ILLINOIS NATURAL HISTORY SURVEY
PRAIRIE RESEARCH INSTITUTE

Conservation guidance for Illinois Chorus Frog (*Pseudacris illinoensis*)

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Illinois Natural History Survey has undertaken a project producing documents that provide conservation guidance for listed species in Illinois for the Illinois Department of Natural Resources. The project is titled: *Conservation Guidance for Species in Greatest Need of Conservation (SGNC)* T-96-R-001. The primary purpose of guidance documents is to provide various project developers/land managers with information on the species, how their actions may impact the species, and how they can minimize/mitigate/monitor those impacts. In addition, the documents may be useful for identifying research needs to direct various funds, as a first step towards recovery planning, or for informing the general public. We intend the documents to be comprehensive and inclusive of scientific and experiential knowledge of the species and its conservation. The documents incorporate information on current conservation efforts, conservation opportunities and research needs.

Interviews with stakeholders were held to identify information that should be included in conservation guidance documents. We prioritized document production for species that were frequently the subject of Incidental Take Authorizations or were consulted on in the IDNR's EcoCat program. Initial literature reviews was conducted to produce first draft documents. Then a list of potential document reviewers, including academic taxa experts, conservation organizations, private consultants, and government agency staff, was compiled for each species. The documents underwent two rounds of review and revision. What follows is the final document providing conservation guidance for Illinois Chorus Frog, which was reviewed by 20 individuals.

Conservation Guidance for

Illinois Chorus Frog

Pseudacris illinoensis Smith, 1951

IL status:
Threatened

US status:
Under review

Global rank:
Vulnerable[1]

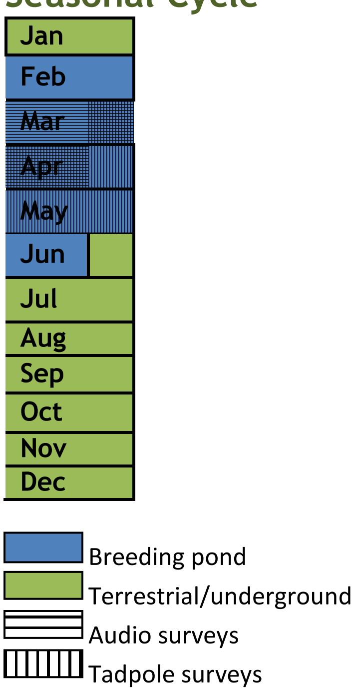
Trend:
Declining[1]

Family:
Hylidae

Habitat:
Sand prairie, sandy old fields, ephemeral pools, ditches, flooded depressions, marshes

Similar species:
Upland chorus frog, Western chorus frog

Seasonal Cycle



Species information

Characteristics

Adult Illinois chorus frog. Photo by John Tucker[6]

The Illinois chorus frog (ICF) is a small (1.4 to 1.75 in. and 0.2 oz.) tan to gray frog[2]. Its body is stout and toad-like with robust forearms. Its skin is granular rather than smooth. It has dark brown or black lines on its back with a white belly. It has a characteristic **dark mask-like stripe from snout to shoulder, a dark spot under each eye, and a V- or Y-shaped mark between the eyes.** The throat (vocal pouch) of the male ICF darkens during the breeding season. ICF tadpoles can be distinguished from other tadpoles by their round shape, large size, forward attachment point of the tail, and large tail height. Once they develop two functioning limbs, they also develop other ICF markings including the dark "Y" between the eyes[3].

ICF are rarely seen because they spend most of their lives underground, emerging only during the breeding season. The males' breeding call is a series of **high-pitched, rapid, birdlike whistles** that can be heard as much as 1.3 mile away[4]. Listen here: https://www.youtube.com/watch?v=UaBUvAsHc00.

Habitat

ICF is fossorial, spending around 85% of its life burrowed underground in sparsely vegetated areas with sandy soil, near ephemeral (i.e. temporary) breeding ponds[5,6]. ICF is found in loose soils that allow easy burrowing, such as sand, loamy sand, or sandy loam[4]. Bare areas (blow outs) or sparsely vegetated areas, such as sand prairies and old fields, provide habitat that allow burrowing because plant roots do not fill the soil[7,8]. Forested

Illinois chorus frog breeding pond. Photos by Eric Smith.

habitats are seldom suitable terrestrial habitats but savannas may be suitable[2]. As a fossorial feeder, ICF require habitat with adequate soil invertebrates[9]. ICF continues to be found in agricultural landscapes with little other habitat around, and recently metamorphosed frogs have been found burrowing in wheat fields[7]. However, ICF have been found migrating into and out of old field, but not using adjacent lawn and agricultural fields[5]. The habitat quality of agricultural fields for ICF is unknown.

ICF emerges after heavy, early spring rains to breed in nearby ponds, flooded fields, wetlands, and stagnant ditches[10,11]. ICF have been heard calling from many types of water bodies, but are absent from flowing or large, permenent bodies of water[4]. Breeding pond depths have been measured at 4-30 in.[12] Ponds must also have emergent or dead vegetation to provide protective cover and suitable structure to secure egg masses[13,14]. Eggs and larvae develop in these bodies of water, which must be fishless to prevent predation and persist through June to allow breeding and metamorphosis[5,12,15,16]. Individual breeding sites fluctuate due to stochastic and environmental factors, so that it is necessary to have a diversity of breeding sites available in the area to maintain populations[10].

Taxonomy

The taxonomic status of the Illinois chorus frog and Strecker's chorus frog (*P. streckeri*) has been debated in the literature. The principle range of *P. streckeri* is from central Texas and adjacent Louisiana through Oklahoma to extreme south-central Kansas and over to central Arkansas. There are a few separated populations in west-central and southwestern Illinois, southeastern Missouri and adjacent Arkansas of what has been considered the sub-species *P. streckeri illinoensis*[17]. *P. illinoensis* was proposed as a separate species due to its separated geographic distribution and distinct physical features[18]. However, recent work has shown *P. s. illinoensis* and *P. s. streckeri* are not genetically different and the disconnected populations have only recently separated from the Texas populations[19]. Still, physical features vary geographically[17]. The International Union for Conservation of Nature recognizes a single species, *P. streckeri*, with disjunct populations[20]. The Integrated Taxonomic Information System recognizes both *P. streckeri* and *P. illinoensis* as valid species[21]. In Illinois, the ICF was recognized as *P. s. illinoensis* until the 2009 revision of the endangered and threatened species list, when it was listed as *P. illinoensis*.

Illinois chorus frog breeding pond. Photos by Bob Bluett[49].

Distribution

ICF populations are restricted to Missouri, Arkansas, and Illinois. ICF likely migrated into Illinois along river floodplains that contain sands or sandy soils deposited by either water or wind[10,22]. In Illinois, ICF records occur in three widely separated sandy floodplain regions[23].

The northern region covers the largest area; it occurs along the east side of the Illinois River in the central portion of the state from Tazewell County in the north to Scott County in the south and east to Logan County. The central region near the Mississippi River in Monroe and Madison counties has been greatly reduced to an area of roughly 250 acres in Madison County[5,24]. The southern region near the junction of the Ohio and Mississippi Rivers in extreme southern Illinois in Alexander County has a single population with multiple breeding ponds in the area around Horseshoe Lake Conservation Area[25]. A genetic comparison of the northern and southern regions of the state found the populations were genetically different, indicating little to no connectivity between the regions[19]. Habitat conditions that are similar to these three regions have been identified in additional areas in Illinois, but there is no evidence ICF has ever inhabited these areas[26].

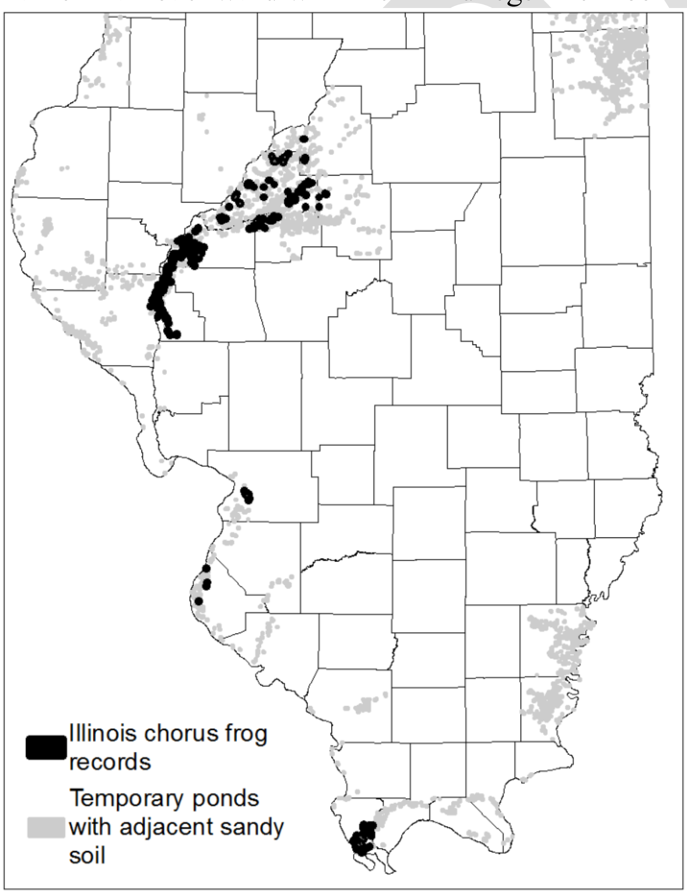
Status

In Illinois, there are 29 ICF population records from the Natural Heritage database [27]. There are 24 ICF population records in the northern region but population sizes have never been assessed. ICF in this region were found to have low genetic diversity, perhaps due to inbreeding, reduced population size, or low connectivity[3]. The central region has a single, small population (~400 individuals), largely due to loss of non-breeding habitat[5,24]. This population is probably the most imperiled and has been greatly impacted by development and flooding[12]. In the southern region, surveys in the mid-1990s estimated population size around 100-250 adults[25].

Changes in abundance and distribution are difficult to gauge due to the limitations of past studies. A long term monitoring program was initiated in 2015 to detect long term changes in occupancy greater than 30-50% [28]. Initial ICF monitoring estimated that 56% of sections with suitable habitat were occupied[28].

Natural History

Illinois chorus frogs spend most of their life underground, where they dig forward through the sandy soil with their unusually strong forearms, rather than backward with their hind legs like most fossorial amphibians[29]. Only four ICF burrows have ever been observed and documented; they were found in April and November in areas free of vegetation[7,30]. The burrows observed have varied in depth between 4-8 in. and from roughly level (into a hill side) to nearly straight down[7,30]. There is some evidence (surface depressions and lab experiments) that ICF may surface at night, especially in association with rain storms, yet very little is known about this behavior[29,30]. No overwintering burrows have been located, but ICF is not freeze tolerant and must therefore burrow below the freeze line to overwinter[31]. One season of soil temperature monitoring at a Madison County site indicated that ICF must burrow at least 5 in. below the surface, perhaps as deep at 10 in. to avoid freezing[31]. In a 12 in. deep aquarium experiment, ICF was found burrowed at depths from less than 1 in. up to 9 in. deep[8]. When there is a shallow layer of clay below the upper layer of sandy soil, it will likely limit the depth of ICF burrowing and impede ICF overwintering in that area.



Illinois chorus frog records from the Illinois Natural Heritage Database[23] and modeled potential habitat[26]

ICF are the only known frog capable of feeding below ground[32] , but surface feeding is also likely[16]. During the breeding season, adult ICF diet consists of small insects and burrowing larvae including moth and butterfly larvae (specifically the agricultural pest dingy cutworm *Feltia ducens*), true bugs (specifically nabids), beetles (specifically curculionids), and flies[16,25]. Very little is understood about their fossorial behavior and their ability to locate prey items. Although many adult frogs are visual predators, ICF cannot use sight while feeding underground. It is presumed prey are eaten as encountered[29], but ICF may be using vibrations or chemical cues to track and detect prey as has been observed in some other amphibians[33–35]. Interestingly, other fossorial species are known to detect the movements of prey by vibrations that travel through the ground in coarse sandy soils, similar to those preferred by ICF[36,37].

ICF are among the earliest of Illinois frogs to emerge and call, often while snow is on the ground and air temperatures are below freezing in late winter or early spring (February to April)[4]. ICF emergence often coincides with heavy rainfall (1 in. or greater), although it is unknown which cue triggers the emergence: moisture, temperature, vibration, etc[16]. The emergence of other fossorial frogs has been shown to be triggered by vibrations from spring thunderstorms or ATVs[38]. ICF may not breed in years without suitable breeding conditions, such as drought. Breeding begins soon after emergence and continues irregularly for approximately seven weeks[4]. ICF may be able to detect the presence of fish and forego breeding ponds containing fish[16].

Upon emergence, breeding males gather in wetlands to form choruses, calling at night to attract females[39]. Most choruses consist of 1-20 males but may have as many as 100 males[4]. The males temporarily maintain calling territories with about 5 ft. between them[39]. Most males call from water while clasping emergent vegetation to keep their vocal sac above the water line[14]. Advertisement calls that attract females have a dominant frequency around 2.2 kHz and can be heard from more than 1 mile away[4,39]. Breeding mostly takes place in the center of ponds in deeper water and further from the shoreline[14]. Females approach and swim around the calling male until the male jumps onto and clasps the female's back. The pair then deposits eggs and sperm clusters of 10-40 eggs on the underside of submerged or floating vegetation[13,39]. Egg masses quickly become covered by silt and debris, perhaps disguising and protecting them[24]. No further parental care is given.

ICF eggs likely hatch into tadpoles within a few days. As tadpoles they eat suspended matter, organic debris, algae, plant tissue, and plankton. There is evidence that some ICF tadpoles may be cannibalistic, capable of eating smaller ICF tadpoles when necessary to ensure their metamorphosis prior to drying of breeding ponds[40]. After about two months, ICF tadpoles undergo metamorphosis into the terrestrial form and disperse from the pond, around late May or early June[15]. They have been found more than half a mile from their pond of origin[5] and are likely capable of traveling much further, perhaps as much as 2-3 miles away[10]. Immature ICF grow rapidly and are capable of breeding after one year of growth[15,41]. Most ICF were not found to return to their birth pond for breeding but dispersed across the landscape colonizing other breeding ponds[16].

Illinois chorus frog as a late-stage tadpole.
Photo by Lisa Hebenstreit

Population dynamics

Little is known about the population dynamics of this species but the few studies conducted on the Madison County population suggest ICF is not a long-lived species and is at risk of extinction[5,24]. Mark-recapture surveys on the Madison County population have shown annual adult survivorship of about 26% and juvenile survivorship from froglet to adult at 2.8%[42]. ICF life span is typically 2-3 years but individuals may survive as much as six years[6,42]. In total, ICF lay clutches of around 400-700 eggs[13,24,25], although as many as 1,000 eggs have been found in a reproductive female in Arkansas[43]. Egg to tadpole survivorship has not been assessed in the field, but in captivity ICF egg to tadpole survivorship is around 66%[40]. However, under natural conditions generally only 2-7% of amphibian eggs reach metamorphosis[44].

Environmental stochasticity can result in years with unfavorable breeding and transformation conditions that may result in zero productivity at individual breeding ponds. One study found recruitment in the Madison County population in 8 of 16 years[6]. Years of failed reproduction can have a considerable impact on the population of short-lived species such as ICF[16]. Therefore, the dispersal and colonization of new breeding ponds that may have been extirpated is important for population stability[10]. While individual breeding sites may fluctuate, there may be more consistency at a broader scale due to the diversity of wetland types and recolonization. Indeed, an ICF habitat model was better able to predict presence at the larger, one-mile scale than at individual breeding sites[45], perhaps due to the variable nature of individual breeding sites. Population modeling of wood frog (Rana sylvatica), a species with comparable population dynamics, shows that local populations are prone to stochastic events, even with intact protected habitat, and depend on recolonization from nearby ponds for landscape level stability[46].

Community Associations
ICF are characteristic animals of dry-mesic sand prairies[47]. Other animal species characteristic of sand prairies include: plains hog-nosed snake *(Heterodon nasicus*), bullsnake *(Pituophis catenifer sayi*), lark sparrow *(Chondestes grammacus*), savannah sparrow *(Passerculus sandwichensis*), vesper sparrow *(Pooecetes gramineus*), grasshopper sparrow *(Ammodramas savannarum*), and plains pocket gopher *(Geomys bursarius*)[47].

Sand prairie vegetation with appropriate habitat characteristics for ICF includes grasses, such as three awn (*Aristida* spp.), sand dropseed (*Sporobolus asper*), hairy grama grass (*Bouteloua hirsuta*), side oats grama (*Bouteloua curtipendula)*, junegrass (*Koeleria cristata*), little bluestem (*Andropogon scoparium*), bluejoint grass (*Calamagrostis canadensis)*, sand love grass (*Eragrostis trichodes)*, and Canada wild rye (*Elymus canadensis*), and forbs, such as purple prairie clover (*Dalea purpurea*), fringed puccoon (*Lithospermum incisum*), hairy puccoon (*Lithospermum caroliniense*), dotted mint (*Mondarda punctata*), hairy wild petunia (*Ruellia humilis*), partridge pea (*Chamaecrista fasciculata*), rough blazing star (*Liatris aspera*), showy tick trefoil (*Desmodium canadense*), pale penstemon (*Penstemon pallidus*), sand coreopsis (*Coreopsis lanceolata*), sky blue aster (*Symphyotrichum oolentangiense*), sessile-leaved tick trefoil (*Desmodium sessilifolium*), pale purple coneflower (*Echinacea pallida*), golden aster (*Chrysopsis camporum)*, and showy goldenrod (*Solidago speciosa*).

Other amphibians that may be found in ICF breeding ponds include American toads (*Bufo americanus*), spring peepers (*Pseudacris crucifer*), western chorus frogs (*Pseudacris triseriata*), southern leopard frogs (*Rana sphenocephala*), plains leopard frogs (*Lithobates blairi*), eastern spade foot toads (*Scaphiopus holbrookii*), upland chorus frogs (*Pseudacris feriarum*), spotted salamanders (*Ambystoma maculatum*), Fowler's toads (*Bufo woodhousii*), and gray treefrogs (*Hyla versicolor*). Potential predators of ICF include fish, snakes, bullfrogs (*Rana catesbeiana*), turtles, tiger salamander larvae (*Ambystoma tigrinum*) and smallmouth salamander larvae (*A. texanum*). Invertebrate predators include dragonflies (mostly Gomphidae and Aeshnidae), beetles (Dytiscidae), and water striders (Gerridae)[6].

Conservation and Management

Threats
The largest threat to ICF populations is likely loss of breeding habitat, which is associated with agricultural drainage. Additional threats, such as loss of terrestrial habitat, invasive species, pollution, disease, and climate change are also of concern. Between 2003 and 2014, 21 Incidental Take Authorizations have been issued for ICF in Illinois for municipal and commercial development, road construction, a drainage ditch, a wind farm, pipelines, and electric transmission lines.

<u>Habitat Loss</u>
Loss of breeding habitat is likely the greatest threat to ICF. Hydrology has been altered on a large scale by agricultural production and other developments[48] that have eliminated some breeding habitats, caused others to dry up before tadpoles have time to undergo metamorphosis, and reduced habitat connectivity of individual breeding ponds. There are reports of ICF attempting to breed in flooded agricultural fields and lawns, but unless water is retained successful reproduction is unlikely[16]. In addition, some temporary wetlands have been dammed creating permanent water bodies that allow fish to survive, making unsuitable ICF habitat [16].

Illinois chorus frog breeding pond on agricultural land.
Photo by Jacob Randa

Loss of terrestrial habitat is associated with an increased chance of extinction and reduction in population size for other frog species, even when wetland habitat and a narrow buffer is maintained[46].Terrestrial habitat around ICF breeding ponds has been greatly altered by agricultural cultivation. However, the impact of agricultural production on ICF is not well understood. ICF were found migrating out of non-cultivated old fields, but not adjacent agricultural fields and lawns[5]. However, the continued presence of ICF in agricultural areas that appear to have no remaining non-agricultural habitat suggests that agricultural production does not preclude ICF[25,49]. Nevertheless, activities that decrease soil biodiversity and abundance, such as intensive soil management and high chemical inputs, likely reduce prey for ICF[50].

Fragmentation

Fragmentation of habitat, such as by highway construction, reduces dispersal and limits connectivity, which decreases population persistence and genetic diversity in the long term[24,51]. In recent years there have been numerous linear development projects, such as roads, underground pipelines, and transmission lines, which have crisscrossed ICF habitat and increased fragmentation. Road kills are common around breeding ponds as frogs disperse to terrestrial habitat across roadways. Frog species that migrate to breeding ponds, such as ICF, are especially prone to road mortality[51]. Roads were found to decreases frog populations up to 0.9 mi away and could cause 20-25% annual mortality[51].

Habitat Degradation

Even areas that are protected may become unsuitable due to habitat degradation from invasive species and succession. Invasive species can alter ICF habitat, making it unusable. For instance, woody encroachment of black locust (*Robinia pseudoacacia)* or red cedar (*Juniperus virginiana*) into sand prairie openings consolidates soil making it difficult for ICF to burrow. Introductions of new invasive species may have direct or indirect impacts on ICF. Even native species, such as bullfrogs and fish, can reduce ICF reproduction if they are introduced to breeding ponds[2]. The lack of regular disturbance, such as prescribed fire, can lead to an increase in ground cover and loss of the open soil condition preferred by ICF.

Chemical, Noise, and Light Pollution

Although not specific to ICF, there is concern about the impacts of light, chemical, and noise pollution on frogs. Nutrient and pesticide pollution have been found to be more influential than physical habitat quality on some Midwestern amphibian populations and communities[52]. Environmental contaminants, such as pesticides, pharmaceuticals, and metals, are known to result in endocrine disruption, infertility, genetic damage, increased susceptibility to disease, and death in wildlife[53]. Since the early 2000s, the use of systemic insecticides, such as neonicotinoids, has increased across the agricultural and residential landscape, and a large portion of corn and soybean seeds planted in the USA are now coated with insecticides[54–56]. Although potential direct impacts cannot be ruled out, indirect impacts may be a greater concern because neonicotinoids are persistent in the environment and efficiently target and devastate prey insect populations at very low doses[54,55,57].

There is increasing awareness and concern about the impacts of human-caused noise on wildlife[58]. Noise has been found to interfere with frog behaviors related to reproduction[59]. While some frog species have the ability to adjust their call to compensate for noisy environments, other species do not[60,61]. Increased calling is known to be energetically demanding, and may have negative survival impacts[62]. Noise and vibrations produced by ATV activity has interfered with cues used by fossorial toads to time their emergence with appropriate environmental conditions[38]. No studies have been conducted on the impact of noise interference on ICF, but it has been noted that some choruses ceased calling when disturbed by noise or vibration[10]. Low and high frequency noises from increasing road density and the proposed development of wind farms within ICF habitat may have the potential to interfere with ICF's ability to locate mates and/or prey.

Artificial lighting increases with human development and has been found to alter various frog behaviors related to reproduction, development, and survival[63–65].

Climate Change

ICF is rated as "Extremely Vulnerable" or "Highly Vulnerable" to climate change due to potential drying of ephemeral pools, which is worsened by fragmented landscapes and increased water demand for irrigation[66]. ICF reliance on sandy soils essentially restricts them to islands of habitat hindering their ability to move to more suitable areas. Illinois is projected to have increased rainfall in spring, which may be beneficial for ICF breeding habitat but decreased summer rainfall, which may cause premature drying of breeding ponds[67].

Disease

Infectious diseases caused by viral, bacterial, water mold, metazoan, trematode, and fungal agents have caused declines in amphibian populations across the globe and are a potential threat to ICF populations[68]. Ranavirus, a contagious virus capable of infecting amphibians, reptiles, and fish, has been found in Illinois[69]. It is implicated in population declines of frog populations and has been found to cause mortality in *Pseudacris* spp, but impacts specific to ICF are unknown[70]. Chytrid fungus (*Batrachochytrium dendrobatidis*) is a leading cause of global amphibian declines, and although the chytrid fungus has persisted in Illinois for over 100 years and has been found in *Pseudacris* spp., its impacts to ICF are unknown[71,72].

Regulations

In Illinois, it is illegal to "take" any threatened or endangered species, such as ICF. "Take" is defined as "to harm, hunt, shoot, pursue, lure, wound, kill, destroy, harass, gig, spear, ensnare, trap, capture, collect, or attempt to engage in such conduct", is prohibited by the Illinois Endangered Species Protection Act: http://ilga.gov/legislation/ilcs/ilcs3.asp?ActID=1730&ChapterID=43

The IDNR Impact Assessment Section reviews proposed actions to assess potential impacts to listed species, using their online tool EcoCAT: http://dnr.illinois.gov/ecopublic/

IDNR can authorize the taking of listed species that is incidental to otherwise lawful activities. To receive Incidental Take Authorization, one must prepare a conservation plan and notify the public of the impact. See http://www.dnr.illinois.gov/conservation/NaturalHeritage/Pages/ApplyingforanIncidentalTakeAuthorization.aspx

Research, handling, and possession of listed species may require IDNR permits, including a Scientific Collector Permit and an Endangered and Threatened Species Possession Permit, and additional site permits if research takes place on IDNR land or a dedicated Nature Preserve: http://www.dnr.illinois.gov/conservation/NaturalHeritage/Pages/ResearchPermits.aspx. Risks and impacts of research methods on the species survival must be weighed against the benefits to justify the activity. For example, protocols must include measures to prevent the spread of disease.

Species Conservation Goal

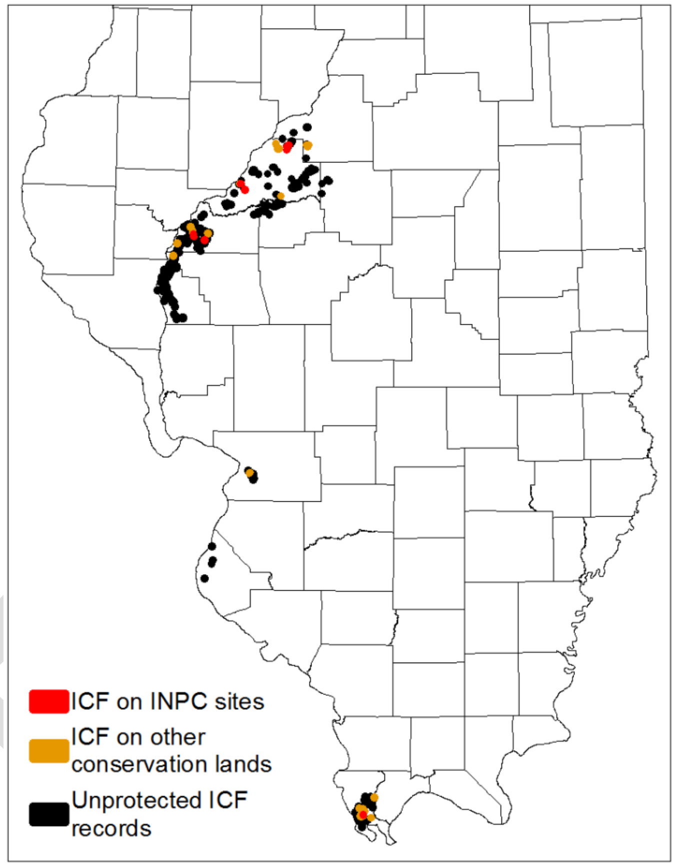
The 2015 Illinois Wildlife Action plan has set goals of maintaining or increasing occupancy of ICF and increasing the number of ephemeral wetlands and upland sand prairie habitat in the Mason County Conservation Opportunity Area (Illinois River and Mississippi River Sand Areas) by 10% (or approximately 100 wetlands) during the next 10 years[73].

Conservation Efforts

ICF is a focal species of the Wetlands Campaign in the Illinois Wildlife Action Plan, which has prioritized habitat conservation actions for ICF[73]. In addition, IDNR is developing a conservation plan for ICF. A range-wide monitoring program has been initiated and will continue for at least 10 years.

Six out of twenty-nine population records occur at least partially on protected Illinois Nature Preserve sites[27]. An additional four records occur partially on other types of conservation lands[74]. The other 19 ICF records remain unprotected.

ICF habitat improvements have been made on state and private lands, especially in the Mason County Sands Area. These improvements include creation of over 20 breeding ponds in Tazewell, Mason, Menard and Cass counties[73]. Newly created breeding ponds have been successfully colonized but the population impacts of these efforts are unknown. Existing wetlands have also been restored in Mason and Cass counties and 116 acres of the surrounding sand prairie habitat has been managed to remove invasive and encroaching vegetation[73]. Over 198 acres of private agricultural land has undergone wetland restoration through the Conservation Reserve Program (USDA) for ICF habitat in Mason County with a Signup Incentive Payment from IDNR[73]. A number of agencies have provided support for ICF habitat work including the USDA's Conservation Reserve Program/State Acres for Wildlife Enhancement (SAFE) program, IDNR's State Wildlife Grant program, and the US Fish and Wildlife Service's (USFWS) Landowner Incentive Program and Partners for Wildlife program.



Illinois chorus frog records from the Illinois Natural Heritage Database found on INPC sites (dedicated Nature Preserves and Land and Water Reserves), other "conservation" lands as identified by Ducks Unlimited, and non-conservation lands[23,74].

Survey Guidelines

Monitoring for trends

To detect a 30-50% decline in ICF occupancy, 75-90 sections with ICF habitat should be surveyed annually[28]. To increase detection, two surveys should be done but during drought years three surveys will be needed[28]. Surveyors travel around the perimeter of the target section stopping to listen for calling ICF[28].

Surveys for presence

Calling surveys can be used to determine presence of ICF at aquatic locations. Surveys must be completed between March and mid-April, after at least 1 in. of rainfall by a qualified biologist[12,16,28]. Known breeding ponds in the area can be visited to ascertain ICF have emerged and are calling to ensure the appropriate calling period is surveyed. Surveys should begin at least 30 minutes after sunset and end by midnight to evaluate the most active calling period[28], and be conducted when temperatures are above 32˚ F and winds less than 18 mph with a lack of heavy rainfall[45]. At a minimum, the surveyor must listen at a particular spot for 15 minutes. The number of surveys necessary to conclude absence to any degree of certainty is dependent on detection rates, which vary between surveys (see table)[28]. Data recording should include air temperature, humidity, wind speed, presence of moonlight, the number of cars that passed by during the survey, and the level of human-caused noise. Calling ICF can be heard at a distance of up to 1.3 miles, making it difficult to identify local populations and specific habitat use[4]. Specific breeding locations should be triangulated by using multiple survey locations (at least 3) around the area of interest. General guidelines for frog calling surveys can be found in Dorcas et al. [75]

Table indicating the number of surveys necessary to determine presence or absence to various degrees of certainty[28].

Number of surveys	Low detection rate (0.6)	Median detection rate (0.77)	High detection rate (0.9)
1	60%	**77%**	90%
2	84%	**95%**	99%
3	94%	**99%**	99%

Another potential method for determining ICF presence in a breeding pond is to analyze water samples (at least 3) for environmental DNA; this method has not yet been utilized for ICF[76].

Survey methods are not available for terrestrial habitat and presence should be assumed in an area if it contains sandy soil and is within 1 mile of an occupied breeding pond.

Monitoring for impacts

Surveys to monitor impacts of habitat alterations at specific locations, such as habitat restoration or Incidental Take Authorization, should evaluate changes in abundance, survival, reproduction or recruitment. Due to the great influence of environmental variability on ICF populations, a control site and multiple survey years are necessary for comparison and a before-after-control-impact (BACI) design should be followed. All ponds in the impacted area should be surveyed as well as similar control sites that should be close enough to impact sites to have similar environmental variation but far enough away to be uninfluenced by the impact of concern. Ideally, surveys should be conducted for two years prior to impact and for six years after impact to cover the life span of the species. Late-stage tadpoles may be the most efficient life stage to survey. After call surveys confirm ICF activity in the area, dip net surveys should be conducted in the ponds of interest. Surveys should be conducted on nine separate days distributed between mid-March and late May with 12 net sweeps per pond per day (Chris Phillips pers. comm.). Data recording should include presence of fish and other predators, vegetation structure, pond area, and pond depth. Survey reports should detail methods used and include raw data and statistical analysis that evaluate changes in abundance, survival, reproduction or recruitment.

Stewardship recommendations

Areas known to support ICF or thought to be suitable for ICF should be managed to maintain suitable habitat for ICF and its biological community. Fish and other predators should be prevented from establishing populations in breeding ponds by maintaining ephemeral hydrology, but water should be maintained in ponds through June to allow for metamorphosis[6,42].

Emergent vegetation, such as arrowhead (*Sagittaria spp.)*, spikerush (*Eleocharis spp.*), pickerelweed (*Pontederia cordata)*, wild celery (*Vallisneria Americana*), or bulrush (*Scirpus spp.),* should be established and maintained. Roadside breeding ponds should not be mowed. Livestock access to wetlands should be restricted to prevent trampling of vegetation and pollution of waters. Woody encroachment around some wetland sites may alter the hydrology and cause ponds to dry prior to metamorphosis[49]. These sites may be improved through removal of woody species. In some cases, invasive species may need to be controlled in breeding ponds to prevent filling in or drying of wetlands.

In terrestrial areas, control of woody and exotic vegetation and maintenance or establishment of sparse native sand prairie vegetation may be

Using a dip net to sample aquatic biota. Photo by Jutta Schmidt-Gengenbach[101].

Illinois chorus frog tadpole (top) with Western chorus frog (bottom) for comparison. Note the large size, round shape, tall dorsal fin with forward fin attachment of ICF. Photo by John Tucker[6] necessary to prevent sod formation and maintain open soil areas, such as blowouts, for burrowing. Prescribed burning is an important part of maintaining sand prairie communities and should be conducted in the fall when ICF are underground. Late summer to early fall mowing of vegetation can be used to maintain terrestrial habitat[77]. It has also been suggested that some agricultural practices are generally compatible with this species needs, in that it prevents woody encroachment and maintains open soil[49], but the impacts of specific practices, such as disking and chemical use, are unknown. If necessary, mechanical and chemical removal of vegetation should follow INPC stewardship guidelines (http://www.dnr.illinois.gov/INPC/Pages/INPCManagementGuidelines.aspx).

Adjacent land owners and local residents should be informed of the presence of ICF and of practices that they can perform to support ICF survival, such as natural landscaping, reducing the use of insecticides, reducing impermeable surfaces, eliminating mesopredator resources, reducing artificial lighting, and preventing pets from roaming freely[78]. Agricultural best management practices, such as cover crops, buffer strips, conservation tillage, constructed wetlands and integrated pest management, should be encouraged in the surrounding watersheds[79].

Because some ICF populations may harbor infectious diseases, it is important to decontaminate prior to moving between ICF occupied sites. Decontamination requires washing and disinfecting all equipment, boots, and waders with a 3% bleach solution or other disinfectant. See the NEPARC Disinfection Protocol[80].

Avoidance, Minimization, Mitigation

Avoidance measures

Due to the secretive nature of ICF, avoiding impacts from development is only possible through complete avoidance of suitable habitat. To avoid impact, breeding ponds and the surrounding terrestrial areas (within 1 mi) with sandy soil should not be impacted[81,82]. The hydrology of ICF habitat should not be altered by damming, draining,

Sand prairie with created breeding ponds and encroaching woody vegetation. Photo credit Bob Bluett[49]

dredging, or channelizing water flowing into or out of occupied breeding ponds.

Minimization measures

Timing

If habitat cannot be avoided, timing of activities may minimize impacts. Activities destructive to breeding ponds should occur between July 1 and January 31. Destructive activities in terrestrial habitats should be conducted from March 1 to April 30 when frogs are more likely to be in aquatic habitats.

Compatible design

Development projects should be compatible with continued use by ICF. If breeding ponds will be impacted, efforts should be directed towards maintaining their temporary to semi-permanent hydrology in order to preserve their suitability. Efforts should also be directed towards maintaining isolation of wetlands from larger bodies of water with predatory fish and preventing introduction of predatory fish into breeding ponds. Hydrologic and soil surveys may be necessary to understand the impacts. If soil disturbance and restoration is required, efforts should be made to restore the soil profile. Terrestrial areas should include sparse sand prairie vegetation.

General application of pesticides, herbicides, or fertilizers should be prohibited to avoid impacts to ICF. Noise and vibrations, such as from traffic or construction activities, should be minimized, especially from February to April between sunset to midnight. Artificial lighting should be minimized from February to June[83].

New and existing roads and railways, especially those bisecting habitat, should be designed or retrofitted with safe passage systems[84]. Amphibian road mortality can be prevented by as much as 95% by installing permanent barrier walls and culvert systems around high traffic roads[85]; however, population impacts are unclear[51]. Road mortality surveys can be used to identify optimal locations for passageways[86]. Barrier fencing should extend half a foot underground and at least two feet aboveground with an overhang to prevent some species from climbing over and entering the roadway[87,88]. Although wire mesh or plastic fencing may be used, it will require considerable amounts of maintenance to be effective; a concrete wall or steel barrier will be longer lasting and may be more effective[89]. Barrier walls and curbing around developments have also been suggested as ways to deter ICF from entering dangerous areas. The effectiveness of passageways depends on their openness and light permeability[90,91]. Openness is defined as (height x width)/length of the culvert or passage. An openness of at least 0.82 should be maintained[90,92]. Bridges are preferred to culverts due to their natural open conditions[93]. Flat-bottomed or elliptical culverts with natural substrate are ideal, and "skylights" can be used to increase light permeability[51]. Reduced speed limits and "Break for Wildlife" signs on roads with ICF mortality have also been proposed as strategies for reducing mortalities, but the benefits are questionable[51,94]

<u>Construction practices</u>
Construction and maintenance practices should be sensitive to impacts to ICF and their habitat. Clearing of native vegetation should be limited. Staging areas should be located far from sensitive areas. Erosion and sediment controls should be strictly implemented, monitored, and maintained for the duration of the project. Debris and excess materials should be removed and properly disposed. All project personnel should be informed of the sensitive nature of the project and notified of the proper procedures to follow if a frog is found.

Work within ICF habitat should avoid the use of heavy machinery to prevent crushing of subterranean frogs. The area impacted should be reduced as much as possible, and areas that are not to be disturbed should be flagged or fenced to alert construction personnel. When heavy machinery must be used, mat or corduroy roadways and equipment with low psi tires or tracks may minimize subterranean pressure.

Amphibian exclusion fencing may reduce the number of ICF entering a construction zone. A standard silt fence that is 3 ft. tall and trenched 6 in. into the soil with turn-arounds at the ends to redirect frogs away from the site should reduce access[95]. The fencing must be installed when the species is not present (during the breeding season if working in terrestrial area). The interior and exterior of the fenced area should be examined daily to release any trapped ICF to suitable habitat and to maintain its integrity. Alternatively, trapping and relocating ICF to nearby suitable habitat has been used to reduce the number of frogs impacted at a construction site; they should be moved to the closest safe location by an IDNR authorized person.

Mitigation and Conservation Opportunities
Mitigation opportunities include protection, stewardship, and creation/restoration of ICF habitat.

<u>Protection</u>
Habitat modeling and call surveys have identified ICF populations that occur on unprotected land and may be at risk of habitat destruction. Site protection should consist of both breeding and non-breeding habitat to provide for the needs of the full life cycle. Priority should be given to protecting wetlands occupied by or near current ICF records and adjacent sandy soil. In addition, protection of sites that are between occupied habitats will improve connectivity and may increase the long term survival of those populations. Priority areas for protection in Mason and Tazewell counties [77] and other potentially suitable habitat[26] have been identified. Additional wetlands and sandy soil locations can be located using publically available spatial information (http://www.fws.gov/wetlands/Data/Mapper.html; http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

Land protection may consist of acquisition or conservation easement. Acquired land could be donated to a conservation agency or local conservation organization. Conservation easements may provide a level of protection without acquisition. The Illinois Nature Preserves Commission permanently protects high quality areas and habitat for listed species on both private and public lands in the Illinois Nature Preserve System. Conservation easements on agricultural land can also protect ICF habitat through retirement of farmed and prior converted wetlands from agricultural production. Such a program was initiated in the Mason County Sand Areas with the Farm Service Agency, Natural Resources Conservation Service, and Soil and Water Conservation District and may be a useful model to expand ICF conservation on agricultural lands in other counties. Under this design the cost of habitat protection is approximately $235 per acre per year[49,96] . Organizations that are active in the ICF geographic range and may be interested in partnering on conservation efforts, include Friends of Sangamon Valley, HeartLands Conservancy, and Prairie Land Conservancy. Additional conservation organizations can be identified through the Prairie State Conservation Coalition (http://www.prairiestateconservation.org).

<u>Stewardship</u>

Beyond protection of ICF habitat there is considerable stewardship work that may be required to maintain ICF habitat that is already protected. See Stewardship Recommendations section. ICF habitat stewardship opportunities exist on state-owned properties, USFWS-owned properties, and private properties. One terrestrial habitat restoration project controlled woody and invasive species on 50 acres and established native vegetation on 10 acres for an estimated $20,000[49].

<u>Restoration/Habitat creation</u>

In addition to protection and stewardship of existing habitat, there are opportunities to create additional ICF habitat within its range. Habitat creation should incorporate both breeding ponds and terrestrial habitat[6]. Created ponds should be located near existing populations (within 0.6 mi.) to allow for natural colonization of the site[6]. The suggested minimum dimensions of a breeding pond are around 15 ft. across and no more than 3 ft. deep with gradual sloping sides[97]. Constructed ponds must persist until mid-June and should not last year round. Water level surveys at the site should be conducted to ensure the created pond will provide suitable conditions. In ideal locations, very little excavation is necessary as shallow depressions that will hold water may be suitable and readily restored under the right conditions[98]. Disabling or removal of agricultural drainage tiles may be all that is necessary in some locations. Pond liners 75 by 125 ft. in size have been used to ensure water is retained in some ponds. To enable amphibians to burrow into the sediment and allow the establishment of aquatic vegetation, liners should be installed at a depth of 4 ft. and covered with 2 ft. of excavated topsoil, and leftover material should be graded out 40 ft. from the pond. Some pond creations have used water control structures or well pumps to ensure suitable water levels are maintained through metamorphosis, but this is often not necessary for ephemeral ponds. Where pond levels are controlled, they should be drained by July[6]. Before creating a pond, the water quality at the site should be tested for contaminants. Ponds should have dead grasses or other emergent vegetation to act as structure for egg deposition and to provide cover for tadpoles and breeding adults. In ephemeral ponds, terrestrial vegetation that grows after the pond dries can provide this structure, but aquatic vegetation may also provide structure.

There are different methods for creating ephemeral ponds with costs varying between $350 and $3000[99] (http://herpcenter.ipfw.edu/outreach/vernalponds/vernalpondguide.pdf). Breeding pond creation practices correspond to National Conservation

Created pond with appropriate structure for egg attachment. Photo credit Eric Smith

Practice Standards Shallow Water Development and Management (NRCS Code 646) and Wildlife Wetland Habitat Management (NRCS Code 644), and Conservation Reserve Program Practice Non-floodplain Wetland Restoration (CP 23A) and Shallow Water Areas for Wildlife (CP9).

For the terrestrial portion of the conservation area, creation or restoration of sand prairie habitat should be planned[6]. The first step of prairie restorations is generally controlling weeds and invasive species, often with agricultural cultivation[100]. Exotic trees, which are often present, should also be removed. Selection of grasses and forbs for planting should be appropriate for the local conditions. Although there is currently no experimental evidence that native vegetation is better for ICF than old-field vegetation, the sand area must support significant subterranean invertebrate populations[6] and restoration of prairie may benefit other organisms. See stewardship section above for appropriate species. A basic mix of grasses and forbs can be purchased from Pheasants & Quail Forever for $110 per acre (2015 mix #1-08-327 Dry Soils). Aggressive species that create dense root systems and eliminate bare ground, such as big bluestem, eastern gramma grass, and wild bergamot, should be avoided. Drill seeding is ideal but broadcast seeding can also be used. Ongoing management needs of the restoration site may include fall prescribed burns and invasive species control. More information on prairie restoration can be found at: https://www.dnr.illinois.gov/publications/documents/00000285.pdf . Terrestrial habitat creation corresponds to National Conservation Practice Standard Upland Wildlife Habitat Management (NRCS Code 645).

Research needs

What are the limiting factors to ICF population growth?

- Investigate survival, reproduction, and recruitment rates related to various habitat and climate conditions. Investigate the effects of management activities on these rates.

What are the fossorial habits of ICF?

- Determine ICF underground movement patterns, how they detect prey, how they respond to drought.

What are the migration patterns of ICF?

- Track the movements of ICF between breeding ponds and upland habitat.

What is the impact of surface activity on frogs below the surface?

- Investigate how they respond to surface pressure, noise, and disking.

What are the effect of insecticides, especially neonicotinoids, on ICF and their prey?

- Determine the presence and pathways of various insecticides in ICF habitat. Assess the effects of various insecticides on ICF and their prey.

What are the most effective survey methods?

- Investigate the detection rates of environmental DNA and tadpole surveys.

Additional information

http://wwx.inhs.illinois.edu/collections/herps/data/ilspecies/ps_strecke/

http://www.inhs.illinois.edu/animals_plants/herps/species/ps_strecke.html

http://explorer.natureserve.org/servlet/NatureServe?searchName=Pseudacris+streckeri+illinoensis

http://www.amphibiaweb.org/index.html

http://herpcenter.ipfw.edu/outreach/vernalponds/vernalpondguide.pdf

References

1. NatureServe. NatureServe Explorer: An online encyclopedia of life [web application]. *NatureServe, Arlington, Virginia.* 1–8 (2015). Available at: http://explorer.natureserve.org. (Accessed: 17th October 2016)
2. Phillips, C., Brandon, R. & Moll, E. *Field guide to amphibians and reptiles of Illinois*. (Illinois Natural History Survey, Manual 8, 1999).
3. Schneider, E. A. Population genetics of the Illinois chorus frog (Pseudacris illinoensis). (University of Illinois Urbana-Champaign, 2011).
4. Brown, L. E. & Rose, G. B. Distribution, habitat, and calling season of the Illinois Chorus Frog (Pseudacris streckeri illinoensis) along the Lower Illinois River. *Illinois Nat. Hist. Surv. Biol. Notes* **132,** 13 (1988).
5. Tucker, J. K. in *Status and conservation of Midwestern amphibians* (ed. Lannos, M. J.) 94–101 (University of Iowa Press, 1998).
6. Tucker, J. K., Chick, J. H. & Szafoni, R. *The Illinois chorus frog (Pseudacris illinoensis) and wetland mitigation : What*

has worked? *Illinois Natural History Survey Technical Report 2008(26)* (2008).

7. Tucker, J. K., Camerer, J. B. & Hatcher, J. B. Pseudacris streckeri illinoensis (Illinois Chorus frog). Burrows. *Herpetol. Rev.* **26,** 32–33 (1995).
8. Brown, L. E., Jackson, H. O. & Brown, J. R. Burrowing behavior of the chorus frog, Pseudacris streckeri. *Herpetologica* **28,** 325–328 (1972).
9. Tucker, J. K. & Wilson, B. *The Illinois chorus frog (Pseudacris streckeri illinoensis) and the dredge material deposition sites at Beardstown, Illinois*. *Illinois Natural History Survey Technical Report* (2002).
10. Beltz, E. *Distribution and status of the Illinois chorus frog , Pseudacris streckeri illinoensis, in Cass, Menard, Morgan, and Scott Counties of West-central Illinois*. 18 (Report to the Illinois Department of Conservation, Division of Natural Heritage, 1993).
11. Beltz, E. Illinois chorus frog, Pseudacris streckeri illinoensis, 1991 survey of Cass, Menard, Morgan, and Scott Counites, Illinois. 18 (1991).
12. Brandon, R. A. & Ballard, S. R. in *Status and conservation of Midwestern amphibians* (ed. Lannoo, M. J.) (University of Iowa Press, 1998).
13. Tucker, J. K. Fecundity in the Illinois chorus frog (Pseudacris streckeri illinoensis) from Madison County, Illinois. *Trans. Illinois State Acad. Sci.* **90,** 167–170 (1997).
14. McCallum, M. L., Trauth, S. E., Mcdowell, C., Neal, R. G. & Klotz, T. L. Calling site characteristics of the Illinois chorus frog (Pseudacris streckeri illinoensis) in Northeastern Arkansas. *Herpetol. Nat. Hist.* **9,** 195–198 (2006).
15. Tucker, J. K. Early post-transformational growth in the Illinois chorus frog (Pseudacris streckeri illinoensis). *J. Herpetol.* **8,** 437–440 (1995).
16. Tucker, J. K. & Philipp, D. P. *Population status of the Illinois chorus frog (Pseudacris streckeri illinoensis) in Madison County, Illinois: Results of 1994 surveys*. *Report to Illinois Department of Transportation* (1995).
17. Trauth, J. B., Johnson, R. L. & Trauth, S. E. Conservation implications of a morphometric comparison between the Illinois Chorus Frog (Pseudacris streckeri illinoensis) and Strecker's Chorus Frog (P. s. streckeri) (Anura: Hylidae) from Arkansas, Illinois, Missouri, Oklahoma, and Texas. *Zootaxa* **1589,** 23–32 (2007).
18. Collins, J. T. Viewpoint: A new taxonomic arrangement for some North American amphibians and reptiles. *Herpetol. Rev.* **22,** 42–43 (1991).
19. Barrow, L. N., Bigelow, A. T., Phillips, C. a. & Lemmon, E. M. Phylogeographic inference using Bayesian model comparison across a fragmented chorus frog species complex. *Mol. Ecol.* **24,** 4739–4758 (2015).
20. IUCN. Pseudacris streckeri. The IUCN Red List of Threatened Species 2015. (2015).
21. ITIS (Integrated Taxonomic InformationSystem). ITIS Standard Report Page: Pseudacris illinoensis. (2015). Available at: http://www.itis.gov. (Accessed: 9th September 2015)
22. Dodd, C. K. *Frogs of the United States and Canada*. 460 (Johns Hopkins University Press, 2013).
23. Illinois Department of Natural Resources. Natural Heritage Biotics 5 Database. (2016).
24. Tucker, J. K. & Philipp, D. P. *Population status of the Illinois chorus frog in Madison County, Illinois: results of 1995 surveys*. (Illinois Department of Transportation, 1995).
25. Tolch, K. L. Reproductive biology of the Illinois chorus frog, Pseudacris streckeri illinoensis Smith 1951, (Anura: Hylidae), in Alexander county, Illinois. (Southern Illinois University, 1997).
26. Hinz, L., Hulin, A. & Holtrop, A. M. *Using a landscape approach to refine conservation plans for Illinois chorus frog (Pseudacris streckeri illinoensis)*. 1–16 (Report to Illinois Department of Natural Resources, 2011).
27. Illinois Department of Natural Resources. Natural Heritage Biotics 5 Database. (2015).
28. Cosentino, B. J. *Monitoring plan to detect trends in occupancy of Illinois chorus frogs (Pseudacris streckeri illinoensis)*. 1–40 (Report to Illinois Department of Natural Resources, 2014).
29. Brown, L. E. Subterranean feeding by the chorus frog Pseudacris streckeri (Anura: Hylidae). *Herpetologica* **34,** 212–216 (1978).
30. Axtell, R. W. & Haskell, N. An Interhiatal Population of Pseudacris streckeri from Illinois, with an Assessment of Its Postglacial Dispersion History. *Nat. Hist. Misc.* 7–9 (1977).
31. Packard, G. C., Tucker, J. K. & Lohmiller, L. D. Distribution of Strecker's chorus frogs (Pseudacris streckeri) in relation to their tolerance for freezing. *J. Herpetol.* **32,** 437 (1998).
32. Brown, L. E. & Cima., J. E. in *Status and Conservation of Midwestern Amphibians* (ed. Lannoo, M. .) 301–311 (University of Iowa Press, 1998).
33. Jaeger, R. G. in *Sensory ecology* (ed. Ali, M. A.) 169–196 (Plenum Press, 1978).
34. Narins, P. M. Seismic in communication in anuran amphibians. *Bioscience* **40,** 268–274 (1990).
35. Christensen-Dalsgaard, J. & Narins, P. M. Sound and vibration sensitivity of VIIIth nerve fibers in the frogs, Leptodactylus albilabris and Rana pipiens pipiens. *J. Comp. Physiol. A* **172,** 653–662 (1993).
36. Devetak, D., Mencinger-Vračko, B., Devetak, M., Marhl, M. & Špernjak, A. Sand as a medium for transmission of vibratory signals of prey in antlions Euroleon nostras (Neuroptera: Myrmeleontidae). *Physiol. Entomol.* **32,** 268–274 (2007).
37. Young, B. a & Morain, M. The use of ground-borne vibrations for prey localization in the Saharan sand vipers (Cerastes). *J. Exp. Biol.* **205,** 661–665 (2002).
38. Brattstrom, B. H. & Bondello, M. C. *Environmental Effects of Off-Road Vehicles*. 167–206 (Springer New York, 1983). doi:10.1007/978-1-4612-5454-6
39. Owen, P. C. & Tucker, J. K. Courtship calls and behavior in two species of chorus frogs, genus Pseudacris (anura: Hylidae). *Copeia* **2006,** 137–144 (2006).
40. McCallum, M. L. & Trauth, S. E. Are tadpoles of the Illinois chorus frog (Pseudacris streckeri illinoensis) cannibalistic? *Trans. Illinois State Acad. Sci.* **94,** 171–178 (2001).
41. Tucker, J. K. Description of newly transformed froglets of the Illinois chorus frog (Pseudacris streckeri illinoensis). *Trans. Illinois State Acad. Sci.* **90,** 161–166 (1997).
42. Tucker, J. K. Growth and survivorship in the Illinois chorus frog (Pseudacris streckeri illinoensis). *Trans. Illinois State Acad. Sci.* **93,** 63–68 (2000).
43. Butterfield, B. P., Meshaka, W. E. & Trauth, S. E. Fecundity and egg mass size of the Illinois chorus frog, Pseudacris streckeri illinoensis (Hylidae), from northeastern Arkansas. *Southwest. Assoc. Nat.* **34,** 556–557 (1989).
44. Berven, K. a. Factors affecting population fluctuations in larval and adult stages of the wood frog. *Ecology* **71,** 1599–1608 (1990).
45. Hulin, A. C., Golden, E. P. & Bluett, R. D. *Monitoring occupancy of the Illinois chorus frog (Pseudacris streckeri illinoensis): Are plots or ponds the best fine-scaled sampling unit for call surveys?* (Illinois Department of Natural Resources, 2015).

46. Harper, E. B., Rittenhouse, T. a G. & Semlitsch, R. D. Demographic consequences of terrestrial habitat loss for pool-breeding amphibians: Predicting extinction risks associated with inadequate size of buffer zones. *Conserv. Biol.* **22,** 1205–1215 (2008).
47. Illinois Department of Natural Resources. *The Standards and Guidelines for the Illinois Natural Areas Inventory*. (2013).
48. Dahl, T. E. *Wetlands losses in the United States 1780's to 1980's*. (U.S. Deartment of the Interior, Fish and Wildlife Service, 1990).
49. Bluett, B. *Habitat conservation initiative for the Illinois chorus frog: Phase I.* (Illinois Department of Natural Resources, 2009).
50. Thiele-Bruhn, S., Bloem, J., DeVries, F. T., Kalbitz, K. & Wagg, C. Linking soil biodiversity and agricultural soil management. *Curr. Opin. Environ. Sustain.* **4,** 523–528 (2012).
51. Beebee, T. J. C. Effects of road mortality and mitigation measures on amphibian populations. *Conserv. Biol.* **27,** 657–668 (2013).
52. Jordan, M. A. *et al.* Influence of instream habitat and water chemistry on amphibians in channelized agricultural headwater streams. *Agric. Ecosyst. Environ.* **230,** 87–97 (2016).
53. Boone, M. *et al.* in *Amphibian Conservation Action Plan* (eds. Gascon, C. et al.) 32–35 (The World Conservation Union (IUCN), 2007).
54. Simon-Delso, N. *et al.* Systemic insecticides (Neonicotinoids and fipronil): trends, uses, mode of action and metabolites. *Environ. Sci. Pollut. Res.* **22,** 5–34 (2015).
55. Gibbons, D., Morrissey, C. & Mineau, P. A review of the direct and indirect effects of neonicotinoids and fipronil on vertebrate wildlife. *Environ. Sci. Pollut. Res. Int.* **22,** 103–118 (2015).
56. Hladik, M. L., Kolpin, D. W. & Kuivila, K. M. Widespread occurrence of neonicotinoid insecticides in streams in a high corn and soybean producing region, USA. *Environ. Pollut.* **193,** 189–196 (2014).
57. Pisa, L. W. *et al.* Effects of neonicotinoids and fipronil on non-target invertebrates. *Environ. Sci. Pollut. Res. Int.* **22,** 68–102 (2015).
58. Barber, J. R., Crooks, K. R. & Fristrup, K. M. The costs of chronic noise exposure for terrestrial organisms. *Trends Ecol. Evol.* **25,** 180–189 (2010).
59. Bee, M. A. & Swanson, E. M. Auditory masking of anuran advertisement calls by road traffic noise. *Anim. Behav.* **74,** 1765–1776 (2007).
60. Lengagne, T. Traffic noise affects communication behaviour in a breeding anuran, Hyla arborea. *Biol. Conserv.* **141,** 2023–2031 (2008).
61. Parris, K. M., Velik-lord, M. & North, J. M. A. Frogs call at a higherpitch in traffic noise. *Ecol. Soc.* **14,** 25 (2009).
62. Kaiser, K. *et al.* When sounds collide: the effect of anthropogenic noise on a breeding assemblage of frogs in Belize, Central America. *Behaviour* **148,** 215–232 (2011).
63. Baker, B. J. B. J. & Richardson, J. M. L. R. M. L. The effect of artificial light on male breeding-season behaviour in green frogs, Rana clamitans melanota. *Canadian Journal of Zoology* (2006).
64. Buchanan, B. W. in *Ecological Consequences of Artificial Night Lighting* (eds. Rich, C. & Longcore, T.) 192–220 (Island Press, 2006).
65. Perry, G., Buchanan, B., Fisher, R., Salmon, M. & Wise, S. E. in *Urban Herpetology* (eds. Mitchell, J. C., Brown, R. E. J. & Bartholomew, B.) 239–256 (Herpetological Conservation, 2008).
66. Walk, J., Hagen, S. & Lange, A. *Adapting Conservation to a Changing Climate: An Update to the Illinois Wildlife Action Plan*. 120 p. (Report to the Illinois Department of Natural Resources, 2011).
67. Hayhoe, K., VanDorn, J., Croley, T., Schlegal, N. & Wuebbles, D. Regional climate change projections for Chicago and the US Great Lakes. *J. Great Lakes Res.* **36,** 7–21 (2010).
68. Daszak, P. *et al.* Emerging infectious diseases and amphibian population declines. *Emerg. Infect. Dis.* **5,** 735–48
69. Duffus, A. L. J. *et al.* in *Ranaviruses: Lethal Pathogens of Ectothermic Vertebrates* (eds. Gray, M. J. & Chinchar, V. G.) (Springer International Publishing, 2015).
70. Miller, D., Gray, M. & Storfer, A. Ecopathology of ranaviruses infecting amphibians. *Viruses* **3,** 2351–73 (2011).
71. Phillips, C. A., Wesslund, N. A. & MacAllister, I. E. Occurrence of the chytrid fungus Batrachochytrium dendrobatidis in amphibians in Illinois, USA. *Herpetol. Rev.* **45,** 238–240 (2014).
72. Talley, B. L., Muletz, C. R., Vredenburg, V. T., Fleischer, R. C. & Lips, K. R. A century of Batrachochytrium dendrobatidis in Illinois amphibians (1888–1989). *Biol. Conserv.* **182,** 254–261 (2015).
73. Illinois Department of Natural Resources. *2015 Implementation guide to the Illinois wildlife action plan*. (2015).
74. Ducks Unlimited. Conservation and Recreation Lands (CARL). (2013).
75. Dorcas, M. E., Price, S. J., Walls, S. C. & Barichivich, W. J. in *Amphibian Ecology and Conservation: A Handbook of Techniques* (ed. Dodd, C. K.) (Oxford University Press, 2008).
76. McKee, A. M. *et al.* Assessment of environmental DNA for detecting presence of imperiled aquatic amphibian species in isolated wetlands. *J. Fish Wildl. Manag.* **6,** 498–510 (2015).
77. Berger, A. J., Schneider, E. A. & Phillips, C. A. *Strategies for recovery of an amphibian and a reptile inhabiting sand areas in Mason and Tazewell Counties.* (INHS Technical Report 2010(08), 2010).
78. Church, J. Storm water best management practices start at home. *University of Illinois Extension* (2016). Available at: http://extension.illinois.edu/lcr/stormwater.cfm.
79. Illinois Department of Agriculture. *Illinois Nutrient Loss Reduction Strategy*. (2015).
80. Northeast Partners in Amphibian Conservation. *Disinfection of Field Equipment to Minimize Risk of Spread of Chytridiomycosis and Ranavirus*. *NEPARC Publication 2014-02* 4 (2014).
81. Kingsbury, B. & Gibson, J. *Habitat Management Guidelines for Amphibians and Reptiles of the Midwestern United States*. 155 (Partners in Amphibian and Reptile Conservation Technical Publication HMG-1, 2012).
82. Karraker, N. E., Gibbs, J. P. & Vonesh, J. R. Impacts of road deicing salt on the demography of vernal pool-breeding amphibians. *Ecol. Appl.* **18,** 724–734 (2008).
83. Gaston, K. J., Davies, T. W., Bennie, J. & Hopkins, J. Reducing the ecological consequences of night-time light pollution: options and developments. *J. Appl. Ecol.* **49,** 1256–1266 (2012).
84. FHWA (Federal Higway Administration). Wildlife crossing structure handbook: design and evaluation in North America. (2011).
85. Dodd, C. K., Barichivich, W. J. & Smith, L. L. Effectiveness of a barrier wall and culverts in reducing wildlife mortality

on a heavily traveled highway in Florida. *Biol. Conserv.* **118,** 619–631 (2004).
86. Langen, T. a. *et al.* Methodologies for surveying herpetofauna mortality on rural highways. *J. Wildl. Manage.* **71,** 1361–1368 (2007).
87. Taylor, S., Stow, N., Hasler, C. & Robinson, K. *Lessons learned: Terry Fox Drive wildlife guide system intended to reduce road kills and aid the conservation of Blanding's Turtle (Emydoidea blandingii). Proceedings of the Transportation Association of Canada* **2,** (2014).
88. Woltz, H. W., Gibbs, J. P. & Ducey, P. K. Road crossing structures for amphibians and reptiles: Informing design through behavioral analysis. *Biol. Conserv.* **141,** 2745–2750 (2008).
89. Baxter-Gilbert, J. H., Riley, J. L., Lesbarreres, D. & Litzgus, J. D. Mitigating reptile road mortality: Fence failures compromise ecopassage effectiveness. *PLoS One* **10,** 1–15 (2015).
90. Kuhns, A. R. Culvert dimensions for the safe passage of Blanding's Turtles, Emydoidea blandingii, under Illinois Route 26, Lee County, Illinois. **2014,** (2014).
91. Smith, D. J. *Monitoring wildlife use and determining standards for culvert design.* (Final report presented to the Florida Department of Transportation for Contract BC354-34., 2003).
92. Massachusetts Department of Transportation. *Design of bridges and culverts for wildlife passage at freshwater streams*. 294 (2010).
93. Lesbarrères, D. & Fahrig, L. Measures to reduce population fragmentation by roads: What has worked and how do we know? *Trends Ecol. Evol.* **27,** 374–380 (2012).
94. Johnson, G. *Testing the effectiveness of turtle crossing signs as a conservation measure*. 1–14 (Final Report to St.Lawrence River Research and Education Fund, 2010). doi:10.1017/CBO9781107415324.004
95. Wisconsin Department of Natural Resources. Amphibian and reptile exclusion fencing protocols. (2009).
96. United States Department of Agriculture. Conservation Reserve Program, Monthly summary – December 2015. (2015). Available at: http://www.fsa.usda.gov/programs-and-services/conservation-programs/reports-and-statistics/conservation-reserve-program-statistics/index.
97. R.E., S., Phillips, C. A., Ballard, S. R., Brandon, R. A. & Kruse., G. *Illinois landowner's guide to amphibian conservation*. (Illinois Natural History Survey Special Publication 22, 2002).
98. McClain, W. E., McClain, R. D. & Ebinger, J. E. Flora of temporary sand ponds in Cass and Mason counties, Illinois. *Castanea* **62,** 65–73 (1997).
99. Biebighauser, T. R. *A Guide to Creating Vernal Pools*. 1–33 (USDA Forest Service, 2003).
100. Rowe, H. I. Tricks of the trade: techniques and opinions from 38 experts in tallgrass prairie restoration. *Restor. Ecol.* **18,** 253–262 (2010).
101. National Park Service. Wetlands monitoring. *Inventory and Monitoring* (2015). Available at: http://science.nature.nps.gov/im/units/sien/monitor/wetlands.cfm. (Accessed: 26th July 2016)

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