Best Management Practices for Maintaining Sinkhole Ponds as Amphibian Habitat in the Sinkhole Plain of Southwestern Illinois

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Introduction

Twenty-four species of frogs, toads and salamanders are known to inhabit the karst regions of southwestern Illinois (Smith 1961, Phillips et al., 1999). Two of the 24 amphibian species are listed as state threatened or endangered; eastern narrowmouth toad, *Gastrophryne carolinensis* (T), and Strecker's chorus frog *Pseudacris illinoensis* (E). Two species, the wood frog (*Lithobates sylvaticus*), and the pickerel frog (*Lithobates palustris*), are identified as species of conservation concern in the Illinois Wildlife Action Plan (IDNR, 2005).

All amphibians possess thin, permeable skin that they use for respiration. To function as an organ of respiration the amphibian's skin must be kept moist. Because of this, amphibians are dependent on water and moisture and are usually found in or near water sources, or in very moist microhabitats. Thin permeable skin and aquatic lifestyles make amphibians are very sensitive to environmental pollution and disturbances (Jensen et al. 2008). As such, they are good indicators for the overall health of an ecosystem. If amphibians are absent or declining in an area, that may be an indication of environmental pollution or habitat degradation.

Amphibian populations the world over are experiencing precipitous declines from a multitude of factors, including climate change, disease, pollution, and habitat degradation (Gardner 2001). Two emerging diseases, one caused by a virus (Ranaviral disease) and one by a fungus (chytridiomycosis), are decimating amphibian populations even in pristine habitats (Daszak et al., 1999). According to a 2008 report by the International Union for Conservation of Nature and Natural Resources nearly 1/3 (32%)

of the world's amphibian species are in danger of extinction in the immediate future (IUCN, 2010). In North America a principle thread to amphibians is habitat loss (Lannoo, 2005). Many of the ephemeral ponds that serve as amphibian breeding habitat have been filled in or otherwise destroyed, and adjacent forest habitat likewise destroyed or fragmented (Baldwin et al. 2006, Trauth et al. 2006).

Though often overlooked by the average person, amphibians are vital components of their ecosystem, and provide an important link between aquatic and terrestrial ecosystems, in particular through nutrient transfer (Regester et al. 2006). This is because of their dual lifestyle in which the adults are terrestrial or semi-aquatic, but are dependent on aquatic systems for egg deposition and larval maturation. Amphibians play a role in the control of insects, preying upon both adults and larval stages, and as prey for larger animals such as raccoons, snakes, and turtles. From an aesthetic standpoint, many people enjoy listening to choruses of calling frogs on warm spring and summer evenings, and this timeless natural symphony is in jeopardy of vanishing.

In areas of karst topography, including the sinkhole plain of southwestern Illinois, sinkhole ponds provide excellent habitat for breeding amphibians, as most are naturally fishless and are often surrounded by sheltering forest habitat. However, anthropogenic modifications can reduce the suitability of this habitat for amphibians, particularly during the breeding phase of their life cycles. Vegetation is often cleared around the perimeter of ponds, reducing the amount of habitat for adults, and resulting in increased erosion and sedimentation, which negatively impacts water quality. Agriculture is a major industry in many karst areas. Some common agricultural practices can negatively impact sinkhole ponds as amphibian habitat. Pesticides can contaminate ponds and harm amphibians (Szafoni et al. 2002). Livestock can increase water turbidity by churning up silt and mud and cause nutrient pollution by introducing fecal and urinary waste. Fish, particularly sunfish like green sunfish and largemouth bass, can decimate amphibian populations in breeding ponds (Sexton and Phillips, 1986). Many naturally fishless sinkhole ponds are stocked with predatory sportfish by humans, and these fish make short work of both adult and larval amphibians, as well as their eggs.

Sinkhole ponds are highly variable in terms of size, hydrology, depth, aquatic vegetation, and many other factors. They can range from small ephemeral depressions less than 12 inches deep to large, permanent bodies of water more than 10 feet deep and more than a hundred feet across. This variation provides a slew of different habitats that cater to different species of amphibians and enables more species diversity in a region. The structure of sinkhole ponds is often similar to that of an inverted cone: they have steep sides that taper down to a deep bottom, and even ponds with a small surface area may have a depth of several meters or more. Often only a plug of mud or debris separated a sinkhole pond from the subterranean network of tunnels and waterways that constitute cave systems of karst regions. Because of this, sinkhole ponds will occasionally drain partially or completely into a cave or the underground aquifer. Likewise, the reverse also occurs, wherein ponds are supplied with a flow of water from underground sources. Dry sinkholes are open conduits that directly connect the surface watershed to the subterranean aquatic systems. The karst regions of southwestern Illinois contain the greatest number of caves in the state, including the most biologically important cave systems (Moss, 2009). As such, it is vital to protect sinkholes and sinkhole ponds from pollution and contamination as this can quickly contaminate entire aquifers and adversely impact both surface and subterranean wildlife, as well as humans.

Sinkhole ponds are a resource to both humans and wildlife. Larger ponds are often used by people for recreational purposes such as swimming and fishing. Ponds may also be used for irrigation for agriculture, and for watering livestock, or as retention ponds to collect runoff and effluent. Human development in rural areas often threatens the integrity of the sinkhole ponds and the underlying aquifer due to discharge from substandard or improperly maintained septic systems (Krohe 1999).

The karst portions of Monroe, St. Clair and Randolph counties in southwest Illinois, together with the adjacent blufflands comprise the 130,625 acre Hill Prairie Corridor/ Karst Sinkhole Plain Conservation Opportunity Area (COA) (Figure 1) under the Illinois Wildlife Action Plan. Sinkhole ponds are abundant in this area (Figure 2), with more than 10,000 known. In some areas of the COA density may reach 100-200 sinkholes per square mile (Panno et al. 2008). The purpose of this study is to determine best management practices for maintaining sinkhole ponds as amphibian habitat in the Hill Prairie Corridor/ Karst Sinkhole Plain COA. The study was conducted in support of three Southwestern Illinois Wildlife Action Plan goals; Goal 3: Restore and maintain wetland areas, with emphasis on their significance as breeding areas for species in greatest need of conservation, to include herpetofauna and avifauna, Goal 4: Increase karst area protection, and Goal 5: Encourage landholders and policy makers to adopt sound land and wildlife management practices (SWIWAP).

Methods and Results

During the course of this project seven sinkhole ponds in St. Clair and Monroe counties were visited (Figure 1) between 25 May and 27 May, 2010 to experience the diversity of pond habitats and amphibian communities. Each pond was sampled for amphibians (both adults and larvae), observations were made about surrounding vegetation, and physical data were recorded (Table 1, Appendix 1). Sampling methods incorporated the use of seines, dipnets, listening for calls, and hand capture to ascertain what species were present at each location. Twenty-one of the 24 species of amphibians known to occur in the study area are pond-breeding and would likely utilize sinkhole ponds as breeding habitat (Table 2). Scientific nomenclature used in this report follows the Center for North American Herpetology's current scientific names (CNAH).

During the field surveys, nine amphibian species were captured and identified, or identified via vocalizations on the margins of sinkhole ponds (Table 2). Both adult and larval amphibians were encountered. Each pond represented different characteristics (i.e. depth, vegetation, turbidity) and supported different amphibian species assemblages (Table 1). Two of the ponds surveyed had been stocked with fish. Both ponds were located in Monroe County. These were the largest ponds sampled and supported large populations of sport fish, as well as non-sport fish such as mosquitofish (*Gambusia affinis*) and fathead minnows (*Pimephales promelas*). The first of these sampled (McMahon Pond) supported large numbers of fish-tolerant frogs such as bullfrogs (*Lithobates catesbeianus*), leopard frogs (*Lithobates utricularius*), and cricket frogs (*Acris crepitans*). Adults, tadpoles, and frog eggs were found in this pond. The second pond (Caferetta Pond) had large numbers of bass, with many young fish caught in our seine nets. This pond had little evidence of amphibian life. No larval amphibians were observed. Newly metamorphosed American toads were the only amphibians observed. The landowner frequently observes large bullfrogs, though none were observed in our survey.

Two ponds supported populations of salamanders. Larvae of both the tiger salamander (*Ambystoma tigrinum*) and spotted salamander (*Ambystoma maculatum*) were found in Hollis Pond, a woodland sinkhole pond in St. Clair County. This pond supported six taxa of amphibians, the highest diversity in the field study. A specimen on the central newt (*Notophthalmus viridescens)* was collected in Daubach Pond, the smallest Monroe County pond sampled.

A literature search was conducted to garner references and research amphibians, karst, and the relationship between them. The collection of scientific literature at Southern Illinois University was utilized, as was their online access to journal databases such as JSTOR. Keywords used in search analyses included “amphibians in sinkhole ponds,” “amphibians in farm ponds,” “amphibians and karst,” and “karst topography.”

Discussion

The most important factors contributing to amphibian success and species diversity at a site are the absence of fish and the presence of border vegetation (Hecnar and M’Closkey 1997, Davidson and Knapp 2007). The vegetation around ponds provides vital habitat for adults and juveniles, slows runoff and prevents siltation, and leaches chemicals out of the water. Fish are aggressive predators of amphibian eggs, larvae and adults. Large sport fish such as bass (*Micropterus* spp.) are the most detrimental to amphibians, while small, native fishes such as *Gambusia* spp or *Pimephales* spp. may pose no threat. Larval toads, bullfrogs and some leopard frogs have skin toxins and or other defenses that allow them to survive the presence of fish (Szafoni, et al, 2002).

Studies indicate that the habitat surrounding a pond is crucial for adult amphibians, with some species requiring terrestrial habitat that extends for more than 100 meters beyond the edge of the breeding pond (Regosin et al. 2005). Newly transformed juveniles of some species have also demonstrated an aversion to terrestrial habitat that lacks canopy cover or is fragmented, such as edge habitat (deMaynadier and Hunter 1999). Regosin et al. (2007) recommend that the best method for conservation of pond breeding amphibians is the preservation of surrounding forest and maintaining connectivity between breeding sites. It has also been observed that breeding for species such as spotted salamanders (*Ambystoma maculatum*), is positively correlated with maturity and size of surrounding forest (Baldwin et al. 2006). Morris and Maret (2007) found that spotted salamanders and marbled salamanders (*Ambystoma opacum*) can recover from disturbances fairly quickly, and repatriated ponds situated in clear-cut forest after a decade of re-growth. This implies that altered habitat can be recovered, and that amphibians do possess some resilience to disturbances. Management of sinkhole ponds for amphibians should encompass not just the pond itself, but also the surrounding landscape. Maintaining border vegetation around ponds provides habitat, prevents erosion and siltation of the pond, and helps to filter pollutants in runoff. Siltation can quickly disrupt the chemistry of a pond, lowering the dissolved oxygen content and clouding the water. These are conditions that are unfavorable for amphibians, which depend on high oxygen for transdermal respiration (Jensen et al. 2008). In addition to maintaining living vegetation, it is beneficial to amphibians to leave logs, leaf litter, rocks and other natural cover in place (Szafoni, et al, 2002).

Some species of amphibians benefit from varying hydroperiods, wherein breeding ponds are not permanent bodies of water (Cunningham et al. 2007). Occasional pond drying precludes predatory fish from colonizing the pond, and also may discourage the presence of other aquatic predators such as turtles. Sinkhole ponds can be very ephemeral, drying quickly in the absence of regular rainfall (figure 3). Some sinkhole ponds experience periodic "failures" when the sediment plug at the bottom of the sinkhole collapses into a void and the pond drains (figure 4). This can be disturbing to the landowner who may view a pond as permanent. Most naturally drained sinkhole ponds eventually form a new sediment plug and refill with water. Assemblages of amphibians also are known to change from year to year as conditions and precipitation affect hydrology of ponds, catering to the needs of different species in different years (Church 2008). Such natural fluctuations are a vital facet contributing to the diversity of amphibians in a region, and they should not be interrupted.

Sinkhole ponds are commonly found on farms in the COA. Agricultural ponds are known to serve as habitat for amphibians and to bolster their populations, provided that fish are absent (Knutson et al. 2004). However, agricultural activities can also poses a potential threat to amphibians from pesticides. Pesticides have been shown to have an even more detrimental effect when present in combination with other stressors, including fish (Davidson and Knapp 2007). Agricultural runoff can filter into sinkhole ponds and chemicals such as Atrazine are known to cause severe developmental problems in amphibians (Semlitsch 2000). Un-mowed grassy borders around sinkholes can help prevent agricultural runoff from adversely affecting water quality in sinkhole ponds. Many farmers use sinkhole ponds for watering livestock. This can prove detrimental to the integrity of the pond itself as hoofed animals churn up the soil and contribute to erosion and siltation of the pond (figure 5). Fecal waste from livestock can cause eutrophicaton of ponds, leading to hypoxia. It is recommended that livestock be kept from sinkhole ponds if possible, or their access limited. If multiple ponds are available select at least one for protection by fencing.

Many landowners prefer to incorporate their ponds into an aesthetic landscape, and submerged aquatic vegetation/algae control is a high priority for them. Based on our field observations, copper sulfate is a chemical commonly used in the study area to control algae growth in ponds, but this algaecide is very toxic to amphibians and invertebrates (USGS, 1998). Because sinkhole ponds are hydrologically connected to the rest of the karst landscape, the use of copper sulfate poses a threat to many aquatic organisms beyond pond. There are state and federally endangered invertebrates, such as the Illinois cave amphipod (*Gammarus acherondytes*) and the Eastern Ozark cave snail (*Fontigens antroecetes*), within the subterranean aquifer that could be adversely affected by the use of this chemical (Krohe 1999). Alternative methods of controlling algae are highly recommended and include cost efficient and ecologically friendly means such as alfalfa balls. These are commonly used in small ornamental ponds as natural algaecides and possess no toxic nature. They have been used to good effect even in large ponds. Another algae control method that is not detrimental to amphibians is aeration of the pond. In fact, this may prove beneficial to amphibians by improving water quality and dissolved oxygen content. Aquashade is a dye that can be added to ponds to reduce algal growth by reducing the amount of light that penetrates the water column. This product appears to be amphibian-friendly. For landowner who wish to introduce emergent vegetation and border plants a list of native Illinois aquatic plants that benefit amphibians and be found in the Illinois Landowner's Guide to Amphibian Conservation (Szafoni, et al, 2002). This list includes attractive flowering plants such as pickerelweed (*Pontederia cordata*), water lily (*Nymphaea tuberosa*) and buttonbush (*Cephalanthus occidentalis*). Submerged and emergent aquatic vegetation can increase survival rates of amphibians in ponds where fish are present.

Sinkhole ponds are an important component of the larger karst landscape. They are at once both isolated and interconnected, and offer vital habitat to amphibians and other wildlife. In the face of global declines in amphibian populations, landowners in the Hill Prairie Corridor/Karst Sinkhole Plain Conservation Opportunity Area should consider the following recommendations when managing sinkhole ponds:

- Do not stock fishless ponds with predatory fish
- Plant native aquatic vegetation in existing fish ponds
- Avoid mowing or brush cutting around sinkhole ponds
- Leave downed logs and natural debris around pond margins
- Use only amphibian-friendly algae control methods
- Restrict livestock access to sinkhole ponds that support amphibians
- Remember the relationship between sinkholes, sinkhole ponds, and the underlying karst aquifer.

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Figures and Tables

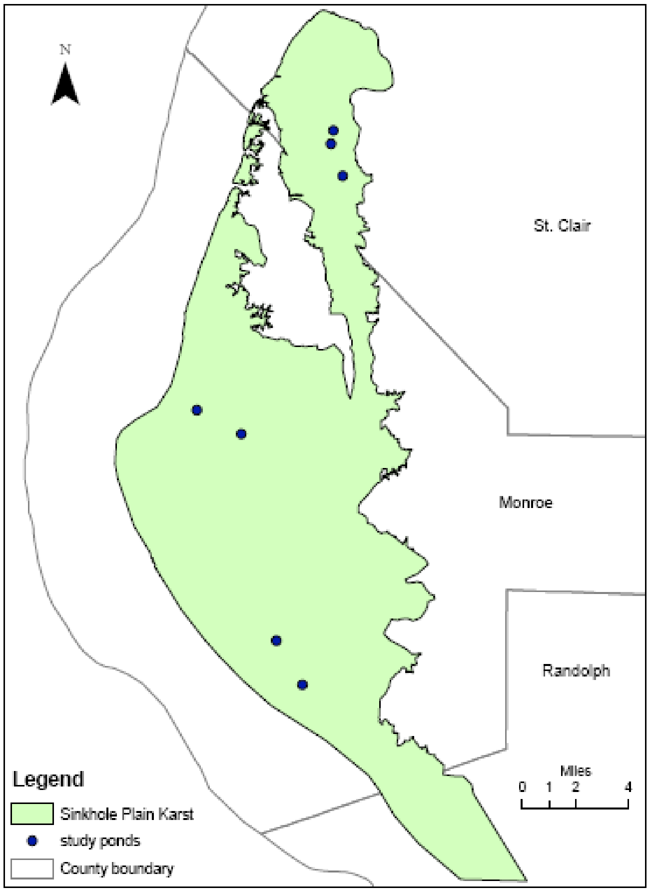

Figure 1. Sinkhole ponds sampled within the Hill Prairie Corridor/Karst Sinkhole Plain Conservation Opportunity area.

Figure 2. Numerous sinkholes and sinkhole ponds are seen in this aerial photo of a farmstead in the karst sinkhole plain of southwestern Illinois.

Figure 3. A sinkhole pond that dried up in late spring. This pond is used as a breeding site by several species of frogs and toads in early spring. Photo by Bob Weck.

Figure 4. An example of a large sinkhole pond that failed suddenly. Photo by Bob Weck.

Figure 4. Increased turbidity and fecal contamination due to livestock activity reduces the ability of this small sinkhole pond to support amphibians. Photo by Bob Weck.

Table 1. Summary of important sinkhole pond properties examined in this study.

Pond name	County	Depth	Temp.	Dimensions	Adult Amphibian Taxa	Larval Amphibian Taxa	Fish
Daubach	Monroe	20"	68° F	48’ X 52’	2	1	absent
McMahon	Monroe	unknown	78° F	small lake	2	2	present
Caffereta	Monroe	unknown	78° F	small lake	1	0	present
D’Angelo	Monroe	14"	80° F	115’ X 150’	0	1	absent
Hollis	St. Clair	5'	77° F	81’ X 92’	3	4	absent
Weck	St. Clair	6"	85° F	16’ X 32’	2	2	absent
Krim	St. Clair	3'	73° F	130’ X 160’	2	2	absent

Table2. Pond breeding amphibians known from Karst Sinkhole Plain area. (E) indicate Illinois state endangered and (T) indicate state threatened.

Scientific Name	Common Name	County Occurrence	Encountered During Survey
Ambystoma maculatum	Spotted salamander	Monroe, St. Clair	yes
Ambystoma opacum	Marbled salamander	Monroe, Randolph	no
Ambystoma texanum	Smallmouth salamander	Monroe, Randolph, St. Clair	no
Ambystoma tigrinum	Tiger salamander	Monroe, Randolph, St. Clair	yes
Notophthalmus viridescens	Eastern newt	Monroe, St. Clair	yes
Anaxyrus americanus	American toad	Monroe, Randolph, St. Clair	yes
Anaxyrus fowleri	Fowler's toad	Monroe, Randolph, St. Clair	no
Acris crepitans	Cricket frog	Monroe, Randolph, St. Clair	yes
Hyla chrysoscelis/versicolor	Gray Treefrog complex	Monroe, Randolph, St. Clair	yes
Pseudacris crucifer	Spring peeper	Monroe, Randolph, St. Clair	yes
Pseudacris illinoensis (E)	Illinois chorus frog	Monroe	no
Pseudacris triseriata	Western chorus frog	Monroe, Randolph, St. Clair	no
Gastrophryne carolinensis (T)	Eastern narrowmouth toad	Monroe, Randolph	no
Scaphiopus holbrookii	Eastern spadefoot	Monroe, St. Clair	no
Lithobates blairi	Plains leopard frog	Monroe, Randolph, St. Clair	no
Lithobates catesbeianus	Bullfrog	Monroe, Randolph, St. Clair	yes
Lithobates clamitans	Green frog	Monroe, Randolph, St. Clair	no
Lithobates palustris	Pickerel frog	Monroe, Randolph, St. Clair	no
Lithobates utricularius	Southern leopard frog	Monroe, Randolph, St. Clair	yes
Lithobates sylvaticus	Wood frog	Monroe	no

Appendix 1: Individual Pond Data sheets.

St. Clair County Sinkhole Pond Survey Date: May 25, 2010 Researchers: Bob Weck and Simon Bade	
Pond Location: N38.44826° W90.15259° Landowner: Mike and Jenny Krim	
Surrounding land use: Light agriculture and pastureland. Approximately 20 feet of border vegetation consisting of soft woods such as silver maple and persimmon trees.	
Environmental conditions: Sunny. 84% humidity. 73° F.	
Aquatic vegetation: Small amount of duckweed. Emergent willows, silver maple.	
Water turbidity: 14” Pond Dimensions:130’ X 160’	Pond depth: 3 feet Permanence: Semi-permanent
Border vegetation: Approximately 20 feet of border vegetation consisting of soft woods such as silver maple and persimmon trees. Smartweed and Beggar’s tick present.	
Adult amphibians present: Bullfrogs (*Lithobates catesbeianus*), American toads (*Anaxyrus americanus*)	
Larval amphibians present: *Pseudacris* spp., Southern Leopard Frogs (*Lithobates utricualrius*)	

St. Clair County Sinkhole Pond Survey	Date: May 25, 2010	Researchers: Bob Weck and Simon Bade
Pond Location: N38.46592 W90.16100 Landowner: Bob and Nancy Weck		
Surrounding land use: Pasture		
Environmental conditions: Sunny. Water temperature 85° F.		
Aquatic vegetation: Sedges		
Water turbidity: 3” Pond Dimensions: 16’ X 32’		Pond depth: 6” Permanence: Ephemeral
Border vegetation: 5-foot wide border of sedge and smartweed		
Adult amphibians present: Cricket frog (*Acris crepitans*), American toad (*Anaxyrus americanus*)		
Larval amphibians present: Chorus frogs (*Pseudacris triseriata*), American toads (*Anaxyrus americanus*)		
Notes: Heavy use by domestic animals (goats, llamas, horses), very turbid		

St. Clair County Sinkhole Pond Survey	Date: May 25, 2010	Researchers: Bob Weck and Simon Bade

Pond Location: N38.47322
W90.15932

Landowner: Rich and Gail Hollis

Surrounding land use: Pastureland/Woodland

Environmental conditions: Sunny. Water temperature 77° F.

Aquatic vegetation: Duckweed.

Water turbidity: 19”	Pond depth: Approx. 5 feet
Pond Dimensions: 81’ X 92’	Permanence: Semi-permanent

Border vegetation: Jewelweed and Beggar’s Tick in a 9-foot border. Mixed Hardwoods (Oak-Hickory) surrounding pond.

Adult amphibians present: Cricket frog (Acris crepitans), Gray tree frog (Hyla chrysoscelis), Bullfrog (Lithobates catesbeiana)

Notes:

Monroe County Sinkhole Pond Survey	Date: May 27, 2010	Researchers: Bob Weck and Simon Bade
Pond Location: N38.16795° W90.17856° Landowner: Terry and Cheryl McMahon		
Surrounding land use: Woods on ½, restored prairie and grape vineyard on other ½		
Environmental conditions: Sunny. Water temperature 78° F.		
Aquatic vegetation: Emergent buttonbush, black willow. No submergent or floating vegetation.		
Water turbidity: Turbid-14" Pond Dimensions: Small lake.		Pond depth: Deep-unknown. Permanence: Permanent
Border vegetation: Oak-hickory woods – 50 ft. border on North, West and East, Continuous on South.		
Adult amphibians present: Bullfrogs (Lithobates catesbeiana), Leopard frogs (Lithobates sphenocephala)		
Larval amphibians present: Bullfrogs (Lithobates catesbeiana), Cricket frog (Acris crepitans) egg mass		

Monroe County Sinkhole Pond Survey	Date: May 27, 2010	Researchers: Bob Weck and Simon Bade
Pond Location: N38.30576 W90.22229 Landowner: Howard Caffereta		
Surrounding land use: Residential on one side, forest and agriculture on others		
Environmental conditions: Sunny. Water temperature 78° F.		
Aquatic vegetation: Duckweed, American lotus, sedges.		
Water turbidity: 33” Pond Dimensions: Very large		Pond depth: 15’ Permanence: Permanent
Border vegetation: ½ mowed grass, ½ wooded.		
Adult amphibians present: Newly transformed American toads (*Anaxyrus americanus*)		
Larval amphibians present: None.		

Monroe County Sinkhole Pond Survey	Date: May 27, 2010	Researchers: Bob Weck and Simon Bade
Pond Location: N38.19224° W90.19691° Landowner: Carl and Pen Daubach		
Surrounding land use: Woodland (Oak-hickory forest)		
Environmental conditions: Sunny. 58% humidity. Air temperature 72° F. Water temperature 68° F.		
Aquatic vegetation: Duckweed.		
Water turbidity: Surface (Duckweed) Pond Dimensions: 48' X 52'		Pond depth: 20" Permanence: Permanent
Border vegetation: Fully vegetated Oak-Hickory to edge		
Adult amphibians present: Eastern Newt (*Notophthalmus viridescens*), Spring Peeper (*Pseudacris crucifer*)		
Larval amphibians present: *Pseudacris* spp.		
Notes: Surrounding woods managed by controlled burns, removal of invasive plants.		

Monroe County Sinkhole Pond Survey	Date: May 27, 2010	Researchers: Bob Weck and Simon Bade
Pond Location: N38.31888 W90.25360 Landowner: Mark D'Angelo		
Surrounding land use: Agricultural field on one side, restored forest on others		
Environmental conditions: Sunny. Water temperature 80° F.		
Aquatic vegetation: Emergent willows, grasses. Creeping primrose.		
Water turbidity: Tea colored but clear. Pond Dimensions: 115' X 150'		Pond depth: 14" Permanence: Permanent
Border vegetation: Willow, Beggar's tick		
Adult amphibians present: None		
Larval amphibians present: Pseudacris spp.		
Notes: Drainage from agricultural field empties into pond. Owner planted some vegetation around pond. Entire parcel was row crops in 1994.		