Assessing the Current Distribution of Blanding's Turtles (*Emydoidea blandingii*) Relative to Suitable Habitat in Northeastern Illinois

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Previous Work

With biodiversity rapidly declining worldwide (Butchart et al. 2010), preventing the extinction of imperiled species is of utmost concern. We are currently seeing unprecedented vertebrate extinction rates, conservatively estimated up to 100 times higher than background rates, indicative of a sixth mass extinction well underway (Ceballos et al. 2015). Herpetofauna are the most imperiled vertebrate taxa with approximately 35% of reptile and 41% of amphibian species considered globally threatened (IUCN 2017). Over half of all turtle species evaluated by the IUCN Red List are considered vulnerable to extinction, 33% of which are regarded as endangered, some critically (Rhodin et al. 2017). These species declines are attributed to a marked increase in anthropogenic stressors on the environment, manifested by habitat loss and degradation, climate change, invasive species, pollution, disease transmission, and collection for the pet trade (Gibbons et al. 2000). Wetland habitat in particular, which many reptile and amphibian species rely on during some aspect of their life history, has undergone extensive destruction. In the United States, less than half of historic wetland acreage remains today, with six states retaining 15% or less of the wetlands they once had (Dahl and Allord 1996).

The Blanding's Turtle (*Emydoidea blandingii*) is one such wetland species that has suffered dramatic population declines throughout much of its geographic extent, which generally consists of the Great Lakes region and upper Mississippi River basin, although scattered populations exist east of the Appalachians (van Dijk and Rhodin 2011). It is recognized as a species of conservation concern in every state and province where it occurs (MWPARC 2010). In Illinois, *E. blandingii* was initially listed as Threatened in 1999, until being elevated to Endangered status in 2009 (Mankowski 2011). Once common, it now occupies only 22% of its native range in Illinois and is generally present in low numbers (King 2013). The largest population of *E. blandingii* in Illinois occurs at Spring Bluff Nature Preserve in the very northeast corner of the state, the preserve itself bounded by Lake Michigan and the Wisconsin border (Kuhns 2010). Even with an estimated 130-154 individuals residing collectively at Spring Bluff and the adjacent Chiwaukee Prairie preserve in Wisconsin, a population viability analysis showed that this population has a 95% chance of becoming extinct in the next 50 years if left unassisted (Kuhns 2010). This conclusion has dire implications for smaller *E. blandingii* populations throughout the state and underscores the need for immediate and resolute conservation action if this species is to persist in Illinois.

First described by Holbrook (1838), *E. blandingii* is readily identified by its distinctive yellow chin and throat which highlights its notched upper jaw giving the impression of a smile (Phillips et al. 1999). This semi-aquatic turtle species primarily occupies wetlands and slow-moving waterways but is also capable of traveling long distances over land (Congdon et al. 2008). Home range estimates of *E. blandingii* vary widely from less than one hectare up to 123 ha (Rowe 1987; Ross and Anderson 1990; Rowe and Moll 1991; Joyal 1996; Hamernick 2000; Piepgras and Lang 2000). These differences are likely due, in part, to the variation in quality and quantity of habitat available at different study sites. From late May through early July, females may traverse up to 4.5 km in search of nesting sites (Beaudry et al. 2010). Nest site selection and timing of nesting can affect both hatching success and sex determination due to the influence of temperature during embryonic development (Gutzke and Packard 1987). Eggs incubated below 28°C produce males, whereas those incubated above 30°C produce females, and those incubated at or below 22°C do not survive (Gutzke and Packard 1987).

Certain life history traits of *E. blandingii* complicate conservation efforts and make success of such endeavors difficult to assess in the short-term. While *E. blandingii* is a long-lived species with the oldest recaptured in 2016 and estimated to be at least 83 years old (Erickson 2016), a caveat presents itself in the way of delayed sexual maturity. Not until 14-20 years of age do *E. blandingii* become capable of reproduction (Congdon et al. 1993). This requires high juvenile survival, ~78%, accompanied by yet higher adult survival, ~94%, to maintain stable populations (Congdon et al. 1993). Even slight reductions in adult survival have been shown to cause population declines (Congdon et al. 1993). Furthermore, after females become sexually mature, they only produce up to one clutch per year and some years they may not nest at all (Standing et al. 1999; Banning 2007). These synergistic factors result in a lengthened generation time of 37 years (Congdon et al. 1993).

It is understood that wetlands are a necessary component of *E. blandingii*'s natural history, yet this species has been described as somewhat of a habitat generalist (Anthonysamy et al. 2014). While *E. blandingii* may use an assemblage of permanent and ephemeral wetlands during the spring and summer, in winter months this species prefers to hibernate in permanent wetlands deep enough to remain at least partially unfrozen (Edge et al. 2009). Furthermore, research has shown *E. blandingii* avoiding wetlands overrun with cattails (Kasuga 2007). Ideal nesting areas consist of sparsely vegetated, well-drained, loose soil exposed to ample sunlight (Sajwaj et al. 1998; Kinney 1999; Congdon et al. 2000). Not all uplands will provide suitable nesting habitat and, if they do, may be adversely affected by surrounding predator populations often associated with urban areas (Urbanek et al. 2016). Overall, given the terrestrial mobility of this species, it seems the most important aspect of *E. blandingii* habitat is extent, since larger tracts of suitable habitat will reduce many of the factors contributing to population declines.

Numerous compounding threats are responsible for the struggling recovery of *E. blandingii*. Habitat loss and fragmentation have been the primary causes leading to the imperiled status of *E. blandingii*. Historically, wetland drainage and conversion of prairie to support agricultural production were the main drivers of habitat alteration in Illinois (Henning and Hinz Jr. 2016). Nearly 90% of Illinois' wetland acreage has been lost in the last 200 years (IDNR 2018), with less than 1% of its native prairie remaining (Corbett 2004). What habitat remains is often degraded by invasive species (Kasuga 2007), pollution (Kuhns 2010), altered hydrology (Owen-Jones et al. 2016), and encroachment of woody vegetation (Reid and Thiel 2016). Scattered habitat tracts harboring small, isolated populations of *E. blandingii* will likely lead to a loss of genetic diversity through genetic drift and possibly inbreeding depression, the latter of which is made possible by long generation times (Klut 2011; Sethuraman et al. 2014; Anthonysamy et al. 2018).

Climate change threatens to exacerbate the issues related to habitat fragmentation, since isolated populations of *E. blandingii* may not have the ability to migrate elsewhere should their existing habitat become unfavorable (Walk et al. 2011). An increased frequency and/or duration of summer drought will cause some wetlands to dry up, forcing *E. blandingii* to shift their habitat use or cease activity altogether (Anthonysamy et al. 2013). Resultant to a controlled drawdown of a Minnesota lake, which would simulate a drought-induced scenario, one *E. blandingii* population experienced increased mortality from predation, vehicle collisions, and winterkill (Hall and Cuthbert 2000).

As urbanization intensifies, adjacent *E. blandingii* habitat becomes further restricted leading to negative impacts on this species' survival. Over the past century, Illinois' human population has more than doubled from 5.6 million in 1910 to 12.8 million at the last census (Forstall 1996; U.S. Census Bureau 2010). This burgeoning populace is especially apparent throughout Chicago's metropolitan region in northeastern Illinois where *E. blandingii* was once prevalent. As urban expansion continues, road density and traffic volumes increase comparatively, further fragmenting the landscape. Roadways, paved or not, have been shown to act as an impediment to movement in both male and female *E. blandingii* (Proulx et al. 2014). The majority of adult mortality in many urban turtle populations can be attributed to vehicle collisions (Banning 2006; Taylor et al 2014; Janzen 1994; Bishop et al 1998; Aresco 2005). Furthermore, disturbed areas along roads and railways often attract nesting females, which may put both the adults and any hatchlings at an increased risk for mortality, further compromising populations already in jeopardy (Congdon et al. 1983). Since many predators, such as fox and coyote, use these areas as travel corridors, nests in these locations may be more likely to be predated (Kuhns 2010).

Several head-start programs have been implemented in northeastern Illinois. Head-starting entails captively incubating *E. blandingii* eggs and rearing hatchlings for several years in captivity prior to release. By reducing nest predation and hatchling mortality, head-starting in DuPage, Lake, and McHenry Counties has increased hatching rates by 55% and demonstrated annual juvenile survival of 66% (Glowacki 2015). These programs can serve to augment low population numbers by offsetting unsustainably high mortality rates. However, without addressing the root issues causing decreased survival, head-starting will only provide a temporary solution to an enduring conservation issue.

Many case studies have been conducted on individual populations of *E. blandingii* throughout its geographic range, including Illinois. However, little research has been done on the broader, metapopulation scale at which conservation success will be measured. Understanding where *E. blandingii* is present in relation to where suitable habitat exists is imperative to effectively facilitating lasting recovery of this species.

Justification

The fact *E. blandingii* has been listed on Illinois' threatened and endangered species list since 1999, almost 20 years, warrants earnest attention. Conservation measures should be implemented as efficiently as possible to promote the recovery of this sensitive turtle species. Habitat fragmentation has resulted in many disjunct populations of *E. blandingii* throughout Illinois, especially in the greater Chicago region where urbanization continues to intensify. Prior research in Illinois has focused largely on isolated, individual *E. blandingii* populations. While conserving this species is important at the local scale, a broader approach will be vital for the long-term persistence of *E. blandingii*.

A regional assessment is needed to evaluate the current distribution of *E. blandingii* in conjunction with presently available habitat suitable for this species. My proposed research seeks to address this need by surveying documented occurrences of *E. blandingii* in northeastern Illinois and using geographic information systems (GIS) to model where potential habitat exists on the landscape. Ultimately, this assessment will allow wildlife managers to maximize limited conservation dollars by investing in areas that will prove most beneficial for *E. blandingii*'s recovery in Illinois.

Objectives

1. **What is the detection probability of traditional hoop-net trapping for *E. blandingii*?**
   Determining the presence or absence of *E. blandingii* in historic wetlands of the Chicago region is important to recovery efforts. Modeling the probability of positive detection of this species in a wetland will maximize the efficiency of these efforts. This model will become a conservation tool for land managers to apply in their continued monitoring of this species.

2. **Which element occurrence records (EORs) still harbor *E. blandingii*?**
   To successfully conserve this state-endangered species, we must first understand where *E. blandingii* occurs on the landscape. Due to rapid urbanization of northeastern Illinois during the last century, historical occurrence records of *E. blandingii* may have since been extirpated. An updated assessment using modern occupancy and detection methods is necessary to determine where this species persists.

3. **Where does suitable habitat for *E. blandingii* exist in the greater Chicago region?**
   While *E. blandingii* may be found in small, remnant wetlands throughout urbanized landscapes, individual turtles do not necessarily represent viable populations. If this species is not able to reproduce in a given location, then the population is demographically extinct despite relict turtles potentially surviving for decades. GIS software will help identify wetlands providing adjacent upland nesting habitat, a buffer from roads, and sufficient wetland acreage to sustain a population of *E. blandingii*.

Procedures

STUDY SITE
I will conduct my research in northeastern Illinois, which encompasses the greater metropolitan area surrounding Chicago, and extending to Rockford in north-central Illinois. The nine counties bounding my study area are: Boone, Cook, DuPage, Kane, Kendall, Lake, McHenry, Will, and Winnebago County (see Figure 1). Historically, *E. blandingii* was widespread throughout this region, and, although its distribution has been restricted due to habitat loss associated with urban development, the species is still known to exist in these counties (INHS 2018).

Figure 1: Study area comprised of 9 counties in northeastern Illinois.

MODELING DETECTION PROBABILITY
Previous turtle trapping data will be analyzed to determine what factors influence the probability of detecting *E. blandingii* at a site when it is known to be present. This prior data, provided by the Illinois Natural History Survey, contains trapping records from seven locations across northeastern Illinois and one location adjacent to the Wisconsin-Illinois border along Lake Michigan (see Table 1).

Table 1. Recent E. blandingii *trapping datasets used for detection probability model.*

Site Name*	County (State)	Trapping Timeframe	Total Trapping Records
Chiwaukee Prairie SNA	Kenosha (WI)	June 2005 – June 2010	231
Spring Bluff NP	Lake (IL)	June 2004 – May 2010	422
Illinois Beach SP	Lake (IL)	June – July 2006	21
Pratt’s Wayne Woods FP	DuPage (IL)	May – September 2017	158
Keepataw Preserve	Will (IL)	August 2005 – September 2017	1191
Romeoville Prairie NP	Will (IL)	April 2007 – June 2010	153
Lockport Prairie NP	Will (IL)	June 2004 – June 2016	836
Goose Lake Prairie SNA	Grundy (IL)	June 2006 – June 2009	181

*SNA=state natural area, NP=nature preserve, SP=state park, FP=forest preserve

All datasets will be combined and analyzed collectively. The three sites in Lake and Kenosha County—Chiwaukee Prairie SNA, Spring Bluff NP, and Illinois Beach SP—essentially represent one contiguous natural area since these protected sites share municipal boundaries or are directly linked by protected habitat. The same can be said for the three sites along the Des Plaines River in northern Will County—Keepataw Preserve, Romeoville Prairie NP, and Lockport Prairie NP—although Lockport Prairie is 3.5 miles south following the Des Plaines River from Romeoville Prairie.

Each trapping record contains information which will be incorporated, either directly or indirectly, as variables in the detection probability model. These include: trap location, trap type, consecutive dates trap was checked, dates bait was changed, and the number of turtles caught per species each day. From this raw data, I will use program R (R Core Team 2018) to transform the dates into Julian days and calculate additional variables including: number of traps set per day at a given site, number of days since trap was set, and number of days since trap was freshly baited.

Daily weather data for precipitation amount (inches), minimum, maximum, and mean air temperature (°F) will be obtained from the National Oceanic and Atmospheric Administration (NOAA 2018) to be included as additional variables potentially affecting detection probability (see Table 2). From this weather data, I will use program R (R Core Team 2018) to calculate the previous day, 3-day, and 5-day averages of the minimum, maximum, and mean air temperatures (°F).

Table 2. Weather stations used to obtain daily precipitation and temperature data.

Site(s)*	**Weather Station Location**	**Weather Station ID**
Chiwaukee SNA Spring Bluff NP Illinois Beach SP	Kenosha, WI	GHCND:USC00474174
Pratt's Wayne Woods FP	Elgin, IL	GHCND:USC00112736
Keepataw Preserve Romeoville Prairie NP Lockport Prairie NP	Romeoville Weather Forecast Office, IL	GHCND:USC00117457
Goose Lake Prairie SNA	Channahon Dresden Island, IL	GHCND:USC00111420

*SNA=state natural area, NP=nature preserve, SP=state park, FP=forest preserve

With all these variables gathered and standardized using a z-transformation, I will produce generalized linear mixed models using the glm function within the lme4 R package (Bates et al. 2015), my dependent variable being the binary success or failure of detecting *E. blandingii* at each trap check. I will use ridge regression to diagnose multicollinearity amongst independent variables and resolve any issues via variable reduction. I will then select the best-fit model using the AICcmodavg package (Mazerolle 2016). The variables from the top model will be used to create a Microsoft Excel interface, allowing land managers to manually input values for each parameter and receive an output showing the probability of detecting *E. blandingii* given their circumstances.

UPDATING ELEMENT OCCURRENCE RECORDS

Element occurrence records (EORs) represent historical locations where *E. blandingii* have been documented. Of the 310 EORs in Illinois, the oldest record dates back to 1878 in Chicago, with the most recent report occurring in 2017 as the EOR database is continually updated (INHS 2018).

I will assess each EOR within my 9-county study area, of which there are 182 distributed among 116 separate locations, to verify continued presence or declare the absence of *E. blandingii* via trapping efforts when necessary.

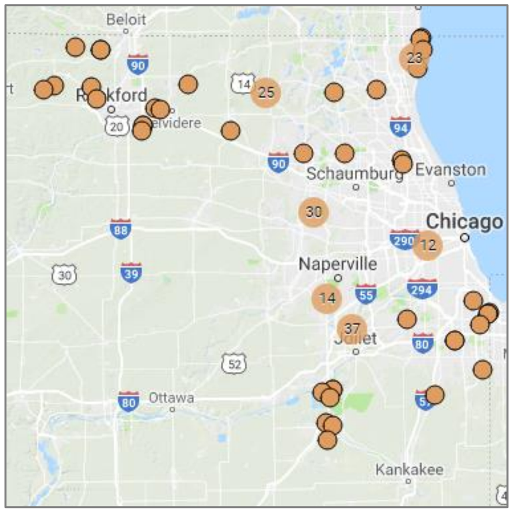

Figure 2. Blanding's Turtle records from the Illinois Natural Heritage Database.

I will initially view each EOR against recent satellite imagery in ArcGIS to determine, especially for older records, if any potential habitat remains or if the site has since been developed or converted to agriculture. For EORs older than 5 years, those documented prior to 2013, at which it appears *E. blandingii* could still be present, I will apply for trapping permits (on state- and federally-owned land) or request landowner permission to trap (on private property).

At wetland sites where permission is granted, I will set hoop net traps baited with canned sardines (Legler 1960). Trapping will occur during months when turtles are most active, mid-May through August (Bourque 2006). I will check traps daily and re-bait them as needed. Trapping will continue at a site until *E. blandingii* is detected or until I reach an acceptable probability of detection according to my model. In case of the latter scenario in which *E. blandingii* is not detected, I will ascertain the species to be absent.

Although I am primarily interested in the presence or absence of *E. blandingii* at each site, I will also collect detailed trapping information in hopes it can be used to bolster the original detection probability model. When setting each trap, I will record its GPS coordinates (UTM, NAD83) along with the following observations using the measurement units and equipment listed in parentheses:

- canopy cover (percentage; spherical concave densiometer)
- distance to shore (meters; Bushnell Scout DX rangefinder)
- water depth (cm; fiberglass folding ruler)
- vegetation present (categorical; classified as submergent, emergent, surface, or none)
- upland description (categorical; classified as natural, developed, agriculture, or mowed)
- size of wetland (hectares; digitized with ArcGIS software)
- total number of traps set concurrently within wetland boundary

When checking each trap, I will record the date and time along with environmental conditions. A Kestrel 3000 will be used to measure air temperature (°C), wind speed (m/s), and relative humidity (%). Surface water temperature (°C) will be measured with a substrate thermometer. Cloud cover will be recorded in intervals from 0-25%, 26-50%, 51-75%, and 76-100%. Precipitation will be recorded as light, moderate, heavy, or none. Turtles will be recorded by species, sex, and quantity per trap check.

For each *E. blandingii* captured, I will record morphological characteristics as well as its sex and stage (hatchling, juvenile, or adult). Morphometric data will include weight (g), carapace width, carapace length, plastron length, and shell height (all in mm). I will also count and measure annuli using digital calipers. If the turtle is a recapture, as indicated by scute notches, I will record its ID. If no notches are apparent, I will give the turtle a unique ID by notching a combination of marginal scutes as described by (Cagle 1939). I will also photograph their dorsal and ventral sides to aid in future identification should their marks be obscured over time.

DELINEATING SUITABLE HABITAT

Spatial analysis will be conducted using GIS software to identify suitable *E. blandingii* habitat currently available in the state of Illinois. While I am predominantly interested in habitat present within the 9-county study area, these counties are highly urbanized which may severely limit opportunities for expansion of protected areas if deemed necessary following the results of this analysis. Since the map layers I will use are available statewide, I will evaluate habitat for the entire state and then focus on results within the study area. This approach may provide valuable insight for the conservation of other *E. blandingii* populations in Illinois.

Understanding not all habitat is equal in terms of quality and composition, there is no one-size-fits-all approach to defining what constitutes suitable habitat for *E. blandingii* in a GIS framework. Therefore, I will instead aim to identify baseline habitat areas in existence meeting minimum thresholds for supporting *E. blandingii* on both the individual and, more importantly, the population level. This initial assessment will identify suitable habitat upon which potential improvements and expansions can be made to provide higher quality and/or larger habitat tracts in the future.

Suitable habitat will be generally defined in terms of undeveloped land containing both wetlands and adjacent uplands for nesting, which is a safe distance from roads and railways. Ideally, I would place a buffer around wetlands to identify upland nesting sites, remove any locations in which this core habitat is intersected by a transportation right-of-way or development, and designate the remaining areas as suitable habitat. However, no accurate GIS wetlands layer currently exists for the state of Illinois (Matthews et al. 2016). I will instead take these buffers into consideration using another approach.

While home range estimates vary widely for *E. blandingii* (Hamernick 2000), there is some consensus as to the extent of wetland buffers required to protect upland nesting sites and terrestrial movements. A study by Congdon et al. (2011) found a 1000-m and 2000-m buffer sufficient in protecting 87% and 100% of adult *E. blandingii* activity, respectively, guidelines which have been adopted in recommendations for this species' conservation elsewhere, including Illinois (Hartwig et al. 2009; King 2013). These buffers also encompass the 450-m buffer necessary in protecting 100% of nests (Congdon et al. 2011).

Although I cannot directly model wetland buffers in GIS without an accurate wetlands layer, I will alternatively use these buffer zones to calculate an area around a hypothetical wetland, which can then be interpreted as minimum size requirements for core *E. blandingii* habitat. Since the actual area encompassed by a buffer is inextricably linked to the size of the wetland itself, I will use a conservative 0.2ha (50-m diameter, 0.5ac) wetland for modeling purposes. A 1000-m buffer around this hypothetical wetland results in a total area of 330ha (815ac), which represents the area needed to protect 87% of adult movements. For 100% of adults, a 2000-m buffer around this small wetland results in a total protection area requiring 1290ha (3188ac). With the buffer zones calculated, I will use GIS to identify areas of undeveloped land, after excluding transportation right-of-ways, which meet these size requirements. I will then manually assess whether wetlands are present at each site.

In the interest of designating areas representing the greatest conservation value to *E. blandingii*, habitat need not only be suitable for individual turtles to survive, but also large enough to sustain a viable population. Gibbs and Shriver (2002) propose the necessity of at least 1000ha of intact habitat for self-sustaining populations (500-1000 turtles) of Emydidae. A recommendation of at least 50 adults per population was put forth in the Illinois Conservation Assessment for the Blanding's Turtle (King 2013) in accordance with prior research by Franklin (1980) and Soule (1980), which stated 50 adults was a minimum threshold to avoid inbreeding. Given the low density (0.25-0.99 turtles/ha) at which *E. blandingii* currently occur in northeast Illinois (Rubin et al. 2004; Dreslik et al. 2007), it would require 50.5-200ha of habitat to support this minimum threshold of 50 adult turtles. To support a self-sustaining population of 500 turtles at these densities, it would require 505-2000ha. I will further model protection areas consistent with these size recommendations using the same methods described above.

Expected Results

This research will lead to a broader understanding of *E. blandingii*'s distribution in northeastern Illinois and generate implications for improved management decisions. I anticipate detections of *E. blandingii* to be relatively infrequent at EORs where the species has not been documented in over a decade. In these instances, given potential habitat still exists, it may require prolonged trapping effort to obtain a high probability of detection. Many of the more recent EORs are located within protected areas such as forest preserves, nature preserves, and state parks, all of which are likely to remain intact making it more plausible to find *E. blandingii* persisting. Recognizing the extent to which urbanization and agriculture have contributed to habitat loss in northeastern Illinois, I expect many of the remaining individuals to be found in small and/or isolated habitat areas. My initial GIS analysis may identify few, if any, areas of suitable habitat large enough to sustain viable populations of *E. blandingii*, which may necessitate further examination to identify adjacent lands offering potential for acquisition and restoration.

Using a combined approach at both the local and landscape level, this research will help facilitate the long-term conservation of *E. blandingii* in Illinois. My EOR assessment will provide an updated account of EORs within the Illinois Natural Heritage Database. I will disseminate my research findings to the greater scientific community by presenting at wildlife conferences and publishing articles in peer-reviewed journals.

Timeline

August 2017 – May 2018	Develop detection probability model
May – August 2018/2019	Assess historical occurrence records
September 2018 – May 2019	GIS modeling to identify suitable habitat
September 2019 – May 2020	Compile and publish results; draft thesis

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