Cover Page

The Illinois chorus frog (*Pseudacris illinoensis*) and wetland mitigation: What has worked?

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A State Wildlife Grant Project

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Executive Summary

The purpose of this project was to examine three mitigation projects designed to produce habitat suitable for the Illinois chorus frog (*Pseudacris illinoensis*), a state threatened amphibian. The three projects are located in Madison, Morgan, and Cass Counties. There is a need to evaluate these completed projects to determine what the best mitigation strategies are for future mitigation efforts. The Morgan County site, which was the simplest management plan involving only pond construction, was a complete failure. The relatively simple Cass County plan resulted in breeding in 50% of the eight years that surveys have been conducted. Of these years the ponds persisted long enough for transformation in only 50% of these four years. Recruitment occurred in only two (25%) of the eight years that frog activity was monitored at Cass County. The Madison County site had an extensive restoration program conducted including wetland restoration, prairie restoration, hydrologic monitoring prior to pond construction, and extensive post mitigation management (prescribed fires and vegetation reintroductions). Frogs bred successfully at this site in 62.5% of the 16 years post construction. However, froglets and resulting recruitment was estimated at 50% of the years examined including the time period of this study. Thus, the simpler Cass County program and the much more complex Madison County program had roughly equal estimates of success. This assumes that recruitment is the valid measure of success. The two factors that both of these sites share is a good preconstruction survey that yielded an understanding of frog usage at the site and an understanding of the hydrology of the site to allow proper breeding pond construction. Thus, it appears that the keys to successful Illinois chorus frog mitigation are knowing where the frogs are and knowing how deep the ponds need to be to get water levels to last from March to June. Nonetheless, other restoration activities such as wetland restoration and prairie restoration along with public ownership of breeding and nonbreeding habitats may be required for long-term protection of the Illinois chorus frog.

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Introduction

Several attempts have been made to combine statutory wetland mitigation with efforts to preserve Illinois threatened and endangered species that need wetlands at some stage in their life cycle. Judging the effect and result of wetland mitigation follows well-established procedures (e.g. Bailey et al., 2006). Gauging the effect on target animal species, however, has had little comprehensive study (Pechmann et al., 1991). The purpose of this project was to examine three mitigation projects designed to produce habitat suitable for the Illinois chorus frog (*Pseudacris illinoensis*), a state threatened amphibian (Herkert, 1992). This study was designed to determine the level of habitat modification or wetland mitigation that is required to permit successful breeding by the Illinois chorus frog. Although only three sites have been selected they are unique, because previous mark/recapture efforts have been made at these sites. Such pre-project data are absolutely necessary to achieve the purpose of the project.

The Illinois chorus frog (*Pseudacris illinoensis*) is a small hylid anuran that has a unique fossorial life history (Brown, 1978; Brown et al., 1972; Tucker, 1997a). This frog is listed as threatened in Illinois (Herkert, 1992). It occupies sand prairie habitats (Brown and Rose, 1988; Paukstis and Brown, 1987), but breeds in wetland habitats that can border sand habitats. This species has a limited range in Illinois (Figure 1; Phillips et al., 1999), but also occurs in Arkansas and Missouri (Conant and Collins, 1998).

Several previous publications provided details on the life history of *Pseudacris illinoensis* including information on underground feeding behavior (Brown, 1978), burrowing behavior (Axtell and Haskell, 1977; Brown et al., 1972; Tucker, 1995; Tucker et al., 1995), chorus sites (Brown and Rose, 1988), fecundity (Butterfield et al., 1989; Trauth et al., 1990; Tucker, 1997b), post-metamorphic growth (Tucker, 1995), and morphological adaptations to fossorial existence (Brown et al., 1972; Brown and Means, 1984; Paukstis and Brown, 1987; 1991).

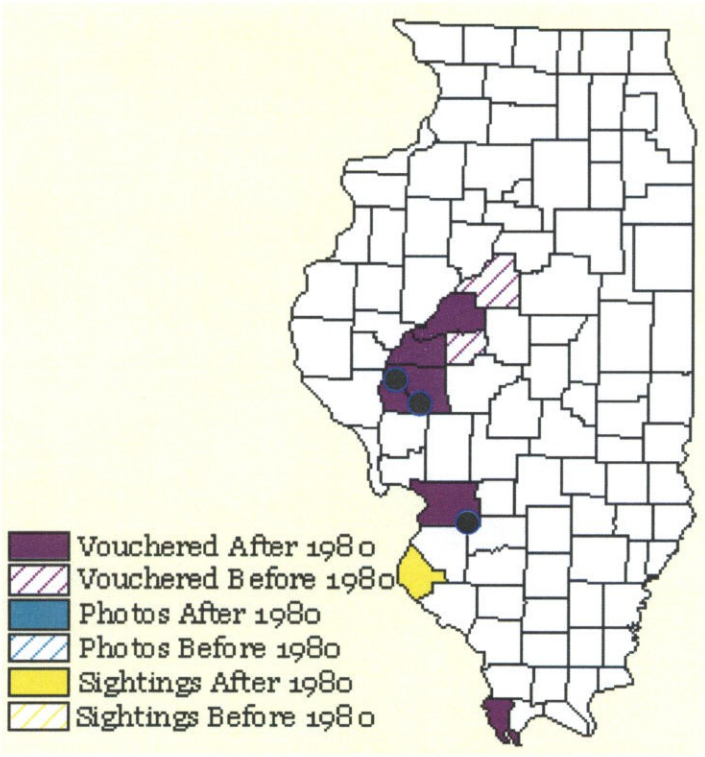

Figure 1. The distribution of the Illinois chorus frog (*Pseudacris illinoensis*) in Illinois. Map from WWW.inhs.uiuc.edu/cbd/collections/amprep. Black circles indicate approximate locations for each of the three sites.

Highway construction such as the improvements to U.S. Route 67 in Morgan and Cass Counties and construction of a new bridge across the Illinois River at Beardstown may have detrimental effects on the Illinois chorus frog. Projects designed to mitigate habitat loss for the Illinois chorus frog have been attempted. Three such projects have been completed in Illinois including one each in Madison (e.g., Tucker and Philipp, 1993, 1994, 1995, 1996, 1997; Tucker, 1998, 1999; 2000a, 2001, 2002a, 2003c, 2004b, 2005b), Morgan (Tucker, 2003b, 2005a, 2006a, 2007), and Cass Counties (Tucker, 2002a, 2003a; 2004a, 2006b and c). The response of the frog to these projects has not been completely determined. There is a need to evaluate these completed projects to determine what the best mitigation strategies are for future mitigation efforts. The question is what level of effort is needed to be successful? Is creating a breeding pond enough or is complete and expensive wetland and upland habitat restoration needed to create successful projects?

The need and value of analysis of mitigation efforts is supported by elements of the Illinois Comprehensive Wildlife Conservation Plan & Strategy (IL WAP). The Illinois chorus frog is a state threatened species (IL WAP X/Appendix 1/306) and a critical species in greatest need of conservation (IL WAP IV/B/134). Moreover the habitats where these mitigation projects are located are part of the Illinois River Sand Areas Natural Division (IL WAP IV/C/143). The Illinois chorus frog is listed as a critical species in this division (IL WAP IV/C/143). It is also important that three reptiles are also listed as critical species in this habitat. These include the ornate box turtle (*Terrapene ornata*), the Illinois mud turtle (*Kinosternon flavescens*), and the western hog-nosed snake (*Heterodon nasicus*). The latter two species are listed as state endangered and state threatened, respectively (IL WAP X/Appendix 1/306). Thus methods that are shown to be successful in mitigating habitat loss for the Illinois chorus frog may also be applicable to two other critical species.

Objectives

Objective 1. Construct characteristic matrix and identify management actions at each site from previously submitted reports and documents.

Objective 2. Survey mitigation sites for breeding activity.

Objective 3. Identify characteristics of sites with successful breeding.

Methods

Objective 1. The site examinations included examination of pond construction, hydrologic studies, effort made to ensure access to nonbreeding habitats, habitat restoration efforts, and acquisition of buffer zones to protect sites from agricultural encroachment, and the estimated costs to acquire, manage, and modify the site. Costs for each site are estimates made in consultation with project managers at each agency. These sources include Calvin Hance, Morgan County Highway Engineer, Tom Brooks, Illinois Department of Transportation, and Steve Johnson, US Army Corps of Engineers. Exact expenditures are difficult to arrive at because each project has extended over a number of years and many separate contracts have been completed.

The researcher is uniquely qualified to assess this because he was involved in planning site management for all three sites. Because sites vary in the degree of modification, breeding success can be used to identify successful sites. Thus, a preliminary assessment of the minimum management actions associated with successful mitigation can be given.

The three sites are briefly described here.

Morgan County: This site was selected to mitigate potential chorus frog habitat loss with the construction of Yeck Road in Morgan County. Three newly constructed wetland depressions were bulldozed into a small drainage ditch running west of the road (Fig. 1). These depressions were designed to act as ephemeral wetlands that would be suitable for breeding sites for anuran amphibians that breed in ephemeral fishless sites. Construction activities were completed by Morgan County.

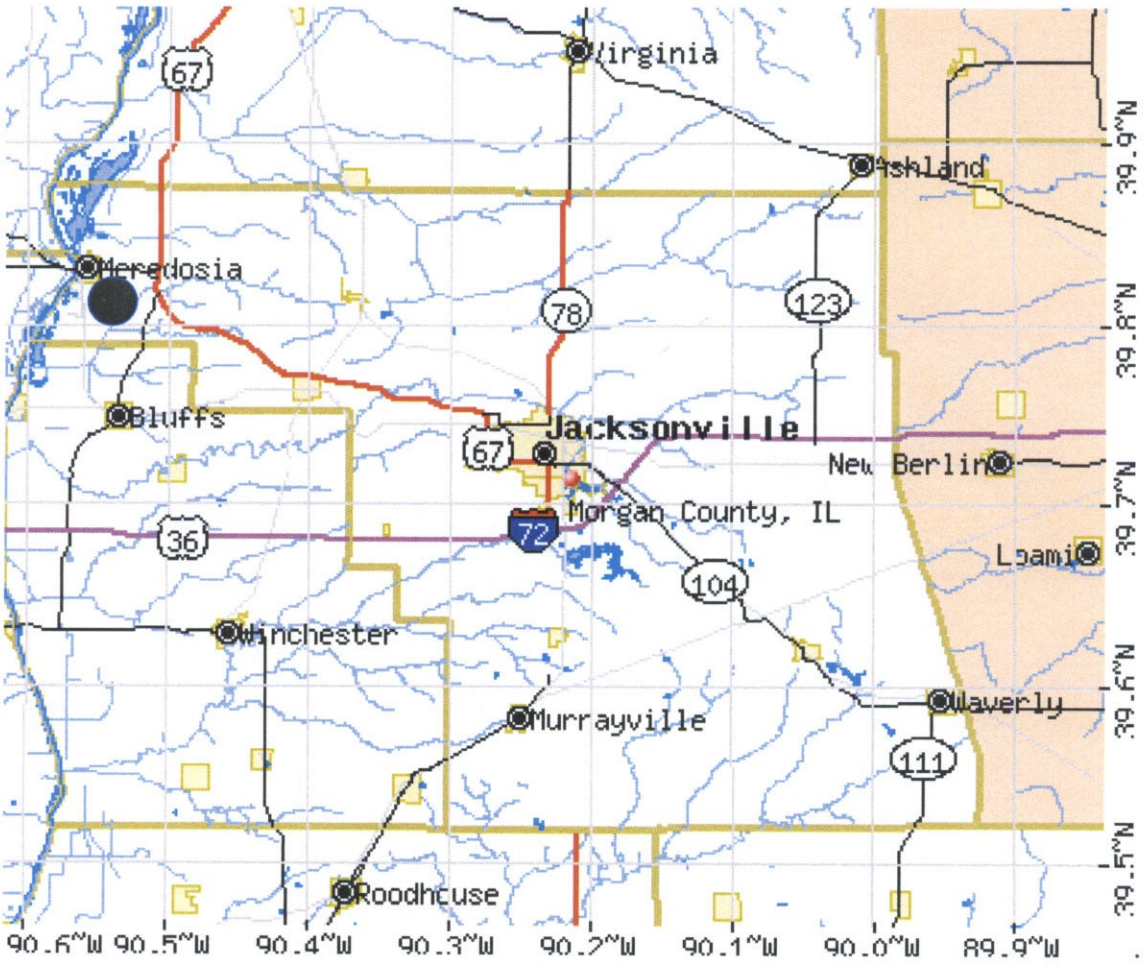

Figure 2. Map of Morgan County, Illinois. The black circle marks the location of the Morgan County Illinois chorus frog (*Pseudacris illinoensis*) mitigation site.

Cass County: This site was selected to mitigate possible Illinois chorus frog nonbreeding habitat due to off-channel deposition of main channel dredge material. The site is located on the east side of the Illinois River near Sixth Street in Beardstown, Illinois (Fig. 2). Two breeding ponds were constructed at the site by the U.S. Army Corps of Engineers.

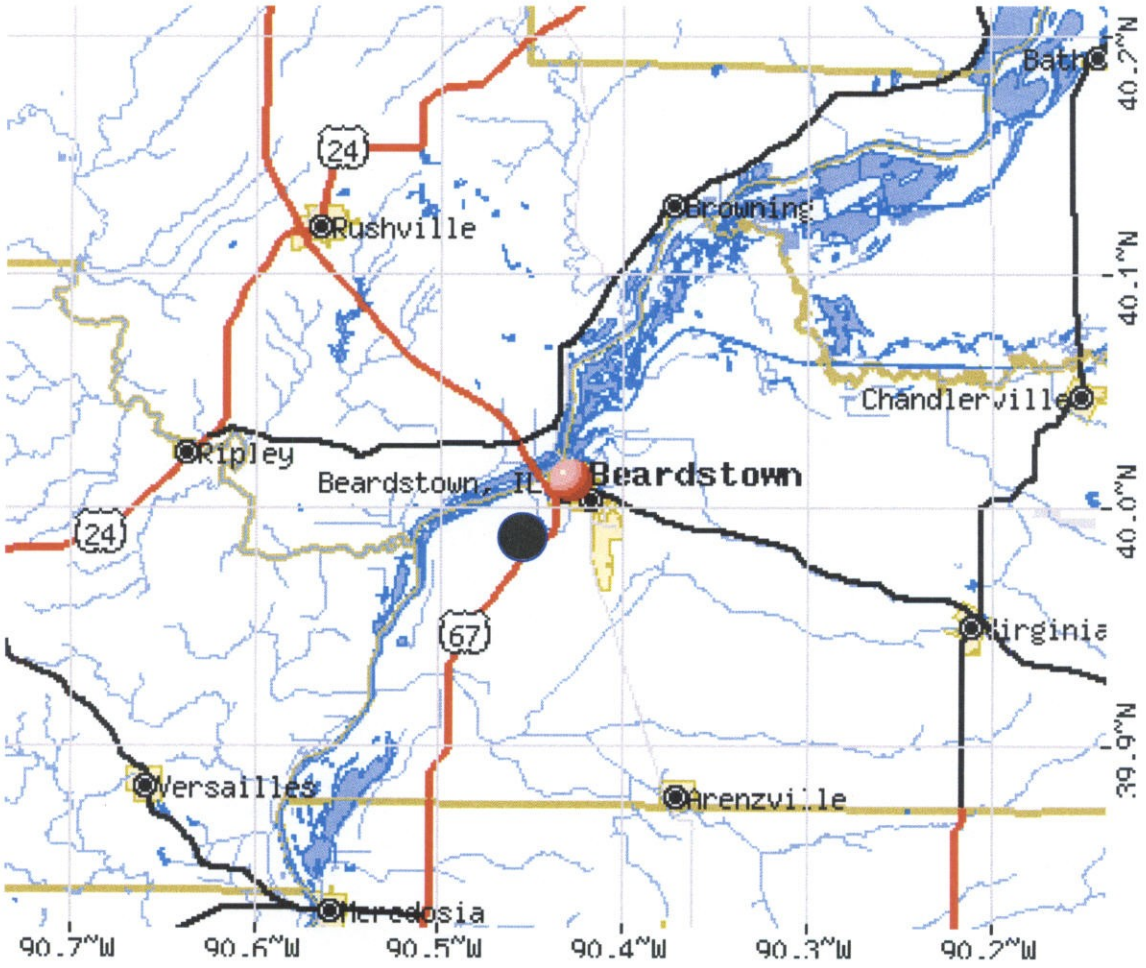

Figure 3. Detail of the Beardstown site in Cass County. The black circle represents the location of the U.S. Army Corps of Engineers Illinois chorus frog (*Pseudacris illinoensis*) mitigation site and dredge deposition location

Madison County: This site was purchased to mitigate for wetland loss during construction of Illinois Route 255. Overpass construction for this road impacted Illinois chorus frog nonbreeding habitat. Thus, a site where both wetlands could be constructed and Illinois frogs occurred was selected. The site lies west of

Sand Road (Fig. 3). Site alterations were made by Illinois Department of Transportation contractors and by grantees from the Illinois Natural History Survey for hydrologic monitoring and by Illinois Department of Natural Resources for prairie restoration.

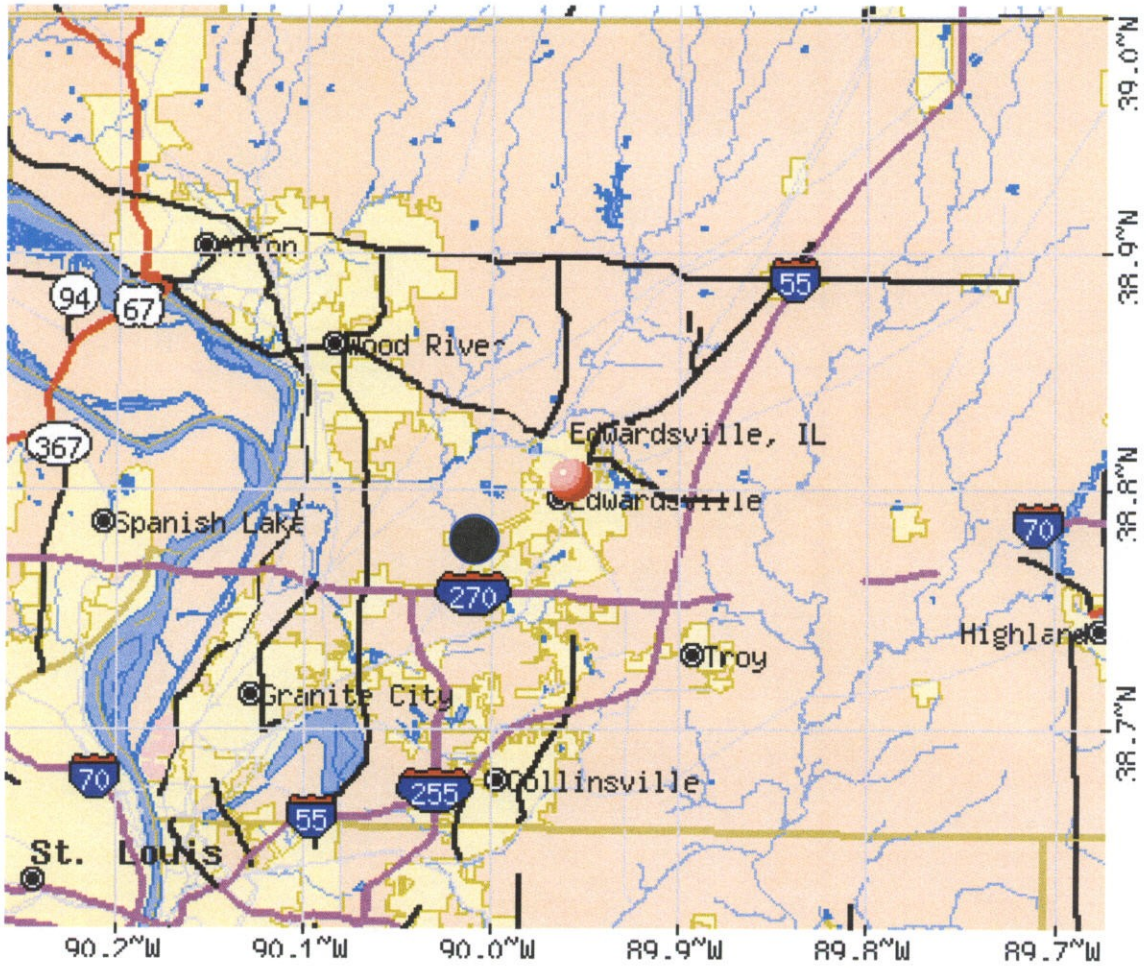

Figure 4. Map of Edwardsville, Madison County, Illinois. Black circle indicates the location of the Illinois Department of Transportation, Sand Road, Illinois chorus frog (*Pseudacris illinoensis*) mitigation site.

Objective 2. Nighttime calling surveys were used to establish which of the sites the frogs used. This frog is an early spring breeder. Consequently call surveys were conducted in February through May 2008 at each site. All species of anurans calling at each site were recorded. Calling Illinois chorus frogs were captured, marked, and released. Site visits were planned to give equal effort per site and the numbers per site are reported below..

However, because Illinois chorus frogs call at a site does not prove that they also deposited eggs. Day surveys were made to locate eggs and tadpoles to establish which sites were actually used as breeding sites. Tadpole development was followed to identify which sites had successful breeding and recruitment (Tucker, 1995; 1997b).

All three sites have previously marked adult frogs. Continued marking of adult frogs (Green, 2001) and recapture of previously marked frogs allows population estimates (Bailey, 1951; Donnelly and Guyer, 1994) and survivorship estimates (Smith, 1987; Tucker, 2000b). Survivorship estimates were made using the recruitment, the most important criteria of success, is only proven when recruitment can be shown. Successful recruitment requires tadpoles to transform into froglets and then return to the site to breed. In this species, transformation occurs in late May and June. Due to the timing of funding for this project, transforming froglets will be searched for in May and June of 2007. Such froglets will be uniquely marked such that they could be recognized at recapture in 2008. Transforming froglets will also be searched for in May of 2008, the last month of the study. However, only froglets transforming in 2007 will be available for recapture in 2008 assuming they return in 2008 to breed.

Objective 3. For a wetland habitat to be a successful habitat for Illinois chorus frogs, it is necessary that it be fishless and persists from February to June to allow breeding and transformation. Pond persistence was tracked from September-December 2007 and January-May 2008. Breeding pond physical parameters such as maximum depth, presence and nature of submersed and emergent vegetation, and survey of potential predators was conducted at each site. Ponds that dry prior to metamorphosis are by definition unsuccessful.

A successful site will be one that progresses through the following steps: 1) adult frogs called from the site (established during calling surveys); 2) adult frogs bred at the site (established by the presence of amplexing adults, observation of egg masses, or presence of tadpoles); 3) tadpoles transform into froglets (established by observation of newly transformed froglets); 4) froglets were recruited into population. A score of 0 indicates that no Illinois chorus frog activities were observed. Determination of each criterion for each site is the basis for scoring level of success on a scale of 0-4. Attainment of criteria 1-3 is preliminary evidence of success. If criteria 4 can be ascertained, then the site can be considered a certain success.

Predators were surveyed by dipnetting. In order to remove the temporal variable, surveys were conducted on 8 April 2008 at the Madison County site and on 9 April 2008 at the Morgan County and Cass County site. Because the available area varies from 0.25 ha to 4.2 ha, the number of net drags was set to yield about the same number of drags per ha. At the smallest site (Morgan County), 6 drags (2 each for the three ponds) were made (= 24 drags per ha). In contrast, 16 drags were made at the Cass County site (8 each in two ponds) and 100 net drags were completed at the Madison County site. Potential invertebrate predators belonging to odonates (mostly Gomphidae and Aeshnidae), coleoptera (Dytiscidae), and hemiptera (Gerridae) were counted. Tiger salamander larvae (*Ambystoma tigrinum*) and smallmouth salamander larvae (*A. texanum*) were counted as potential vertebrate predators (Phillips et al., 1999). Snakes could not be surveyed by dipnetting but all species known to forage in wetlands were counted. Snakes, and especially those of the genus *Thamnophis*, may be a particularly important predator of adult frogs (Conant and Collins, 1998; Phillips et al., 1999). Turtles are potentially another vertebrate predator but none were encountered while dipnetting. However, previous surveys at Cass County and Madison County recorded species that are present.

Results

Objective 1. Characteristic matrix and management actions at each site from previously submitted reports and documents are included in Table 1. Obviously the Madison County mitigation site had the most effort expended and the Morgan County site had very minimal action taken (Table 1). Pond construction varied among these three sites. The Morgan County ponds (N = 3) were constructed by bulldozing shallow depressions perpendicular to a drainage ditch. The Cass County site had two breeding ponds bulldozed near a berm separating the old field nonbreeding habitat from an area being used for off-channel placement of dredge material. Pond depth was based on historic river levels from March to June (Table 1). In contrast, the Madison County site used a berm to hold sufficient water in a newly expanded wetland based on three years of hydrologic monitoring. Monitoring wells were placed in the area for wetland expansion and in the upland nonbreeding areas. This monitoring allowed berm construction designed to retain water in the wetland from March to June (Table 1).

Table 1. Characteristic matrix and management actions with estimates of area in each class.

Site	Wetland	Sand habitats	Prairie restoration	Hydrology	Nonbreeding habitat
Morgan County	0.25 ha	none	none	unknown	none
Cass County	0.6 ha	5 ha	none	river level	5 ha
Madison County	4.2 ha	8 ha	4 ha	monitored	4 ha

The estimated costs associated with each site are listed in Table 2. Variation in mitigation activities and the amount of land acquired accounted for the marked differences in the estimated cost for each project (Table 2). The Morgan County site was by far the least expensive of the three. However, the site was completely ineffective as a breeding site for the Illinois chorus frog (Table 3). The Cass County and Madison County sites were fairly similar excepting that the Madison County site had considerably more land acquired (Table 2). Moreover, monitoring at the Madison County site included hydrologic studies, prairie restoration and prescribed burns, and chorus frog monitoring.

Table 2. Cost estimates (in dollars) for three Illinois chorus frog (*Pseudacris illinoensis*) mitigation sites.

Site	Land acquisition	Monitoring costs	Other costs	Total
Morgan County	3000.00	15,000.00	no direct costs*	18,000
Cass County	23,000	100,000.00	no indirect	123,000
Madison County	860,000	320,000.00	400,000.00**	1,580.000

* Excavation work was done by Morgan County employees in the course of their normal work days; ** these costs include the hydrologic study, prairie restoration, which included site preparation and seeding,

other indirect costs associated with prairie burns are not included because they were parts of other Illinois Department of Natural Resources budgeted activities.

Objective 2. Frog breeding criteria are summarized in Table 3. The Morgan County site scored a 0. No indications of use by the Illinois chorus frog was observed during the study (Table 3). In 2008, the nearest chorus for this frog was near Sand Lane about 1 km east of the site. Historically, Illinois chorus frogs have never been observed breeding at the site (Table 4). However, in 2006 a chorus of Illinois chorus frogs was located in a roadside ditch just across Yeck Road but not at the mitigation site (Figure 5). The number of visits for each of the three sites was roughly equal throughout the study (Table 5). Thus, differences in observed frog activities were not due to sampling effort.

Table 3. Frog breeding activities observed at three Illinois chorus frog (*Pseudacris illinoensis*) mitigation sites in Illinois during the 2007-2008 study periods.

Site	Calling	Eggs/tadpoles	Froglets	Recruitment
(Score)	(1)	(2)	(3)	(4)
Morgan County	None	None	None	None
Cass County	Called	Tadpoles	None	Likely but not during study
Madison County	Called	Tadpoles	Froglets	Proven

Table 4. Historical summary of frog breeding activities observed at three Illinois chorus frog (*Pseudacris illinoensis*) mitigation sites in Illinois and the likelihood that recruitment occurred for each site. It is likely that Cass and Madison Counties will have transforming froglets during 2008 and subsequent recruitment classes for this year.

Site (Score)	Calling (1)	Eggs/tadpoles (2)	Froglets (3)	Recruitment (4)	Duration
Morgan County	Never	Never	Never	Never	2003-2008
Cass County	All years	4 of 8 years	3 of 8 years	3 of 8 years	2001-2008
Madison County	All years	10 of 16 years	8 of 16 years	8 of 16 years	1993-2008

Figure 5. Two male Illinois chorus frogs (*Pseudacris illinoensis*) caught from a chorus located in a ditch on the east side of Yeck Road in 2006.

Table 5. Number of visits made to three Illinois chorus frog (*Pseudacris illinoensis*) mitigation sites in Illinois

Site	2007				2008		
	May	June	July/August	Sept.-Dec.	Jan.-Feb.	March	April
Morgan County	6	5	3	2	1	6	6
Cass County	7	4	3	2	1	5	8
Madison County	6	4	4	3	1	7	8

The Cass County site scored a 2. Illinois chorus frogs called at the site and tadpoles were observed (Figures 6 and 7). However, no sign of transformation was observed in 2007, a dry year (Table 3). Pond levels have been good in 2008 and transformation is expected. Froglets from the 2008 breeding season can be expected in June of 2008, which is beyond the time frame for this project. However, recruitment can be expected for 2008 (Table 3). Transformation was not observed in 2007 though. The site has been only moderately successful in the past with transformation observed in 2 years and recruitment observed in only 1 year (Table 4). Many of the years between 2002 and 2007 were dry years. Only 2001 and 2008 had relatively wet springs. During 2001 transformation was confirmed and recaptures of frogs marked as froglets confirmed recruitment in 2002.

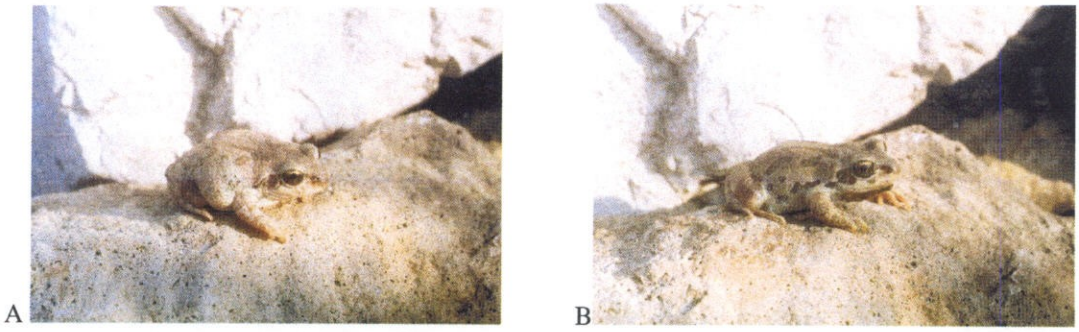

Figure 6. Two Illinois chorus frogs (*Pseudacris illinoensis*) caught at the Cass County mitigation site. One of the specimens (A) is a gravid female and the other a male (B).

Figure 7. An Illinois chorus frog (*Pseudacris illinoensis*) tadpole caught by dip net at the Cass County mitigation site on 15 May 2008. Note the origin of the dorsal fin at midbody, a characteristic of the genus and species.

The Madison County site scored a 4 during this study (Table 3). Several adults were caught in choruses that began on March 10 and continued through May 11, 2008 (Figure 8). Froglets were observed in 2007 (Table 4) and are expected in 2008 (Figure 9). One frog of six marked in 2007 was recaptured during the 2008 breeding season. This site has had fairly good success in the past (Table 4) with transformation occurring in about half the years observed. The small number of frogs caught in most years is concerning,

though. Chorus size at this site always seems small with fewer than 10 frogs heard calling on any one night. The largest number of males caught at any one time was five during the 2001 breeding season.

A.  B. 

Figure 8. Two Illinois chorus frogs (*Pseudacris illinoensis*) from the Madison County mitigation site. One of the males (A) was photographed on 8 April 2008 at the site. Note the dead grass substrate, which is a typical calling site for this species. The other (B) was caught 8 April 2008 and photographed later in the day.

Figure 9. An Illinois chorus frog (*Pseudacris illinoensis*) tadpole collected 26 May 2008 at the Madison County mitigation site. This individual is about 5 to 8 days from complete metamorphosis.

Objective 3. Identification of past management activities. Actions taken at each site are listed in Table 6. The most important of these activities are a preconstruction survey. The purpose of the survey is two fold. First, are there Illinois chorus frogs at the site? Second, what information is needed to construct an ephemeral wetland that persists from March to June? Wetland restoration is a common feature of all sites. However, wetland restoration without knowing whether the site is used by Illinois chorus frogs and without knowing necessary pond depth can result in a failure so far as the frog is concerned.

Table 6. Past management activities performed at each of three Illinois chorus frog (*Pseudacris illinoensis*) mitigation sites.

	Action				
County	Preconstruction survey	Pond construction	Wetland restoration	Prairie restoration	Site maintenance
Morgan	No	Yes	None	None	None
Cass	Yes	Yes	None	None	None
Madison	Yes	Yes	Yes	Yes	Yes

Actions taken at each site differ considerably and a range of effort is demonstrated in Table 6. The smallest efforts were made at the Morgan County site. Here three simple depressions were constructed to serve as breeding ponds. No preconstruction survey was conducted and the site was known only to be "near" other known Illinois chorus frog sites. Until 2006, the closest known breeding sites were at Sand Lane and Toehead Road. These sites are 0.6 km and 2 km distant from the site selected for mitigation. Illinois chorus frogs have called at Sand Lane and along Towhead Road whenever sufficient spring rain has occurred.

The Cass County site had a preconstruction survey and was know to be a site where Illinois chorus frogs bred close to the construction area. However, once the ponds were constructed the site was left as it was. No other restoration activities were conducted. The potential nonbreeding habitat was not protected from development.

The restoration of the Madison County site involved the most complex set of activities. There was a preconstruction survey that extended over multiple years followed by wetland and prairie restoration. The site is still being actively managed to maintain both the prairie and wetland. Maintenance activities include

periodic prescribed burns of the prairie and reintroduction of wetland plants. The impact of these activities on the frog is unknown but it is known that the frog prefers open sandy areas as nonbreeding habitat.

Measurement of pond parameters, which was part of Job 3, could not be completed due to unanticipated failures in equipment (range finders). Regardless, 2007 was so dry that the Morgan and Cass County sites failed to hold water during the summer of 2007. The Madison County site was reduced to a small pond of about 0.2 h in area with a maximum depth of 20 cm. These dryings made transformation impossible in 2007.

Predators were common at all sites. However, they were numerically greatest at the Cass County site. Remarkably, odonate larvae averaged over 1.5 individuals per dip. In contrast, the Morgan County site had few insect predators. Madison County had fewer predators per dipnet drag for all predator classes than the Cass County site. However, vegetation is much thicker at the Madison County site and interferes with dipnet use. Thus, the results for the Madison County site and the Cass County site may not be directly comparable.

Snakes that forage in water were observed at the Cass County site and the Madison County site during the course of the current survey and also during past surveys. The most important of these were two species of *Thamnophis*. The eastern garter snake (*Thamnophis sirtalis*) was observed at both localities. These snakes were observed on 7 occasions at the Cass County site and on 12 occasions at the Madison County site during 2007-2008. The western ribbon snake (*Thamnophis proximus*) was common at the Cass County site and was seen foraging on 20 occasions.

Turtles were observed in previous surveys at the Cass County and the Madison County sites. None were observed at the Morgan County site. The same three species (common snapper, *Chelydra serpentina*; painted turtle, *Chrysemys picta*; and the red-eared slider, *Trachemys scripta elegans*) were observed at each location.

Table 7. Potential predators collected by dipnet at three Illinois chorus frog (*Pseudacris illinoensis*) mitigation sites on 8 April (Madison County) and 9 April (Morgan County and Cass County). Units are individual per dipnet drag.

Site	Salamanders	Diving beetles	Hemipterans	Odonates
Morgan County	0.33 ATx	0	0.5	0.1
Cass County	0.56 Atg	0.81	0.75	1.56
Madison County	0.26 Atg	0.37	0.62	0.48
	0.08 Atx			

Abbreviations: ATg = Tiger salamander larvae (Ambystoma tigrinum), Atx = Smallmouth salamander.

Discussion

Natural history review. The Illinois chorus frog, *Pseudacris streckeri illinoensis*, is restricted to areas of sandy substrates found in the floodplains of the Mississippi and Illinois rivers in Arkansas, Illinois, and Missouri (Conant and Collins, 1991). Because these habitats have been converted to agriculture or developed for other human activities, *P. s. illinoensis* is now uncommon. It is listed as a threatened species in Illinois (Herkert, 1992), as a rare species in Missouri (Anonymous, 1992), as a species of special concern in Arkansas (R. Roberg, pers. comm.), and as federal C-2 species (Dodd et al., 1985).

This highly fossorial frog is distributed in Illinois mainly along the central part of the Illinois River (Smith, 1951, 1961, 1966; Morris and Smith, 1981; Taubert et al., 1982; Brown and Rose, 1988; Morris, 1990; Beltz, 1991 and 1993). Other populations are also scattered along the Mississippi River floodplain from Madison to Alexander Counties, Illinois (Holman et al., 1964; Brown and Brown, 1973; Axtell and Haskell, 1977; Morris and Smith, 1981; Taubert et al., 1982; Gilbert, 1986; Brown and Rose, 1988; Morris, 1990; Beltz, 1991 and 1993; Tucker and Philipp, 1993; 1994; 1995).

Several previous publications and unpublished reports provide details on the natural history of *P. s. illinoensis*. It is important to review the natural history because a through understanding is needed to

decide when and where mitigation should be attempted and to order the practices from most important to least important for long-term viability. The dominant feature of this anurans natural history about which all other natural history traits revolve is the fossorial life style (Brown et al., 1972; Tucker et al., 1995). This frog spends about 10 months out of 12 or almost 85% of its time underground. This activity pattern was confirmed at the Madison County site where drift fences were monitored throughout the year (e.g., Tucker and Philipp, 1996 and 1997). Overall 1261 frogs were captured and released from these fences. Excepting one capture made in September 1998 (Tucker, 1999), every other capture was made between late February and early March.

This period of activity also applies to transforming froglets (Tucker & Philipp, 1993; Tucker, 1995). Froglets of this species are rather large at transformation averaging about 20 mm in snout to vent length (Tucker, 1997c). They rapidly leave their natal ponds and burrow into sandy substrates within a few days of transformation. They also grow rapidly during this period (Tucker, 1995). Many are able to return to breed in the subsequent year (Tucker and Philipp, 1995; Tucker, 2000b). Although froglets spend relatively little time moving away from natal ponds they are able to disperse at least 1.5 km from their natal ponds (Tucker and Philipp, 1994; Tucker, 1999). Moreover, once these froglets are mature, they are known to be able to return to their natal ponds to breed (Tucker and Philipp, 1994).

The breeding season is therefore about the only time that observations can be made on the frog (Brown and Rose, 1988; Tucker and Philipp, 1994). During this time frogs emerge from their subterranean burrows and find ephemeral ponds to breed in (Brown and Brown, 1973; Tucker and Philipp, 1994 and 1995; Owen and Tucker, 2006). These ponds must be fishless or provide extensive areas of vegetative cover, because fish prey on the eggs and tadpoles of this frog (Butterfield et al., 1989; Tucker and Philipp, 1995). Once the adults find a suitable breeding site, the female lays 400-600 eggs (Butterfield et al., 1989; Tucker, 1997b). Females attach their eggs to stems of dead plants most often to grass blades in small clusters of 20 or so eggs (Tucker, 1997b). Eggs hatch a few days after being deposited. Tadpoles generally transform in late May or early June (Tucker, 1995).

Pond persistence is an important factor for mitigation planning. To be successful any ponds constructed must be able to persist until late June to allow transformation. Reproductive output will be lost when ponds dry prior to this time. However, ponds need to be ephemeral to keep them fishless. In natural conditions,

frogs are stimulated to move to breeding sites after or during heavy rainfall (2.5 cm or greater; Tucker and Philipp, 1994 and 1995). These heavy rains produce the ponds needed for breeding and subsequent rain then is needed to keep the ponds from drying. Hydrologic patterns at any proposed mitigation site can govern pond construction or wetland construction.

Sand substrates are absolutely critical to the natural history of this frog. It is highly adapted to burrow (Paukstis and Brown, 1987 and 1991). Moreover, this frog burrows using their front legs (Brown and Means, 1978; Brown et al., 1972). During their time above ground adult frogs feed heavily on insects and especially lepidopteran larvae (Tucker, 1997a). However, this species is quite capable of subterranean feeding (Brown, 1978; Brown and Means, 1984). The ability to feed underground probably allows the frog to remain buried from one breeding season to the next. Consequently, subterranean invertebrate populations may be important and sand lacking invertebrates may be avoided by the frogs (Tucker, 2002b). Subterranean life also protects the frog from subfreezing temperatures by allowing it to burrow below the freeze level in the soil. Because the species is not freeze tolerant (Packard et al., 1998), it will die should its body temperature fall below freezing.

Although the presence of sandy substrates is the first requirement, the nature of the vegetative cover is important. Because the frog cannot burrow where plant roots fill the soil, the best habitats will be those that are sparsely vegetated. Sand prairies with patchy areas of open sand are the sorts of habitats that the frog used prior to disturbance (Smith, 1961; Phillips et al., 1999). Forested habitats are seldom suitable postbreeding habitats but savannas are often suitable (Phillips et al., 1999).

Thus sand soils with sparse or moderate vegetative cover are the first requirement for Illinois chorus frog habitat and consequently any mitigation plan. The sandy area can adjoin the mitigation area or preferably be part of the entire package. Including areas of such sandy substrate provides protection to the areas the frogs will spend the bulk of their lives in while not breeding. Protecting the habitat that is going to provide food, protection from freezing, protection from predators, and post-transformation habitat is almost certainly as important as providing a place for the species to breed.

Natural history suggests that the following habitat landscape features must be present:

1. A significant area of sandy substrate must be included in the plan or at least be nearby.
2. The sand area must support significant subterranean invertebrate populations.

3. The sand must not be consolidated by physical or vegetative processes and consequently impossible to burrow in.

4. Breeding ponds should not persist year-round to prevent fish populations from developing.

5. Constructed ponds must persist from mid-February to mid-June to provide time for breeding and tadpole development.

6. The ponds must be within, adjoining, or at least close to nonbreeding habitat.

7. Ponds should have dead grasses or other emergent vegetation to act as substrates for egg deposition and to provide protection for tadpoles and breeding adults.

8. Where pond levels can be controlled, they should be drained in mid-June to reduce breeding success of salamander larvae.

Population parameters as a measure of success. A single project in a single year may represent a preliminary study. However, each site has been studied in the past for a minimum of six years (Morgan County) to as many as 16 years (Madison County). The results of the current project and those of past years strongly suggest that overall the Madison County site has been most successful when based on breeding parameters (see Tables 8 and 9).

Table 8. Summary of population parameters for the Cass County mitigation area.

Year	Number caught	Recaptures	year marked	Population estimate	recruits?	% Surv.
2001	96	70	2001	230	yes	---
2002	35	6	2001	525	yes	6.3
2003	6	0	---	---	NO	---
2004	3	1	2003	---	NO	16.6
2005	16	2	2001	689	NO	2.1
2006	6	2	2005	126	NO	12.5
2007	2	0	---	---	NO	---
2008	12	4	2005	514	yes	---
Total	156	79	---			
Averages				417	3/8	9.4

Table 9. Summary of population parameters for the Madison County mitigation area. Surveys were not conducted in 2005 and 2006.

Year	Number caught	Recaptures	year marked	Population estimate	recruits?	% Surv.
1993	722	---	----	---	yes	---
1994	150	20	1993	420	yes	4.5*
1995	16	6	1993	344	NO	28.3
1996	41	8	94-93	179	yes	4.8*
1997	86	23	various	450	yes	11.1*
1998	22	21	various	108	NO	26.5
1999	151	78	various	623	yes	28.6
2000	2	2	1999	---	NO	1.3
2001	12	8	various	70	yes	---
2002	47	23	1999	245	NO	15.2
2003	1	0	---	---	NO	---
2004	0	0	---	---	NO	---
2007	6**	4	2002	94	yes	8.5
2008	5**	1	2007	205	yes	16.7
Total	1261	194				
Averages				274	6/12	14.6

* Survivorship estimate based on recaptured froglets only

** Adults caught in choruses only; no drift fences

The Morgan County site is a complete failure so far as reproduction in the Illinois chorus frog is concerned. Consequently, there were no successful population parameters. Frogs were not observed using the newly constructed breeding ponds in any of the six years the site was surveyed. Moreover, the Illinois chorus frog did not breed there in 2007 or 2008. The latter year was very wet and ample water was available.

Comparisons of the Cass County and Madison County sites where frog use is well documented are more important to the project. If recruitment is the primary measure of success, then the Madison County site was the most successful. During the current project (2007-2008) recruitment appears to have happened in both years. In contrast, recruitment could only be confirmed in one of those two years at the Cass County site. Historical data gathered from previous surveys at these sites (Tables 8 and 9) support the conclusion of the current study. Between 1993 and 2008, recruitment occurred at the Madison County site in at least 6 of the 12 years (50%, Table 9). At the Cass county site recruitment seems to have occurred in 3 of the 8 years (37.5%, Table 8) or almost half as often compared to the Madison County site.

There are other important differences in the overall comparisons. Population estimates for Cass County have consistently been higher than for Madison County (means: 417 frogs versus 274 frogs, respectively). However, survivorship estimates for adult and froglets combined at Cass County (9.4%) are lower than the similar estimates for Madison County (14.6%). Consequently the Madison County site despite possibly smaller populations seems to produce recruitment classes more regularly and to have more frogs survive from year to year than the Cass County site. These are important findings needed to judge effect of differing mitigation efforts at these two sites.

Longevity is also an important life history trait. Surveys at the Madison County site has resulted in recaptures from which both survivorship and longevity can be estimated. Froglets initially marked in 1993 were recaptured at this site in 1999. These frogs would be six years old. Adults marked in 1994 were also recaptured in 1998 and 1999 indicating that they had persisted as adults for at least six years. Although some frogs are known to survive for six years, the conclusion is based on recaptures of two 1993 in 1999 frogs and four 1994 frogs in 1999. These data are consistent with the adult survivorship estimate of 28% made from subsequent recaptures of 1994 frogs (Tucker, 2000b) at Madison County.

It is not possible to use longevity to compare success at the Madison County and Cass County sites because the length of the monitoring period differs between the two. Nonetheless, a preliminary comparison can be drawn keeping that caveat in mind. The longest lived frogs at Cass County were individuals marked as adults in 2001 and recaptured in 2005. These adult frogs had survived for a minimum of four years. It may be that longevity is lower at the Cass County site (four years minimum) than at the Madison County site (six years minimum). Increased longevity at Madison County would be expected given that survivorship at this site appears to be greater than at Cass County.

Mitigation actions. The mitigation actions at three sites selected for this project differ remarkably. The simplest project at Morgan County (Tucker, 2003b, 2005a, 2006a, and 2007) consisted of digging three small depressions along a small ditch in farm fields. The Cass County (Tucker, 2002a, 2003a; 2004a, 2006b and c) project was more intensive and involved wetland construction, but did not do other tasks such as hydrologic studies, acquisition of post-breeding habitat, or prairie restoration. The Madison County project (Tucker and Philipp, 1993, 1994, 1995; 1996; 1997; Tucker, 1999; 2000a, 2001, 2002a, 2003c, 2004b, 2005b) was the most intensive with wetland restoration, acquisition of post-breeding habitat, prairie restoration, and hydrologic studies. It is important to have a range of effort so that each step up in complexity can be compared. If the simplest project is as effective as the most complex (and expensive), then simpler and less expensive projects might yield the desired results.

What are the steps needed to give a mitigation project aimed at the Illinois chorus frog the best chance to be successful? I have given these a somewhat arbitrary ranking from most to least important.

1. **Preproject survey**. With the Illinois chorus frog the adage that 'if you build it, they will come' does not apply (e.g., the Morgan County site). Due to the cost involved in even minor efforts (Table 2) it is critical to understand the habitat use patterns of nearby populations of the Illinois chorus frog. These frogs are fairly mobile but only as newly transformed froglets. They are known to make post-transformation migrations of more than 1.5 km (Tucker and Philipp, 1994; Tucker, 1999). Adults are also known to be able to return to their natal ponds from this same distance (Tucker and Philipp, 1994; Tucker, 1999). The preproject survey then should determine current breeding sites using a call survey and locate the closest areas suitable for post-breeding habitat based on soil types and vegetative cover. Such post-breeding habitats will have sandy soil

substrates with sparse vegetative cover. Calling surveys need to be conducted between March and early May during the frogs' breeding season. These frogs sometimes call during daylight but calling surveys should be conducted two hours or so after sunset. The Illinois chorus frog is usually an intermittent caller. Breeding chorus can fall silent for as long as 10 to 15 minutes and then resume calling vigorously for another 20 minutes. Consequently, calling surveys have to incorporate extended stops to listen even when calls are not heard initially. At a minimum the surveyor must listen at a particular spot for 15 minutes. Weather also has an important effect on calling. Nights where rainfall exceeds 2.5 cm in March and April are times of maximum breeding activity (Tucker and Philipp, 1996). Such nights are best for a calling survey. Since the frog has no surface activity after May, surveys such as transects or other such methods will not be of any use. Even drift fence surveys during this period are unlikely to catch frogs (Tucker, 1999).

2. **Site acquisition**. Generally the cost of land acquisition for a mitigation project is a major part of the project overall costs (Table 2). Consequently acquisition of a site that cannot provide a suitable breeding area along with post-breeding habitat may fail to support long-term frog use. Often the wetland mitigation becomes the driving aspect of site selection. Even if the restored wetland adjoins suitable post-breeding habitat, subsequent development of the post-breeding habitat can lead to loss of the frog population (Tucker, 1998).
3. **Hydrologic survey**. Once the habitat use of the frog is established for the site and the site is acquired, the next important step should be to understand the hydrology of the site **before** wetland or pond construction starts. A grasp of the hydrology at a particular site is needed to judge the nature of wetland or pond construction needed to provide suitably ephemeral sites. The goal should be to construct a breeding site that can hold water until mid-June but that does not become a permanent pond likely to be colonized by fish.
4. **Vegetation**. Where pond construction has been completed and post-breeding habitat has been acquired, then the nature of the vegetative background becomes important. For the wetland or aquatic portion of the habitat, some sort of substrate suitable for egg deposition, for use by calling males, and for cover for both adults and young needs to be present or established. Dead grasses are essentially always present at Illinois chorus frog breeding sites that I have surveyed. If the

hydrologic study has been done, periods when the pond dries during the summer, fall, or winter may allow colonization by grasses or they can be planted by managers. If pond construction occurs in the summer and if the constructed pond or wetland does not have water, then warm-season grasses can be planted. For the terrestrial portion of the mitigation area, creation of sand prairie habitat should be planned. One of the steps in this process should be removal of exotic trees, which are often present. Selection of grasses and forbs for planting should be governed by local managers. Prairies require fire to maintain them. Prescribed burns can be safely conducted after late May. At this time all adults and newly transformed froglets can be expected to be below ground. Fire had no effect at this point in the life cycle (Tucker and Phillip, 1996 and 1997). Burns should be avoided during the spring, a time when adults and froglets may be above ground.

5. **Post-mitigation monitoring**. Funding post-mitigation monitoring is a critical step in judging the effectiveness of mitigation. The Illinois chorus frog is exquisitely sensitive to spring rainfall. This species may fail to breed at all in years with reduced spring rainfall (see Table 9 for 2003 and 2004). As a consequence post-mitigation monitoring should be expected to have to continue for several years post-project. The amount of time devoted to post-mitigation monitoring is not the only consideration. There is no standard method to judge the success of the mitigation project. Are simple call surveys sufficient? Such surveys only determine that the breeding habitat was used by the frog. Success could only be based on the assumption that if they are calling they must be breeding successfully. More comprehensive efforts aimed at catching adults and transforming froglets either in choruses (adults) or with drift fences or other passive capture techniques (adults and froglets) are required to confirm that breeding activity actually led to recruitment of new cohorts and the survivorship rates. Mark and recapture methods would have to be used. Since longevity is at least six years for some individual Illinois chorus frogs, an acceptable monitoring period should be no less than six years.
6. **Others**. Finally there may be other potential variables to address in mitigation plans for the Illinois chorus frog. One variable that may be important is the predator load at any particular site. During the current study potential predators were surveyed but it is not possible to judge their importance relative to Illinois chorus frog breeding success without an experimental design.

However, large numbers of *Thamnophis* species such as occur at the Cass County site may represent a problem for adult frogs. Moreover, large number of bullfrogs (*Rana catesbeiana*) may also be a threat. These are not at all common at the Cass County site but are relatively common at the Madison County site. This frog feeds on other anurans including species of *Pseudacris* (Henshaw and Sullivan, 1990). Consideration may be given to removing *Thamnophis* species and *Rana catesbeiana* during early stages of wetland construction. Salamanders due to their fossorial habits would be impossible to remove. Reducing predator loads has been shown to have complex effects on the western chorus frog (*Pseudacris triseriata*) causing an increase in tadpole numbers (Smith, 1983). However, intraspecific competition in the absence of predators can lead to lowered recruitment (Smith, 1983). Removal of predators (*Thamnophis* species and *Rana catesbeiana*) on adult Illinois chorus frogs would likely have the largest positive impact on recruitment.

Site by site management practices. For each of the three sites a brief summary of the mitigation actions taken are given here.

Morgan County. The mitigation actions taken here did not include steps 1, 3, or 4. No preproject survey or hydrologic survey was conducted yet land was acquired and ponds were constructed. Once the ponds were constructed, no attempt was made to establish suitable vegetation. The lack of these important steps was directly responsible for the dismal results at this mitigation site. There simply was little frog use of wetlands in the area. Moreover the soil type was Darwin silt-loam, a soil type not suitable for post-breeding habitat (Brown et al., 1972). Consequently, adult frogs would not be expected to be burrowed in such soils. Although important steps were omitted, the post-mitigation monitoring was adequate. Had the frogs used the mitigation ponds they would have been detected.

Cass County. Mitigations steps that were taken here included steps 1, 2 (in part), and 5. At this site, previous Illinois Natural History Survey surveys had recorded Illinois chorus frogs here and in the vicinity. The records were present in the Illinois Department of Natural Resourses Natural Heritage data base. Site acquisition made no provision for post-breeding habitat and was limited to the immediate area of the mitigation ponds. No hydrologic survey was conducted. Instead river levels were considered an accurate proxy for ground water levels. Step 4 or vegetation remediation were omitted for the terrestrial portion of

the site. An attempt was made to encourage grasses in the constructed ponds but willow trees were not excluded. There was at least a minimally adequate post-mitigation surveying.

. These actions resulted in breeding in 50% of the eight years that surveys have been conducted including the time covered by this study. Of these years the ponds persisted long enough for transformation in only 50% of these four years. Recruitment occurred in only three (38%) of the eight years that frog activity was monitored. Survivorship was relatively low at 9.4% per year for juvenile and adult survivorship estimates.

Although little post-breeding habitat was acquired, much of the surrounding area is in the Conservation Reserve Program (CRP). This would provide some protection from development. However, sand prairie could not be reestablished under CRP. A reasonable hypothesis is that survivorship is low here because the vegetative structure consists mostly of introduced species, which may not provide adequate soil invertebrate populations.

Madison County. All five steps were conducted at this site. Wetland construction was made only after extensive hydrologic surveys were conducted. The wetland was designed to be ephemeral. Vegetation was remediated in the wetland with additions of less common wetland vegetation. More importantly, a large area (42 h) of post-breeding habitat was incorporated into the site. Sand prairie vegetation was reintroduced into the post-breeding habitat to provide a natural background for frog use.

Thus, the Madison County site had an extensive restoration program conducted including wetland restoration, prairie restoration, hydrologic monitoring prior to pond construction, and extensive post mitigation management (prescribed fires and vegetation reintroductions). Frogs bred successfully at this site in 62.5% of the 16 years post construction despite extensive droughty weather. Froglets and recruitment was estimated at 50% of the years examined including the time period of this study. Survivorship estimates at the Madison County site were on average the highest calculated (14.6%) with adult survivorship of almost 30%. Population estimates are lower than the Cass County site (274 frogs versus 417 frogs, respectively).

Management Recommendations.

When to mitigate. Most mitigation results from statutory requirements and especially to mitigate wetland loss. However, two (Morgan and Cass Counties) were initiated to specifically mitigate for damage to habitat in Illinois chorus frog inhabited areas. The need for mitigation then is not well established. From a herpetological view point mitigation should be considered where significant harm to frog habitats could occur. If a few acres of habitat are to be impacted, then the need for mitigation is reduced. However when 10+ acres in known Illinois chorus frog habitats are damaged, mitigation should be considered. Damage to habitats may be more significant than is known where barriers to breeding migrations or post-transformation migrations occur. These could easily occur where habitat use by the frog is not known. Where possible in Illinois chorus frog habitats, wetland mitigation should be planned to both fulfill the statutory requirement and as a by product provide habitat suitable for the Illinois chorus frog as was done at the Madison County site.

Preconstruction surveys. All potential mitigation projects should begin with a preconstruction survey. Such surveys are the lynch pin of successful mitigation. No amount of habitat restoration will produce productive Illinois chorus frog habitat where there are no frogs to begin with. Such surveys should be conducted during the spring breeding season and call surveys are the most efficient method. Areas of sandy soil near calling sites should be assumed to be post-breeding habitat. In contrast, breeding sites isolated in nonsandy soils are possible but the post-breeding site will be in nearby areas of sandy soil. There is little use in mitigation if only one portion of the life cycle is considered.

Time table for best management practice.

1. The need to mitigate should be established first through consultation with statutory authorities such as the Natural Heritage Division of the Department of Conservation or Federal authorities concerned with wetland issues.
2. Once the need to mitigate is clear. Site selection for mitigation should be driven by surveys of Illinois chorus frog use. These could be purpose driven surveys contracted prior to land acquisition or historical surveys available in the herpetological literature or conservation data bases.

3. Purpose driven surveys must be conducted during the spring calling season and are most effective when a standard calling survey is used. With the Illinois chorus frog this may require 30 minute or longer listening periods due to the frogs' intermittent calling pattern.

4. After habitats used for breeding are located, then areas of sandy soil used for post-breeding habitat should be recognized. Any mitigation project should optimally be designed to produce, improve, or save breeding habitat and provide a place for the adults and juveniles to survive.

5. Once land is acquired then the nature of the wetland to be constructed must be determined by survey of the hydrology of the site. The ideal plan designs wetlands that will be ephemeral but persist until late June in most years.

6. After the wetland is built, a basic decision on the restoration actions of the post-breeding habitat should be made. The most successful site surveyed (Madison County) had sand prairie restored on the post-breeding areas. Returning native vegetation may be important to frog survivorship. It is important to realize that more than 80% of the frogs' life is subterranean. There is currently no experimental evidence that native vegetation is better than old-field vegetation. However, restoration of prairie will also benefit other organisms and broaden the use of the site.

7. Managers must come to a conclusion on post-construction monitoring. Such monitoring should begin following initial call surveys and continue for a period sufficient to allow habitat modifications to be in place. I expect that any site will have a minimum of five years post-mitigation monitoring.

8. The nature of post-mitigation monitoring has to be decided. Simple call surveys post-mitigation will only establish that male frogs have found the site. A mark and recapture plan is required to investigate population parameters. This survey can be based solely on capture of adult frogs in choruses. This is the simplest survey and given sufficient time can provide an estimate of adult survivorship, of population size, of recruitment based on tadpoles, and of breeding patterns. A more comprehensive

study using drift fences can also be used particularly when the spatial ecology are needed. Chorus surveys should be expected to consume at least four month in the spring (February to May). Drift fence surveys need to extend the entire year to be effective.

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