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Monitoring Occupancy of the Illinois Chorus Frog (*Pseudacris streckeri illinoensis*): Are Plots or Ponds the Best Fine-scaled Sampling Unit for Call Surveys?

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ABSTRACT

We conducted a pilot study to evaluate strategies for monitoring long-term trends in occupancy of the Illinois Chorus Frog (ICF; *Pseudacris streckeri illinoensis*) across its range in Illinois. Standard protocols for call surveys are not sensitive to extinctions of local populations of the ICF because its loud vocalizations create a large sampling area around each listening post. Therefore, we evaluated two spatially explicit, fine-grained alternatives – habitat polygons indicative of breeding sites and sections (a standard unit for land surveys; 2.59 km^2). Our design relied on a GIS model to identify areas with suitable habitat. We tested the model by comparing its predictions to locations where ICFs were collected during an independent study. Most sections with records of ICFs had ≥1 habitat polygon (91%). Ability of the model to predict exact locations of collections was poor by comparison (54% occurred in a habitat polygon). We also evaluated effects of spatial scale on naïve rates of occupancy in central and southern Illinois during 2011–2014. Call surveys (N = 171) conducted at 30 random sections with ≥1 habitat polygon (N = 119) yielded a greater naïve rate of occupancy for sections (63%) than individual breeding sites within those sections (40%) when years and regions were pooled. Annual estimates were generally greater and less variable for sections than breeding sites. The number of breeding sites occupied by ICFs varied from 1–6 per section where ICFs were detected ($\bar{x} = 2.5$). We favor use of sections as sampling units for practical, statistical, and ecological reasons. Our findings provide an intermediary but important step toward a formal monitoring plan.

INTRODUCTION

Successful monitoring programs have clear objectives and a sound statistical framework (Guillera-Arroita et al. 2010). Both require decisions about where sampling will occur, how effort will be allocated, which data will be collected, and in what amount (MacKenzie and Royle 2005). Some choices are intuitive. For example, well-known limits of a species' range might define boundaries for sampling its presence. Other decisions are hampered by lack of information. We faced this problem while designing a monitoring program for the Illinois chorus frog (ICF; *Pseudacris streckeri illinoensis*). Past studies offered a poor framework for sampling because they used a convenience method of choosing sites for surveys and often reported presence – but not absence – of ICFs (Berger et al. 2010, Brandon and Ballard 1998, Tucker 1998, Beltz 1993, Brown and Rose 1988, Taubert et al. 1982). Therefore, we developed a GIS model to predict limits of occurrence and locations of patches of suitable habitat within its confines. Potential applications of the model included defining a statistical area of inference and choosing a stratified random sample of sites for monitoring.

Natural volatility in abundance of amphibians makes it difficult to identify long-term trends indicative of a change in status (Houlahan et al. 2000, Blaustein et al. 1994, Pechmann et al. 1991). Our ultimate goal was to detect meaningful changes in occupancy of ICFs (30–50%) during a 10-year period with a reasonable amount of confidence ($\alpha = 0.20$). We chose occupancy as a state variable because it is a reliable and practical approach for monitoring anurans at large spatial scales (Weir et al. 2009, Weir et al. 2005, Pellet and Schmidt 2005). Observed or naïve occupancy describes the proportion of sites where a species was found. This value underestimates true probability of occupancy when organisms were detected imperfectly. Therefore, modern methods rely on multiple surveys of sites during the same season to identify cases where status of units changed from "absent" to "present" with additional observations (MacKenzie et al. 2006). Outcomes are used to calculate probabilities of detection and correct naïve estimates of occupancy.

Dynamics of occupancy are sensitive to size of sampling units (MacKenzie et al. 2006, Rahbek 2005, Hartley and Kunin 2003, He and Gaston 2000). Large units tend to have greater probabilities of occupancy and are less sensitive to extirpations than small ones (Brown et al. 2012, Gould et al. 2012, Hecnar and M'Closkey 1997). Therefore, one might fail to detect a long-term decline in occupancy of ICFs if sampling was conducted in large units where persistence of some breeding populations masked losses of others. This was a concern in our study because calls of ICFs can be heard far from their origin, creating a large potential area of detection at each listening post (ca. 14 km^2) if standard protocols for auditory surveys were employed (e.g., North American Amphibian Monitoring Program; Weir and Mossman 2005). We favored smaller, spatially constrained units and considered two alternatives. One was a grid-based strategy similar to that recommended by the International Union for Conservation of Nature (IUCN Standards and Petitions Subcommittee 2014). Grid size was one section, which is a standard unit of land survey (1.6 km X 1.6 km; 2.59 km^2). Habitat polygons indicative of breeding sites were another fine-grained option.

Polygons with soil and hydrological features considered indicative of breeding sites were identified by the GIS model. Our first objective was to evaluate ability of the model to predict presence of ICFs at two spatial scales. Reliability was deemed "good" if ≥80% of locations where Schneider (2011) collected specimens during an independent study fell within habitat polygons or sections with ≥1 habitat polygon. Our second objective was to compare magnitude and variability of naïve rates of occupancy for the two sampling units. A pilot study allowed us to determine whether naïve rates of occupancy exceeded 0.25, which is considered a threshold for estimating trends reliably (Wier et al. 2005). Our assessment of variability was subjective due to small sample size. Ancillary objectives included estimating the amount of suitable habitat in our study area, comparing the number of breeding populations per occupied section to past studies, and identifying possible covariates of occupancy.

METHODS

Study Animal. Historically, ICFs occurred in nine counties in Illinois (Phillips et al. 1999). Records exist for four sites in Monroe County, Illinois where populations might have been extirpated by extensive flooding of the Mississippi River during the 1990's (Brandon and Ballard 1998, Gilbert 1986). Tucker (1998) noted populations in Madison County (IL) were restricted to fewer sites and a smaller area than reported 15–20 years earlier. Status in other parts of Illinois is unclear. Experts advocated a monitoring program (Beltz 1993, Brown and Rose 1988, and Taubert et al. 1982) but none was implemented.

Ranges of dates for breeding are mid-February to mid-April in southern Illinois and early March to late May in the central part of the state (Brandon and Ballard 1998). Breeding begins soon after emergence and continues for approximately seven weeks with sporadic activity early and late during this period of time (Brown and Rose 1988). Most choruses consist of ≤10 males (Tucker and Philipp 1993, Brown and Rose 1988). Calls are distinctive, frequent, and can be heard up to 2.1 km away (Brown and Rose 1988). Probability of detecting ICFs during auditory surveys is high, so differences between naïve and true rates of occupancy are small when using our protocols (Cosentino 2014).

Breeding occurs in ephemeral to semi-permanent bodies of water. Examples include flooded farm fields, shallow ponds, wetlands, and stagnant ditches (Beltz 1993). Suitability of a breeding site is determined by its hydrology and proximity to habitat used at other times of the year (Brown and Rose 1988). The ICF spends approximately 85% of its life underground (Tucker et al. 2008). Soils classified as sand, loamy sand, or sandy loam support its fossorial habits (Taubert et al. 1982). Deposits of these substrates confine the ICF's distribution at a landscape scale and presence at a local scale (Beltz 1993, Brown and Rose 1988, Taubert et al. 1982).

Study Area. Our study area encompassed five counties in central Illinois (Mason, Menard, Cass, Morgan, Scott) and one in the southern part of the state (Alexander). Past studies described ecology of ICFs in these areas (Brandon and Ballard 1998, Tolch 1997, Beltz 1993, Brown and Rose 1988, Taubert et al. 1982). We did not include Tazewell County for logistical reasons. We did not include Madison County because ICFs occur in a small area that has been studied extensively (100 ha; Tucker 1998), or Monroe County, where the ICF's persistence is questionable (Brandon and Ballard 1998).

Habitat Model. ArcGIS (Version 10.2, Environmental Systems Research Institute, Redlands, CA) was used for all geographic information analyses and development of data. Waterbodies from the National Hydrologic Dataset (NHD) and hydric soil inclusions from the Soil Survey Geographic Database (SSURGO) were selected for use within the model. Large features from NHD (≥2.02 ha) were censored because lakes and large, permanent ponds offer poor habitat for ICFs.

Preliminary polygons were identified within the model as either pond (remaining NHD features) or hydric (SSURGO features) and buffered by 90 meters. This distance was arbitrary, but fell within a range of values recommended for buffering wetlands to enhance conservation of amphibians (e.g., 30–137 m; Kingsbury and Gibson 2012, Missouri Department of Conservation 2000). Buffered polygons with boundaries that overlapped those of neighbors were combined to form single polygons. Doing so reduced our chances of identifying nearby features as separate sampling units when in fact they joined to form a single unit during periods of high groundwater or excessive precipitation.

All polygons with boundaries that intersected sandy soils were considered suitable habitat for ICFs. Soil types we considered sandy were described by the U.S. Department of Agriculture and Natural Resources Conservation Service as well drained or excessively drained sand, loamy sand, or sandy loam deposited by wind or outwash and associated with secondary terraces of the Mississippi, Illinois, and Sangamon rivers. Soil surveys for counties in our study area were accessed online (http://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/illinois/). Our list of sandy soils was similar to that of Taubert et al. (1982).

Known Locations of ICFs. The Illinois Department of Natural Resources' Biotics Database contains >400 records of occurrence for the ICF (Hinz et al. 2011). Accuracy and precision of locations varies among records because of changes in technology (e.g., availability of Global Positioning Systems; GPS) and access issues that necessitated approximations. Therefore, we validated model predictions by comparing them to sites where Schneider (2011) collected specimens and determined locations with a GPS in Alexander (N = 2), Mason (N = 24), Menard (N = 3), and Tazewell counties (N = 6).

Call Surveys. Counties were assigned to one of three regions [Alexander (AL); Cass, Morgan, Scott (CMS); Mason, Menard (MM)] that reflected gaps in distribution of suitable habitat (Fig. 1) and availability of observers. In each region, sections with ≥1 habitat polygon were identified by the model and assigned a number. We used a random numbers table to choose 10 sections per region. Two sections were rejected by observers because of excessive ambient noise or lack of access from public roads. These sections were replaced with others chosen randomly.

We defined breeding sites as isolated habitat polygons or groups of polygons that occurred too close together to distinguish in the field (<50 m apart). Lumping was a practical matter, but it also reduced the likelihood of violating a statistical assumption of closure of sites within a season (Petranka et al. 2004, Skelly et al. 2003). Lumping was rare in MM (no sites) and CMS (N = 2). In AL, 19 breeding sites contained multiple habitat polygons. Decisions about lumping were made a priori and specified on forms

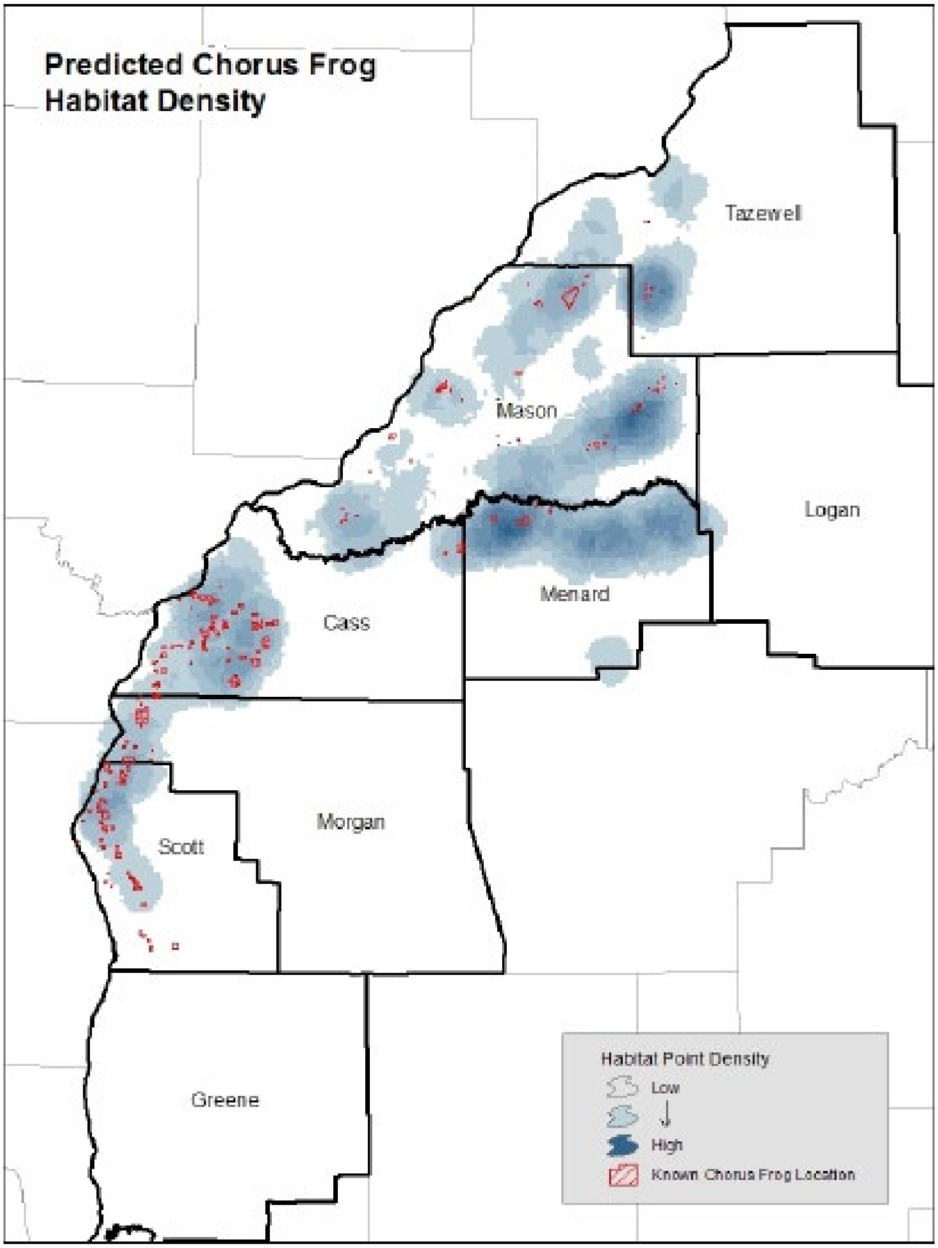

Figure 1. Predicted distribution and density of suitable habitat for the Illinois Chorus Frog (*Pseudacris streckeri illinoensis*) in central Illinois based on presence of small bodies of water or hydric soil inclusions and sandy soils within a 90-m buffer. Known chorus frog locations are records from the Illinois Department of Natural Resources' Biotics Database.

used for data collection. Each breeding site was surveyed if its centroid occurred within the section.

Observers were familiar with general protocols for anuran surveys and calls of ICFs because of past herpetological experience. All had worked in regions where they were assigned, so they were also familiar with habitats used by ICFs and general landmarks for navigation. We supplied observers with topographic maps and satellite imagery of assigned sections; both delineated habitat polygons. Observers chose the order in which they sampled sections and locations of listening posts on public roads. Most sections were bounded by public roads on two or more sides, which aided sampling and identification of units at night. Tactics for isolating the origin of choruses within a section included limiting distances from roads to habitat polygons, intercepting boundaries of neighboring sections, and triangulating from multiple listening posts. We used Microsoft Excel (Version 2010) to calculate value of a Pearson product-moment correlation between numbers of breeding sites per section and numbers of listening posts per section.

Observers confirmed initiation of breeding activity in their region before conducting surveys. They did so by visiting sites where ICFs were known to occur consistently in the past or by contacting knowledgeable landowners who lived near such sites. Observers conducted at least two surveys per season. In AL, the earliest survey occurred on 1 Feb; 16 Mar was the latest date. Surveys in MM and CMS started and ended later (8 Mar; 8 Apr) because phenology differed from southern Illinois. The same observers sampled the same sections each season and each year. Protocols required temperatures > 0˚ C, winds ≤ 30 km/hr, and lack of heavy rainfall during surveys. Start times varied from an hour before to an hour after sunset. All surveys were completed by 0100 hrs.

No waiting period was required between arrival at listening posts and initiation of surveys. Observers listened for three minutes at each post unless calls of ICFs were detected sooner. For each breeding site, observers reported ambient temperature, time survey began, presence or absence of ICFs, calling intensity of choruses of ICFs (if present), identity of other species of anurans (if present), and sources of auditory interference (if present). For each section, observers reported date, wind direction, wind velocity, and number of listening posts. Overall, numbers and locations of listening posts for each section were consistent within and among years. Exceptions occurred when velocity and direction of wind required changes to better determine presence or absence of ICFs at a particular breeding site.

RESULTS

Performance of Model. Most sections where ICFs were collected by Schneider (2011) had ≥1 habitat polygon (91%). Fifty-four percent of Schneider's (2011) collections occurred in habitat polygons. Two sites were close enough to habitat polygons (<30 m) to suspect errors in GPS coordinates or, more likely, differences in hydrology when these areas were mapped during soil surveys. These cases were not counted as collections in habitat polygons.

Availability of suitable habitat and relationships with sampling effort. The model identified 504 sections and 946 breeding sites with suitable habitat (Table 1). Our standard sampling effort of 10 sections per region equated to 2.9% of all sections with suitable habitat in MM, 7.6% in CMS, and 30.3% in AL. The proportion of habitat polygons sampled in each region was also lower in MM (5.0%) and CMS (10.9%) than AL (92.3%). Our random sections had an average of four potential breeding sites (range = 1-13). The number of breeding sites occupied by ICFs varied from 1-6 per section where ICFs were detected ($\bar{x}$ = 2.5). The number of listening posts per section varied from 1-13 ($\bar{x}$ = 2.7), and was highly correlated with the number of breeding sites per section (r = 0.92).

Dynamics of occupancy. In MM, we visited 10 sections three times per season during 2011 and 2012. Sites in AL were visited twice per season during 2011 and 2012. In CMS, we visited eight sections twice during 2011 and 10 sections twice during 2012–2014. In all, we completed 171 surveys (i.e., each visit to a section counted as a survey). We detected ICFs in 63% of sections and 40% of breeding sites when all years and regions were pooled (Table 2). Naïve rates of occupancy were greater in 2011 (54% of sections, 36% of habitat polygons) than 2012 (40% of sections, 15% of habitat polygons; Tables 3–4).

Table 1. Number of areas in six Illinois counties that a GIS model deemed suitable habitat for *Pseudacris streckeri illinoensis*. A section is a standard unit for land surveys (2.59 km_2); a polygon is indicative of a breeding site with a small body of water or hydric soil inclusion and sandy soils within a 90-m buffer.

County	No. sections	No. sections with ≥1 polygon	No. polygons
Alexander	264	33	65
Cass	387	85	169
Morgan	574	19	28
Scott	251	28	60
Mason	583	232	397
Menard	320	107	227
All	2379	504	946

Table 2. Attributes of random sections sampled for occupancy of *Pseudacris streckeri illinoensis* (ICF) via call surveys in central and southern Illinois, 2011-2014.

County	No. years surveyed	No. sections surveyed	No. sections where ICF detected[a]	No. potential breeding sites surveyed	No. potential breeding sites where ICF detected[a]
Mason, Menard	2	10	2	31	8
Cass, Morgan, Scott	4	10[b]	8	28	13
Alexander	2	10	9	60	27
Total	-	30	19	119	48

[a]Detections are cumulative (i.e., for all years combined).

[b]Eight sections with 16 breeding sites were visited twice in 2011.

Table 3. Naïve rates of occupancy for random sections sampled via call surveys to determine presence of *Pseudacris streckeri illinoensis* in central and southern Illinois, 2011–2014.

	Year			
County	2011	2012	2013	2014
Mason, Menard	0.20	0.10	-	-
Cass, Morgan, Scott	0.50	0.30	0.80	0.70
Alexander	0.90	0.80	-	-
All	0.54	0.40	-	-

Table 4. Naïve rates of occupancy for breeding sites within random sections sampled via call surveys to determine presence of *Pseudacris streckeri illinoensis* in central and southern Illinois, 2011–2014.

	Year			
County	2011	2012	2013	2014
Mason, Menard	0.26	0.03	-	-
Cass, Morgan, Scott	0.25	0.15	0.39	0.36
Alexander	0.43	0.22	-	-
All	0.36	0.15	-	-

DISCUSSION

Agreement between the model and presence of ICFs in sections where Schneider (2011) collected specimens exceeded our a priori threshold. Performance of the model at this spatial scale was enhanced by existence of multiple habitat polygons per section, at least one of which was classified correctly. This relationship was fortuitous. Nevertheless, cumulative rates of naïve occupancy for sections sampled in AL (90%) and CMS (80%) also suggested the model performed well at this spatial scale. Naïve occupancy in MM was comparatively low (20%). We considered this an artifact of sampling rather than a problem with portability of the model. Half of our random sections in MM occurred in northern Menard County, where recent encounters of ICFs are rare despite high ratings for habitat suitability (Hinz et al. 2011) and historical records of their presence (Beltz 1993, Taubert et al. 1982). This was an interesting result, but not characteristic of the region as a whole. Allocating sampling effort proportionately to the amount of suitable habitat in each region would improve our initial design (Cosentino 2014).

Agreement between habitat polygons and Schneider's (2011) collection sites was relatively poor. Schneider's (2011) sites included flooded road ditches that were not identified consistently by NHD or SSURGO. This was a relatively minor flaw in the model, as road ditches comprise a small proportion of breeding sites (12%; Beltz 1993). Discrepancies also occurred because Schneider's (2011) sites were >90 m from sandy soils. Illinois Chorus Frogs disperse 0-0.9 km ($\bar{x}$ = 0.59 km) from breeding sites to burrow underground in sandy soils (Tucker et al. 2008, Tucker 1998). Substrate of a breeding site is less important than its proximity to sandy soils. For example, nearly half of the breeding sites examined by Brown and Rose (1988) occurred on "non-sandy soils" but few (8%) were farther than 200 m from sand or loamy sand. Increasing the size of our buffer to better reflect the ICF's habits (e.g., 200–600 m) might have increased accuracy of the model. However, doing so would have shifted its focus from spatially explicit prediction to landscape composition at a comparatively coarse scale (Shifley et al. 2009).

Most breeding sites are formed by depressions or terraces in fields (Brown and Rose 1988). Hydrology of a particular site varies with depth of the depression or height of the terrace as well as local precipitation and groundwater conditions. It is unlikely that all sites are suitable for breeding during a given year or that the status of an individual wetland remains the same over time (Brown et al. 2012, MacKenzie 2012, Skelly et al. 1999). Some habitat polygons that remained unoccupied during our study might have been used by ICFs under a broader range of hydrological conditions. Our premise is supported by greater rates of naïve occupancy for cumulative (pooled) estimates than their annual counterparts because new sites were colonized during the study.

A severe drought coincided with the ICF's breeding season during 2012 (Illinois Department of Natural Resources 2013). Naïve rates of occupancy declined 26% for sections and 58% for individual breeding sites. Estimates returned to pre-drought levels in CMS, where we continued sampling during 2013 and 2014. Like others (Tucker 2005, Crawford and Kuhns 2004), we suspect drought caused males to reduce or abandon attempts to attract mates by chorusing. These events can be troublesome when using call surveys to estimate trends in occupancy. Possible solutions include increasing the number of visits per site during droughts (Cosentino 2014) or using precipitation during the breeding season as a covariate to explain annual differences in propensities to breed (Pechmann et al. 1991).

Monitoring programs are uninformative when the target species is encountered infrequently (Walls et al. 2011, Weir et al. 2009, Pellet and Schmidt 2005). Performance of both sampling units was acceptable when years and regions were pooled (naïve occupancy > 0.25). Our comparison warrants a caveat. Simultaneously estimating naïve rates of occupancy for sections and breeding sites allowed valid comparisons of spatial scales by controlling for detection and geographic variation in presence of ICFs. However, this approach differed from a design where breeding sites are drawn completely at random. We suspect that doing so would have yielded lower rates of occupancy for breeding sites because our model did a relatively poor job of predicting presence of ICFs at this spatial scale.

Beltz (1993) reported an average of 1.2 breeding populations per occupied section during a drought in 1991 and 1.9 per occupied section when wetter conditions prevailed in Cass, Menard, Morgan, and Scott counties (IL) during 1993. Estimates of Beltz (1993) were similar to Brown's (1984) findings in Morgan and Scott counties (IL; $\bar{x} = 1.4$ breeding sites per occupied section). Our estimates were slightly greater for CMS and MM when years were pooled ($\bar{x} = 2.1$) and for all regions during all years ($\bar{x} = 2.5$). We suspect differences between our estimates and those of earlier studies were due in part to sampling efficiencies afforded by the GIS model. In general, breeding populations occur at low densities on the landscape and few males participate in choruses. These attributes suggest occupancy of sections will be sensitive to pervasive changes in the status of ICFs (Royle 2004).

Power to detect a trend is affected by magnitude of occupancy and its variability (Weir et al. 2009, Petranka et al. 2004). These relationships favored sections for statistical reasons. The concept of using uniform "plots" to assess biological variables is well-founded in ecological literature and has advantages over using individual breeding sites or spatially unconstrained sampling units for monitoring trends in occupancy (Efford and Dawson 2012, Mac Kenzie 2012, Petranka et al. 2004). For example, availability of breeding and upland habitats as well as their spatial arrangement can be calculated on the same per-unit-area basis as occupancy and explored as covariates (Andelt et al. 2009).

A long-term, range-wide monitoring program is warranted by uncertainties about the ICF's status, its threatened designation in Illinois, importance of the state's populations to regional distribution, and a host of putative threats. Cosentino's (2014) power analyses of our data indicated robust estimates of trend can be obtained by sampling 75–90 sections annually. We support implementation of Cosentino's (2014) recommendations and refinement of strategies as data accumulate over time. We also support studies of ICFs at smaller spatial scales to estimate abundance, recruitment, and other metrics that could reveal causes of trends in occupancy.

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