Karst wreckage: Subterranean fauna as collateral damage

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In the course of our consulting work we have encountered the aftermaths of too many catastrophic events, where subterranean communities were destroyed and species driven to the brink of extinction. Some of these disasters are limited to relatively small geographic areas, while others cut swaths across our landscap

Not one, but two, catastrophes have occurred at Indiana University (IU) on the Bloomington and New Albany campuses, where insecticides annihilated entire groundwater communities.

At the main campus in Bloomington, Jordan Hall (the biology building) was built over a spring used as the water supply for laboratory studies of cavefish by Dr. Carl Eigenmann. A community of subterranean invertebrates lived in the spring, e.g., Jordan's groundwater isopod (*Caecidotea jordani*), but the community composition will never be known since the habitat was poisoned to eradicate termites invading the building. Specimens of the endemic groundwater amphipod *Bactrurus cellulanus* were not discovered in the university collection until long after the community was eradicated, and the species was extinct at the time of its description in 2001. On the campus of IU Southeast in New Albany the groundwater isopod *Caecidotea teresae* and an undescribed amphipod *Stygobromus* met a similar fate from insecticides.

Those events only touched geographic pinpoints, but other disasters involving chemical poisoning stretched across larger karst landscapes. At the Dickson, Tennessee landfill tetrachloroethylene (TCE), an industrial solvent, was dumped on karst and poisoned an entire groundwater ecosystem (we were involved as part of the Natural Resource Defense Council's (NRDC) team of expert witnesses). Called by some the "Poster child for environmental racism", the TCE was released into the groundwater supply for a small, predominantly black community in a county that is over 95% white. The toxic chemicals in the water produced cancers that inevitably killed people.

The site of the NCKMS 2015 in Cave City, Kentucky sits atop the groundwater basin of Hidden River Cave, where over the past century the cave and its fauna have suffered from the effects of massive groundwater degradation (Lewis, 1996). In the 1960's the cave's main stream received the effluents of the Cave City and Horse Cave sewage treatment plants, including waste from a metal plating plant and creamery. After the development of a regional sewage treatment facility water quality improved markedly, but the report of the rebirth of Hidden River (Lewis, 1993) was probably premature. The sewage worms that once lined the edge of the Hidden River are gone, but the Southern cavefish (*Typhlichthys subterraneus*) and cave crayfish (*Orconectes pellucidus*) seen today by visitors on the cave tours only occur in significant numbers at the confluence of a relatively unpolluted tributary with Hidden River. New research (Lewis et al., 2015) showed that the fish and crayfish emerge into the main river from a side passage called Blindfish Alley, then disappear downstream from the confluence (figure 1). There the animals apparently succumb to toxins, e.g., residual heavy metals in the substrate remaining from years of receiving plating plant effluent. A pollution event in the spring of 2015 killed much of the fauna in Blindfish Alley, demonstrating that no place in the system is safe.

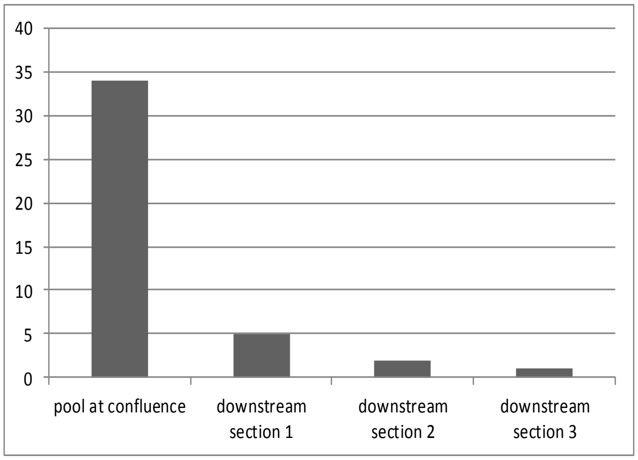

Figure 1. Results of a census of total numbers of the Southern cavefish (*Typhlichthys subterraneus*) and cave crayfish (*Orconectes pellucidus*) in the main stream in Hidden River Cave on 30 September 2014. Most of the animals occurred in a large pool at the confluence of the Blindfish Alley and the main stream. The histogram shows the abundance of the fauna at the large pool at the confluence, then the disappearance in the next three sections of the stream over a distance of about 500 feet (Lewis, et al., 2015).

In the southeastern Indiana karst the ordnance industry wreaked havoc with the karst environment. Lewis (1995) described operations at the Indiana Army Ammunition Plant (INAAP), where starting during World War II nitrocellulose propellants were manufactured by combining nitric acid with cotton. The waste product of the process was nitric acid laden with explosive nitrocellulose particulates and other toxic chemicals like sulfuric acid, nitrobenzene and aniline. This effluent was discharged into the environment at an average rate of 22,500 gallons/minute, at a temperature of 80° F and pH of 2.3. Released into Jenny Lind Run, the limestone floor of the creek was entrenched by the acid as much as 8 feet deep and 10 feet wide. The effluent spread through underground channels, enlarging existing caves and creating new ones where none existed before. Needless to say, no cave animals can exist in rivers of nitric acid and the subterranean fauna was extirpated.

In the adjacent counties from INAAP, the U.S. War Department created the Jefferson Proving Ground (JPG), where starting in 1941 a great variety of ordnance was tested: ranging from artillery rounds to rockets, almost anything that could be shot, dropped or thrown on a battlefield was tested there. At the peak of activity, 175,000 rounds per month were fired at JPG. In addition to conventional weapons, from 1984-1994 100,000 depleted uranium (DU) tank penetrator rounds were fired. Despite recovery operations over 150,000 pounds of DU remained on the impact fields, along with 1.5 million rounds of conventional unexploded ordnance (UXO).

After JPG was closed in 1995, over 50,000 acres containing UXO was dedicated as the Big Oaks National Wildlife Refuge (BONWR). A bioinventory of caves, springs and wells on BONWR by Lewis and Rafail (2002) showed that some sites were devastated by ordnance impacts and UXO contamination. A follow-up project in 2015 to conduct cave stream censuses compared cave communities in UXO and DU impact fields with others in relatively unaffected areas. Results indicated that Isaiah Irwin Cave had been damaged by ordnance impacts and the cave stream community was sparse, mostly comprised of surface species. Stream communities in other caves within the impact fields were unaffected, as were those outside of ordnance testing areas (figure 2).

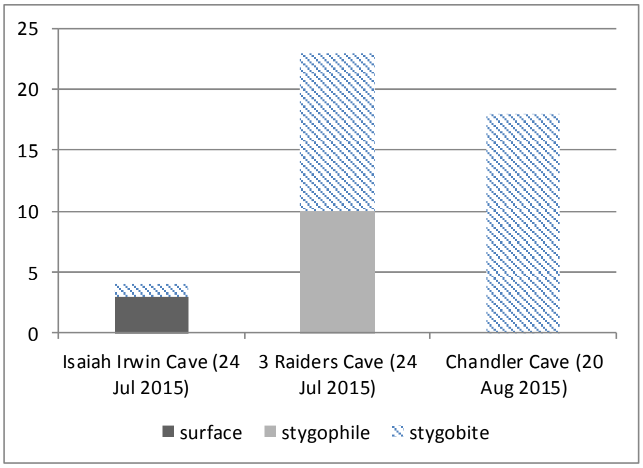

Figure 2. Histogram of cave stream censuses indicating total numbers of animals in three sites at BONWR. The fauna of Irwin Cave, contaminated by UXO, is sparse and mostly comprised of non-cavernicolous species. Despite being in the DU area, the fauna of 3 Raiders Cave is diverse and appropriate for the area. Chandler Cave is in an area little affected by UXO contamination (Lewis and Lewis, 2015).

To summarize, the scars are irreparable: entire subterranean communities poisoned by toxic chemicals; karst landscapes with acid entrenched streams, pocked with shell craters and caves collapsed by explosions. Entire cave faunas extirpated by sewage, heavy metals and other toxic cocktails. In some caves varying degrees of recovery has occurred through re-colonization by some subterranean species (Lewis, 1996). In tragedies like the Dickson, Tennessee landfill the NRDC obtained millions of dollars in mitigation, but money does not restore lives nor create quick fixes for the environment. The only solution seems to lie in the axiom "those who cannot remember the past are condemned to repeat it" …to prevent catastrophes before they happen.

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