Mapping Presumptive Habitat for Subterranean Aquatic Species of Concern

Philip L. Moss and Thomas Aley
Ozark Underground Laboratory
1572 Aley Lane
Protem, Missouri 65733
Phone: 417-785-4289
E-mail: oul@tri-lakes.net

Abstract

Generally, populations of species of concern are located by direct observation or capture. This is a severe limitation when dealing with cavernicoles, since a very small percentage of potential habitat is accessible to investigators. The Ozark Underground Laboratory is promoting the concept of presumptive habitat; that is all groundwater that has subsurface hydrological interconnections should be presumed to contain the aquatic species of concern that are found in accessible parts of the groundwater system and that the entire groundwater system be managed accordingly. Groundwater tracing using fluorescent dyes is a powerful, empirical tool for delineating groundwater basins and demonstrating hydrological interconnections between groundwater basins. The recharge area boundaries representing known and presumptive habitat are important tools for biological analysis and conservation management. Dye traces help evaluate tested portions of the groundwater system; dye passes readily only through relatively open conduits; a significant requirement for most aquatic cavernicoles. Aquatic cavernicoles can generally move against the hydraulic gradient and cross drainage divides under more variable flow conditions than does tracer dye. The migration of fauna against the hydraulic gradient permits more gene flow than may be suggested by dye tracing.

Generally, subterranean, aquatic species of concern are located by direct observation or capture. This is a severe limitation when dealing with aquatic cavernicoles, since a very small percentage of their potential habitat is accessible to investigators. Even large caves typically have a relatively small "footprint" within their groundwater basins. A few examples from caves containing important communities for which recharge areas have been delineated are listed below. The values represent the cave stream area divided by the recharge area multiplied by 100. Each of these caves has been demonstrated to have the distal reaches of their respective recharge areas connected to them via conduit flow.

- Tumbling Creek Cave (Taney County, Missouri) permits examination of approximately 0.01% of its 9.1-square-mile groundwater basin.
- Fogelpole Cave (Monroe County, Illinois) permits examination of approximately 0.40% of its 7.2-square-mile groundwater basin.
- Stemler Cave (St. Clair County, Illinois) permits examination of approximately 0.036% of its 6.7-square-mile groundwater basin.
- Cave Spring Cave (Benton County, Arkansas) permits examination of approximately 0.004% of its 19-square-mile groundwater basin.

These values are probably representative of the relationship between accessible subterranean aquatic habitat and the size of the groundwater basin in which it is located. These numbers are low, in part, because they imply that the entire groundwater basin is potential habitat.

Karst is often considered to have three porosities—matrix porosity, fracture porosity, and conduit porosity. Only the latter two porosities have large enough voids and have sufficient interconnectedness to provide habitat for macroscopic fauna. Worthington *et al.* (2000) provided calculations of matrix, fracture, and conduit porosity in the Mammoth Cave area of Kentucky as representative of Paleozoic carbonates. The sum of their values for fracture and conduit porosity (0.093%) around Mammoth Cave is lower than the values for the accessible conduits provided in the examples above. However, porosity is a three-dimensional characteristic and may not correlate well with the two dimensions of area, which is the subject of this paper. Worthington *et al.* (2000) also present the percentage of void represented by known cave divided by the minimum area required to contain the cave. These values ranged from 0.5% to 7.5%. The range is inherently lower than the sum of fracture and conduit porosity, since the measurements are restricted to conduits large enough for human traverse. However, these values appear more representative of the potential habitat void percent for a groundwater basin in carbonate rocks.

If we assume that fracture and conduit porosity occupies a generous 10% of a groundwater basin, then the values of observable cave stream area provided in this paper increase by an order of magnitude. However, the highest presented is Fogelpole Cave, which would permit examination of approximately 4% of the potential habitat.

Within a groundwater system we may have access to springs, cave streams, karst windows, or wells. These all provide observation points in somewhat different habitats and none may be representative of the complete biological community inhabiting the groundwater system. In total, these sampling points access a very small percentage of the groundwater basin.

We know that there are both unknown populations of cavernicolus aquatic species and that a given population's habitat extends into parts of the groundwater system inaccessible to observers. We know that there are unknown populations because new populations are often found by qualified investigators while conducting bioinventories. We also occasionally discover a new population when a spill flushes fauna out of inaccessible parts of the groundwater basin. A liquid fertilizer spill demonstrated populations of southern cavefish (*Typhlichthys subterraneus*) and Salem cave crayfish (*Cambarus hubrichti*) not previously known at Maramec Spring, Missouri (Crunkilton, 1984).

From a conservation perspective, we must recognize that the area to be managed for subterranean, aquatic species of concern is the recharge area for their groundwater system. We know that degraded water recharging the groundwater system is likely to negatively impact the aquatic community. By protecting the entire recharge area, we protect the observable population and we also protect the inaccessible habitat within the groundwater basin.

It is well-established practice to presume that most species observed in cave streams occupy all the available, appropriate habitat within the entire groundwater basin. As new caves are discovered within a groundwater basin or new cave passages discovered in well-known caves, the same fauna is generally found in these previously unknown sections as in the long-known sections. Lewis *et al.* (2003) demonstrated similar fauna in separate caves within both the Annbriar Spring and Pautler Cave systems in Illinois.

We need to recognize that some fauna classified as stygobites would probably be better classified as phreatobites if we had more complete information on their preferred habitat. As in the case of cavefish and cave crayfish being flushed out of Maramec Spring, the fauna were not observed at the spring, even by cave divers, but lived in unobserved and perhaps inaccessible parts of the groundwater system. Examining the spring did not demonstrate the presence of cavefish or cave crayfish, despite their presence in the groundwater basin. This suggests that both of these species may be phreatobites.

Because of previous pollution events, Hidden River Cave (Kentucky) had areas devoid of cave-adapted life, but when water quality was rehabilitated, cave life came back relatively quickly. The quick recovery is almost certainly due to colonization from biologic reservoirs in the groundwater basin (Lewis, 1993).

The Ozark Underground Laboratory has conducted many recharge area delineations to help land managers design and apply protective strategies to all lands that contribute water to important groundwater. These recharge area delineations perform two functions:

1) They show where to be especially protective of water quality, and

2) They define the groundwater basin that presumably provides habitat outside the known cave passages.

While tracing groundwater flow, we commonly find that there are interconnections between groundwater basins that are not simple distributary systems (Aley *et al.* 2000; Aley and Moss 2001a; Aley and Moss 2001b). Dye only flows readily through relatively open groundwater systems; the same kind of conduit systems that provide habitat for aquatic species of concern. Some of these interconnections are perennial interconnections, some are overflow routes, and some are difficult to characterize beyond the fact that they share recharge areas.

With the constraints of time and budget, it is unlikely that dye tracing reveals all of the hydrologic interconnections between groundwater basins. It is quite probable that there are frequently both air-filled and water-filled interconnections between groundwater basins. Interconnections demonstrated by dye tracing represent the minimum number of interconnections between groundwater basins.

Aley and Moss (2001b) demonstrated subsurface hydrologic interconnections between two adjacent groundwater basins in Monroe County, Illinois. These were the Annbriar Spring basin and the Pautler Cave basin. Lewis *et al*. (2003) demonstrated very similar communities in both basins including both the regional endemic and Federally endangered Illinois cave amphipod (*Gammarus acherondytes*) and the only two known populations in the region of the Illinois cave millipede (*Ergodesmus remingtoni*). This suggests that the groundwater flow paths may permit terrestrial species such as millipedes to migrate between the groundwater basins in addition to aquatic species like the Illinois cave amphipod.

We have concluded that if a groundwater basin has hydrologic interconnections with another groundwater basin containing species of concern, it should be managed as if it were known to contain the same biological community. We have taken this position because of the strong presumption that aquatic species are moving between the groundwater basins, at least under some flow conditions.

In the case of a road corridor study (Aley and Moss, 2001a), the Ozark Underground Laboratory's investigation demonstrated subsurface hydrological interconnections between the Reed Spring groundwater basin and the Cave Spring Cave groundwater basin, which is known to provide habitat for Ozark cavefish. The Arkansas State Highway and Transportation Department accepted our conclusion that the Reed Spring groundwater basin presumably provided habitat for Ozark cavefish (*Amblyopsis rosae*) and that it was prudent and protective of the Ozark cavefish to not permit the road corridor to cross either the Reed Spring or the Cave Spring recharge areas.

Another example is found in the case of the designation of Tumbling Creek Cave system as a significant cave system under the provisions of the Federal Cave Resources Protection Act. No known cave passage exists under Federally-owned property. The closest known cave passage is approximately 1.75 miles away from the closest National Forest land, yet the Forest Service has recognized that part of the Tumbling Creek Cave system underlies land administered by them.

Aquatic species of concern can move more freely between groundwater basins than does dye. Dye is passive and flows down the hydraulic gradient at the water levels that exist during the trace. In contrast, fauna can propel themselves upstream, sometimes in just a film of water. The fauna are present for all ranges of flow conditions. It is almost certain that they move between the basins upon occasion and in some systems they may be able to move between groundwater basins under all flow conditions.

GIS themes representing dye traces, hydrologic interconnections, and recharge area boundaries are created by Ozark Underground Labratory for the use of land mangers and investigators. These can be integrated with other GIS data to better understand and manage lands to be protective of subterranean, aquatic species of concern.

If we accept the concept of presumptive habitat, then these areas must be identified before protective strategies can be effectively implemented. Dye tracing is a scientifically credible and legally-defensible tool for identifying some presumptive habitat. Dye tracing can be used to delineate recharge areas, groundwater basins, and hydrologic interconnections between groundwater basins. It cannot identify presumptive habitat without a known population nearby. However, the data generated by dye tracing supports prudent land management over greater areas than are currently identified as habitat.

References

Aley, T.; P. Moss; and C. Aley. 2000. Delineation of recharge areas for four biologically significant cave systems in Monroe and St. Clair Counties, Illinois. Ozark Underground Laboratory contract study report for the Illinois Nature Preserves Commission and the Monroe County Soil and Water Conservation District with funding from the Illinois Department of Natural Resources Conservation 2000 Program. 254 pp + maps and appendices.

Aley, T. and P. Moss. 2001a. Northwest Arkansas regional airport access corridor groundwater tracing investigations. Ozark Underground Laboratory contract study for Barnard Dunkelberg, Inc. 46 pp + appendices.

Aley, T. and P. Moss. 2001b. Recharge area delineation of the Pautler Cave system and

Annbriar Spring in Monroe County, Illinois. Ozark Underground Laboratory contract study for the Illinois Nature Preserves Commission with funding from the U.S. Fish and Wildlife Service. 124 pp + appendices.

Crunkilton, R. 1984. Subterranean contamination of Maramec Spring by ammonium nitrate and urea fertilizer and its implications for rare cave biota. "Proceedings of the 1984 National Cave Management Symposium" in *Missouri Speleology,* vol 25, no. 1-4, pp 151-158.

Lewis, J.J. 1993. "Life returns to Hidden River Cave: the rebirth of a destroyed cave system." *NSS News,* August 1993, pp 208-213.

Lewis, J.J.; P. Moss; D. Tecic; and M.E. Nelson. 2003. "A conservation focused inventory of subterranean invertebrates of the southwestern Illinois karst." *Journal of Cave and Karst Studies*, vol 65, no. 1, pp 9-21.

Worthington, S.R.H.; D.C. Ford; and P.A. Beddows. 2000. "Porosity and permeability enhancement in unconfined carbonate aquifers as a result of solution." in A.B. Klimchouk, D.C. Ford, A.N. Palmer, and W. Dreybodt, eds. *Speleogenesis*: National Speleological Society, pp 463-471.

Biographical Sketch

Philip Moss is Senior Geologist at the Ozark Underground Laboratory. He is a licensed professional geologist in the states of Missouri and Illinois. As a geologist, he has conducted geotechnical, hazardous waste, or karst investigations in ten states over the past 14 years.