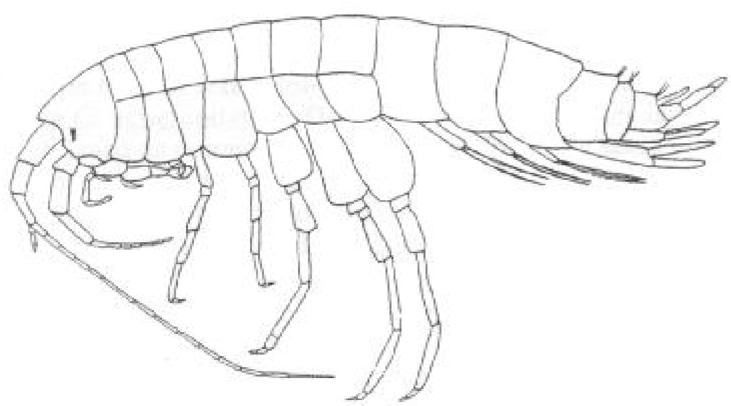
Illinois Cave Amphipod
(*Gammarus acherondytes*)
Recovery Plan



Gammarus acherondytes
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U.S. Fish and Wildlife Service
Great Lakes-Big Rivers Region (Region 3)
Fort Snelling, Minnesota

Illinois Cave Amphipod (*Gammarus acherondytes*) Recovery Plan

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EXECUTIVE SUMMARY

Current Species Status: The Illinois cave amphipod (*Gammarus acherondytes*) is currently listed as endangered. Historically, it was known to occur in six cave systems in Monroe and St. Clair Counties, Illinois. Its presence has not been reconfirmed in Madonnaville Cave, Monroe County and it appears to be extirpated from Stemler Cave, St. Clair County. Additional populations have been found in eight groundwater systems in Monroe County. Habitat loss and degradation of groundwater quality resulting from urbanization, agricultural activities, and an influx of human and animal waste are the principle threats.

Habitat Requirements and Limiting Factors: The Illinois cave amphipod is a species that lives in streams primarily in the dark zone of caves in parts of the Salem Plateau of Illinois. Little is known of the biology and habitat requirements of this species although it has been collected in mainstream gravel riffles, smaller tributary streams, rimstone pools, and from streams with silt overlying bedrock. As a group, amphipods require cool water temperatures and are intolerant of wide ranges in temperature. Limiting factors may include increased nutrient load, sedimentation, hydrologic changes and changes in water quality.

Recovery Strategy: Surface activities that have the potential to contribute to the degradation of groundwater and cave habitats are best managed at the individual landowner and community level. Agricultural land use employing best management practices may offer greater protection for the Illinois cave amphipod than alternative developments such as subdivisions or industrial complexes. Protection of Illinois cave amphipod populations is achievable by informing residents within recharge areas of groundwater values, threats, and stewardship responsibilities; and by recruiting, involving, and assisting them in voluntary and incentive-driven stewardship efforts, including protection of the animals themselves.

Recovery Goal: Delisting.

Recovery Criteria: The Illinois cave amphipod (*Gammarus acherondytes)* may be considered for reclassification from endangered to threatened when five viable, stable populations in five separate groundwater basins with distribution in two of three sub-regions remain extant and there is a significant increase in use of best management practices in the groundwater recharge areas in each of the five groundwater basins. The subregions are Columbia, Waterloo, and Renault Sub-regions of the Illinois Salem Plateau.

The Illinois cave amphipod (*G. acherondytes)* may be considered for delisting when five viable, stable populations in five separate groundwater basins with distribution in two of three sub-regions remain extant and are supported by persistent use of best management practices substantially protecting the groundwater recharge areas of the five groundwater basins. The subregions are Columbia, Waterloo, and Renault Sub-regions of the Illinois Salem Plateau.

Actions Needed:

1. Protect current populations and their habitats from known and suspected threats.
2. Restore degraded habitat and reintroduce the species into historic habitats.
3. Research basic biology and habitat requirements to increase the knowledge base about the species.
4. Inform the public and provide technical assistance to local units of government and planning agencies.

Total Estimated Cost of Recovery (in $1,000's):

Year	Need 1	Need 2	Need 3	Need 4	Total
2003	296	50	310	75	731
2004	286	50	185	75	596
2005	286	50	185	75	596
2006	286	0	185	75	546
2007	286	0	185	75	546
2008-2023	2,985	0	1,125	1,125	5,235
Total	4,425	150	2,175	1,500	8,250

Date of Recovery: 2023

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I. BACKGROUND

The Illinois cave amphipod (*Gammarus acherondytes,* Hubricht and Mackin 1940) (Figure 1) is a small freshwater crustacean which has been found in cave streams in Monroe and St. Clair Counties in southwestern Illinois (Bousfield 1958, Cole 1970a, 1970b, Holsinger 1972, Hubricht and Mackin 1940, Nicholas 1960, Page 1974, Peck and Lewis 1978, Webb 1993, 1995, Webb *et al.* 1993, 1998). Historically, it has been reported from six cave systems; Illinois Caverns, Fogelpole, Krueger-Dry Run, Madonnaville, Pautler, and Stemler caves. Recent collections (Webb 1995, Webb *et al.* 1998) suggest this amphipod is in low abundance in Krueger-Dry Run Caves, has not been reconfirmed in Madonnaville Cave, and is apparently extirpated in Stemler Cave. However, it may still be extant somewhere within these systems. Only a moderately large population was found in Illinois Caverns. It occurs in good numbers in Frog Cave and Fogelpole Cave systems, and is present in the Annbriar Spring, Luhr Spring, Reverse Stream, and Dual Spring groundwater systems (Lewis 2001).

The known distribution of this amphipod is an approximately 230 square kilometer (89 square mile) area within the Salem Plateau karst region in southwestern Illinois (Figure 2). This karst area is characterized by numerous surface sinkholes reflecting the presence of solutionally modified limestone in the subsurface. In southwestern Illinois, including the area where the amphipod has been found, the limestone is often overlain by glacial deposits or loess. These sinkholes feed into joints and fractures in the limestone allowing surface waters to flow rapidly into subsurface strata. This water contains carbonic acid which reacts with and dissolves carbonate rock to form subsurface conduits and caves. The potential for rapid transport of surface and subsurface contaminants into these systems presents a major threat to the Illinois cave amphipod.

Hydrogeology of Illinois' Salem Plateau

Monroe, Randolph, and St. Clair Counties contain the most intensely developed karst region of Illinois. Sinkhole density in southwestern Illinois is as high as 90 sinkholes/square kilometer (Panno 1996). Shallow groundwater in this region is susceptible to rapid contamination due to the karstified nature of the landscape (White 1988, Ford and Williams 1992). Much of the recharge to groundwater in these areas often does not involve slow filtration through fine-grained materials that provide an environment for chemical, biological and physical degradation and retardation of contaminants. Recharge in karstic regions is typically rapid and often nearly instantaneous. Recharge waters often contain materials from the surface that include agricultural chemicals, human and animal wastes, and other potential contaminants. Consequently, the risk of contamination is very high.

Figure 1. The Illinois cave amphipod, *G. acherondytes*. Photograph by L. M. Page, INHS

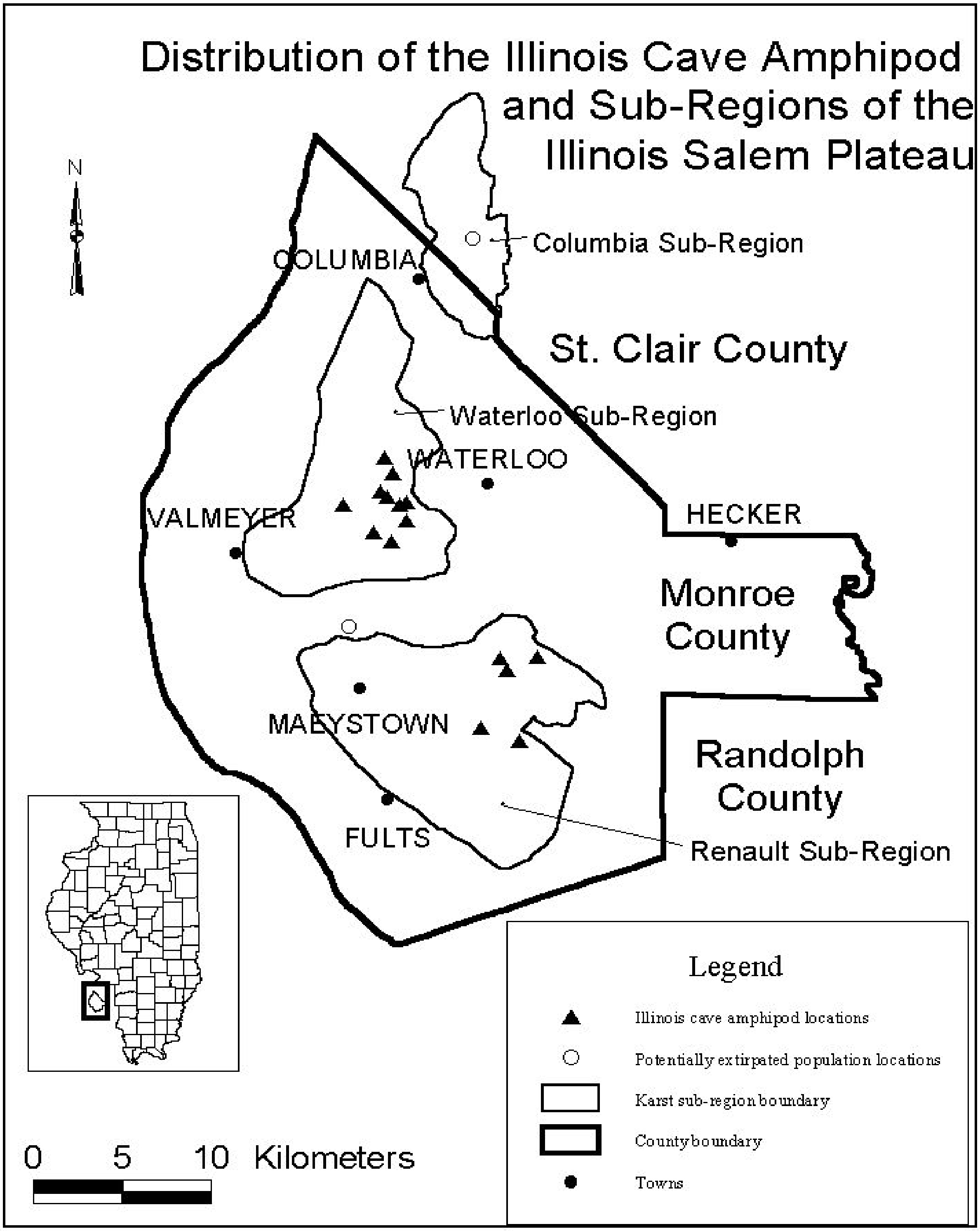

Figure 2. Distribution of the Illinois cave amphipod and sub-regions of the Salem Plateau

Land Use

Land use in the area is dominated by agriculture, with both livestock and row crops interspersed with forested tracts and rural housing. Crops grown in the region include milo, alfalfa, soybeans, wheat, corn and barley. Insecticides used on alfalfa include carbaryl, carbofuran, malathion, permethrin and phosmet and are typically applied in May and again in July or August. Herbicides are applied in April and May (timing is dependent on field conditions) and include alachlor, atrazine, bentazon, chlorimuron, cyanazine, glyphosate, imazaquin, imazethapyr, metolachlor, sethoxydim and trifluralin (M. Roegge, Cooperative Extension Service, University of Illinois, pers. comm. 1993).

Cultivated fields in the Sinkhole Plain are often tilled to the throat of open sinkholes, or completely through shallow, closed sinkholes. Sinkholes and sinkhole ponds often serve as a watering source for livestock, thus providing another route for contamination.

Some private sewage disposal systems drain directly into sinkholes (Panno *et al*. 1997). Over half of the private sewage disposal systems used in the Sinkhole Plain do not meet State of Illinois minimum requirements for discharge of fecal coliform bacteria and at least 10% of the systems have no treatment at all (Panno *et al*. 1997). All three sources described above (croplands, livestock and sewage disposal systems) contribute to relatively high concentrations of nitrates.

Given the current land use practices in this karst area, little stands in the way between agrichemical runoff, animal and human waste, and the shallow karst aquifers where the Illinois cave amphipod resides. Sinkholes are often artificially plugged to hold water to create farm ponds and lakes for housing developments. Once plugged, the filled ponds slowly seep through the plugs into the subsurface, which may improve the quality of the water entering the underlying karst aquifer. However, it is also possible that the ponds may catastrophically fail and discharge large volumes of water, sediment, and materials which may have high BOD (biochemical oxygen demand) into the groundwater system. The threat of this event outweighs the benefits provided by a sinkhole plugged pond.

Despite these potential pathways for contamination, agricultural land use employing best management practices may offer greater protection for the Illinois cave amphipod than alternative developments such as subdivisions or industrial complexes.

Listing Status

The Illinois cave amphipod was listed as endangered on September 3, 1998 (USFWS 1998) under the provisions of the Endangered Species Act (Act) of 1973, as amended. The U.S. Fish and Wildlife Service listed the species based on degradation of its habitat through groundwater contamination as a result of urbanization, agricultural activities, and human and animal waste from residential septic systems and livestock feedlots. The Service determined that designation of critical habitat for the Illinois cave amphipod would not provide additional benefit to the species beyond that conferred by listing, and therefore such designation was not prudent for the amphipod.

All species determined to be endangered or threatened under the Act are assigned a recovery priority number after the final rule listing. The amphipod's recovery priority number is 2. The recovery priority number assignment considers degree of threat, recovery potential, and the taxonomy. The Illinois cave amphipod is recovery priority 2. This means that the degree of threat is high (i.e., extinction is almost certain in the immediate future because of rapid population decline or habitat destruction) and the species recovery potential is high (i.e., the biological and ecological limiting factors are well understood, threats to the species existence are well understood and easily alleviated, and management needed is not intensive or management techniques are well documented with high probability of success).

Biology, Life History

Very little is known of the biology or life history of *G. acherondytes.* Thus, the following discussion is supplemented with information about species that are either related to *G. acherondytes* or inhabit similar environments.

Description

Gammarus acherondytes was originally described by Hubricht and Mackin (1940). Sexually mature males measure up to 20 mm (0.8 in) long; sexually mature females are 12-16 mm (0.5-0.63 in) long. They are usually light gray-blue and their eyes are small, sub-reniform (J. Lewis, Lewis and Assoc. Biol Consult., pers. com. 2001), degenerate, with the pigment drawn away from the facets in an irregular black mass. The first antenna is long and slender, more than half the length of the body. The flagellum of the antenna has up to forty articles and the accessory flagellum has up to six. The flagellum has up to 18 articles, and lacks sensory organs in either sex.

The palmar margin of the propodus of the first gnathopod of the male is very oblique, straight, and continuous with the posterior margin (Figure 3). The palmar margin of the second gnathopod of the male is only slightly oblique, straight or concave. The palmar margins of both gnathopoda of the female are strongly convex. The propodus of the second gnathopod is almost twice as long as it is wide in the male, and is twice as it is long as wide in the female.

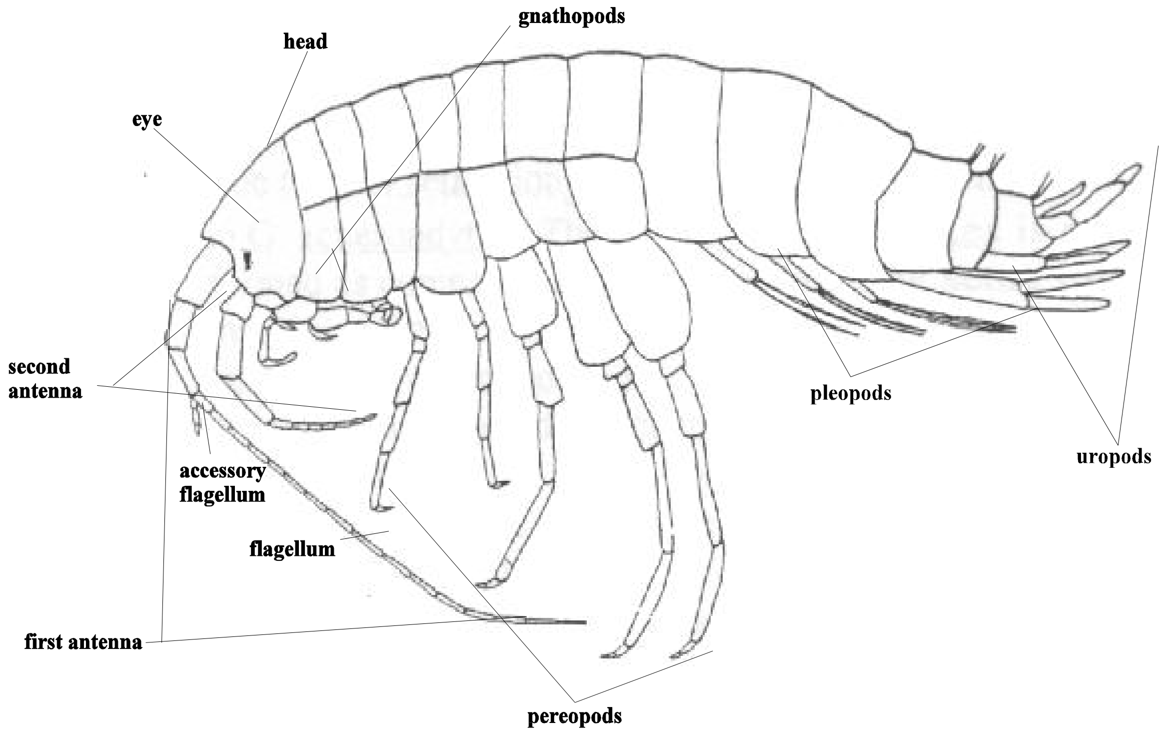

Figure 3. Illinois cave amphipod morphology.

The third uropod of the male has slightly curved rami, the inner ramus being about 0.75 times as long as the outer ramus. The outer margin of the outer ramus is armed with numerous fascicles of 1-10 setae. One seta in each fascicle is plumose, except in those fascicles which contain spines, in which case there are no plumose setae. The inner ramus and the inner margin of the outer ramus are armed with small fascicles of 1- 4 setae, one of which is plumose. The second segment of the outer ramus is not armed with plumose setae. The third uropod of the female is similar to that of the male but smaller in proportion to the body.

The telson exceeds the peduncle of the third uropod in length, is cleft to the base, and armed distally with 2-3 spines and several setae, and laterally with one spine and a variable number of setae.

General Amphipod Biology

The Illinois cave amphipod is a member of the crustacean order Amphipoda (commonly called scuds or sideswimmers). Amphipods commonly range in size from about 13 - 55 mm (0.5 - 2 in.) in length. Freshwater amphipods inhabit rivers, streams, springs, seeps, ponds, lakes and groundwater. Freshwater members of the genus *Gammarus* are most commonly found in cooler temperate-zone waters.

In *Gammarus minus*, pairs may remain in amplexus for around two weeks prior to fertilization (Culver *et al.* 1994), but duration of amplexus probably varies between cave and spring populations of this species. Eggs of *G. minus* are released into the brood pouch of the female, and young are released about a month later (Jones *et al.* 1992). For at least some Gammaridae, the incubation period varies with temperature (Hynes 1954, Steele and Steele 1972). Depressed oxygen levels can interfere with mate-guarding behavior in freshwater *Gammarus* (Hoback and Barnhart 1994, 1996).

Amphipods exhibit direct development, with young similar in appearance to the adults. Sexes cannot be distinguished until later juvenile instars, when the development of oostegites in females and penes on males are diagnostic (e.g., Morgan and Woodhead 1984). Pairing occurs for the first time in the eight or nuptial instar and the ninth and subsequent instars form the adult period. Adults continue to molt up to 20 times.

In general, subterranean animals are characterized by a reduction in pigment and eyes, with other sensory structures being more highly developed. Culver *et al.* (1994) report longer antennae, smaller eyes, and larger bodies for cave populations of *G. minus*. Food consists of bits of dead vegetation washed into the caves and thin bacterial scum covering submerged surfaces.

Groundwater amphipods, like other subterranean (hypogean) animals generally have reduced metabolic rates relative to their epigen (above ground) relatives (Barr 1968, Ercolini *et al.* 1987, Hervant and Mathieu 1995, Hüppop 1986, Poulson 1963,Thinès 1969, Vandel 1965), even when differences in food availability are taken into account (Spicer 1998). This may not be the case, however, in subterranean systems with high availability of nutrients (Hoffmann and Parsons 1991, Spicer 1998).

Feeding

Amphipods are typically thought of as scavengers (Pennak 1953), shredding coarse organic debris. More recently, it has been recognized that amphipods may sometimes filter fine particulate matter from water and can be predators on other taxa (MacNeil *et al.* 1997). Densities of cave invertebrates have been found to be correlated with fungal populations (Dickson 1975), suggesting fungi as an important food source. Bärlocher and Kendrick (1973) have noted greater weight gain by young *G. pseudolimnaeus* when offered leaves with fungal colonies present than on leaves with only bacteria or autoclaved leaves. Jenio (1972, 1980) successfully maintained laboratory populations of *G. troglophilus* on elm leaves.

Lewis (2001) noted the following:

> Dissection of the gut from the Illinois cave amphipod and examination of the contents under low power magnification revealed an amorphous mass light brown in color. Placement of this material on a glass slide and examination with a compound microscope under high power revealed a mixture of brown, somewhat gelatinous material (clay particles plus mucous?), bacterial cells and occasional minute particles of sand.
>
> Observing *G. acherondytes* in a shallow (<3cm deep) gravel stream substrate in Fogelpole Cave suggested that the amphipods graze the substrate by slowly walking the bottom. The mouthparts are essentially a network of setose structures that are net or rake-like and can be used to gather material from the substrate and direct it at the animal's mouth. Presumably the amphipods are harvesting a mixture of the inorganic substrate material along with the microbiota present and eating the entire mixture. The organic part is absorbed while the inorganic component is moved through the gut and eliminated.

Life Cycle: Seasonality and Reproduction

Taylor and Webb (2000) showed size distribution of *G. acherondytes* can be explained in part by seasonal variation, probably indicating there is a seasonal component to reproduction in this species. Young are generally more abundant in springtime, but size of individuals varies widely within all seasons. Lack of a pronounced seasonal pattern of reproduction is consistent with observations by Culver *et al*. (1995) for Appalachian populations of cave inhabiting *G. minus.* They noted cave populations showed less distinctive seasonality in reproduction than did associated epigean populations. However, young *G. minus* also show a springtime peak in abundance in cave populations (Culver 1971, Jones 1990), although seasonal patterns in cave populations of this species are less clear than in resurgence populations. Gammarids in epigean habitats often have annual life cycles, breeding continuously or with multiple breeding (Nelson 1980). Other amphipods may live two years, producing a brood each year (e.g., the estuarine gammarid *Leptocheirus pinguis*, Aoridae) or only producing a brood during their second year (e.g., *Casco bigelowi*, Gammaridae, also estuarine) (Wildish 1980). In cave streams of the Illinois' Salem Plateau, springtime populations of *G. acherondytes* and *G. troglophilus* populations tend to be composed of smaller individuals which are found in greater densities (Taylor and Webb 2000). A resurgence population of *G. troglophilus* in Union County, Illinois, reproduced throughout the year, but immature amphipods in this population were most abundant in the springtime (Jenio 1972, 1980). Resurgent populations of *G. minus* in the Appalachians form pre-copulatory pairs more commonly in the winter months (Culver *et al*. 1995, Kostlos 1979, Man 1991). Taylor and Webb (2000) found few amphipods (primarily *G. troglophilus*, *G. acherondytes*, and *C. forbesi*) in Illinois cave streams with ova in the marsupium, and suggest this may reflect that a relatively small portion of the population is reproductively active. Taylor and Webb (2000) found no ovigerous females of *G. acherondytes*, and females of *G. troglophilus* carrying ova were more common in the winter months, but were present also in April and August.

Lewis (2001) reported *G. acherondytes* has not been observed mating, although the mechanism is presumably similar to that observed in *Gammarus troglophilus* in which males are seen riding atop females. It is presumed the Illinois cave amphipod mates in gravel riffles where it is most commonly found.

One indication of the fecundity of *G. acherondytes* can be obtained by examining ovigerous females. In amphipods, structures known as brood plates, or oostegites, are produced on the ventral side of females, interior to the coxa of the pereopods. As the amphipod reaches sexual maturity brood plates become fringed distally. The fringes interlock in ovigerous females, forming an enclosed brood chamber in which eggs are carried. In the Illinois cave amphipod up to 21 eggs were reported by Holsinger (1972).

Brood pouches of two ovigerous *G. acherondytes* females (approximately 12 mm in length), collected on 27 September 2001 from Reverse Stream Cave, Monroe Co., Illinois, were dissected and the contents examined (Lewis 2001). One had 17 ovoid, undifferentiated eggs, approximately 0.8 mm in length. The other had 6 embryos, approximately 1.3 mm in length, with differentiated antennae and pereopods, but no indication of pigmented eyes.

Of 24 *G. acherondytes* collected from Spider Cave, Monroe Co., Illinois on 6 September 1998, two possessed obvious brood plates (Lewis 2001). In an 11 mm female the brood plates appeared fully formed, but loosely enveloped the area of the marsupium. In a 13 mm female the brood plates were encapsulated to form a tightly closed brood pouch. This was opened and examined; no embryos were visible under a dissecting microscope. It seems likely embryos were present and were still below the level of resolution of the low power of a dissecting microscope.

<u>Sex Ratios</u>

The only indication of sex ratio of the Illinois cave amphipod is that which can be determined by examining collections, since sex identification of non-ovigerous live amphipods is essentially impossible (Lewis 2001). Ovigerous females can be ascertained by the presence of the bulging brood pouch. Otherwise, mature males are identified by the presence of two tiny, infacing papillae on the ventral side between the coxae of pereopods 7. Females and juveniles lack these papillae and can not be accurately identified. Thus, in *G. acherondytes* with populations skewed toward smaller size cohorts, it is not possible to determine sex of most individuals, and therefore sex ratio.

A biased (non-randomized) collection made by J. Lewis and P. Moss from Reverse Stream Cave, Monroe County on 27 September 2001 consisted of seven males and two ovigerous females. (Lewis 2001). Other unpublished information provided by Dr. John R. Holsinger (pers. comm., e-mail, 2001) are as follows: 1 male - Fogelpole Cave, 26 June 1965; 1 ovigerous female –

Fruth's Spider Cave, 26 June 1965; 2 males, 1 female, 1 juvenile – Pautler Cave, 27 October 1965; 1 male, 3 ovigerous females – Stemler Cave, 9 October 1938.

Life Span

No information exists on the lifespan of the Illinois cave amphipod. Examination of census data demonstrates populations that are skewed toward smaller size cohorts. This is usually indicative of species that reproduce frequently or in relatively large numbers and exhibit low survival to reproductive size and short lifespan (Lewis 2001). Jenio (1980) determined the life expectancy of adult *Gammarus troglophilus* males to be 158 days (96-245) and 142 days (74-276) for females, with the total life expectancy of an individual to be 52 weeks. These values, however are based on laboratory reared specimens, which may not be representative of normal life expectancy for this species. Taylor and Webb (2000) note that using the same data from Jenio (1980) one can alternatively estimate a life expectancy of 69 weeks. Life cycles and life spans of some amphipods are thought to be much longer. Dickson and Holsinger (1981) suggested a life cycle as long as 8-10 years for *Crangonyx antennatus*, and Wilhelm and Schindler (2000) reported that alpine populations of *Gammarus lacustris* can take three years to reach sexual maturity, but only one year at lower elevations. Late maturity and longer life spans are common adaptations of subterranean species (Poulson and White 1969), including amphipods (Dickson and Holsinger 1981, Ginet 1960, Holsinger and Holsinger 1971).

Habitat Requirements

Gammarus acherondytes was collected in mainstream gravel riffles by Webb *et al.* (1998). But it is also known from tributary streams as small as one foot (31 cm) in width, from rimstone pools, and from silt overlying bedrock (Lewis *et al.* 1999). Freshwater *Gammarus* species sometimes exhibit differences in microhabitat preferences on the basis of sex and developmental maturity (*e.g.*, Wilhelm and Lasenby 1998). *Gammarus roeseli*, a freshwater interstitial species, has been shown to select microhabitats on the basis of oxygen availability (Henry and Danielopol 1999).

Lewis (2001) conducted an analysis of all *G. acherondytes* censused in 2001, examining the microhabitat preference as a function of substrate versus water depth (Figure 4). Water depth was characterized by taking the average of the lowest/highest depth.

It was found that 90.3% of all Illinois cave amphipods noted were inhabiting substrate that had at least some gravel or cobble present. Scoured limestone bedrock or breakdown floored habitat lacking any gravel or cobble was used by 7.6% of the amphipods. Only 2.1% occurred on mud-floored habitat.

Shallow water was preferred by the Illinois cave amphipod. Of the animals censused, 71.7% were found at depths between 0-10cm, 17.2% between 10-20 cm, 9.7% between 20-30 cm, and only 1.4% between 30-40 cm. The preferred habitat demonstrated by this data was gravel/cobble riffles less than 10 cm in depth where 69.0% of the Illinois cave amphipods were found. However, there may be sampling bias due to the difficulties of working in deeper waters.

Substrate	**Site**	**Water Depth Range (mean of lowest/highest)**			
		0-10cm	10-20cm	20-30cm	30-40cm
Gravel/Cobble	Pautler	31	0	2	0
(90.3%)	Frog	46	19	9	0
	Wednesday	1	1	0	0
	Fogelpole	17	0	0	0
	Illinois Caverns	5	0	0	0
Bedrock/Breakdown					
(7.6%)	Frog	0	1	3	2
	Illinois Caverns	1	4	0	0
Mud	Pautler	3	0	0	0
(2.1%)		**104**	**25**	**14**	**2**
		(71.7%)	(17.2%)	(9.7%)	(1.4%)

Figure 4. Habitat use by *G. acherondytes* as a function of water depth and substrate (Lewis 2001).

Species Interactions and Substrate Characteristics

Studies by Culver (1970, 1971) and Culver and Fong (1991) have demonstrated interspecific interactions between species of macrocrustaceans in Appalachian cave streams. They (Culver and Fong 1991) examined species presence/absence data under individual stones, and concluded that various competitive and predator/prey interactions occur. Given the similarity of the community composition within the range of *G. acherondytes*, it is likely such relationships exist in Illinois cave streams. Data from Taylor and Webb (2000) are supportive of this claim, indicating substrate characteristics and interactions with other amphipod and isopod species are important factors in the biology of *G. acherondytes*, though the details of these factors are not understood. *Gammarus acherondytes* displays a preference of some gravel size classes over others, as does the co-occurring *G. troglophilus* (Taylor and Webb 2000). These data point towards the importance of a porous substrate, such as stream gravels, to the Illinois cave amphipod. Miller and Buikema (1977) suggest spaces between stream gravels may be important in keeping cave-dwelling populations of *G. minus* from being washed downstream, and Culver has examined washout rates of Appalachian cave amphipods in streams resulting from intra- and interspecific interactions. The above data, then, clearly indicate stream substrate is an important factor affecting the biology of cave amphipods, including *G. acherondytes*, a conclusion which generally applies with freshwater aquatic macroinvertebrates (Minshall 1984).

Lewis (2001) observed that of the species that regularly occur with *G. acherondytes*, the most likely predators are salamander larvae (presumed to be those of the cave salamander *Eurycea lucifuga*) and the flatworm *Sphalloplana hubrichti.* Other species (amphipods and isopods) that occur regularly in caves of the Sinkhole Plain area are probably microbial or detritival omnivores. Crayfish occur in Fogelpole and Krueger/Dry Run systems (including Spider Cave), although it is difficult to ascertain their importance as predators, since only dead (thus unidentifiable) specimens have been found while censusing. In Madonnaville cave crayfish (*Orconectes* sp.) are fairly common. Fish occur sporadically with *G. acherondytes*, many of which are game species (e.g., catfish *Ictalurus* spp., sunfish *Lepomis* spp.) possibly stocked in sinkhole ponds that allow the fish into cave streams. The actual effects of any of these potential predators on the *G. acherondytes* populations are unknown. However, *Ictalurus* spp. are able to reproduce and live in Perry County, Missouri caves and thus may have an adverse effect on cave fauna (G. Adams, So. IL Univ., pers. comm. 2002).

Distribution

Hubricht and Mackin (1940) originally recorded *G. acherondytes* from Illinois Caverns (as Morrison's Cave), Monroe County, and Stemler Cave, St. Clair County. Holsinger (1972) reported it from four caves in Monroe County and one cave in St. Clair County, but did not specify which caves. Peck and Lewis (1978) reported it from Fogelpole Cave, Fruth's Spider Cave (which is part of the Krueger-Dry Run system), Illinois Caverns and Pautler Cave, all in Monroe County. These are the four caves from Monroe County referred to by Holsinger (1972) (J. Holsinger, Old Dominion University, pers. comm. 1996). A biodiversity inventory of eighty caves throughout the karst regions of Illinois was conducted in 1992 and 1993 (Webb 1993, Webb *et al.* 1993, 1998), including four of the five caves from which *G. acherondytes* was previously recorded. The entrance to the only other previously recorded site, Pautler Cave, apparently had been closed by the landowner. During this time, *G. acherondytes* was collected only in Fogelpole Cave and Illinois Caverns. In addition, material collected during a study of 84 Illinois caves by Oliver and Graham (1988) was examined by Webb *et al.* (1993) and a single specimen from Madonnaville Cave (Monroe County) was found in this material and constituted a new drainage basin for this species. However, the occupancy of the species at this locality has not been confirmed. Lewis *et al.* (1999) discovered populations in two additional groundwater systems within the already known range of the species in Monroe County, found them to be extant in the Pautler system, and collected the species at different localities within other known groundwater systems. Additional work reported by Lewis (2001) demonstrated populations in two more groundwater systems.

Fogelpole Cave, Illinois Caverns, and Krueger-Dry Run Cave groundwater basins are located in the Renault sub-region in Monroe County (Figure 2) and lie adjacent to each other. Their recharge areas share borders (basin boundaries) and in some cases, share recharge areas (Aley *et al.* 2000). Groundwater in each basin generally flows southeast where each discharges to surface streams via springs (Aley *et al*. 2000).

Pautler Cave, Annbriar Spring, Luhr Spring, and Frog Spring groundwater basins are located in the Waterloo sub-region (Figure 2). The recharge areas share borders (basin boundaries), and in some cases, share recharge areas (Aley and Moss 2001). These cave systems flow generally northward, although Annbriar Spring also receives recharge from the north side of Fountain Creek, and discharge to the surface via springs (Aley and Moss 2001).

The Stemler Cave groundwater system is in the Columbia sub-region (Figure 2) and flows north to Sparrow Spring (Aley *et al.* 2000), where it is the headwaters of Sparrow Creek.

The following provides an overview of the current status of *G. acherondytes* in each cave in which it has been found. See Table 1 for census data as discussed below and Table 2 for exploration data.

<u>Fogelpole Cave Groundwater System</u>
Fogelpole Cave, Monroe County

Fogelpole Cave is the main cave in the Fogelpole Cave Groundwater Basin. This groundwater system is generally bounded on the north by the Illinois Caverns groundwater system and is approximately 18.5 sq. km (7.14 sq. miles) in area (Aley *et al.* 2000). Groundwater flowing through this system discharges from Indian Hole and Tierce spring (Aley *et al.* 2000) at rates that range from 1500 gpm to in excess of 130,000 gpm (Panno *et al.* 1998). Groundwater from this spring discharges to the South Fork of Horse Creek.

In 1995, five sites in this cave were examined for amphipods (Webb 1995, Webb *et al.*, 1998). *Gammarus acherondytes* was collected in association with *G. troglophilus* and *Crangonyx forbesi* in gravel-cobble riffles in the main cave stream and in the calcite-gravel-sand-silt riffles and pools of a small tributary stream. Of 363 amphipods collected from the five sites, *G. acherondytes* made up 9% of the specimens. In the two riffle sites where collected it made up 15% of the amphipods. *Gammarus acherondytes* was collected in Fogelpole Cave in 1965 (1 specimen, J. Holsinger collection), 1986 (1 specimen, INHS collection), 1993 (10 specimens, INHS), and 1995 (33 specimens, INHS).

Lewis (2000) found three *G. acherondytes* at the census site at the intersection of the entrance passage and the main stream (Lewis 2000). None were found during his 2001 census. Also in 2000, three *G. acherondytes* were found in the census area just downstream of the intersection of Mud Alley passage. Again, none were found during the 2001 census. The 2001 community census in Fogelpole Cave confirmed that it was the least diverse and the most overrun by *Caecidotea brevicauda* of any cave censused. Of the 306 animals present in the 20 quadrats, 296 were *C. brevicauda* (Lewis 2001).

An additional upstream part of Fogelpole Cave was censused in September 2001, since the community censused in the part of the cave accessible via the historic entrance demonstrated poor quality. The new census demonstrated the second largest number of *G. acherondytes* from any currently known site with 17 individuals found (Lewis 2001).

<u>Illinois Caverns Groundwater System</u>
Illinois Caverns, Monroe County

Illinois Caverns is the main cave in the Illinois Caverns groundwater system. This system is bounded generally on the south by the Fogelpole Cave groundwater system and on the north by the Krueger-Dry Run Cave groundwater system. This basin is approximately 5.4 sq. km (2.1 sq. miles in area) (Aley *et al.* 2000) and discharges at the surface from Dye Spring, as well as Walsh Cave and Spring, about three miles to the southeast of the main entrance (Aley *et al.* 2000).

Gammarus acherondytes was collected in this cave in 1938 (25 plus specimens, U.S. National Museum collection), 1965 (14 specimens, J. Holsinger collection), 1974 (6 specimens, INHS collection), 1992 (20 specimens, INHS collection), 1993 (1 specimen, INHS collection), and 1995 (56 specimens, INHS collection). In 1995, 19 sites in this cave were examined for amphipods (Webb 1995, Webb *et al.*, 1998). *Gammarus acherondytes* was collected only in the gravel-cobble riffles and pools of the main cave stream in association with *G. troglophilus* and *Crangonyx forbesi. Gammarus acherondytes* made up 25.1% of the 223 amphipods collected, and comprised 30.6% of the amphipods in the two riffle-pool sites where it was collected.

Lewis (2001) found that *G. acherondytes* occurs at a population density ranging from 0.1 - 0.4 amphipods/square foot (slightly greater than 1/4 m.square) in the upstream section of the cave. Although it could theoretically be found below the "T" intersection, it was not found there in previous censusing (Lewis 2001).

<u>Krueger-Dry Run Cave Groundwater System</u>

Krueger-Dry Run Cave groundwater system is the system containing Krueger-Dry Run Cave. The basin is generally bounded on the south by the Illinois Caverns groundwater system. The basin is approximately 14 sq. km (5.4 sq. miles) in area (Aley *et al.*, 2000) and discharges at the surface at Kelly Spring (Aley *et al.* 2000). This drainage basin is a hybrid of a surface watershed that sinks, and an area that is recharged through sinkholes.

Krueger-Dry Run Cave, Monroe County

In 1995, amphipods were collected at two sites in this cave (Webb 1995, Webb *et al.*, 1998). Two specimens of *G. acherondytes* were collected in a gravel-cobble riffle of the main cave stream in association with *G. troglophilus* and *Crangonyx forbesi.* At this riffle site, *G. acherondytes* made up 5.7% of the sample, but constituted 3.1% of the 64 amphipods collected from this cave. *G. acherondytes* was collected in this cave in 1965 (1 specimen, J. Holsinger collection) and 1995 (2 specimens, INHS collection). It was not collected here in 1986 or 1993 (Webb, 1993). The population of *G. acherondytes* appears to be low in the Krueger-Dry Run section of the cave system.

Spider Cave, Monroe County

Gammarus acherondytes appears to have been extirpated from Spider Cave, an upstream tributary of Krueger-Dry Run Cave. It appears that a pollution event occurred and resulted in a microbial mat forming over the stream substrate (Lewis 2001). However, in 1999, 25 *G. acherondytes* were collected from the cave (Lewis *et al.* 1999).

Madonnaville Cave Groundwater System
Madonnaville Cave, Monroe County

A single specimen of *G. acherondytes* was collected from Madonnaville Cave in 1986 during a preliminary inventory of natural resources in select caves in Illinois (Oliver and Graham 1988) in association with two specimens of *G. troglophilus* and one specimen of *C. forbesi* (Webb 1993, Webb *et al.*1998). In 1995, two sites in the dark zone of this cave were examined for amphipods. No specimens of *G. acherondytes* were collected among the 673 specimens of amphipods collected in 1995. *Gammarus minus* made up 96% of the specimens collected. This was the only cave of the five examined in 1995 in which *G. minus* was the dominant species of amphipod of the sites sampled. *Gammarus acherondytes* has been collected in this cave only in 1986 (1 specimen, INHS collection, Webb *et al.* 1998).

Pautler Cave Groundwater System

There are several caves included in the Pautler Cave groundwater system. Two of them are known to contain *G. acherondytes.* They are Pautler Cave and Rose Hole. Cave mapping indicates that Rose Hole is tributary to Pautler Cave (Moss 2001). The recharge area of the Pautler Cave groundwater system is approximately 20.75 sq. km (6.30 sq. miles) (Aley and Moss 2001).

Pautler Cave, Monroe County

The entrance to Pautler Cave was reported as being closed by the landowner (Oliver and Graham 1988, Webb *et al.* 1993), but was found to be open during 1999 where 53 *G. acherondytes* were collected from gravel bars in the main stream passage (Lewis *et al.* 1999). A smaller tributary stream produced 7 *G. acherondytes,* 6 *G. troglophilus,* and 1 *C. forbesi.*

In May 2001, the historic section of Pautler Cave was censused. That area was found to have the third largest number of *G. acherondytes* presently known. In 20 quadrats, 17 *G. acherondytes* were found with troglobitic species comprising 30% of the fauna noted in the quadrats. In September 2001, 19 *G. acherondytes* were found with troglobitic species comprising 24% of the fauna noted in the quadrats. Population density in the two transects, which are combinations of gravel riffles and adjacent mud-bottomed pools, ranges from 0.4-1.3 *G. acherondytes* per square foot. The amphipods are primarily found in the gravel riffles rather than the mud-bottomed substrate.

Rose Hole, Monroe County

This cave contains a small stream, which begins as a trickle and is no more than a foot (31 cm.) wide after the first few hundred feet (Lewis *et al.* 1999). During two visits to this cave 32 *G. acherondyes* were collected (Lewis *et al.* 1999).

<u>Stemler Cave Groundwater System</u>
Stemler Cave, St. Clair County

Stemler Cave is the main cave in the Stemler Cave groundwater system and is located in the Columbia sub-region (Figure 2) in St. Clair County. The basin drains an area of about 18.5 sq. km (7.14 sq. miles) (Aley *et al.* 2000) and discharges at Sparrow Spring north of the basin (Aley *et al.* 2000).

Collections of amphipods were made at five sites in 1995, but no specimens of *G. acherondytes* were among the 561 amphipods collected (Webb 1995, Webb *et al.* 1998). This cave is one of the type localities for *G. acherondytes* and additional specimens were collected in 1965 (numerous specimens, J. Holsinger collection; syntype specimens in USNM). No *G. acherondytes* have been collected there since 1965, although sampling was conducted in 1993, 1995, 1998 and 1999 (Webb 1993, 1995; Webb *et al.* 1998, Lewis *et al.* 1999).

Frog Cave Groundwater System
Frog Cave, Monroe County

This is one of the new drainage basins in which *G. acherondytes* has been found (Lewis et al. 1999). This cave consists of about 300 feet of stream passage (Lewis et al. 1999). The groundwater system discharges into Bond Creek (Aley and Aley 1998). It is a groundwater system adjacent to and west of the Annbriar Spring groundwater system. This spring's base level discharge is similar to that of Kelly Spring draining the Krueger-Dry Run Cave System (Aley and Aley, 1998) and should have a similar size recharge area.

Frog Cave has the largest known number of *G. acherondytes* found at any site with a density that varies between 0.6 - 3.3 amphipods/square foot. Twenty-one *G. acherondytes* were collected from broad gravel bars in 1999 (Lewis et al. 1999). Results of two surveys in May and July 2001, revealed 27 *G. acherondytes* in 20 quadrats with troglobites comprising 17% of the fauna in May, and 53 *G. acherondytes* with 47% of the animals noted in the quadrats being troglobitic in July (Lewis 2001).

Annbriar Spring Groundwater System

The Annbriar Spring groundwater system is bounded to the east by the Pautler Cave groundwater system. This is one of the new drainage basins in which *G. acherondytes* has been found (Lewis *et al.* 1999). This spring drains land on both the north and south sides of Fountain Creek (Aley and Aley 1998). Four caves in this system are known to contain *G. acherondytes*: Wednesday Cave, Reverse Stream Cave, Cedar Ridge Caves, and Triple Delight (Aley and Moss 2001). The Annbriar Spring groundwater system is approximately 19.69 sq. km. (5.97 sq. miles) (Aley and Moss 2001).

Cedar Ridge Cave, Monroe County

This is a small cave that allows only a very thin person to penetrate. From the stream beyond the constriction, 6 *G. acherondytes* were collected in 1999 (Lewis *et al.* 1999).

Wednesday Cave, Monroe County

This is a short cave with a small stream (Lewis *et al.* 1999). From this stream 9 *G. acherondytes* were collected in 1999 (Lewis *et al.* 1999). In May and July of 2001, this stream was again censused. Only one *G. acherondytes* was found in each survey, with troglobitic fauna composing 6% and 13% of the quadrats for May and July, respectively.

Reverse Stream Cave, Monroe County

This is a short cave with a large stream flowing through it. Nine adult specimens of *G. acherondytes* were collected from this cave (Lewis 2001).

Triple Delight, Monroe County

This cave has not been explored or mapped. A stream is located a few feet from the entrance. *Gammarus acherondytes* specimens were noted at this cave (Lewis 2001).

<u>Luhr Spring Groundwater System</u>
Rick's Pit, Monroe County

One cave, Rick's Pit, was examined in this system. A single collection demonstrated that *G. acherondytes* is present in the system (Lewis 2001). A dye trace was conducted that showed the cave discharges at Luhr Spring (Aley and Moss 2001). Based on base flow spring discharge, the Luhr Spring groundwater system may be the smallest known that provides habitat for *G. acherondytes.*

<u>Dual Spring Groundwater System</u>
Snow White, Monroe County

One cave, Snow White, was examined in this system. A single collction demonstrated that *G. acherondytes* is present in the system (Lewis 2001). Dye tracing studies showed the cave discharges at Dual Spring (Aley and Moss 2001). Dual Spring is a relatively large spring, which receives approximately one-third of its base flow recharge from losses through the Fountain Creek channel (Aley *et al.* 1998).

Reasons for Listing

As stated in the final rule listing the Illinois cave amphipod as endangered (63 FR 46900) the primary reason for listing this species was the present or threatened destruction, modification, or curtailment of its habitat or range due to degradation of habitat through groundwater contamination resulting from agricultural practices and urbanization. At the time of listing, the amphipod was known to occur in only four of six historical cave systems. Also, inadequate protection of water quality in a sensitive geological formation (karst topography) through current state and local regulations offered little hope of reducing these threats.

Present Threats

The species survival is threatened by factors affecting shallow karst groundwater. These include agricultural and residential pesticides and fertilizers; human and animal wastes from residential sewage disposal systems and livestock; sedimentation from agricultural and residential runoff; oil well production; surface runoff from roads, storm sewers, and increased surface paving due to urban development; sinkhole dumping of solid waste; and disruption of groundwater flow paths from quarry operations. Excessive visitation to caves and over-collecting for scientific purposes may also threaten the species.

Problems with many of these pollutants are increased by their rapid transport through sinkholes (Martel 1894) and other karst features, with little or no dilution, filtration or attenuation (Edworthy 1987). One way of thinking about karst system sensitivity to perturbations relative to other environments is given by Tercafs (1992). He notes that subterranean environments have strong "inertia", *i.e.*, the ability to absorb disturbance without affecting the basic biotic and abiotic components of the system, relative to short-term climatic changes, but weak "inertia" relative to water pollution. He also describes karst environments as being relatively low in resilience, *i.e.*, the environment's capacity to return to its initial state after disturbance, relative to other kinds of environments. Concerns about the possible implications of pollutants in karst groundwater systems are not merely a matter of theoretical concern as numerous instances of contamination have been documented (*e.g.*, Tercafs 1992, *op cit*.).

Almost nothing is known about the specific effects of metals, pesticides, fertilizers, oxygen levels, ionic balance, and sedimentation on the Illinois cave amphipod. However, there is a large body of this sort of ecotoxicological literature that pertains directly to other amphipods. The importance of metals to amphipods has been the focus of a number of studies, including examination of effect of cadmium (*e.g.*, Ahsanullah and Williams 1991; Borgmann *et al.* 1991; Dickson *et al.* 1982; Hong and Reish 1987; Kemp and Swatz 1988; Rainbow and White 1989; Stephenson and Mackie 1989a, 1989b; and Sundelin 1983), chromium (*e.g.*, Ahsanullah 1982, Ahsanullah and Williams 1991), copper (*e.g.*, Ahsanullah and Florence 1984; Blockwell *et al.* 1998, Icely and Nott 1980; Kedwards *et al.*, 1996; Moore *et al.*, 1995; Rainbow 1992; Rainbow and White 1989; Soto *et al.* 2000; and Weekes 1993), lead (*e.g.*, Kutlu and Sumer 1998), magnesium (Morritt and Spicer 1993), mercury (*e.g.*, Ahsanullah 1982) , molybdenum (*e.g.*, Ahsanullah 1982), nickel (*e.g.*, Ahsanullah 1982) and zinc (*e.g.*, Ahsanullah and Williams 1991; Moore *et al.*, 1995; Rainbow 1992; Rainbow and White 1989; and Weekes 1992, 1993). Unfortunately, few toxicological and physiological studies focus on *Gammarus*. Of these, the study organism is often a marine or brackish water species (*e.g.* Lockwood *et al.* 1973; Morritt and Spicer 1995; Schmitz *et al.* 1967 and Shires *et al.* 1994). The only exclusively subterranean amphipod species that has received close scrutiny is *Niphargus rhenorhodeanensis* (*e.g.*, Hervant *et al.* 1995; Hervant and Matheiu 1995; Hervant 1996).

There is some evidence that freshwater Gammaridae (in particular, *Gammarus*) may require higher oxygen levels and less polluted water that some amphipods such as *Crangonyx* (*e.g.*, MacNeil *et al.* 2000), though evidence for such a generalization is not yet conclusive. MacNeil *et al.* (2000) suggest that Crangonyctidae, and in particular *Crangonyx pseudogracilis* should be considered more pollution tolerant than Gammaridae, the latter being considered an indicator of relatively unpolluted waters in a number of systems for scoring biotic indices of stream pollution.

Agricultural and Residential Fertilizers

Nitrate nitrogen in groundwater is an anion that can be derived from several naturally occurring sources and does not adsorb to soil components. Thus, it readily migrates through the soil into the groundwater system (Burt *et al.* 1993; Panno *et al.* 1996). Wells and Kroethe (1989) and Ferguson *et al.* (1991) concluded that macropores (fractures and other relatively large conduits) in topsoil and glacial till overlying limestone in southern Indiana allowed nitrate nitrogen derived from fertilizer to infiltrate through as much as 18 m of clay-rich sediment and enter underlying karst aquifers. Others have come to the same conclusions (Gish and Shirmohammadi 1991).

Panno *et al.* (1996) were able to determine a background threshold of 1.4 mg/L for nitrate nitrogen in the Sinkhole Plain region of Illinois based on a probability technique developed by Sinclair (1974). Concentration levels below 1.4 mg/L were considered natural in their derivation, and those above 1.4 mg/L were considered to be of man-made origin (Panno *et al.* 1996).

Much of the nitrate nitrogen introduced into Monroe and St. Clair Counties is derived from row crop agriculture. During the spring, fields in these counties are sprayed with fertilizer and a variety of herbicides. Added to this situation is an extensive increase in home development which adds its own form of fertilizer and pesticides to the shallow surface till. Only occasionally does the level of nitrate nitrogen in the groundwater exceed the U.S. Environmental Protection Agency maximum contaminant level (USEPAMCL) of 10 parts per million (ppm) but generally there is a chronic year round level of 5-9 ppm, which is well above the background threshold.

Recently, Panno *et al*. (2001) used isotopes of the nitrate ion to identify the sources of relatively high nitrate concentration in ten large karst springs throughout the Sinkhole Plain. Nitrate concentrations in the springs were elevated above background and ranged from 2.3 to 7.5 mg/L as nitrogen. On the basis of their isotope work, they found that the dominant source of nitrate in spring water was from the application of fertilizers on crop lands.

To date, no studies have been reported on the long term effects (if any) of chronic nitrate levels on the health and fecundity of amphipods. However, comparisons of biota in cave streams with high nutrient enrichment levels to those with lower concentrations showed reduced biodiversity with high nutrient levels (Elliott 2000).

Ammonia

Ammonia is a highly toxic to aquatic life. In neutral or basic conditions such as limestone caves, it is less toxic than in more acidic waters.

Ammonia (NH_3) in spring water and other shallow groundwater, present as an ammonium ion (NH_4^+), typically occurs in concentrations below 0.1 mg/L (as N) (Panno *et al.* 2002). Ammonium ions are strongly adsorbed onto mineral and organic surfaces (Hem 1985) and as such, readily become immobilized in the soil zone. Subsequent bacterially-mediated chemical reactions typically convert NH_3 to the more mobile nitrate (NO_3^-) ion under aerobic conditions through a process called nitrification. The NO_3^- ion is easily leached from the soil zone and is present in spring and cave water in concentrations ranging from 2.3 to 7.5 mg-N/L (Panno *et al.* 2001).

Sources of NH_3 may be naturally occurring as soil organic matter, or can be derived from agrichemicals (N-fertilizers), animal waste, and septic systems. The agrichemicals anhydrous ammonia and urea (primarily) are applied to the fields to be planted with corn as a source of nitrogen in southwestern Illinois in early spring. Urea and ammonium nitrate are applied in winter for wheat (Panno *et al.* 2001).

NH_3 derived from agrichemicals and/or animal wastes can make its way into shallow karst aquifer as runoff from source areas via sinkholes. The first rainfall following application of these N-chemicals to the fields will result in elevation of the concentration of NH_4^+ in spring water. Panno *et al.* (2002) found that NH_3 concentrations as high as 0.56 mg/L (as N) were present in groundwater discharging from Kelly Spring (the resurgence of Krueger-Dry Run Cave) on June 2, 1994, following a relatively intense rainfall of over one inch in less than two hours. The rainfall occurred within a few days of the application of agrichemicals to the fields and is probably a worst-case scenario for NH_4^+ in cave and spring water. The highest concentrations of NH_3 coincided with the highest stage of the flood pulse at Kelly Spring.

Agricultural and Residential Pesticides

On the glacial till of Monroe and St. Clair Counties, a wide variety of pesticides are applied in the spring and summer. Data from studies of other amphipods show the adverse effects from agrichemicals. Bermingham *et al.* (1998) showed that the level of the herbicide Mecoprop to which leaves (food) had been exposed was a major factor in food choice by *G. pseudolimnaeus*. Soto *et al.* (2000) reported the rate at which 50 percent of the test group (juveniles of the marine, soft-sediment amphipod *Ampelisca araucana*) died from a variety of toxicants. The results range from 0.09 mg/L for a fungicide to 91.2 mg/L for a herbicide.

Webb *et al.* (1993) reported the presence of historic-use insecticides in aquatic macroinvertebrates sampled from caves and springs in the Sinkhole Plain. DDE (1,1-dichloro-2,2-bis(chlorophenyl) ethylene) and DDD (1,1-dichloro-2,2-bis(p-chlorophenyl) ethane) persistent breakdown products of DDT (1,1,1-trichloro-2, 2-bis-(p-chlorophenyl) ethane) and dieldrin, the persistent breakdown product of aldrin showed up at levels in the Fogelpole Cave isopods at the following levels: o,p-DDE: 0.0305 ppm and dieldrin 0.0163 ppm with DDD not detected. The presence of dieldrin and DDT metabolites in the karst systems is particularly alarming because they are known endocrine disruptors which have been implicated as causative agents in vertebrate, including human, developmental problems associated with disruption of the endocrine system (*e.g.*, Crews *et al.* 2000, Colborn and Thayer 2000).

The data in Webb *et al.* (1993) suggest that not only are the invertebrate samples revealing historic usage of chemicals, but that they can do so in cases where water sample analysis does not detect chemicals. The water sample taken at the same time as the water sample from Fogelpole Cave did not have detectable levels of DDD, DDE or dieldrin. This strongly supports the idea that cave invertebrates accumulate these toxins, and thus serve as indicators of past and present contamination, while the water only reflects contamination levels at the moment of sampling (Field 1989; Libra *et al.* 1986; Quinlan and Alexander 1987).

Bacterial Contamination

Research in the area has shown that the caves, springs, and surface water of the Illinois Sinkhole Plain contain relatively high levels of bacteria (Panno *et al*. 1996; Panno, 1996; Panno *et al*. 1997; Panno *et al*. 1998; Panno *et al*. 1999a; Panno *et al*. 1999b; Panno *et al*. 1999c, Taylor *et al*. 2000). Fecal bacteria present in these waters are typical of bacterial populations normally present in soils and surface waters, and of bacteria that probably originated from native wildlife wastes, livestock wastes, and possibly effluent from private septic systems. Total aerobic (TA), total coliform (TC), fecal coliform (FC), and fecal *Streptococcus* (FS) bacteria, and other selected bacterial species were isolated and identified from all water samples from springs and caves. The results of this effort revealed that at least 15 bacterial species could be isolated from the samples. The genera and species included soil bacteria, bacteria from cold-blooded vertebrates, and bacteria from warm-blooded animals. The latter bacteria included FS (e.g., *Enterococcus faecalis* and *E. faecium*) and FC (e.g., *Escherichia coli*).

Bacteria in high levels can directly impact organisms through infections, or can indirectly affect aquatic cave dwellers like the Illinois cave amphipod by depleting the dissolved oxygen in the water column either directly or indirectly as it decomposes on the streambed. Bacteria can also favor nonindigenous species over native fauna.

Potential sources of the bacterial contamination in spring and cave waters in southwestern Illinois include wildlife, livestock (including pets), and human-related sources (i.e., private septic systems), as discussed previously. Wildlife such as racoons contribute to the bacterial load of the cave and may be observed both on the surface and in the subsurface. Grazing within recharge areas probably also contributes to the cave's bacterial load. Further, most residents of the Sinkhole Plain use private septic systems. Panno *et al.* (1997) showed individual private sewage disposal systems in the Sinkhole Plain (many of which discharge directly into sinkholes) often were not performing at an acceptable level (relative to state and county regulations for FC < 400 cfu/100 mL), and that about 10% of the systems consisted of no treatment at all. Incorporation of animal waste and human waste into surface water flowing into some caves in southwestern Illinois has been observed directly by the authors. Wastes from wildlife, livestock, and private septic systems have ample opportunity to flow into caves of the Sinkhole Plain.

Panno *et al*. (1999a) showed that water sampled quarterly from ten relatively large springs in the Sinkhole Plain contains greater than 3 million cfu/100 mL of TA bacteria, greater than 2419 cfu/100 mL of TC, and tens to hundreds of cfu/100 mL of FC bacteria. Taylor *et al.* (2000) found similar bacterial populations during monthly sampling of the main stream of four large caves in the Sinkhole Plain in 1999. Five of the 12 water samples collected monthly from February through January exceeded 200 cfu/100 mL for FC bacteria and four of the 12 samples exceeded 400 cfu/100 mL. Taylor *et al*. (2000) found the highest concentrations of FC and FS bacteria occur in the spring and winter months.

Sedimentation

Much of the sediment generated within the Salem Plateau is directly associated with row crop agriculture. Crops are often planted in sinkholes, and on occasion completely through shallow sinkholes. Sedimentation associated with residential and commercial development and highway construction has also been documented as a problem in other karst areas (Werner 1983).

Glacial till and loess within the karst area where *G. acherondytes* has been reported are typically less than 15 m thick and are often absent in sinkhole bottoms. Open sinkholes allow for the rapid transportation of silts into the subterranean cave systems from surface runoff. Sedimentation in groundwater is a serious problem (Dysart 1985, Walker 1985) and the conduits formed by cave streams form natural traps for sediments (Palmer 1984). In turn, these sediments can transform a rubble or bedrock bottom cave stream into a sediment bottom stream, drastically changing the structure of the aquatic cave community (Culver 1982, Dickson and Kirk 1976, Poulson 1991). *Gammarus acherondytes* is an organism that is generally found under large cobblestones and within the interstitial space of coarse gravel. When these areas become covered with sediment, it deprives the organisms of suitable habitat for feeding, reproduction and escaping predation.

Oil Production

Oil and gas operations have been in existence in St. Clair and Monroe Counties since the first half of the twentieth century. Salt-water is forced into oil and gas wells in an effort to increase the recapture of these products. This enhanced retrieval process increases the potential for affecting the water quality of the groundwater systems in which *G. acherondytes* has been reported. Currently, these oil and gas operations are situated along the Dupo syncline. Chloride levels in the groundwater of the springs and caves examined by Webb *et al.* (1993, 1998) do not show higher than normal concentrations. At this time, the salination process does not appear to be affecting the cave drainage basins from where *G. acherondytes* has been reported. However, should oil and gas development occur within the range of the amphipod, it could become a threat.

One spring located in the vicinity of the oil and gas field just southwest of Columbia, Monroe County, discharges saline with a strong hydrogen sulfide odor. Analysis of the spring water showed that it contained over 10,000 mg/L sodium and chloride; normal sodium and chloride concentrations in groundwater for the area is less than 50 mg/L (Panno 2000).

Brine pollution from oil production has been associated with reduced numbers of organisms (Elliott 2000). Leaking or spilling of oil or gas directly into the groundwater could decimate a stream population.

Surface Runoff from Urban Development

The more rapid movement of surface water into groundwater systems in the Sinkhole Plain increases threats to the Illinois cave amphipod from a variety of contaminants (*e.g.*, motor oil, antifreeze, road salt, lawn care products). Bolner *et al.* (1989) studied dripping water at 42 cave sites under a residential area, and documented chemical and microbial contamination from faulty septic systems, residential application of garden chemicals, and road salts. Werner (1977) documented elevated levels of chloride ions associated with deicing road salts at karst springs in West Virginia. Schmitz *et al.* (1967) showed that the freshwater amphipod *G. pulex* has a much lower median survival period than the brackish water species *G. tigrinus*. Thus, there are significant differences in salt tolerance among riverine gammarids.

Sinkhole Dumping

The past and present dumping of yard, household, farm or industrial wastes into sinkholes or sinking streams poses a serious threat of direct contamination of the groundwater. Sinkhole dumping provides an unrestricted passageway to the groundwater and does not permit any filtering and cleansing through the soils. The average household generates considerable quantities of waste in a year. Wastes include relatively harmless solid materials such as paper, wood, metal cans, and food debris; and more hazardous, generally liquid materials such as solvents, adhesives, cleansers, lighter fluids, waste oil, paint thinners, pesticides, and antifreeze. Sinkholes, quarries and ravines are incapable of adequately containing wastes.

Catastrophic Spills

Catastrophic contamination from pipeline failures, train derailments, tanker truck accidents, underground storage tank failures, and industrial accidents could potentially impact the Illinois cave amphipod. Incidents have occurred at other locations such as a 1985 truck accident which spilled hazardous solvents that may have leaked into Kentucky cave shrimp habitat (USFWS 1988). The likelihood of such incidents increases with increasing urbanization.

Disruption of Groundwater Flow

Quarry operations and the construction of new roads could significantly alter the current drainage pattern of the groundwater system. For example, the Columbia Quarry Plant No. 1 is within 1000 feet (304.8 m.) of the recharge area for Stemler Cave in St. Clair County. Assuming quarry operators would plan to expand excavations eastward it could have an impact on the Stemler Cave ecosystem. Although no *G. acherondytes* have been collected there since 1965, Stemler Cave is historical habitat and the species may still be residing in the upper reaches of the basin or could be restored to the ecosystem once water quality improves. New road development can result in filling sinks or opening sinks by changing the hydrography of the area.

Human Visitation to Caves

There are a variety of consequences of human visitation including alteration of the physical structure of the cave, alteration of water chemistry, alteration of air movements and microclimates, introduction of artificial light, compaction or liquification of substrate, erosion of or disturbance of sediments, destruction of fauna, or introduction of alien fauna or materials. These can be exacerbated by increases in numbers of visitors and frequency of visitation (Watson *et al.* 1997).

With one notable exception, Illinois Caverns, the caves that are currently known to contain populations of *G. acherondytes* have little or no recreational cave visitation. Visitation has not been demonstrated to be a hazard to amphipod populations. However, the threats of cave visitation to *G. acherondytes* include:

1) direct take resulting from crushing or collecting by cave visitors
2) nutrient enrichment from waste left by cave visitors
3) degraded water quality from potentially toxic or hazardous materials, such as spent batteries or calcium carbide, abandoned in the cave
4) habitat structure degradation.

The best available data indicate that most specimens of *G. acherondytes* have been collected in riffles dominated by loose gravels. Since the riffles are relatively shallow, they are often the preferred place for visitors to traverse the stream. This convenient and accessible area focuses the traffic in what seems to be the most vulnerable habitat.

Until demonstrated to the contrary, it is prudent to minimize cave visitation to ensure that unnecessary stresses are not made on the *G. acherondytes* populations. Little quantitative data exist on cave visitation except to Illinois Caverns. Visitation should be monitored so that it may be correlated, along with other relevant data, with population trends.

Excessive Collecting of Specimens

Although cave entrance access can be controlled on public property, and access to caves on private lands, even those designated as State Nature Preserves, is controlled by the landowner, overexploitation or scientific collecting are not believed to be current factors affecting the species' continued existence. Federal protection under the Act prohibits unauthorized collection of individuals of the species. "Take" of an endangered species for any purpose, including scientific research, requires a scientific take permit from the U.S. Fish and Wildlife Service, and the purpose must comply with the objectives of this Recovery Plan. It is, therefore, the Service's responsibility to monitor the level of take to ensure that it does not exceed levels that are detrimental to the survival of the species.

Ongoing Conservation Efforts

Since 1995, the Illinois Sinkhole Plain has had a Karst Educator funded by the Illinois Department of Natural Resources. The Karst Educator's main job has been to educate landowners about the unique and delicate features of the Sinkhole Plain. Unfortunately, the funding for this position will end in 2002.

Illinois Caverns State Park has done much to advance the area's knowledge about caves, karst topography, and the Sinkhole Plains. However, its population of *G. acheroandytes* is threatened by increasing visitation. The educational benefits from the park are ongoing. However, more needs to be done to curb the impacts of cave visitation.

Biological Constraints and Needs

The major constraint in planning for the recovery of this species is that it is cave-dwelling aquatic organism living in the streams connected to groundwater basins in the Illinois Sinkhole Plain. The analogy to the "canary in the mine" is very close to the Illinois cave amphipod in the groundwater since water quality is critical to its survival and critical for human use. As the groundwater becomes polluted, the species may be eradicated in that basin instantly. Should the pollution become widespread, the groundwater would likely have to be treated before use in homes and farms, and costs could approximate those for bottled water.

In addition, little is known about the life history, population dynamics or range of the species, which limits our ability to describe viable populations.

II. RECOVERY

Recovery Strategy

The goals of this recovery plan are to ensure the protection and viability of the Illinois cave amphipod in order to reclassify the species from endangered to threatened status, and eventually to delist it when the recovery objectives outlined in this plan have been accomplished and it no longer requires the protection of the Endangered Species Act. The quality and condition of groundwater in the amphipod's habitats are intimately tied to land use practices within cave recharge areas. Surface activities that have the potential to contribute to the degradation of groundwater and cave habitats are best managed at the individual landowner and community level. Agricultural land use employing best management practices may offer greater protection for the Illinois cave amphipod than alternative developments such as subdivisions or industrial complexes. Protection of Illinois cave amphipod populations is achievable by informing residents within recharge areas of groundwater values, threats, and stewardship responsibilities; and by recruiting, involving, and assisting them in voluntary and incentive-driven stewardship efforts, including protection of the animals themselves.

To achieve recovery, this plan has defined tasks by four categories of recovery needs:

1) Protect current populations and their habitats from known and suspected threats.
2) Restore degraded habitat and reintroduce the species into historic habitats.
3) Research basic biology and habitat requirements to increase the knowledge base about the species.
4) Educate the public and provide technical assistance to local units of government and planning agencies.

Recovery Goals

Reclassification Criteria

The Illinois cave amphipod (*G. acherondytes)* may be considered for reclassification from endangered to threatened when five viable, stable populations in five separate groundwater basins with distribution in two of three sub-regions remain extant and there is a significant increase in use of best management practices in the groundwater recharge areas in each of the five groundwater basins. The subregions are Columbia, Waterloo, and Renault Sub-regions of the Illinois Salem Plateau.

Delisting Criteria

The Illinois cave amphipod (*G. acherondytes)* may be considered for delisting when five viable, stable populations in five separate groundwater basins with distribution in two of three sub-regions remain extant and are supported by persistent use of best management practices substantially protecting the groundwater recharge areas of the five groundwater basins. The subregions are Columbia, Waterloo, and Renault Sub-regions of the Illinois Salem Plateau.

Narrative of Recovery Tasks

This narrative provides a detailed explanation of the recovery actions believed necessary to recover this species.

Need 1. Habitat Protection

The degradation of habitat through the contamination of groundwater is believed to be the primary threat to the Illinois cave amphipod. Karst terrain, where this amphipod is found, is a geologic land formation typified by sinkholes and fissures that provide direct and rapid conduits for water and water-bourne material from the surface to the groundwater, thereby avoiding the filtering and cleansing mechanisms normally provided by overlying soils. In addition, bacterial contamination from human and livestock wastes and excessive visitation can impact this species.

1.1. Recharge Area Protection - Agricultural. Many programs are now in place that can provide incentives for farmers and rural landowners toward beneficial land stewardship practices. Agricultural land use employing best management practices may offer greater protection for the Illinois cave amphipod than alternative developments such as subdivisions or industrial complexes.

1.1.1. Encourage voluntary best management practices and land use protection plans through land owner contacts using incentives from existing tools of the Department of Agriculture such as Conservation Reserve Program (CRP), Rural Development, and others, and promoting new programs specific to the Sinkhole Plains. Use these programs to encourage profitable methods of farming that will protect and improve water quality (Best Management Practices). Develop new and/or modify existing programs to address special land use concerns particularly in regards to sink holes and groundwater recharge areas.

Examples of Best Management Practices

1. Promote development of whole farm conservation plans which address all forms of discharges and land use practices on a farm. These will provide a blueprint to the landowner for groundwater protection, and should result in a reduction of impacts from sediment, pesticides and nutrients to the groundwater.

2. Provide incentives for nutrient management. Test soils to determine the types of nutrients that currently exist in the soil. This eliminates the application of nutrients that are not needed.

3. Encourage proper pesticide management through use of integrated pest management.

4. Encourage use of minimum tillage methods and enrollment of acres including buffers in CRP and other programs. Encourage whole farm conservation planning.

5. Support the use of vegetative buffer strips and grassed waterways around the opening of sinkholes and gullied areas away from the sink hole.

6. Implement best management practices for livestock. Implement a program to deal with livestock facility location, runoff diversion, and manure handling and storage. Implement livestock pasture management programs, fence livestock out of streams and sinkholes, develop alternative water sources away from streams and open sinks, and develop rotational pasture management to improve pasture quality. Promote the use of incentives where feasible.

7. Programs should be developed to provide an incentive for landowners to protect their forested land in the Sinkhole Plain. If logging is needed or desired, a qualified forester should guide the operation. Practices should only include selective cutting strategies that minimize ground disturbance and minimize downed woody material that could impact drainage patterns and nutrient input.

1.1.2. Establish a board (Local Ecosystem Marketing Board) that will develop and facilitate the implementation of a strong coordinated marketing program highlighting the special needs of this area and its ecosystem, along with the Best Management Practices that will protect the ecosystem. Both the short and long-term success of the recovery plan depends on the desire of the local people to protect this very special ecosystem. In order to enlist support to protect this special area, information on the significance of the karst habitat, how preserving those areas effects plant, animal and human existence, and the importance of protecting the ecosystem will need to be provided to landowners. Support should also be provided to facilitate the preservation of agricultural lands as they are less of a threat to the groundwater than alternative developments such as subdivisions and industrial complexes.

1.2. Recharge Area Protection - Residential. The Sinkhole Plain of Southwestern Illinois has seen a tremendous population growth. The karst areas present a natural beauty which makes them highly desirable for residential development. According to the U.S. Census Bureau, Monroe County had the highest growth rate of any county in the St. Louis metro-east area between 1990 and 1995. The number of building permits issued for residential dwelling units increased by 269% between 1983 and 1993.

1.2.1. Sewage Treatment **-** The major threat from residential developments is human waste from inadequate septic systems discharging directly into sinkholes or groundwater recharge areas. The impacts to the groundwater include high biological oxygen demand which can deplete the oxygen in stream waters, and nutrient enrichment which can work to favor non-endemic species. Improving sewage treatment will improve groundwater quality.

1.2.1.1. Improve new and existing sewage treatment facilities (public and private) to achieve standards protective of karst groundwater. Ensure that all new developments install septic systems protective of karst topography and its groundwater. There is a special concern for both sewage disposal and sewage treatment. The important factor is how adequately each system treats the effluent it receives. Monroe and Randolph Counties have adopted private sewage disposal regulations specific to karst areas. Local governments should be encouraged to adhere to these regulations. Similar regulations should be adopted in all areas of the Sinkhole Plain within the range of the Illinois cave amphipod. Regulations should be reviewed and updated as new information becomes available.

1.2.1.2. Provide cost share to demonstrate alternative, better and approved systems. Cost effective and efficient private sewage treatment systems may be available but local landowners are not aware of them. By providing incentives, technology may improve and landowners may be encouraged to seek more efficient treatment.

1.2.1.3. Encourage development of a regional sewer district with a centralized sewage treatment and collection system. By employing a centralized sewage treatment system, compliance with sewage treatment regulations should be consistent and widespread.

1.2.2. Storm water Runoff - Storm water runoff transports pollutants from the ground surface to water supplies including groundwater. In the Sinkhole Plain, runoff transports pollutants (including trash, oil, road salt, etc.) quickly to the groundwater with little or no filtration. While it is very important to eliminate the sources of pollution, it is also important to control runoff that transports the pollution.

1.2.2.1. Encourage implementation and enforcement of adequate storm water control ordinances that deal with the unique features of karst terrain. Encourage inclusion of practices for karst areas in the Illinois Urban Manual and encourage local planning boards to adopt these practices. Coordinate with the Illinois Department of Transportation, the counties and townships to reduce adverse impacts to groundwater from storm water runoff from roads.

1.2.2.2. Discourage inappropriate industry from locating in karst topography. Industries which are difficult to regulate but may pose significant hazards to groundwater from runoff such as confined animal feeding operations should be discouraged from locating in karst areas.

1.2.3. Solid Waste Disposal - Local solid waste disposal programs should emphasize the unique karst features in its public outreach programs. Ongoing programs should also include support for local recycling programs.

1.2.3.1. Encourage enforcement of existing regulations pertaining to dumping of waste in sinkholes and other karst features. Implement a program to clean-up existing sinkhole dumps. Encourage composting of yard waste away from sinkholes. Support local recycling programs. Sponsor household hazardous waste clean-up programs.

1.2.4. Hazardous Materials. Hazardous materials are especially problematic in the karst region due to the immediate potential to contaminate groundwater. Therefore, special precautions should be taken to reduce the probability of spills and the likelihood spills will impact groundwater.

1.2.4.1. Encourage use of above-ground storage facilities in the Sinkhole Plain when necessary. Periodic maintenance and inspection of both above and below ground tanks is very important to ensure that leaks are controlled.

1.2.4.2. Coordinate with response agencies to ensure that spills of toxic substances from traffic accidents or other sources do not enter the groundwater system. Local response agencies need to be prepared to contain spills in a manner which will not endanger the groundwater. Concerns for the karst groundwater should be incorporated into their spill preparedness documents.

1.2.5. Encourage development of residential land use plans and regulations which would prevent perturbations to surrounding land and its groundwater systems. These should include good land use management practices such as maintaining large green spaces, or vegetated areas, as possible in drainage ways that drain to karst features; controlling erosion on construction sites; reseeding areas of bare soil; use of gravel or other permeable surfaces for driveways and walkways; and the best management practices listed for rural areas (1.1.1.).

1.3. Cave Ecosystem Protection. As cave systems are vulnerable to disturbance, visitation should be limited and be compatible with the species. Partnerships should be formed with the caving community working to minimize disturbance to caves.

1.3.1. Discourage publicizing names of specific caves, entrances, or entrance locations. Where publication regarding populations is necessary, it should be done using groundwater system terminology or other methods that do not focus public attention on specific caves.

1.3.2. Monitor visitation trends in selected caves containing *G. acherondytes.* Different methods may be appropriate for different caves. Monitoring may take the form of visitor logs, passive measurement devices, or reporting of visitation by researchers or managers. This information should be related to potential impacts to habitat of *G. acherondytes.*

1.3.3. Reduce the potential impacts of visitation in Illinois Caverns. Reduction may take the form of group size limits or daily, monthly, or annual limits on the numbers of visitors. Reduction of impacts may include construction of walkways made of inert materials to prevent visitors from entering the stream in the more sensitive parts of the cave. Guided or at least accompanied trips along a designated trail will also reduce impacts on the cave environment by assuring compliance with protection strategies. Administratively closing parts of the cave, especially the upstream portion that supports a healthier population of *G. acherondytes*, will also reduce overall impact. Informing visitors of the necessity of refraining from littering the cave and polluting the stream, and periodic monitoring of visitor behavior are strategies that should be implemented to minimize the threats to the Illinois Caverns populations.

1.3.4. <u>Utilize measures to assist with controlling access to caves.</u> Controlling the level of visitation may be necessary in several caves due to increased visiting interest. Installation of cave gates, signs and fences, and the use of patrols and marked trails are measures that may be used protect the amphipod and its habitat. Providing incentives may increase landowner participation.

Acquiring protection of cave entrances that could provide practical access to the cave streams containing *G. acherondytes* is also important. Control of these can be through memoranda of understanding, conservation easements, or purchase of title in fee simple. Access will be provided for water quality monitoring, censusing, life history studies, or other relevant research. Another method that may be used to prevent increased visitation pressure is to keep the cave locations obscure.

1.3.5. <u>All caves should be mapped by qualified individuals with suitable experience in mapping techniques.</u> Accurate cave maps are a critical tool for managing caves. Obtaining maps for caves with *G. acherondytes* will provide graphic documentation of important cave features and sampling locations, and will help to identify the above ground surface and its possible impacts to the cave environment. In particular, a map may be used to identify where pollutants may be entering a cave stream, or which passages support larger populations of *G. acherondytes*. Maps may already be available for some caves. The Illinois Speleological Survey (ISS) maintains a cave and karst database and can provide information on the availability, authorship and usage of cave maps.

1.3.6. <u>Researchers and cavers should be encouraged to locate new cave entrances.</u> Many caves are still being discovered in the Illinois Sinkhole Plain. Almost five miles of previously unknown cave passage have been mapped in this area during the year 2000 (Philip Moss, personal communication, 2000). The Rose Hole cave, discovered in 1999, has proved to have an exceptionally high biodiversity and includes *G. acherondytes* (Lewis *et al.* 1999). There are numerous large and small springs in the Illinois Sinkhole Plain that have no known cave feeding them. Some of these groundwater systems may contain populations of *G. acherondytes* and other important fauna. As these caves are located they should be examined for the presence of aquatic habitat and qualified biologists should be funded to identify collections made in these caves.

1.3.7. <u>Delineate all sinkholes and surface recharge areas in the Columbia, Waterloo, and Renault Sub-regions of the Illinois Salem Plateau</u>. Identification of these direct links to the groundwater is necessary in order to prioritize land use management activities.

Need 2. Restoration and Reintroduction

Restoration and reintroduction are tools which may be needed to recover the Illinois cave amphipod. Habitat restoration would be undertaken if distribution needed to be expanded into a basin that was previously degraded in order to preserve the diversity of the species. Reintroduction should only take place after threats to that habitat have been removed.

2.1. Habitat Restoration - There are considerable data indicating that water quality is degraded throughout the range of *G. acherondytes.* Improving water quality is the major factor in habitat restoration or enhancement. Once the habitat has been restored, measures to protect the habitat and water quality for the future must be in place.

2.1.1. Assess the feasibility and suitability of restoring historical Illinois cave amphipod populations that have been extirpated. The Illinois cave amphipod's presence has not been reconfirmed in Madonnaville Cave and it has presumably been extirpated from Stemler Cave. No amphipods have been collected in these cave systems since 1986 and 1965, respectively. The reason(s) why they no longer occur in these habitats and others should be determined and steps taken to improve habitat conditions in these two caves systems.

2.2. Reintroduction Into Historical Habitats - Once the historical habitats have been restored and water quality secured, reintroduction may be assessed. Factors such as genetic diversity, associated species, and potential for survival should be considered.

2.2.1. Reintroduce the Illinois cave amphipod into the historical habitats. Pending the results of Task 2.1.1., restoring amphipod populations to historical habitats should be assessed. Specimens for reintroduction may be taken from the largest populations available with consideration for the closest genetic relative. The reintroduced populations should be monitored yearly according to a protocol that limits impacts to the species to determine success.

Need 3. Research

There are few data on which to base population, productivity, or trend estimates for this species. Sampling for cave fauna is difficult at best, and the challenges of surveying are compounded by the relatively small size of this species and the difficulty of researchers to distinguish it from other similar amphipods in the field. This information will be needed in order to assess recovery.

3.1. Biology, Ecology, Life History and Habitat Requirements - Information in these general areas will need to be obtained before reintroduction and/or recovery can be adequately assessed.

3.1.1. Conduct studies aimed at increasing our understanding of the biology and ecology of *G. acherondytes*, including life history and behavior. These studies may be carried out in conjunction with surveys performed or with surrogate species where possible to minimize the loss of individuals. Studies should be directed at understanding seasonality of reproduction and recruitment which can help determine sensitive periods of the year for the Illinois cave amphipod and potential cues that elicit reproduction. This will facilitate decision-making pertaining to times of the year to limit cave access and pinpoint critical temporal scales for examining water quality parameters. Fluctuations in population abundance due to recruitment would be critical in interpreting temporal changes in abundance. In addition, population level genetics research should be conducted to determine the genetic integrity of individuals that may be reintroduced.

3.1.2. Assess potential adverse effects of contaminants and other water quality factors on the Illinois cave amphipod Adverse effects of contaminants and water quality parameters such as dissolved oxygen should be assessed to characterize the importance of focusing recovery efforts on activities that help to maintain conditions suitable for viable populations of the Illinois cave amphipod. Adverse effects would include chronic, population level impacts and acute individual impacts. Such assessments should be conducted via nonlethal bioassay procedures. Non-lethal bioassay methodology (based on quantification of feeding, mate-guarding, or other behavioral attributes) should be developed using the surrogate species *G. troglophilus*. Such assessment would be greatly facilitated by the development of methodologies for long-term maintenance of populations of *G. troglophilus*, and then *G. acherondytes*, in a laboratory setting. Preliminary studies by Jenio (1972, 1980) with *G. troglophilus* and by various authors (see Culver *et al*. 1995) working with *G. minus* demonstrate that development of a laboratory rearing protocol is feasible. In addition to providing information critical to recovery of *G. acherondytes*, bioassay procedures coupled with maintenance of laboratory populations provide unique opportunities to learn more about the life history, physiology and behavior of the species.

3.2. Determine the Current Range of the Species - Webb *et al*. (1998) report the species as occurring almost exclusively in larger drainage basins based on historical data and their own research. However, Lewis *et al*. (1999) report the species from smaller drainage basins within the known range of the species. Further, the Madonnaville Cave record reported by Webb *et al*. (1998) was based on a single 1988 collection, and was not reconfirmed in subsequent surveys. The recent discoveries by Lewis *et al*. (1999) suggest that other small drainage basins might warrant more intensive examination. Also, a lack of intensive focused surveys for the Illinois cave amphipod in the Salem Plateau north and south of the known range of the species and a lack of intensive surveys of troglobites in the Sinkhole Plain karst areas directly across the Mississippi River (Perry County to Pike County, Missouri) from the known range of the species, provides evidence that its range is not completely understood.

3.2.1. Conduct surveys to determine the species' current range. Surveys of small drainage basins not previously examined, and of segments of known basins not well examined (e.g., various parts of the Fogelpole Cave system, the downstream section of the Krueger-Dry Run system) within the range of the species, as well as potential habitat north (northern St. Clair County through Calhoun County, Illinois), south (southern Monroe County through Randolph

County, Illinois) and west (Perry County through Pike County, Missouri) need to be conducted. Surveys under this heading may include take of amphipods, allowing detailed study of populations and deposition of voucher material in well established scientific collections.

3.2.2. Delineate all groundwater basins within the range of the Illinois cave amphipod. In recent years, considerable progress has been made in determining the drainage basins within the known range of the Illinois cave amphipod (Aley *et al.* 2000). Management, and thus recovery, requires a sound understanding of the limits of drainage basins. Where such data are missing or inadequate within the known range of the species (including any basins not yet identified), high priority shall be given to delineation of these basins by dye tracing and, as appropriate, cave mapping.

3.3. Monitor the Status of the Species and its Environment - Basic to the conservation and management of the habitat of *G. acherondytes* is the ability to list and monitor the resources, including the fauna, associated with the karstic systems in which the species is found (Gall and Christian 1984, Hummel 1983). Quantitative monitoring will be used to assess implemented recovery actions, assess impacts of changes in landscape use and possible long-term weather pattern changes, monitor for catastrophic habitat disruption, and determine when population status warrants reclassification and eventual delisting of the species.

3.3.1. Quantitatively monitor population status of the Illinois cave amphipod. Populations of aquatic cave-dwelling species naturally experience fluctuations in response to yearly variations, and our ability to sample populations is affected by seasonal and year-to-year fluctuations in water levels. Therefore, it is preferable to monitor populations annually. To compare population data of all sites and during a particular time-frame, monitoring should be quantitative, include a quantitative assessment of size classes, microhabitat and macrohabitat (drainage basin) characterization, and cover a variety of traversable passages within each of the major drainage basins. To assess community health, quantitative sampling will include other relatively large macroinvertebrate taxa (e.g., other amphipod taxa, isopods, insects, flatworms, snails). Monitoring techniques should also be non-lethal, so that populations are not negatively impacted. A sampling regime which is widely spaced in time (e.g., 2-5 year intervals) would fail to identify various fluctuations, leading to the likely possibility that the limited data would either a) point towards a significant decline in populations when long-term stability actually exists, or b) point towards healthy populations when the long-term populations level is in decline. Very limited take from formerly known populations that now appear extirpated (e.g., Stemler Cave, Madonnaville Cave) may be appropriate to secure voucher material when presumptive populations of the Illinois cave amphipod appear to be present.

3.3.2. Monitor and evaluate trends in land use practices. Land use practices are key to the long-term recovery of the Illinois cave amphipod. Understanding how land use practices are changing will allow focusing of relatively limited resources towards the perceived problematic issues. Land use (such as farming, road maintenance and development, urban growth, industrialization, rural housing, quarrying activities, and oil and gas operations) within the known range of *G. acherondytes* should be quantified at least every five years.

3.3.3. Water quality (including chemical and microbial contamination and basic water chemistry parameters) both above ground and in shallow karst aquifers within the known range of *G. acherondytes* should be monitored every five years. Quantitative data are essential for effective management. Monitoring methodology should be consistent and focus on capturing a general picture of all of the basins from which the amphipod has been reported (see Panno *et al.* 1996; Panno *et al.* in press). Consideration should be given to installing remote probes which can detect instantaneous changes in water quality and store the data for periodic downloading.

Need 4. Education and Technical Assistance

Due to the nature of karst habitats and their vulnerability to contamination by surface activities, protection of the Illinois cave amphipod is dependent on the cooperation and stewardship of recharge areas by landowners and local inhabitants. Protection of recharge areas is essential to prevent extinction of the species. Thus, it is necessary to develop and conduct a long term, public information program focusing on karst groundwater resources and karst terrains, including: karst groundwater quality and contamination, pollution impacts and preventative measures, protection of aquatic cave and shallow groundwater communities, and endangered species legislation, species protection, and recovery.

4.1. Hire a permanent full time karst resource coordinator, to be housed in the Illinois Sinkhole Plain, to implement the education program and other outreach duties. This person should have the training and experience necessary to implement an education program, e.g. familiarity with karst and karst issues, knowledge of Best Management Practices for avoiding impacts to karst groundwater from agriculture, domestic waste management and residential use of pesticides and herbicides. Suggested duties include the following.

Work with schools in the Salem Plateau to incorporate karst and groundwater related educational material into their curricula.

Develop and implement a karst-related educational program geared toward local politicians, civic leaders, developers, farmers, planners and land managers.

Plan, organize and conduct field tours and informational seminars geared toward all public sectors that address water quality and karst related issues.

Write, publish, and distribute public informational news releases, flyers, and/or newsletters which highlight accomplishments of the recovery team as well as other noteworthy events relating to karst and karst groundwater in the Salem Plateau.

Advise and assist regulatory and political entities on ways to make regulations/laws and their implementation more consistent with best management practices in the Salem Plateau karst.

Develop, maintain, and refine a detailed list of best management practices (BMP’s) for use in the area.

Enroll in the Groundwater Guardian program and develop a local program.

Assist farmers, landowners, and developers with access to information and implementation of groundwater protecting BMP’s.

Maintain an extensive database on sinkholes and other karst features. Information regarding features should be collected and then entered along with map coordinates in the county Geographic Information System (GIS).

Enhance cooperation among agencies.

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IV. GLOSSARY

Terms Relevant to the Southwestern Illinois Sinkhole Plain

Aquifer: a body of rock or sediment that will yield a useable quantity of water to a well or spring. A karst aquifer is one whose porosity and permeability are dominated by interconnected conduits (e.g., joints, fractures, crevices, caves, tubes) that were enlarged by dissolution of the surrounding, relatively impermeable rock. Karst aquifers are characterized by extremely rapid recharge and rapid, often turbulent flow of water through the conduits at velocities comparable to those of surface streams.

Cave: a naturally occurring void in earth materials, which is humanly enterable for at least twenty feet.

Cave system: an assemblage of karst features that may contain multiple caves, water inlets, and springs that are all related speleogenetically. For management purposes, the cave system is generally the category of interest. The fauna and the water in the system are rarely restricted by the condition that it is impassable to people.

Cave recharge area: the land that contributes water to a particular cave.

Groundwater: water that is naturally stored in or transmitted through earth materials.

Groundwater basin: synonym for recharge area.

Groundwater system (karst): the karst conduits and the bedrock in which they are formed that hydrologically connect recharge features to their springs, which are the downstream terminus of a groundwater system. In map view, groundwater system boundaries are generally identical to those of recharge area, however, the groundwater system is only in the subsurface.

Karst: a three-dimensional landscape underlain by soluble rocks and having appreciable groundwater flow through dissolved out openings (internal drainage) in the rock.

Karst valley: a valley that is like an ordinary valley on the upper slopes, but has sinkholes in the bottom draining it. The sinkholes are often aligned along the valley bottom.

Macrohabitat: a habitat of sufficient extent to present considerable variation of environment, contain varied ecological niches, and support a large complex flora and fauna.

Macroinvertebrate: an invertebrate animal (animal without a backbone) large enough to be seen without magnification.

Microhabitat: a precise location within a habitat where an organism is usually found.

Rimstone pools: usually made up of relatively small pools of water rimmed by dams made of calcium carbonate that precipitate from the mineral-laden cave water. Rimstone pools form when the water seeping into a cave is saturated with calcite and other carbonate minerals and flows over a naturally rough surface.

Sinkhole (geologic): a natural, closed depression in the surface of the earth; having internal drainage. All land draining into a sinkhole is part of the sinkhole. Monroe and Randolph Counties have a somewhat different definition written into their regulations. This is the definition used for labeling restrictions for agricultural chemicals.

Sinkhole Plain: the Sinkhole Plain located in southwestern Illinois, is an area with an abundance of sinkholes. The Sinkhole Plain, which covers parts of three counties, contains a total of about 10,000 sinkholes with densities up to 230 sinkholes per square mile.

Troglobitic: see troglobite.

Troglobite: an obligate cave dweller that lives and reproduces only in caves. Some define these as those animals living in terrestrial (dry) environments in caves.

Water table: that level in a shallow well or opening in the earth where you find standing water (groundwater).

V. IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines actions and estimated costs for the recovery program. It is a guide for meeting the objectives discussed in Part II of this Plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. These actions, when accomplished, should lead to the recovery of the species and protect its essential habitat. The estimated funding needs for all parties anticipated to be involved in recovery are identified, and, therefore, Part V reflects the total estimated costs for the 20-year recovery program for this species. If delisting occurs, a minimum of five years of monitoring is required by the Act to assess the adequacy of recovery actions and determine if there will be cause to consider relisting.

Priorities in the first column of the following Implementation Schedule are assigned as follows:

Priority 1: An action that ***must*** be taken to prevent extinction or to prevent the species from declining irreversibly in the ***foreseeable*** future.

Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to meet the recovery objectives.

Abbreviations:

FWS - U.S. Fish and Wildlife Service
FWS- PL - U.S. Fish and Wildlife Service, Division of Refuges, Private Lands
FWS- EQ - U.S. Fish and Wildlife Service, Division of Environmental Quality
ILDNR - Illinois Department of Natural Resources
ILEPA - Illinois Environmental Protection Agency
NRCS - Natural Resource Conservation Service, U.S. Department of Agriculture
SWCD - Soil and Water Conservation District, IL Dept. of Agriculture
USEPA - U.S. Environmental Protection Agency

IMPLEMENTATION SCHEDULE FOR ILLINOIS CAVE AMPHIPOD

Priority	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
1	1.1.1	Encourage voluntary best management practices and land use protection plans through land owner contacts using incentives from existing USDA tools such as EQUIP, CRP, Rural Development, and others, and promoting new programs specific to the Sinkhole Plains.	Ongoing	NRCS SWCD FWS-PL	1000	50	50	50	
1	1.1.2	Encourage development of a board (Local Ecosystem Marketing Board) that works toward a strong coordinated marketing program highlighting the special needs of this area and its ecosystem, along with the Best Management Practices and preservation of agricultural lands.	Ongoing	SWCD County Private	100	5	5	5	
1	1.2.1.1	Bring new and existing sewage treatment facilities (public and private) standards protective of Karst groundwater.	Ongoing	USEPA ILEPA County Private	2000	100	100	100	
1	1.2.5.	Encourage development of residential land use plans and regulations which would prevent perturbations to lands and its groundwater system. Provide cost share to demonstrate alternative, better systems	Ongoing	ILEPA County Private	500	25	25	25	

IMPLEMENTATION SCHEDULE FOR ILLINOIS CAVE AMPHIPOD

Priority	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
1	1.3.4.	Utilize measures to assist with controlling access to caves.	Ongoing	ILDNR Private	200	10	10	10	
1	1.3.7.	Delineate all sinkholes and surface recharge areas in the Columbia, Waterloo, and Renault Sub-regions of the Illinois Salem Plateau	5	All	125	25	25	25	
1	3.1.1	Conduct studies aimed at increasing understanding of the biology and ecology of *G. acherondytes*, including life history, behavior, and population level genetics.	5	ILDNR FWS	175	35	35	35	
1	3.2.1	Conduct surveys to define the species' range.	5	ILDNR FWS	125	25	25	25	
1	3.2.2	Delineate all groundwater basins within the range of *G. acherondytes*.	5	ILDNR FWS	250	50	50	50	
1	3.3.1	Quantitatively monitor population status of *G. acherondytes*.	20	ILDNR FWS	1000	50	50	50	
1	4.1	Hire a permanent full time karst resource coordinator, located in the Sinkhole Plain, to implement the education program and other outreach activities.	Ongoing	ILDNR County	1500	75	75	75	
2	1.2.1.3	Encourage development of a regional sewer district with a centralized sewage treatment system.	5	ILEPA County	25	5	5	5	

IMPLEMENTATION SCHEDULE FOR ILLINOIS CAVE AMPHIPOD

Priority	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
2	1.2.2.2.	Discourage inappropriate industry from locating in karst topography	Ongoing	ILEPA County	100	5	5	5	
2	1.2.3.1	Encourage enforcement of regulations pertaining to dumping of waste in sinkholes and other karst features. Implement a program to clean-up existing sinkholes.	5	ILEPA County	50	10	10	10	
2	1.2.4.1	Encourage use of above-ground storage facilities in the Sinkhole Plain.	Ongoing	ILEPA County	40	2	2	2	
2	1.2.4.2	Coordinate with response agencies to ensure that spills of toxic substances from traffic accidents or other sources do not enter the groundwater system.	3	ILEPA FWS-EQ County	6	2	2	2	
2	1.3.1	Discourage publicizing names of specific caves, entrances, or entrance locations.	Ongoing	All	0	0	0	0	
2	1.3.3	Reduce the potential impacts of visitation in Illinois Caverns.	5	ILDNR	75	15	15	15	
2	3.1.2	Assess potential adverse effects of contaminants and other water quality factors on Illinois cave amphipod	5	ILDNR FWS	125	25	25	25	
2	3.3.2	Monitor and evaluate trends in land use practices.	20	ILDNR FWS NRCS	100	25	0	0	every 5 years

IMPLEMENTATION SCHEDULE FOR ILLINOIS CAVE AMPHIPOD

Priority	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
2	3.3.3	Monitor water quality both above ground and in shallow karst aquifers within the known range of G. acherondytes.	20	ILDNR FWS	400	100	0	0	every 5 years
3	1.2.1.2	Provide cost share to demonstrate alternative, better systems.	5	ILEPA County	125	25	25	25	
3	1.2.2.1.	Encourage adequate storm water control ordinances that deal with the unique features of a karst terrain are implemented and enforced.	5	NRCS ILEPA County	25	5	5	5	
3	1.3.2	Monitor visitation trends in selected caves containing *G. acherondytes*.	20	ILDNR	40	10	0	0	every 5 years
3	1.3.5	All caves should be mapped by qualified cavers with suitable experience in mapping techniques.	5	ILDNR Private groups	10	2	2	2	
3	1.3.6.	Researchers and cavers should be encouraged to locate new cave entrances.	Ongoing	ILDNR Private groups	0	0	0	0	
3	2.1.1	Assess the feasibility and suitability of restoring extirpated *G. acherondytes* populations to historical habitats.	3	ILDNR FWS	75	25	25	25	
3	2.2.1	Reintroduce *G. acherondytes* into historical habitats if feasible.	5	ILDNR FWS	125	25	25	25	

VI. TABLES

Table 1. Summary of 2001 Basin Community Census Data (Lewis 2001).

Site Name	Gammarus troglophilus	Gammarus acherondytes	Crangonyx forbesi	Bactrurus brachycaudus	Caecidotea packardi	Caecidotea brevicauda	Physella	Sphalloplana hubrichti
Annbriar Spring Basin								
5/28/01								
transect 1 (10 quadrats)	2	1	1	0	0	27	0	1
transect 1 rock count (17 rocks)	0	0	1	0	0	3	2	0
7/6/01								
transect 1 (10 quadrats)	9	1	13	0	0	3	1	3
transect 1 rock count (23 rocks)	0	0	0	0	0	2	0	1
Fogelpole Basin								
7/5/01								
transect 1 (10 quadrats)	5	0	0	0	0	154	0	0
transect 1 rock count (16 rocks)	0	0	0	0	1	17	0	1
transect 2 (10 quadrats)	5	0	0	0	0	142	0	0
transect 2 rock count (24 rocks)	0	0	0	0	0	16	3	0
9/28/01								
transect 1 (10 quadrats)	44	17	0	0	0	116	0	0
transect 1 rock count (15 rocks)	7	0	0	0	0	9	10	1

Table 1. Summary of 2001 Basin Community Census Data (Lewis 2001).

Site Name	Gammarus troglophilus	Gammarus acherondytes	Crangonyx forbesi	Bactrurus brachycaudus	Caecidotea packardi	Caecidotea brevicauda	Physella	Sphalloplana hubrichti
Frog Basin								
5/26/01								
transect 1 (10 quadrats)	5	6	0	0	0	49	0	0
transect 1 rock count (14 rocks)	0	0	0	0	2	15	0	0
transect 2 (10 quadrats)	19	21	0	0	0	66	0	1
transect 2 rock count (13 rocks)	3	4	1	0	0	22	0	0
7/4/01								
transect 1 (10 quadrats)	3	20	0	0	3	17	1	0
transect 1 rock count (17 rocks)	0	6	0	0	0	12	0	0
transect 2 (10 quadrats)	3	33	2	0	2	46	0	6
transect 2 rock count (18 rocks)	0	1	0	0	1	7	0	0
Illinois Caverns Basin								
7/3/01								
transect 1 (10 quadrats)	8	1	0	0	0	1	0	0
transect 1 rock count (21 rocks)	2	0	0	1	0	0	0	1
transect 2 (10 quadrats)	14	3	0	1	4	18	0	0
transect 2 rock count (33 rocks)	0	0	0	0	1	1	0	1

Table 1. Summary of 2001 Basin Community Census Data (Lewis 2001).								
Site Name	Gammarus troglophilus	Gammarus acherondytes	Crangonyx forbesi	Bactrurus brachycaudus	Caecidotea packardi	Caecidotea brevicauda	Physella	Sphalloplana hubrichti
9/2/01								
transect 1 (10 quadrats)	9	3	0	0	1	0	0	0
transect 1 rock count (21rocks)	1	0	0	0	1	0	0	0
transect 2 (10 quadrats)	4	4	0	0	0	8	0	0
transect 2 rock count (21 rocks)	0	0	0	0	2	0	0	0
Krueger-Dry Run Basin								
7/2/01								
transect 1 (10 quadrats)	16	0	2	0	1	57	0	3
transect 1 rock count (25 rocks)	0	0	0	0	0	10	0	1
transect 2 (10 quadrats)	10	0	2	0	3	124	0	17
transect 2 rock count (22 rocks)	0	0	0	0	1	15	0	1
9/1/01								
transect 3 (10 quadrats)	1	0	0	0	1	38	0	7
transect 3 rock count (16 rocks)	0	0	0	0	0	7	0	0
transect 4 (10 quadrats)	0	0	0	0	0	9	0	0
transect 4 rock count (18 rocks)	0	0	0	1	0	1	0	0

Table 1. Summary of 2001 Basin Community Census Data (Lewis 2001).								
Site Name	Gammarus troglophilus	Gammarus acherondytes	Crangonyx forbesi	Bactrurus brachycaudus	Caecidotea packardi	Caecidotea brevicauda	Physella	Sphalloplana hubrichti
Pautler Basin								
5/26/01								
transect 1 (10 quadrats)	8	4	1	0	1	9	2	0
transect 1 rock count (1 rock)	0	0	0	0	1	2	0	0
transect 2 (10 quadrats)	16	13	3	0	0	3	0	0
transect 2 rock count (12 rocks)	4	0	0	0	2	4	2	0
Paultler Basin								
9/26/01								
transect 1 (10 quadrats)	22	6	4	0	1	24	0	0
transect 1 rock count (1 rock)	0	0	0	0	0	0	0	0
transect 2 (10 quadrats)	11	13						
transect 2 rock count (15 rocks)	0	0	0	0	3	1	0	0

Table 2. SUMMARY OF 2001 BASIN COMMUNITIES IN ILLINOIS EXPLORATION DATA (Lewis 2001).

Site Name	Gammarus troglophilus	Bactrurus brachycaudus	Caecidotea brevicauda	Sphalloplana hubrichti	Gammarus acherondytes	Crangonyx forbesi	Caecidotea packardi	Eurycea lucifuga
Luhr Spring Groundwater Basin, Monroe Co. Species Noted	X	X	X	X	X	X	X	X
Dual Spring Groundwater Basin, Monroe Co. Species Noted	X	X	X	X	X	X		X
Stemler Groundwater Basin, St. Claire Co. Species Noted	X		X	X		X		
Shivery Slither, Monroe Co. Species Noted	X	X	X	X				
Annbriar Spring Groundwater Basin, Monroe Co. Species Noted	X		X	X	X	X	X	X

APPENDIX 1

Summary of agency and public comment on the Illinois cave amphipod draft recovery plan

This appendix provides a summary of the comments the Service received during the comment period. On August 4, 2002, the U.S. Fish and Wildlife Service released the Illinois Cave Amphipod Draft Recovery Plan for public comment. The comment period ended on September 5, 2002.

Three letters commenting on the draft and two peer review letters were received. Two of the public comment letters were received from Farm Bureaus and one from a conservation group. These comments have been considered and have generally been incorporated into the approved recovery plan. In general, the commentors support the proposals put forth for recovery of the Illinois cave amphipod.

Most letters requested explanation of various points made in the draft plan and included suggestions for clarity, other information sources, or future research. A general summary of the comments are listed below with our response.

Comment 1: The statement, "Agricultural land use employing best management practices may offer greater protection for the Illinois cave amphipod than alternative developments such as subdivisions or industrial complexes", is important and should receive greater emphasis in the plan.

Service response: We concur that this is an important point and have included it as a Recovery Strategy.

Comment 2: Delineation of all groundwater basins within the range of the amphipod should receive a priority of (1).

Service response: We concur that this is important along with identifying surface level sources for those basins and have changed its ranking and modified the text accordingly on the implementation schedule.

Comment 3: There is no allowance for study of population level genetics.

Service response: This has been added to Task 3.1.1. and we concur with its need to receive a priority ranking of (1).

Comment 4: Though we know very little about the biology or life history of this species, little attention or funding was given to this topic in the Recovery Tasks. For example, understanding seasonality of reproduction and recruitment can help determine sensitive periods of the year for the Illinois cave amphipod and potential cues that elicit reproduction.

Service response: We concur that increasing our knowledge regarding the biology and life history of the species is integral to its recovery. Greater emphasis was placed in this area in the Recovery Tasks for the final document.

Comment 5: We are concerned about lack of adequate data and how it relates to the original listing of the species. The recovery section, however, appears logical.

Service response: The Illinois cave amphipod was determined to be an endangered species pursuant to the Endangered Species Act of 1973 based on analysis of the five listing factors using the best available information at the time (63FR46900). The listing status may be reviewed at any time based on new information in the context of the five listing factors and a change in status may be proposed if appropriate. Based on threats we know to date, we believe that the species is endangered and that pursuit of recovery actions as outlined in this Recovery Plan is merited.

Comment 6: References to best management practices should be stated as voluntary.

Service response: We have clarified that Recovery Task under 1.1.1 to state, "Encourage voluntary best management practices...".

Comment 7: To require 100% compliance with best management practices for recovery will be difficult if not impossible to reach or determine.

Service response: We concur that this statement does not seem reasonably attainable and have modified the recovery criteria accordingly.