16: 103-113.

Means, M. 1993. Population dynamics and movements of Ozark cavefish in Logan Cave NWR, Benton County, Arkansas with additional baseline water quality information. Thesis, University of Arkansas, Fayetteville, Arkansas.

Means, M. and J. Johnson. 1995. Movement of threatened Ozark cavefish in Logan National Wildlife Refuge, Arkansas. The Southwestern Naturalist 40(3): 308-313.

Merrit, R., and K. Cummins, editors. 1996. An introduction to the aquatic insects of North America, 3rd edition. Kendall/Hunt Publishing Company, Dubuque IA. 862 pp.

Moulton II, S., and K. Stewart. 1996. Caddisflies (Trichoptera) of the Interior Highlands of North America. Memoirs of the American Entomological Institute, Volume 56. The American Entomological Institute, Gainesville Florida. 313 pp.

Natural Diversity Database. 1999. Data query. Arkansas Natural Heritage Commission, Little Rock, Arkansas.

Nicholas, G. 1960. Checklist of macroscopic troglobitic organisms of the United States. American Midland Naturalist 61(1): 123-160.

Notemboom, J., S. Plenet, and J. Turquin. 1994. Groundwater contamination and its impact on groundwater animals and ecosystems. Pages 477-503, Gibert, J., D. Danielopol, and J. Stanford, editors. Groundwater Ecology. Academic Press, San Diego, California.

Packard, A. 1888. The cave fauna of North America, with remarks on the anatomy of the brain and origin of the blind species. Memoirs of the National Academy of Science 4: 1-156.

Paige, K., C. Tumlison, and V. McDaniel. 1981. A second record of *Typhlichthys subterraneus* (Pisces: Amblyopsidae) from Arkansas. Southwestern Naturalist 26(1): 67-92.

Patterson, D. 1992. Free-living freshwater protozoa: a color guide. John Wiley and Sons, Inc., New York, NY. 223 pp.

Pearson, W., C. Boston Jr., and T. Jones. 1995. Population densities of *Amblyopsis spelaea* in several Indiana and Kentucky caves. Abstracts and information: Ozark Cavefish Conference II. Missouri Department of Conservation.

Peck, S. 1998. A summary of diversity and distribution of the obligate cave-inhabiting faunas of the United States and Canada. Journal of Cave and Karst Studies 60(1): 18-26.

Pennak, R. 1989. Fresh-water invertebrates of the United States: protozoa to mollusca, 3rd edition. John Wiley and Sons, Inc., New York, NY. 628 pp.

Petersen, J., J. Adamski, R. Bell, J. Davis, S. Femmer, D. Freiwald, and R. Joseph. 1998. Water quality in the Ozark Plateaus. U S Geological Survey Circular 1158.

Poulson, T. 1961. Cave adaptation in Amblyopsid fishes. Dissertation, University Microfilms 61-2787. University of Michigan, Ann Arbor, Michigan.

Poulson, T. 1963. Cave adaptation in Amblyopsid fishes. The American Midland Naturalist 70(2): 257-290.

- 1964. Animals in aquatic environments: animals in caves. Pages 749-771 in Handbook of Physiology. D. Dill, editor. American Physiological Society. Washington, District of Columbia.

- 1976. Management of biological resources in caves. Pages 46-52 in Proceedings of the 1st National Cave Management Symposium. Speleobooks, Albuquerque, New Mexico. 146 pp.

- 1978. Community organization. Pages 41-45 in S. Wells, editor. Cave Research Foundation 1978 Annual Report. Yellow Springs, Ohio.

- 1990. Developing a protocol for assessing groundwater quality using biotic indices in the Mammoth Cave region. Proceedings of the First Mammoth Cave National Park Karst Conference. National Park Service, Mammoth Cave, Kentucky.

Raper, K. 1984. The Dictyostelids. Princeton University Press. Princeton, New Jersey. 453 pp.

Robison, H., and T. Buchanan. 1992. Fishes of Arkansas. University of Arkansas Press, Fayetteville, Arkansas. 536 pp.

Schram, M. 1980. The troglobitic Asellidae (Crustacea: Isopoda) of Northwest Arkansas. Thesis, University of Arkansas. Fayetteville, Arkansas.

Sinton, L. 1984. The macroinvertebrates in a sewage-polluted aquifer. Hydrobiologia 119: 161-169.

Smith, K. 1984. The status of Cambarus zophonastes Hobbs and Bedinger, an endemic cave crayfish from Arkansas. Arkansas Natural Heritage Commission, Little Rock, Arkansas.18 pp.

Smith, C., and K. Steele. 1990. Nitrate concentrations of ground water, Benton County, Arkansas. Miscellaneous Publication No. 73. Arkansas Water Resources Research Center. University of Arkansas, Fayetteville, Arkansas.

Spalding, R., and M Exner. 1993. Occurrence of nitrate in groundwater – a review. Journal of Environmental Quality 22: 392-402.

State of Arkansas, 77th General Assembly. 1989. Act 523: The Arkansas Cave Resources Protection Act.

Steele, K. 1985. Groundwater in northwest Arkansas. The Arkansas Naturalist, July, Volume 3 (7): 5-10.

Stitt, R. 1976. Wilderness cave management. Pages 53 to56 in the National Cave Management Symposium Proceedings. Speleobooks, Albuquerque, New Mexico. 146 p.

Strayer, D. 1994. Limits to biological distributions in groundwater. Pages, 287-310 in J. Gibert, D. Danielopol, and J. Stanford, editors. Groundwater Ecology. Academic Press, San Diego, California. 571 pp.

Tousley, R. 1976. National Park System objectives and philosophies of cave management. Pages 142 to143 in the National Cave Management Symposium Proceedings. Speleobooks, Albuquerque, New Mexico. 146 p.

U. S. Fish and Wildlife Service. 1996. Recovery Plan for the Cave Crayfish (*Cambarus aculabrum*). Atlanta, Georgia. 37 pp.

- 1989. Ozark Cavefish Recovery Plan. U. S. Fish and Wildlife Service. Atlanta, Georgia. 42 pp.

- 1988. *Cambarus zophonastes* Recovery Plan. Atlanta, Georgia. 18 pp.

White, W. 1993. Analyses of karst aquifers. Pages 471-489 in W. Alley, editor. Regional Ground Water Quality. Van Nostrand Reinhold, New York, New York. 634 pp.

Willis, L. and A. Brown. 1985. Distribution and habitat requirements of the Ozark cavefish (*Amblyopsis rosae*). American Midland Naturalist 114(2): 311-317.

Woods, L., and R. Inger. 1957. The cave, spring, and swamp fishes of the family Amblyopsidae of central and eastern United States. American Midland Naturalist 58: 232-256.

World Conservation Monitoring Center. 1999. Animals Database. http://www.wcmc.org.uk/species/animals/animal_redlist.html.

APPENDIX I. DEFINITION OF HERITAGE RANKS

G1	Critically imperiled globally because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G2	Imperiled globally because of rarity (6-20 occurrences or few remaining individuals or acres) or because of some factor(s) making it especially vulnerable to extinction.
G3	Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single western state, a physiographic region in the East) or because of other factors making it vulnerable to extinction throughout its range; in terms of occurrences, in the range of 21 - 100.
G4	Apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery.
G5	Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
GH	Of historical occurrence throughout its range, i.e., formerly part of the established biota, with the expectation that it may be rediscovered (e.g., Bachman's Warbler).
S1	Extremely rare. Typically 5 or fewer estimated occurrences in the state, or only a few remaining individuals, may be especially vulnerable to extirpation.
S2	Very rare. Typically between 5 and 20 estimated occurrences or with many individuals in fewer occurrences, often susceptible to becoming extirpated.
S3	Rare to uncommon. Typically between 20 and 100 estimated occurrences, may have fewer occurrences but with large number of individuals in some populations, may be susceptible to large-scale disturbances.
S4	Common, apparently secure under present conditions. Typically 100 or more estimated occurrences, but may be fewer with many large populations, may be restricted to only a portion of the state, usually not susceptible to immediate threats.
S5	Demonstrably widespread, common, and secure in the state and essentially ineradicable under present conditions.
SH	Historically known from the state, but not verified for an extended period, usually 15 years.
?	A question mark is used temporarily when there is some indecision regarding the rank assignment or when an element has not been ranked.

APPENDIX II. SUMMARY OF CAVE BIOINVENTORIES

This table summarizes the bioinventories performed during the study period (July 1999 to July 2000). Each animal is listed to the lowest taxon identified to date, and the associated count is an estimate of total numbers seen, and does not represent a true population estimate. This summary is not inclusive of other surveys, and does not represent the entire species richness or abundance of these habitats.

Location Name	County	Taxon	Count
3 Be 532	Benton	*Caecidotea stiladactyla*	100
		Eurycea lucifuga	4
		Larval Salamander	50
		Lirceus sp.	100
		Pipistrellus subflavus	1
		Plethodon glutinosus	1
		Stygobromus sp.	1
Above the Waterfall Cave	Madison	*Eurycea longicauda*	1
		Nematomorph	1
Bear Hollow Cave	Benton	*Caecidotea ancyla*	2
		Cambarus aculabrum	9
		Dipteran	1
		Fungus Gnat Larva	1
		Larval Salamander	13
		Millipede	1
		Pipistrellus subflavus	3
		Rana palustris	1
		Stygobromus ozarkensis	1
Bella Vista Trout Farm Cave	Benton	*Caecidotea sp.*	2
		Pipistrellus subflavus	4
Big Mouth Cave	Benton	*Caecidotea sp.*	3
		Caecidotea stiladactyla	10
		Ceuthophilus sp.	50
		Eurycea longicauda	1
		Eurycea lucifuga	4
		Millipede	1
		Notophthalmus viridescens louisiar	2
		Pipistrellus subflavus	40
		Plethodon glutinosus	4
		Pseudacris crucifer crucifer	50
		Typhlotriton spelaeus	10
Big Spring	Benton	*Caecidotea stiladactyla*	5
		Cottus carolinae	10
		Darter	2
		Flatworm	2
		Gammarus sp.	100
		Onchorhyncus mykiss	20
		Orconectes neglectus neglectus	15
		Pylodictis olivaris	1
		Snail	10

Location Name	County	Taxon	Count
Blowing Springs Cave	Benton	*Eurycea longicauda*	2
		Hirudinea	1
		Larval Salamander	15
		Millipede	1
		Pipistrellus subflavus	60
		Typhlotriton spelaeus	1
Blue Heaven Cave	Marion	*Eurycea longicauda*	1
		Eurycea lucifuga	2
		Larval Salamander	8
		Typhlotriton spelaeus	1
Blue Spring	Carroll	Flatworm	10
		Gammarus sp.	50
		Lirceus sp.	30
Brey Cave	Washington	*Eurycea lucifuga*	1
		Neotoma floridana	1
		Sayornis phoebe	1
		Pipistrellus subflavus	1
Brock Spring	Washington	*Caecidotea sp.*	200
		Dendrocoelopsis americana	7
		Dugesia sp.	100
		Eurycea lucifuga	3
Cave Spring	Washington	*Caecidotea sp.*	3
		Ceuthophilus sp.	2
		Eurycea longicauda	4
		Eurycea lucifuga	2
		Larval Salamander	10
		Lirceus sp.	8
		Millipede	3
Cave Springs Cave	Benton	*Amblyopsis rosae*	166
		Eurycea longicauda	12
		Eurycea lucifuga	69
		Gammarus sp.	1
		Gerris remigis	3
		Lycosa sp.	1
		Mosquito	2
		Orconectes punctimanus	80
		Sayornis phoebe	1
		Plethodon glutinosus	1
Chambers Hollow Cave	Benton	*Ceuthophilus sp.*	25
		Dipteran	100
		Eurycea lucifuga	6
		Larval Salamander	20
		Pipistrellus subflavus	130
		Plethodon glutinosus	1
Chilly Bowl	Newton	*Eurycea lucifuga*	1
		Larval Salamander	2
		Millipede	20
		Spider	1
		Typhlotriton spelaeus	1

Location Name	County	Taxon	Count
Civil War Cave	Benton	*Amblyopsis rosae*	1
		Caecidotea antricola	1000
		Millipede	1
		Stygobromus clantoni	100
		Stygobromus ozarkensis	100
Cold Cave	Benton	*Caecidotea salamensis*	1
		Cave Amphipod	50
		Ceuthophilus sp.	2
		Eurycea longicauda	4
		Eurycea lucifuga	2
		Flatworm	9
		Insect - other	3
		Larval Salamander	5
		Millipede	1
		Pipistrellus subflavus	35
		Plethodon glutinosus	5
		Pseudacris crucifer crucifer	1
		Spider	1
Copperhead Cave	Newton	*Arrhopalites pygmaeus*	1
		Caecidotea sp.	6
		Collembola	1
		Eurycea longicauda	2
		Eurycea lucifuga	4
		Insect - other	1
		Pipistrellus subflavus	20
		Plethodon glutinosus	1
		Stygobromus sp.	1
		Typhlotriton spelaeus	5
Cosmic Cavern	Carroll	*Onchorhyncus mykiss*	20
		snail	100
Covington's Cave	Benton	Fungus Gnat Larva	1
Crystal Cave	Benton	Collembola	50
		Millipede	100
		Mite	100
		Pipistrellus subflavus	2
		Spider	100
Crystal Dome Cave	Newton	*Eurycea lucifuga*	1
		Pipistrellus subflavus	1
Dickerson Cave	Benton	*Caecidotea stiladactyla*	15
		Eurycea lucifuga	1
		Gammarus sp.	15
		Larval Salamander	5
		Plethodon glutinosus	1
		Stygobromus ozarkensis	1
Dot Spring	Washington	*Pipistrellus subflavus*	1

Location Name	County	Taxon	Count
Eagle Hollow Cave	Benton	*Ceuthophilus sp.*	3
		Eurycea lucifuga	1
		Pipistrellus subflavus	50
Farmer's Cave	Washington	*Pipistrellus subflavus*	1
Fish Pond Cave	Benton	Beetle	3
		Caecidotea sp.	20
		Ceuthophilus sp.	5
		Dipteran	6
		Eurycea longicauda	5
		Eurycea lucifuga	13
		Larval Salamander	22
		Lirceus sp.	10
		Pipistrellus subflavus	10
		Ursus americanus	3
Fitton Cave	Newton	*Caecidotea sp.*	10
		Eurycea longicauda	1
		Eurycea lucifuga	3
		Homoplectra doringa	2
		Orconectes sp.	2
		Stygobromus sp.	1
		Typhlotriton spelaeus	2
Fitton Spring Cave	Newton	Crayfish	1
		Eurycea longicauda	1
		Eurycea lucifuga	3
		Lirceus sp.	3
		Typhlotriton spelaeus	2
Frank Kelly's Cave	Washington	*Plethodon glutinosus*	6
Friday the 13th Cave	Newton	*Ceuthophilus sp.*	20
		Eurycea longicauda	1
		Eurycea lucifuga	2
		Gordius sp.	1
		Neotoma floridana	1
		Pipistrellus subflavus	200
		Plethodon glutinosus	2
		Stygobromus sp.	10
		Typhlotriton spelaeus	2
Gourd Cave	Marion	*Corynorhinus townsendii*	14
Granny Parker's Cave	Washington	*Caecidotea sp.*	60
		Ceuthophilus sp.	10
		Dipteran	6
		Eurycea longicauda	3
		Larval Salamander	5
		Millipede	10
		Mosquito	4
		Nematomorph	1
		Opilionid	1
		Phoebe sp.	1
		Planaria	5
		Snail	1
		Snake	1
		Spider	40

Location Name	**County**	**Taxon**	**Count**
Hell Creek Cave	Stone	*Caecidotea sp.*	1
		Cambarus zophonastes	2
Hurricane River Cave	Searcy	*Arrhopalites clarus*	1
		Pseudosinella argentea	1
Indian Creek Cave	Newton	*Lirceus sp.*	2
		Myotis sp.	20
		Paraleptophlebia sp.	1
		Pipistrellus subflavus	20
Indian Rockhouse Cave	Marion	*Lirceus hoppinae*	20
		Typhlotriton spelaeus	7
Ivy Springs Cave	Madison	*Caecidotea ancyla*	2
James Ditto	Benton	*Amblyopsis rosae*	3
		Crayfish	1
		Eurycea lucifuga	4
		Larval Salamander	3
John Eddings Cave	Newton	*Caecidotea sp.*	10
		Orconectes neglectus neglectus	5
		Typhlotriton spelaeus	4
Joyce Cemetary Cave	Benton	*Campodeidae sp.*	1
		Eurycea lucifuga	3
		Inflectaris sp.	2
		Larval Salamander	50
		Pipistrellus subflavus	10
Little Devil's Den Cave	Newton	*Caecidotea sp.*	5
		Ceuthophilus sp.	30
		Gordius sp.	2
		Pipistrellus subflavus	121
		Plethodon glutinosus	4
		Typhlotriton spelaeus	10
Little Mouth Cave	Benton	*Caecidotea sp.*	5
		Ceuthophilus sp.	100
		Eurycea lucifuga	1
		Larval Salamander	50
		Pipistrellus subflavus	15
Logan Cave	Benton	*Amblyopsis rosae*	31
		Cambarus aculabrum	24
		Cottus carolinae	3
		Eurycea longicauda	2
		Millipede	3
		Mite	100
		Orconectes neglectus neglectus	6
		Orconectes punctimanus	7
		Pipistrellus subflavus	50
		Pseudoscorpion	1000
		Typhlotriton spelaeus	2
		Isotoma desoria trispinata	1
		Neelus murinus	1

Location Name	County	Taxon	Count
Marshall Caves	Benton	*Caecidotea ancyla*	60
		Eurycea longicauda	1
		Fungus Gnat Larva	1
		Larval Salamander	3
Mitchell Cave	Madison	*Corynorhinus rafinesquii*	1
Nesbitt Springs Cave	Stone	*Caecidotea sp.*	1
		Cottus carolinae	7
		Lepomis sp.	2
No name #02	Madison	Beetle	2
		Caecidotea sp.	1
		Stygobromus sp.	100
		Ceuthophilus sp.	5
		Collembola	3
		Eurycea lucifuga	1
		Eurycea multiplicata griseogaster	1
		Millipede	1
		Pipistrellus subflavus	1
		Spider	3
No name #05	Benton	*Eurycea lucifuga*	7
No name #14	Newton	*Arrhopalites clarus*	1
		Pseudosinella argentea	1
No name #17	Benton	*Caecidotea sp.*	4
		Ceuthophilus sp.	1000
		Larval Salamander	6
		Nematomorph	2
		Pipistrellus subflavus	1
		Plethodon glutinosus	2
		Typhlotriton spelaeus	1
No name #21	Benton	*Ceuthophilus sp.*	20
		Didelphus virginiana	2
Nursery Pond	Benton	*Caecidotea sp.*	15
Old Pendergrass Cave	Benton	*Caecidotea ancyla*	8
		Stygobromus sp.	1
		Collembola	1
		Dipteran	1
		Fungus Gnat Larva	1
		Larval Salamander	1
		Millipede	1
		Pipistrellus subflavus	50
		Stygobromus ozarkensis	2
Old Spanish Treasure Cave	Benton	*Corydalus cornutus*	1
		Fungus Gnat Larva	1
		Myotis grisescens	1
Pigeon Roost	Benton	*Pipistrellus subflavus*	75
Pine Creek Cave	Madison	*Stygobromus sp.*	1
		Cottus carolinae	8
		Eurycea longicauda	2
		Eurycea lucifuga	2
		Pipistrellus subflavus	100

Location Name	County	Taxon	Count
Prairie Creek Cave	Benton	*Ctenopharyngodon idella*	1
		Lepomis sp.	20
Pregnant Nun Cave	Benton	*Ceuthophilus sp.*	100
		Collembola	10
		Millipede	10
		Pipistrellus subflavus	10
		Snail	2
Pretty Clean Cave	Newton	*Ceuthophilus sp.*	5
		Pipistrellus subflavus	2
		Typhlotriton spelaeus	1
Reed Cave	Marion	*Corynorhinus townsendii*	100
Rootville Cave	Benton	*Caecidotea ancyla*	15
		Collembola	20
		Larval Salamander	4
		Pipistrellus subflavus	55
		Typhlotriton spelaeus	1
Rory Cave	Stone	Nematomorph	2
		Typhlotriton spelaeus	4
Rowland Cave	Stone	Collembola	1
		Millipede	5
Saunder's Mill Cave	Washington	Beetle	1
		Darter	8
		Lepomis sp.	1
Seep at Weddington	Washington	*Caecidotea sp.*	100
		Hirudinea	100
		Lirceus sp.	100
		Planaria	10
		Plecopteran	1
Sherfield Cave	Newton	*Caecidotea sp.*	50
		Castor canadensis	1
		Ceuthophilus sp.	10
		Cottus carolinae	1
		Dipteran	3
		Ephemeropteran	1
		Larval Salamander	10
		Lirceus sp.	4
		Myotis grisescens	200
		Orconectes sp.	3
		Pipistrellus subflavus	10
		Stygobromus sp.	2
Small Cave		*Eurycea lucifuga*	1
Spring at Hulet Cave	Washington	*Caecidotea sp.*	50
		Stygobromus sp.	30
		Hirudinea	5
Spring on Butler Creek Road	Benton	*Caecidotea stiladactyla*	3
		Copepod	1
Tanyard Creek Cave	Benton	*Caecidotea sp.*	2

Location Name	County	Taxon	Count
Tom Allen Cave	Benton	*Amblyopsis rosae*	2
		Cambarus sp.	2
		Ceuthophilus sp.	10
		Eurycea lucifuga	2
		Larval Salamander	1
		Procyon lotor	1
		Rana palustris	1
		Semotilus atromaculatus	1
		Snail	1
		Spider	1
		Typhlotriton spelaeus	1
Tom Allen Cave #2	Benton	*Amblyopsis rosae*	7
		Caecidotea sp.	10
		Cambarus sp.	5
		Ceuthophilus sp.	20
		Cottus carolinae	1
		Cyprinid	3
		Eurycea lucifuga	1
		Gerris remigis	1
		Larval Salamander	1
		Lycosa sp.	1
		Orconectes neglectus neglectus	2
		Pipistrellus subflavus	3
		Rana palustris	2
USFS Cave #23010		*Stygobromus sp.*	1
Van Dyke Spring Cave	Newton	*Caecidotea sp.*	2
		Castor canadensis	1
		Ceuthophilus sp.	50
		Cottus carolinae	1
		Crayfish	1
		Eurycea longicauda	3
		Eurycea lucifuga	1
		Hirudinea	1
		Larval Salamander	2
		Lepomis sp.	1
		Lirceus sp.	2
		Millipede	1
		Pipistrellus subflavus	33
		Plethodon dorsalis	19
		Spider	15
		Typhlotriton spelaeus	3
War Eagle Cavern	Benton	Beetle	1
		Cambarus sp.	1
		Ceuthophilus sp.	10
		Gammarus sp.	1
		Larval Salamander	2
		Lirceus sp.	1
		Millipede	1
		Myotis grisescens	10000
		Orconectes sp.	4
		Spider	5
		Typhlotriton spelaeus	4

Location Name	County	Taxon	Count
War Eagle Creek Cave	Madison	*Caecidotea steevesi*	3
		Cottus carolinae	1
		Pipistrellus subflavus	18
Whippoorwill Cave	Madison	*Pipistrellus subflavus*	15
		Typhlotriton spelaeus	1
Wildcat Hollow Cave		*Caecidotea sp.*	10
Withrow Springs Cave	Benton	*Eurycea longicauda*	1
		Eurycea lucifuga	1
		Orconectes sp.	1
		Pipistrellus subflavus	2
		Plethodon glutinosus	1
Wolf Creek Cave	Newton	*Caecidotea sp.*	100
		Flatworm	100
		Lirceus sp.	10
		Myotis sodalis	1
		Pipistrellus subflavus	1
		Stygobromus sp.	1
Wonderland Cave	Benton	*Caecidotea antricola*	7
		Eurycea lucifuga	7
		Larval Salamander	3